SEALING SYSTEM LEAKAGE

SEALING SYSTEM LEAKAGE ANALYSIS GUIDE

SECTION 1: Introduction

The Oil Seal Manufacturing Industry is committed to provide functional, efficient radial lip seals for all applications. If a sealing system leaks, it is most important that the manufacturer be provided with as much data about the sealing system and its environment as possible in order to provide a timely and correct solution.

The mere return of a leaking seal is not sufficient information on which to base corrective action. The following is a Leakage Analysis Guide prepared by the Technical Committee of the Oil Seal Subdivision of the Rubber Manufacturers Association.

SECTION 2: Sealing System

There are four elements to any sealing system:

2.1 The sealing device
2.2 The shaft or running surface
2.3 The housing bore
2.4 The medium to be sealed

It is not possible to provide an accurate analysis of a leaking sealing system without examination of all four elements.

SECTION 3: Purpose

The purpose of this document is:

3.1 To provide the seal user with a systematic method of documenting all factors related to a sealing system and its immediate environment.

3.2 To provide a comprehensive list of probable causes for the factors of conditions found.

3.3 To provide possible corrective actions for conditions found. This may enable the user to solve the problem without consulting the seal manufacturer.

3.4 To provide the seal manufacturer with comprehensive documentation of a sealing system deficiency.

SECTION 4: Use of this document

This document contains a three-part checklist designed to lead an investigator through a sequential sealing system leakage analysis.

Part 1 Examination of the sealing system and immediate environment with the seal in place.

Part 2 Examination of the seal after removal

Part 3 Examination of the other three elements (i.e., housing, shaft and lubricant) of the sealing system.

Completion of this three-part checklist should provide the examiner and eventually the seal manufacturer with sufficient information to diagnose the problem.

For each abnormal condition of the checklist, there is a reference code. Each reference code represents a page in the Causes and Countermeasures section of this guide. If a condition is checked on the list, the guide will provide a number of possible causes for that condition, as well as a number of possible countermeasures or corrective actions that could be taken by the responsible agency.

If the problem is not correctable by the user, the checklist should be forwarded, with the seal in question, to the seal manufacturer.

If it is not possible to provide all of the information requested on the checklist, it would be of benefit to the seal manufacturer to have access to all elements of the sealing system so that all relevant information can be gathered.

SEALING SYSTEM LEAKAGE ANALYSIS CHECKLIST

PART 1

An examination of the sealing system and immediate environment with the seal in place.		
Seal Application: Miles/Hours of Operation:	Equipment Identification: Complaint:	
Before removal, carefully inspect the seal, the shaft and the immediate area around the leakage site. Follow this check-list:		
Amount of Leakage		
Slight ☐	Immediate area damp ☐	Heavy leakage ☐
Source of Leakage		
Check	Location	Reference Code
☐	Between shaft and seal lip	------
☐	Between OD of seal and bore	B.2.5
☐	At retainer bolt holes	B.3.1
☐	At retainer gasket	B.3.2
☐	Between wear sleeve and shaft	B.3.7
☐	Through seal on assembled seal	B.3.8
Condition of Immediate Environment		
Seal area clean ☐	Mud or dust packed in seal area ☐	B.2.1
Wipe Immediate Area Clean and Inspect		
Check	Condition	Reference Code
☐	Nicks on bore chamfer	B.1.1
☐	Seal loose in bore	B.1.2
☐	Paint spray on seal lip	B.2.2
☐	Seal cocked in bore (amount)_____	B.2.3
☐	Seal installed in wrong orientation (backwards)	B.2.4
☐	Seal case deformed	B.2.6
☐	Shaft to bore misalignment	B.3.5
Rotate Shaft if Possible Check for Radial & Axial Play		
☐	Excessive shaft end play (amount) _____	B.3.3
☐	Excessive shaft runout (amount) _____	B.3.4
Note: If location of leakage cannot be confirmed at this point, either introduce ultra-violet dye into the sump or spray area with white powder, operate for 15 minutes and check for leakage with ultraviolet or regular light. When above analysis is complete, mark the seal at the 12 o'clock position and carefully remove from the application.		
☐	Oil sample obtained	B.3.6
Completed by: _____		Date:

SEALING SYSTEM LEAKAGE ANALYSIS CHECKLIST

PART 2

Clean the removed seal in a mild solvent. Do not attempt to scrape away carbon, etc. Inspect the seal using this checklist.

Primary Lip Area

Check	Condition	Reference Code
☐	Normal wear	C.2.1.1
☐	No wear	C.2.1.1
☐	Excessive wear	C.2.1.1
☐	Eccentric wear	C.2.1.3
☐	Inverted lip due to poor installation	C.2.1.10
☐	Nicks, scratches or cuts at lip contact area	C.2.1.4
☐	Hardened or cracked rubber	C.2.1.6
☐	Coked oil on lip	C.2.1.8
☐	Softening or swelling	C.2.1.9

Seal Outside Diameter

Check	Condition	Reference Code
☐	Normal	----------
☐	Severe axial scratches	C.2.2.2
☐	Peeled rubber	C.2.2.3
☐	Hardened rubber	C.2.2.4
☐	Nonfills or cuts	C.2.2.5

Spring and Spring Groove Area

Check	Condition	Reference Code
☐	Spring normal and in place	---------
☐	Spring missing	C.2.3.1
☐	Spring corroded	C.2.3.2
☐	More than one spring	C.2.3.4
☐	Separated spring	C.2.3.5

Make the Following Measurements

Primary lip inside diameter?	(_____)	C.2.1.7
Primary lip radial force?	(_____)	C.2.1.7
Seal outside diameter?	(_____)	C.2.2.1
Spring inside diameter?	(_____)	C.2.3.3
Spring tension?	(_____)	C.2.3.3
Primary lip wear band width?		
Min.	(_____)	
Max.	(_____)	

Comments:

Completed By: _____ Date:

SEALING SYSTEM LEAKAGE ANALYSIS CHECKLIST

PART 3

An examination of the housing, shaft and lubricant (after seal removal).		
Inspect the Housing Bore Area		
Check	Condition	Reference Code
☐	Measure bore diameter: (_____)	C.1.1
☐	Bore chamfer damaged	C.1.2
☐	Flaws or voids in housing	C.1.3
☐	Tool withdrawal marks in bore	C.1.4
☐	Bore surface scratched or galled	C.1.5
Inspect the Shaft in the Seal Contact Area		
Check	Condition	Reference Code
☐	Measure shaft diameter: (_____)	C.3.1
☐	Shaft surface corroded	C.3.3
☐	Seal wear path in wrong location	C.3.4
☐	Scratches or nicks at lip contact area	C.3.5
☐	Measure wear path width: (_____)	C.3.7
☐	Discoloration on shaft surface	C.3.8
☐	Coked lubricant present	C.3.8
☐	Shaft chamfer damaged or missing	C.3.11
☐	Wear sleeve loose on shaft (if applicable)	C.3.13
Remove Shaft from Application for Further Inspection		
	Characteristic	Reference Code
☐	Measure surface roughness: (_____Ra)	C.3.2
☐	Measure depth of wear path: (_____)	C.3.6
☐	Measure shaft lead: (_____Deg)	C.3.9
☐	Measure shaft hardness: (_____Rc)	C.3.10
☐	Check for proper shaft material	C.3.12
Inspect the Lubricant		
Check		Reference Code
☐	Contaminates (particulates) in filtered lube	C.4.1
Compare Lubricant from Application with New Lubricant for Proper Type		
Check	Condition	Reference Code
☐	Color different	C.4.2
☐	Viscosity different	C.4.2
☐	Odor different	C.4.2
Completed By: _____		Date:

SEALING SYSTEM LEAKAGE ANALYSIS CHECKLIST

SHORT FORM

Intended for field or shop work where the more comprehensive 3-part checklist may not be practical.			
Seal Application: **Miles/Hours of Operation:**		**Equipment Identification:** **Complaint**	
Step 1: Inspect the Seal Application Before Removal			
Amount of leakage Condition of area Leakage source	☐ Slight ☐ Clean ☐ Between lip and shaft ☐ At retainer gasket ☐ At retainer bolt holes	☐ Seal area damp ☐ Dusty ☐ Between OD and bore ☐ Between elements of seal ☐ Between wear sleeve and shaft	☐ Heavy leakage ☐ Mud packed
Step 2: Wipe Area Clean and Inspect			
Check Conditions Found	☐ Nicks on bore chamfer ☐ Seal cocked in bore ☐ Seal installed wrong ☐ Shaft to bore misalignment	☐ Seal loose in bore ☐ Seal case deformed ☐ Paint spray on seal ☐ Other	
Step 3:Rotate Shaft if Possible			
Check Conditions	☐ Excessive end play	☐ Excessive runout	
Step 4: If the location of the leak cannot be confirmed at this point, either introduce ultra violet dye into the sump or spray area with white powder, operate for 15 minutes and check for leakage with ultraviolet or regular light.			
Step 5: Mark the Seal at the 12 O'Clock Position and Remove it Carefully			
	☐ Retain an oil sample		
Step 6: Inspect the Application with Seal Removed			
Check Conditions Found	☐ Rough bore surface ☐ Shaft clean ☐ Coked lube on shaft ☐ Shaft damaged	☐ Flaws or voids in bore ☐ Shaft corroded ☐ Shaft discolored	
Step 7: Inspect the Seal			
Primary Lip Wear Primary Lip Condition Seal OD Spring	☐ Normal ☐ None ☐ Normal ☐ Soft (flexible) ☐ Normal ☐ In Place ☐ Corroded	☐ Excessive ☐ Damaged ☐ Axial scratches ☐ Missing	☐ Eccentric ☐ Hardened (stiff) ☐ Damaged rubber ☐ Separated
Comments:			
Completed By: _____		Date:	

TROUBLE SHOOTING

SEALING SYSTEM LEAKAGE

B.1.1 Nicks on Bore Chamfer

Probable Causes	Action or Countermeasures
1. Mishandling prior to seal installation (Fig. 1)	Check bore/housing machining
2. Insufficient material removal	Check casting dimensions for proper material allowance. Check machining locations for proper gage points.
3. Tool chatter on chamfer surface (Fig. 2)	Review machining procedures for proper tool configuration, feed, speed and coolant.

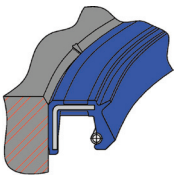


Fig. 1

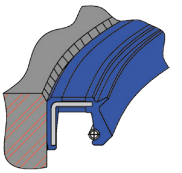


Fig. 2

B.1.2 Check for Looseness in Bore

Probable Causes	Action or Countermeasures
1. Oversized bore ID.	Check bore machining dimensions for out of tolerance condition.
2. Undersize seal OD.	Check seal OD for out of tolerance.
3. Rolling of seal into bore during installation.	Review installation procedure and use proper installation tools.
4. Bore sizing.	Increase bore material hardness or use bore sealant.
5. Excessive shrinkage/hardening of rubber OD seal.	Review application temps, and seal material specifications.
6. Deformation of seal during installation (Fig 1).	Review installation procedure and use of proper tool.

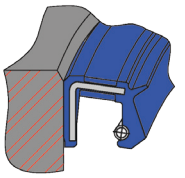


Fig. 1

B.2.1 Contaminants (Mud or Dust) Packed in Seal Area

Probable Causes	Action or Countermeasures
1. Failure of auxiliary lip. (Fig. 1)	Look for cut or damaged auxiliary lip. Look for auxiliary lip worn excessively.

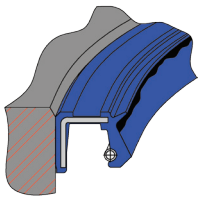
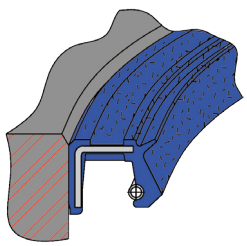


Fig. 1

B.2.2 Paint Spray on Seal Lip

Probable Causes	Action or Countermeasures
1. Lack of paint mask	Review paint procedure, recommend a mask
2. Service or in field paint procedure	Issue a service bulletin to prevent paint overspray or specify a mask



Paint spray particles

B.2.3 Check for Seal Cocking

Probable Causes	Action or Countermeasures
1. Seal installation (Fig. 1)	Use proper installation tool. Check installation force to insure complete installation
2. Insufficient or improper bore chamfer	Provide proper amount and lead in angle for chamfer
3. Excessive seal interference with rubber OD seal	Check bore ID and seal OD for proper dimensions

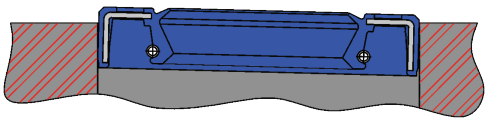


Fig. 1

B.2.4 Check for Proper Installation and Orientation Relative to Assembly

Probable Causes	Action or Countermeasures
1. Backward installation caused by lack of proper installation tool or visual aide (Fig. 1)	Provide foolproof installation tool and/or visual aide to identify proper orientation
2. Improper axial location of seal (Fig. 2)	Provide proper installation tool
3. Improper axial position of shaft (Fig. 3)	Provide proper installation tool and visual aide for proper position

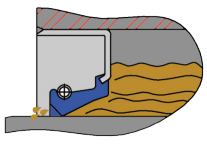


Fig. 1

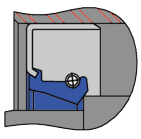


Fig. 2

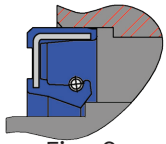
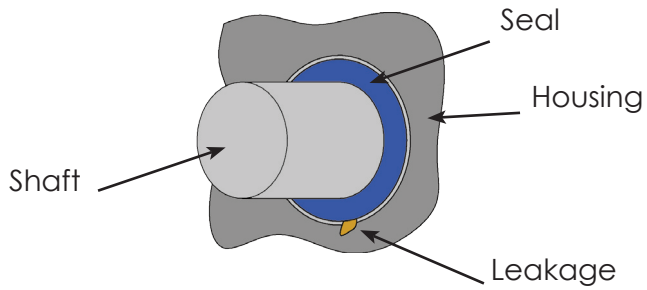


Fig. 3

TROUBLE SHOOTING

B.2.5 Check for OD Leakage

Probable Causes	Action or Countermeasures
1. Oversized bore/undersized seal	Check bore and seal diameters at removal
2. Damaged housing	Check upon removal
3. Damaged seal	Check for OD damage upon removal
4. Differential thermal expansion (aluminum or magnesium housing)	Calculate fit at maximum temperature



B.2.6 Check for Case Deformation (dishing or damage)

Probable Causes	Action or Countermeasures
1. Dented heel face caused by hammer installation	Provide proper installation tool
2. Dished heel face caused by improper tool	Provide proper installation tool

TROUBLE SHOOTING

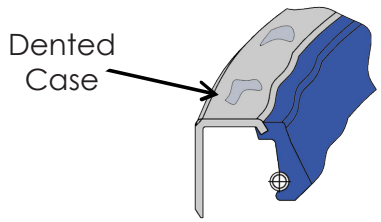


Fig. 1

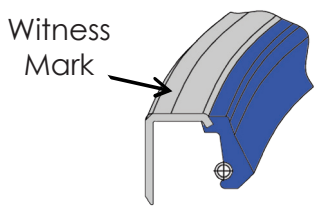


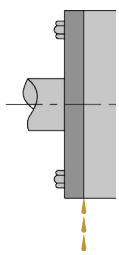
Fig. 2

B.3.1 Check Bolt Holes for Leakage

Probable Causes	Action or Countermeasures
1. Threads in housing tapped into fluid reservoir	Review product machining specifications
2. Insufficient bolt tightening	Provide proper installation tool
3. Undersize bolt diameter or oversize thread tap	Measure bolt and bolt hole for fit
4. Material thermal expansion incompatability	Insure the bolt, housing material have similar thermal characteristics for temperature extremes
5. Vibration	Use locking method so bolt won't work loose
6. Bolt fracture	Check bolt loading specs and operating parameters
7. Contamination	Insure bolt hole is free of particles or corrosive fluids prior to bolt installation
8. Corrosion	Insure bolt housing and material are compatible with application environment
9. Bolt missing	Install specified bolt
10. Cross threading	Retap and use correct bolt
11. Improper bolt	Change to correct bolt size
12. Improper head type	Change to correct bolt

B.3.2 Check Gaskets for Leakage

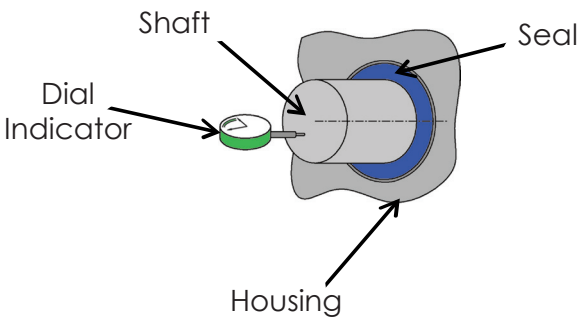
Probable Causes	Action or Countermeasures
1. Heat aging causes stress or cracking	Use high temperature gasket material compression set
2. Improper machining or mating surface	Review machining procedure for proper machining techniques
3. Casting porosity or other hardware surface	Inspect hardware surface for visual defects prior to gasket installation
4. Excess gasket preload resulting in compression	Review bolt torque requirements set
5. Gasket swell, soft, hard from chemical attack	Check fluid compatibility of gasket materia
6. Torn gasket	Use proper installation procedures and tools
7. Crimped or folded gasket	Use proper installation procedures and tools
8. Gasket blown out	Review system pressure specs, field application conditions, check gasket hardness
9. Dry gasket	Replace gasket
10. Wrong size	Use correct gasket
11. No sealant on gasket	Apply sealant
12. No gasket	Install gasket



TROUBLE SHOOTING

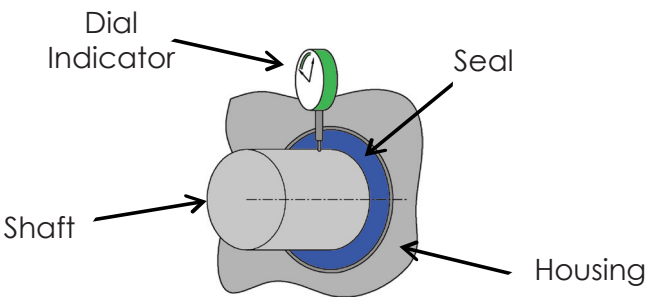
B.3.3 Check for Axial Shaft End Play

Probable Causes	Action or Countermeasures
1. Worn thrust bearing	Replace bearing
2. Shearing of lock ring or locking key	Check hardness of lock device and dynamic
3. Wear sleeve on shaft is loose	Check press or bond fit for sleeve
4. Negative stack-up in hardware tolerances	Review product prints



B.3.4 Check for Excessive Shaft Runout

Probable Causes	Action or Countermeasures
1. Failed bearing	Exceeded bearing load capacity. Excessive wear or contamination-replace bearing.
2. Excessive shaft deflection	Balance shaft and/or support shaft better
3. Shaft machined out of tolerance	Review shaft print specs and production limits and tolerances, and adjust process



B.3.5 Check for Shaft to Bore Misalignment

Probable Causes	Action or Countermeasures
1. Poor initial alignment (Fig. 1)	Review design and assembly operations and provide accurate alignment
2. Seal manufactured with high radial wall variation	Review production quality data, adjust process

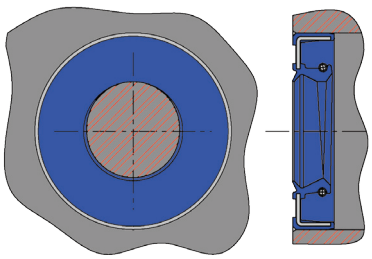


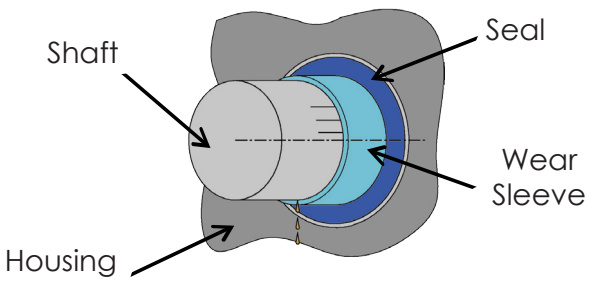
Fig. 1

B.3.6 Obtain Oil or Sealed Lubricant Sample

Probable Causes	Action or Countermeasures
1. Wrong fluid	Correct procedure for initial fill
2. Degraded fluid	Review fluid specification verses sump temperature and change the fluid requirement or sump temperatures
3. Degraded pre-lube	Specify pre-lube with temperature capabilities equal or better than fluid sealed
4. Contaminated fluid	Locate source of contamination and remove

B.3.7 If a Wear Sleeve is Used, Check for Leakage Between Shaft and Sleeve

Probable Causes	Action or Countermeasures
1. Improper sleeve press fit	Inspect at removal
2. Damaged shaft	Inspect at removal
3. Improperly finished shaft (chatter)	Inspect at removal



B.3.8 If Assembled Seal, Check for Leakage Between Clamped Elements

Probable Causes	Action or Countermeasures
1. Improper seal manufacturing (insufficient clamping force) (Fig. 1)	Consult seal manufacturer
2. Severe dish or bulge of seal assembly at time of installation (Fig 2)	Excessive interference between seal OD and bore

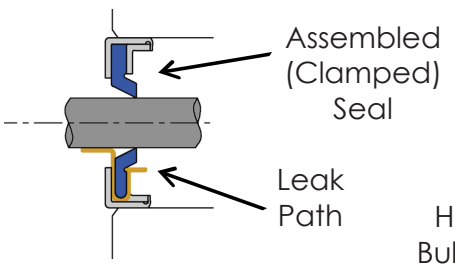


Fig. 1

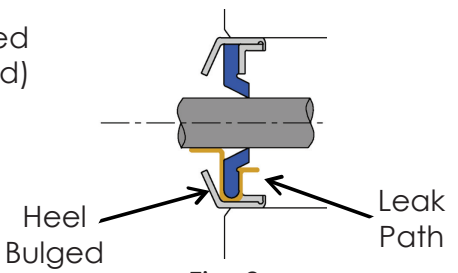
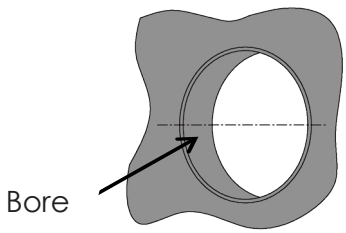


Fig. 2

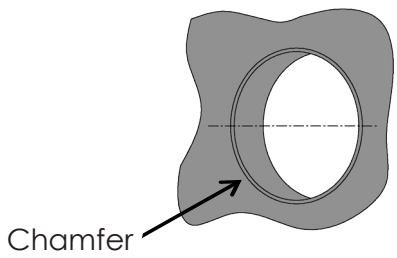
C.1.1 Measure Bore Diameter

Probable Causes	Action or Countermeasures
1. Seal loose	Use correct OD seal- machine bore to correct size
2. Oversize bore diameter resulting from seal press fit deformation	Check seal for proper OD size. Increase housing radial wall in area of seal gland
3. Tapered bore diameter resulting from improper machining techniques	Specify maximum axial diameter taper
4. Undersize or oversize bore due to design error	Contact OEM for corrective action
5. Oversize bore not in dimensional agreement with OEM specification	Unit may be a rebuild. Check seal OD diameter and order proper replacement part
6. Seal collapsed	Replace damaged seal with correct size



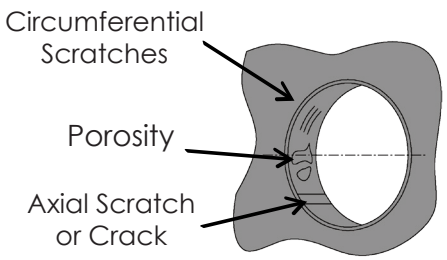
C.1.2 Check Bore Chamfer

Probable Causes	Action or Countermeasures
1. Chamfer lead-in not adequate to install seal due to improper chamfer angle	Review machining practices and product drawing
2. Deformation of lead-in chamfer edge due to chamfer diameter less than maximum OD of seal	Check OD of seal to insure not oversize, check ID of chamfer to insure it meets specs
3. Chamfer not present due to machining or product drawing error	Review product drawing and make the appropriate changes
4. Chamfer deformed due to seal installation	Increase bore hardness, use rubber OD seal
5. Chamfer too long causing insufficient flat area for seal retention	Check drawing and chamfer angle. Measure seal width to insure proper part and fit.



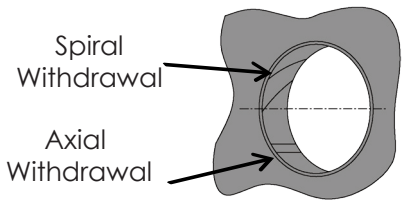
C.1.3 Inspect for Flaws or Voids in Housing

Probable Causes	Action or Countermeasures
1. Porosity in housing resulting from casting defect	Review foundry practices
2. Circumferential scratches, burrs, and gouges due to machining	Review machining techniques and specification
3. Cracks in housing due to heat treating or mishandling	Review material heat treating specification and handling practice
4. Grinding media embedment producing rough surface	Review machining practices



C.1.4 Check for Tool Withdrawal Marks on Bore

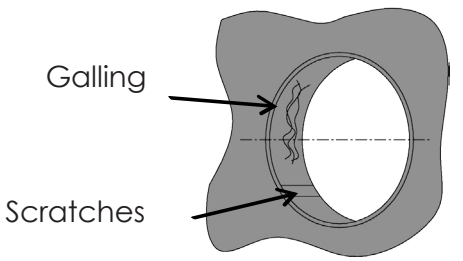
Probable Causes	Action or Countermeasures
1. Poor machining practices. Tool in contact with surface during removal	Review machining techniques
2. Leakage thru machine marks	Apply OD sealant to seal and/or bore. Machine to larger OD and use larger seal. Machine bore and install sleeve.



TROUBLE SHOOTING

C.1.5 Check for Severe Scratches or Galling Marks on Bore

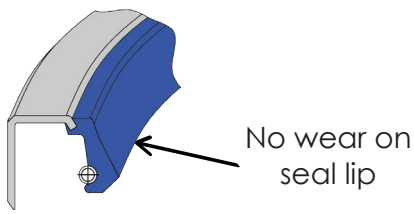
Probable Causes	Action or Countermeasures
1. Scratches and galling due to poor handling techniques	Review handling and shipping practices
2. Scratches and galling due to machining operations	Review machining practices
3. Scratches and galling due part assembly; i.e. shaft, seal and bearings	Review assembly practices
4. Leakage through imperfections.	Machine and use larger OD seal. Machine and install sleeve.



C.2.1.1 Lack of Wear

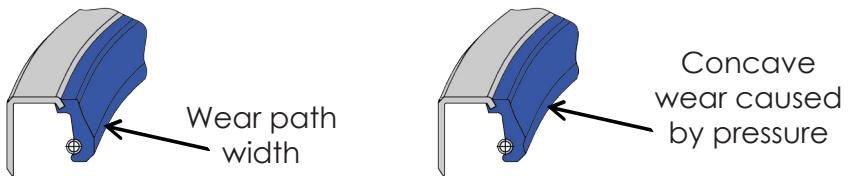
Usually associated with insufficient radial force or over-abundance of lubrication

Probable Causes	Action or Countermeasures
1. No interference with shaft	Check seal ID for garter spring. Check shaft dia. Observe shaft for evidence of contract. Look for concave distortion on outside face of seal
2. Very light interference with shaft	Check seal ID for low radial load. Look for concave distortion on seal outside face
3. Seal installed backwards	Check installation method and teardown report
4. Heavy continuous leakage from startup, possible from another source	Check fluid consumption reports – look for excessive interference. Leakage may be occurring through a defect; check seal ID and shaft for defects
5. Dynamic lift-off centrifugal force, flutter or stick-slip action	Check for low radial load and spring presence. Check lip opening pressure on shaft size mandrel.
6. Reverse hydrodynamic pumping direction	Check shaft rotation direction with helix. Check for spiral lead or axial scratches on shaft.



C.2.1.1 Excessive Wear

Probable Causes	Action or Countermeasures
1. Excessive interference	Check seal ID and shaft size (interference)
2. Excessive radial force	Check for high radial load. Look for small ID garter spring
3. Excessive pressure on lip	Check system pressure at operating conditions
4. Rough shaft finish	Inspect shaft for defects, measure surface finish
5. Insufficient lubrication at seal lip	Provide lube on seal airside or between lips



C.2.1.3 Eccentric Wear

Probable Causes	Action or Countermeasures
1. Seal cocked in assembly (Fig. 1)	Check shaft for wide wear path. Check installation procedure and equipment
2. Excessive radial wall variation of lip	Measure seal radial wall variation and relate to wear pattern
3. Excessive shaft to bore misalignment	Check shaft to bore offset (Fig. 2)
4. Angled or cocked shaft (Fig. 3)	Check shaft alignment, excessive runout or bent shaft
5. Side load applied to shaft	Check possible side deflection or loose bearings

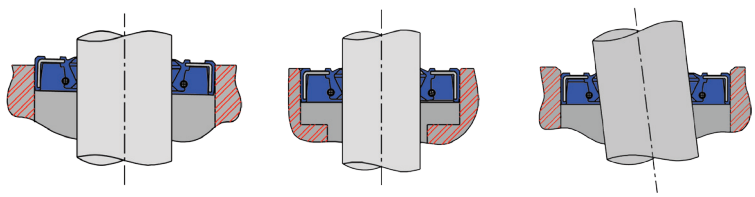


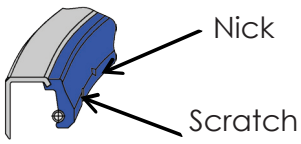
Fig 1
Cocked Seal

Fig 2
Excessive STBM

Fig 3
Cocked Shaft

C.2.1.4 Nicks, Scratches or Cuts at Lip Contact Area

Probable Causes	Action or Countermeasures
1. Sharp edge or burrs on end of shaft	Inspect shaft for burrs or sharpness
2. Sharp edge or burrs on installation tool	Inspect installation tool for burrs, sharp edge
3. Seal installed over keyway or splines	Use installation sleeve for splines, keyways
4. Trimming knife cuts	Check supplier's knife trimming methods
5. Nibbled appearance at sealing edge	Defects may be caused by bulk finishing or handling by supplier
6. Cuts from packaging method	Check supplier's packaging and shipping methods



C.2.1.5 Tears or Separations in Lip Area

Probable Causes	Action or Countermeasures
1. Stress fatigue in flex section (Fig. 1)	Check system pressure. Seal may be deformed in ID flex section
2. Bond separation at ID of metal case (Fig. 2)	Check seal for bond, burrs, and blisters
3. Migration of low temperature crack	Check lip contact area for minor cold cracks. Suspect severe side load at low temperature
4. Circumferential tear behind lip (Fig. 3) possibly from another source	Look behind lip at base for circumferential tear caused by pressure or fatigue
5. Caused during disassembly or removal	Review teardown and seal removal methods and check tools used

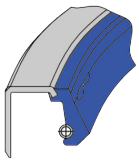


Fig. 1

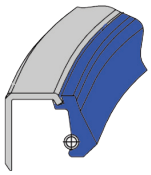


Fig. 2

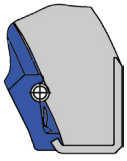
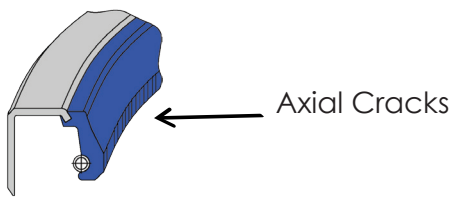


Fig. 3

TROUBLE SHOOTING

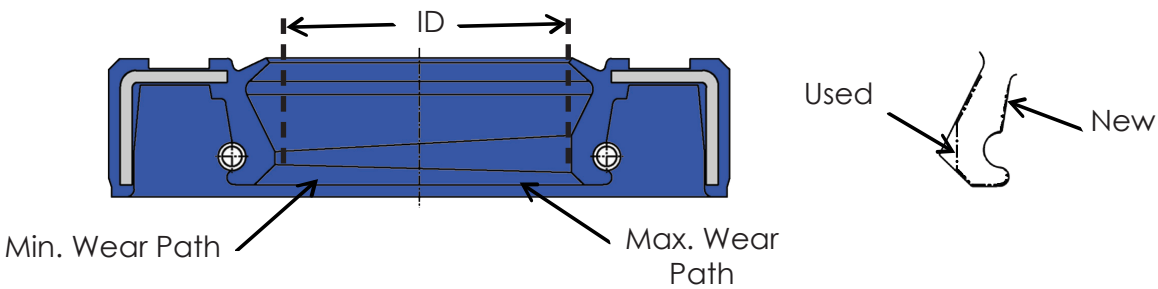
C.2.1.6 Hardening or Cracking of Rubber

Probable Causes	Action or Countermeasures
1. Prolonged or excessive high temp exposure	Check rubber spec. vs. system temp profile
2. Flexing of lip at temps below rubber capability	Check rubber spec. vs. system temp profile. Check offset, runout and sideplay
3. Extended dry running causing localized high temperature under lip	Check fluid level, check that shaft isn't too smooth
4. Cracking from disassembly or observation techniques	Review procedures and look for other damages
5. Ozone exposure	Check other dry areas of rubber, consider excessive solar or electrical exposure



C.2.1.7 Measure ID and Radial Load

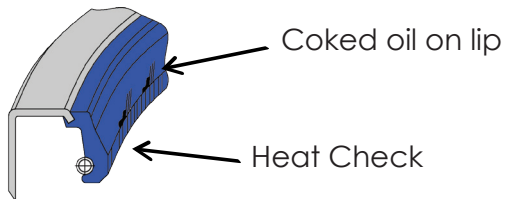
Probable Causes	Action or Countermeasures
1. Measure ID using non-contact device	Use optical comparator or linear scope. Record min/max readings and relate to leak
2. Measure wear pattern width and variation	Use optical means, photographic, or cross sections in comparator
3. Compare profile with profile of new seal	Section seal and mount on glass slide for magnified comparator viewing
4. Measure radial ID force	Use electronic split mandrel type radial load device (ref: RMA doc. OS-6)



TROUBLE SHOOTING

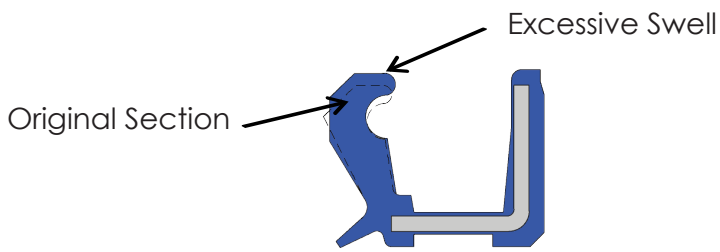
C.2.1.8 Coked Oil on Lip

Probable Causes	Action or Countermeasures
1. Hard and glazed deposit on ID	Possibly decomposed fluid. Scrape and analyze
2. Insufficient hydrodynamic pumping action	Helices ineffective
3. Excessive under-lip temperature	Check fluid specs vs. operating parameters



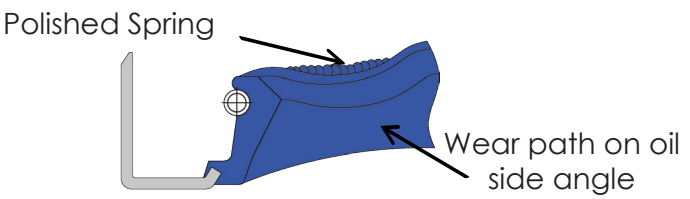
C.2.1.9 Softening or Swelling

Probable Causes	Action or Countermeasures
1. Volume change of material very high	Refer to elastomer physical data, check fluid
2. Reversion	Check elastomer/fluid compatibility specs
3. Exposure to solvent used during teardown	Review teardown procedure and elastomer compatibility with solvents
4. Operational contamination of fluid being sealed	Check for possible exposure to unspecified media coming in contact with seal



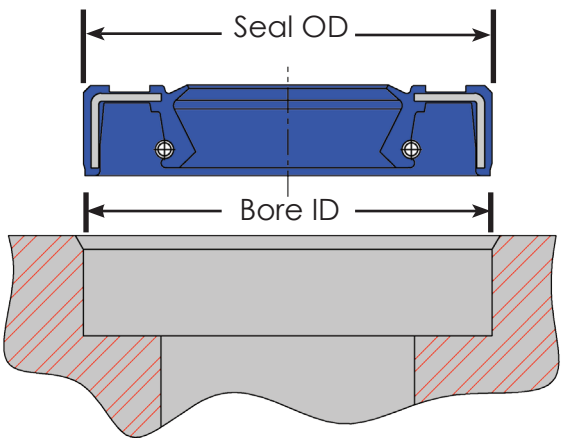
C.2.1.10 Inverted Lip Due to Poor Installation

Probable Causes	Action or Countermeasures
1. Oil to air side assembly	Provide installation aide such as bullet nose for shaft
2. Lack of proper concentricity assembly	Provide centering aide for assembly such as locating pins



C.2.2.1 Measure Seal Outer Diameter

Probable Causes	Action or Countermeasures
1. Wrong seal for application	Check for proper seal identification
2. Bore or housing reworked	Check housing print. Also check for evidence of rework such as chuck marks



C.2.2.2 Check for Severe Scratches on OD

Probable Causes	Action or Countermeasures
1. Damaged bore or bore chamfer (Fig. 2)	Check bore and chamfer condition
2. Die scratches from case operation	Check for OD coating or sealant in scratch (Fig. 1)

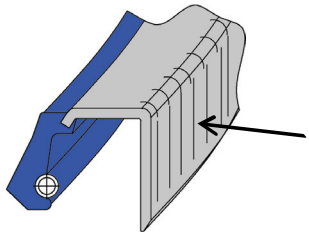


Fig. 1

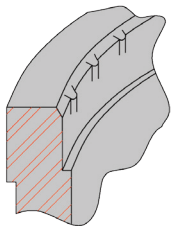


Fig. 2

C.2.2.3 Check for Peeled Rubber on OD

Probable Causes	Action or Countermeasures
1. Poor rubber bond to case (Fig.1)	Case OD clean at rubber interface
2. Lack of lubrication of OD at assembly	Case OD has rubber adhering to it
3. Lack of proper lead-in chamfer (Fig. 2)	Check bore chamfer condition

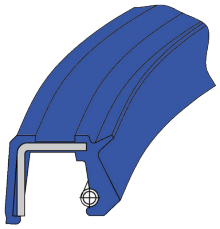


Fig. 1

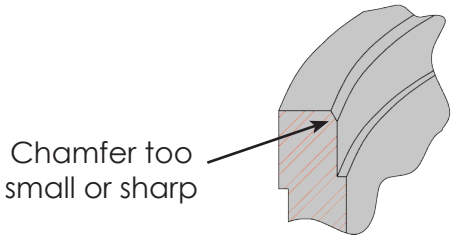
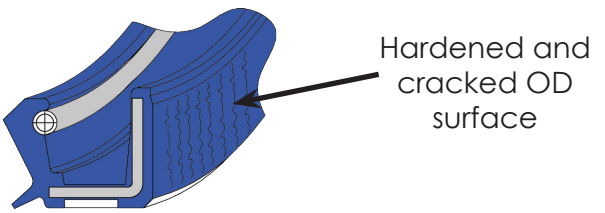


Fig. 2

C.2.2.4 Check for Hardened Rubber on OD (Rubber OD Design)

Probable Causes	Action or Countermeasures
1. Excessive heat in application	Check for other evidence of overheating
2. Improper seal material selection	Check material vs operating temperature of lube compatibility



C.2.2.5 Rubber OD Nonfills/Cuts

Probable Causes	Action or Countermeasures
1. Improper seal manufacture. Prep weight or shape out of spec. (Fig. 1)	Consult seal manufacturer
2. Bore chamfer sharp or damaged. (Fig. 2)	Inspect bore chamfer

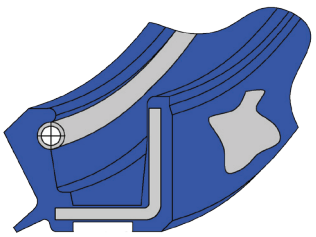


Fig 1

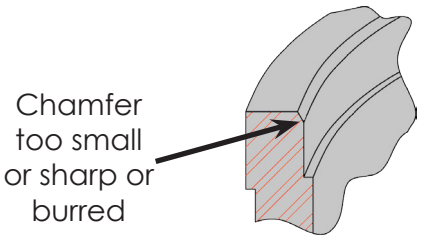
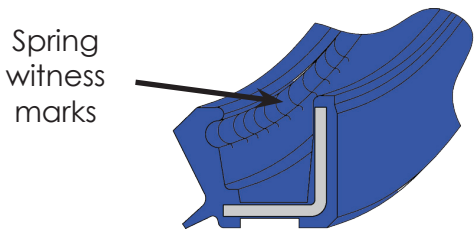


Fig 2

C.2.3.1 Missing Spring

Probable Causes	Action or Countermeasures
1. Seal may never have had a spring	Check for spring witness marks in spring groove. Also light wear on primary lip
2. Spring may have become dislodged during seal or shaft installation	Check installation procedures
3. Spring joint may have separated	Check installation procedures. Check garter spring joint quality (RMA OS-5)

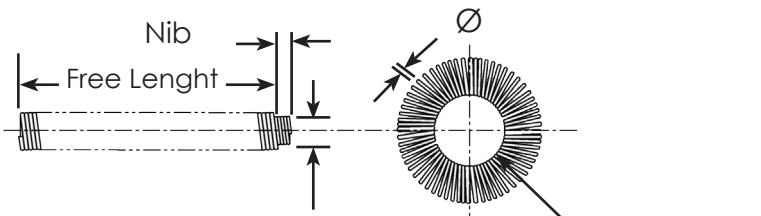


C.2.3.2 Corroded Spring

Probable Causes	Action or Countermeasures
1. Spring may not have had proper rust.	Check new seals from same supplier
2. Application may be exposed to excessive moisture	Check for moisture in lube or corroded components
3. Application may contain a corrosive fluid	Specify stainless steel spring
4. Seal may have been improperly packaged and/or stored prior to installation	Check service stock
5. Wrong spring material	Consult supplier

C.2.3.3 Check for Correct Dimensions and Spring Load

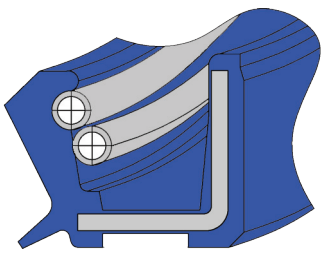
Probable Causes	Action or Countermeasures
1. Wrong spring on seal (excessive or no wear on primary lip) groove	Check seal drawing for spring dimensions. Also light wear on primary lip
2. Spring not properly normalized	Check seal drawing. Check for proper heat treatment (RMA OS-5)
3. Improperly manufactured spring	Check seal drawing for spring dimensions



Body diameter = D
Wire diameter = d
Free lenght = (Free ID + d)π
Free ID = Free lenght/ π-d

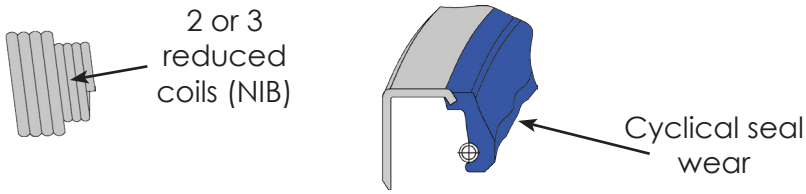
C.2.3.4 Multiple Springs

Probable Causes	Action or Countermeasures
1. Malfunctioning spring installation equipment at seal manufacturing location.	System audit at supplier.
2. Loose springs at seal installation station. Extra spring installed by assembler	Review installation station. Remove any loose springs. Review seal design and packaging.



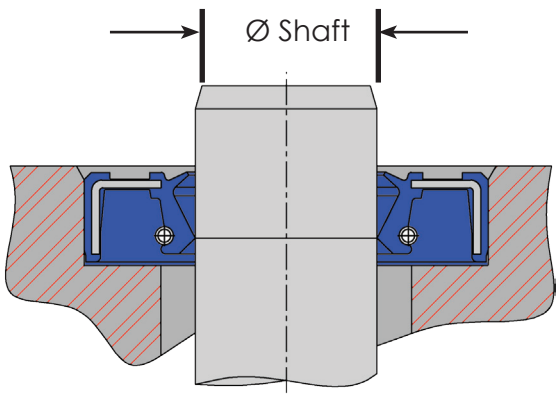
C.2.3.5 Separated Spring

Probable Causes	Action or Countermeasures
1. Improper spring nib configuration	Inspect spring per RMA OS-5
2. Excessive vibration or stick-slip of seal.	Inspect primary lip for excessive, cyclical seal wear
3. Improper seal installation. Review installation procedures.	



C.3.1 Shaft Diameter

Probable Causes	Action or Countermeasures
1. Oversize shaft may accelerate lip wear, increase heat generation, shaft wear may cause lip to invert during installation	Replace shaft, or, if oversize, machine to proper diameter.
2. Undersize shaft may result in insufficient lip interference to seal properly, resulting in premature leakage.	

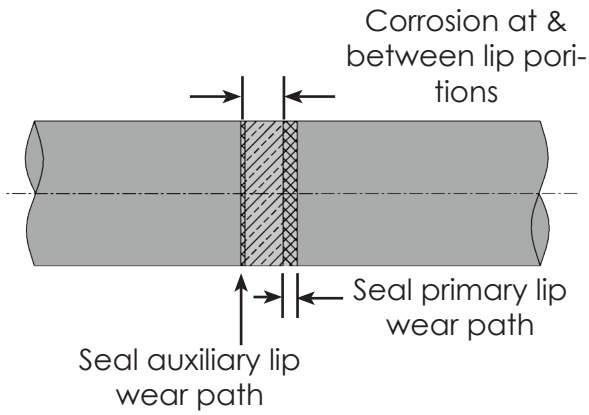


C.3.2 Shaft Surface Roughness (Primary Sealing Surface)

Probable Causes	Action or Countermeasures
1. Excessively rough shaft may accelerate lip wear and if too rough, leak upon initial startup 2. Undersize shaft may result in insufficient lip interference to seal properly, resulting in early leakage	Replace shaft or, if oversize, machine to proper diameter

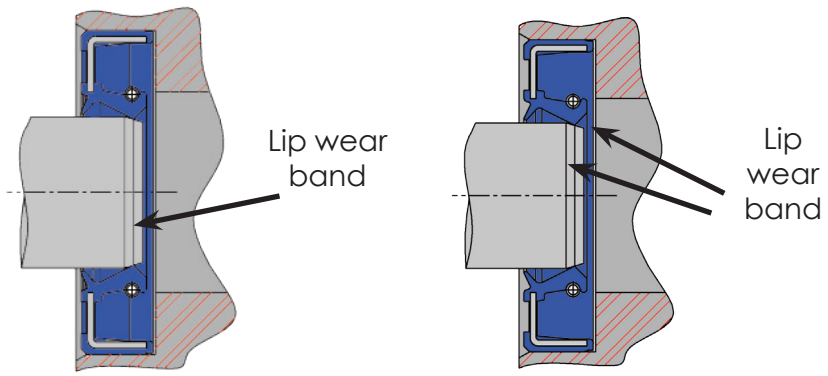
C.3.3 Shaft Corrosion

Probable Causes	Action or Countermeasures
	Apply corrosion-resistant shaft material
1. Corrosion on the shaft in the area of the lip contact will interfere with lip's ability to seal against the shaft surface properly. The increased surface roughness may provide leakage paths and lip wear may increase from higher roughness	Use Replaceable corrosion-resistant shaft sleeve Change assembly design to limit access of corrosive contaminates Change to seal design that will protect shaft from corrosion so lip can function normally. If corrosion from inventory storage before assembly- change inventory system.



C.3.4 Lip Wear Band in Wrong Location on Shaft

Probable Causes	Action or Countermeasures
1. Insufficient/excessive lip interference may occur affecting lip's ability to seal.	Make sure proper seal is used (width to specs?)
2. Improper seal of seal lip may contact shaft resulting in high temperature or leakage due to improper lip orientation	Make sure seal installed to proper depth (not too deep/shallow) installation tool/procedure may be revised to ensure proper depth.
	Check shaft or assembly per specs
4. Seal moving after installation	Check install method, seal and bore diameter
5. Metal case of seal deformed during installation.	May orientate lip improperly.

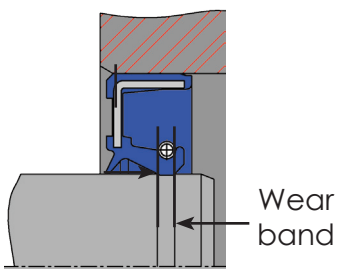


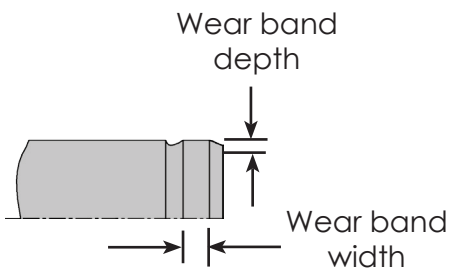
C.3.5 Scratches or Nicks at Lip Contact Area on Shaft

Probable Causes	Action or Countermeasures
1. Scratches or nicks (if large enough) across the seal contact area of shaft act as leakage paths.	Check handling procedures of shaft from time shaft is machined until it reaches assembly area special carrying trays that protect shafts from hitting each other area suggested. Special cardboard or nylon mesh sleeves are commonly used.
2. Shaft damaged during actual assembly.	May require assembly method or jig change.
3. Worker mishandling causing damage.	Improve handling method
	It may be possible to rework shaft to remove defect but shaft roughness or diameter should not be altered outside of design spec.
	Harden shaft to minimum RC 45 to improve resistance to scratching or nicking.

C.3.6 Excessive Shaft Wear

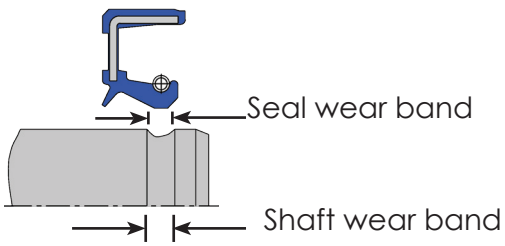
Probable Causes	Action or Countermeasures
1. Seal lip will have difficulty sealing against the shaft wear band if depth is too large or width is too wide.	Check shaft hardness, may get harder shaft
	Outside contaminant ingestion may cause problem. Use contaminant-resistant design.
	Improper lubrication can cause accelerated shaft wear. Check lube compatibility with lip and quantity of lubricant reaching seal.
4. Contaminant present in fluid to be sealed.	Check compatibility and change fluid more frequently or filter more effectively.
	Proper lip interference. Check shaft diameter and seal to make sure to specs.
6. Excessive eccentricity can cause unusual wear.	Check for excessive runout or shaft to bore misalignment.





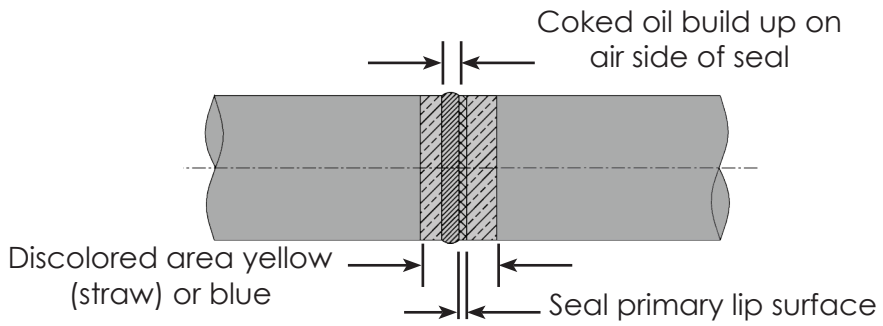
C.3.7 Wide Shaft Wear Band Relative to Seal Wear Band

Probable Causes	Action or Countermeasures
1. Leakage may result prematurely as lip cannot maintain proper orientation against the shaft	Check for seal cocking and correct installation procedure if found.
2. Leakage may occur as wide shaft wear band may act as leakage path.	Excessive axial motion can cause this type of wear. Check assembly and replace bearing if defective or worn.



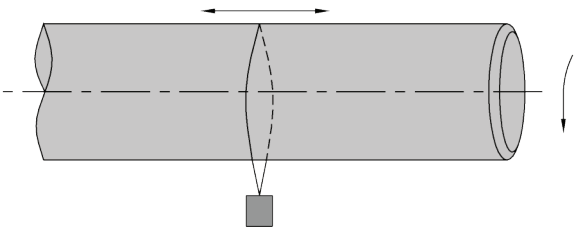
C.3.8 Shaft Discoloration or Coked Oil on Shaft

Probable Causes	Action or Countermeasures
1. Discoloration may indicates excessively high temperatures. The high temperatures may affect other characteristics of seal (lip hardness) resulting in premature failure.	Check quantity of lubricant reaching seal and increase if necessary.
2. Coked oil buildup will interfere with the seal lip's ability to contact shaft which will result in failure	Was shaft diameter or lip ID causing too much interference? Change to reduce interference.
3. Bearing preload too high causing temperatures in seal area to be very high.	Set bearing to proper preload.
4. Shaft too smooth causing seal to run hot.	Check shaft roughness.
5. Excessive pressures in seal cavity can load seal lip excessively against shaft causing high temperatures.	Reduce pressure or use pressure-resistant seal design.
	Change oil to high temperature resistant fluid.
	Reduce operating temperature of final assembly to range compatible with lube and seal material.



C.3.9 Machine Lead

Probable Causes	Action or Countermeasures
1. Machine lead may hydrodynamically pump medium to be sealed out, depending on shaft rotation direction.	Finish shaft as recommended in RMA document OS-1 to eliminate machine lead.



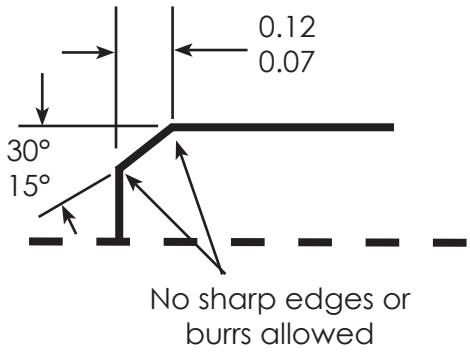
Shaft being checked for lead per procedure in OS-1

C.3.10 Shaft Hardness

Probable Causes	Action or Countermeasures
1. Shaft with hardness less than Rc 30 may experience accelerated wear, especially if sealing in a highly abrasive environment.	Harden shaft or use harder shaft material proper diameter.
2. Rc 45 is the preferred hardness if handling defects (scratches or nicks) are likely.	Use wear sleeve.
	Reduce amount of contaminants reaching seal by changing to contaminant-resistant seal design or changing assembly design to limit outside contaminants. Change fluid more frequently if inside contaminants. Using better wear resistant bearing, gear, or other metal components inside assembly will help reduce contaminants in lubricant.

C.3.11Shaft Chamfer Condition

Probable Causes	Action or Countermeasures
1. Insufficient chamfer may cause seal lip to invert, cause garter spring to pop off or make installation very difficult.	Apply proper shaft chamfer as recommended in RMA document OS-4.
2. Sharp edges or burrs may cut seal lip or cause lip to invert.	Use a shaft sleeve, mandrel or bullet to protect seal lip during installation.

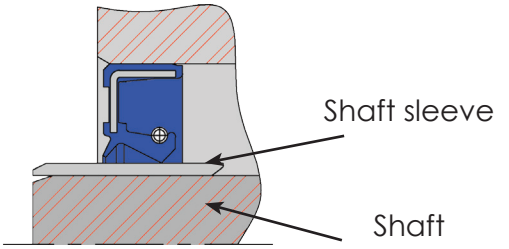


C.3.12 Proper Shaft Material

Probable Causes	Action or Countermeasures
1. Primary concern is achieving recommended shaft hardness and/or resistance to corrosion if in a highly corrosive environment.	Change shaft material to compatible material for application Shaft wear sleeve may be applied.

C.3.13 Wear Sleeve Fit

Probable Causes	Action or Countermeasures
1. Improper fit of the sleeve may result in a deformed sleeve.	Follow proper installation methods to insure sleeve is not damaged during installation.
2. Leakage may occur between sleeve ID and shaft diameter	Check shaft chamber for burrs or nicks or improper angle/ depth and correct
3. If sleeve is loose, it may rotate separate from shaft resulting in excessive heat generation	Use additional sealant to prevent sleeve ID/shaft interface leakage Check shaft diameter OD/ sleeve ID to see if correct-replace if necessary. Also, sealant such as loctite or permatex may prevent sleeve from spinning.



C.4.1 Contaminants in Oil

Probable Causes	Action or Countermeasures
1. Inadequate cleaning of unit prior to assembly.	Review procedure to insure removal of machining debris prior to part assembly.
2. Ingestion of contaminates past seal.	Inspect seal for presence of exclusion lip. For spring load seal, check for spring.
3. Wear debris: e.g. bearing, shaft and other dynamic contact parts.	Inspect dynamic components for excessive wear.
4. Oil contamination during storage	Check storage procedures for bulk oil supply.
5. Oil contamination by vendor	Check in-house and incoming oil containers for contaminates.
6. Break-down of hydraulic hosing and similar system components due to material deterioration	Check material fluid compatibility.
7. Sobotage	Install tamper-proof fill cap.
8. Worn seal	Replace oil, filter oil, and clean housing.
9. Sintered (powdered metal) components	

C.4.2 Composition of Lubricant Compared to New

Probable Causes	Action or Countermeasures
1. Changes in fluid lubricity, viscosity	Send oil sample to vendor for analysis
2. Apparent color differences	Send oil sample to vendor for analysis
3. Noticeable odor difference	Send oil sample to vendor for analysis
4. Noncompatible "substitute" fluid	Use fluid specified by OEM
5. Contaminates in fluid	Replace fluid; filter fluid