Safety Dose Analysis of LDLB by NAME_LSC Code
(NAME_LSC: Nuclear-reactor Accident's Modeling and effects Evaluation by LEE, Seung- Chan)

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1. Introduction

The purpose of this calculation is to check the performance of NAME-LSC in case of the Small Line Break Outside of Containment event (or LDLB: Let Down Line Break) presented in DBA of FSAR [1-8].
NAME-LSC code is developed to estimate and to simulate the DBA accident effects by KHNP-CRI's LEE(2017~2020). In accordance with SRP 15.6.2, the source term is prepared for this performance. In accordance with the assumptions of the current analysis of record for this event, a reactor trip is not assumed.
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.
In this study, the concurrent iodine spike case is selected from this reason.
NAME-LSC code's performance is tested by comparing with the results of RADTRAD 3.03 of US NRC.
RADTRAD 3.03 code was developed to estimate DBA accident in SAR and FSAR by US NRC. In the previous study, the accident effects analysis of LDLB by RADTRAD 3.03 has been carried out by KHNP-CRI. For the NAME-LSC performance test, the LDLB estimation results of RADTRAD 3.03 is used.
From the performance test results, NAME-LSC's percent error is evaluated[1-11].

2. Methodology

2.1. Source Term of 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. Generally speaking, PIS (Pre Iodine Spiking), initial-iodine spike activity is assumed up to 60uCi/gram.

But the PIS case is well known to be limited by the GIS of LDLB. GIS(Generated Iodine Spiking) case consider the escape rate of fission products, the purification rate of Chemical Volume Control System (CVCS) and the decay rate of fission products [1].

2.2. Thermal Power level Assumption

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

2.3. Release 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

In this study, PIS case is not considered, because the limiting case is GIS.

2.4. General Assumptions

For LDLB modeling, some assumptions are 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 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.

2.5. Offsite Dispersion Factor

PAVAN code needs the data-set for modeling of calculating the dispersion factor. 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 of NAME-LSC

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

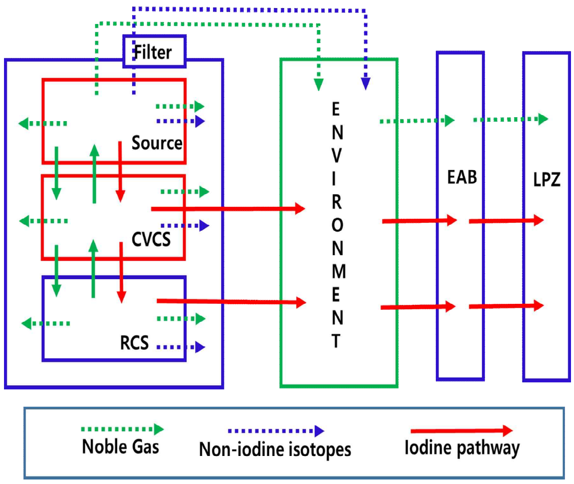

Fig. 1 LDLB modeling concept in NAME-LSC code

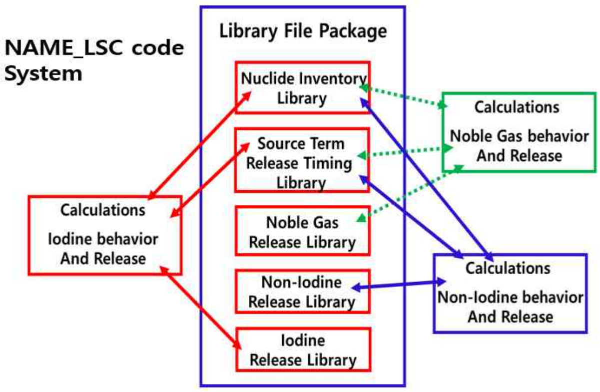

Fig. 2 The creation of Library File Package for LDLB radiological estimation (NAME-LSC code)[4]

In Fig.1, the environment compartment is to simulate the fission product's diffusion.
In the environment compartment, dispersion effect is evaluated in every time by using the PAVAN code output.
The Fig.2 shows the relation between the calculation process and NAME-LSC library package.
NAME-LSC code make library file and use that.
To calculate the DBA radiological dose, If it is needed, NAME-LSC's library file materials can be made by user interface.

3. RESULTS AND DISCUSSIONS

3.1. Iodine Spike 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.
Table 1 shows "Iodine Spike release" for GIS case.

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 Rate

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.

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 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 as like Table3.
Here, EAB is "Exclusion Area Boundary" and LPZ is "Low Population Zone".

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. Performance Test of NAME-LSC code

Above all things, LDLB estimation is carried out.
NAME-LSC code is in good agreement with RADTRAD 3.03 in same conditions.
Both of EAB and LPZ are less than 0.28% in the difference of comparisons.

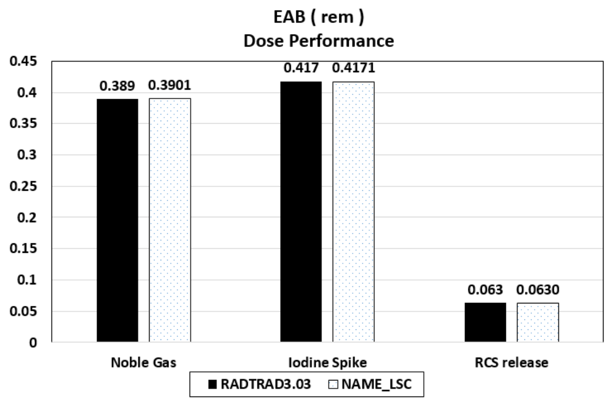

Fig. 3 Performance Test at EAB in NAME-LSC

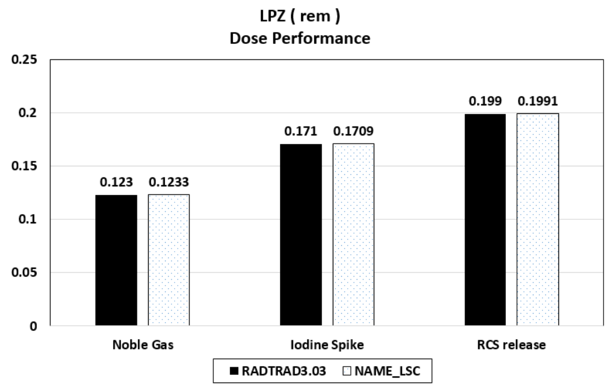

Fig. 4 Performance Test at LPZ in NAME-LSC

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 0.1233 rem of EAB and 0.1709 rem of LPZ.
Reviewing the results of NAME-LSC, the both of EAB and LPZ are within 0.28% error range.
In comparison results of NAME-LSC, the error range is from 0.02% to 0.28% in LDLB effects analysis.

Table4. Concurrent Iodine Spike TEDE results from LDLB in this study (NAME-LSC)

Location	Performance Test Results
EAB (rem)	Noble Gas : 0.3901 GIS iodine spike : 0.4171 RCS Activity release : 0.063 Error : 0.02% ~ 0.28%(comparing with RADTRAD)
LPZ (rem)	Noble Gas : 0.1233 GIS iodine spike : 0.1709 RCS Activity release : 0.20 Error : 0.05% ~ 0.24%(comparing with RADTRAD)
TEDE Dose Criteria (rem)	EAB & LPZ : 2.5 *TEDE : Total Effective Dose Equivalent From RG 1.183

4. CONCLUSIONS

The LDLB radiological estimation is used and the LDLB modeling is carried out by NAME-LSC code. The main cases of GIS are selected and simulated.
From this study, some conclusions are as below:

a. NAME-LSC code performance is in good agreement with RADTRAD 3.03 in LDLB accident and in same conditions.
b. Offsite atmospheric dispersion factors for EAB and LPZ are used 6.700e-04 sec per cubic-meters.
c. Dispersion factors of LPZ are ranged 2.550e-06 ~ 3.570e-05.
d. The performance of NAME-LSC is within the error range between 0.02% and 0.28%.

From some conclusions we know that the performance of NAME-LSC code is in good agreement with RADTRAD 3.03 in LDLB accident effects analysis.

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[4] Seung Chan Lee, "Develop. of Program equivalent to RADTRAD for DBA Safety Evaluation", KNS, Spring(2021).
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[8] NUREG 1431.
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[10] Federal Guidance Report No. 11.
[11] Federal Guidance Report No. 12.