Study on in situ measurement of heat leak into transfer line

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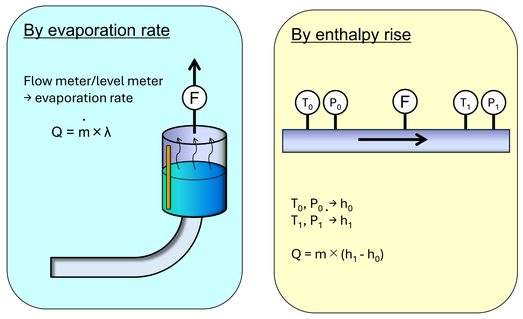
Abstract

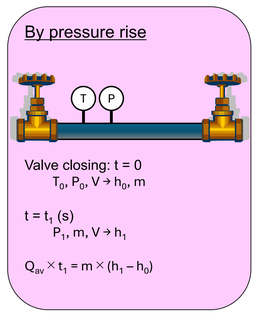
In fusion experimental devices and accelerators, superconducting magnets and cavities are cooled by cryogen supplied through transfer lines from helium liquefier/refrigerators. Since those devices have become larger recently and are operated continuously for a long time, the heat leak into transfer lines 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. In the present study, a 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, 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 mass of the confined helium gas keeps constant. Since the initial enthalpy and density (mass/volume) 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 (mass/volume). 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. As the results that the heat leak was measured using the above method, the heat leak of 62.5 W was obtained for the first time after installation and the proposed method was confirmed to be effective.

Heat leak measuring methods

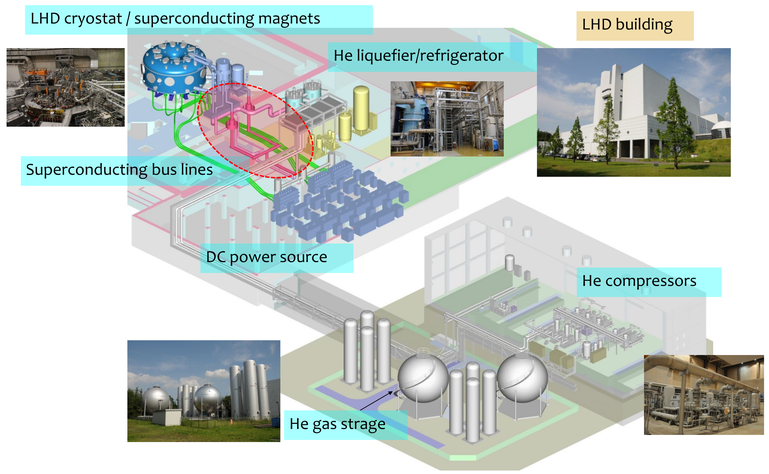
Typical methods



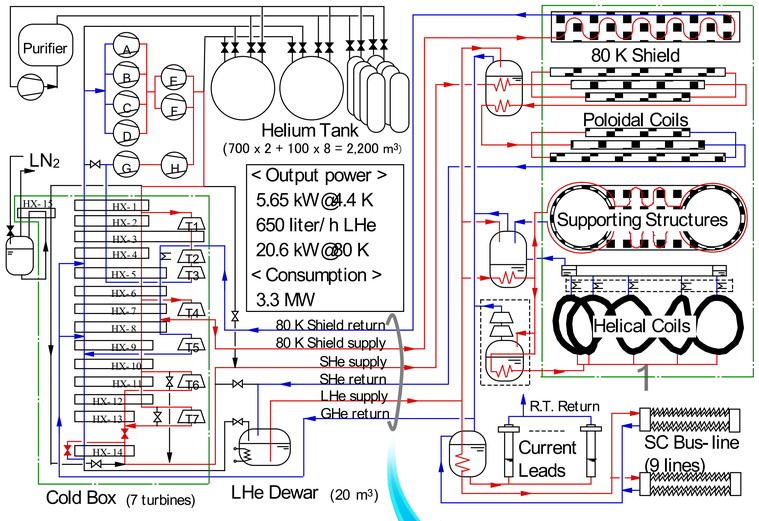
Proposed method



Cryogenic system for LHD superconducting magnets



Flow diagram



Spec. of transfer line

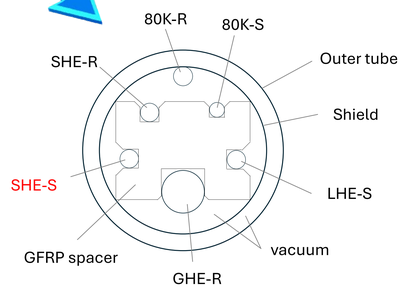
- Outer tube: 650A*t5 (68m long)
- 80K shield: Φ550*t5
- Six inner tubes

  SHe-S, SHe-R, LHe-S: 50A*t2

  GHe-R: 125A*t3

  80K-S: 40A*t2

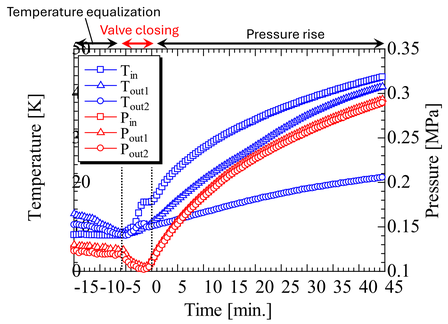
  80K-R: Φ63 w/ fin



Cross sectional view

Experimental results and discussion

Pressure rise after valve closing



Time variation of T, P in confined SHE-S line

80K shield temperature

101.75-104.71 K (av. 103.3 K) <- almost constant

t=0

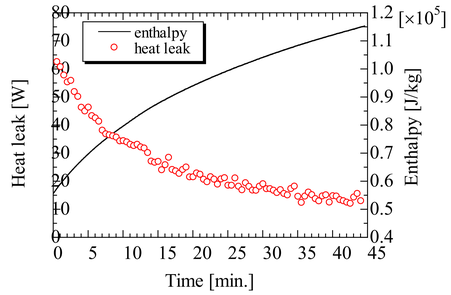
T_0= 8.27 K	P_0= 0.117 MPa
h_0= 55689 J/kg	ρ= 7.185 kg/m^3
V= 0.161 m^3	m= 1.157 kg

t = 0
T_0, P_0, V → h_0, m

t = t_1 (s)
P_1, m, V → h_1

$Q_{av} \times t_1 = m \times (h_1 - h_0)$

Heat leak evaluation



Enthalpy and heat leak after valve closing

Measured heat leak

62.5W @8.27K

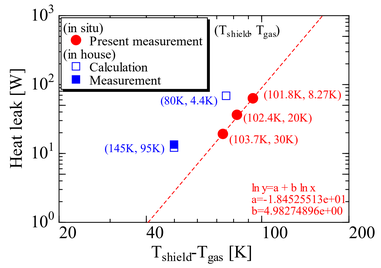
36.0W @20K

19.0W @30K

Heat leak estimation before installation

	Measurement 91K/145K	Calculation 91K/145K	Calculation 4.4K/80K
GHE-R	28.14	25.94	146.83
SHE-S	13.31	12.02	68.04
LHE-S	12.17	12.52	70.87
SHE-R	13.61	12.27	69.46
Total	67.23	62.75	355.2

Comparison with design



Comparison of present measurement and heat leak estimation before installation

Summary

- ✓ A simple method to measure heat leak into transfer lines by the pressure rise was proposed.
- ✓ After the temperature of the target transfer line (SHE-S in the LHD) was equalized with cryogenic helium gas, the valves at both ends of the line were closed. Then, the increase of the enthalpy was calculated from the pressure rise by HEPAK®.
- ✓ The heat leak of 62.5 W was obtained for the first time after installation and the proposed method was confirmed to be effective.

Acknowledgement

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