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THE OPERATIONAL EXPERIENCE OF E-LINAC CRYOGENIC SYSTEM AT TRIUMF*

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Abstract

The new Advanced Rare IsotopE Laboratory (ARIEL) is a major expansion of the Rare Isotope Beams (RIB) facility at TRIUMF. Superconducting radio-frequency (SRF) cavities cooled down to 2 K are the key part of ARIEL electron linear accelerator (e-linac).

Design of the cryogenic system was bound to follow both phased project schedule and existing building infrastructure. Due to the scheduling of commissioning and R&D activities of ARIEL project, high availability requirements were set for e-linac cryogenic system during its commissioning stage. Various upgrades were introduced during system commissioning in order to improve overall availability and reliability of the system.

This paper presents the details of operational experience, commissioning activities and continuous improvement of various operational aspects of e-linac cryogenic system.

SYSTEM OVERVIEW

For budgetary reasons the e-linac project is planned in two phases. The first stage includes two cryomodules (Injector Cryomodule and Accelerator Cryomodule #1). The addition of second Accelerator Cryomodule is under consideration. Phased project schedule required staged installation and commissioning of cryogenic system components.

Detailed system architecture was reported elsewhere [1]. Overall structure of the ARIEL cryogenic system is shown on Fig. 1.

System includes two Kaeser screw-type compressors. The main compressor capacity is 112 g/s at 14.5 bar and the recovery/purification compressor capacity is 15 g/s at 15 bar. In the event of a power failure the emergency power generator is used to recover helium boil-off using recovery compressor.

The helium liquefier manufactured by Air Liquid Advanced Technologies (ALAT) was commissioned in 2013 demonstrating liquefaction performance of 367 L/hr and refrigeration performance of 837 W [2].

Sub-atmospheric operation for 2 K refrigeration is supported by four Busch Combi DS 3010B pumping units.

Helium purification system is based on a stand-alone custom-built freeze-out helium purifier (manufactured with assistance from Fermi National Accelerator Laboratory).

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Commissioning of the e-linac cryomodules was reported elsewhere [3].

SYSTEM OPERATION

Starting from the initial coldbox commissioning run in 2013, the cryogenic system of e-linac went through multiple stages of modifications and upgrades during 2014-2018 operational runs.

During initial installation and commissioning phase of the injector cryomodule in 2014, all major subsystems of e-linac were commissioned and integrated for production of the first accelerated beam [3]. Liquid helium distribution system, sub-atmospheric return piping and heat-exchanger, and sub-atmospheric pumping system were installed, tested and integrated as a part of the cryogenic system of e-linac.

After achieving accelerated beam milestone, accelerator cryomodule was installed and cooled down to demonstrate simultaneous operation of both cryomodules. New modules of helium distribution system were installed and sub-atmospheric piping connection was extended to support the operation of second cryomodule.

In 2015, multiple system modifications and upgrades were performed, including installation of the helium purifier and upgrades applied to the control system. At the end of 2015, TRIUMF went through a replacement of liquid nitrogen storage infrastructure (two 9,000 gallon storage tanks) due to a renewal of new liquid nitrogen supply contract.

During 2016 run, system was restarted in configuration with injector and accelerator cryomodules for 3 months of commissioning for accelerator and RF systems. The injector cryomodule was then replaced with identical cryomodule manufactured for Variable Energy Cyclotron Calcutta (VECC) for testing and commissioning [4].

After the beam test of VECC cryomodule, the original injector cryomodule was placed back into the beamline in early 2017 for commissioning of machine protection systems, followed with installation of accelerator cryomodule reassembled with the second niobium cavity for the beam testing.

Accelerator cryomodule went through the refurbishment and maintenance in 2017 and was installed back for the beam testing in 2018.

The installation and removal of cryomodules for R&D and maintenance required liquid helium distribution to be frequently reconnected. Modular design of the distribution system with field joints (Fig. 2) allowed reconnecting liquid helium supply and return lines in-situ without degradation of thermal insulation properties.

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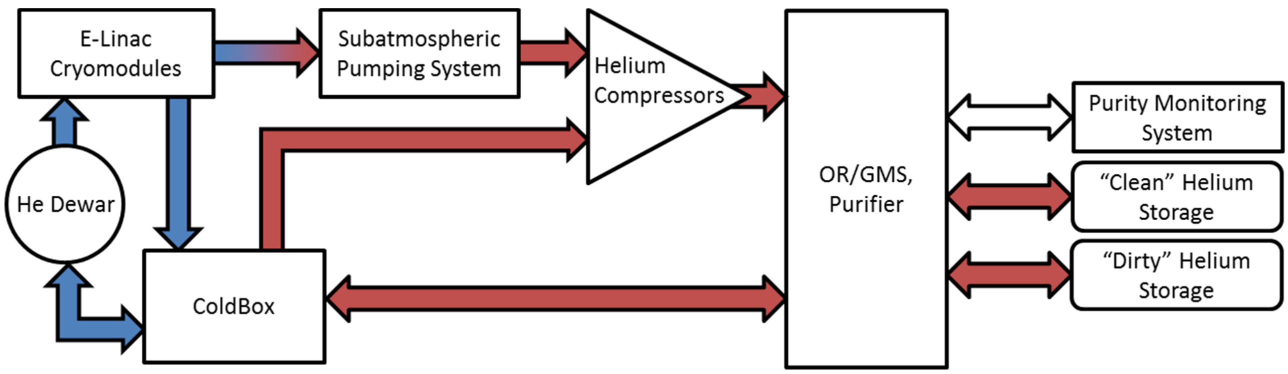

Figure 1: Architecture of the e-linac cryogenic system.

SYSTEM DOWNTIME

The main contribution to the downtime of e-linac cryogenic system during 2014-2018 runs was associated with power interruptions (short period power "bumps" as well as continuous outages) followed by control system upgrades (Fig. 3).

During 2014 run, cryogenic system was operated with ancillary systems under commissioning, causing frequent interruptions caused by service outages. The run of 2015 was cancelled due to the continuous improvements of the control system of both cryoplant and TRIUMF's EPICS based control system. The following runs in 2016 and 2017 were interrupted by a number of site-wide power outages, as well as interruptions caused by turbine safety interlocks of the cryoplant (under investigation with the manufacturer).

OPERATIONS CREW

Main operational responsibilities for the e-linac cryogenic system are carried by a dedicated cryogenic operator and a backup operator. Automated control systems for both cryoplant and cryomodule support allow to transfer 24/7 monitoring of the cryogenic system to the main operations team. Cryogenic operators are involved into system cooldowns and warmups, components commissioning, SRF performance testing and system troubleshooting.

Cryoplant control system is interfaced to TRIUMF's EPICS based control system, allowing monitoring and alarming functionality for both cryoplant and TRIUMF cryogenic systems to be presented in a consistent way for site-wide operations team (Fig. 4).

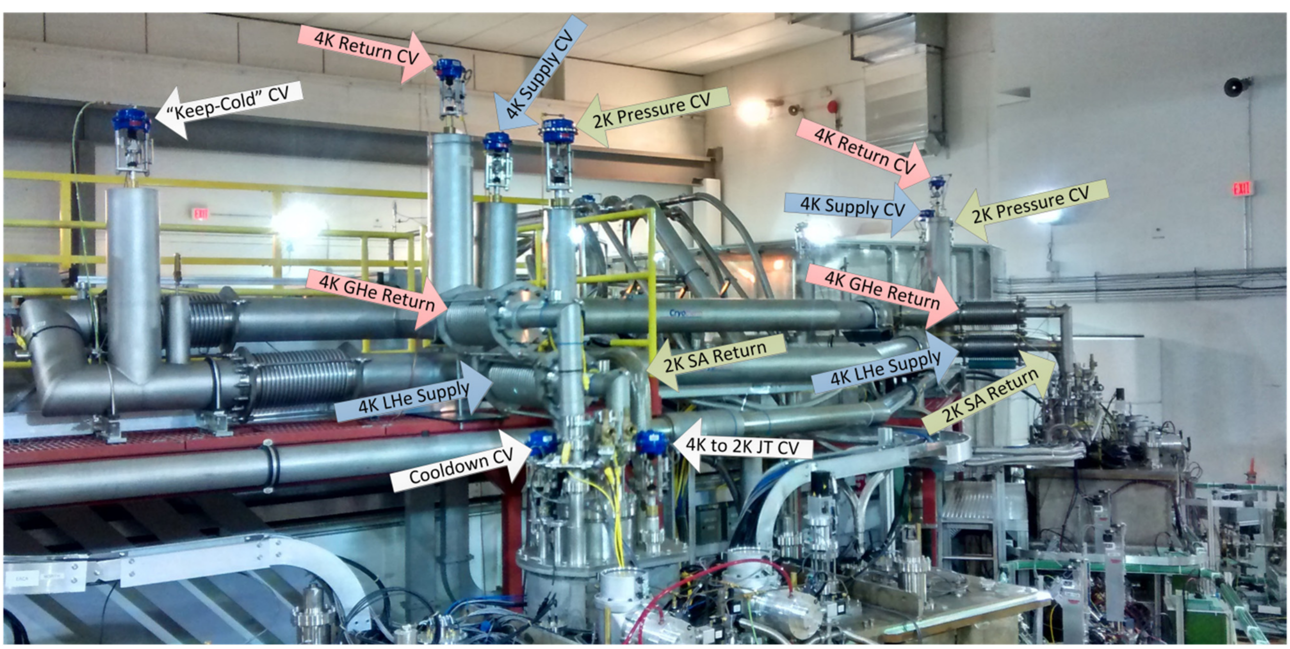

Figure 2: Close-up look at the modular liquid helium distribution system and sub-atmospheric return system around accelerator cryomodule (indicated cryogenic valves).

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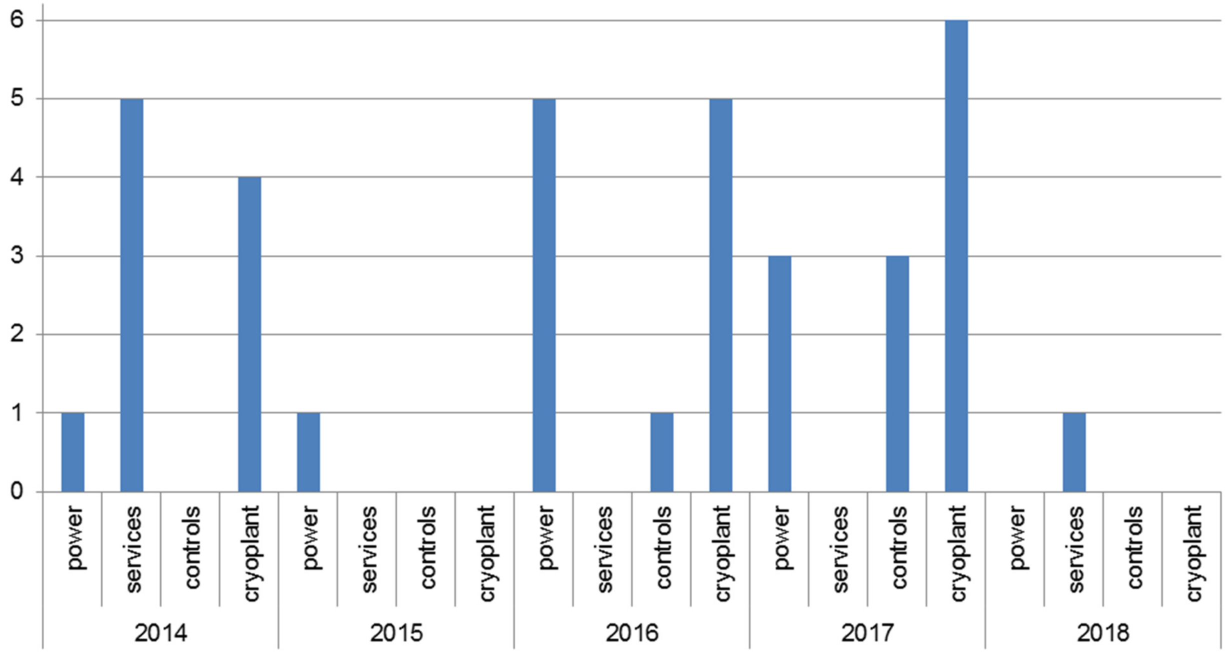
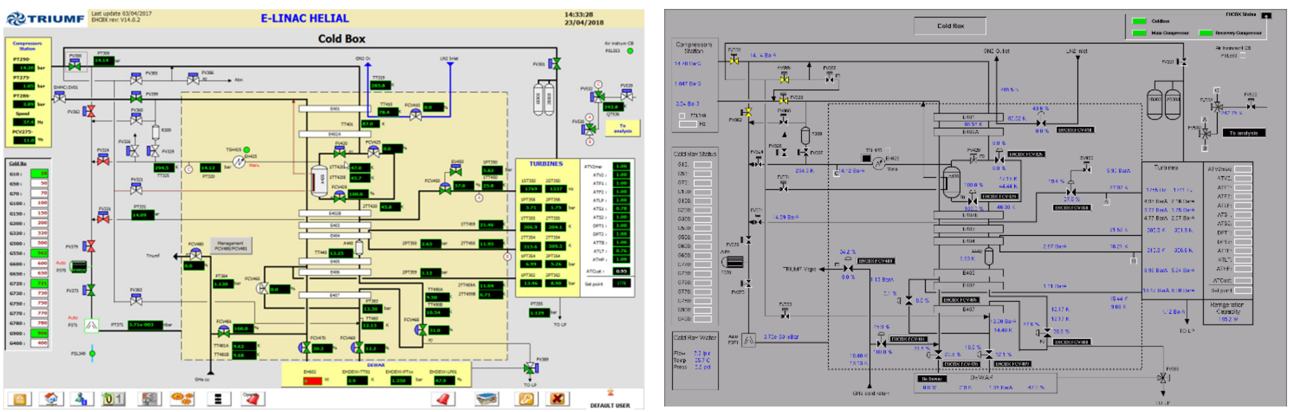


Figure 3: Interruptions of cryogenic system operation over 2014-2018 runs.



a) b)

Figure 4: Control system interfaces of helium cryoplant: a) local control panel for cryogenic operators; b) mirrored EPICS control panel for monitoring and alerting purposes.

CONCLUSION

Cryogenic system of e-linac is as complex "life-support" system for SRF cryomodules. In order to meet both budgetary and physical restrictions introduced at the early stages of the ARIEL project, cryogenic system was designed and implemented utilizing modular architecture. This approach allowed TRIUMF to successfully install and commission e-linac components within a tight project schedule. Operational flexibility of the system also allowed supporting accelerator and SRF R&D at early stages of e-linac commissioning without compromising system availability.

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