§15. Measurement of Velocity of Helium Bubbles in Liquid Helium by Laser Sensors

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The superconducting helical coils are operated using 4.4 K liquid helium under pool-boiling cooling condition in the Phase I operation condition of the Large Helical Device (LHD). The liquid helium is supplied into the winding sections of the coils through ten inlets 1) which are connected to the inlet piping from the "Helical Valve Box" that functions to distribute the coolant both to the helical coils and the supporting structures.

Since thermal input energy of 20 W was expected in the transfer line of liquid helium (located between the coil inlets inside the LHD cryostat and the liquid helium tank inside the "Helical Valve Box"), special attention was paid for preventing the generated helium bubbles in the transfer line from entering the coil inlets, which would otherwise deteriorate the cryogenic stability of the winding conductors by decreasing the heat transfer coefficient from the conductor surface to liquid helium. In this connection, the transfer line was designed to have a slight inclination (up toward the "Helical Valve Box") so that the helium bubbles tend to move backward into the "Helical Valve Box". Moreover, it was decided to install special venting pipes to release the helium bubbles from the inlet section to the outlet header. In order to practically decide the necessary angle for the inclination of the transfer line as well as the necessary diameter for the venting pipes, the velocity of helium bubbles in liquid helium was required to be precisely given. Since we could not find an appropriate literature for giving this value, we have decided to measure it by ourselves.

Measurement of the velocity of helium bubbles was carried out by preparing glass tubes (length : 600 mm, diameter : 15 mm and 30 mm) installed in a glass dewar. Resistive heaters made of stainless steel wires were used to generate helium bubbles at the bottom of the glass tubes immersed in liquid helium. A set of oscillator and receiver of laser beam was situated at the upper region of the dewar to detect the passing of rising helium bubbles.

Figure 1 shows the measured waveforms of the heater pulse and the intensity of the received laser signal. As seen in Fig. 1, the laser signal shows a sharp decrease at about 2 s after the heater pulse was initiated. This corresponds to the passing of helium bubbles at the laser path. From the delay between the rising time of the heater pulse and the falling time of the laser signal, the velocity of helium bubbles can be evaluated and the result is plotted in Fig. 2 as a function of the heater power. As seen in Fig. 2, the bubble velocity increases as the heater power increases. This might be due to the increase of bubble size as the input energy increases. The bubble velocity in the real situation might be given by extrapolating the obtained results in Fig. 2 up to the zero heater power level, since the helium bubbles should be formed by an extremely low power density in a quite wide area in the transfer lines. The velocity of helium bubbles thus evaluated is about 200 mm/s under the atmospheric pressure. In the experiment, the bubble velocity was examined also with a steady state flow of helium bubbles by modulating the heater power. In this case, the velocity was observed to become much higher than that evaluated at the bubble front. This might be due to the formation of liquid helium flow from the bottom inlet of the glass tube to the upper outlet.

According to the above experimental results, the inclination angle of the transfer line was determined to be 5 degrees and the two sets of venting pipes with a diameter of 10.5 mm were installed in the LHD cryostat.

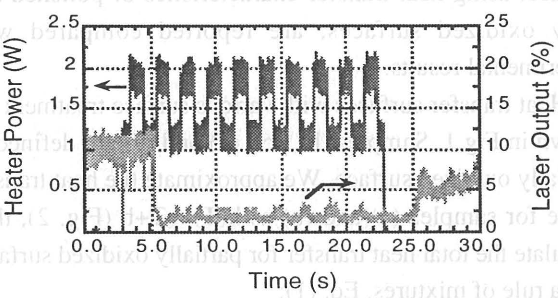

Fig. 1 Waveforms of the heater power and laser signal.

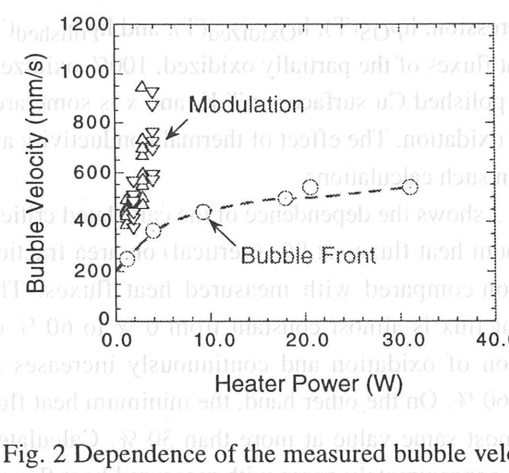

Fig. 2 Dependence of the measured bubble velocity on the heater power.

References

1) Imagawa, S., Yanagi, N., Mito, T., "Cooling System and Current Feeder of Helical Coils for LHD", in this Annual Report.