TPS

51ST TURBOMACHINERY & 38TH PUMP SYMPOSIA

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Effects of Seal Configuration on Seal Performance in Contaminated Applications

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Flowserve

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Introduction

- Gas liquefaction plant in Algeria produces up to 4.7 million tones of LNG/year
- Liquefaction process requires heating and cooling of natural gas
- Heat Transfer Fluid is utilized in a temp. range of 200 – 250°C (392 – 482°F)
- Hot oils used as heat transfer fluids can be either synthetic or hydrocarbon-based
    - Fluid properties are designed for long life, low degrees of fouling and pumpability
- In this case, the customer uses “MT” 605, a highly refined hydrocarbon from base stocks with improved oxidation and thermal cracking properties

Operating Conditions

Pump Style	BB2 (2 seals, DE & NDE) per API 610
Pumped Product	Heat Transfer Mineral Oil (Mobiltherm 605)
Temperature	165°C norm / 235°C max (329/455°F)
Viscosity	1.5 cSt
Speed	1480 rpm
Suction Pressure	7 bar norm / 10 bar max (101/145 psi)
Discharge Pressure	20 bar norm (290 psi)
# of Pumps in Loop	3 (2 continuously running, 1 spare)

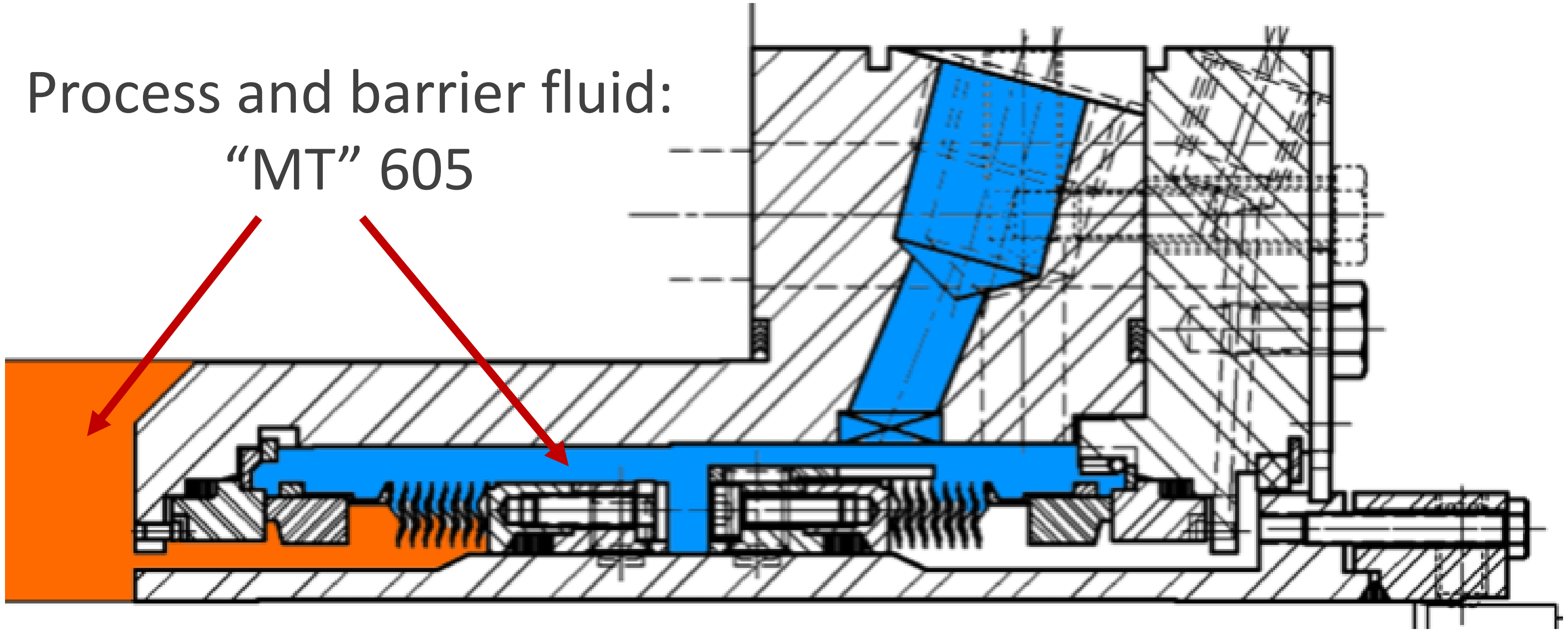
Mechanical Seal & System Design

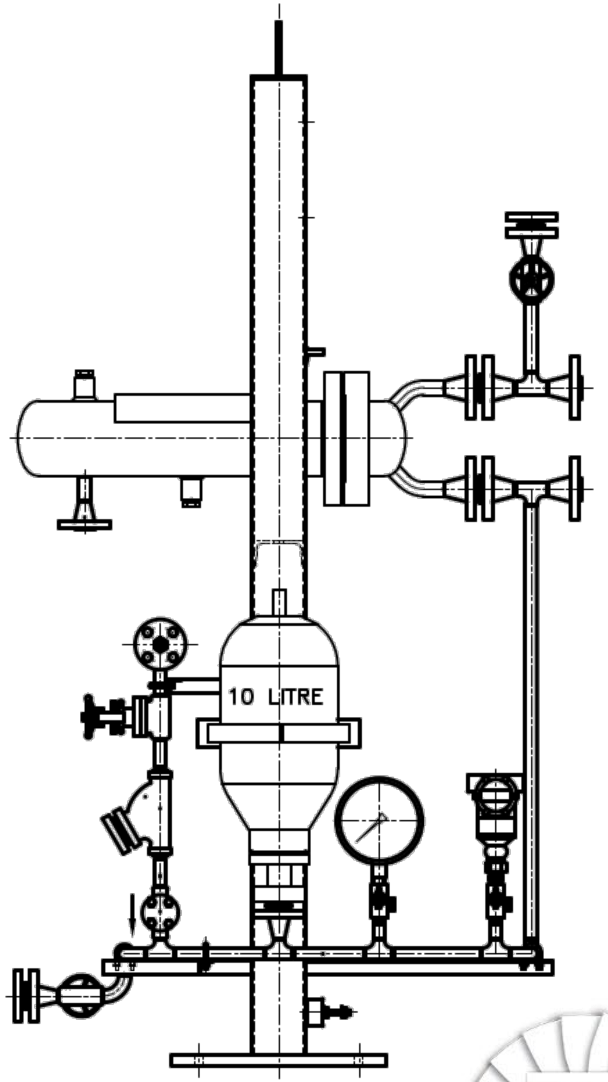
- Metal bellows mechanical seal selected, Type C, back-to-back, Arrangement 3, per API 682 requirements
- Both inboard and outboard seals with soft vs hard faces (carbon/silicon carbide), graphite gaskets, Alloy 718 bellows
- Plan 53B pressurized system configured with a 10 liter accumulator and bundle type cooler
- Plan 61 atmospheric control in seal, unused at plant
- Two seals per pump, two 53Bs per pump

Mechanical Seal & System Design

- Seal Type : HT bellows/HT bellows 5.500/5.500
- Seal Configuration : Type C, 3CW-BB
- Shaft Size : 125 mm (4.921")
- Auxiliary System : Plan 53B (10L Accumulator)
- Barrier pressure : 12 to 19 barg

Process and barrier fluid:
"MT" 605



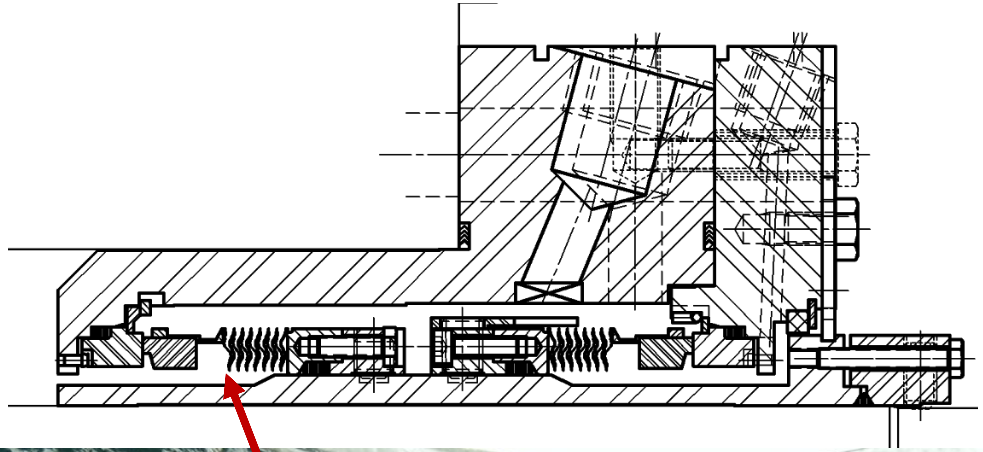


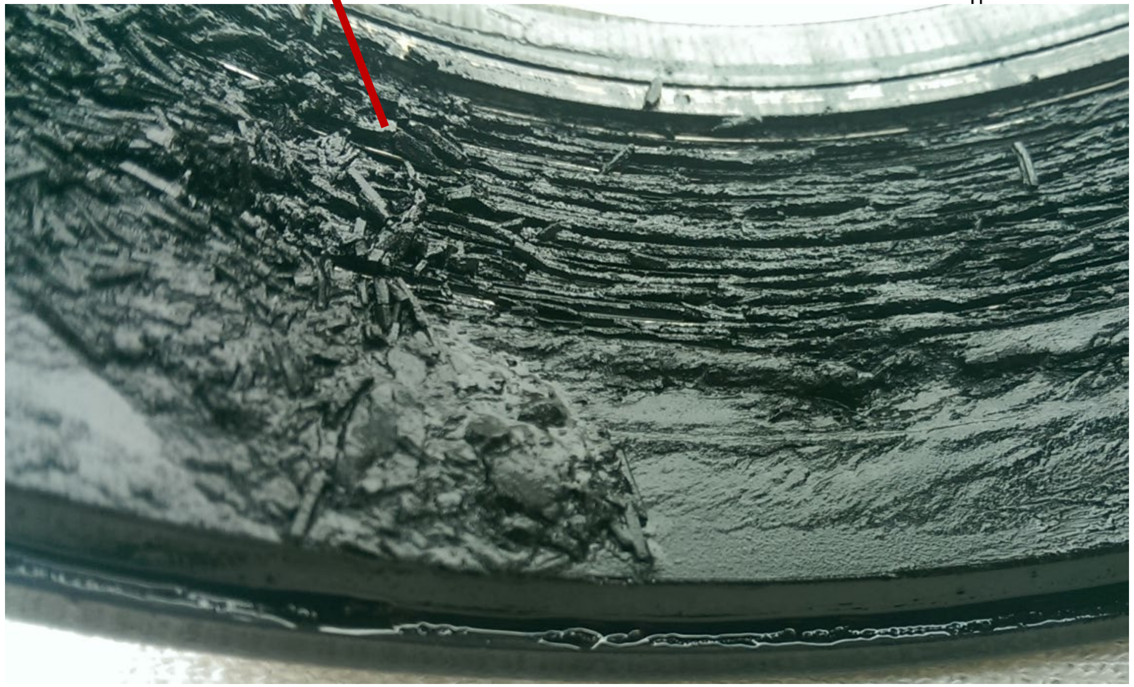
Failure Evaluation

- Several failures after plant commissioning, MTBF <8 weeks
- Failure = rapid barrier pressure loss
- Failure especially evident when pump is put on standby
- External evidence:
  - No atmospheric leakage observed
- Internal evidence:
  - Seal barrier and atmospheric side very clean
  - All seal faces in good condition
  - Inner seal bellows clogged with sludge / solidified coke particles

Failure Evaluation

- Typical findings



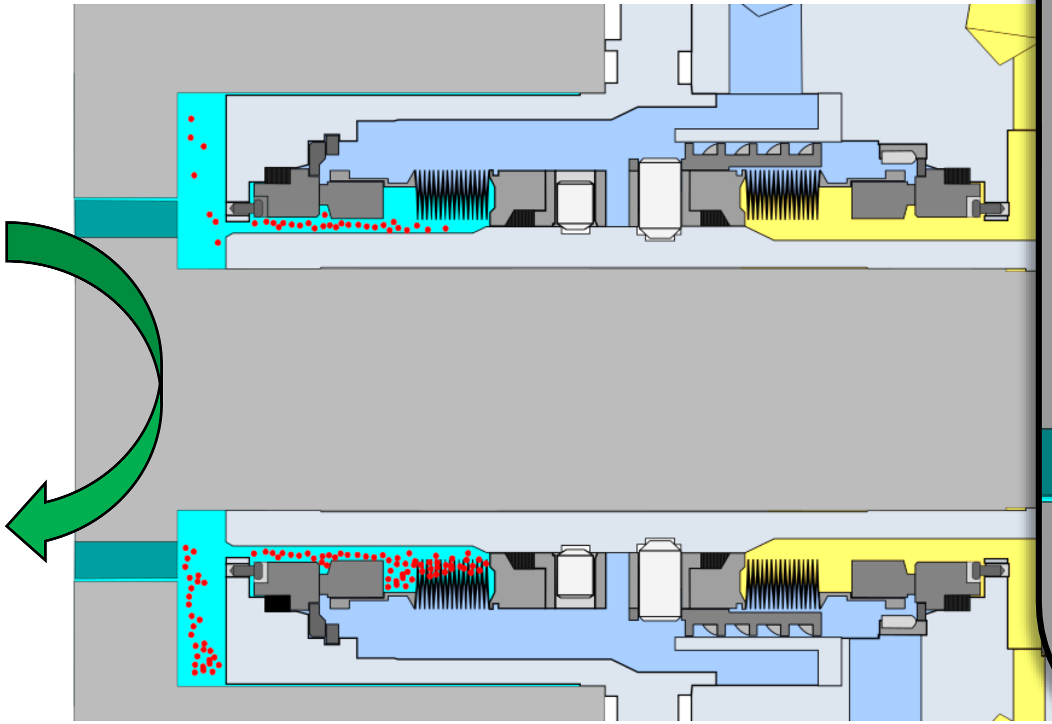


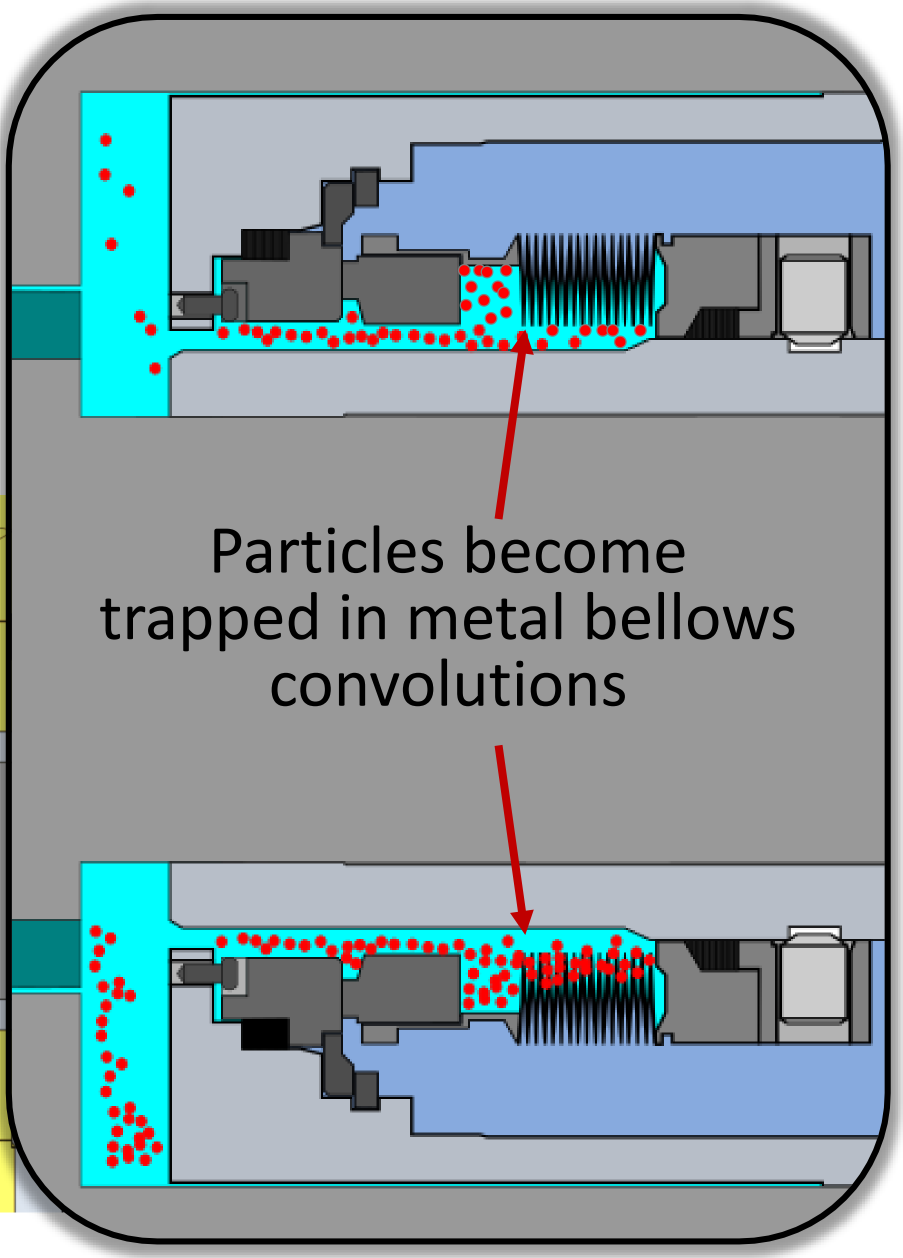
Analysis

- Hot oil process meant to be clean and filtered has fine coke particulate
- Pump location promotes settling of particles in the pump and seal chamber - lowest point in the system
- From all inspections, inboard metal bellows found effectively solid
- B2B arrangement seals succumb to particle collection, clogged bellows convolutions and prevention of “spring” function
  - Centrifugal effects actively promote particle accumulation inside the bellows
  - No possibility for cleaning or flushing

Failure Mode

- Shaft rotation centrifuges solids





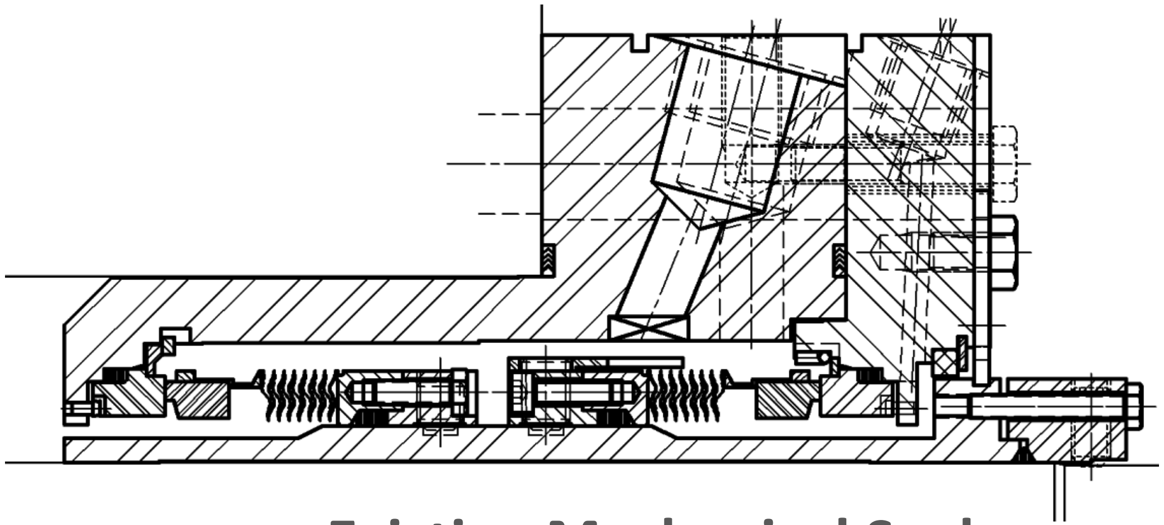
Other Challenges

- Required average 25 days between refilling as per API 682 3rd edition
- No possibility to use flushing piping plans (Plan 11, 31, 32 …etc.)
  - No piping modification (cost and complexity) and/or external source allowed
- No possibility to modify 53B support system
  - No accumulator size or cooling capacity changes
- No possibility to change process loop filter design

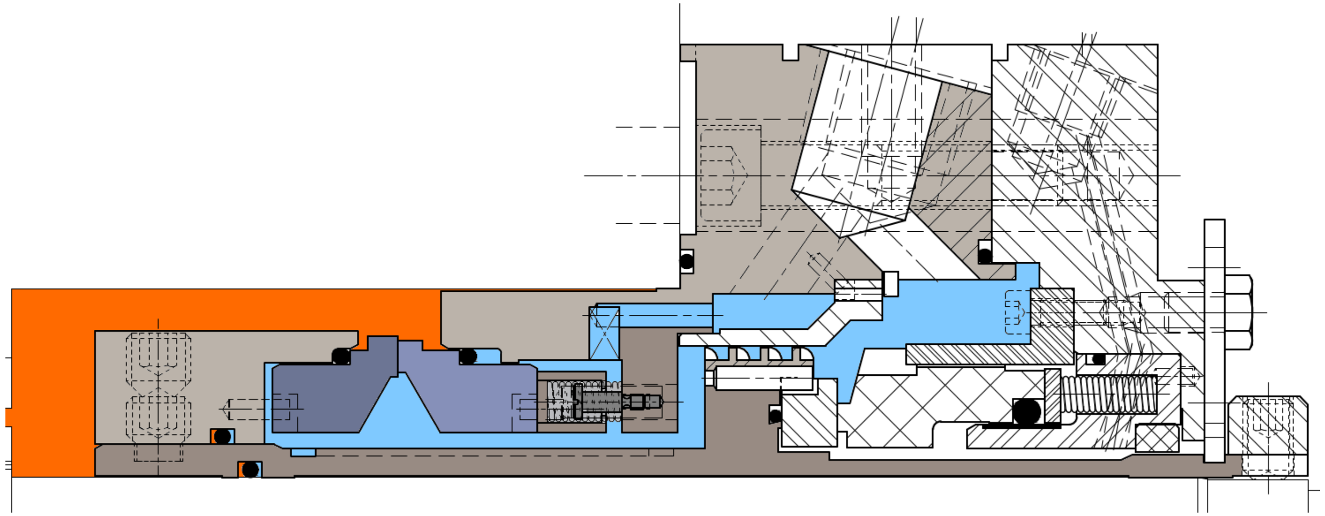
Proposed Solution

- Keep process on the outside diameter to promote “self-cleaning” effect
- Mitigate solids with Face-to-Back arrangement
- Pusher seals are capable of 19 barg differential pressure
- Although max temperature is above the usual recommendations for a pusher seal, O-rings are available
- Flexible element should be outside the process with dynamic gasket at stationary face

Proposed Solution



Existing Mechanical Seal



Proposed Replacement

- Metal bellows seal, Type C, B2B
- OD pressurized IB seal
- Flexible elements in contact with process

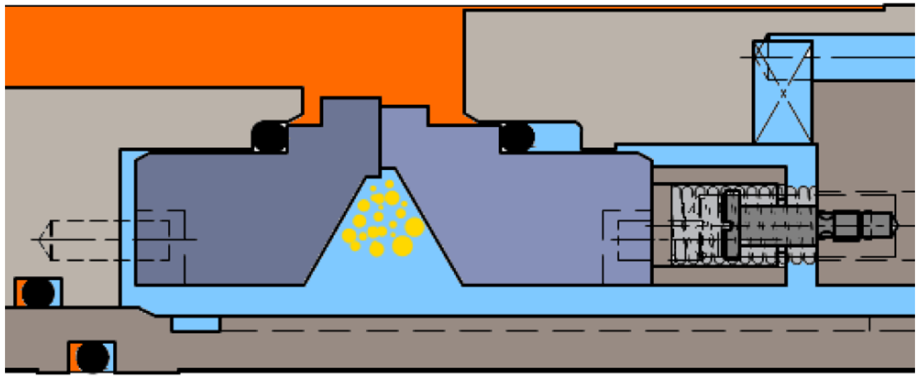
- Pusher seal, Type A, F2B
- ID pressurized IB seal
- Flexible elements away from process

Proposed Solution Validation

- Before site implementation, factory validation required
- Dynamic testing performed under simulated site conditions
- Different face material tested on inner seal
  - Carbon vs RBSC
  - RBSC vs RBSC
- More than 500 hrs. testing

Proposed Solution Validation

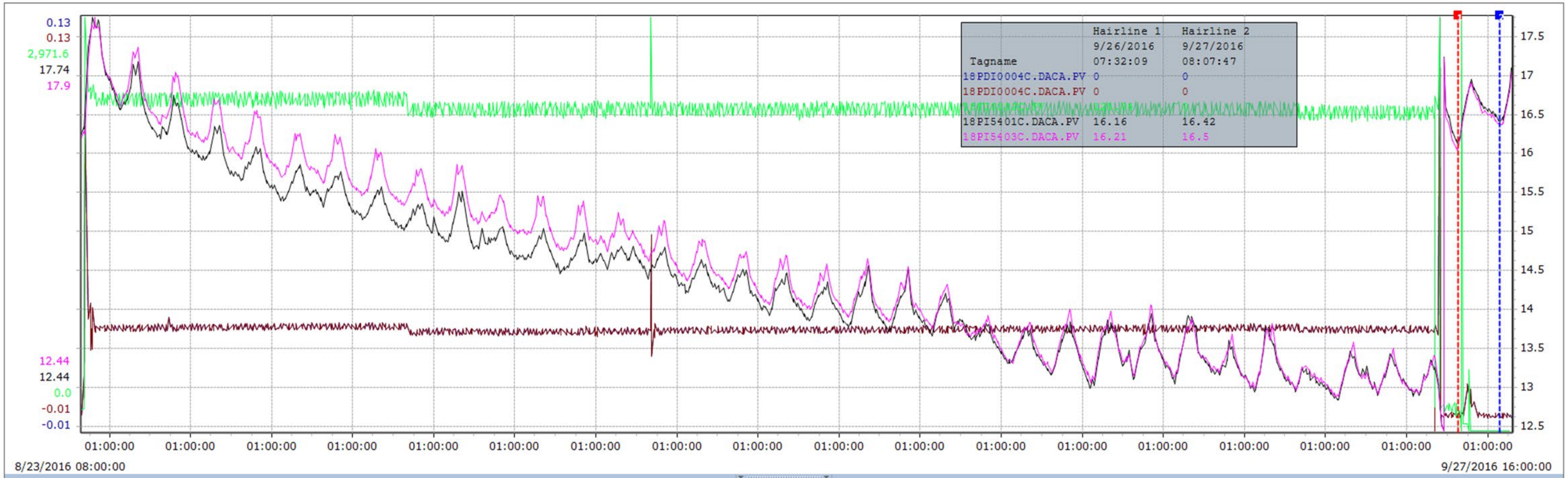
- During testing, face wear and leakage was examined in all combinations
- Plain faces in RBSC/RBSC showed least wear and low leakage
- Wear attributed to initial venting and dry running caused by face orientation / shape
- Long runs didn't produce further/propagated wear



Field Implementation

- Seals were validated through testing and installed in August 2016
- No seal failure reported since installation
- Low mechanical seal leakage achieves > 23 days between refills
- All pumps were upgraded with the F2B pusher seal

Field Results



Item Alias	Item Name	Visible	Description	Aggregate	Interval (s	Units	MinConf	YRange	Style	Color	Value
18PDI0004C.DACA.PV	18PDI0004C.DACA.PV	☑	18-MJ01 INDICATION PRESSION DIFF	[BestFit]	[25M3	bar	0	Auto	Solid	0, 0, 160	0
18PDI0004C.DACA.PV	18PDI0004C.DACA.PV	☑	18-MJ01 INDICATION PRESSION DIFF	[BestFit]	[25M3	bar	0	Auto	Solid	128, 0, 0	0
18FI0002C.PV	18FI0002C.PV	☑	18-MJ01 INDICATION FLUX	[BestFit]	[25M3	m3/h	0	Auto	Solid	0, 255, 64	0
18PI5401C.DACA.PV	18PI5401C.DACA.PV	☑	18-MJ01-C INDICATION PRESSION	[BestFit]	[25M3	bar	0	Auto	Solid	Black	17.1
18PI5403C.DACA.PV	18PI5403C.DACA.PV	☑	18-MJ01-C INDICATION PRESSION	[BestFit]	[25M3	bar	0	Auto	Solid	255, 0, 255	17.16

Lessons Learned

- Verify actual cleanliness of “clean processes”
- Seal arrangement plays a role in contamination tolerance
- Pusher seals can be used on high temperature applications
- Plan 53B refill cycle goals can be achieved
- Identify addressable problems and execute a plan
- Customer/supplier cooperation is essential