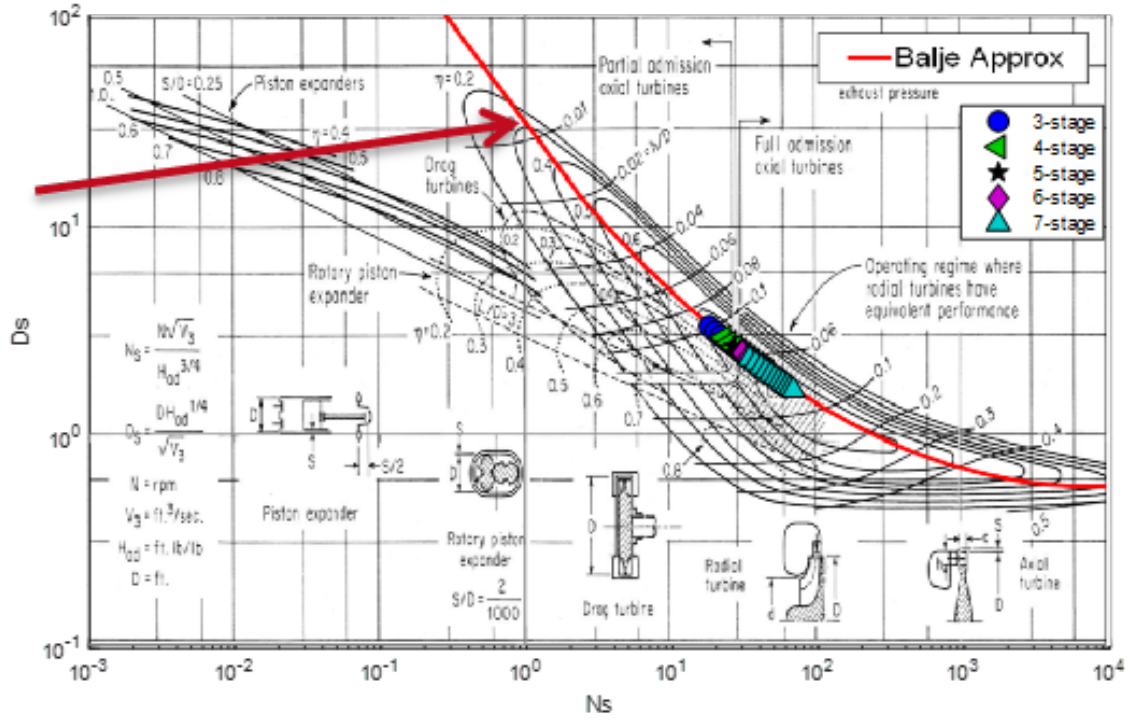
Supercritical CO_2 Power Cycles Symposium

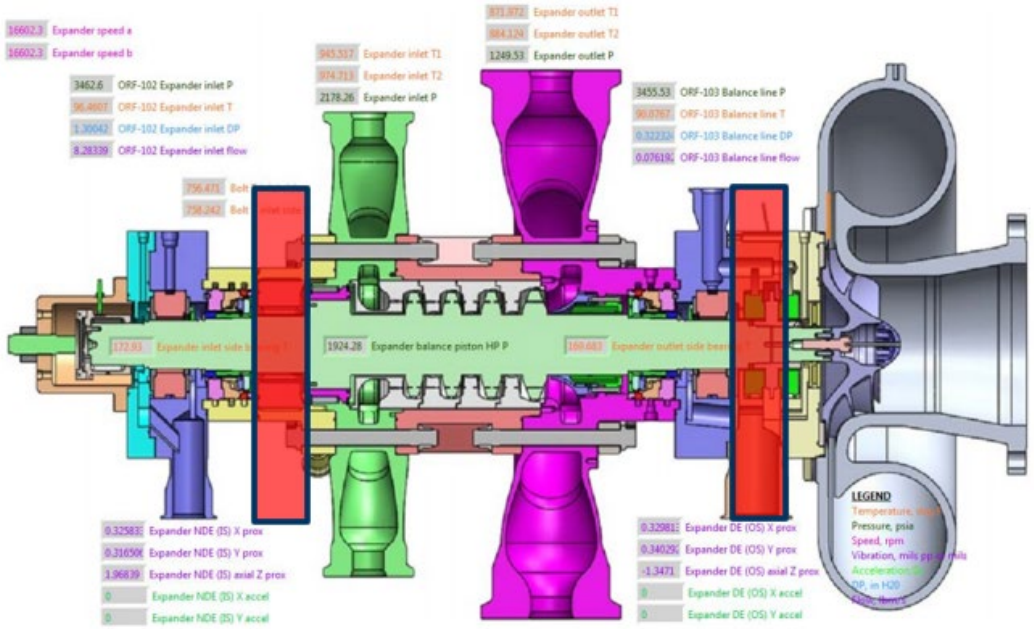
Development of a Dry Gas Seal for high-temperature supercritical carbon dioxide (sCO2) turbines

Jakson Andretta (EagleBurgmann)

Background

1-D turbine analysis (Balje Approximation)





Cutaway of GE/SwRI SunShot rotor showing thermal seal regions in red. 2018

DGS Requirements

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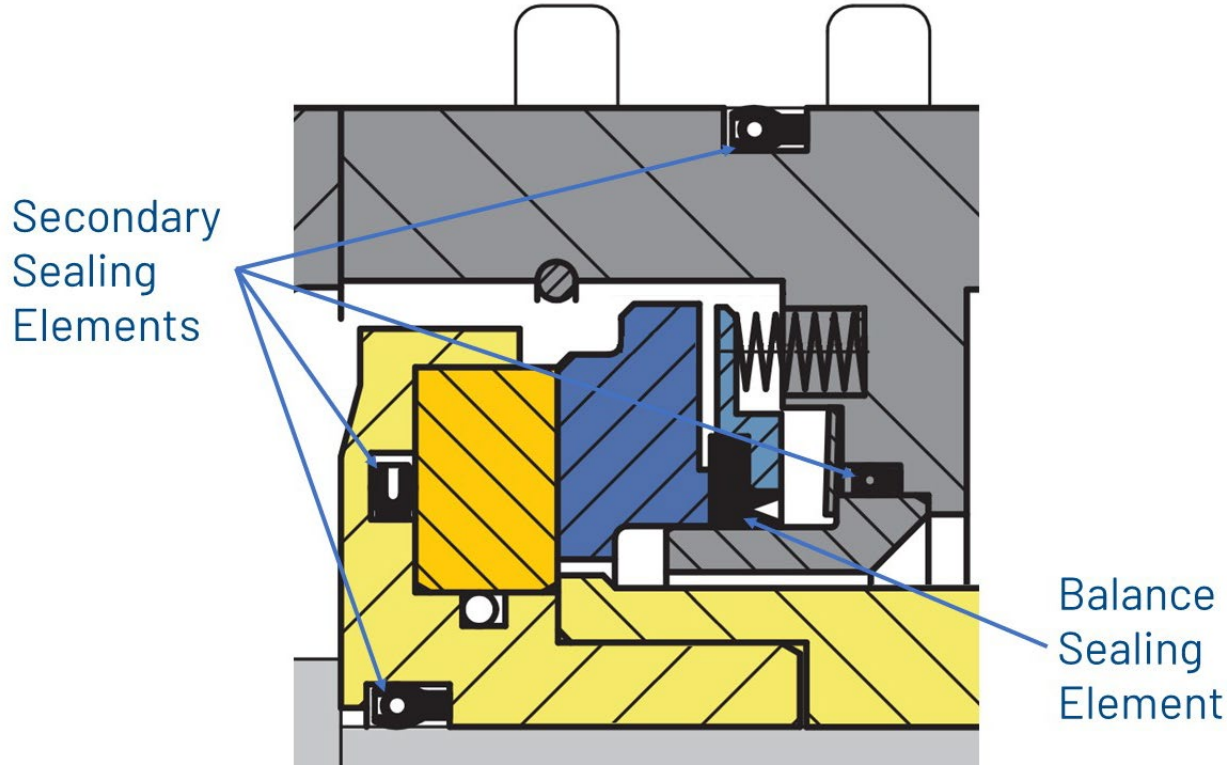
Gas inlet temperature	510 °C	950 °F
Material design temperature	600 °C	1110 °F
Sealing pressure (static)	114 bar	1650 psi
Sealing pressure (dynamic)	89 bar	1290 psi
Seal leakage rate	1,5 Nl/min/bar	0,053 scfm/psi (4,7 scfm @ 89 bar)
Axial movement	± 3,2 mm	± 1/8 in
Radial vibration	50 μm_{p-p}	2 mils p-p
Normal operating speed	18000 rpm	
Turbine shaft diameter	110 mm	4,33 in

Temperature Limiting Components

- Polymers and elastomers: T_{max} 200-250 °C (~392°F)
- Balance sealing element
  - Thermal growth
  - Vibration and wear
  - Friction force
  - Leakage tightness



Project Overview

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	1st phase BSE @ RT	2nd phase BSE hot	3rd phase DGS @ RT	4th phase DGS hot
Medium	Air	CO_2	Air/He	CO_2
Design Temperature	No	Yes	No	Yes
Design Pressure	Yes	Yes	Yes	Yes
Rotation	No	No	Yes	Yes
Linear motion	Yes	Yes	Yes	Yes
Test location	EagleBurgmann	SwRI	EagleBurgmann	SwRI

Nielson, J. et. al. Component Testing of a High Temperature Dry Gas Seal. In Proceedings of the Seventh International Symposium—Supercritical CO2 Power Cycles, San Antonio, TX, Feb; 2022.

Project Phases

1st phase: Development of Balance Sealing Element at RT

2nd phase: Tests of Balance Sealing Element at design temperature

3rd phase: Development of a high-temperature DGS

- Static Tests of Balance Sealing Element
- Dynamic Tests with Air-He at RT (at EagleBurgmann)

4th phase: Dynamic Tests with sCO2 at 510 °C (at SwRI)

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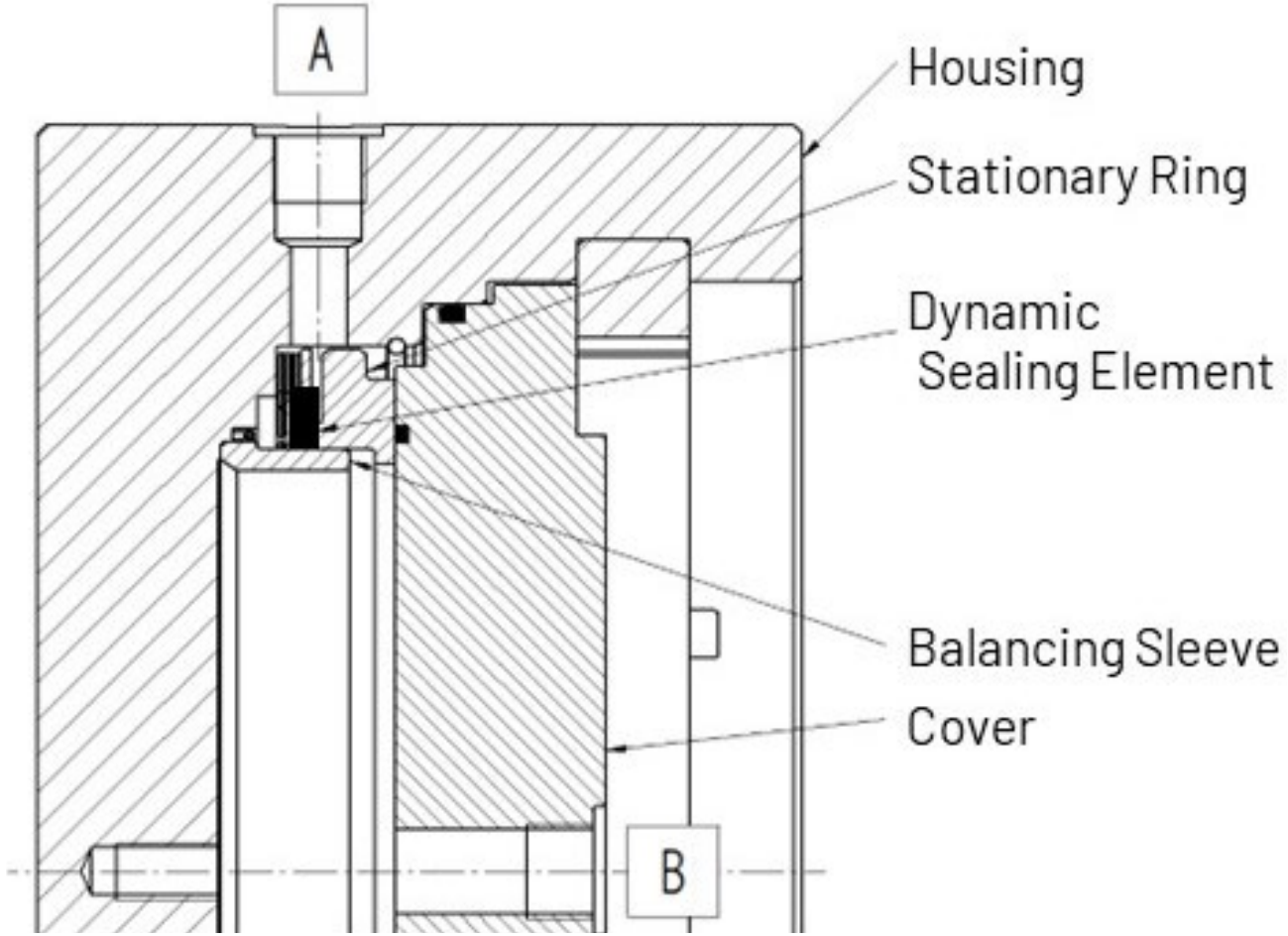
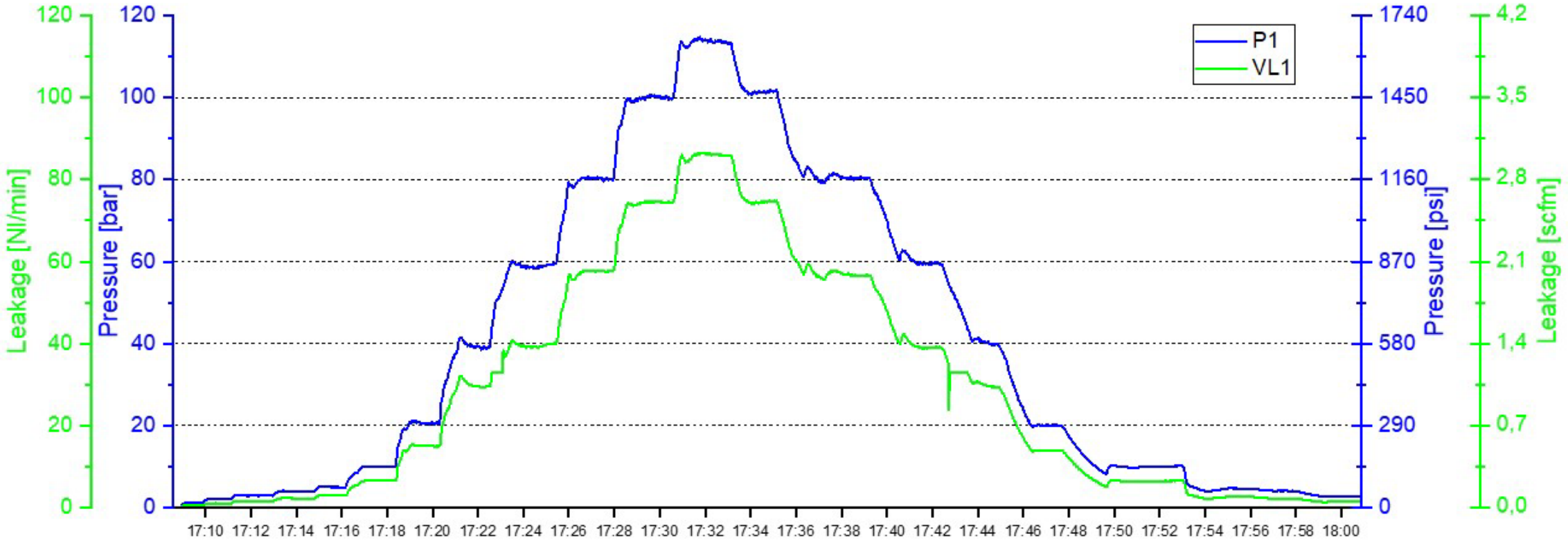
Static Tests of a Balance Sealing Element

- Design pressure: 114 bar (1650 psi)
- Air supplied at RT
- Static tests
- Seal-ID: 150,5 mm (5,92 in)
- Pressurization and depressurization steps
- Acceptance criteria: leakage rate and stability



Static Tests of a Balance Sealing Element



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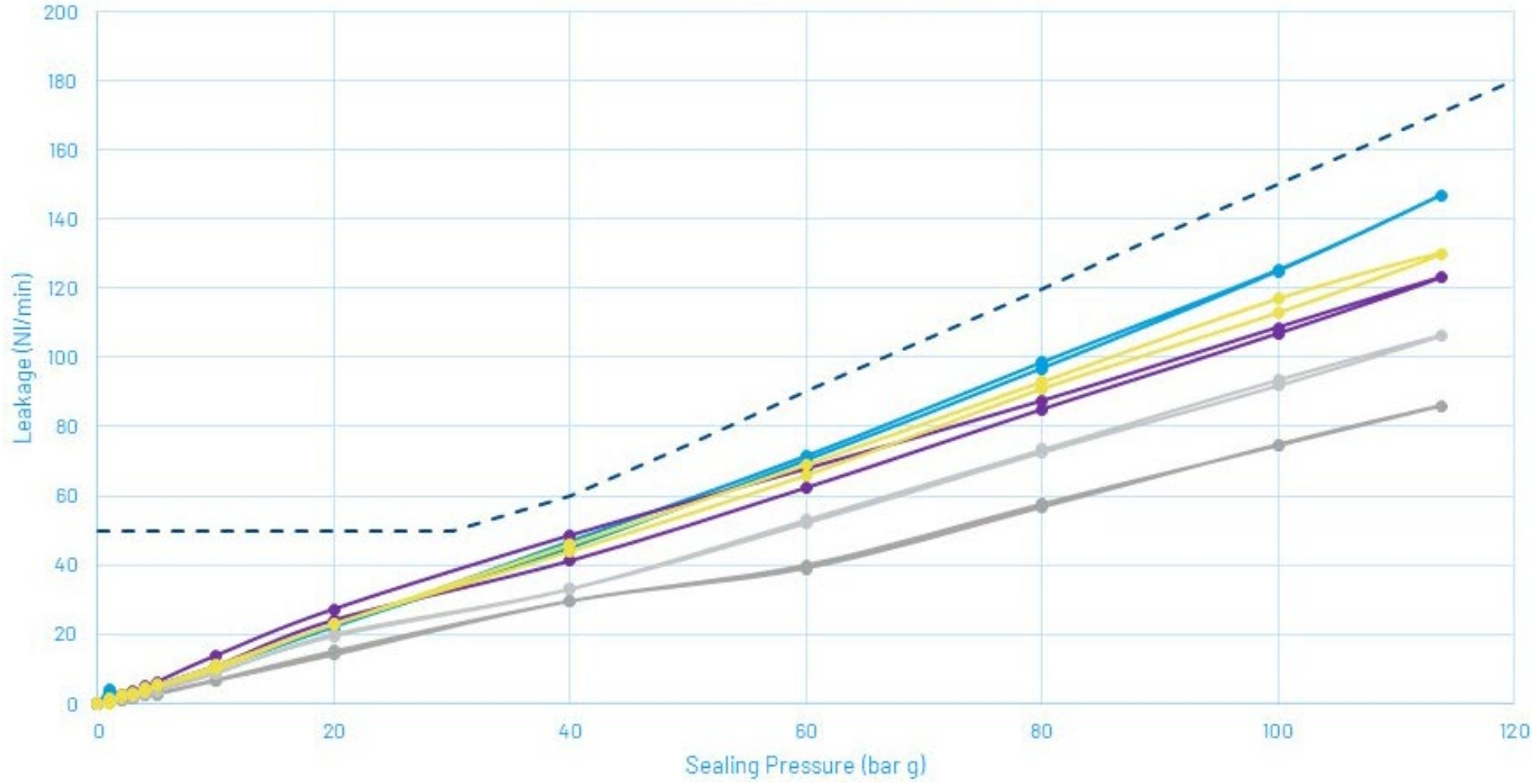

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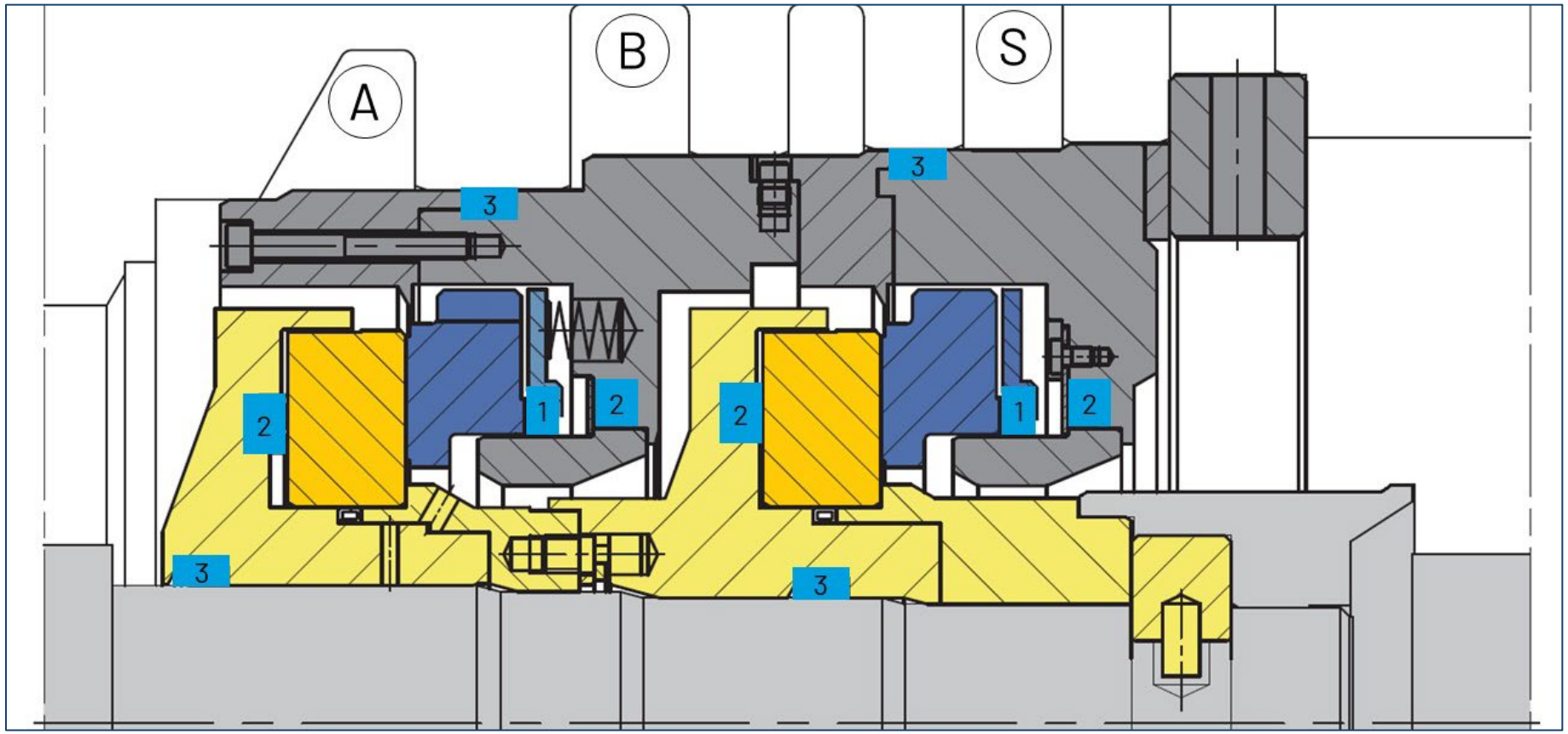

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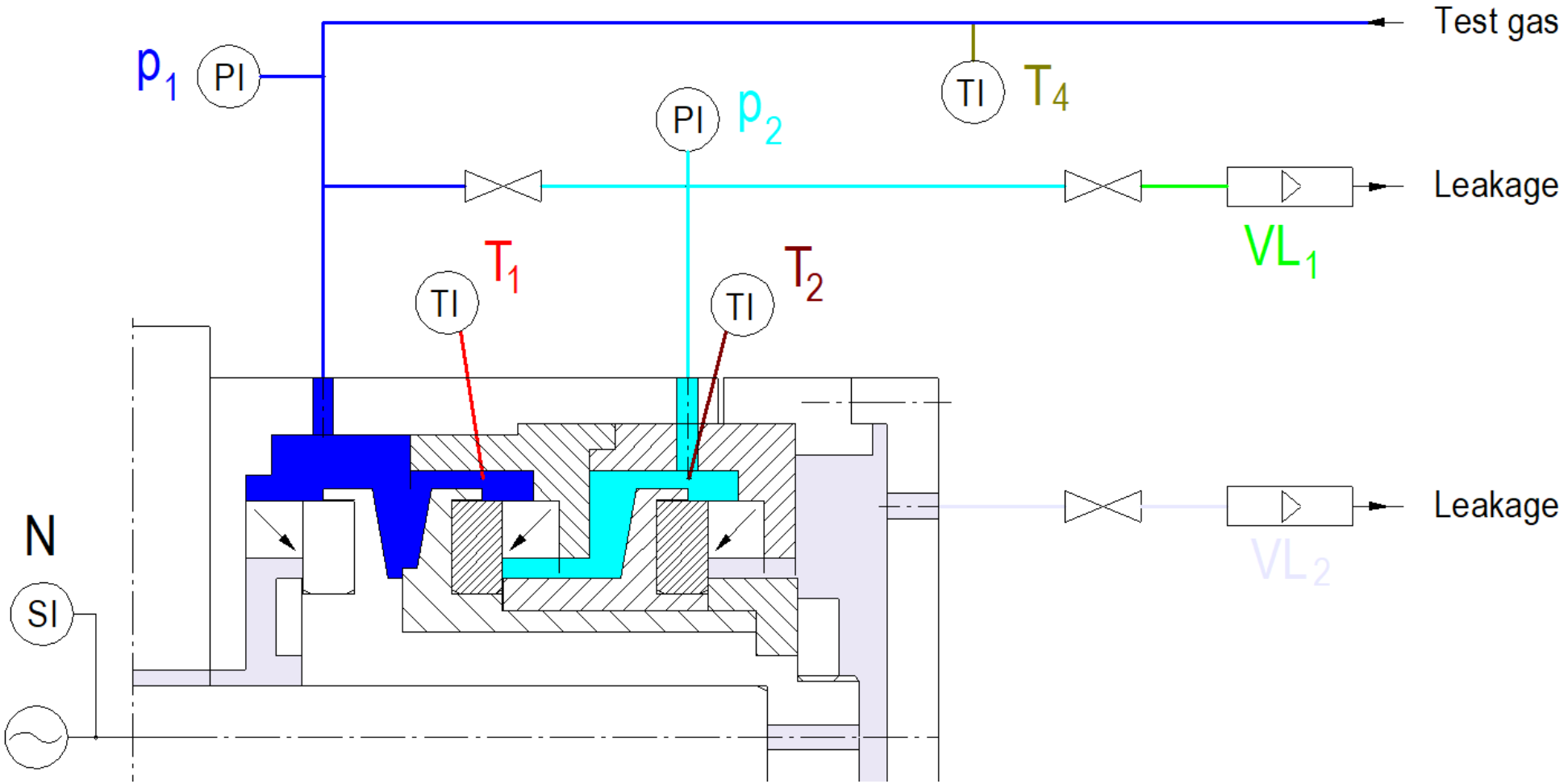
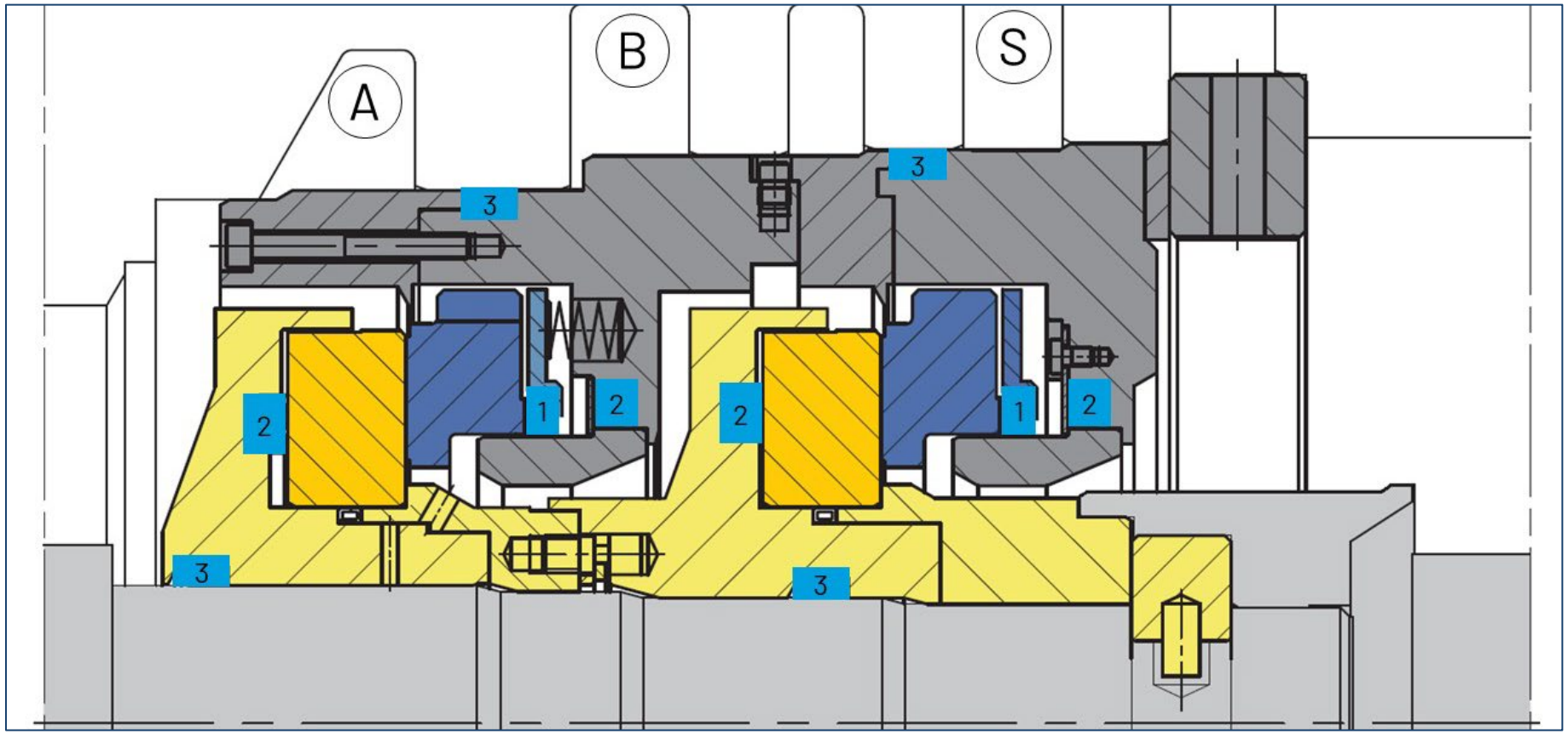
Test Step	Balance SE (Pos1)	Core SE (Pos 2)	Housing SE (Pos 3)
1st	O-Ring	O-Rings	O-Rings
2nd	High-temp. resistant	O-Rings	O-Rings
3rd	High-temp. resistant	High-temp. resistant	O-Rings
4th	High-temp. resistant	High-temp. resistant	High-temp. resistant

Dynamic Tests at EagleBurgmann



Dynamic Tests at EagleBurgmann

- Pressure: 113,8 barg (1650 psi) (static) | 89 barg (1290 psi) (dynamic)
- Speed: 18000 rpm (165 m/s | 3,28 ft/s on rotating ring OD)
- Max temperature: 250 °C (482 °F)
- Medium: 75%Air/25%He
- Test steps:
  - Static cold
  - Dynamic
  - Static hot



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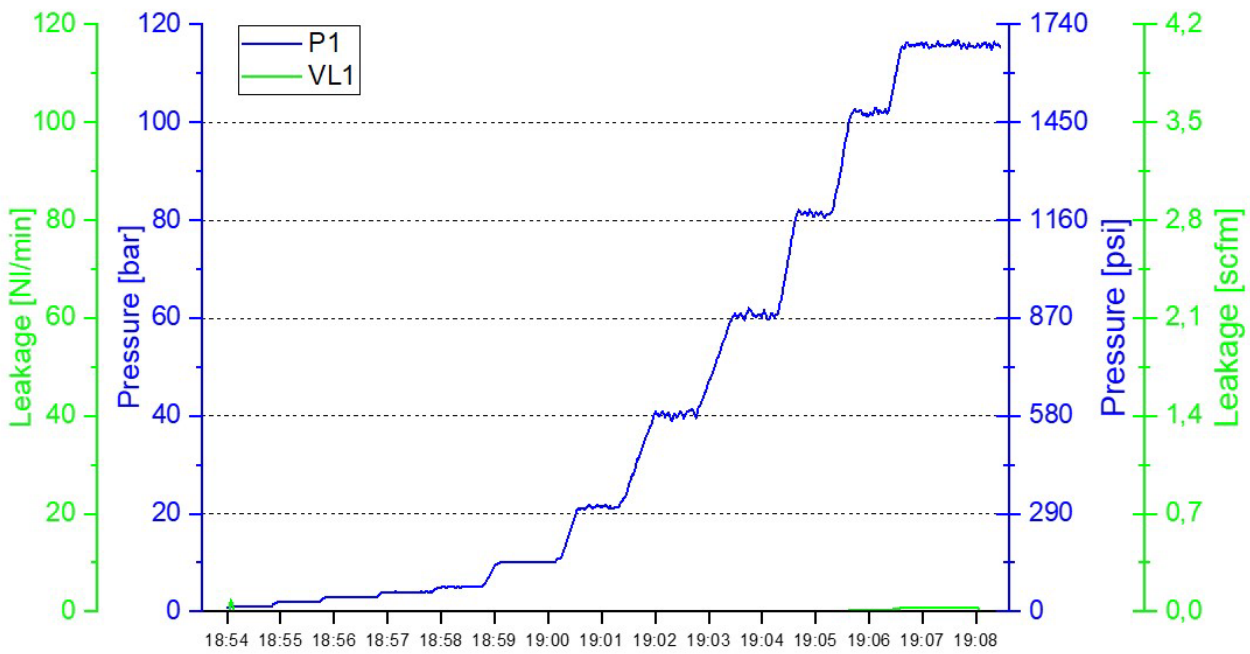
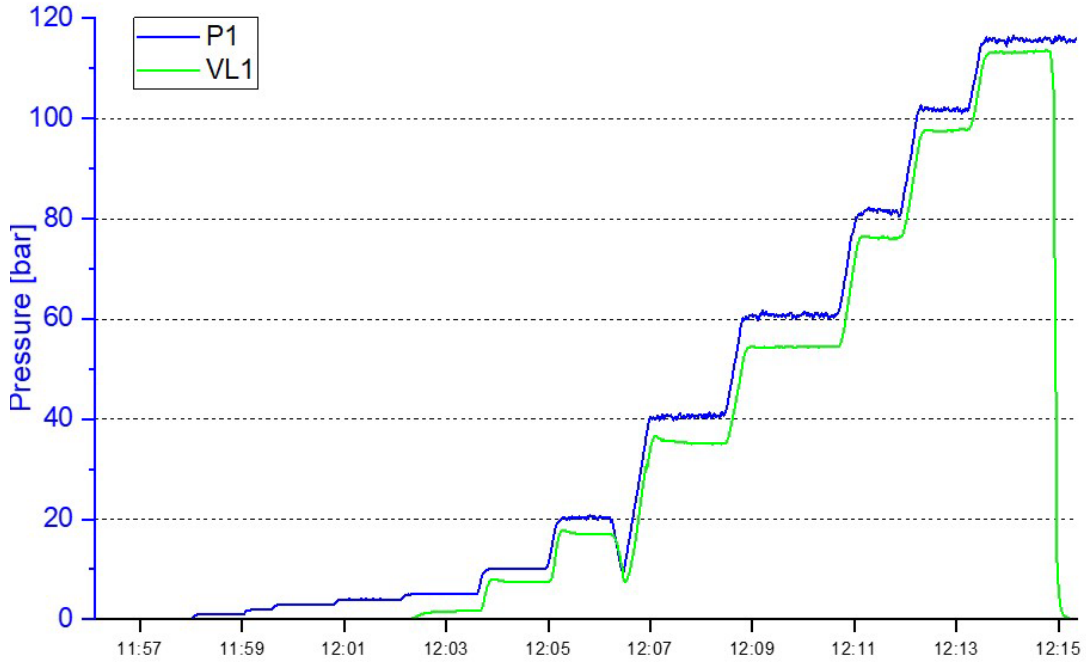
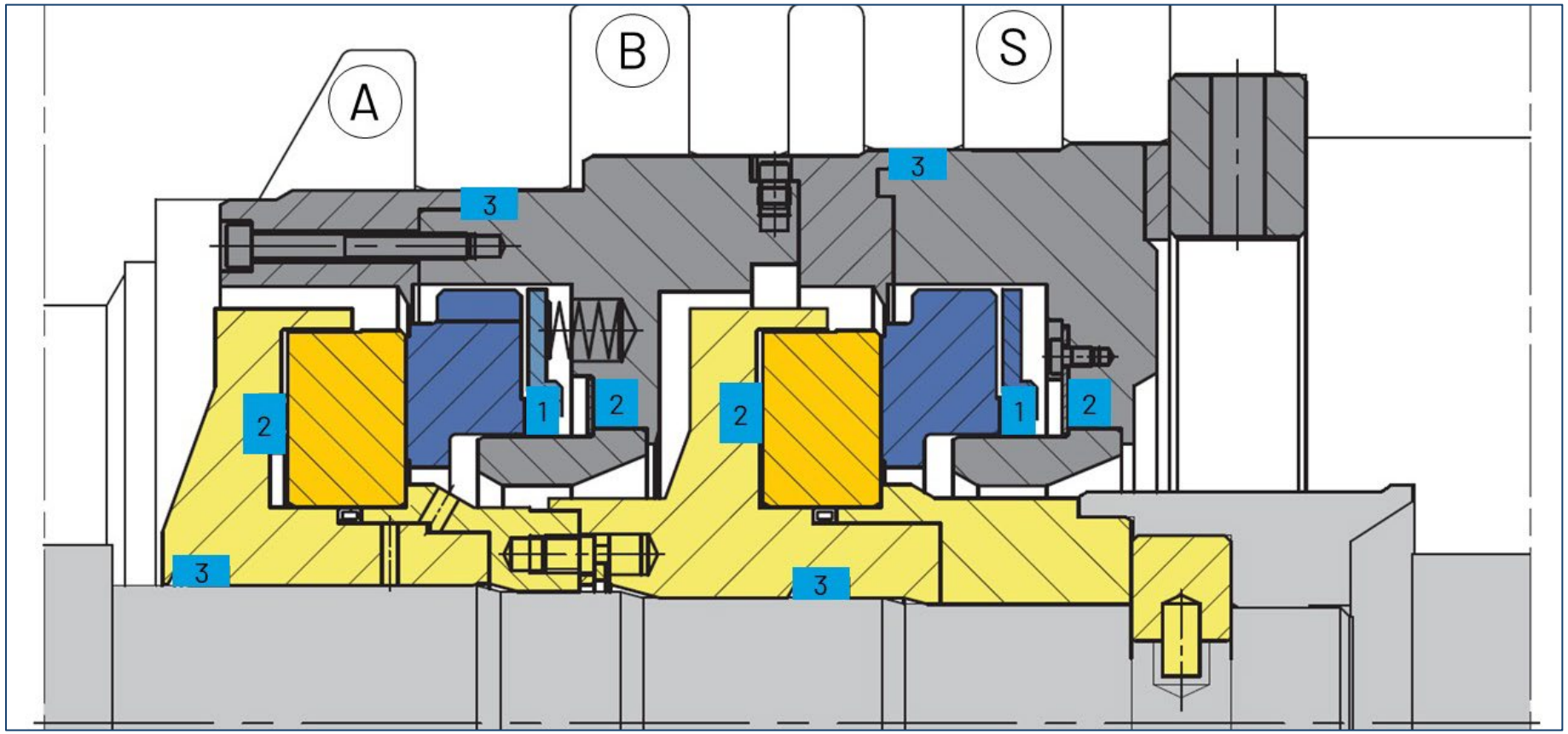


1st Step: O-Ring as balance sealing element



2nd Step: HT-resistant SE as balance sealing element



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Dynamic Tests at EagleBurgmann

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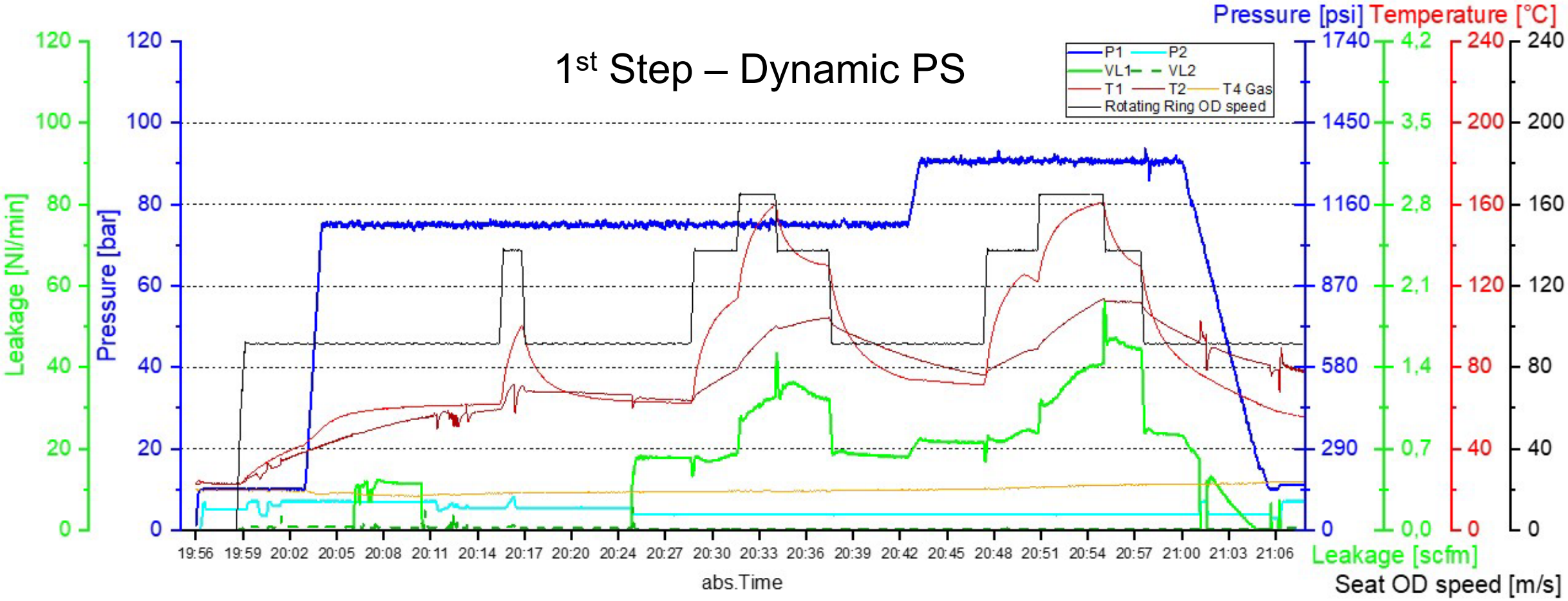

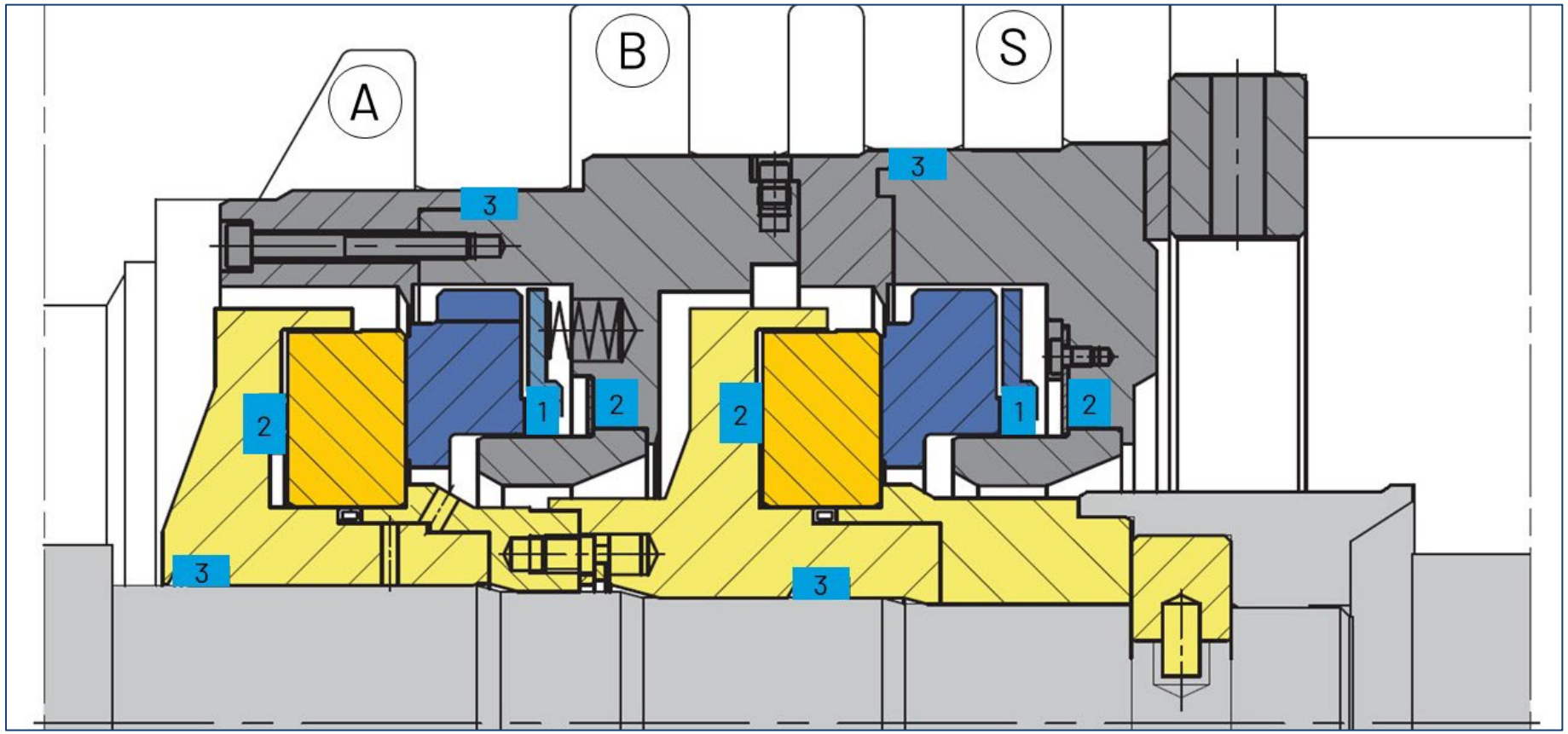

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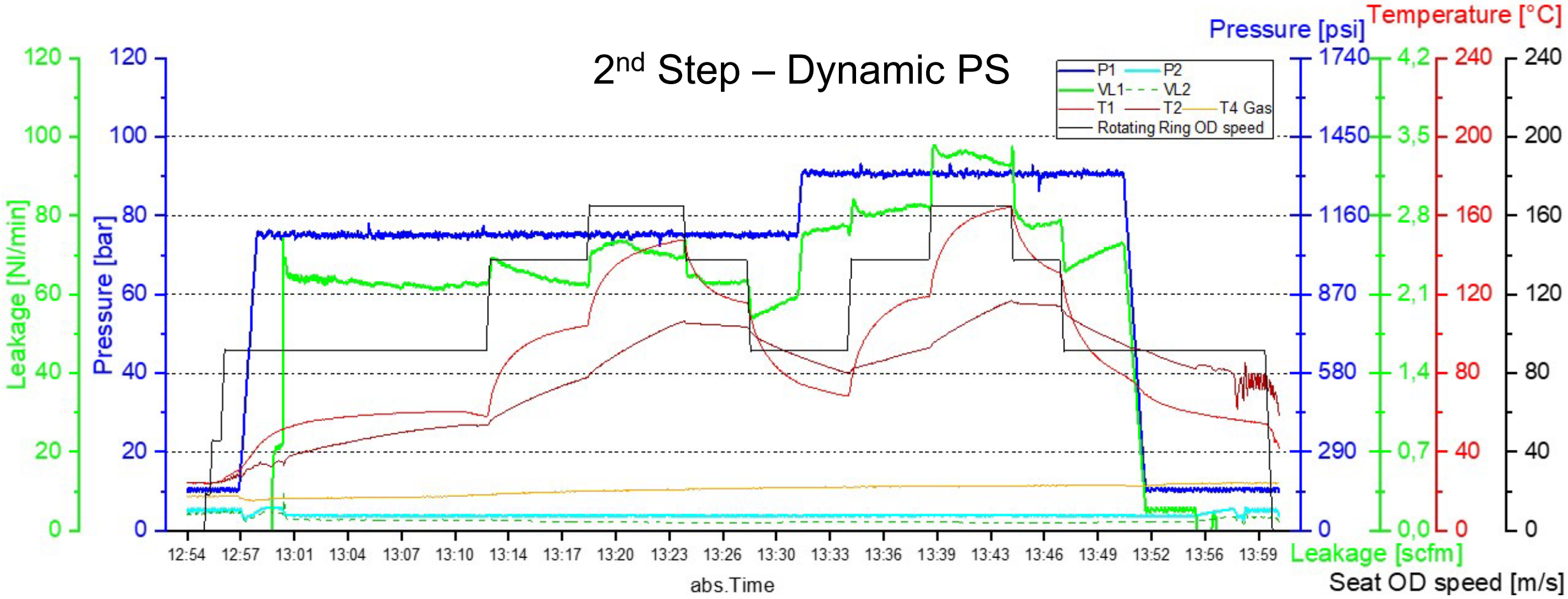
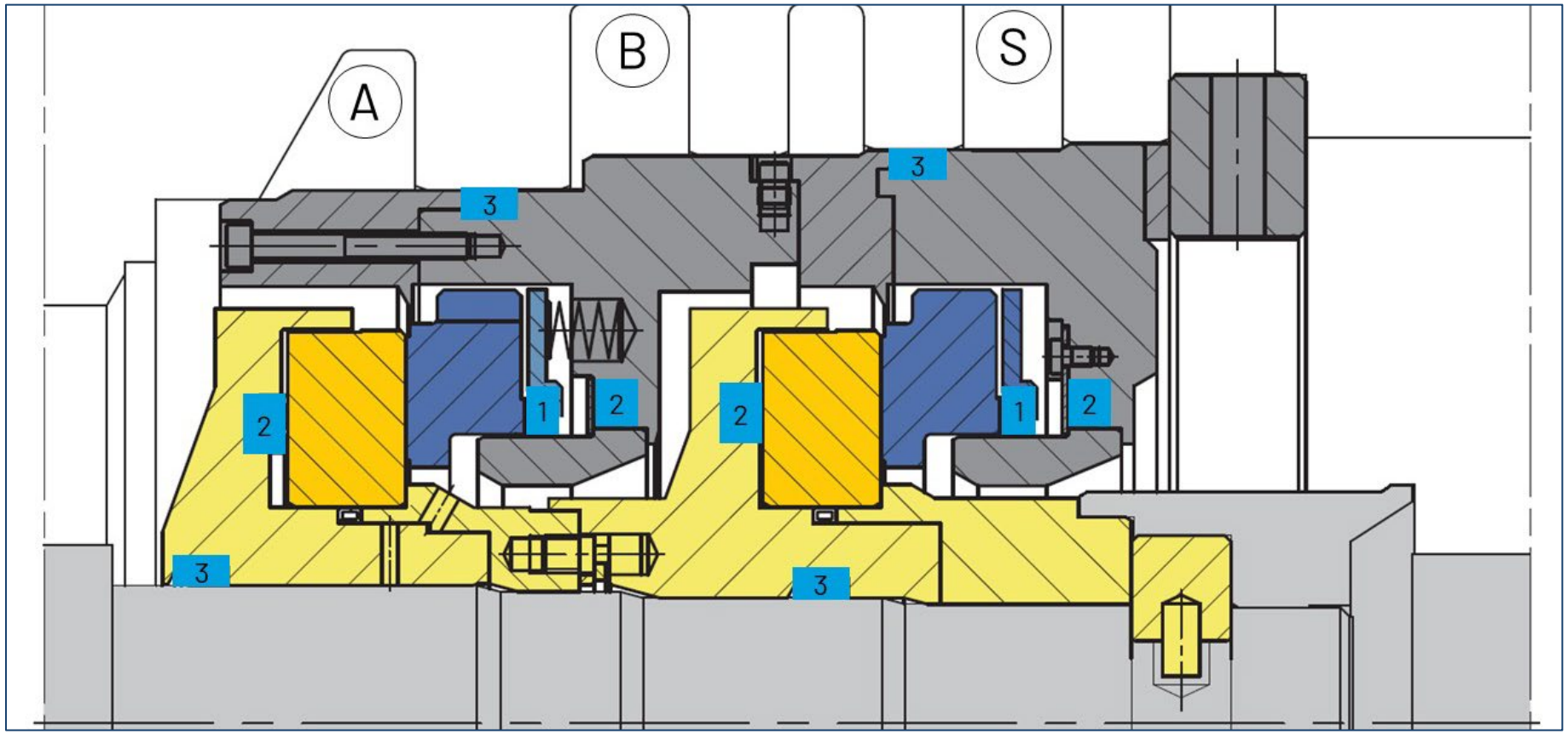
Dynamic Tests at EagleBurgmann





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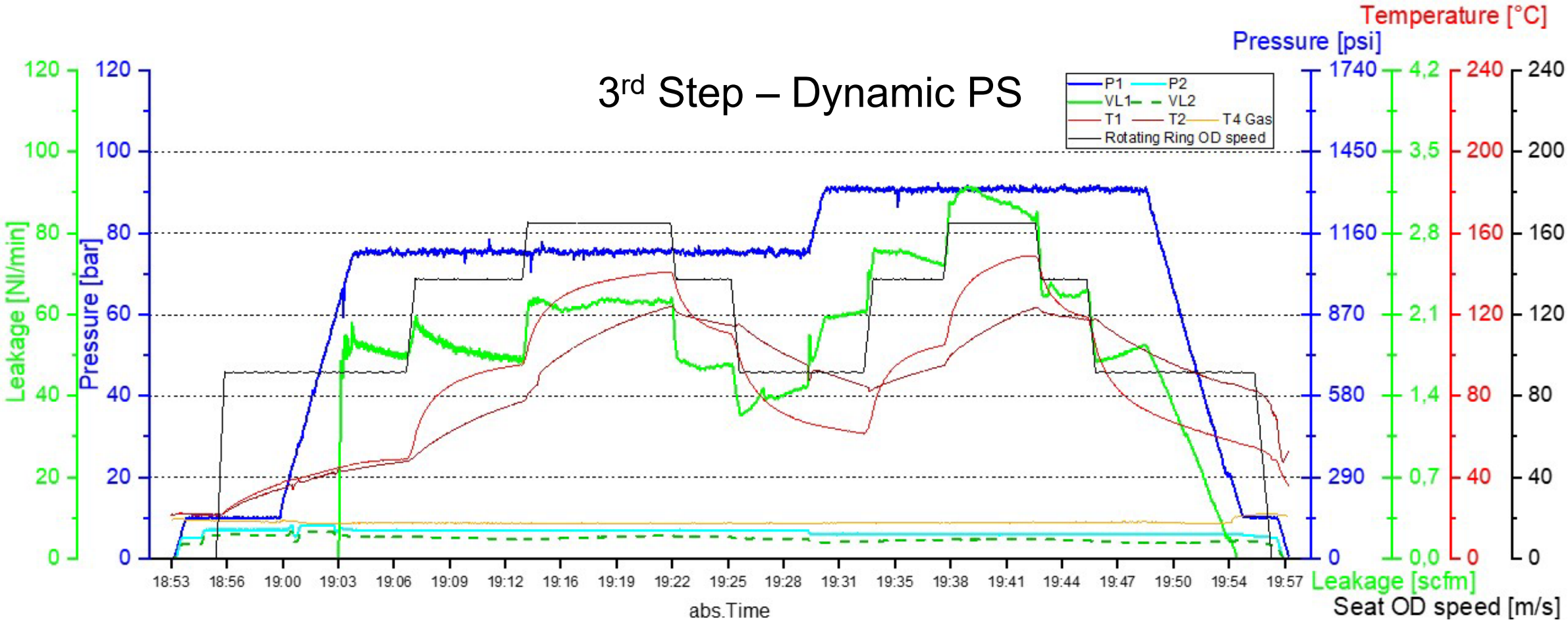

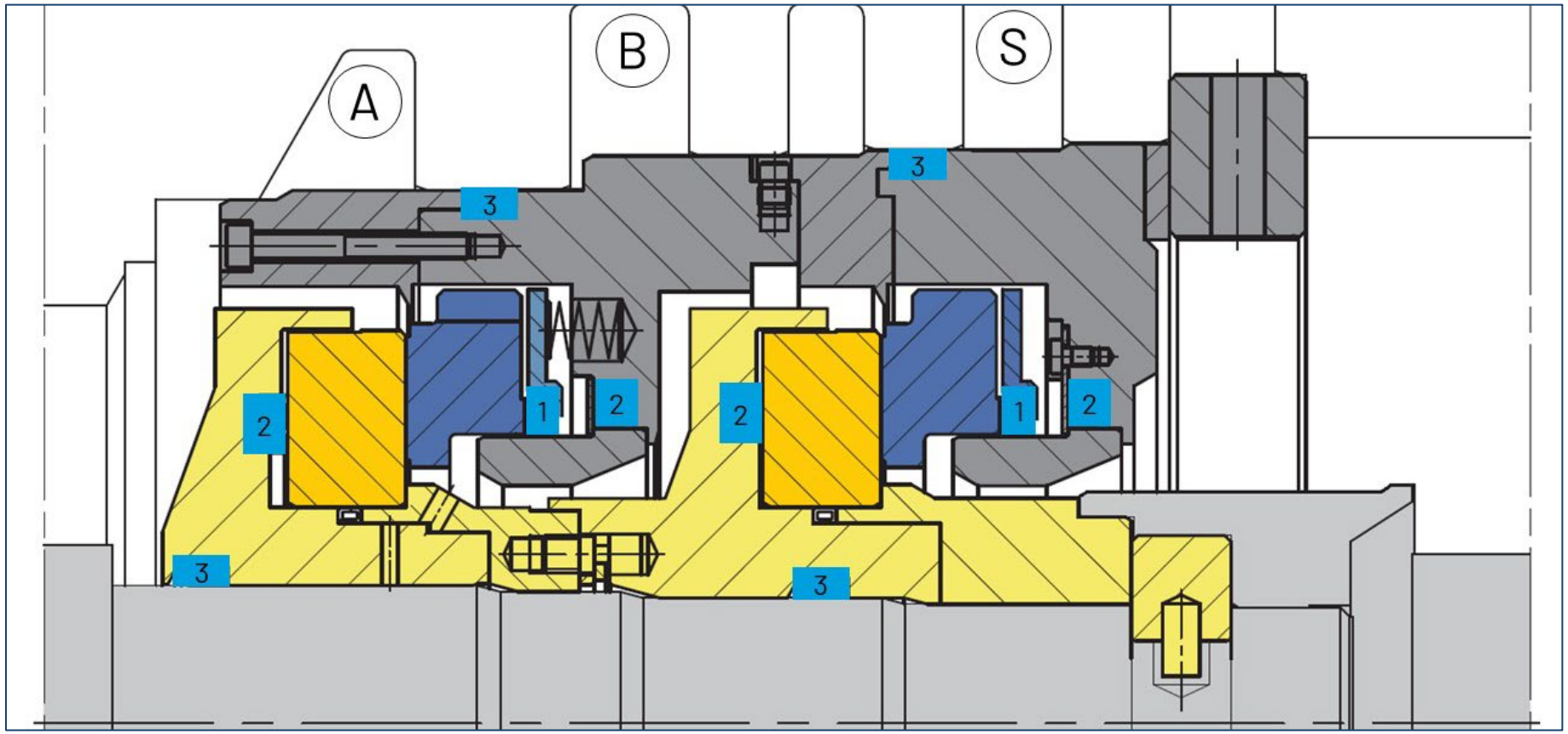

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Dynamic Tests at EagleBurgmann

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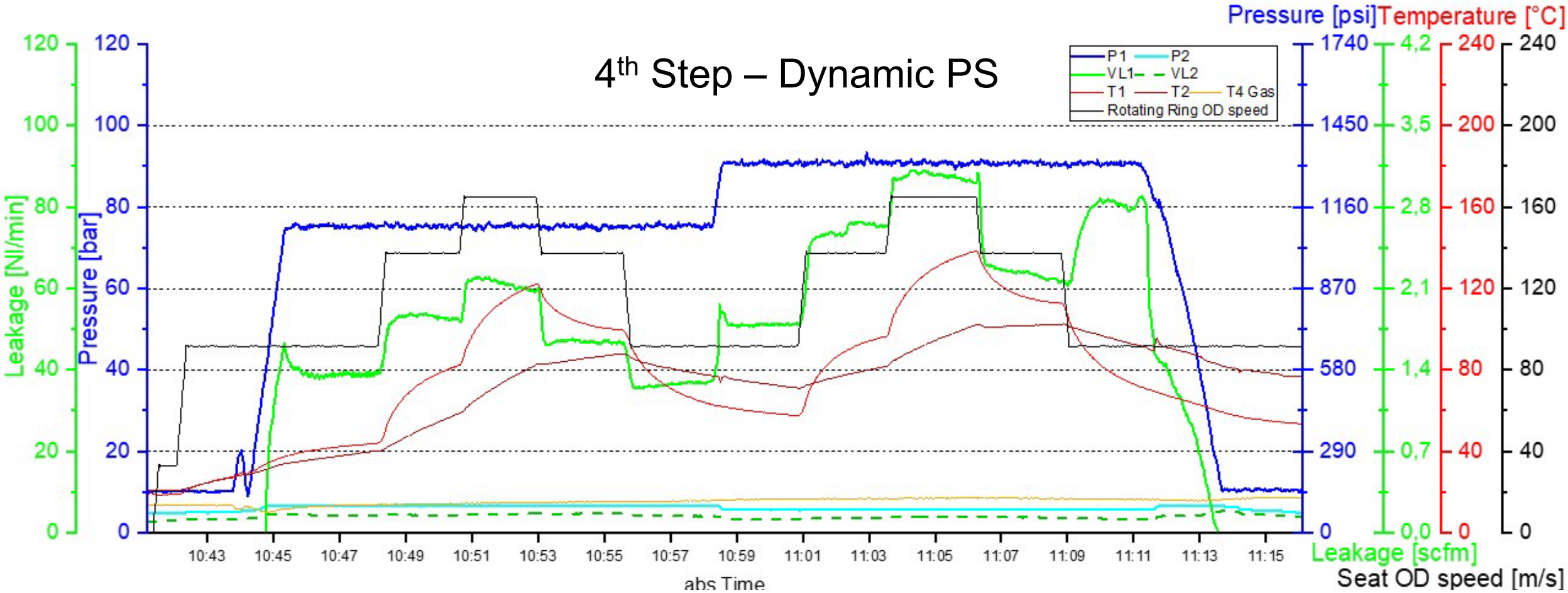

Conclusions

- Technical feasibility of high-temperature DGS for sCO2 turbines up to 250 °C (482 °F) and air/He proven
  - Leakage behavior very similar among all test steps, what means a good repeatability of test results
  - Leakage below target of 1,5 Nl/min/bar (0,053 scfm/psi)
  - Leakage stable after changing operating conditions
- Tests with sCO2 at 510°C (950 °F) planned for this 2024Q2 at SwRI

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