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Study for Analyzing the Radiological Consequence of Small Line Break Outside of Containment in Design Basic Accident

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1. Introduction

The purpose of this calculation is to analyze the radiological consequences of the Small Line Break Outside of Containment event (or LDLB: Let Down Line Break) presented in DBA of FSAR [1-8]. This analysis uses new methodology to analyze LDLB.

The general guidance of the Reg. Guide will be supplemented with guidance from Standard Review Plan (SRP) section 15.6.2. In accordance with SRP 15.6.2, the source term for this calculation will assume an accident-generated or concurrent iodine spike. In accordance with the assumptions of the current analysis of record for this event, a reactor trip is not assumed.

The previous analysis of this event included a pre-accident iodine spike case and a Tech. Spec. RCS activity case. A pre-accident iodine spike is not required by the SRP. In addition, the Tech. Spec. RCS activity case will be bounded by the concurrent iodine spike case; therefore, only the concurrent iodine spike case is needed in analysis. The total dose for this event will consist of the dose from the initial RCS non-iodine nuclides plus the dose from the concurrent iodine spike.

In this paper, for analyzing the LDLB, the new methodology is introduced using source term library, fission product release timing library, scenario library.

This work helps to understand Spike phenomena and the modeling-method of DBA dose analysis in case of LDLB. Dose analysis method is based on regulatory guide 1.183(RG 1.183) [1-8].

Also, in this work, fission product's behavior in atmosphere is simulated by atmospheric dispersion factor calculated by PAVAN code [5-10].

2. Methodology

2.1. Source Term Generation for LDLB

The iodine activities in the source term were adjusted to achieve the TS(Technical Specification) limit of 1.0uCi/gram dose equivalent I-131. The non-iodine isotopes were adjusted to achieve the TS limit of 100/E-bar for non-iodine isotopes. RCS activities is used to determine the iodine generation rate for accident generated iodine spike calculation of this evaluation source term. Otherwise, in the case of PIS (Pre Iodine Spiking), initial-iodine spike activity is assumed up to 60uCi/gram.

But the PIS case of this event is well known to be confined by the GIS case of LDLB. Because of that, this study is focused in GIS case. And the GIS case consider the escape rate of fission products from fuel, the purification rate of Chemical Volume Control System (CVCS) and the decay rate of fission products [1].

2.2. Thermal Power level for Dose Analysis

For conservation of analysis, licensed thermal power level of 2,815 MWt is multiplied by the factor of 1.02, which is considered the uncertainty of 2%.

2.3. Release Pathways Modeling

In LDLB analysis, the pathways are shown as follow [1,3]:

a. Accident Generated Iodine Spike (Concurrent Iodine Spike, GIS case) :
   -Noble Gas Release
   -Iodine Spike Release
   -RCS Activity release
b. Pre Iodine Spike (PIS case):
   - Release rate is confined by GIS case
   - Activity release is confined by GIS case

From above things, in this study, PIS case is not considered.

2.4. Analysis Assumptions

For LDLB modeling, some assumptions are listed below [1,5,6]:

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 the gross activity limit of 100/E-bar.
b. Before the accident, the specific activity of iodine of SG secondary side is at the Technical Specification limit of 0.1 uCi/gram dose-equivalent I-131.
c. The iodine spiking factor is assumed as 500.
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. Accident duration time is 0 ~ 2 hours at EAB and is 0 ~ 8 hours at LPZ

2.5. Offsite Dispersion Factor

PAVAN code needs the data-set for modeling of calculating the dispersion factor. The necessary meteorological data is about recent 2 year-data-set. The data file contains about 50,000 data made by every 10-minute -meteorological values during 365 days. In this study, about 150,000 data sets over 3years are used. The reference of meteorological data is in the site of domestic OPR1000 NPP.

The dispersion factor is modeled as joint frequency matrix (considering stability, wind speed, wind direction, the level difference between 10m and 58m and vertical temperature in atmosphere).

2.6. Modeling Concept and New Methodology of LDLB Estimation

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

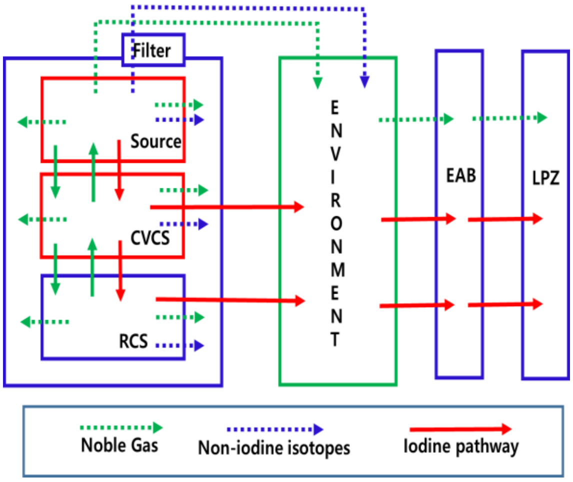

Fig. 1 LDLB modeling concept in RADTRAD code

In Fig.1, the environment compartment is the space for simulating the radioactive material's diffusion behavior. In this compartment, every dispersion effect is evaluated by using the input material from PAVAN code output in the area such as EAB (Exclusion Area Boundary or offsite boundary) and LPZ (Lowe Population Zone). The general diffusion simulation carried out by inserting the PAVAN's output into EAB compartment and LPZ compartment by RADTRAD input option.

In the Fig.2, the new methodology of radiological estimation is introduced. This new method is the first try for LDLB radiological calculation from this study. The methodology in this study is different from any other study. In this work, the library file can control any radiological sequences such as the simulation of isotopes release, source term generation and let down line break. In this work, all everything calculation process is carried out by only library files. Fig. 2 shows the work frame as new methodology. RADTRAD code is much strong to make library file to calculate the DBA radiological dose. If it is need, library file materials can be made by user interface. In order to make the new methodology system, the library file package is generated by this study.

The useful work frame is shown in Fig.2. In this methodology, library files are easily changed to simulate the radiological event. This is easier than any other estimation methods because the exchange of library file is easier than the generation of input file.

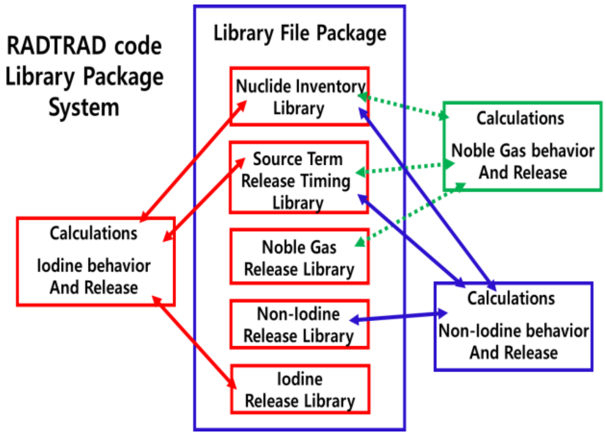

Fig. 2 The creation of Library File Package for the new methodology of LDLB radiological estimation

3. RESULTS AND DISCUSSIONS

3.1. Iodine Spike Dose Contribution Modeling

The nuclide inventory file was changed to represent the generated iodine spike. A multiplier 500 for concurrent iodine spike is used according to SRP 15.6.2 and Regulatory Guide 1.183 Appendix E. Table 1 shows the release model calculation results in GIS as follows.

Table1. Iodine Spiking release behavior in GIS

Input	Duration release
Purification Flow (lbm/min)	- 720
Leakage Flow (lbm/min)	- 60
RCS mass (lbm)	- 420
Iodine Removal constant(min^{-1}) (Purification + leakage)	- 0.000997
Total Removal Constant (min^{-1})	- λ131 : 0.001015 - λ132 : 0.005900 - λ133 : 0.001431 - λ134 : 0.015200 - λ135 : 0.002630

3.2. RCS Activity Release of Concurrent Iodine Spike

Table 2 shows the iodine spike release rate per unit time. In this case, spiking factor is 500.

From iodine spiking factor 500 and total removal constant, a spiked equilibrium appearance rate is calculated. The spiked equilibrium appearance rate is used to estimate total released iodine amounts during the LDLB accident.

Table2. Source generation by spiking factor 500

Input Items	Equivalent I-131 values
Equilibrium Concentration (uCi/gram)	- I-131 : 0.809 - I-132 : 0.195 - I-133 : 0.828 - I-134 : 0.077 - I-135 : 0.390
RCS mass (gram)	- 270,000,000
Iodine Activity (Ci)	- I-131 : 218.43 - I-132 : 52.65 - I-133 : 223.56 - I-134 : 20.79 - I-135 : 105.3
Total Removal Constant (min^{-1})	- λ131 : 0.001015 - λ132 : 0.005900 - λ133 : 0.001431 - λ134 : 0.015200 - λ135 : 0.002630
Equilibrium Appearance Rate (Ci/min)	- I-131 : 0.2217 - I-132 : 0.3106 - I-133 : 0.3199 - I-134 : 0.3160 - I-135 : 0.2769
Concurrent Spiking factor	- 500
Spiked Equilibrium Appearance Rate (Ci/min)	- I-131 : 110.853 - I-132 : 155.318 - I-133 : 159.957 - I-134 : 158.004 - I-135 : 138.470

From Table 2, iodine appearance rate of I-131 through I-135 is ranged 0.2217 Ci/min ~ 0.3199 Ci/min and is spiked by multiplying the spiking factor of 500.

And then, the spiked iodine equilibrium appearance rate of I-131 through I-135 is ranged 110.853 Ci/min ~ 159.957 Ci/min.

3.3. Results of Offsite Dispersion Factors

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 6.700e-04 at EAB and is ranged from 2.550e-06 to 3.570e-05 at LPZ.

Table3. Offsite Dispersion Factors from PAVAN calculation

Input	Calculated results
Offsite Dispersion Factors (sec/cubic meter)	EAB : 6.700e-04 (0~2hours) LPZ : 3.570e-05(0~8hours) 2.880e-05(8~24hours) 1.228e-05(24~96hours) 2.550e-06(96~720hours)

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

Above all things, the verification of this study is carried out by comparing this study results with the results of a common method using the radiological scenario input change method.

From Fig.3 and Fig.4, this study results is in good agreement with the common methods.

Both of EAB and LPZ are less than 1 % in the difference of comparisons.

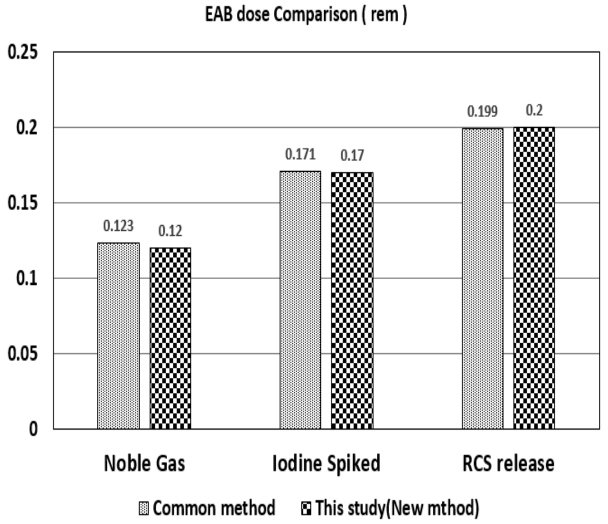

Fig. 3 The comparison between common method and this study (new methodology) in EAB dose at LDLB

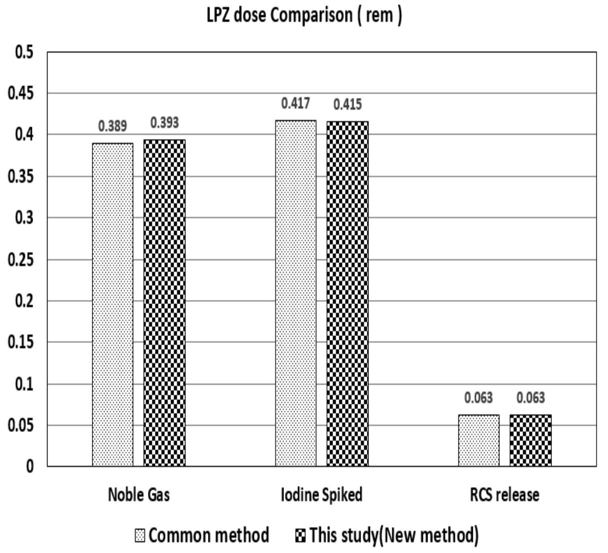

Fig. 4 The comparison between common method and this study (new methodology) in LPZ dose at LDLB

Table 4 shows the final results of LDLB analysis. According to R.G. 1.183, the dose-limit of of GIS is 2.5 rem.

In GIS case, the result is 0.871 rem of EAB and 0.490 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 65.16% ~ 80.4% in GIS case.

Table4. Concurrent Iodine Spike TEDE results from LDLB in this study

Location	GIS results
EAB (rem)	Noble Gas : 0.393 GIS iodine spike : 0.415 RCS Activity release : 0.063 Total : 0.871 (Safety margin : 65.16%)
LPZ (rem)	Noble Gas : 0.12 GIS iodine spike : 0.17 RCS Activity release : 0.20 Total : 0.490 (Safety margin : 80.4%)
TEDE Dose Criteria (rem)	EAB & LPZ : 2.5

4. CONCLUSIONS

The new methodology for the LDLB radiological estimation and the LDLB modeling is carried out by RADTRAD code. And offsite atmospheric dispersion factor is calculated by PAVAN. The main cases of GIS are selected and simulated.
From these analysis results, we find some conclusions as below:

a. Various library file generation method allows to calculate the complex LDLB analysis and to make the calculation easier.
b. Offsite atmospheric dispersion factor of EAB is 6.700e-04 sec/cubic meter in EAB.
c. Offsite atmospheric dispersion factor of LPZ is ranged 2.550e-06 ~ 3.570e-05.
d. The comparison results between the common method and this study (new methodology) are within 1% difference.
e. GIS case safety margin is ranged from 65.16 % to 80.4%.

From some conclusions we know that the new methodology using the various library file generation method is easier in case of the calculation of the complex problem of radiological analysis. The comparison results are in good agreement with the common method. In GIS case, the safety margin is sufficient in OPR 1000 NPP.

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