Commissioning test on vapor adsorption and desorption using a small scale AMSB

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1. Introduction

Helium Cooled Ceramic Reflector (HCCR) blanket has been developed to test tritium breeding capability and extraction of high-grade heat in ITER. In order to extract the bred tritium, the TBM is connected to Tritium Extraction System (TES) where hydrogen isotopes (Q_2) and water vapor (Q_2O) are separated and adsorbed, desorbed and delivered to Tritium Plant. As a major process for the TES, Cryogenic Molecular Sieve Bed (CMSB) and Ambient Molecular Sieve Bed (AMSB) were adopted for Q_2 [1] and for Q_2O, respectively.

In particular, AMSB was selected for Q_2O adsorption and desorption since this has been widely used in industry including petroleum and catalyst, and proven its performance in reducing water concentration in the process gas. Recently, the AMSB apparatus was constructed to test Q_2O adsorption and desorption performance for the HCCR systems including the TES in National Fusion Research Institute [2], where the test section is designed to replace beds with diverse diameters and lengths in order to be able to investigate their effects on the performance.

In this work, a series of commissioning results of the AMSB apparatus are introduced. The adsorption was conducted with 20 ppmv of water vapor under 330 kPa of a pressure condition. The desorption was conducted by heating up to 400℃ during the regeneration procedure, and the desorbed water amount was measured.

Fig. 1. Layout of AMSB apparatus ; (a) dryer, (b) vapor generator, (c) test section with furnace and (d) vapor analyzer

2. Experimental description

Fig. 1 shows the layout of AMSB apparatus, which consists of gas supply module, dryer, vapor generator, replaceable test section and vapor analyzer. The schematic diagram is shown in Fig. 2. Compressed air or helium, is supplied by mass flow controller as a main carrier gas. After passing through the dryer where background vapor concentration of the carrier gas is reduced to 30~40 ppbv, the gas is mixed with moisture at the vapor generator. The carrier gas containing water vapor flows to the test section where MS5A adsorbent is packed as a bed, and the vapor in the gas is separated by the adsorbent in room temperature condition. The properties of the MS5A are listed in Table 1[3]. After the test section, the vapor analyzer [4] with Cavity Ring Down Spectroscopy (CRDS) type measures the vapor concentration in the gas. This type was chosen because of its fast response and accuracy.

The desorption starts after the breakthrough of the vapor in the bed is achieved. The temperature to regenerate absorbent increases to 300℃ at the speed of 50℃/30min and maintain the temperature for enough time. When the measured vapor is decreased to around 1 ppmv, the furnace is again heated up to 400℃ at the same speed in order to desorb residual water. After the vapor analyzer indicates sufficiently low vapor concentration, then the desorption is finished and the furnace cools down to room temperature.

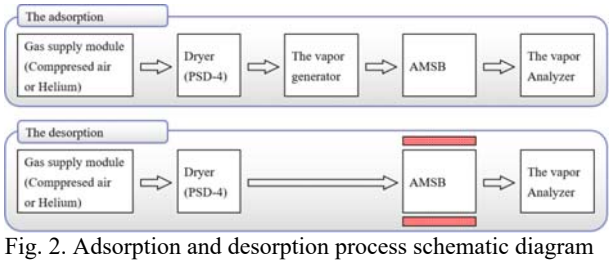

Fig. 2. Adsorption and desorption process schematic diagram of AMSB module

Table 1. The properties of MS5A, ZEOCHEM® Z5-01 [3]

Properties	Value
Tapped bulk density	770 kg/m^3
Bead size	1.6-2.6 mm
Equilibrium water adsorption capacity	21% @20℃/50%rh
Residual water content, 550℃ as shipped	1.5 %
Heat of adsorption	4200 kJ/kg water
Specific heat	1.07 kJ/kg℃
Recommended regeneration	240 – 300℃

Table. 2. The diverse sizes of MSB

H/D ratio		Inner diameter		
		16 mm	20 mm	24 mm
Height	24 mm	1.5	1.2	1
	64 mm	4	3.2	2.7
	128 mm	8	6.4	5.3

To develop a proper design of molecular sieve bed, Testing of various sizes of the bed is planned as summarized in Table. 2. The initial commissioning has been conducted using the MS5A bed with diameter of 16 mm and height of 24 mm, in particular to test the effect of flow rate on the adsorption/desorption performance. For this, 20 ppmv water vapor was introduced to the bed at 2 and 10 SLM with compressed air, respectively.

3. Experimental results

Fig.3 shows the commissioning result for 20 ppmv water concentration with flow rate of 10 SLM and pressure condition 330 kPa. In the beginning, the water concentration decreases to 77 ppbv then the adsorption breakthrough starts to occur. The concentration slowly increases but the breakthrough is not fully achieved until 110 hours. It is to be noted that the general trend during the breakthrough does not follow the typical S-shaped one as found in research [5]. This is speculated that the amount of the absorbent is too small to capture the water vapor for this flow rate.

2 SLM with the same concentration was performed to determine the effect of low flow rate and the result is shown in Fig. 4. While the trend in the beginning is similar to 10 SLM case, this shows clearer S-shaped breakthrough curve than that of the high flow rate. This result suggests the bed should be larger to have a typical S-shaped breakthrough curve under the condition of high flow rate such as 10 SLM.

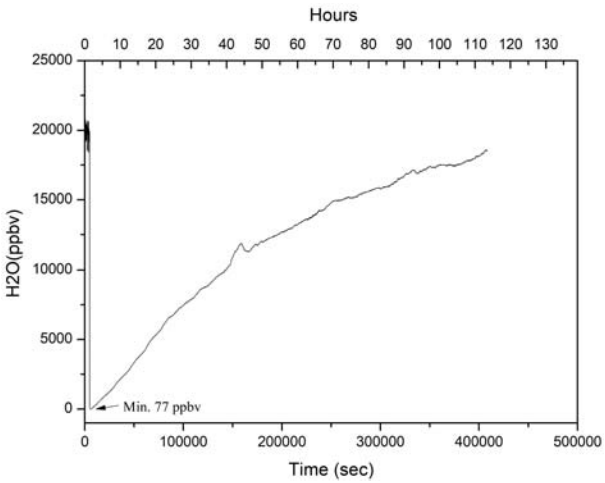

Fig. 3. Adsorption breakthrough curve : 10 SLM, 20 ppmv

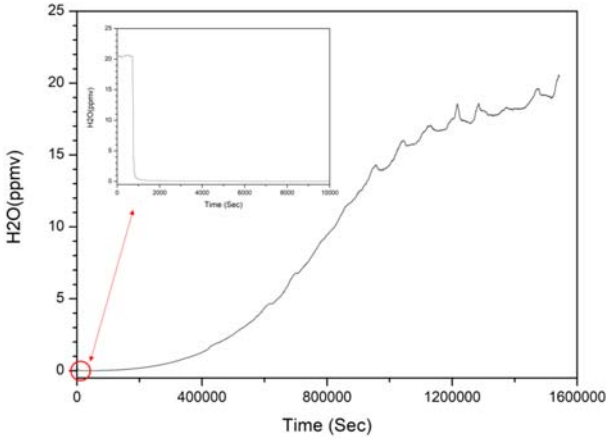

Fig. 4. Adsorption breakthrough curve : 2 SLM, 20 ppmv

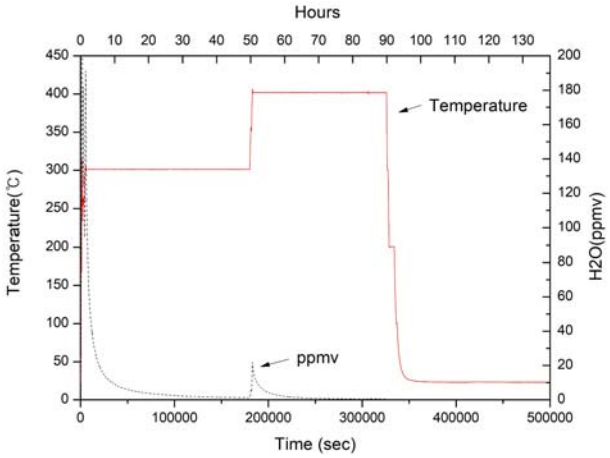

Fig. 5. Amounts of vapor on the desorption with various time (Red line : temperature, dashed line : ppmv)

During the regeneration, the temperature history and desorbed water concentration are shown in Fig. 5. The most of water, 380 mg, was desorbed in the first heat-up process when the bed was heated and maintained to 300℃. The vapor concentration decreased to 1.2 ppmv after 48 hours. Then, 40 mg of water was further released when heated to 400℃. The vapor concentration finally reached 400 ppb. To be noted that 240~300℃ temperature range is recommended by the adsorbent vendor, more works will be followed to find the proper temperature for regeneration.

4. Conclusions and further works

The commissioning of vapor adsorption and desorption were conducted using the AMSB apparatus to develop the AMSB module for the TES. The obtained adsorption breakthrough curve deviated from typical ones reported in the literature especially when flow rate is lower. This suggests that a larger amount of the adsorbent, thus larger size of beds with diverse diameters and heights, needs to be studied. During the regeneration, approximately 90% of water was desorbed when heated to 300℃which is the upper temperature

range recommended by the vendor. Further study is expected to elaborate on the regeneration conditions.

Acknowledgments

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REFERENCES

[1] S.C. Park, S.K. Son, M.Y. Ahn A. Young, S. Cho, Y.H. Park and Y. lee, Hydrogen adsorption performance for large-scale cryogenic molecular sieve bed, Fusion Engineering and design, Vol. 146, pp. 1863-1867, 2019.
[2] C.W. Shin, E.H. Lee, S.K. Kim, H.G. Jin, D.W. Lee, M.Y. Ahn, S.C. Park and S.K, Son, Test facility for vapor adsorption using molecular sieve in helium coolant purification system, Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, 9-Jul-2020.
[3] ZEOCHEM, personal communication.
[4] TIGER OPTICS, personal communication.
[5] W.C. Jung, Y.M. Kim, S.W. Han, H.M. Moon, M.H. Chang, H.G. Lee, A study on the treatment process for trace amount of CH_4 and H_2O, 12th International Conference on Tritium Science & Technology (Tritium 2019), Busan, Korea, 25-Apr-2019.