§1. Optimization of the Control of the Subcooling System of the LHD

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The cooling system of the LHD helical coil has been modified. We changed the cooling method from pool-cooling to subcooling in order to reduce the coil temperature and to improve its performance. A schematic diagram of the subcooling system is shown in Fig.1. A two-stage cold compressor has been introduced for generation of 3 K saturated helium. Subcooled helium is generated having a heat exchange between the 3 K saturated helium. We equipped a bypass line with a valve and a heater to control the helium mass flow rate through the cold compressor. The objectives of this study are to clarify an optimal control scheme of the cold compressor and to establish a compressor-protection sequence for an emergency. Therefore, we investigated on the characteristics of the modified cooling system.

At first we have made clear understanding about the relation between the cold compressor characteristics and the opening degree of the bypass valve and the input power of the heater for various cold compressor turbine rotation speeds.

Figure 2 (a) and (b) show characteristics diagrams of the 1st and 2nd-stage of the cold compressor. The marks of ○ and ● indicate the results for the cases that the mass flow rate was controlled with the bypass valve and with the heater, respectively. For the case of the heater controlling, we can see from these figures that this compressor shows similar characteristics to those obtained from the previous R&D of the subcooling system. This fact leads a confirmation that this compressor works on a designed performance under the condition of 95 % of set-up value of the rotation speed. On the other hand for the case of the bypass valve controlling, the compressor shows different characteristics from the normal characteristics. These characteristics are caused by the fact that the high temperature gas exhausted from the 2nd-stage of the compressor flows into the inlet of the 1st-stage through the bypass line. From these results, it is decided that the compressor is controlled with the heater during the normal operation.

For the next step, we carried out experiments that the rotation speed of the turbine was decreased with a constant rump rate in order to establish a sequence of quick decrease in the rotation speed for an emergency. The experimental results of helium mass flow rate and controlled parameters are shown in Fig.3. We used not only the heater controlling but also the bypass valve controlling except the high rotation speed period expecting less period for the decrease with keeping an enough helium flow rate. Owing to the bypass valve controlling, we could operate the compressor that returns to the standby mode from the rated rotation speed mode in about 40 minutes keeping the enough flow rate that does not induce surging (more than 12 g/s).

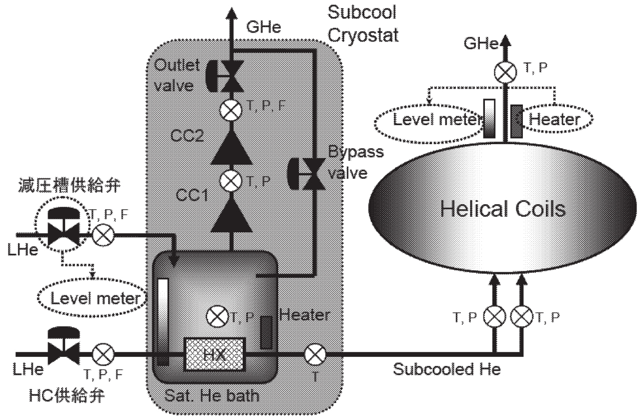

Fig. 1 Subcooling system for the LHD

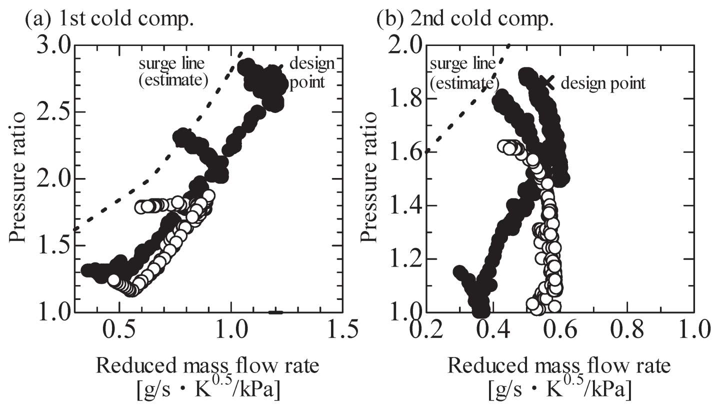

Fig. 2 Performance curve of cold compressors

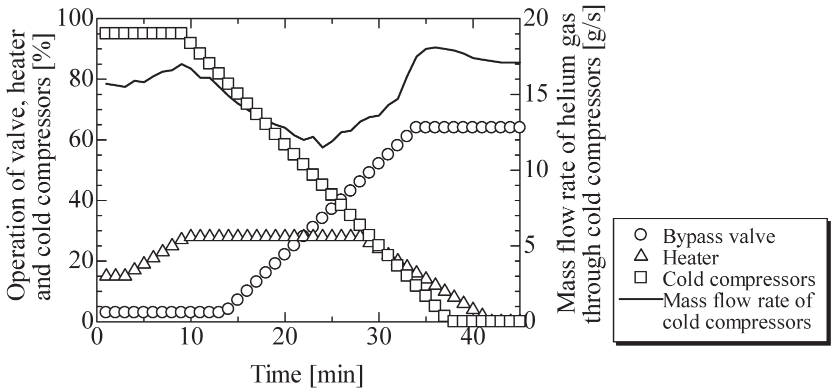

Fig. 3 Operation and mass flow rate of cold compressor system during ramp down test of cold compressors.