Release and Distribution of Fission Products for SMART100 under the SBO accident with ERVC using MELCOR

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1. Introduction

This paper shows the preliminary analysis results for the distribution of fission product release during SBO (Station Black Out) accident with ERVC (Ex-Reactor Vessel Cooling) from SMART100 with thermal power of 365 MW_{th}. This analysis has performed with MELCOR.

The distribution of fission product release in the SMART100 was categorized into eight types such as RPV (Reactor Pressure Vessel), LCA (Lower Containment Area), UCA (Upper Containment Area), water tanks, passive residual heat removal system loops, safety injection tank rooms, turbine room and environment. The release fractions of each fission product are calculated based on their initial inventories. The design leak rate from the containment under the normal operation was modeled based on the leak rate of 0.1 volume percent per a day.

From the calculation, most of the released fission products are captured within the RRT (Radioactive material Removal Tank) by pool scrubbing. Some of fission products are still remained within the RPV inside. Release fraction of Xe to the environment by the design leak is in the order of ten to the minus four. Release fraction of Cs, Te, and CsI to the environment by the design leak are in the order of ten to the minus five.

Consequently, overall release of fission products to the environment by the design leak during the SBO was shown as negligible.

2. Methods and Results

2.1 Input Model of SMART100

In the SMART100, containment consists of two parts; the LCA and the UCA. The whole volume of the LCA and the UCA are about 10,000 m^3 and 50,000 m^3 each.

To analyze the accident sequence conservatively, it was assumed that passive residual heat removal system, passive safety injection system and a backup spray system are not operable during the accident. If these systems are functional, the severe accident can be delayed or even, arrested. It was assumed that cavity flooding system is operable, so the half-height of the RPV submerges in the coolant after the valve opens.

It was predicted that the possibility of leak or rupture by over-pressure can be negligible under the SBO in SMART100 because the maximum pressure of the UCA was predicted as 1.26 bar which is below the design pressure. So, the design leak rate was considered to calculate the release fraction of fission products. The design leak rate from the containment under the normal operation was modeled based on the leak rate of 0.1 volume percentage per a day. This design leak rate corresponds to the break area of about 4.0E-3 m^2 from the UCA to the environment. Fig. 1. shows the nodalization of SMART100 for MELCOR.

It was assumed that the cladding will rupture at the surface temperature of 1173 K. When the cladding fails, the gap release of fission product to channel starts. The CORSOR-M with surface to volume ratio option was selected to simulate the amount of fission product release from the damaged core. It was assumed that the part of released Cs and the whole released I atoms combine to form CsI molecules. The distribution of fission product release in the SMART100 was categorized into eight types as the following Table I. The release fractions of each fission product are calculated based on their initial inventories.

Hygroscopic model was applied to simulate the aerosol behaviors. Application of this model will lead to a growth of the aerosol particle size as water condenses onto the soluble particle. Total sixteen classes of fission product are grouped into three components to calculate aerosol transport, removal and release. The first component is the water and the second one is the water-soluble particles such as CsOH, CsI and the last, third one is the non-water-soluble particles.

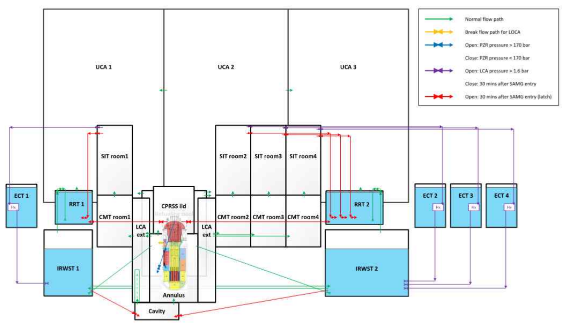

Fig. 1. SMART100 Nodalization for MELCOR

Table I: Categorized Spaces for Fission Product Distribution

Type no.	Space
1	RPV (including primary side of SG and pressurizer)
2	LCA
3	Water tanks (IRWST, RRT, CMT, and SIT)
4	UCA
5	PRHRS loop, Secondary side of SG
6	CDL, loop from SIT room to RRT
7	Turbine
8	Environment

2.2 Distribution of Fission Product in Containment

Fission products start to release when the oxidation of cladding starts at 13.7 hours. Because oxidation starts from the 30 minutes after the SAMG entry, most of fission products are discharged to the RRT through the ADS. The discharged steam condensed in the RRT pool, and released fission products are captured by the pool scrubbing.

After the massive corium relocation to the lower head which occurs at 15.9 hours, the strong release of fission products from the core is almost ended. Although most of fission products were almost discharged to the UCA through the RRT, a part of fission products still remain within the RPV. The release to the RRT from the RPV stops since the pressure of the RPV and the RRT is balanced after the lower plenum dry-out at 20.6 hours. In other words, there is no additional release of steam and fission products from the RPV after the lower plenum dry-out because ERVC was assumed to be available by the cavity flooding system in this analysis (i.e. RPV failure does not occur).

Also, release of fission products to the UCA depends on the state of the RRT pool. If the pool reaches a saturation condition, a part of captured fission products are released instantly. The RRT pool starts to boil at 17.6 hours.

The calculation results for the release fraction of each fission product from SBO accident are shown in table II based on the categorized eight spaces.

Xe is always a vapor with infinite vapor pressure. Therefore it is released to the UCA without any trapping within the RPV or any scrubbing through the pool.

Water soluble fission products such as Cs and CsI, are released in the order of ten to the minus one from the initial inventory as shown in Fig. 2. They continue to release from the RPV until the pressure of the RPV and the RRT are balanced after the lower plenum dry-out.

Water insoluble fission products are released for a relatively short time than the soluble ones. When the RRT pool starts boil, captured fission products in the RRT are released to the UCA so that the release fraction on the water tank space decreases.

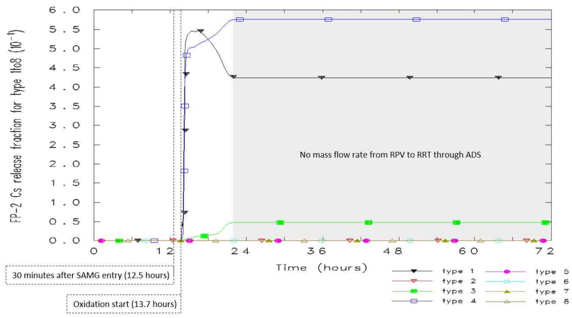

Fig. 2. Release fraction of water soluble fission products

Table II: Release Fraction at 72 hours

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8
Xe	3.62927 E-05	0	3.72322 E-04	9.52193 E-01	0	0	0	5.60419 E-04
Cs	4.23748 E-01	0	4.71452 E-02	5.75646 E-01	0	0	0	7.83453 E-05
Ba	9.44940 E-03	0	4.85209 E-03	3.22873 E-03	0	0	0	2.69735 E-07
Te	4.62694 E-01	0	9.90702 E-02	5.04469 E-01	0	0	0	6.61691 E-05
Ru	9.47932 E-07	0	1.22359 E-06	4.26144 E-07	0	0	0	1.37054 E-11
Mo	4.22894 E-02	0	5.96127 E-02	3.02415 E-02	0	0	0	2.00823 E-06
Ce	1.54647 E-07	0	1.93357 E-07	6.19012 E-08	0	0	0	1.39189 E-12
La	5.73067 E-05	0	7.57323 E-05	2.70625 E-05	0	0	0	9.45940 E-10
U	5.92595 E-05	0	7.48125 E-05	2.60517 E-05	0	0	0	8.36419 E-10
Cd	4.75409 E-02	0	5.84335 E-02	2.69516 E-02	0	0	0	1.58686 E-06
Sn	4.26057 E-02	0	6.18555 E-02	2.84785 E-02	0	0	0	1.67474 E-06
CsI	3.42441 E-01	0	3.90491 E-02	5.36763 E-01	0	0	0	7.30472 E-05

3. Conclusions

Release fraction of Xe fission products to the environment by the design leak is in the order of ten to the minus four. Release fraction of Cs, Te, CsI to the environment by the design leak are in the order of ten to the minus five, and that of Ru, Ce, La, U to the environment by the design leak are in the order of ten to the minus ten or less. Consequently, overall release of fission products to the environment by the design leak during the SBO is shown as negligible.

The effect of the cesium molybdate was not considered because of the limitation of the analysis code in this study, so the further study is required to cover this issue.

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