FRIB Cryogenic Distribution System and Status

Rao Ganni[1], Kelly Dixon[1], Nate Laverdure[1], Shirley Yang[1], Tim Nellis[2], Shelly Jones[2], Fabio Casagrande[2]

[1]Cryogenics Group, Engineering Division, Thomas Jefferson National Accelerator Facility, 12000 Jefferson Ave., Newport News, VA 23606, USA
[2]Facility for Rare Isotope Beams, Michigan State University, East Lansing, MI 48824, USA

Introduction

The planning efforts for large accelerator cryogenic refrigeration and distribution systems typically involve one-of-a-kind specialized equipment designs which must meet the requirements of:

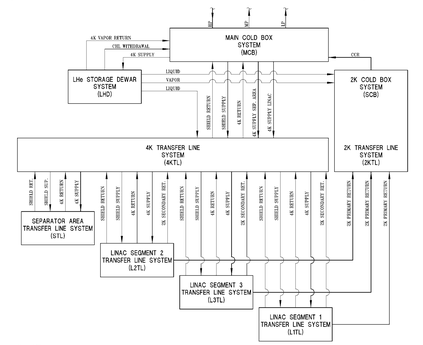
- Steady-state operating modes at varying capacities
- Phased commissioning of the subsystems
- Transient modes of operation such as during cool down and recovery from upset conditions
- Partial system operation during maintenance activities
- Some error tolerance (uncertainties in load estimation, variables from actual manufacturing processes, etc.)
- Future upgrade plans

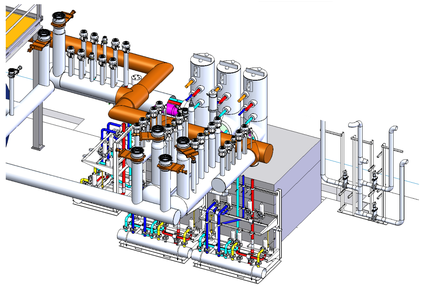
The MSU FRIB cryogenic system supports the independent 2K primary, 4K primary, and 35-55K shield operations of the SRF cavities and superconducting magnets in two main portions of the accelerator and experimental areas. Line sizing in the accelerator portion of the distribution system is based on 150% of the nominal flow in linac segment 2, which has the largest load.

Division of loads

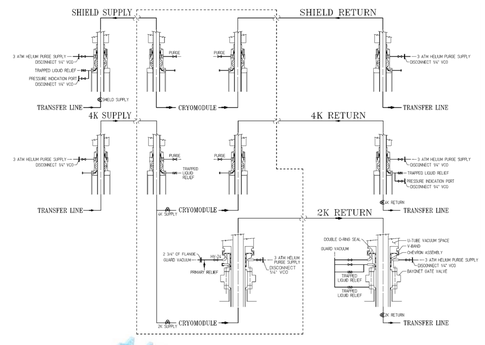
The cryogenic distribution system is divided into four independent process paths, one for each linac segment and one for the separator area. These transfer lines connect the refrigeration system with each segment of the linac. The linac transfer lines are further divided from the individual loads using bayonet-type disconnects. Although these bayonets between the cryomodule and the distribution system impose a heat load that must be offset by additional refrigeration capacity, this cost to the refrigerator is outweighed by benefits of the incremental linac commissioning, improved availability, maintainability, and expanded linac operating capabilities that are provided when cryomodules can be added to, or removed from, the operating distribution system.

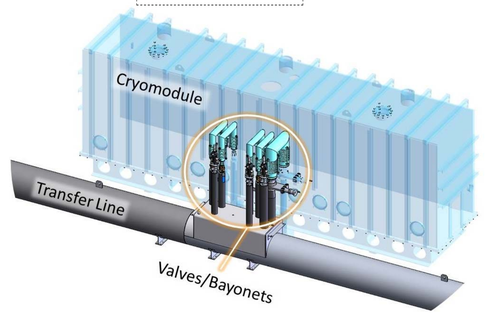
U-tube connections between linac segment transfer lines and refrigerator





U-tube connections between cryomodules and transfer line





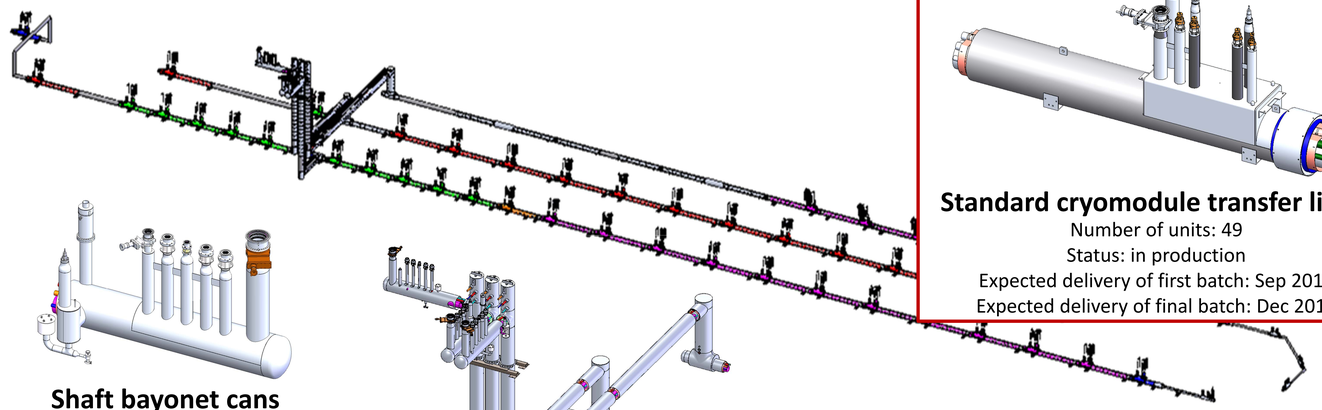
Relief system

The majority of pressure relief valves for the cryogenic distribution system are located in the cold box room near the vertical chase which penetrates the ceiling of the linac tunnel. The relief exhausts are collected into a header and vented to the outdoors through a penetration in the roof of the cold box room. On positive-pressure cryogenic systems, reliefs are connected to the system through diverter valves. A small number of spares are planned to be kept on-hand for relief changeover operations due to a scheduled calibration, a frozen-open valve, etc.

On subatmospheric cryogenic systems, reliefs are captured within a secondary enclosure which is itself protected by a parallel plate relief device. During normal operation the enclosure is isolated from guard vacuum so that a pressure indicator may be used to determine the integrity of the relief valve within.

Work Supported by DOE contract No. DE-AC05-06OR23177

Status and production plan for initial 4K operations



Shaft bayonet cans

Number of units: 3
Status: in design
Expected delivery of final batch: June 2016

Shaft transfer lines

Number of units: 3
Status: in production
Expected delivery of first batch: Aug 2015
Expected delivery of final batch: April 2016

4K cold box bayonet cans

(Not shown)
Number of units: 3
Status: in design
Expected delivery of final batch: Aug 2016

Standard cryomodule transfer lines

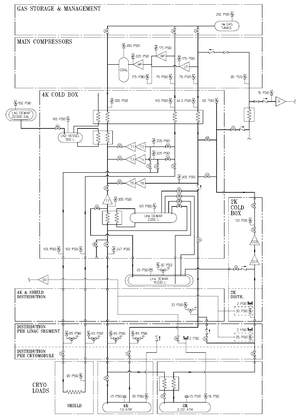
Number of units: 49
Status: in production
Expected delivery of first batch: Sep 2015
Expected delivery of final batch: Dec 2016

FRIB may begin initial 4K commissioning and operation once any one of the three linac segments is assembled within the linac tunnel. These linac segments connect to the refrigerator via independent bayonet cans and are made up of:

- Shaft transfer lines which connect the cold box room to the linac tunnel via a vertical chase approximately 30’ in height.
- Many standard cryomodule transfer line sections, which are produced in a discrete number of lengths matching the lengths of the cryomodules.; these are produced with identical interfaces.
- Interconnecting sections of transfer line including extensions, crossovers, and turnaround units which are used for cooldown.
- Additional sections to support the 4K operation of dipole magnets.

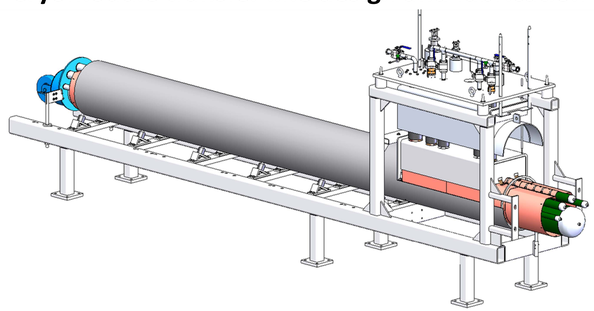
Overall pressure relief strategy for cryogenic distribution system

- Ensure safety in all modes
- Adequately relieve system
- Maximize system integrity
- Reduce risk of contamination
- Minimize helium loss
- Prevent ODH (vent outdoors)



Fabrication of first units

Cryomodule transfer line design and fabrication



An assembly fixture was developed at JLab to fabricate and test the sections of cryomodule transfer line. Using this fixture, two prototype sections of standard cryomodule transfer line were built and supplied to MSU for combined testing with a prototype FRIB cryomodule in the ReAccelerator (ReA) area. Lessons learned from this fabrication experience were incorporated into the final design package, which included build-to-print fabrication drawings and step-by-step assembly and testing procedures. The completeness of this design package, tested with two prototypes, enables any reasonably experienced manufacturer to produce a cost effective product with minimal technical risk.

Three additional assembly fixtures have since been fabricated to support the full production of the 49 cryomodule transfer line sections needed for FRIB. These fixtures have formed the basis of three parallel lines of production which have enabled the rapid fabrication and testing of these transfer lines.

At JLab, two customized fixtures have been developed for the production of the connecting transfer lines between the linac segments and the cold box room. Production of these connecting transfer lines is proceeding.

Presented at the Cryogenic Engineering Conference, Tucson AZ, 28-June to 2-July, 2015 C1PoD