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IRWST Thermal Mixing of Containment Pressure and Radioactivity Suppression System(CPRSS) for SMR

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1. Introduction

In the SMR(Small Modular Reactor), steam generators, pressurizer, and reactor coolant pump are installed in the reactor vessel, so it allow to exclude piping line. This design configuration of SMR have the benefit of implementing a passive safety system for containment cooling. The passive containment cooling system has the function of suppression of containment pressure in the accident without any active components within 72 hours required by the regulatory requirement. The CPRSS is proposed as the one of passive containment cooling method [1]. The system delivers steam from the reactor to IRWST(In-containment Refueling Water Storage Tank) to remove residual heat through direct condensation. The thermal stratification of IRWST plays an important role for enhancing the system's performance. The object of this paper is to evaluation the thermal mixing for IRWST.

2. Description of the System

Figure 1 shows the conceptual design of the CPRSS. The safety functions of CPRSS are to reduce containment pressure and temperature for Loss of Coolant Accident and to suppress fission products in containment atmosphere. The system consists of LCA(Lower Containment Area), pressure relief line between LCA and IRWST, IRWST, UCA(Upper Containment Area) and ECTHS(Emergency Cooldown Tank Heat Removal System). LCA represents the region surrounded in containing the reactor vessel, CMT(Core Make-up Tank) and SIT(Safety Injection Tank). The lower part of LCA has a steel liner structure and the top of the reactor head is covered with a steel lid. The IRWST is located beside LCA and divided into liquid area and gas area. The pressure relief lines are connected from LCA to IRWST. The 6 exits of pressure relief line are submerged in 7 m depth of IRWST and arranged as like in Fig. 2. In accident, the mixture of steam and radioactive material is discharged to IRWST by pressure difference between the UCA and the IRWST following LOCA(Loss of Coolant Accident). IRWST serves to suppress the steam and radioactive material released from LCA by 72 hours. The steam discharged from LCA to IRWST is directly condensed by the water of IRWST and the iodine is dissolved in the water. The gas at the top of the IRWST finally emits to the UCA through the vent line. The ECTHX is applied as a means of long-term cooling for reactor decay heat after 72 hours.

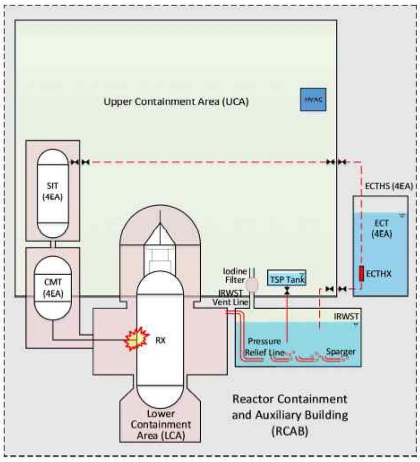


Fig. 1.Conceptual design view for CPRSS

3. Analysis Method and Results

3.1 Analysis Model

Figure 2 is domain for CFD calculation of IRWST. The temperature in the IRWST pool is monitored for three different observing regions on vertical and horizontal planes given in Fig. 2. The cross-sectional area of the IRWST pool is 782.75 ㎡(25.25 m x 31.0 m) and the height of the IRWST pool is 9.0 m including the atmosphere part. In the 6 inlets, water 100℃ is supplied into the IRWST pool by 5 kg/sec of mass flow rate.

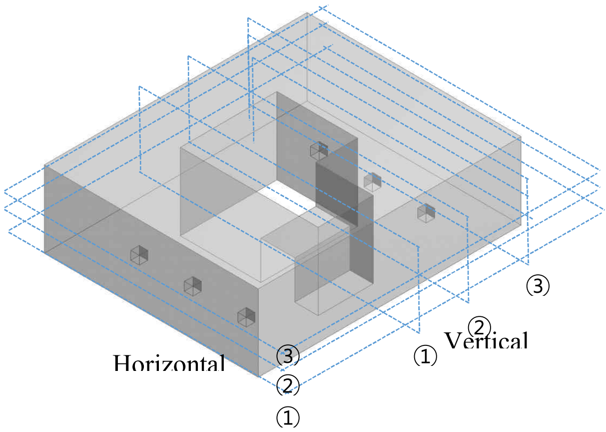
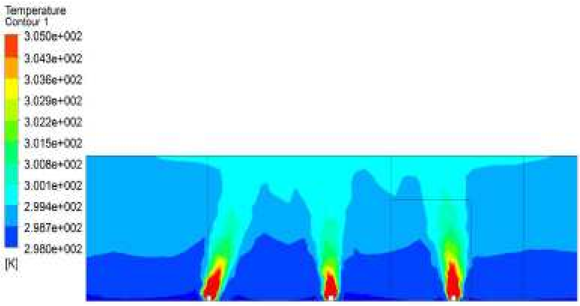
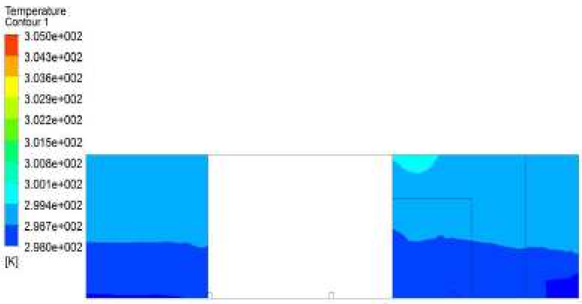


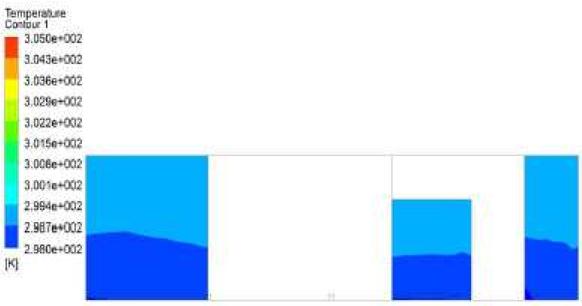
Fig. 2. Temperature monitoring regions for IRWST(vertical and horizontal plane)



(a) Region ①



(b) Region ②



(c) Region ③

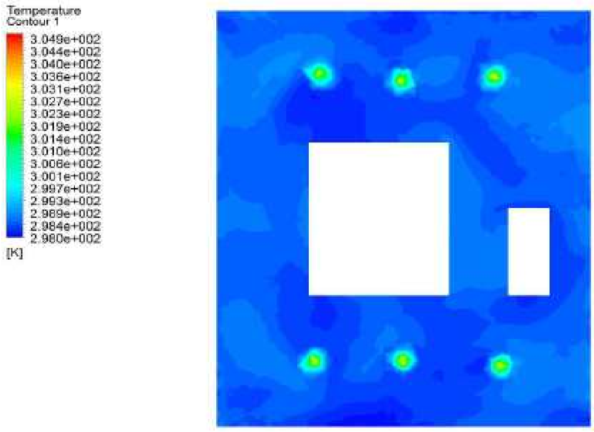
Fig. 3.Temperature distribution in each monitoring region at 1000 sec(vertical plane)

3.2 Analysis Results

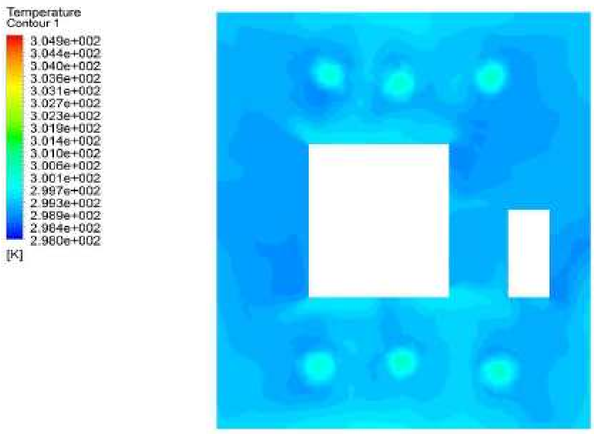
Figure 3 and 4 are temperature distribution in each monitoring plane. The heat near the spargers is transported to the surrounding water, water temperature increases and its density decreases. Heated water moves upwards due to the relative difference in density and simultaneously transfers the heat to surrounding cold water. Owing to the buoyancy, hot water tends to be distributed in the upper region of the IRWST pool and this leads to thermal stratification (Fig. 3 and 4).

4. Conclusions

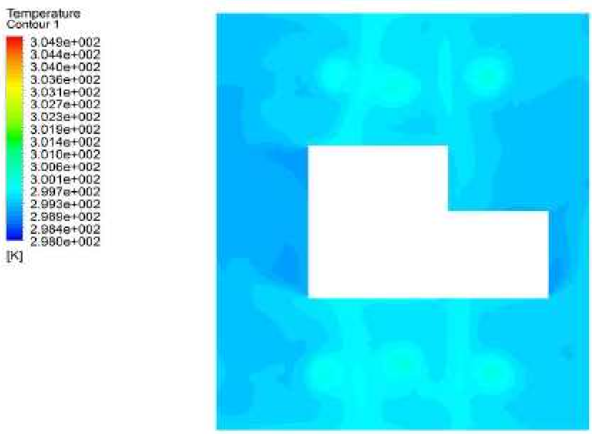
The preliminary thermal mixing evaluation of CPRSS was performed by CFD analysis. As the results of CFD analysis, the discharging flow from the six inlets can be make the thermal stratification inside the IRWST.



(a) Region ①



(b) Region ②



(c) Region ③

Fig. 4.Temperature distribution in each monitoring region at 1000 sec(horizontal plane)

REFERENCES

[1] K.J.Kang, Y.I.Kim et al, Radioactive Material Reduction Facility and Nuclear Power Plant having the same, 10-2014-003632, Korea Patent(2014)