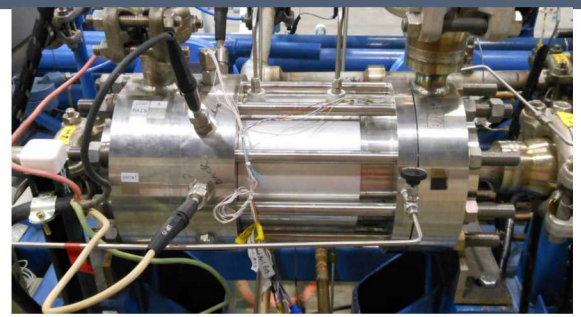
SAND2019-10928C

Experimental Testing of a 1MW sCO2 Turbocompressor



Logan Rapp
Sandia National Laboratories

3rd European sCO2 Conference

September 20, 2019

David Stapp
Peregrine Turbine Technologies

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History of sCO2 research at Sandia National Laboratories

Heat Exchanger Testing

Pressure Fatigue Testing

Turbomachinery Testing

Bearings Testing

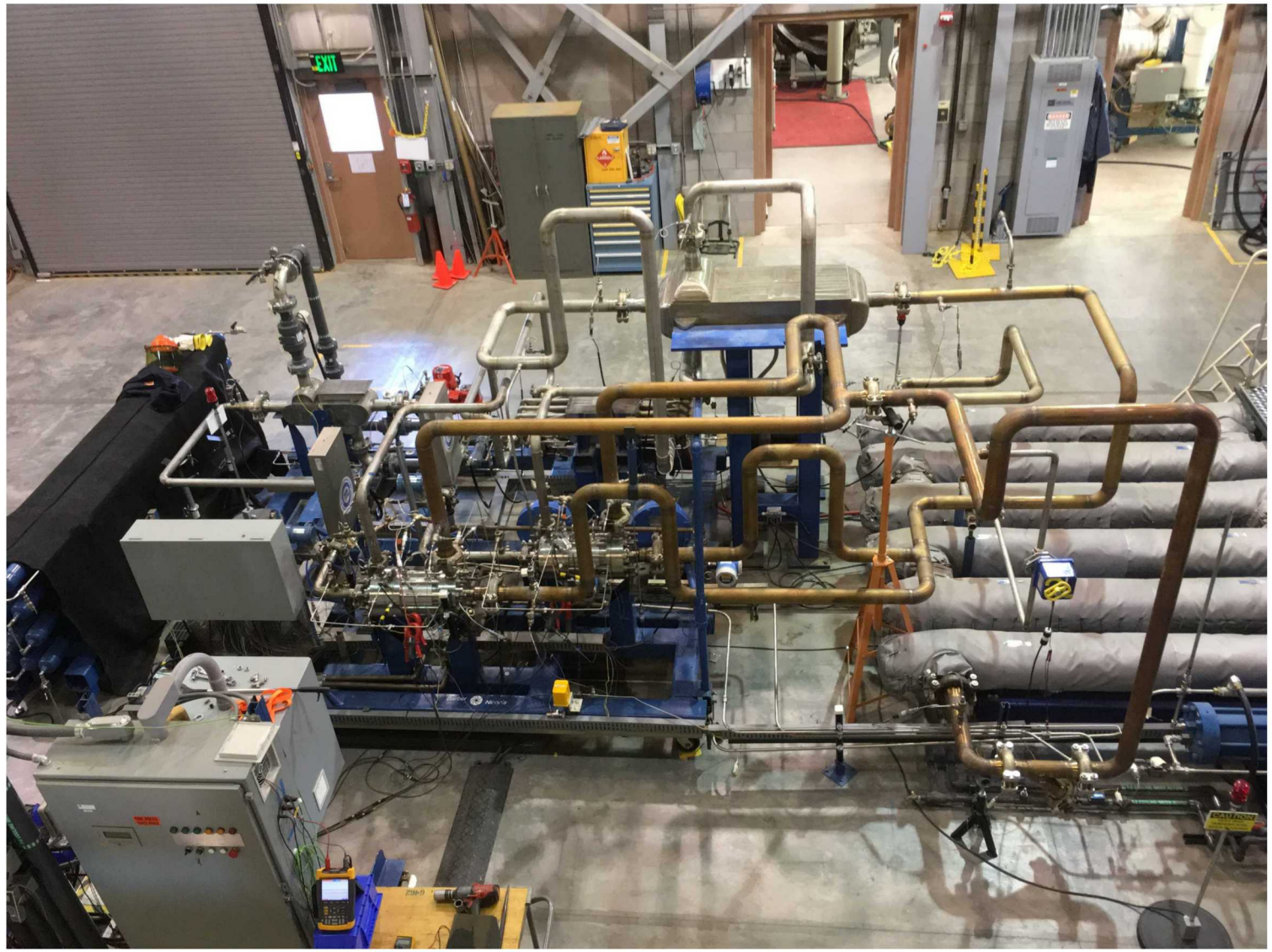
Seals Testing

Recompression Closed Brayton Cycle (RCBC) configuration

Commissioned in 2012

Only experimental sCO2 RCBC ever to have been operated

Many papers and conference proceedings have been published on the data from the RCBC experiments



TurboMachinery Development Platform at SNL

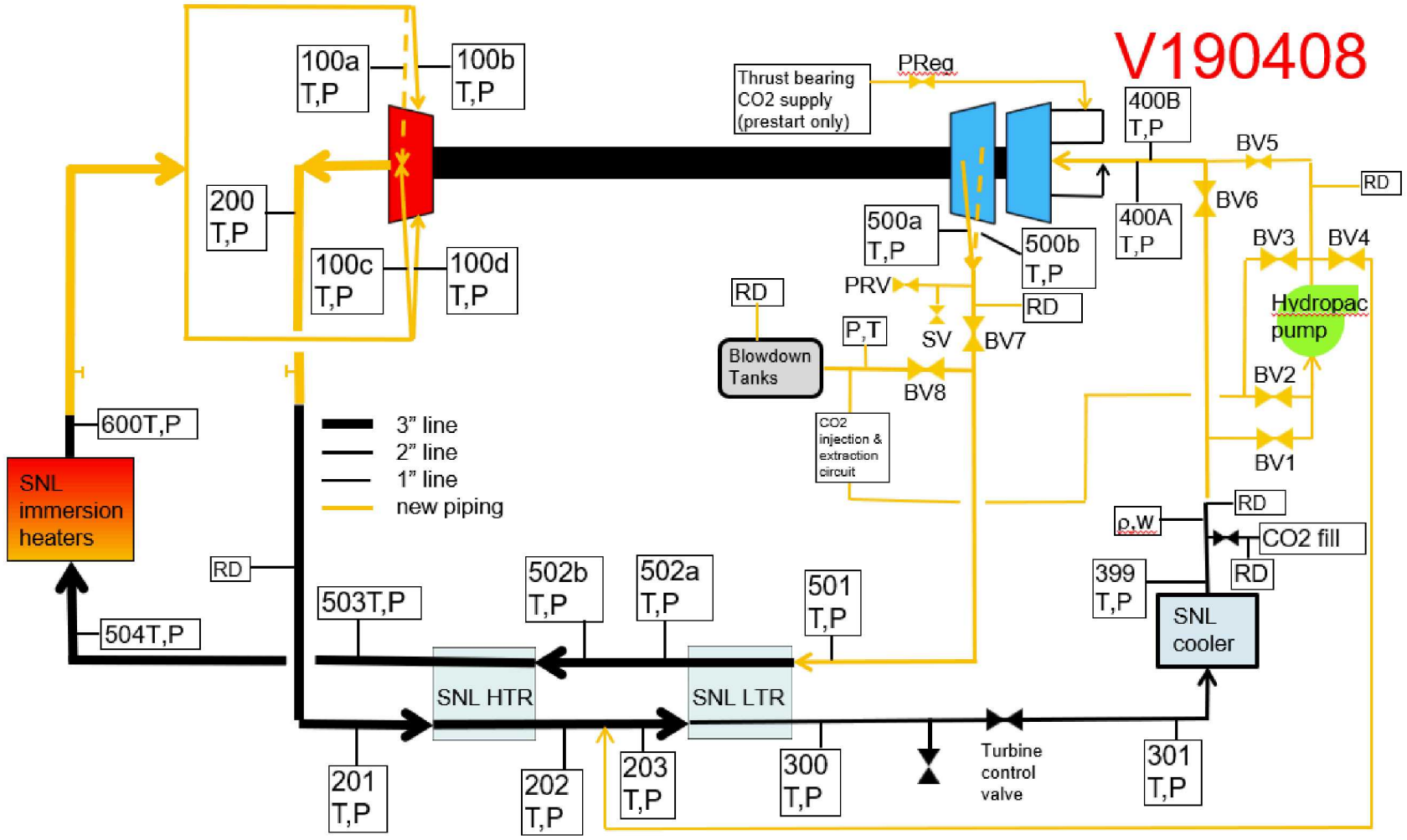
780 kW electric immersion heat

2.3 MW duty High Temp Recuperator

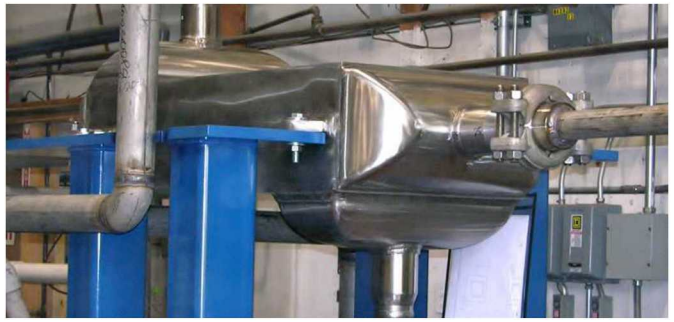
1.6 MW duty Low Temp Recuperator

540 kW water/sCO2 cooler

Hydro-Pac Piston compressor pump



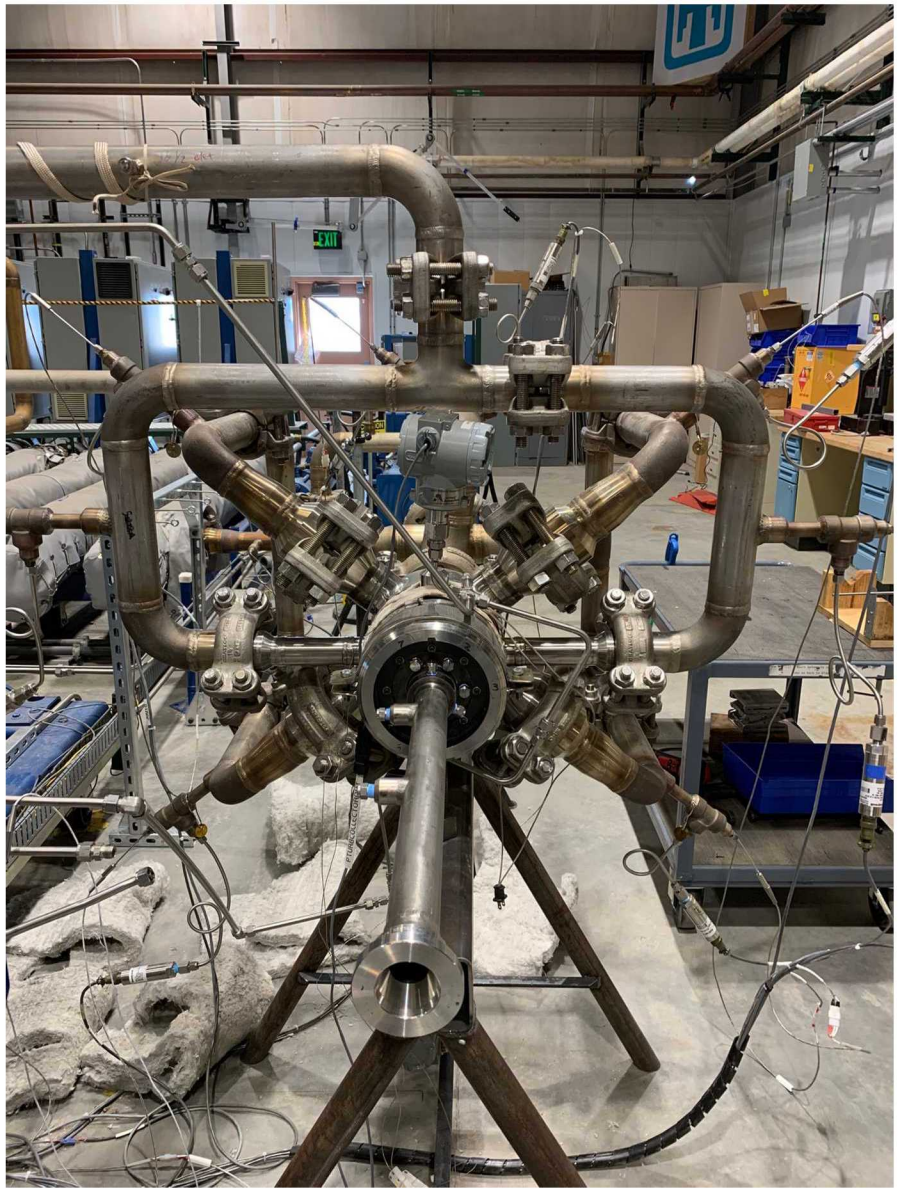
TurboMachinery Development Platform at SNL

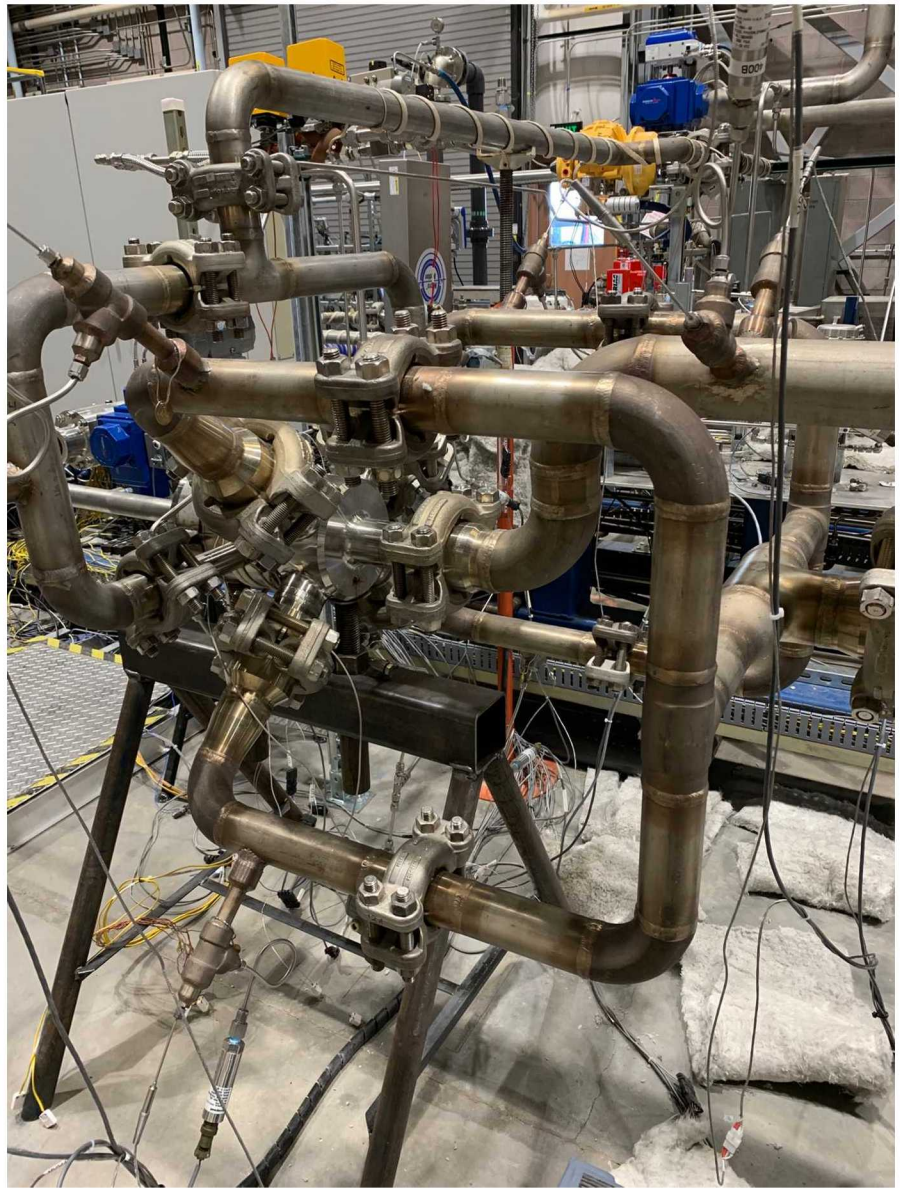


Peregrine Turbine Technologies Turbocompressor

Design Conditions:
- 118,000 RPM
- 750 C Turbine Inlet
- 42.9 MPa compressor discharge

Loop Maximum Conditions:
- 538 C Turbine Inlet (1000 F)
- 17.2 MPa compressor discharge (2500 psi)





Blowdown Start Method

Loop is preconditioned using Hydropac

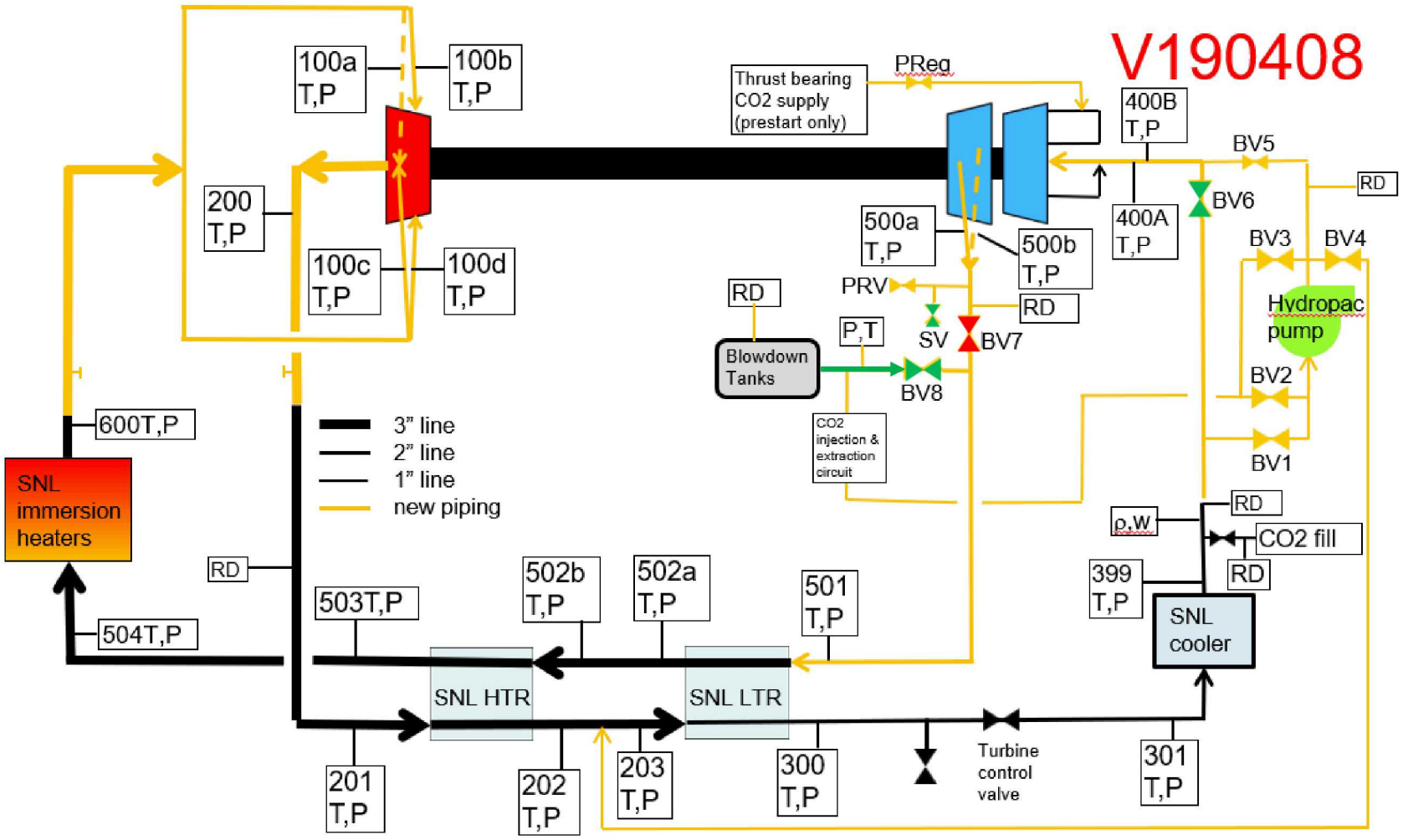
- Compressor inlet above supercritical conditions
- Turbine inlet at approximately target for test

Valve Positions

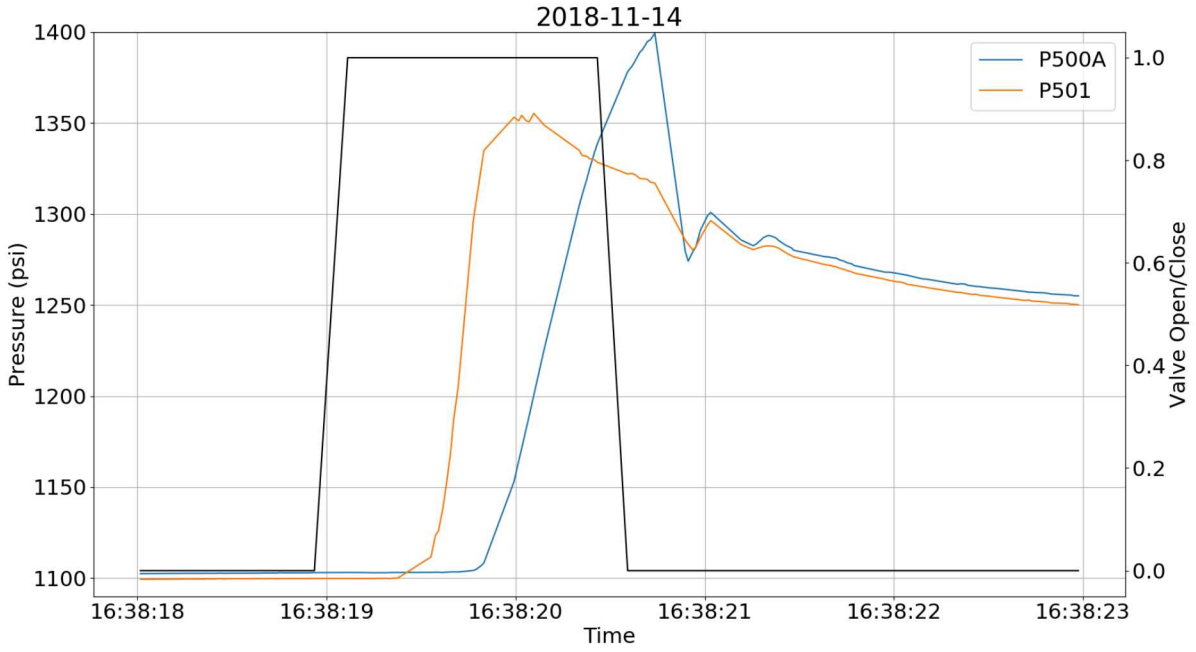
- BV7 is closed
- BV8 and SV are opened

Once P500A -P501 > dP_min:

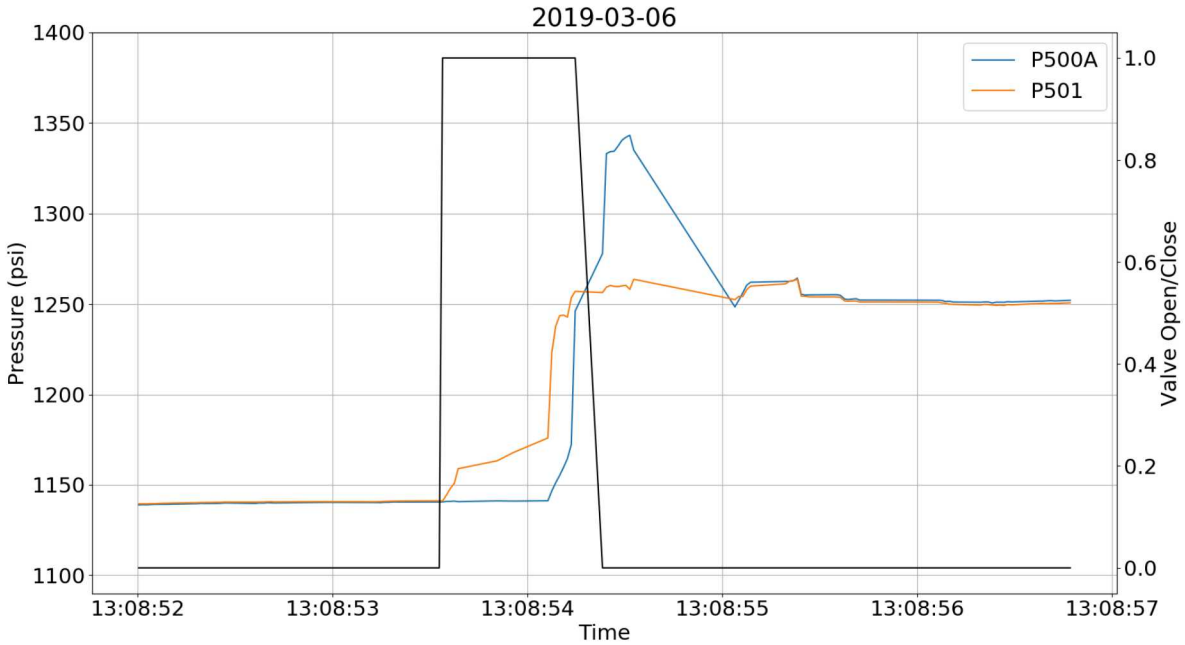
- BV7 is opened and BV8 and SV are closed



Blowdown start plots



Blowdown Pressure=1670 psi



Blowdown Pressure=1400 psi

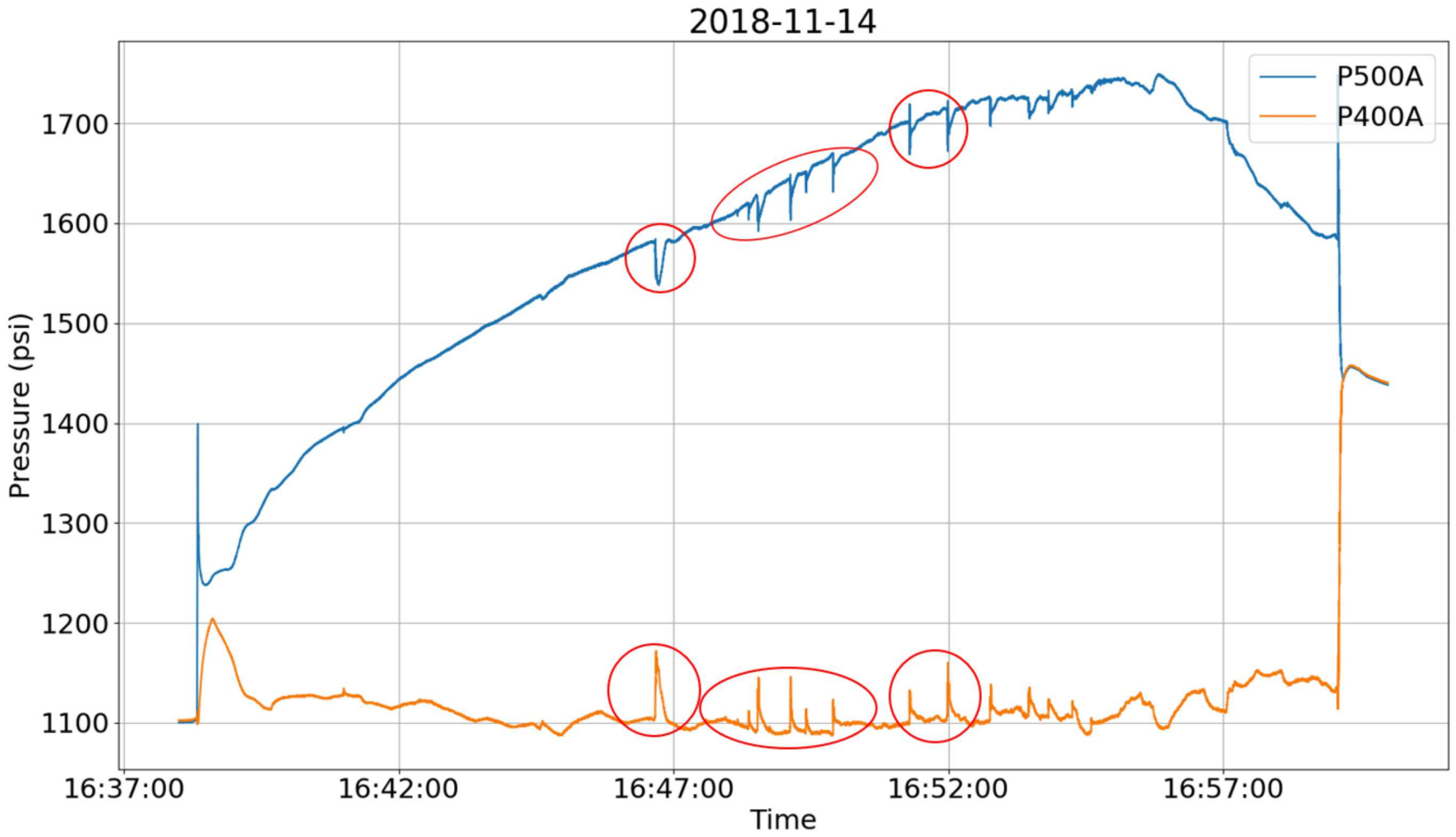
Summary of tests to date

Test Number	Test Date	Test Duration	TIT (°F)	Compressor Discharge Pressure (psi)	Max PR
1	8/9/2018	00:00:32	225	1240	1.2
2	10/10/2018	00:18:40	420	1400	1.25
3	11/14/2018	00:20:46	645	1750	1.59
4	3/1/2019	00:03:32	610	1460	1.26
5	3/6/2019	00:08:23	530	1510	1.3
6	4/4/2019	00:03:18	530	1510	1.28
7	5/7/2019	8:05:44	570	1475	1.27

Bearing Issues

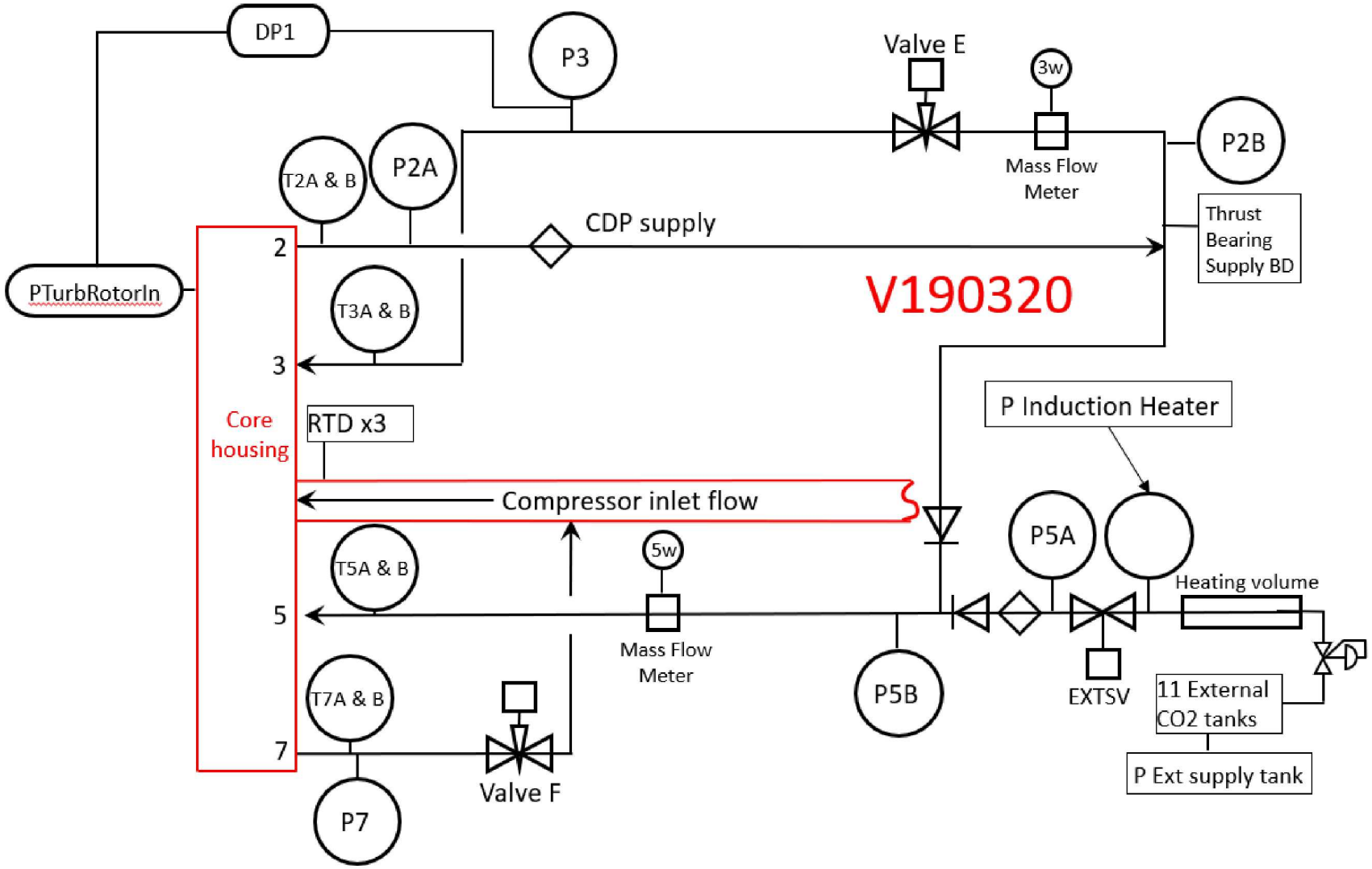
In Tests #1-3, both the thrust bearing and the radial bearings experienced rubs/failures

Spikes in pressure indicate thrust bearing rubs

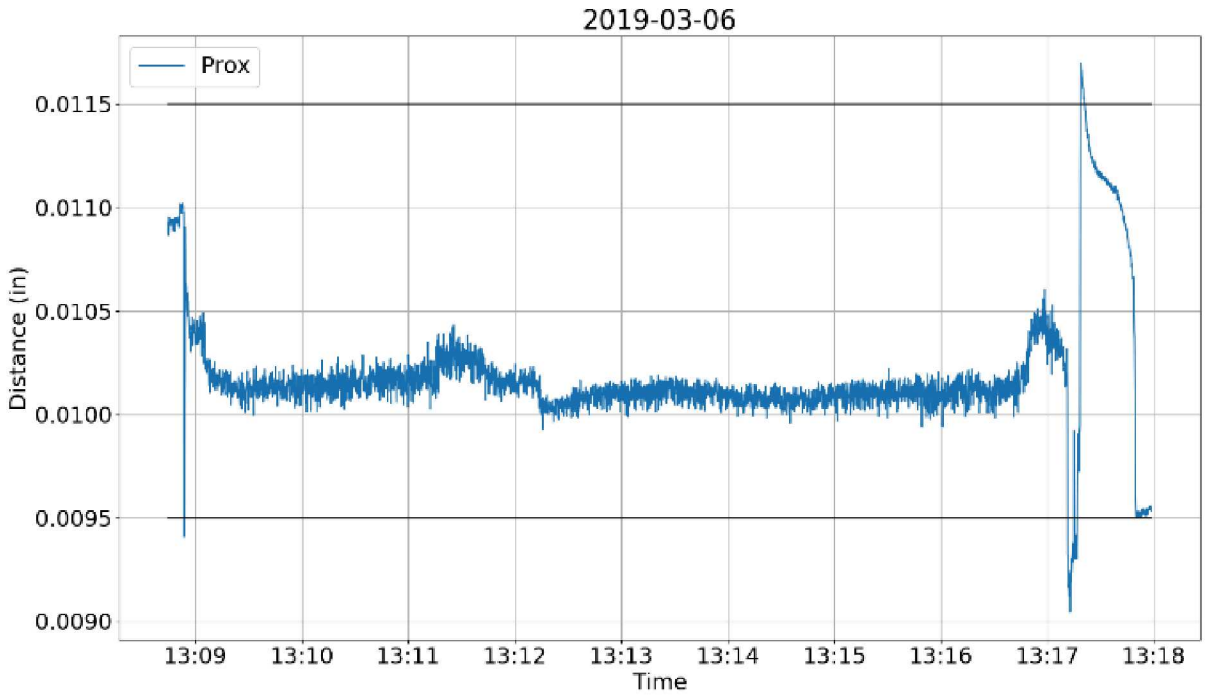


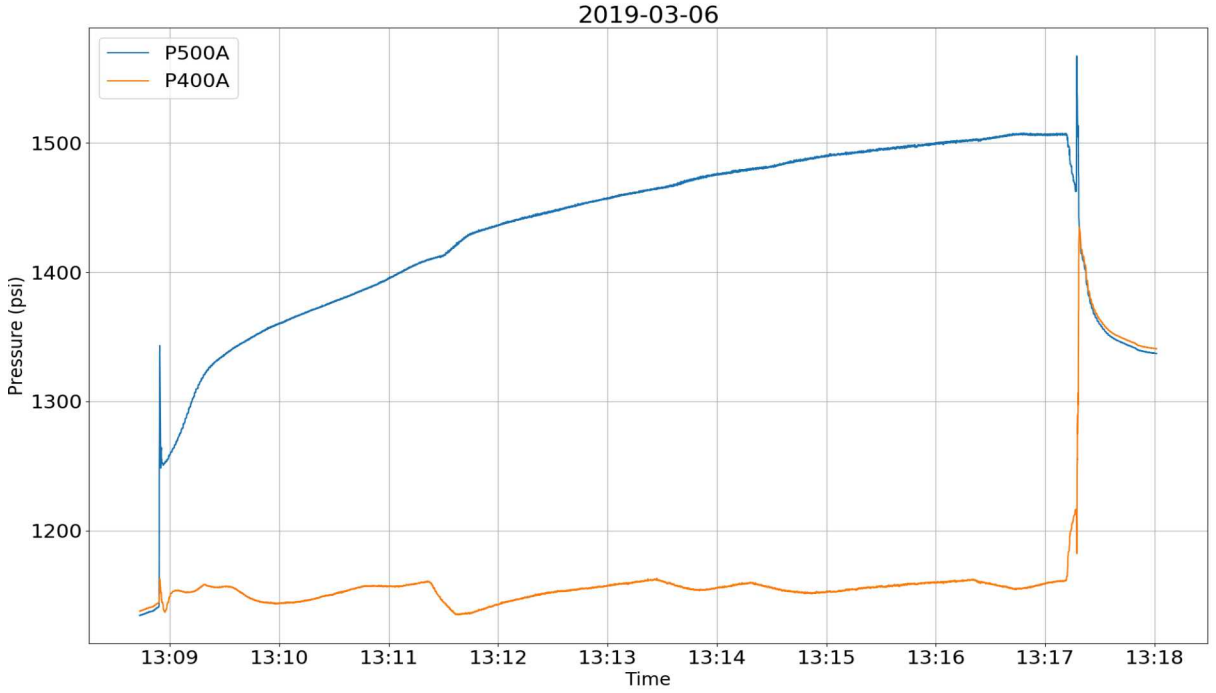
Secondary Flows

Valve F regulates venting pressure on aft side of thrust disk rotor – acts as balance piston



Thrust bearing issue resolved





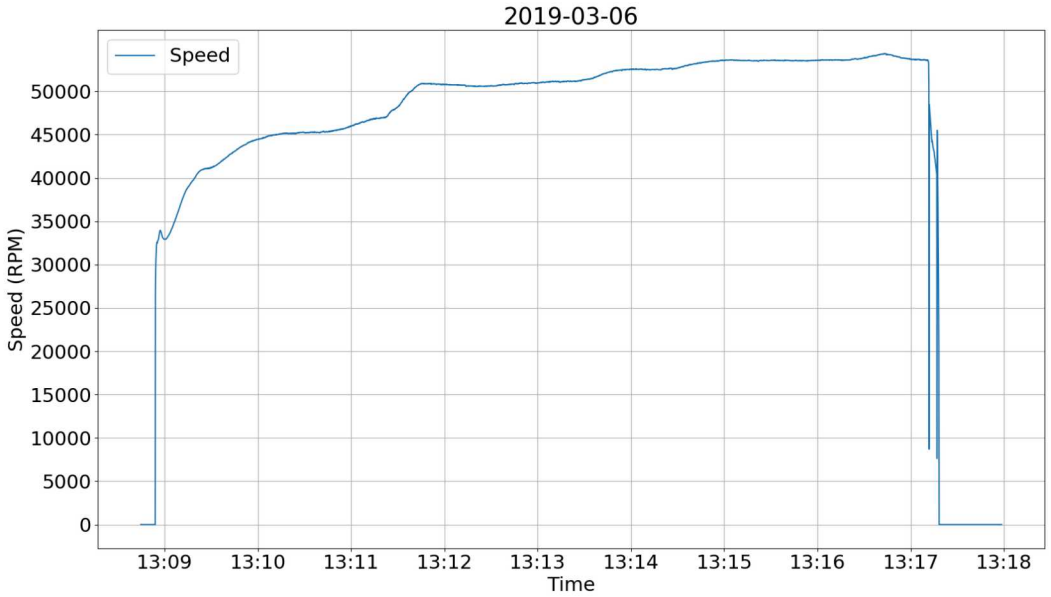
By adjusting Valve F and the TCV the force on the rotor was balanced.

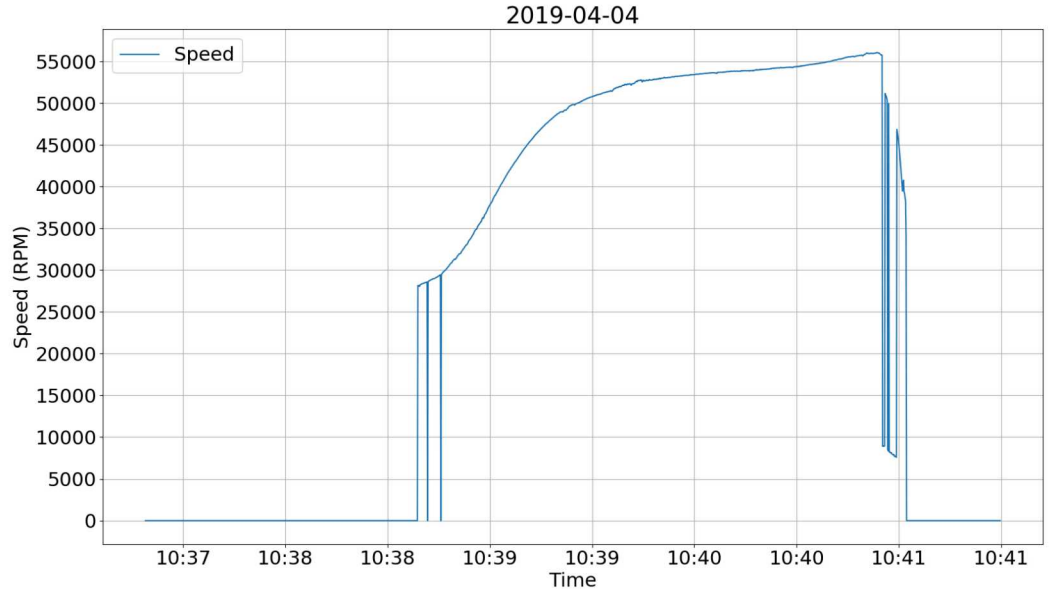
Radial Bearing Issues

In all tests (except #7 – 8 hr test), the turbine end radial bearing failed

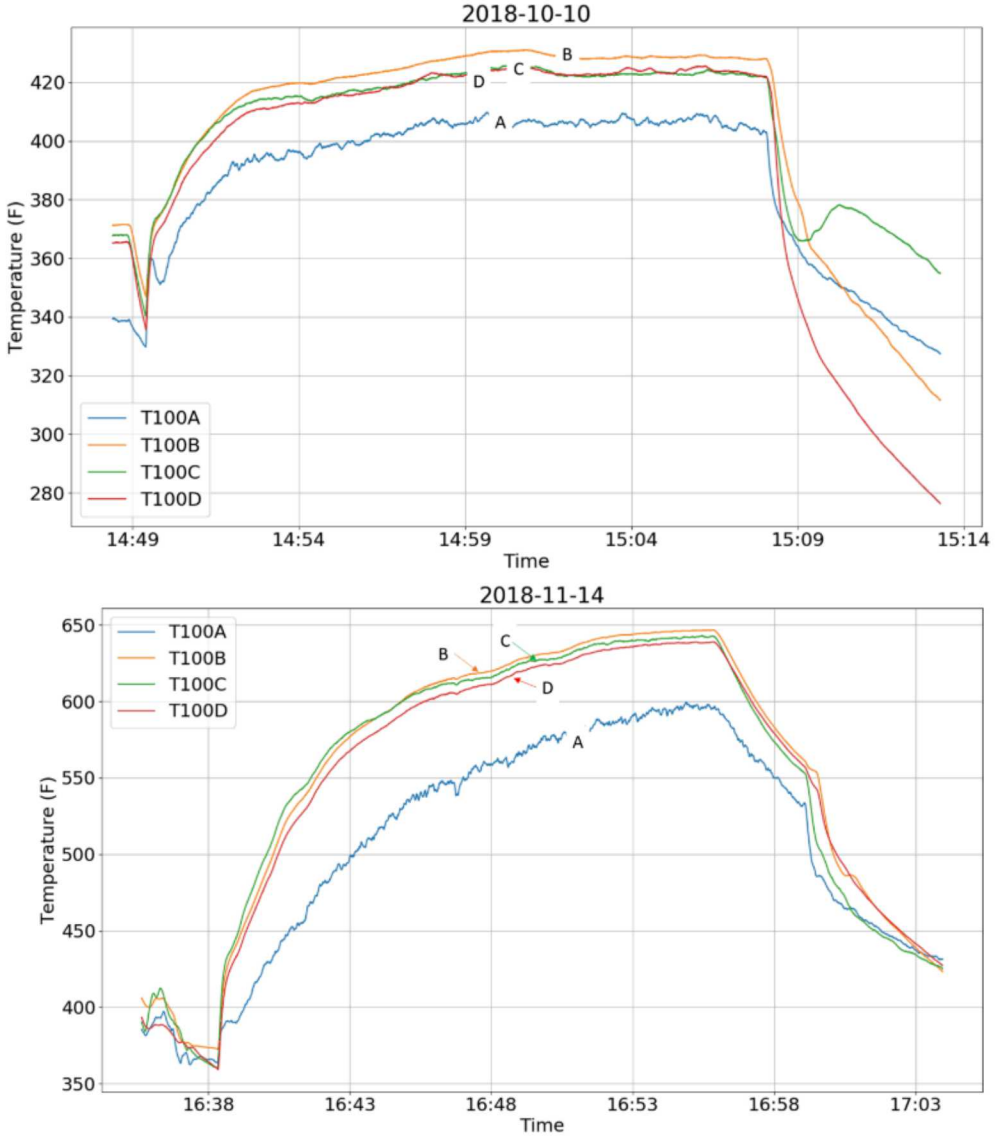
Possible causes of failure:

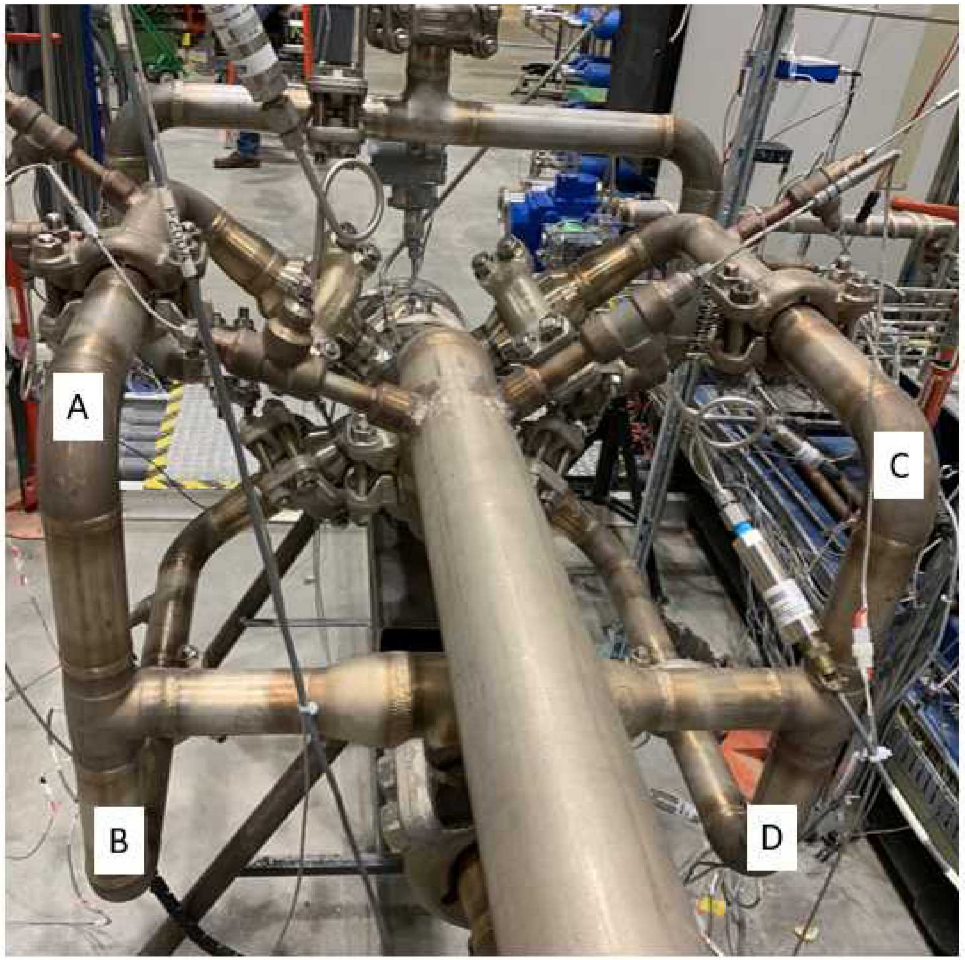
- Blowdown start
  - Reduce blowdown pressure
- Critical speed causing rotor instability
  - Physical evidence of bearing failure shows yielded foils at a specific clocking; not indication of rotor instability
- Radial load caused by non-uniform turbine inlet conditions
  - Resolved with instrumentation





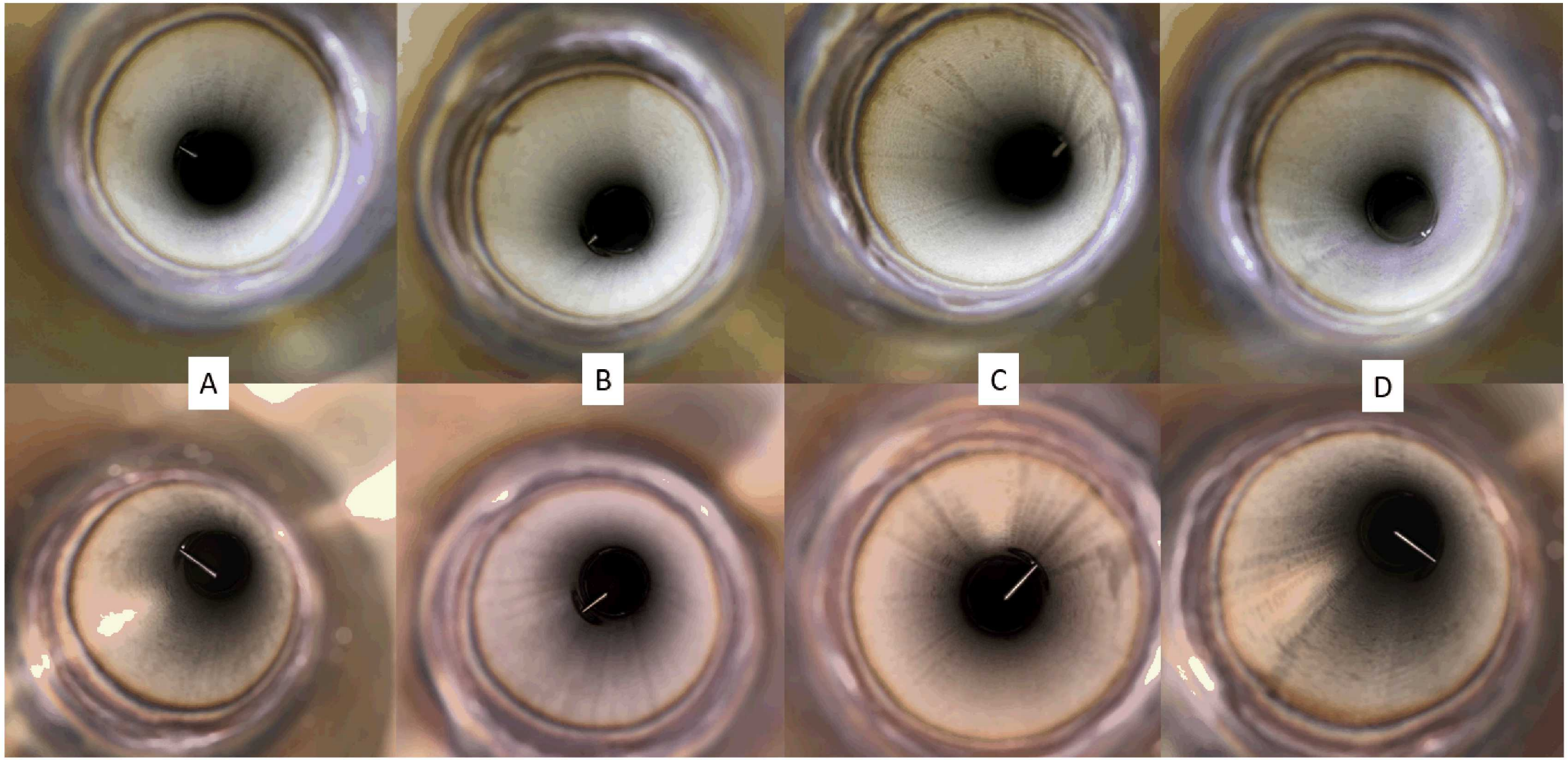
Turbine Inlets





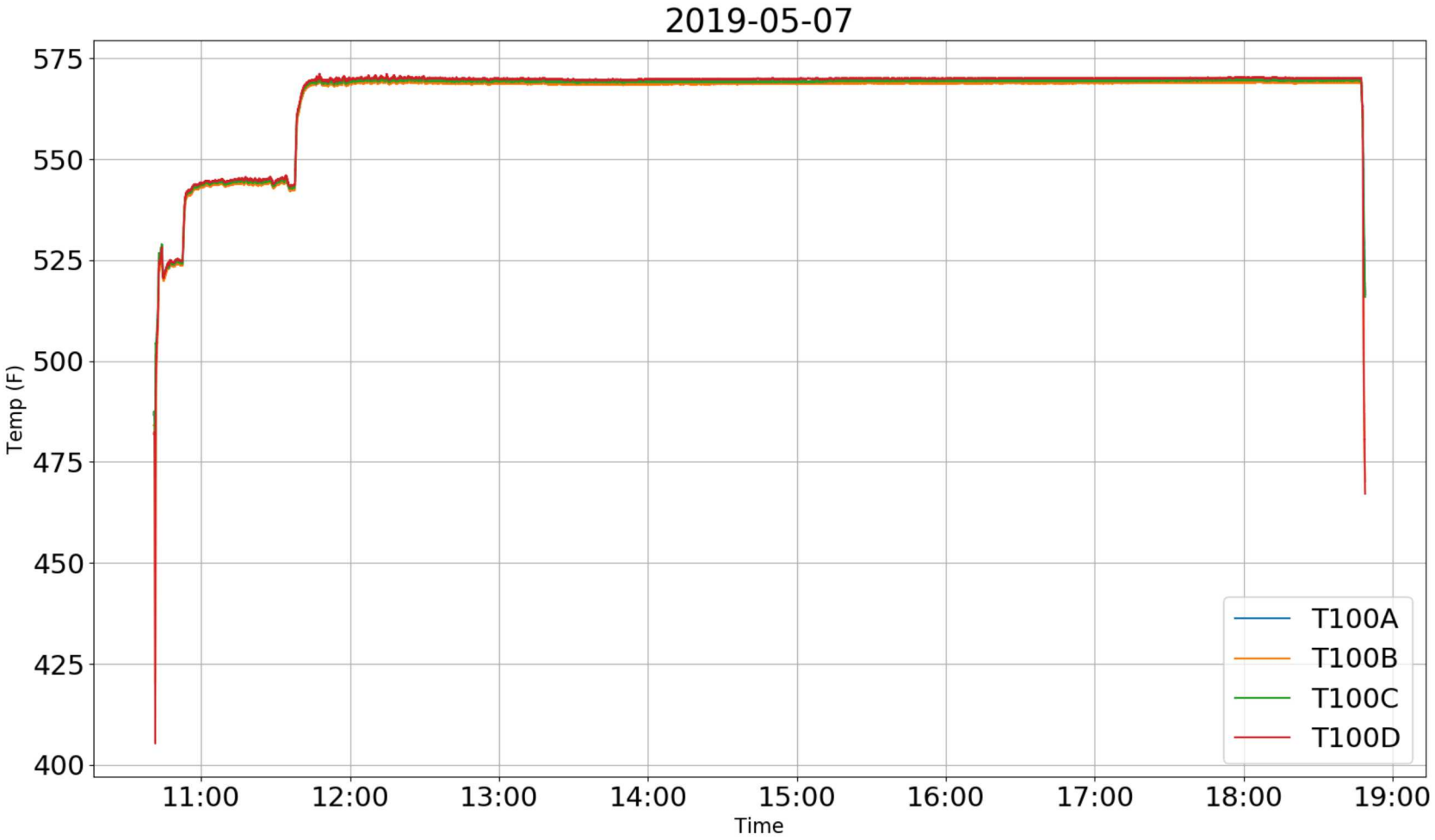
Leg “A” was consistently lower temperature than the other 3

Original and New Turbine Inlet RTD insertions



Turbine Inlet Temp with new Insertion depth

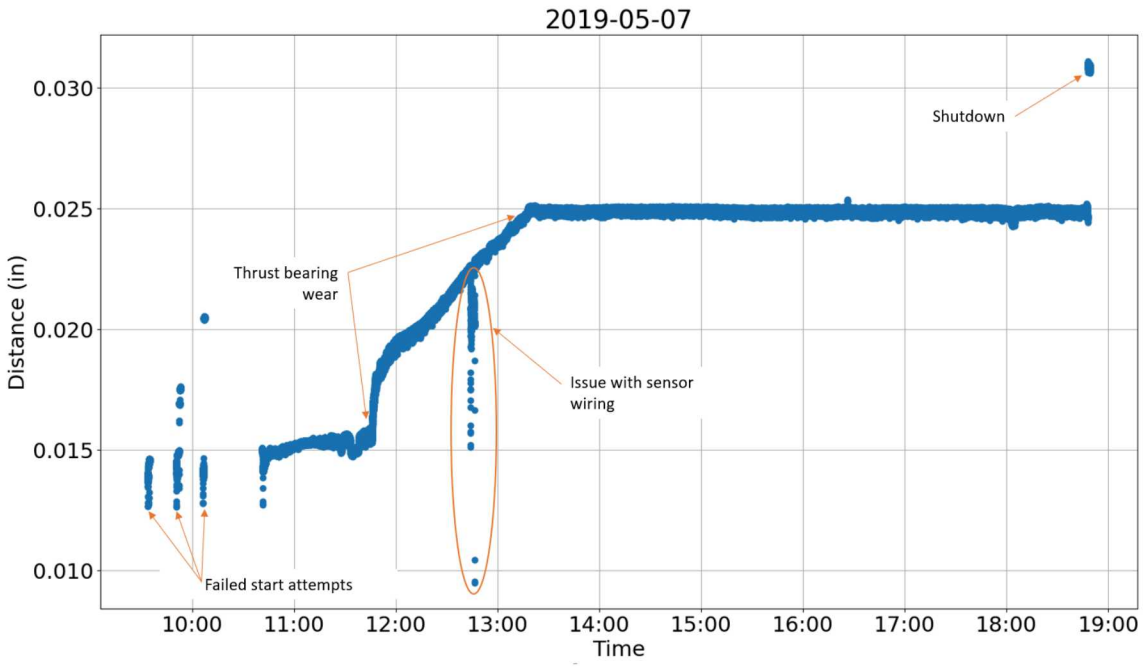
No difference in centerline temperature of turbine inlets

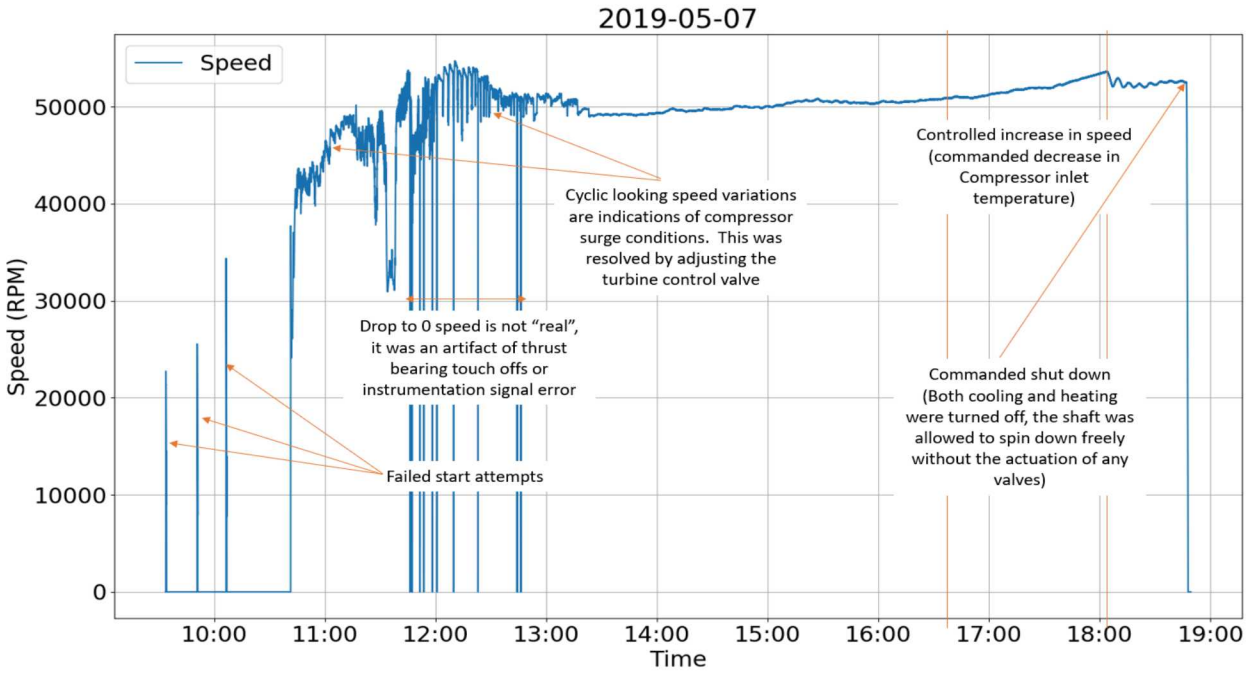


Increased L/D of aft radial bearing

The aft radial bearing length/diameter ratio was increased to increase load capacity and the damping of the bearing

Start Number	Turbine Inlet Temp (F)	Blowdown Pressure (psi)	Outcome
1	460	1330	Unsuccessful
2	500	1360	Unsuccessful
3	525	1425	Unsuccessful
4	550	1450	Successful





Next Steps

Test turbocompressor up to limits of current loop (1000F @ 2500 psi)

Run sensitivity tests of turbocompressor performance with compressor inlet temperature

Map performance of turbocompressor over variety of off-design conditions

Thank you