Iodine Re-vaporization at Scrubbing Pool in Filtered Containment Venting System

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1. Introduction

A Filtered Containment Venting System (FCVS) has been adapted outside of the containment building to keep the integrity of the containment building during the severe accident in a nuclear power plant. The FCVS is important to mitigate a severe accident involving significant core degradation, where the melted core could react with coolant and structures, thereby causing the continuous generation of steam and gases. Eventually, the containment building would be damaged by overpressure due to the release of abundant steam and gases if the safety systems in the containment building do not work normally.

Some aerosols such as CsI can dissolve in water during the FCVS operation. Then CsI aerosols were dissolved as ions of Cs^+ and I^-. Nonvolatile iodine ion (I^-) in water converted into several kinds of iodine compounds, such as HOI, I_3, IO_3^-, etc. These nonvolatile iodine compounds can react with water radiolysis products such as ·OH, H_+, H_2O_2, and HO_2 such that volatile elemental iodine (I_2) would be generated in the aqueous solution of FCVS and re-vaporized into the environment. Therefore, it is very important to evaluate the volatile elemental iodine generation rate in the aqueous solution after FCVS operation [1].

The iodine re-vaporization at scrubbing pool after FCVS operation are estimated according to the models, pH, and dose rate.

2. Methods and Results

Y. S. Na, et al. [2, 3] estimated the decontamination factor of CsI on a scrubbing solution in the FCVS. They simulated an SBO occurred in the OPR 1000 by using MELCOR computer code and calculated accumulated mass of CsI aerosol in the pool of FCVS which consisted of a cylindrical vessel with a 3 m diameter and 6.5 m height as shown in Fig.1. When the temperature of a pool approached its saturation temperature, the decontamination factor of CsI aerosol started to decrease. Particle capture in a scrubbing solution can be affected by both the steam condensation in the early FCVS operation and the pool evaporation. They clearly observed that the decontamination factor of CsI aerosol on a scrubbing solution can be dependent on the thermal-hydraulic conditions in the FCVS [3]. Based on the results by Na [3], the pool conditions after FCVS operation are summarized in Table 1.

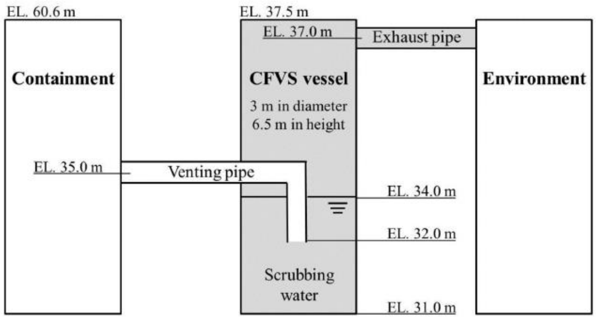


Fig. 1. Target vessel in FCVS[2]

Table 1: The pool conditions after FCVS operation

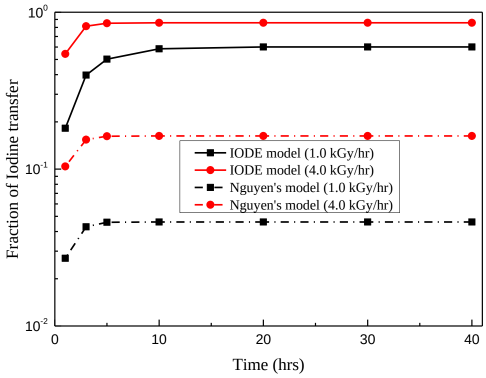
Conditions	Values
Pool Temp (K)	420.5
Depth of pool(m)	1.0
Diameter of pool (m)	3.0
Accumulated mass of CsI aerosol (g)	1500
Molecular weight of CsI (g/mol)	259.8
Concentration of I^- (mol/l)	2.75E-4

Table 2: Models for generating elemental iodine in pool

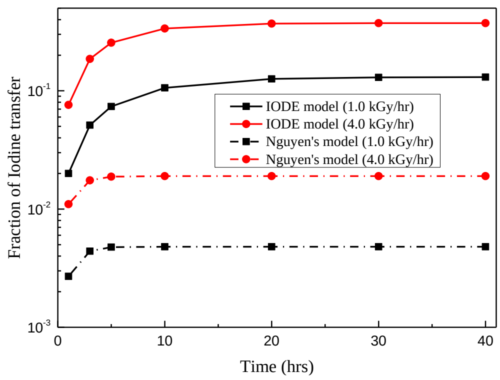
Code	Models	Unit D
IODE	$\frac{d[I_2]}{dt} = k_d D[I^-][H^+]^{0.5} - k_r[I_2]$ $k_d = 1.7x10^{-3}; k_r = 2x10^{-5}$	Gy/s
ASTEC V1.1	$\frac{d[I_2]}{dt} = 1.35x10^{-7} D - 5.4x10^{-9} \frac{[I_2]}{[I^-][H^+]^{0.5}}$	Gy/s
IMPAIR 3.0	$\frac{d[I_2]}{dt} = 1.5 \times 10^{-3} D[I^-][H^+]^{0.35} - 10^{-10}[I_2]$	kGy/hr
Nguyen	$\frac{d[I_2]}{dt} = 0.63\ D[I^-][H^+]_o^{0.5} - 0.82\ [I_2]$	kGy/hr

Under gamma irradiation from radioactive aerosols, the formation of gaseous iodine species is a function of radiation dose, pH solution, and total iodine concentration. However, determinations of the rates of all chemical processes are rather complicated because iodine could exist in various kinds of oxidation states with ranging from -1 to +7 such as I^-, I_2, HIO, IO_2^-, IO_3^-, etc. Many chemical modeling efforts have also been performed to estimate the generation of volatile iodine I_2 from nonvolatile iodide I^- in the aqueous phase by radiolytic oxidation. The several empirical correlations with a limited set of reactions are practically used in severe accident codes, such as IODE [4], IMPAR-3 [5], ASTEC [6], and Nguyen [1] as shown in Table 2.

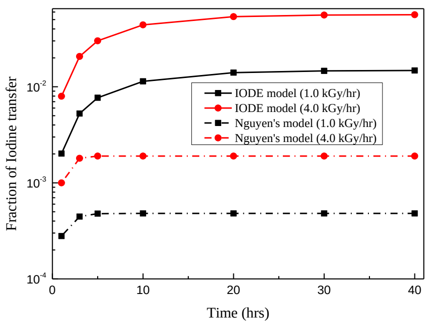
Two models such as Nguyen [1] and IODE [4] are used to evaluated the re-vaporization of iodine in pool after FCVS operation according to time, pH, and dose rate. Figure 2 show that the I_2 conversion fraction from iodine ion along with time, pH, and dose rate in solution by Nguyen [1] and IODE [4] correlations. As shown in Fig. 2, the I_2 conversion fractions are saturated within 20hrs and increase as pH increase from 3 to 7, and the I_2 conversion fractions increase as dose rate increases and pH decreases. The IODE model [4] overestimates I_2 conversion fraction as compared with Nguyen model [1]. This is why the Nguyen correlation [1] was proposed at pH 3 to 5, and 10^{-3} to 10^{-4} M iodide solutions. At the condition, the IODE code generally overestimates the I_2 concentration as shown in Fig. 3 [1].



(a) pH 3



(b) pH 5



(c) pH 7

Fig. 2. Comparison of I_2 conversion faction by Nguyen model[1] with IODE model [4] at 1.0 and 4.0kGy/hr

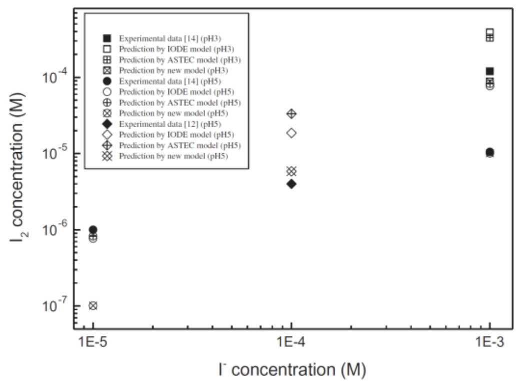


Fig. 3. Comparison of I_2 concentration between Ishigure's [7] and Gorbovitskaya's [8] experimental data and predictions by IODE[4], ASTEC[6], and new (Nguyen) models[1]

3. Conclusions

The iodine re-vaporization at scrubbing pool after FCVS operation were estimated according to the models, pH, and dose rate. The I_2 conversion fractions increase as dose rate increases and pH decreases. The IODE model overestimated I_2 conversion fraction as compared with Nguyen model. the I_2 conversion fractions were saturated within 20hrs and increase as pH increased from 3 to 7.

Further works should be performed to find the method for reducing the iodine re-vaporization in scrubbing pool after FCVS operation.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (Ministry of Science and ICT) (No. NRF-2017M2A8A4015280) and by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korean government (Ministry of Trade, Industry and Energy) (No.KETEP-20181510102400).

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