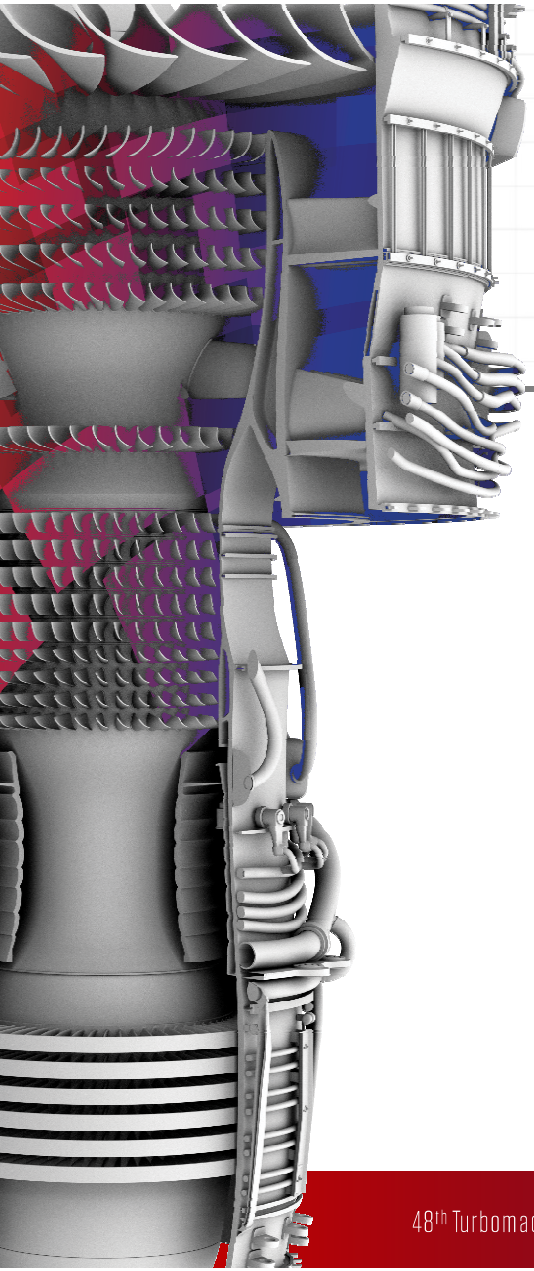


TURBOMACHINERY & PUMP SYMPOSIA

Extending MTBF of Seals in Boiler Feed Water Service

Case Study – Christopher “Topher” Ropp

Principal Engineer - Flowserve AMSS, Kalamazoo MI

FLOWSERVE

Problem

- The customer experienced short seal life on a set of multi-stage, double ended pumps that were commissioned in 2009.
- A single seal design with piping plan 23 system was used with pump cooling jackets.
- The average seal life was less than 12 months (1 year) MTBF.
- There were 10 Seal Failure Analysis performed before a team was pulled together to analyze the system.

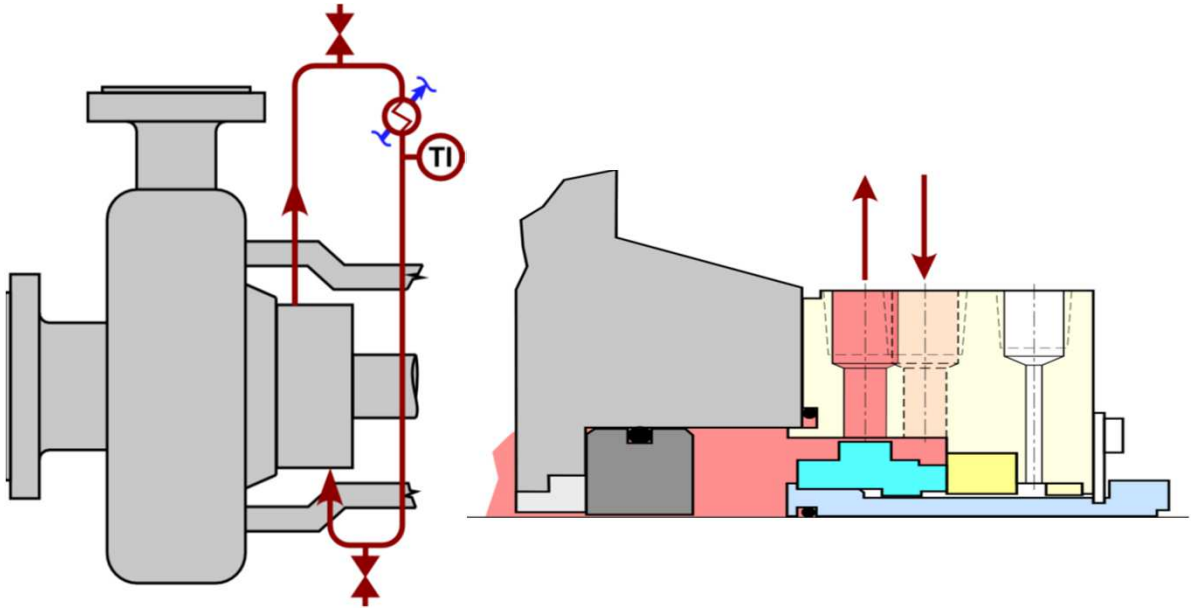
Service

- Pumps: Double Ended Multi-Stage
- Product: Boiler Feed Water (BFW)
- Temperature: 264 to 360°F
- Suction Pressure: 160 to 540 psig
- Chamber Pressure: 540 to 609 psig
- Discharge Pressure: 3480 psig
- Speed: 3200 to 5500 rpm
- Cooling Water: 80 to 110°F
- CW Flow: 5 to 8 gpm

Piping Plan

Plan 23

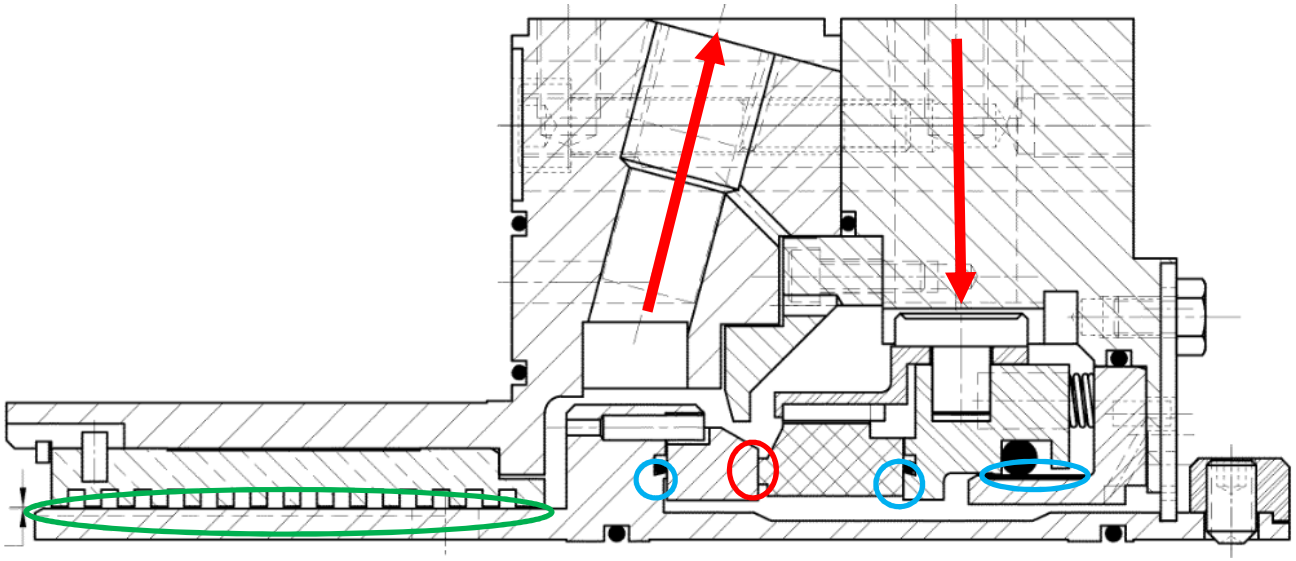
- Seal Flush from internal pumping device through cooler.
- Efficient seal cooling with lower cooler duty (reduces fouling).
- Standard flush plan in hot water services.



Root Cause Analysis

Three RCA's were performed that pointed to areas of concern:

1. Inadequate plan 23 cooling (Red)
2. Excessive Fretting (Blue)
3. Bushing Contact (Green)



1. Inadequate Cooling

Issues Included:

- Plan 23 - Seal Cooler Product Temp

  Temp In & Out should be below **160°F**

- Cooling Water Delta Temps

  Both the Plan 23 Cooling Water and Pump Jacket Cooling Water Delta Temps were elevated - above **20°F**

Measured Temperatures of Feed Pump Seals on 9/20/2016	A-PUMP	
	Drive End	Non-Drive End
Pump Started Up on 8/24/16	96 days	
Speed (rpm)	5295	
Boiler Feed Water Temp at the pump (°F)	315	
Plan 23 - Seal Cooler		
Seal Cooler Temp In (°F)	190	191
Seal Cooler Temp Out (°F)	176	151
Seal Cooler Delta Temp (°F)	14	40
Seal Cooler Cooling Water		
Seal Cooler Cooling Water Temp In (°F)	104	105
Seal Cooler Cooling Water Temp Out (°F)	133	125
Seal Cooler Cooling Water Delta T (°F)	29	20
Pump Jacket		
Pump Jacked Cooling Water Temp In (°F)	104	105
Pump Jacked Cooling Water Temp Out (°F)	142	134
Pump Jacket Cooling Water Delta T (°F)	38	29

1. Inadequate Cooling

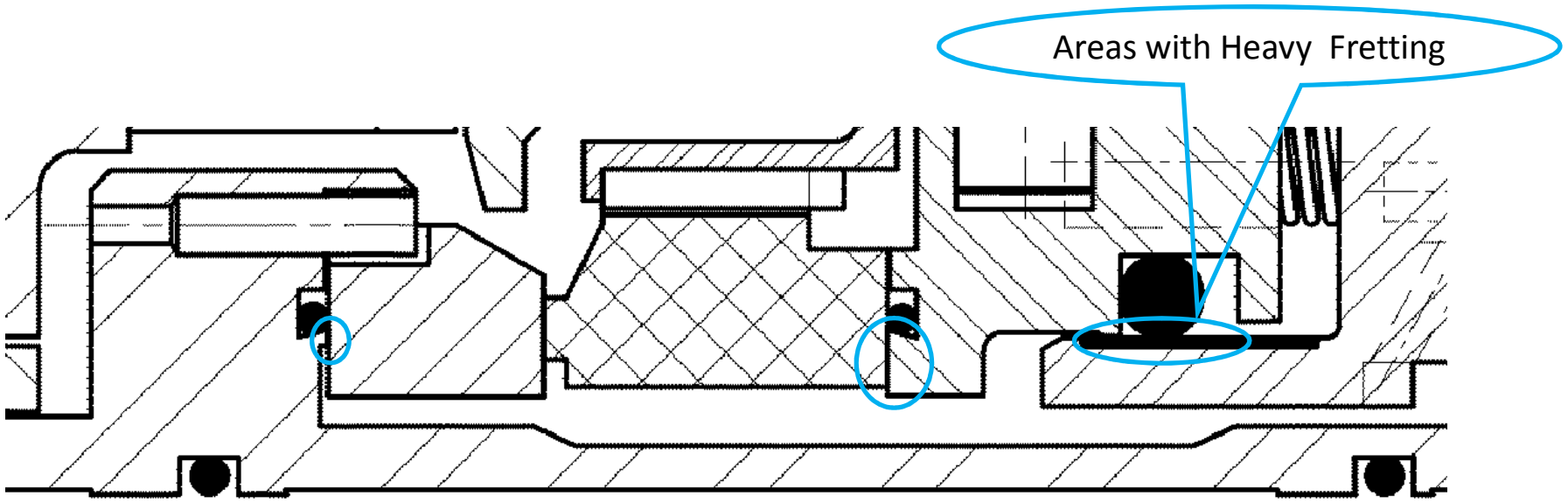
Lead to Excessive Face Damage

Carbon - Stator

Silicon Carbide - Rotor

2. Excessive Fretting

Heavy Fretting was noticed in three (3) distinct areas



2. Excessive Fretting

Heavy Fretting was noticed in three (3) distinct areas

Figure 38: Back of rotating face

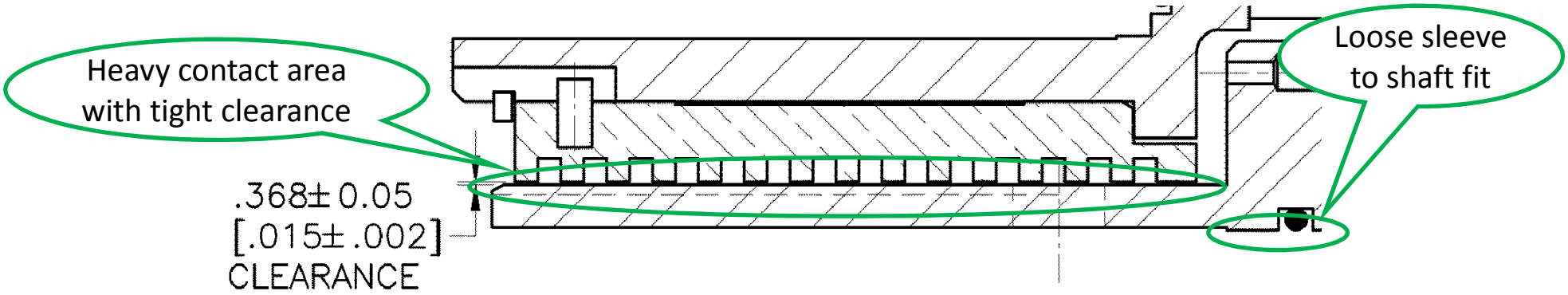
Figure 32: Back of stationary face

Figure 52: Fretting marks on dynamic

3. Heavy Bushing Contact

Heavy contact between the Sleeve OD and Bushing ID

- The Long Metal Bushing was designed for Pressure Breakdown
- Tight 0.015” radial clearance
- Loose sleeve ID to shaft OD clearance
- One key slot was in the bottom of the sleeve



3. Heavy Bushing Contact

Figure 3 - Entire Sleeve as Returned

Figure 19: Sleeve (1) bottom half

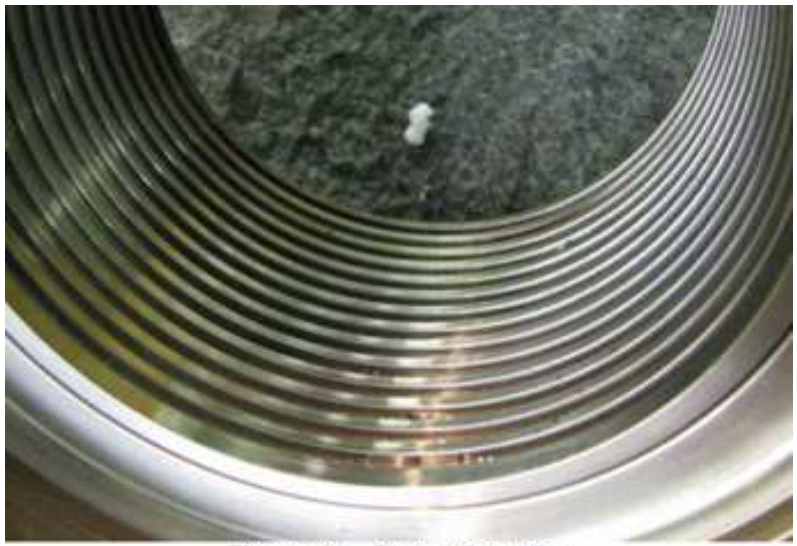
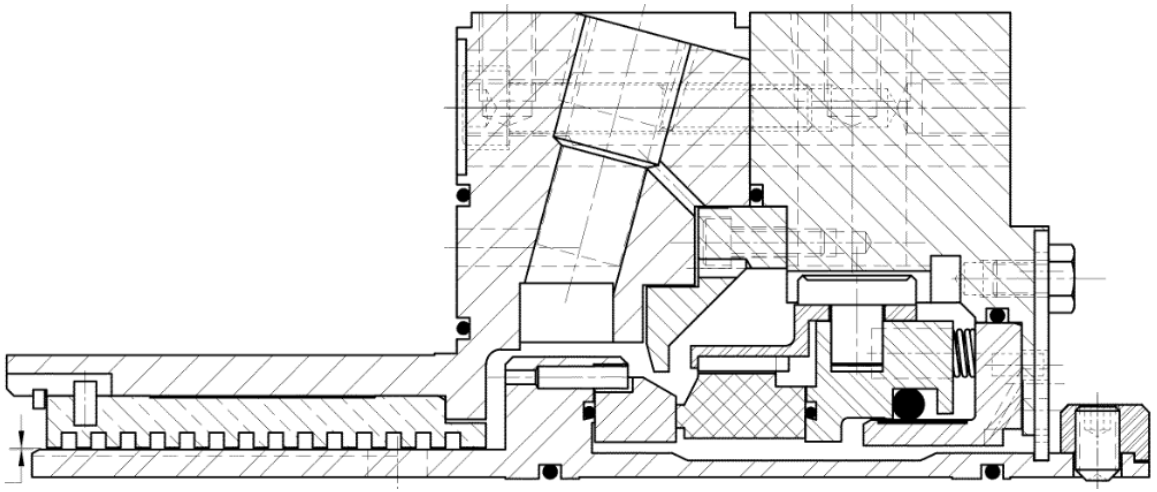


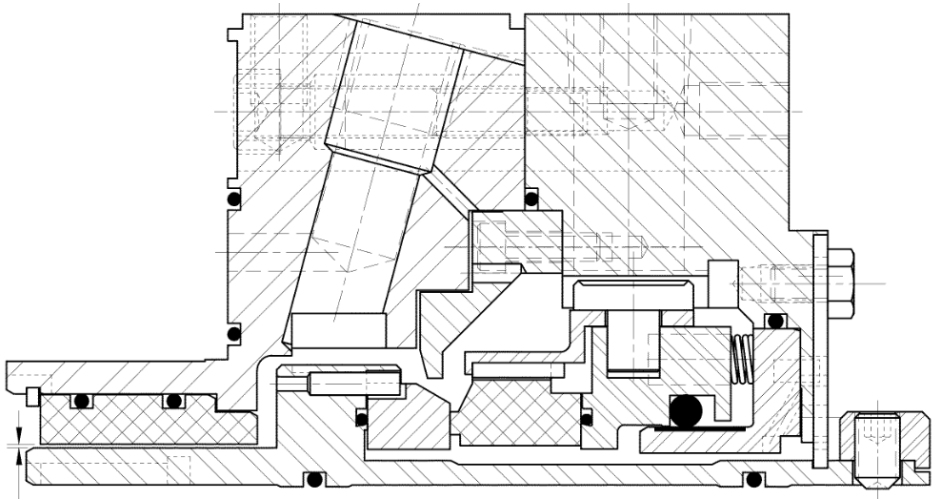
Figure 20 - Throat Bushing

Redesigned Seal

Original Seal

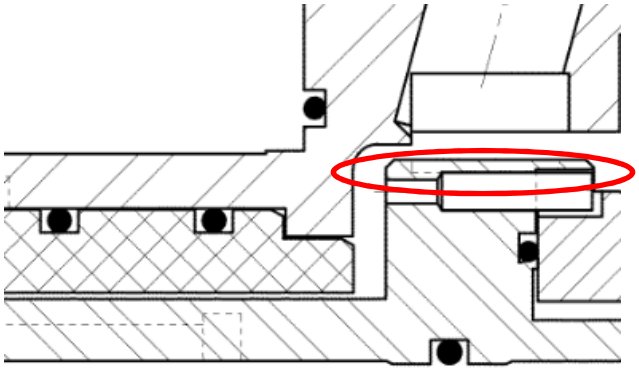


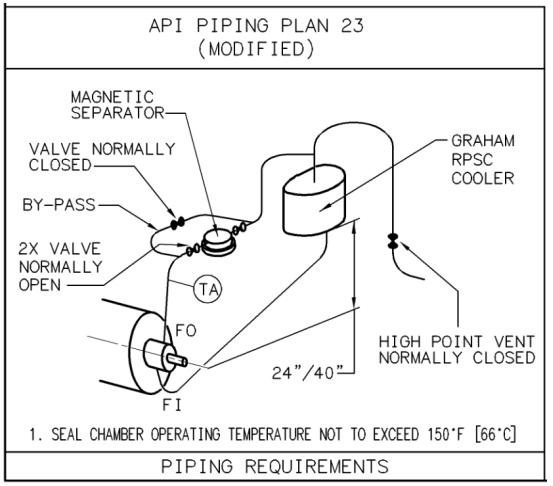
Redesigned Seal



Solution

1. Inadequate Plan 23 Cooling
   - Added an internal pumping device to OD of Sleeve to increase the seal circulating device flow (3 – 5 gpm)
   - Installed larger capacity Plan 23 seal coolers
   - Needed more CW flow to remove heat - ran new CW piping to each end of the pump (10 - 15 gpm)

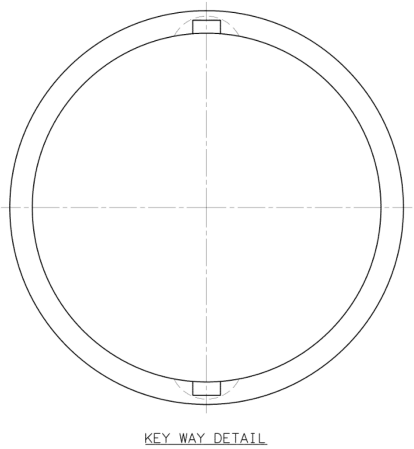


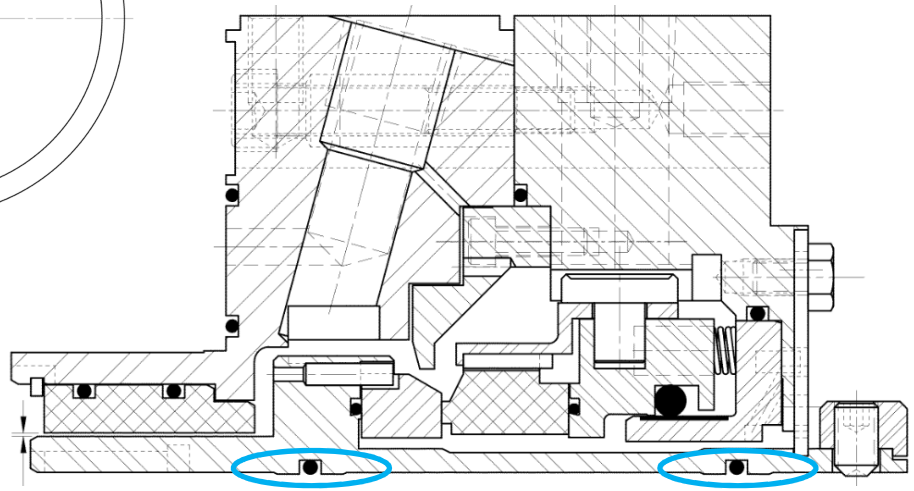


Solution

2. Excessive Fretting

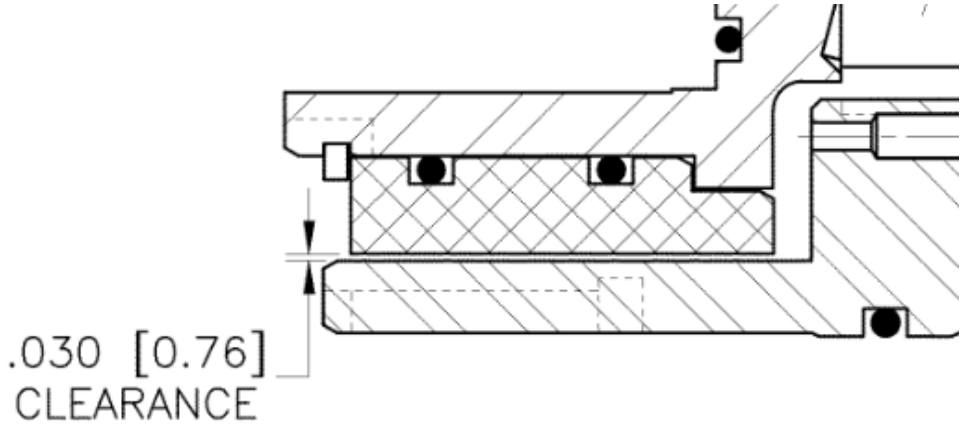
- Seal cavity temperatures above 160°F can cause flashing and instability within the seal
- Reduced sleeve to shaft clearance to API 682 fits of F7/h6 will reduce seal wobble
- Added 2nd key slot to the sleeve ID for higher speed mechanical stability at 5500 rpm





Solution

3. Heavy Bushing Contact
   - Redesign bushing to a shorter Carbon thermal break design vs. Metal pressure breakdown design
   - Increased Bushing clearances to ensure no contact between the Bushing and Sleeve
   - Changed sleeve to 17-4 material that is stronger and lower thermal expansion rate



Results

- Redesign seals and upgrades were completed during Q1-17, started 4/17
- Pumps experienced a couple “Hard Shut downs” during start up, with no leakage. Seals are running leak free, with no issues
- Before and After Redesigned Seal Measured Temperatures:

	A Pump		B Pump	
	Before	After	Before	After
Seal Cooler Temp In (°F)	190 / 191	143 / 147	168 / 190	145 / 144
Seal Cooler Temp Out (°F)	176 / 151	116 / 121	155 / 170	120 / 118
Seal Cooler Delta Temp (°F)	14 / 40	27 / 26	13 / 20	25 / 26

Lessons Learned

- Reducing the sealing system temperatures below 160°F will result in stable seal system to adequately lubricate the mechanical seal. Doing this may require increased seal circulation, larger seal coolers with higher cooling water flow rates
- API 682 defined F7/h6 sleeve to shaft clearances allow for ease of installation and still have proper fits.
- Replace longer, tight clearance Metal pressure breakdown bushing with a shorter, loose Carbon thermal break bushing will reduce heat soak load as well as contact issues.
- Adding of a 2nd key slot to the sleeve ID for increased stability at higher speeds.