Investigation into Thermal-hydraulic Behavior in the KALIMER-600 Pool in a Steady State

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1. Introduction

The conceptual design of KALIMER-600 (Korea Advanced Liquid MEtal Reactor) has been developed under the Mid- and Long-term Nuclear R&D Program[1]. In the design of those nuclear reactors securing a reliable decay heat removal system and evaluating its capability is a important safety criterion. Especially various studies are necessary in order to assess the major parameters affecting the transient decay heat removal performances. One of the approaches for those studies is numerical analysis based on 3D thermal hydraulic codes such as COMMIX[2].

COMMIX-1AR/P code is a three-dimensional transient single-phase computer program for a thermal-hydraulic analysis. Especially the porous-medium formulation which has been implemented in the COMMIX code allows the user to simulate a complex geometrical arrangement as well as a simple one.

As the first step of an investigation into the transient behavior in KALIMER-600 after the shut down, the modeling approaches were introduced and the thermal-hydraulic behavior of KALIMER-600 in a steady state condition was investigated briefly.

This study will provide the basic design information for modeling KALIMER-600 and the thermal-hydraulic behavior of it in a steady state condition.

2. Methods and Results

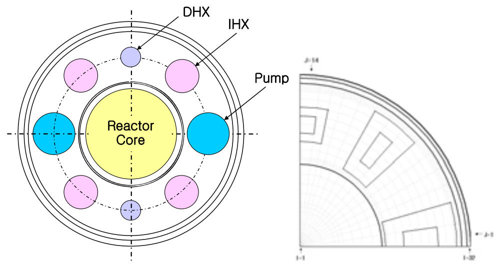
In this research the COMMIX-1AR/P code is utilized for analyzing three dimensional phenomena such as the single-phase fluid flow and heat transfer in KALIMER-600. The code includes physical models for a volume porosity, surface permeability, surface heat flux, volumetric heat source, thermal interaction between an immersed structure and the surrounding fluid, and a turbulence.

The modeling approaches for internal structures are described and related results in a steady state will be described briefly. The internal structures include a pump, reactor core, and IHX. The other components were modeled as a simple adiabatic block such as DHX and UIS.

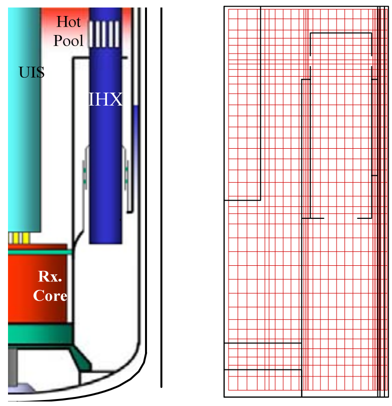
2.1 Geometry and Grid

Figure 1 (a) and (b) represent the XY and XZ plane view of the KALIMER-600 geometry and the related grid system respectively. In the present calculation a quarter of the reactor geometry was modeled in a cylindrical coordinate system, which includes a quarter of a reactor core and a UIS, half of a DHX and a pump and a full IHX. The lower concave region under the reactor core is simplified to be a flat one. Number of grid in each direction is as follows.

- NXxNYxNZ=33x14x39
- Non-Uniform Grid



(a) XY plane view



(b) XZ plane view (J=8)

Figure 1. KALIMER-600 geometry and grid system

The effect of radiation heat transfer is included between reactor baffle and reactor vessel, reactor vessel and containment vessel, and containment vessel and air separator.

2.2 Heat balance of PHTS

Figure 2 shows the steady state heat balance of PHTS in KALIMER-600[3]. The power and mass flow rate of each internal structure was modeled based on this information. As prescribed in figure 1 the mass flow rate of PHTS pump is the sum of two pumps.

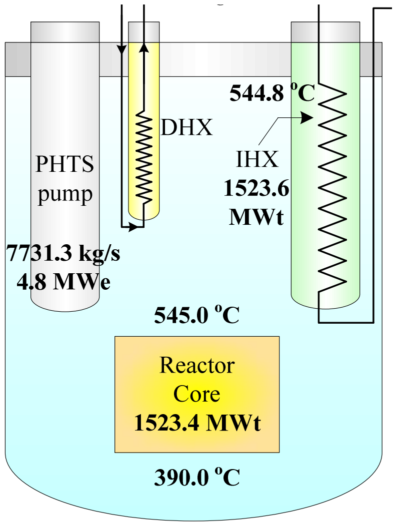


Figure 2. Heat balance of PHTS in KALIMER-600

2.3 Pump Model

For our analysis, a homologous pump model, one of the provided pump models in COMMIX-1AR/P is utilized. The head and speed of pump is 54.18 m and 450 rpm respectively[4].

2.4 Reactor Core Model

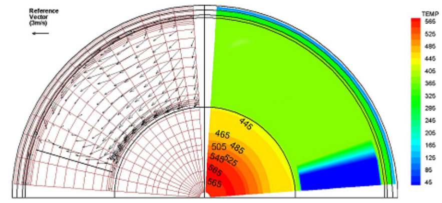
The reactor core is composed of an inner driver, middle driver, outer driver and other components. The total power amounts to 1523.4 MWt and the power is allocated to each thermal structure by the amounts of 38.0%, 31.9%, 28.5% and 1.6% respectively in the reactor core model[5].

2.5 IHX Model

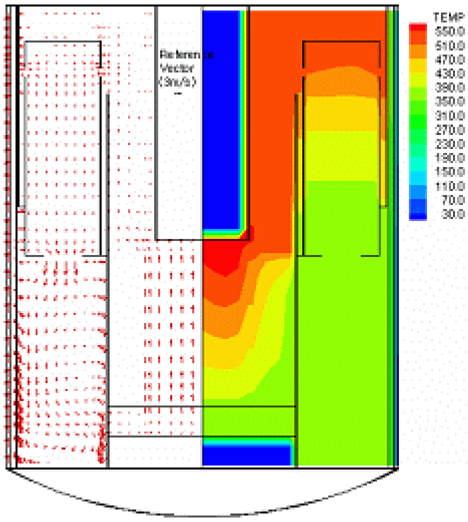
Most of the heat is removed through four IHXs in normal operation condition. The total no. of tubes in one IHX are 4188 and volumetric heat loss through the tubes amount to 69 MWt/m^3.

2.6 Thermal-Hydraulic Behavior

Figure 3 (a) and (b) shows the XY plane and XZ plane view of the velocity and temperature distribution in a steady state at K=15 and J=8 respectively. The UIS, pump and lower region of the inlet plenum is assumed to be adiabatic in this calculation. As shown in the figure the average velocity and temperature profile presents the behavior of sodium flow in a reactor vessel reasonably.



(a) XY plane view (K=15)



(b) XZ plane view (J=8)

Figure 3. Velocity and temperature distribution in KALIMER-600

3. Conclusion

Modeling approaches using COMMIX-1AR/P was introduced and the thermal-hydraulic behavior in steady state condition was presented in this study. This information will be useful to understand the temperature and velocity distribution in the pool and utilized as the initial condition for the further investigation on transient behavior in KALIMER-600 after the shut down.

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