Initial Simulation Test Results of In-bed Calorimetry on a ZrCo Bed

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1. Introduction

The roles of the ZrCo hydride bed in the ITER storage and delivery system (SDS) is to store and supply the D-T fuel during DT plasma operation. The hydride bed requires the performance of fast recovery and delivery of D-T and function of the in-bed calorimetry for tritium inventory measurement during plasma operation [1, 2]. 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. Prime purpose of the present study is to demonstrate the required time to achieve steady state temperature in the bed by using a full scale ZrCo bed. Recently we constructed Korea's first full scale ZrCo bed designed for ITER application.

This paper present the initial simulation test results of the in-bed calorimetric measurement by using ZrCo hydride ($ZrCoH_{1.8}$) and tritium decay heat simulation heaters.

2. Experimental Apparatus

Fig. 1 shows an over all P&ID (process and instrument flow diagram) of the experimental apparatus used for this study. The full scale ZrCo bed (Top left) is composed of primary and secondary vessels. The former contains ZrCo layer (8 mm thickness, weight of ZrCo beads 894g, beads size 1mm), tritium decay heat simulation heaters, Cu fins to enhance heat transfer from the heater to ZrCo hydride layer ($XrCoH_{1.8}$) and to internal Cu piping, which is the flow path of He gas circulating through the external He loop. The primary vessel consists of a large central cylindrical filter (pore size: 0.5 μm) and cable heaters attached inner surface of the filter cylinder and outer surface of the primary vessel (total heater power 3.3 kW). (Watlow cable heater, outer-heater: 1.8 kW, inner heater: 1.5 kW) were installed on the outer surface of the primary vessel and the inner surface of the cylindrical filter. ZrCo powder (< 1 mm diameter.) is loaded into the 8 mm gap between the primary vessel (5 mm thickness) and the filter cylinder. Six thermal reflectors (material: SS 316) are inserted in the high vacuum zone between the primary and secondary vessels to minimize the heat loss from the primary vessel to the secondary vessel.

The external He loop comprises a metal bellows pump, a mass flow controller, two-stage He gas heater to control inlet temperature of He gas at a constant temperature with ± 0.1℃ precision.

3. Experimental Results

Table 1 summarizes the experimental conditions with two cases of He flow rate. Input power of heater was 10.3W (equivalent tritium inventory is 32.2g). Fig. 2 shows the change of outlet He temperature (T_{out}) and temperature rise (ΔT) (= temperature difference of inlet and outlet He temperature). This Figure revealed that the required time to establish a steady state of T_{out} (and ΔT) is approximately ~25h - ~35h for two He flow rates.

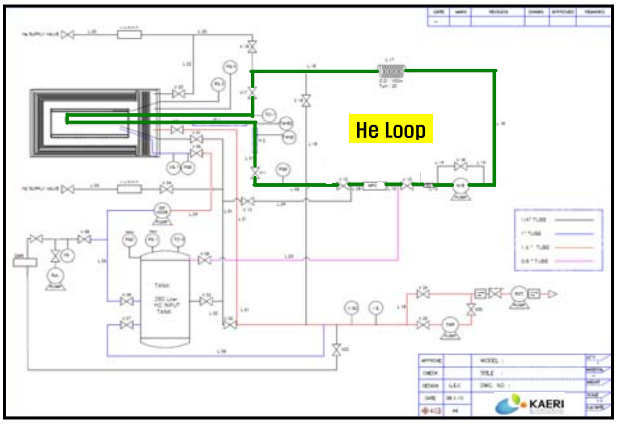

Fig. 1 Overall process and instrument diagram of experimental apparatus.

Table 1: Experimental Conditions

He gas circulation	Flow rate: 7, 15 std. L/min
	Loop pressure: 68 / 90 kPa
	Inlet temperature: 298 K ∓ 0.1℃
	He purity: 99.999%
Vacuum	$< 10^{-5}$ Pa (continuous evacuation)
Calibration	Heater power: 10.3 W (Equivalent tritium inventory: 32.2g)
	Stoichiometry of $ZrCoH_x$: x = 1.8

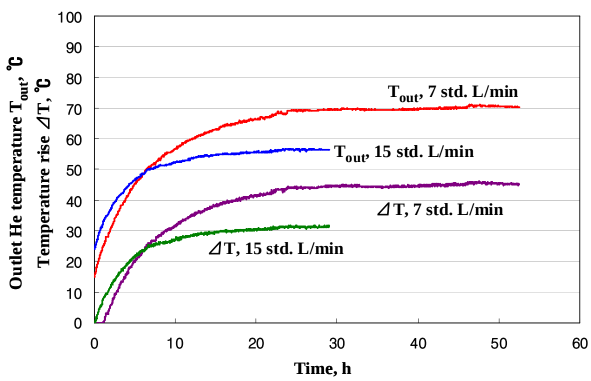

Fig. 2 Change of outlet temperature and temperature rise of He flow

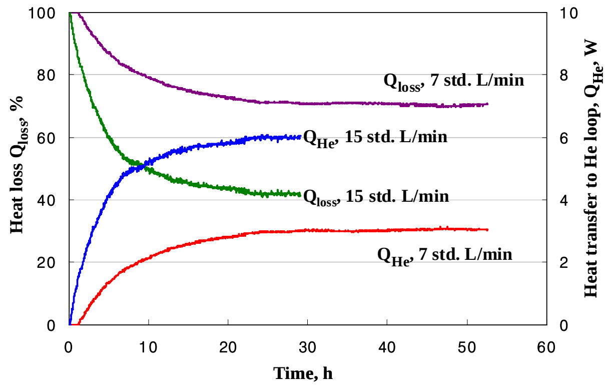

Fig. 3 Heat balance during calorimetric measurement (Heater input = 10.3W)

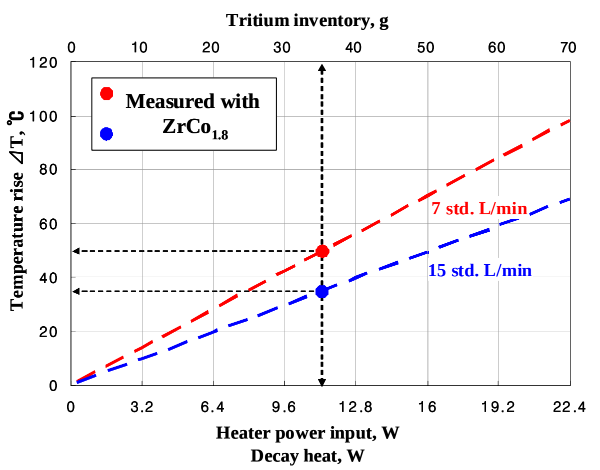

Fig.4. Calibration curve of the in-bed caloremetry test of full scale ZrCo bed.

Fig. 3 shows heat balance during calorimetric measurement. The outlet He temperature change from time 0 to a steady state corresponds to the heating time for the entire primary vessel. When temperature distribution in the entire primary vessel (including internal and external heaters, ZrCo hydride, Cu fines, etc) is equilibrated, a steady state of T_{out} (and/or T) is established. Heat loss observed till 25-35h mainly reflects heat consumption for heating the entire primary vessel, Heat loss in the steady state time reflects heat loss from the primary vessel to the outside of the ZrCo bed through the secondary vessel. The dominant heat loss is caused by conductance through piping penetration and electrical sleeve penetration.

4. Conclusions

We have provided first data of in-bed calorimetric measurement performance of Korea's first full scale ZrCo bed designed for ITER application. The test results revealed that required time (1) to obtain a steady state temperatures (T_{out} or ΔT) for accurate measurement of tritium inventory in the rage of 1-30g will be much longer than 24h, and (2) to obtain calibration curve of accurate standard deviation in the level of ∓ 1-3 will be a couple of week or more.

Similar simulation test will be performed in the full range of the SDS bed by using our 2nd full scale ZrCo bed improved from the 1st full scale bed.

Acknowledgements

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