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

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Studies on the control of the subcooling system of the LHD have been carried out since 2006. At first, we confirmed about the characteristics of the subcooling system and established the operating scheme that 3.2 K subcooled helium is stably supplied at 50 g/s. Secondly, we found out a smooth transition process between the stand-by mode (@ 4 K cooling) and the subcooling mode (@ 3 K cooling), aiming at an automatic operation of the subcooling system. For the next step of this study, we have investigated on an operation for a fast transition process in order to establish a fast shut-down mode of the cold compressors for emergency.

A schematic diagram of the control equipments in the present subcooling system is shown in Fig. 1. The rotation speed of the cold compressor turbines is about 1500 rps in the subcooling mode and it is about 700 rps in the stand-by mode. The opening degrees of the bypass valve are about 5 % and 70 % at the subcooling mode and the stand-by mode, respectively.

In the case of emergency, the liquid helium inlet valve for the saturated helium bath is closed. The cold compressors have to be stopped before the liquid helium in the bath dries out, because the evaporated helium gas is essential for the stable operation of the cold compressors. On the other hand, it is not desirable that the cold compressors are stopped abruptly from the subcooling mode taking into account of damages etc. Therefore, we examined the operation that the rotation speed is decreased as fast as possible from 1500 rps to 700 rps at first keeping the stable condition, and then stopped the cold compressors completely.

In order to estimate the time period that the liquid helium level in the bath decreases from 70 % to 40 % after the liquid helium inlet valve is closed, we measured the lowering speed of the helium level. The result is shown in Fig. 2. Helium mass flow rate of the cold compressors is controlled to be 18 g/s in this measurement. The cold compressors work stably at the mass flow rate around 18 g/s. We have estimated from Fig. 2 that the time period will be about 8 minutes.

From the above result, we can say that the rotation speed of the cold compressors is desirable to decrease from 1500 rps to 700 rps within 8 minutes for emergency. In the present study, we performed the test that the rotation speed was decreased in 20 minutes and 15 minutes, respectively. The time period for the normal transition process is 30 minutes. We applied the automatic control function for the helium flow through the compressors with the heater in the saturated helium bath. The time traces of variable parameters in the period of the transition process are shown in Fig. 3. The helium flow rate of the cold compressors is successfully controlled in the range of 17.8 – 18.9 g/s. Moreover, we cannot find any remarkable changes of the flow control characteristics when the transition period was shortened. These facts lead the expectation that the present automatic control method can be applied for the faster transition process *e.g.* emergency case.

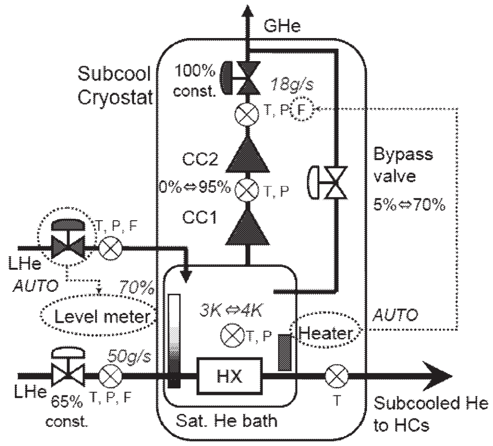

Fig. 1 Schematic diagram of the control equipments.

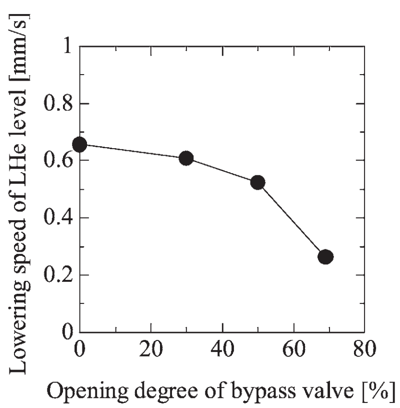

Fig. 2 Lowering speed of liquid helium level in the

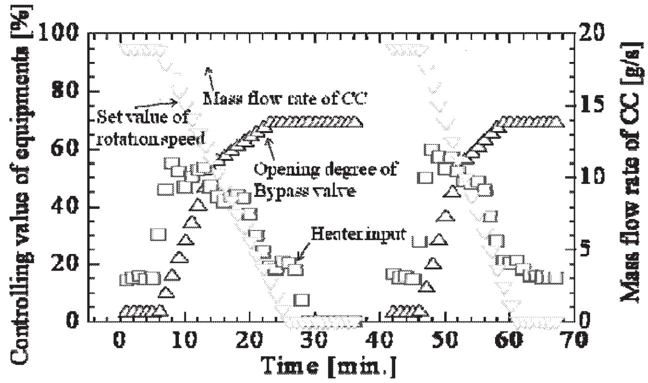

Fig. 3 Time traces of variable parameters in the period of the fast transition process.