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Design of a one quarter mock-up for the ITER ZrCo SDS bed

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1. Introduction

For a DT fuel supply in the International Thermal Experimental Reactor (ITER) Storage and Delivery System (SDS), a preliminary design concept of ZrCo hydride bed was developed [1]. The SDS bed is composed of a primary vessel which contains ~ 3.5kg ZrCo, an inner heater (cartridge heater) tube and an outer heater (cable heater), heat transfer fins, He loop for in-bed tritium measurement, and a secondary vessel which forms a pressure and tritium confinement boundary. Target value of the accuracy for the in-bed tritium measurement accuracy should be measured at is reported to be 1~3% accuracy within 8~24 hours [2]. The SDS bed stores D-T gas mixture (tritium inventory ≤ 100g) and supplies D-T gas to the ITER isotope separation system (ISS) for the multiple DT pulse operation and/or directly to the ITER fuel injection systems for 1-3 pulses experiment. Off-loading from the SDS bed is carried out by vacuum pumping at 300-350 ℃. In the case of direct supply, the required time average off-loading rate is approximately 20 Pam^3/s for 25 min. Present report provides design detail of a quarter scale mockup for experimental demonstration of the SDS bed functional performance.

2. One quarter mock-up and experimental apparatus

2.1 Structure of the one quarter mock-up

Table 1 compares key design parameters of the full scale SDS bed and the quarter scale mock-up. Figure 1 shows the structure of the quarter mock-up. ZrCo powder (875g) is filled in between six copper fins (1mm thickness, 10mm interval, 33.4mm-ID x 108mm-OD). A cartridge heater (400W) is inserted in the inner wall of the primary vessel and cable heater (950W) is attached on the outer wall of the primary vessel. Eight small lines of the He loop for the in-bed tritium measurement are incorporated inside the primary vessel. Five thermal reflectors are placed between the primary vessel and secondary vessels. Pipe nozzles for vacuum pumping and He filling are provided to the secondary vessel for insulation and cooling.

2.2 Experimental plan for recovery and delivery

Table 1. Key design parameters of the full scale SDS bed and the quarter scale mock-up.

Bed type	Full scale	Quarter scale
Tritium	100g	25g
90T-10D	107.4g (414.8L)	26.85g (103.7L)
X of ZrCoHx	1.59	1.59
ZrCo	3500g	875g
Tritium decay heat	32.4W	8.1W
Inner heater	1.2kW	400W
Outer heater	3.8kW	950W

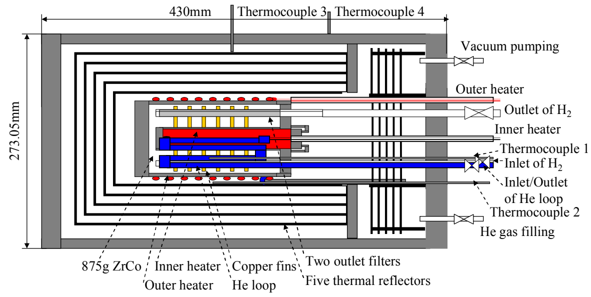

Figure1. Structure of the one quarter mock-up.

2.2.1 H_2 absorption (Hydrogen recovery)

The quarter scale mockup absorbs H_2 (103.7 L-STP) and forms a hydride ($ZrCoH_{1.59}$) at room temperature. The temperature of ZrCo hydride increases to about 300℃ in an adiabatic condition due to the exothermic reaction ($ZrCo + 1/2H_2 \rightarrow ZrCoH +$ 82.81kJ/mol-H_2) [2, 3]. Effective measure for the removal of the exothermic reaction heat is required to achieve rapid recovery of the DT gas in the SDS bed. Cooling performance of the quarter mock up bed under several conditions (vacuum pumping, He gas filling in the secondary vessel or He gas circulation in the He loop) will be discussed.

2.2.2 H_2 off-loading (Hydrogen delivery)

Average delivery rate, residual amount of H_2 in the ZrCo and equilibrium hydrogen pressure will be measured every 25 min delivery operation. The 25 min is the equivalent time duration of the ITER operation (plasma dwell time of 1350s). Temperature of the secondary vessel outer surface will be measured and evaluate the heat transfer efficiency and insulation effect of thermal reflectors in the quarter mockup bed. Pressure drop across the filter tube placed in the ZrCo hydride section will be measured to evaluate impact on the hydride disproportionation [4-6] during delivery operation. Cooling performance and thermal reflector efficiency at other operation conditions of the SDS bed will be discussed based on the ongoing heat analysis. The experimental diagram for these tests is shown in Figure 2.

2.3 Experimental plan for in-bed tritium measurement

Because of tritium decay heat (0.32 W/g-T), He circulating through the 8 He flow loops in the ZrCo hydride bed is adiabatically heated. For the in-bed tritium measurement, temperature difference between inlet and outlet of He gas loop of the SDS bed is measured. Table 2 shows correlation between the temperature difference and the required He flow rate to measure tritium inventory in the range of 0.1-100g by assuming 100% adiabatic condition. Figure 3 shows the experimental diagram for the demonstration of in-bed tritium measurement by using the quarter scale mockup bed.

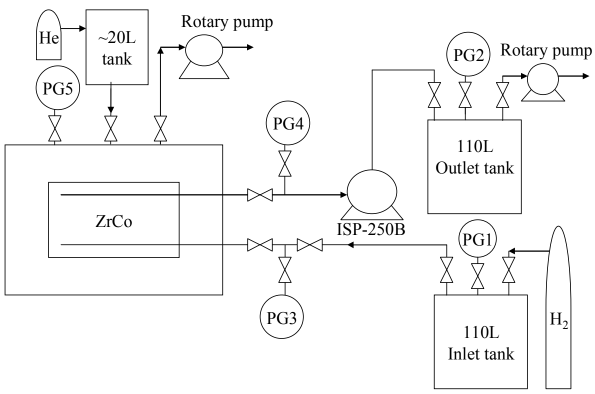

Figure 2. Experimental diagram for the hydrogen recovery and delivery tests

Table 2. Required He flow rate for in-bed tritium measurement.

Temp. difference (℃)	Tritium inventory (g)			
	0.1	1	10	25
	He flow rate (Standard L/m)			
75	0.028	0.276	2.759	6.90
100	0.021	0.207	2.069	5.17
125	0.017	0.166	1.655	4.14

3. Conclusion

A quarter mockup of ZrCo hydride bed was designed for the development of ITER SDS bed. Outline of the experimental program to demonstrate performance of

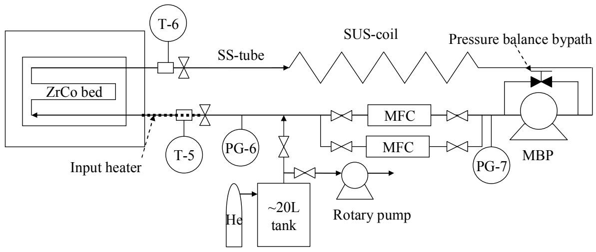

Figure 3. Experimental diagram for demonstration of in-bed tritium measurement

key operation function such as hydrogen recovery, delivery, cooling, and in-bed tritium measurement are presented. Heat transfer characteristics such as (i) rapid heating of ZrCo hydride to compensate endothermic reaction heat during hydrogen off-loading, (ii) convection cooling to minimize disproportionation (which occurs at temperature > 350℃ with higher hydrogen pressure > ~30kPa), (iii) convection cooling to remove decay heat during storage of 100g tritium, and (iv) thermal reflector efficiency to achieve outer vessel temperature ≤ ~ 60 ℃ can be investigated in deep by the present test program.

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