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

Soon Joon Hong[a*], Manwoong Kim[b], Ju Yeop Park [b]
[a]*FNC Tech., SNU 135-308, Daehak-Dong, Kwanak-Gu, Seoul, 151-742, S. Korea*
[b]*Korea Institute of Nuclear Safety, 19 Gusung-Dong, Yuseong-Gu, Daejeon, S. Korea, 305-755*
[*]*Corresponding author: sjhong90@fnctech.com*

1. INTRODUCTION

Currently, for the resolution of GSI (General Safety Issue)-191, ECCS (Emergency Core Cooling System) strainer clogging, many countries are making much effort. Among them, the report, NEI 04-07 of Nuclear Energy Institute is one of noticeable methodologies [1]. According to the baseline methodology of NEI 04-07, it proposed methodologies on break selection, debris generation, latent debris, debris transport, and head loss. As to the debris transport evaluation, it used a debris transport chart which is composed of blow-down transport, wash-down transport, and pool fill-up transport. According to this methodology, 100% transport is assumed for the wash-down transport [1]. In the appendix of safety evaluation report (SER) to NEI 04-07 of the USNRC (United State Nuclear Regulatory Committee), USNRC has quantitatively evaluated the wash-down transport and concluded the recommended that wash-down transport fraction in NEI 04-07 was sufficiently conservative [2]. However, the methodology of USNRC on the wash-down transport seems very complicated and includes so many uncertainties depending on the containment shape and engineering judgment in the evaluation steps. Due to the dependency on plant type, there is a limitation to generalize the conclusion on wash-down transport of USNRC, when the considered plant is different from the volunteer plant or the same type plant in SER.

This study introduced a new wash-down transport analysis with the proposed free over-fall flow based on the containment spray flow, condensate water flow, and floor flow characteristics including floor configuration. In addition, a wash-down transport analysis has also conducted for Ulchin 3&4 [3] and is also presented.

2. TRANSPORT MODEL DEVELOPMENT

Following the blow-down transport, all the debris is located somewhere inside containment. Debris which is located on the grating will be washed-downed by the containment spray flow. If some debris is located over the top of concrete structure, its transport will be, therefore, subject to the debris transport to the bottom floor due to the wash-down transport.

In general, containment spray flow can be classified two; one falls on grating and the other falls on concrete floor. Spray flow can be obtained from the pump specification data. One more important flow which contributes to the bottom flow is condensate flow. Condensate flow can be calculated from CONTAIN2.0 analysis [4].

To analyze the flow field of floor flow using CFD (Computational Fluid Dynamics) steady calculation, the water depth, inflow, and outflow for some floor sector are need to be specified. But inflow and outflow is easily defined by spray flow and condensate flow. Moreover, the movable transport can be easily determined by comparing flow field with tumbling velocity or others. Therefore, the only undetermined parameter is the water depth.

To determine the water depth, one approach is to identify the free over-fall flow phenomena as shown in Fig. 1. The figure shows that if the approaching flow is subcritical, the water depth must pass through the critical depth [5].

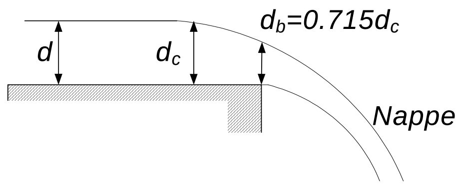


Fig. 1 Free Overfall Flow

Critical depth is given by

$$\frac{d_c}{b} = \text{function of } \left(Ad_h^{1/2}/b^{5/2}\right) \quad (1)$$
$$= \text{function of } \left(Q/g^{1/2}\right)$$

Where,

A : Channel cross-sectional area
b : Channel width
d_b : Brink depth
d_c : Critical depth
d_h : Hydraulic depth
g : Gravity constant
Q : Volume flow

For a given volumetric flow (which is averaged water flow during wash-down transport phase) and channel width, corresponding value is given in the form of table in reference 5. Thus, we can get the value of left hand side of Eq. (1), and finally critical depth. This critical depth is used as a flow depth in floor flow for the conservatism.

Summarized flow chart of analysis methodology is shown in Fig. 2

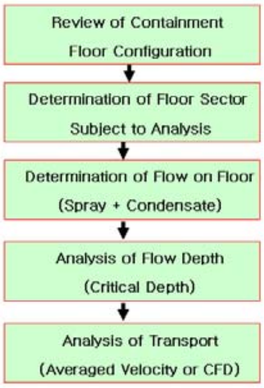
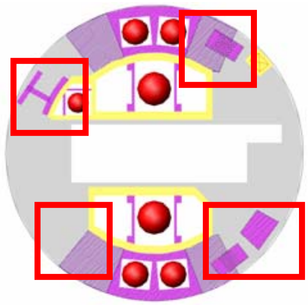


Fig. 2 Flow Chart of Developed Methodology

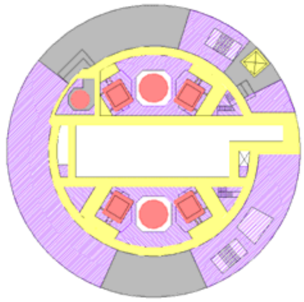
3. FLOW PATH IDENTIFICATION

Containment of Ulchin 3&4 has 4 major floors; The highest one is 142ft, the next 122ft, the next 100ft, and the lowest is 86 ft. In 86ft floor, the ECCS sump is located and this is not subject to wash-down transport.

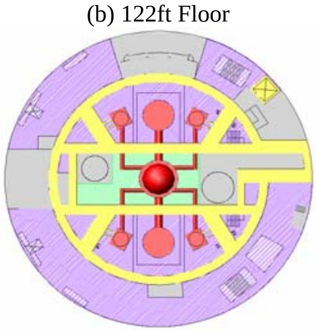
Fig.3 shows the lay out of upper 3 floors.



(a) 142ft Floor



(b) 122ft Floor



(c) 100ft Floor

Fig. 3 Layout of Containment Floor
(Solid gray: concrete/hatched violet: grating)

Through the intensive observation following facts can be identified:

- In 142ft floor at only the 4 red boxed brinks, the flow falls on the grating of 122ft floor.
- All the flow in 122 ft floor falls on the grating of 100ft floor.
- Just minor floor flow in 100ft floor is expected. Most of the flow is through the grating.

Thus, only the red boxed brinks are subject to floor flow analysis.

4. WASHDOWN TRANSPORT ANALYSIS

4.1 Containment Spray Flow Analysis

There are two pumps and each design flow is 258kg/sec at 56psi and 200˚F

4.2 Condensate Flow Analysis

CONTAIN2.0 analysis showed averaged condensate flow near the 4 red boxes is 110kg/sec.

4.3 Floor Flow Analysis

Concrete area to the floor all area ratio is about 3/5, and only the 3/5 of spray flow falls on the concrete. Thus, the calculated floor flow is around 420kg/s. The total width of gratings in 4 red boxes is about 7X7m. Therefore, the critical depth is calculated as 3.07mm from the Eq. (1). And channel average velocity is about 3.1m/s, which is extremely large compared to the Nukon tumbling velocity, 0.03658m/s. This means all the Nukon debris is transported to the bottom floor of containment.

5. CONCLUSIONS

This study proposed a simple and creative analysis methodology and procedure based on the proposed free over-fall flow model. To evaluate the recirculation sump performance, the identification of wash-down flow path in the containment floors and condensate flow assessment were carried out using CONTAIN2.0 for Ulchin 3&4. In conclusion, the critical depth calculation showed that since the containment floor flow is very high velocity, most of the debris is, therefore, expected to be transported to the bottom floor.

REFERENCES

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[5] Robert D. Blevins, Applied Fluid Dynamics Handbook, Van Nostrand Reinhold Company, 1884