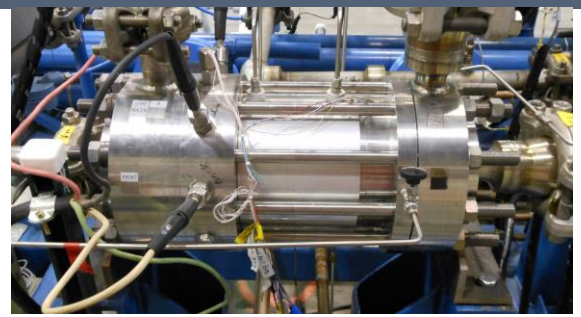
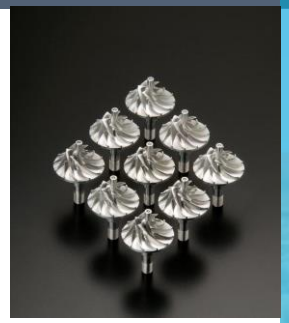
# Experimental Testing of a 1MW sCO2 Turbocompressor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3rd European sCO2 Conference

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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

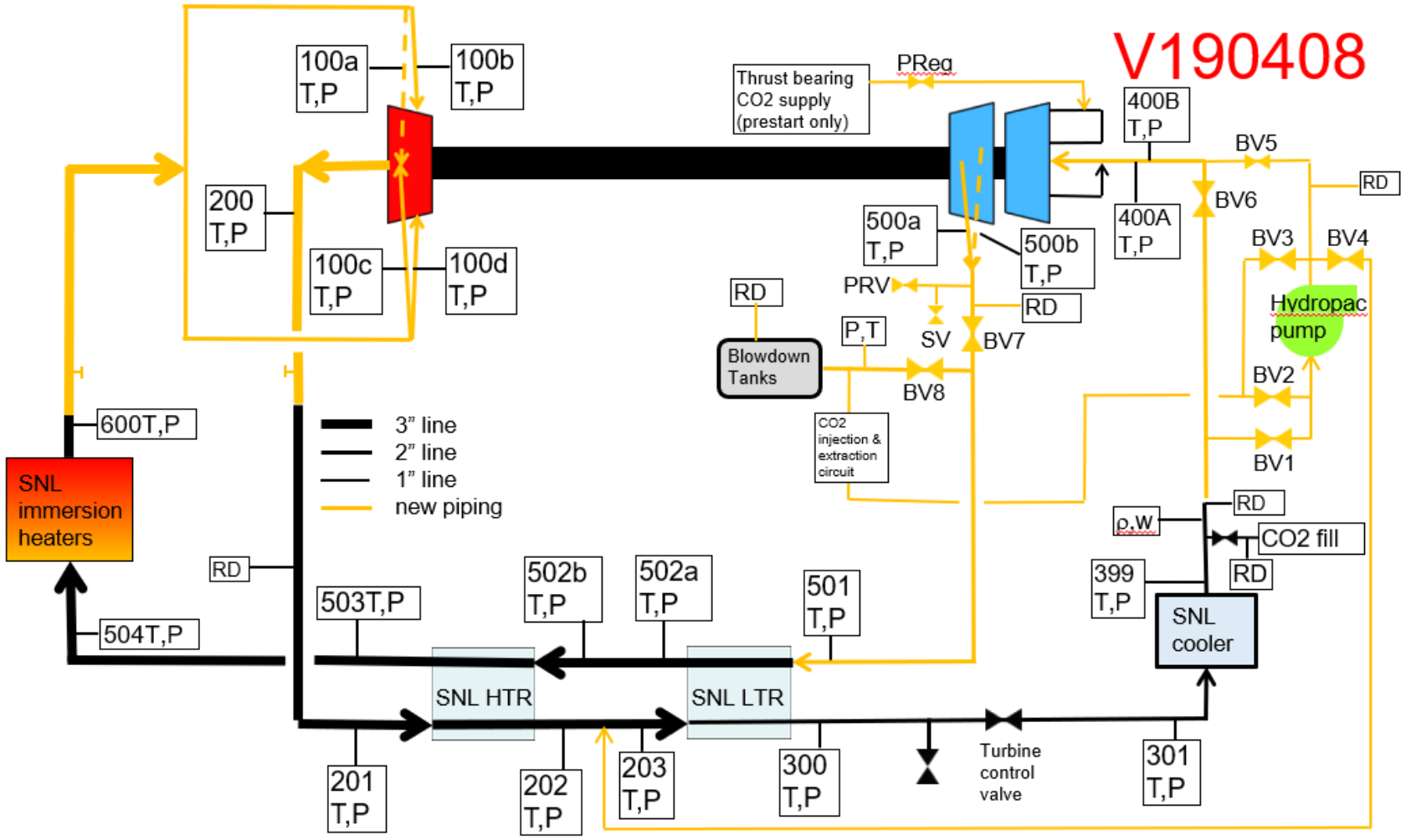
780 kW electric immersion heat

2.3 MW duty High Temp Recuperator

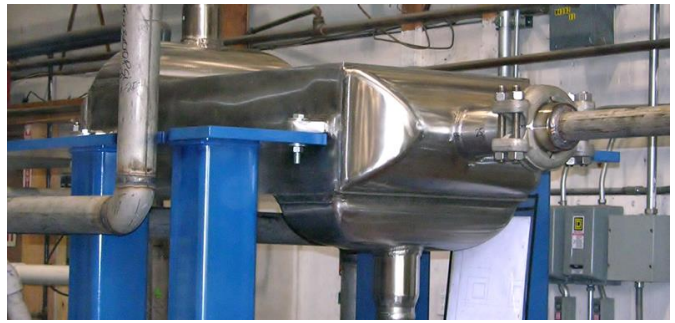
1.6 MW duty Low Temp Recuperator

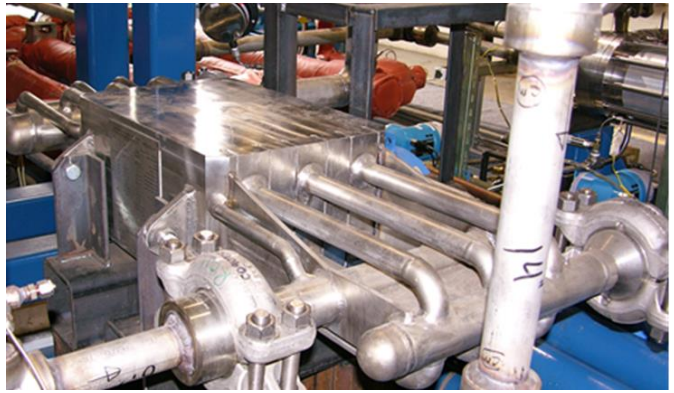
540 kW water/sCO2 cooler

Hydro-Pac Piston compressor pump



# TurboMachinery Development Platform at SNL

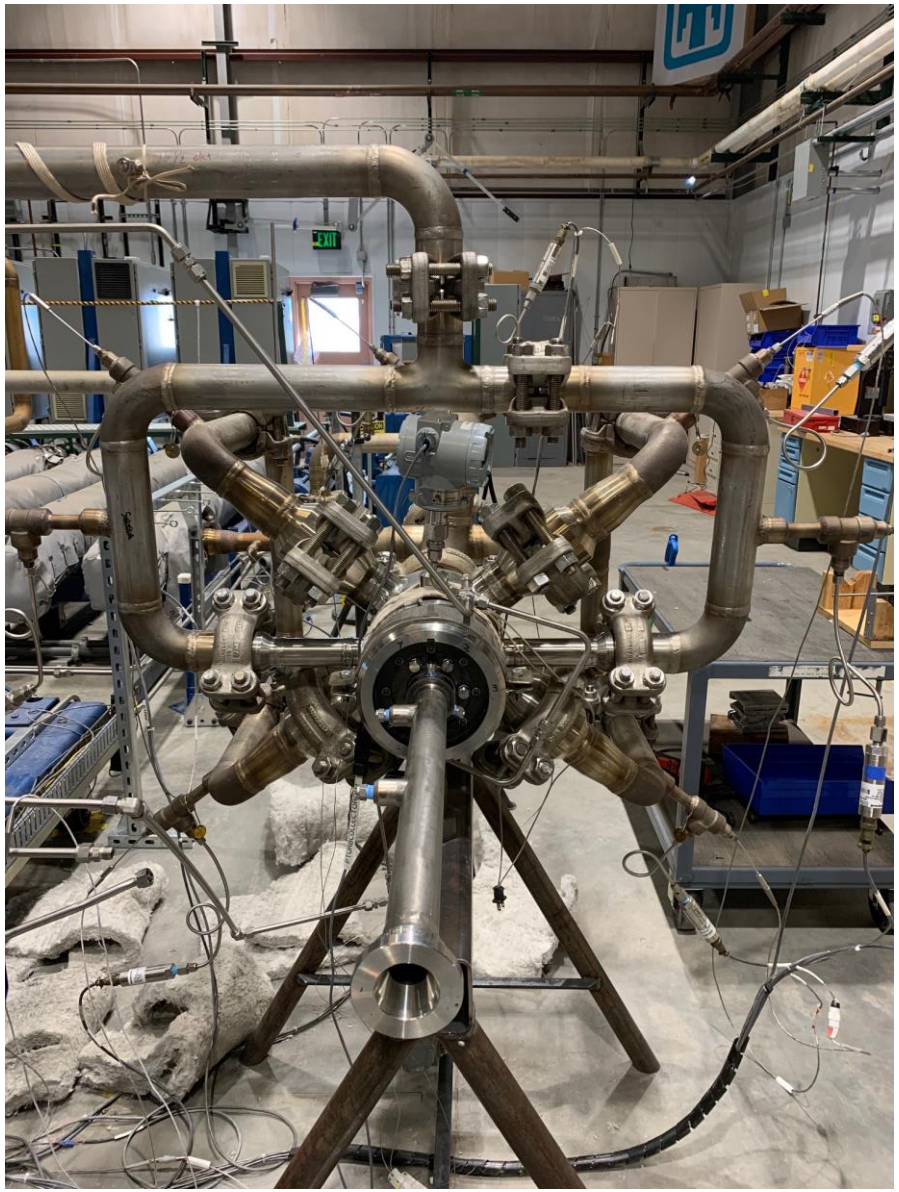



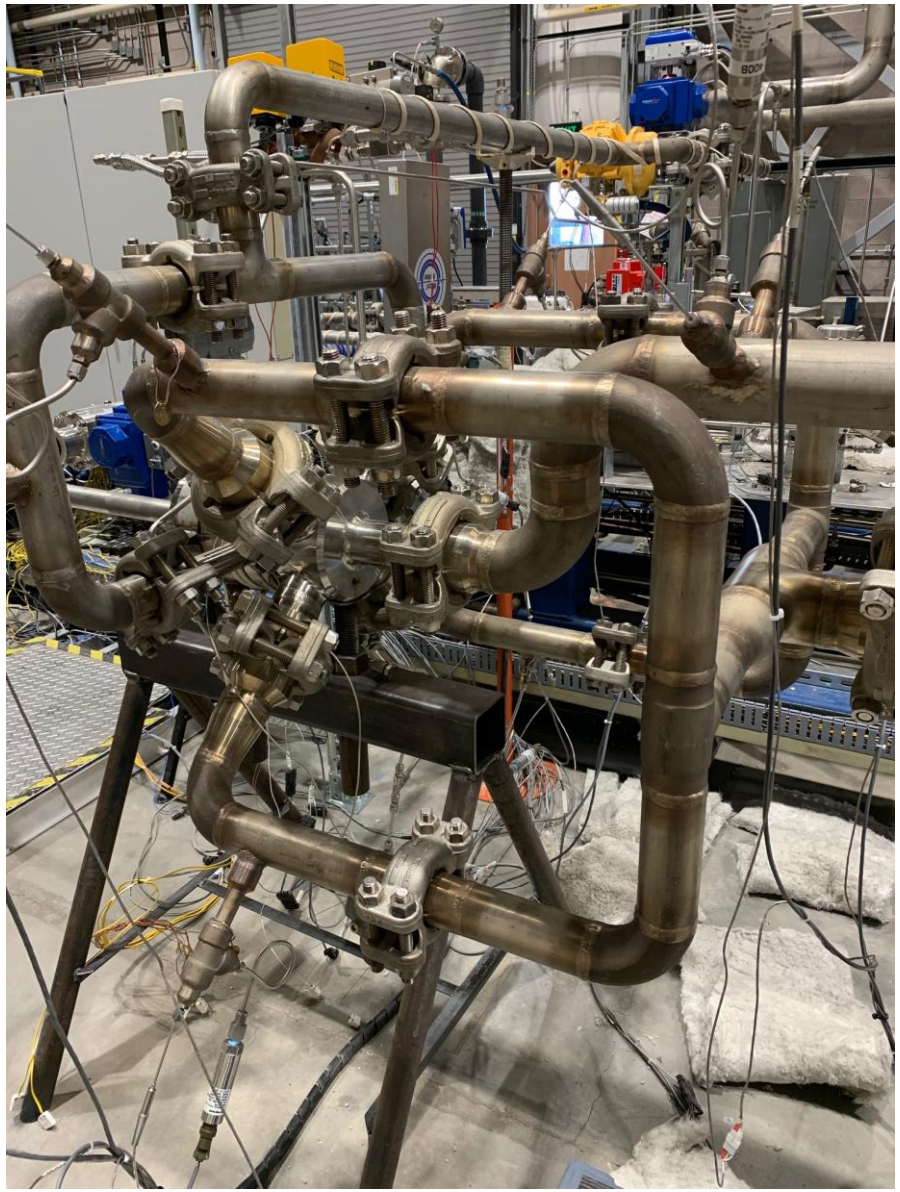


# Peregrine Turbine Technologies Turbocompressor

Design Conditions:
- 118,000 RPM
- 750 C Turbine Inlet (1382 F)
- 42.9 MPa compressor discharge (6222 psi)

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





# Blowdown Start Method

Loop is preconditioned using Hydropac

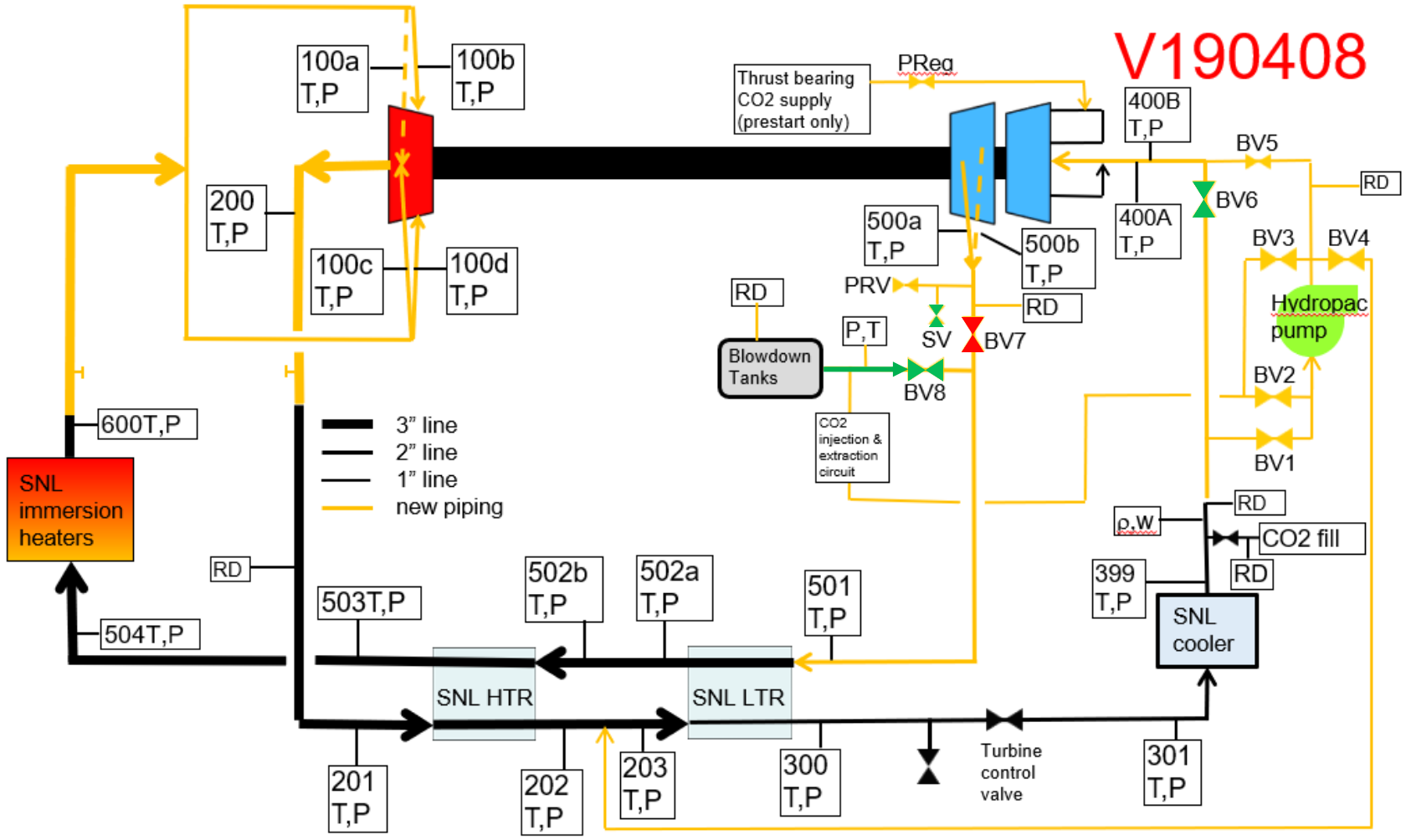
- Compressor inlet above supercritical conditions
- Turbine inlet at approximately target for test

## Valve Positions

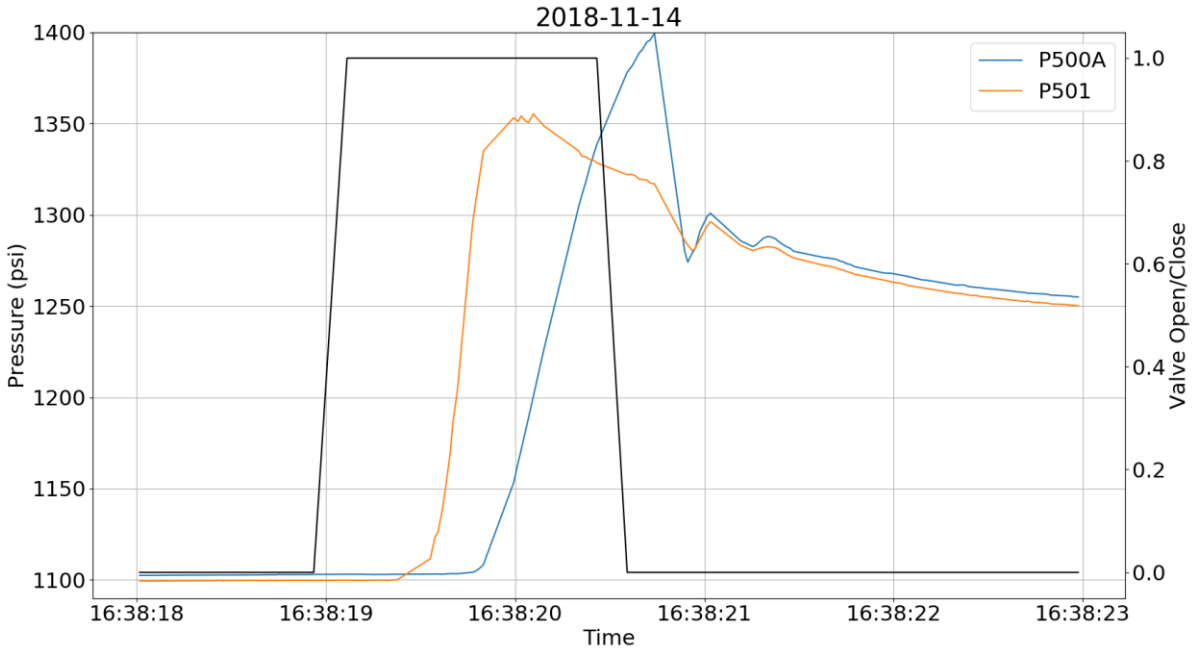
- BV7 is closed
- BV8 and SV are opened

Once P500A –P501 > dP_min:

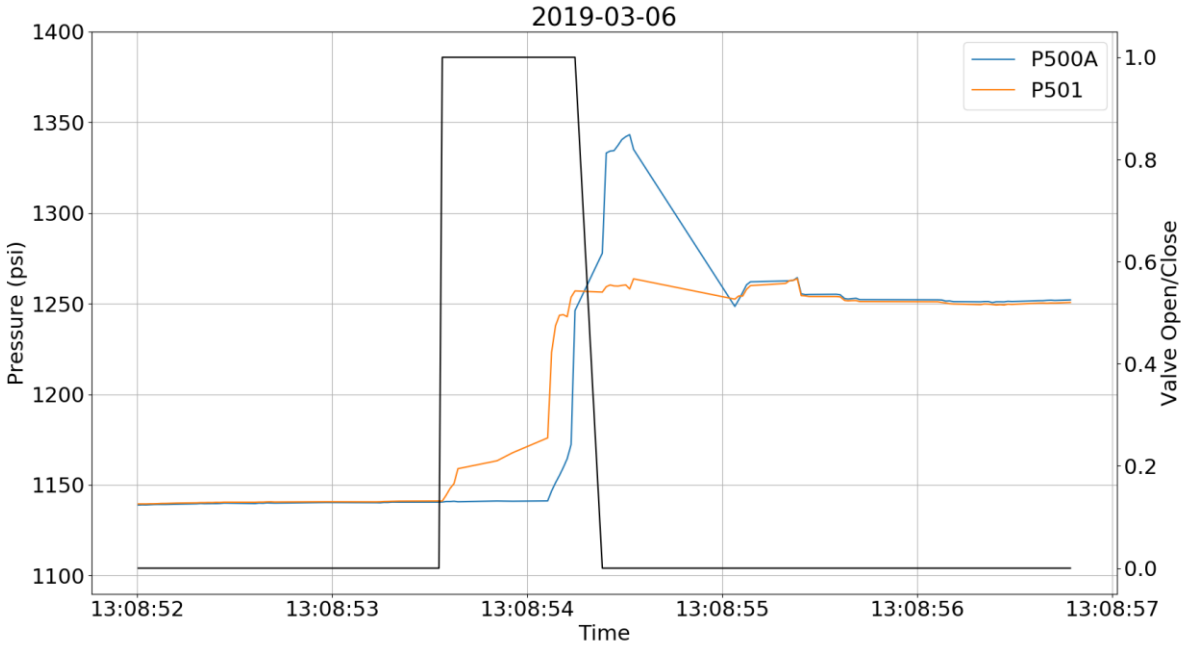
- BV7 is opened and BV8 and SV are closed



# Blowdown start plots




Blowdown Pressure=1670 psi




Blowdown Pressure=1400 psi

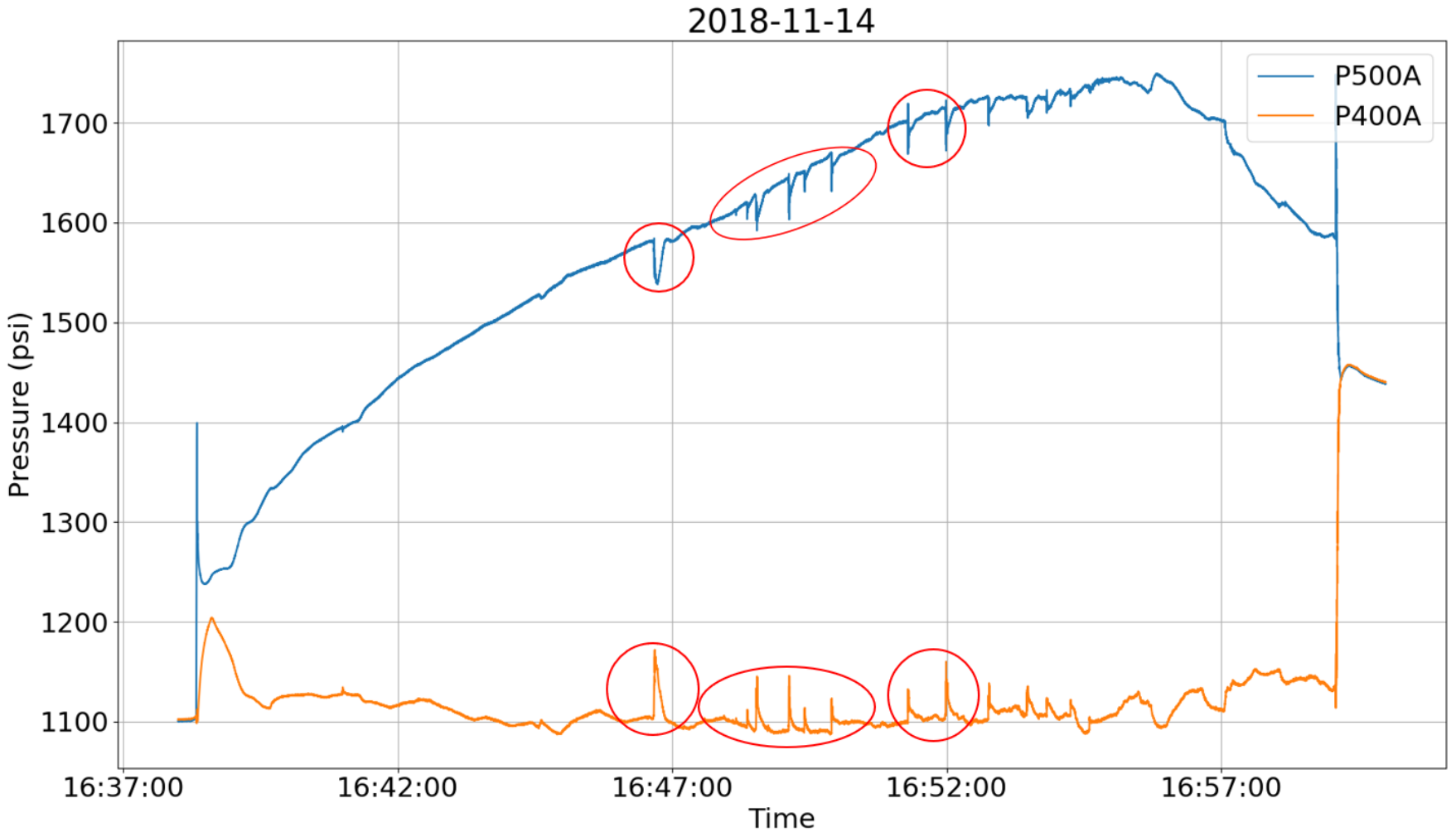
# Summary of tests to date

| 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

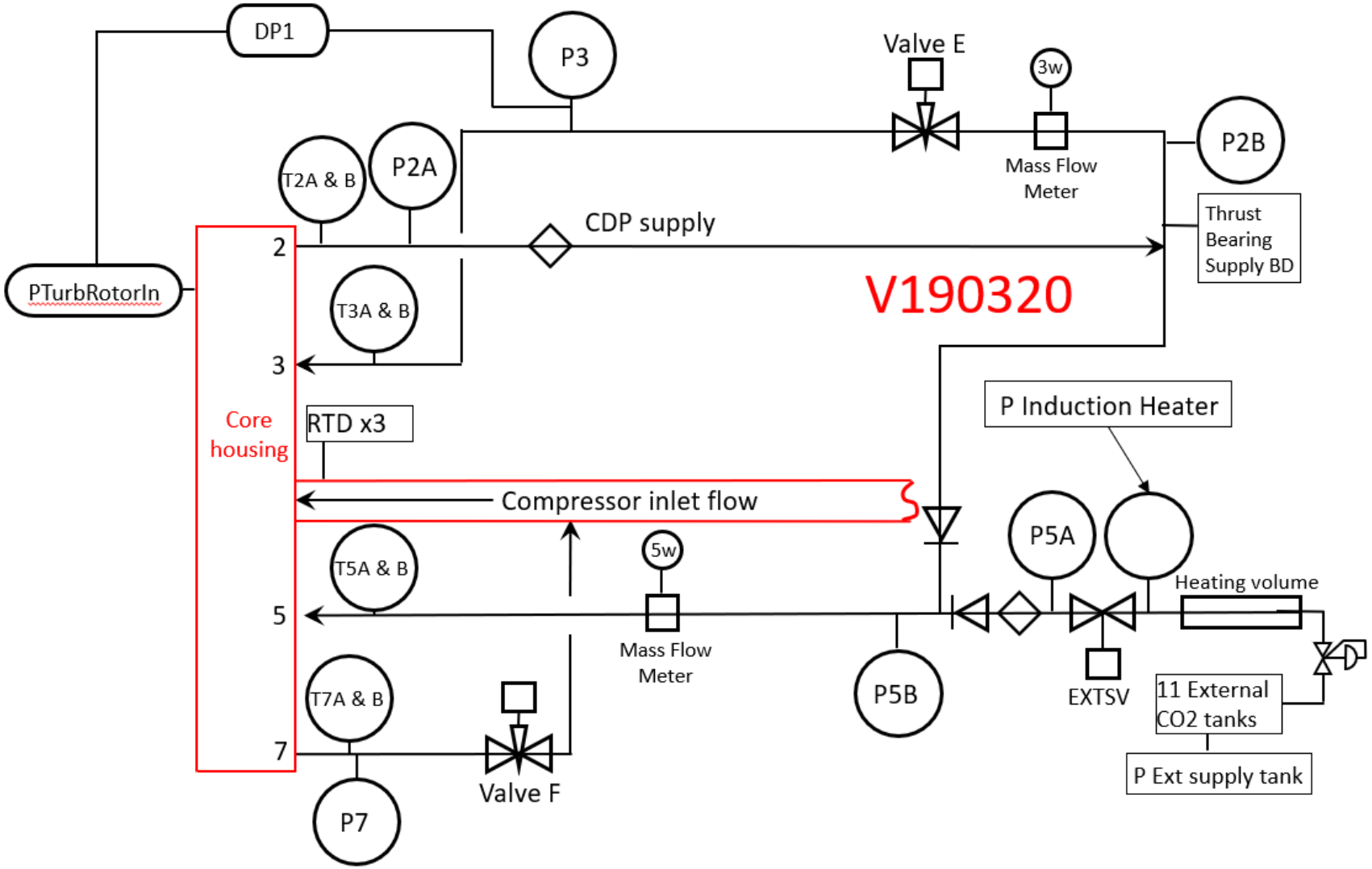
In Tests #1-3, both the thrust bearing and the radial bearings experienced rubs/failures

Spikes in pressure indicate thrust bearing rubs

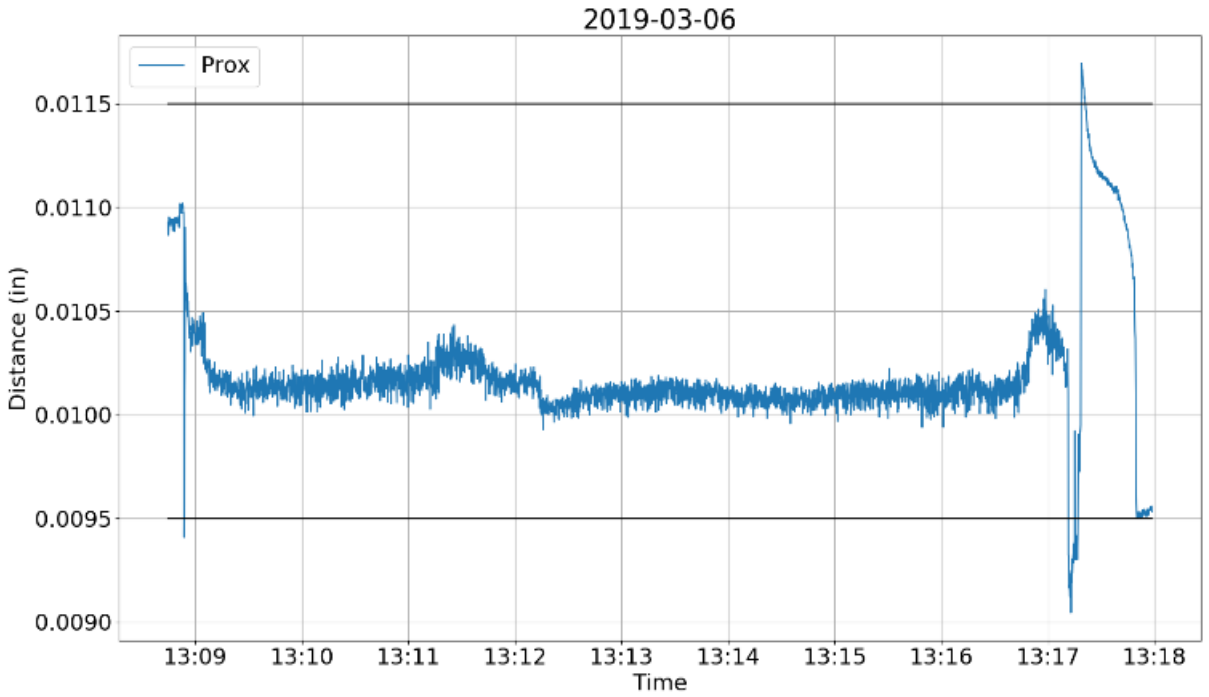


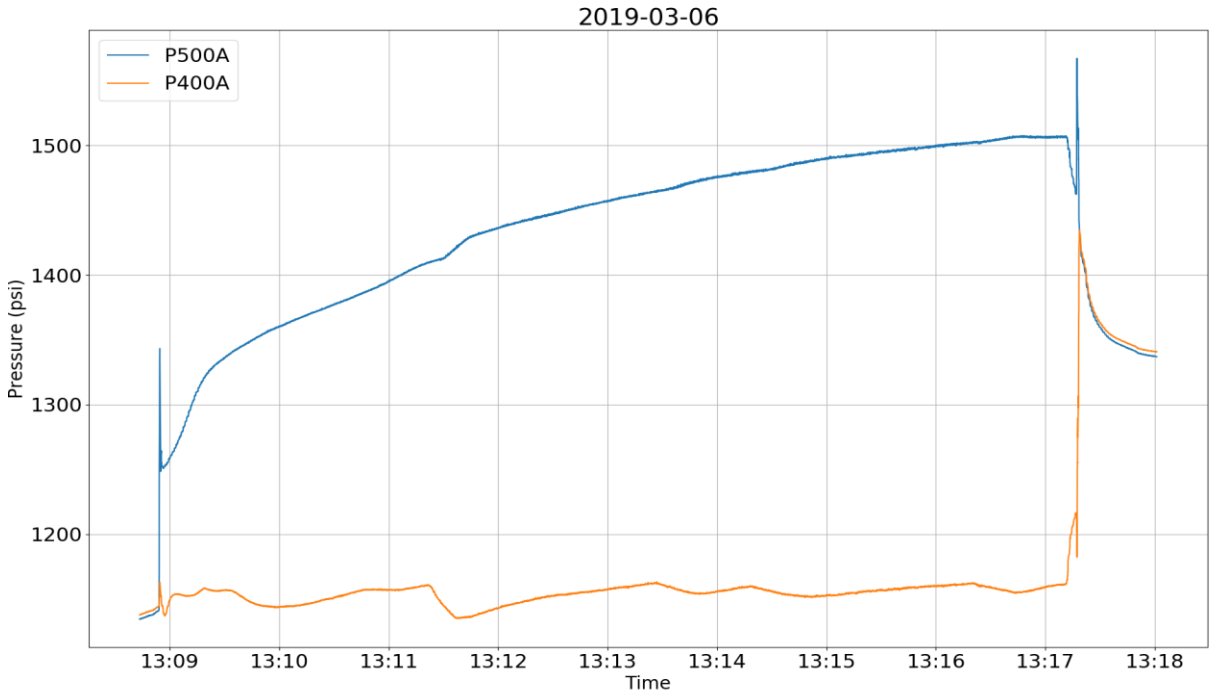
# Secondary Flows

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



# Thrust bearing issue resolved



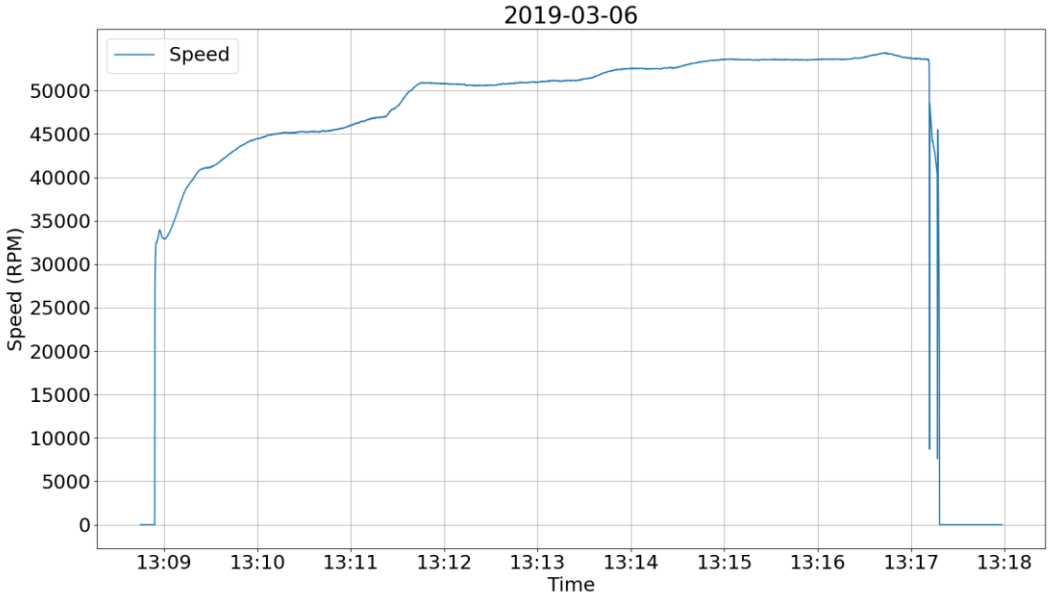

By adjusting Valve F and the TCV the force on the rotor was balanced.

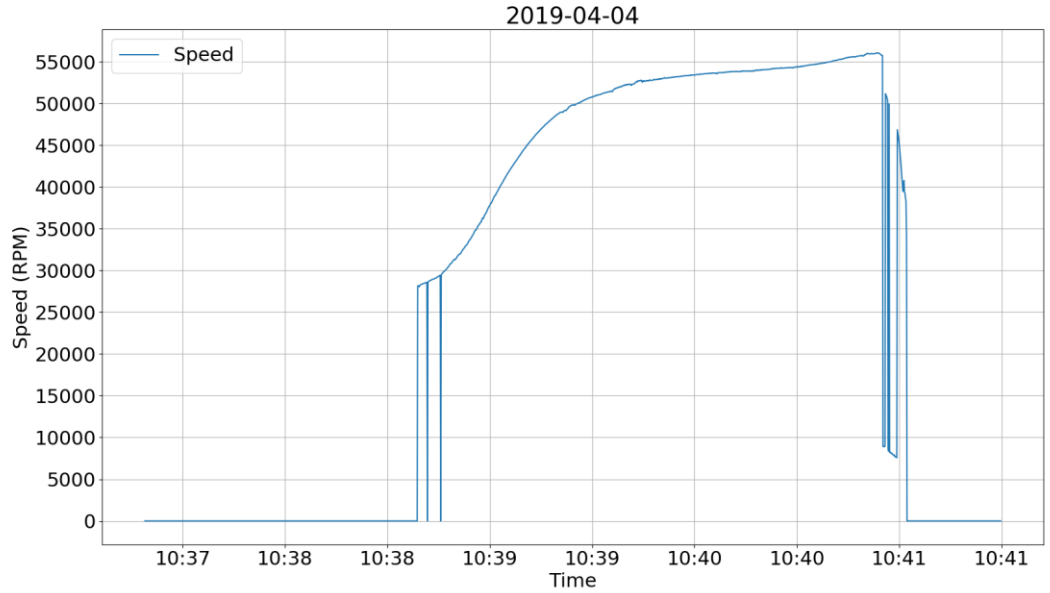
# Radial Bearing Issues

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

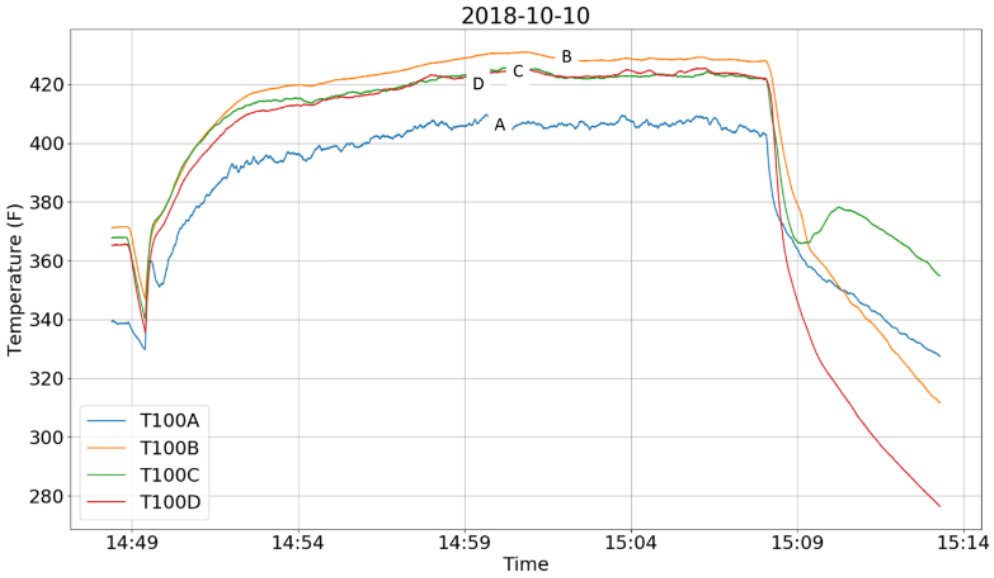
Possible causes of failure:

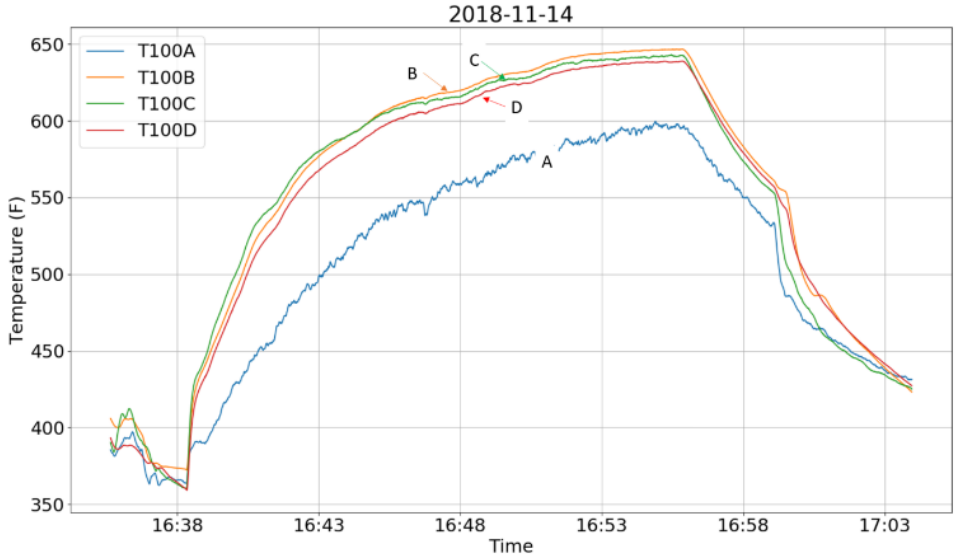
- Blowdown start
  - Reduce blowdown pressure
- Critical speed causing rotor instability
  - Physical evidence of bearing failure shows yielded foils at a specific clocking; not indication of rotor instability
- Radial load caused by non-uniform turbine inlet conditions
  - Resolved with instrumentation

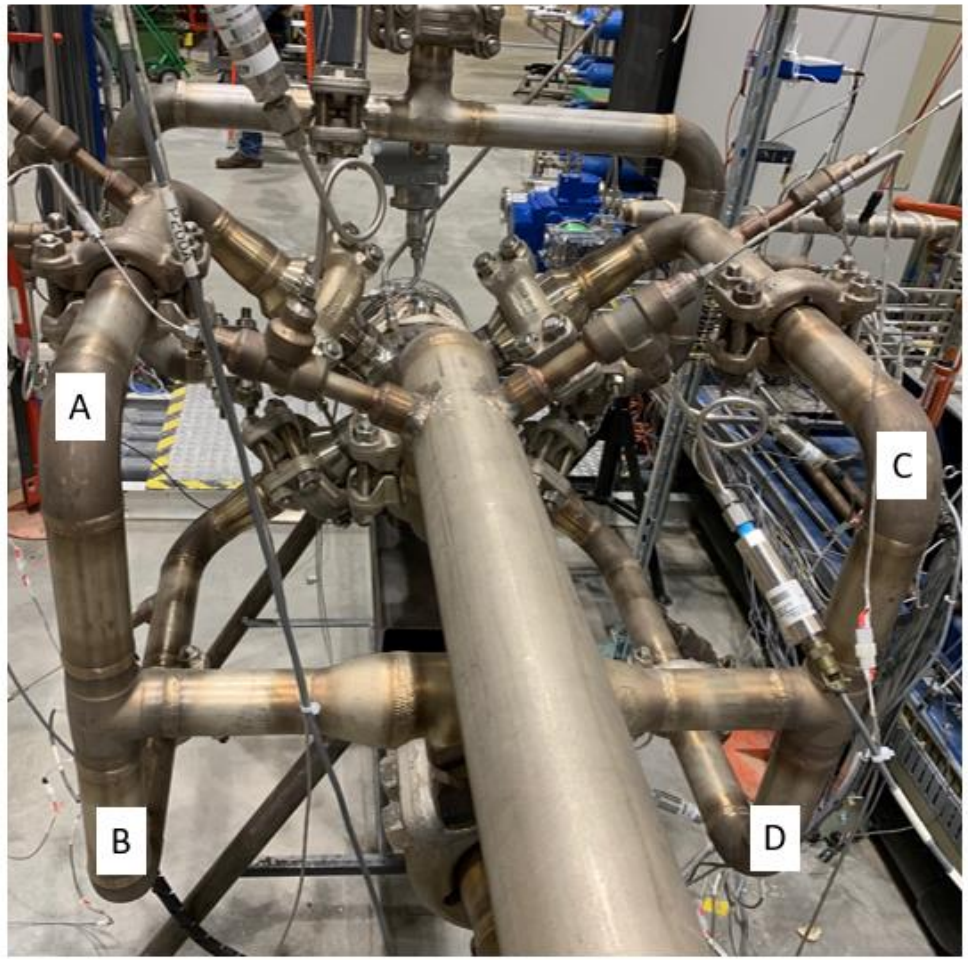


# Turbine Inlets

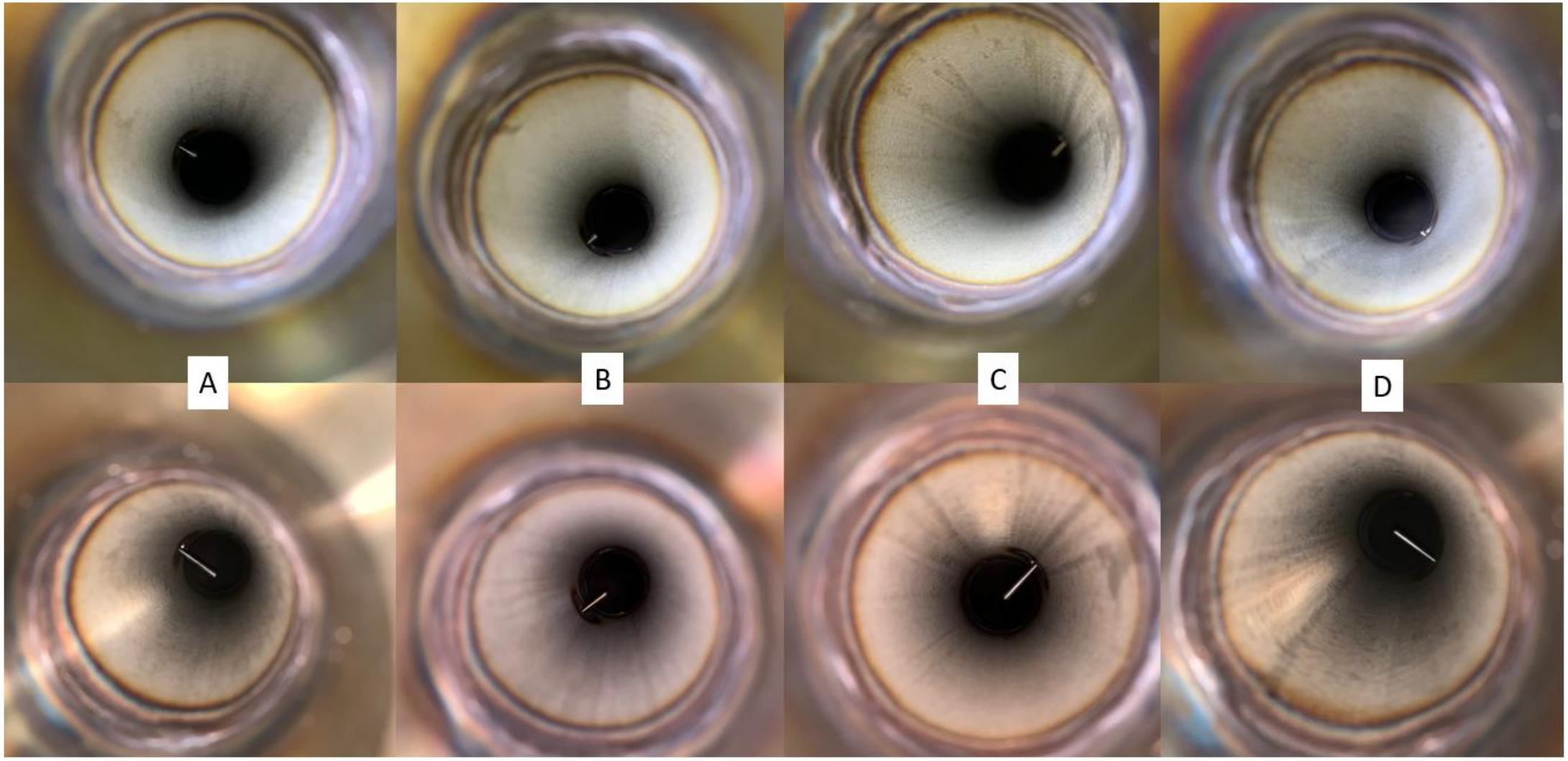


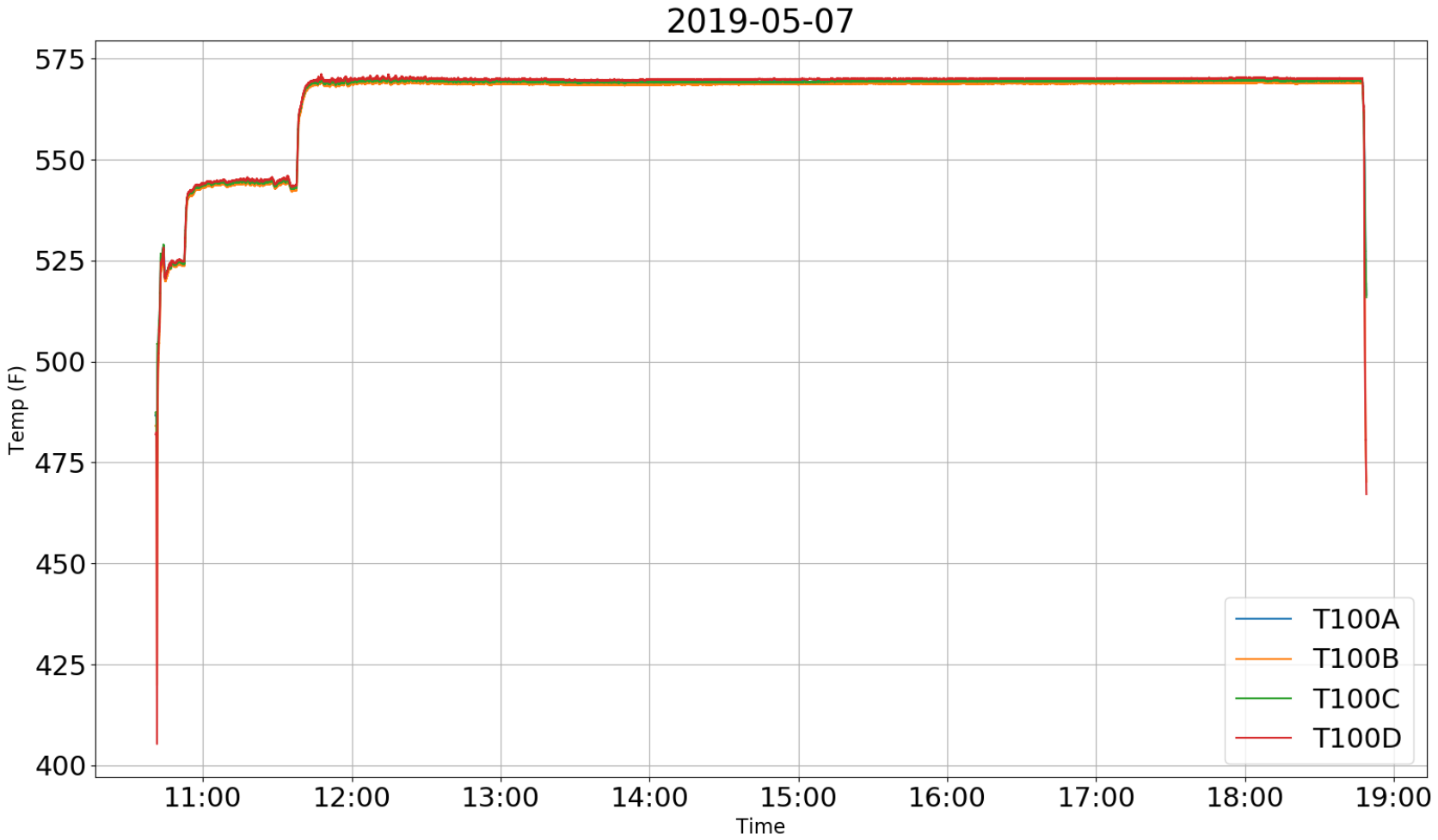

Leg “A” was consistently lower temperature than the other 3

# Original and New Turbine Inlet RTD insertions



# Turbine Inlet Temp with new Insertion depth

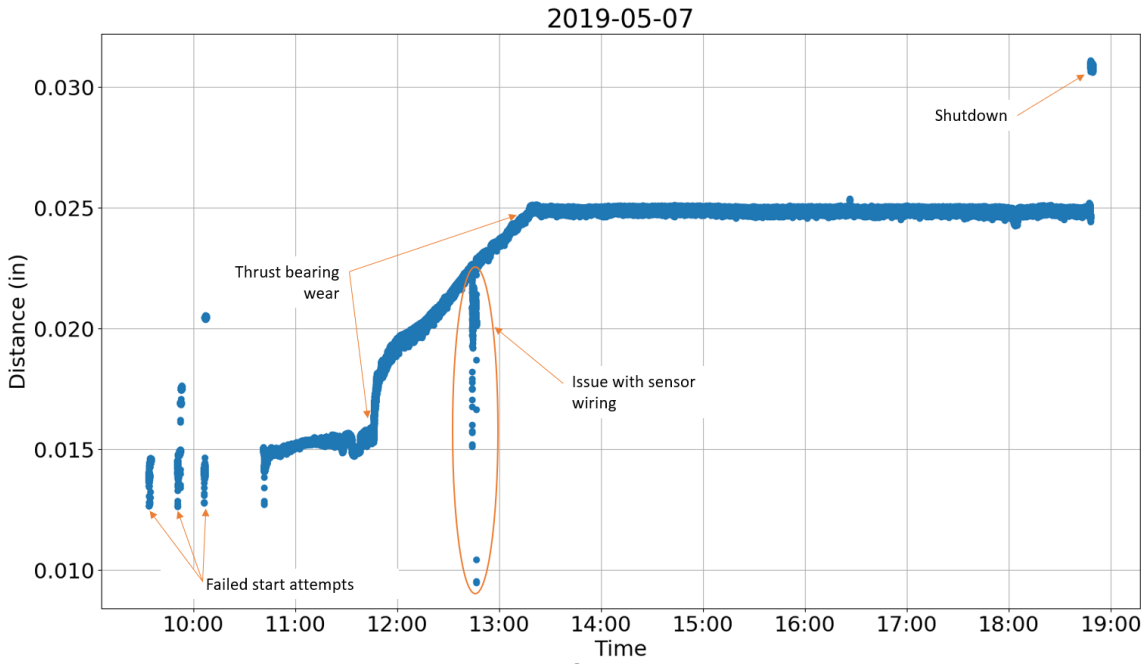
No difference in centerline temperature of turbine inlets

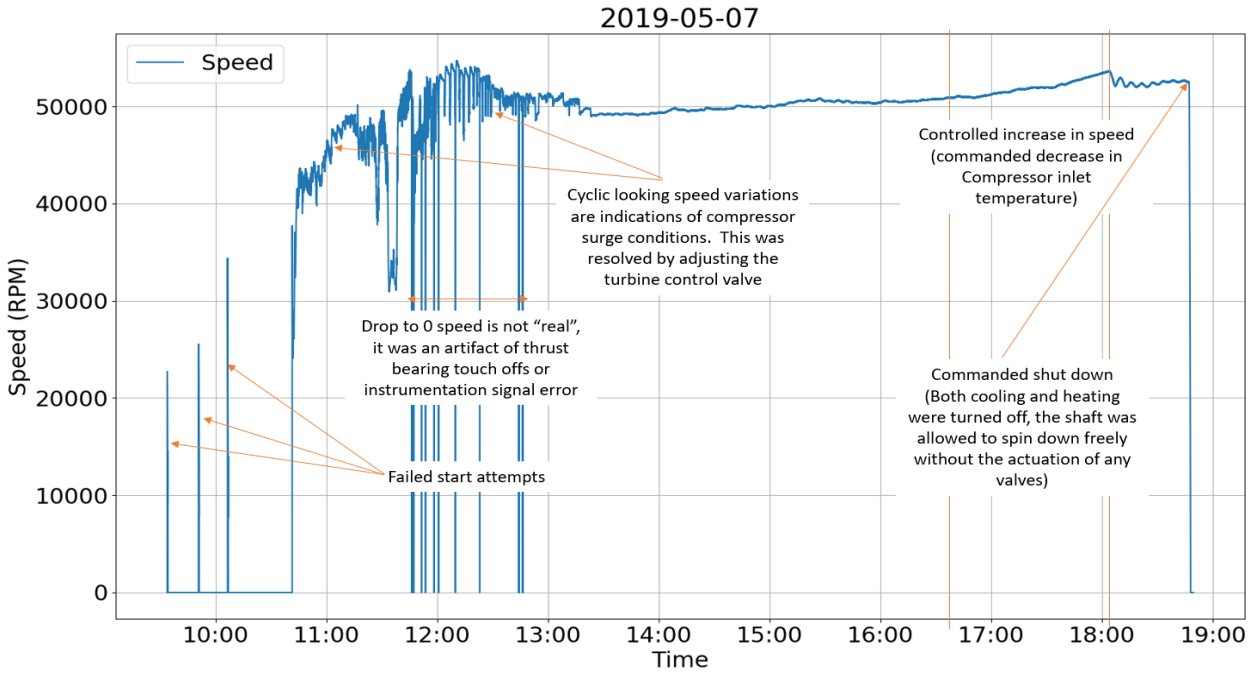


# Increased L/D of aft radial bearing

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

Work with Peregrine Turbine Technologies to test turbocompressor up to full design conditions

# Thank you