Thermal Hydraulic Study for the KALIMER-600 by a Scaled Water Model

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1. Introduction

KAERI is developing a KALIMER-600 reactor, which is a pool-type sodium-cooled fast reactor. Due to the importance of the fluid system design, the thermal hydraulic studies are necessary in the reactor vessel. We plan to investigate by using a scaled water model prior to the sodium model because a scaled water model installation has the benefits of a lower cost as well as the ease of measurement of the flow and temperature in a vessel. In addition, optical flow visualization techniques can be applied with transparent vessels. In this study, we intend to investigate the thermal hydraulic condition in 1/10 water scaled reactor vessel models and apply the results to optimize the KALIMER-600.

2. Scale analysis for water similitude

To design a scaled water reactor model, similarities between a scaled water model and the KALIMER-600 should be matched exactly. Scale analysis requires that the geometrical similarity and pressure drop ratio, Richardson number(Ri), Peclet number(Pe) and Reynolds number(Re) are the same. Richardson number represents the ratio of fluid buoyancy to its inertia. In this study, Richardson number ratio is set for $Ri_{or}=1$. At the scaled water model, pressure drops decrease due to the reduction of viscous friction and form loss. Thus, addition flow restriction is needed to compensate for the pressure drop. In order for investigation on natural circulation after scram, as well as forced circulation with various pump operating conditions, the pump is scaled with approximately 30% full power load.

Table 1. Scaling results: KALIMER-600 and a water simulation.

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%)
△T across core	155.0	14.59
Ri ratio	-	1.0
Velocity ratio	-	0.1
Time ratio	-	1.0

Table 2. Scaling results of pump

Parameter		Full power	30% power
Head [m]	Actual	4.515	1.35
	Total	5.418	1.62
Flow rate [m^3/min]		0.854	0.2562
Diameter [mm]		240	-
Revolution [rpm]		1423	-
Specific speed		370.33	-

3. Experimental setup and method

Figure 1 shows the geometries of 1/10 scaled KALIMER-600 water model. All components sizes are scaled down to 1/10. A scaled water model consists of four IHX(intermediate heat exchanger), two DHX(decay heat exchanger) and two pumps. Total 56kW electric heaters are used instead of nuclear fuel rods. Almost all of the components, except the reactor head and bottom of reactor vessel are made of transparent Plexiglas for flow visualization and measurement using optical methods. Each IHX and DHX is connected to a chiller. The performance of a pump can be adjusted by an inverter and a controller in various working conditions. In order to correctly measure and decrease the errors from light and vibration, the installation is completed in a discrete room. The de-ionized water is used for the working fluid. For the flow visualization and measurement, we intend to use PIV(particle image velocimetry), UVP(ultrasound velocity profile) and a dye injection method. The PIV is an optical method of flow visualization and using this method we can take 2D instantaneous velocity field. The temperatures are measured using the thermocouple and LIF(laser induced fluorescence). We can take 2D instantaneous temperature distribution using LIF. In addition, PIV method and LIF method can be used simultaneously, because the PIV system and LIF system are made of almost the same apparatus laser, CCD camera and optical lens. Therefore, instantaneous velocity field and temperature distribution can be obtained simultaneously. The experimental setup is shown schematically in Figure 2. The experimental room consists of two floors. A hoist is installed on the roof to enable the maintenance of experimental model.

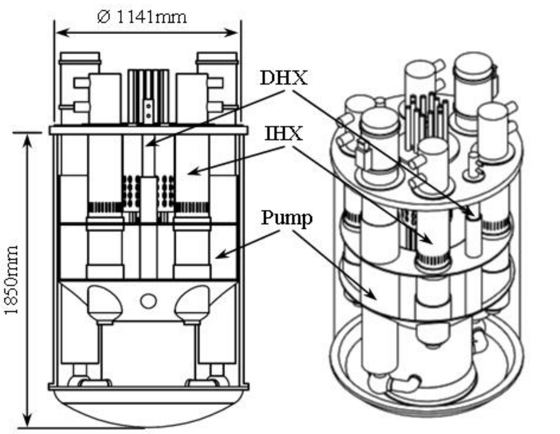

Figure 1. 1/10 scaled down KALIMER-600 model

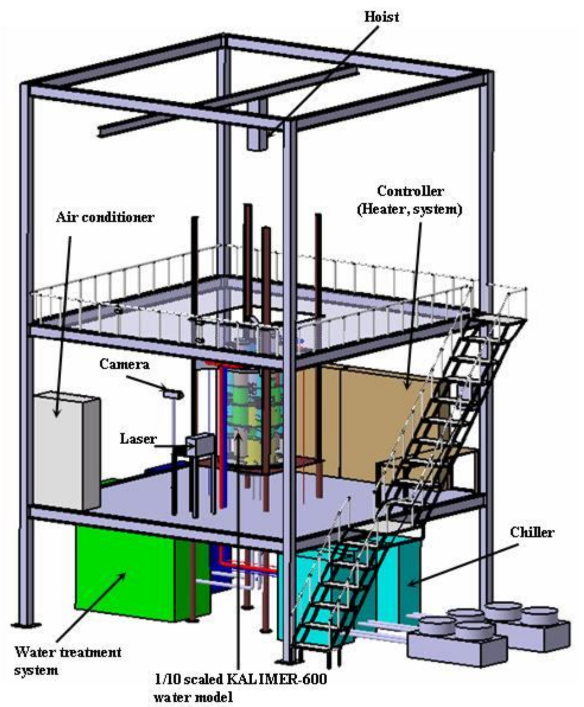

Figure 2. Bird's eye view of the test facility

3. Conclusion

In order to extrapolate thermal hydraulic condition in a large sodium reactor KALIMER-600, we intend to investigate thermal hydraulics phenomena in a 1/10 water scaled reactor model instead of a sodium model. Scaled water simulation has the benefit of a lower installation cost as well as the ease of measurement of the flow and temperature. Scaled water models can be used to provide pertinent information for thermal hydraulics phenomena. In addition, the results from a scaled water simulation can be used to validate the calculated results and apply to a thermal hydraulic optimization in full size KALIMER-600.

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