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A Study on Fission Product Model Comparison between MAAP4 and MAAP5

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1. Introduction

The korean regulatory body published the new regulatory requirements of nuclear power plants in July, 2016. The newly added safety goal required that the sum of the accident frequency that the release of the radioactive nuclide Cs-137 to environment exceeds the 100TBq should be less than 1.0E-6/RY. This requirement is known to be come from the provision for preventing the long term ground contamination due to the release of radioactive material. Validation of this standard was performed by many researchers recently. [1]

In the outlook 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.

The purpose of this study compare fission product model in MAAP4 and MAAP5. So the same accident will be simulated as MAAP4 and MAAP5. And will compare fission product release fraction. This will help to improvements obtained to meet the regulatory requirements of Cs-137.

2. Methods and Results

2.1 Fission Products in Severe Accident

Four phases (Gap release phase, In-vessel release phase, Ex-vessel release, Late in-vessel release phase) of fission product release in the course of Severe accident. With the exception of the noble gases and a small amount of the iodine, fission products will be released to the containment atmosphere as aerosol particles. Severe accident source terms in PWR are defined as Table. 1. [2]

Table 1: Severe Accident Source Terms

Radionuclide	Gap release	In-vessel release	Ex-vessel release	Late in-vessel release
Xe, Kr	0.05	0.95	0	0
I	0.05	0.35	0.29	0.07
Cs	0.05	0.25	0.39	0.06
Te	0	0.15	0.29	0.025
Sr	0	0.03	0.12	0
Ba	0	0.04	0.10	0
Ru	0	0.008	0.004	0
Ce	0	0.01	0.02	0
La	0	0.002	0.015	0
Duration	0.5	1.3	2.0	0
Nonradioactive mass	0	350	3800	0

2.2 Fission Product Model Comparison between MAAP4 and MAAP5

Fission products are modeled to consist of up to 65 nuclides, which are isotopes of 25 elements, and assume 18 chemical groups in MAAP5. Most of fission product mass conversion is straight-forward. For Iodine, modeling parameter FELEI and FORGI specify the fraction of I in group 14 and 15. The rest of the I is assumed to form CsI and RbI. For Cesium, modeling parameter FCSI specifies the fraction of I that forms CsI in group 2(CsI+RbI). Modeling parameter FCS2MOO4 specifies the fraction of Cs forming Cs_2MoO_4 in the Cs mass excluding the Cs in CsI. The rest of Cs is assumed to form CsOH. For Te, all the mass is initially assigned to group 11. MAAP users may need to convert MAAP5 outputs of fission product compounds into elements by themselves. But MAAP4 assumed 13 chemical groups.

MAAP5 improved fission product model. Cs will initially form CsI. The remaining Cs(not interated with I) is split into CsOH and Cs_2MoO_4. Fraction of the remaining Cs that will form Cs_2MoO_4 is controlled model parameter FCS2MOO4. [3]

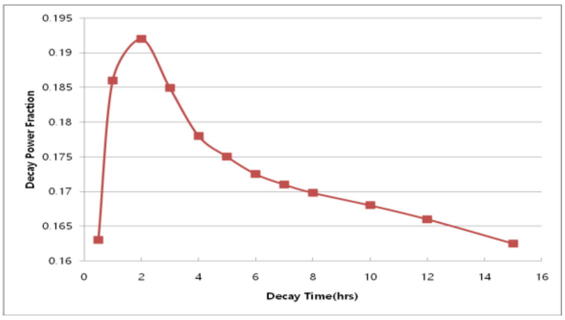

Fig 1. Decay Power Fraction of Iodine

And fission product decay heat fractions changed from constant value to time-dependent values in MAAP5.

Fission products release from individual core nodes on a fission product group basis. Release rate is a function of temperature. Iodine chemical form can be specified by user in MAAP5. No release until cladding bursts due to ballooning or until temperature criteria is met. Cladding burst can be bypassed by the user so that fission product release occurs only after collapse of a core node. Fission products are released as vapors, no condensation to surfaces until above the core. MAAP5 has 7 model options (6 for MAAP4) for the in-vessel fission product release.

Fission products released as vapors. Most will condense to form air-borne aerosols and be transported by gas flow. Aerosols can be deposited on surfaces or washed into water pools. Aerosol dynamics is very important. Aerosols are removed from being air-borne by a number of mechanisms that depend on particle sizes. Removal rates are calculated as functions of dimensionless parameters. MAAP accounts for size distribution that used correlations developed at FAI. Removal rate correlations have been created for the limiting aerosol states. Interpolation is used to determine the aerosol removal rate for cases between the two limiting aerosol states (transition mode). In MAAP version prior to MAAP5.0.2, when in transition mode, aerosol removal rates due to multiple mechanisms were combined additively. In MAAP5.0.2, combining relationships are used to govern the aerosol removal rate by two or more simultaneous mechanisms while in transition mode.

2.3 Analysis of Accident Scenarios

In order to compare fission product release fraction during the severe accident, the preliminary assessment was performed for the representative source term category(STC) of OPR1000 type nuclear power plants using MAAP4 and MAAP5. Among Several STC, STC08 was selected for the representative STC. STC08 was the STC group due to late containment failure. The initial event for STC08 is the station blackout. The core damage had been progressed due to the failure of auxiliary feed-water system. At the same time, the opening of the valves in the safety depressurization system and the safety injection systems had been failed. Since the operation of the containment spray system had been failed, the partial leak of the containment has been occurred at the late period. [4]

Two versions of MAAP were used to consider the effect of the update for the fission product behavior model. The major result of MAAP4 and MAAP5 run are summarized in Table 2.

Table 2. Major Accident Progression

	MAAP4	MAAP5
Core Uncover	6,702	7,323
RV Fail	14,205	14,791
CV Fail	129,600	129,604

As shown in Table 2, there is no difference in view point of the progression of accident.

2.4 Fission product analysis result

In Table 3, fission product release fraction to the environment calculated by MAAP4 and MAAP5 are summarized.

Table 3. Comparison of Fission Product Release Fraction

FP Group	MAAP4		MAAP5	
	Isotopes	Fraction	Isotopes	Fraction
1	NOBL,IN	9.89E-01	NOBL,IN	9.93E-01
2	CsI	4.60E-02	CsI	1.86E-01
3	TeO_2	2.57E-02	TeO_2	2.88E-02
4	SrO	9.89E-05	SrO	1.58E-03
5	MoO_2	2.77E-03	MoO_2	6.19E-03
6	CsOH	2.10E-02	CsOH	8.80E-02
7	BaO	1.35E-03	BaO	4.43E-03
8	La_2O_3	1.33E-05	La_2O_3	8.09E-05
9	CeO_2	2.87E-05	CeO_2	3.45E-04
10	Sb	5.33E-02	Sb	7.69E-02
11	Te_2	4.08E-05	Te_2	3.91E-03
12	UO_2(fuel)	4.28E-08	UO_2(fuel)	7.03E-07
13	Ag	1.49E-02	Ag	2.99E-02
14			I_2	9.89E-01
15			CH_3I	9.89E-01
16			Cs_2MoO_4	8.52E-03
17			RuO_2	3.02E-05
18			PuO_2	5.45E-05

As shown in this table, fission product release fraction calculated by MAAP5 is more conservative than that calculated by MAAP4.

3. Conclusions

This paper was a comparison of MAAP4`s fission product models with those of MAAP5. And this paper simulated the station blackout accident to compare MAAP4 and MAAP5 fission product release fraction. So far Level 2 PSA analysis used MAAP4. And this result failed to meet the regulatory requirements of Cs-137 up to now. Fission product release fraction calculated by MAAP5 is more conservative than that calculated by MAAP4. Therefore, using MAAP5 is more difficult to meet the requirements of Cs-137.

Thus, Level 1 PSA analysis must find ways to reduce CDF and Level 2 PSA analysis must find ways to reduce CFF in order to meet regulatory requirements. Not only, it seems to be required a study on the possible safety systems to alleviate the containment failure after the core damage.

REFERENCES

[1] Applicability of 100TBq cesium 137 release into environment as a safety criterion for consequence assessment at reactor design approval stage, Silva, K., & Okamoto, K., 2015

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[3] Fission Product Model Overview, Paul McMinn, 2016

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