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Design of distribution system for cryogenic subcooled research platform

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ABSTRACT

To improve the efficiency of the Experimental Advanced Superconducting Tokamak (EAST) subcooled helium cryogenic system, the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP), is manufacturing a cryogenic subcooled research platform (CSRP). The CSRP system consists of a helium refrigerator with a capacity of 1200 W/4.5 K + 720 W/3 K and a distribution system that provides a supercritical forced flow cooling by using a helium circulation pump and 3 K subcooled helium generated using a two-stage cold compressor (CC) for the superconducting magnet and other devices. The distribution system not only distributes refrigeration to the cold components, but also serves as a test platform for some key equipment, such as the helium pump, CC, and venturi flow meter.

1. Introduction

With the development of cryogenic technology and the requirement for stronger magnetic fields, increasing numbers of helium cryogenic systems with a cold compressor (CC) are being used to obtain subcooled/superfluid helium [1–5]. The Experimental Advanced Superconducting Tokamak (EAST) at Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP) is an advanced, steady-state plasma physics experimental device. The cryogenic system of EAST is designed with a capacity of 1050 W/3.5 K + 200 W/4.5 K + 13 g/s liquid helium (LHe) + 13 kW/80 K, which is approximately equivalent to a helium refrigerator with a capacity more than 2 kW at 4 K [6]; the toroidal field (TF) coils of EAST are cooled using supercritical helium to work at 3.5 K. Subcooled helium (3.5 K) is obtained using an oil ring pump (ORP) at ambient temperatures by pumping saturated LHe. However, the helium refrigerator is usually operated in the 4.4 K refrigeration mode, and it is difficult to ensure reliable long-term operation of the subcooled helium cryogenic system [7]. As the preliminary technical storage for the EAST subcooled helium improvement project, ASIPP is manufacturing a CSRP system to distribute refrigeration to cold components and test crucial equipment, including the CC, helium pump, and venturi flow meter. In the present work, the design of the distribution system of CSRP is discussed. The distribution system consists of a distribution box, two compressors, a helium pump, and 14 cryogenic control valves. A schematic flow sheet of the distribution system is shown in Fig. 1.

Liquid helium is precooled as it flows through a HX into the subcooled LHe vessel. The temperature of the subcooled LHe vessel decreases when the CC pumps saturated helium gas. The gas helium flows through the HX, CC, and the compressor in one cycle. To reach the subcooled temperature of 3 K, two CCs can produce the required pressure ratio (about 4.3).

2. Cryogenic distribution box

As shown in Fig. 2, the cryogenic distribution box, a vertical vacuum dewar, consists of 80 K thermal shields cooled by liquid nitrogen, a subcooled liquid helium vessel, and a sub-atmosphere heat exchanger (HX). From the viewpoint of developing the 1.8 K superfluid helium system in future, two standby interfaces for CCs and a standby interface for the helium pump in the distribution box are provided. The cold box consists of an outer box and an inner box. The interfaces of the transfer lines, measuring leads, and other equipment are set atop the outer box, but the interfaces of the transfer lines to the cold components and safety valves are set on the flank of the outer box, and the vacuum interface is set on the inner box. The specifications of the cold box are listed in Table 1.

2.1. Thermal shields

The 80 K thermal shields are used to reduce heat radiation from the vacuum vessel to the subcooled helium vessel. The copper thermal shield is divided into three parts, namely, outer thermal shield, right-lower thermal shield, and left-lower thermal shield, which are cooled

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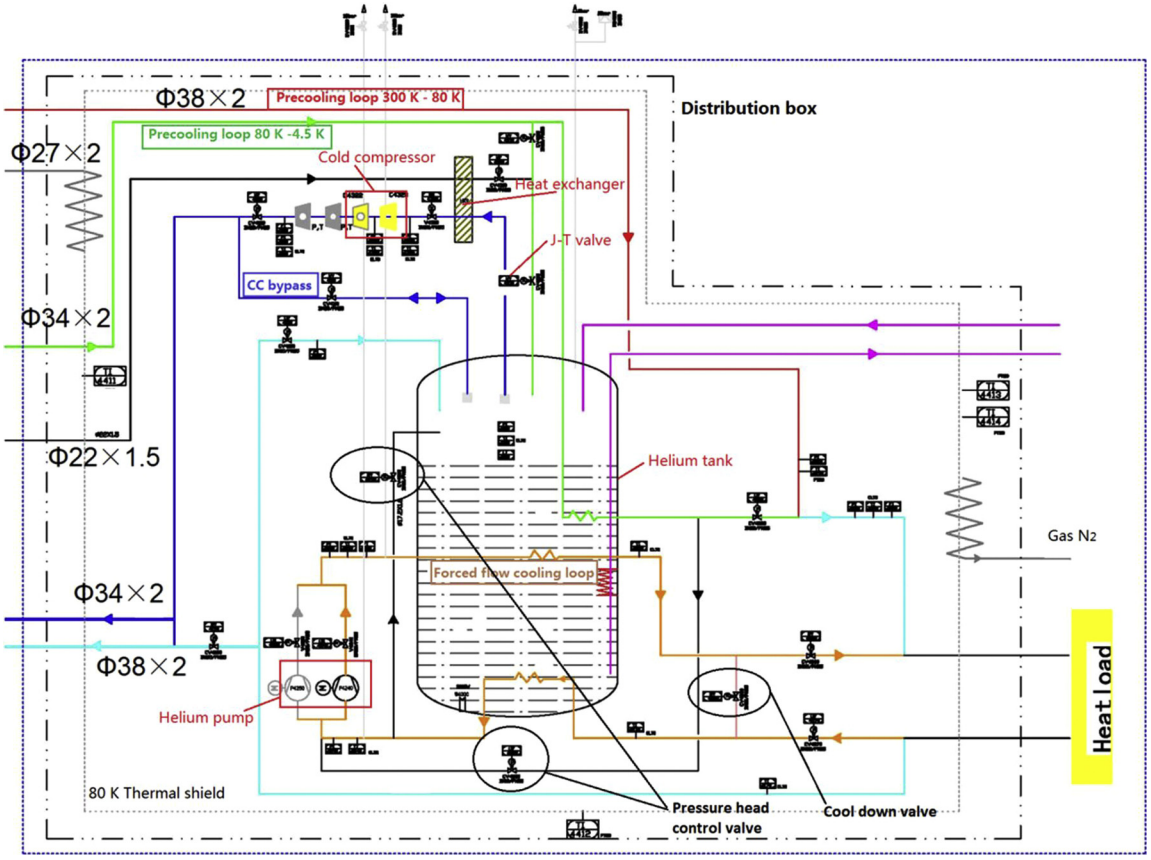

Fig. 1. Schematic flow sheet of the distribution system.

Fig. 2. Distribution box.