Characteristic Design of an ITER SDS Bed for a Rapid Recovery and Rapid Delivery

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1. Introduction

In the International Thermal Experimental Reactor (ITER) Storage and Delivery System (SDS), SDS beds recover, store and supply 90%T-10%D and 50%T-50%D. It has been considered that DT gas stored in the ZrCo hydride bed should be supplied rapidly to the tokamak through the gas injection systems (GIS) [1-2] during a pulse plasma experiment (burn time 450 s, dwell time 1350 s, and pulse cycle time 1800 s). That is, the DT gas from the SDS beds is sent to the GIS via the DT supply gas reservoirs during a dwell time, and then the DT gas is injected into the tokamak vacuum vessel from the GIS during a burn time. The role of the SDS is to meet the following requirements of a fuel supply: Constant D-T compositions, Constant flow rates and Constant pressure. The GIS controls the DT composition in a wide range of tritium concentrations such as 10%T to 90%T. Rapid cooling of the SDS beds is eventually required for a rapid recovery of DT gas for a successive pulse plasma operation. The present paper describes two characteristic designs of the ZrCo bed developed by the authors, and two typical ZrCo bed designs reported by JA-PT and EU-PT for a so called rapid delivery during a DT plasma operation.

2. Design of the amount of $ZrCoT_x$ in a SDS bed

Maximum tritium inventory in a SDS bed is designed to be 70 g for a safety reason. In a SDS bed, approximately 1274 g ZrCo is contained in the primary vessel of the SDS bed, which recovers a maximum of 70 g of tritium as 8.49(moles)$ZrCoT_{2.75}$ as a physical limit.

For a delivery operation, stoichiometry of x[T]/[ZrCo] should be less than 2.0 because the equilibrium pressure of $ZrCoT_x$ should be less than ~ 0.9 bar at 20~300℃ for safety. In the case of a delivery operation from $ZrCoT_{2.0}$ to $ZrCoT_{0.1}$, ~50 g tritium is supplied from a SDS bed. Delivery from $ZrCoT_{0.1}$ to ZrCo takes a longer time because the equilibrium pressure of $ZrCoT_{0.1}$ is low and all the hydrogen is not delivered at 350℃ under a vacuum pumping. Compared to the original 100 g tritium storage bed [2, 3], ~50 g tritium storage SDS bed increases the number of SDS beds by least twice.

3. Factors on the delivery rate of SDS bed

For a rapid delivery at 350℃ under a vacuum pumping from SDS beds, the heat transfer from a heater to ZrCo hydride should be high by providing a large heating area to ZrCo and a short distance between the hydride powder and heater. In addition, the pressure drop through a filter should be (<< ~3 kPa) as low as possible to avoid the risk of a severe disproportionation. From this point of view, a large heating area, short distance between the hydride powder and heater, and a large filter area are fulfilled in the design of the SDS bed, if a so called rapid delivery is required.

Table 1 shows a comparison of the structure and delivery rate of ZrCo beds at TLK and TPL, which were developed and tested for a rapid delivery operation in the ITER SDS bed [3, 4, 5]. The ZrCo bed at TLK has a 1.52 times higher delivery rate than the ZrCo bed at TPL, which had a temperature drop from 350℃ to 300℃ during a delivery, because it had a little larger heating area and faster heat transfer through 46 Cu fins between the heaters and ZrCo.

4. Characteristic design for rapid delivery

For the ITER SDS bed, two characteristic SDS beds designs were developed. In Design 1 (Fig. 1), ZrCo powder of ~1274 g is loaded between a 0.5 μm filter

Table 1. Comparison of structure of ZrCo bed at TPL and TLK [3, 4, 5].

Bed type	ZrCo bed at TPL	ZrCo bed at TLK
ZrCo (g)	280	2000
Scale	1/10	1:1
T(g) for operation	10 ($ZrCoT_{1.79}$)	70 ($ZrCoT_{1.75}$)
T(g) as physical limit	15.35 ($ZrCoT_{2.75}$)	110 ($ZrCoT_{2.75}$)
Heating area (cm^2)/ 1g ZrCo	0.63	0.68
Filter (μm)	1	5
Filter area (cm^2)/ 1g ZrCo	0.103	0.045
Height (mm) of ZrCo packed in a reactor	<100	~64
Delivery rate (Pam^3/s)	~0.92	~10
Delivery rate (Pam^3/s) /1g ZrCo	3.29×10^{-3}	5.0×10^{-3}
Position of He loop	Inside ZrCoTx (Inside the primary vessel)	
Contacting area (cm^2) of He loop / 1g ZrCo	0.18	0.09
Accuracy of in-bed calorimetry	±3% (8-12h) ±1% (24h)	±0.5g (~16.7h)

Table 2 Comparison of structure of two characteristic design

Bed type	Design 1	Design 2
ZrCo (g)	1274	1274
Scale	1:1	
T(g) for operation	50.9 ($ZrCoT_{2.0}$)	
T(g) as physical limit	70 ($ZrCoT_{2.75}$)	
Heating area (cm^2)/ 1g ZrCo	1.69	0.94
Filter (μm)	1	
Filter area (cm^2)/ 1g ZrCo	1.634	0.828
Height (mm) of ZrCo packed in a reactor	7	3
Delivery rate (Pam^3/s)	15 *1	
Delivery rate (Pam^3/s) /1g ZrCo	11.8 x 10^{-3}	
Position of He loop	On the primary vessel (Outside the primary vessel)	Inside ZrCoTx (Inside the primary vessel)
Contacting area (cm^2) of He loop / 1g ZrCo	1.74	0.44
Accuracy of in-bed calorimetry	±1g (12-24h) *2	

**1 Target delivery rate: delivery from $ZrCoT_{2.0}$ to $ZrCoT_{0.1}$ within 20 minutes (=180.6L/20min)*
**2 Target value of in-bed calorimetry*

tubes and the primary vessel at a 3 mm distance. A He loop for an in-bed tritium measurement is placed on the outer surface of the primary vessel, and He gas is circulated through a baffle in the He loop tube. In Design 2 (Fig. 2), ZrCo powder of ~1274 g is loaded between a 0.5 μm filter tube and the primary vessel at a 7 mm distance. He loop (1/8 inch tube) is placed inside the ZrCo packed bed between the filter tube and the primary vessel.

Table 2 compares the structure of these beds. They are characterized by the following design aspects: larger heating area, larger filter surface area, shorter packed height of the ZrCo powder, larger contacting area of the He loop with ZrCo and a higher heater power than the ZrCo beds at TLK and TPL. Design 1 has a 1.8 times larger heating area, two times larger filter surface area, 2.3 times shorter height of ZrCo and four times contacting area of the He loop with ZrCo than the Design 2 bed. For a ±1 g (~24 h) accuracy of the in-bed tritium measurement, effective baffle should be installed between the primary vessel and He loop vessel in order to obtain a 100% He gas circulation through the He loop vessel.

5. Conclusion

Two characteristic designs were developed for the so called rapid recovery and rapid delivery and rapid cooling/recovery of SDS bed. They are characterized by the following design aspects: larger heating area, larger filter surface area, shorter packed height of the ZrCo powder, larger contacting area of the He loop with ZrCo and a higher heater power than the ZrCo beds reported by at JA-PT(JAEA/TPL) and RU-PT(FzK/TLK).

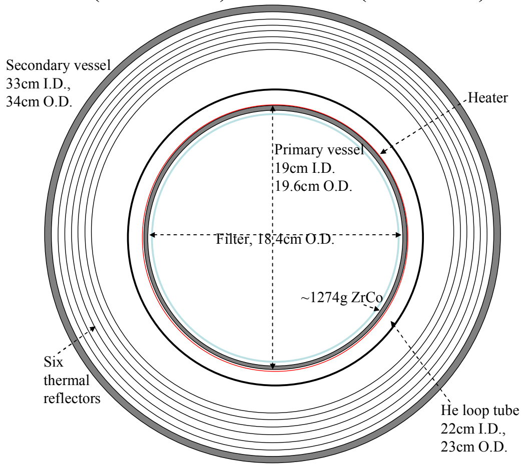

Figure 1. Design of ITER SDS bed with in-bed tritium He loop on the surface of primary vessel.

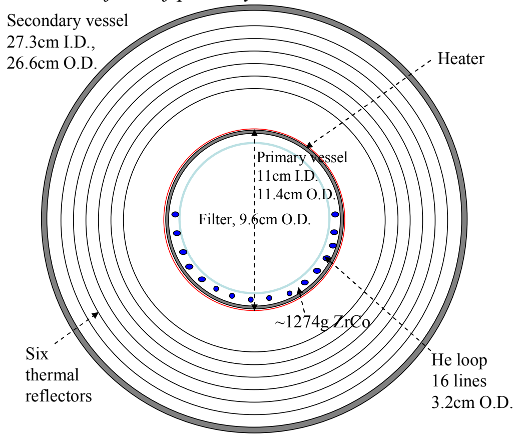

Figure 2. Design of ITER SDS bed with in-bed tritium He loop inside packed ZrCo of the primary vessel.

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