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Study on in situ measurement of heat leak into transfer line

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In fusion experimental devices and accelerators, superconducting magnets and cavities are cooled by cryogen supplied through transfer lines from helium liquefier/refrigerators. Since those devices have become larger recently and are operated continuously for a long time, the heat leak into transfer lines has a large influence on the cooling capacity of the helium liquefier/refrigerators. Therefore, it is essential to evaluate the heat leak accurately. Nevertheless, it is difficult to measure the heat leak in situ after installation, although the heat leak is just estimated by numerical analysis or measured by mock experiment before installation. Generally, the heat leak is evaluated by measuring evaporation rate of cryogenic liquid or enthalpy difference between inlet and outlet of flowing cryogenic gas through a tube. In the device after installation, however, the measurements using existing instruments to be necessary for operation are required, and therefore the instruments are not optimized for the location and the working range to be measured. In the present study, an alternative method to measure heat leak into transfer lines by using existing pressure gauges and thermometers, which are relatively installed at many points, is proposed. In the proposed measuring method, the inlet and outlet valves of a transfer line, the pressure gauge and the thermometer within the transfer line are used. After the temperature of the target transfer line is equalized with cryogenic helium gas, the valves at both ends of the line are closed. Then, the pressure increases over time, while the mean density of the confined helium gas keeps constant because the mass of that keeps constant. Since the initial enthalpy and density of the helium gas can be calculated by HEPAK® from the initial pressure and temperature, the increase of the enthalpy can be calculated from the pressure rise and the density. The heat leak into the transfer line is determined from the increase of the enthalpy, the mass of the helium gas and the confinement time. In the present paper, results of the demonstration on the in situ measurement of a transfer line in the cooling system for the superconducting magnets of the Large Helical Device at National Institute for Fusion Science are reported. The transfer line is a vacuum insulated tube and has six inner tubes wrapped with multi-layer insulations and an 80 K shield, which are housed in a 68 m long outer tube with a diameter of 660 mm. The measured tube is a supply line of supercritical helium that is one of the inner tubes. Although the heat leak into the tube was evaluated by numerical analyses and short sample tests before installation, the heat leak had never been measured after installation. As the results that the heat leak was measured using the above method, the heat leak of 58 W was obtained for the first time after installation and the amount of the measured heat leak was relatively consistent with that of the evaluated heat leak before installation. Consequently, the proposed method was confirmed to be effective.

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