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Integrated design of an 18kW@4.5K/4kW@2K helium cryogenic refrigeration system for CiADS

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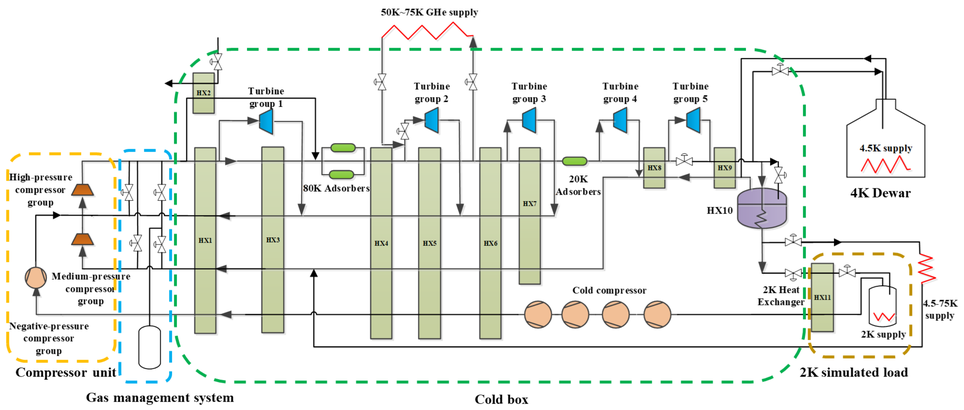
Abatract

Large cryogenic refrigeration systems are the only means to achieve a low-temperature environment for large scientific devices. As an important part of the China Initiative Accelerator Driven System (CiADS), an 18kW@4.5K/4kW@2K large helium cryogenic refrigerator is mainly used to cool down superconducting magnetic cryostats. It has been designed by Technical Institute of Physics and Chemistry, Chinese Academy of Sciences at the end of 2023. This paper gives an overview on the performance characteristics and working principle of the 18kW@4.5K/4kW@2K large helium cryogenic system. The integrated design of this helium cryogenic refrigerator is introduced. The overall engineering layout design based on the experimental building at Zhongshan Institute of Advanced Cryogenic Technology has been completed. The design result has been used to guideline the engineering and manufacturing phase. Its commissioning tests will be carried out and completed at the end of this year.

Working principle and Performance characteristics



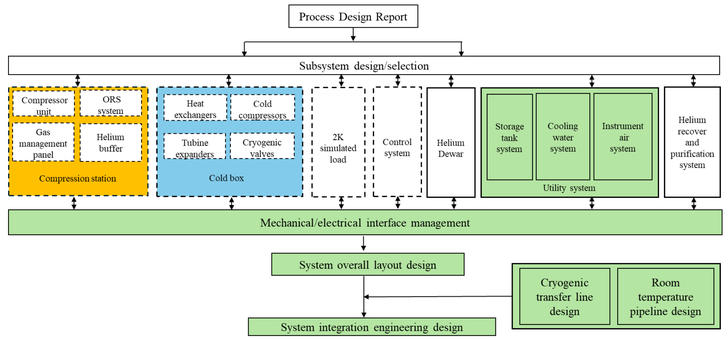
The schematic diagram of 18kW@4.5K/4kW@2K large helium cryogenic refrigerator

- The compressor unit is composed of three stages of compressor groups, and realizes steady pressure at 0.36 bar, 1.05 bar, 4.05 bar and 19 bar together with the gas management system.
- The cold box includes five groups of turbine expanders and four cold compressors.
- 4K Dewar is used for gas-liquid separation after throttling, and storage the liquid helium to supply the cool capacity at 4.5K.
- 50K helium gas after the second stage of turbine is supplied.
- Subcooled liquid helium after HX10 is throttled into the 2K simulated load Dewar, achieving 2K cooling output and depressurization by the cold and negative-pressure compressors.
- Subcooled liquid helium after HX10 is also supplied as 4.5K-75K cooling capacity.

The performance characteristics of 18kW@4.5K/4kW@2K helium cryogenic refrigerator

Work mode	2K heat load [W]	4.5K heat load [W]	4.5-75K heat load [W]	4.5-20K heat load [W]	50-75K heat load [W]	Equivalent heat load [W]
2K mode	≥5000	--	≥5000	--	≥15000	≥5400@1.8K
4.5K mode	--	≥4000	--	≥24000	≥15000	≥18000@4.5K

Integrated design



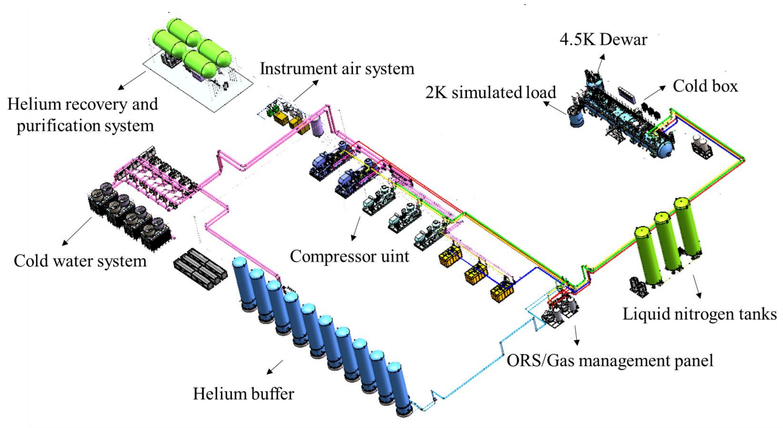
The integrated design process flowchart

The design parameters of the compressor unit

Parameter	High-pressure compressor group	Medium-pressure compressor group	Negative-pressure compressor group
Supply voltage (V)	10k	10k	380
Pressure (bar)	4 -19	1.05 - 4.05	0.36 - 4.05
Motor power of one machine (kW)	2240	450	375
Cooling water flowrate of one machine (t/h)	374	18	12

The design parameters of utility systems

Description	Unit	Data
Cooling water flowrate	m^3/h	~1330
Cooling water temperature	℃	<16
Cooling capacity	kW	~7000
Instrument air flowrate	m^3/min	~32
Instrument air pressure	MPa	>0.6
Volume of liquid nitrogen tank	m^3	~300
Pressure of liquid nitrogen supply	MPa	0.3
Volume of helium buffer	m^3	~1000



The overall layout design of the 18kW@4.5K/4kW@2K system

Conclusion

- To meet the requirements of CiADS, an overview on the integrated design of an 18kW@4.5K/4kW@2K large helium cryogenic refrigeration system is given.
- Based on our design, this system can supply cold capacity at 2K, 4.5K, 4.5K to 75K, and 50K to 75K.
- The integrated design process is planned, with the designs for the compressor unit, cold box, utility systems, and other components completed.
- The overall engineering layout design of this helium cryogenic system based on the experimental building at ZIACT has been completed.
- The design result has been used to guideline the engineering and manufacturing phase.