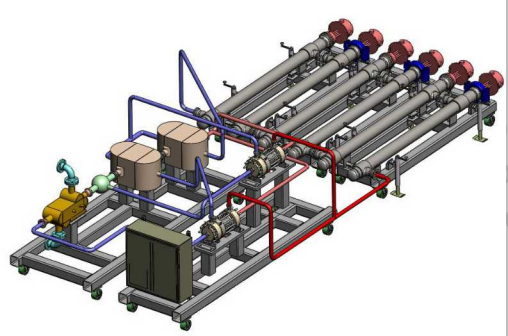
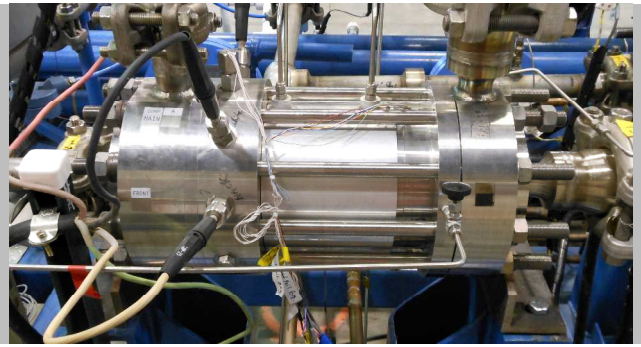
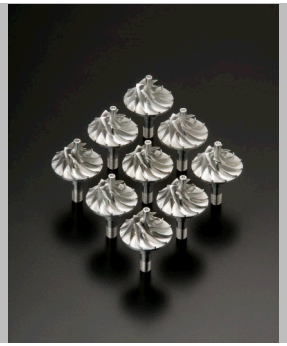
SAND2014-4856C

Exceptional service in the national interest

Sandia National Laboratories







SUPERCRITICAL CARBON DIOXIDE RECOMPRESSION CLOSED BRAYTON CYCLE: FACILITY OPTIMIZATION

Gary Rochau, (505) 285-7543, gerocha@sandia.gov
Jim Pasch, (505) 284-6072, jjpasch@sandia.gov
6221 Advanced Nuclear Concepts
Nuclear Energy Systems Laboratory/Brayton Lab (ne.sandia.gov/nesl)

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Test Facility Objectives

Sandia National Laboratories

- Execute CBC tests in a safe and reliable fashion
- Generate data of sufficient quality to baseline models
- Maximize test assembly availability

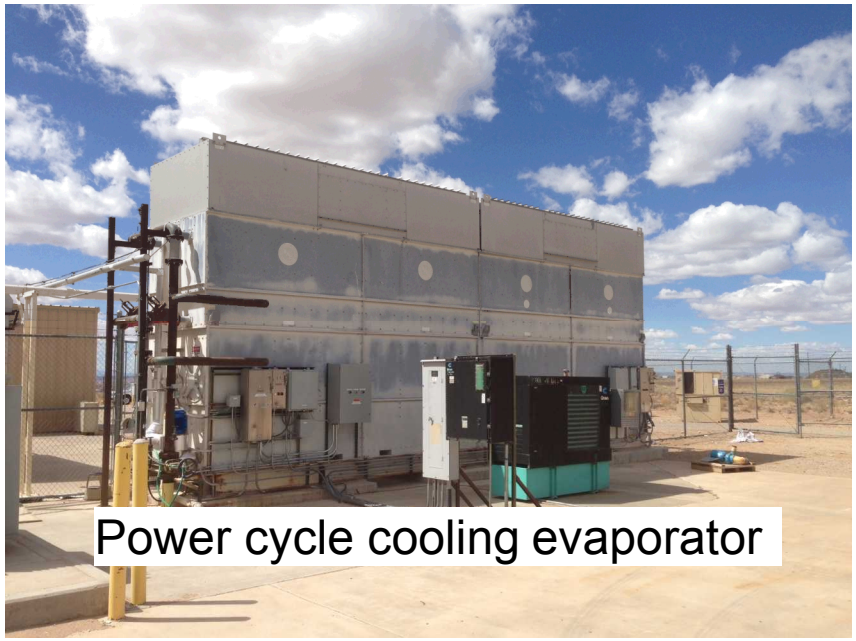
The DOE RCBC at Sandia

Sandia National Laboratories

Recent picture of the recompression closed Brayton cycle at Sandia NESL/Brayton Lab

Heat Rejection

- Power cycle heat rejection requirements are not the same as for secondary systems cooling.
- Accommodate the two cooling requirements by segregating the cooling circuits.

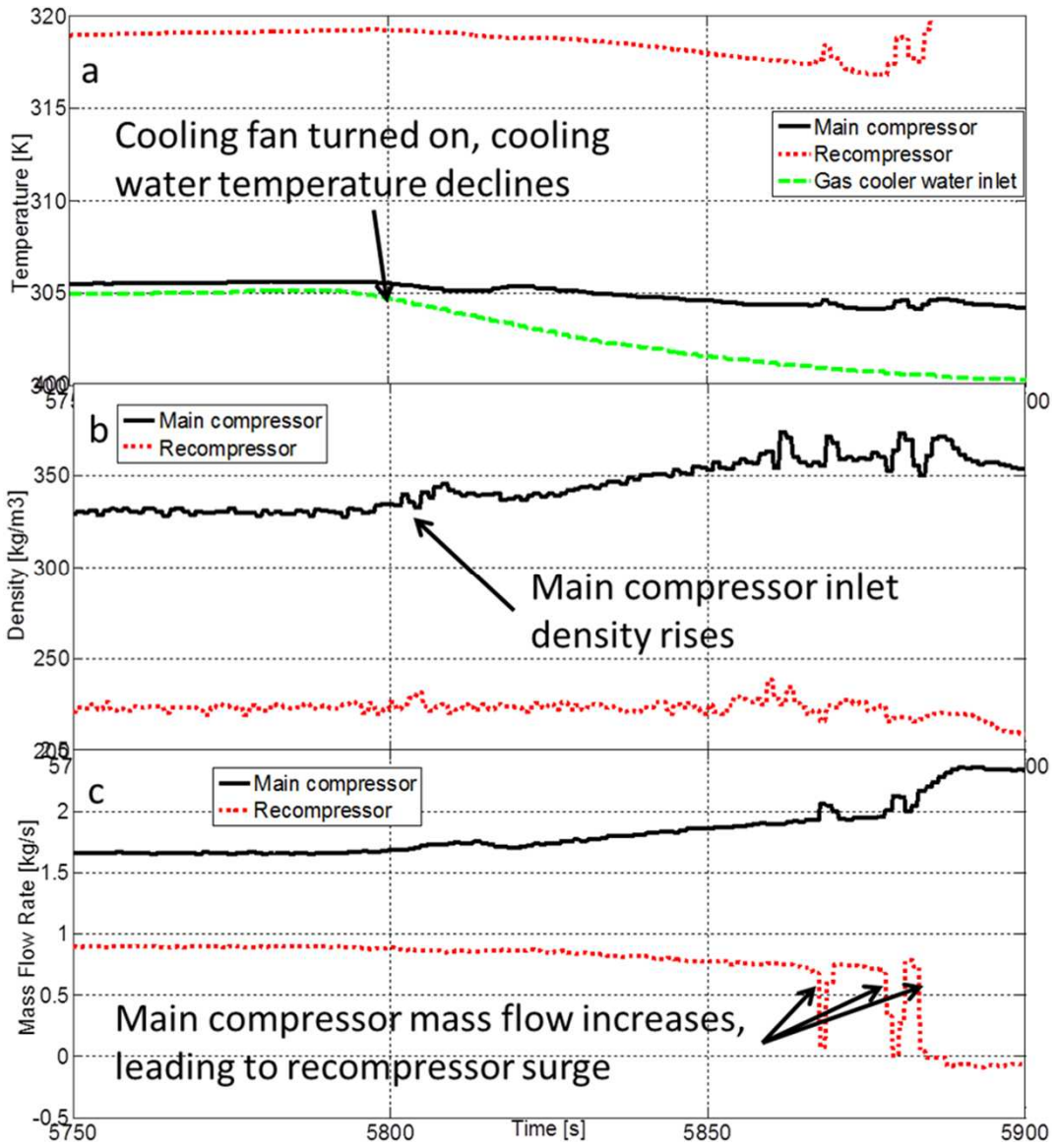


Power cycle cooling evaporator

Newly installed evaporator for secondary cooling circuit

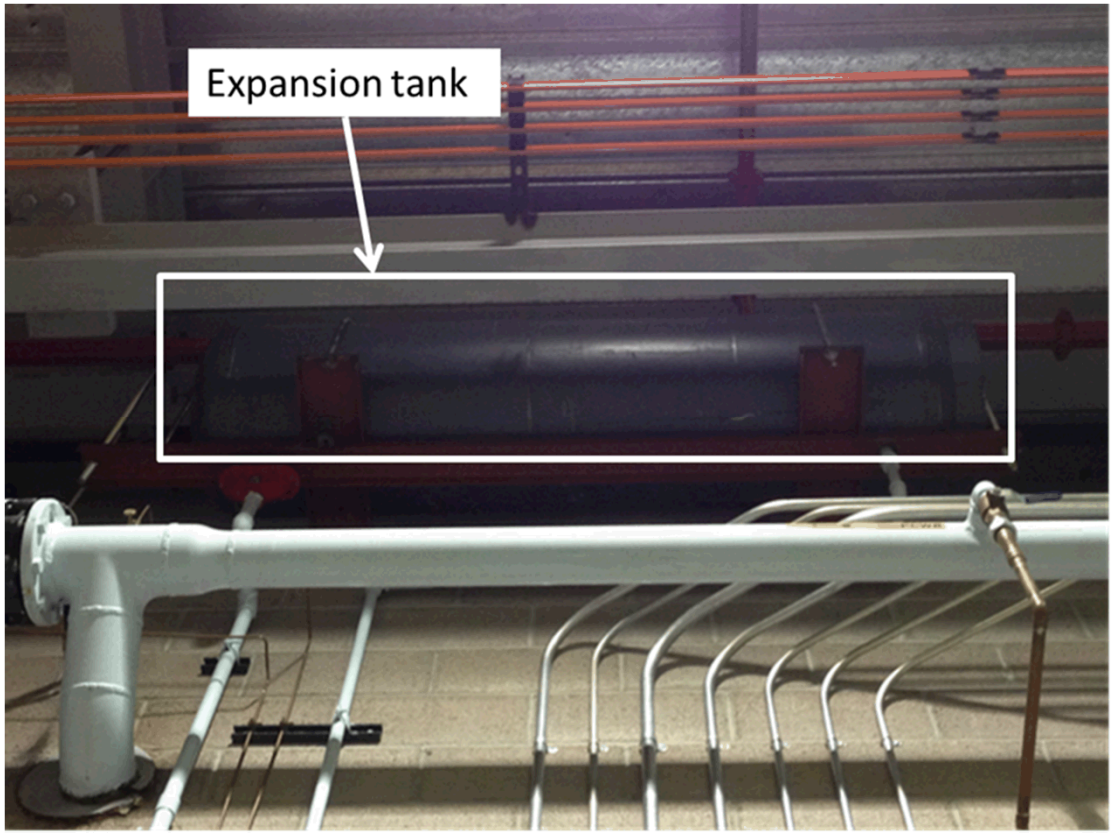
Heat Rejection

- Changes in heat rejection can have a dramatic effect on main compressor inlet conditions.
- Effect of operating near the critical point.
- Replace on/off heat rejection functions with graded functionality.



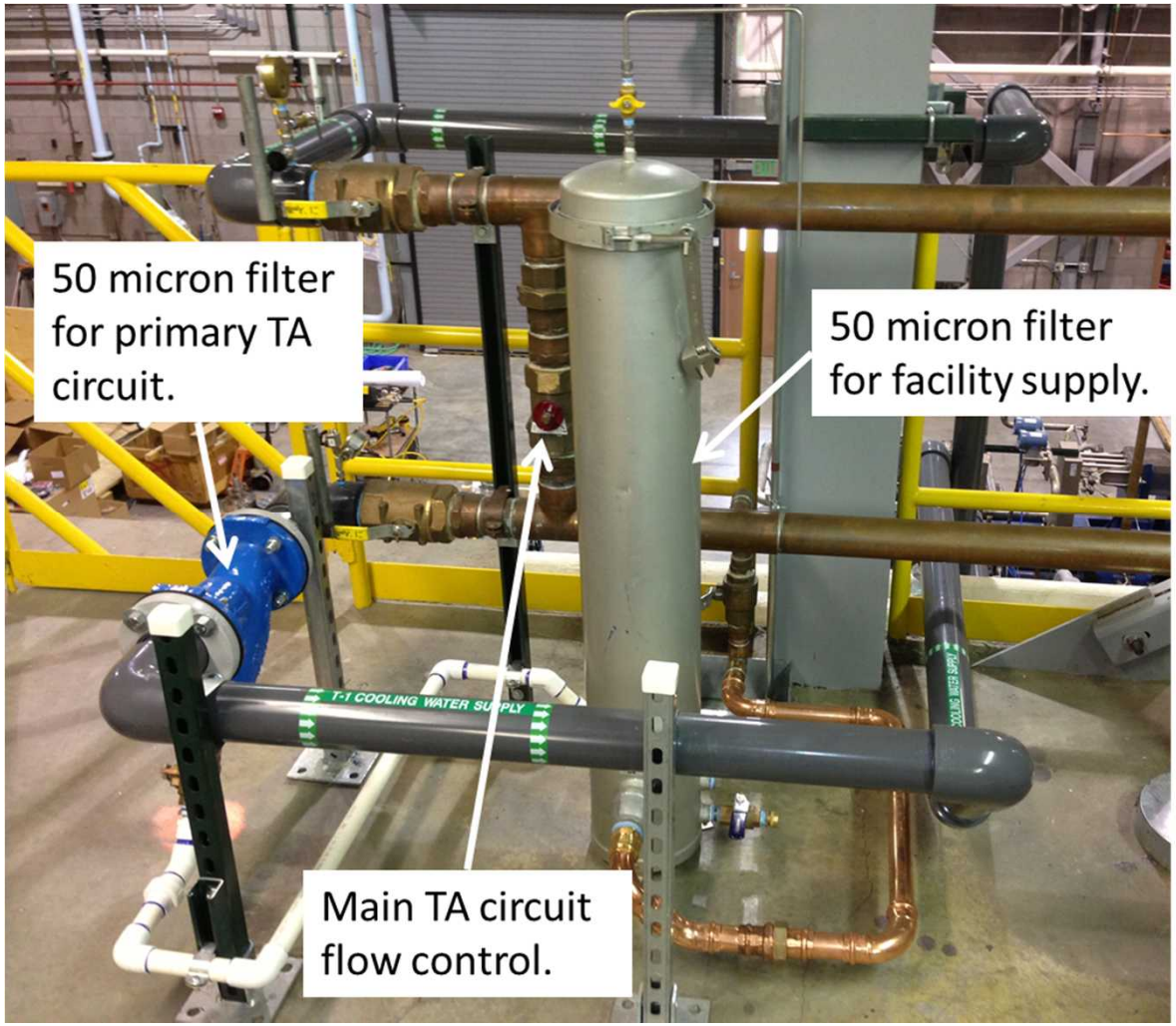
Power Cycle Heat Rejection

- As a test progresses, the cooling water circuit warms up and the water expands. A hard circuit cannot accommodate the rise in pressure.
- Install a water expansion tank.



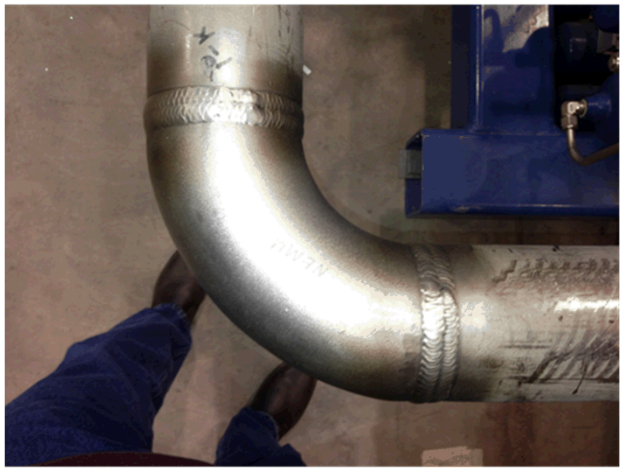
Cooling circuit cleanliness

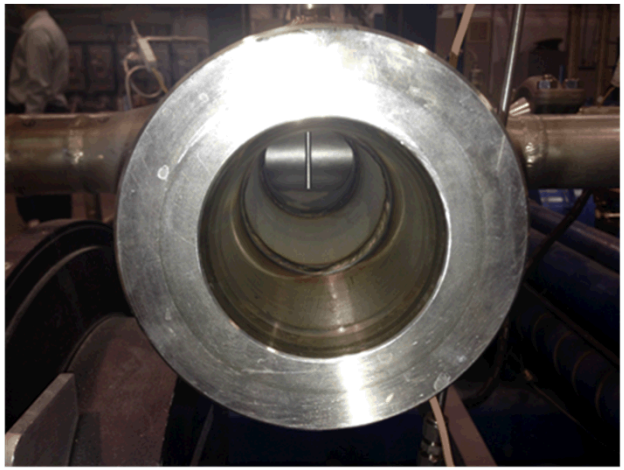
- FOD in water circuit can clog filters and reduce performance.
- Install appropriate filters.
- Inspect and clean filters on a regular basis.



Piping Welds

- Early DOE budgets did not afford the highest level of pipe welding rigor.
- An appropriate level of pressure safety assurance was imposed, relying on ASME code B31.3
- When funds became available, pipe welding changes were implemented to comply with the more rigorous B31.1.

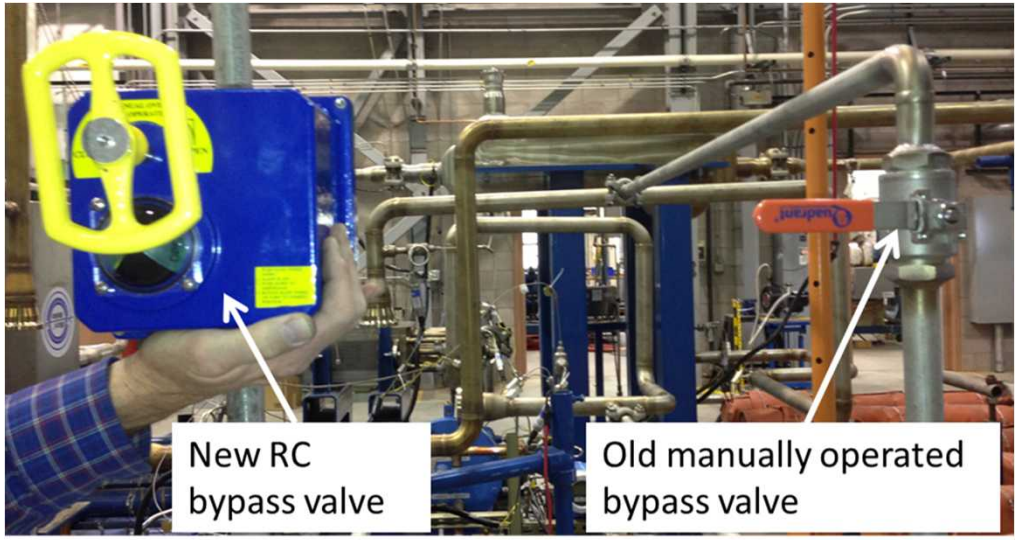


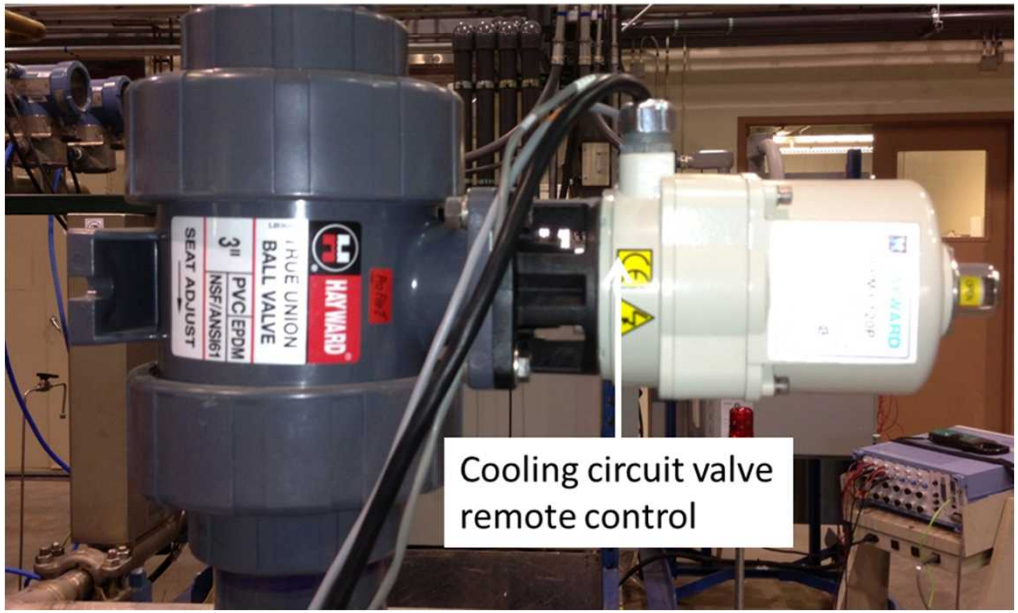


No evidence of overheating, fittings properly aligned, 3 weld passes, even penetration, no concavity

Personnel Safety

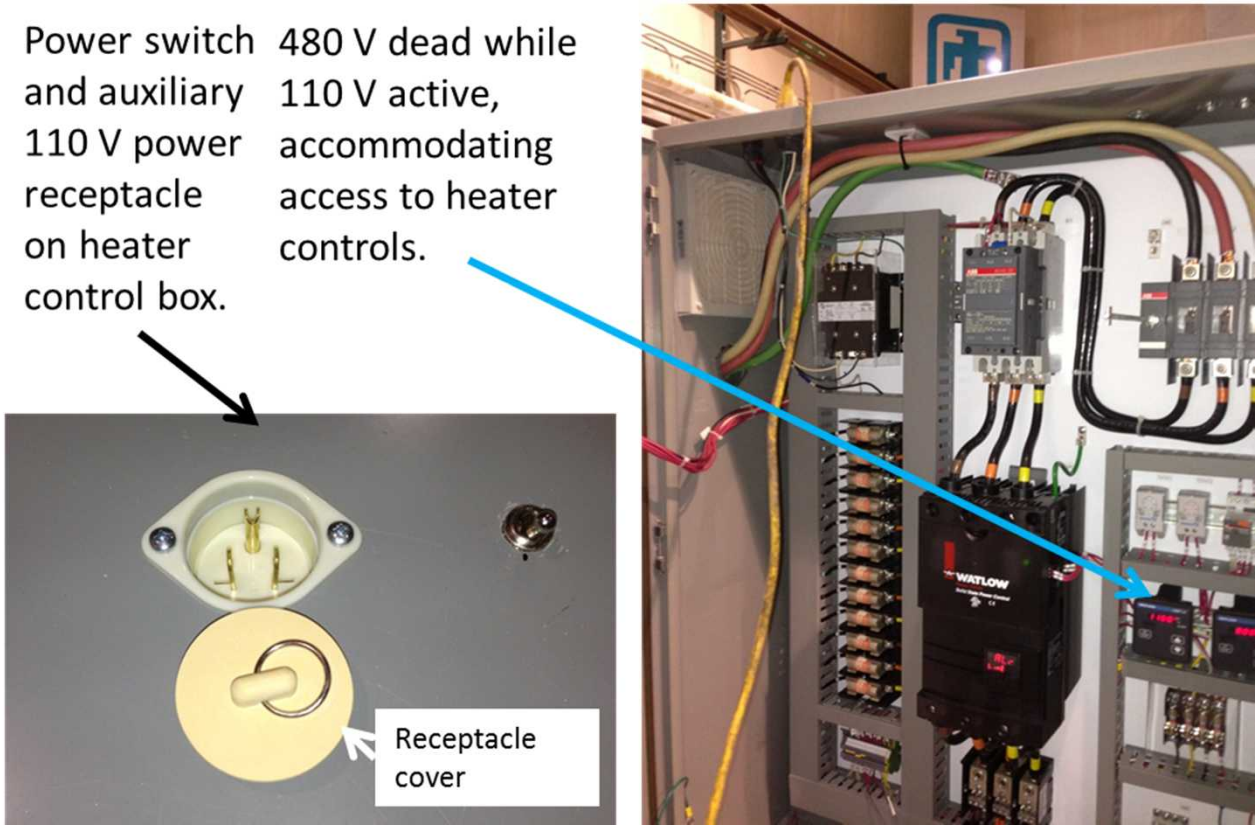
- Personnel safety remains a top priority at Sandia, and NESL in particular.
- The NESL facility leads the way at Sandia in implementing engineered safety.
- System modifications that minimize personnel entry into the test room are continuously installed.
- These pictures show that remote control valves have been installed in lieu of manual operation





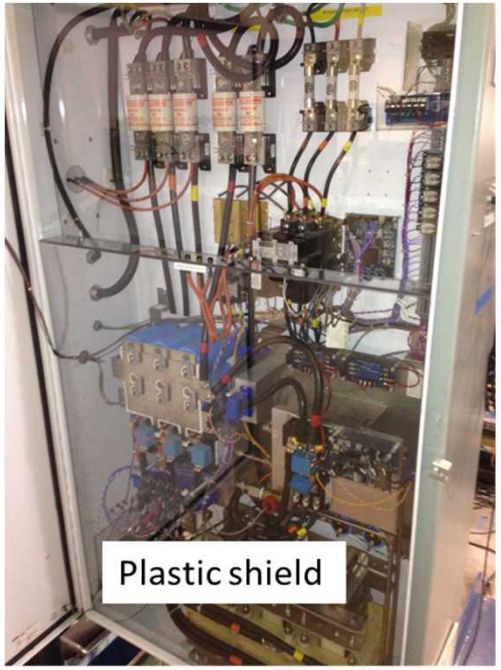
Personnel Safety

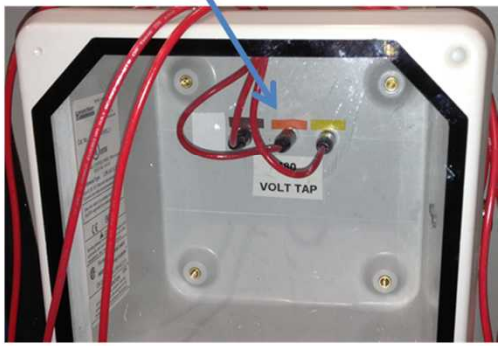
- Access to heater controller was problematic due to presence of 480 V circuits.
- Method to power the 110 V controller without activating the 480 V circuits was installed.

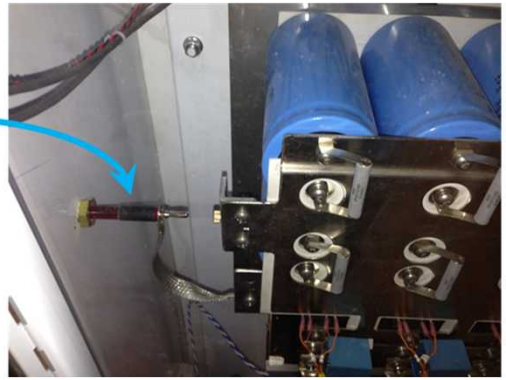


Personnel Safety

- Additional electrical safety precautions installed in the motor controller.
- Motor controller door can now be open while testing, even with 480 V circuits.



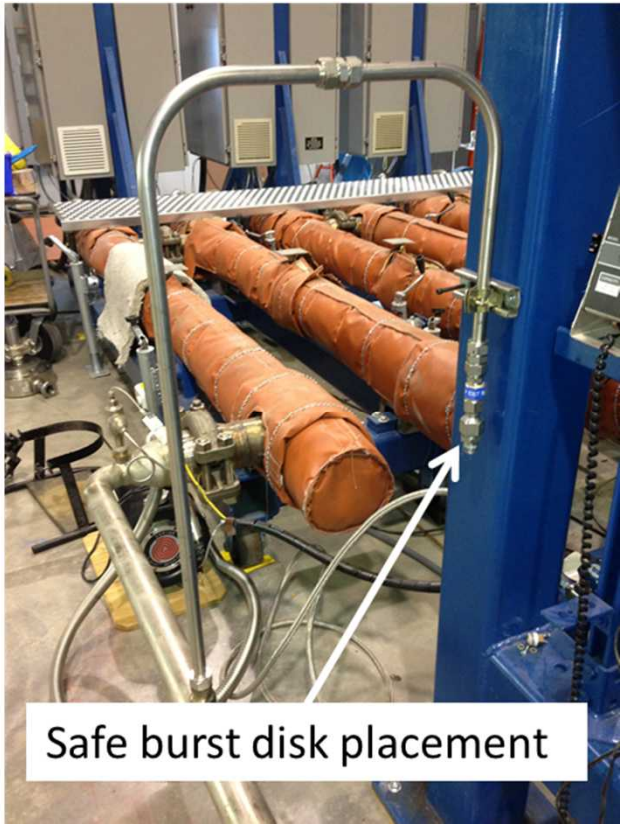




Personnel Safety

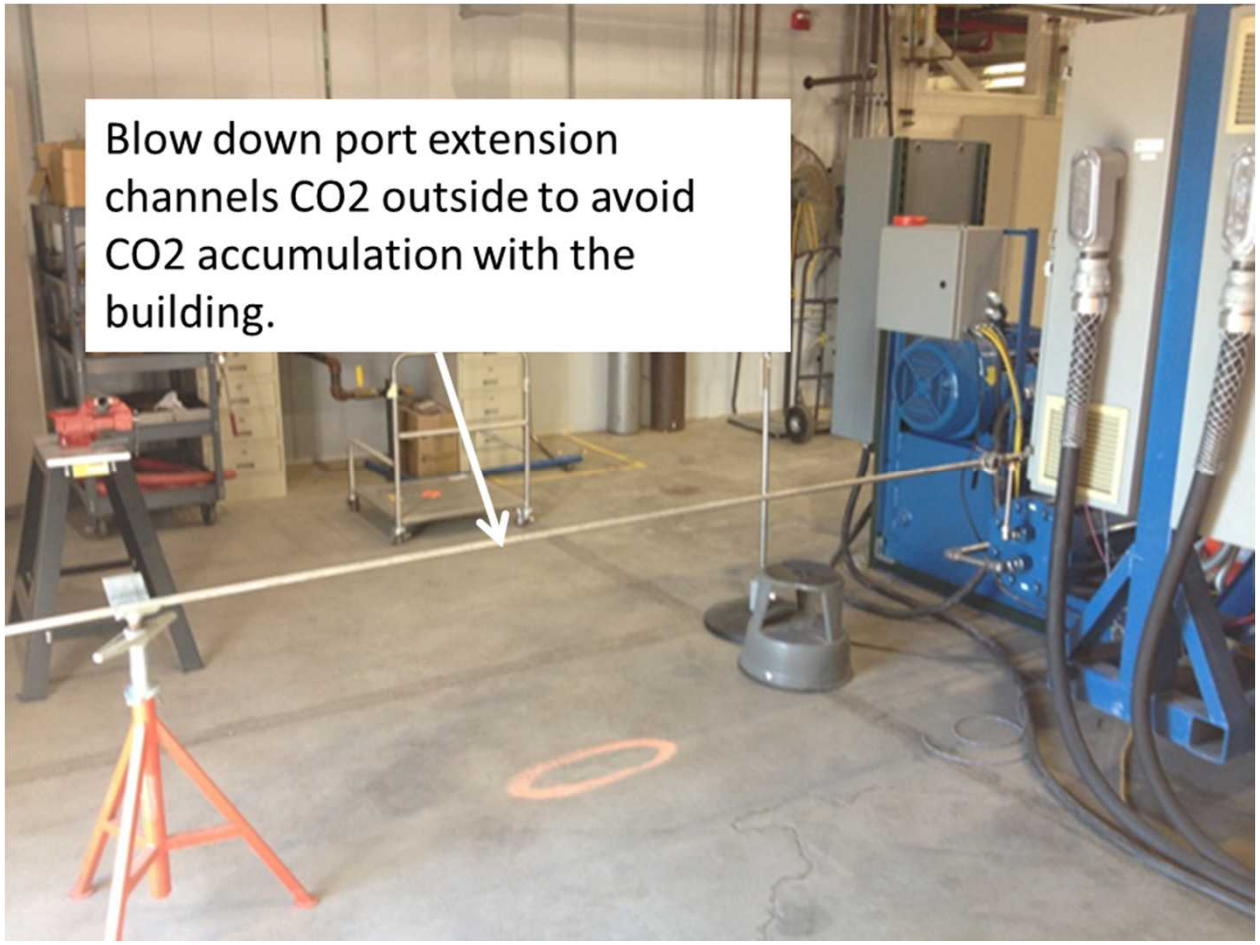
- Hot piping warning system installed.
- Burst disks have been located such that they cannot release onto a person

Hot piping warning system


Safe burst disk placement

Personnel Safety

- Safe CO2 purging operations installed.

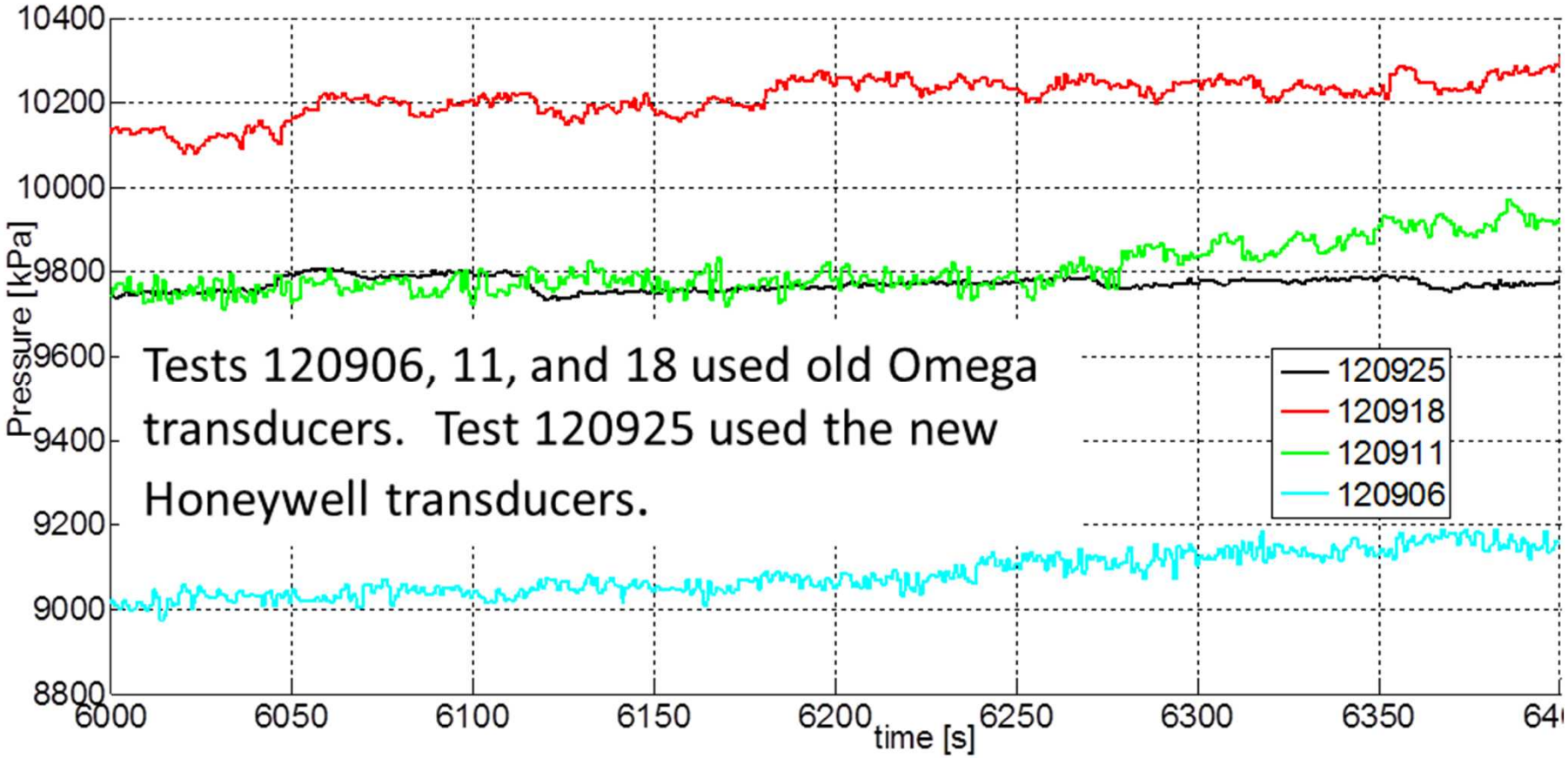


Thermal Insulation

- Old insulation was very thin, had large gaps, and exhibited signs of melting after high temperatures were attained.
- New insulation is 4” thick, and has a jacket specifically designed for these heaters and insulation.
- Similar insulation will be placed on hot piping in near future.

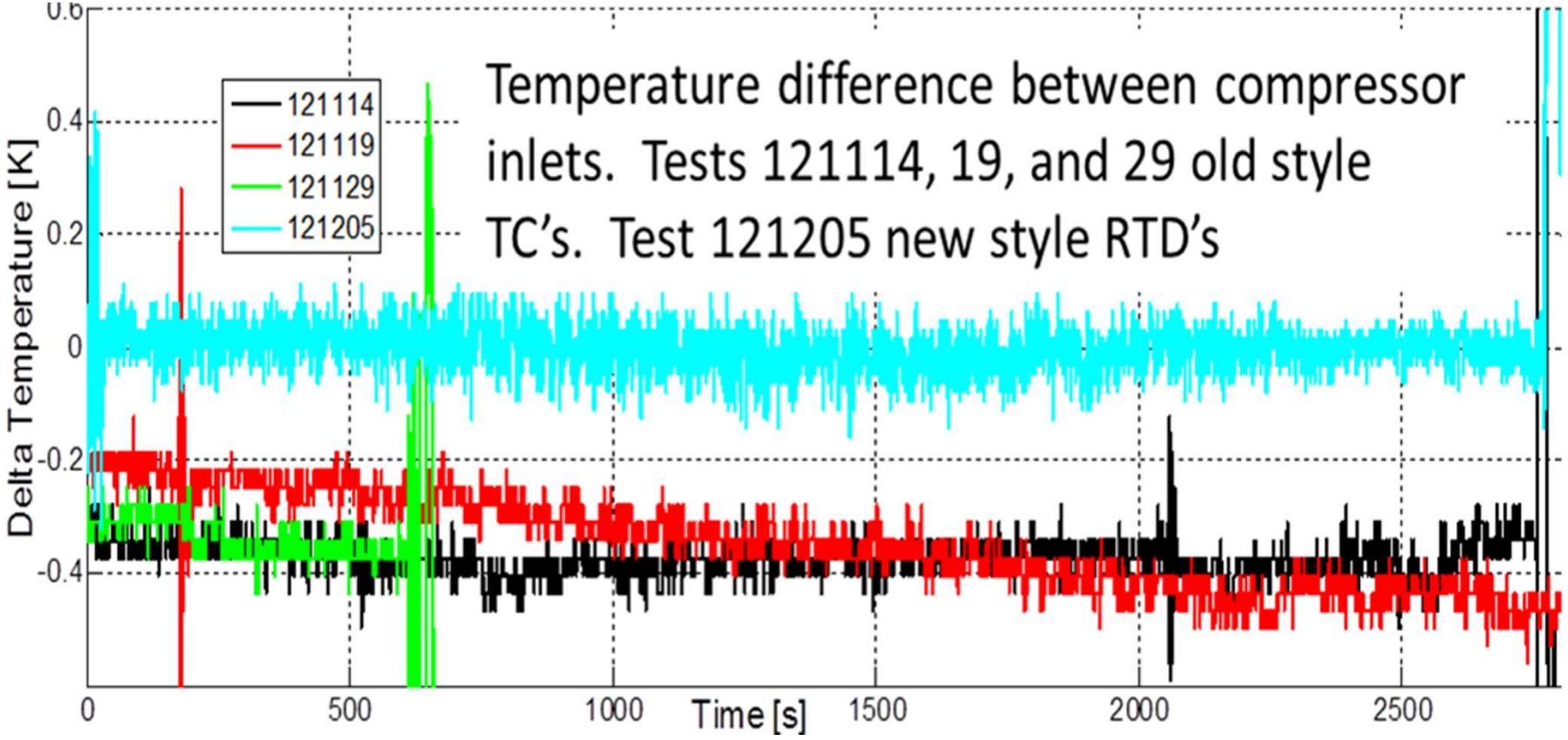
Data Quality

- Omega pressure transducers replaced with higher accuracy and better precision Honeywell transducers



Data Quality

- TC temperature measurements at turbomachinery ins and outs replaced with higher accuracy and higher precision RTDs.
- Similar replacement recently completed at recuperator ins and outs.



Quality of operations at Man-Machine Interface

- Real time windage calculations added in LabView

$$P_{turb} = 0.155\omega^{2.8}\left(\frac{\rho}{21.1kg/m^3}\right)^{0.8}\left(\frac{\mu}{1.49uPa\cdot s}\right)^{0.2}$$

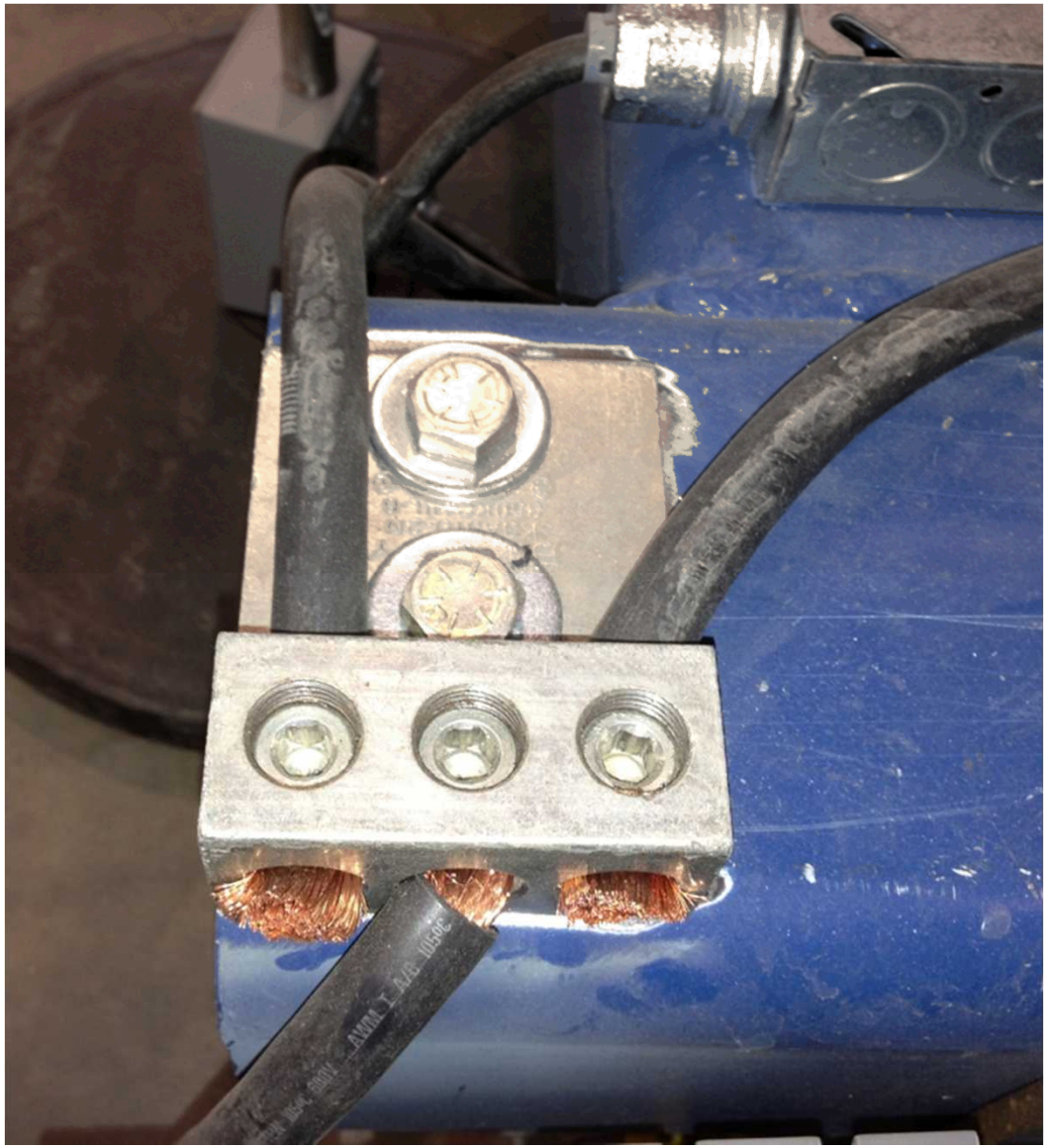
- Real time rotor shaft thrust state added. This includes force calculations from pressures on turbine and compressor wheels, and the following thrust bearing load capacity

$$W = (0.0172\cdot\omega - 209.3)\left(\frac{\rho}{26.1kg/m^3}\right)^{0.5}\left(\frac{D_o}{0.1016m}\right)^{4.10}$$

- Other improvements in LabView implemented

Data Quality

- Better grounding of TACs, to prevent noise to the instrumentation signals.



Improved instrumentation placement

- With SCO2 being such a good solvent, it is important to minimize materials in the loop that can introduce undesirable chemicals.
- TAC internal temperature instrument constraint method was chemically based.
- Adhesive replaced with a mechanical constraint.

Remote diagnostic ports to Motor Controller

- Effective, reliable, and safe instrumentation access ports installed on motor controller box.

Materials Characterization

- Understanding the chemistry of the working fluid is vital to understanding corrosion and erosion processes.
- Mass Spectrometer installed to obtain necessary data between the heater discharge and the turbine inlets.
- High temperature, high pressure chemistry.

CO2 Inventory

- Knowledge of the amount of CO2 flowing in the circuit is an important variable.
- Expansion tanks, which comprised 1/3 of the loop volume, introduced a huge uncertainty as they were installed with open communication with the primary flow path.
- Tanks have been removed from open communication, and now syphon CO2 out of loop through a remote control valve.
- Tank skid is mounted on scale to know how much CO2 has been removed during a test.

Summary

- Numerous improvements have been implemented into the Sandia NESL/Brayton Lab testing infrastructure.
- Sandia is committed to safety, operational, and performance improvements that make sense.
- Objective is to
  - Minimize risk to personnel
  - Maximize controllability
  - Optimize the quality and range of data to inform our understanding of the operational characteristics of an SCO2 CBC.