Supercritical CO_2 Power Cycles Symposium

Component Testing of a High Temperature Dry Gas Seal

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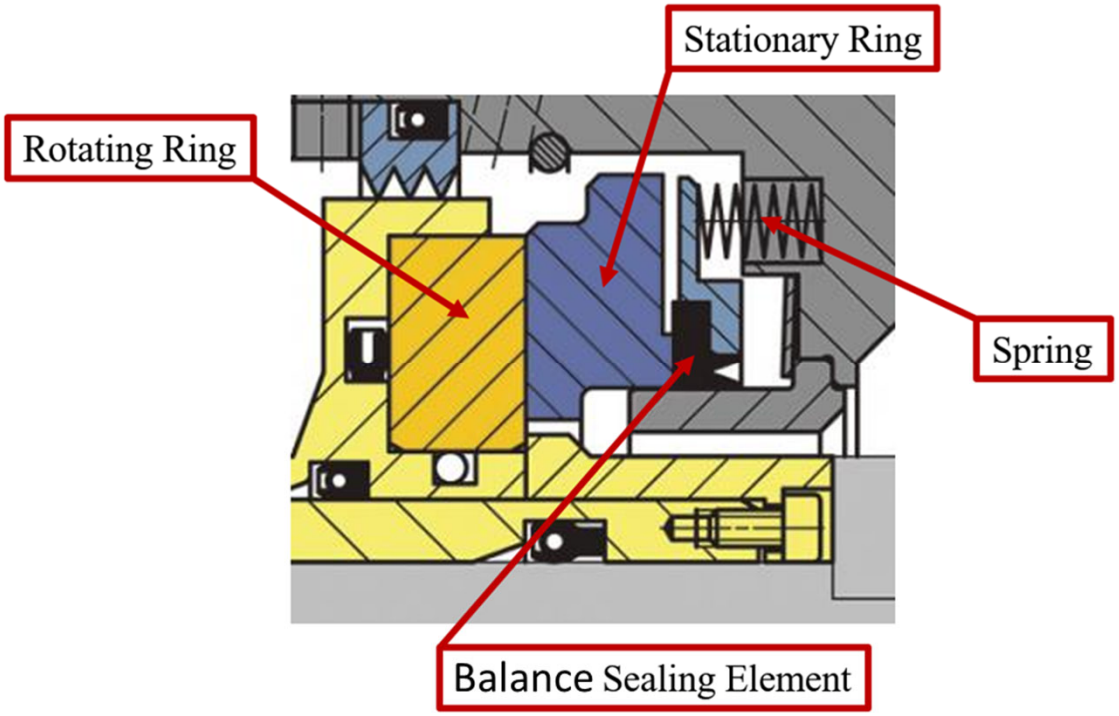
Funded by the
Department of Energy
DE-EE0008740

Dry Gas Seal Principles

Balance Seal

- Typically made from Elastomers
- Limited to 200°C



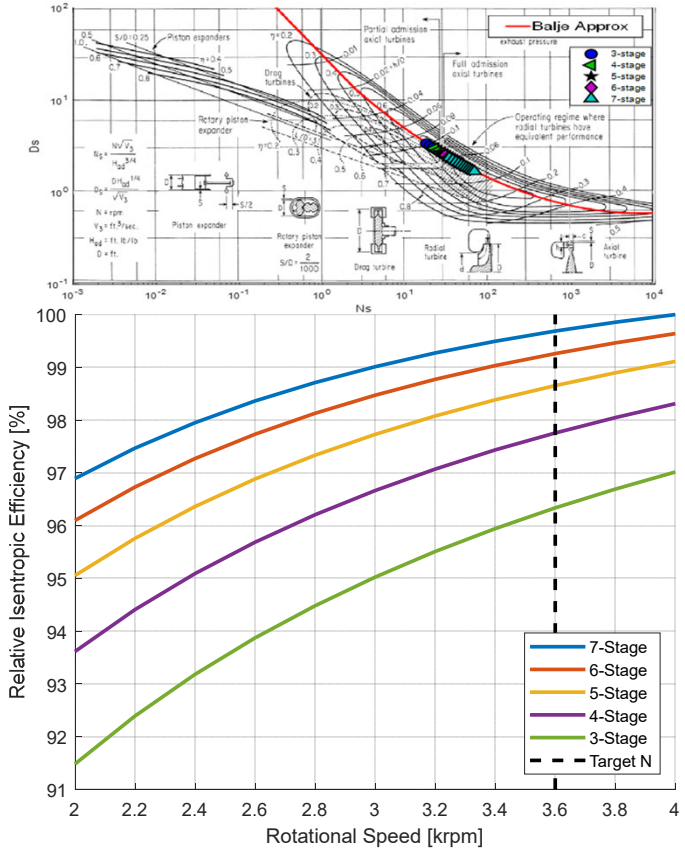
Innovation: Improved Efficiency

- Performed a study using a 1-D turbine analysis (Balje Approximation)
- Major Assumption: replace the thermal management zone with extra stages
- Input the new turbine efficiency into a cycle analysis

Ballje Approximation based on Diameter and Speed

Adding additional stages diameter decreases while the speed increases .
•Increases isentropic Efficiency 2%
•Decreases inlet/outlet losses.

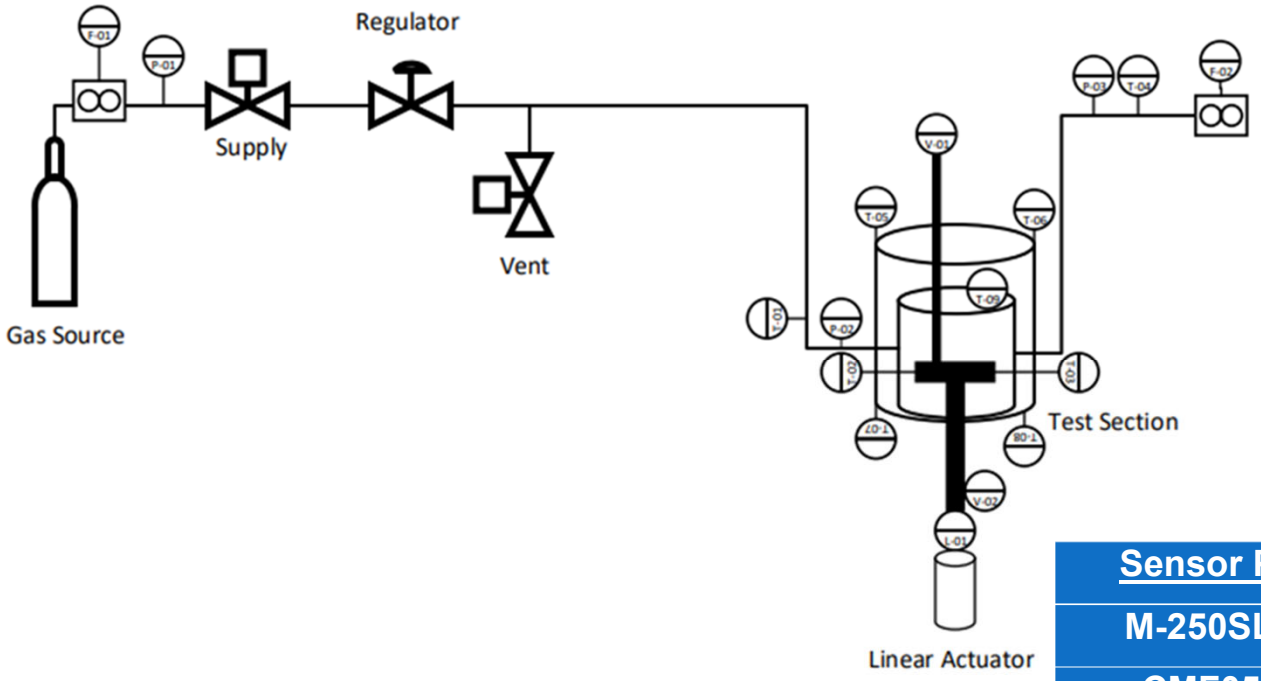
Increased stages, increases efficiency



Design Requirements/Targets

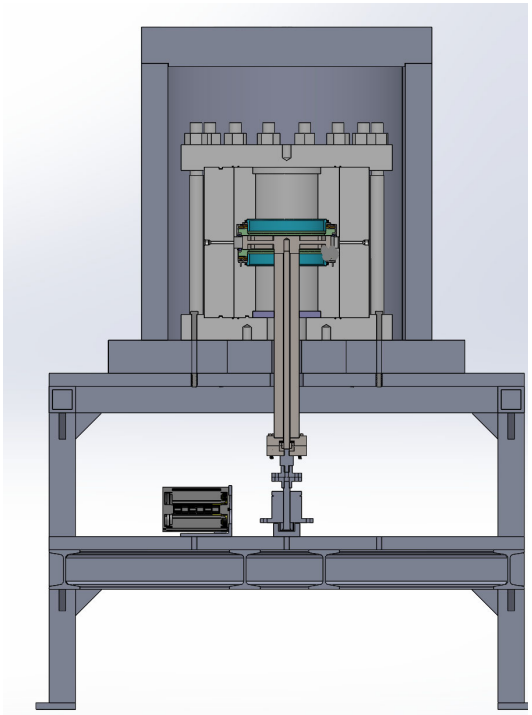
Requirement	Unit	Value
Temperature	°C	500
Pressure	MPa	7.4
Leakage	Nl/min	120
Friction	N	1,000
Range of Movement (thermal expansion)	mm	6.35
Range of Movement (dynamic oscillations)	µm	50

Test Rig P&ID

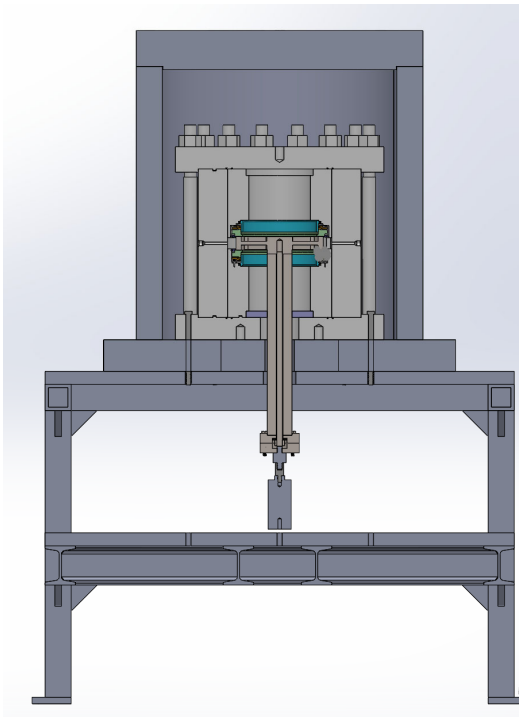


Sensor PN	Sensor Type	Accuracy
M-250SLP	Thermal Mass flow	0.5%
CMF050	Coriolis Mass Flow	0.25%
Rosemount 3051	Pressure	0.04%

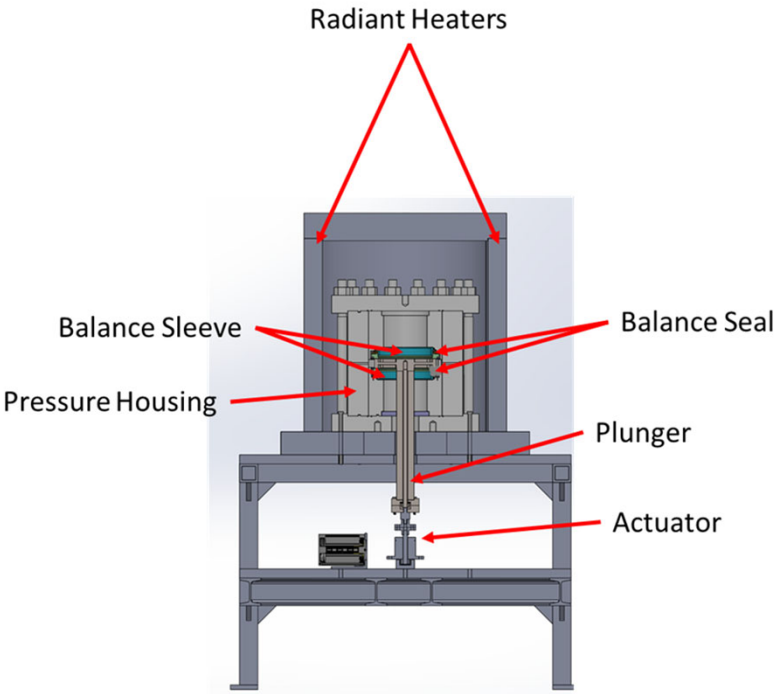
Test Rig



Slow Movement (0.25”)



Fast Movement (Vibration)

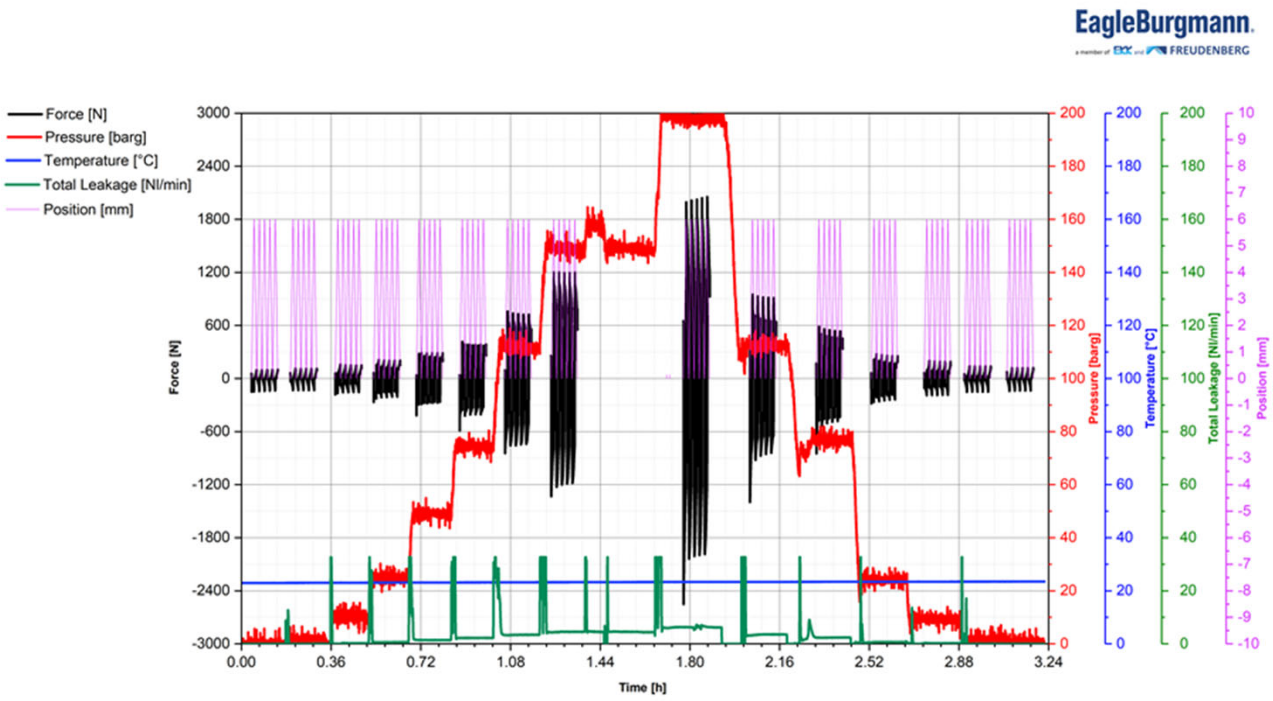


Testing Summary

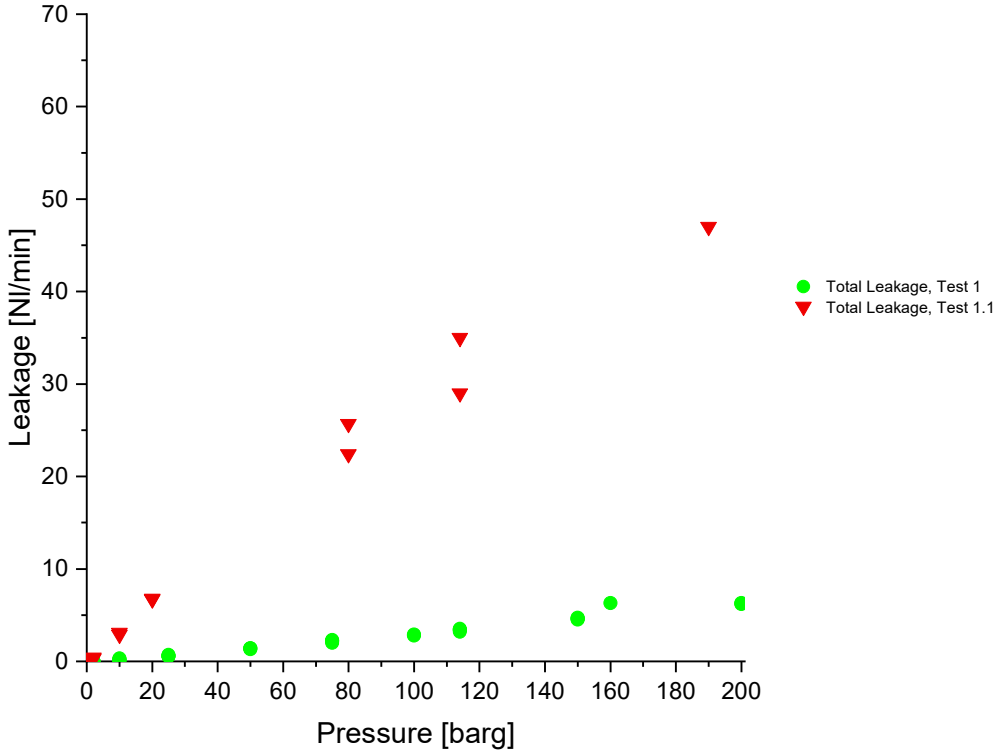
Test Nr	Balance Seal	Balance Sleeve	Backing Seal	Temp	Leakage rating	Force rating
1	Type 1	Sleeve 1	Seal 1	Ambient	1	1
1.1	Type 1	Sleeve 1	Seal 2	Ambient	2	--
2	Type 3 D1 M1	Sleeve 2	Seal 1	Ambient	4	2
3	Type 4 D1	Sleeve 2	Seal 1	Ambient	5	4
4	Type 3 D1 M2	Sleeve 2	Seal 1	Ambient	4	3
5	Type 2 D1	Sleeve 1	Seal 1	Ambient	3	3
6	Type 2 D2	Sleeve 1	Seal 1	Ambient	3	3
7	Type 3 D2	Sleeve 1	Seal 1	Ambient	2	2
8	Type 3 D2	Sleeve 2	Seal 1	Ambient	2	2
9	Type 3 D3	Sleeve 2	Seal 1	Ambient	3	3
10	Type 3 D2	Sleeve 1	Seal 2	500C	2	2

Leakage/Force is rated 1-5 where
-1 is the baseline measurement
-2 means it meets the target +/- 15%
-3 is between the target and 2X the target,
-4 is 2-5X the target
-5 is greater than 5X

Testing Methodology (Baseline)

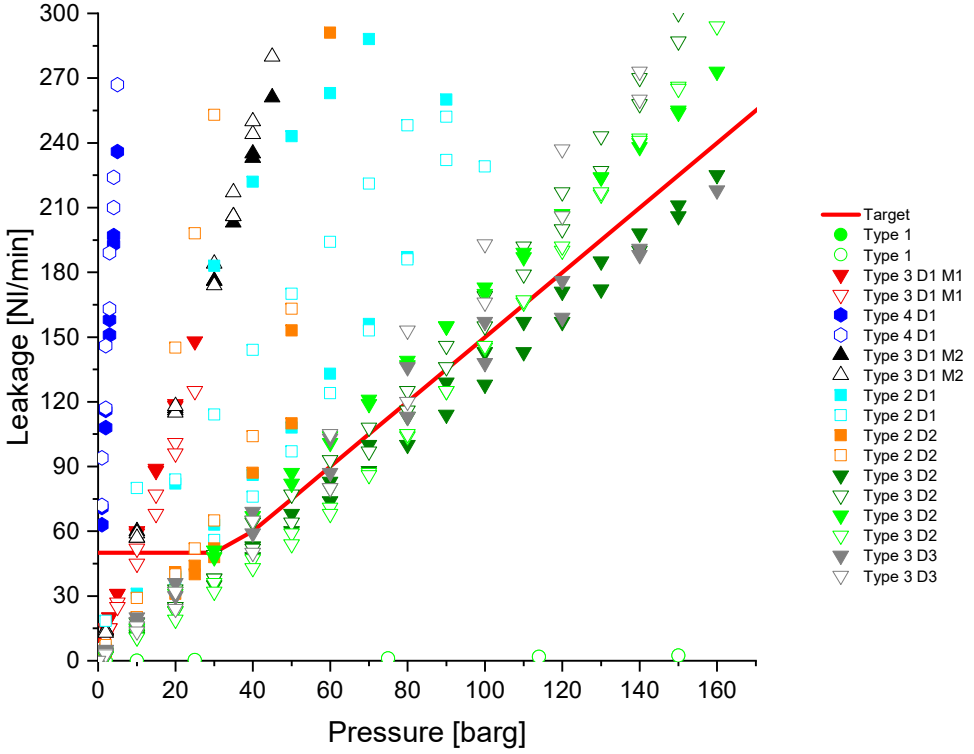


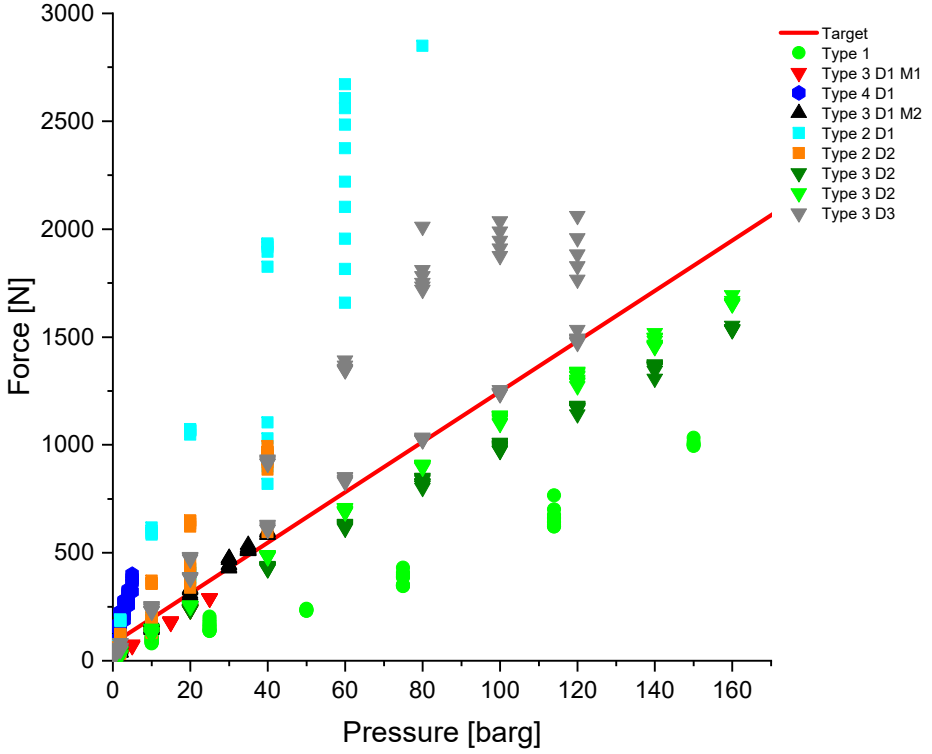
Testing Results (Backing Seal)



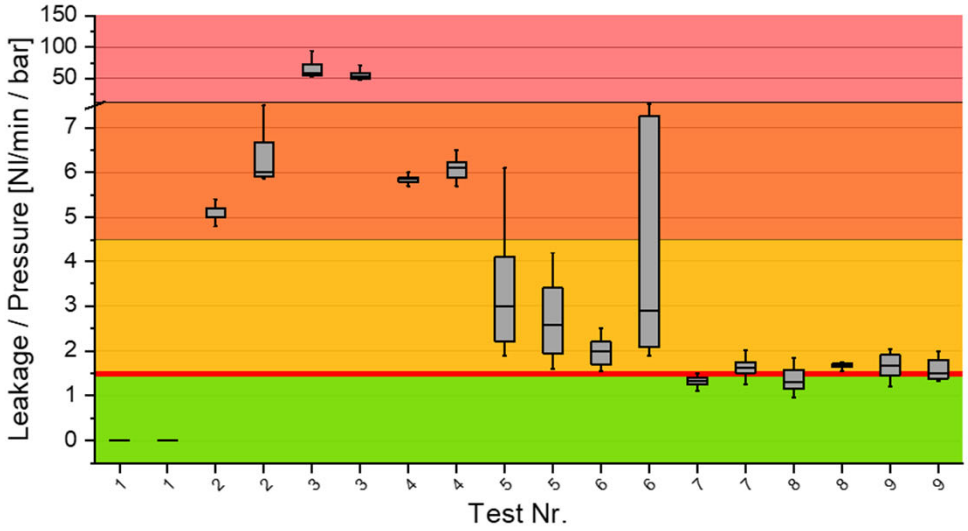
The metal Backing seal had 5X the leakage of the baseline elastomer and will be redesigned for the final installation

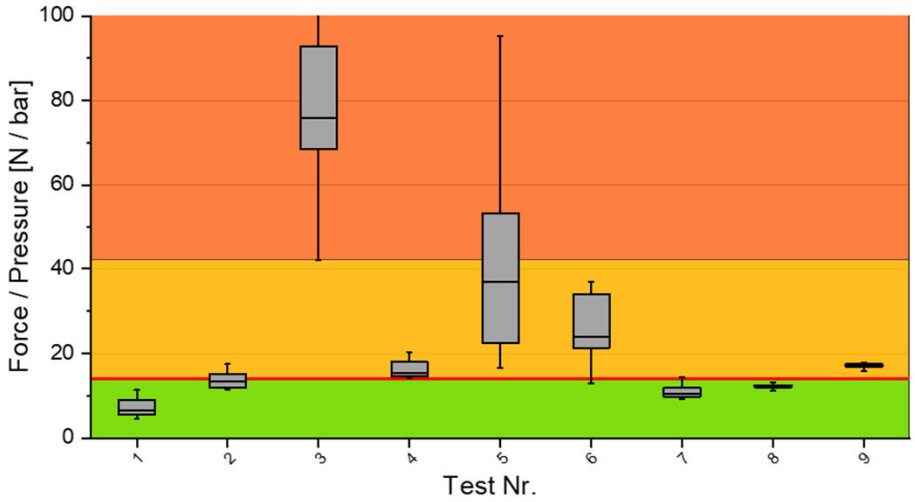
Testing Results



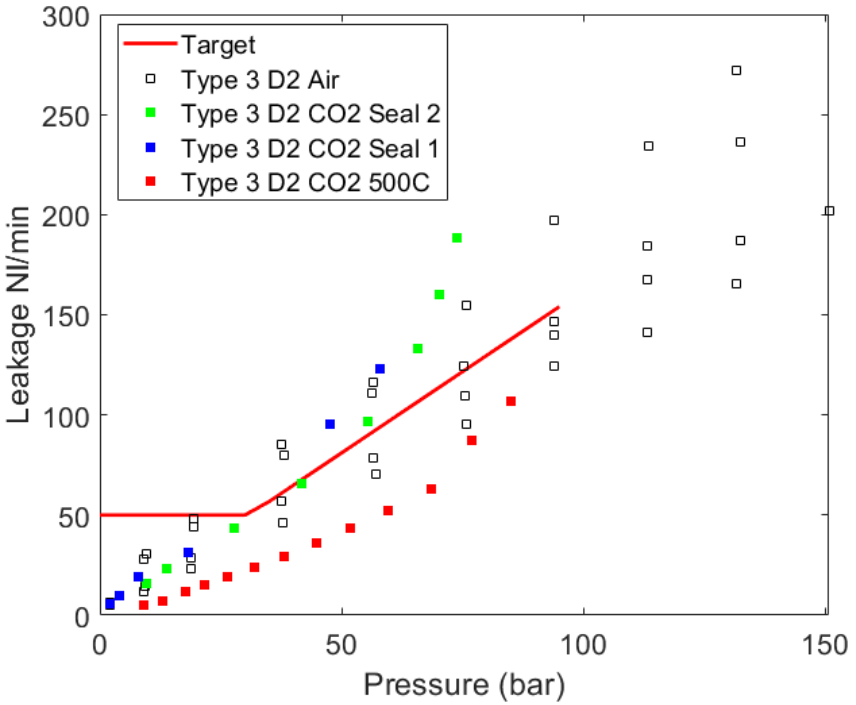


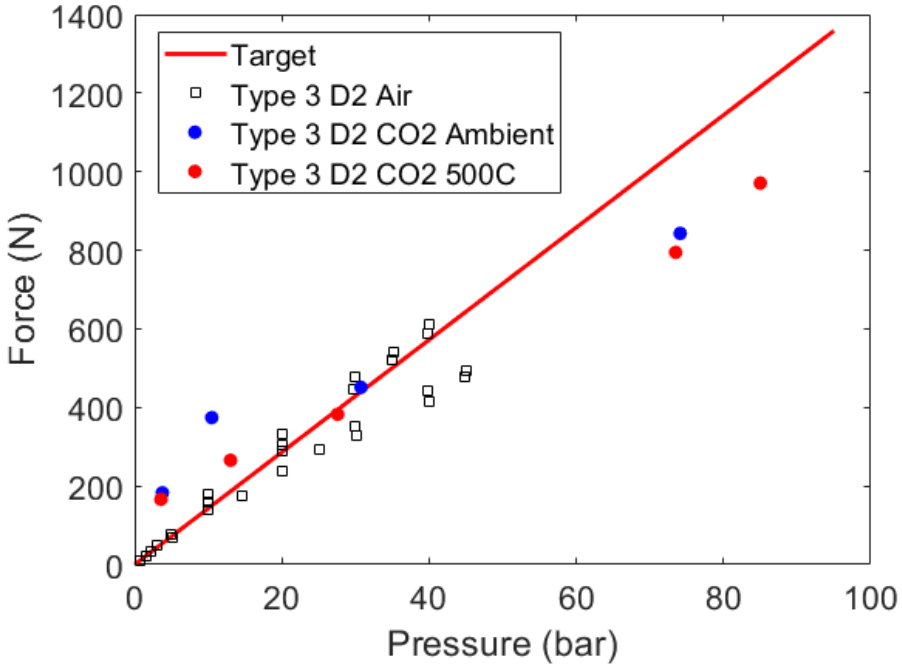
Testing Results (Statistical)



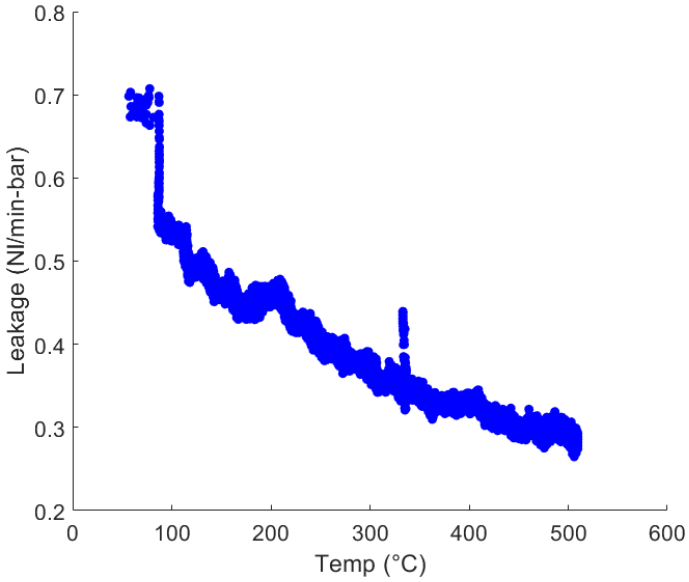


High Temperature Test Results

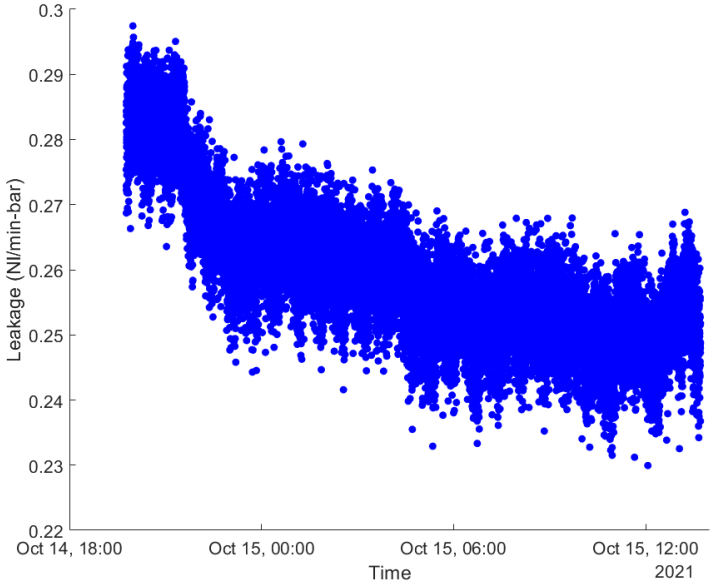




Dynamic Movement Tests



Heat Up



Long Duration

Teardown showed minimal damage to the balance seal

Conclusions

- The team was able to design and test a balance seal capable of 500 C and 7.4 MPa
- The seal was capable of both large and small movement at full pressure meeting the 1,000 N target friction force
- The leakage was below the target of 120 Nl/min
- Leakage reduced at high temperature due to CO2 properties

Moving Forward

- The team is currently procuring components for the full Dry Gas Seal and Rotating Test Rig
- The full Dry Gas Seal will be tested under simulated turbine outlet conditions.

Thank you!

- Thank you for the support from the DOE DE-EE0008740