Presentation ID: C3Po1B-04

Development of an 18 kW@4.5 K & 4 kW@2 K Helium Refrigerator

Jing Li[1], Gang Zhou[1,], Liqiang Liu[1,2], Zhengyu Li [1], Junjun Du[2], Jihao Wu[1,2], Jinzhen Wang[1], Linghui Gong[1,2]*

[1] Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing, 100190, China

[2] University of Chinese Academy of Science, Beijing 100049, China

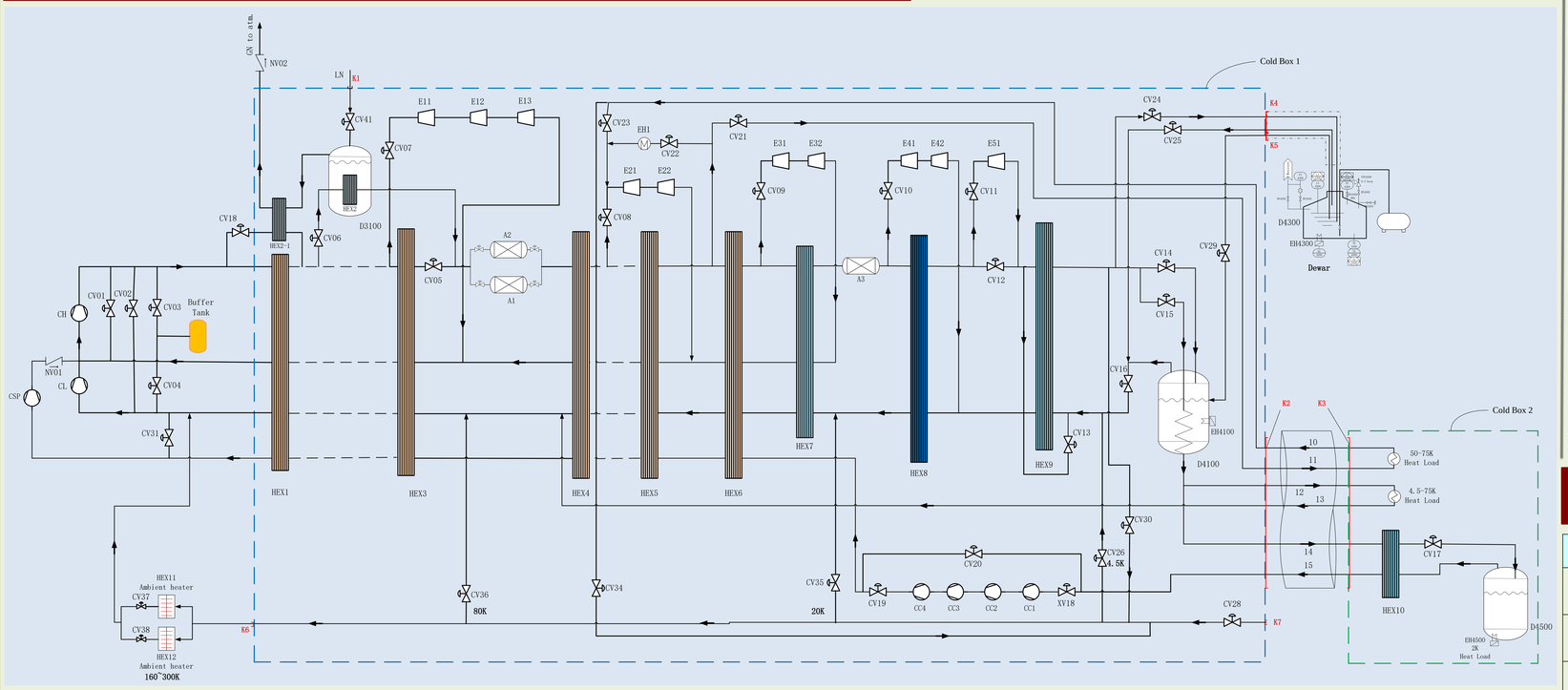
[*]Corresponding author: zhougang@mail.ipc.ac.cn

Technical Institute of Physics and Chemistry, Chinese Academy of Sciences

Abstract

An 18 kW@4.5 K & 4 kW@2 K helium refrigerator is being developed in China by the Technical Institute of Physics and Chemistry, CAS. This large-scale helium refrigerator provides different cooling capacity at the 50-75 K, 4.5-75 K and 2 K levels. This helium refrigerator works based on Claude cycle refrigeration process, which uses 5 sets of turbines (10 turbines totally) to bring the temperature down to 4.5 K. Four cold compressors are arranged in series to pump gaseous helium from atmospheric pressure to 0.03 bar in order to decrease the temperature of 2 K helium bath from 4.5 K down to 2 K. A set of subatmospheric pressure compressors is used to compress subatmospheric helium gas downstream from cold compressors to medium pressure 4.05 bar and is connected directly to high pressure compressors. This paper provides an overview on the process design, system design and preliminary component design results in the development of this 18 kW@4.5 K & 4 kW@2 K helium refrigerator.

Process Flow Diagram of the 18 kW@4.5 K & 4 kW@2 K Helium Refrigerator



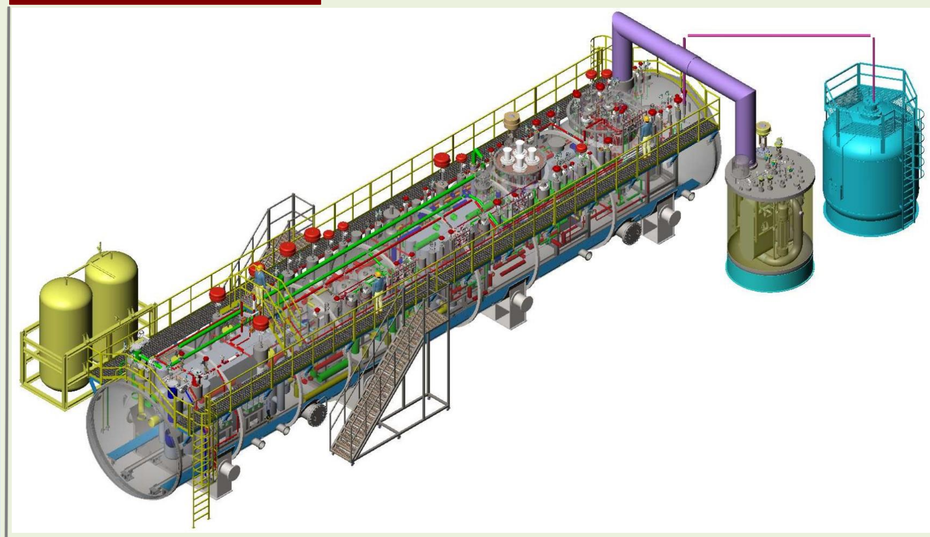
- 2 K heat load > 4400 W; 4.5-75 K heat load > 4300 W; 50-75 K heat load > 13500 W.
- Is able to service three different consumers with different cooling capacity at the 50-75 K, 4.5-75 K and 2 K levels.
- Two cold boxes: the main cold box and the thermal loads test cold box. The main "all-in-one" cold box combines a 4.5 K refrigerator cycle with a 2 K subcooler cycle.
- Design a recovery line to recover cooling power for different thermal loads.

Designed Parameters of Key Components: Compressors and Cold Compressors

Item	High pressure compressor	Low pressure compressor	Subatmospheric pressure compressors
Mass flow rate (g/s)	1736.26	627.26	255.00
Inlet pressure (bara)	4.05	1.05	0.40
Inlet temperature (K)	298.00	296.00	296.00
Outlet pressure (bara)	19.00	4.05	4.05
Outlet temperature (K)	300.00	300.00	300.00
Energy consumption (kW)	2716.70	864.46	854.86
Adiabatic efficiency (%)	85.00	80.00	70.00

Item	CC1	CC2	CC3	CC4
Mass flow rate (g/s)	255.00	255.00	255.00	255.00
Inlet temperature (K)	3.228	5.735	8.783	12.355
Inlet pressure(kPa, static pressure)	2.90	8.12	17.10	30.80
Outlet temperature(K)	5.735	8.783	12.355	16.408
Outlet pressure(kPa)	8.12	17.10	30.80	50.00
Adiabatic efficiency(%)	65.00	65.00	65.00	65.00
Energy consumption(kW)	3.305	4.017	4.719	5.363

Design of Cold Box



- The Cold-box of the 18 kW@4.5 K & 4 kW@2 K helium refrigerator is a horizontal vacuum insulated cold box with a diameter of 4.2 m and a length of 28 m.
- This cold box has a skid-mounted structure.
- The 10 static gas bearing turbines and 4 centrifugal cold compressors are installed vertically on the cold-box, which is convenient for installation and maintenance.
- Maintenance platforms are set both outside and inside of the cold box for maintenance.

Designed Parameters of Key Components: Turbines

Item	E11	E12	E13	E21	E22	E31	E32	E41	E42	E51
Mass flow rate (g/s)	80.00	80.00	80.00	260.00	260.00	420.00	420.00	450.00	450.00	433.10
Inlet pressure (bara)	18.79	12.00	7.00	17.99	9.00	17.99	7.00	17.99	6.00	17.99
Inlet temperature (K)	130.01	113.04	95.58	72.32	58.77	23.49	17.96	13.98	10.06	6.53
Outlet pressure (bara)	12.00	7.00	4.08	9.00	4.13	7.00	4.15	6.00	1.23	13.00
Outlet temperature (K)	113.04	95.58	80.77	58.77	46.54	17.96	15.39	10.06	6.32	6.50
Shaft power (kW)	7.23	7.38	6.23	18.95	16.83	11.64	5.21	7.05	5.81	0.80
Adiabatic efficiency(%)	80.00	80.00	80.00	78.00	78.00	72.00	72.00	70.00	65.00	52.00

Conclusion and Outlook

- An overview on the process design, system design and preliminary component design results in the development of an 18 kW@4.5 K & 4 kW@2 K helium refrigerator has been proposed in this paper.
- This 18 kW@4.5 K & 4 kW@2 K helium refrigerator has been designed and is being assembled and will be commissioned next year.
- This 18 kW@4.5 K & 4 kW@2 K helium refrigerator will be the largest helium refrigerator designed in China so far.

Supported by the fund of Strategic Pilot Science and Technology Projects of Chinese Academy of Sciences (Grant No. XDC10040000)