Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

Heat Transfer Test on the High Temperature Capsule Mockup (11M-01K)

Young-Hwan Kang *, Sung-Je Park, Ki-Nam Choo, Man-Soon Cho, Sang-Jun Park

Korea Atomic Energy Research Institute, Daedeok-Daero 989-111, Yuseong, Daejon, Republic of Korea, 305-353

**Corresponding author: yhkang2@kaeri.re.kr*

1. Introduction

A major advantage of a high-temperature irradiation capsule using an LBE(Lead Bismuth Eutectic) as a thermal medium is expected to be its excellent performance at high temperatures [1-4]. In an effort to investigate the thermal behavior of an LBE capsule at a temperature of 25℃ to 750℃, a capsule mock-up, which was designated as 11M-01K, was designed and manufactured [2]. A series of heat transfer experiments as well as thermal analyses were also implemented to study the effect of an increase in the value of the heat source and its influence on the temperature distribution in the capsule.

2. Heat Transfer Experiment

For the heat transfer experiments, a mockup capsule was fabricated. Three heaters, which were placed at the center of the thermal media as shown in Fig. 1, were used to simulate the expected heat source which will be presented during irradiation. The capsule mockup was instrumented with 14 type K thermocouples at 3 different levels for monitoring and controlling the surface temperature of the heater's cladding (the specimen temperature), bulk temperature of an LBE, and the surface temperature of an internal tube (LBE container). The main body of the capsule mockup, which is about 56mm in diameter and approximately 1361 mm long, consists of three heaters of 12 kW as three simulated specimens, LBE as a thermal media, an internal tube as an LBE container, and an external tube. Fig. 1 is a photograph of the instrumented capsule's mockup that was used and shows the thermocouple locations installed in the test mockup.

The heat transfer experiments were performed at a single channel test loop using a full-scale mock-up of an LBE capsule. The gas mixing system of the I&C system (GSF-2002) was used to understand the effects of the gas mixing ratio and the heater power on the specimen temperature, as shown in Figure 2. The main test conditions are the mass flow rates of 50 cc/min of He/Ne gas, a gas pressure of 2 kg/cm^2, a heater power of 1 to 12 kW with 5 different mixing ratios of He to Ne gas.

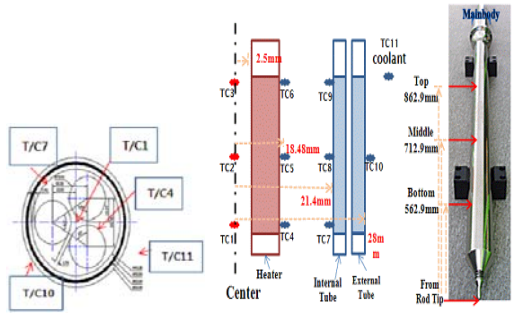

Fig. 1 Thermocouple locations of the Capsule's Mockup (11M-01K)

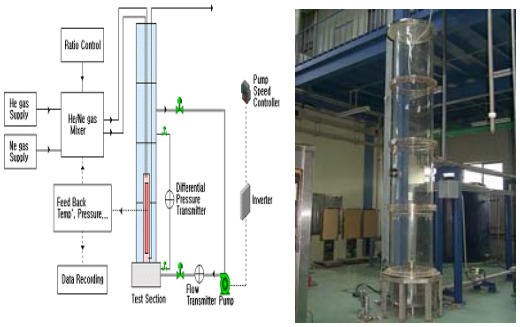

Fig. 2 Schematic diagram of a single channel test loop [4]

Fig 3 shows the measured maximum temperature increased almost linearly with a heater power up to 12kW at a constant He gas pressure of 2 Kg/cm^2. The temperature increase rate was found to be lower than that of the previous 09M-01K capsule mockup [3]. The maximum temperature differences in the top, middle, and bottom of the mockup are relatively negligible and amount to a maximum of 7.7%, which can provide a more favorable environment for a high temperature test, and a maximum controllable temperature with variations of mixing gas ratio was observed to be 260℃. The maximum temperature of the specimen was observed at 743℃ with a heater power up to 9kW at a constant Ne gas pressure of 2 Kg/cm^2.

The temperature calculations for a newly designed capsule with 3 heaters as a heat source were performed using a finite element analysis program, ANSYS [5]. The experimental results obtained from the heat transfer tests are directly compared with theoretical values calculated using an ANSYS code in Fig. 4. There is reasonable agreement between the calculated temperature and experimental data to within 4%, as shown in Figure 4.

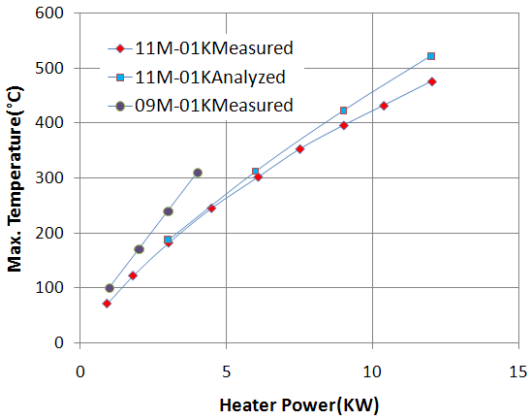

Fig. 3 Regional temperature with variation of heater power at 2 kg/cm^2 of He gas.

From the neutron radiography for the structural integrity assessment of the capsule mockup used for the heat transfer experiments, the deformation of the LBE container including the gas gap was not found in the mockup.

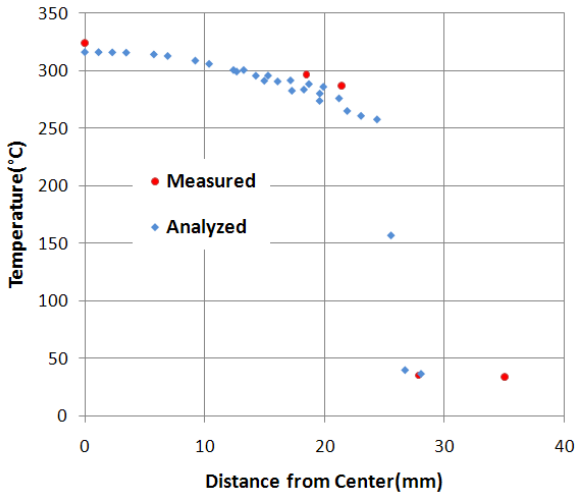

Fig. 4 Temperature profile in the radial direction at a constant heater power of 6kW and He gas pressure of 2 Kg/cm^2.

3. Conclusions

The heat transfer experiment with a full-scale mockup of an LBE capsule (11M-01K) was performed to understand the thermal characteristics an LBE capsule up to around 750℃. From the test results, it was found that the specimen temperature of a mockup increased linearly with an increase of heat input, the regional temperature distribution of a mockup in the horizontal direction was relatively uniform, which can provide a more favorable environment for a high temperature test. This data will also be used directly for developing the new concepts of a capsule to support a user's programs.

ACKNOWLEDGEMENTS

This work was supported by the Nuclear Research & Development Program of the National Research Foundation of Korea (NRF) grant funded by the Korean government (MEST).

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