Analysis on a Cooling Experiment of Prototype Thermal Siphon System for Single Crystal Silicon Ingot Growing Magnet

Woo Seung Lee1, Kwang Myung park1, Yong Chu2, and Kwang Pyo Kim3,*

2. National Fusion Research Institute (NFRI), 169-148 Gwhak-ro, Yuseong-gu, Daejeon 34133, Korea (e-mail: kpkim@nfri.re.kr) * Corresponding Author

Introduction

- Silicon wafer is usually made from silicon ingot. Czochralski (CZ) process is the most popular way to build the silicon ingot by growing the ingot from molten silicon in a crucible.
- Single Crystal silicon ingot growing (SCG) superconducting magnet is one of the most important parts of the system for CZ process.
- Design method and cooling performance of prototype thermal siphon system is investigated as a candidate of cost effective cooling system for SCG magnet.

Schematic of Thermal Siphon System

- Thermal siphon cools a heat load by circulating cryogen through a channel (supply & return).
- The cryogen, helium, is filled through access port to helium chamber.
- Liquid helium flows supply line and takes heat away from heat load by conduction of cooling channel.
- Gas and liquid helium returns through return line.
- The gas is liquefied by cold head through recondensing line.
- Thus, the cooling capacity of the cold head is spread to the system.

Design of the Prototype Thermal Siphon System

- Size of the prototype system is determined by analyzing dynamics of helium inside the system.

| Table I. Summary of Full Scale Prototype System
| Parameter | Full Scale | Prototype |
| Height of half of siphon (cm) | 48.9 | 15.6 |
| Heat load (MW) | 1.2 | 0.9 |
| Recondensing block size (cm) | 40 X 40 | 10 X 10 |
| Experimental condition | 1.0 MW/44 K (24th stage) | 1.0 MW/44 K (24th stage) |

| Table II. Cooling System Performance of Prototype System
| External Heat Load (MW) | Heating Block Temperature (K) |
| 0 | 4.94 |
| 0.15 | 4.92 |
| 0.30 | 4.83 |
| 0.45 | 4.79 |
| 0.60 | 4.75 |
| 0.75 | 4.70 |
| 0.90 | 4.67 |
| 1.05 | 4.66 |
| 1.20 | 4.65 |

Setup of Experiment

- The prototype system has been set for experiment.
- (Cold head)
  ➢ RDK-415D, 1.5 MW/44 K (24th stage).
  ➢ Helium load: Cartridge heater, 36 Ω.
  ➢ Molded into heating block, brazed to the cooling channel.
- (Miscellaneous)
  ➢ Pressure sensor at access port.
  ➢ Censor sensor for heating block.
- Liquid helium level sensor: Opening of the helium chamber.
- Recondensing heater: 41.7 Ω at the bottom of the helium chamber.

Cooling Experiment with Different Heat Load

- Rounding heater generates heat if the chamber pressure becomes too low.
- To prevent negative pressure.
- In the 30 minute average heat input by recondensing heater is 1.45 W.
- Almost full of the cold head cooling capacity is transferred to the system.

Conclusion

- A prototype thermal siphon system for the SCG magnet is designed, and tested with various conditions.
The prototype system showed a stable cooling performance.
The entire cooling capacity of the cold head is supplied to the system.
The temperature and the chamber pressure are remained stable under 0.75 W heat load condition.
Some unstable pressure increase is detected, which can be explained by convection block model.
An advanced topology is suggested.

- Even though some modification is needed in the prototype system, enough possibility of the thermal siphon system has been demonstrated though the research.

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