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MSLB Dose Modeling of OPR 1000 in RADTRAD code

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1. INTRODUCTION

The purpose of this work is to introduce the method of modeling of Main Steam Line Break (MSLB). This accident has a major effect in the secondary system. In secondary system break case, this is limiting case. In this paper, some scenario cases are introduced and modeled. Specially, MSLB has some kinds of the radiological and physical phenomena. The specific characteristic of MSLB has two case scenarios such as pre iodine spike and coincident iodine spike (or accident-generated iodine spike). Iodine spike is the phenomena in which the iodine concentration increases explosively based on the state of NPP operation condition such as RCS pressure, temperature and etc.

This work helps to understand Spike phenomena and the modeling-method of DBA dose analysis in case of MSLB. Pre Iodine Spike (PIS) and accident Generated Iodine Spike(GIS) will be modeled using RADTRAD 3.03. Dose analysis method is refer to regulatory guide 1.195(RG 1.195). But dose results will be calculated by Total Equivalent Dose Effect (TEDE). The reason is very easy to compare PIS case with GIS case in each other. In this work, in order to use the dose limit criteria of TEDE, the dose limit of R.G. 1.183 will be used.

Also, in this work, fission product's behavior in atmosphere is simulated by atmospheric dispersion factor calculated by PAVAN code [1-4].

2. METHODOLOGY

2.1. Source Term Generation for MSLB

For this event, the noble gases are assumed to be transported directly from RCS to environment without duration. The other isotopes are carried to the Steam Generator (GS) by primary-to-secondary leakage.

In the faulted steam generator, all of the primary-to-secondary leakage is assumed to flash to vapor and be released to environment is dependent on the SG water level. In primary system, the initial-iodine spike phenomena are assumed up to 60uCi/gram in PIS. And GIS consider the escape rate of fission products from fuel, purification rate of Chemical Volume Control System (CVCS) and decay rate of fission products [1].

2.2. Thermal Power level of MSLB for Dose Analysis

Licensed thermal power level of 2,815 MWt is multiplied by 1.02 and goes to generate the core inventory at thermal power level of 2,872 MWt (2,815X1.02), which is providing a 2% safety margin for thermal power uncertainty.

2.3. Release Pathways Modeling

In MSLB analysis, two cases of pathways are shown as follow [1,3]:

a. Pre Accident Iodine Spike :
   -Noble gas release
   -Iodine spike release
   -Initial Steam Generator Iodine
b. Accident Generated Iodine Spike(Concurrent Iodine Spike) :
   -Noble Gas Release
   -Iodine Spike Release
   -RCS Activity release
   -Initial Steam Generator Iodine

2.4. Analysis Assumptions

For MSLB modeling, some assumptions are below [1,3,4]:

a. RCS activity set to the Technical Specification limit of 1.0 uCi/gram dose-equivalent I-131 and the non-iodine isotope concentrations at te gross activity limit of 100/E-bar.
b. Before the accident, the specific activity of iodine is at the Technical Specification limit of 0.1 uCi/gram dose-equivalent I-131.
c. The maximum RCS iodine concentration allowed by the Technical Specification during full power operation is 60uCi/gram.
d. The cooling time of RCS is finished at 212 ˚F. And intact steam release is based on a cool down 212 ˚F in eight hours.
e. The steam generator moisture carryover fraction during normal plant operation is ranged 0.05% ~ 0.1%. But in this work, 0.2% is assumed conservatively.

2.5. Offsite Dispersion Factor

PAVAN uses the meteorological-data-set to model the dispersion phenomena. The necessary meteorological data is about recently 2 year-data-set. Generally, a one-year data consists of 50,000 data files roughly. The number of 50,000 data files is made by every 10-minute -meteorological values during 365 days. In this study, 100,000 data sets over 2years are used. The reference of

meteorological data is derived from domestic OPR1000 NPP's site.
The meteorological data set are recorded and saved on the location of the tower at 10 m and 58m, respectively.

2.6. Modeling Concept

Fig.1 shows the frame of MSLB event considering Noble gas release and non-Noble fission-product release. Here, the dotted line shows the behavior of noble gas release and the solid line is the pathway of non-noble gas fission products.

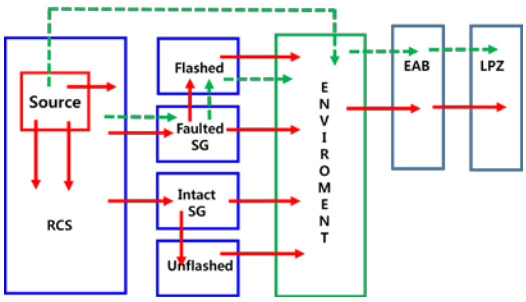

Fig. 1 MSLB modeling concept in RADTRAD code

In the environment component of Fig.1, radioactive material's diffusion behavior is simulated in the pathway from source to EAB and to LPZ. The diffusion behavior can be evaluated by the offsite dispersion factor calculated by PAVAN code.
The atmospheric dispersion factor is used as the input of RADTRAD. The general diffusion simulation carried out by inserting the output of PAVAN calculation into EAB compartment and LPZ compartment in RADTRAD input option.

3. RESULTS AND DISCUSSIONS

3.1. Fission-product Release Modeling

The pre-accident iodine spike and the concurrent iodine spike phenomena are appeared prior to the event in which the primary coolant iodine concentration is raised to the maximum value allowed by Technical Specification. Table 1 shows the release model calculation results in both of PIS and GIS as follows.

Table1. Fission products release behavior in PIS and GIS

Input	Duration release
Flashed Intact SG Tube leakage (lbm/min)	- 0 ~ 0.1 hours : 0.50 - 0.1 ~ 0.25 hours : 0.38 - 0.25 ~0.5 hours : 0.34
Intact SG Steam release (lbm/min)	- 0 ~ 2.0 hours : 38 - 2.0 ~ 8.0 hours : 33
Unflashed Intact SG Tube leakage (lbm/min)	- 0 ~ 0.1 hours : 5.7 - 0.1 ~ 0.25 hours : 5.87 - 0.25 ~0.5 hours : 5.99 - 0.5 ~ 8.0 hours : 5.99
Faulted SG Tube leakage	- 0 ~ 2.0 hours : 2.082 - 2.0 ~ 8.0 hours : 2.082
Faulted SG Steam release	- 0 ~ 2.0 hours : 1.0e+06 - 2.0 ~ 8.0 hours : 1.0e+06

3.2. RCS Activity Release of Concurrent Iodine Spike

Table 2 is written to show the iodine spike release per unit time. In this case, spiking factor is 500.
Finally, Table2 make the source term of RCS activity inventory at the end of concurrent iodine spike scenario.

Table2. Source generation by spiking factor 500

Input Items	Equivalent I-131 values
Equilibrium Concentration (uCi/gram)	- I-131 : 0.809 - I-132 : 0.642 - I-133 : 1.310 - I-134 : 0.133 - I-135 : 0.545
RCS mass (gram)	- 275,460,943
Iodine Activity (Ci)	- I-131 : 223 - I-132 : 178 - I-133 : 280 - I-134 : 36 - I-135 : 150
Appearance rate (min^{-1})	- I-131 : 0.001999 - I-132 : 0.006755 - I-133 : 0.002300 - I-134 : 0.015143 - I-135 : 0.017003
Equilibrium Appearance (Ci/min)	- I-131 : 0.4566 - I-132 : 1.2299 - I-133 : 0.7100 - I-134 : 0.5000 - I-135 : 0.5252
Concurrent Spiking factor	- 500

From Table 2, Iodine appearance of I-131 through I-135 is ranged 0.4566 Ci/min ~ 0.7100 Ci/min and is spiked by multiplying the spiking factor of 500 into the equilibrium appearance.

3.3. Results of Offsite Dispersion Factors

In this work, using PAVAN code, the atmospheric dispersion factor of EAB/LPZ is calculated. These values are used as input for offsite fission product's diffusion behavior simulation. Offsite dispersion factor is 6.225e-04 at EAB and is ranged from 3.910e-06 to 3.426e-05 at LPZ.

Table3. Offsite Dispersion Factors from PAVAN calculation

Input	Calculated results
Offsite Dispersion Factors (sec/cubic meter)	EAB : 6.225e-04 (0~2hours) LPZ : 3.426e-05(0~8hours) 2.340e-05(8~24hours) 1.125e-05(24~96hours) 3.910e-06(96~720hours)

3.4. Results from Dose Calculation EAB and LPZ in MSLB analysis

Table 4 shows the final results of MSLB analysis. According to R.G. 1.183, the dose-limit of PIS is 25 rem and that of GIS is 2.5 rem.

In PIS case, the result is 2.11 rem of EAB and 1.12 rem of LPZ.

In GIS case, the result is 1.381 rem of EAB and 0.95 rem of LPZ.

Reviewing the results, the both of EAB and LPZ are meet the dose criteria of R.G. 1.183 with the safety margin of 91.56% ~ 95.5% in PIS case.

And also, GIS safety margins of EAB and LPZ are ranged between 44.76% and 62.0%.

Table4. Pre-Accident Iodine Spike TEDE results

Location	PIS results
EAB (rem)	Noble Gas : 0.43 PIS iodine spike : 1.6 Initial SG Iodine : 0.08 Total : 2.11 (Safety margin : 91.56%)
LPZ (rem)	Noble Gas : 0.22 PIS iodine spike : 0.78 Initial SG Iodine : 0.12 Total : 1.12 (Safety margin : 95.5%)
TEDE Dose Criteria (rem)	EAB & LPZ : 25

Table5. Concurrent Iodine Spike TEDE results

Location	GIS results
EAB (rem)	Noble Gas : 0.43 GIS iodine spike : 0.78 RCS Activity release : 0.081 Initial SG Iodine : 0.09 Total : 1.381 (Safety margin : 44.76%)
LPZ (rem)	Noble Gas : 0.22 GIS iodine spike : 0.23 RCS Activity release : 0.39 Initial SG Iodine : 0.11 Total : 0.95 (Safety margin : 62.0%)
TEDE Dose Criteria (rem)	EAB & LPZ : 2.5

4. CONCLUSIONS

MSLB analysis modeling is carried out by RADTRAD code. And offsite atmospheric dispersion factor is calculated by PAVAN. The main cases of PIS and GIS are selected and simulated.

From these analysis results, we find some conclusions as below:

a. Offsite atmospheric dispersion factor of EAB is 6.225e-04 sec/cubic meter in EAB.
b. Offsite atmospheric dispersion factor of LPZ is ranged 3.910e-06 ~ 3.426e-05.
c. PIS case safety margin is ranged from 91.56% to 95.5%.
d. GIS case safety margin is ranged from 44.76 % to 62.0%.

From some conclusions we know that the PIS safety margin is bigger than GIS case. Because the PIS case has the initial condition of constant iodine specific concentration of Technical Specification by multiplying factor of 60. But the GIS case has the flexible spiking phenomena of iodine concentration in time dependent. In another word, “GIS spiking concentration” is increase timely and is based on equilibrium appearance by multiplying factor of 500. From these conclusions, GIS case is less than PIS case in the view of safety margin.

REFERENCES

[1] Final Safety Analysis Report
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[4] NUREG/CR-6604, “Simplified Model for RADionuclide Transport and Removal and Dos Estimation”, (2002).