Introduction

We developed a turbo-Brayton refrigerator with Ne gas as a working fluid for a 3φ-66/6.9kV-2MVA superconducting transformer with coated conductors which was bath-cooled with subcooled LN2. The two-stage compressor and expansion turbine had non-contact magnetic bearings for a long maintenance interval. In the future, we intend to directly install heat exchanger into the GFRP cryostat of a transformer and make a heat exchange between the working fluid gas and subcooled LN2.

In this paper, we investigate the behavior of subcooled LN2 in a test cryostat, in which heater coils were arranged side by side with a flat plate finned-tube heat exchanger.

Construction of Test Cooling System

A turbo-Brayton refrigerator with Ne gas as a working fluid and a cooling capacity of 30kW at 76k was developed. An expansion turbine and a two-stage turbine compressor with non-contact magnetic bearings were adopted.

Future

Cold box
Turbo-expander
Sub-cooled LN2
He gas
He gas
Turbo-compressor
Heat exchanger
Sub-cooled LN2
LN gas
LN gas
Test cryostat

Experiment

1) LN2 at 77 K was first transferred into the test cryostat. 500 liter of LN2 was held. Surface level of LN2 was 1.32 m.
2) By operating the He turbo-Brayton refrigerator and flowing He gas into the copper pipe of the heat exchanger, LN2 was cooled down to a subcooled state.
3) Pressure at the surface was atmospheric one.
4) Temperature of the He gas at the inlet of the heat exchanger was controlled so that the temperature of LN2 did not decrease to less than 63.3 K.
5) By overcoiling, freezing LN2, clogging between the fins of the heat exchanger.
6) By heating with heater coils, temperatures started to rise up. When all the heater coils generated heat evenly and the total heat power was less than 1 kW, no bubble was observed. In that case, a rising current of LN2 in the cooling channel surrounded by a glass pipe became visible even if no bubble appeared.
7) When the uppermost and lowermost coils generated heat power of 200 W each, bubbles were produced. However bubbles rose up by several cm from the top of the heater coils and then re-condensed and disappeared by cooling by circumambient subcooled LN2.
8) Just under the LN2 surface, a stationary layer of LN2 was created over the depth of 8 cm and temperature dropped from 77 K to 70 K with depth while, in the lower level than that, a natural convection current of LN2 was formed and temperature was almost uniform at 66 K over around 1 m depth. The boundary plane was visible.

Summary

We built a test system to investigate the behavior of subcooled LN2 in a cryostat, in which a flat plate finned-tube heat exchanger for cooling and heater coils were arranged side by side in the LN2 bath. A He turbo-Brayton refrigerator was connected with the heat exchanger and He gas as a working fluid was introduced into the copper pipe of the heat exchanger.

The pressure at the surface of LN2 was atmospheric. Just under the LN2 surface, a stationary layer of LN2 was created over the depth of 8 cm and temperature dropped from 77 K to 70 K with depth while, in the lower level than that, a natural convection current of LN2 was formed and temperature was almost uniform at 66 K over around 1 m depth.