Preliminary analysis of iodine behavior in ISLOCA

Youngsu Na* and Kwang Soon Ha
Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 34057, Korea
*Corresponding author: ysna@kaeri.re.kr

1. Introduction

In Inter-System Loss of Coolant Accident (ISLOCA) that is one of the most threaten scenarios, the fission products can be released directly into the outside environment through the auxiliary building consisting of various compartments. Pipe lines connected with the primary system in the containment pass through the compartments. Recent study calculated ISLOCA in OPR1000 using MELCOR code [1]. A coolant in the primary system was discharged from a ruptured pipe located in the auxiliary building, and a pool was then generated in a compartment. Fission products generated in a core can pass into a pool before releasing into the outside environment. Especially, it is necessary to assess the behavior of iodine, because various chemical reactions regarding iodine can be occurred in a pool. This study applies the iodine pool chemistry model that has been using in a MELCOR code to the recent calculation of ISLOCA.

2. Methods and Results

2.1. ISLOCA modeling

In an ISLOCA scenario, it is assumed that the isolation valves on a Shutdown Cooling System (SCS) pipe that connects between a hot leg in the containment and a Low Pressure Safety Injection (LPSI) pump in the auxiliary building open, and a pipe in front of a LPSI pump is then ruptured by the pressure difference between the primary system and the atmosphere, as shown in Fig. 1 [1].

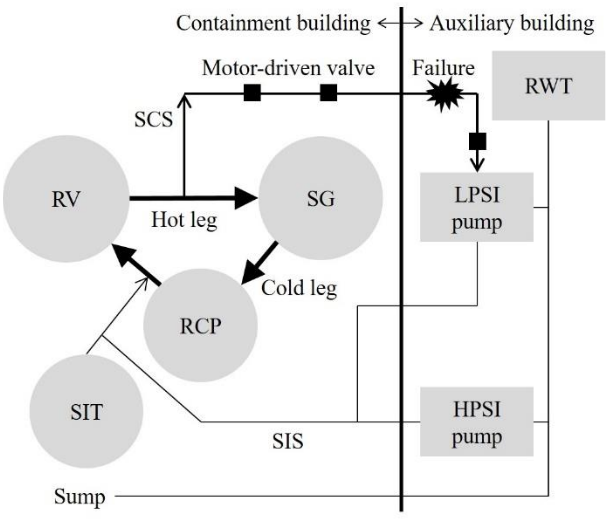

Fig. 1. Conceptual image of ISLOCA scenario.

In a MELCOR input, a SCS pipe line and some compartments in the auxiliary building were simply modeled by four and six control volumes, respectively, based on the geometric information of them [1]. A ruptured pipe in diameter of 0.45 m is located 1.5 m above from the bottom of a LPSI room that is the first of six control volumes of the auxiliary building. A coolant discharging from a ruptured pipe generates a pool in a LPSI room, and the fission products are then released into a pool. This study activated the MELCOR iodine pool chemistry model in a LPSI room.

2.2. Iodine pool chemistry model

The iodine pool chemistry model in MELCOR code calculates the iodine concentration in a pool and the atmosphere. The model calculates sequentially as follows; (1) check the atmosphere volume above 0.1 m^3, (2) setup the materials such as iodine (I_2), methyl iodine (CH_3I), hydrochloric acid (HCL), nitric acid (HNO_3), nitrogen, vapor, oxygen, hydrogen, carbon dioxide, and methane (CH_4) in the atmosphere, (3) convert a term of mass transport of acids from atmosphere to wall into a term of the generation induced by radiolysis, (4) initialize species such as cesium iodide (CsI), boric acid (H_3BO_3), phosphate (PO_4^{3-}), acids, cation, silver (Ag), and iron (Fe) in a pool, (5) initialize a coefficient of a reaction rate, (6) calculate acids generated from atmospheric radiolysis, and a code calculates the mass transport of acids from the atmosphere to a pool or wall by using a film transport model, (7) check the existence of iodine and a pool, pressure less than 1 MPa, and pool temperature less than 425 K, (8) calculate hydrogen ion concentration (pH) by charge balance, (9) calculate silver iodide (AgI) when the fraction of silver in a pool is over 10^{-6}, (10) determine speciation in a pool by the equations of water radiolysis, iodine reaction, ferrous ion reaction, and organic reaction, (11) calculate the mass transport of I_2 and CH_3I from a pool to the atmosphere by using the partition coefficients that depend on temperature, (12) calculate decomposition of iodine and recombination reaction by atmospheric radiolysis, here, the reduction of iodine is in proportion to a dose rate, (13) calculate the iodine deposition on wall, (14) output the final results.

2.3. Iodine behavior

In an ISLOCA scenario, the fission products enter into a pool with a depth of 2.3 m through a ruptured pipe, as shown in Fig. 2. This study calculated the mass of iodine in the atmosphere above a pool in a LPSI room, and it was compared with iodine mass without activating the pool chemistry model, as shown in Fig. 3. Iodine has been entering into a pool since an initial gap release at 3075 s, and its mass in the atmosphere then increases after a time delay of 500 s. A peak mass of iodine is three times higher than that without activating the iodine pool chemistry model. The iodine mass decreases with time after a peak, because iodine with bulk fluids moves to the downstream compartments in the auxiliary building. Iodine mass from the chemistry model increases again after about 8800 s. It is expected that the increment of the HNO_3 mass in the atmosphere at about 8800 s, as shown in Fig. 4, could influence the iodine behavior.

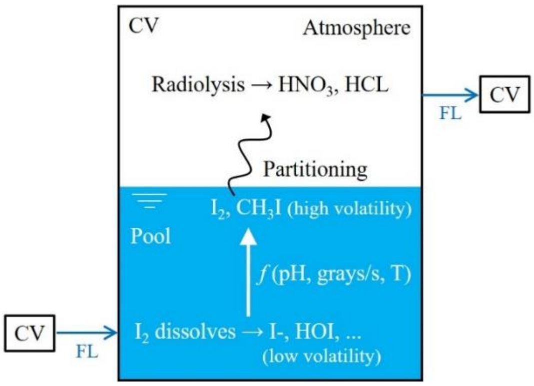

Fig. 2. Conceptual image of iodine pool chemistry behavior.

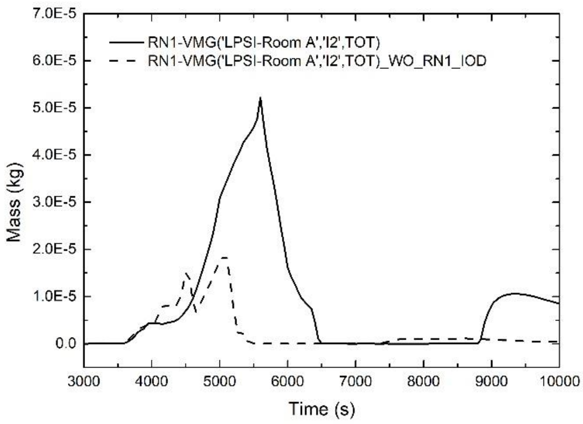

Fig. 3. Iodine mass in the LPSI room atmosphere.

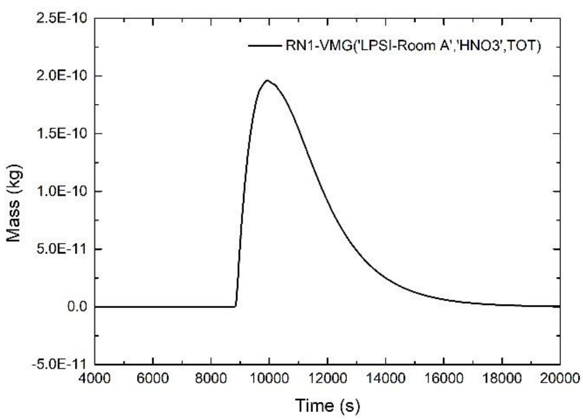

Fig. 4. HNO_3 mass in the LPSI room atmosphere.

Fig. 5 shows that pH in a pool has been kept as about pH 9 since an initial gap release. The generation of HNO_3 in the atmosphere, as shown in Fig. 4, is negligible to change the hydrogen ion concentration of a pool. A large amount of C_SOH in a pool could influence dominantly the hydrogen ion concentration of a pool.

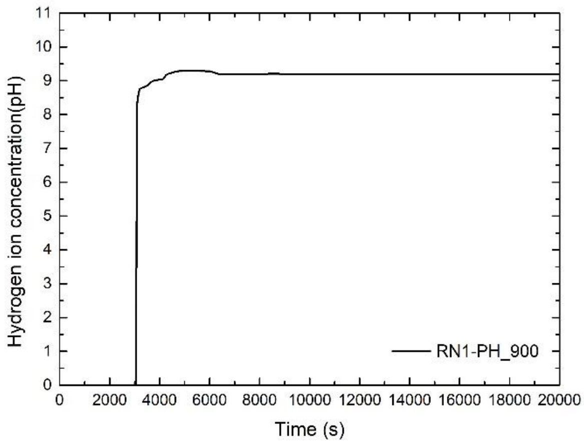

Fig. 5. Hydrogen ion concentration in the LPSI room pool.

3. Conclusion

This study applied the iodine pool chemistry model to a MELCOR calculation of an ISLOCA. A coolant discharging from a ruptured pipe generated a pool in a LPSI room where the fission products were released into. This preliminary analysis showed that iodine mass in the atmosphere above a pool was higher than that without activating the iodine pool chemistry model. It seems that nitric acid generated by radiolysis could not influence the hydrogen ion concentration in a pool, and it could affect the iodine behavior in a late accident. In the future, it is necessary to analysis the pool scrubbing model as well as the pool chemistry model in details. This effort can contribute to induce key variables influencing the behavior of the fission products.

ACKNOWLEDGMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (Ministry of Trade, Industry and Energy) (No. KETEP-20171510101970). The authors wish to record our appreciation to Dr. Song-Won Cho who provided us with technical advice of the MELCOR calculations.

REFERENCES

[1] Y. S. Na, S.-W. Cho, and K. S. Ha, Thermal-hydraulic analysis of Inter-System Loss-Of-Coolant-Accident in OPR1000, 2019 International Workshop on Post-Fukushima Challenges on Severe Accident Mitigation and Research Collaboration, Daejeon, Korea, November 6-8, 2019.