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Performance Evaluation of an AHX for Thermal Energy Storage System Test Loop

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1. Introduction

The thermal energy storage experimental verification test loop(TESET) is a test facility that demonstrates a range of operations associated with the charging, storage, and utilization of a high-temperature sodium thermal energy storage system [1]. The TESET consists of a loop heater as a heat source, a hot storage tank to store thermal energy, a sodium-to-air heat exchanger(AHX) and blower to use the stored thermal energy, a cold storage tank to store sodium that has lost energy after use, and an electromagnetic pump to transfer the sodium. The AHX is the ultimate heat sink in the TESET, which discharges the heat from the thermal energy storage system to the atmosphere. It is a key component in demonstrating the performance of the TESET. Therefore, a performance evaluation of the AHX is required to demonstrate the operational performance of the TESET.

2. Methods and Results

2.1 AHX Design

The AHX adopts the shell-and-tube structure with helical tubes to maximize the heat transfer area and to ensure the structural integrity against thermal expansion. A bank of helical tubes is installed around an inner cylinder or bobbin installed at the center of the AHX, as shown in Fig. 1.

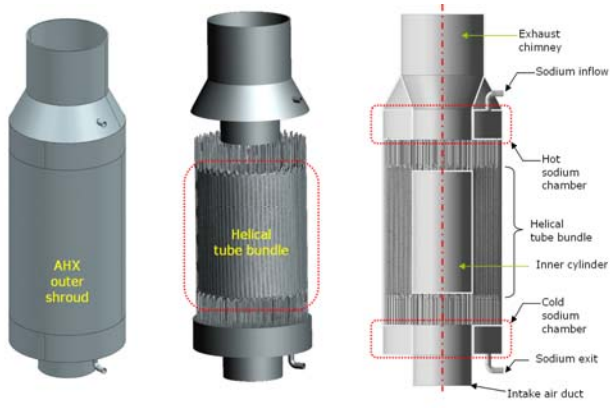

Fig. 1. AHX Design

The hot sodium discharged from the hot storage tank flows into the hot sodium chamber at the top of the AHX and is distributed to each helical tube. The hot sodium entering each helical tube flows downwards along the inside of the helical tube and is cooled by countercurrent heat transfer from the outside air. The cold sodium cooled by the AHX is collected in the cold storage tank in the TESET. Table I shows the main design parameters for the AHX [2].

Table I: AHX Design Parameters

Parameters	Design Value
No. of Tubes, EA	60
Tube ID, m	0.0114
Tube Arrangement	Helical Coil
Effective Tube Length, m	3.723
Inner Cylinder OD, m	0.508
Na Inlet Temperature, °C	700
Air Inlet Temperature, °C	20

2.2 AHX Modeling

The performance evaluation of the AHX was carried out using the GAMMA+2.0 code. The GAMMA+2.0 code has built-in heat transfer and pressure drop correlations to evaluate the heat transfer performance of the helical type heat exchanger [3].
Fig. 2 shows the GAMMA+2.0 code nodalization of the AHX.

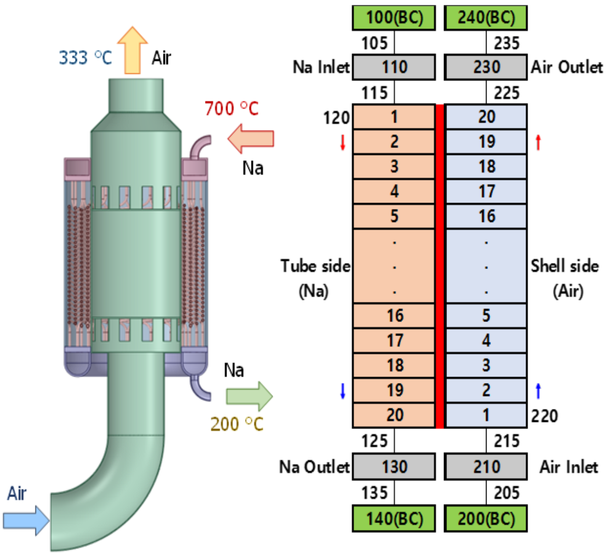

Fig. 2. GAMMA+ 2.0 Nodalization for the AHX

Nodes 120 and 220 are the active heat transfer regions in the AHX where the main heat transfer between sodium and air occurs. They were simulated in detail with 20 sub-volumes each. The inlet and outlet regions of the sodium and air sides of the AHX were simulated with boundary conditions. The design mass of sodium in the hot storage tank is 7,156 kg.

The sodium flow conditions were selected by considering the total amount of sodium and the discharge duration from the hot storage tank as shown in Fig. 3. The air side temperature was assumed to be 20°C and to remain constant throughout the simulation period. Based on these initial conditions and assumptions, the AHX performance was evaluated for various sodium and air inlet flow conditions at the design sodium temperature.

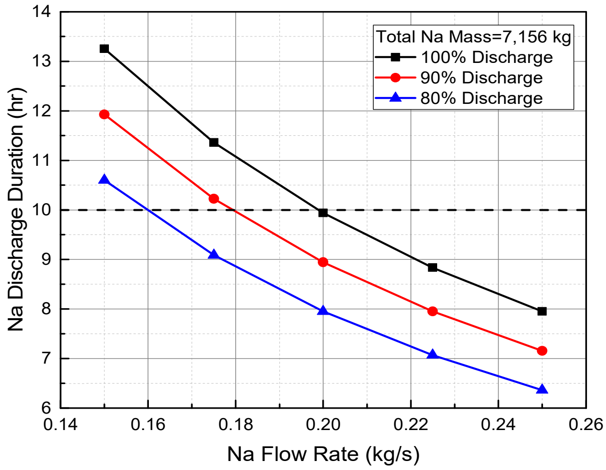

Fig. 3. Sodium Discharge Duration as a Sodium Flow Rate

2.3 Analysis Results

Under conditions of low sodium flow rate and high air flow rate, heat removal from the tube increases. This increases the temperature difference at the inlet and outlet of the tube as shown in Fig. 4.

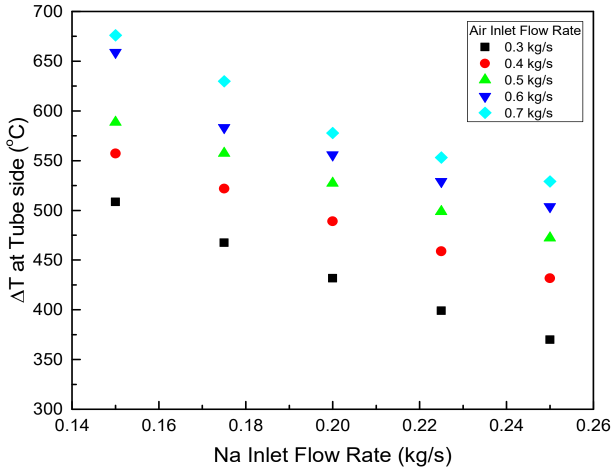

Fig. 4. In/Outlet Temperature Difference on the Tube Side

However, a sharp decrease in the temperature at the sodium outlet may cause the sodium to solidify in the tube, which may lead to structural integrity problems of the TESET. Therefore, under the condition that the sodium outlet temperature is above 150℃, which is higher than the solidification temperature of sodium, the operating range of the TESET was derived according to the sodium and air inlet flow conditions of the TESET was derived as shown in Fig. 5.

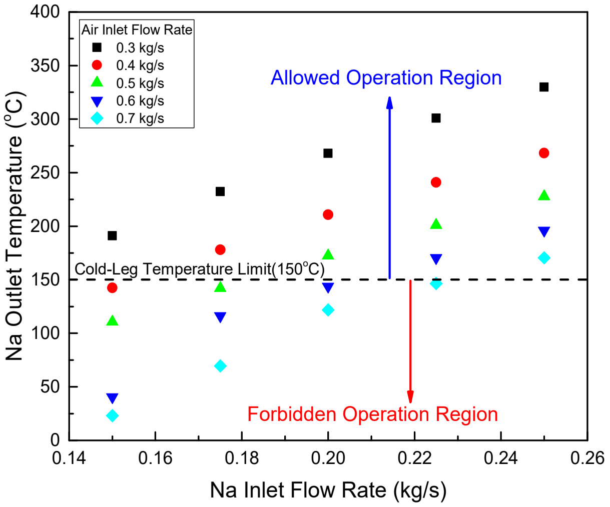

Fig. 5. Allowable Operating Range of the TESET

3. Conclusions

The performance evaluation of the AHX in the TESET was carried out using the GAMMA+2.0 code. Allowable operating conditions in the TESET were derived. The evaluation results will be used to develop operating procedures and scenarios of the TESET.

ACKNOWLEDGMENTS

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