ZrCo Bed Design Concepts for the Storage and Supply of Fusion Fuels

Myung-Hwa Shim,a Hongsuk Chung,c Chang-Shuk Kim,b Seungwoo Paek,c Minsoo Lee,c Kwang-Rag Kim,c Sung-Paal Yim,c Do-Hee Ahn,c

a University of Science & Technology,52 Eoeun-dong, Yuseong-gu, Daejeon,305-333 Korea

b ITER Korea TFT,52 Eoeun-dong, Yuseong-gu, Daejeon,305-333 Korea

c Korea Atomic Energy Research Institute,150 Deokjin-dong, Yuseong-gu, Daejeon,305-353 Korea, hschung1@kaeri.re.kr

1. Introduction

Fusion research is considered worth pursuing because it promises to be a widely available energy source with an essentially unlimited supply and manageable environmental impact. Therefore for the fusion research, ITER is planned to operate at a nominal fusion power of 500 MW_t. Fusion fuel gases such as deuterium and tritium are stored in metal hydride beds. The design delivery rate from each bed is 20 Pam^3/s. Each ZrCo storage bed has a storage capacity of 100g tritium. It is equipped with an in-situ calorimetry to determine the actual tritium inventory. Tritium accountancy is performed by measuring the temperature increase of a constant helium flow through the bed [1, 8]. The authors suggest a new bed structure which improves the heat transfer characteristics and assures accurate tritium accountancy.

2. Characteristics and structure of the ZrCo bed

The JAERI ZrCo bed and JET U bed are compared and the design of the 100g tritium ZrCo bed is suggested in table 1 [2-5].

2.1 Rapid recovery

In the ZrCo bed, D-T is recovered within a few minutes at room temperature. By the exothermic reaction, the temperature of the ZrCo powder should not increase above 100^oC. Therefore the cooling gas in the central tube in the primary vessel and secondary vessel should be effectively circulated.

2.2 Rapid supply

An averaged mass flow of 200Pam^3/s of D-T gas for 450 s or 3000 s is supplied to the fueling system. Rapid recovery and supply of D-T fuel to accommodate the pulsed plasma operation is required. For this purpose, tritium is supplied from an electrically heated bed. JAERI ZrCo bed supplies D-T fuel up to a maximum of 20Pam^3/s at the initial supply stage [6]. But the supply speed obtained in the bed is a little slower than that required. Therefore the authors suggest the use of heat transfer enhancement fins which transfer the heat effectively to/from ZrCo hydride powder.

Table1. Comparison of various beds

Bed type	JAERI ZrCo bed	JET U bed	ZrCo bed in this study
Primary vessel	5 bar 600^oC	16 bar 600^oC	5bar 600^oC
Secondary Vessel	4 bar 60^oC	16 bar 200^oC	4 bar 60^oC
Heater	on the outer surface of primary vessel	in the central tube in primary vessel	in the central tube in primary vessel
Thickness of primary vessel	1.5mm	5mm	1.5mm
Heat transfer	1mm Cu balls (3.5kg ZrCo + 1.5kg Cu balls)	Copper block in the central tube Ni fins	Copper block in central tube Ni fins/ Cu balls
Cooling of primary vessel	Gas cooling in the secondary vessel	Gas cooling in the central tube in primary vessel	Gas cooling in the central tube and secondary vessel
Calorimetry	He loop in the primary vessel ±1% accuracy within 24 hours	Thermal insulation on the primary vessel ±5% accuracy within 16 hours	He loop in the primary vessel ±1% accuracy within 10 hours
Secondary vessel	Gas cooling & vacuum heat barriers outer wall	Vacuum layer outer wall	Gas cooling & vacuum heat barriers outer wall

2.3 ZrCo disproportionation and treatment

Hydrogen isotopes are reversibly recovered and supplied to ZrCo between 20^oC and 350^oC. At 400~450^oC and a hydrogen pressure higher than the equilibrium pressure, $ZrCoH_x$ is disproportioned to ZrH_2 and $ZrCo_2$. For example, after ten times of a recovery and supply of hydrogen at 400^oC, ZrCo is disproportioned to 40% [7]. By a thermal treatment at 500^oC for several hours, ZrH_2 and $ZrCo_2$ are regenerated to ZrCo and the recovery capacity is completely restored. Disproportioned ZrCo can be regenerated at 500^oC under a vacuum for 1~2 hours and reused at room temperature. Experimental results show that no disproportionation was observed in the

ZrCo beds at pressures equal or smaller than 10^5 Pa and at temperatures equal or smaller than 350°C.

2.4 Accurate and rapid accountancy

The amount of tritium stored in the bed should be measured at less than a ±1% accuracy within 8~12 hours. JAERI ZrCo bed had a He loop installed in the primary vessel and the temperature difference of the He gas at the inlet and outlet was measured to evaluate the amount of tritium. It showed ±3% accuracy within 12 hours and ±1% accuracy within 24 hours [6].

After a rapid supply or rapid recovery, heat is removed by circulating He or N_2 gas in the central tube of the primary vessel and in the cooling layer of the secondary vessel. After removing the heat, the cooling gas is evacuated by using a vacuum pump. In the He loop, He gas is circulated and the temperature of the He gas at the outlet is measured. As the contact area between the He loop and $ZrCoT_x$ increases, the total tritium decay heat will be rapidly absorbed, so the measuring time decreases. The temperatures at the outlet of the He loop and in the primary vessel should be under 100°C, so the flow rate of the He gas should be properly adjusted. In the secondary vessel, three heat barriers reduce the released heat by a radiation. Rapid cooling, high insulation, effective He loop and an optimal He flow rate assure an accurate tritium accountancy.

2.5 Structure of the ZrCo bed

Figure1 shows the structure of the ZrCo bed for 100g tritium storage. In the primary vessel, the heating tube and Ni fins directly heat up the $ZrCoT_x$ to desorb the hydrogen isotopes. In the cooling tubes, N_2 gas circulates to remove the heat from the primary vessel during the hydrogen isotopes absorbing step. Through the four paths of the He loop in the primary vessel, the tritium decay heat is removed. In the secondary vessel, N_2 gas removes the heat of the primary vessel. The secondary vessel is kept under a vacuum during a calorimetry operation.

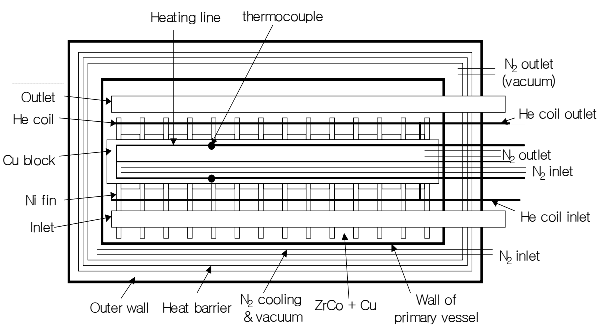

Figure1. Structure of ZrCo bed for 100g tritium storage

3. Conclusion

Fusion fuel gases such as deuterium and tritium are stored in metal hydride beds. The design delivery rate from each bed is 20 Pam^3/s. Each ZrCo storage bed has a storage capacity of 100g tritium. It is equipped with an in-situ calorimetry to determine the actual tritium inventory. Tritium accountancy is performed by measuring the temperature increase of a constant helium flow through the bed. The authors suggest a new bed structure which improves the heat transfer characteristics and assures accurate tritium accountancy.

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