Review on the NEI Methodology of Debris Transport Analysis in Sump Blockage Issue for APR1400

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1. Introduction

Since USNRC (United State Nuclear Regulatory Committee) initially addressed post-accident sump performance under Unresolved Safety Issue USI A-43, sump blockage issue has gone through GSI-191, Regulation Guide 1.82, Rev. 3 (RG. 1.82 Rev.3), and generic Letter 2004-02 for PWRs (Pressurized Water Reactors) [1,2,3,4]. As a response of these USNRC's activities, NEI 04-07 was issued in order to evaluate the post-accident performance of a plant's recirculation sump [5]. The baseline methodology of NEI 04-07 is composed of break selection, debris generation, latent debris, debris transport, and head loss. In analytical refinement of NEI 04-07, computational fluid dynamic (CFD) is suggested for the evaluation of debris transport in emergency core cooling (ECC) recirculation mode as guided by RG. 1.82 Rev.3. In Korea nuclear industry also keeps step with international activities of this safety issue, with Kori 1 plant as a pioneering edge.

Korean nuclear industry has been also pursuing development of an advanced PWR of APR1400, which incorporates several improved safety features. One of the key features, considering sump blockage issue, is the adoption of IRWST (In-containment Refueling Water Storage Tank). This device, as the acronym implies, changes the emergency core cooling water injection pattern. This fact makes us to review the applicability of NEI 04-07's methodology.

In this paper we discuss the applicability of NEI 04-07's methodology, and more over, new methodology is proposed. And finally the preliminary debris transport is analyzed

2. Review of NEI Methodology

NEI methodology assumes 4 debris transport modes; blowdown transport, washdown transport, pool fill-up transport, and recirculation mode. As conventional PWRs have RWST (Refueling Water Storage Tank) outside of containment, switchover to sump recirculation mode is essential for the long term cooling after LOCA (Loss of Coolant Accident). After this switchover the sump recirculation initiates, while before this switchover the break flow and spray flow just accumulate on the bottom floor of containment with the water of no direction motion. Thus, before switchover to sump recirculation mode the debris is not transported to sump. Only after the switchover the debris can be transported to sump.

NEI methodology is based on these phenomenological characteristics, and the substantial debris transport is evaluated for sump recirculation mode using 3-dimensional CFD analysis. Therefore, NEI methodology can be applied only if the ECC injection undergoes the switchover from RWST to recirculation sump.

3. Design Features of APR1400

As mentioned above APR1400 has different features from conventional PWRs in that it adopts IRWST instead of RWST and recirculation sump. The configuration of IRWST is shown in Fig.1, layout of bottom floor of containment is sketched in Fig.2, and vertical elevation relation among each device is presented in Fig.3.

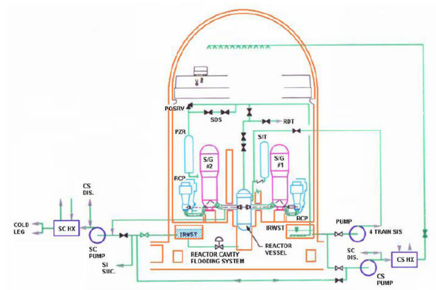

Figure 1 Configuration of APR1400 Containment and IRWST

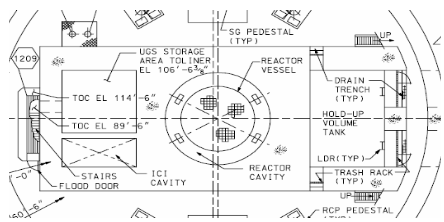

Figure 2 Layout of Bottom Floor

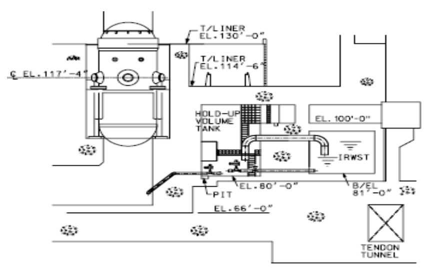

Figure 3 Vertical Elevation Relation among each Device

The water from break falls down, is directed to bottom floor, drains down to HVT (Holdup Volume Tank) through trenches, and finally is collected in IRWST via spillways because ECC pumps suck the IRWST water. This means the debris can be transported to IRWST in very earlier stage of LOCA. Resultantly, NEI methodology cannot be directly applied to APR1400's case.

4. Proposal of New Methodology

We propose a new methodology for the debris transport for APR1400: free surface CFD calculation is needed for the early phase of LOCA. Current CFD skill can calculate the free surface flow using advanced schemes, for example VOF (Volume Of Fluid) model. Break flow from the initial release is modeled, and the fallen water flow is calculated. Using these velocity profile debris transport fraction can be evaluated.

5. Free-surface Flow Calculation

FLUENT was used for the simulation of free surface flow[6]. Break location is determined hot leg near steam generator, since this location is known to generate the large amount of debris.

5.1 Geometry and Domain

From the several feasibility studies an optimized geometry was decided as shown in Fig. 4 [7].

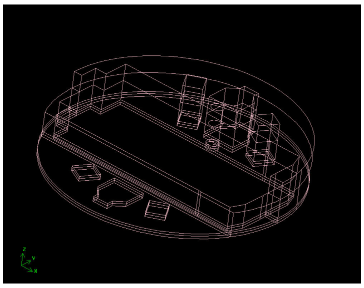

Figure 4 Geometry and Domain for CFD Analysis

5.2 Mesh and Modeling

GAMBIT was used to generate mesh and about 1 million meshes were configured. Fig. 5 shows the mesh. VOF model was used for the free surface calculation.

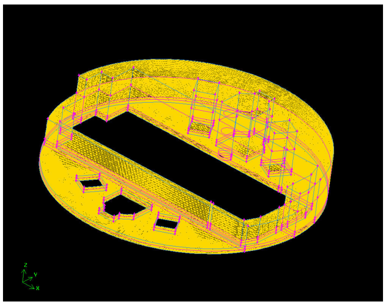

Figure 5 Meshes

5.3 Results

Typical flow field is shown in Fig.6.

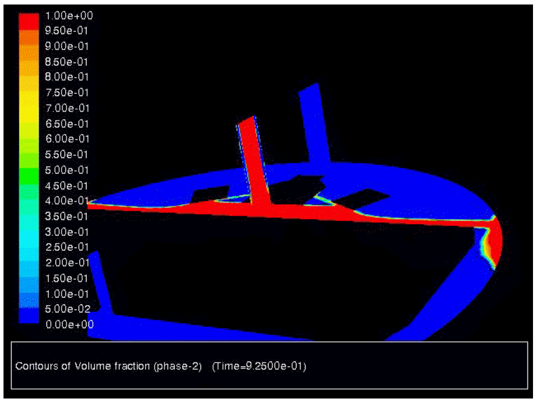

Figure 6 Water Fraction in Free Surface Flow

6. Concluding Remarks

NEI methodology was reviewed for APR1400 and a new appropriate methodology was proposed. And preliminary free surface flow calculation shows the feasibility for the debris transport evaluation.

REFERENCES

[1] NEI, "Pressurized Water Reactor Sump Performance Evaluation Methodology", NEI 04-07 (2004)
[2] 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), 'Pressurized Water Reactor Sump Performance Evaluation Methodology'
[3] USNRC, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident", Regulation Guide 1.82 Rev. 3 (2003)
[4] NRC Generic Letter 2004-02: Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors
[5] "Pressurized Water Reactor Sump Performance Evaluation Methodology," Nuclear Energy Institute, NEI 04-07
[6] FLUENT 6.2 & GAMBIT
[7] APR1400 SSAR