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Thermal insulation test of new designed cryogenic pipes for the superconducting DC power transmission system in Ishikari, Japan

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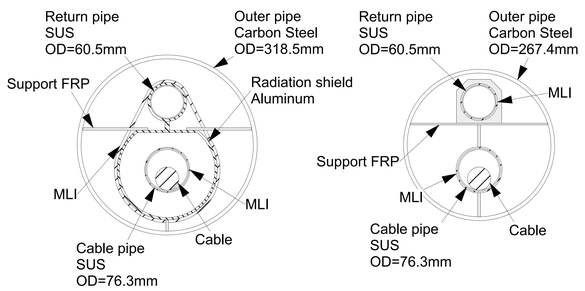
Introduction

The cryogenic pipe is one of the primary components of the superconducting DC power transmission systems. Low heat leak cryogenic pipes are demanded, because the energy to pump out the heat by the heat leak of the cryogenic pipes is a main source of the energy loss and, eventually, determines the efficiency of the entire transmission systems. New cryogenic pipes were designed for the superconducting DC power transmission systems constructed in the Ishikari area in Japan. Test pipes were constructed and heat leak was measured to evaluate their efficiencies.

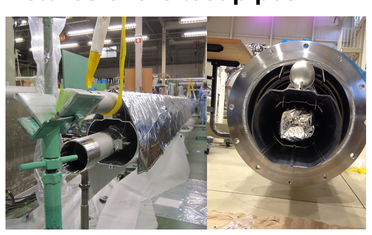
Test pipes



(a) With a radiation shield (b) Without a radiation shield

- ✓ Two inner pipes are installed in a single outer pipe.
- ✓ Straight pipes are used to reduce pressure loss.
- ✓ A radiation shield is adopted in one of the designs
- ✓ Two types of test pipes with and without a radiation shield were constructed and evaluated.

Pictures of the test pipes



With a radiation shield

Without a radiation shield

Application of Multi-Layer Insulation

- ✓ MLI used was KFHN-9B05 supplied by Kaneka Co.
- ✓ Butting ends of MLI were overlapped by 3 cm for the hoop direction and 10 cm and 3 cm for the pipes with and without a radiation shield, respectively, for the axial direction

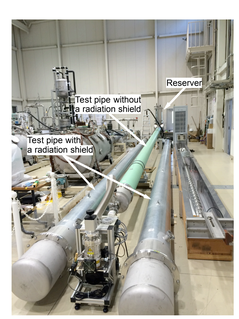
<u>The test pipes with a radiation shield</u>

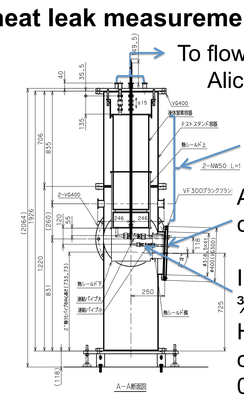
- ✧ Around the shield(axially 3 units)
  - ✓ 7x3: 7 layers of MLI were bundled and 3 bundles were wrapped (21 layers in total).
  - ✓ 3x3: 3 layers of MLI were bundled and 3 bundles were wrapped (9 layers in total).
  - ✓ 21x1: 21 layers of MLI were bundled and 1 bundles were wrapped (21 layers in total).
- ✧ Around the cable pipe
  - ✓ 1 layer of MLI was wrapped.

<u>The test pipes without a radiation shield</u>

- ✧ Around the cable pipe and the return pipe (axially 8 units for the cable pipe and 9 units for the return pipe)
  - ✓ 21x1: 21 layers of MLI were bundled and 1 bundles were wrapped (21 layers in total).

The set up for the heat leak measurements





To flow meters
Alicat Scientific inc. M series

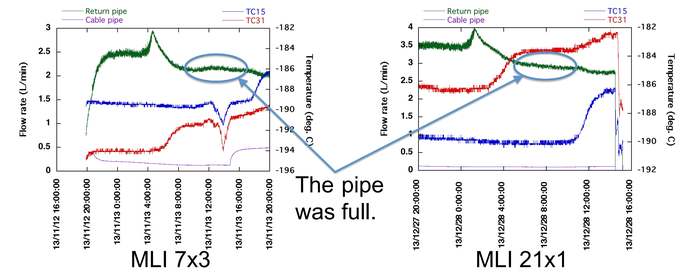
LN2 tanks

Angle of the test pipe connection: 2˚

Inner pipe connection: ¾ in. and ½ in. pipes
Heat leak through the connection: less than 0.06 W

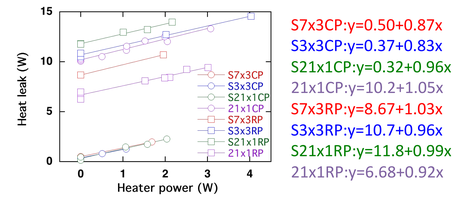
Heat leak was obtained from the flow rate of evaporated nitrogen gas. The flow meters were calibrated at 20 ˚C, 1 atm. 1 W is measured as 0.2593 L/min @20 ˚C, 1 atm.

Examples of the flow rates (Test pipes with a radiation shield)



The flow rate when the inner pipe was full was used for evaluation.

Calibration verification



The increase of heat leak was measured with respect to the heater power. The deviations between these were less than 5% except for three cases. The deviations were included in the errors as calibration errors.

Results

Table1: Heat leak of the test pipes with a radiation shield

	7×3	3×3		21×1	
Outer pipe temperature (˚C)	12.2	7.5	9.0	1.6	7.1
Total heat leak per 12m (W)	8.81±0.30	11.4±0.5	11.5±0.5	11.8±0.2	12.1±0.2
Heat leak of the cable pipe (W)	0.50±0.07	0.48±0.09	0.63±0.11	0.39±0.03	0.45±0.03
Heat leak of the return pipe (W)	8.31±0.30	10.9±0.5	10.9±0.5	11.4±0.2	11.6±0.2
Total heat leak per 1m (W/m)	0.73±0.03	0.95±0.04	0.96±0.04	0.99±0.02	1.01±0.02

Table2: Heat leak of the test pipe without a radiation shield

Outer pipe temperature (˚C)	6.5	11.5	13.0	16.1
Total heat leak per 12 m (W)	15.8±0.7	16.9±0.8	17.5±0.8	18.2±0.8
Heat leak of the cable pipe (W)	9.5±0.5	10.2±0.5	10.6±0.5	10.8±0.6
Heat leak of the return pipe (W)	6.2±0.6	6.7±0.6	7.0±0.6	7.3±0.7
Total heat leak per 1 m (W/m)	1.31±0.06	1.41±0.07	1.46±0.07	1.51±0.07

<u>The test pipe with a radiation shield</u>

- •Heat leak of 7x3 is smallest and 0.73 W/m.
- •Heat leak to the cable pipe is nearly constant and 0.04 W/m.
- •The overlap of butting ends may affect the difference between 7x3 and 21x1.

<u>The test pipe without a radiation shield</u>

- •Heat leak is around 1.4 W/m.
- •Heat leak is significantly larger than that with a radiation shield.