Natural Circulation Test of the KALIMER-600 Water Scaled Model

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1. Introduction

The thermal hydraulics phenomena have been investigated in a 1/10th water scaled model for the KALIMER-600. On the basis of an isothermal global flow test [1], the natural flow test was conducted in the transparent water scaled facility.

2. Experimental Facility and Test Results

The KALIMER-600 is a pool-type Sodium-cooled Fast Reactor (SFR) with a 600MWe generation capacity [1]. Figure 1 shows the 1/10 scaled Reactor Vessel test section for the KARIMER-600 SFR. All components are linearly scaled down to 1/10 exactly if possible. To design a scaled water reactor model, similarities between the 1/10 scaled water model and KALIMER-600 reactor should be an exact match. For natural circulation phenomena, it was necessary to match the scaling parameters such as Richardson number, and Euler number on the basis of geometrical similarity. Major scaling parameters are summarized in the Table 1 and 2.

All components except the reactor head and bottom of the reactor vessel are made of transparent Plexiglas and Polycarbonate for flow visualization and measurement using optical methods. The reactor vessel was made using transparent 25mm thick Plexiglas. The performance of the PHTS pump can be adjusted by the inverter with various working conditions.

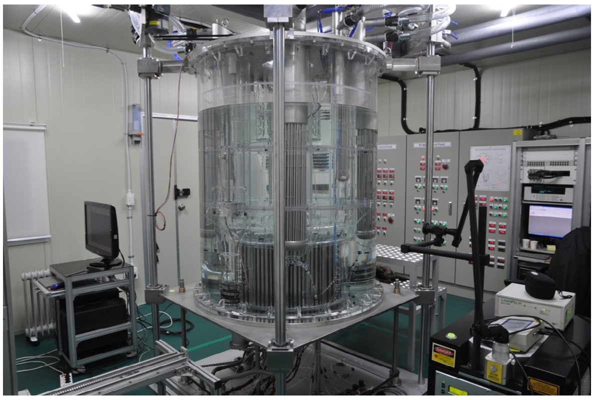

Figure 1. Photo of RV test section

Figure 2 shows the schematics of RV thermal hydraulics test facility. A total of 69 electric heaters are assembled in the core, which have 220V-100kW capacity. There are four IHX and two DHX in the reactor vessel, which are made by stainless steel SUS 304. The heat exchangers are cooled with two sets of chiller units, which have 78kW and 58kW cooling capacity, respectively. The flow rate and temperature of each cooling line is measured by the vortex flow meter(Rosemount, 200LPM) and 1/16" T-type sheath thermocouples.

The scaled transparent reactor vessel is installed in a separate room since its temperature can be controlled to reduce the heat loss from the reactor vessel. De-ionized water is used for the working fluid. The detailed specifications of the experimental facility are described in reference [2]. The velocity field and temperature field are measured using PIV(Particle Image Velocimetry) and more than 300 T-type thermocouples, respectively.

Table 1. Properties of water and liquid sodium

			Water	Sodium
Temperature	T	[°C]	30	467.5
Specific volume	ν	[m^3/kg]	0.001004	0.001190
Density	ρ	[kg/m^3]	995.7	840.1
Specific heat	Cp	[J/kg-K]	4179.8	1269.4
Thermal conductivity	κ	[W/m-K]	0.6155	69.75
Viscosity	μ	[Pa-s]	0.000797	0.000263
Thermal expansion coefficient	β	[1/K]	0.000303	0.000285
Thermal diffusivity	α	[m^2/s]	1.48E-07	6.54E-05
Prandtl number	Pr	[-]	5.4	0.005

Table 2. Major scaling parameters

Parameter	KALIMER-600	Water model
RV length [m]	18.5	1.85
RV diameter [m]	11.41	1.14
Power [MW]	1523.6	0.56 (×10%)
ΔT across core [°C]	155.0	14.59
Ri ratio	-	1.0
Velocity ratio	-	0.1
Time ratio		1.0

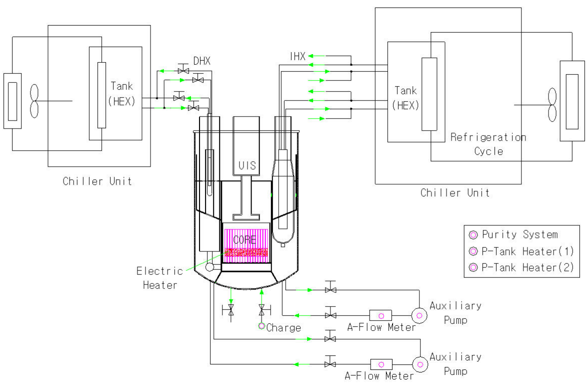

Figure 2. Schematics of RV TH test facility

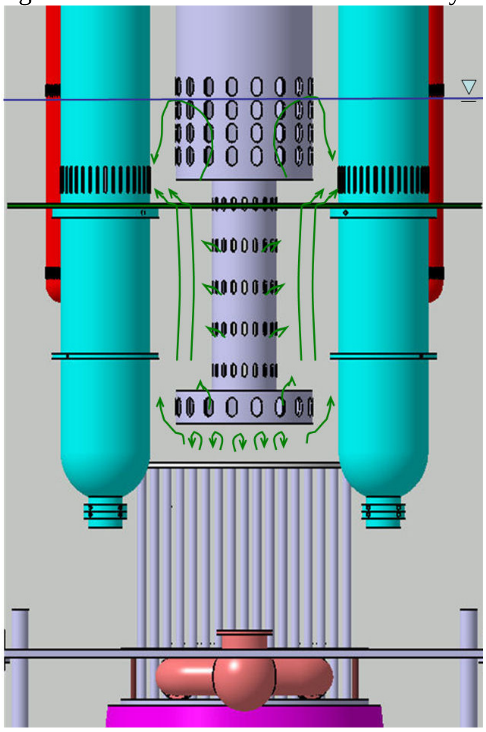

Figure 3. Flow distribution in the hot pool

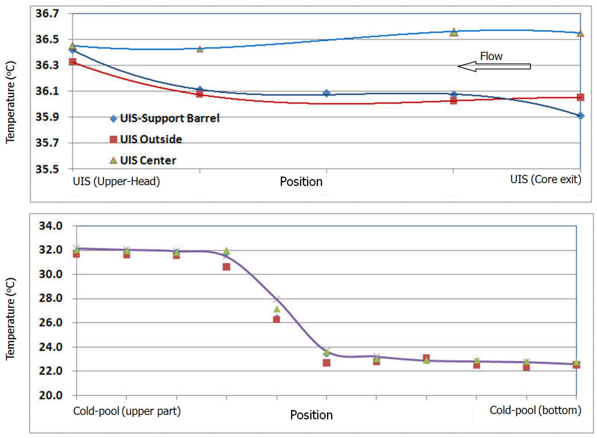

Figure 4. Temperature distribution hot-cold pool

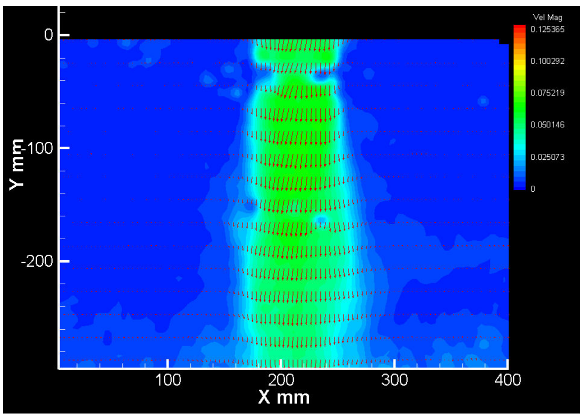

Figure 5. Flow distribution in the IHX exit

Figure 3 shows the flow field between the core exit and free surface under the isothermal cold flow test condition. Flow recirculation existed in the region between the core exit and UIS under plate. Flow passing the UIS bottom hole can flow smoothly upward. Part of the flow was entrained from the hole in the inner region of the UIS neck. The flow near the free surface entered into the IHX inlet which the large circulation and IHX inlet flow were not uniform with the circumference direction.

Figure 4 shows the temperature distribution in the hot pool and cold pool under the natural circulation condition. For the natural circulation flow, the energy balance was controlled by the core heater input and IHX-DHX heat sink. Figure shows a temperature distribution at around 2% decay heat of scaled condition. The temperature profile shows a typical flow mixing characteristics between the active core and non active core in the hot pool region. Thus, it shows the modeling validity of this RV thermal hydraulic test facility. There is partial temperature stratification in the cold pool.

Figure 5 shows the flow distributions of the IHX exit in the cold pool. Compared with the isothermal cold flow test, the flow was oscillatory ejected from the IHX exit. There is a flow recirculation along the pump duct inner surface in the vicinity of the pump inlet region. However, there is no swirl in the downstream of the pump propeller owing to non rotation of propeller. The IHX exit flow hits the RV bottom wall, and part of the flow was circulated between the pump inlet and IHX exit. A slightly complicated flow mixing was also shown in this area.

3. Summary

In order to extrapolate the thermal hydraulic condition in a large sodium reactor KALIMER-600, the thermal hydraulics phenomena has been investigated in a 1/10th water scaled reactor model. A natural flow test was conducted on the basis of the isothermal global flow test. The constructed RV thermal hydraulic test facility shows a good performance to simulate a natural circulation test for the KALIMER-600.

ACKNOWLEDGMENTS

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[2] J.E. Cha, et. al., 2011, Water Scaled Model Installation for the Sodium-Cooled Fast Reactor KALIMER-600, KAERI/TR-4518/2011, KAERI Technical Report