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A Review of the Critical Design Parameters for Labyrinth Type Separation Seals on Dry-gas-seals

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Biography: Dian J. Hanekom

Dian is a Rotating Equipment Engineer with 30 years experience in the Petrochemical and Nuclear industry, currently working for TASNEE Co. in Saudi Arabia. His main expertise in rotating machinery is design, reverse engineering, vibration analysis, reliability engineering, best practices and project specifications. His specialties are dry-gas-seals, lube-oil-systems, centrifugal compressors and steam turbines.

Abstract

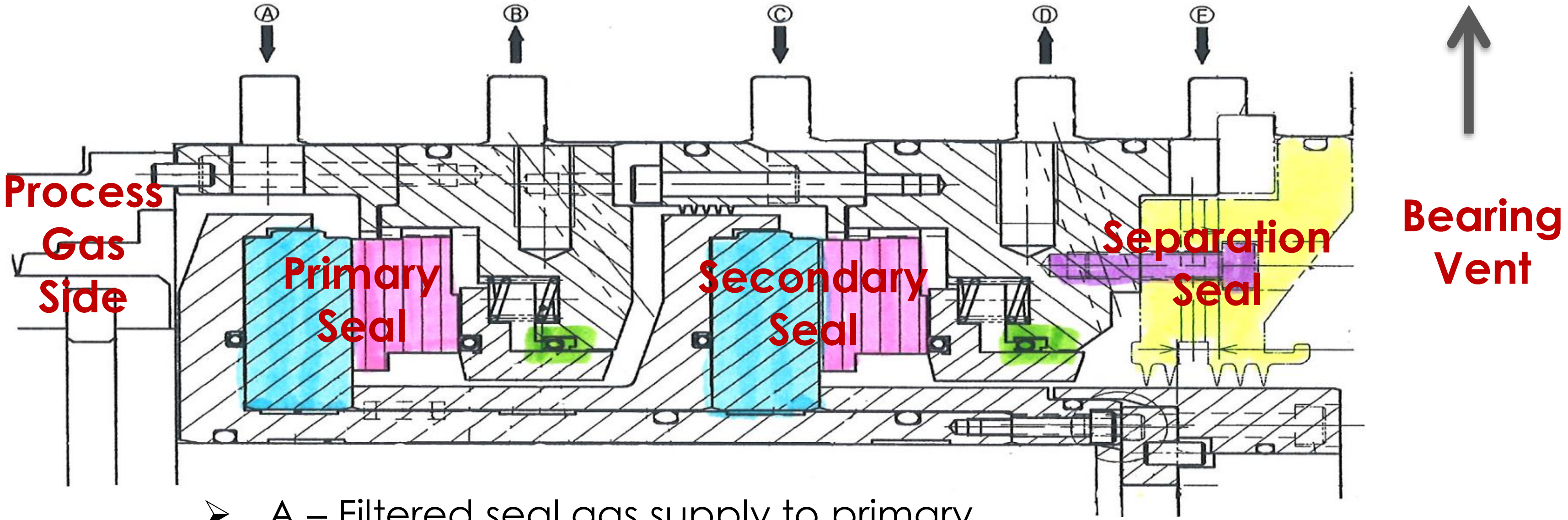
An ethylene compressor experienced a dry-gas-seal (DGS) hang-up condition and a RCA concluded that a possible root- or contributing cause is lube oil passing the labyrinth type separation seal into the secondary DGS cavity, causing the dynamic O-ring to malfunction. Detailed modeling and design review of the separation seal system enabled the investigators to postulate several scenarios to explain how lube oil could migrate into the DGS. The presentation presents a procedure how to calculate the exit velocities of labyrinth type separation seals and the effects of changes in various design parameters.

Contents

Introduction

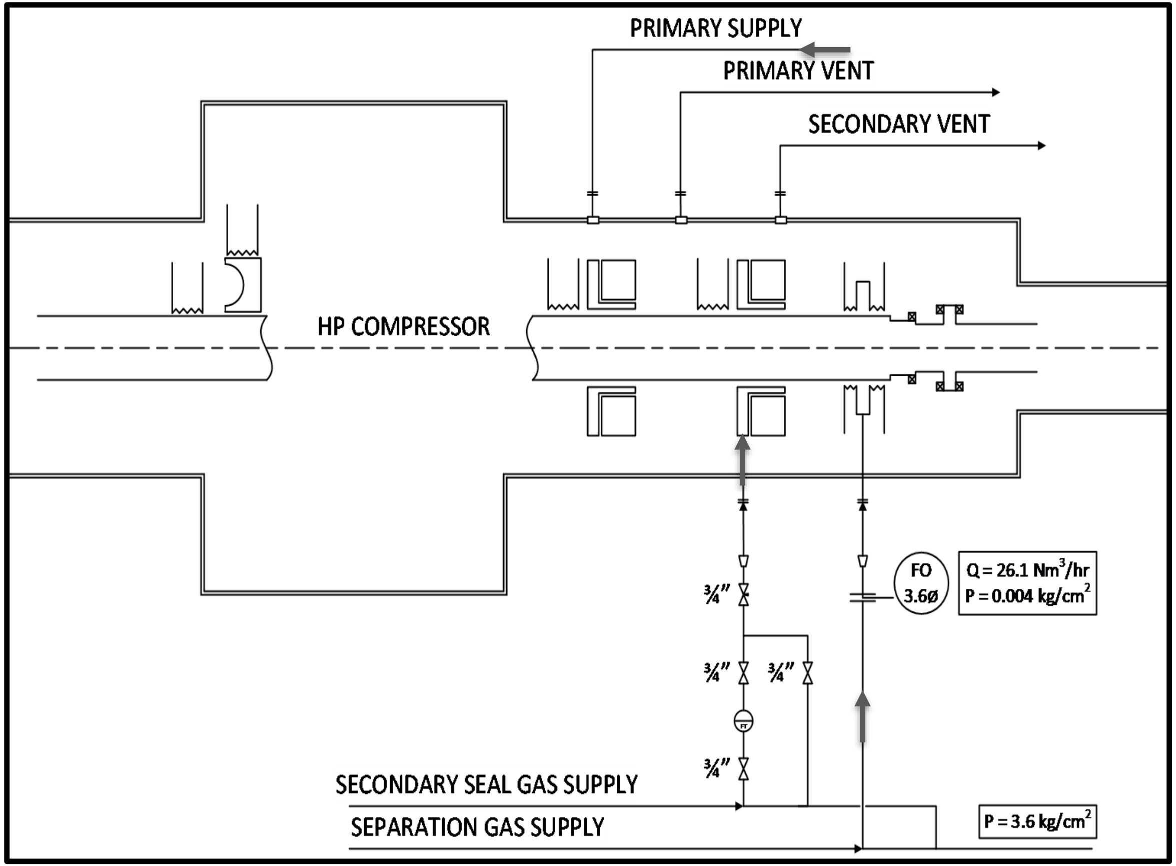
- A DGS hang-up situation developed after a boiler trip in an Olefin's Plant Ethylene Compressor, HP-DE side;
- The seal almost returned to its normal operating position in following-up months, but during upcoming TAM inspection, the secondary seal was found failed;
- Turn-around-maintenance inspection also revealed that oil had entered into the secondary DGS-cavity;
- A detailed investigation was launched into the root cause of oil passing and seal hang-up;

Introduction (Cont.)



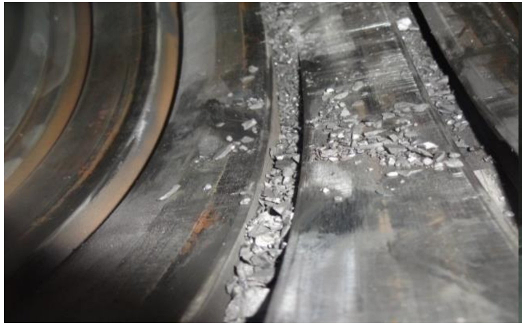
- A – Filtered seal gas supply to primary
- B – Primary seal vent to flare header
- C – Secondary seal gas supply
- D – Secondary seal vent to atmosphere
- E – Seal gas supply to separation seal

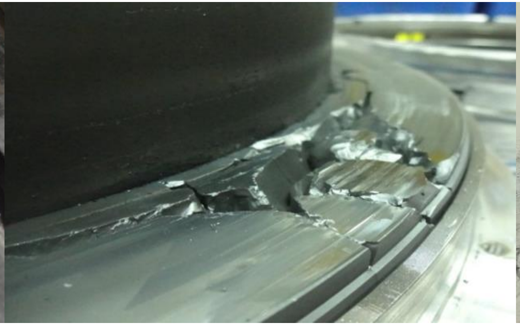
Introduction (Cont.)

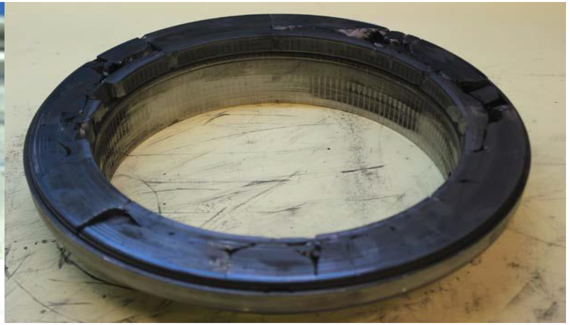


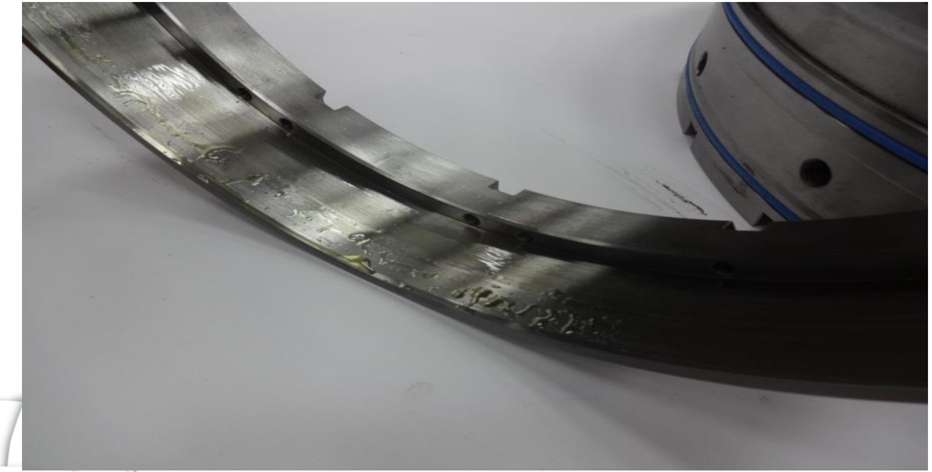
<u>Requirement: –</u>
Design velocity 5 m/s at <u>double</u> max. clearance and 15 m/s at max. clearance

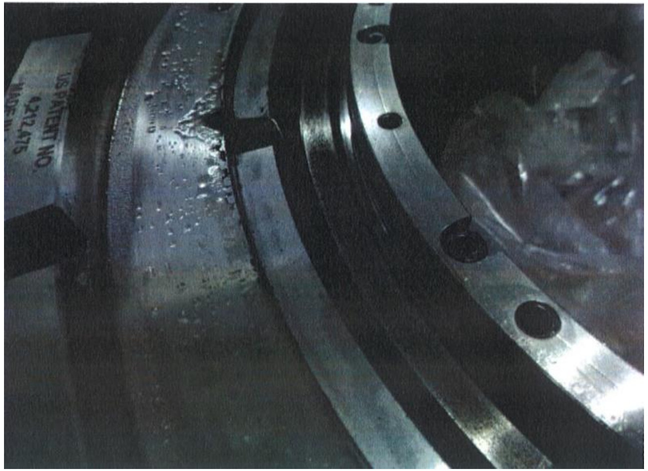
Introduction (Cont.)







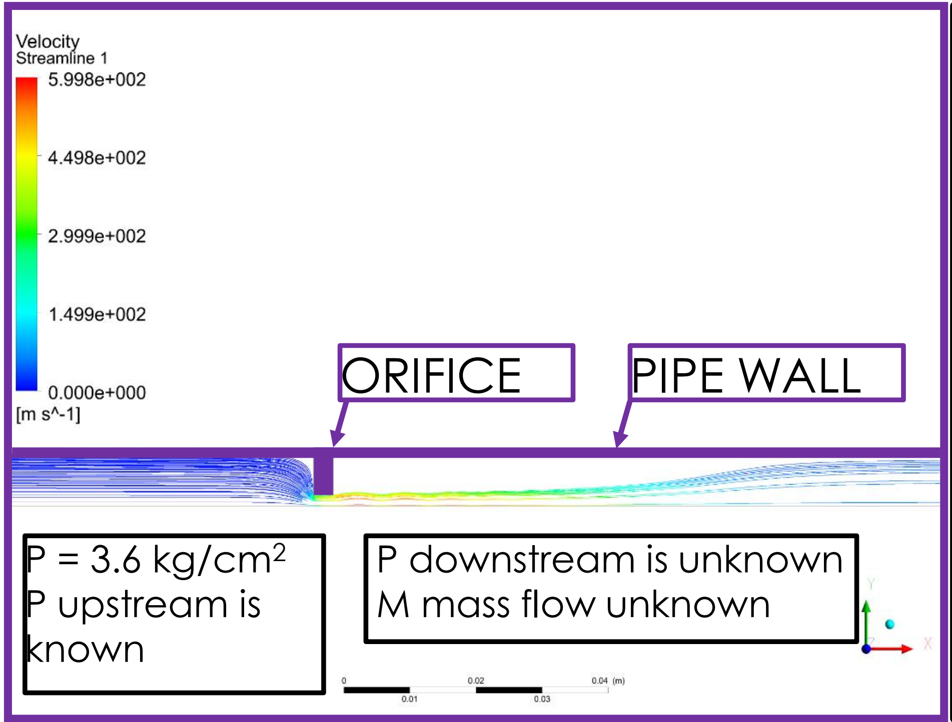


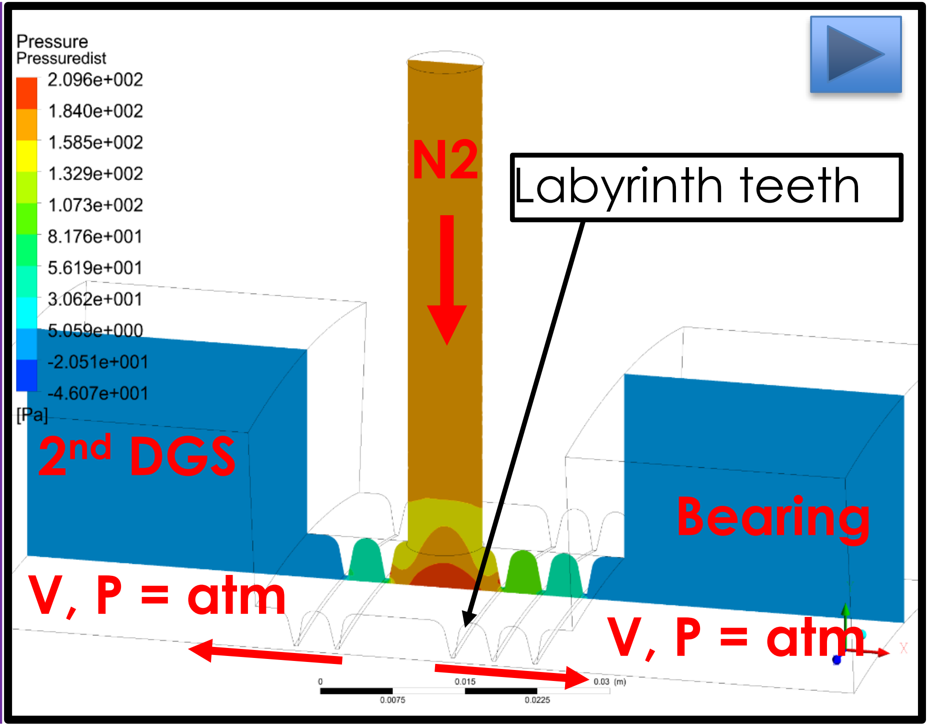


Calculations Theory

- The calculation of exit velocities were based on the theory of gas flow in straight-through labyrinth seals;
- The flowrates and pressure distributions were calculated by using the Neumann Modified Method ("Moody's Friction-Factor Model"),Y. Dereli & D. Eser, ;
- The model incorporate the orifice plate and the labyrinth together with a supply pressure of 3.6 kg/cm^2;
- Flow through the orifice plate was calculated using the computational procedure detailed in ISO 5167-2.

CFD analysis





Calculations Procedure

- Starting with a known N2-supply pressure (3.6 kg/cm^2) and an assumed mass flow rate, pressure drop through the orifice plate and labyrinth seal is calculated.
- The mass flow rate is then varied in an iterative process until the discharge pressure equals atmospheric pressure.
- For each iteration, the gas properties are re-calculated as the pressure varies.
- In this manner the correct mass flow rate is established and the flow velocities in the different stages of the labyrinth can be calculated.

Design criteria

- **5 m/s** at double the **maximum design clearance**.
- **15 m/s at maximum design clearance**.

Best practice design values varied between 12 – 18 m/s, based on two compressor manufacturers, one seal vendor and an international consultant.

Calculations and Analysis Results

Design velocities ≥ 15 m/s & ≥ 5 m/s at 2x max Cl)

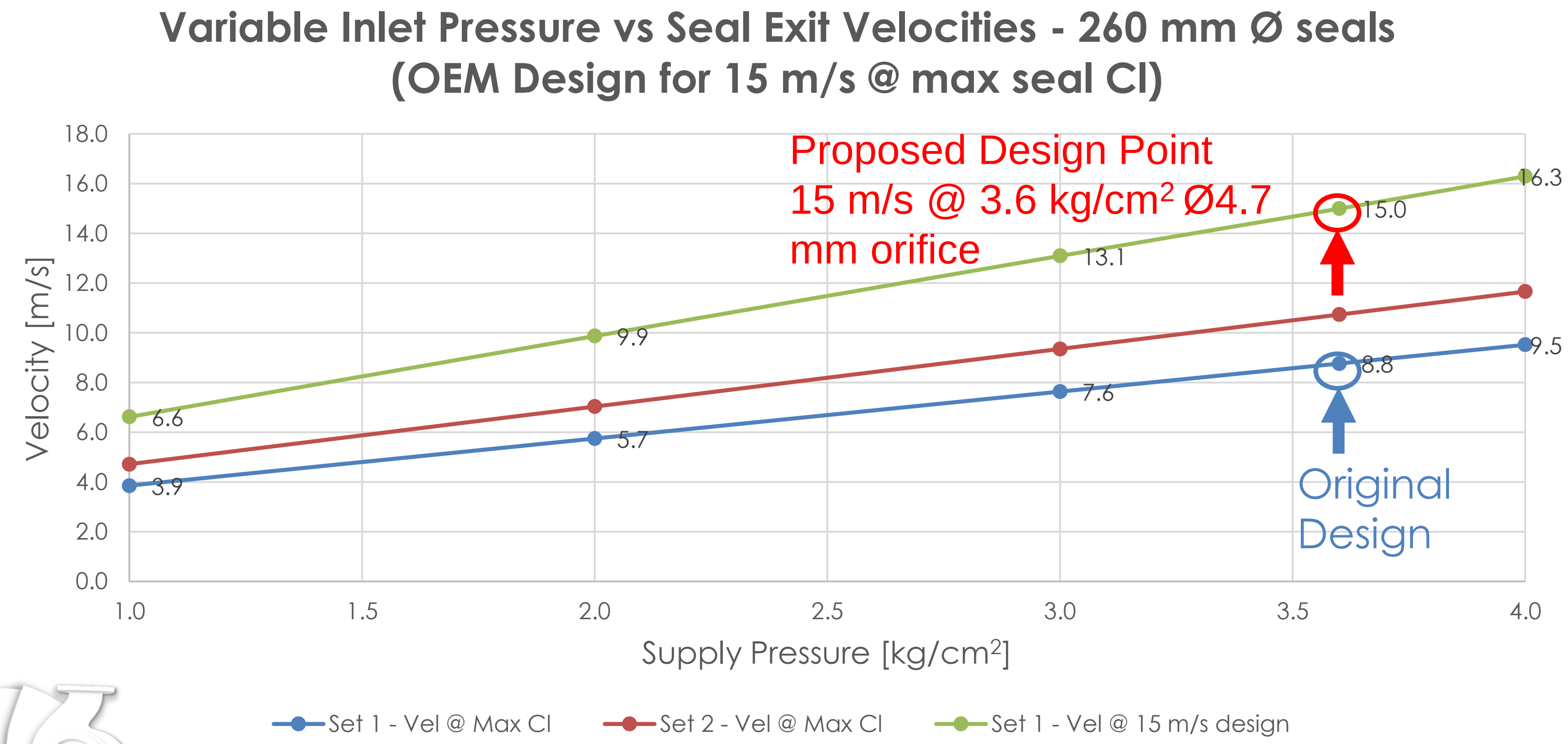
		Dereli/Eser Model	CFD Model	3rd Party	OEM P&ID
Volume flowrate	Nm^3/h	24.82	24.85	26.1	26.1
Orifice massflow	kg/s	0.0086	0.0086	-	-
Laby set 1 mass flow	kg/s	0.0039	0.0039	-	-
Laby set 2 mass flow	kg/s	0.0048	0.0047	-	-
Laby up-stream Pressure	Bar(g)	0.0012	0.0018	0.0011	0.0039

Calculations and Analysis Results

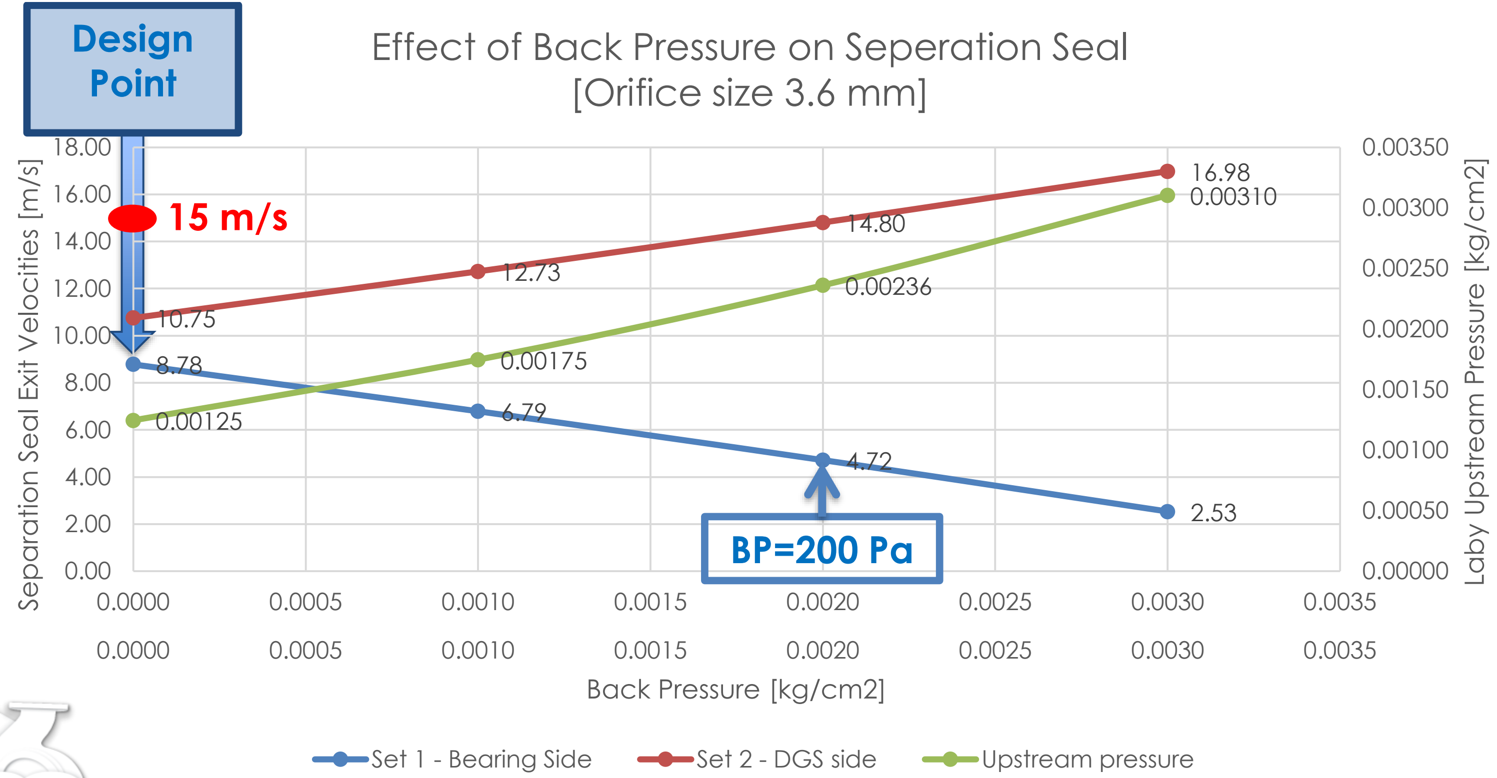
Labyrinth tooth velocities

		Dereli/Eser Model	CFD Model	3Rd Party	OEM P&ID
Set 1, Tooth 1	m/s	8.77	8.55	**9.08**	**15.1**
Set 1, Tooth 2	m/s	8.77	8.55		
Set 1, Tooth 3 (bearing side)	**m/s**	**8.77 (-42 %)**	**8.55**		
Set 2, Tooth 1	m/s	10.74	10.21	11.12	
Set 2, Tooth 2 (DGS side)	m/s	10.74	10.21		

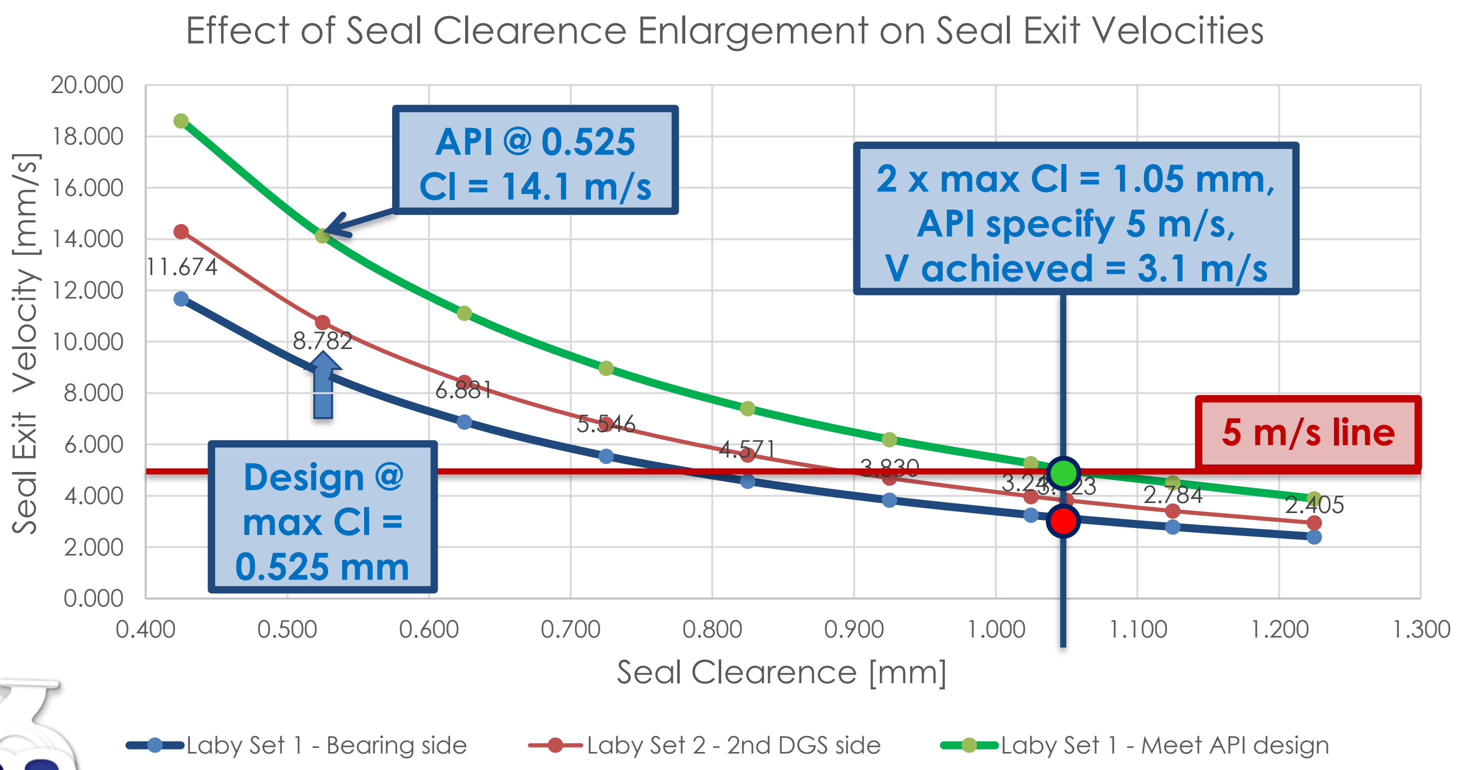
Seal supply pressure sensitivity



Seal back pressure sensitivity

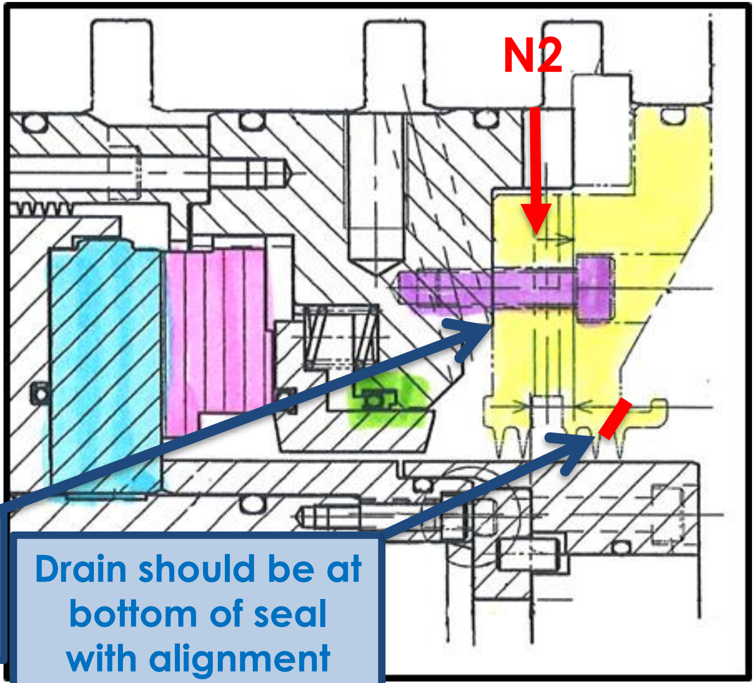


Separation seal clearance sensitivity



Design Deficiencies

- O-ring missing on the inside of hold down bolts.
- Oil drain in labyrinth towards bearing side installed upside down.



No O-ring installed. Oil leak path

Drain should be at bottom of seal with alignment pin for correct orientation

Conclusions

- The OEM design velocities are 42% (8.8 m/s) lower than what was specified by the OEM (15 m/s);
- The design velocity specification of 15 m/s at max clearance is on par with other design practices;
- Back pressure on the bearing housing was a likely contributing cause of low seal gas exit velocities;
- Oil leaked through the hold-down-bolts of the seal with no O-ring installed on the inside of the bolts.

Conclusions (Cont.)

- The labyrinth seal oil drain was installed upside down due to no alignment pin.
- Other important factors like a) Nitrogen "on" before lube-oil start-up, b) cleanliness of supply orifices, c) orifices installed sizes, were all correct.
- Suggested improvements: -
  - Have a shutdown interlock and timer between LO- and seal-gas shutdown. Seal gas "ON" for 3 hours after LO-stopped;
  - Have a back pressure measurement;
  - Have an online DGS monitoring system.

Thank You

- References: - “Flow Calculations in Straight-Through Labyrinth Seals by using Moody’s Friction-Factor Model”, Yilmaz Dereli and Dursun Eser.
- Recognitions: - My thanks to Mr. Gysbert van Zyl for his support for software debugging, calculation review and for reviewing this presentation.