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Construction of a high temperature and pressure helium supplying system for ITER TBM

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1. Introduction

One of the major objectives of International Thermonuclear Experimental Reactor (ITER) is to develop a tritium breeding module with self-sufficiency for a power producing nuclear fusion reactor. In Korea, Helium Cooled Solid Breeder (HCSB) Test Blanket Modules (TBM) was proposed to be tested in ITER [1]. In the TBM, high pressure (8 MPa) and high temperature (350–500 ℃) helium gas is considered as a coolant and therefore a helium supplying system, one of the essential parts of the TBMs, has been developed. In present study, a scale downed helium supplying system has been designed and constructed at Korea Atomic Energy Research Institute (KAERI) to obtain manufacturing and operational experiences on the helium supplying system and to connect with a high heat load test facility (Korea Heat Load Test Facility-2, KoHLT-2) for examination of various kinds of mock-ups for the TBM structure.

2. Design of the Helium Supplying System

The scale downed Helium Supplying System (HeSS) was designed referring to HCSB design. Design temperature, pressure and helium gas mass flow rate of the HeSS are 500 ℃, 9.0 MPa and 0.5 kg/sec (one third scale of HCSB, 1.5 kg/s), respectively. A Printed Circuit Heat Exchanger was installed to cool down helium temperature up to room temperature because of a limitation of inlet temperature of the circulator of the HeSS. P&ID and construction figure of the system are shown in Fig. 1 and 2.

Table I: Design parameter of the HeSS

Facility	Helium Supplying System
Operation conditions of HeSS for KO HCSB TBM [1]	Temperature: 350 - 500 ℃ Pressure: 8.0 MPa He mass flow rate: 1.5 kg/s
Design parameters	Temperature: 550 ℃ Pressure: 9.0 MPa He mass flow rate: 0.5 kg/s (1/3 scale)
Heater power	Gas heater: 300 kW KoHLT-2 80 kW
Test chamber (KoHLT-2)	Heat Power: 80 kW (DC 200V, 400 A) Type: Box-type vacuum chamber Size: 1.2×1.2×2.4 m^3
Cooling water (fresh water)	Inlet temperature: 20 ℃ Pressure: 0.1 – 0.5 MPa Water mass flow rate: 5 kg/sec

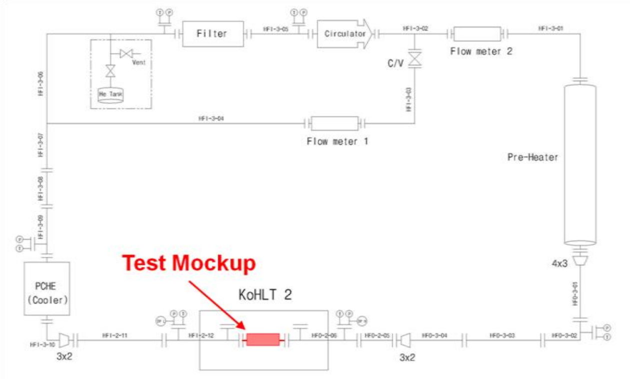

Fig. 1. P&ID of the helium supplying system and KoHLT-2

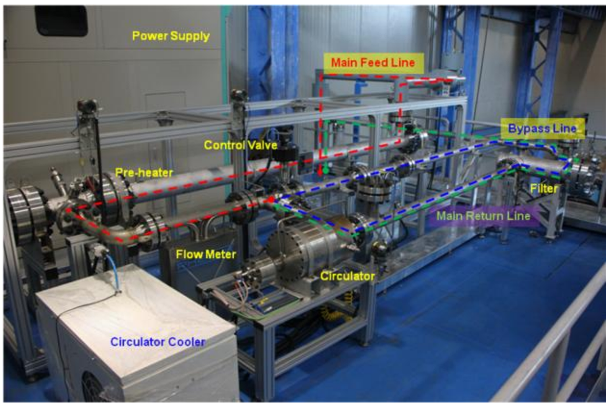

Fig. 2. Construction of the helium supplying system

3. Main Components

Preliminary CFD analysis was performed to verify the design of the pre-heater (Fig. 3) by ANSYS-CFX for thermal-hydraulic analysis [2]. A heater rod was modeled to be 15.9 mm x 4000 mm (diameter x length) and 16.7 kW/rod same as the per-heater design. A constant heat flux was applied to each heated rod and the pressure (8 MPa) and coolant inlet temperature (50 ℃) were kept to be the same as the operational condition of HCSB.

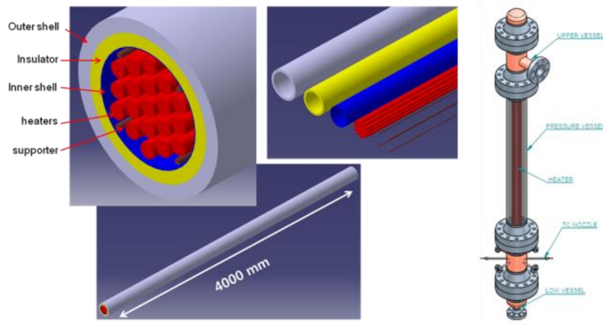

Fig. 3. Design of the helium pre-heater (3-D Drawing)

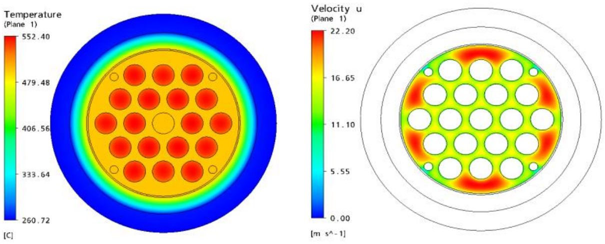

Fig. 4. CFD analysis results of the pre-heater: (a) temperature distribution at exit (b) helium velocity at exit

The calculated temperature distributions are shown in Fig. 4. The maximum temperatures on the heater rod surface and in the heater rod were calculated as 539 ℃ and 553 ℃, respectively and the calculated maximum temperature of the heater rod is less than upper category temperature of Inconel600.

KoHLT-2 was connected with the HeSS to study preliminary experimental investigation on a HeSS of HCSB TBM and to evaluate soundness of mock-ups for the TBM structure (Fig. 5). KoHLT-2 consists of a target assemble, test chamber (1.2 x 1.2 x 2.4 m^3, with vacuum system), DC power supply, water cooling system and data acquisition system (DAS) [3]. The maximum electric power is 80 kW, the target area is 700 mm x 100 mm and other specifications are summarized in table II.

Table II: Specifications of KoHLT-2

Parameters	
Heat flux (target area) [MW/m^2 (mm^2)]	0.46 (700x100)
Pulse operation	steady
Heating element	graphite panel
Power supply [kW]	80 (DC 200 V, 400 A)
Test chamber size [m^3]	1.2 x 1.2 x 2.4
Cooling water	25-120 °C, 3 MPa
Be compatible	N/A

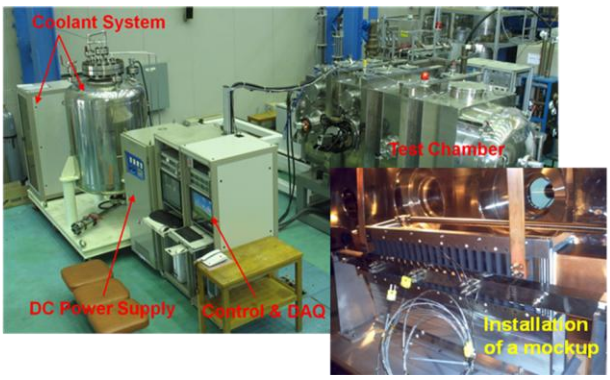

Fig. 5. Picture of KoHLT-2 and installation of a mock-up

4. Conclusions and Further Works

The 1/3 scale downed helium supplying system was constructed at KAERI for development of manufacturing techniques and operational experience of the helium supplying system of HCSB TBM. The system was designed to operate maximum helium temperature of 500 ℃ and pressure of 9.0 MPa, and to circulate helium gas at a mass flow rate of 0.5 kg/sec. For the pre-heater, the proposed design was verified through the preliminary CFD analysis and investigated the operation conditions and characteristics, in present study. However, the other major components such as the circulator, the PCHE were designed and manufactured by the manufacturing companies.

In the facility, helium is used as cooling gas and high heat flux can be supplied by the KoHLT-2 up to 0.5 MW/m^2 (will be upgraded up to 5.0 MW/m^2 with E-beam system). Therefore, various kinds of mock-ups can be tested to examine thermal-hydraulic performance and to validate code analyses using the test data by the HeSS with the heat load test facilities. In the near future, these main components are examined by preliminary experimental investigation to obtain manufacturing and operational experiences on the HeSS and the facility with heat load test facilities are utilized to test various mock-ups and to validate code with the thermal-hydraulic test data.

REFERENCES

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