Conceptual design of the cryogenic system for large scale superconducting Coil Test

Zhigang Zhu, Ming Zhuang, Liangbing Hu, Ping Zhu, Linhai Sheng and Keping Wu*
Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 231031, P.R. China
Email: zzg@ipp.ac.cn

MT 26 International Conference on Magnet Technology
Vancouver, Canada | 2019
ID: Wed-Mo-Po3.03-04

1. Introduction

• With the development of superconductivity technology, more and more large scale superconducting coils or magnets are used in the scientific installation like tokomaks, particle accelerators and colliders.
• Before installation, each coil is needed to cold test at nominal operating current and cryogenic temperature before tokomak assembly to check its electromagnetic, stability, thermal and hydraulic performance.
• Hence, a helium refrigerator with an equivalent cooling capacity of 5 kW at 4.5 K for large scale coil test facility is proposed. It can provide 3.7 K ,4.5 K supercritical helium for coil, 50 K cold helium with a 10 g/s flow rate for High Temperature superconducting (HTS) current leads and 50 K cold helium with a cooling capacity of 1.5 kW for thermal shield.

2. Structure of cryogenic system and cooling requirements

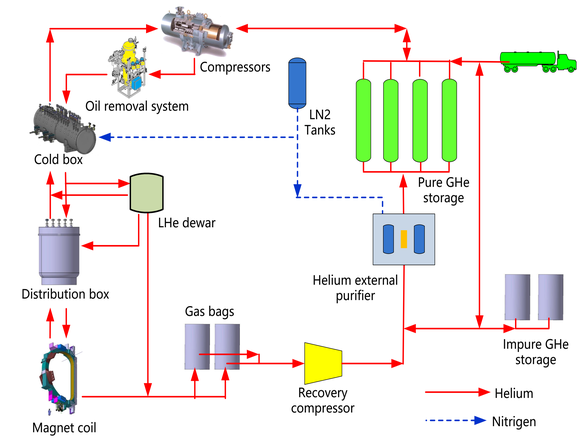

Fig 1. cryogenic system of large scale coil test facility

Refrigeration Requirements:

- 50 K helium at 16 bara with a refrigeration power of 1.5 kW for thermal shields
- 50 K helium at 4 bara with 10 g/s mass flow rate for the High Temperature superconducting (HTS) current leads
- Supercritical helium at 4.5 K and 4 bara with a refrigeration power of 2.5 kW for magnet coil and its structures
- Supercritical helium at 3.7 K and 4 bara with a refrigeration power of 1.5 kW for coil or cryopump test.

3. Thermodynamic design of helium refrigerator

- Two stage compression.
  LP/MP/HP:1.05/4/20 bara
- Modified Claude cycle with liquid nitrogen precooling
  5 dynamic gas bearing turbines with eddy current braking
  11 aluminum plate fin heat exchangers
- The lowest refrigeration temperature is 3.8K
  by 1 cold compressor
- Double 80K adsorbers, single 20K adsorber

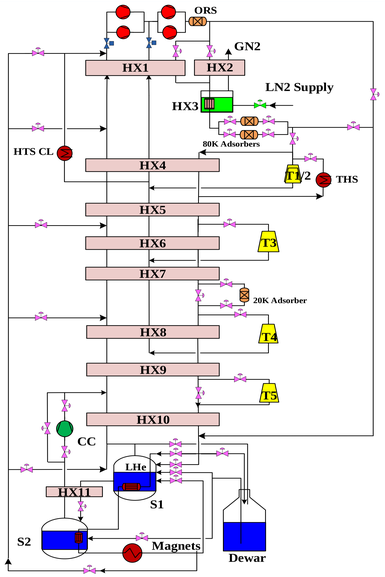

Fig 2. Process flow of the helium refrigerator

Fig 3. T-S diagram of the helium refrigerator

Table 1. Performance of the helium refrigerator

Item	Unit	Value
Cooling capacity at 3.7K	kW	1.5
Cooling capacity at 4.5K	kW	2.873
TS cooling capacity (50-70K)	kW	1.5
HTS CL cooling capacity (50-300K)	g/s	10
Equivalent cooling capacity at 4.5K	kW	5.17
Liquid nitrogen consumption	g/s	69.54
Mass flow rate of HP compressors	g/s	430
Electricity Power	MW	1.3
FOM	%	25.09

4. Summary

The concept design of cryogenic system with the equivalent cooling power of 5kW at 4.5K has been carried out to ensure the demand of large scale superconducting coil test at cryogenic temperature. One cold compressor is applied to get the temperature of 3.7 K.