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Nuclear Fusion Fuel Cycle Bed Materials

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1. Introduction

The Korea Atomic Energy Research Institute (KAERI) and National Fusion Research Institute (NFRI) are investigating nuclear fusion fuel cycle hardware including a nuclear fusion fuel Storage and Delivery System (SDS). To obtain better knowledge of the nuclear fusion fuel cycle bed technology, we present our research efforts on the structural materials used for the beds.

2. Nuclear Fusion Fuel Cycle

The fusion process requires tritium, a radioactive form of hydrogen with a half-life of 12.3 years. Although the amount of tritium used during plasma pulses is very small, only a few grams at any one time, the confinement of this radioelement within the fuel cycle is one of the most important safety objectives.

The fusion reaction in the Tokamak is powered with deuterium and tritium, two isotopes of hydrogen. Stored deuterium and tritium are introduced into the vacuum chamber, where only a small percentage of the fuel is consumed. The plasma exhaust is removed and processed through an isotope separation system that extracts out the fusion fuels for reinjection into the fuelling cycle. Fig. 1 shows an example of the nuclear fusion fuel cycle [1].

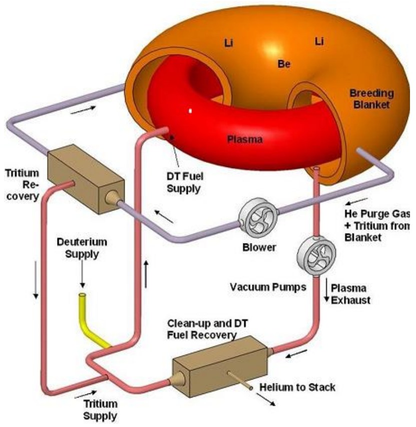

Fig. 1. Nuclear fusion fuel cycle [1].

3. Storage and Delivery System

We have been studying SDS, particularly depleted uranium (DU) hydride beds. We studied the hydriding and dehydriding performances of a DU bed [2]. Fig. 2 shows the test schematics of the bed performance. A rig is used for a measurement of the hydrogen recovery and delivery rates. The amount of hydrogen used for the initial activation, and the hydriding and dehydriding runs, is measured based on the hydrogen pressure in the measuring tank. A control and data acquisition system (DAS) was provided. Fig. 3 shows the temperature variation of the primary vessel cooled by radiation and natural convection. The elapsed time during which the primary vessel has been cooled from 300°C to 100°C by natural convection is approximately an hour shorter than that by radiation. For natural convection, the secondary vessel was filled with helium of 639 Torr at 300°C. Fig. 4 shows the bed hydriding performance.

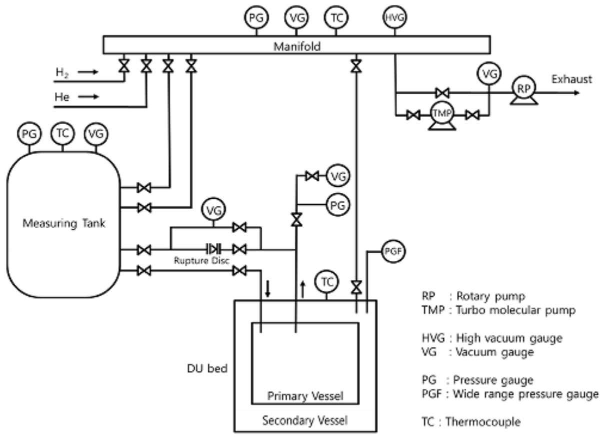

Fig. 2. Bed performance test schematics [2].

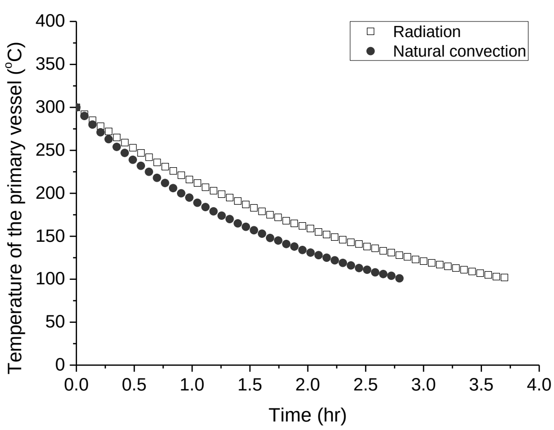

Fig. 3. Bed cooling performance.

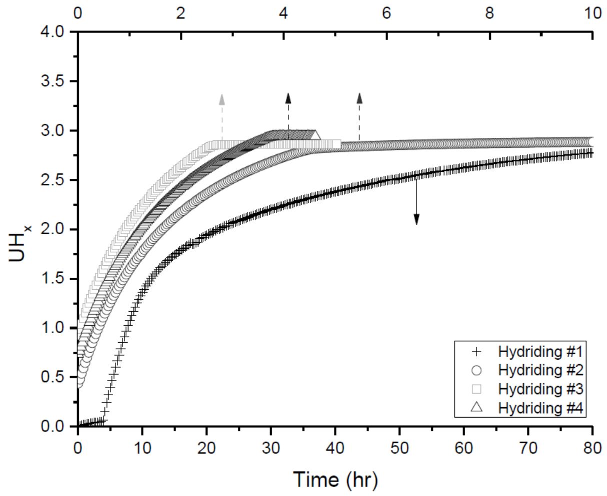

Fig. 4. Hydrogen storage performance [2].

4. Bed Materials

4.1 Bed System

The bed consists of a primary vessel and a secondary vessel. The primary vessel contains DU. Fig. 5 shows the dissociation pressures of UQ_3. We need 435 or 471℃ for 1 or 2 atm. in the case of UH_3 [3]. We used this chart for determining the shell thickness of the components under external pressure developed for austenitic steel, 16Cr-12Ni-2Mo, STS316 [4].

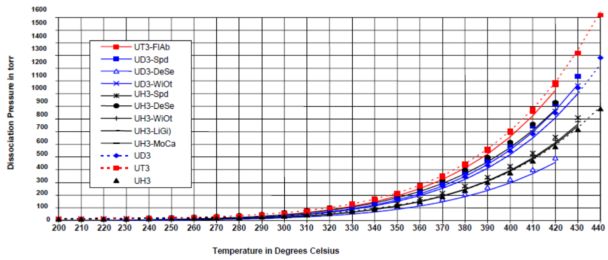

Fig. 5. Dissociation pressures of UQ_3 [3].

4.2 Bed Tubing and Test Rig

We have a rig for a DU-hydrogen performance testing of high-pressure tubing beds. Fig. 6 shows the rig in which the volume of the measuring tank is 2,657.58 cm^3. Metal powder in the beds is activated through several repetitions of hydriding and dehydriding. The amount of hydrogen used for the initial activation and hydriding, and the dehydriding runs, is measured using hydrogen pressure filled into the loading vessel and manifold. A control and data acquisition system (DAS) is provided. Fig. 7 shows a schematic the tubing bed. For hydrogen gas of 2,240 cm^3 STP, DU of (2/3)*238 or 15,867 mg is required, as an example. The bed is used to test the performance of the hydrogen recovery and delivery.

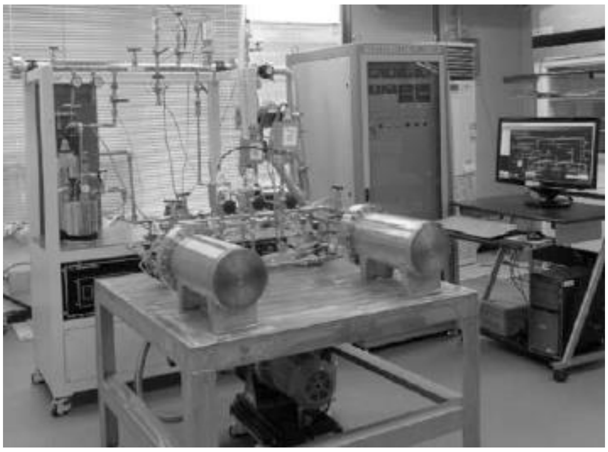

Fig. 6. Rig for DU-hydrogen performance testing [5].

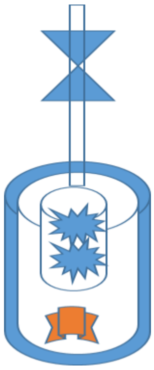

Fig. 7. Tubing bed schematic.

5. Concluding Remarks

To acquire better knowledge of the nuclear fusion fuel cycle, we presented our research efforts, not only on SDS but also on the fuel storage beds. We have been conducting a study on SDS, particularly depleted uranium (DU) hydride beds. We have also studied the hydriding and dehydriding performances of a DU bed. A bed performance test rig is used for the measurements of the hydrogen recovery and delivery rates. The amount of hydrogen used for the initial activation, and the hydriding and dehydriding runs, is measured based on the hydrogen pressure in the measuring tank. A control and data acquisition system (DAS) was provided. It is important to enhance the cooling performance of the DU bed because of the hydriding rates of amelioration. Our DU bed was designed to cool the primary vessel by natural convection, as well as by radiation. Cooling by natural convection from 300°C to 100°C shows a better cooling speed compared with that by radiation. In addition, we presented another smaller rig for DU-hydrogen performance testing of high-pressure tubing beds. The volume of its measuring tank is 2,657.58 cm^3. Metal powder in the beds is activated through several repetitions of hydriding and dehydriding. The amount of hydrogen used for the initial activation and hydriding and dehydriding runs is measured using the hydrogen pressure filled in the loading vessel and manifold. Our efforts to enhance the tritium confinement will continue for the development of cleaner nuclear fusion power plants.

ACKNOWLEDGMENTS

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