§3. Behavior of Cold Compressor System of the LHD Helical Coils in Quick Discharge

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In 2006, a helium subcooling system was installed in the cooling system of the LHD helical coils to improve the cryogenic stability of the coils by lowering the operating temperature. In the system, the liquid helium supplied to the coils is subcooled by utilizing a series of two cold compressors. After the installation, the coils have been cooled by the subcooled helium of 3.2 K at the inlet of the coils and achieved the maximum operating current of 11.833 kA. Also, the system has stably been operated and the total time of the subcooling operation is about 10,000 hours.

In 2009, the quick discharge of the coils (the time constant is 30 sec.) occurred twice. The cold compressors were suddenly shut down and the subcooling system was disconnected from the main cryogenic system by an emergency program in the first case. Fig. 1 shows the valve motions in emergency. On the other hand, the cold compressors continued to work in the second case. Here, the behavior of the cold compressor system during the quick discharge is reported in both cases.

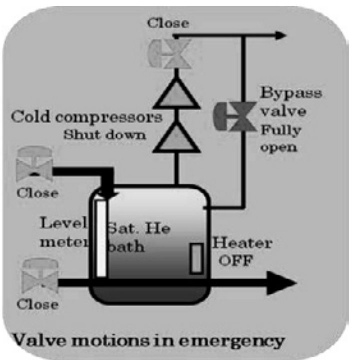

Fig. 1. Valve motions in emergency.

In the first case, the cold compressors were shut down after the quick discharge. Fig. 2 shows the performance curve of the cold compressors after the first quick discharge started. During the rotational speed of the cold compressors decreased, the operational points of the cold compressors passed through the stable operation area. The validity of the valve motions of the emergency program was confirmed. In the second case, the cold compressors kept running for reasons not clearly understood. Fig. 3 also shows the performance curve of the cold compressors after the second quick discharge started. The operational points of the first stage cold compressor exceeded the estimated surge line, while those of the second stage cold compressor reached it. That is because the helium flow through the cold compressor line was reduced drastically due to increase of the outlet pressure of the cold compressor line by the influence of the back pressure (See Fig. 4). Fortunately, surge phenomenon didn't occur in this case thanks to the automatic helium flow control, but it was a very hazardous situation.

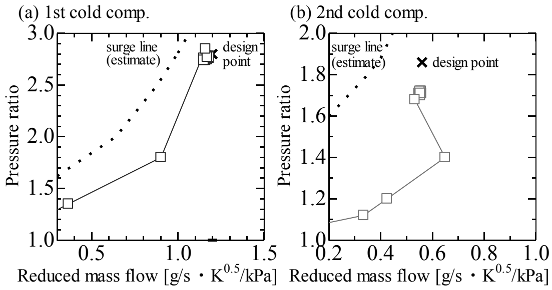

Fig. 2. Performance curve of the cold compressors in the first case.

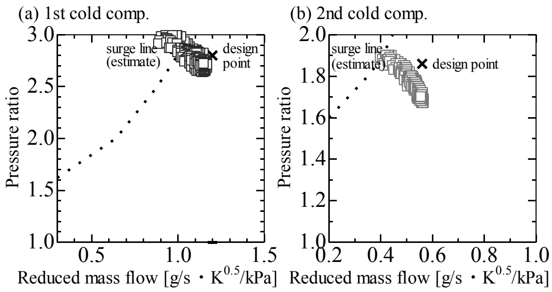

Fig. 3. Performance curve of the cold compressors in the second case.

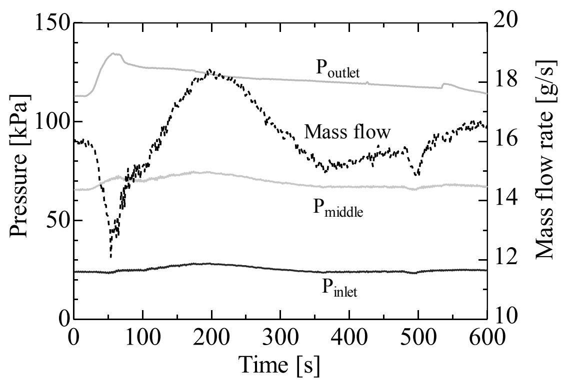

Fig. 4. Time variation of the pressure and mass flow rate of the cold compressor line after the second quick discharge started.

The cold compressor system has experienced the quick discharge of the helical coils twice. The cold compressors could be shut down safely in the first case. On the other hand, the operational points of the first stage cold compressor exceeded the estimated surge line in the second case, because the helium flow through the cold compressor line was reduced drastically due to increase of the back pressure. Consequently, the shutdown of the cold compressors was preferable to the running when the quick discharge occurred.