



ASIA TURBOMACHINERY & PUMP SYMPOSIUM
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Dry Gas Seal (DGS) Separation Seal Failure

Case Study from ExxonMobil Singapore



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Abstract

This case study presents the failures experienced on separation seals installed on several compressors. The failures resulted in oil migration to the dry gas seals.

Segmented contact-type carbon ring bushing separation seals were installed in multiple compressors in an ethylene plant. It was observed that the secondary drain was collecting oil after a few months of operation in spite of maintaining the optimum N₂ supply pressure for the separation seals. Subsequent inspection of the dry gas seals confirmed oil ingress into the secondary seals which led to contact between seal faces. Excessive wear on the separation seal carbon bushings was also observed.

Failure analysis was performed and root cause identified. Various solutions were studied and some preliminary design changes were implemented in the seals. However these changes did not improve the oil migration issue. Further site evaluation combined with OEM support resulted in implementation of two design changes which have effectively mitigated the oil migration

This case study will present the problems encountered, root causes analyzed, solutions implemented, learnings and the results after 4 years of operation.



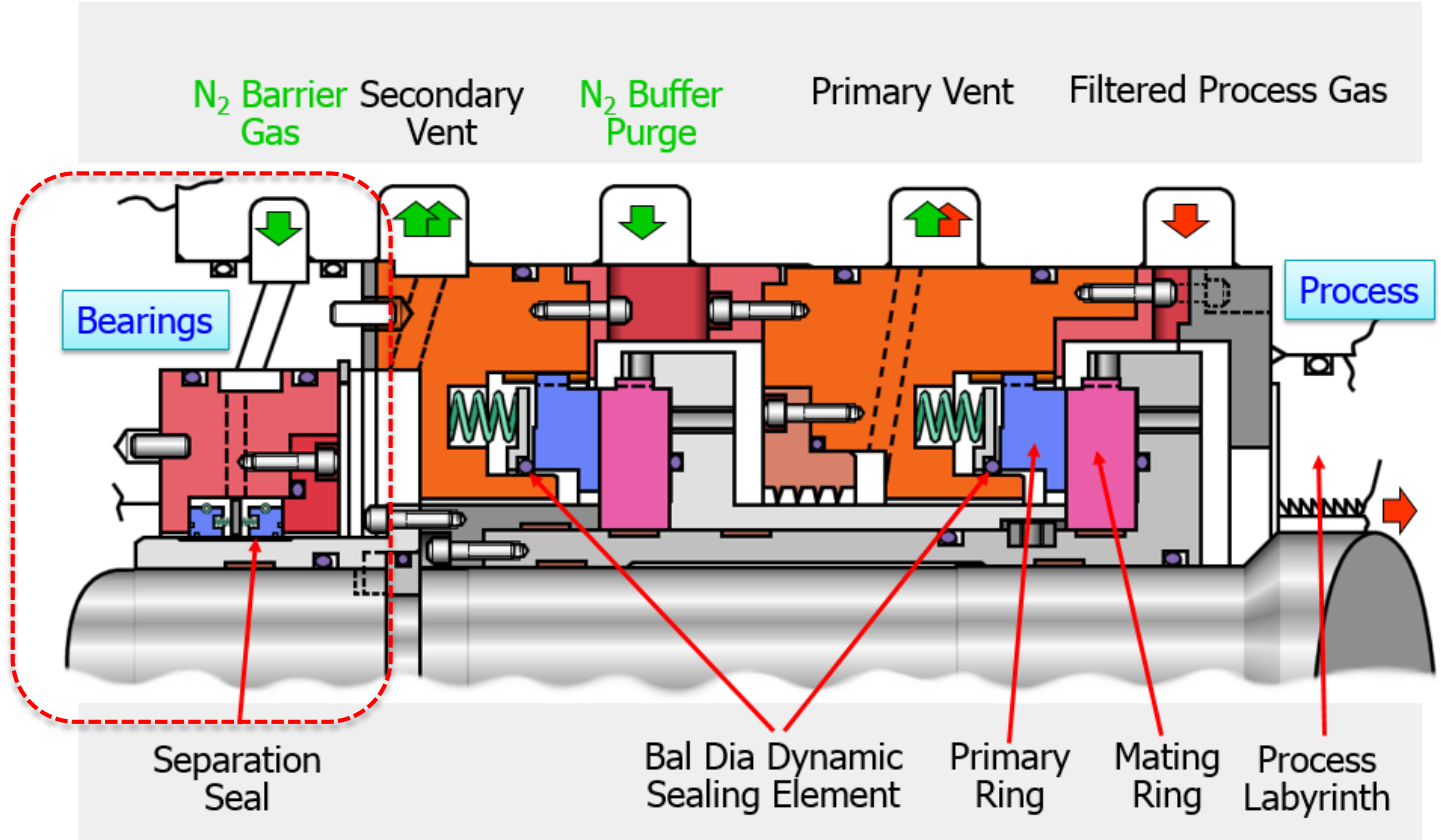
Agenda

- 1 Dry Gas Seal System Overview
- 2 Failure Observations on Plant 1
- 3 Root Cause Analysis on Separation Seal Failure
- 4 Solution Implemented
- 5 Mitigation Steps Implemented in Plant 2
- 6 Other Potential Solutions (Design Improvements)
- 7 Learning & Summary



Dry Gas Seal & Barrier Seal Arrangement

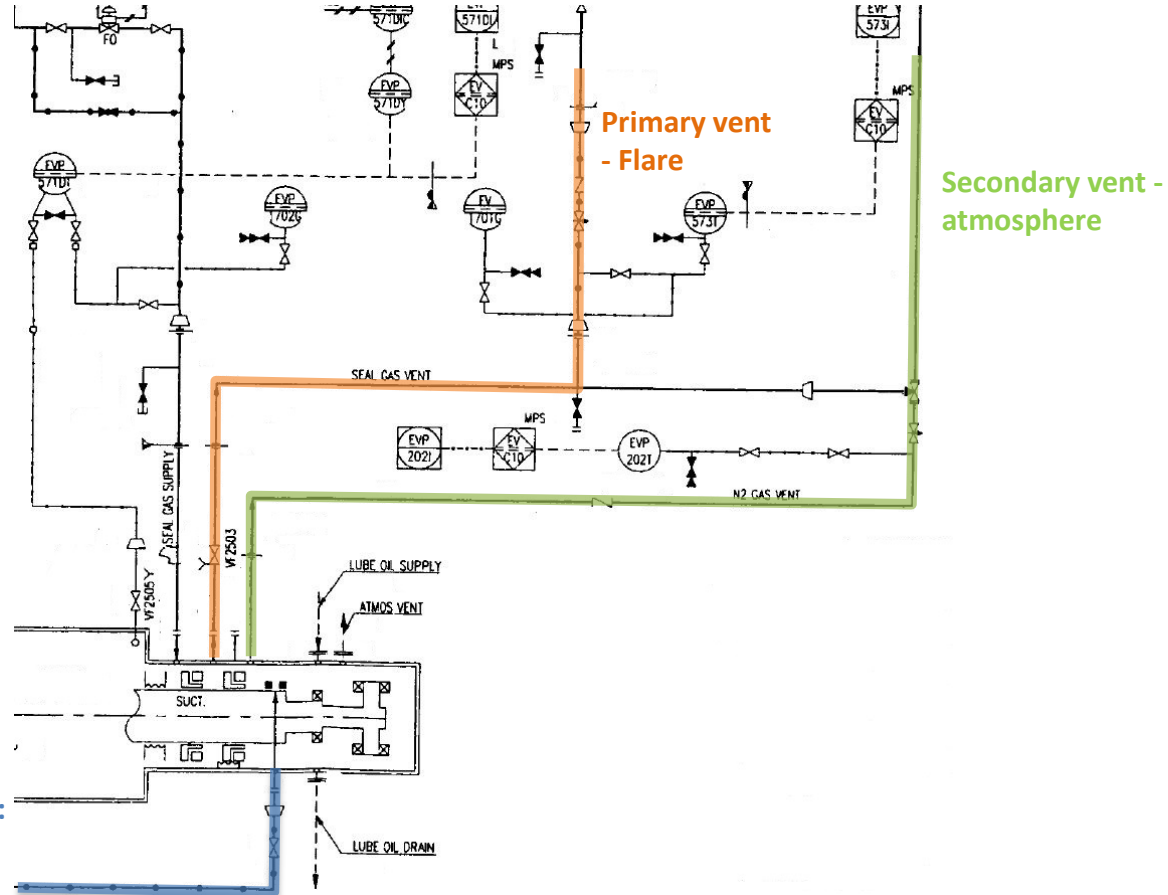
Contact type segmented carbon bush barrier seal



Dry Gas Seal System Overview – Plant 1

Details:

- Tandem arrangement dry gas seal
- Contact type carbon bushing separation seals installed
- Use of cryogenic nitrogen used as separation gas
- No secondary seal gas supplied



Separation seal gas supply:

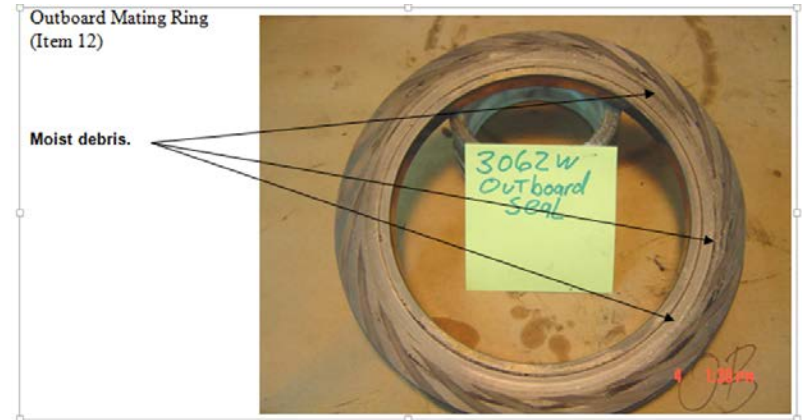
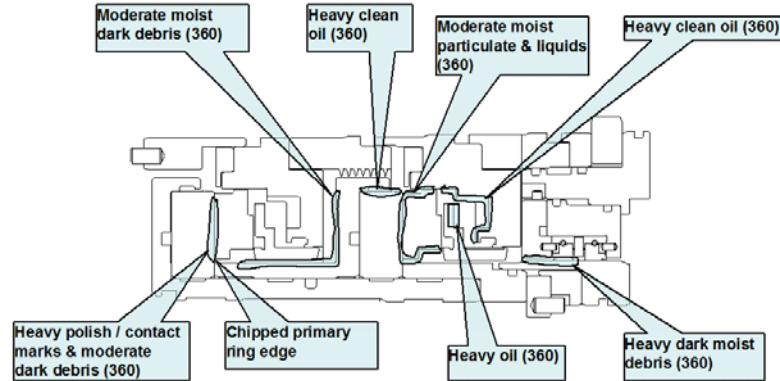
- Pressure = 45 kPag
- Flow = 1 ~ 4 Nm³/hr



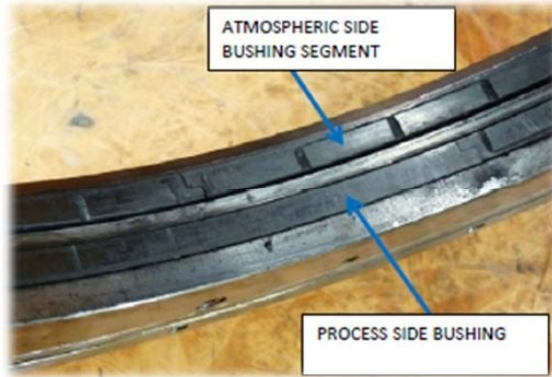
Failure Observations – Plant 1

2005:

- Heavy wear observed in DGS inboard/outboard seal head during every seal replacement (4-yearly)
 - Oil observed migrated past secondary seal faces into DGS assembly
 - Heavy contact marks are present on the primary ring-sealing surface
 - Dark debris and polish marks are present on the sealing surface of the mating ring.
- Contact type separation seals observed to have significant wear



Failure Observations – Plant 1



The close up on the bushing segment of the barrier seal. Initial findings shows heavy wearing marks on the contacting surface of the segment rings. Liquid contamination is visible on the surfaces of the components.



Picture shows the barrier seal sleeve. Contact wear mark on sleeve outer diameter coated surface.



Picture 1 shows the inboard mating ring assembly. Thick traces of wet hydrocarbon contaminants (suspected to be mixture of hydrocarbon contaminants & bearing lube oil) is visible on the polished surface of the mating ring.

Root Cause Analysis of Separation Seal Failure

Direct Cause:

Accelerated wear of carbon bushing resulting from the lack of lubrication through use of ultra-dry cryogenic nitrogen as separation gas. Excessive wear led to less than adequate sealing capability.

Expected Performance of carbon bushing installed:

- Up to -25°C no issues. Normal wear is expected
 - -25°C to -40°C : Higher wear can be expected compared to the normal
 - -40°C and below: Accelerated wear is expected
-
- Specification of cryogenic nitrogen used: - 60 to -75°C dew point



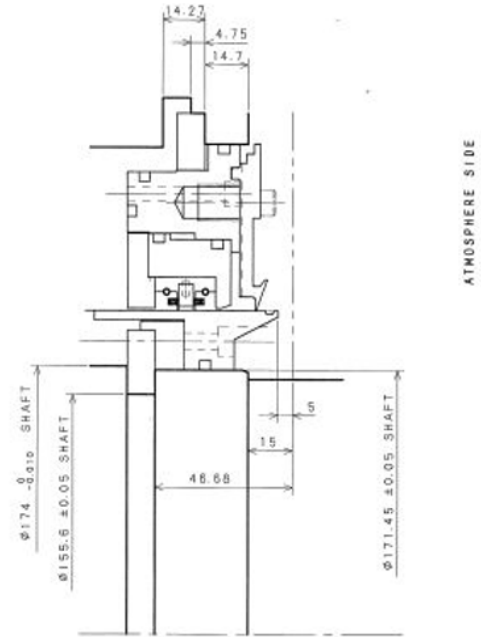
Solutions Implemented– Plant 1

2009:

- Secondary drain sight glasses installed
- Modified Barrier seal with Oil baffle
- Oil observed in sight glasses after few months of start-up (new seals) and required 4 Pcs of mating rings to be scrapped out of 10 pair of seals
- **Modifications did not help in oil migration to dry gas seals**

2013:

- Contact type bushing separation seals were replaced with conventional labyrinth seals with following axial clearance between separation seal and bearing
- **Modification successfully prevented oil migration to seals**



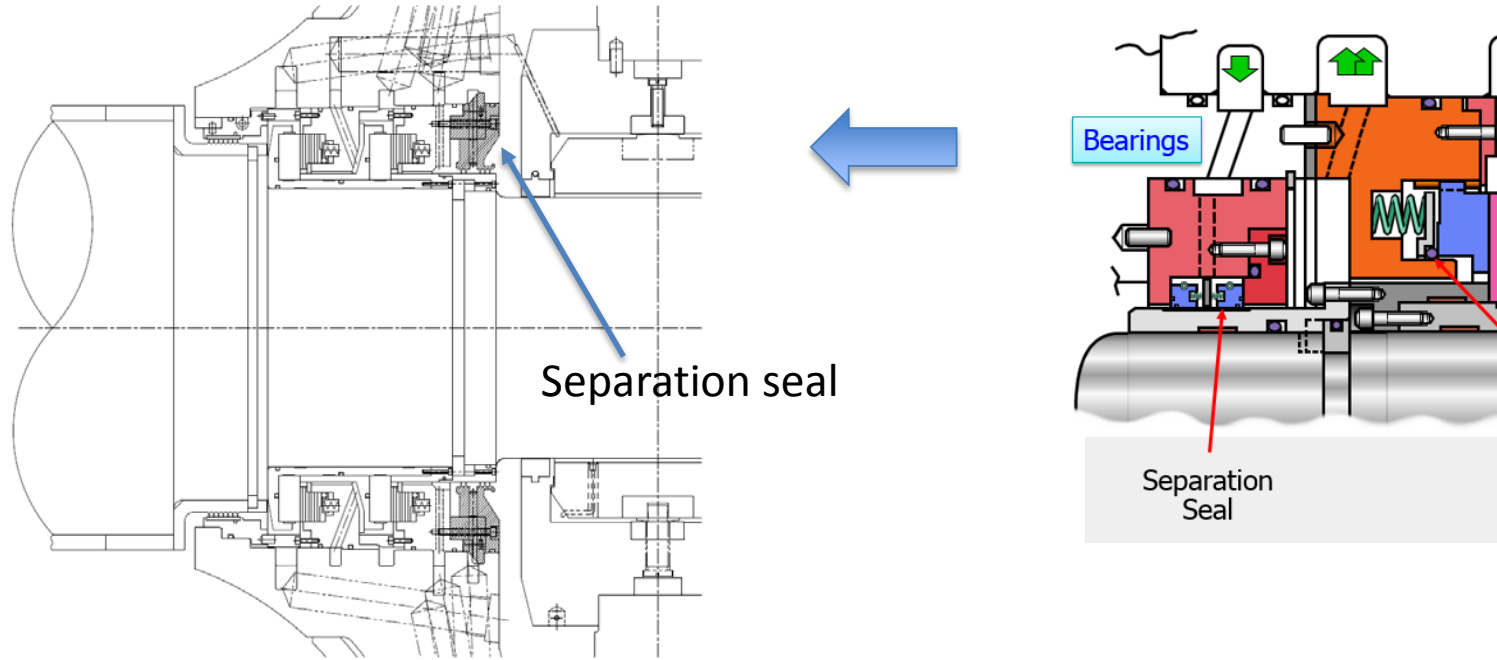
After 2009 modification

Plant 1	ELC 10 PGC LP	ELC 10 PGC MP	ELC 10 PGC HP	EVC 10 PRC	EVC 20 ERC
	20 mm	20 mm	20 mm	20 mm	16 mm
Shaft Dia.	$\phi 234$	$\phi 234$	$\phi 174$	$\phi 234$	$\phi 134$



Solution Implemented in Plant 1

Replaced existing contact type carbon bushing with conventional labyrinth seals



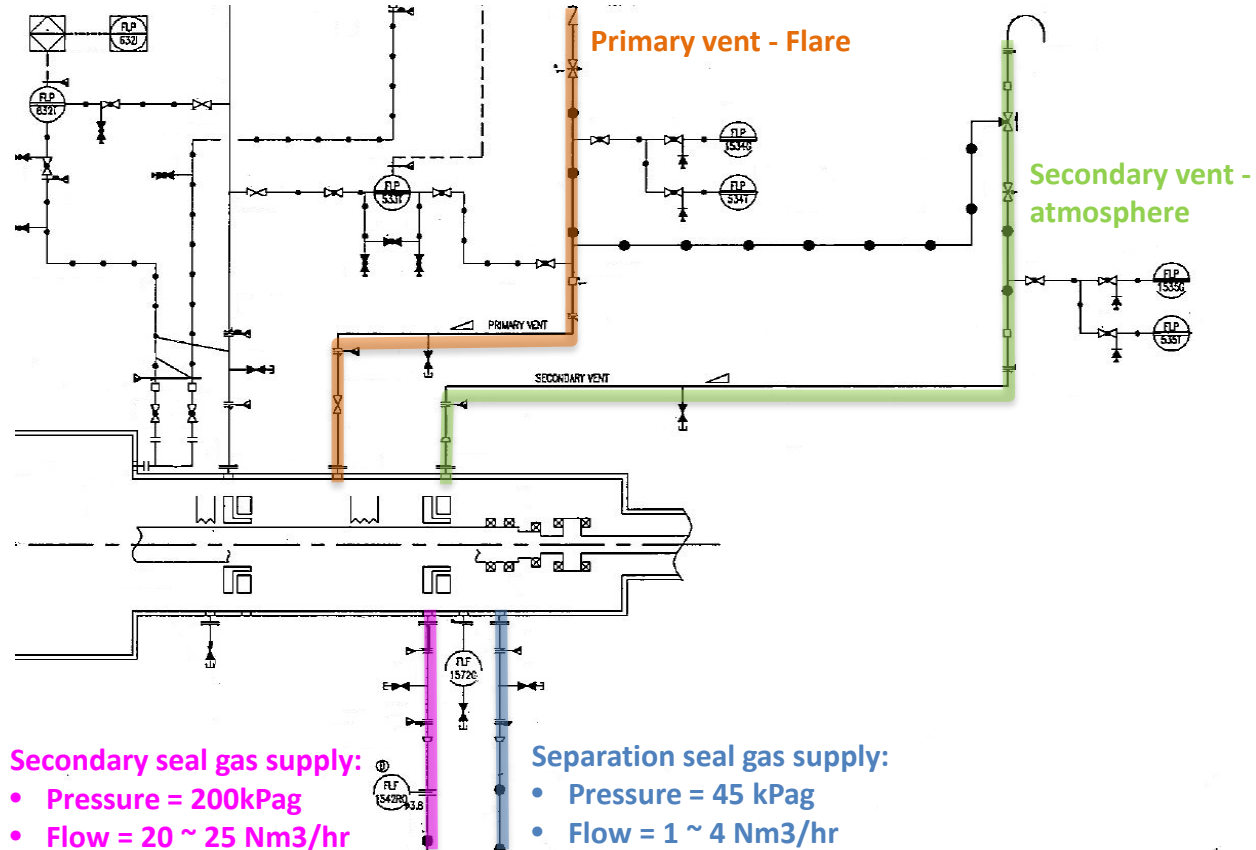
Dry Gas Seal System Overview – Plant 2

Similarity to Plant 1:

- Same contact type carbon bushing separation seals installed
- Same cryogenic nitrogen used as separation gas

Differences from Plant 1:

- Availability of secondary seal gas

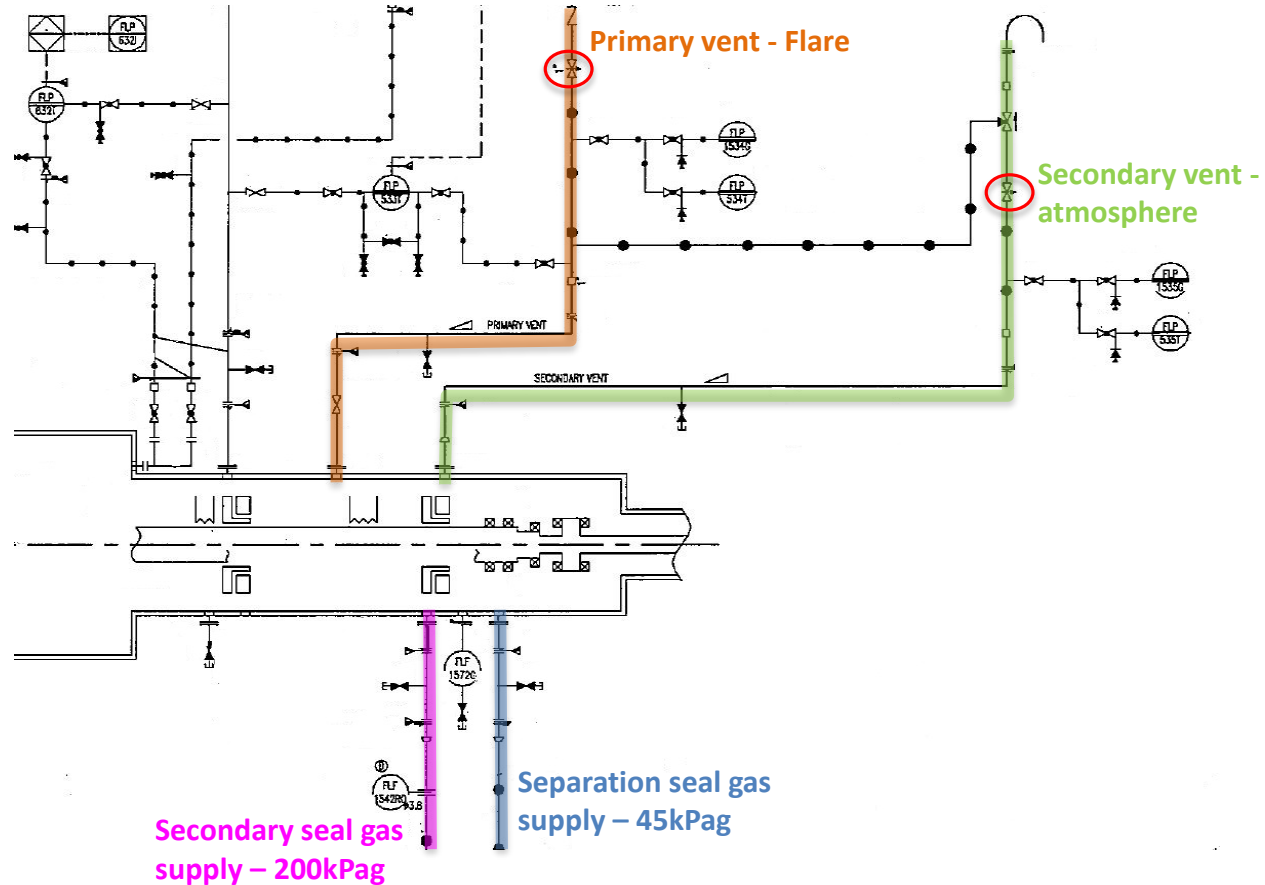


Mitigation Steps To Prevent Oil Migration in Plant 2

- Use of needle valve in secondary vent to maintain low pressure of 5 – 15kPag in secondary vent line
- Primary vent pressure maintained at about 20 ~ 50kPag

Results:

- All 10 units have been in service since 2013 and no oil has been observed in the secondary drain sight glasses.



System Improvements in Plant 2

Disadvantage of existing system:

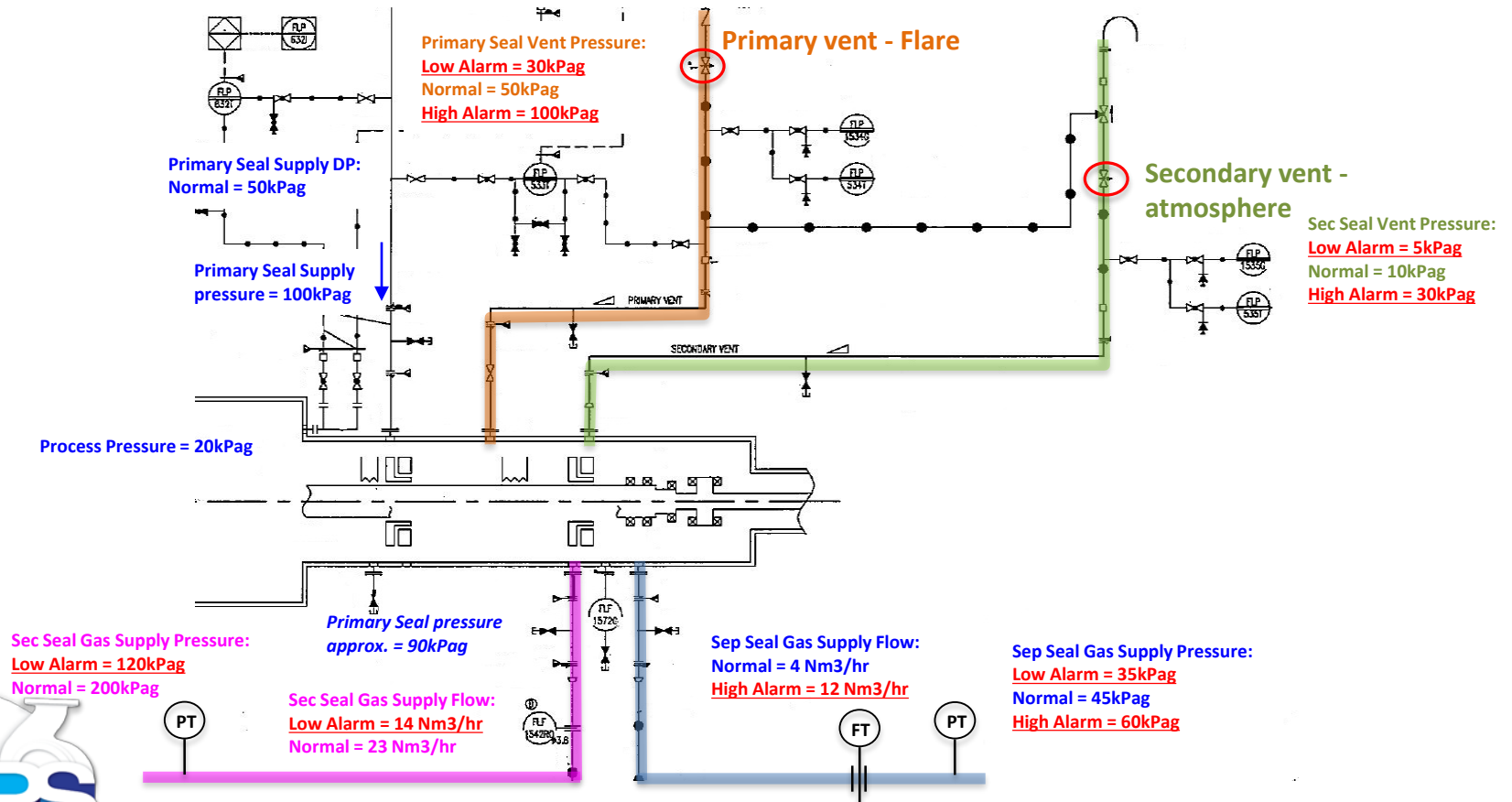
Potential risk of secondary seal reverse pressurization in the event of increased secondary vent pressure

Mitigations:

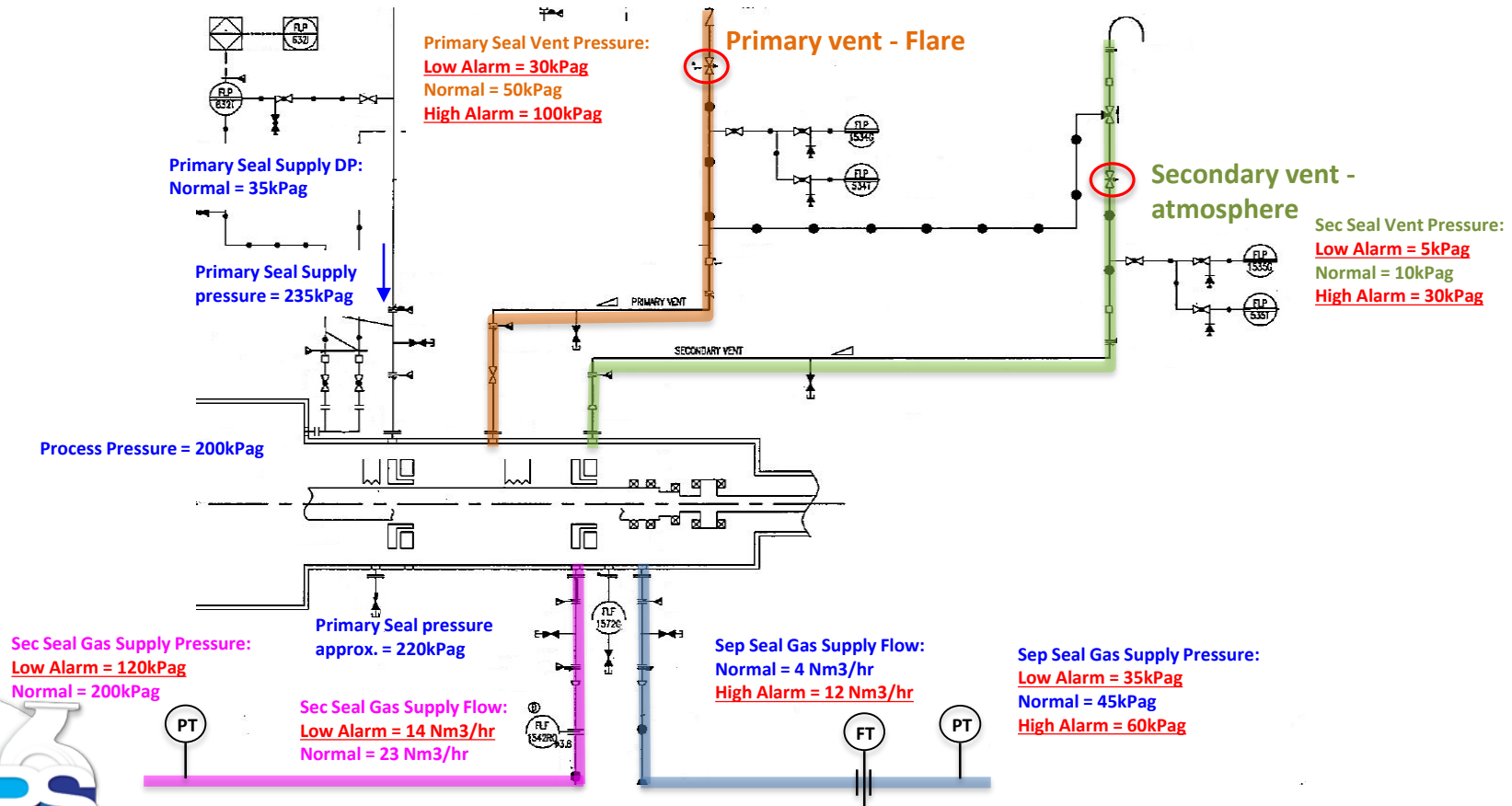
- Implement low (5kPag) and high (30kPag) pressure alarm setting in secondary vent pressure
- Maintain high primary vent pressure of 50kPag (> separation supply gas pressure)
- Configure the following alarms to detect seal failures:
 - Secondary seal failures:
 - high secondary seal vent pressure (reduce setpoint to 30kPag)
 - Primary seal failures:
 - High primary vent pressure (set alarm at 100kPag)
 - Low suction pressure casing: Increase primary seal supply DP to 50kPaD
 - High suction pressure casing: Primary seal supply DP can remain at 35kPaD
- Upgrade system to separation seals with better reliability or install conventional labys as per experience in Plant 1



System Improvements in Plant 2 – Low Suction Pressure



System Improvements in Plant 2 – High Suction Pressure



Design Improvements Under Evaluation

1. Evaluate the use of non-contacting separation seals (Floating ring fixed clearance bushing)
2. Evaluate the use of contacting segmented bushing seals with improved carbon materials which are suitable for ultra-dry Nitrogen



Broader Learning

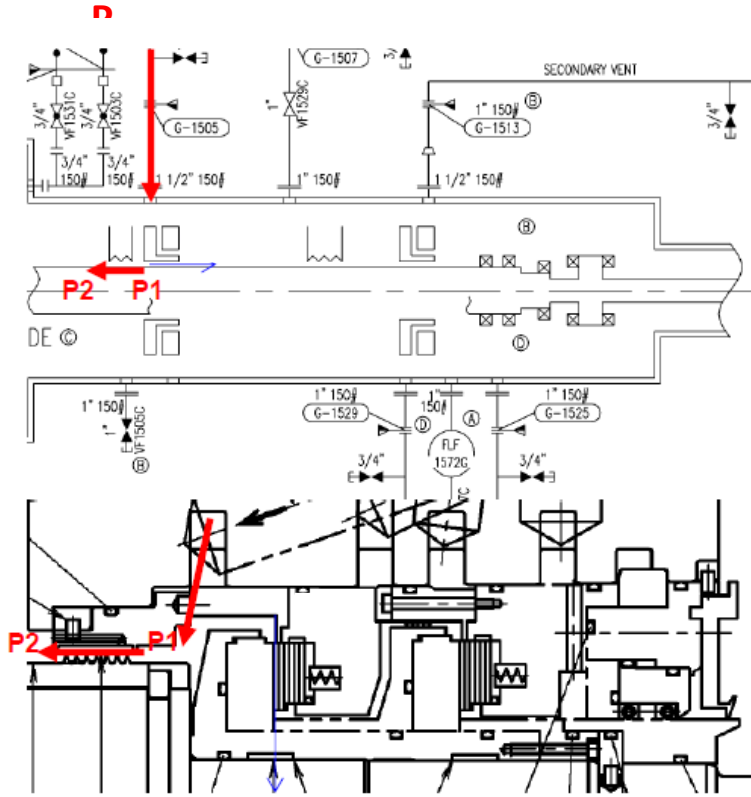
- Seal gas specification should be reviewed during design stage to identify issue related to gas dryness
- There are a lot of flexibilities in designing dry gas seal systems, but thorough review of the seal system with both the seal vendor and the compressor manufacturer is critical to the reliability of the seals
- Good controls such as alarms and procedures need to be in place to operate the seals with maximum reliability
- Other good practice include installation of sight glasses on secondary seal drains to prevent oil migration to the non-contacting seal faces



BACK-UP



Site Pressure Survey for Case Labyrinth Pressure Drop



Casing	P _{supply} (kPag)	P1 (kPag)	P2 (kPag)
PGC LP	100	90	70
PGC MP	455	440	420