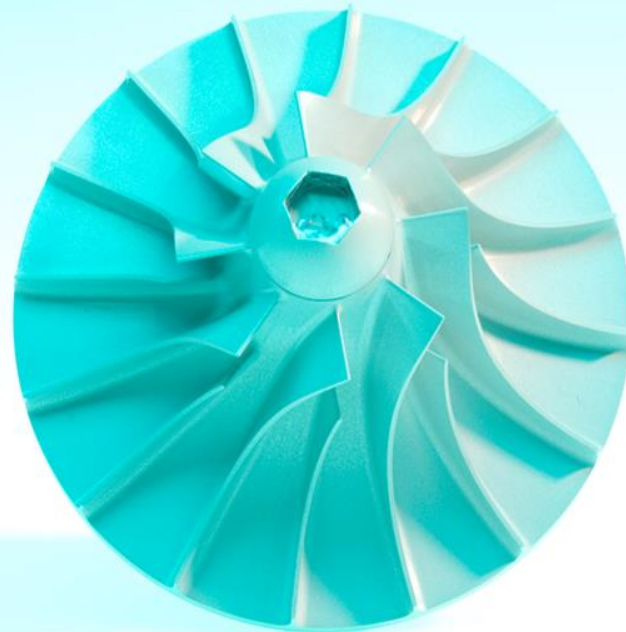


ICEC25-ICMC2014, Enschede, NL
July 9th, 2014

Superfluid Helium Refrigeration System. Design, Project Execution and Commissioning for Fermilab's CMTF.

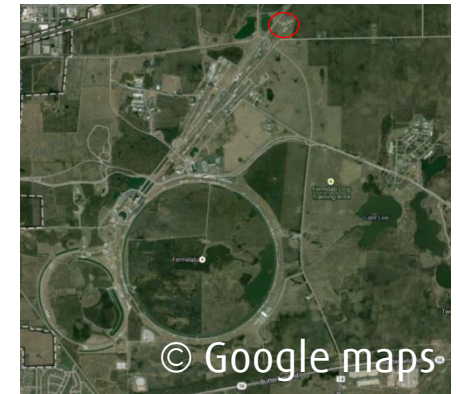
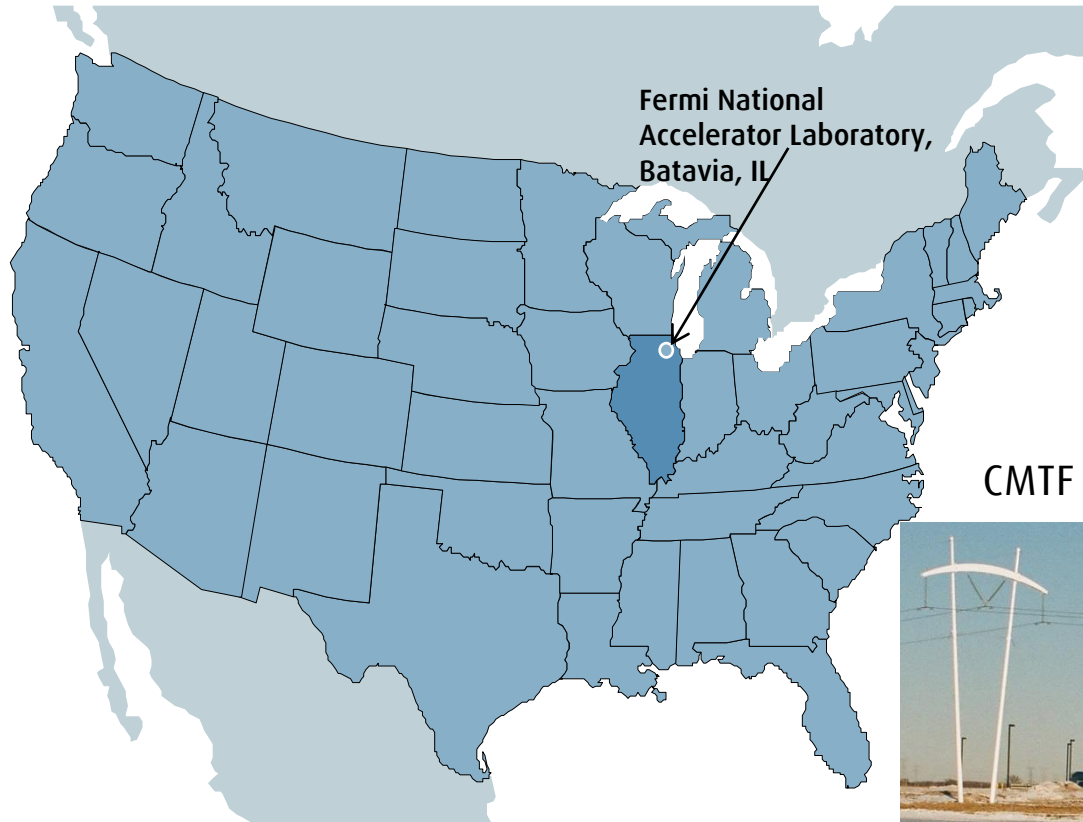


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Location of the plant Fermi National Accelerator Laboratory



CMTF – Cryomodule Test Facility

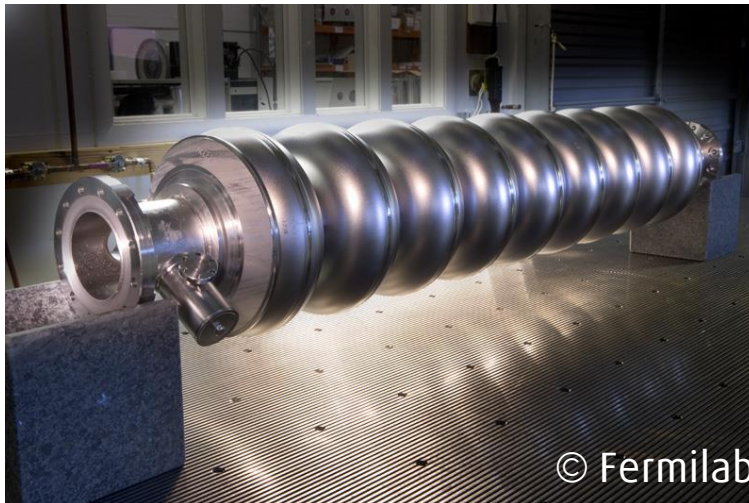


Purpose and requirements of the plant SRF testing



Purpose

- Provide cooling for the Cryomodule Test Facility (CMTF) to measure the performance of superconducting radiofrequency (SRF) cryomodules
- SRF components are the basis for future high intensity accelerators such as Project X, International Linear Collider and Muon Collider



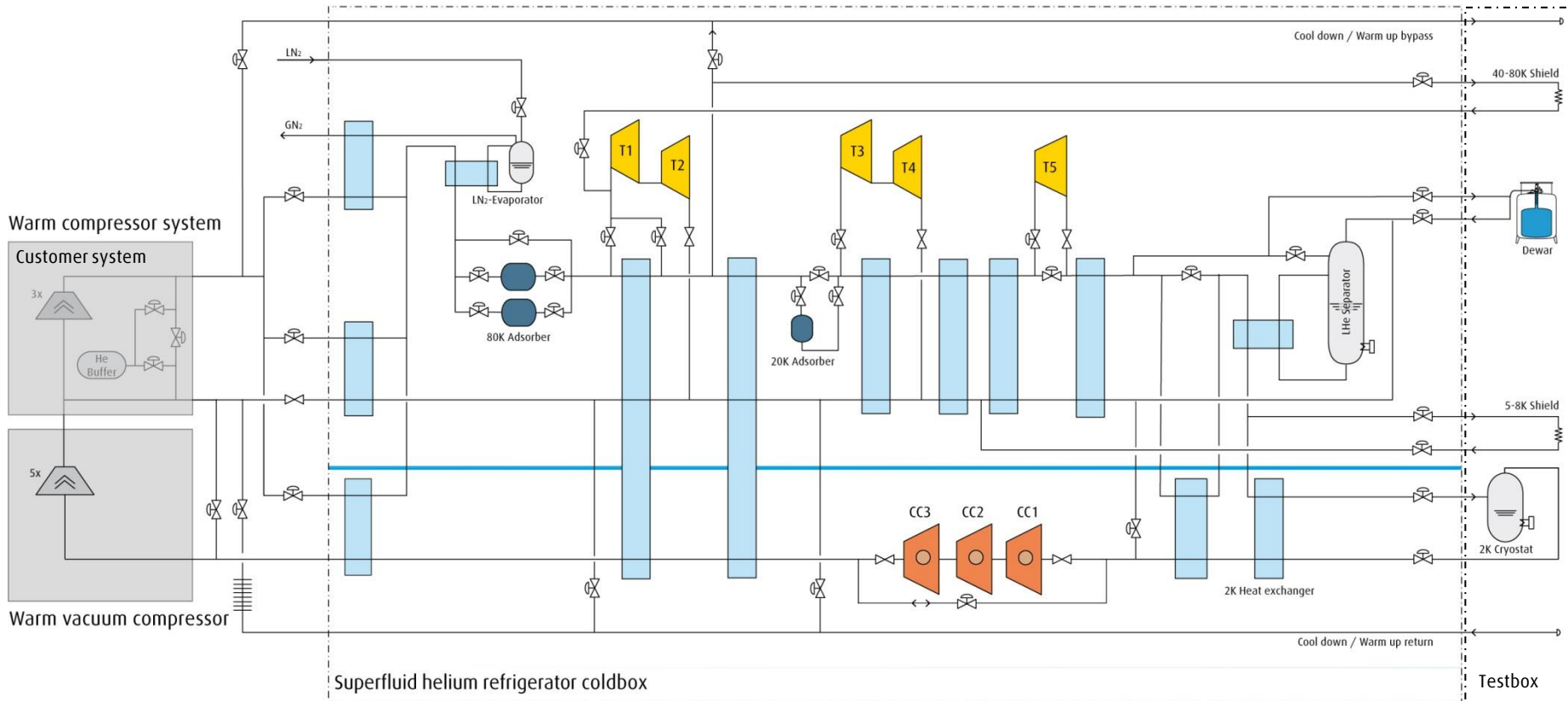
Purpose and requirements of the plant

Requirement

- Flexible Helium Refrigeration system which provides cooling to the SRF cryomodules in a wide temperature range
- Helium bath cooling from 1.8 to 2 K or 4.5 K
- 40 – 80 K shield refrigeration
- 5 – 8 K shield refrigeration
- Liquefaction to the dewar as load adjustment or stand-alone operation
- Automatic load adaption
- High availability

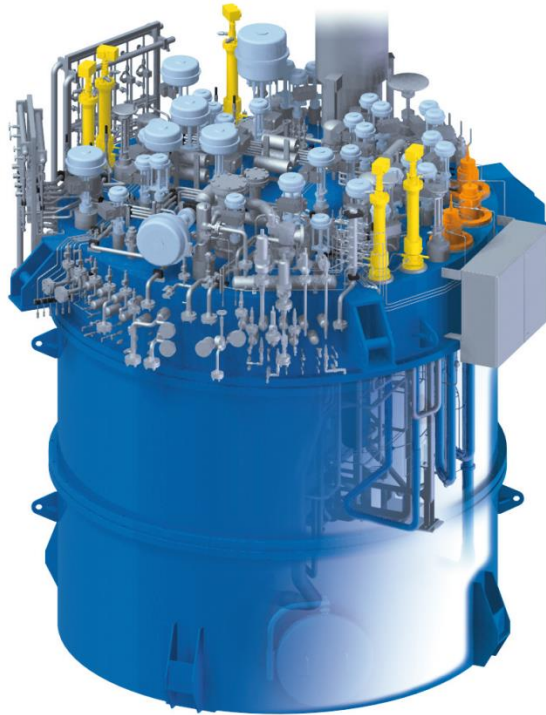


Process flow diagram



All-in-One Design

4.5 K cycle and 2 K cycle in one Coldbox



4.5 K cycle

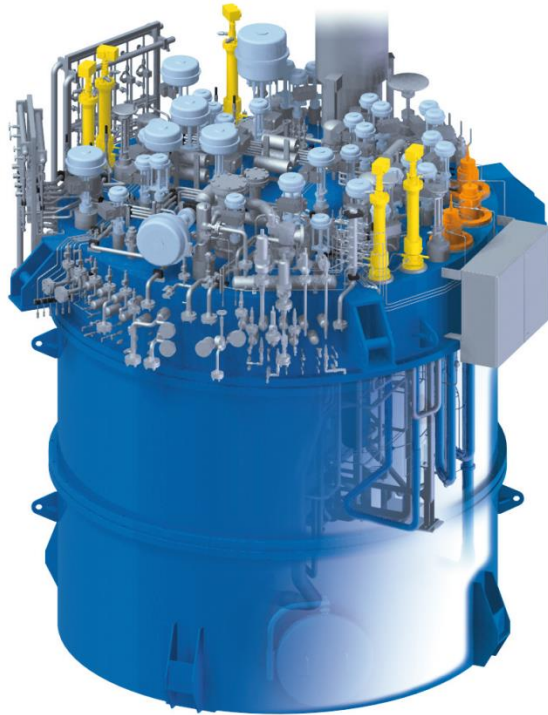
- Five gas bearing turbines arranged in three turbine strings
- Redundant 80 K Adsorbers with bypass
- 20 K Adsorber with bypass
- LN2 precooling
- LHe-Separator with Evaporator

2/1.8 K cycle

- Mixed cycle of three cold compressors in series and five parallel warm vacuum pumps
- First-time use of special designed 2K plate fin heat exchanger
- All components exposed to subatmospheric conditions are guarded with helium atmosphere

All-in-One Design

4.5 K cycle and 2 K cycle in one Coldbox

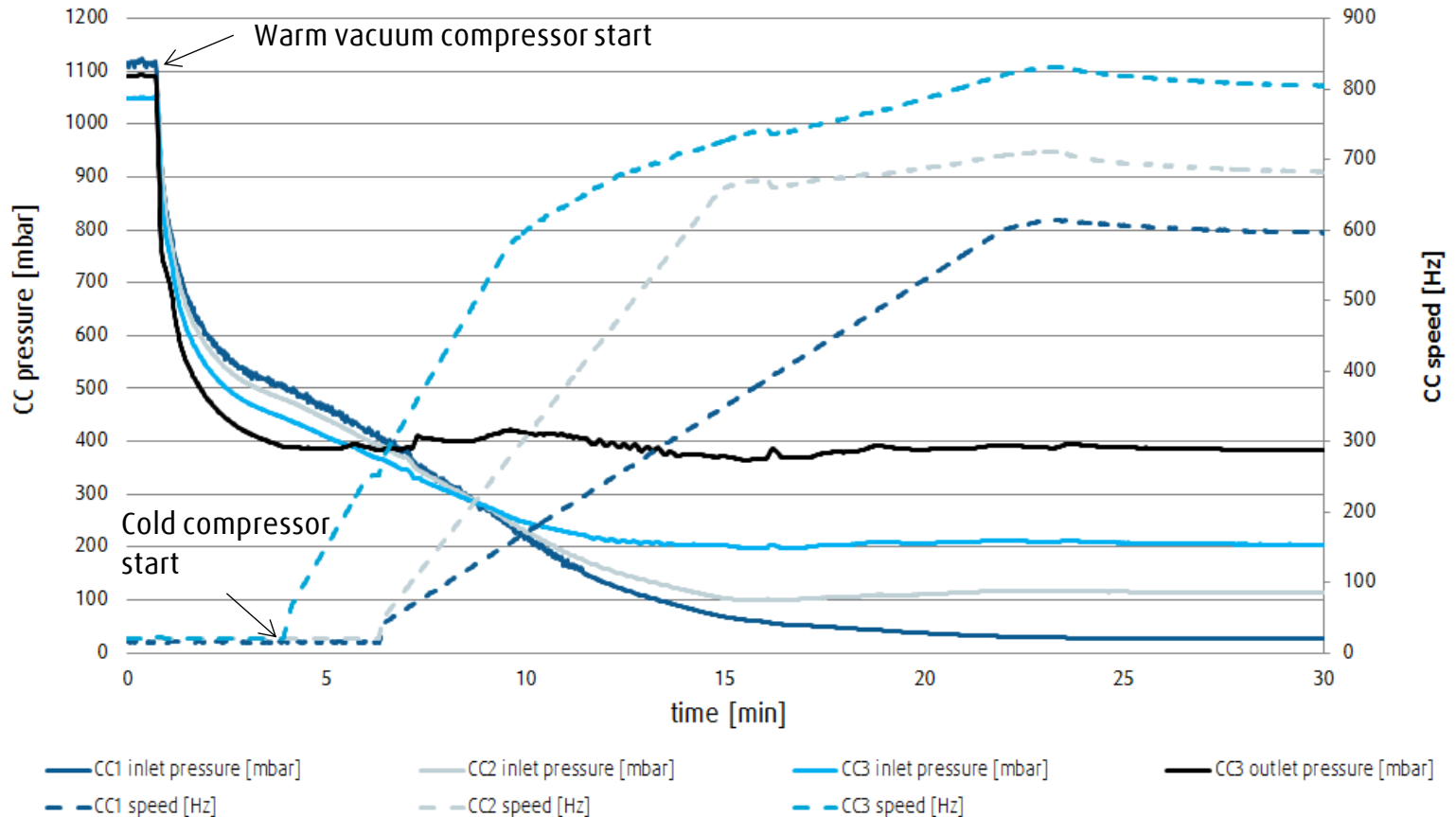


Advantages

- Cost efficient and compact design: 21 t/29 m³
- Suspended coldbox in a steel structure, easy accessibility
- Low space requirement to open coldbox completely below the steel structure
- Compact coldbox design needed special manufacturing procedure: "onion sequence"

A step ahead – automated pumpdown

24 mbar achieved within 30 minutes with testbox setup



Performance data

All guaranteed values achieved



Guaranteed	2.0 K Mode	1.8 K Mode	Liquefaction
Cryostat	500 W	250 W	-
5 to 8 K Shield	600 W	600 W	100 W
40 to 80 K Shield	5000 W	5000 W	700 W
Liquefaction	-	-	16 g/s

Acceptance Test	2.0 K Mode	1.8 K Mode	Liquefaction
Cryostat	527 W	257 W	-
5 to 8 K Shield	619 W	619 W	115 W
40 to 80 K Shield	6136 W	6136 W	720 W
Liquefaction	-	-	25.3 g/s

Project Execution

Challenging project scope split



Linde Kryotechnik AG:

- Engineering
- Design
- Procurement
- Commissioning

Linde Cryogenics:

- Procurement
- CBX Manufacturing
- CBX Installation

Fermilab:

- Warm compressor system
- Buffer system
- Water chiller system
- Field piping and field cabling
- Steel construction
- Commissioning assistance

- Manufacturing simultaneous to continuing engineering and design phase
- Progressive alignment between engineering and manufacturing workload & workflow

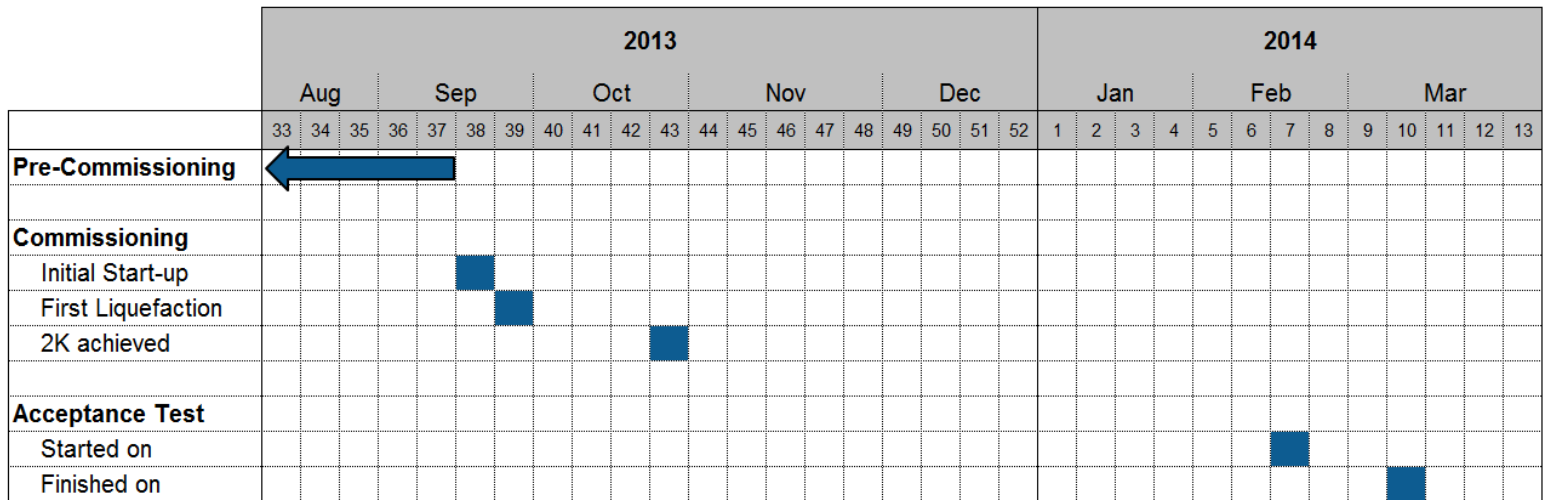
Project Execution

Commissioning milestones



Despite the complex scope split between Fermilab and Linde and the exceptionally complex system, the commissioning time remained short.

The key point was the supportive and objective-oriented cooperation among the three parties.



Summary



1) All-in-One Design

- 4.5 K and 2 K refrigeration cycle combined in one coldbox
- Highly compact and cost efficient design

2) Design for very flexible operation

- Refrigeration at 1.8 K, 2 K, or 4.5 K
- Liquefaction
- 5 to 8 K Shield and 40 to 80 K Shield load
- Total automatic load adaption for easy and safe plant operation
- Cold compressors completely automatically controlled, fast and smooth pump down

3) Design for very high availability

- Three turbine strings, exchangeable during coldbox operation
- 3 stage cold compressor string, exchangeable during coldbox operation
- Redundant 80 K adsorbers and 20 K adsorber with bypass valves

Thank you for your attention.

