Results of the Preliminary Test in the 1/4-Scale RCCS of the PMR200 VHTR

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1. Introduction

The PMR200, a demonstration plant of the VHTR, is under development by KAERI under the auspice of MSIP. The Reactor Cavity Cooling System (RCCS) is a key ex-vessel passive safety system that will ensure the safety of the PMR200, and its performance needs to be verified [1-3]. For the difficulty of the full-scale test, a 1/4-scale RCCS facility, NACEF (Natural Cooling Experimental Facility), has been constructed at KAERI [4,5], and a shakedown test has been performed. A brief design and the preliminary test results of this facility are described.

2. Description of NACEF

Fig.1 shows the natural cooling phenomena in the RCCS. The decay heat during an accident transfers from the fuels by conduction to the graphite block and in turn to the reactor vessel by radiation. The reactor vessel needs to be cooled down below the design temperature to prevent its failure by the RCCS through the radiation heat transfer.

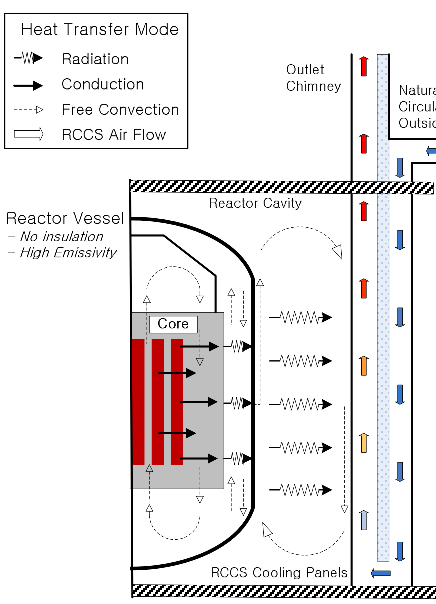

Fig. 1. Natural cooling phenomena in the RCCS

A 1/4-scale mockup of the RCCS (NACEF) was designed and constructed at KAERI, the height of which is 1/4 and the distance from the reactor vessel to the RCCS risers remains the same as the prototype. Figs. 2 and 3 show the side view of a NACEF and a plan view of the test section, respectively.

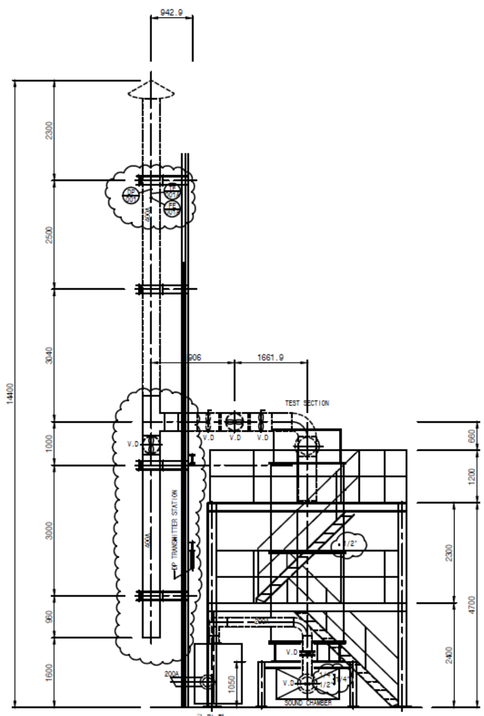

Fig. 2. Side view of the NACEF

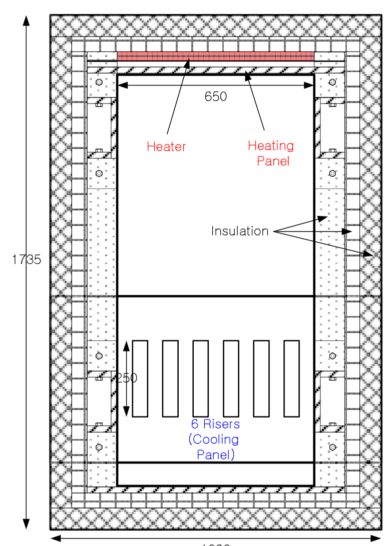

Fig. 3. Plan view of the test section

The hot panel, the mockup of the reactor vessel, is constructed to be 4 m in height, and two chimneys are to be 8 m in height. The ceramic mold heaters of 52 kW (the maximum heat flux of 20 kW/m^2) are equipped on the hot plate. Two flow meters of ~ 2 m^3/s are installed in the downstream of the two chimneys of 0.4 m in diameter. Fig. 4 shows a photograph of the indoor components of the NACEF after construction.

Fig. 4. Indoor components of the NACEF

2. Preliminary Test Results

A preliminary test was performed in NACEF. The purposes of this test are first a shakedown test for the functioning of the facility, and second, an oxidation test of the hot panel to acquire a black oxidized surface to provide a high emissivity.

A total of 10 DC power supplies of 130 V and 40 A attached to panels of 25 mm apart from the hot panel supplied electrical power and gradually increased the hot panel temperature, which reached and was maintained at ~ 420°C which was the calculated value during an accident scenario [6].

Fig. 5 shows the power input to the heaters and at the end, each heater was supplied with ~ 2.7 kW. Fig. 6 shows the temperature of the hot panel along with the elevation (0 ~ 4 m) at its maximum and final temperature. The highest temperature reached ~ 430°C, which is very close to the predetermined temperature. The temperature above 2 m in elevation is more or less the desired temperature but that around 2 m and below 1 m is fairly low. The reason for this is the heat loss to the flanges connecting the lower heater panel and the upper heating panel. The lower and upper panels are well contacted with the bottom flanges, but almost separated with the top flanges owing to the weight of the hot panels. For this reason, the heat loss to the bottom flanges turns out to be larger than that to the top flanges.

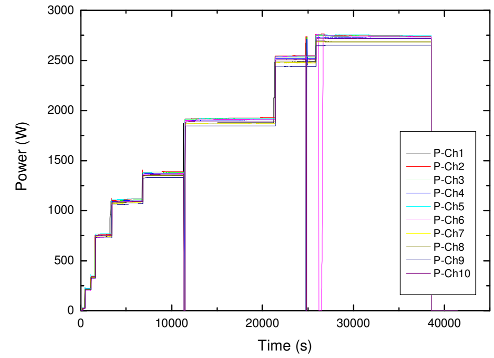

Fig. 5. Power in put to the heaters

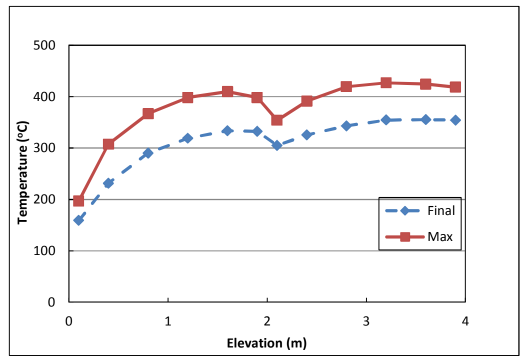

Fig. 6. Hot panel temperature

Fig. 7 shows the buoyancy driven natural circulation air flow rates in the two chimneys. This figure shows flows formed in both chimneys at 20,000 s but finally the flow was maintained only in one chimney, S-6(N). This implies that once the flow path stably forms, it tends to maintain its path. The sudden jumps in the flow rate are caused by a poor resolution of the sensors at low values. More precise sensors will be installed for a more accurate measurement.

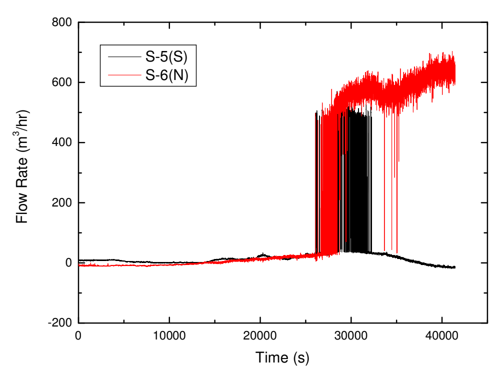

Fig. 7. Air flow rates in two chimneys

In this test, the instrumentations are heavily equipped in the inner and outer surface of a rectangular riser facing the hot and cold panels at 12 elevations. In addition, the inner surfaces of the two side walls of the riser are instrumented at four elevations. For example, the temperature history of the upper hot surface of the riser is presented in Fig. 8.

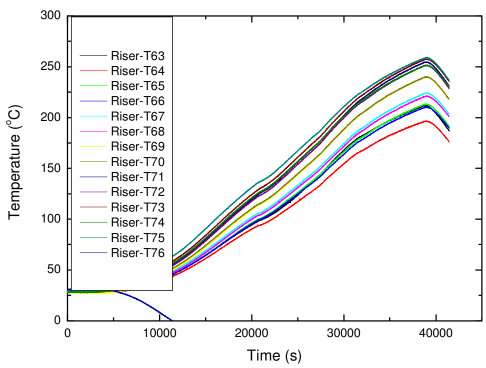

Fig. 8. Temperature history of the upper hot surface of the riser

Based on the riser surface temperature, the heat transfer coefficient in the riser by natural convection was calculated and is presented in Fig. 9. In addition, the heat transfer coefficient obtained from the correlation in [7] is shown in the same figure. The calculated heat transfer coefficient shows a fair agreement with that from the correlation except below an elevation of 1 m. For the region below 1 m, it is thought that the heat is lost dominantly by conduction to the unheated riser bottom section.

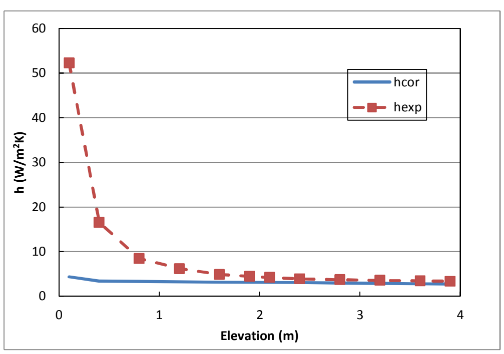

Fig. 9. Heat transfer coefficient

3. Conclusions

A 1/4-scale RCCS mockup of PMR200, NACEF, was constructed and tested preliminarily. The functioning of the facility worked quite well. Moreover, the preliminary test results show a fairly good agreement with past work except for the conductive heat transfer region in the riser bottom. After a remedy such as the installation of more precise flow meters and a more improved insulation, the test facility is likely to work well.

ACKNOWLEDGEMENTS

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