Experimental study for vapor adsorption characteristic using molecular sieve in air flow

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ABSTRACT : The coolant purification system (CPS) is designed to capture the tritium in helium cooling system (HCS) of the nuclear fusion reactor. 1 % of helium flow is bypassed in CPS from HCS and is purified. In the system, the tritium is oxidized by the oxide bed and the oxidized tritium Q_2O is physically adsorbed by an ambient molecular sieve bed (AMSB). To confirm the function of AMSB, the test facility is designed by KAERI and KFE. Tests were performed to compare absorption rate and saturation characteristics according to vapor concentration and gas flow rate. The purpose of this paper is to experimentally confirm the adsorption capacity and properties of small AMSBs at various air flow rates.

Introduction

- **Objectives of Test Blanket Module**
  - Tritium breeding as a fuel for fusion reaction (Tritium Extraction system)
  - Conversion and extraction of energy by fusion reactor (Helium Cooling System)
  - Neutron and γ-ray shielding for the protection of vacuum vessel and superconducting magnet
- **KO HCCR TBM: Helium Cooled Ceramic Reflector**
  - Four sub-module concept
  - Transportation of irradiated TBM for PIE
  - Reduction of EM force
  - Endurance of internal over-pressure
- **Graphite as neutron reflector**
  - Reduce the amount of Be multiplier up to 50%
  - Decrease of cost
  - Comparable nuclear performance

Table 1. Design parameter and materials of TBM-set

Parameter	Values
Structural material	KO-RAFM (ARAA) (< 550 °C)
Breeder	Li_2TiO_3 (< 800 °C), ~80 kg 70% enrichment Li-6
Multiplier	Be (< 650 °C), ~100 kg
Reflector	**Graphite** (<1200 °C)
Size	1670(P) x 462(T) x 605(R) (mm)
Coolant	8 MPa, 300 °C inlet / 500 °C outlet He 1.14 kg/s (Nominal)
Purge gas	He with 0.1 % H_2

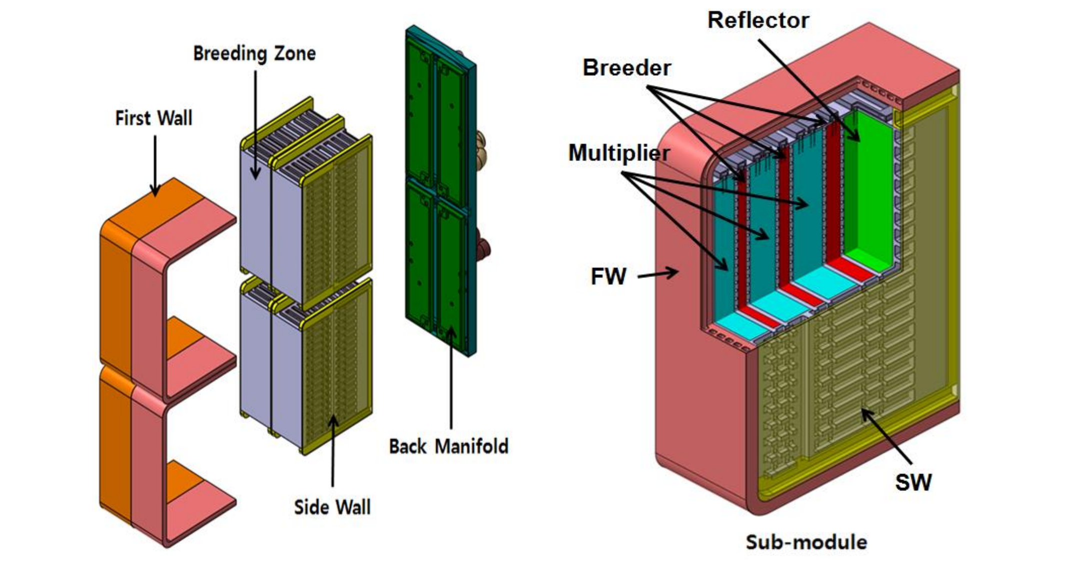

Figure 1. HCCR TBM-set configuration at conceptual design(CD) phase

Coolant Purification System

- **Main objectives of CPS**
  - Maintenance of Tritium under certain level in Helium Cooling System (HCS)
  - Transfer the captured Tritium to Tritium Accountancy System(TAS)
  - Extraction of impurity gases and dust in helium coolant
- **Operation Conditions**

Pressure / Temperature (@ CPS inlet)		8 MPa / 50 ° C
Flow rate		54.9 L/min (11.4 g/s = 1% of HCS coolant flow rate)
Efficiency		95% (assumption)
Partial pressure in HCS (calculated)	Tritium	0.02 Pa (less than 0.8 Pa)
	Hydrogen	0.324 Pa

- **CPS design**

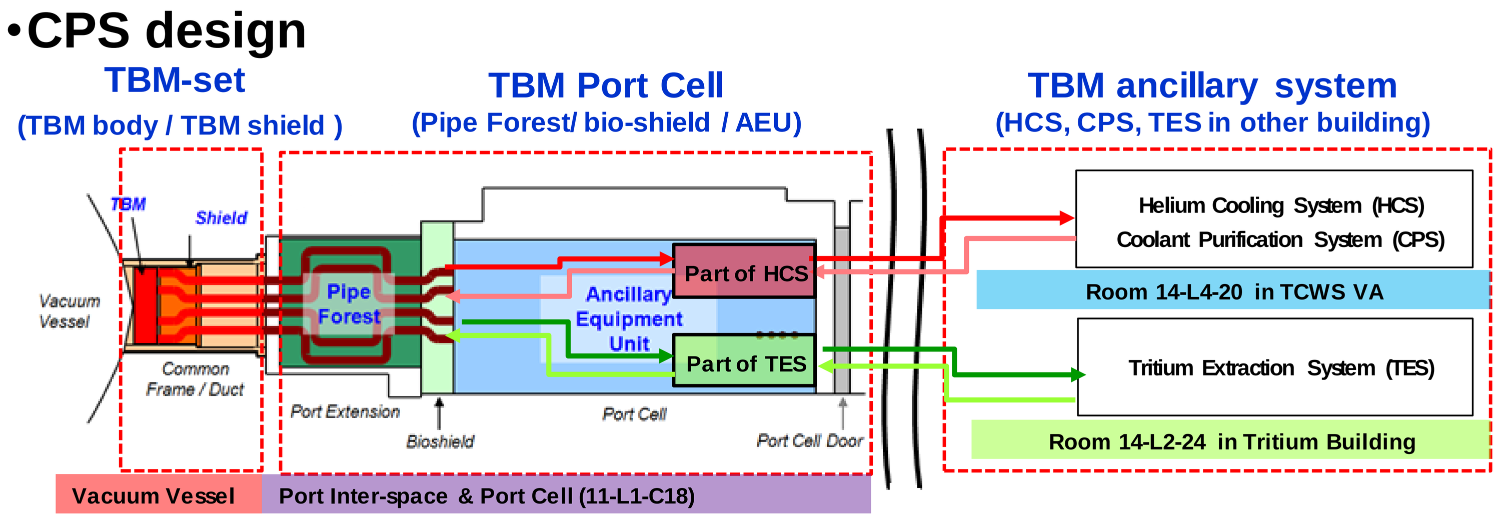

Figure 2. schematic diagram of TBM-set and auxiliary systems

- Simple process diagram:

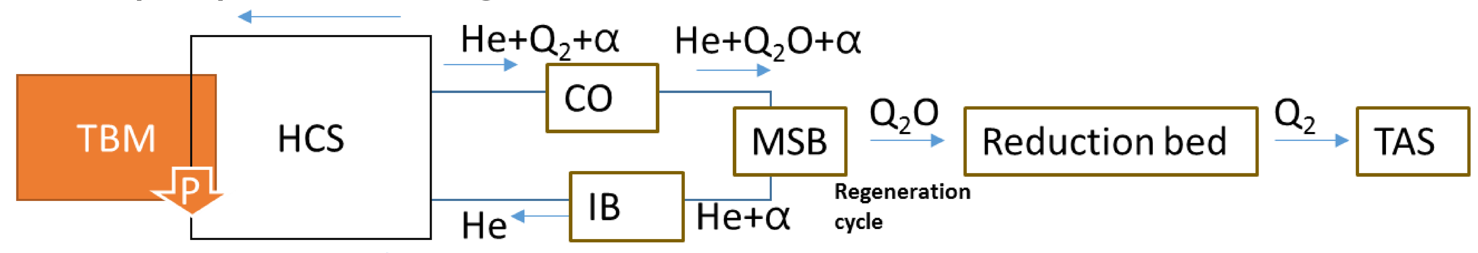

Figure 3. schematic diagram of CPS

Research Apparatus for Vapor Adsorption and Desorption (RAVAD)

- Characteristics of scaled-down test facility, RAVAD
  - Test condition

Parameter	Value
System pressure	0.2 - 0.4 MPa
Temperature	25 ℃
Vapor concentration	0.3 - 7 Pa ~
Superficial velocity of air	0.05 - 0.3 m/s

  - Test section (AMSBs)

I.D	L	Vol.	M	capacity
16mm	32/64mm	6.43ml	4.94g	168mg

  - Properties of MS5A, ZEOCHEM® Z5-01

Properties	Value
Tapped bulk density	770 kg/m³
Bead size	1.6-2.6 mm
Equilibrium water adsorption capacity	21% @20℃/50%rh
Heat of adsorption	4200 kJ/kg water
Specific heat	1.07 kJ/kg℃
Recommended regeneration	240 – 300℃

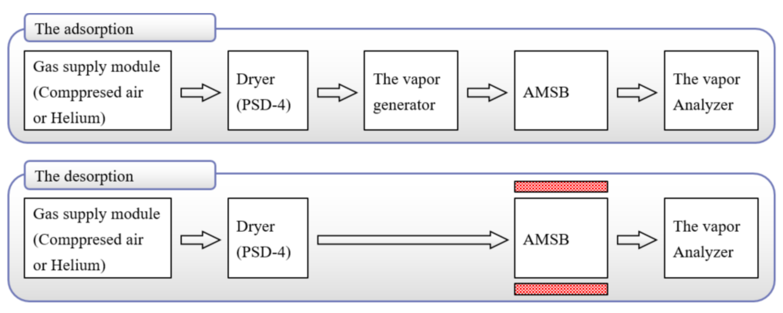

Figure 4 Adsorption and desorption process schematic diagram of the AMSB

Figure 5 Layout of the AMSB apparatus: (a) dryer, (b) vapor generator, (c) test section with a furnace and (d) vapor analyzer

Results of Air Test

- Effect of the difference on the velocity
  - Module 1(D: 16 mm, H: 24 mm),
  - Times for maintaining adsorption efficiency rates of 99% and 95% under the 2 ppm

Adsorption efficiency	Air flow rate		
	2 SLPM	5 SLPM	10 SLPM
99%	93 hr	20 hr	N/A
95%	150 hr	97 hr	20 hr

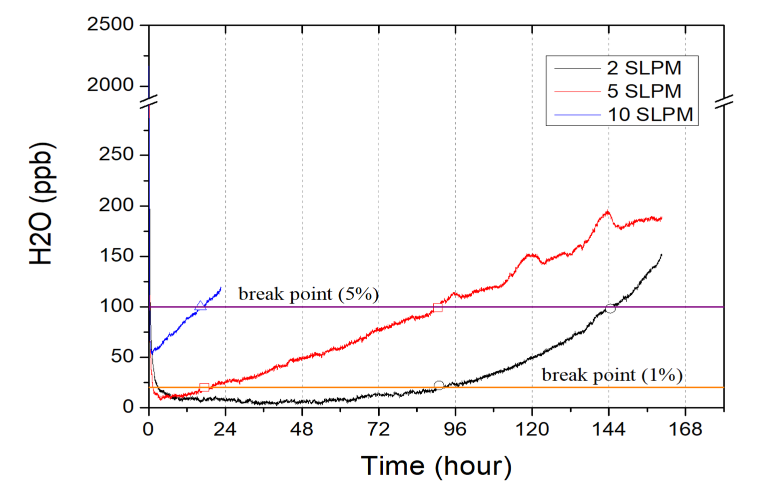

Figure 6 Breakthrough curves with a vapor concentration of 2 ppm with various gas velocities

- Effect of the difference on the length at concentration of 2 ppm/20 ppm
  - Module 1(D: 16 mm, H: 24 mm), Module 2(16 mm, H: 64 mm)

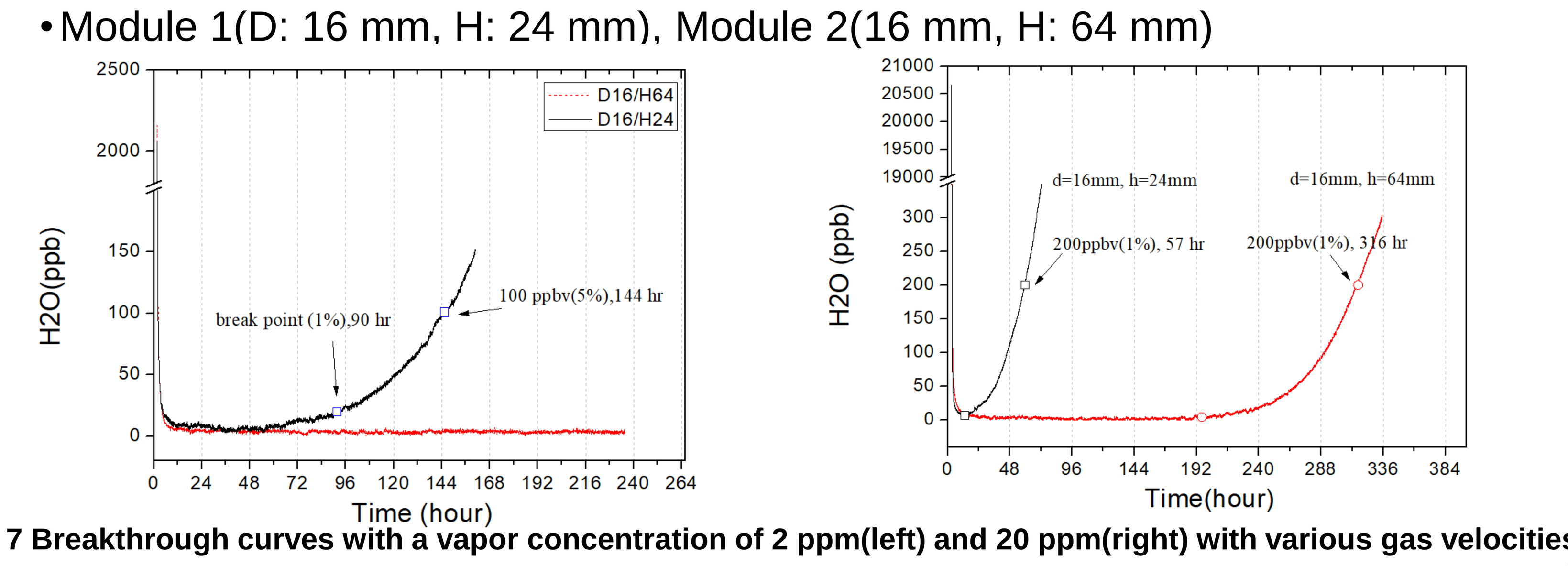

Figure 7 Breakthrough curves with a vapor concentration of 2 ppm(left) and 20 ppm(right) with various gas velocities

CONCLUSIONS : In order to verify the adsorption characteristics under a very low concentration of Q_2O, the test facility with compact AMSBs has been constructed and tests were performed to compare absorption rate and saturation characteristics according to vapor concentration and gas flow rate. Due to the short length of 24 mm and high speed environment, the operating time was shorter than that of the analysis, and the result showed lower efficiency than the generally known efficiency of AMSB. The experimental results will be supplemented through additional experiments to derive the optimal adsorption environment. Through this research, more reliable AMSB design is expected.

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