§9. Heat Transfer Characteristics of Liquid Hydrogen for Superconducting Devices

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Introduction

Liquid hydrogen is expected as a coolant for a HTS large scale superconducting magnet because of its excellent cooling properties. However, there has been a lack of an extensive heat transfer data of liquid hydrogen in forced flow condition for superconductor cooling.

As a first step, this year, the experimental setup, which can be used for Preliminary tests were successfully carried out in a pool cooling and forced flow cooling for wide range of sub-coolings, flow velocities and pressures up to supercritical condition. The mass flow rates during the forced flow tests were measured by the weight change of the main cryostat. All the control valves, the heating control and measuring system were remote-operated through optical fiber connected computer controls. It was confirmed that the control and measuring systems were operated well as designed.

A basic test of heat transfer in liquid hydrogen was carried out by quasi-steadily increasing heat inputs to horizontal flat plate with pool cooling and vertical tubes with forced flow cooling.

Experimental Setup

Experimental setup was designed and made for liquid hydrogen thermal hydraulics test as shown in Fig.1. Main components of the setup are a main cryogenic tank, a sub cryogenic tank (receiver tank), a transfer tube with a flow control valve, compressed hydrogen clustered cylinders and vent lines. The main tank is a vacuum insulated cylindrical stainless steel vessel whose inner diameter is 406 mm and height is 1495 mm. Its inner capacity and the filling ratio are 100 L and 50 %, respectively. The sub tank has almost the same configuration as the main tank, but its inner capacity and filling ratio are 80 L and 75 %, respectively. Both tanks are designed for pressures up to 2.0 MPa.

Test Section

Three test heaters can be installed in the main tank at once. Four power leads introducing the heating current up to 400 A through the top flange to the test heater were installed. All the test sections were resistance-heated with the direct current. In this test, one flat Manganin panel test heater (Test section C : 10 mm-wide, 100 mm-long, 0.1 mm-thick) was set for heat transfer test in a pool Additionally, two stainless steel pipe test heaters (Test section A: 3.0 mm-inner diameter, 0.5 mm-thick, 100 mm-long and Test section B : 5.95 mm-inner diameter, 0.2 mm-thick, 100 mm-long) were set for forced flow heat transfer test as shown in Fig.2.

Steady State Heat Transfer in Forced Flow Cooling

Fig.3 shows one of the test results for the heat transfer process in the forced flow condition with the test section of 6 mm outer diameter. The main tank pressure was kept 0.4MPa, the inlet bulk liquid temperature Tb was 21.1K and the sub-cool temperature ΔTsub was 5.2 K. The flow velocity was changed as 0.9, 2.0 and 4.0 m/s. As the flow velocity increases, the heat transfer coefficient in the non-boiling regime, the inception of the nucleate boiling and also the critical heat flux increase.

Y. Shirai ,et. al., Advances in Cryogenic Engineering: Transaction of the Cryogenic Engineering Conference – CEC, Vol. 55, American Institute of Physics, 2010.

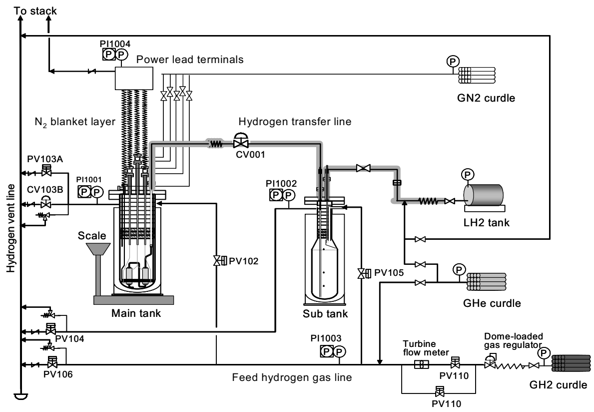

Fig.1 Schematic of experimental setup for Liquid Hydrogen Thermal-Hydraulics test.

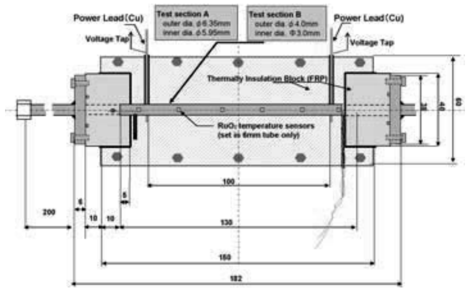

Fig.2. Test Heater for forced flow cooling test.

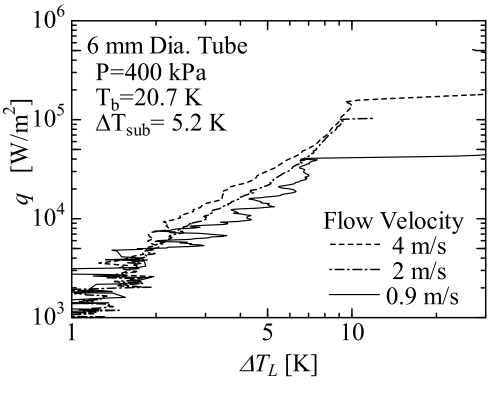

Fig.3. Heat transfer process in forced flow cooling obtained by quasi-steadily increasing heat input.