§5. Operation and Control of the Subcooling System in the 11th LHD Experiment Campaign

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Helical coils of the Large Helical Device (LHD) are large scale superconducting magnets for heliotron plasma experiments. The helical coils have been cooled by subcooled helium from 2006 in order to lower the operating temperature of the helical coils. In this report, the operation and control of the subcooling system are described in the 11th LHD experiment campaign.

Fig. 1 is schematics of the subcooling system for the helical coils. It also shows the operating method of the subcooling system. Helium pressure, temperature, mass flow rate and liquid level are measured for the operation as shown in the figure. The subcooling system have two operating mode, which are a waiting mode and a subcooling mode. In the waiting mode, a supply valve of the helical coils kept 65 % open, an outlet valve of the cold compressors kept fully open and a bypass valve kept 70 % open. The LHe level of the saturated helium bath was automatically controlled by an inlet valve of the bath. The set value of rotation speeds of the cold compressors was 0 %. The power of the heater in the saturated helium bath was 0 W. Consequently, subcooled helium of 50 g/s at 4.0 K could be supplied stably. From the above condition, the bypass valve was limited to 5 % and then the rotation speeds of both cold compressors were increased linearly while the mass flow rate of gas helium through the cold compressors was regulated by the heater in the saturated helium bath manually. The mass flow rate was kept 16-18 g/s to prevent the cold compressors from entering surge and choke. Consequently, designed mass flow rate of the subcooled helium of 50 g/s at 3.0 K could be supplied stably when the set value of the rotation speed of the cold compressors was 95 % and the mass flow rate was 16 g/s. In the 11th LHD experiment campaign, the operating time over 3,000 hours was achieved without problems in the subcooling mode.

Fig. 2 shows the LHe level and temperature profiles at the HC outlet during excitations (from 50 min. to 65 min.). The LHe level of the outlet header of the helical coils was normally controlled by heaters, attached on the surface of the outlet pipe of the helical coils. In the waiting mode (upper), the LHe level increased slightly and then it decreased, because the helical coils were cooled with the saturated helium and the heat by AC losses during the excitation caused the boiling in the helical coils. In this case, the change of the LHe level was small and the recovery time was within ten minutes. Thus, it was possible to control the LHe level by the heaters automatically. In the subcooling mode (lower), however, the LHe level increased greatly, because the helical coils were cooled with the subcooled helium and the volume of the subcooled helium increased by the temperature rise of the subcooled helium in the helical coils. In this case, the change of the LHe level was larger and the recovery time far exceeded two hours. Thus, the automatic control of the LHe level could not be utilized because it reduced the total mass of the subcooled helium. So, the uniform heat input was applied to this case because it was essential to maintain the total mass of the subcooled helium.

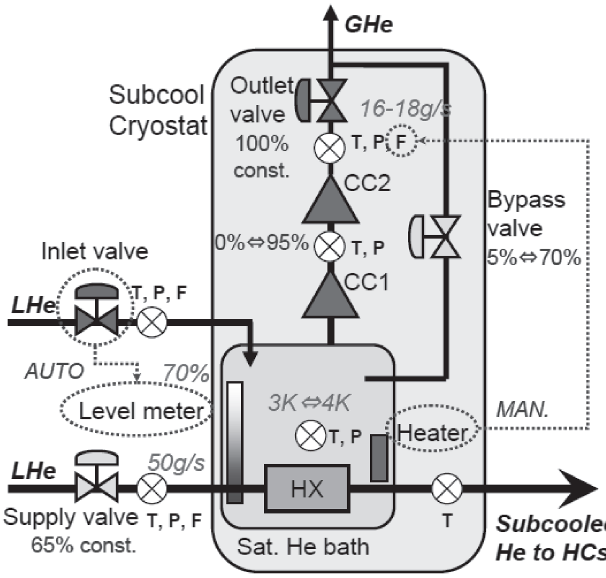

Fig. 1. Schematics of the LHD subcooling system.

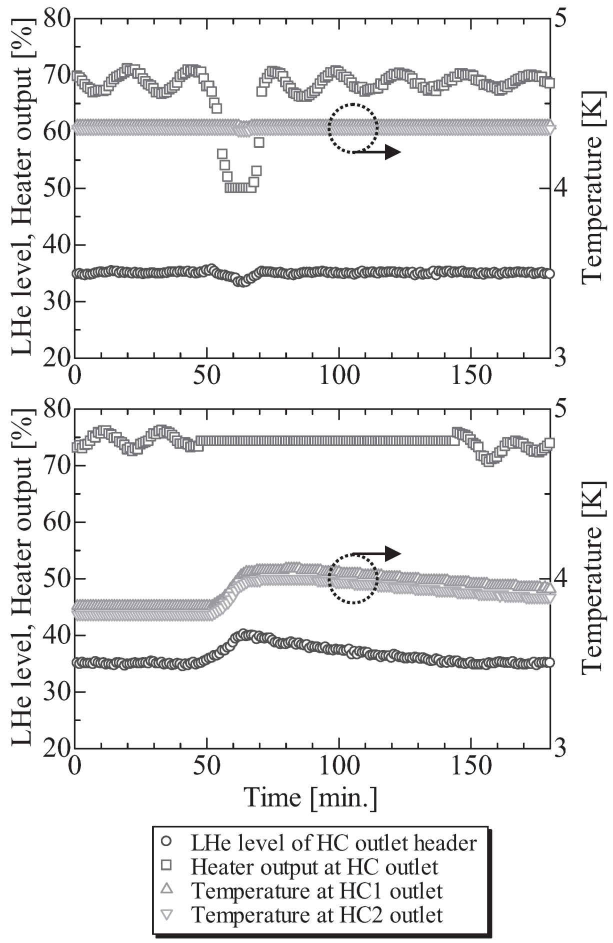

Fig. 2. Time traces of LHe level and temperature at the HC outlet during excitation. (Upper: waiting mode, Lower: subcooling mode)