Cold head maintenance with minimal service interruption

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Outline

- Motivation
- Cold head maintenance
- Finite element modeling
- Proof of principal experiment
- Summary

Motivation

- Increasing prevalence of superconducting devices
  - Especially for medical applications
    - Hadron radiotherapy
    - PET isotope production
    - MRI
  - Non-specialist end users
  - Turn-key solutions
- Increasing scarcity of helium
  - Probable decrease in recondensing helium systems
  - Reliance on dry, conduction-cooled systems
- Continuing improvements in cryorefrigerator technologies

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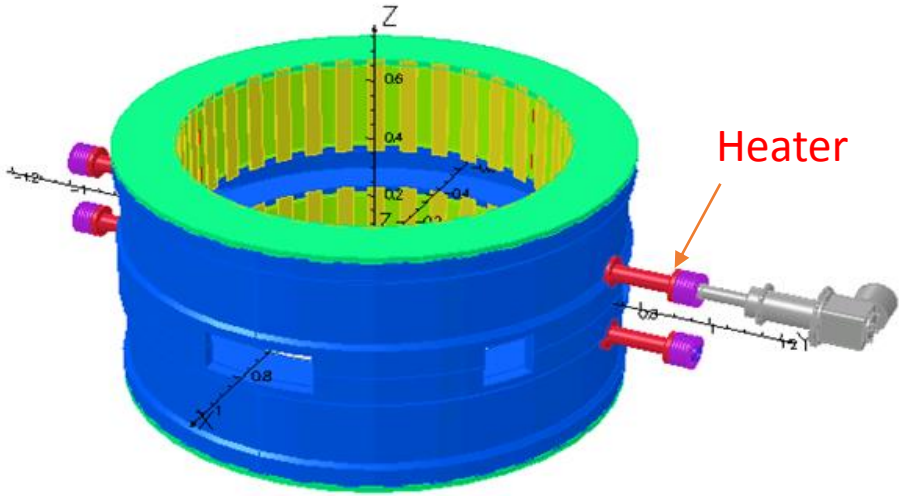
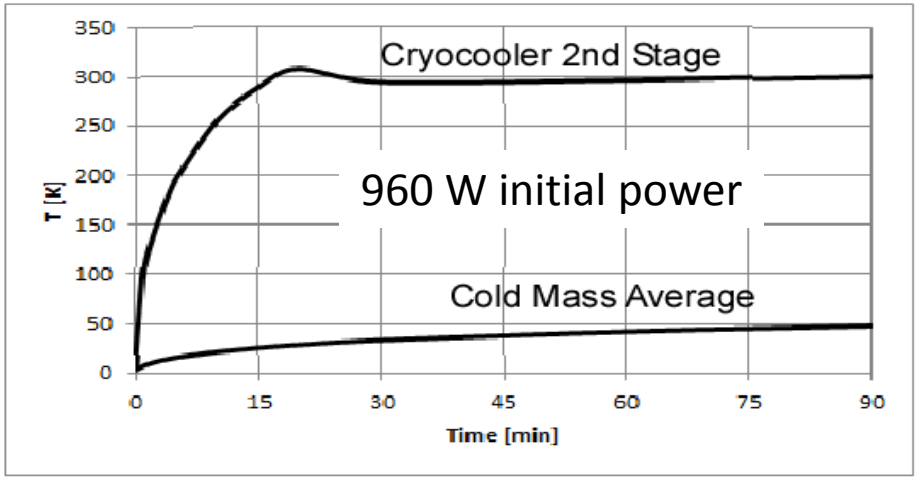
Cold head maintenance

- Widespread use of GM coolers
  - Conduction cooling of multi-ton cold mass
  - Annual displacer replacement recommended
  - Near room temperature maintenance required
- Near continuous applications (e.g. patient treatment)
  - Year-round availability required
  - 4-day shut-down target (warm-up, maintenance, cool-down)
- Servicing options, with cryogenic cold mass
  - Complete removal and replacement (cold coupling needed)
  - Servicing inside of vacuum glove box (limited solvent use)
  - Cold head warming only

Finite element modeling

- Vector Fields model of full-size coil and cryocooler
- Temperature dependent properties
- Thermal response evaluation
- Thermal stress evaluation



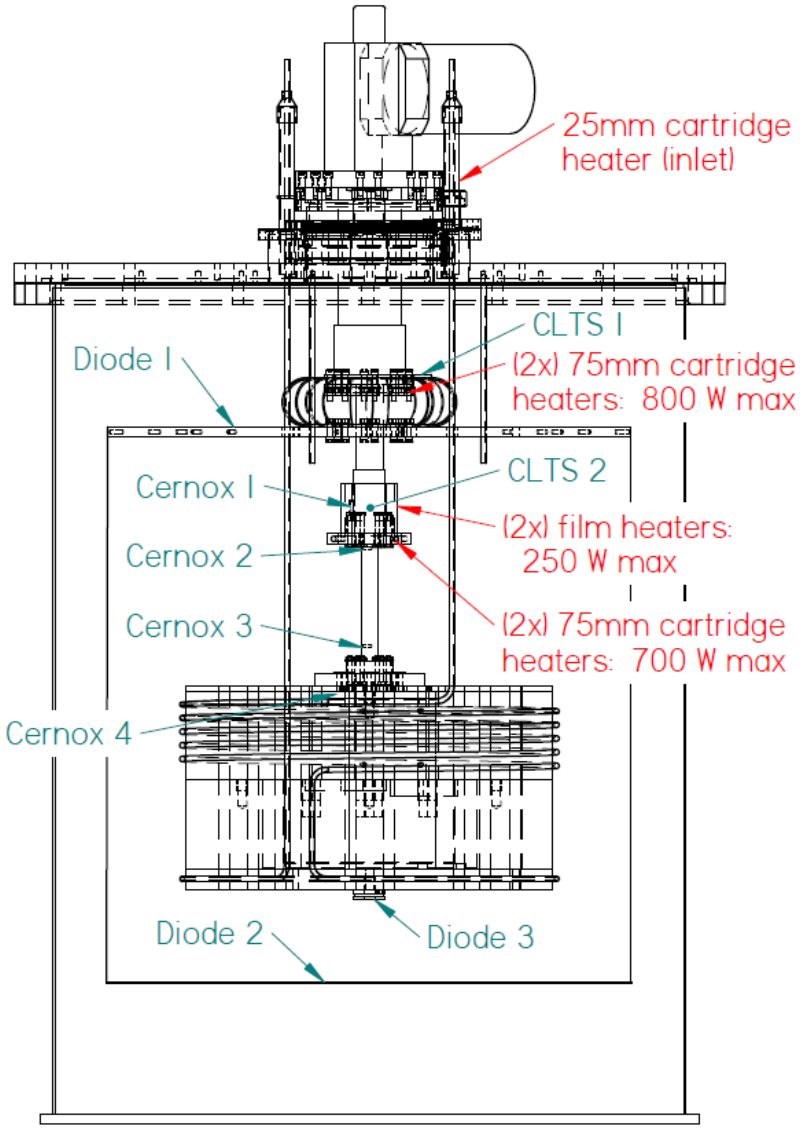


Proof of principal investigation

- Fabrication of small-scale model
  - 275 kg iron cold mass
  - Leybold Cool-Power 4.2GM cryocooler
  - High-power density cartridge and film heaters
- Optimization of cold finger
  - Scaling to match cold mass
  - Trade-offs between cool-down, standard operation, and maintenance requirements

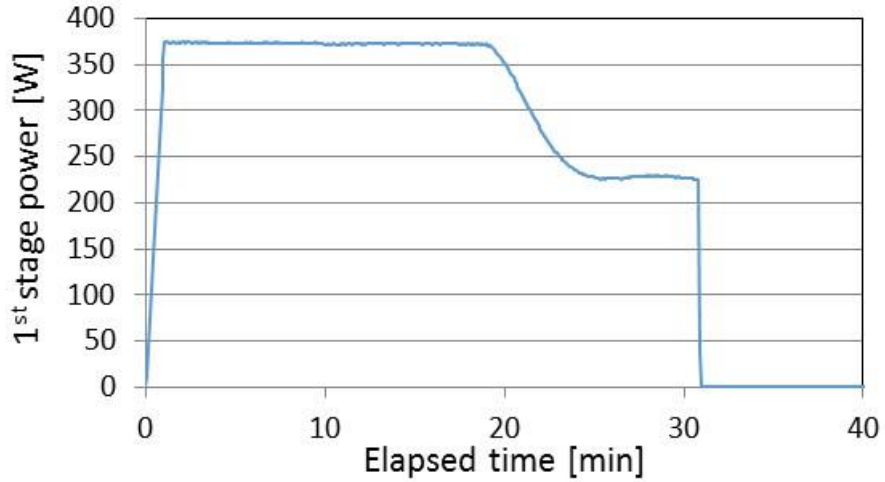
Instrument map

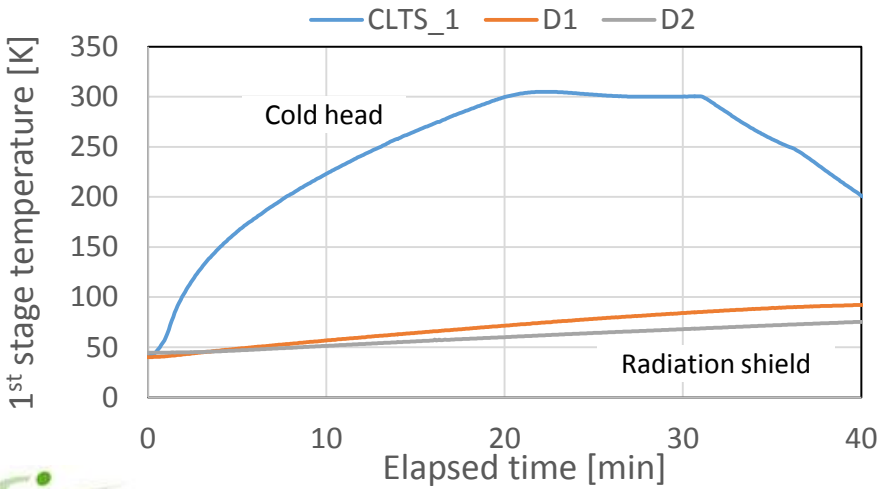
- CLTS sensor at each stage for monitoring and feedback control
- Silicon diode sensors: adiation shield and base of cold mass
- Cernox sensors: 2nd stage, top and bottom of cold finger, and top of cold mass
- 800 W max. cartridge heaters at 1st stage
- 700 W max. cartridge heaters at 2nd stage
- 250 W max. film heaters at 2nd stage



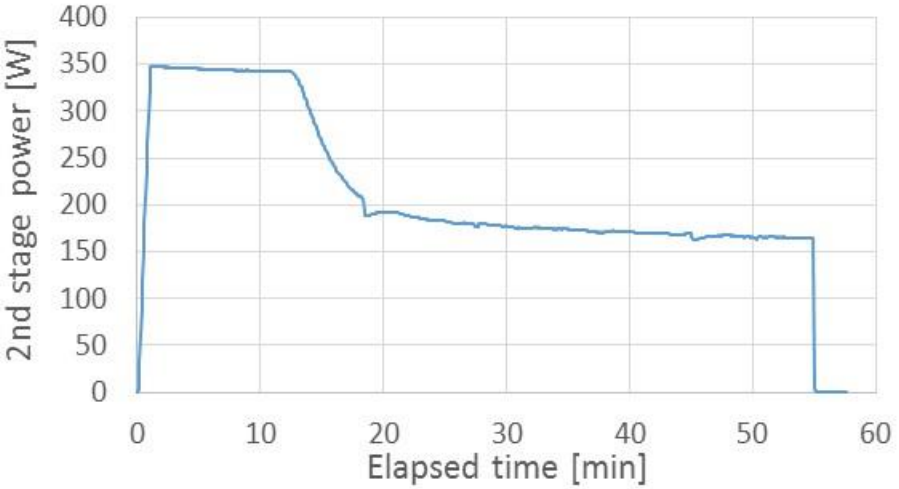
Heating profiles and temperature rise

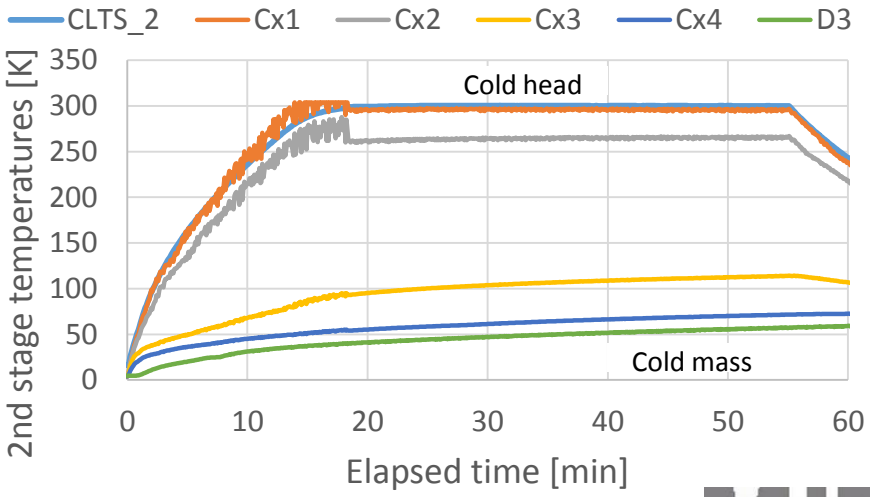
1st stage





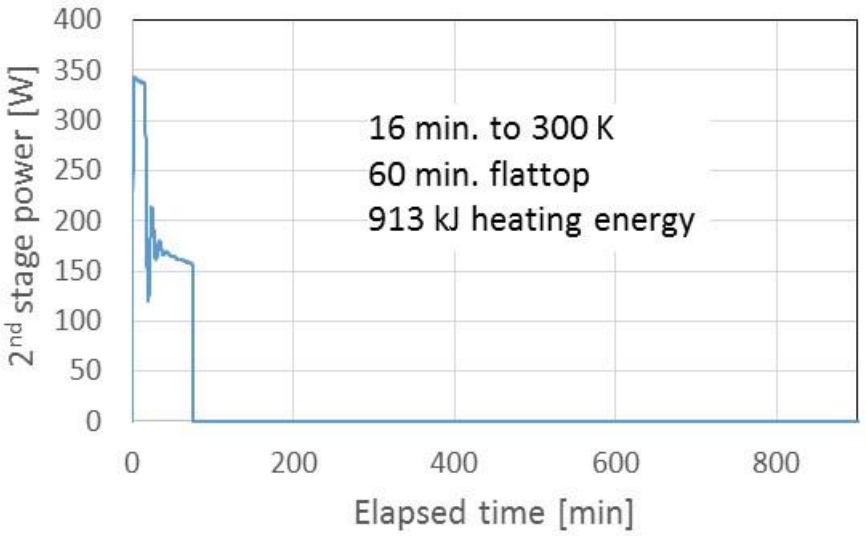
2nd stage

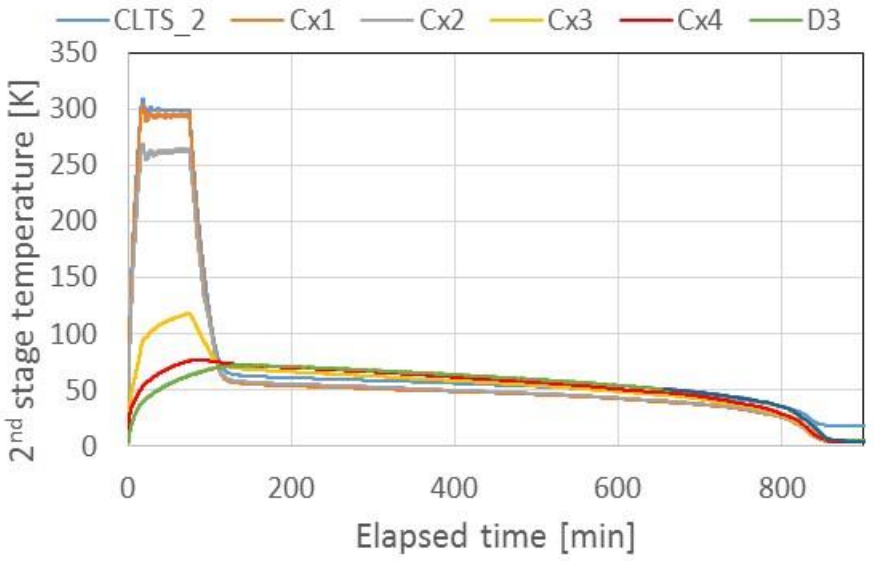




Recool duration

- Thermal cycle dominated by 2nd stage response
- Substantial temperature gradient along 2nd stage cold finger
- Minimal heating of cold mass during 1 hr hold (< 80 K peak)
- Rapid recooling of 2nd stage towards cold mass temperature
- Complete thermal cycle within 1 day





Summary

- Rapid warm-up/recool concept demonstrated
  - 300 K temperature at cold head shell within 15~20 min
  - Moderate radiation shield and cold mass temperature rise with cold head shell held at 300 K for 1 hr
  - Return of shield and cold mass to cryogenic base temperatures within 1 day after resumption of cooling
- Scale-up to full-size coil system presently under development by industrial partner
  - 1~2 kW 2nd stage heating power
  - More robust components
  - Slightly longer than 1 day anticipated recool