MELCOR-RAIM Analysis of Iodine Behavior during a Severe Accident in a Model Plant

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1. Introduction

Iodine behavior has been studied because of its importance in the public health following a severe accident. Therefore, Korea Institute of Nuclear Safety (KINS) has been participating in several international research projects on this issue such as ISTP (International Source Term Program), OECD-BIP (Behavior of Iodine Project), OECD-STEM (Source Term Evaluation and Mitigation) and EU-SARNET2 (Severe Accident Research Network of Excellence 2). As a result, a simple iodine model, RAIM (Radio-Active Iodine chemistry Model) was developed [1], based on the IMOD methodology and coupled with MELCOR, replacing the pool chemistry model (PCM) of this code [2].

This coupling model, MELCOR-RAIM, had been tried to simulate some of the above experiments. Previous analysis of the above experiments showed that the iodine chemistry model should not be activated for some control volumes which could have errors frequently, due to lack of water, small atmospheric volume or insufficient atmospheric recirculation [3]. Based on this experience, an analysis was tried to simulate iodine behavior in the multi-compartments of the containment during a severe accident initiated by a station blackout at a model plant similar to OPR1000. This study is described herein, and representative results of the calculations are presented.

2. Analysis Method

The containment was modeled by four compartments as the base case; for sensitivity analysis, one compartment and twenty compartment models were also developed. Fig. 1 shows the twenty-compartment containment model. Our preliminary calculations showed that the total amount of gaseous iodine did not change for a long time after the initiation of the accident. In order to reduce the calculation time, the containment analysis only was conducted with the information about mass and energy release of various materials, including steam and radionuclides, into the containment given by the preliminary calculations.

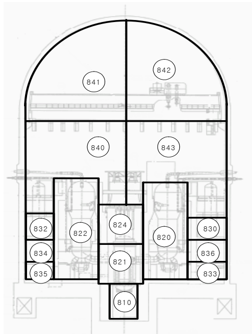


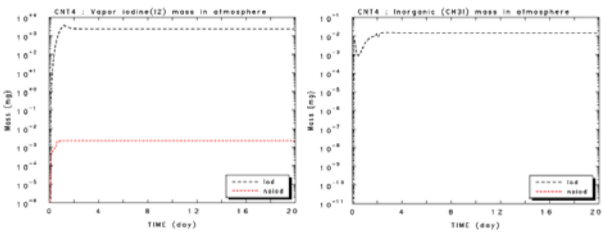
Fig. 1. Nodalization for the containment

Among the compartments, activation of the iodine chemistry model was limited to the steam generator compartment and sump. For this analysis six transported species such as organic iodide, HCl, HNO3, HPO4, IM(Metallic Iodine), AgI were added to the default 16 classes provided by MELCOR. It was assumed that iodine entered the containment mostly as CsI aerosols with very small amount of elemental iodine. The pH and dose rates were adopted from the previous experimental data. For this analysis, calculation was done until several days after the initiation of the accident.

3. Analysis Results

3.1 Effect of Iodine Chemistry Model

As expected, quite a lot of inorganic and organic iodine in the atmosphere were formed by activation of the iodine chemistry model as shown in Fig. 2 (a) and (b). Organic iodide was formed only with the model under activation condition.

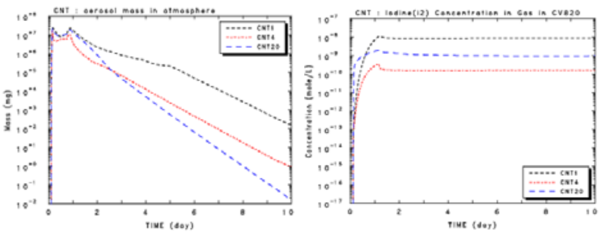


(a) Inorganic iodine (b) Organic iodide

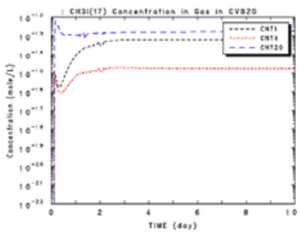
Fig. 2 Effect of iodine chemistry model on the gaseous iodine mass (4-cell containment)

3.2 Effect of Containment Nodalization

Fig. 3 (a) – (c) show the effect of the containment nodalization, especially the number of nodes, on the masses of aerosols, inorganic and organic iodide. As shown in figures, the more there were nodes, the more aerosols settled down and were removed from the atmosphere. This is because the cell height becomes low in proportion to the number of nodes, which accelerates the deposition of aerosols. However, the gaseous iodine mass were not affected by this effect. So there should be further study to understand these results.



(a) Aerosol mass (b) Inorganic iodine

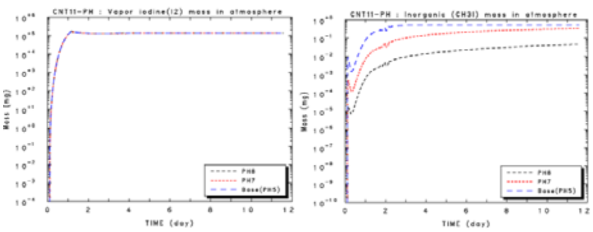


(c) Organic iodide

Fig. 3. Effect of the containment nodalization on iodine mass

3.3 Effect of Solution pH

Fig. 4 (a) and (b) show that solution pH did not affect the mass of inorganic iodine in the atmosphere but affect that of organic iodide.

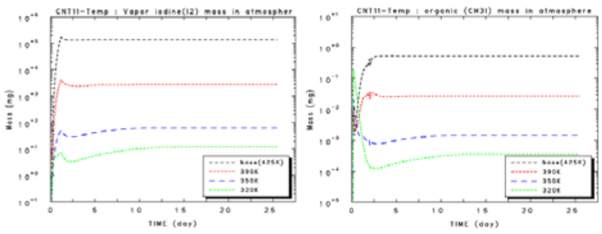


(a) Inorganic iodine (b) Organic iodide

Fig. 4. Effect of pH on gaseous iodine mass

3.4 Effect of Solution Temperature

Fig. 5 (a) and (b) show that the mass of gaseous iodine was in proportion to the solution temperature. However, this trend was opposite to the previous understanding obtained by a parametric study with RAIM [4]. Therefore, it should be further studied.

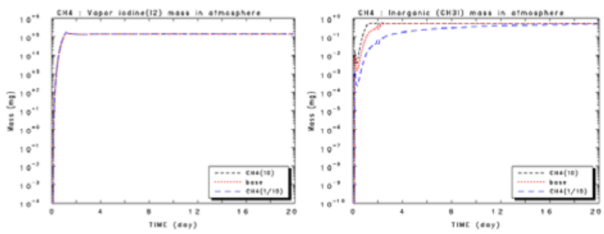


(b) Inorganic iodine (b) Organic iodide

Fig. 5. Effect of solution temperature on gaseous iodine mass

3.5 Effect of CH_4 concentration

The reactions between iodine species and paints in the aqueous phase were simulated by the interaction of iodine and methane to produce CH_3I. Therefore, it was assumed that methane exists in the atmosphere with such a large mole fraction that it would dissolve in the aqueous phase and interact with iodine. Fig. 6 (a) and (b) show that CH_4 concentration did not affect inorganic iodide mass but affected that of organic iodide.



(a) Inorganic iodine (b) Organic iodide

Fig. 6. Effect of CH_4 concentration on iodine mass

3. Conclusions

Iodine behavior in the containment following a station blackout at a model plant was simulated with MELCOR-RAIM and multi-compartment input models. The results show that the iodine chemistry model made a big change in the gaseous iodine concentration. Parametric studies revealed the needs of phenomenological understanding of the effects of the containment nodalization, solution pH and temperature, and CH_3 concentration on the gaseous iodine mass.

REFERENCES

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