An Overview of the Rolls-Royce sCO_2-Test Rig Project at Cranfield University

Ian Bunce
Michael Johnston

Eduardo Anselmi
Ian Bunce
Vassilios Pachidis
Pavlos Zachos
Michael Johnston

6th International Supercritical CO_2 Power Cycles Symposium
March 27 - 29, 2018, Pittsburgh, Pennsylvania

Outline

- Introduction
- Test rig development
- Lessons learned
- Questions

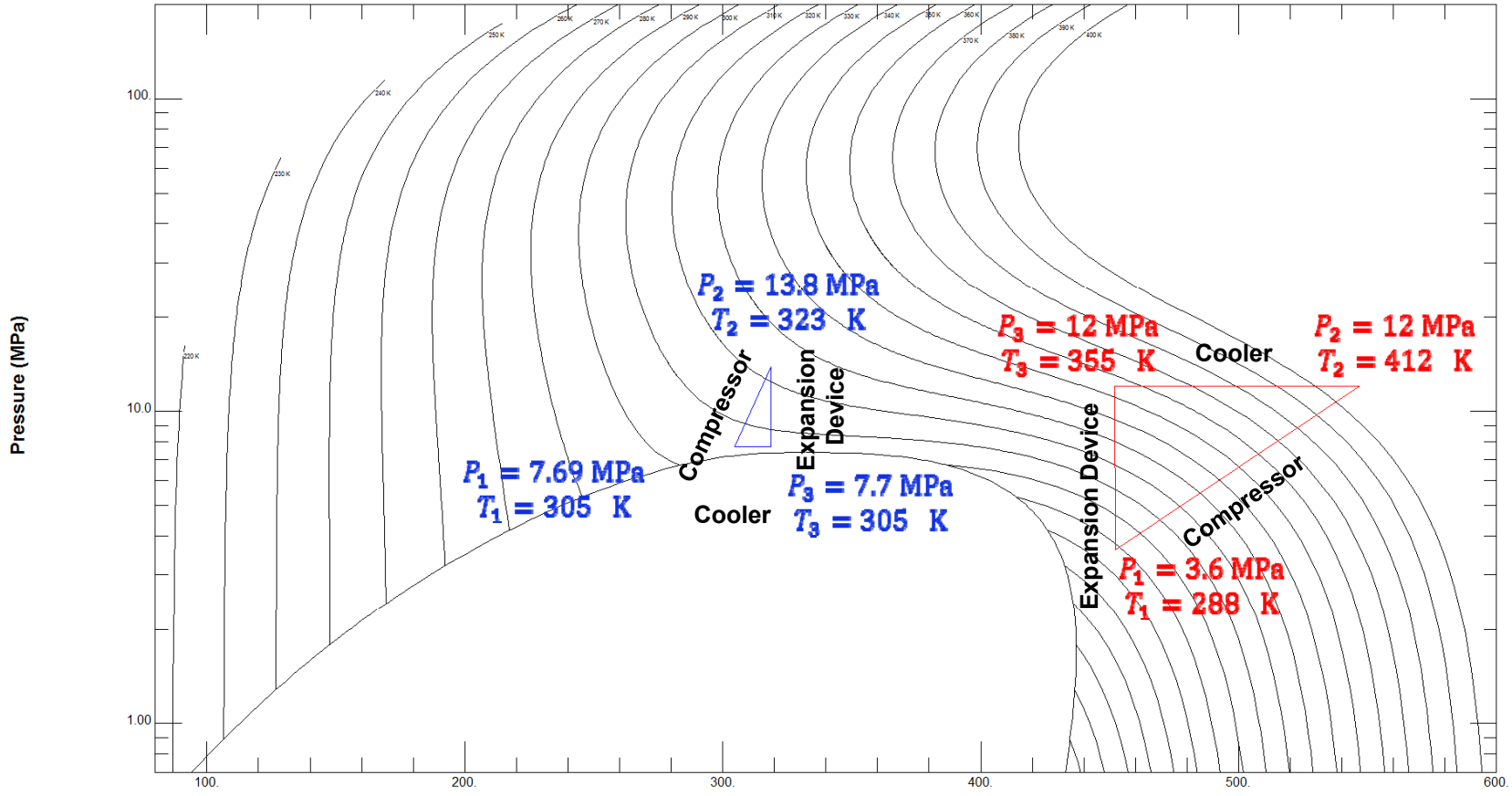
Aim of the project

Design, build and commission a closed loop s-CO_2 system to enable critical component testing and whole cycle demonstration of a representative waste heat recovery system for marine GTs

Initial objectives

- Design s-CO_2 cycles for waste heat recovery (marine applications)
  - Select cycle for proof-of-concept
- Understand their design point, off-design and transient behaviour across a range of operating conditions
- Identify critical components and key requirements for rig testing
- Define full scope of rig testing
- Design & commission a s-CO_2 closed loop test facility

Rig design considerations

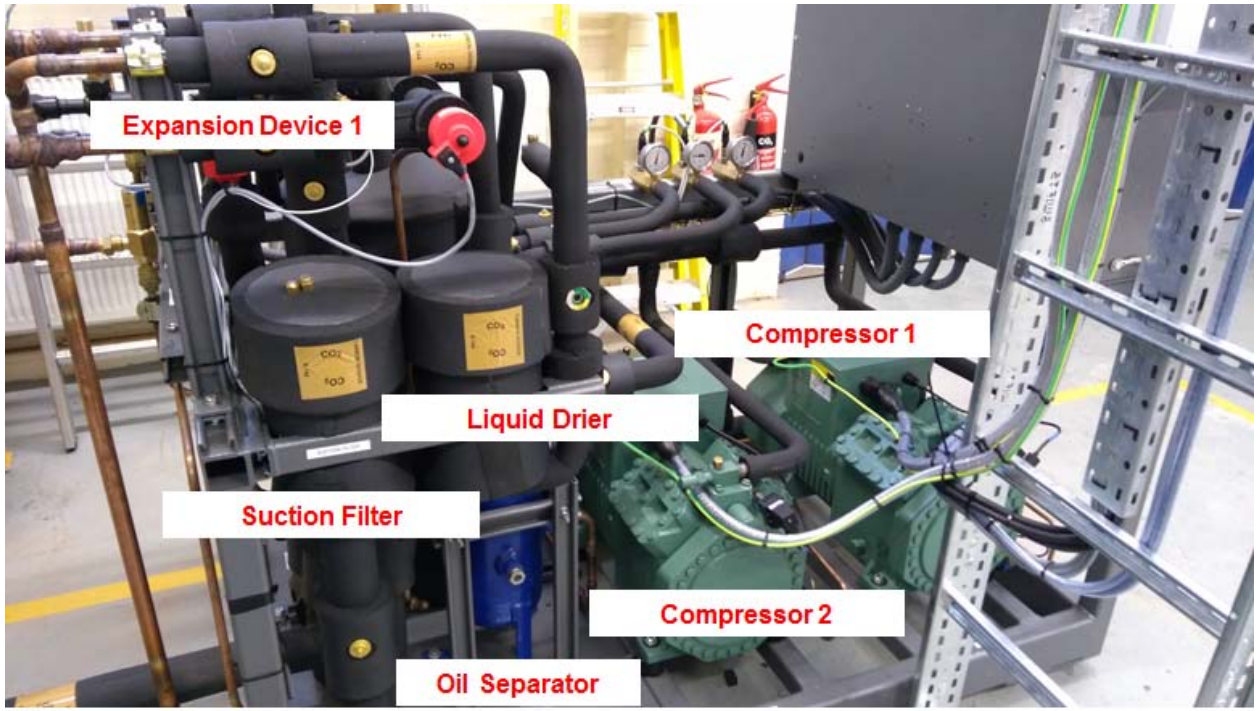


Fluid CO_2: Fluid Properties estimated using NIST REFPROP

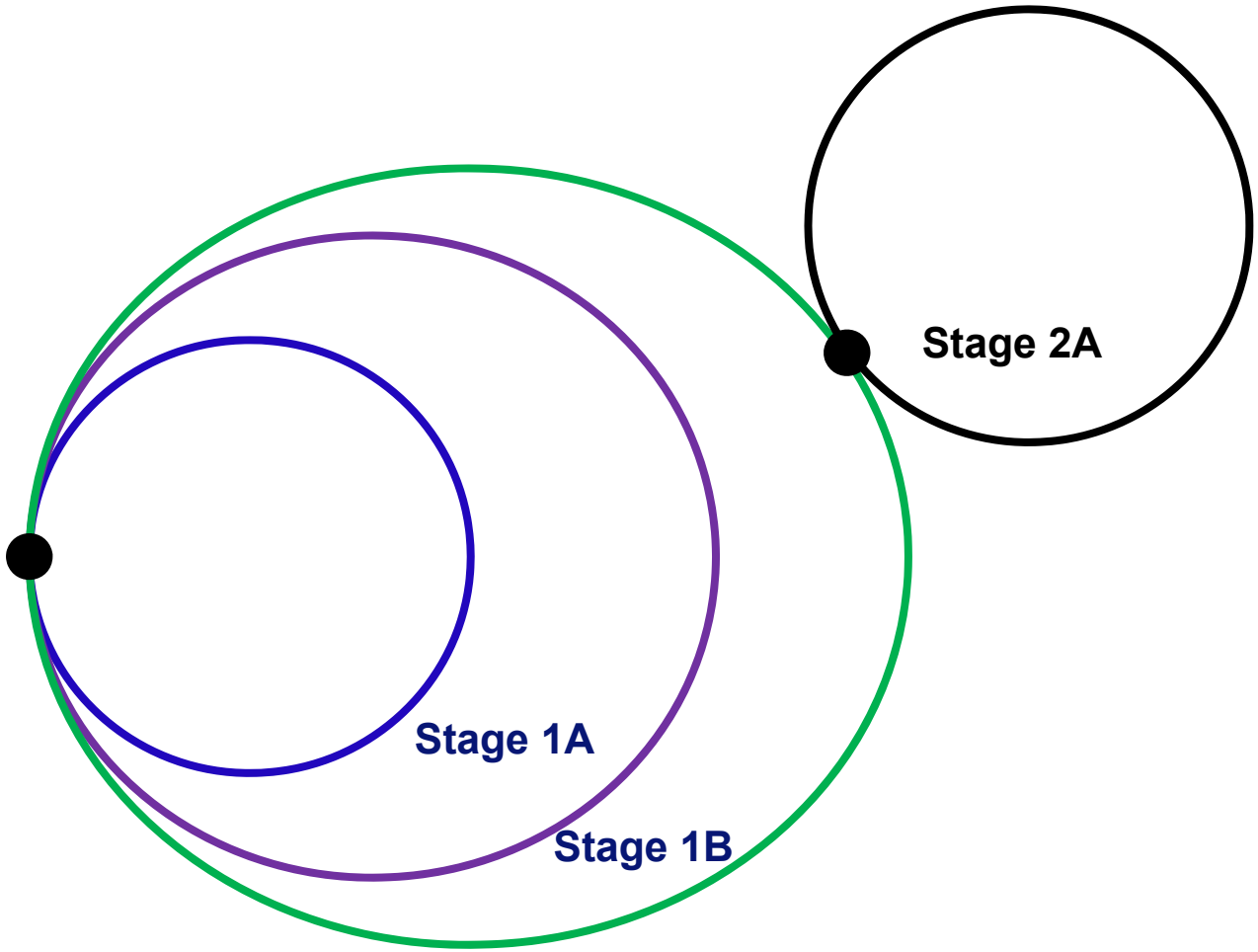
sCO_2 Compression loop test SANDIA

sCO_2 Gas Triangle Innovate UK

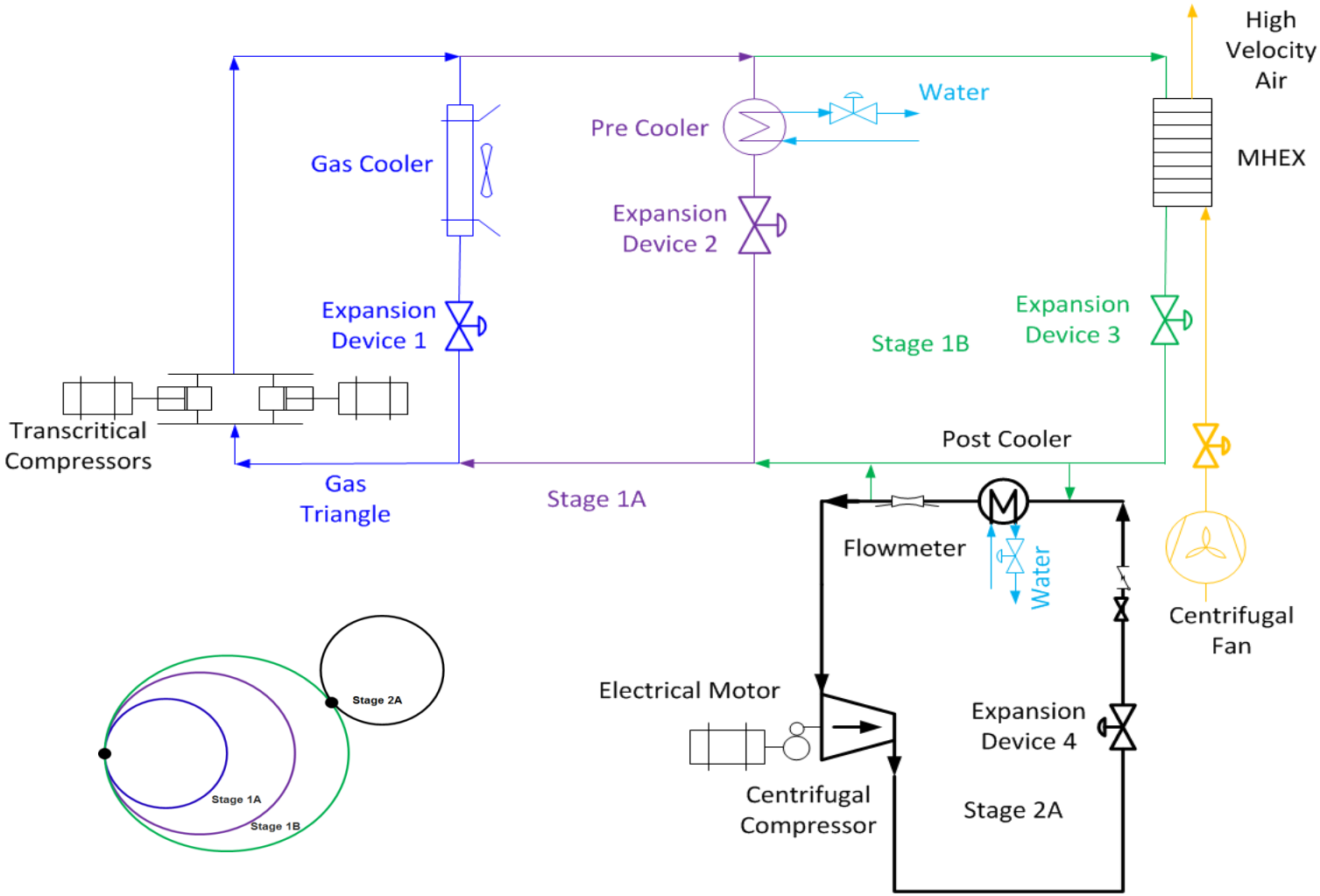
Physical layout initial stage



Test rig development – Parabolic Pencil Concept



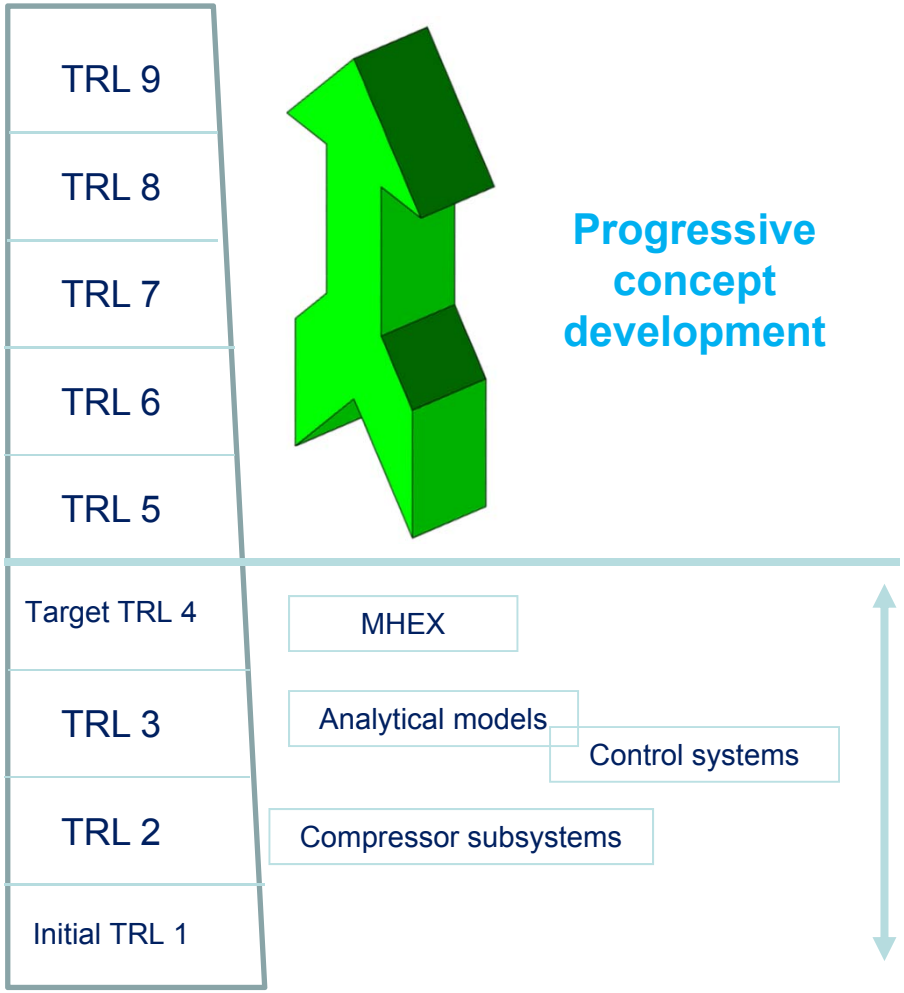
Test rig roadmap



Roadmap and its outcomes

Period	Stage	Components	Outcomes
March	GT	Circulation compressor, gas cooler, expansion valve 1 (refrigeration)	- De-risk s-CO_2 loop. - Demonstrate component/rig robustness and proof of concept.
June	1A	Circulation compressor, pre cooler, expansion valve 2	- Characterize pre cooler performance. - Validation of SIMULINK models.
August	1B	MHEX, fan, circulation compressor, expansion valve 3	- Test MHEX performance: Cold air runs only.
December	2A	Centrifugal compressor, post cooler, expansion valve 4	- De-risk compressor installation. - Develop supporting technology for turbomachinery design

Lessons learned



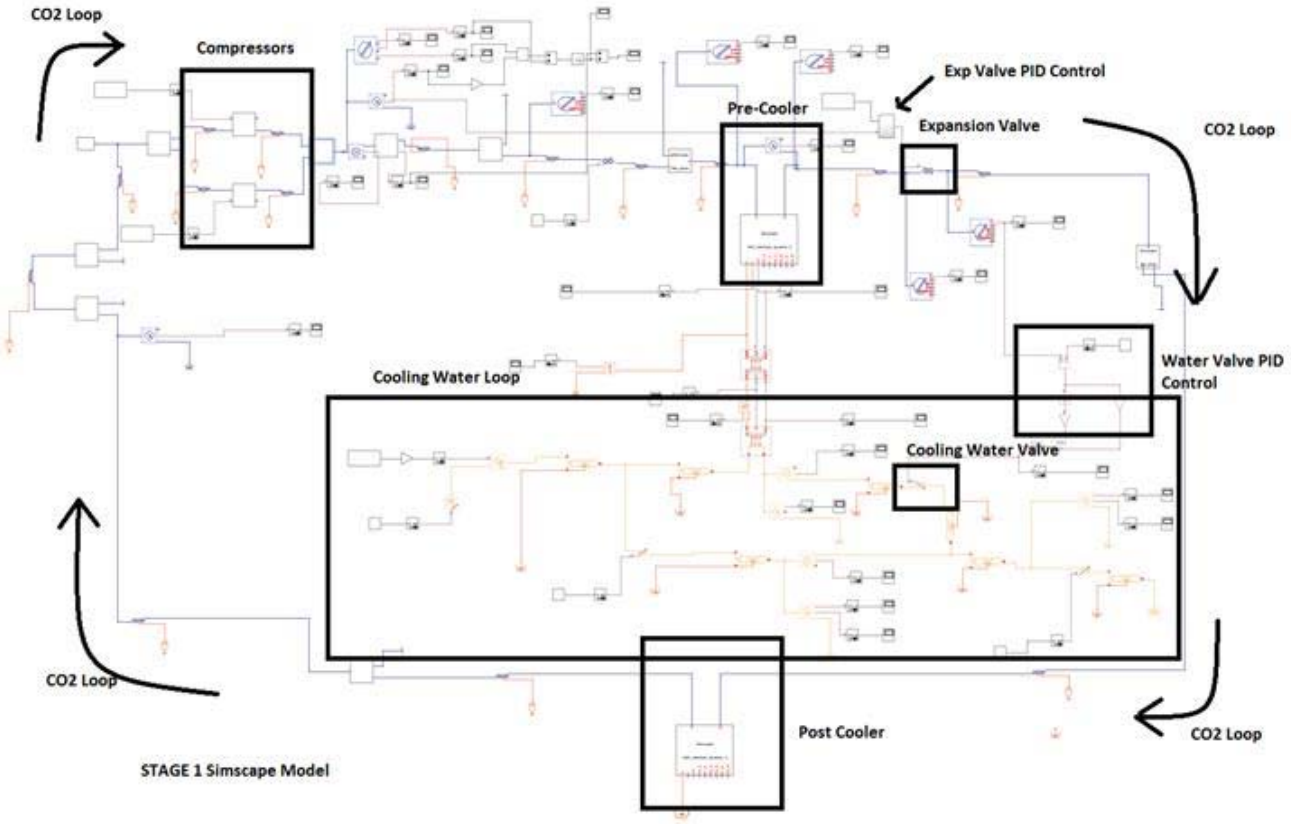
General lessons

- Costing of components
- Identifying an appropriate supply chain
- Managing procurement processes

Specific lessons

- Modelling – Control systems
- Compressor design
- Main heat exchanger design

Modelling



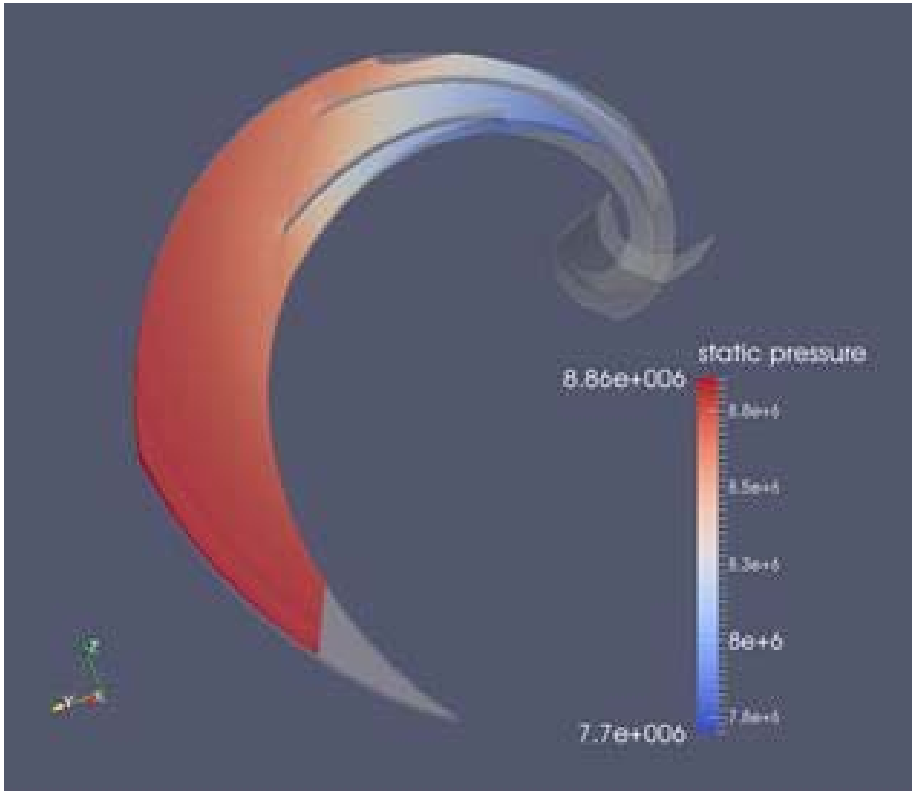
Development of analytical models in SIMULINK to predict test rig:

- Steady state performance
- Part load performance
- Transient response

Compressor development

Initial compressor studies - 2016

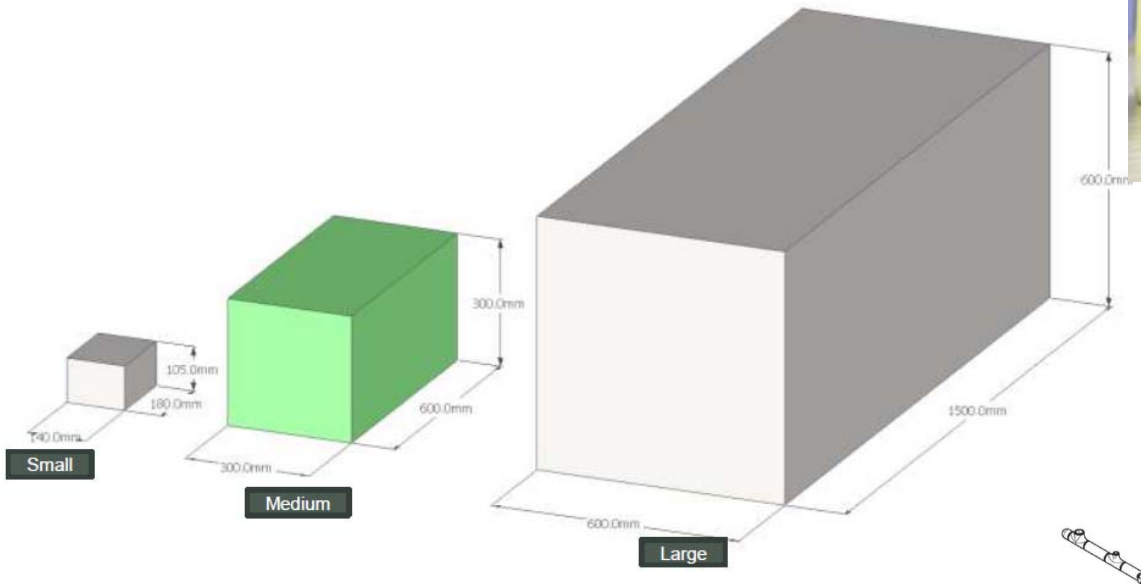
Impeller studies - 2017



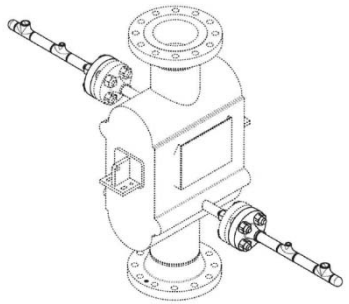
Preliminary simulation results using the “real gas” model at inlet conditions of P = 7.7 MPa, T = 691.2 K - 2018

Main heat exchanger

Successful hybrid design (PCHE + FPHE)



Preliminary designs tested

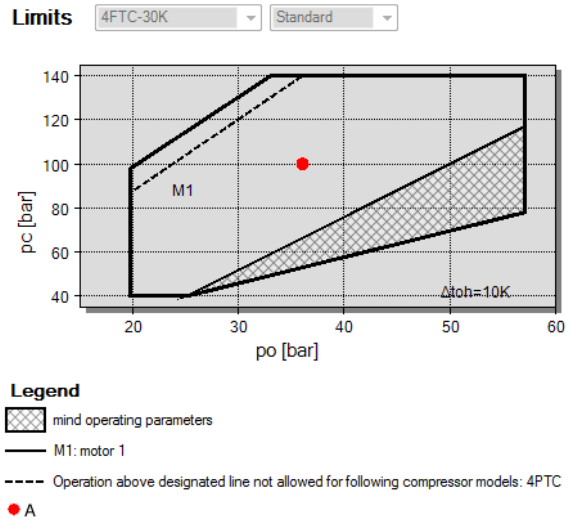


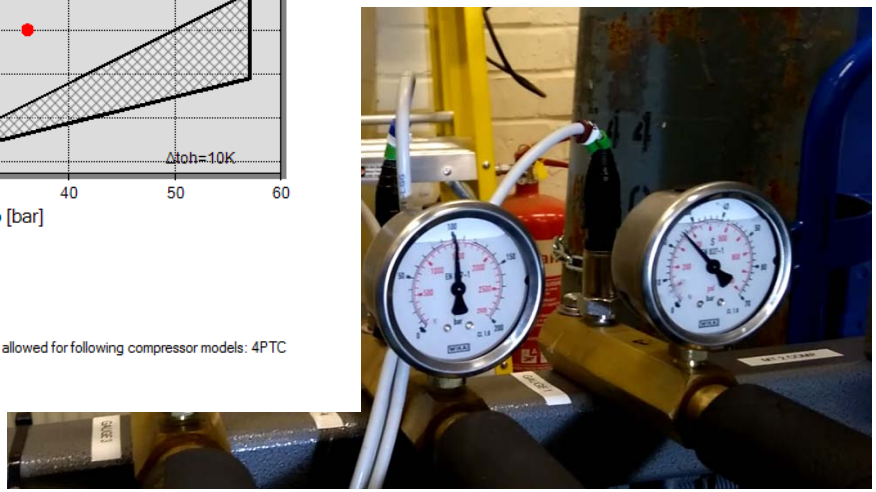
First MHEX released to manufactured - 2018

Acknowledgements

This research has received funding from Innovate UK under project reference 101982. The authors are grateful to Rolls-Royce plc and Heatric Division of Meggitt UK Ltd organisations for their support during the project. The authors would like to thank Robert Collins, Mark Hassan, Anmol Manohar, Joseph Palmer, Pawel Safuryn and Russell Limbrick for their input into this research effort.

…. Thank you





Friday 8th December 2017
Achieved supercritical CO_2 conditions for the first time