# A Comparative Study of the RAIM and Alternative Iodine Adsorption Models

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## 1. Introduction

Iodine is one of the most important radioactive materials that could be generated during a severe accident at a nuclear power plant. Physical and chemical behavior of iodine has become a major issue in the international nuclear research projects for a long time.[1] KINS has been carrying out research on the iodine behavior using MELCOR, the integrated severe accident assessment code. Meanwhile, KINS has developed the stand-alone code, RAIM, and then coupled it with MELCOR to build MELCOR-RAIM.

Adsorption of iodine vapor is one of key mechanisms for its removal and production of organic iodide. This mechanism may become more interesting to the analysis of the plant using $B_4C$ control rod, where much portion of iodine releases into the containment in the gas form.[2] However, the MELCOR code does not treat adsorption and absorption in detail, while it deals with condensation and evaporation of aerosols in the gas phase. On the other hand, RAIM takes simple assumptions for the adsorption velocity. Therefore, improvement of this model was required. The Belval-Haltier's iodine adsorption model developed from PHEBUS-FP experimental result was one alternative. This paper presents the results from the comparative study of the default adsorption model of RAIM and the Belval-Haltier's model.

## 2. Default adsorption model of RAIM

It has been shown that the RAIM code agrees reasonably with the experiment results from EPICUR, as shown in Fig. 1.[3]

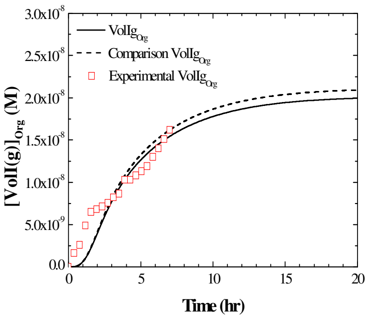


Fig.1. Comparison of the calculated values of organic iodides with the experiment result (S1-7 experiment)

The adsorption rate of RAIM for painted surface is calculated using:

$$K_{AD} = V_{AD} \cdot \left(\frac{A_g}{V_g}\right)$$

$$\ln(V_{AD}) = \ln\left(V_{P(298K)}\right) + \left(\frac{\Delta E_{V_{AD}}}{R}\right) \cdot \left(\frac{1}{298} - \frac{1}{T_W}\right)$$

where, $k_{AD}$ is the adsorption rate constant ($s^{-1}$) and $v_{p(298K)}$ is deposition velocity of iodine onto dry painted surfaces at 25 ℃ ($dm \cdot s^{-1}$). $\Delta E_{V_{AD}}$ is the adsorption rate's activation energy (J/mol), R is the gas constant (J/K · mol), and $T_W$ is the wall temperature.[4] This adsorption formula is a kind of the Arrhenius equation.

## 3. Belval-Haltier's adsorption model developed from the PHEBUS-FP experimental results

The adsorption velocity in the gas phase was studied by Belval-Haltier for the representative reactor conditions. It was found that both the temperature of the carrying gas and the preconditioning temperature of the paint affect the adsorption velocity.

$$K_{adsg} = -7.68 \times 10^{-4} T + 1.75 \times 10^{-3} T_{MAX} - 0.084$$

Where, $K_{adsg}$ is the adsorption velocity in dm/s, T is the temperature of the gas in ℃, and $T_{MAX}$ is the maximum exposed temperature of paint in ℃. This relation is valid in the temperature range of 90-130℃ only. It was verified that the adsorption velocity was consistent with the preceding formulation for on the results of one experiment conducted in the CAIMAN facility under condensing conditions.[5]

When pressure and temperature are changed in the gas phase, we may observe condensation of gas at the surface area. The amount of adsorbed gas on the wall depends on the temperature, pressure, the type of gas and the material of wall. If pressure is maintained, the adsorption capacity is associated only with temperature changes.[6]

## 4. Comparison of Belval-Haltier's adsorption model with the default RAIM model

For comparison of the two adsorption rate equations, they were applied to the PHEBUS-FP experiment on painted surface at 90℃.

4.1 Concentration of iodine vapor in the atmosphere

Fig. 2 shows the concentration of iodine gas in the atmosphere. The default RAIM model estimated about 10 times more than the Belval-Haltier's model.

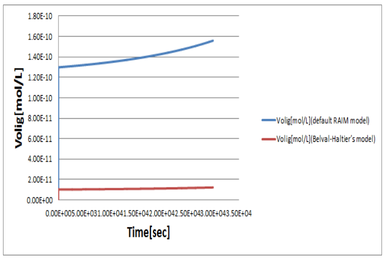


Fig.2. Concentration of iodine vapor in the atmosphere

4.2 Organic iodide concentration

Fig. 3 shows that the amount of the organic iodide in the gas phase. Both models match up exactly.

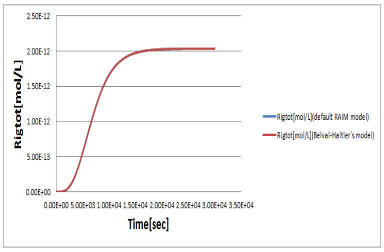


Fig.3. Organic iodide generation

4.3 Adsorption of iodine gas

Fig. 4 shows that both models estimated the same amount of adsorption of iodine gas except the data for the first 12 seconds.

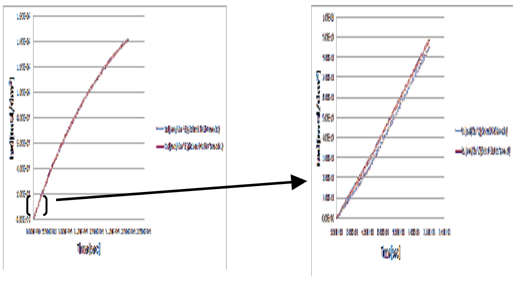

Fig.4. Adsorption of iodine gas for the whole test period and for the first 12 seconds

4.4 The amount of total iodine

Fig. 5 shows that the estimates of the total amount of iodine were equal for both models. It means that the mass balance for both cases was maintained.

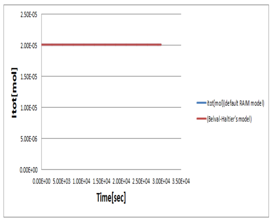


Fig.5. Total amount of iodine

## 5. Conclusions

In order to improve the iodine adsorption model of RAIM, an adsorption rate equation developed from the PHEBUS-FP experimental results for painted surface was applied to the RAIM code.

Comparison of this alternative model with the default model showed that both models agree well for the estimation of iodine concentration except that of iodine vapor in the atmosphere. The reason for this difference is being examined. After fixing the problem, the RAIM model with the alternative adsorption rate equation can be applied to simulate experiments such as PHEBUS-FP experiments.

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