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LOCA Analysis Modeling with RADTRAD Code

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1. INTRODUCTION

In the final safety analysis report (FSAR), various kinds of design basis accident(DBA) are written and analyzed based on each event sequence. The one of the limiting accident cases in the FSAR is loss of coolant accident (LOCA).

The specific characteristic of LOCA is that the source term is much more than any other scenario cases.

Because of that, the release of radioactive materials is larger than any other case.

In the case of dose estimation and the case of thermal hydraulic and safety analysis, this event is very important. In this paper, in the view of LOCA safety dose analysis, the detailed modeling and estimation methodology is carried out and introduced. The concept of LOCA modeling is introduced in the view of RADTRAD input.

In LOCA modeling work, offsite atmospheric dispersion factor, dose estimation, and safety margin are analyzed by regulatory guide 1.195(R.G. 1.195) and 1.23(R.G. 1.23). The calculation of offsite atmospheric dispersion factor is carried out by PAVAN code [1-5]. In this paper, the methodology of LOCA analysis and modeling is different from the current methodology in the view of splitting the containment volume into 8 pieces for some more detail modeling (ex. 3 sprayed regions, 3 un-sprayed regions, dome and sump volume). In the current methodology, the containment volume consists of 3 volumes such as containment dome, spray region and un-spray region.

2. METHODOLOGY

2.1. Source Term Generation for LOCA analysis

According to core inventory based on R.G. 1.195, noble gas and halogen isotopic materials are solely existed in the core fuel.

Generally speaking, for domestic NPP, the sequences of LOCA are analyzed using TID-14844 source term methodology updated by R.G. 1.195.

This source term methodology is generally to assess compliance with 10CFR 50, Appendix A, General Design Criterion (GDC) 19 and 10CFR 100 Section 100.11 dose criteria.

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.

In the maximum power level, noble gas of 100% and iodine of 50% are released from fuel inside to the containment atmosphere. After that time, iodine is removed by spray system and natural deposition up to 50% again [1-5].

2.2. Release Pathways in LOCA modeling.

In LOCA analysis, the three release pathways are shown as follow [5]:

a. Containment leakage model: The radioactive release from the fuel is assumed to mix instantly and homogeneously through the containment free volume. The primary containment is assumed to leak at the allowable Technical Specification peak pressure leak rate of 0.1% by weight for the first 24 hours. This leak rate is reduced to 0.05% by weight after 24 hours.
b. Recirculation sump leakage model: ESF system recirculates sump water. This water is pass through the aux building during recirculation pump operation. This release source includes leakage through valve packing glands, pump shaft seals, flanged connections and other some components.
c. Containment purge system release model: Containment small volume purge system is open during about 5 seconds before a containment isolation valve close. The duration is the release for 5 seconds as short time.

2.3. Analysis Assumptions for LOCA modeling

For LOCA modeling, some assumptions are below:

a. Containment spray operation is functioned up to iodine remove rate of 90%.
b. Containment mixing rate is assumed to be 2 turnovers of the containment free volume per hour.
c. Containment sump water pH is assumed to be more than 7 based on the SRP 6.5.4.
d. Since the temperature of the ESF leakage or recirculation sump leakage exceeds 150 ˚F, the fraction of total iodine in the liquid changing into vapor is assumed equal to the fraction of the leakage being flashed and being changed into vapor. This flashing fraction(FF) is determined using a constant enthalpy. The FF of 10% is used for the entire duration of the recirculation sump leakage [1-3].

2.4. Offsite Dispersion Factor Modeling

In LOCA modeling, the main three pathways is the release path of source term pass through containment into environment and go to the exclusion area boundary (EAB) and to the low population zone(LPZ). In these all pathways, radioactive release behavior is strongly affected by offsite atmospheric dispersion factor. This atmospheric dispersion factor is modeled and calculated by PAVAN code which is licensed and designed by US NRC.

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 is 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.

2.5. LOCA Analysis Modeling by RADTRAD code

LOCA analysis modeling is carried out by RADTRAD code. RADTRAD code is licensed and designed by US NRC. Here, volume component, pathway component, recirculation component, filter component, environment, MCR, EAB and LPZ are modeled by the concept of Fig. 1.

Fig.1 shows the frame of LOCA event considering the containment leakage model, sump leakage model and the containment purge release model.

Dotted lines are considered for the sump and containment purge model. Solid lines are considered for the containment leakage model.

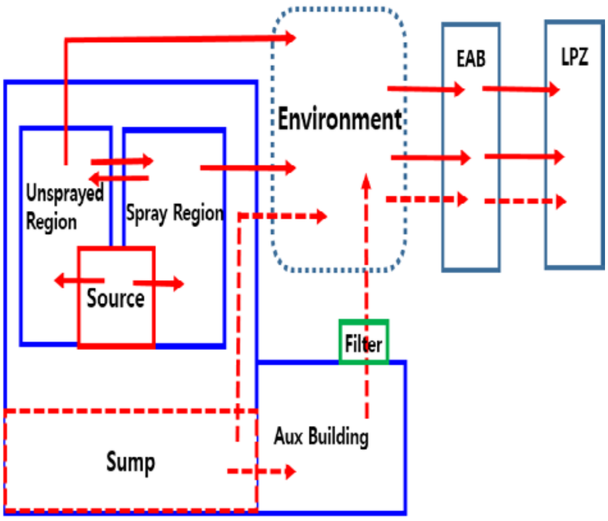

Fig. 1 LOCA modeling concept in RADTRAD code

In the environment component of Fig.1, radioactive material's dispersion behavior is used. This behavior can be simulated by the offsite dispersion factor from PAVAN calculation.

The dispersion modeling of radioactive materials in RADTRAD code is carried out by inserting the input as the output from PAVAN calculation.

2.6. Input Parameters of Analysis

The necessary parameter ranges are shown in Table 1. From Table 1, iodine removal parameters, containment leak rate, and containment design volume are key parameters in the initial condition of LOCA scenario.

In the beginning of LOCA, the mixing rate between the sprayed region and the unsprayed region is ranged from 0.261e+04 cfm to 1.572e+04 cfm roughly.

In order to calculate the thyroid dose, the breathing rate is referred from R.G. 1.195.

The selected value is 3.5e-04 cubic meter/second. The very important case of LOCA modeling is containment leakage model. According to Table 1, the initial leak rate referred from Technical Specification. The first 24hours required as the Tech. Spec. maximum leak rate. After 24hours, the half of the initial value is required. This method is very conservative.

Table1. Range of input parameter for LOCA analysis

Input	Values
Containment leakage flow rate (Volume% per day)	Containment leakage - 0 ~ 24 hours : 0.1~0.3 - 24 ~ 720 hours : 0.05 ~ 0.15
Removal rate or Decontamination Factors	Iodine removal rate - Elemental iodine by spray : 0 ~ 50 - Particulate iodine by spray : 0 ~ 1.0 - Natural deposition : 0~10 Iodine Decontamination Factor - Elemental iodine by spray : 0 ~ 10 - Iodine by deposition : 100
Containment internal Volume (cubic feet)	Free volume : 2.727e+06 Main spray region : 2.05e+06 Sub spray region : 3.4e+05 Total spray region : 2.39e+06 Unsprayed region : 3.4e+05

3. RESULTS AND DISCUSSIONS

3.1. Parameters of Containment leakage model

From Technical Specification, the containment leak rate of the first duration of initial 24 hours is selected as 0.1% containment volume per day. Since 24hours, the containment leak rate is reduced as 0.05% containment volume per day. The calculated key parameters of containment leakage model are shown Table 2 in detail.

Table2. Calculation results of key parameters and the offsite dispersion factors

Input	Calculated results
Containment leakage flow rate (Vol% per day)	Containment leakage - 0 ~ 24 hours : 0.1 - 24 ~ 720 hours : 0.05
Removal rate or	Elemental Iodine removal rate

Decontamination Factors	- Main spray region : 20 - Sub spray region : 45.1 - Unsprayed region : 0.0 Particulate iodine removal rate - Main spray region : 0.33 - Sub spray region : 0.067 - Unsprayed region : 0.0 Natural deposition removal rate - Main spray region : 1.62 - Sub spray region : 5.50 - Unsprayed region : 5.50 Iodine Decontamination Factor - Elemental iodine by spray : 8.57 - Iodine by deposition : 100
Offsite Dispersion Factors (sec/cubic meter)	EAB : 5.334e-04 (0~2hours) LPZ : 3.264e-05(0~8hours) 2.329e-05(8~24hours) 1.120e-05(24~96hours) 3.913e-06(96~720hours)

3.2. Parameters of Containment purge system leak

Containment purge system is closed during accident. But the system's close actuation function is delayed about 5 seconds. During this time, the purge system is open and some radioactive materials is directly release into environment. For 5 seconds, the release speed is assumed as sonic velocity. After 5 seconds, the purge system release is rapidly closed and stopped. The release rate through into environment is about 23,363cfm for 5 seconds.

3.3. Recirculation Sump leakage model

Recirculation sump leak is occurred by pump operation and valve operation and go to the aux building. The aux building HVAC filter efficiency is 99% and the filter flow rate is 1.2e+04 cfm.
From this modeling, the calculated pump leakage is 0.0057 cfm and the calculated valve leakage is 0.0016 cfm. These values are general in domestic NPP compared with FSAR.

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

Table 3 shows the final results of LOCA analysis. According to R.G. 1.195, the dose limits are 300 rem (thyroid) and 25 rem (whole body). In this study, the results of EAB are 259 rem at thyroid dose and 10.1 rem at whole body dose. The results of LPZ are 135 rem at thyroid dose and 2.42 rem at whole body dose.
The both of EAB and LPZ are meet the dose criteria with the safety margin of 14% ~ 55.3% in case of thyroid dose.
And also, the whole body's safety margins of EAB and LPZ are in the range between 59.6% and 90.3%.

Table3. Calculation results of LOCA analysis

Location	Results of LOCA analysis
EAB (rem)	Containment leakage model - Thyroid : 257 - Whole body : 10.1 Containment purge system model - Thyroid : 2.38 - Whole body : 0.0056 Recirculation Sump leakage model - Thyroid : 0.41 - Whole body : 0.0016
LPZ (rem)	Containment leakage model - Thyroid : 134 - Whole body : 2.42 Containment purge system model - Thyroid : 0.14 - Whole body : 0.0003 Recirculation Sump leakage model - Thyroid : 1.0 - Whole body : 0.0013
Dose Criteria (rem)	EAB & LPZ Thyroid : 300 Whole body : 25

4. CONCLUSIONS

LOCA analysis modeling is carried out by RADTRAD code. And offsite atmospheric dispersion factor is calculated by PAVAN. The main three pathways as containment leakage model, containment purge model and recirculation sump model are selected and simulated.
From these analysis results, we find some conclusions as below:

a. Offsite atmospheric dispersion factor of EAB is 5.334e-04 sec/cubic meter in EAB.
b. Offsite atmospheric dispersion factor of LPZ is ranged 3.913e-06 ~ 3.264e-05.
c. Thyroid dose safety margin is ranged from 14% to 55.3%.
d. Whole body dose safety margin is ranged from 59.6% to 90.3%.
e. The confined case is containment leakage model because of release time and of release amount.
f. The maximum contribution of containment leakage model is over 99%.

From some conclusions we know that the contribution of containment leakage model is stronger than any other models such as containment purge model and recirculation sump leak model.

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