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Procedure for Qualification Testing of ITER HCCR Test Blanket Sub-module

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1. Introduction

The sub-modules for HCCR (Helium Cooled Ceramic Reflector) TBM (Test Blanket Module) in Korea [1,2] will be fabricated to install inside ITER port, and some performance qualification and integrity testing and thermo-hydraulic analysis will be completed in the operational conditions. In accordance with ITER vacuum handbook [3] and TBM manufacturing procedure [4], some acceptance tests for the performance qualification should be achieved to procure test blanket modules; such as the hot helium leak test, pressure test, heat load and flow distribution profiles, and so on. Hot helium leak test procedure for acceptance tests shall be accepted in advance. Test conditions, pressure and temperature, for the helium leak test should be similar to the design conditions. Also, each testing will be carried out with the component at ambient temperature. For the HCCR TBM, ITER vacuum classification is VQC1A, so maximum acceptance leak rate is below 10^{-10} Pa·m3/sec (air equivalent) [3]. Hot leak test condition is 8 MPa at operational coolant pressure and 520 °C at the maximum surface temperature of first wall. The high heat flux test facility, KoHLT-EB (Korean heat load test facility using an electron beam) [5] will be used to evaluate the cooling performance and coolant profile distribution, so KoHLT-EB will be modified to connect with the helium cooling system.

2. Methods and Results

2.1 Manifold fabrication of sub-module

HCCR TBM is composed of TBM main body and water shield. And TBM body consists of 4 sub-modules. Fig. 1 shows the ITER HCCR TBM sub-module and the inner structure for breeder, multiplier, and reflector.

After the manufacturing of the TBM sub-module, the dedicated performance qualification testing, such as Hydrostatic pressure test, helium leak test, and the coolant flow distribution, should be carried out before the procurement in accordance with ITER guidance [3,4]. First wall manifold for the performance testing is shown in Fig. 2.

2.2 Performance qualification testing

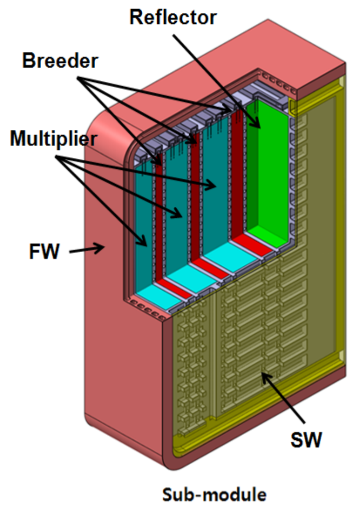

Fig. 1. ITER HCCR TBM sub-module.

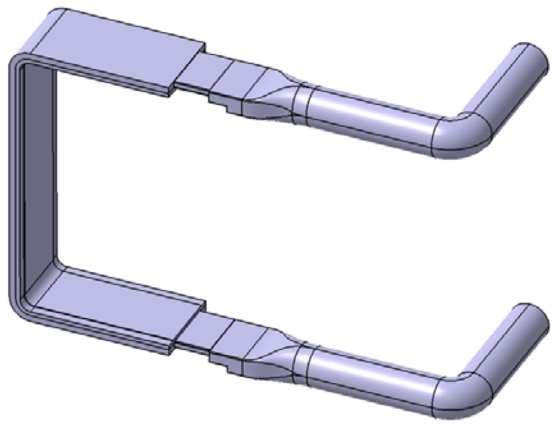

Fig. 2. HCCR TBM first wall and manifold for the performance testing.

The hydrostatic pressure test should be performed on each equipment with a liquid or water. The various pressure/temperature combinations for calculating the components and determining the test pressure must be taken into account in the different operating situations. The test pressure (PT) is defined by the following equation,

$$PT = Max\left[\left\{1.25 \cdot PD \cdot \frac{S_{mA}(T_{test})}{S_{mA}(T)}\right\};\{1.43 \cdot PS\}\right],$$

where,

PS: maximum allowable pressure. PS cannot be less than the pressure in the equipment operating conditions to which the equipment would be subjected during normal operating conditions, including normal operating incidents, startup and shutdown.

PD: Design pressure.

T: temperature associated with PD.

T_{test} : test temperature.

$S_{mA}(T_{test})$: allowable stress at the test temperature T_{test}.

$S_{mA}(T)$: allowable stress at temperature T.

The aim of the Hot Helium Leak Test (HHLT) is to ensure acceptable vacuum leak tightness of the active-cooling in-vessel components. Fig. 3 below describes the test steps of the HHLT procedure that shall be performed on each ITER internal component after the manufacturing process and hydraulic pressure test.

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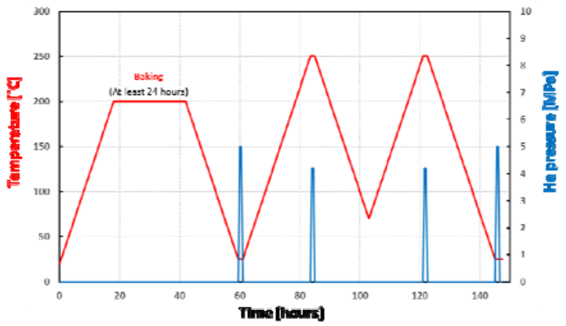

Fig. 3. Schematic illustration of hot helium leak test sequence.

2.3 Thermo-hydraulic performance testing

Korea heat load test facility by using electron beam (KoHLT-EB) [5] is operated in KAERI. KoHLT-EB facility with an electron gun for a high heat flux with a maximum beam power of 300 kW is now in operation to conduct high heat flux tests for the plasma facing components, as shown in Fig. 4. KoHLT-EB is connected to the water cooling system for the thermo-hydraulic testing of sub-module and manifold. Also helium cooling system of a high temperature and high pressure is connected to this facility.

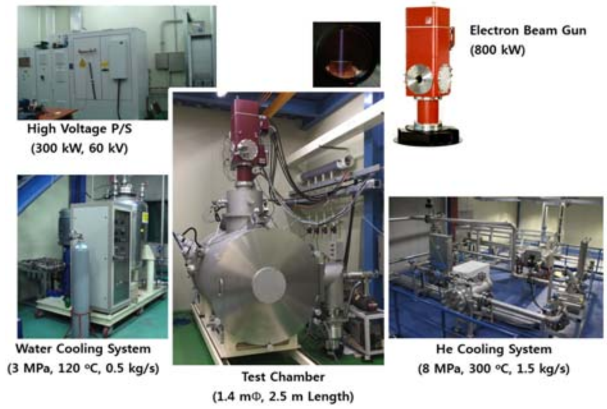

Fig. 4. High heat flux testing facility, KoHLT-EB

3. Conclusions

The sub-modules for HCCR TBM will be fabricated to install inside ITER vacuum vessel, so some performance qualification, integrity testing and thermo-hydraulic analysis will be completed in the ITER operational conditions. In accordance with ITER vacuum handbook, some acceptance tests for the performance qualification should be achieved to procure test blanket modules; such as the hot helium leak test, hydraulic pressure test, heat load and flow distribution profiles. HHLT procedure for acceptance tests shall be accepted in advance. After the fabrication of HCCR sub-module, these performance test should be carried out as a factory acceptance test before the procurement.

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