FRIB Cryogenic Plant Status

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Abstract. After practical changes were approved to the initial conceptual design of the cryogenic system for MSU FRIB and an agreement was made with JLab in 2012 to lead the design effort of the cryogenic plant, many activities are in place leading toward a cool-down of the linacs prior to 2018. This is mostly due to using similar equipment used at CHLII for the 12 GeV upgrade at JLab and an aggressive schedule maintained by the MSU Conventional Facilities department. Reported here is an updated status of the cryogenic plant, including the equipment procurement status, plant layout, facility equipment and project schedule.

1. Introduction
The FRIB cryogenic plant is on schedule for a cool-down to 4.5 K at the end of 2017. Most of the major components such as the warm compressors and 4.5 K cold boxes have been ordered or, like the liquid storage dewars and cold compressors, are in the bid process. Cold and warm piping design is ongoing and the installation of the major lines should start in the late spring of 2016. JLab is also finishing the design and supporting the procurement of the cryogenic distribution system scheduled for installation starting in the fall of 2015.

2. Design Basis
The FRIB cryogenic helium refrigeration system is based on a modified JLab CHLII plant (second Central Helium Liquefier added for the 12 GeV upgrade) [1] comprised of warm compressors, oil removal, gas management, and 4.5 K cold box which have operated successfully for the past two years by meeting major design goals while adopting the ‘Ganni Cycle Floating Pressure Technology’ [2, 3, 4, 5]. Much of this equipment was developed as a result of over 30 combined years of 2 K operational experience at JLab and the Spallation Neutron Source at ORNL.

The FRIB plant design incorporates some improvements to the subsystems using lessons learned from the first generation systems and has additional requirements to support 4.5 K loads making it somewhat different from the JLab CHLII system [1]. The civil layout is unique since it is primarily driven by the integrating the new FRIB accelerator and the existing Cyclotron experimental areas. The FRIB cryo plant design takes into account the new process and civil requirements while incorporating them into the new plant layout where the equipment is oriented to maximize operability and access. More specifically:
• All of the main compressors are nearly the same size and design as JLab CHLII [6], except that one first stage unit has its flow rate increased by 20% to handle the additional 4.5 K refrigeration load. Other than some initial problems with flex-hoses during the first few months of operation, these compressors are proving to be an efficient and sound design [7].

• The FRIB 4.5 K cold box is a modified design of JLab CHLII [1, 3, 4] and is equipped to handle 50% more shield load, an additional 4.5K refrigeration load and incorporates newly designed 300-80 K heat exchangers; since the liquid nitrogen usage of the JLab cold box was double at maximum capacity compared to its guaranteed performance (these heat exchangers within the CHLII are in the process of being replaced by the vendor).

• The preliminary design of the sub-atmospheric (SA) cold box has been greatly simplified by eliminating the LN cooled motors and thermal shield, as well as, having its 2 K/4 K heat exchanger moved to each cryomodule [8] similar to the SNS arrangement (reducing exergy supplied by the cold box to the load, for the same load). The complication and risks associated with adding a thermal shield at the 4 K to 30 K levels were assessed to be greater than the benefit due to the small reduction in the capacity (the SNS ‘2 K’ Cold Box has no active thermal shield).

• The 10 kL, standard model liquid helium dewar at FRIB will incorporate a similar neck can design to JLab/SNS with cryogenic connections. The dewar is mainly used for inventory management and peak load handling.

• There are some similarities but many differences between the FRIB cryogenic distribution system [9] and the JLab CHL system. Its design and status are presented elsewhere in this Volume[10].

3. System Description
The layout of the FRIB main refrigerator room that houses the 4.5 K cold boxes, sub-atmospheric cold box, liquid helium dewar, cold box headers and linac interface is given in figure 1. The upper cold box section (300 – 60 K) of the 4.5 K cold box has been moved indoors for building and weather considerations, shortening inter-connecting warm and cryogenic lines, and simplifying access to it from the lower cold box section (60 – 4.5 K) platform. The cryogenic interface between the above-ground refrigeration system to the cryomodules and magnets consists of three independent transfer lines to the three linac segments in the tunnel and eventually an isolated transfer line to the separator area [8,9,10]. JLab/FNAL style cryogenic couplings, also called ‘bayonets’, connect the main 4.5 K and sub-atmospheric cold boxes to each linac transfer line in the tunnel. This interface, an improvement over the baseline design that featured only a single transfer line to all linacs, is planned to provide flexibility for independent commissioning of each linac segment and provide partial linac operations during maintenance. The location of the distribution system relief devices and bayonets are in the refrigerator room, which like JLab and SNS, will also facilitate maintenance and improve safety conditions [10].

The compressor room houses the six compressors, their individual downstream oil coalescers, gas management valve and instrumentation racks, purifier compressors, instrument air back up system, oil processor and the guard vacuum pumps as shown in figure 2. Trenches that surround a 30 cm thick monolithic slab provide space and leak containment for the water and oil piping to the compressors. This room, like the cold box room, is serviced by a 10 t crane that covers over 90% of the area and is sized to handle individual components like the compressor bodies and motors.

Outside of the main plant enclosure are the final oil removal vessels, the 57 m³ nitrogen dewar and up to 10,400 Nm³ of helium gas storage (not shown). The final oil removal vessels are within a diked enclosure preventing migration in the event of a major spill. The gas storage vessels are located remotely on top of the SRF building having its piping routed through a bridge between buildings.
**Figure 1.** Cold box room layout

**Figure 2.** Compressor room layout
Figure 3. View of lower cold box piping during assembly

4. Project Schedule and Procurement Status
The status of the major main cryogenic plant sub-systems is given in the following table and is progressing toward meeting the scheduled finish. Overall, the goal is to cool the plant to 4.5 K by December of 2017 and at 2 K by March of the following year.

Table 1. Sub-system status and scheduled finish

| Sub-system                          | Status                     | Scheduled Finish |
|-------------------------------------|---------------------------|------------------|
| 4.5 K Cold Boxes                    | Expect delivery Dec '15   | Jul '16          |
| SA Cold Box and Cold Compressors    | CC contract award imminent| Jul '17          |
| Warm Compressors                    | Expect delivery Feb '16   | Jul '16          |
| Gas Storage System                  | Tanks arriving now        | Jul '16          |
| Liquid Storage Systems              | Bidding process, expect May '16 | Jul '16 |

5. Conclusions
The FRIB cryogenic plant design is based on the experience gained at JLab and SNS. The procurement of the key sub-systems is progressing. At present, there are no major changes to the cryogenic plant since it was initially redesigned by JLab in 2012 [1].
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