Mechanical and Process Design of the Interface to a 20,000 Liter Liquid Helium Dewar

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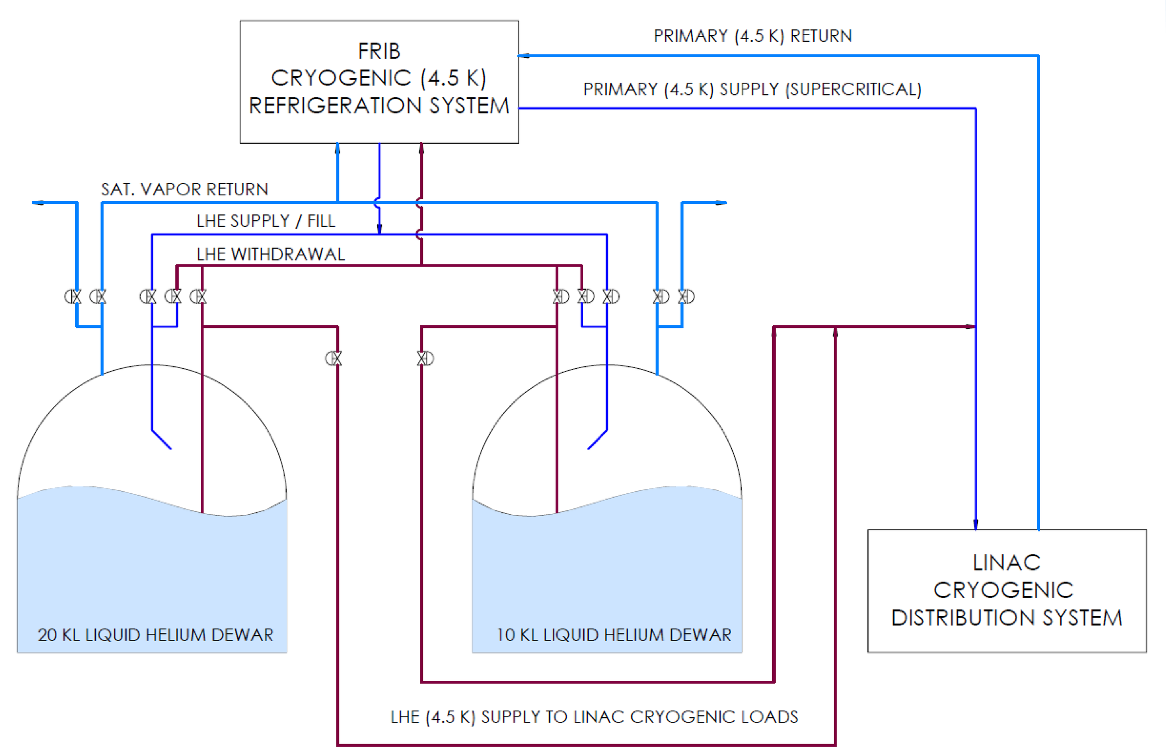
Background Information

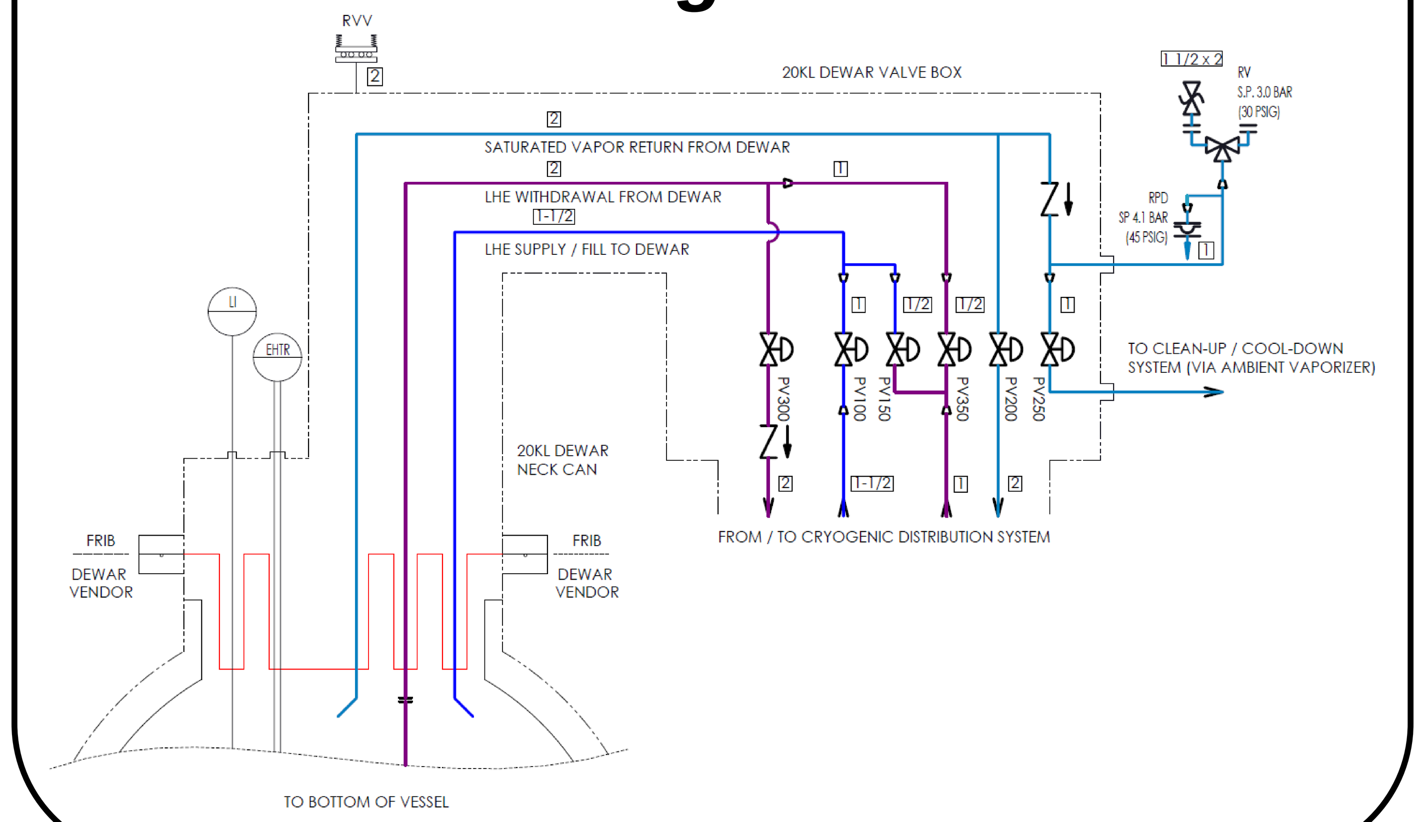
- ❑ The Facility for Rare Isotope Beams (FRIB) at the Michigan State University (MSU) houses a cryogenically cooled (nominally at 4.5 K and 2.0 K) superconducting radio-frequency (SRF) linear accelerator (LINAC) with its associated experimental system.
- ❑ LINAC contains 46 SRF cryo-modules and 4 superconducting dipole magnets. The total liquid helium inventory stored in these cryostats and associated distribution system can be up to 20,000 liters (approx.).
- ❑ An additional 20,000 liters (approx.) of liquid helium inventory is stored in the superconducting magnet cryostats from the experimental system.
- ❑ At present, two 10 kL liquid helium dewars (one for the LINAC cryo-modules, the other for experimental system superconducting magnets) aid the management of liquid helium inventory during operational transients and maintenance periods.
- ❑ It is imperative to maintain sufficient storage capacity to preserve the helium inventory in a large-scale cryogenic facility (*e.g.*, FRIB) during maintenance periods.
- ❑ Based on FRIB helium inventory, a 20 kL liquid helium dewar is procured and integrated to the FRIB LINAC cryogenic system.
- ❑ Traditionally, liquid helium dewars were only used for storage, and were designed with smaller diameter '*neck*' tubes (diameter ~ 100 mm) to minimize the heat leak into the stored liquid helium.
- ❑ To incorporate additional capabilities efficiently and contently, more process pipes need to interact with the vapor and liquid helium in the dewar. So, recent liquid helium dewars in this class (5-20 kL) have been designed with a larger diameter (~300 mm) '*neck*' tubes.

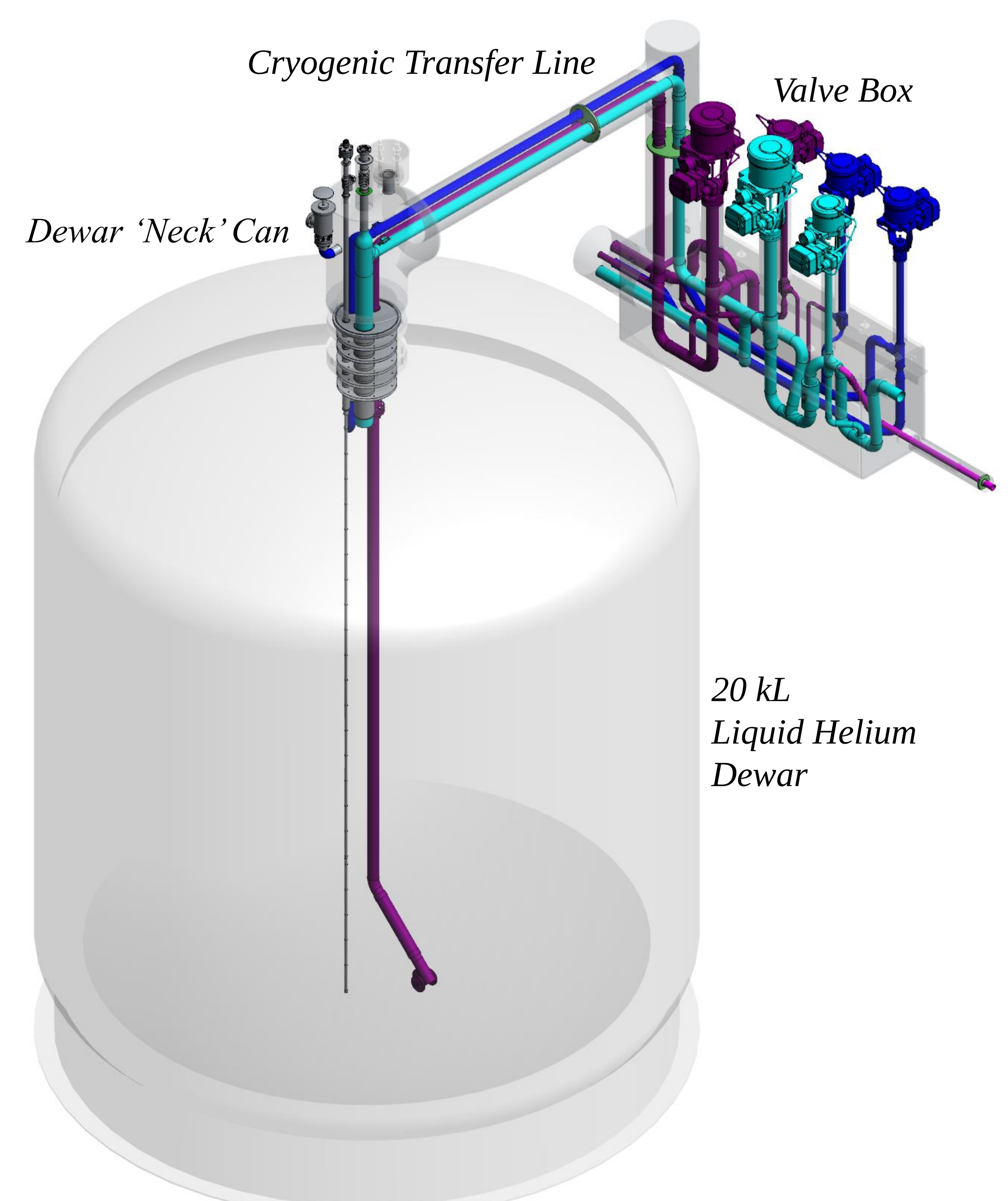
Process Requirement



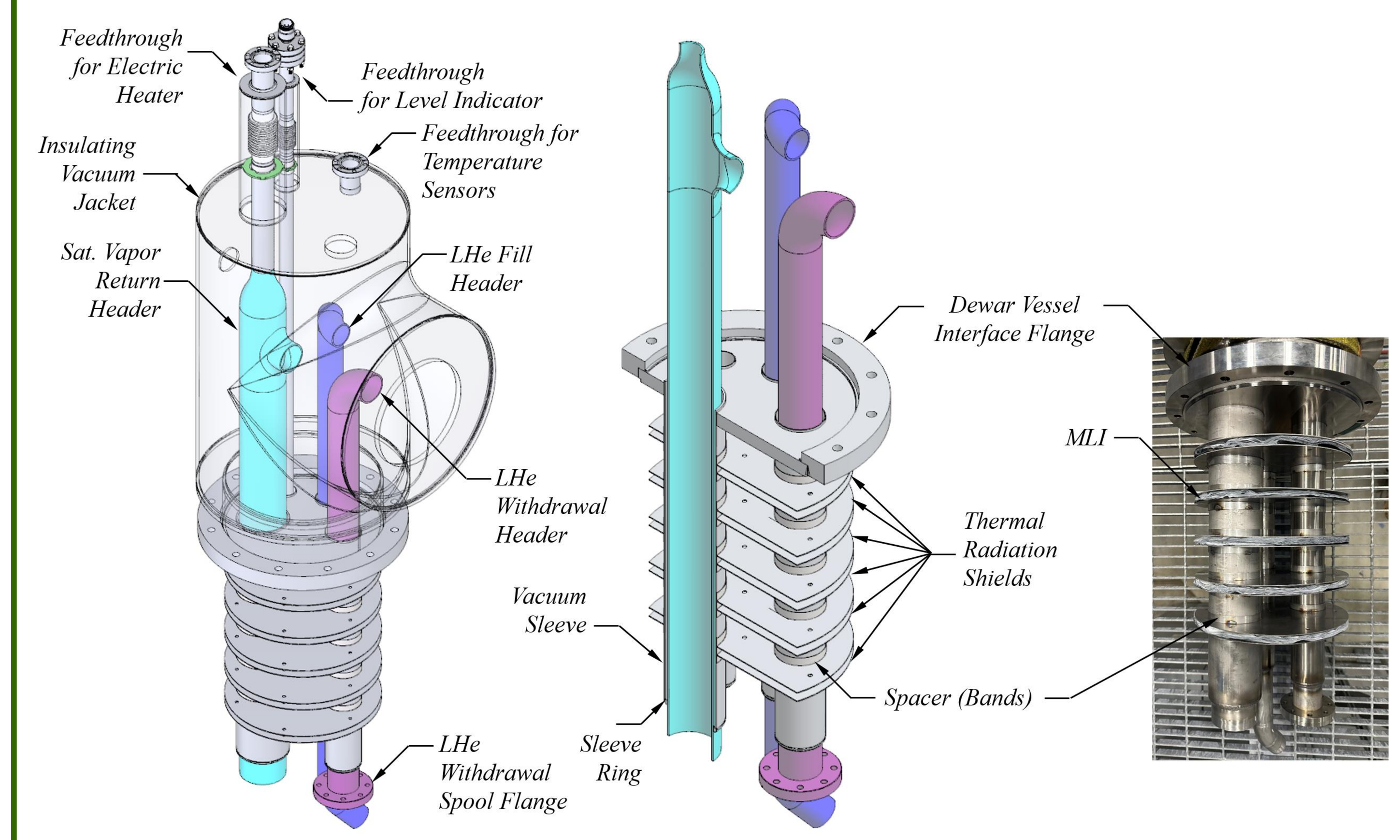
- ❑ The preliminary purpose of the FRIB 20 kL liquid helium dewar is to serve as a storage vessel during maintenance.
- ❑ It should be able to transfer liquid helium to and from the cryogenic distribution and other cryogenic tanks for storage and withdrawal.
- ❑ It should be able to generate saturated vapor helium (boil-off) in case, helium is required in gaseous form. The flash or boil-off (saturated vapour) associated with this transfer process will be recovered by the FRIB cryogenic refrigerator (*i.e.,* will not be vented).
- ❑ This dewar is also required to serve as a cryogenic buffer vessel to handle operational transients (as a backup to the existing 10 kL liquid helium dewar if it is unavailable)

Piping and Instrumentation Diagram



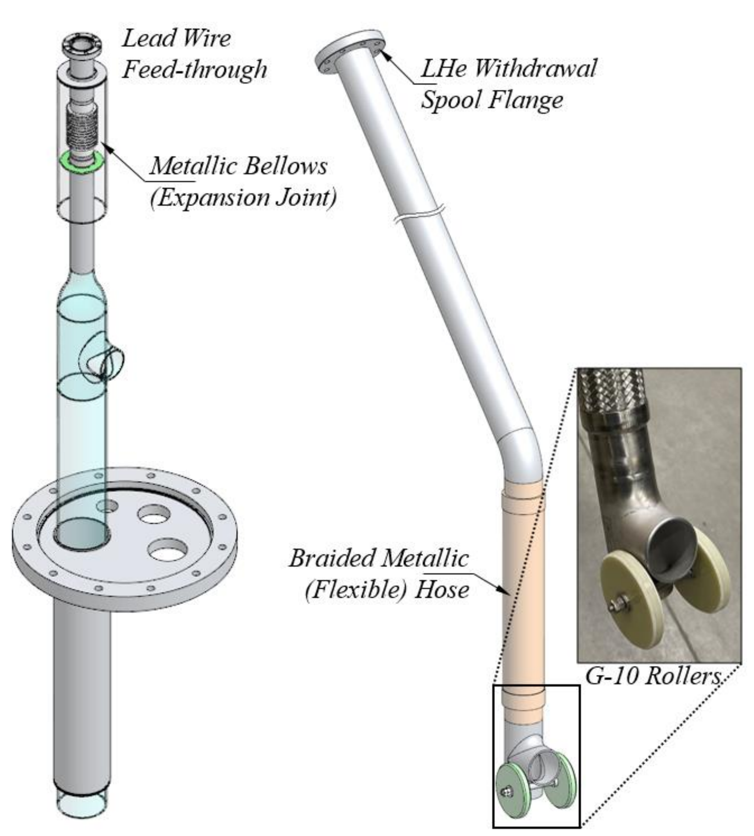


Dewar 'Neck' Can



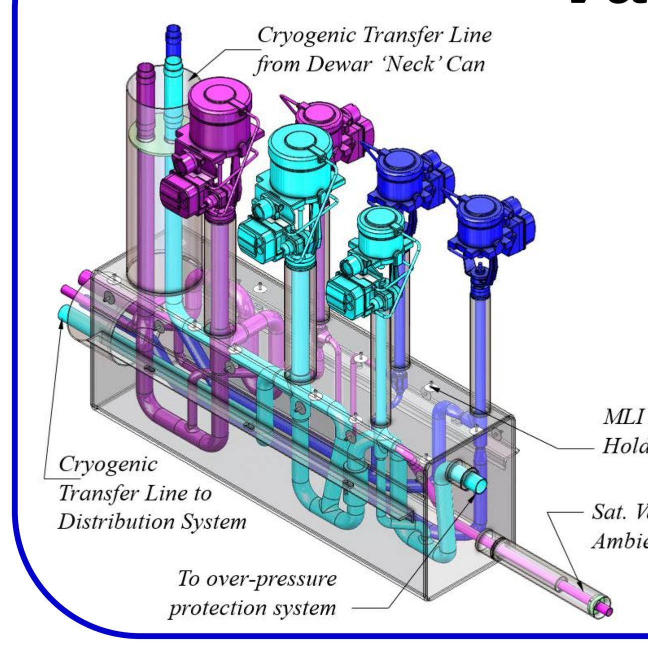
- ❑ Cryogenic fluid (within the dewar) is thermo-mechanically isolated using an interface flange. The three process headers, and the liquid level instrumentation is connected to the dewar through penetrations in the interface flange.
- ❑ Vacuum sleeves are used around each of these penetrations to minimize thermal conduction heat in-leak from the interface flange.
- ❑ 5 layers of radiation shielding are used to minimize radiation heat in-leak to the liquid helium surface. Each layer of the radiation shield is constructed using a MLI blanket sandwiched between two stainless steel plates. The radiation shield diameter is very similar to the '*neck*' tube inner diameter (with appropriate tolerance for installation).

Miscellaneous Components



- ❑ Each pipe in (un-shielded) cryogenic transfer line, are individually wrapped in MLI, and the overall structure is then wrapped using a MLI blanket.
- ❑ Nylon rope is used to avoid direct thermal short between the two MLI blankets.
- ❑ Externally finned rod type electric heaters are used. Multiple heating elements are installed for redundancy. Heater max. capacities are chosen in such a way that only half the rated capacity usage is required.
- ❑ The electric heaters are installed in the dewar via the sat. vapor return header.
- ❑ Fiber-glass epoxy composite (G-10) rollers are added to the liquid withdrawal pipe end with a flexible (braided) metallic hose.

Valve Box



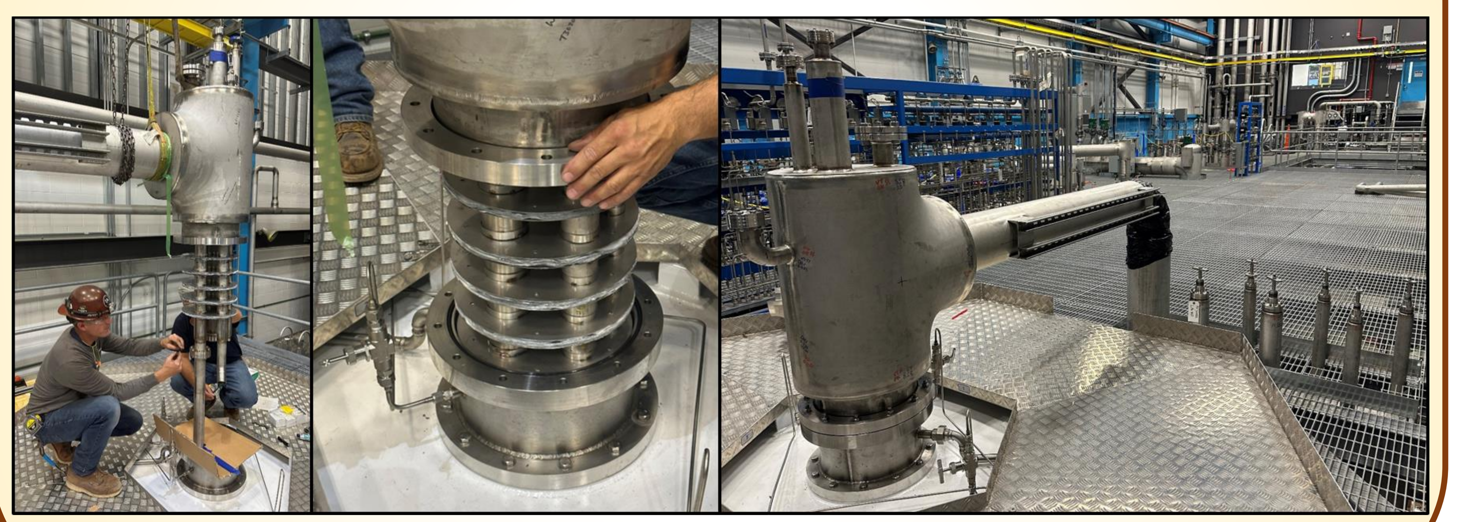
- ❑ Consists of six pneumatically actuated cryogenic valves, the cryogenic process headers, and the associated branches
- ❑ The two cryogenic transfer line branches penetrating the valve shares a common insulating vacuum with the dewar '*neck*' can.
- ❑ Vacuum sleeve type barriers are used in the rest of the penetrations.
- ❑ Rod type holders are used to attach MLI blankets at the inner surface of the insulating vacuum jacket (box).

Estimated Heat In-Leak

#	Component	Estimated Heat In-Leak [W]	Description
1	Heater Lead Wire	1.76	4x AWG 14 copper wiring, 0.8 m conduction length
2	Heater Feed-Through	0.04	50 mm diameter (avg.) stainless steel bellows with 0.3 m conduction length
3	Liquid Level Probe	0.14	6.5 mm diameter G-10 rod, 1.0 m conduction length
4	Thermal Radiation	0.16	Shield plate temperature 94.2 K, view factor 0.56, effective emissivity 0.013
5	Vacuum Sleeve		Stainless Steel Tubes
a	*LHe Fill*	0.59	50 mm diameter, 0.5 m conduction length
b	*Sat. Vapor Return*	1.10	95 mm diameter, 0.5 m conduction length
c	*LHe Withdrawal*	0.73	62 mm diameter, 0.5 m conduction length
	Total	**4.53**	LHe (Bath): 1.04 W; Vapor (Superheat) : 3.49 W

- ❑ Conservative analysis considering a 90% filled vessel.
- ❑ Approx. 1.0 W is estimated to be added to the liquid bath.
- ❑ Estimated liquid helium inventory loss or boil-off is approx. 0.2% of the total 20,000 liters per day.
- ❑ This rate is solely due to the heat in-leak from the dewar '*neck*' can components. An additional 0.1-0.2% is expected due to thermal radiation to the vessel surface.

Fabrication and Installation



Summary

Several design aspects of a liquid helium dewar interface – starting from process requirements, to fabrication and installation are discussed. With elevated pricing of helium, such designs are becoming increasingly crucial. The design methodology discussed in this paper can serve as a reference for future interface designs for helium storage dewars.

FRIB FACILITY FOR RARE ISOTOPE BEAMS

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