C1PoA-6

Performance of a 10 kJ SMES Model Cooled by Liquid Hydrogen Thermo-Siphon Flow for ASPCS Study

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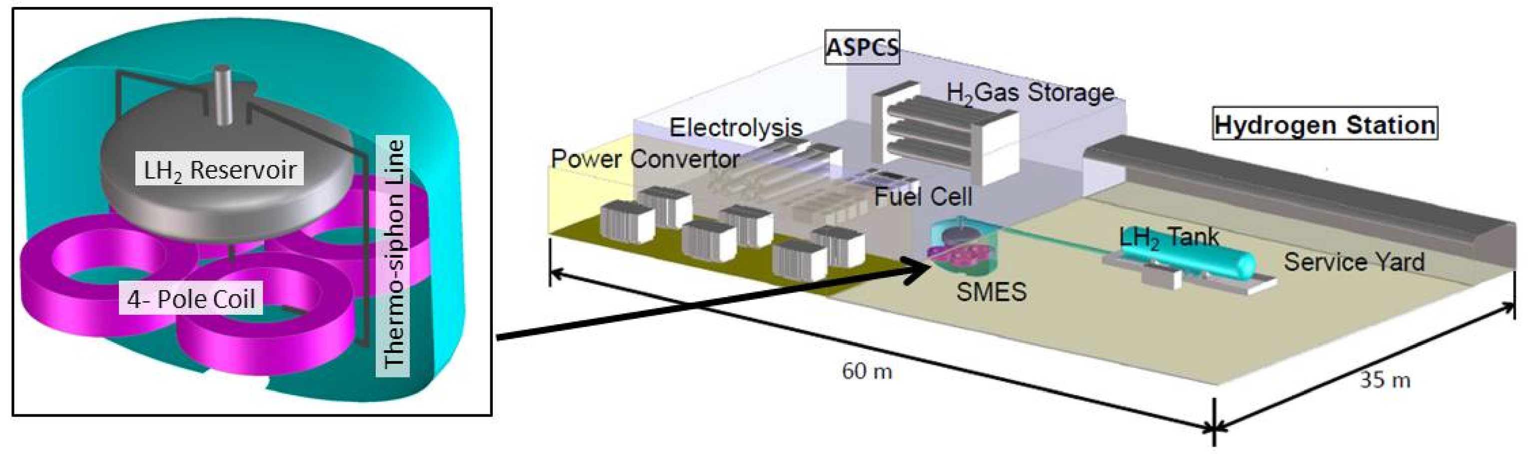
Background

To effectively use renewable energy sources such as wind and photovoltaic power generations, we propose a new electrical power storage and stabilization system, called an Advanced Superconducting Power Conditioning System (ASPCS), that consists of superconducting magnetic energy storage (SMES), a fuel cell-electrolyser (FC-EL), hydrogen storage, direct-current-to-direct current (DC/DC) and direct-current-to-alternating-current (DC/AC) converters, and a controller. The ASPCS compensates for fluctuating electrical power generation by combining the SMES with quick response and hydrogen energy storage with unlimited capacity

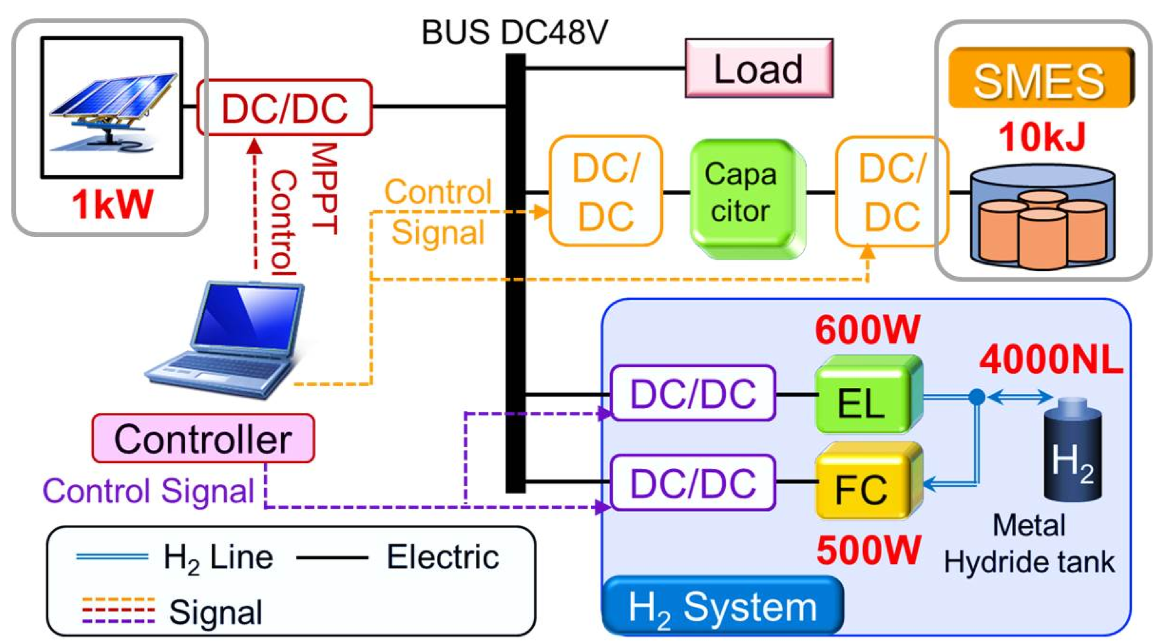


Objectives

Many engineering studies and development efforts are required to produce an ASPCS. The most important topics are (1) establishment of combined input/output power control loops and sequences of both SMES and FC-ELs for ASPCS operation and (2) confirmation of the feasibility of the liquid hydrogen-based cooling scheme. A small model of the ASPCS was developed to demonstrate the ASPCS's effects and to study these topics. The ASPCS model, which handles 1-kW power generated by a solar cell system, consists of a 10-kJ SMES, an FC unit, an EL unit, a hydrogen storage tank, and a control system.

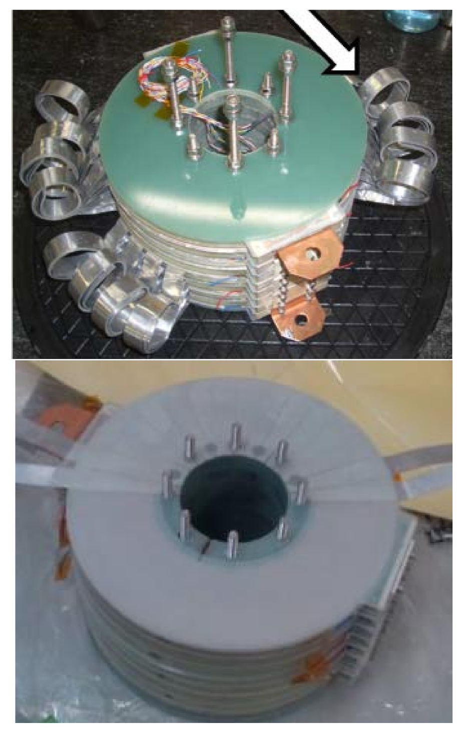
Confirmation of the cooling scheme by liquid hydrogen

- **Safety cooling** by liquid hydrogen.
- **Conductive cooling:** The coil is kept at appropriate temperature by liquid hydrogen cooling through thermal conduction path in pure aluminum sheets.
- **Thermo-siphon flow:** To minimize the distance of the conduction path, liquid hydrogen must be supplied through a pipe nearby the coil. A thermo-siphon, without any active pumps, drives liquid hydrogen through the pipe to transfer a heat load from the coil
- **AC Loss:** A mount of eddy current loss induced in the pure aluminum strips is small enough for SMES operation.

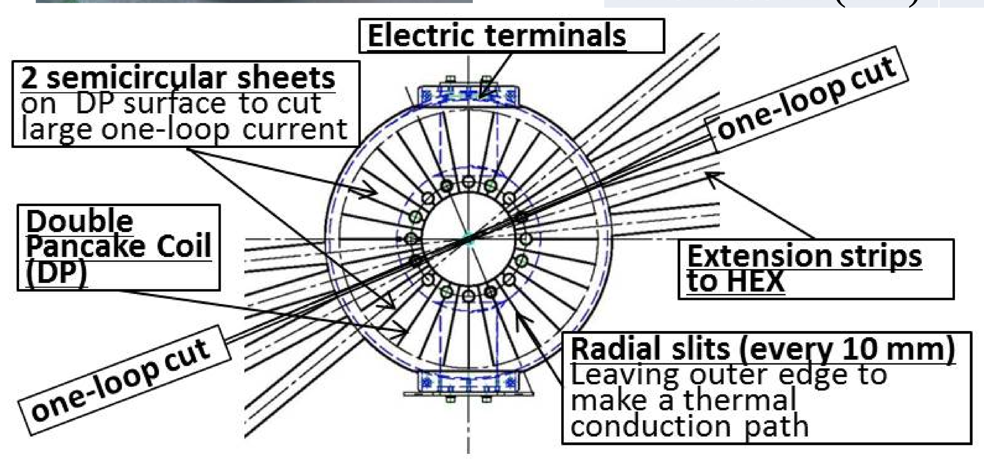


Design and Fabrication

Coil Assemble with AL sheet

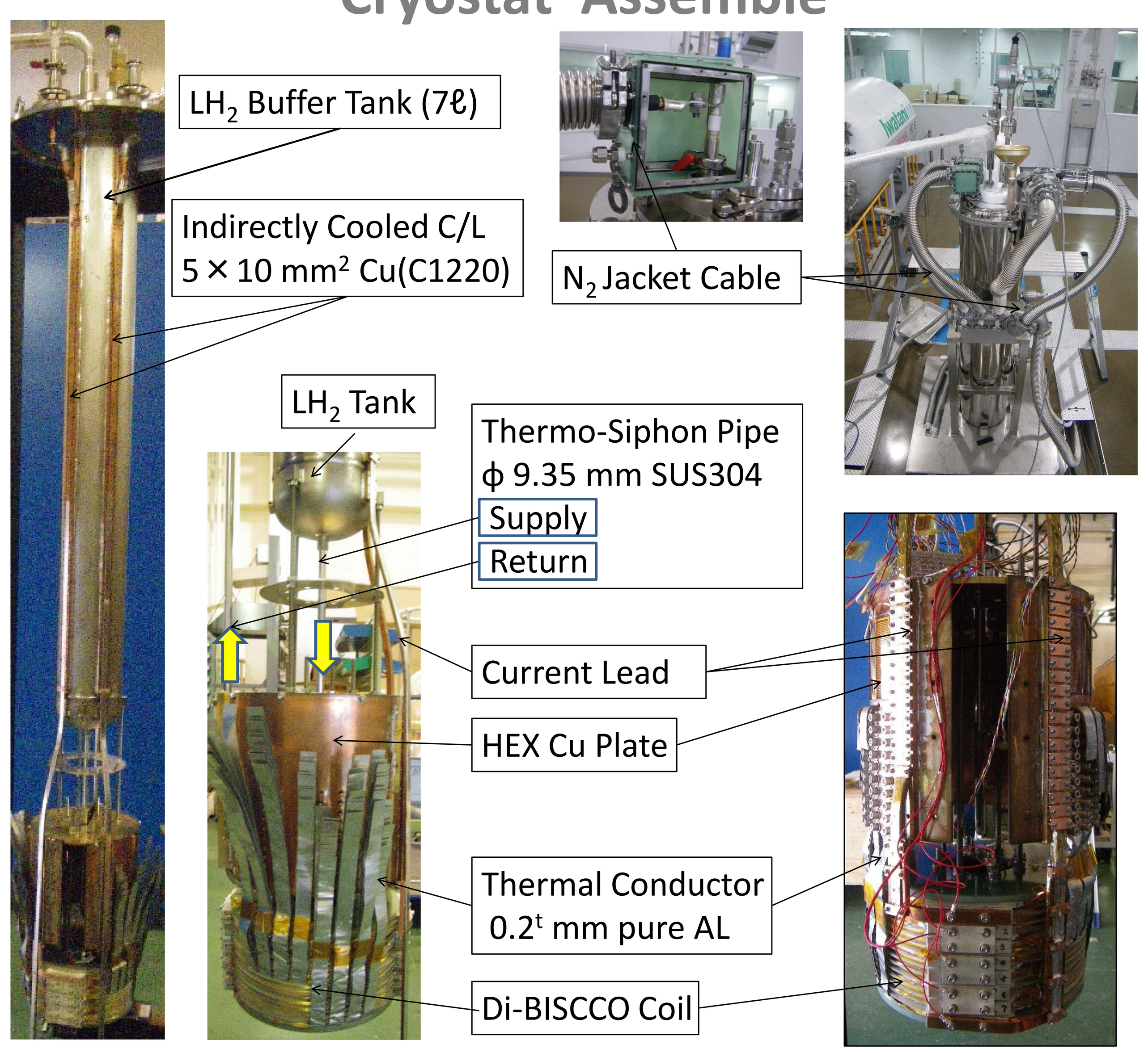


Model Coil Parameter		
Winding	Double Pancake	
No. of D.P	8	6
Superconductor	Di-BISCCO-HT-SS	
Ic at 77 K	180 A (Self field)	
Stored Energy (kJ)	10	6.22
Coil I.D. (mm)	100	100
Coil O.D. (mm)	193.8	193.8
Coil Height (mm)	75.4	56.6
Inductance (H)	0.494	0.311
Total turn	2144	1608
B central (T)	3.32	2.63
B max (T)	4.32	3.81
Turn per DP	134×2	
Thickness Al (mm)	0.2	



The conductor in the 7th pancake was ripped up, while a voltage tap was. So, a bus connection in the coil bypasses the 7th and the 8th coil for the time being.

Cryostat Assemble



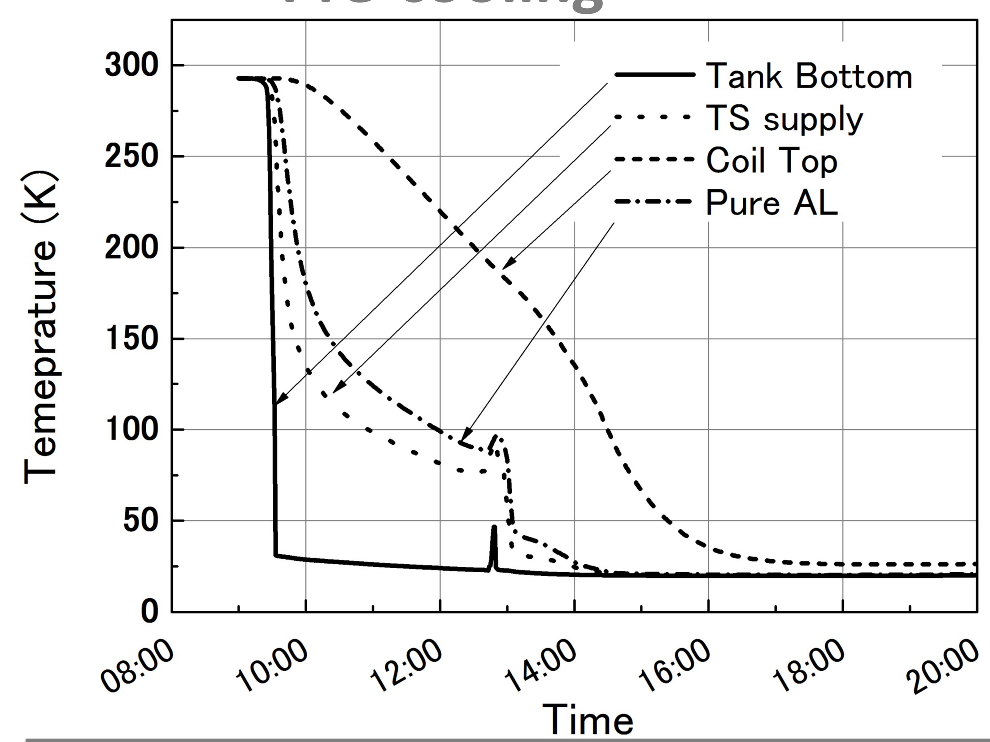
Conclusion

A design and performance evaluation for a Di-BSCCO SMES model coil for an ASPCS experimental study—specifically, the safe use of its liquid hydrogen-based cooling scheme—is presented.

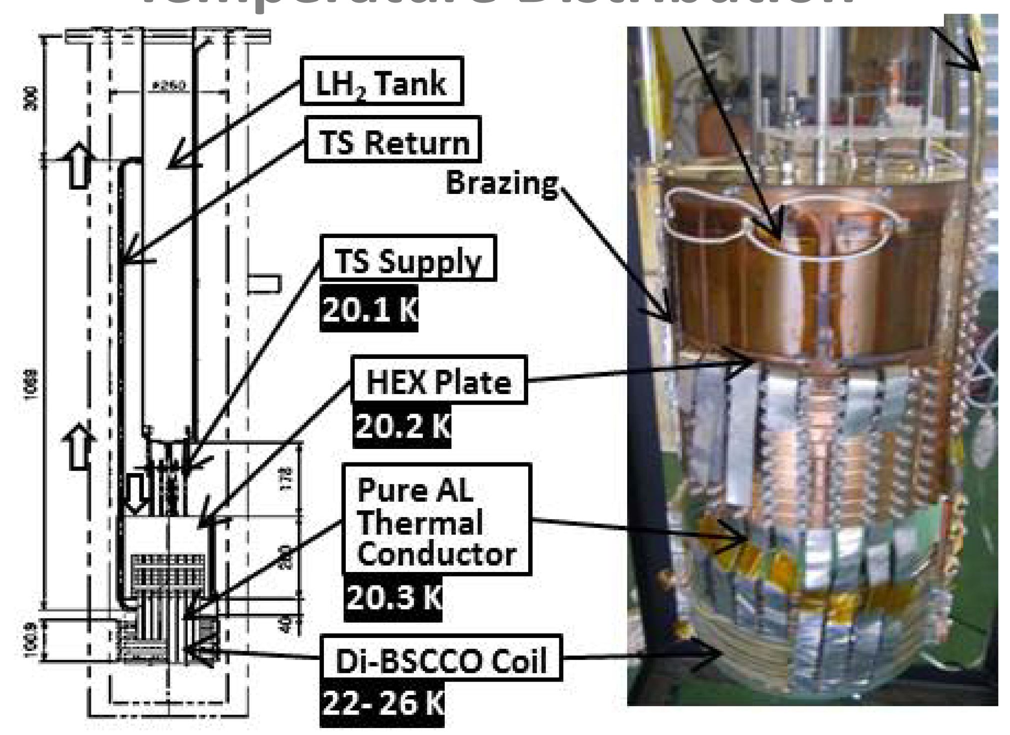
- ✓ A two-phase thermo-siphon loop supplies liquid hydrogen flow from a buffer tank nearby the coil, from which pure aluminium sheets thermally connect the coil.
- ✓ To prevent from large AC loss in the thermal conductors themselves due to SMES operation, many slits and one-turn-cuts are devised.
- ✓ The coil has been successfully cooled down and charged up to a nominal current of 200 A.
- ✓ Measured AC loss of 10 W induced in the pure aluminium sheet is rather larger than predicted value of 0.16 W, because one turn loops still left in the coil. But temperature rise is low enough to continue AC excitation.

Performance Test Results

Pre-cooling

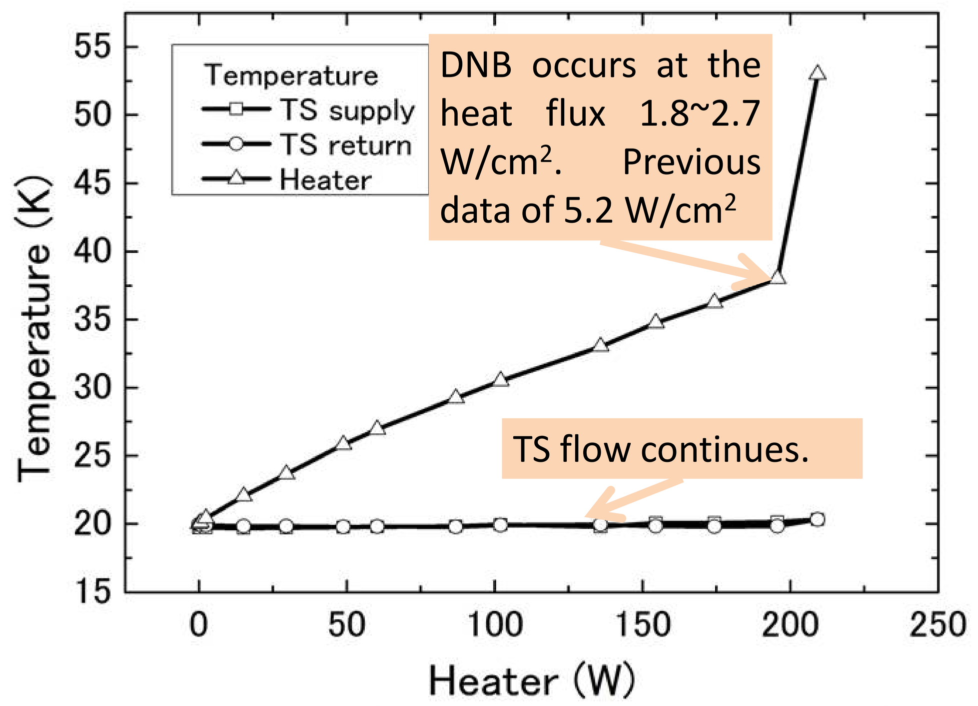


Temperature Distribution

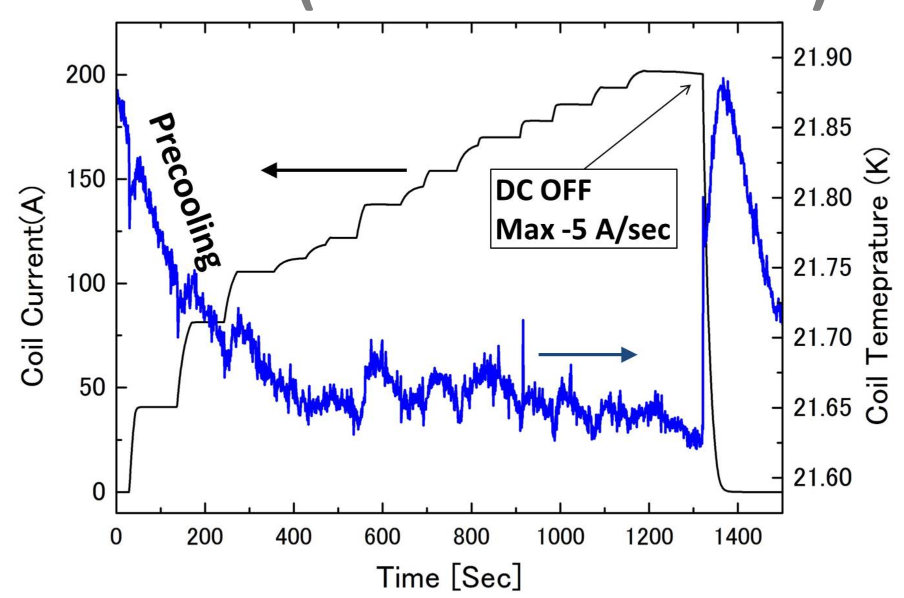


Temperature observations at precooling and steady-state cooing indicate that there may be substantial thermal resistance between the aluminum thermal conductor and the coil.

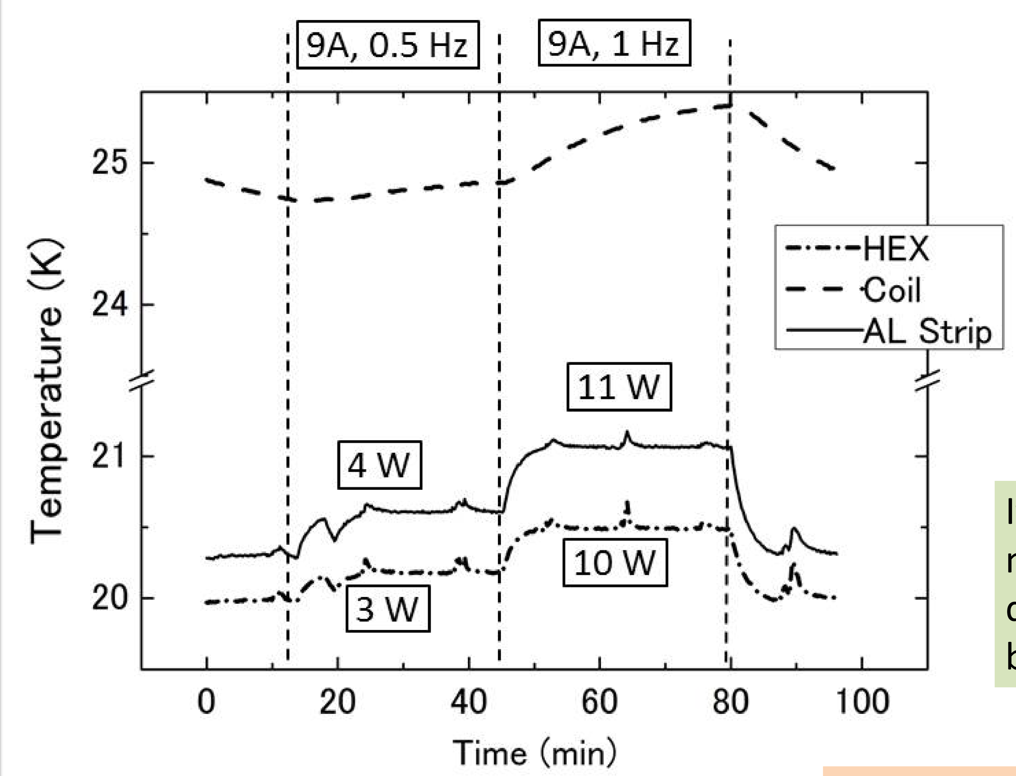
Thermo-siphon Cooling Capacity

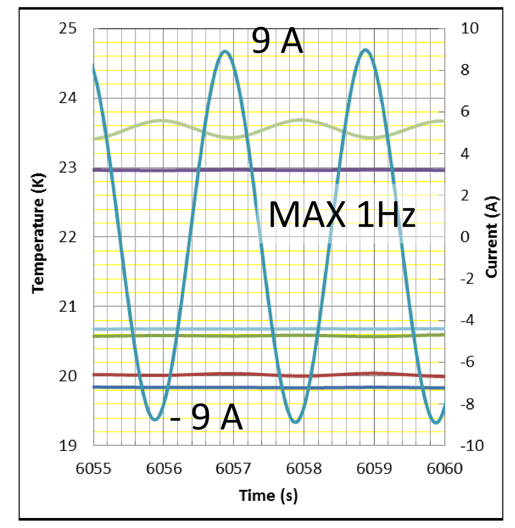


DC 200 A (Nominal Current)

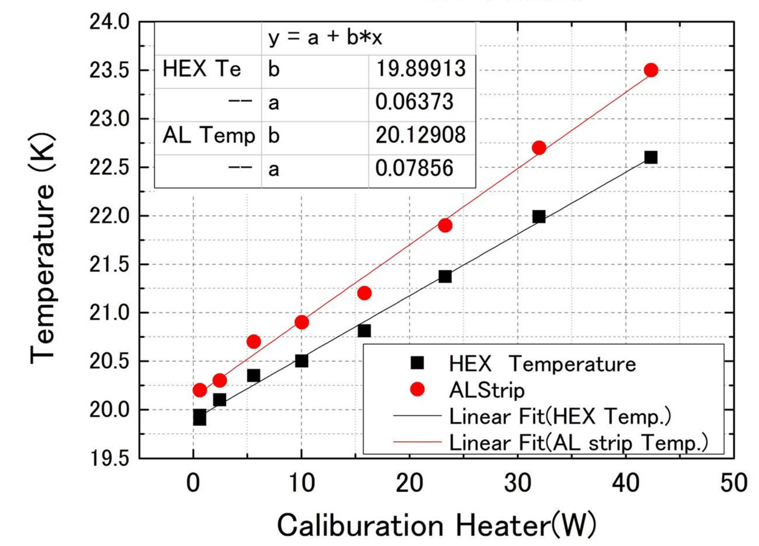


AC Loss





It is planned that the SMES model coil performs charge and discharge with 10 A and 0.1 Hz by ASPCS control system.



The estimated eddy current loss is estimated 0.14W at ± 9 A peaks and 1 Hz. The measured AC loss of 10 W is much larger than the estimation. Because 3 set of the semicircular aluminum sheet in the pancakes are connected due to any assembling errors, which induces about 8 W. But fortunately the temperature margin of the conductor is large enough for the measured temperature rise.

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