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Calorimetric Tests for a Simple Bed

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1. Introduction

In the International Thermonuclear Experimental Reactor (ITER) storage and delivery system (SDS), SDS beds recovery, store and supply DT fuel gases [1, 2]. One of the major roles of the SDS bed is an in-situ measurement of the tritium inventory by using tritium decay heat (0.32 W/g). In-bed calorimetric measurement method has been developed by T. Hayashi et al [3,4] by using a 1/10 scale ZrCo bed of the SDS bed. Objective of the present study is the development of an in-bed calorimetry design for a full scale SDS bed containing 70g tritium. This paper presents the results of the preliminary experimental tests performed by using a dummy SDS bed.

2. Experimental Setup

In the D-T SDS bed, characteristic information and handling ability of tritium is very important to control the SDS bed. Tritium has a radioactive decay heat (0.324±0.009 Watt/g). If decay heat occurs in the bed, bed temperature will be increased. So, appropriate cooling is required to prevent the over-heating of vessel and measure the tritium inventory. To measure the accurate tritium inventory, the test bed has six reflectors to reduce the convection and radiation heat loss. So, we can assume that the heat generation in the bed is removed by helium gas flowing.

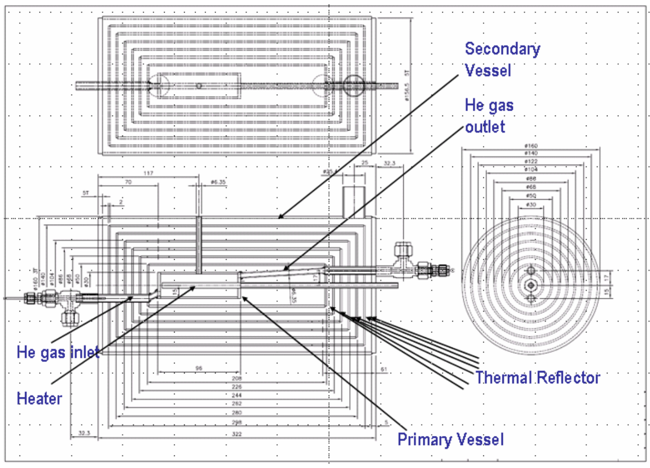

Fig.1. Two-dimensional view of the test bed

Fig.1 shows a two-dimensional view of the internal structure of the simple design test bed. This bed is composed of primary and secondary vessels, which form pressure and tritium confinement boundaries. The primary vessel contains a cartridge heater, two He gas flow hole. High vacuum zone between the primary and secondary vessels contains six thermal reflectors for a reduction of the radiation, convection and conduction heat loss from the primary vessel to the secondary vessel.

Each loop comprises a gas transfer pump, a mass flow controller, a mass flow meter, a He gas inlet heater and so on. Thermocouples are placed in the He gas inlet and outlet nozzles of the test bed to measure the temperature increase resulting from the decay heat simulating the heat. Table 1 lists the major design parameters of the test bed.

Table 1: Mechanical design parameters of dummy SDS bed

Maximum design temperature [℃]	600
Maximum design pressure [MPa]	0.5 (internal)
Minimum design pressure [MPa]	Full vacuum
Number of Thermal reflector (SS316L)	6
Maximum Cartridge heater Power [W]	500
Primary vessel (SS316L) [cm]	Outer diameter: 3 Inner diameter: 2.6 Length: 9.6
Secondary vessel (SS316L) [m]	Outer diameter: 16 Inner diameter: 15.6 Length: 32.2

3. Results and Discussion

Fig.2 and Table 2 show a comparison of the measured $T_{exp.}$ and calculated $\Delta T_{cal.}$ difference. We didn't have acceptable results in a small power range (0.8W ~ 3.2W) with a 15 liter per minute gas flow rate during the preliminary tests. So, we decided to change the circulating helium flow rate during the tests to 10 liter per minute from 0.8W to 3.2W to increase the temperature difference in the small power range (0.32W~3.2W). And in the 6.4W to 22.4W power range, we performed the tests with a 15 liter per minute circulating helium flow rate. The internal heat in the bed was removed by both a helium circulation and thermal a conduction of the inner structural connections.

Fig. 3 shows the heat loss by the conduction effect. Conduction heat transfer is directly proportional to the heat power.

Table 2: Test result summary

Tritium Inventory[g]	Heater power, W	ΔT (Experiment), °C	ΔT (calculation), °C	Heat loss by conduction , %
2.5	0.8	5.1	5.09	-0.078
5	1.60	7.80	10.44	25.35
10	3.20	19.20	22.09	13.08
20	6.40	30.51	29.89	11.33
30	9.60	40.93	44.83	8.69
40	12.80	52.00	59.77	13.01
50	16.00	62.65	74.72	16.15
60	19.20	71.56	89.66	20.19
70	22.40	82.63	104.61	21.01

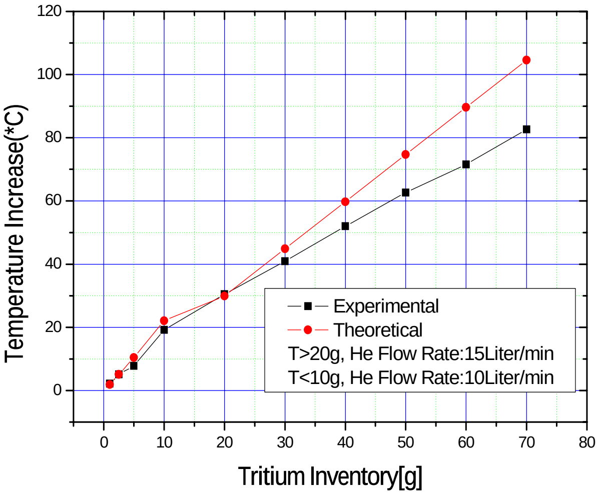

Fig.2. Inlet and outlet temperature profiles

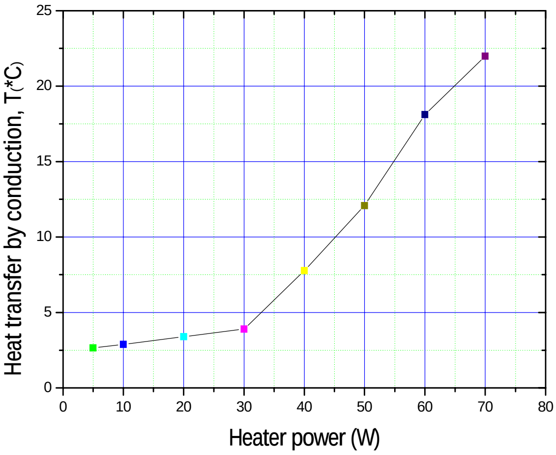

Fig.3. Heat transfer by conduction

4. Conclusions

In-bed calorimetry tests were performed to measure the temperature difference at the 1/4 scale-down simple design test bed using by internal cartridge heater which are simulating the tritium decay heat (2.5g ~ 70g). We made a test bed to maintain the high vacuum range (10^{-9} torr). And based on the tests results, we observed two heat transfer phenomenon. One is heat sink by helium gas circulation; another is conduction heat transfer due to the installation of internal cartridge heater line. From the heat loss calculation, conduction heat transfer measured about 0 to 25%. To develop applicable design for ITER, it needs to complement very small heat (below 0.8W) range test. And, highly accurate prototype bed test and reduction the experimental error is required.

Acknowledgements

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