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Assessment on Recirculation Sump Performance for Pressurized Water Reactor Equipped with Incontainment Refueling Water Storage Tank

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1. Introduction

In 2003 USNRC (United State Nuclear Regulatory Committee) revised Regulation Guide 1.82 (RG. 1.82) to revision 3, and in 2004 issued generic Letter 2004-02 for PWRs (Pressurized Water Reactors)[1,2]. According to these regulatory actions sump blockage issue again has been placed on important safety problem. As a response of these USNRC's activities, NEI 04-07 was developed in order to evaluate the post-accident performance of a plant's recirculation sump, and has been used as a standard methodology[3]. 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 blowdown transport, washdown transport, pool fillup transport, and recirculation transport. Such a debris transport chart was found suitable to PWR which is equipped with RWST (Refueling Water Storage Tank) outside the containment, and it was proposed that some improvement be required in order to apply to PWR which has IRWST (Incontainment Refueling Water Storage Tank) [4].

This paper discusses a full-scope evaluation method and gives evaluation results for APR1400 (Advanced Power Reactor 1400 MWe).

2. Review of Reference Plant Design and Debris Movement

APR1400 has different features from conventional PWRs in that it adopts IRWST instead of RWST and recirculation sump. Thus, the water source for long term cooling is always IRWST, and there is no switching process to recirculation sump for long term cooling water source. The configuration of IRWST is shown in Fig.1 [5].

In case of LOCA (Loss of Coolant Accident) the water from break falls down, and a part of water is directed to bottom floor. Since HVT (Holdup Volume Tank) is located below the bottom floor the water drains to HVT through trenches. And the water is finally collected in IRWST via spillways. The water in IRWST is provided to RCS (Reactor Coolant System) by ECC (Emergency Core Cooling) pumps. Debris is expected to move together with break flow behaviors.

In earlier phase of accident the break flow will sweep out and spread wide on the bottom floor. The debris which is located in high velocity region will be transported to HVT. When the water level in HVT reaches the spillway, the water will flood to IRWST, and some debris will be also transported to IRWST. It is very difficult to evaluate how much debris will enter the spillway, because the flow patter in HVT is much complicated and the relation of water and debris behavior is not clearly found out in that flow pattern. Thus, assumption of 100% transport of debris in HVT is conservative.

Since ECC pumps and containment spray pumps operate and inflow from/through spillways exists, steady flow field is formed in IRWST. Thus, some debris will move to the suction part of pumps. In this study 100% of debris from spillways is assumed to move to pump suction part for the sake of simplicity. Detailed evaluation will reduce the transport fraction.

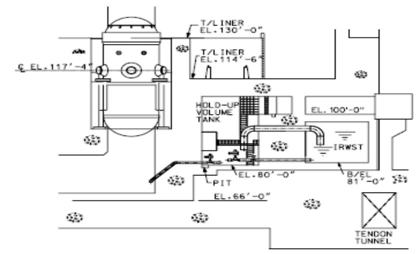

Figure 1 Vertical Elevation Relations among each Device

3. Proposal of New Methodology

As described in section 2 the bottom water sweeps out, spreads wide, and then flows toward HVT in early phase of LOCA. Therefore, if flow velocity is faster than threshold of tumbling velocity, debris on floor is transported to HVT ant then finally transported to pump suction parts. This phenomenon is different from the assumption of NEI methodology in which the water from break is collected on containment floor and not transported to sump before recirculation mode. Thus, this methodology should be modified considering above transport phenomenon. This transport phenomenon was also reviewed in reference 4 already.

Now, we propose that sweepdown transport should be considered. The sweepdown transport means the debris transport by sweeping and spreading flow in early phase of LOCA. For the evaluation of sweepdown transport free surface CFD (Computational Fluid Dynamics) calculation is needed. Detailed debris transport process is explained by debris transport chart, which is discussed in next section.

4. Evaluation of Debris Transport

4.1 Debris Transport Chart

Intensive review of plant design, break flow behaviors on the bottom floor, and the suggestions in reference 4 we decided 7 headings in debris transport chart: debris size classification, blowdown transport, sweepdown transport, washdown transport, pool fillup transport, and recirculation transport. Fig.2 shows the debris transport chart for fiberglass debris.

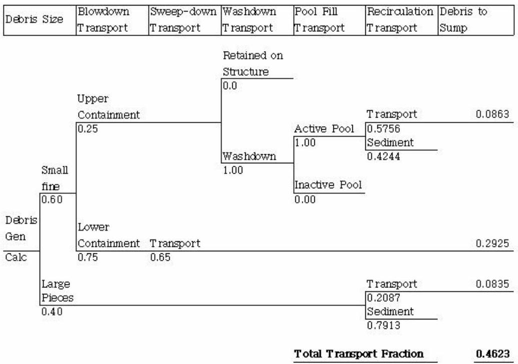

Figure 2 Debris Transport Chart for Fiberglass Debris

4.2 Transport Fraction in each Step

<u>Debris Size Classification</u>
According to NEI 04-07 the size of debris was classified. Fraction of fine and small debris is 0.6.

<u>Blowdown Transport</u>
Initial blowdown of break flow will move a part of debris to upper containment or to lower containment. 0.75 was assumed to fall on bottom floor [3].

<u>Sweepdown Transport</u>
Sweepdown transport is evaluated for the debris on lower containment according to the methodology of section 3. Flow pattern was analyzed at first. From the insight of the analysis, transport fraction can be evaluated. Initially the debris is located near the break. The CFD result shows the flow split when it collides with secondary shield wall or structures (Figs. 3 and 4). At this time the debris is also assumed to be split by a half. From this assumption the transport fraction was evaluated as 0.65.

<u>Washdown Transport</u>
For the conservative evaluation, it is assumed that 100% of debris is transported by washdown transport.

<u>Pool Fillup Transport</u>
No debris is assumed to fall down to inactive pool for conservatism.

<u>Recirculation Transport</u>
Debris from upper containment by washdown transport is assumed to spread uniformly on the bottom floor. The result in SPIRT meeting was used [6].

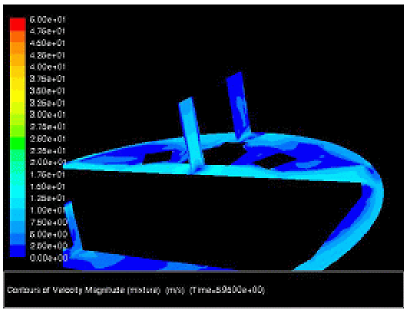
Figure 3 Velocity Field

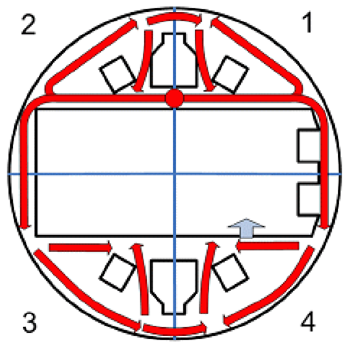

Figure 4 Flow pattern on bottom floor

5. Concluding Remarks

NEI methodology was improved for assessment on recirculation sump performance for IRWST equipped PWR. And the successful evaluation was conducted. However, there are much conservatism in each evaluation step, and a lot of analysis refinement is necessary in order to reduce the debris transport fraction.

REFERENCES

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