Analysis of Scrubbing Effect to Reduce Fission Product Release in ISLOCA

Tae-young Shin*, Mi Ro Seo
KHNP-CRI, 70, 1312-gil, Yuseong-Daero, Yuseong-Gu, Daejeon, 34101, Korea
**Corresponding author:teayoung.shin@khnp.co.kr*

1. Introduction

Nuclear society of Korea was only interested in the lareg early release frequency in the Level 2 PSA results.[1] However, the newly added safety goal required that the sum of the accident frequency that the release of the radioactive nuclide Cs-137 to the environment exceeds the 100TBq should be less than 1.0E-6/RY.[2] Accordingly, there is a growing interest in the fission products release in severe accident.

In the existing analysis, the focus was not on the fission products release, but on the containment failure time and containment failure modes. So there was little interest in the fission products release and scrubbing effect. For this reason, in order to satisfy the condition that the sum of the frequency of accidents is a Cs-137 released over the current regulatory requirements 100Tbq less than 1.0E-6 was no research to reduce the fission products release. However, various studies are needed to meet the new regulatory requirements.

From the viewpoint of damaging the containment building, we think that the fission products are released into the environment directly during the BYPASS accident. However, considering the scrubbing effect, Cs-137, which is a water-soluble substance, may be released below 100 TBq. Therefore, in this analysis, we want to confirm the reduction effect of fission product (especially Cs-137) through scrubbing effect in interfacing system loss of coolant accident (ISLOCA accident).

2. Methods and Results

2.1 Characteristic of Cs-137

Cesium is an element of atomic number 55 and is an element that has become famous for the Fukushima nuclear accident.[3] The material that was leaked out of this accident and became a subject of fear is the Cs-133 isotope present in nature as Cs-137 produced by fission. The melting point of cesium is 28.44 ° C, which is one of the few metals that melt at room temperature. Because of its high reactivity, it exists only as a compound in its natural state. Cs-137, which we are interested in, has a half-life of 30.17 years and is being used as a radiation source for cancer therapy and industrial instruments.

Cs-137 is β-decayed and becomes the metastable nucleus isomer Ba-137m of Ba-137. Ba-137m has a half-life of 2.55 minutes and emits 661.66 kev of high energy γ-rays. Therefore, the main risk factor for Cs-137 is Ba-137m, which releases gamma rays.

$$^{137}Cs \xrightarrow[T_{1/2}\,30.17year]{\beta^- \ decay} {}^{137m}Ba \xrightarrow[T_{1/2}\,2.55\,\mathrm{min}]{\gamma \ decay} {}^{137}Ba\,(stable)$$

Cesium reacts with oxygen to ignite spontaneously, and reacts violently with water to form cesium hydroxide. Most cesium salts are also soluble in water.

2.2 Severe Accident Analysis Code

MAAP 5.0.3 was used in this study. MAAP is used as a comprehensive accident analysis code for severe accident analysis, accident management analysis, probabilistic safety assessment (PSA) thermal hydraulic analysis in nuclear power plant. And it is also used as a tool for severe accidents education / training. In addition, the fission products of 65 nuclides are analyzed as 18 fission product groups. The Cesium is analyzed by being included in three release groups of CsI + RbI, CsOH + RbOH, and $CsMoO_4$.[4]

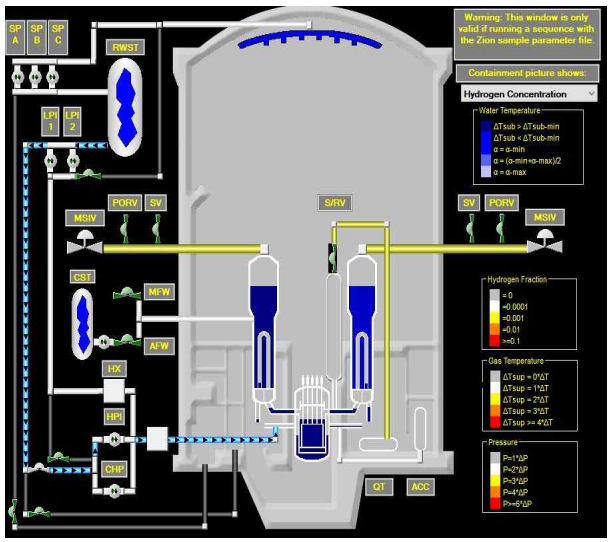

Fig. 1. GRAAPH5 provided by MAAP5

As shown in the Figure 1, MAAP generally does not model the auxiliary building. However, in this study, we have added an auxiliary building model to implement ISLOCA.

2.3 Accident Scenario and Method

Usually BYPASS accidents means ISLOCA (Interfacing System Loss Of Coolant Accident) and SGTR(Steam Generator Tube Rupture). In this study, we simulated the ISLOCA accident to clarify the scrubbing effect in APR1400. The target pipe in which

ISLOCA can occur is the shutdown cooling pump suction line of the shutdown cooling system and the high temperature pipe injection line of the safety injection system.[5] The frequency of ISLOCA incidence was evaluated to be higher than the possibility of ISLOCA due to the shutdown cooling pump inhalation flow. Therefore, in this study, the suction flow path of the shutdown cooling system with a high possibility of frequency and a larger piping size was selected as a target.

In the event of ISLOCA, the following water sources can flood the auxiliary building.

1. Reactor coolant system coolant: about 454m^3
2. Safety injection tank Coolant: about 210 m^3
3. IRWST coolant injected through the safety Injection pump: approximately 2,460 m^3

The shutdown cooling system is composed of two multi-system flow channels, and is designed so that flooding does not propagate in each area. Therefore, when ISLOCA occurs, only the quadrant of the zone is submerged. The total floodable area of each quadrant is about 990m^2, and the floodable height from the floor of the auxiliary building is about 3m.

The broken location of the pipe where ISLOCA may occur in the shutdown cooling system is from the reactor building penetration to the shutdown cooling pump suction front end. The simplified piping layout is shown in the figure 2.

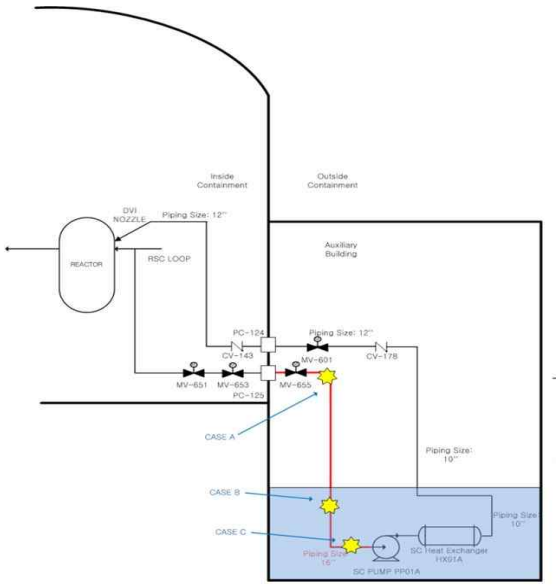

Fig. 2. The location of piping rupture for analysis of scrubbing effect in ISLOCA

As shown in the figure 2, the shutdown cooling pump is located in the bottom of the auxiliary building, and the possibility of flooding the damaged part depends on the broken location of the pipe in ISLOCA. If the broken location of the pipe is higher than the flood level, sufficient scurbbing effect can not be expected.[6]

Therefore, a sufficient cooling water pool may exist at the upper portion of the pipeline rupture only if the piping near the floor of the auxiliary building is broken, and sufficient scrubbing effect can be expected in these cases. In this study, three cases were analyzed as shown in the figure.

Case 1: the pipe broken elevation is near the bottom of the auxiliary building
Case 2: the pipe broken elevation is near the flooded water level
Case 3: the pipe broken elevation is above the flooded water level

2.4 Analysis Result

The analysis shows that the fission product release fractions are different depending on the break elevation. These results appear to be due to the scrubbing effect of the water soluble cesium in the water-pool created in the auxiliary building before it is released into the environment.

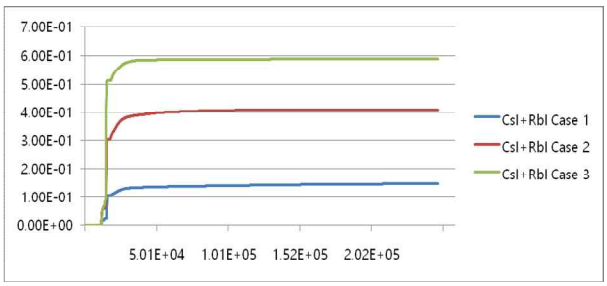

Fig. 3. CsI release fraction according to break position

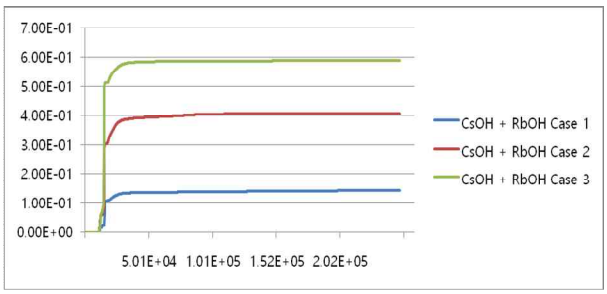

Fig. 4. CsOH release fraction according to break position

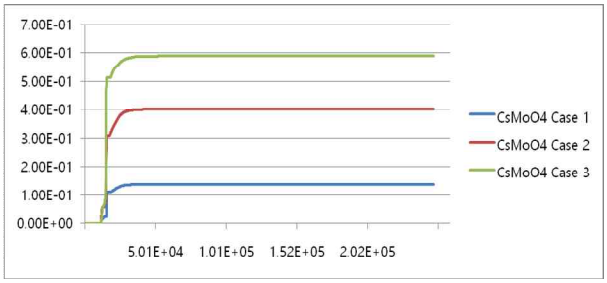

Fig. 5. $CsMoO_4$ release fraction according to break position

As shown in the figure 3, 4, 5, it is known that the fission product release frequency is reduced by about 75% when the broken elevation is at the bottom of the auxiliary building. This phenomenon was equally found in all three fission product release groups related to cesium. It seems that cesium compounds are all water-soluble regardless of their form.

3. Conclusions

Until now, the amount of released cesium has not taken into account the properties of water-soluble cesium. In this study, considering the characteristics of cesium dissolved in water, cesium was dissolved in water in case of accident. As a result of analysis, the amount of cesium was reduced when the release of cesium currently used occurs in water. Based on the results of this study, it will be possible to find a way to satisfy the new regulatory requirements through a detailed analysis of the scrubbing effect.

REFERENCES

[1] Probabilistic Safety Analysis Report for Shin-Kori 3&4, KHNP, 2015
[2] “Detailed criteria of accident management scope and accident management ability evaluation,” Nuclear Safety Commission Notice No. 2016-00, 2016
[3] K. Buesseler, M. Aoyama, and M. Fukasawa, "Impacts of the Fukushima Nuclear Power Plants on Marine Radioactivity," Environ. Sci. Technol. 45, 9931 (2011).
[4] Chan Y. Paik, “MAAP5 Modular Accident Analysis Program User`s manual”, EPRI, 2008.
[5] D.L. Kelly, J.L. Auflick, L.N. Haney, “Assessment of ISLOCA Risk-Methodology and Application to a Combustion Engineering Plant,” NUREG/CR-5745, 1992
[6] Kaneko, I.; Fukasawa, M.; Naito, M.; Miyata, K.; Matsumoto, M., “Experimental study on aerosol removal effect by pool scrubbing”, NUREG/CP--0130-VOL.1, 1993.