Design of re-condensing cryostats for long term use in magnet beamline applications

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Why not Cryofree™ ?

Cryofree ™ - no liquid helium

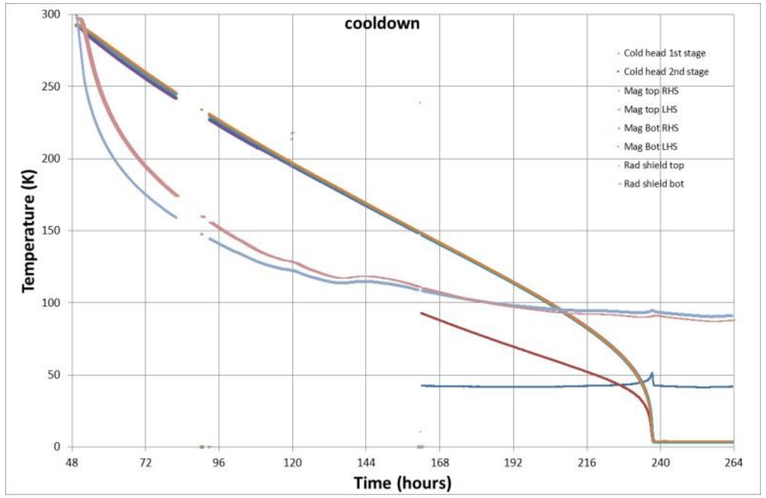
- Eliminates cost of liquid helium
- Liquid storage and handling
- No Helium in the event of quench
- No helium vessel – maximises experimental space, reduces opportunities for leaks and reduces costs

Design constraints

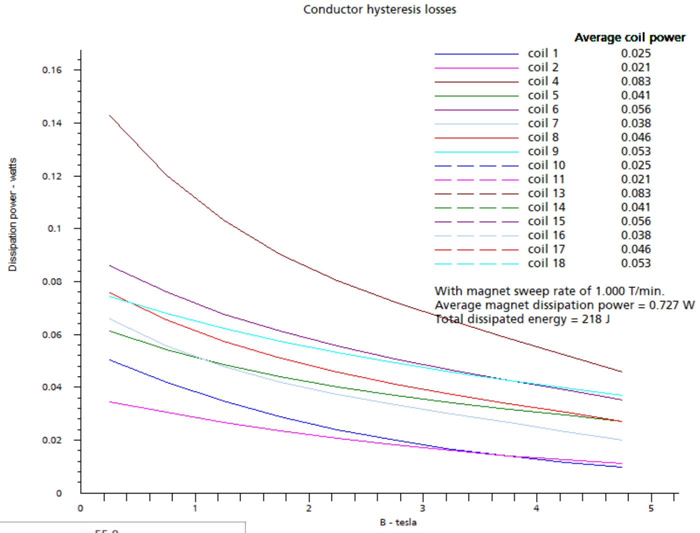
- Coil design temperature
- Wire hysteresis/ramp losses
- Cool down times (without acceleration)
- Outgassing, generally not UHV compatible

Why not Cryofree™ ?

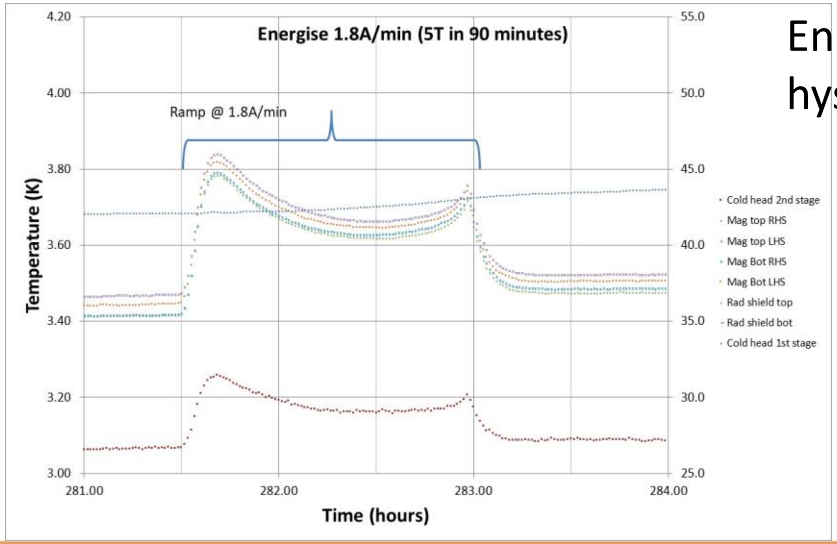
Cryofree ™ - Performance example, ~250Kg cold mass



8 day cool down



Energy dissipation from hysteresis losses



Coil temperatures with magnet ramp

Why recondensing ?

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Recondensing – helium + refrigerator (PTR)

- Nitrogen pre-cool allows faster system set up
- Liquid helium, so stable, essentially isothermal environment
- Positive pressure maintained via PID control
  - protect against air ingress
- Helium provides system "ride through", against power outages etc.
  - maintains experimental environment/preventing system warm up
- Excess condensation capacity
  - allows condensing of helium flows for example through variable temperature inserts, dilution refrigerators etc.
- Allows trade off between cryogen consumption and speed of operation ie faster magnet sweeps and rapid sample cool down (often significant criteria where beam time is expensive and set up times need to be minimised)

("Operation of superconducting magnet with dilution refrigerator insert in zero boil-off regime", Cryogenics 50 (2010) 666-669)

diamond

Diamond Light Source Ltd
Diamond House
Harwell Science & Innovation Campus

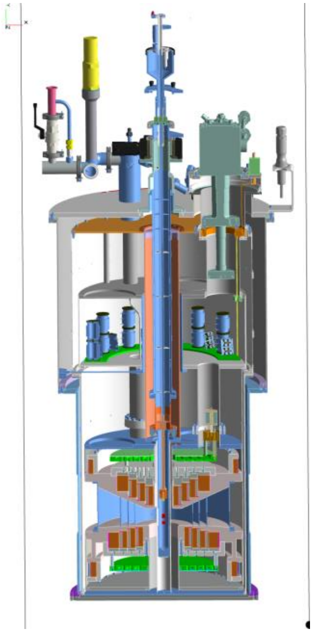
Design features – current leads

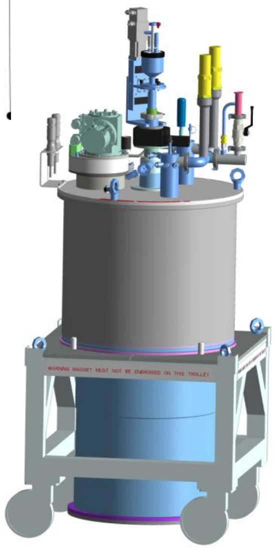
Current leads
Thermally linking the current lead to the PTR 1st stage allows:

- Fixed upper temperature in an HTc applicable range
- Leading to low or zero losses during magnet sweeping

Losses dependent on:

- Sweep rate
- Ullage volume (time to exceed system exhaust valve pressure)
- Insert operation
- Prior operation (recovery from other perturbations such as high sample temperature operation)

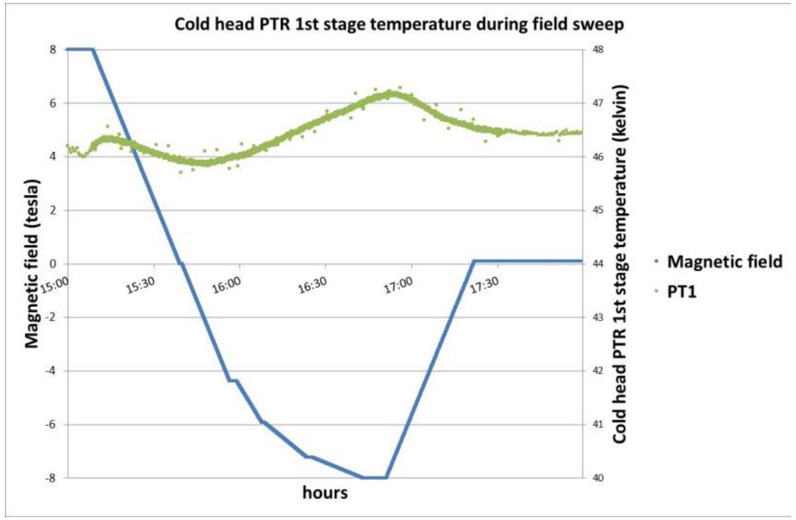




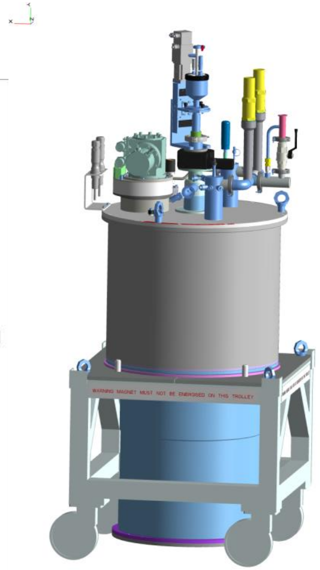
Design features – current leads

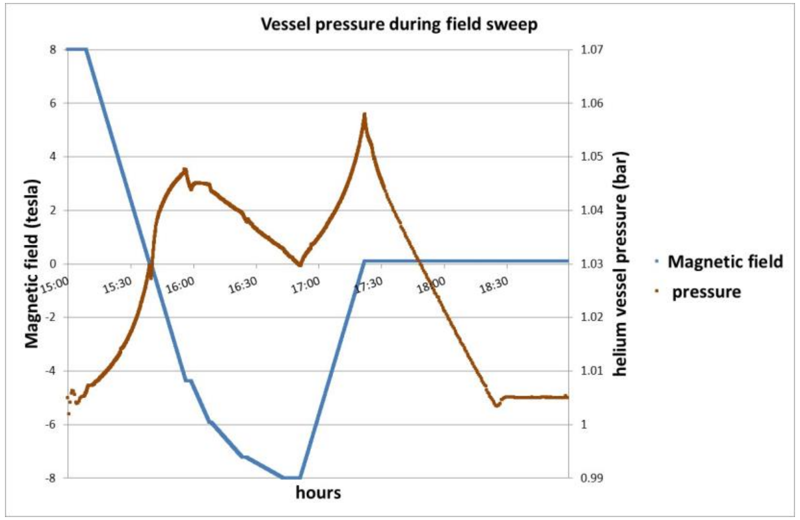
The Business of Science®

HTc Current lead - experimental data

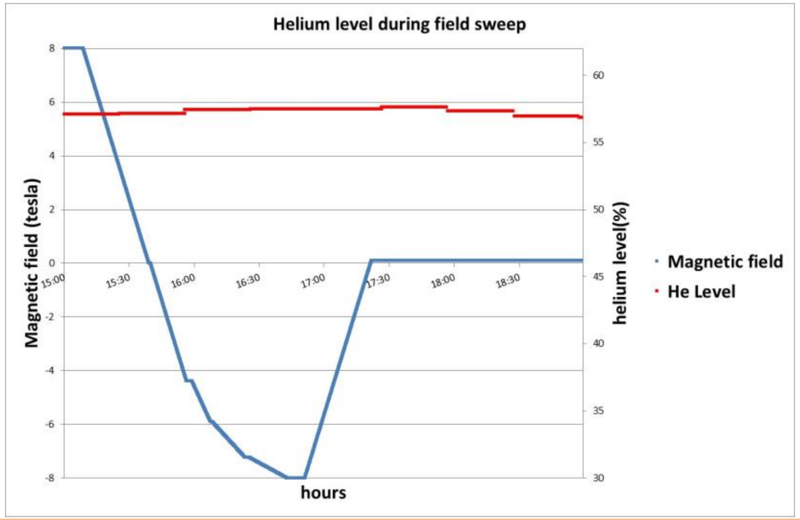


Field, PTR 1st stage T





Field, Vessel pressure

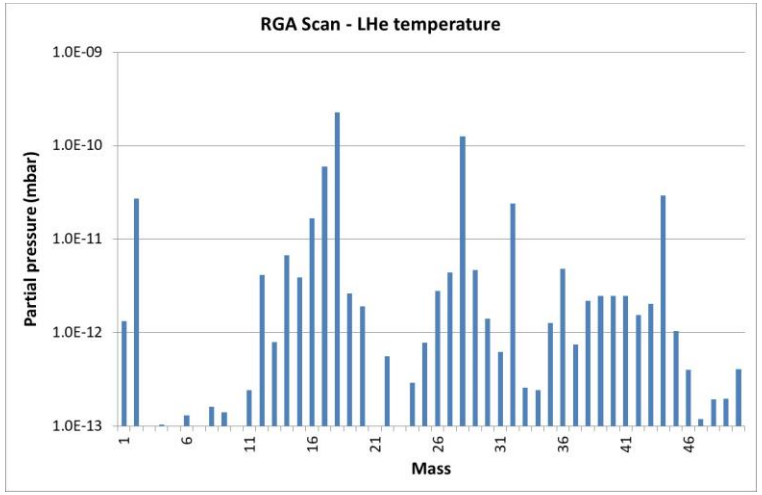


Field, Helium level

Design features – Ultra high vacuum

Some applications require the experimental space to be continuous with a beam line vacuum

- UHV compatible construction materials, cleaning and seals
- No multi layer insulation
  - high radiation heat load driving twin cold head requirement
- Support members from stainless steel
- UHV cleanliness
  - maintained through all stages of manufacture, from receipt of UHV clean components through final assembly
- System bakeout temperatures limited by cold head and magnet components



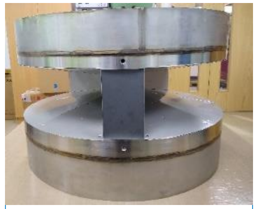
System safety

- It is mandatory that cryogenic vessels have a relief device on their vacuum chamber to prevent over pressurisation. overcome with a fully welded burst disc design.

Design features – radiation shield

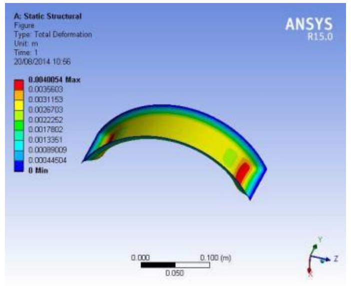
Neutron and X-ray facilities require specific access to the environmental space giving complex constraints on the system design

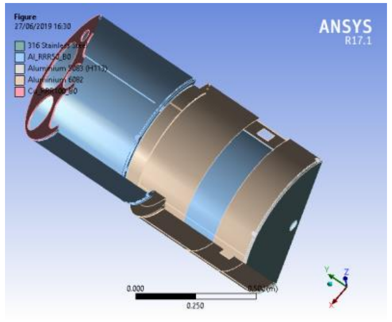
- Magnet aperture profile tends to absorb thermal radiation
- Radiation shield apertures to minimise material that may scatter neutrons etc
- Foil “windows” to cover shield apertures
- Polyimide windows for X rays

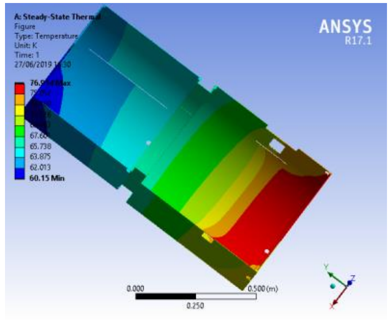


ANSTO

Australian Centre for Neutron Studies

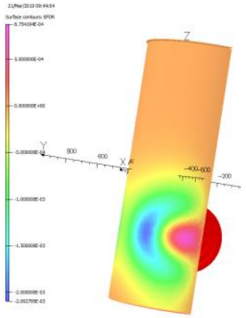


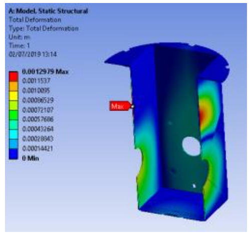




Eddy currents – system resilience against quench

- Slotted shields but mechanically weakened structures
- Increase resistivity (via aluminium grade) but decreased thermal conductivity and increased thermal gradients

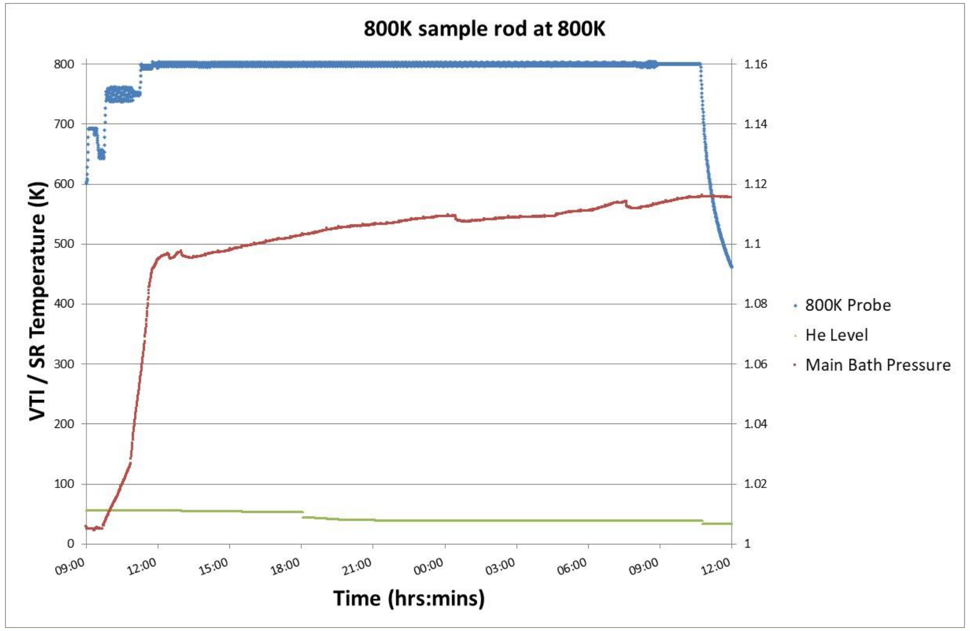


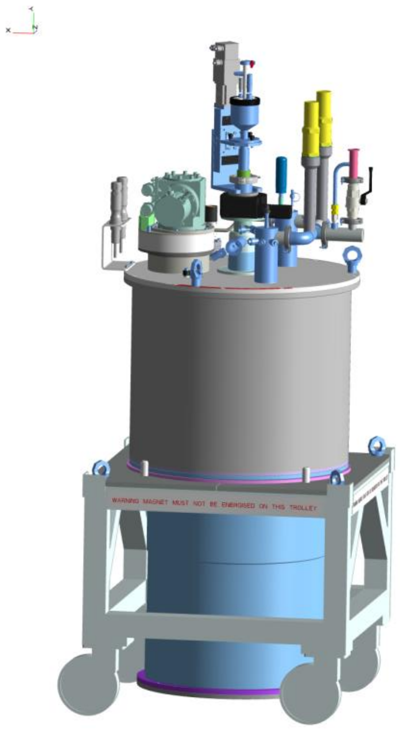


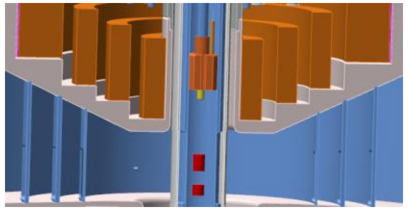
Design features – high temperature sample environments

High temperature experiments

- 800K sample environment available
- Sample in vacuum
- Takes system out of fully recondensing regime as:
  - VTI flow required to maintain indium joints below 400K this exceeds recondensing capability
  - Heat load from VTI temperature causes inner radiation shield temperature increase and consequent 4K heat load







Design features – recondensing with minimimum vibration

Customer requirement for persistent 8T horizontal bore system with **zero cold head** vibration:

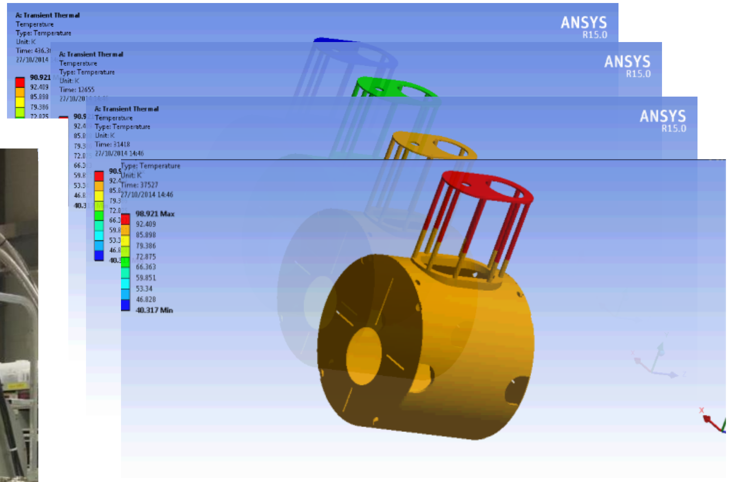
- 10 hour experimental time
- Zero helium loss
- Maximum 14 hour “recovery” time

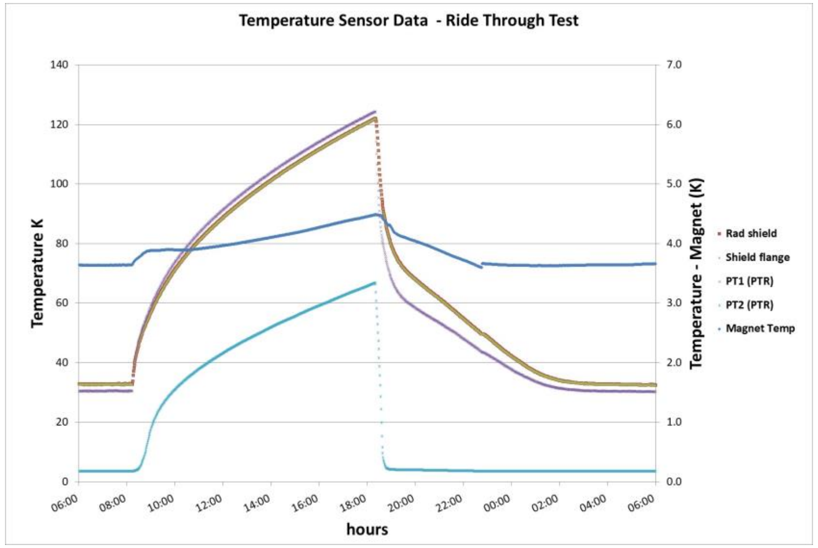
Achieved by

- Sub atmospheric, 500mbarA to 1300 mbarA
- Helium volume, sufficient enthalpy for ride through
- Radiation shield mass, sized to limit warm up and 4K radiation load

Safety

- Helium buffer volume around service ports to prevent air ingress when sub-atmospheric





Summary– Re condensing beamline systems

Enabling cost effective, low (and high!) temperature, high access, high magnetic field beam line environments