§4. Mitigation of Mass Flow Change of Cold Compressors by Heater in Saturated Helium Bath during Quick Discharge

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In 2006, a helium subcooling system was installed in the cooling system of the LHD helical coils (HC) to improve the cryogenic stability of the coils by lowering the operating temperature.[1] In the system, the liquid helium supplied to the coils has been subcooled at a heat exchanger in a saturated helium bath. The bath temperature is reduced by a series of two centrifugal cold compressors (CC) with gas foil bearing and is kept at constant temperature in accuracy of 0.01 K by controlling helium flow through the CC automatically by a heater in the bath. After the installation, 3.2 K subcooled helium at the nominal mass flow rate of 50 g/s has been supplied stably to the coils and the total time of the subcooling operation is about 12,000 hours. However, when a quick discharge of the coils occurred in 2009, the subcooling system worked unsteadily due to the great influence of the pressure increase in the coil cases with the AC loss of about 4 MJ. In the present study, the mitigation of the mass flow change of the CC by the heater during the discharge is reported.

Fig. 1 shows the schematics of the subcooling system. In the subcooling operation, the CC outlet valve (OV) kept fully open and the bypass valve (BV) slightly open. The liquid helium level of the saturated helium bath was automatically controlled to be 70 % by the inlet valve of the bath (IV). The set value of the rotational speed of the CC was 95 %, corresponding to the rated rotational speed. The CC flow rate was automatically controlled to be 16 g/s by the heater in the saturated helium bath, so that the CC could work at the rated operating point.[2]

Fig. 2 shows the time variations of the supplied helium flow of the HC and the outlet pressure of the CC with the helium flow of the CC after the discharge started. The CC outlet pressure was increased up to 135 kPa by the buildup of the back pressure due to the increase of the HC outlet pressure because the CC outlet and the HC outlet were connected. The HC flow rate was also decreased greatly and the helium evaporation by the heat exchange was lowered significantly. Consequently, the CC flow rate was drastically reduced to 12.0 g/s by the both influence in spite of the CC flow control by the heater after quick discharge. However, it was found that the minimum CC flow rate was estimated at 6.1 g/s, when the evaporation by the heater was deducted from the measured CC flow rate (See Fig. 3). The CC flow rate is out of the stable operation range of the CC because the range is between 12 g/s and 20 g/s from previous performance tests. As the results, the compressor surge could be avoided thanks to the mitigation of the CC flow reduction by the automatic flow controlling of the CC with the heater.

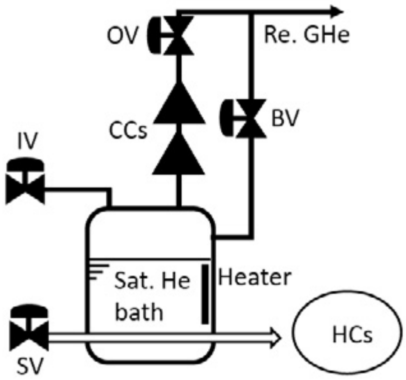

Fig. 1. Schematics of the subcooling system with a series of two centrifugal cold compressors.

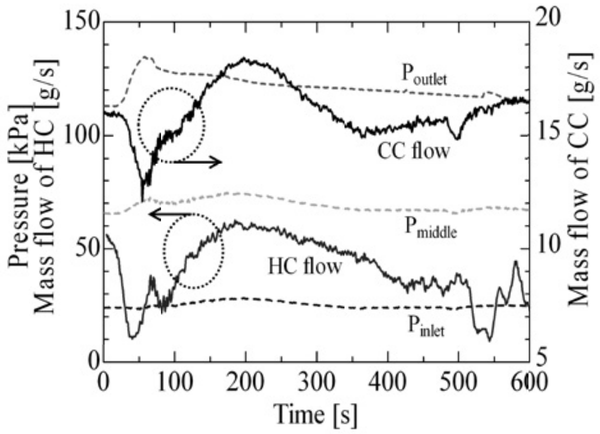

Fig. 2. Time variations of the HC flow rate and the CC outlet pressure with the CC flow rate after the discharge started.

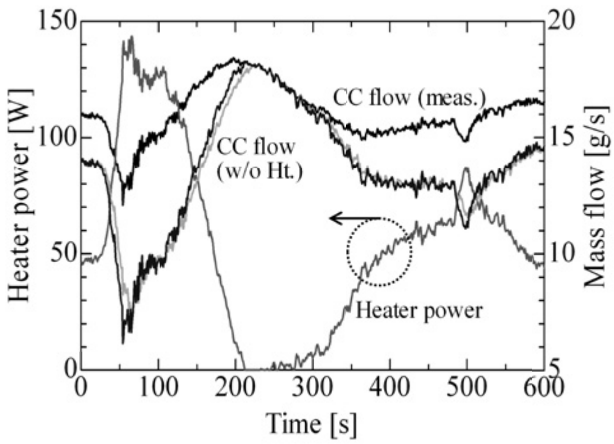

Fig. 3. Time variations of the CC flow rate without the helium evaporation by the heater.

1) S. Hamaguchi et al., Advances in Cryogenic Engineering, **53B** (2008) 1724-1730.

2) S. Hamaguchi et al., Fusion Science and Technology, **58** (2010) 581-585.