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Effect for Recovery of the Containment Spray System to the Release of Cesium

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1. Introduction

The New Safety Goal of Accident Management Plan for the domestic nuclear power plants in Korea was published in June, 2016. According to the New Safety Goal, it is 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. However, this goal is known to be so severe even in the case of the newly designed constructing nuclear power plants. In case of the operating plants, since there were no mitigation facilities against the severe accident at the design stages, it may be hard to meet this criterion.

In the perspective of the amount of Cs-137, the mass of Cs-137 correspondent with the 100TBq is calculated as 32g. However, during the severe accident, if the containment has been failed, it is generally expected that the mass of Cs-137 released to the environment is more than 1kg for most accident sequences

So, the review and improvement of the PSA model in order to reduce containment failure frequency should be needed. Actually, the current PSA model is known to be constructed by the conservative assumptions, especially in the view point of Level 2 PSA model. Therefore, it is necessary to find this conservatism and to improve the Model using the reasonable assumptions.

2. Methods and Results

2.1 Containment Failure Frequency in the Level 2 PSA

The Plant Damage Status frequency of the typical OPR1000 type nuclear power plants is 1E-06 order for the internal events only. Among this frequency, the "Containment Failure" frequency is from 40% to 50% on average [1]. The distribution of the containment failure frequency for typical OPR1000 type domestic nuclear power plants is shown in Figure 1

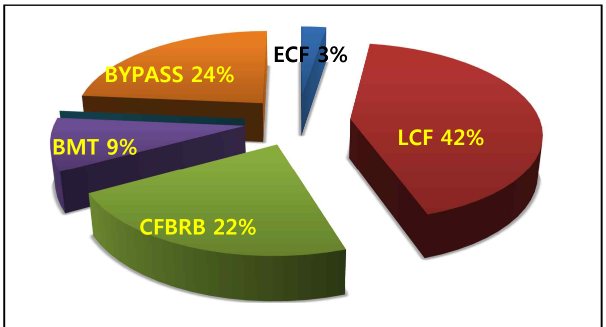

Figure 1. Containment Failure Frequency Distribution

In the case of "Containment Failure", the late containment failure frequency is above 40%, and it becomes the major factor for the containment failure. So, first of all, we tried to find the method to reduce the late containment failure frequency.

2.2 The Containment Spray Systems in the PSA Model

The main reason of the late containment failure is the over-pressurization due to steam and gas that were produced in the severe accident process. The only facility that mitigates the containment over-pressurization in the operating nuclear power plants, such as Westinghouse type or OPR1000 type, is the containment spray system. If the containment spray system is available, the containment failure frequency can be greatly reduced, because this system can be operated to the late period using recirculation operation. In addition to this, the operation of the containment spray system can reduce the amount of fission products released to the environment due to scrubbing effect. Since this system is very important to the mitigation action, if it is not working, the emergency recovery maintenance should be performed by the plant maintenance staffs according to the procedure and the availability of this system should be continuously confirmed by the process prescribed in the SAMG (Severe Accident Management Guideline) [2].

However, in the current Level 2 PSA model, the recovery action of the containment spray system is not credited. And, if the containment spray system is not available in the Level 1 Event Tree, this system is continuously unavailable in the Level 2 PSA model. As a result, the late containment failure frequency due to over-pressurization will be increased

2.3 Cs Release Analysis in case of the Recovery of the Containment Spray system

In order to analysis the effect of the recovery of the containment spray system, the large LOCA accident sequence initiated by the Double Ended Guillotine Break in cold leg was selected. The code used in this analysis is the newest MAAP 5.0.3 version and the targeted plant is the typical OPR1000 type domestic nuclear power plants.

It is assumed That the all SI systems except SIT are not available. Actually the turbine-driven Auxiliary feedwater system can be available up to the battery depletion, but in this analysis, it is assumed that this system is not available. The containment spray system is assumed to be unavailable at the accident initiation, however, to be recovered for some times later after the SAMG action was started. The analysis cases and their results are shown in Table 1.

Table 1. Major Accident Progression Results

Case	Core Uncover (S)	SAMG Entry(S)	RV Fail (S)	CS Recovery (S)	CV Press. At 72hr (PA)
LL-Base	1.9	6.5	4766	NO	8.76E+5
LL-1H	1.9	6.5	4733	3606.5	1.06E+5
LL-5H	1.9	6.5	4766	18006.5	9.93E+4
LL-10H	1.9	6.5	4766	36006.5	9.94E+4
LL-24H	1.9	6.5	4570	86406.5	1.01E+5

The containment pressure change is shown in Figure 2. As shown in the Figure 2, if the containment spray can be recovered, the containment pressure is sharply dropped at the time of actuation. So, it is expected to be helpful to reduce the containment failure frequency.

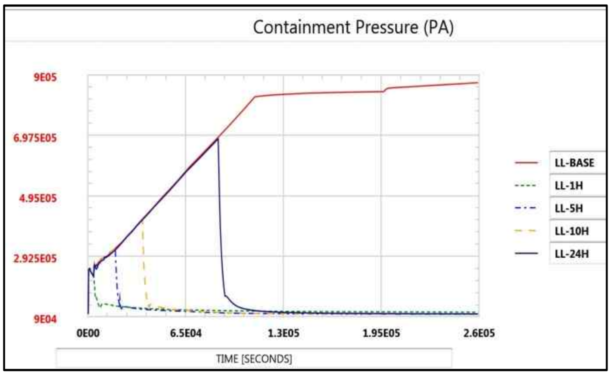

Figure 2. Containment Pressure Change

The mass fraction and the mass for Cesium released to the environment calculated by MAAP5.0.3 is listed in Table 2. The amount of Cesium (mass) released to the environment can be approximately calculated using the mass fraction in Table 2 and the initial mass of CsI, CsOH, and Cs2MoO4 in the initial core inventories of MAAP5 parameter file that was calculated by the ORIGEN Code.

Table 2. Cs Mass Fraction Released to the Environment at 72hr and the Calculated Mass of Cs

Case	CsI	CsOH	Cs_2MoO_4	Cs Mass (g)
LL-Base	1.79E-4	1.06E-4	3.93E-5	≈ 22
LL-1H	8.66E-6	5.97E-6	7.62E-6	≈ 2
LL-5H	3.0E-5	2.95E-5	2.90E-5	≈ 9
LL-10H	3.65E-5	3.64E-5	3.53E-5	≈ 11
LL-24H	3.88E-5	3.97E-5	3.74E-5	≈ 12

Note that the containment failure did not happen even in the base case during 72hr. Therefore the only small amount of cesium can be released to the environment through the nominal leak path. In addition to this, if the containment spray system is recovered, the amount of cesium released to the environment is shown to be greatly reduced from the Figure 3 to Figure 5. Also, we can find that if the recovery of the containment spray system is faster, the amount of cesium released to the environment is also reduced.

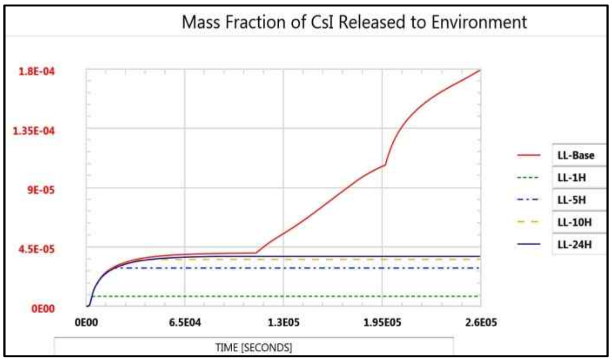

Figure 3. Change of Mass Fraction of CsI released to the Environment

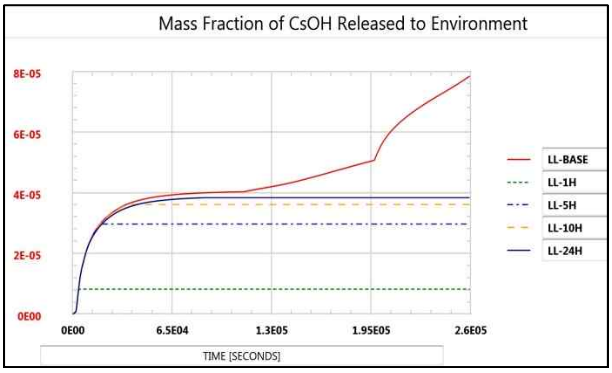

Figure 4. Change of Mass Fraction of CsOH released to the Environment

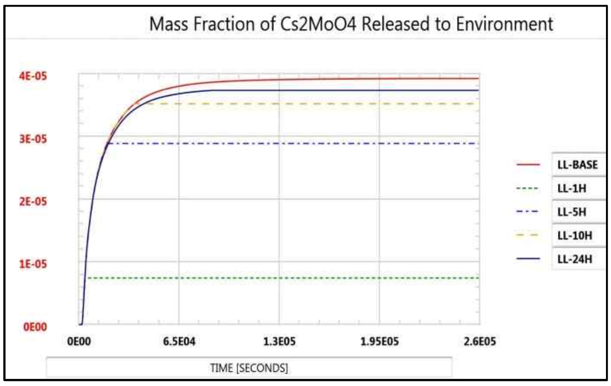

Figure 5. Change of Mass Fraction of Cs_2MoO_4 released to the Environment

From Figure 3 to Figure 5, the changes of mass fraction for CsI, CsOH, and Cs2MoO4 according to the accident sequences are shown respectively.

3. Conclusions

All of the domestic operating nuclear power plants are required to prepare the Accident Management Plan within 3 years and this Accident Management Plan should have to meet the New Safety Goal including the requirement 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.

The containment spray system is the only facility that mitigates the containment over-pressurization in the operating nuclear power plants, such as Westinghouse type or OPR1000 type. However, in the current PSA model, if the containment spray system is not available in the Level 1 sequences, this system is continuously unavailable in the Level 2 PSA model in spite that the emergency recovery maintenance should be performed by the plant maintenance staffs according to the procedure and the availability of this system is continuously confirmed by process prescribed in the SAMG.

In this study, the effects of the containment spray system recovery on the amount of Cesium released to the environment were analyzed. If the recovery of the containment spray system can be applied to the PSA model, it is expected that the containment failure frequency and also the amount of cesium released to the environment can be greatly reduced.

However, we also found that the hydrogen explosion can be occurred for some cases. If the containment spray system is recovered right after the vessel failure during the station black out sequences, it is assessed that the global burn of hydrogen or even the hydrogen explosion can be occurred. Therefore, it is judged that the more analysis should be performed for the appropriate actuation of the containment spray system.

REFERENCES

[1] Probabilistic Safety Analysis Report for Shin-Kori 1&2, KHNP, 2011

[2] Development of Severe Accident Management Guidelines for Shin-Kori 3&4, KHNP, 2013