Mobile Refrigeration System for Precool and Warmup of Superconducting Magnets

A Helium Conservation Tool

Santhosh Kumar Gandla and Ralph C. Longsworth

Sumitomo (SHI) Cryogenics of America, Inc., 1833 Vultee Street, Allentown, PA 18103, USA

SHI Cryogenics Group

Introduction

- Conservation of helium has become more important in recent years due to global shortages in supply and increasing prices. MRI superconducting magnets use approximately 20% of the world's helium reserves in liquid form to cool down and maintain operating temperatures at 4K.
- Efforts are being made to conserve helium in transporting superconducting MRI magnets by shipping them warm and cooling them down at end user locations (i.e. hospitals). This poster describes a mobile cryogenic refrigeration system that has been developed by Sumitomo (SHI) Cryogenics of America Inc. for this purpose.
- The modules of the mobile cryogenic refrigeration system are on carts that can be wheeled to an imaging suite in a hospital or they can be used at a central distribution center to cool down magnets that are then trucked to hospitals in the region.

System Description

- The present system is shown in Fig.1, a schematic of the main components where a refrigerator cryostat houses four (4) Sumitomo CH-110LT expanders, a cryogenic fan, heaters, bayonets for transferring cold/warm gas to and from a magnet cryostat (in this case, a test cryostat), transfer lines, F-70H compressors and system controller.
- Typically a magnet requires an interface tool on the magnet cryostat that the transfer lines plug into.
- Each expander is connected through flexible gas lines to its own Sumitomo F-70 compressor. The four expanders are divided into two pairs, circulating gas being split into two streams and flowing through each pair in series.
- The cryostat, pumps and gas controls are mounted on a dewar cart. Additionally, the compressors and system control are mounted on mobile carts to increase system flexibility. Fig. 3 shows the fully assembled system.

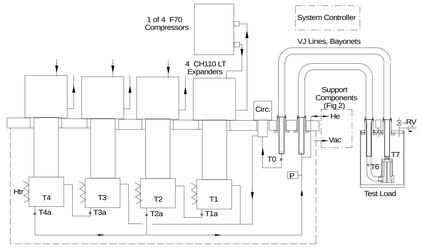

Figure 1. Schematic of the mobile refrigeration system connected to a test load

System Description

- The supporting components, which are mounted on the same cart as the refrigerator cryostat, are shown schematically in Fig. 2.

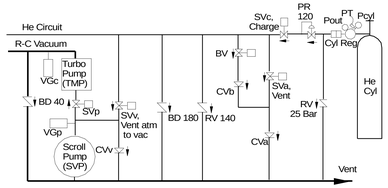

Figure 2. Support components for Mobile Refrigeration System. (VG-vacuum gauge, CV-check valve, BD-burst disc, RV-relief valve, SV-Solenoid valve, BV-Ball valve, PR-pressure regulator, PT-pressure transducer. Pressures in kPa)

- The system controller consists of control hardware with an industrial touch screen PC and custom software. It connects to the system components and sensors shown in Fig. 1 and Fig. 2 with interconnecting cable assemblies.

Figure 3. Mobile refrigeration system

- The system is designed with its own control software as shown in Fig 4 for continuous operation of **precool/cool down, warmup, charge & evacuation, performance tests, stop & disconnect** processes with automatic and manual controls.

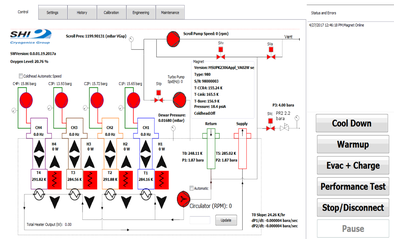

Figure 4. Control software user interface

System Processes, Tests & Results

- The controller with its custom software is designed to control the **precool/cool down** and **warmup** processes of a superconducting magnet from 300K to <40K and 4K to 300K respectively.
- The controller is programmed to **charge and evacuate** the helium circuit before the start of precool of the magnet
- **Component performance tests:** The cooling capacity of a CH-110LT expander at speeds from 2 to 3 Hz is shown in Fig. 5.

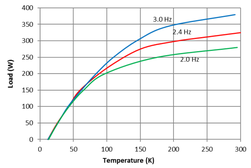

Figure 5. Capacity of CH-110LT expander at 2.0, 2.4 and 3.0Hz

- **Precool/Cool down tests:** Tests on a number of systems have been run in the laboratory and on magnets at customer sites. In Fig. 6, test results are plotted as an overlay of the capacity of the four expanders and the cooling available at the test load for circulation rates of 2, 5, and 10 g/s of helium at 1barg operating pressure.

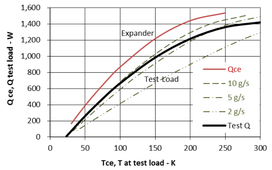

Figure 6. Cooling at four expanders, Q ce, and net cooling at a test load with helium circulation rates of 2, 5 and 10 g/s. The broad line shows the heat load applied in the test cryostat.

- Fig. 7. plots the temperatures and circulation rate for a magnet at 1.2 barg pressure that took several days to cool down (time is normalized). The initial circulator speed was 18,000 rpm and the initial circulation rate was 3.2 g/s. Location of temperature sensors is shown in Fig. 1.

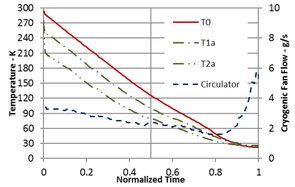

Figure 7. System key temperatures and cryogenic fan flow rate during typical cool down of a magnet.

System Processes, Tests & Results

- **Warmup tests:** Tests similar to Fig. 8. have shown that the cryogenic fan speed and the heater settings allow the warmup rate to be controlled to avoid thermal stresses in the magnet.
- Care is needed when starting the warmup to avoid a sudden vaporization of residual liquid that could rupture a burst disc. Each of the expanders has a 400W heater on the cold end heat exchanger.

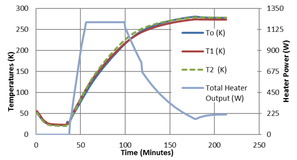

Figure 8. Warmup-system self-test

Conclusions

- A mobile cryogenic system has been developed, which has a cooling power of 1550 W at room temperature and has been demonstrated to cool MRI size magnets from 300K to 22K in 4-7 days. The system has a total heater power of 1600W and can warmup the same magnets in 3-4 days in a controlled way.
- The mobile and modular nature of the system allows it to be adapted to different cooling and service applications.
- The present system is designed to cool down and warm up a magnet. Work is in progress on systems that are designed to maintain cooling at a fixed temperature for a long period of time.

References

[1]R.C.Longsworth, "Fast Cool Down Cryogenic Refrigerator", US patent 8,448,461, May 28, 2013

[2]Z.Ri, T.Koizumi, "Cooling System and Cooling Method", US patent 9,612,062, Apr. 4, 2017

[3]T.Trollier, A.Ravex, J.Trachon, J.Lacapere, "20 K Cryogenic Helium Forced Flow Circulation Loop", Cryocoolers 19, ICC Press, Boulder, CO (2017), pp.

Acknowledgment

This was a joint development project between Sumitomo (SHI) Cryogenics of America Inc., USA, and Siemens Magnet Technology, UK. We would like to thank all the people who supported and contributed to this development at both organizations, especially the contributions of Noel L. Fasnacht, Jr. and Bruce Sloan at SHI.