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

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1. Introduction

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 NFRI. 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.

2. Methods and Results

2.1. Coolant purification system

CPS consists of oxide bed, adsorption bed, impurity bed [1]. First, hydrogen isotopes are converted to Q_2O using metal oxide (CuO or Cu_2O) under 300 ℃ in order to increase the size of the molecule [2]. Secondly, Q_2O is physically adsorbed by zeolite in the AMSB. While the helium passes through the sieve, Q_2O is adsorbed because of large size and polarity. The one of main advantages is that AMSB has a high adsorption efficiency more than 99% at room temperature. Another characteristic is that AMSB can be regenerated by pressure and temperature swing adsorption(PTSA). Therefore, two MSBs in parallel allow CPS to operate continuously. After AMSB, impurities such as CO, O2, N2, CO2, etc are removed through the impurity bed and returns purified helium to HCS.

2.2 test facility for AMSB characteristics

The test facility has been constructed for the verification of the adsorption bed [3]. The low pressure experiment is planned through scaling down due to the lack of helium supply and low concentration of Q_2O [4]. Before the main helium tests, air tests were performed under room temperature and 3.3 bar. Nine AMSBs are planned with different diameters and lengths - 16, 20 and 24 mm and 24, 64 and 128 mm, respectively. For the first set of experiments, the AMSB with a diameter of 16 mm and a length of 24 mm is used. As the zeolite, ZEOCHEM® Z5-01 was used. Tests were performed at three air flow rates: 2 slm, 5 slm and 10 slm. The moisture concentration in the air is 2 ppmv, and the partial pressure is maintained at 0.66 Pa in the system pressure of 330 kPa. The concentration of moisture in the air exiting the AMSB is measured by the vapor analyzer with Cavity Ring Down Spectroscopy (CRDS)

Table 1. Comparison of the experimental results and correlation results for the time maintaining the adsorption efficiency of 99% and 95% under 2ppmv moisture condition and various flow rate

Time [hour]	Adsorption efficiency	Air flow rate		
		2slm	5slm	10slm
Test	99%	93	20	N/A
	95%	150	97	20
Analysis	99%	2668	848	241
	95%	2795	976	369

2.3 test results

Adsorption experiments were conducted by discharging air with a pressure of 330 kPa and moisture of 2 ppm at flow rates of 2~10 slm. Table 1 shows the times to maintain 99% and 95% performance at each flow rate. In addition, the experimental results are compared with the correlation of Nakashima [5], and are shown together in the table. In the case of the 2 slm experiment, the concentration dropped to several ppb, showing very stable adsorption. Maximum adsorption efficiency of the AMSB is 99.9%. The results of the experiment and the results of the correlation were very different. After recording the lowest concentration, the percentage of moisture passing through without adsorbing to AMSB was significantly higher than that of the analysis. In particular, for the case of 10 slm, the maximum adsorption rate is 97.4%. The first reason for this phenomenon is that the length of the AMSB for the verification experiment is short, so the required length of the adsorption bed is not satisfied. In general, for stable adsorption, it is recommended to operate in an environment of less than 0.1 m/s. but, in the case of 5 slm and 10 slm - converted to linear velocity of 0.13 m/s and 0.26 m/s, respectively- exceeds that standard. For such reason, the correlation equation shows an ideal breakthrough curve and suggests sufficient operating time, but the actual experimental results show quite short time. To confirm this analysis, an additional 64mm-long experiment will be conducted as the next stage experiment.

3. Conclusion and further works

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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