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CRYOGENICS INFRASTRUCTURE AT TRIUMF'S PARTICLE ACCELERATOR FACILITIES*

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Abstract

Cryogenic infrastructure is an indispensable part of TRIUMF accelerator facilities. At the moment TRIUMF actively running several helium cryoplants supporting operation for TRIUMF's three major accelerator systems: 520 MeV proton cyclotron, superconductive radio-frequency (SRF) heavy ion linear accelerator at the Rare Isotope Beams (RIB) facility (former ISAC facility), and SRF electron linear accelerator (e-linac) at Advanced Rare IsotopE Laboratory (ARIEL). On the top of it there is a Helium Recovery Facility (HRF) which receives the boil-off coming from several experimental areas equipped with SC magnets, etc. This gas has been purified and reliquefied and given back to experimental groups.

Applications of cryogenic thermal loads vary from cryogenic absorption pumping of the cyclotron vacuum tank to cryogenic cooling of SRF cavities for production accelerators and support of research and development at SRF department. Wide range of production techniques for cryogenic refrigeration includes helium refrigerators based on both piston and turbine expansion coldboxes for both 4 K and 2 K temperature cryogenic loads.

This paper presents the details of TRIUMF cryogenic systems as well as operational experience of various cryogenic installations.

INTRODUCTION

The current configuration of TRIUMF's cryogenic infrastructure is the result of laboratory's development of state-of-the-art particle accelerators for over 50 years (Figure 1). The cyclotron cryogenic system, used for the cryogenic adsorption pumping of the cyclotron tank using 20K and 80K helium gas was heavily upgraded in 2007 to utilize Linde 1630 liquid helium cryogenic refrigerator.

Started as an R&D activity, ISAC heavy-ion accelerator utilizes 4 K liquid helium for half-wave superconducting cavities. Cryogenic system consists of two Linde TCF50 cryoplants and supports both ISAC linac production facility at 4K and SRF test laboratory at both 4 K and 2 K. TRIUMF's ARIEL 2 K SRF e-linac facility is built around Air Liquide Helial LL coldbox as liquid helium cryoplant. Both ISAC and ARIEL systems are equipped with Busch pumps for subatmospheric operation.

Laboratory's HRF based on Linde 1610 liquid helium liquefier equipped with a freeze-out purifier has been operational for four years.

CYCLOTRON CRYOPUMPING SYSTEM

In TRIUMF, 520 MeV cyclotron is used as a proton beam source for most of the experimental facilities. Vacuum tank of the cyclotron is ~100 m^3 chamber operating at 1×10^{-8} Torr pressure during beam production. The vacuum is achieved by the use of two turbo pumps, six cryopumps and two cryopanels. The cryopanels are a form of a cryopump based on cryoabsorbtion of gases such as H_2 and Ne on the surface of gases such as N_2 or O_2 cryocondensed on stainless steel pipes cooled by LHe.

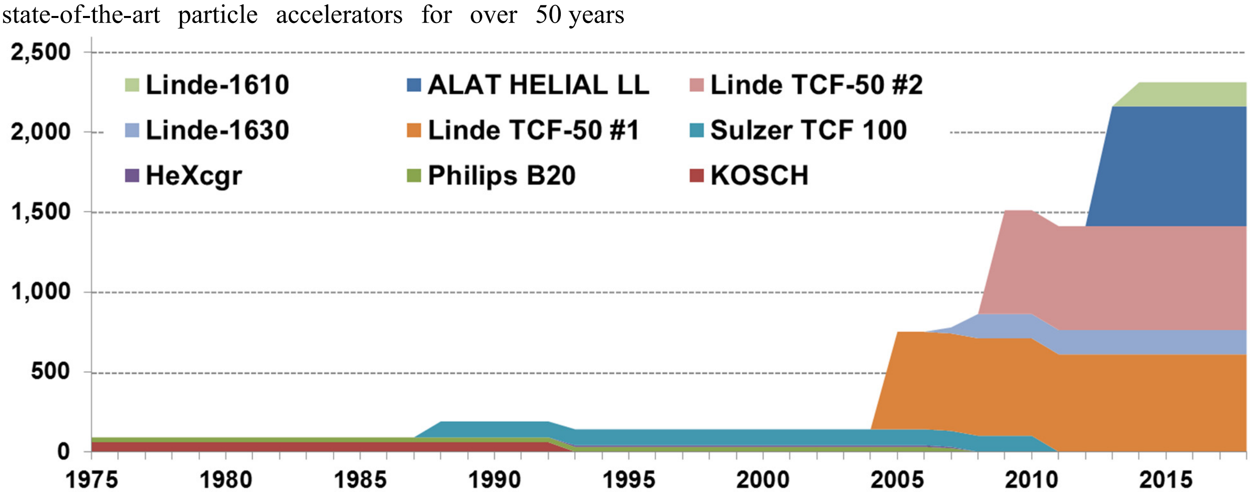

Figure 1: Capacity of TRIUMF's cryogenic infrastructure (shown equivalent cooling power @ 4.5 K).

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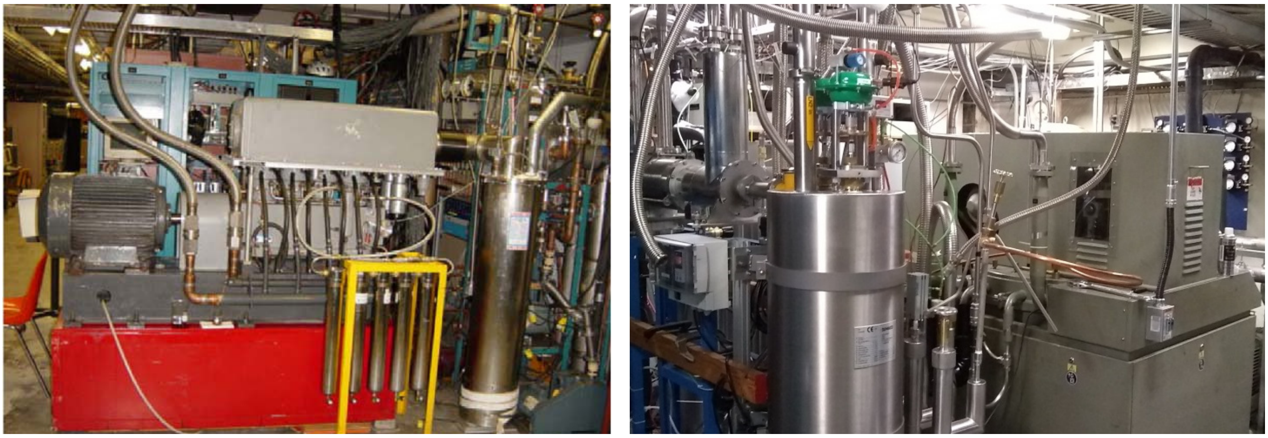

a) b)

Figure 2: a) Philips B-20 cryo-refrigerator; b) Linde 1610 liquid helium refrigerator.

The cryogenic system of cryopanels went through an extensive upgrade from Philips B-20 Stirling cycle cryo-refrigerators to Linde 1630 helium liquefier (Figure 2) in 2007. Open-loop LN2 gravity-driven system was introduced for cryopanels 80 K shielding. The pumping rate for hydrogen was measured and it equals to 26,000 l/sec [1]. Installation of this new helium refrigerator has resulted in improvements in cyclotron vacuum, since the cryopanels are cooled to 4.6 K with liquid helium, compared to the prior system which used 20 K helium gas. This has also improved the cyclotron reliability and increased the time between cryopanels' defrosts.

ISAC CRYOGENIC SYSTEM

The cryogenic system of ISAC superconducting accelerator facility (Figure 3) was installed in two phases. In 2006, the first Linde TCF50 cryoplant was installed and commissioned [2]. Phase-I cryogenic system installation supported five SCB cryomodules with liquefaction rate of ~5 g/s. From the first days of operation the ISAC distribution system allowed for supplying cryogens to SRF test facility for cavities and cryomodule testing. During the Phase-II ISAC facility upgrade the second Linde TCF50 cryoplant was installed and integrated into the existing infrastructure. Liquid helium and liquid nitrogen distribution systems were integrated to the existing lines. At full load both Phase-I (~620 W) and Phase-II (~590 W) cryoplants have enough capacity to handle the entire linac static heat load (in the range of 16 to 23 W per each cryomodule, with additional 95 W for helium distribution lines), allowing minor cryoplants maintenance without warm-up of the cryomodules.

ISAC cryogenic system configuration includes the capability to support the operation of ISAC Phase-I and Phase-II cryomodules at nominal mode with the support of SRF test facility cryogenic tests using both cryoplants, and support five SCB and three SCC cryomodules at maintenance mode (handling static heat load) with the support of SRF test facility cryogenic tests using one cryoplant.

Figure 3: ISAC cryoplants: Linde TCF-50.

ARIEL CRYOGENIC SYSTEM

The Advanced Rare IsotopE Laboratory (ARIEL) is a major expansion of the Isotope Separator and Accelerator (ISAC) facility at TRIUMF. A key part of the ARIEL project is a 10 mA 50 MeV continuous-wave superconducting radiofrequency (SRF) electron linear accelerator (e-linac). The 1.3 GHz SRF cavities are operated at 2 K.

HELIAL LL helium liquefier by Air Liquide Advanced Technologies (Figure 4) with a tuneable liquid helium (LHe) production was installed and commissioned in Q4'2013. It provides 4 K liquid helium to one injector and one accelerator cryomodules. The 4 K to 2 K liquid helium transition is achieved on-board of each cryomodule by using counterflow heat exchanger and a JT valve. The cryoplant, LHe and LN2 distributions, sub-atmospheric (S/A) system and cryomodules were successfully commissioned and integrated into the e-linac cryogenic system [3].

The special consideration is given to the purity of the process gas. The LN2 freeze-out helium purifier was built at TRIUMF with the assistance from FNAL

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Figure 4: ARIEL cryoplant: ALAT Helial LL.

HELIUM RECOVERY FACILITY

Laboratory's experimental installations consume ~20,000 liquid liters of helium per year. Prior to installation of the helium recovery plant, helium inventory used to be vented from experimental cryostats. Since helium is a nonrecoverable resource and due to the rising cost of helium supply TRIUMF has purchased and installed a new helium recovery facility based on Linde 1610 liquid helium cryoplant in 2013/14 (Figure 5).

The system has been operational for four years with over 100,000 liquid liters of helium inventory recovered. Average recovery performance of the system exceeds 90%. TRIUMF has recently upgraded the system by adding LN2 system in order to provide the cryogenic services to the UCN project.

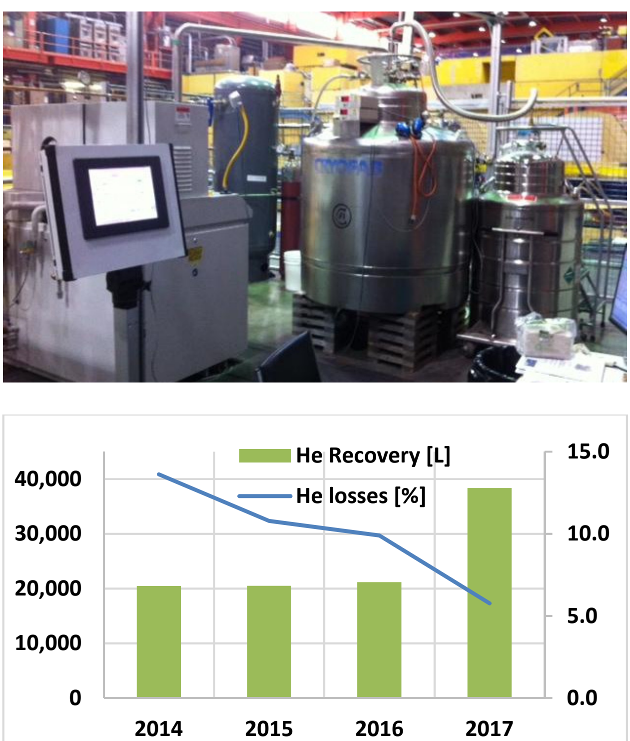

Figure 5: HRF (top) and its production & losses (bottom).

UPGRADE OF LIQUID NITROGEN STORAGE AND SUPPLY

In 2014, TRIUMF has opened the tender to renew LN2 supply contract in order to optimize LN2 use and cost. Three LN2 storage tanks built in the late 70th were replaced with two modern tanks equipped with pressure and level instrumentation and communicating on-line with supplier. In order to maintain cryogenic system operational during the upgrade activities, temporary LN2 storage tanks were used to prevent beam interruption (Figure 6).

Figure 6: Trailers used for temporary LN2 storage.

CONCLUSION

Over 50 years of TRIUMF's existence the cryogenic infrastructure played an essential role for accelerators operations and experimental support. Its growth and complexity were corresponding to the increasing needs especially from two new SRF accelerators. The total cooling power at 4.5 K has increased, roughly, by the factor of ten over the past 15 years.

TRIUMF has formed Cryogenics Systems Group responsible mainly for the operation and support for multiple cryogenic facilities scattered across the lab. The group also participates in conceptual design, supervises detailed design, procures, installs and commissions cryogenic equipment as well as integrates it in existing accelerator or experiment infrastructure.

The group is staffed with experienced cryogenic engineers and technologists which are open to new tasks and challenges.

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