Design of the first prototype ZrCo bed for the ITER SDS bed

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1. Introduction

In the ITER (International Thermal Experimental Reactor (ITER) Storage and Delivery System (SDS), hydride beds require the performance of a rapid recovery and a rapid delivery of DT fuel gases, and an accurate measurement of the in-bed tritium inventory [1]. In the ZrCo bed developed at FzK/TLK for the ITER SDS bed, 90% of hydrogen was delivered in 34 minutes at 350^{o}C without a preheating [2]. For this bed, ~5% of a disproportionation ($ZrCoHx \rightarrow ZrH_2 + ZrCo_2 + (x-1)/2H_2$) occurred in one cycle of a hydriding/dehydriding [2]. In the ZrCo bed developed at JAEA/TPL, 90% of hydrogen was delivered in 60 minutes at 350^{o}C with a preheating at 350^{o}C [3]. For this bed, ~30% of hydrogen was retained after 14 cycles of a hydriding and dehydriding [4]. We have proved that a reduction of the hydrogen pressure (< ~2 kPa) in the ZrCo bed during a delivery is a key measure for a minimization of a disproportionation, and that a filter with a large surface area is essential for a design of the SDS bed using ZrCo [5]. This paper presents a new bed design concept for a higher delivery rate and a lower disproportionation rate.

2. Design of the primary and secondary vessels in the first prototype ZrCo bed

The SDS bed containing 1251 g of ZrCo can store 70 g of tritium as a chemical form of $ZrCoT_{2.8}$. A stoichiometry of 2.8 is considered to be an operation limit of the SDS bed because the SDS operating pressure is limited at < 0.1 MPa.

Figs. 1 and 2 show the structure of the primary vessel. It consists of a filter (Nichidai filter; pore size 0.5μm) cylinder, a He loop (6mm O.D., 4.2mm I.D.), four cartridge heaters for a simulation of the tritium decay heat and Cu fins (1 mm thickness, 4mm gap). ZrCo powder (< 1 mm diameter) is loaded into the 8 mm gap between the primary vessel (5 mm thickness) and the filter cylinder (1.7 mm thickness). A coiled cable heater is brazed into the groove on the outer surface of the primary vessel (~2kW) and attached to the inner surface of the filter cylinder (~2kW) so that the heat is transferred from these heaters to the ZrCo hydride powder through the Cu fins.

Figs. 3 and 4 show the structure of the prototype bed. Six thermal reflectors (2mm thickness) are inserted between the primary vessel and secondary vessel to minimize the heat loss from the primary vessel to the secondary vessel. The space between the two vessels can be maintained at a high vacuum. Hydrogen outlet tube in the primary vessel is designed to be a 1 inch tube to obtain a larger conductance for a vacuum pumping during a delivery. Vacuum tube in the secondary vessel is designed to be a 1.5 inch tube to achieve a high vacuum pressure (< 10^{-5} Pa) in the secondary vessel to reduce a radiation heat conductance. For the measurement of the pressure drop during a delivery, the vacuum pressure sensors are placed between the filter and primary vessel, and on the hydrogen outlet tube.

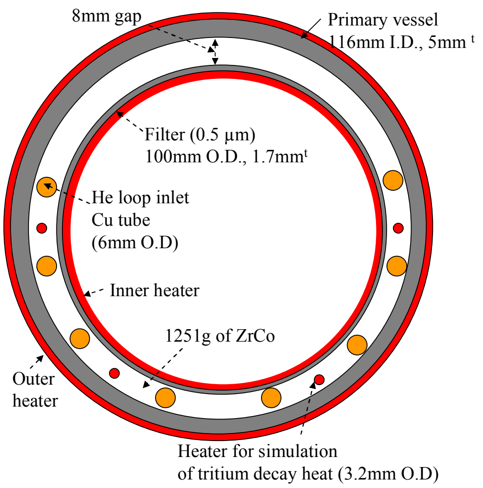

Fig. 1. Radial cross-section view of primary vessel of the first prototype ZrCo.

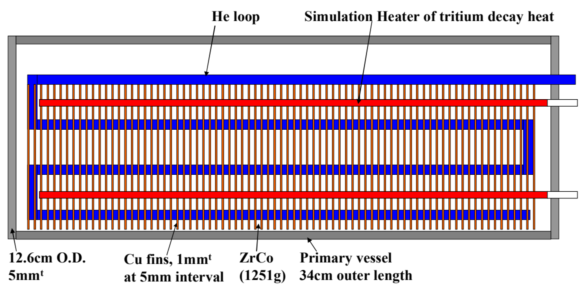

Fig. 2. Horizontal cross-section view of the primary vessel of the first prototype ZrCo bed.

3. Design of the filter

Fig. 5 shows the pressure drop through the filter with the surface area of the filter calculated using the empirical equation of the filter. As the surface area of the filter decreases, the pressure drop increases exponentially. In this bed (surface area of the filter 0.102 m^2), the pressure drop at a delivery rate of 20 and 60 Pam^3/s is ~4 and ~ 12 Pa, respectively.

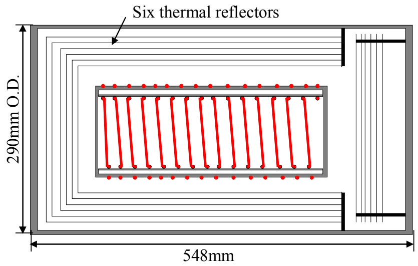

Fig. 3. Horizontal cross-section view of the first prototype ZrCo bed.

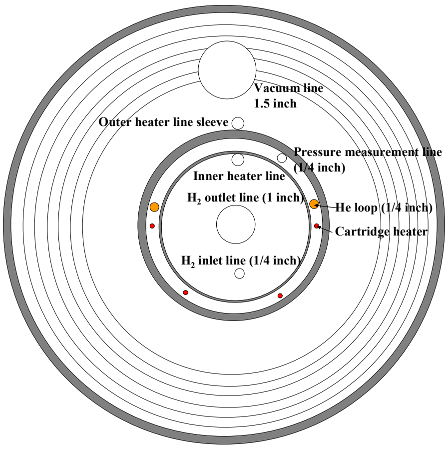

Fig. 4. Radial cross-section view of the first prototype ZrCo bed.

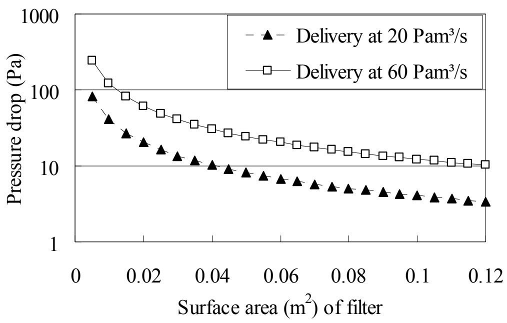

Fig. 5. Pressure drop with the surface area of the filter.

3. Comparison of the structure of the ZrCo beds

Table I compares the typical design features of the ZrCo beds reported by JAEA/TPL [3], FzK/TLK [2] and the author's present work. The important design features of the authors' bed can be listed as below: (i) large relative heating area, (ii) large relative filter surface area, (iii) very small packed height of ZrCo, (iv) large contact area of the He loop.

Table I : Comparison of design features of the ZrCo beds

	ZrCo bed – TPL *1	ZrCo bed – TLK *2	ZrCo bed - authors
Relative heating area (cm^2) / 1g ZrCo	0.63	0.68	1.79
Heat transfer material	Cu fins	Cu balls	Cu fins
Relative filter area (cm^2)/ 1g ZrCo	0.103	0.045	0.567
Height (mm) of ZrCo packed in a reactor	<100	~64	~8
Delivery time (min) of 90% hydrogen	~34	~60	–
Relative contacting area (cm^2) of He loop / 1g ZrCo	0.18	0.09	0.36
Accuracy of in-bed calorimetry	±1% (24h)	–	–

*1 JAEA/TPL [3], *2 FzK/TLK [2]

3. Conclusions

We are expecting that a substantial improvement in the hydrogen recovery/delivery performance can be achieved by introducing these innovative design aspects. Also, the risk of a disproportionation can be avoided by employing a large cylindrical filter tube, a large conductance hydrogen outlet tube, and a thin layer of ZrCo powder in a packed bed.

Acknowledgement

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