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Modification of the Helium Supply System with a PCHE type recuperator

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1. Introduction

One of the major objectives of the ITER project is to develop a tritium breeding module with self-sufficiency for a power producing nuclear fusion reactor. In Korea, a HCCR (Helium Cooled Ceramic Reflector) Test Blanket Module (TBM) was proposed to be tested in ITER [1-4]. In the HCCR TBM, high pressure (8 MPa) and high temperature (300-500 ℃) helium gas is considered as a coolant, and therefore a helium cooling system (HCS), one of the essential auxiliary systems of the KO HCCR TBM, has been designed. The scaled-down helium supply system (HeSS, Ref. 5) was constructed in early 2012 to validate the HCS design and system design code, GAMMA [6, 7].

However, more than 2 MW of heating power was required to heat up a 1.5 kg/s mass flow of helium gas (for full scale HeSS) from room temperature to 300 ℃. In the present study, a recuperator is considered for the HeSS facility to solve the heating issues and the HeSS facility is modified.

2. Design and Construction of the Modified HeSS

In early 2011, KAERI started constructing a scaled-down helium supply system for the development of manufacturing techniques and operational experiences of the helium supply system of the KO TBM [5]. The system consists of a helium pre-heater (300 kW), PCHE type helium cooler, filter, and circulator, and was designed to operate at a temperature of 300 ℃ and a pressure of 8.0 MPa with a maximum helium mass flow rate of 0.5 kg/sec. However, the helium pre-heater did not meet the proper performance because of its mechanical problems during trial runs. Also, about 2 MWe is required to heat up the helium gas to 300 ℃ with a mass flow rate of 1.5 kg/s for a demonstration of real-scale helium cooling. Therefore, a recuperator is considered in the system to dramatically reduce the required electrical power of the helium pre-heater and improve the operational stability. A comparison of the former and modified HeSS is shown in Table I and Fig. 1.

A diffusion-bonded heat exchanger (so-called PCHE, printed-circuit heat exchanger) is installed as a recuperator in the modified HeSS because of its high efficiency and compactness. The helium mass flow rate is controlled by handling the RPM of the circulator and bypass valve-1, and the temperature is controlled by the electric power of the pre-heater and bypass valve-2.

Table I: Comparison between the helium supply systems

Facility	The former HeSS	The modified HeSS
Operation (Design) Conditions	300 (500) ℃ / 8.0 (10.0) MPa / 0.5 kg/s (1/3 scaled-down)	
Working Fluid	Helium gas	
Pre-Heater Power	300 kW	150 kW
Required Heating Power for Real-Scale	2 MW	150 kW
Linked with High Heat Flux Test Facility	KoHLT-2 (Graphite Heater) (80 kW, 0.46 MW/m^2)	KoHLT-EB (Electron Beam) (300 kW, 5 MW/m^2)
Recuperator	None	PCHE type (efficiency: 0.94)

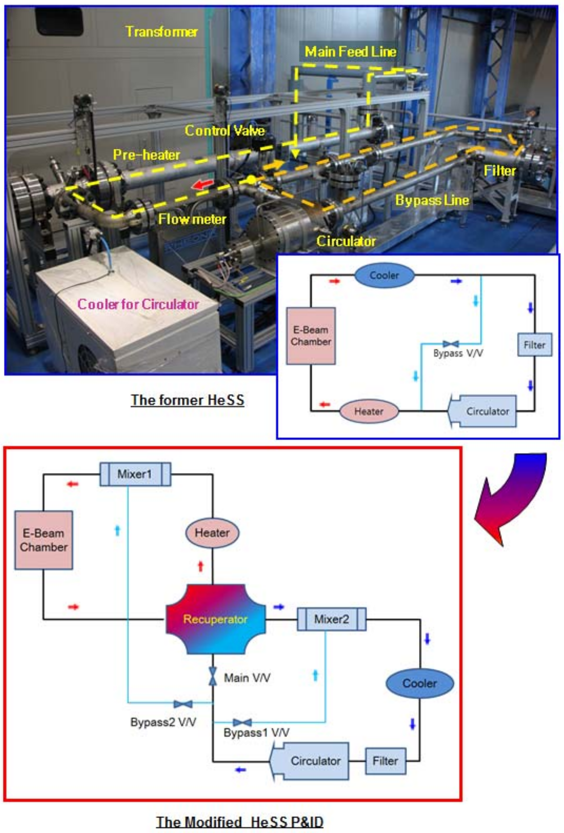

Fig. 1. Schematic diagram of the modified HeSS with a recuperator

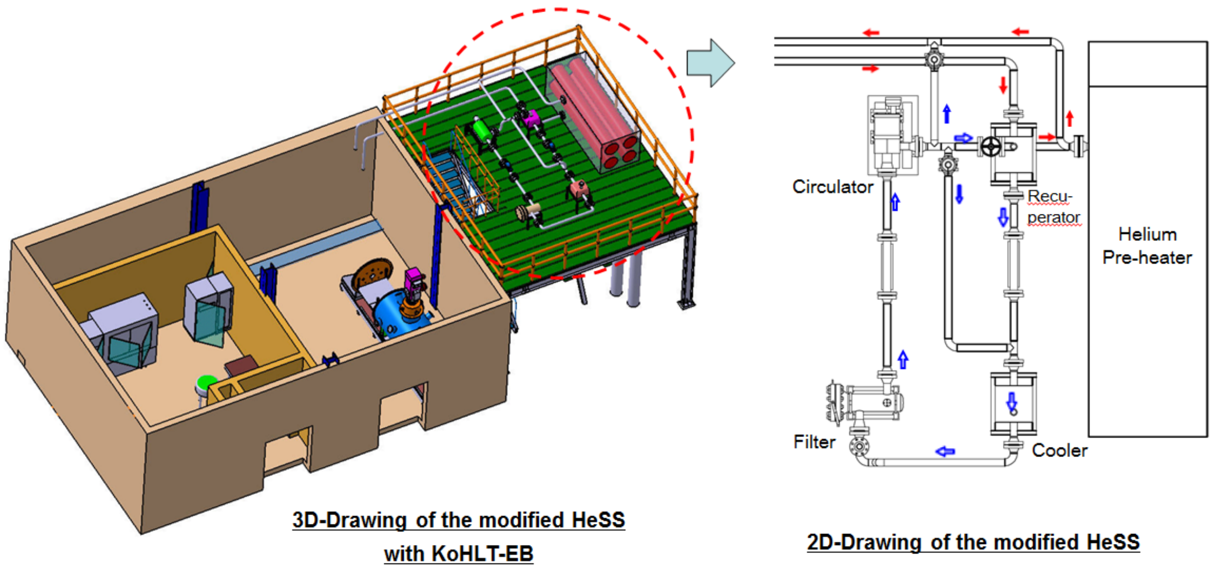

Fig. 2. Arrangement drawings of the modified Hess linked with KoHLT-EB

3. Heat Load Test Plan

A Korean high heat flux test facility, called KoHLT-EB (Korea Heat Load Test facility with Electron Beam) was constructed to evaluate the fabrication technologies required for the ITER TBM first wall using an electron gun (from Von Ardenne GmbH, Germany) with a maximum electron beam power of 300 kW, maximum accelerating voltage of 60 kV, and maximum target size of 700 × 500 mm^2 [8].

The KoHLT-EB facility was linked with the modified HeSS, as shown in Fig. 2, and the facility was successfully tested up to a 60 kW accelerating voltage and 150 (50 kV) electric power, which is equivalent to 2.5 MW/m^2 (at 400 mm x 150 mm surface area). The first wall mock-up of HCCR is installed in the KoHLT-EB for the thermal-hydraulic experiment with a constant heat flux of 0.5 MW/m^2, which is scheduled to start in mid-2013.

4. Conclusion

A 1/3 scaled-down helium supply system was constructed at KAERI for the development of manufacturing techniques and operational experience of the HCS of the HCCR TBM. The PCHE type recuperator was added in the HeSS to dramatically improve the energy efficiency and reduce the required electrical power of the helium pre-heater. The modified HeSS was linked with KoHLT-EB to supply high heat flux (~0.5 MW/m^2) to validate the design and manufacturing techniques for the first wall of the HCCR TBM and obtain thermal-hydraulic experimental data for verification and validation of the GAMMA code. The experiment and code validation are scheduled to start in mid-2013 with the first wall mock-up under normal ITER operation condition.

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