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Design of a tritium adsorption bed in the coolant purification system

Chang Wook Shin*, Eo Hwak Lee, Suk-Kwon Kim , Seong Dae Park, Hyung Gon Jin, Sunghwan Yun, Jae-Sung Yoon, Dong Won Lee

Korea Atomic Energy Research Institute, Daejeon, Republic of Korea
**Corresponding author: cwshin@kaeri.re.kr*

1. Introduction

HCS (Helium cooling system) circulates throughout the tritium breeding system to extract heat in fusion reactor. Then, secondary cooling system extracts heat from HCS to external heat sink. In the cooling process, small tritium continuously permeates to HCS. If tritium is not removed in the HCS and reaches high concentration, it can be exposed to external environment through the secondary cooling system. Coolant purification system (CPS) is for the removal of tritium in the HCS. 1% of HCS flow rate bypasses CPS and is purified. The final purpose of this research is to experimentally verify the efficiency of CPS under operation condition. The test facility is under construction now and the test will be performed soon. In this paper, the design of adsorption bed is introduced.

2. Methods and Results

2.1. Coolant purification system

In spite of various other methods for extracting Q2 in Helium flow, this study utilizes physical capture using molecular sieve. CPS consists of oxide bed [1,2], adsorption bed[3], impurity bed[4] and so on as shown in Fig 1. Since the tritium is too small to be captured by molecular sieves, it will pass through CPS and the system cannot function adequately. Therefore, it should be oxidized to Q2O and then a molecular sieve bed (MSB) captures.

Zeolite molecular sieves are crystalline, highly porous materials, which belong to the class of aluminosilicates. These crystals are characterized by a three-dimensional pore system, with pores of precisely defined diameter. The corresponding crystallographic structure is formed by tetrahedral of (AlO4) and (SiO4). [5] The molecular sieves are classified according to the size. When water is adsorbed, 3-4 Å molecular sieve is often used. Since the critical diameter of helium and H_2O are 2 Å and 2.6 Å, respectively, helium, relatively small compared to pore size, passes through the sieve and H_2O with large size and polarity is adsorbed. Another advantage is high efficiency at room temperature. Generally, it has a high adsorption efficiency of 99% or more.

However, the adsorption capacity varies depending on the adsorbent type, temperature, pressure and partial pressure of steam [6], and the saturation characteristic changes as well [7]. Therefore, the MSB should be designed so that the system can be used for a sufficient time in the operating conditions.

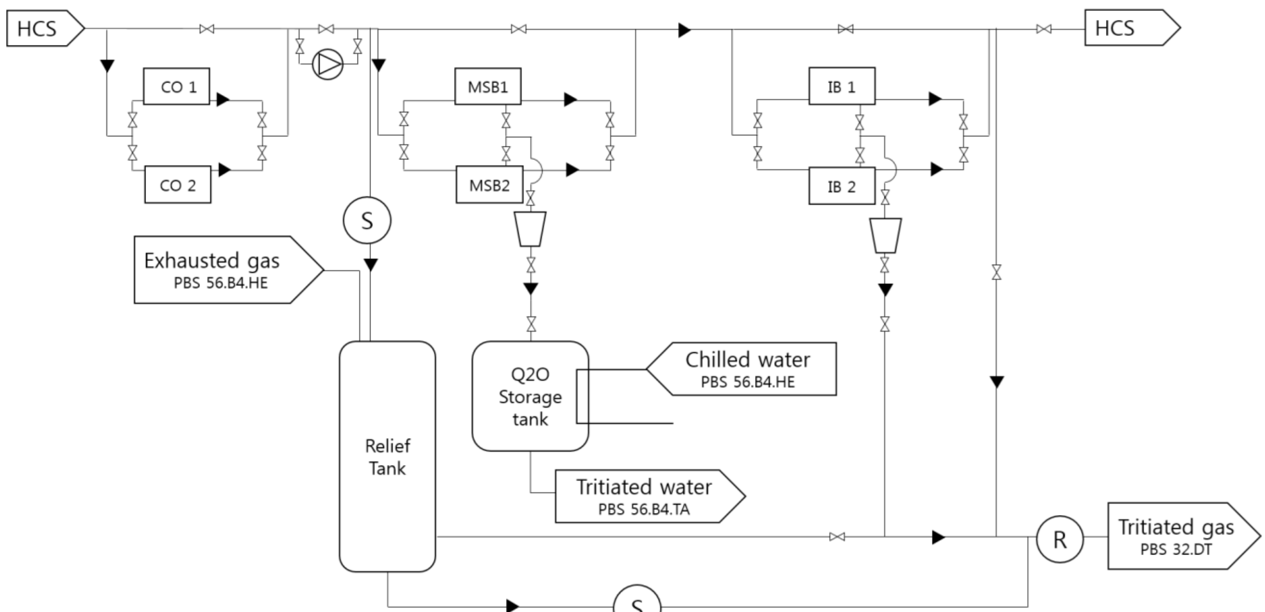

Fig 1 Schematic diagram of CPS (CO: copper oxide bed, MSB: molecular sieve bed, IB: impurities bed)

2.2

molecular sieve bed

The concentration of Q2 in CPS is estimated as 0.3 Pa, which is very low compared to the Helium pressure of 8 MPa. Helium mass flow rate is 0.0114 kg/s which is 1% bypass flow from HCS. To design the size of MSB, the correlation of Nakashima [8] is used. The equation for time to saturation is as follows,

$$t = \left[\frac{Am}{vC_0}\right]\left\{l - \left[\frac{v}{2K \cdot Am}\right]\ln\left(\frac{C_0}{C_B}\right)\right\} \qquad (1)$$

Where,
A: Amounts of HTO adsorbed (mmol/ml)
Am: Maximum adsorption capacity (mmol/ml)
C: Concentration of HTO in the feed gas (mmol/ml)
K: Adsorption rate constant (ml/mmol/min)
v: Linear velocity of the feed gas (cm/min)
C_0: The initial concentration of HTO in the feed gas (mmol/ml).

Maximum adsorption capacity and adsorption rate constant should be experimentally determined. It was developed in relatively high vapor pressure condition, but the variables were applied through linear interpolation. Test to verify this is currently being planned. Table 1 shows the allowable operating time according to the diameter and height assuming that the efficiency is adsorbed conservatively at 99%.

Assuming a target operating time of approximately 6 months and conservatively assuming that only 70% of the adsorption capacity is used, the diameter of 0.1 m and the length of 1 m were calculated to be suitable size with about 265 days.

Table. 1. Time(days) to saturation of MSB

	Height[m]		
Diameter[m]	0.5	1	2
0.1	131	**265**	532
0.2	532	1066	2134
0.5	3336	6674	13350

3. Conclusion and further works

The adsorption of zeolite molecular sieve is used to extract tritium in HCS. The major components of CPS are oxide bed, adsorption bed and impurity bed, which oxidize tritium in helium to water and capture it with MSB. In order to design the MSB, literature review on the adsorbent characteristics and design study was carried out, but previous studies on the adsorption bed operating at very low partial pressures such as CPS were extremely limited. At first, MSB was designed and sized to operate for more than 6 months through the existing correlations. Verification experiment will be performed in the near future. Due to the difficulty of long-term experiments, the size of the MSB was reduced to a small size of several tens of millimeters, and the experimental pressure was reduced so that the helium can be supplied for long time. The effect of pressure and concentration on saturation characteristics will be experimentally determined to improve the correlation and a more reliable MSB design will be derived.

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