RECENT PROGRESS OF CRYOGENIC SYSTEM FOR 40T HYBRID MAGNET

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background

A hybrid magnet facility is planned for the High Magnetic Field Laboratory of Chinese Academy of Sciences in Hefei, China. The facility will be capable of producing more than 40T steady field on axis in a 32mm working bore. The superconducting outsert, which is fully based on Nb_3Sn cable-in-conduit conductor (CICC) technology will provide 11T field in 800 mm room temperature bore. The magnet system whose total cold mass is 11 tonnes will be cooled with forced flow of supercritical helium at 4.5 K.

summary

As very important parts of the helium cryogenic system, the helium refrigerator and recovery system have been in operation for three years, and totally supply more than 100 thousand liters liquid helium for experiments of other superconducting and cryogenic facilities. The recovery ratio of gas helium exceeds 90%. All other manufacture work related is close to the end, and will be assembled at this August. Commissioning and combined commissioning with the superconducting magnet system will be carried out at the end of this year.

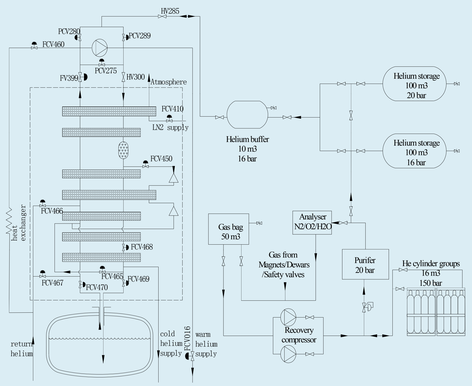
LHe plant

4.5K Heat load (W) requirements on the LHe plant

	Stand-by	10A/s cycling	Nominal operating
Valve box	9.5	10.58	10.58
Magnet cryostat	39.6	132.9	43.9
Busline	7	8.08	8.08
Total	56.1	151.56	62.56
×1.5	84.15	227.34	93.8

*joule heat of electrical joints is included in each segment above.

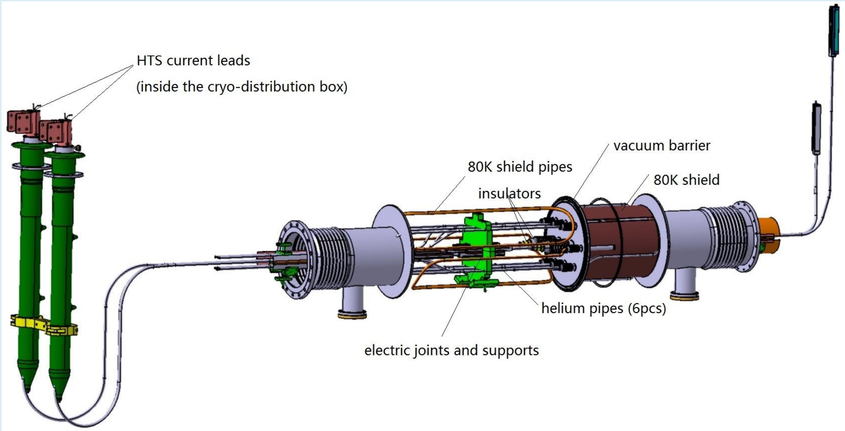
◆The capacity of the LHe plant is 360W@4.5K in refrigeration mode or 110L/hr in liquefaction mode.
◆The LHe plant has been in service at **liquefaction mode** for three years since after commissioning which was finished at early 2012.
◆In each year, more than 40,000 Liters liquid helium are produced and supplied to other cryogenic or superconducting facilities in the Lab.
◆The gas evaporated is recovered through Gas Recovery System, then purified and filled to storage tanks.



Busline and HTS current leads

Inside the busline there are four pipes for helium feeding, two pipes for helium return, a pair of busbars and electrical joints. A vacuum barrier is located at the intermediate section in order to ensure the independence of the different vacuum system of magnet cryostat and cryo-distribution box.

A pair of HTS current leads which are mounted in the cryo-distribution box are connected with the two terminals of the coils through a pair of busbars. Helium from coil A &.B go into the busbars for cooling, then out at the cold ends of the current leads. The HTS sections are cooled by liquid Nitrogen, and the warm copper ends are cooled by city water. Temperature sensors and quenching detecting wires are installed for condition monitoring.



Cryogenic circuit

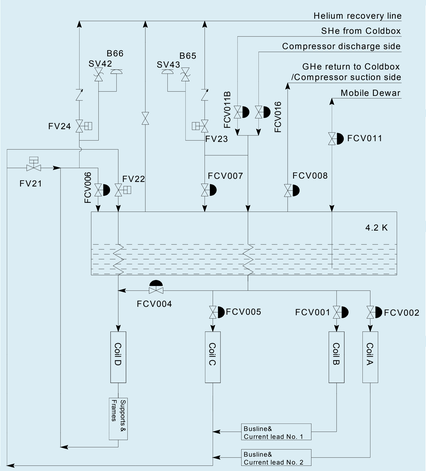
Superconducting coils

◆The superconducting outsert includes four series-connected subcoils, and the three inner coils (Coil A,B and C) are layer wound, while the outer one (Coil D) is pancake wound.
◆The coils are totally divided into 26 cooling-channels which are hydro-dynamically connected in parallel.
◆The inlet supply pressure is 5 bar, meanwhile the outlet pressure is stabilized at 3 bar by PID controller.

Mass flow rate calculation of each channel

channels	Inlet pressure (bar)	Pressure drop (bar)	length (m)	Mass flow rate (g/s)
A-1	5	2	154.54	1.28
A-2	5	2	160.11	1.26
B-1	5	2	181.26	0.77
B-2	5	2	186.79	0.76
C-1	5	2	208.05	0.72
C-2	5	2	213.58	0.70
C-3	5	2	219.11	0.69
C-4	5	2	224.64	0.67
D1-18	5	2	182.32	0.62

Cryo-distribution box



Nominal operating mode
The supercritical helium with temperature of 4.5 K is divided into four flows and get into the four coils separately. The mass flows are regulated by four cryogenic control valves. The return helium from coils flows together to the J-T valve FCV006. The upstream and downstream pressure of the coils is stabilized automatically by the two J-T valves of FCV006 and FCV007.

Fast charge/discharge mode
To increase the mass flow rate of helium inside each cooling channel at higher ramping rate , a series-parallel connection is applied (FV21 and FV22 open, FCV004 closed). The total 26 channels is divided into two groups: 8 channels in high field (Coil A,B and C) and 18 channels in low field (Coil D). The 4.5K supercritical helium firstly go through Group 1, then enter Group 2 before re-subcooled to 4.5K by helium bath.

Cooldown/warmup mode
At temperature above 80 K, the maximum temperature difference among any parts should not exceed 50 K. Therefore, cold gas is mixed with a little of warm gas from HP side of main compressor before it flow into coils. The return gas can go optionally with its temperature to LHe buffer, heat exchanger of coldbox or LP side of the main compressor.

Failure mode
Three classes of protection method are configurated for pressure relief at magnet quenching or such serious situations as loss of vacuum, unprotected quenching, water-cooled insert trip. The setpoints of the automatical valves (FV23/24) are 6 bar. The setpoints of the safety valves (SV42/43) are 16 bar. The setpoints of the burst disks (B65/66) with diameter of 20 mm are 19 bar, and they are able to ensure that the maximum pressure in the coils do not exceed 20 bar at the most serious failure mode.

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