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Performance of cold compressors in a cooling system of an R&D superconducting coil cooled with subcooled helium

S. Hamaguchi*, S. Imagawa, N. Yanagi, K. Takahata, R. Maekawa, T. Mito

National Institute for Fusion Science, 322-6 Oroshi, Toki, Gifu 509-5292, Japan

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Abstract

The helical coils of large helical device (LHD) have been operated in saturated helium at 4.4 K and plasma experiments have been carried out at magnetic fields lower than 3 T for 8 years. Now, it is considered that the cooling system of helical coils will be improved to enhance magnetic fields in 2006. In the improvement, the helical coils will be cooled with subcooled helium and the operating temperature of helical coils will be lowered to achieve the designed field of 3 T and enhance cryogenic stabilities. Two cold compressors will be used in the cooling system of helical coils to generate subcooled helium. In the present study, the performance of cold compressors has been investigated, using a cooling system of R&D coil, to apply cold compressors to the cooling system of helical coils. Actual surge lines of cold compressors were observed and the stable operation area was obtained. Automatic operations were also performed within the area. In the automatic operations, the suitable pressure of a saturated helium bath, calculated from the rotation speed of the 1st cold compressor, was regulated by bypass valve. From these results, stable operations will be expected in the cooling system of helical coils.

Keywords: Subcooled helium; Cold compressor; Surge; Stable operation; Automatic control

1. Introduction

The helical coils of the large helical device (LHD) have been operated by saturated helium at the temperature of 4.4 K and the pressure of 120 kPa [1]. So far, plasma experiments have been carried out at the magnetic field lower than 3 T successfully [2]. However, the operating field has not reached the nominal field of 3 T [3]. So, it is considered that the helical coils of LHD will be cooled with subcooled helium to achieve the field of 3 T and enhance the cryogenic stability. To use subcooled helium as a coolant for the helical coils of LHD, an R&D superconducting coil, wound with superconductors of the helical coils, was tested in subcooled helium [4]. From the results, it is expected that the designed magnetic field of 3 T will be achieved in case of LHD if the helical coils will be cooled down with subcooled helium [5]. Two cold compressors were installed in the cooling system of the R&D coil to lower supplied helium temperature [6]. It is very important that these two cold compressors are operated stably and safely. If the cold compressors enter the surge region

* Corresponding author. Tel.: +81 572 58 2116; fax: +81 572 58 2616.
E-mail address: hamaguchi@LHD.nifs.ac.jp (S. Hamaguchi).

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and then trips occur, there is every possibility of damaging equipments and reducing machine time for plasma experiments of LHD [7]. In the present study, the performance of cold compressors was investigated in the cooling system of the R&D coil for stable and safe operations, especially a surge limit of cold compressors. A control method for automatic operations was also tested, in order to operate cold compressors without a surge. In this paper, the control method of cold compressors to operate stably and safely will be discussed.

Table 1
Main parameters of cooling system for R&D test facility

Supplied subcooled He	
Mass flow	5.0–10.0 g/s
Pressure	120 kPa
Inlet temperature	3.1 K
Cold compressors	
Inlet pressure	23.0 kPa
Inlet temperature	3.0 K
Outlet pressure	120 kPa
Outlet temperature	7.39 K
Overall pressure ratio	5.2
Mass flow	15.9 g/s

2. Experimental setup

Fig. 1 shows a flow diagram of the cooling system of the R&D coil. The cooling system consists of a saturated helium bath with a heat exchanger to generate subcooled helium, two centrifugal cold compressors with gas foil bearings, a bypass valve to adjust mass flow of the cold compressors, a current lead tank above the R&D coil and heaters to control the level of liquid helium. The saturated helium bath was evacuated by two cold compressors in series, from 120 kPa (4.4 K) to 23 kPa (3.0 K). The pressure in the saturated helium bath and the mass flow rate of the cold compressors were regulated by bypass valve, during cooling down and warming up. In the steady state at 3.0 K, the inlet pressure and temperature of 1st cold compressor are 23 and 3.0 K while the outlet pressure and temperature of 2nd cold compressor are 120 kPa and 7.39 K, respectively. The overall pressure ratio is 5.2. The mass flow of the cold compressors is 15.9 g/s. Supplied helium was subcooled up to 3.1 K at the heat exchanger in the saturated helium bath. The subcooled helium was supplied from the bottom of the R&D coil and then flowed out to the current lead tank above. The mass flow rate of subcooled helium was 5–10 g/s throughout the present experiments. These parameters of the cooling system are summarized in Table 1.

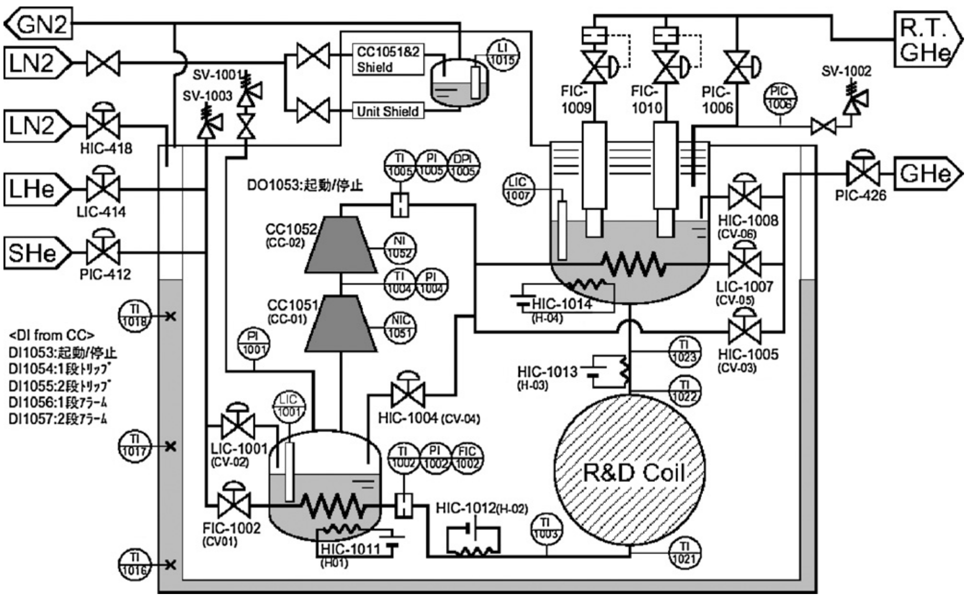

Fig. 1. Flow diagram of the cooling system for the R&D coil.