Analysis of Radioactive Material in Consideration of Containment Filtered Venting System for Wolsong NPP Unit 1

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1. Introduction

Adding CFVS installed as one of the Fukushima actions to an existing nuclear power plant has been suggested as one approach to mitigate the effects of a severe accident. The containment filtered venting system (CFVS) was first installed at Wolsong unit 1 in 2012. CFVS is used to prevent the build-up of excessive pressure in a reactor containment during a severe accident. When the containment pressure exceeds the design pressure of the containment building, the operator opens CFVS isolation valves. Then steam and air in the containment flows out to the environment through the CFVS and the containment pressure decreases below 150 kPa(a) [1]. In addition, the key function of CFVS is to reduce the radioactive material releasing from the containment to the environment. That enables pressure to be reduced using a filtered system that retains and recirculates airborne radioactivity within containment and operates passively without the need for a power supply.

The aim of this study is to analyze the radioactive material in consideration of the CFVS operation for Wolsong unit1 using the MELCOR 1.8.6 code developed at Sandia National Laboratories (SNL) for the U.S. Nuclear Regulatory Commission (NRC). In addition, in order to evaluate the effects of filtration efficiencies for the filters of the CFVS, a sensitivity study according to decontamination factor (DF) of the filters was carried out.

2. Modeling

2.1 MELCOR modeling

The Station Blackout (SBO) accident is chosen to analyze the radioactive material of Wolsong unit 1 in the consideration of the CFVS operation. The on-site and off-site electrical systems are not operating as well as the active components including reactor coolant pumps (RCPs) cannot be used. In this study, we assume that the reactor and the turbine are tripped, and then emergency core cooling system (ECCS), auxiliary feed water (AFW), local air coolers (LACs), moderator cooling and end shield cooling (ESC) are not available. However, CFVS and dousing sprays are assumed to be operated during SBO.

The control volume (CV) and flow path (FL) are responsible for modeling the thermal-hydraulic behavior of liquid water, water vapor, and gases in MELCOR [2]. The model of Wolsong unit 1 consists of the 4 control volumes such as containment (CV820), CFVS (CV860), CFVS building (CV861) and environment (CV940). The 5 flow paths are existed and each flow path connects two control volumes. The venting area of the CFVS is assumed to be 0.13 m^2, where this area indicates a venting diameter of the CFVS for 16 inch. The length of the flow path is specified as 5 m. The control volumes and flow paths of Wolsong NPP unit 1 using MELCOR as shown in Figure 1.

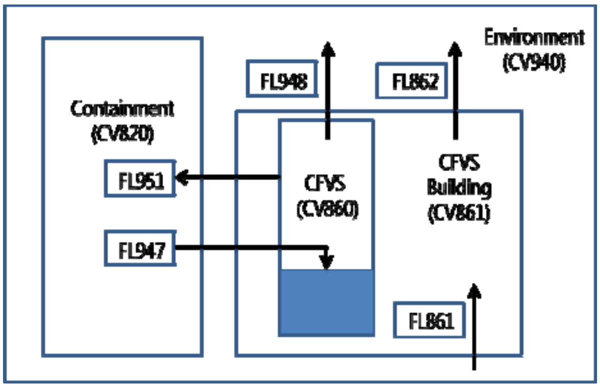

Fig. 1. Control volumes and flow paths of Wolsong NPP unit 1 using MELCOR

2.2 Decontamination Factor

Typically, the decontamination efficiency of a filter for aerosol is required to be 99.9% in order to prevent long-term ground contamination and 99% for elemental iodine and the need for short-term evacuation [3].

Since aerosols decontamination factors for CFVS are usually considered to be high in source term evaluations, of the order of 1,000 in most countries (best-estimate or required values) [4], a decontamination factor of 1,000 for aerosol is assumed in this study. These decontamination factors concern all radioactive material with the exception of the gaseous species because CFVS designs cannot retain noble gases.

3. Results

We have simulated the analysis of the radioactive material and the simulations were run up to 260,000 sec (72 hrs) using the developed MELCOR inputs. To activate the CFVS, the containment isolation valves should be opened by the rupture disc (passive means) when the set-point is reached.

The CFVS was operated 4 times during the simulation time when the CFVS reached the pressure for operation. The CFVS first starts to operate at 65,850 sec and maintains for 9,250 sec as shown in Table 1. During SBO, a large amount of radioactive iodine in gaseous and aerosol form is released in the containment atmosphere. The aerosol forms of radioactive iodine are represented by metal iodides, such as CsI.

During containment venting, a gas mixture consisting of air, hydrogen, noble gases as well as saturated steam flows into the filter with the retention of aerosols and iodine. The CFVS operations resulted in the radioactive material release to the environment including xenon, cesium, iodine, cesium iodide, etc.

Table I: Release fraction of radioactive material according to the CFVS operation

Phase	Start	End	Duration	RN1	RN2	RN3	RN5	RN7	RN8	RN9	RN11	RN16
				Xe	Cs	Ba	Te	Mo	Ce	La	Cd	CsI
1st	65,850	73,100	9,250	7.494	6.12 E-09	6.09 E-09	0	4.59 E-06	6.03 E-12	3.44 E-12	2.35E -13	5.06 E-10
2nd	102,147	112,851	10,704	11.844	7.65 E-06	1.01 E-05	0	2.70 E-05	7.11 E-09	7.43 E-09	4.31E -10	1.47 E-06
3rd	145,888	152,600	6,713	13.316	7.93 E-06	1.01 E-05	0	2.71 E-05	7.13 E-09	7.47 E-09	4.34E -10	1.49 E-06
4th	164,955	181,451	16,496	14.843	4.60 E-05	1.94 E-05	1.20 E-07	4.04 E-05	9.93 E-09	1.28 E-08	6.08E -10	2.90 E-06

Figure 2 shows that the small amounts of radioactive material are slightly released to the environment except for noble gases like Xe. The CFVS filtered most of aerosol form, while that released noble gases to the environment directly. For the release of the noble gas, CFVS cannot play a role of mitigation, but it has a good filtration performance to reduce aerosol form released to the environment.

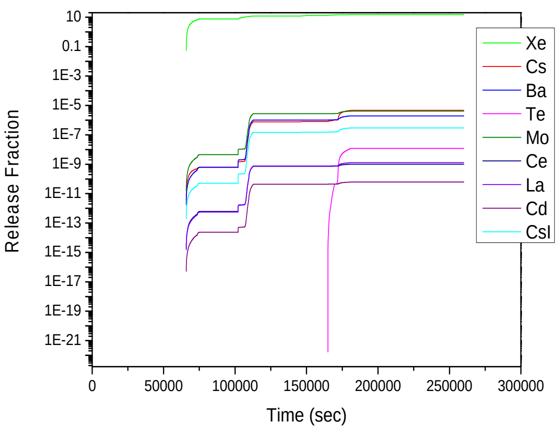

Fig. 2. Release fraction of radioactive material to the environment with the CFVS operation.

MACCS-01 (blue line) represents the CsI mass in containment atmosphere and CsI mass fraction released to the environment is about 2.9 10^{-4}. MACCS-02 (red line) represents the total released CsI mass to the environment including aerosol and vapor as shown in Figure 3 and CsI mass fraction is about 2.9 10^{-7}. Most of CsI releases to the environment are reduced considerably due to the effect of the filters for CFVS.

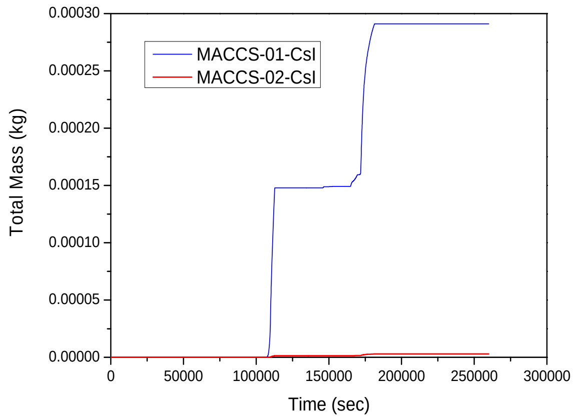

Fig. 3. Release fraction of CsI to the environment with the CFVS operation.

In order to carry out a sensitivity study according to DFs, the decontamination factors as a variable parameter are chosen as 10, 100 and 1000. Figure 4 shows the comparison of Xe release fraction and there are no different results according to DFs. Xe is released directly to the environment because the CFVS cannot retain noble gases as aforementioned.

Compared to decontamination factors of the order of 10 and 100 for CsI, a sensitivity study was carried out. Figure 5 shows that there is considerable difference in the results according to DFs. A decontamination factor of 1,000 results in the best filtration efficiency. Therefore, we can see that the filtration efficiencies of the filters for CFVS considerably depend on DFs.

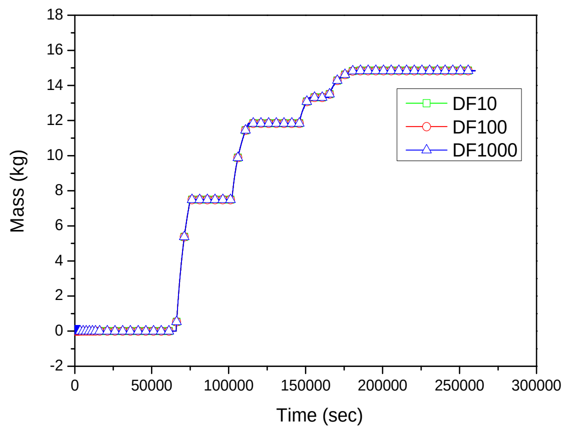

Fig. 4. Comparison of Xe release fraction according to Decontamination Factors

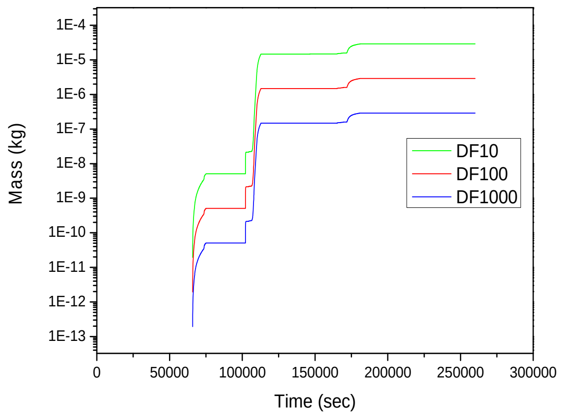

Fig. 5. Comparison of CsI release fraction according to Decontamination Factors

4. Conclusions

The SBO accident is chosen to analyze the release fraction of radioactive material of Wolsong unit 1 in the consideration of the CFVS operation using MELCOR 1.8.6 code. Also, a sensitivity study was carried out to evaluate the filtration performance according to decontamination factor of the filters for CFVS.

The results show that the small amounts of radioactive material are slightly released to the environment except for noble gases. That is, the CFVS filtered most of aerosol form and released noble gases to the environment directly. Therefore, the CFVS has a good filtration performance to reduce radioactive material such as aerosol form. In addition, the filtration efficiencies of the filters for CFVS considerably depend on DFs according to the calculation results of CsI. However, there are no different results of Xe according to DFs because the CFVS cannot retain noble gases.

In the future, a proper requirement for a criteria of decontamination factor for CFVS according to accident scenarios such as LBLOCA, SBLOCA and SGTR, etc. should be evaluated in order to review the licensing for CFVS. Also, analyses of the effects of radioactive material for offsite dose are planning to be conducted to make a connection with MACCS code which performs probabilistic calculations of potential offsite consequences of the atmospheric releases of radioactive material.

Acknowledgements

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