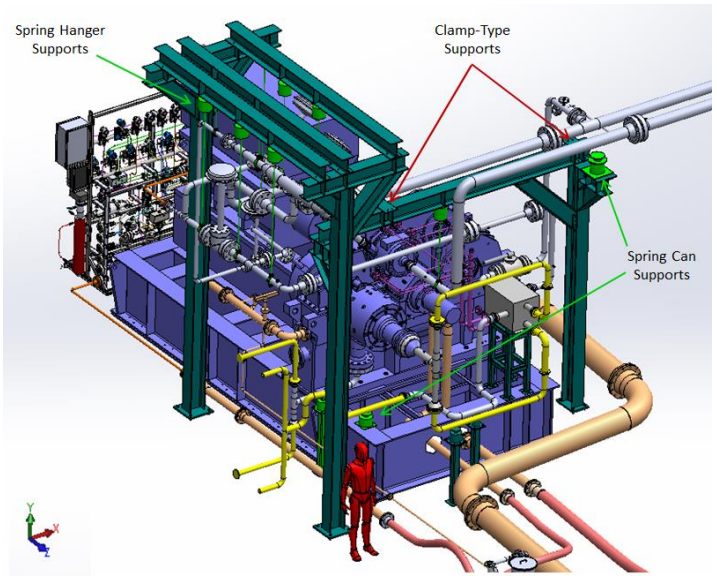
Development of an Ultra-High Efficiency Wide-Range Integrally-Geared Supercritical CO_2 Compressor-Expander



Southwest Research Institute
Award # DE-EE0007114

DOE Funding:	$5,350,000
Cost-Share Funding:	$3,450,000
Principal Investigator:	Jason Wilkes
Other Contributors:	Tim Allison, Karl Wygant, Rob Pelton

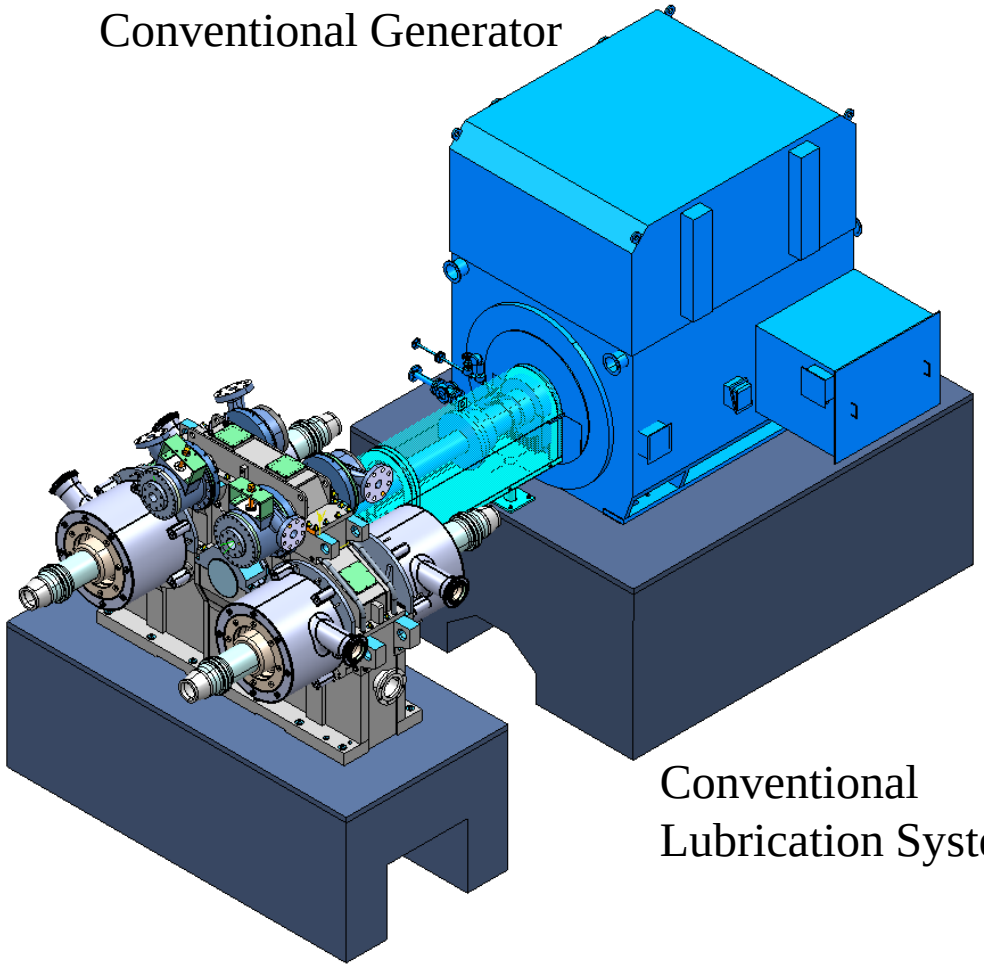
SwRI
SOUTHWEST RESEARCH INSTITUTE

Hanwha Power Systems

Phases of Development Program

- I – Cycle modeling, turbomachinery and loop design [Completed]
- II – IGC fabrication and loop construction [In Process]
- III – Loop and IGC commissioning and full pressure and temperature testing

Conventional Generator

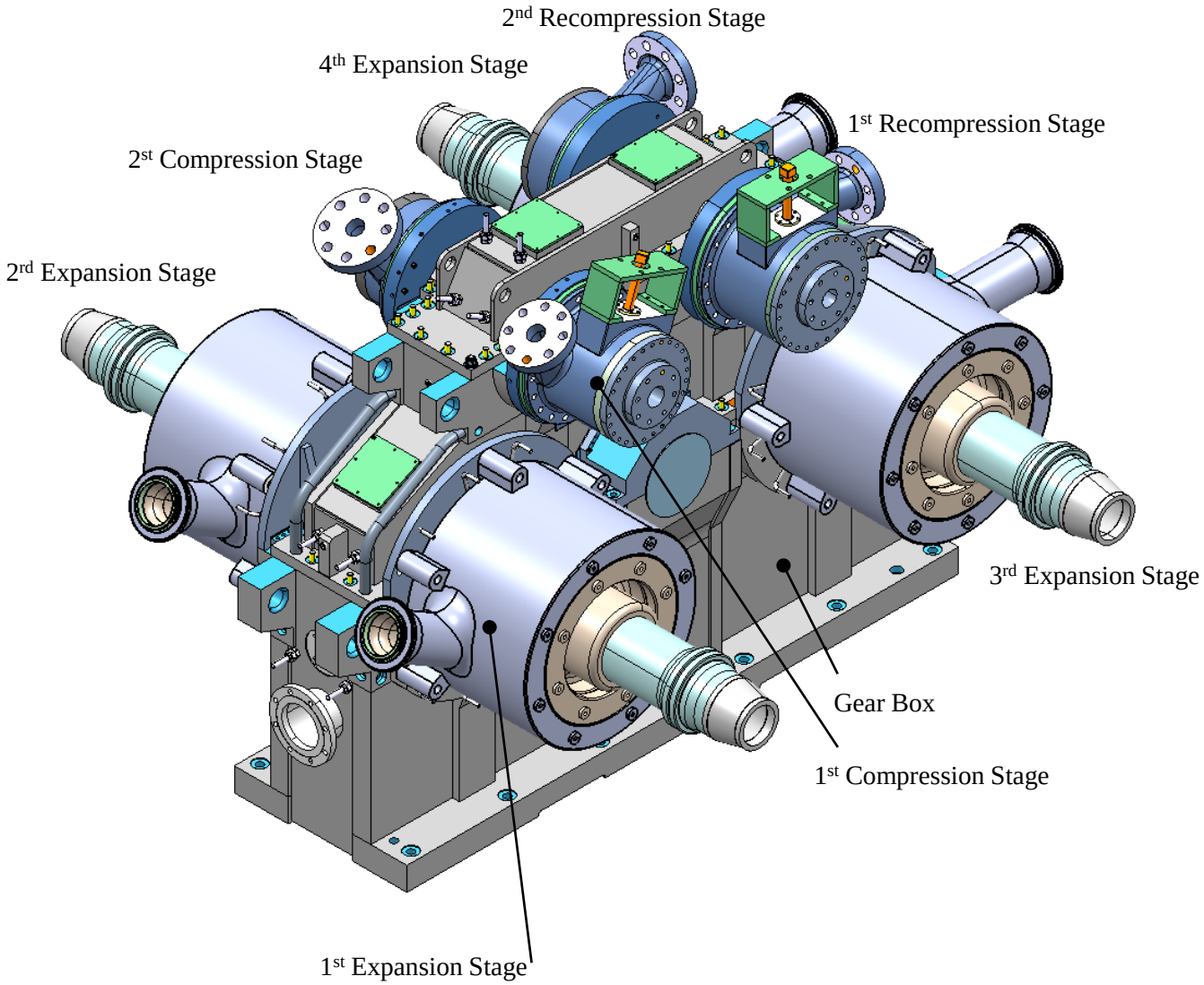


Conventional Lubrication System

Design Objectives

- Design a reduced flow IGC to be tested in SwRI's 1 MW_e test loop.
  - Full flow wide-range compressor (50-70% range)
  - Reduced flow expander (705°C inlet temperature)
  - Full frame core (900$/$kW_e$, 6¢/$kW_e$ LCOE)
- Design a 10 MW_e cycle using a compander as the power block (targeting 50% at design point)
- Investigate off-design cycle operation, wide-range compression capabilities, and control schemes of an IGC based power block
- Test the unit at full temperature and pressure

Configuration of Integrally Geared Compressor-Expander Allows Unparalleled Application Flexibility



Integrated Turbomachinery for:

- Recompression Brayton Cycle,
- Recuperated Cycle,
- sCO_2 Expander Only,
- sCO_2 Compressor Only,
- sCO_2 Re-compressor only,

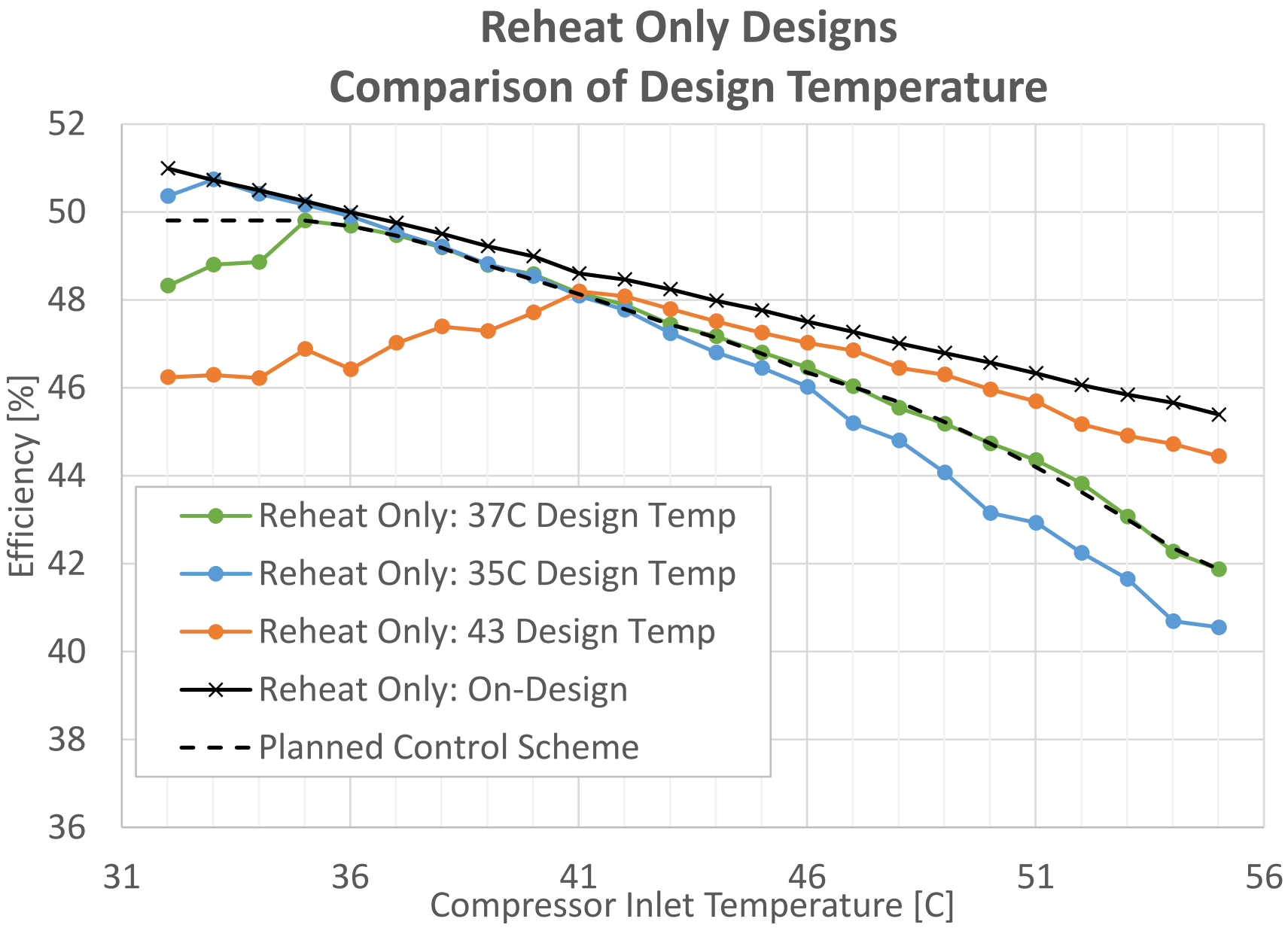
Can Integrate:

- Expander re-heat
- Compressor inter-stage cooling

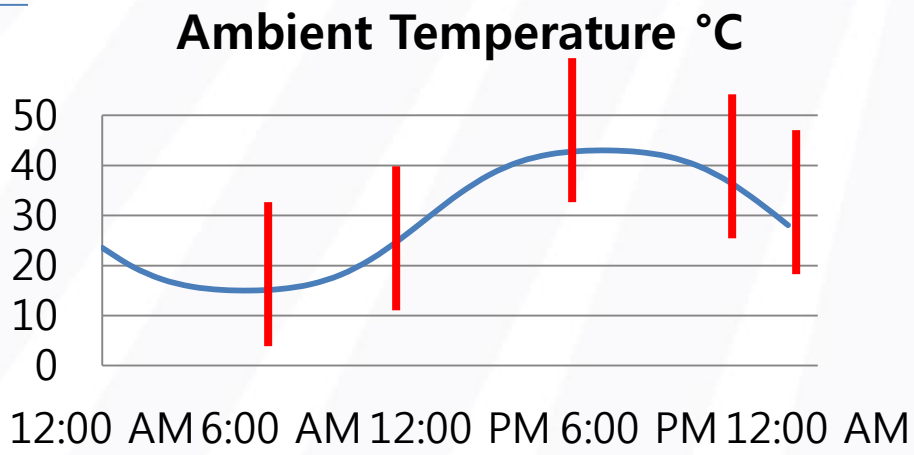
Allows:

- Optimal stage rotational speeds
- Variable flow control

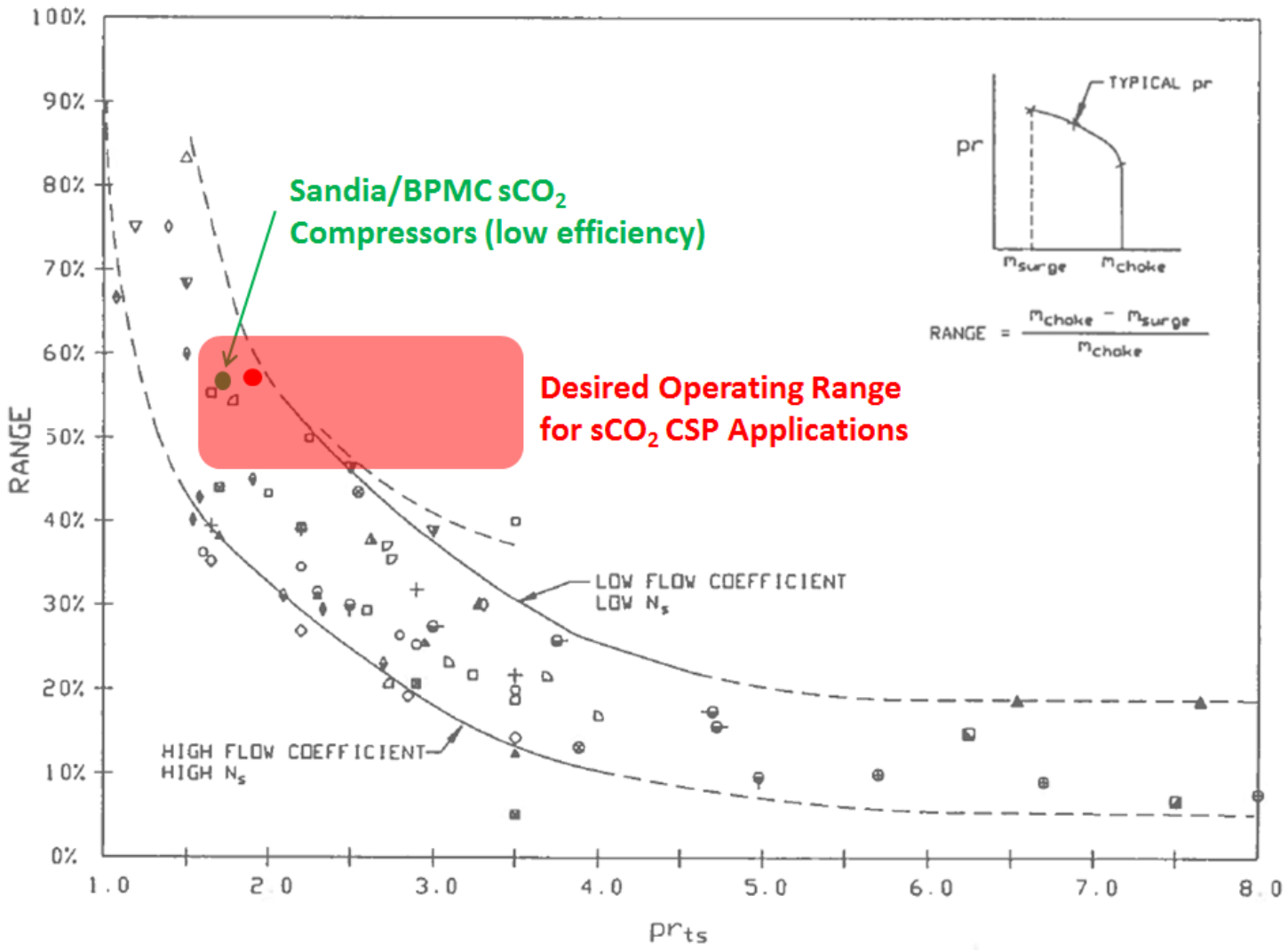
Utilizing the Flexibility of the Compander, a Power Cycle was Optimized to Achieve Maximum Efficiency Across the Range of Ambient Inlet Temperatures



Ambient Cooling Leads to a Variation in Compressor Inlet Temperature

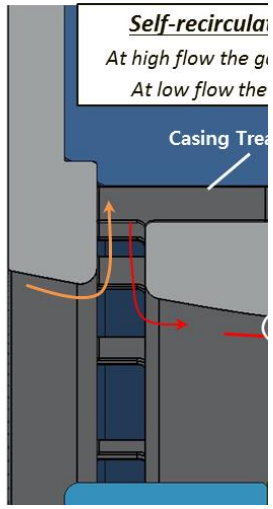


Range Requirements for the Main Compressor First Stage Exceed Current Capabilities



A Partially Shrouded Impeller was Incorporated to Increase Range

Range Extens



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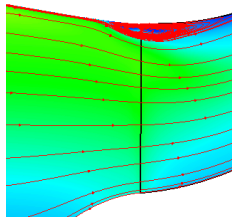
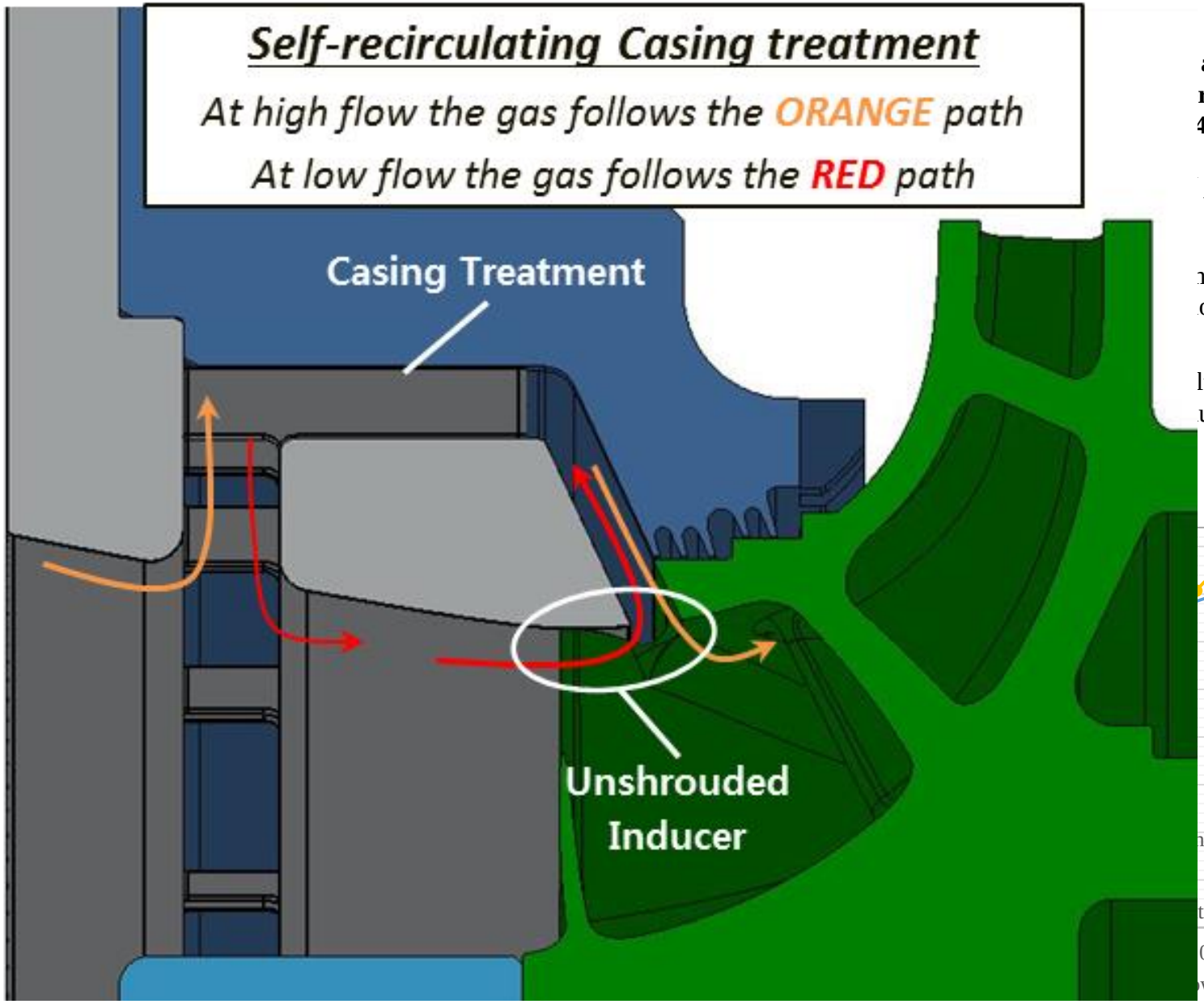


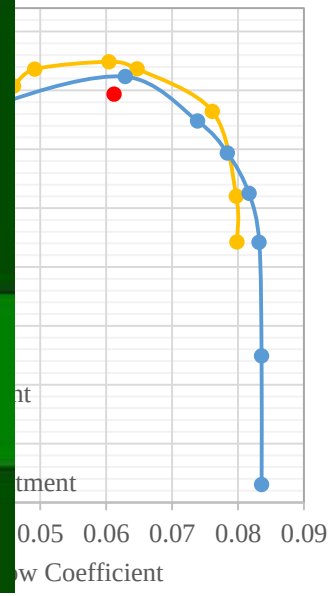


a casing treatment can rating range significantly 4%)

correlation(8% higher CFD test) applied for the head

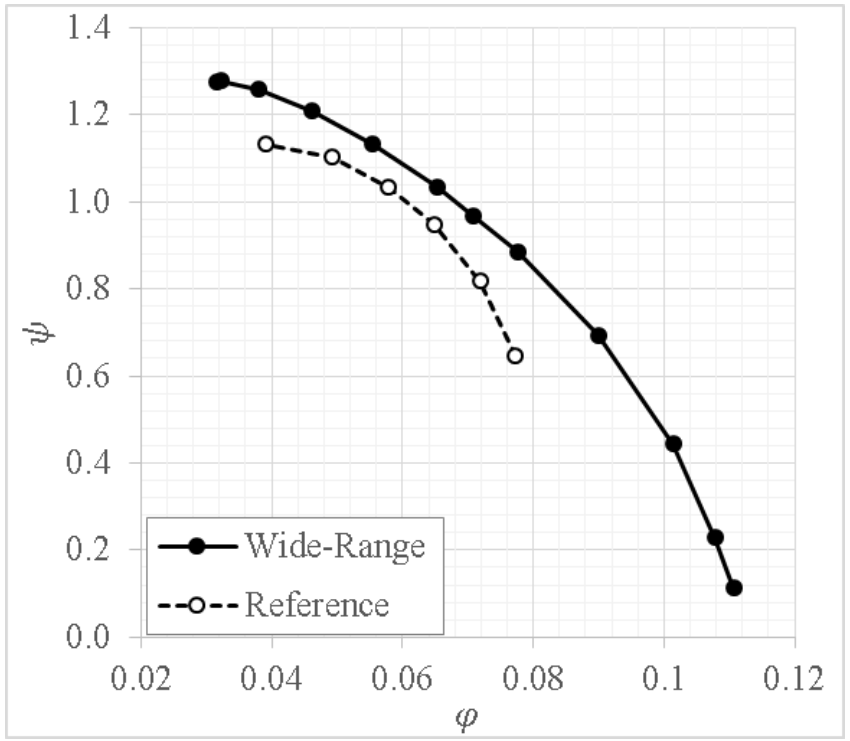
nt designed following the oped from experience with

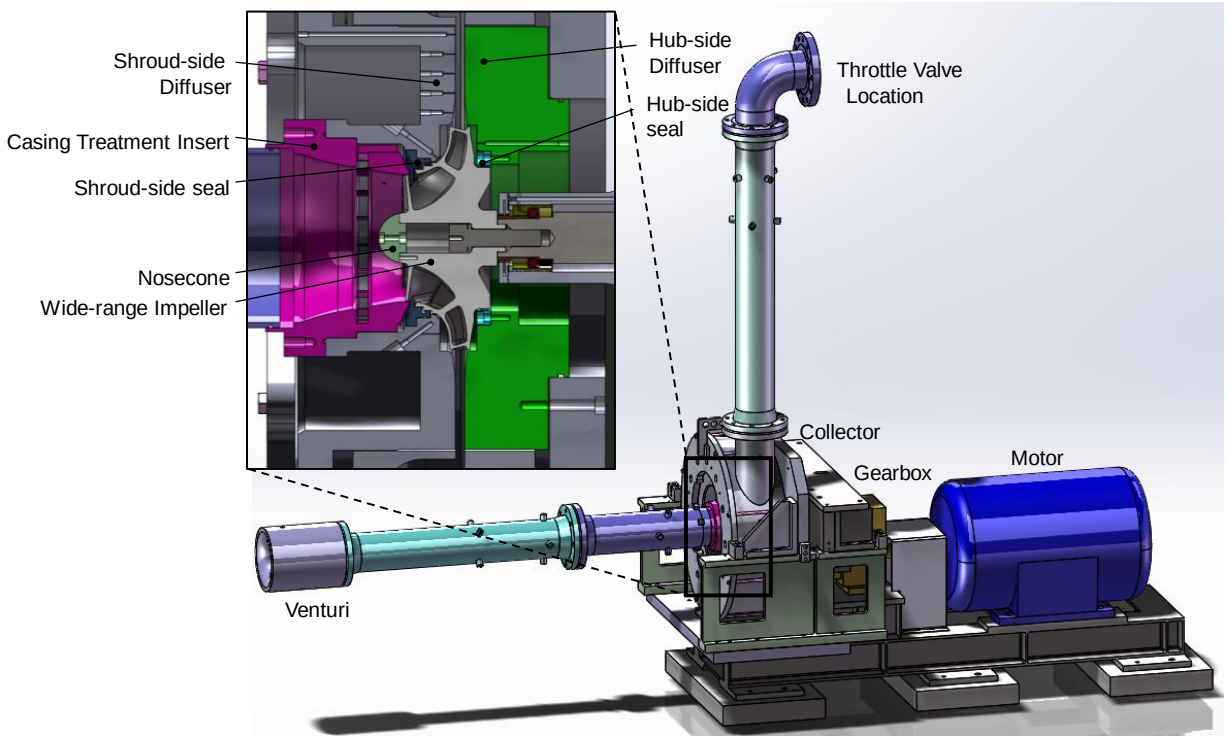
lty is predicted to be less ue to CT



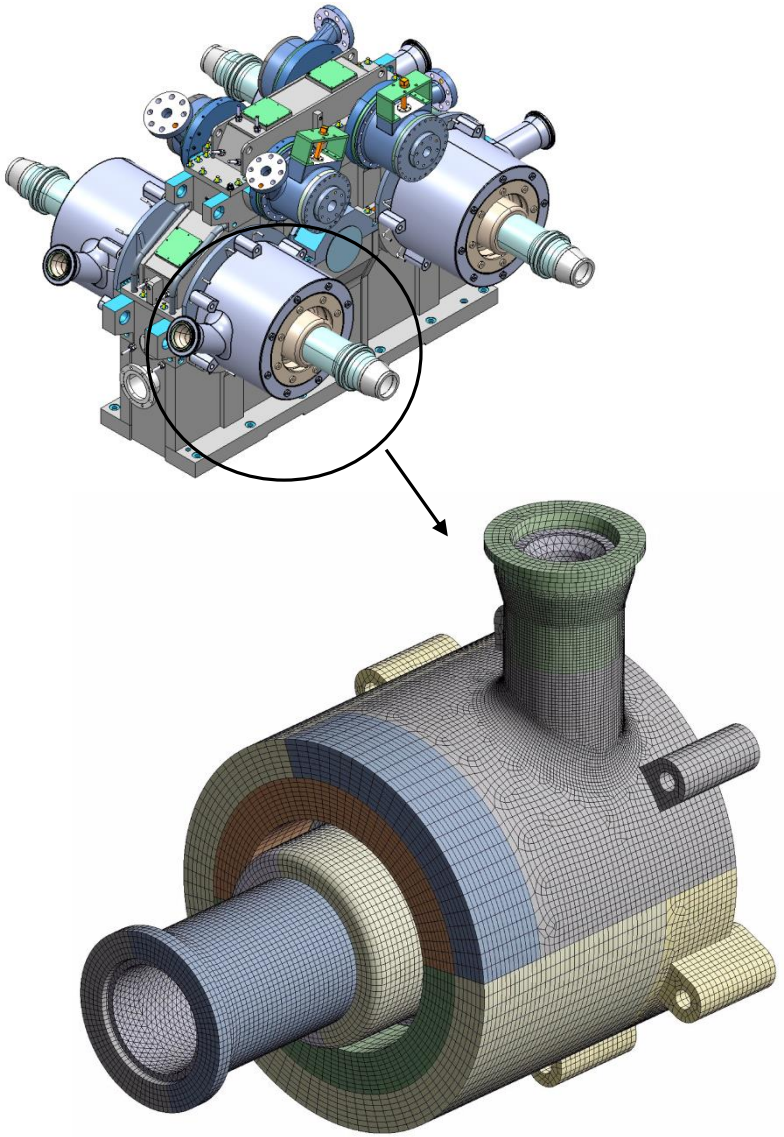
Open Air Back-to-back Tests Showed a Substantial Increase in Range Compared with a Conventional Stage

- Compare results to a fully shrouded referenc e case designed with the same flow coefficie nt and slightly lower head coefficient
- Test in SSTR at same scale and Mach numbe r as the wide-range stage
- Wide-range stage shows a 42% improvemen t in range compared to the reference model, no efficiency loss



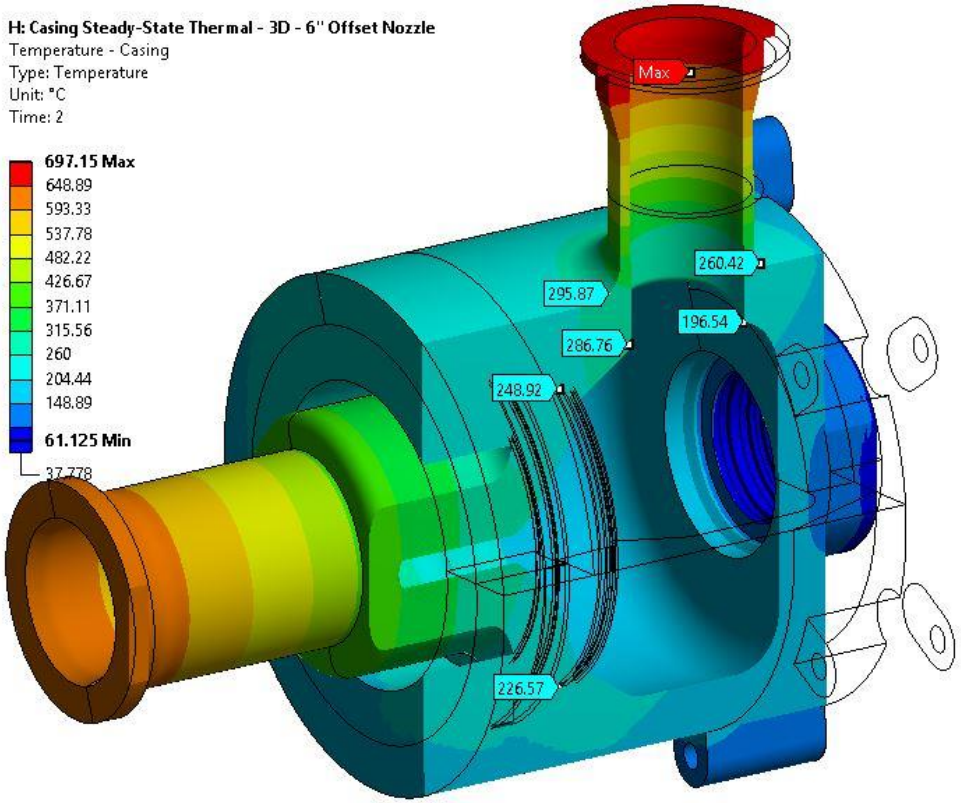


A Patent Pending Internally Shielded Expander Housing Provides a Low-Cost / High-Performance Solution

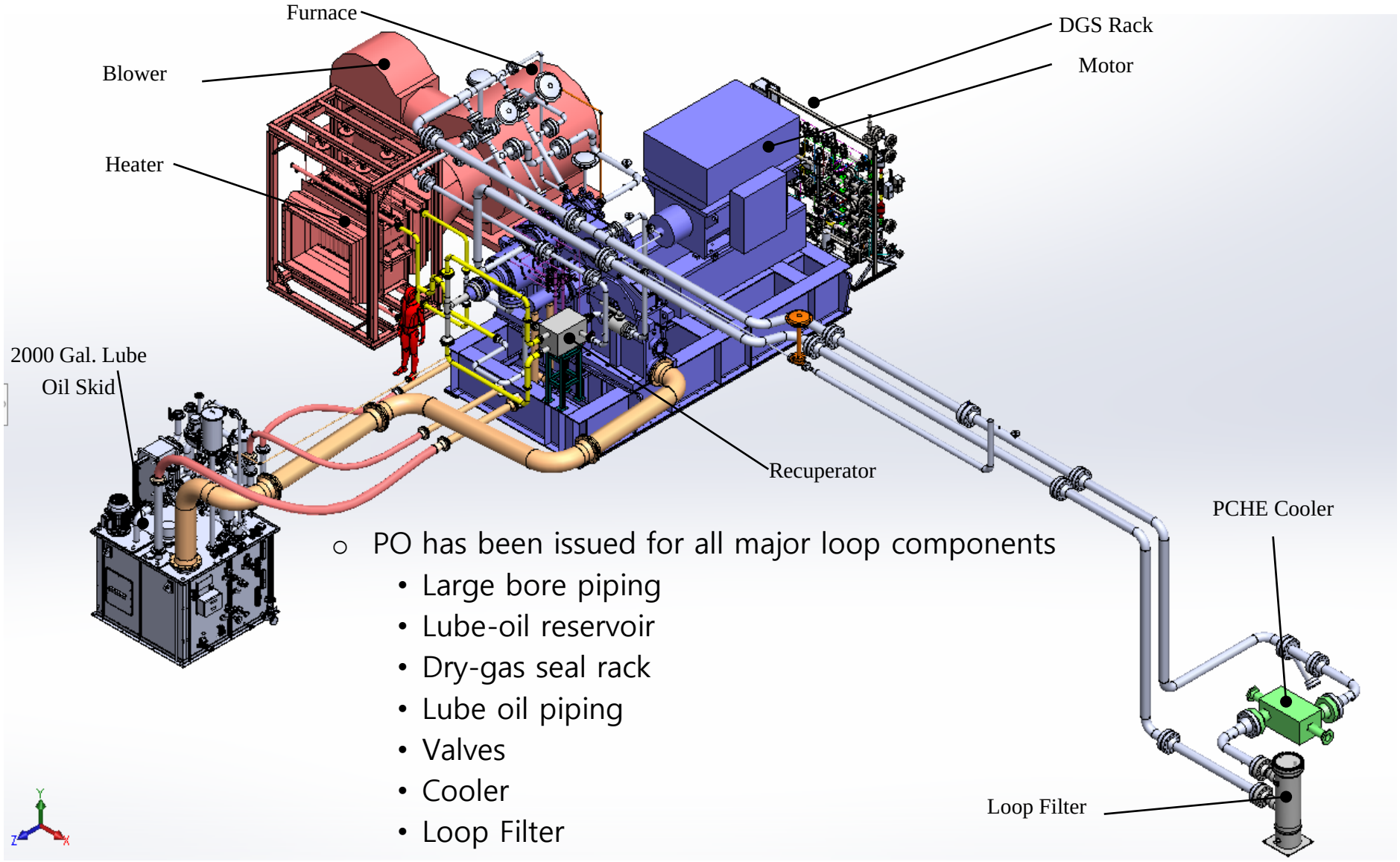


Thermal-Mechanical Stress Levels are Well Managed

- Unique thermal management approach is applied,
- Allows thermal boundary between expander casing,
- Allows thermal boundary between gearbox,
- Meets ASME BPVC for long service life.



Reduced Flow Loop is Finalized and all Purchase Orders have been placed for all loop components

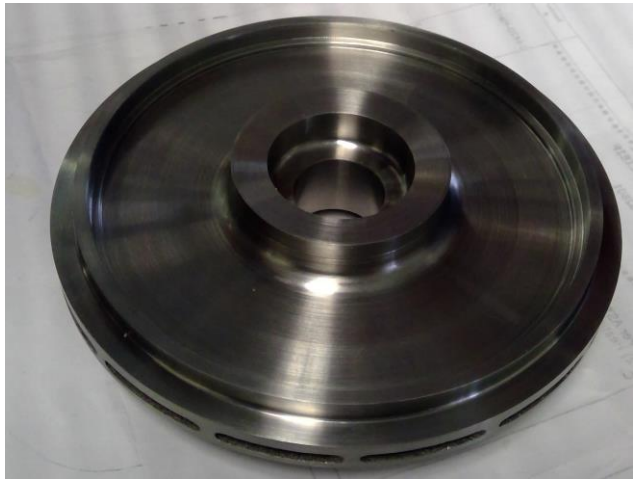


- PO has been issued for all major loop components
  - Large bore piping
  - Lube-oil reservoir
  - Dry-gas seal rack
  - Lube oil piping
  - Valves
  - Cooler
  - Loop Filter

Stage 2 Compressor Impeller

- Completed Processes
  - ✓ Printing
  - ✓ Support material removal
  - ✓ Heat Treat/HIP
  - ✓ Machining
  - ✓ Inspection

- Processes Remaining
  - Cut Hirth coupling
  - CT Scan
  - Extrude Hone
  - Balance/Spin



Procurement Photos

Gearbox Fabrication

Gearbox Machining

Gearbox End Product

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