§7. Operating Experiences of the Helium Refrigerator with a Dummy Load Apparatus for the LHD

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The helium refrigerator operation with a dummy load apparatus for the Large Helical Device (LHD) has been conducted. The apparatus primarily consists of a forced-flow low temperature helium line, a liquid helium supply line and a liquid helium bath. Both supercritical helium and liquid helium mass flow rates can be controlled by control valves adjusted with electro-pneumatic actuators. The design philosophy of apparatus is to simulate two dominant cooling schemes of the LHD: pool-boiling for a helical coil and a forced-flow supercritical helium for the poloidal coils. However, the cold mass and flow path of the LHD is much heavier and more complex than that of the apparatus.

Experiments were conducted with four refrigeration modes: no heat load mode; precooling mode; steady state mode and extra heat input mode. The stable operation of each mode, which simulates the refrigeration requirements for the LHD, was successfully demonstrated under semi-automatic control of the refrigerator. Figure 1 & 2 show the results which was taken on October 1996. For all cases, the supercritical helium mass flow rate was maintained at constant value 100g/s. Mass flow of helium vapor was changed because of various heat inputs to the liquid helium bath. Approximately 400 liters of liquid helium was vaporized under extra heat input mode.

Although each mode was sustained about two hours, it took about an hour to reach the steady state condition. In addition, the pressure oscillation in the refrigeration system was fairly difficult to suppress. This might be caused by adjustments of each parameter in PID controlled electro-pneumatic actuators for valves: small valve movements significantly affect the helium gas pressure in the refrigerator. Fortunately, it was found that the pressure oscillation can be controlled when the LCV2014, a valve which controls the pressure in the 20,000 l dewar, was changed from automatic control to manual operation. The mechanism of pressure oscillation is still unknown at this point.

According to the operation experiences, it may be difficult to achieve fully automatic condition of LHD without accumulating some data base during the first cool-down. The hydraulic behaviour of low temperature helium (supercritical helium, two phase helium) is certainly difficult to estimate with a dummy load appratus.

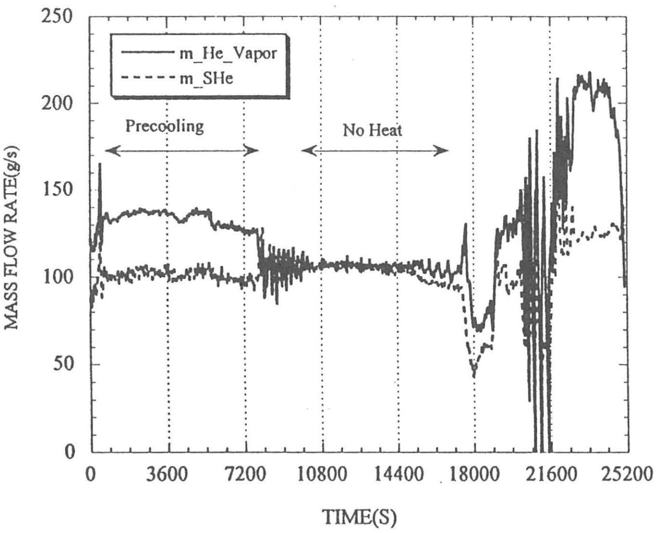

Figure 1. Mass flow rate vs. time for "precooling" and "no heat load" modes.

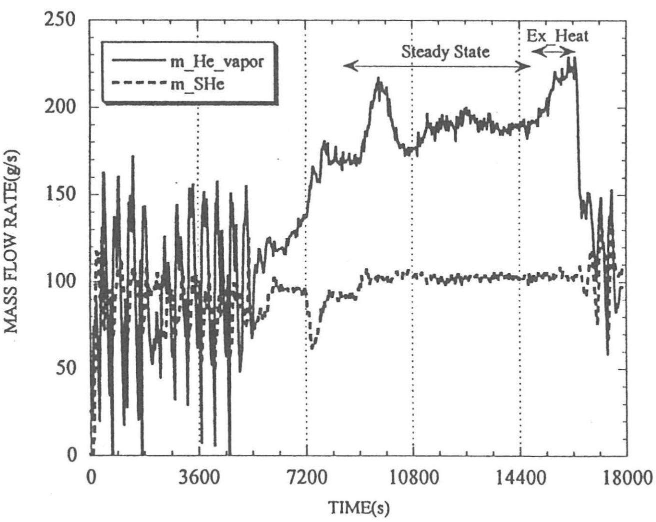

Figure 2. Mass flow rate vs. time for "steady state" and "extra heat load" modes.