Release and Distribution of Fission Products for SMART-100 under the SLOCA with ERVC using MELCOR1.8.6

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1. Introduction

This paper shows the preliminary analysis results for the distribution of fission product release during SLOCA (Small Break Loss of Coolant Accident) with ERVC from SMART-100 (365 Mwt). This analysis has performed with MELCOR version 1.8.6 YV.

The distribution of fission product release in the SMART100 was categorized into eight types such as reactor pressure vessel, lower containment area, upper containment area, water tanks, PRHR loops, SIT 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 which equals to 5.76342E-4 m^3/sec.

From this calculation, most of the released fission products were in LCA and were captured within the RRT by pool scrubbing. Some of fission products are still remained within the RPV inside. Release fraction of noble gas (Xe) to the environment by the design leak is in the order of ten to the minus four. Release fraction of class 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 SLOCA was shown as negligible.

2. Methods and Results

2.1 Input Model of SLOCA for SMAT 100

In The SMART100, containment consists of two parts; the LCA (Lower Containment Area) and the UCA (Upper Containment Area). The whole volume of the LCA and the UCA are 10,205.4 m^3 and 52,486.4 m^3 each.

To analyze the accident sequence conservatively, it was assumed that PRHRS, PSIS and a backup spray system are not operable during the accident. If these systems function, the severe accident can be delayed or even, arrested. It was assumed that CFS (cavity flooding system) is operable. Therefore, the half-height of the RPV was submerged in the coolant after the valve opens.

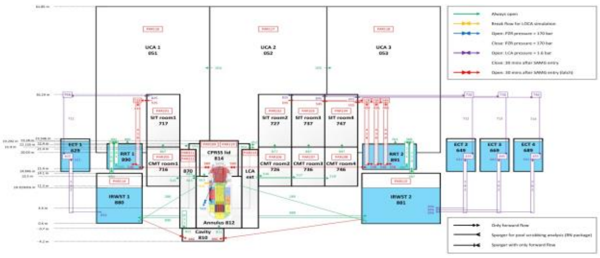

Fig. 2.1.1 SMART100 nodalization for MELCOR

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 which equals to 5.76342E-4 m^3/sec. This design leak rate corresponds to the break area of 3.944E-3 m^2 from the UCA to the environment. Figure 2.1 shows the nodalization of SMART100 for MELCOR input deck [1].

It was assumed that the cladding will rupture at the surface temperature of 1173 K. If the cladding fails, entire fission products in the gap on the same ring start release to channel immediately. The COSOR-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 2.1. The release fractions of each fission product are calculated based on their initial inventories.

Table 2.1.1 Categorized spaces for the distribution of fission product release

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

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.

2.2 Calculation Results on the Distribution of fission Product for SMART 100

SLOCA occurs at 0 second with a break area equivalent to 2 inches diameter on the RCP discharge line. Therefore, the coolant in the RPV was leaked to the LCA. The analysis was done for 72 hours.

Fission products start to release when the oxidation of cladding starts at 3 hours. Until 30 minutes after the SAMG entry, released fission products are discharged to the LCA through the break. During this phase, these fission products are transported to the IRWST through the CSL and CDL by the pressure difference. So these fission products are captured by scrubbing within the IRWST pool or deposited in the CDL.

SAMG entry condition is satisfied when core exit gas temperature reaches 923 K at 2.8 hours. After 30 minutes since SAMG condition, valve on the CSL was closed. At the same time, valves on the ADS pipe line, the CFS pipe line and pipe line from the SIT room to the RRT was opened. So the fission products and steam in the RPV start to discharge to the RRT through the ADS, and those in the LCA start to discharge to the RRT through the pipe line from SIT room to the RRT. Also, ERVC starts. The discharged steam condensed in the RRT pool and released fission products are captured by scrubbing within the pool.

After the massive corium relocation to the lower head which occurs at 7.8 hours, the strong release of fission products from the core is almost ended. Although most of fission products were discharged to the LCA and the UCA, a part of fission products still remain within the RPV.

Figure 2.2.1 shows the release fraction of class 1. Xe, which is a representative nuclide of the class 1 is always a vapor with infinite vapor pressure. Until 13.4 hours when the pressure of the LCA and the RRT are balanced, Xe are transported to the UCA through the IRWST and RRT by the pressure difference without scrubbing in the pool. When the pressure balance between the LCA and the RRT was lost at 52.6 hrs, the fission products are transported to the UCA through the pipe line from the SIT room to the RRT.

Class 2 (Cs) to 16 (CsI) fission products, water soluble and insoluble ones, are released for a relatively short time than the class 1(Xe) fission products. When the RRT pool start boil, captured fission products in the RRT are released to the UCA. It shows that the release fraction on type 3 (water tank) space decreases and the release fraction on type 4 (UCA) space increases.

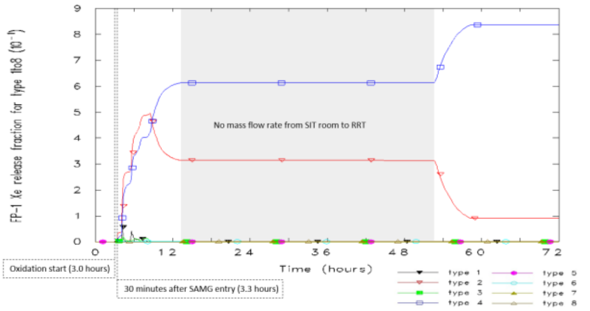

Fig. 2.2.1 Distribution of Xe in SMART100

Table 2.2.1 shows the environmental release fractions for the representative four fission products for SLOCA.

Table 2.2.1 Environmental Release fraction at 72 hrs (SLOCA)

Class	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8
Xe	1.14E-04	8.98E-02	1.25E-05	8.36E-01	0	3.93E-04	0	4.24E-04
Ba	5.43E-03	6.26E-03	3.30E-03	2.47E-03	0	1.20E-06	0	3.58E-07
Mo	2.94E-02	7.28E-02	5.35E-02	1.20E-02	0	1.51E-05	0	2.21E-07
CsI	1.71E-01	4.08E-01	8.87E-02	2.56E-01	0	1.25E-04	0	4.75E-05

3. Conclusions

Release fraction of class 2, 5, and 16 (Cs, Te, CsI) to the environment by the design leak are in the order of ten to the minus five, and that of class 6, 8, 9, and 10 (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 SLOCA was shown as negligible.

The maximum pressure of the UCA during 72 hours under the condition of the SLOCA was predicted as 1.31 bar, which is below the design pressure of UCA (1.9 bar). Therefore, it was predicted that the possibility of leak or rupture by over-pressure was negligible from SLOCA.

REFERENCES

[1] R.O. Gauntt et al., "MELCOR Computer Code Manuals vol.2: Reference Manuals Version1.8.5, COR-RM 103-106, "SNL, Albuquerque, NM 87185-0739, NUREG/CR-6119 (2000).