Mechanical design of the multi-channel liquid helium cryogenic transfer lines

ICEC/ICMC
29th International Cryogenic Engineering Conference
International Cryogenic Material Conference 2024
July 22-26, 2024, Geneva, Switzerland

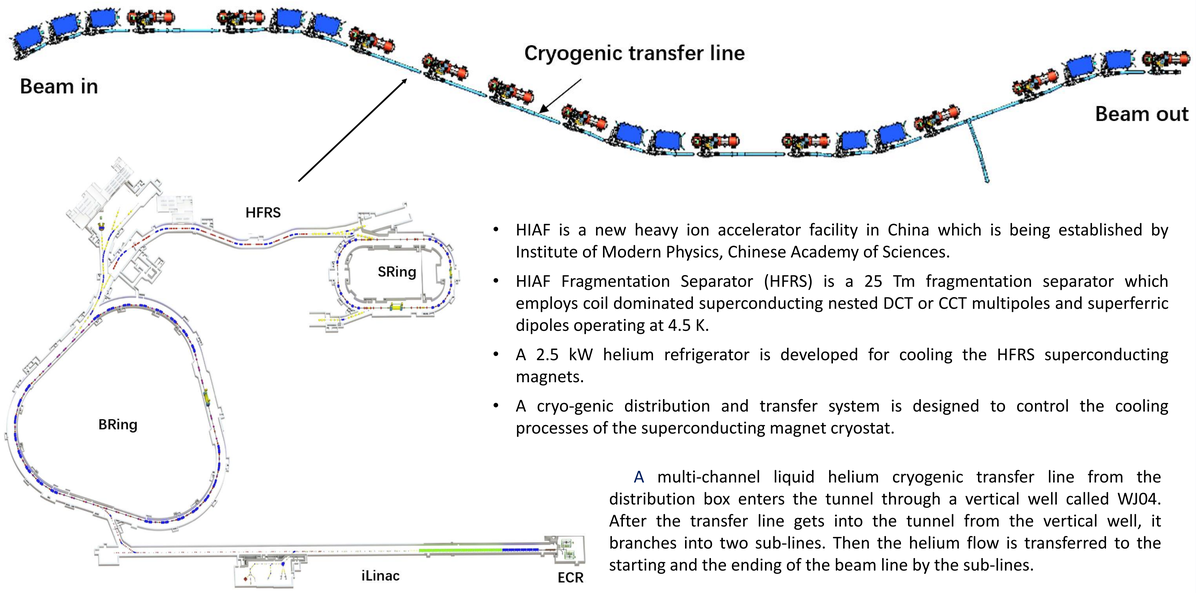
Li Zhu[1], Dongsheng Ni[1], Lishi Wang[1], Pei Wang[2], Qian Cheng[2], Yue Cheng[1], Xudong Wang[1], Xiangqi Qin[1], Guoqing Wang[1], Qinggao Yao[1]

[1]Institute of modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China ; [2] VACREE Technologies CO.,LTD, Hefei, 230088, China

Abstract

The cryogenic distribution system for the High Intensity Heavy-ion Accelerator Facility (HIAF) under construction at IMP has about 146 m cryogenic transfer lines. These transfer lines will be installed between a distribution box on the surface and the connection valve boxes located 12.3 m underground in the tunnel. The transfer line consists of 21 modules. Due to space limitations the lines may have complex routings and require several angular sections. The lines consist of a vacuum jacket, a thermal screen and five internal helium headers. Specific fixed and sliding supports and compensation systems were devised for each line to allow for thermal contraction of the cryogenic pipes. This paper presents the mechanical design of the multi-channel liquid helium cryogenic transfer lines along with fabrication details.

Introduction

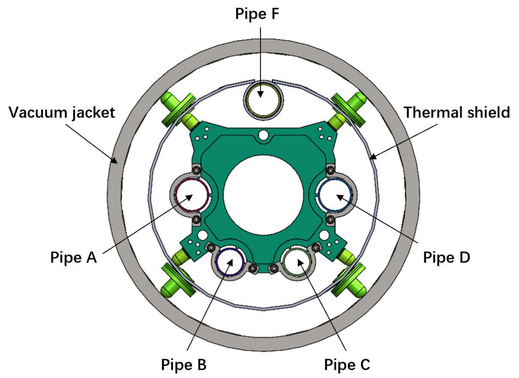


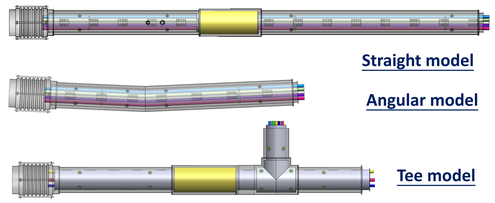
- HIAF is a new heavy ion accelerator facility in China which is being established by Institute of Modern Physics, Chinese Academy of Sciences.
- HIAF Fragmentation Separator (HFRS) is a 25 Tm fragmentation separator which employs coil dominated superconducting nested DCT or CCT multipoles and superferric dipoles operating at 4.5 K.
- A 2.5 kW helium refrigerator is developed for cooling the HFRS superconducting magnets.
- A cryo-genic distribution and transfer system is designed to control the cooling processes of the superconducting magnet cryostat.

A multi-channel liquid helium cryogenic transfer line from the distribution box enters the tunnel through a vertical well called WJ04. After the transfer line gets into the tunnel from the vertical well, it branches into two sub-lines. Then the helium flow is transferred to the starting and the ending of the beam line by the sub-lines.

Mechanical Design

- The Cryogenic transfer line with the diameter of 325 mm and length of 146 mm consists of a vacuum jacket, a thermal shield and five internal helium pipes.
- Due to space limitations the lines are mainly composed of a Tee model, five Straight models and fifteen Angular models.
- Figure shows a cross section of a five-channe cryogenic transfer line. Its all process lines are surrounded by a cylindrical thermal screen wrapped with radiative foils. The thermal shield is connected with the Pipe F, which works as a thermal sink for radiative heat loads absorbed by the shield.
- The supporting system of the cryogenic transfer line is composed of internal and external supporting structures. The internal supporting structures include fixed and sliding supports.
- Cryoline thermal contraction compensation systems employ metallic flexible hoses and natural compensation loops.

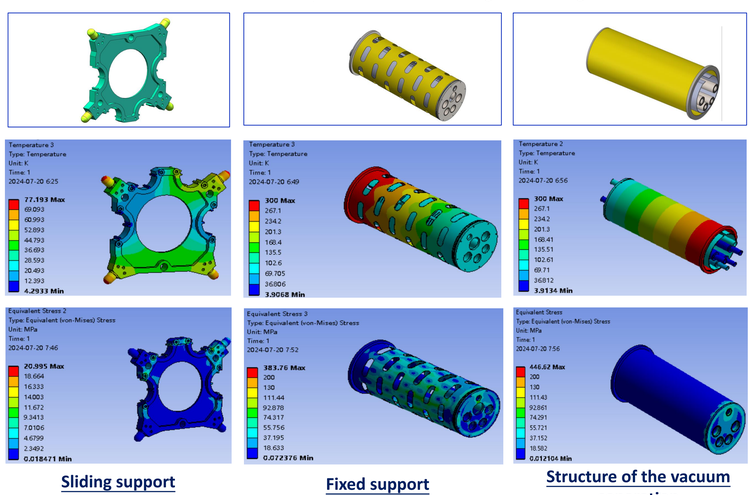




Process pipes	Nominal temperature [K]	Nominal pressure [Bar]	Design pressure [Bar]	Main outer diameter [mm]
A (return)	4	1.3	20	38
B (supply)	4	3	20	32
C (supply)	50	17.5	20	32
D	4-80	-	20	38
F(return)	75	16.5	20	38

Analysis

- Static analysis of the cryogenic transfer line was performed by using ANSYS software. The result shows that it can be well meet the requirement of heat leakage and strength.



Sliding support | Fixed support | Structure of the vacuum separation

Fabrication and erection

- Cryoline modules are assembled from the inner to the outer parts. Their fabrication usually consists of the following steps:

1) Welding of process line sections and vacuum jacket
2) Installation of process line sliding supports, Winding MLI on the process lines
3) Installation of thermal screen, Winding MLI on the thermal screen
4) Inserting the process line sections with their thermal screen into the vacuum jacket, Connection of the process line fixed support to the vacuum jacket
5) Preparation of the cryoline modules for transportation

Sliding supports on the straight module process lins | Aluminium thermal screen of the straight module | MLI radiation foils wrapped on the straight module thermal screen | Straight module assembled

Status

- High Intensity Heavy-ion Accelerator Facility was officially started in December 2018. The whole desired construction time is 7 years.
- The transfer line with the length of 146 mm consists of 21 modules.
- The lines have been completed the mechanical design. And the analysis result shows that it can be well meet the requirement of heat leakage and strength.
- Most of the multi-channel liquid helium cryogenic transfer lines are now ready for the final assembly and test.

References:

[1] J C Yang et al. High Intensity heavy ion Accelerator Facility (HIAF) in China[J]. Nuclear Instruments and Methods in Physics Research B,2013,317:263-265.
[2] D S Ning et al. Conceptual Design of Cryogenic System for HFRS of HIAF Project [C]. In: Presented at ICEC28-ICMC 2022, ATSTC 70, pp. 321–328, 2023.