Transactions of the Korean Nuclear Society Autumn Meeting
JeJu, Korea, May 18-23, 2009

Parametric Study on an Initial Cooling Performance in the KALIMER-600

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1. Introduction

Decay heat removal is very important in a nuclear power plant. The KALIMER-600, Korea Advanced Liquid MEtal Reactor, employs the PDRC(Passive Decay heat Removal Circuit) to remove the decay heat. DHX(Decay Heat eXchanger) in the PDRC of KALIMER-600 is disposed in the DHX support barrel located in the hot pool region. Each DHX support barrel has the lower end communicating with the cold pool such that the sodium free surface inside the barrel is maintained with the same level of the cold pool using the pumping head of the PHTS(Primary Heat Transport System) pumps. Consequently, DHX is not in direct contact with the cold pool sodium during a normal plant operation. Under transient conditions such as the loss of a normal heat sink accident, free surface outside the barrel rises up due to the expansion of the sodium induced by the core decay heat during the initial stage cooling. When it overflows into the cold pool through the DHX support barrel the heat removal via DHX is initiated and the second stage cooling begins.

In order to secure the safety of a reactor until the activation of a second stage cooling by PDRC, it is very important to suppress the core temperature rising by an enhancement of the initial cooling performance. In this study the parametric investigations have been applied to reveal the effect of various design parameters on the initial cooling performance. The various design parameters such as coastdown flow, IHX(Intermediate Heat eXchanger) elevation, heat trnasfer via CCS (Cavity Cooling System) were considered.

The numerical approaches based on a multi-dimensional analysis can be utilized as a useful tool to investigate overall transient behaviors within a pool. In this research the COMMIX-1AR/P code[1] is utilized as a transient analysis tool in KALIMER-600 after a shut down.

This study will provide the basic design information to improve the initial cooling performance in the KALIMER-600.

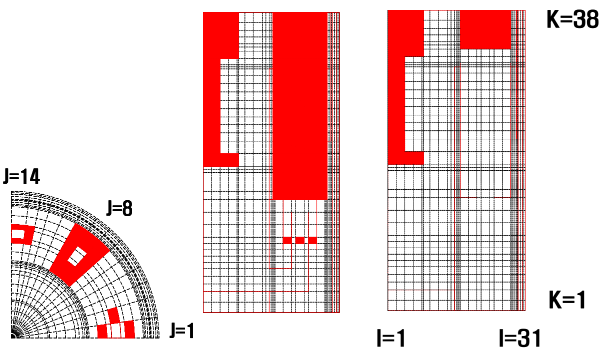
2. Methods and Results

In this research the COMMIX-1AR/P code is utilized to assess the effect of various parameters on the initial stage cooling performance.

The necessary information for the transient analysis are as follows ; decay heat variation, PHTS pump coastdown flow variation, related boundary condition, and etc. In this calculation the decay heat variation profile is based on reference[2]. The coastdown flow is calculated based on reference[3]. The DHX heat loss is not taken into account and IHX heat loss is assumed to become zero as soon as the reactor trip.

2.1 Geometry and Grid

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, a half of a DHX and a pump and a full IHX. The lower concave region under the reactor core was simplified to be a flat one. Number of grids was decided to be 31, 14 and 39 in the X, Y and Z directions respectively as shown in Fig. 1, by considering the degree of the flow field resolution and practical restrictions such as the computing time and storage limitations caused by various calculation conditions.



(a) XY plane (b) XZ plane(J=1) (c) XZ plane (J=8)

Fig. 1 Nodalization of KALIMER-600 geometry

The information related to the calculation under a steady state condition can be found in the reference[4].

2.2 Design Parameters

In this calculation design parameters such as the coastdown flow, IHX elevation, heat transfer via CCS were considered. These design parameters are briefly presented in Fig. 2.

The reference calculation has been done in the reactor without flywheel condition. The effect of coastdown flow on the initial cooling is analyzed by employing the PHTS pump flywheel in the reference reactor. The characteristics of a flywheel such as the pump head variation curve, flow halving time and coastdown flow time were previously decided by numerical code[3]. Flow halving time is defined by the time that it takes for the flow rate to become a half of the initial value. The CDT(CoastDown flow Time) is set to be the time during which the flow rate is decreased to be less than 1.0E-3 kg/s. In this calculation flywheel of CDT=25 is employed.

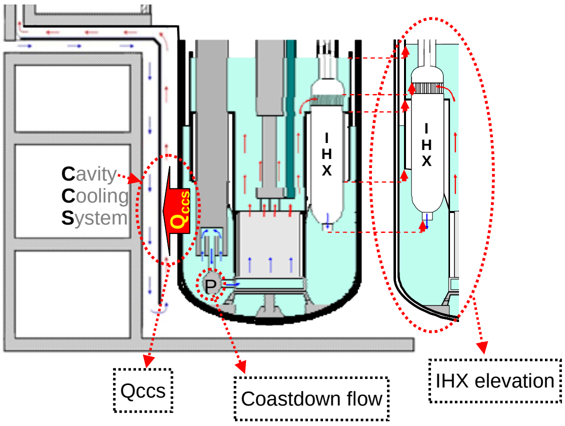


Fig. 2 Various design parameters affecting initial decay heat removal capability

The effect of the IHX elevation is analyzed by varying the vertical position of the IHX. In order to increase the IHX elevation the position of the related geometry such as the separation plate, IHX inlet window, top of support barrel, etc. should be changed. The sodium free surface should also be increased in order to maintain the depth of the IHX inlet window from sodium free surface. In this calculation the vertical position of the IHX is elevated by 1m and the related effects on the initial cooling are evaluated.

The heat transfer effect via CCS on the initial cooling is assessed by modulating the amount of heat removal. It could be done by reducing the inlet velocity of air passing through the duct. In this calculation the heat transfer rate is reduced to be 1% in comparison to that of reference value and its effect on the initial cooling is analyzed.

2.3 Evaluation of initial cooling performance

Fig. 3 shows the effects of various design parameters on the maximum core temperature. The maximum temperature of coolant at the core is evaluated by the highest one among the averaged temperatures in the circumferential direction at every axial grid of the core region.

The symbol represents the maximum temperature at core in reference reactor. Solid line, dashed-dotted line and dashed line represent that of IHX elevated case, coastdown flow supplied case, and reduced CCS heat loss case, respectively. In the reference case the first peak appears at the beginning of reactor trip. This peak is caused by the unbalance between the coolant flow rate and the core power.

The effect of the CCS heat removal on the maximum core temperature is very small. Elevating IHX could reduce the peak temperature however could not remove it. In the case of coastdown flow the peak temperature disappears by employing adequate flywheel. Since the insufficient circulation flow rate at initial stage is compensated by coastdown flow, the peak temperature could be removed. Thus it could be concluded that the coastdown flow is an effective parameter to improve initial cooling performance.

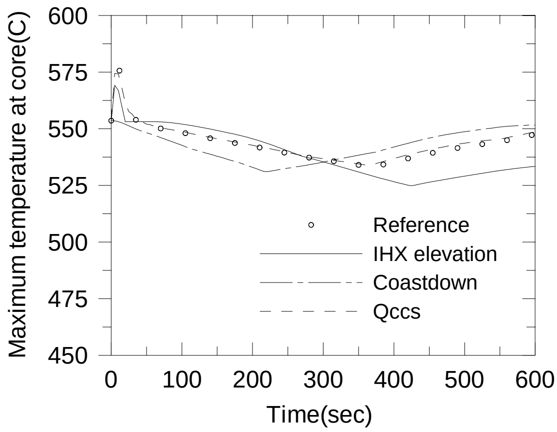


Fig. 3 Effect of various design parameters on coolant's maximum temperature at core

3. Conclusion

In this study the effects of various design parameters on an initial cooling performance were analyzed using COMMIX-1AR/P. The coastdown flow was proven to be an effective parameter to improve the initial cooling performance among the IHX elevation, CCS heat removal and coastdown flow.

REFERENCES

[1] P. L. Garner, R. N. Blomquist, and E. M. Gelbard, COMMIX-1AR/P : A Three-dimensional Transient Single-phase Computer Program for Thermal Hydraulic Analysis of Single and Multicomponent Systems , Volume 2:User's Guide, Argonne National Lagoratory, ANL92-33, 1992.

[2] B. Y. Choi, Thermal-hydraulic analysis in core catcher LMR/FS100-AR-02-Rev.0/07, 2007.

[3] S. K. Choi, Improvement on methodology for setting moment of inertia and coastdown flow in PHTS pump of KALIMER-600, LMR/FS200-ER-03-Rev.0/05, 2005.

[4] J. W. Han, T. H. Lee, J. H. Eoh, and S. O. Kim, Investigation into Thermal-hydraulic behavior in the KALIMER-600 Pool in a steady state, Transaction of Korean Nuclear Society Spring Meeting, pp.61-62, 2008.