High-temp Dry Gas Seals for sCO_2 turbines DE-FE0031924

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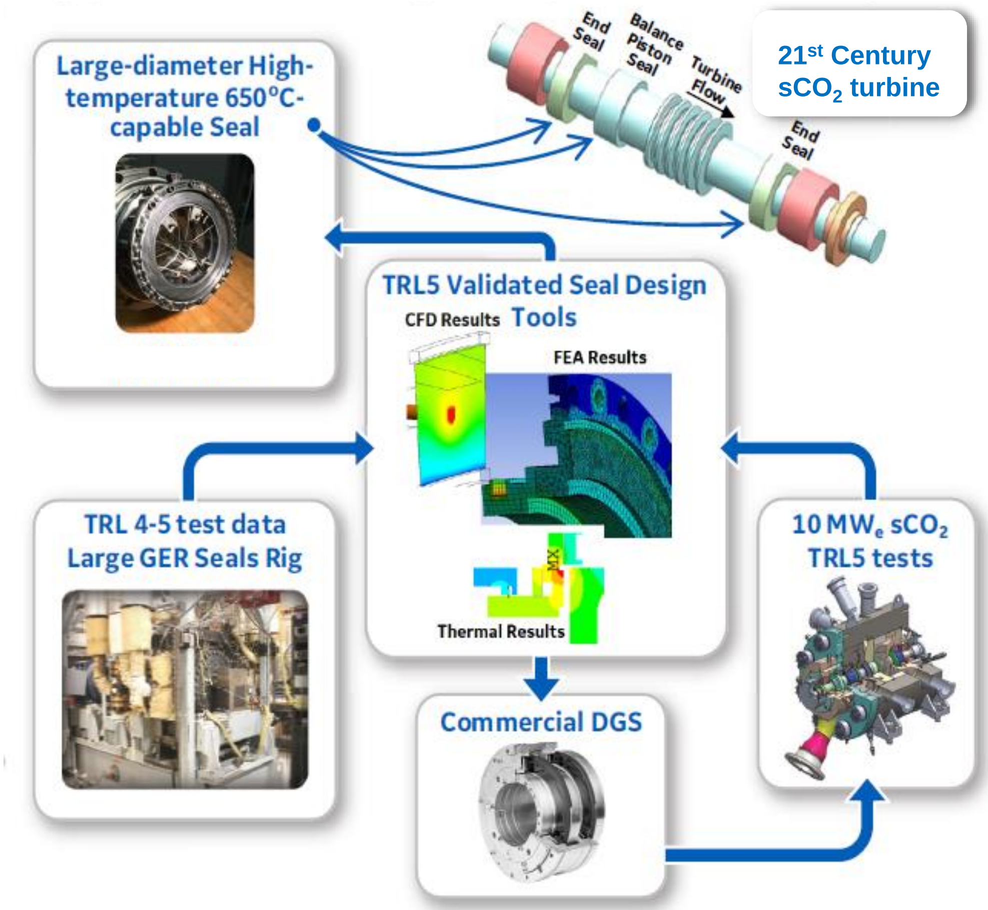
Outline

- Overview
- Commercial DGS Failures & Need for High-temp DGS
- Thermal Modeling and DGS testing in sCO2 compressors – Task 2
- Large-diameter seal design – Task 3
- Summary & Next Steps

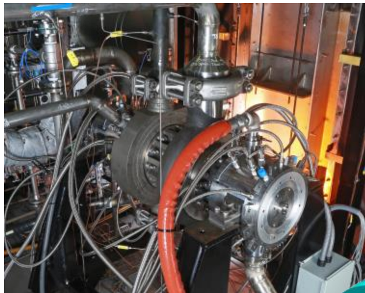
Overview

18-month, $1.25MM Program to Develop High-temperature Dry Gas Seals (DGS) for sCO_2 turbines

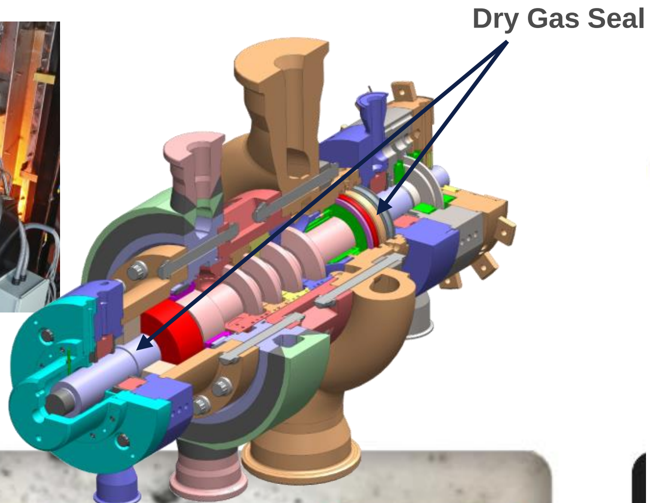


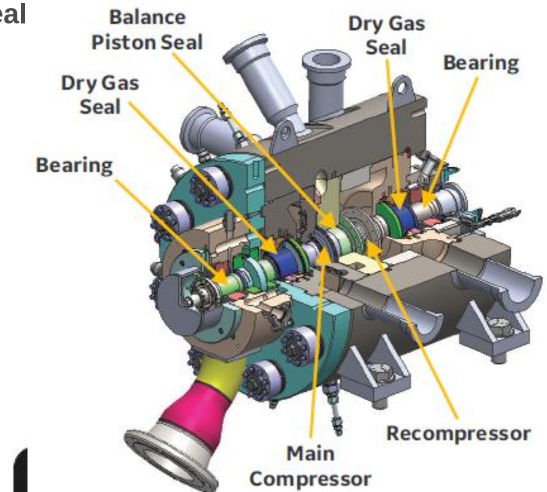
- 10 MW_e scale – Improved reliability of DGS and validation of Seal Design Tools
- 100 MW_e scale – High-temp seal to enable modular sCO_2 21st century turbines

DGS Reliability Issue – 10 MW_e scale



10 MW_e SunShot Turbine





4 MW_e Apollo Compressor

Failed DGS – SunShot Turbine Test at SwRI (2015-2017)

Failed DGS – Apollo Compressor Test (2019)

DGS Failure Leading Root Cause:

- Incorrect seal-system integration
- Seal film capability exceeded during operation

Program Goal # 1
Ensure efficiency realization by investigating DGS reliability issues

Value of High-temp DGS Development

- State-of-the-art low-temp (200 °C) commercial DGS
  - 0.5% to 1.3% cycle efficiency
  - Limit operating ramp rates of turbines

Program Goal # 1
Ensure efficiency realization
by increasing reliability

- High-temp DGS (up to 700 °C)
  - Enable 0.7% to 1.9% cycle efficiency
  - Enable alternative turbine architectures
    - better turbine ramp rates & operation flexibility
    - Higher ramp rates

Program Goal # 2
Enable even better (efficient
& operationally flexible)
Coal FIRST turbines

Turbomachinery	Application	Location and Temperature	Cycle Efficiency Benefit
10 MW_e sCO_2 turbine	WHR, CSP, NGPC, Coal FIRST risk reduction	Shaft-end labyrinth seals (200°C)	0 (baseline)
		Shaft-end DGS (200°C)	1.32%
		Shaft-end and Balance-piston DGS (700°C)	1.96%
10 MW_e sCO_2 compressor	WHR, CSP, NGPC, Coal FIRST risk reduction	Shaft-end labyrinth seals (200°C)	0 (baseline)
		Shaft-end DGS (200°C)	1.32%
		Shaft-end and Balance-piston DGS (200°C)	1.9%
100 MW_e sCO_2 turbine	Coal FIRST	Shaft-end labyrinth seals (200°C)	0 (baseline)
		Shaft-end DGS (200°C)	0.71%
		Shaft-end and Balance-piston DGS (700°C)	0.85%
450 MW_e sCO_2 turbine	Fossil indirect coal plant	Shaft-end labyrinth seals (200°C)	0 (baseline)
		Shaft-end DGS (200°C)	0.52%

Goal # 1 Reliability

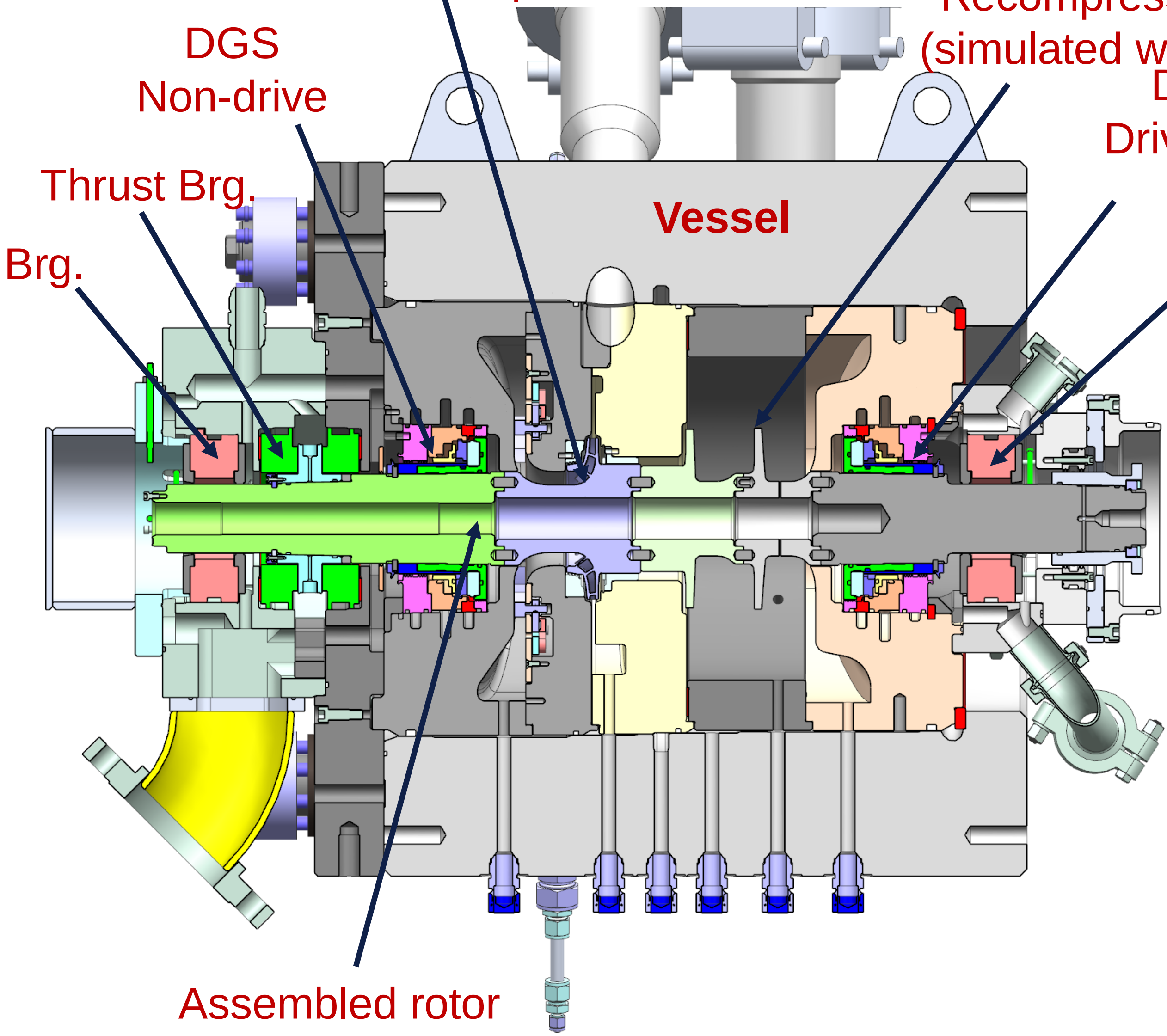
Goal # 2 Higher -Temps

Update on Task 2

Thermal modeling & testing of instrumented DGS in sCO_2 compressor

Test vehicle – Apollo sCO_2 compressor C/S

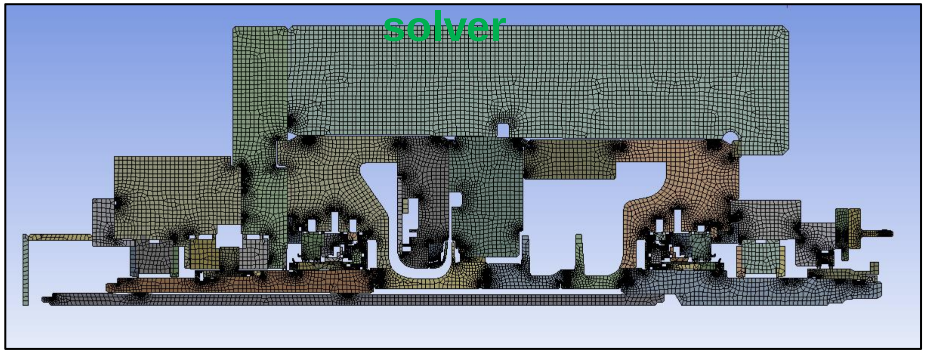
Existing sCO_2 compressor c/s



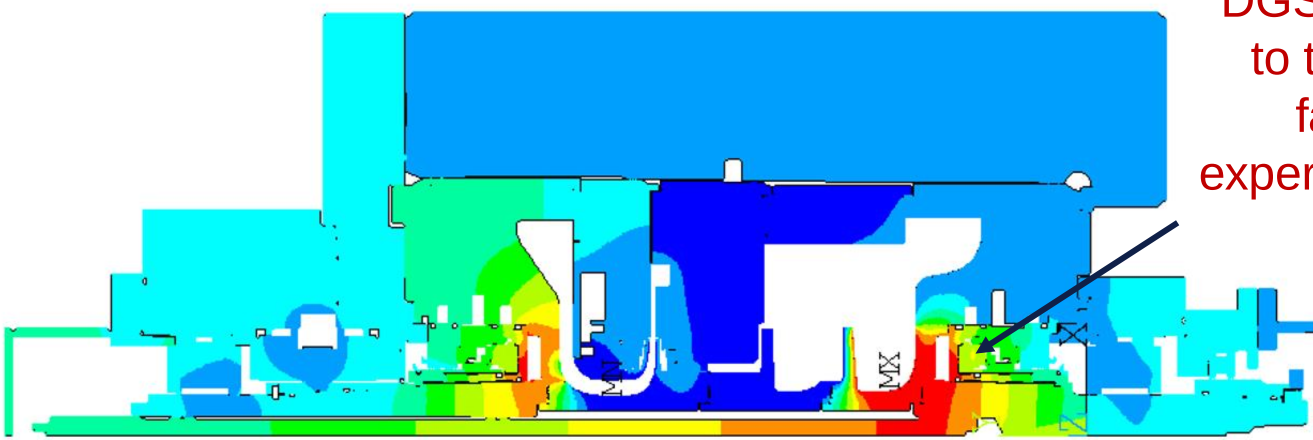
Existing sCO_2 compressor at SwRI

Thermal Modeling of DGS in Compressor

In-house FE-based thermal solver



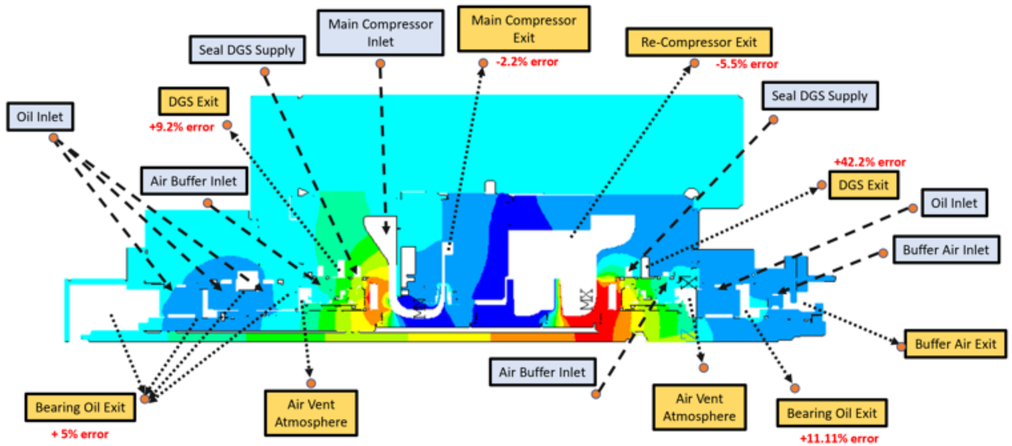
Temperature prediction for



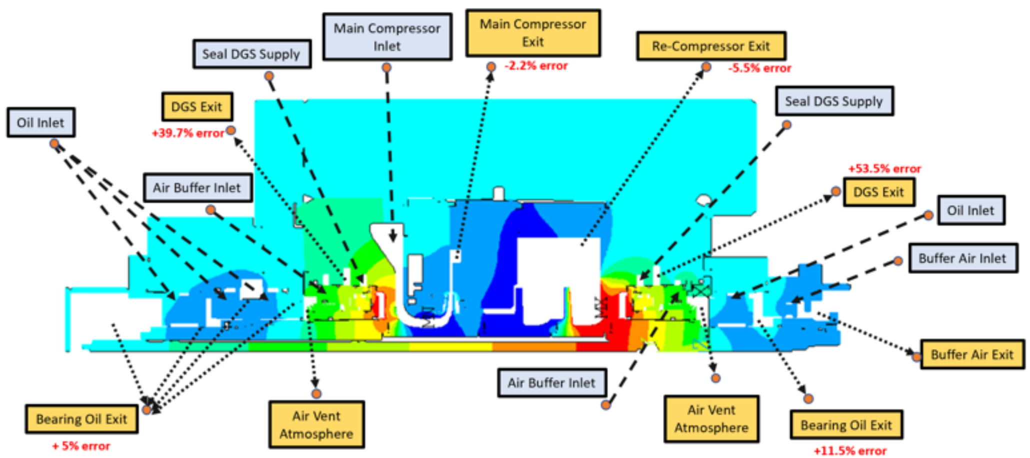
High temperatures in DGS region can lead to thermal stability failure -- need experimental validation

- In-house thermal solver accounts for CO_2 real-gas properties, windage, CFD-based leakage flows, heat transfer coefficients
- High temperatures (and large thermal deformation) predicted near Drive-End DGS due to a combination of large heat generation and low cooling flow

Thermal Predictions for DGS (two vendors)



Metal temp map for Seal Vendor # 1



Metal temp map for Seal Vendor # 2

- Thermal predictions completed for seals from two different commercial DGS

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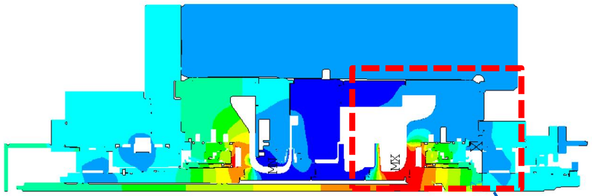
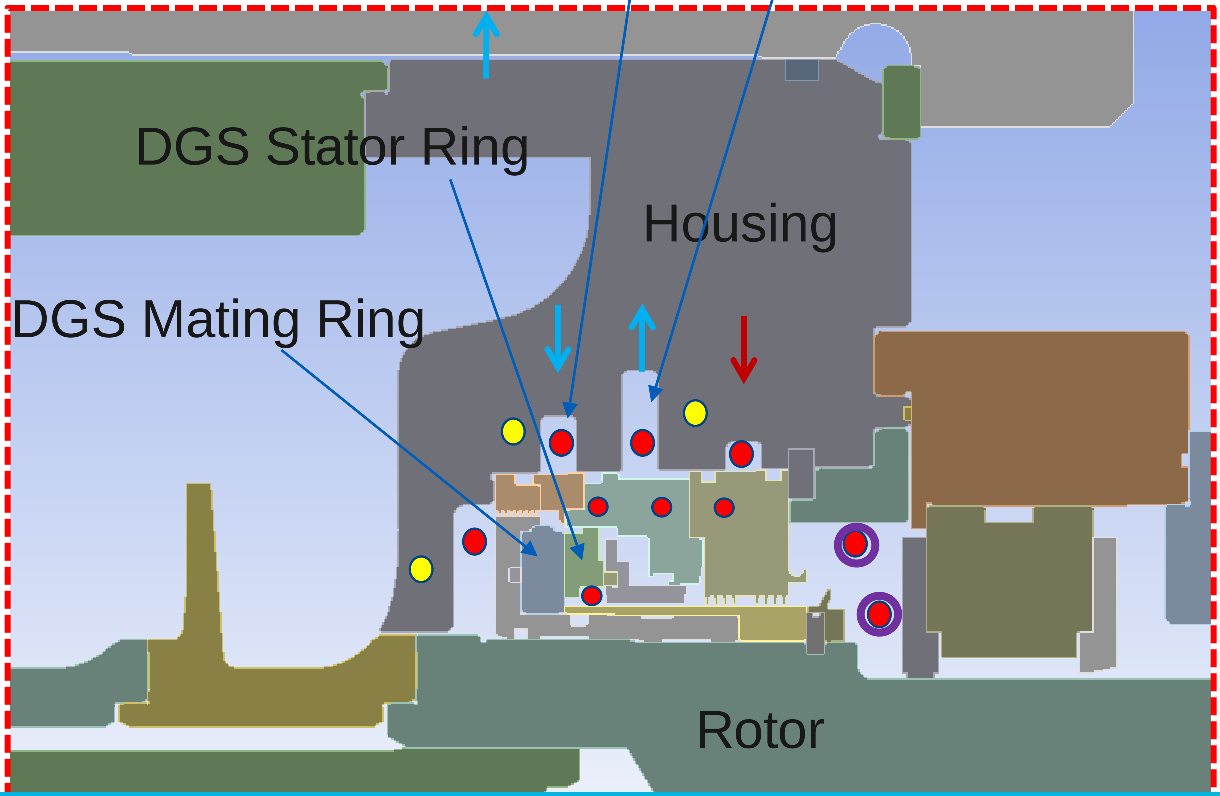
DGS Instrumentation scheme for upcoming testing





- Metal Temperature measurements
- Cavity Temperature measurements
- Orifice Flow Meter Measurement
- Additional Orifice Flow Meter
- Temperatures measured in external lines (Air Vent, Oil Drain)

- Devised cavity and metal temperature measurement scheme to validate thermal predictions
- Worked with commercial DGS vendor to procure DGS with custom instrumentation access
- Worked with in-house machine shop to fabricate new housing with instrumentation access

Update on Task 3

Thermal modeling & testing of instrumented DGS in sCO2 compressor

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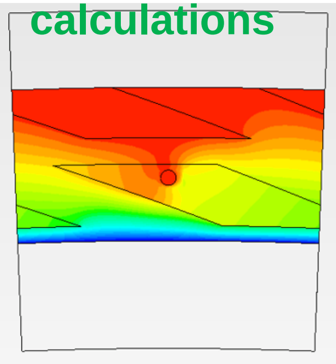
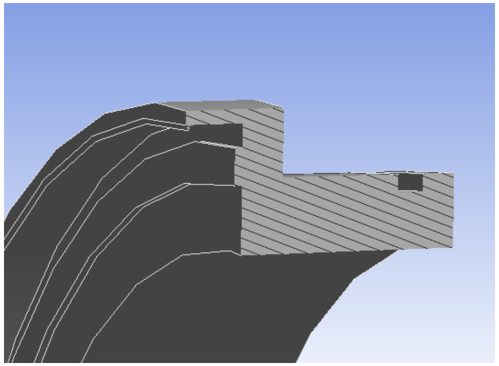
Large-diameter Seal design – ongoing work

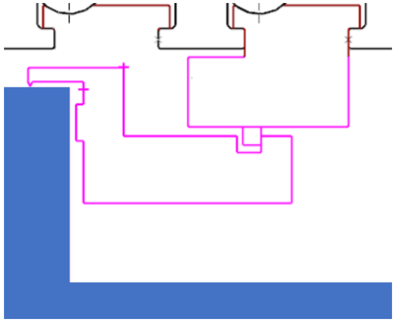
Seal bearing face CFD for force balance & leakage calculations



Seal c/s analysis with FEA for stresses & deflections



Seal packaging in a large land-based turbine to study assembly and space constraints



- Partnering with GE Vernova (Power) team to develop a seal design for a land-based turbine

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Summary & Next Steps

Summary & Next Steps

- Task 2
  - Thermal analysis & pre-test predictions ready
  - Testing commences Jan 2023 with instrumented DGS in sCO_2 compressor
- Task 3
  - Large-diameter, high-temp seal design for a land-based Steam turbine underway

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