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Debris Transport Evaluation during LOCA Blow-down for Recirculation Sump Performance of OPR-1000 Plant

Soon Joon Hong[a], Jonguk Kim[a], Jeong Ik Lee[a], Jin Yong Lee[a],
Manwoong Kim[b], Ju Yeop Park[b], Yong-Ho Ryu[b]
[a]*FNC Tech. Co. Ltd. SNU 135-308, San 56-1, Shinrim 9-Dong, Kwanak-Gu, Seoul, 151-742, S. Korea, sjhong90@fnctech.com*
[b]*Korea Institute of Nuclear Safety, 19 Gusung-Dong, Yuseong-Gu, Daejeon, Korea, 305-755 mwkim@kins.re.kr*

1. Introduction

As a response to Regulation Guide 1.82 Revision 3 (RG. 1.82 Rev.3), and Generic Letter 2004-02 of USNRC (United State Nuclear Regulatory Committee), NEI (Nuclear Energy Institute) submitted a recirculation sump evaluation methodology called NEI 04-07 to USNRC. The baseline methodology of NEI 04-07 is composed of break selection, debris generation, latent debris, debris transport, and head loss, and the debris transport is evaluated using debris transport chart which is composed of Blow-down transport, washdown transport, and pool fillup transport. In this methodology 0.75 was recommended for the Blow-down transport to lower containment based on the study on BWR (Boling Water Reactor) sump clogging issue and engineering judgment[1,2,3]. USNRC quantitatively evaluated the Blow-down transport in the appendix of safety evaluation report (SER) to NEI 04-07, and concluded the recommended Blow-down transport fraction in NEI 04-07 was sufficiently conservative[4]. The methodology of USNRC on the Blow-down transport seems relatively persuasive, however, it includes so many values in evaluation steps which depend much on the containment shape and engineering judgment. In particular the dependency on plant type limits the generality of the USNRC's conclusion on Blow-down transport, when the considered plant is different from the volunteer plant or the same type plant in SER.

Therefore, this study provides the evaluation result on Blow-down transport fraction for OPR1000 (Optimized Power Reactor 1000MWe). Reference plant is Ulchin nuclear power plant units 3&4 (UCN3&4)[5]. CONTAIN 2.0 was used for the analysis of coolant behaviors in containment during Blow-down phase of large LOCA (Loss of Coolant Accident) [6].

2. Geometry of Containment and Debris Characterization

Containment of UCN3&4 is composed of cylinder type wall and hemisphere dome. Inner diameter is 144 ft (43.89 m), height 219 ft (66.75 m), and free volume 2.727x106 ft^3. The containment has 4 floors, and the elevation of bottom floor is 86ft. Fig.1 shows the vertical view of the containment.

According to the FSAR the debris of UCN3&4 are Nukon fiberglass, aluminum sheet (RMI, Reflective Metallic Insulation), carbon steel (RMI), and coatings.

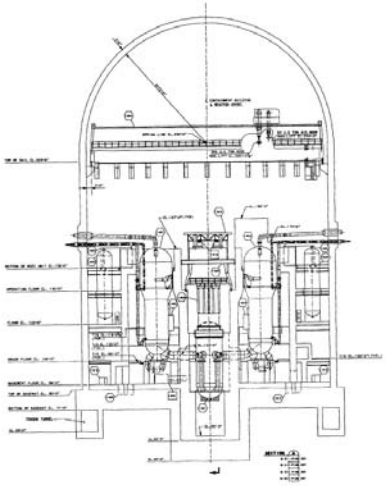

Figure 1 Vertical Section of UCN3&4 Containment

3. Analysis Result with CONTAIN

Break flow behavior was assessed by CONTAIN 2.0 code for the double ended hot leg break LOCA upstream of steam generator which is known to generate most debris. Fig. 2 shows the node for the analysis. Total 28 volumes were decided. About 10.5 seconds was analyzed.

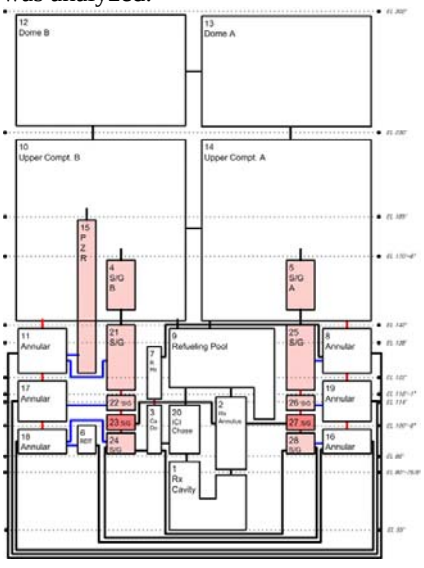

Figure 2 Node of UNC3&4 for CONTAIN analysis

4. Calculation of Debris Transport

The analysis was mostly based on USNRC SER method, but there were some major improvements to the method such as; (1) by analyzing a flow distribution not only near the break area but also the whole containment, the analysis result gained more accuracy than the US NRC result, (2) and also the debris transport was not simply calculated from a volume fraction of a cell (USNRC method) but instead the calculated flow distribution was extensively used. The analysis flow chart is shown in Fig. 3, and the logic tree of debris movement in Fig. 4.

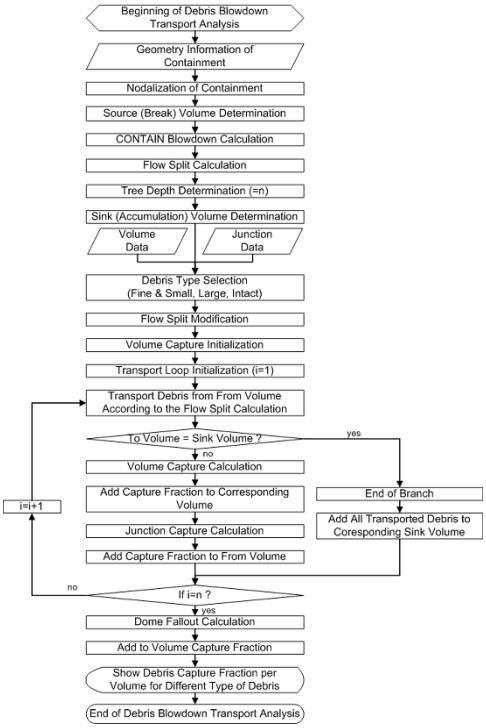

Figure 3 Analysis Flow Chart

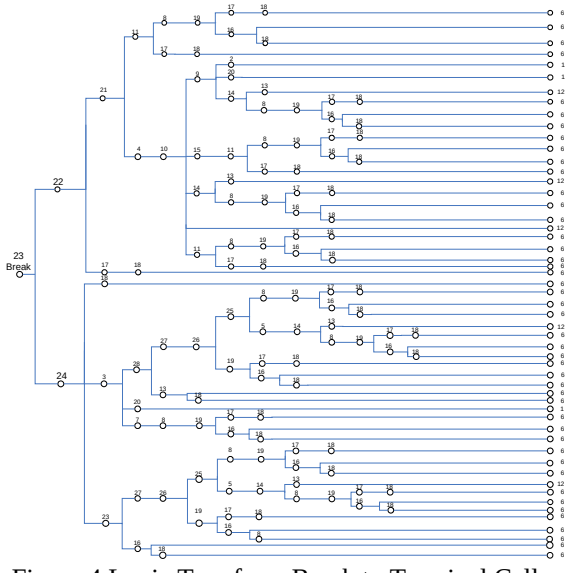

Figure 4 Logic Tree from Break to Terminal Cell

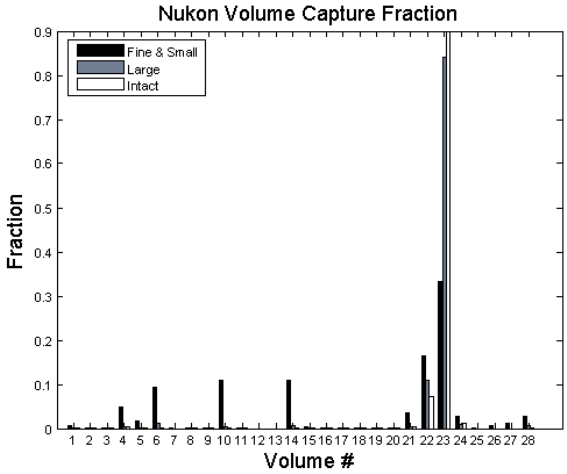

Figure 5 Nukon Fiber Capture Fraction for each Cell

Nukon fiber capture fraction for each cell is representatively suggested in Fig. 5.

5. Concluding Remarks

A debris transport inside the containment during a LOCA under the conditions of OPR1000 plant was analyzed. The analysis was mostly based on USNRC SER method, but there were some improvements to the method.

The analysis results are similar to the USNRC results, and at the same time it is confirmed that the debris transport fraction set by NEI 04-02 is conservative in OPR1000 plant. This analysis bears similar limitation as the USNRC analysis, since classification of a cell and capture rate of each class were based on the BWR studies. From the analysis basis prepared in this study, the PWR debris transport fraction can be calculated by switching raw data with additionally provided data for PWR (Pressurized Water Reactor) conditions and applying the methodology developed here.

REFERENCES

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[6] USNRC, "Code Manualfor CONTAIN 2.0: A Computer Code for Nuclear Reactor Containment Analysis", NUREG/CR-6533, 1997