§5. Influence of Bypass Valve on Helium Mass Flow Rate of Cold Compressors in Sub-cooling System of the LHD Helical Coils

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The sub-cooling system of the LHD helical coils is possible to supply subcooled helium of 3.2 K, 120 kPa with the mass flow rate of 50 g/s at the inlet of the helical coils. [1-3] The supplied helium temperature is controlled by a heater in the bath, a bypass valve and a series of two centrifugal cold compressors with gas foil bearing. It is important to understand the characteristics of these equipments in the sub-cooling system for the purpose of the safe and stable operation of the sub-cooling system. [4-6] In the present study, the characteristics of the sub-cooling system with the cold compressors, especially the influence of the opening degree of the bypass valve, were investigated.

In the present sub-cooling system, the helium mass flow rate of the cold compressors was regulated by the heater in the saturated bath and the bypass valve as the rotational speed of the cold compressors increased / decreased. [7] The amount of the vaporized helium from the saturated helium bath varied in proportion to the heater in the bath, but the opening degree of the bypass valve had an influence on the change ratio of the helium mass flow rate of the cold compressors from our empirical data. Fig. 1 shows the change of the heater power while changing the opening degree of the bypass valve at a constant rate under the constant rotational speed of the cold compressors with the automatic flow control of the cold compressors to be 18 g/s by the heater. Open squares show the heater power and open triangles the opening degree of the bypass valve (PV). As the result, the change ratio of the heater power was not constant even though the opening degree was changed at a constant rate. It was indicated that the helium mass flow rate through the cold compressors did not increase in proportion to the opening degree of the bypass valve.

The helium flow through the cold compressors consists of the helium gas through the bypass line and the helium vaporized by both the heater and the heat exchanger. Thus, the helium gas through the bypass line could be estimated, subtracting the helium vaporized by both the heater and the heat exchanger from the total helium flow through the cold compressors. Fig. 2 shows the increment of the mass flow rate of the cold compressors with the change of the opening degree of the bypass valve. From the result, the change ratio of the helium mass flow rate through the cold compressors in the range of 47-72 % opening of the bypass valve was almost 10 times larger than that in the range of 3-47 % opening. It was supposed that the characteristics were caused by the influence of the high temperature gas, which was exhausted from the 2^{nd}-stage cold compressor and flowed into the bath through the bypass line, on vaporization of the saturated helium in the bath.

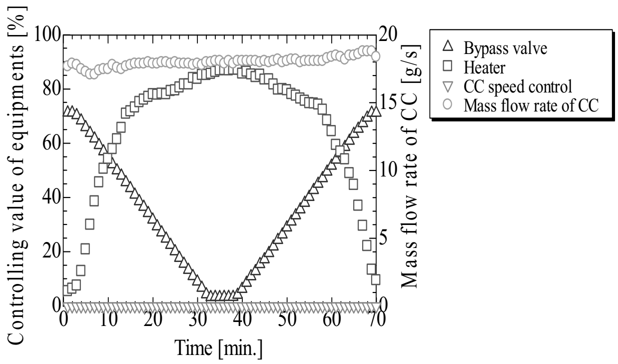

Fig. 1. Time trend of the heater power while changing the opening degree of the bypass valve at a constant rate under the constant rotational speed of the cold compressors with the automatic flow control of the cold compressors to be 18 g/s by the heater.

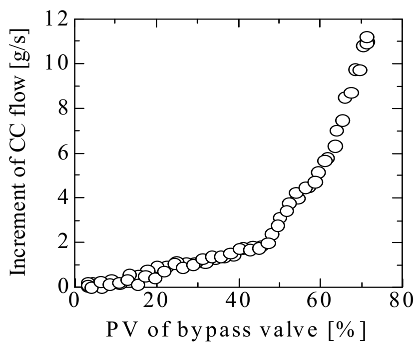

Fig. 2. The relationship between the opening degree of the bypass valve and the increment of the mass flow rate of the cold compressors.

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