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Effect of Cesium-Molybdate on Cs Behavior for Source Term Estimation

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1. Introduction

A principal part of the off-site consequence analysis (CA) of nuclear power plants is to estimate the radiological source term. Typically, the atmospheric release of all radiological materials from a severe accident of a nuclear power plant is called "the Source Term" [1]. In the last decade, there has been a considerable degree of improvement of knowledge on the Source Term according to international R&D programs such as the Phébus FP program [1]. A key finding of the Phébus FP program was that the evidence from the Phébus experiments indicated that Cesium-Molybdate (Cs_2MoO_4) was the dominant chemical form of released Cs. The SOARCA report from USNRC [2] recently utilized the MELCOR code to analyze the Source Term, taking into account this finding.

To utilize this new source term feature, this study intended to adopt the Cesium-Molybdate model into the MELCOR code [3]. The purpose of this study was to investigate the effects of Cesium-Molybdate modeling on the Cs behavior using MELCOR.

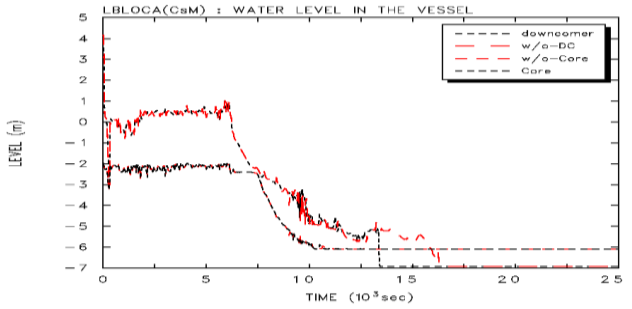
2. Cesium-Molybdate Modeling in MELCOR

To model Cesium-Molybdate in MELCOR, the RadioNuclide **(**RN) package should be modified. The class for Cesium-Molybdate in the RN package was added, and relevant parameters were provided. As an example case, a large LOCA scenario with a late containment failure was selected to investigate the effects of Cesium-Molybdate.

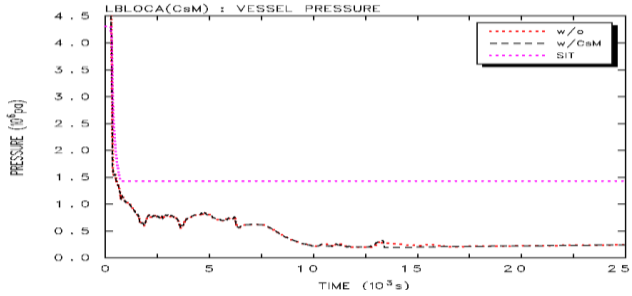
3. Results and Discussion

To investigate the effects of Cesium-Molybdate, cases with and without Cesium-Molybdate were taken into account for similar thermohydraulic conditions and fission products characteristics.

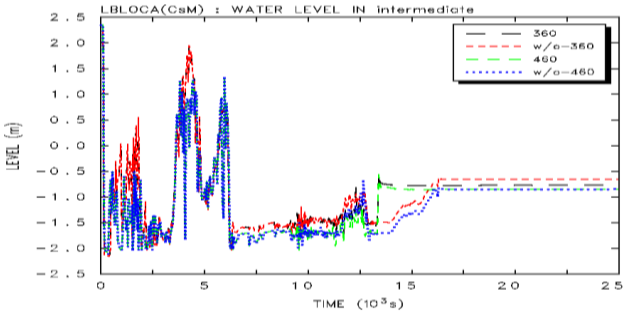
As shown in Fig.1, the differences in thermohydraulic behaviors between with and without Cesium-Molybdate were not observed until containment failed. Slight differences in those behaviors after containment failed were identified, but a further study is required to precisely investigate the causes of these differences.



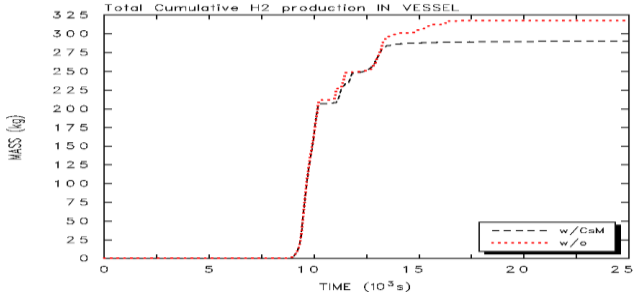
(a) Water level in the vessel



(b) Vessel pressure



(c) Water level in intermediate



(d) Total cumulative H2 production in vessel

Fig 1. Thermohydraulic Parameters

The release mass of fission products classes related to Cs according to thermalhydraulic behaviors are shown in Fig. 2. As shown in Fig. 2, the release mass of Cs and I were affected by the modeling of Cesium-Molybdate. In particular, the results showed that the release mass of Cs was reduced by factors of 2 ~ 5 owing to the Cesium-Molybdate behavior. It was identified that this reduction may be caused by a variation in the amount of aerosols in an aqueous solution.

Comparing the cases with and without Cesium-Molybdate, the following insights were obtained:

- A small variation of release fractions from the core was observed.
- The changing amounts of adhesions on the structure including the chemi-sorption were negligible.
- The amount of Cesium-Molybdate was larger than that of Cesium-Iodine in the aqueous solution according to the partial gas pressure of each chemical form.

As the results of these, the environmental release amount of Cs was reduced by factors of 2 ~ 5 owing to the amount of Cs in the containment atmosphere. Additionally, it is expected that there will be no difference from the effect of Cesium-Molybdate after all water inventory has evaporated from the containment.

4. Concluding Remark

For a realistic estimation, the current knowledge of the Source Term such as the Phébus experiment was taken into account in MELCOR. In this investigation, Cesium-Molybdate affects the Source Term behaviors, which reduce the amount of release fraction of Cs to 20% - 50% compared to the case without it owing to the difference in the aqueous solution between Cesium-Iodine and Cesium-Molybdate.

A further study is recommended to utilize this key finding for a precise estimation of the Source Term.

ACKNOWLEDGEMENT

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REFERENCES

[1] E. Raimond et al., "Use of Phébus FP and other FP programs for atmospheric radioactive release assessment in case of a severe accident in a PWR (deterministic and probabilistic approaches developed at IRSN)," to be published, Annals of Nuclear Energy, 2013.
[2] US NRC, "State-of-the-Art Reactor Consequence Analyses (SOARCA) Report," NUREG-1935, 2012.
[3] US NRC, "MELCOR Computer Code Manuals," NUREG/CR-6119, 2005.

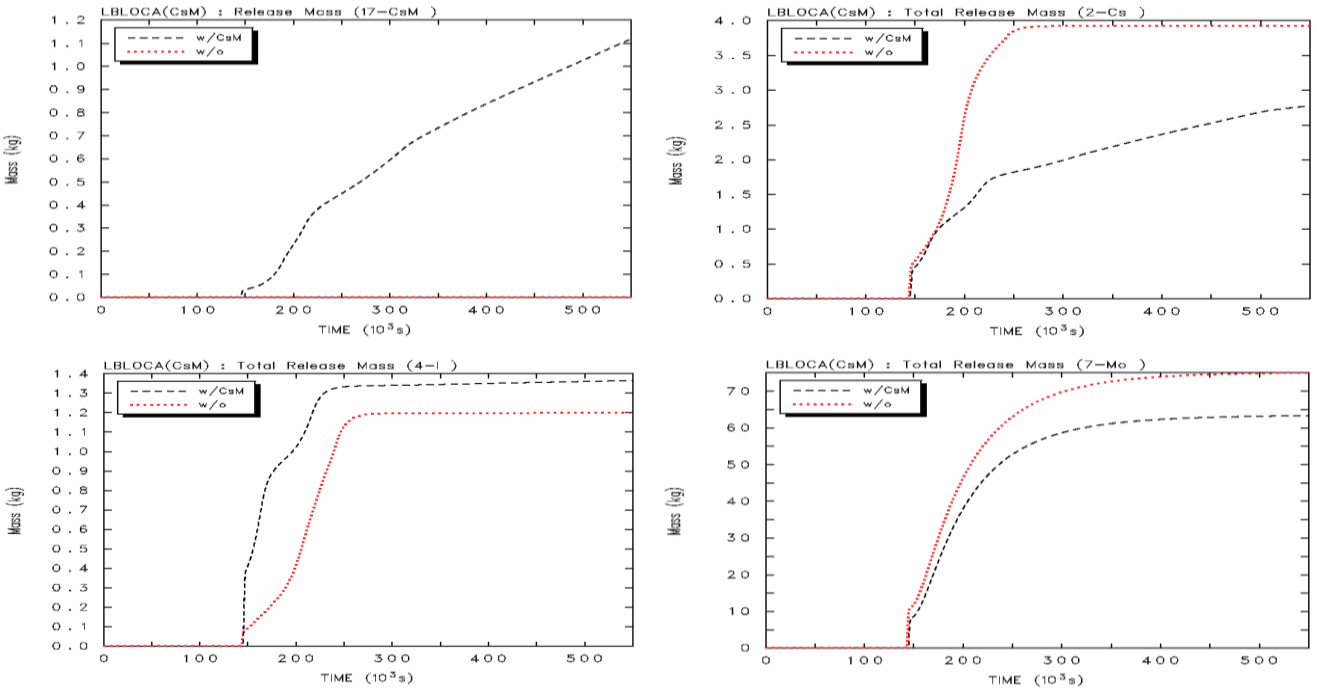

Fig. 2. Release characteristics of fission Products