SIEMENS Healthineers

SHI Cryogenics Group

Hub- and Site-cooling of MRI Magnets using Mobile Cryogenic System

S. K. Gandla and A. Mortensen

Talk Outline

1. Introduction to MRI cooldowns.
2. Site- and hub-cooling concepts.
3. MRI magnet pre-cooler for site- and hub-cooling.
4. Results from using the MRI magnet pre-cooler.

MRI helium consumption

- MRI amounts to **~ 20% of global helium consumption**. Logistics and pre-cooling helium losses are a **significant contribution** to this consumption.
- **4K cold mass** of a large bore superconducting MRI **~ few tons**.
- Global sales of superconducting MRI magnets: **few thousands/year**.

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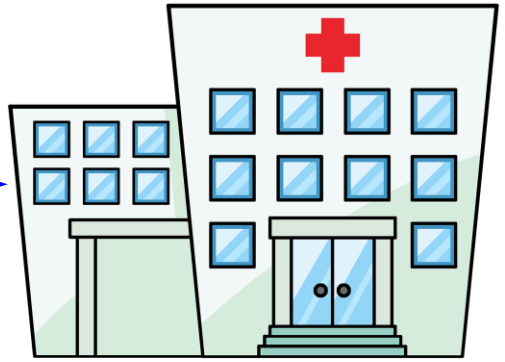
Current Technology Cold-shipping MRI Magnets

- Existing cooling technologies for precooling MRI magnets at the factory
  - **Liquid nitrogen.**
  - **Closed Loop Mechanical Cooler.**
- MRI magnet is **filled with liquid helium (4K) at factory**. Boil-off loss reduced with **helium recovery system**

Cold-shipping to Customer

- The liquid helium acts as a **cold storage buffer** to keep magnet cold until it arrives at customer.

Helium boil-off while in transit



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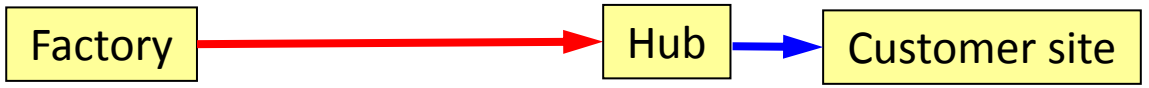
Alternative logistics options for superconducting MRI magnets

Cold-ship to customer

Warm-ship to local hub (Hub-cooling)



Warm-ship to customer (Site-cooling)

Magnet cold-ship characteristics

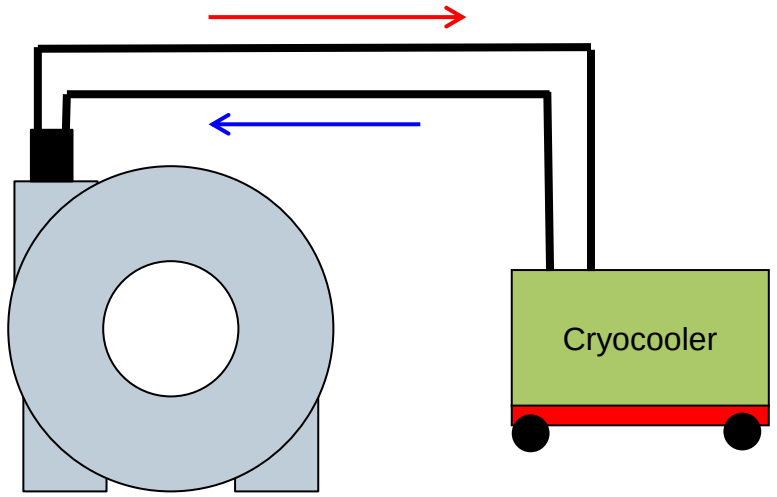
- Magnet cryostat boils off helium during transit to customer site.
- Transit duration has to be kept to a minimum (sometimes airfreighted)

Warm-ship advantages

- Zero transit helium boil-off (site-cooling) or significantly reduced transit helium boil-off (hub-cooling).
- No time constraint on the transit time.
- Increased flexibility in mode of transport.

Site-/Hub-cooling Concept

Closed loop helium gas circuit between MRI magnet helium vessel and a cryocooler used for MRI magnet pre-cooling

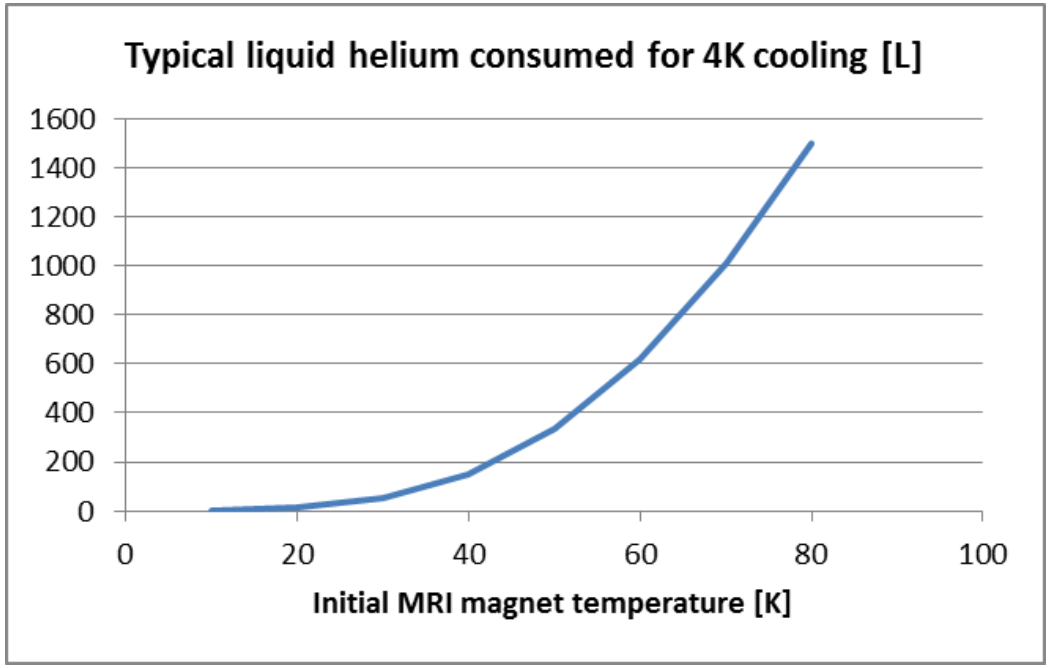


Cryocooler main requirements.

→ Duration of pre-cooling ~ 1 week, i.e., ~1 kW cooling power needed.

→ Operate with electrical power, water cooling, and helium process gas only.

→ Save liquid helium by pre-cooling magnet to < 30 K.



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Realisation of Cryocooler

Cryocooler main components

Helium gas cooling

- 4 single stage coldheads (Sumitomo CH-110LT).
- Custom copper heat-exchangers.
- 4 helium compressors (Sumitomo F-70).

Forced helium gas flow

- Cryogenic gas centrifugal fan.

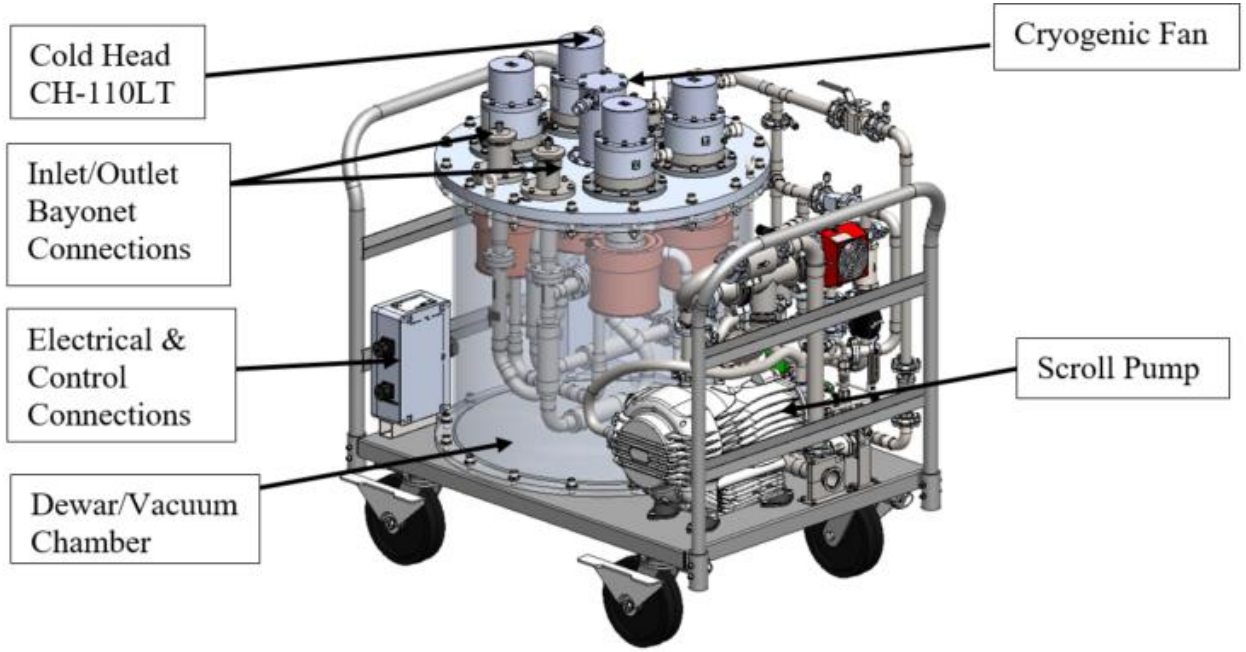
Cleaning of helium circuit

- Scroll pump.

Performance

- Cooling capacity: 1.4 kW (@293 K)

(More information see: S. Gandla, R. Longsworth, 'Mobile Refrigeration System for Precool and Warmup of Superconducting Magnet', CEC/ICMC 2017)



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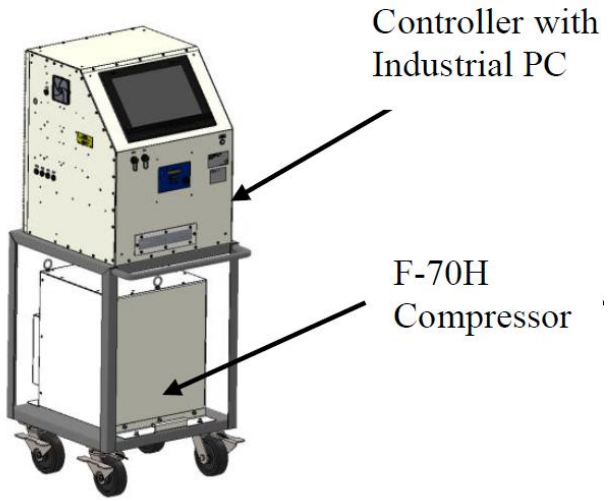
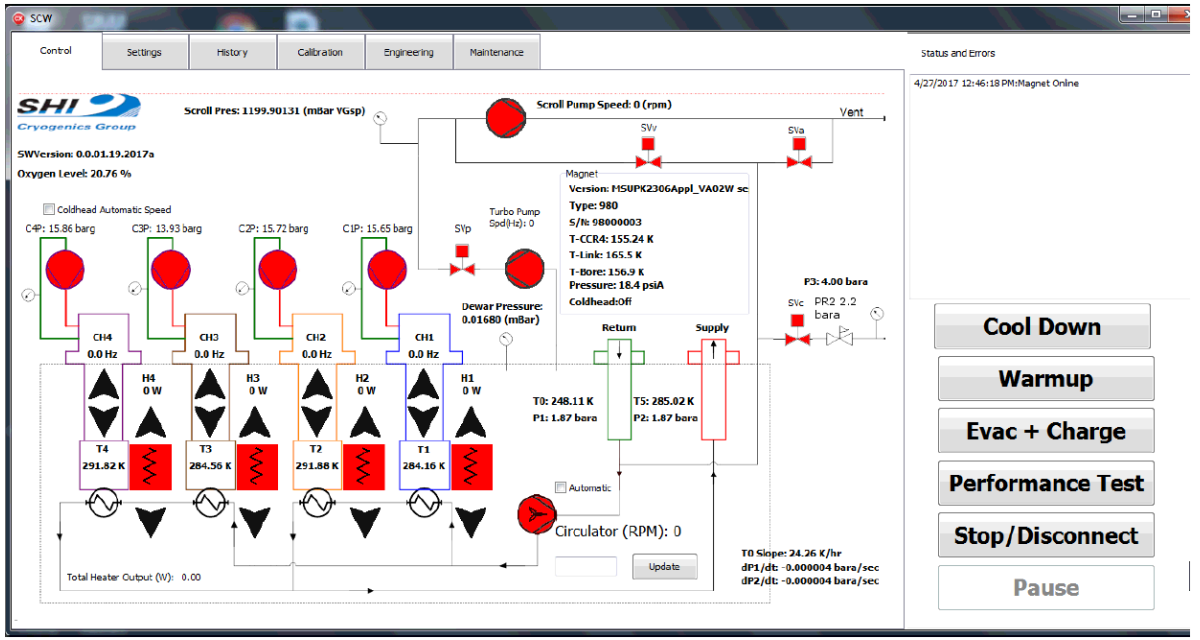
Realisation of Cryocooler: Software Control

Software control main Features

- Automated protocols
- Manual controls for individual components of the cryocooler (touch screen)
- Remote monitoring of the cryocooler.
- Automatic pressure regulation



Screen shot of control screen



Manual controls for individual components of the cryocooler (touch screen)

Automated protocols for push-button control.

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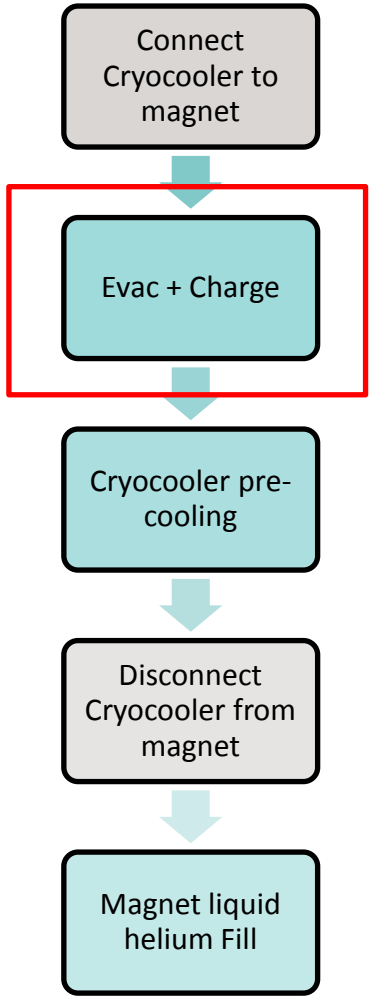
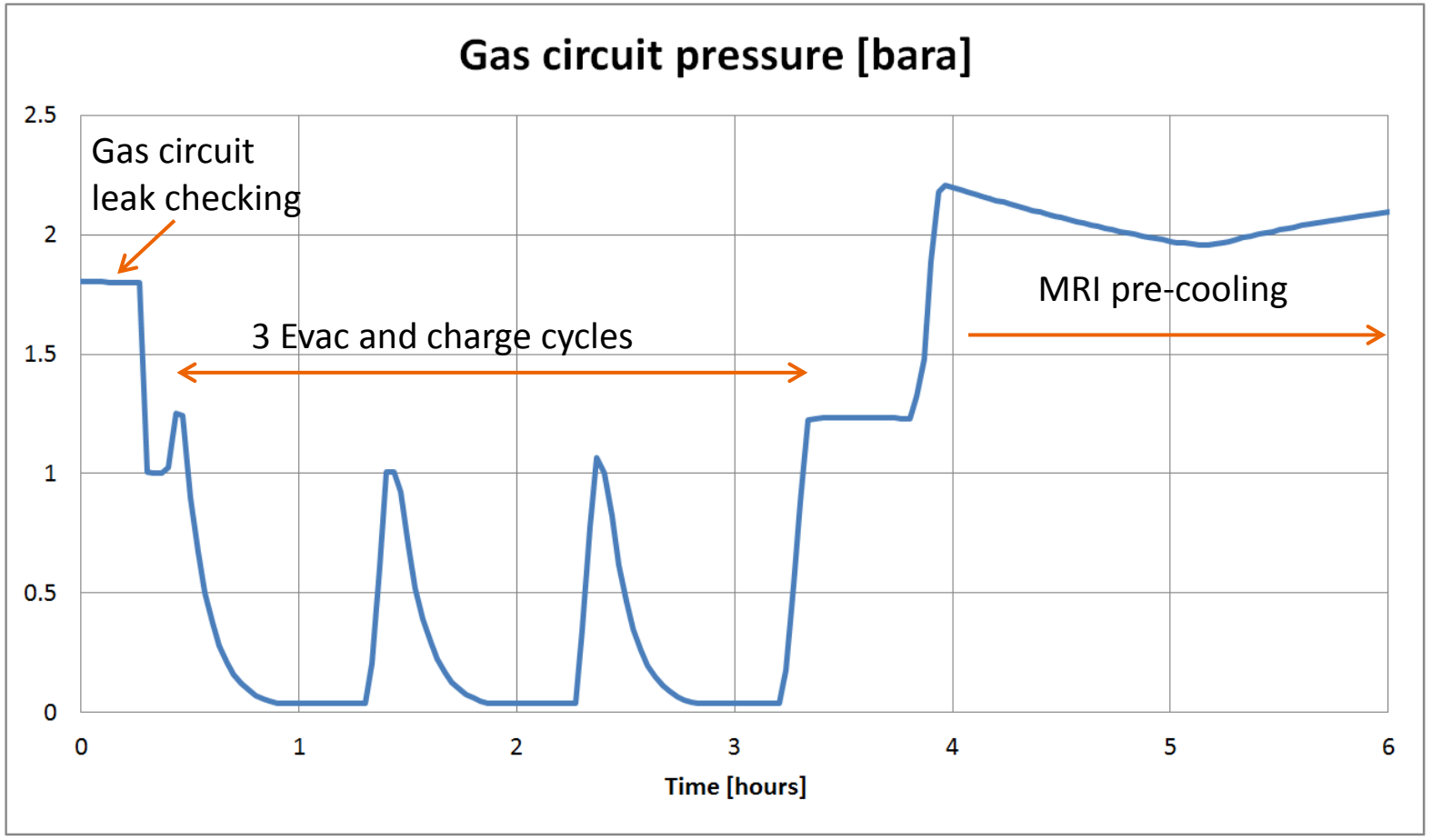
Site/Hub-cooling Steps: Evac + Charge





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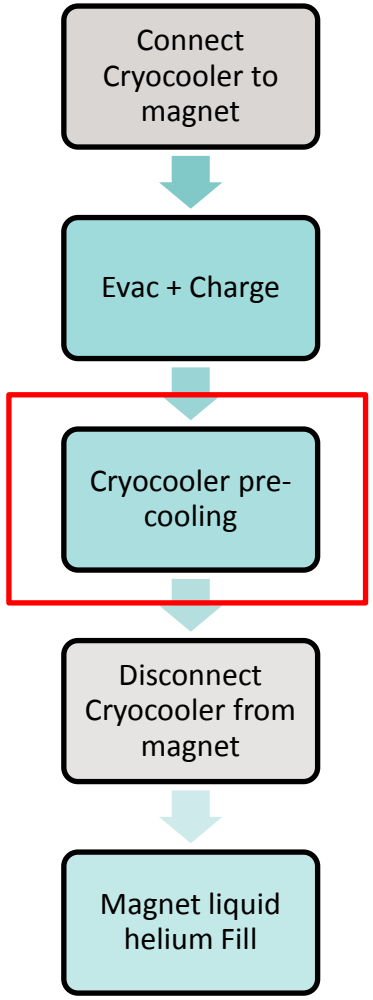
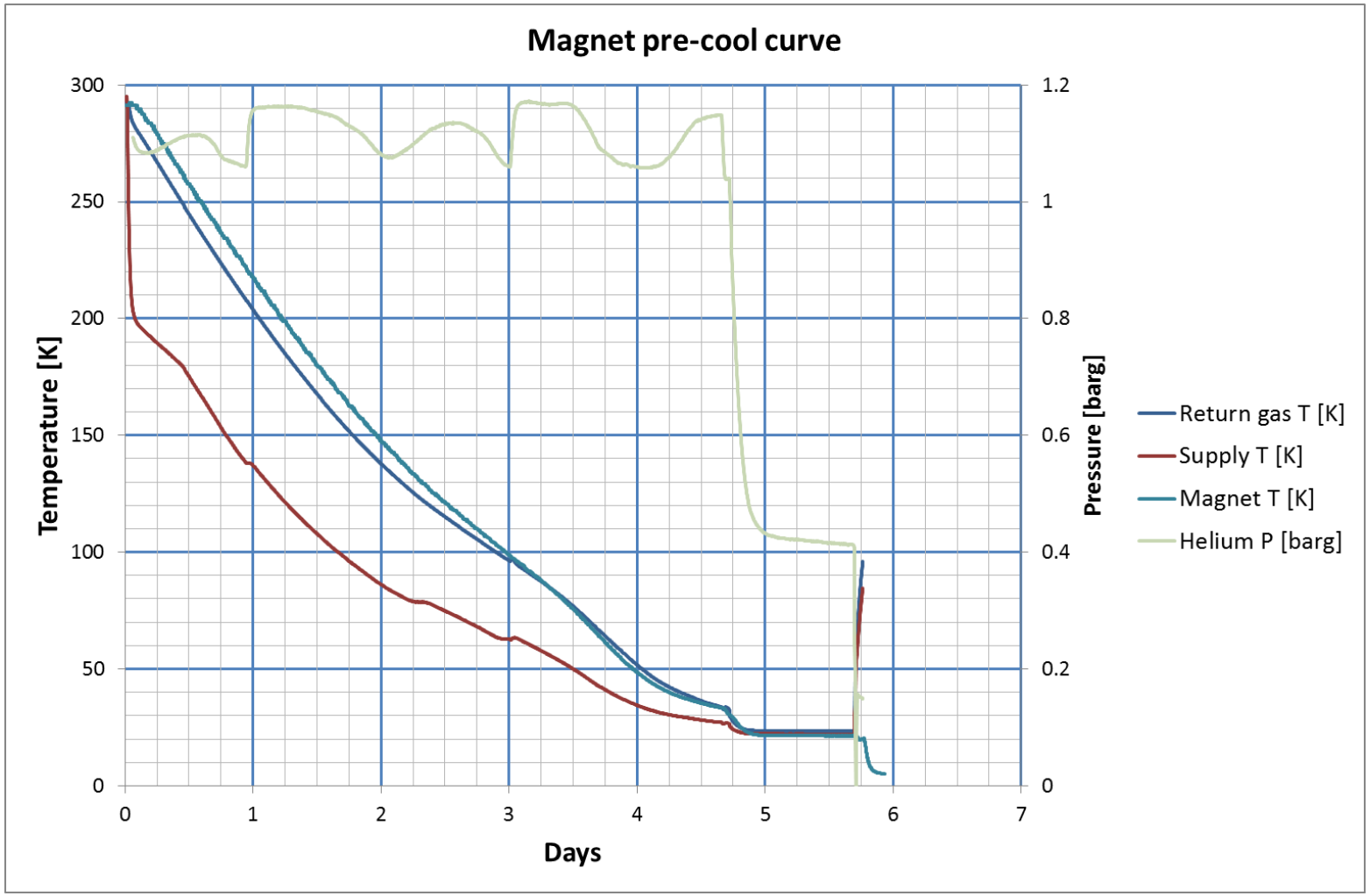
Site-cooling Steps: Pre-cooling





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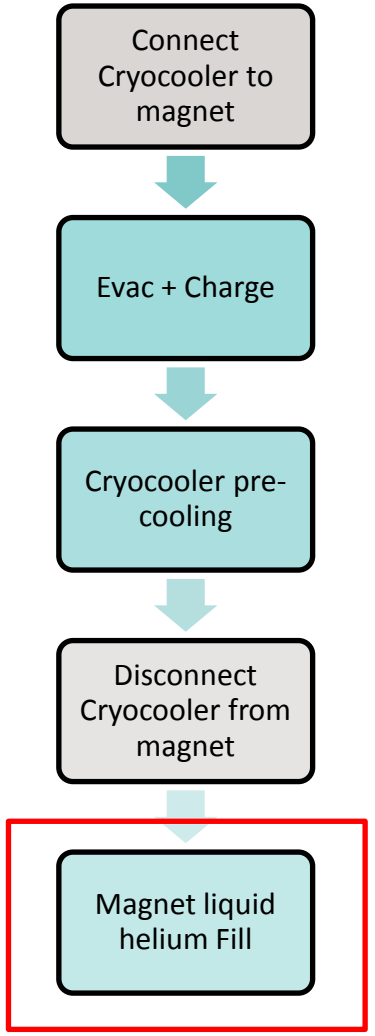
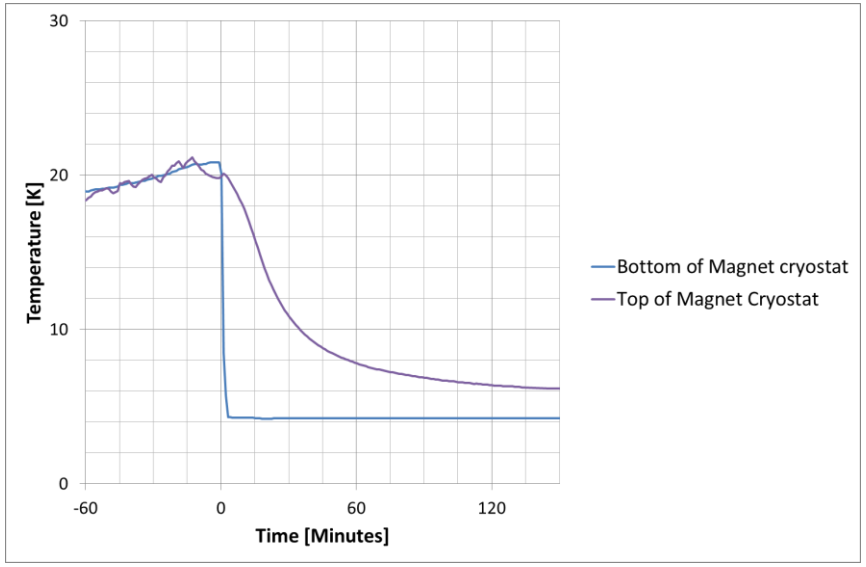
Site/hub-cooling steps: Magnet liquid helium fill



Test: Liquid helium cooling from ~20K to 4K



Test results

- Duration of initial fill: 15 minutes.
- Helium dewar loss: 17 kg (~ 140L).
- MRI Magnet mass gain: 13.5 kg (80% efficiency).
- Almost immediate liquid helium collection in MRI.

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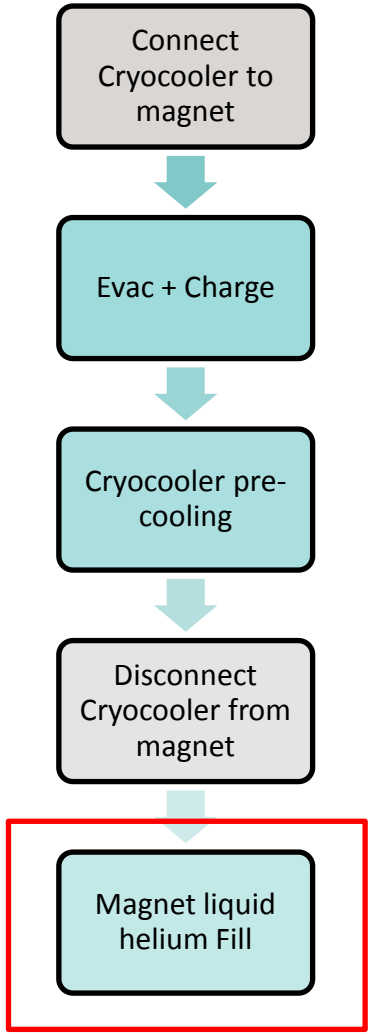
Site/hub-cooling steps: Magnet liquid helium fill



Overall helium fill efficiency

- **No additional helium loss** is incurred in cooling from 20K to 4K.
- **80 %** liquid helium mass **transfer efficiency** (helium syphon efficiency).
- **No liquid helium boil off** after the helium fill as magnet thermal shield < 100K.

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Hub-cooling in Brazil

- Magnets for the Brazilian market warm-ship by sea from Shenzen, China **(Factory)** to Joinville, Brazil **(Hub)** for local assembly.
- Magnets are pre-cooled and liquid helium filled at factory.

- Hub-cooling using a prototype cryocooler was introduced in 2015.
- Since 2015 **majority of MRI magnets for Brazil market have been hub-cooled**.
- **Cryocooler saves > 1000 L liquid helium** per MRI magnet compared to liquid nitrogen pre-cooling.

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Demonstration of site-cooling.

Cryocooler connected to magnet on site.

- Remotely monitored process using internet connection.
- Magnet cooldown successful.

Custom-built Peli-case packaging protects cooler for multiple shipments and easy handling.

Summary and Acknowledgements

Summary

- Warm-shipping MRI magnets and utilising hub- or site-cooling can reduce helium losses and shipping costs.
- A mobile, compact cryocooler for MRI magnets has been designed and tested.
- Hub-cooling in Brazil has been fully implemented.
- Site-cooling has been demonstrated.
- The cryocooler works for complete portfolio of Siemens MRI magnets.

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