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Flow Field Calculation and Debris Transport During Blowdown/Washdown in Containment

Young S. Bang*, Il-Seok Lee, Gil Soo Lee, Byung Gil Huh, In-Goo Kim, and Sweng W. Woo
Korea Institute of Nuclear Safety
*k164bys@kins.re.kr**

1. Introduction

Containment recirculation sump (CRS) in pressurized water reactor (PWR) has been designed to provide water source to the emergency core cooling system (ECCS) and containment spray system (CSS) after the timing of recirculation following a loss-of-coolant accident (LOCA).

It has been noticed that the screen of CRS may be blocked by the debris generated by the LOCA or latent in containment. Thus, CRS blockage has a significant impact on the available net positive suction head (NPSH) of the ECCS and CSS pumps [1].

To evaluate the impact of the sump blockage involves assessments of the debris transport, which is one of the most uncertain areas and strongly dependent on the design of containment. The transport mechanism has been characterized by two processes: blowdown/washdown (BW) transport and pool transport [2]. Since BW transport has been evaluated by engineering decision based on the experimental observation, it may have significant uncertainty and needs extensive justification of the conservatism in amount of debris transported [3].

The present paper aims to discuss a model to calculate the flow field and debris transport in containment during BW process. The model is to simulate the thermal-hydraulic behavior in sub-compartments and flow paths in containment by RELAP5/MOD3.3 code [4] and to determine the debris transport using the flow field.

2. Code and Model

As stated, RELAP5/MOD3.3 code was used. The code has not been applied to the containment thermal-hydraulic behavior due to the limitation of the basic model based on the pipe internal flow. However, the code has a great flexibility in calculating the flow field in complex geometry via momentum conservation equation with crossflow option and non-condensible gas appropriate to the containment flow field calculation.

Figure 1 shows a calculation model to be used in the calculation of the flow field and BW transport. The model was based on the containment of Kori Unit 1, but the geometrical data may be different from the Unit. The containment has four floors including two steam generator (SG) compartments and refueling pool. The containment was modeled by 84 volumes and 116 junctions which simulated the major flow paths includes the floor gratings, the stairways, labyrinth doorway to compartment, and some drainages. Currently, heat structures (HS) were not modeled for simplicity.

The RCS thermal-hydraulic calculation for double-ended hot leg break (DEHLB) was used as a boundary condition. Single failure of the safety system was assumed and containment spray was modeled based on the FSAR.

The debris transport can be expressed by the following simple transport equation assuming no interaction with flow field and external force.

$$\int_V \frac{\partial \varsigma}{\partial t} dV = \int_A \varsigma \vec{v} \cdot d\vec{A} \qquad (1)$$

where ζ and υ denote amount of debris in the volume V and velocity field $\vec{v}$, respectively. The equation can be solved for each volume of the Figure 1 by the simple upwind difference scheme as follows.

$$\varsigma_K^{\,n+1} = \varsigma_K^{\,n} + \sum_{i=1}^{NJ} \frac{\Delta t}{Vol_M} \varsigma_M^{\,n} \upsilon_i^{\,n} A_i \qquad (2)$$

where i, and M denote junction index associated with the Kth volume and upwinding volume of each junction, respectively. The source of debris was specified at the near-break node and the RELAP5 calculated velocity field with respect to time and node was inserted into the Equation (2).

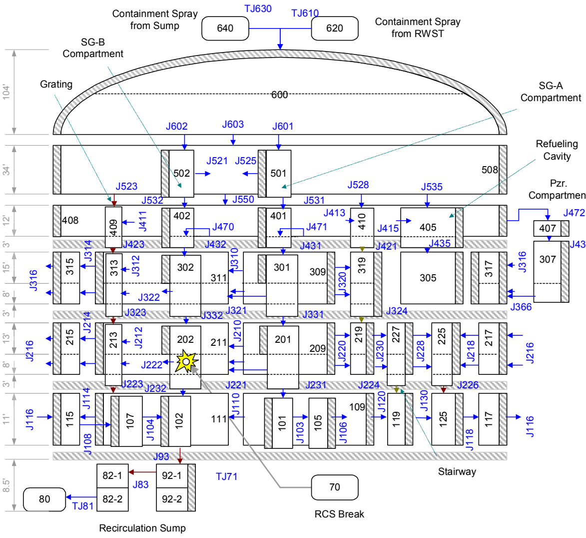

Fig. 1 RELAP5 Containment Model

3. RESULT AND DISCUSSION

The transient calculation was initiated at 100 sec, after steady state initialization. Transient up to 2000 sec was attempted. The recirculation actuation signal was at 1700 sec from the RCS calculation. Figure 2 shows the containment pressure calculated by RELAP5 for DEHLB. The present calculation was compared with the FSAR data. It is shown that it had some deviation due to lack of passive heat sink but overall behavior was generally agreed with the FSAR.

The calculated flow field at the time of blowdown was shown in Figure 3. It is shown that the maximum gas velocity at the top of SG compartment instantaneously exceeds 1000 ft/sec and velocities near break location are substantially high such that all the generated debris could be transported to upper part of containment.

Figure 4 shows a calculated amount of debris at each floor of the containment. Those amounts at the 1st floor and 3rd floor just after the start of blowdown (the first peak) were believed reasonable in a viewpoint of the consistency with the velocity level. However, after that, those amounts decreased by the continuous blowdown flow passing through the 1st floor to upper level. It indicated the further specific transport model should be developed to consider the various driving forces causing the deposition and screening at each volume.

4. CONCLUDING REMARKS

Flow field through sub-compartments in containment was calculated using RELAP5 code. The containment was modeled as appropriate the debris transport. Simple upwind difference scheme was used for debris transport. Flow field was reasonably predicted by comparison with FSAR. It was found that the prediction of the transport of debris was reasonable in initial blowdown transport, however, a specific model driving the deposition of debris at each cell would be needed.

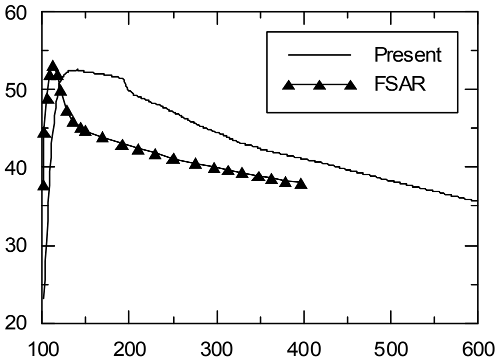

Fig. 2 Comparison of containment pressure

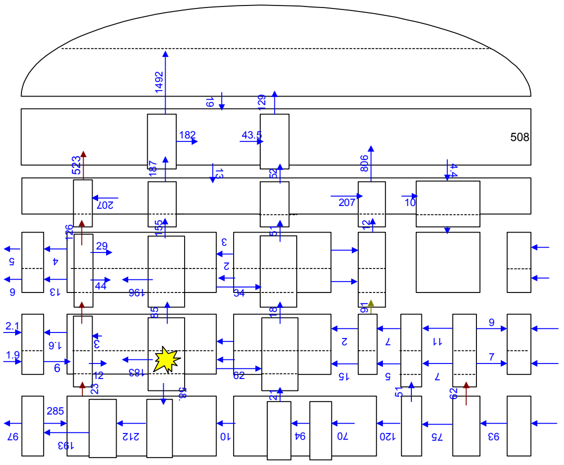

Fig. 3 Flow field in containment at 103 sec.

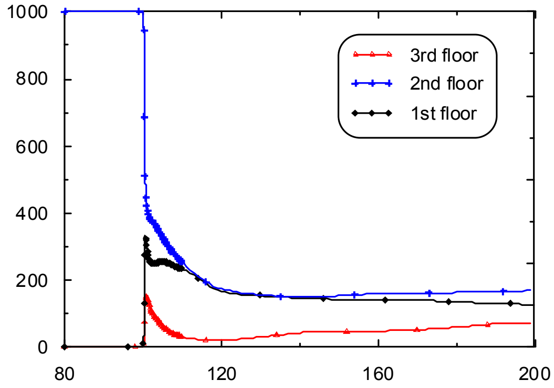

Fig. 4 Amount of debris transported to each level

REFERENCES

[1] A.W.Serkiz, et al, Containment Emergency Sump Performance, Technical Findings Related to Unresolved Safety Issue A-43, NUREG-0897, USNRC, Oct. 1985.

[2] D.V. Rao, et al, Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance NUREG/CR-6808, LANL, Feb. 2003

[3] USNRC. Safety Evaluation by the Office Of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), Dec. 2005

[4] Information System Laboratory, RELAP5/MOD3.3 Code Manual, NUREG/CR-5535, Rev.1, 2001