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Dose Analysis of OPR 1000 in DBA LOCA Model

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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)[1].

This paper shows that LOCA dose analysis carried out with some scenarios and modeling using RADTRAD code. The preliminary study of LOCA dose modeling has carried out by KHNP CRI [2].

In this study, some scenarios of LOCA dose analysis are evaluated and the safety margin is evaluated. And additional results are introduced. This study is to evaluate the post-LOCA exclusion area boundary (EAB), low population zone (LPZ) dose using design input.

As the scenarios of LOCA dose analysis, the containment leakage, the sump leakage and the purge system leakage are used considering post-LOCA release paths. The calculation of offsite atmospheric dispersion factor is carried out by PAVAN code [1-4].

2. METHODOLOGY

2.1. Basic Input for LOCA Dose Analysis

In this study, basic input is based on Regulatory Guide(RG) 1.195 which is published to exchange and update with the Regulator Guide 1.4 of TID 14844. And RG 1.195 includes the general guides of LOCA and non-LOCA DBA evaluation. All things of this study is based on that.

For LOCA dose analysis, some information is needed. The represent information consists of nuclides inventory, dose conversion factor, timing release, pathways, compartments, and event sequence. The nuclide inventory is made by the format of library file which should be written as the regular expression rule. And also the dose conversion factor and the timing release are written as the other regular expression rule such as the nuclide inventory file. The library format is based on NUREG/CR 6604 from US NRC. Pathways and compartments are modeled by RADTRAD code using event sequence.

2.1.1. Nuclide Inventory

The nuclide inventory is directly related to the licensed thermal power level and its uncertainty.

The DBA thermal power level is 102% of normal power level to consider the uncertainty 2%.

In this case, noble gas of 100% and iodine of 50% are released from fuel into the containment atmosphere. And again, the iodine is washed out and settled on the containment inside wall, containment sump by the containment spray system and natural deposition up to 50% again [1-4].

2.1.2. Dose Conversion factor and Timing Release

The previous nuclides are dependent on the dose conversion factor and the timing release library.
The dose conversion factor library includes the information of tissue absorption, external/internal effect of every isotope and physical/chemical behavior effect.
The timing release library includes the time of fission product release, release fraction and fission product's category.

2.1.3. Pathways and Compartments

The pathways and the compartments are similar to the nodal such as the junctions/volumes of thermal hydraulic safety codes.
Pathways compartments are matched with junctions and volumes relatively.
Every pathway consists of the input dates including the deposition rate and the physical behavior characteristic of specific fission products in the conditions of pipe and leakage.
Every compartments consists of the input dates including volume or space size, internal flow rate, spray volume, EAB, LPZ, environment and so on.

2.2. Scenarios for LOCA Evaluation

LOCA evaluation has the three scenarios as follow [1]:

a. Containment leakage scenario: Fission products release from the fuel to the containment and go through the containment leak pathway into the environment. The leak rate is 0.1% free volume per day at the allowable Technical Specification peak pressure condition during the first 24hours. After that, the leak rate is the half rate based on the Technical Specification.
b. Sump leakage scenario: Engineered Safety Feature system actuates the recirculation sump pumps to recirculate the sump water. During the recirculation pump operation, the sump water is pass through the auxiliary building and return to the containment sump. In this time, the coolant

water experience the small leakage from recirculation pathways. The reason is based on the valve packing, pump shaft seals, flange connections and so on.

c. Containment purge system release scenario: Containment has small volume purge system which is opened during about 5 seconds before containment isolation valve close. During this time, some fission products are release from containment to environment.

2.3. Offsite Dispersion Factor

The main three pathways of scenario cases show the fission products behavior from inside to outside of containment. The release behavior from inside containment to the environment such as EAB and LPZ is not shown in these cases. Finally, the fission product's diffusion behavior via the air condition from containment to both of EAB and LPZ is simulated X/Q named as offsite atmospheric dispersion factor. This dispersion factor is evaluated by PAVAN code licensed and made by US NRC.

In this evaluation, the meteorological-data-set during 2 years is used and prepared. The necessary meteorological data is about recently 2 year-data-set. The meteorological data set are recorded and saved on the location of the tower at 10 m and 58m, respectively.

2.4. LOCA Evaluation Concept

LOCA evaluation is carried out using RADTRAD code. Fig.1 shows LOCA evaluation concept considering the containment leakage scenario, sump leakage scenario and the containment purge scenario.

Solid lines and dotted lines are indicated containment leakage pathways and recirculation sump leakage pathways respectively.

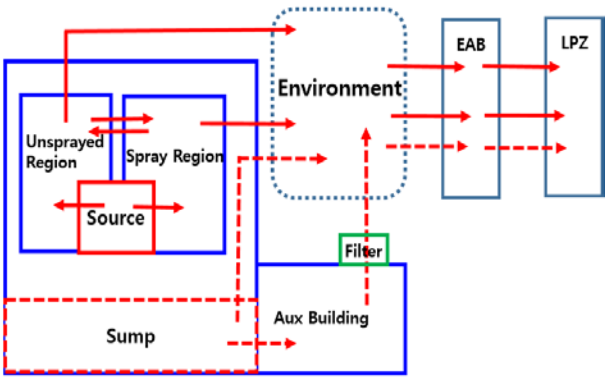

Fig. 1 LOCA Evaluation concept [2]

3. RESULTS AND DISCUSSIONS

3.1. Input Parameter Results

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

The breathing rate of thyroid dose is 3.5e-04 cubic meter/second referred from R.G. 1.195.

Table1 shows three scenario model's leakage input results of three LOCA scenarios as follow:

a. 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.

b. 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 half sonic velocity. After 5 seconds, the purge system release is rapidly closed and stopped. The release rate through into environment is about 11,681cfm for 5 seconds.

c. 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+01 cfm. From this modeling, the calculated pump leakage is 0.0055 cfm and the calculated valve leakage is 0.0012 cfm. These values are general in domestic NPP compared with FSAR.

The parameters of Removal/Decontamination factors are written in Table 2.

Table 3 shows offsite atmospheric dispersion factor of EAB and LPZ. The atmospheric dispersion factor is 6.225e-04 sec/cubic at EAB and ranged 3.910e-06 ~ 3.426e-05 at LPZ.

Table1. Leakage parameters for LOCA analysis

Input	Calculated results (duration time : flow rate)
Containment leakage flow rate (Vol% per day)	Containment leakage - 0 ~ 24 hours : 0.1 - 24 ~ 720 hours : 0.05
Containment purge system leakage flow rate (cfm)	Before containment isolation: strongly conservative assumption (flow rate is sonic velocity half) - 0 sec ~ 5 sec : 11.681e+03 After containment isolation - 5sec ~ 720hours : 0.000e+00
Recirculation Sump leakage flow rate (cfm)	HVAC filter efficiency: 99.0 % HVAC flow rate : 1.200e+01 Sump leakage : 5.500e-03 Valve leakage : 1.200e-03

Table2. Removal/Decontamination parameters in compartments

Input	Calculated results
Removal rate or Decontamination	Elemental Iodine removal rate - Main spray region : 20

Factors	- 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

Table3. Offsite Dispersion Factors by PAVAN

Input	Calculated results (sec/m^3)
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)

3.2. Dose Analysis Results of EAB and LPZ

Fig. 2 and Fig. 3 are resulted from EAB dose analysis. Fig. 4 and Fig. 5 are resulted from LPZ dose analysis.
From these results, containment leakage, purge leakage and sump leakage scenarios are compared in each other. From Fig2 to Fig.5, dose analysis results show the strong effects in the containment leakage scenarios. The contribution of containment leakage scenarios is 98.5% at EAB and 97.6 % at LPZ in the case of thyroid dose. In the case of whole body dose, the contribution of containment leakage case is over 99.8 % .
According to R.G. 1.195, the dose limits are thyroid 300rem and whole-body 25rem.
In this study, the EAB results are 220 rem of thyroid dose and 10 rem of whole body dose. The LPZ results are 110 rem of thyroid dose and 1.38 rem of whole body dose.
From Table 4, the safety margin is ranged 30 % ~ 60.4% in the containment leakage scenario of EAB.
And also, in the case of same scenario of LPZ, the safety margin is ranged 63.3 % ~ 92%.
Both of EAB and LPZ have same trends in the radiation dose effects. According to event sequence of FSAR, the containment scenario (or containment leakage scenario) keep going until the final stage of LOCA of the duration of 30 days considering the maximum design leak rate of the technical specification of NPP. Because of that, the dose effect of the containment leakage scenario is stronger than any other case. Otherwise, the containment purge release scenario and the sump leakage scenario are very small and within 2% in the case of distribution and the dose effect. This small fraction of effects is due to the short duration time and the small release fraction of fission products.

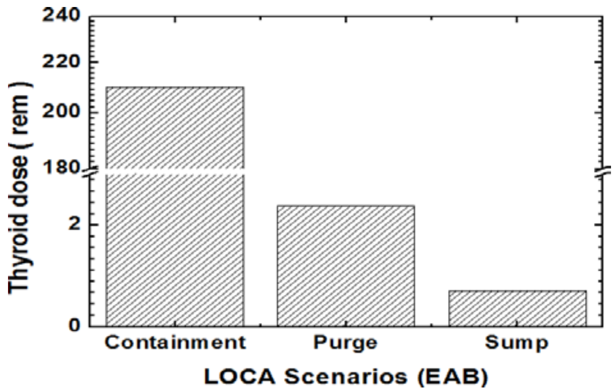

Fig. 2 Thyroid dose results in EAB

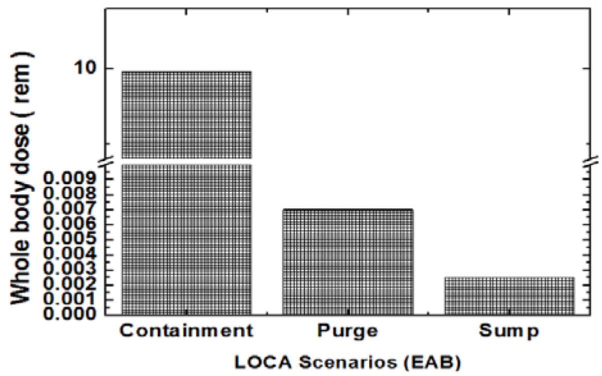

Fig. 3 Whole body dose results in EAB

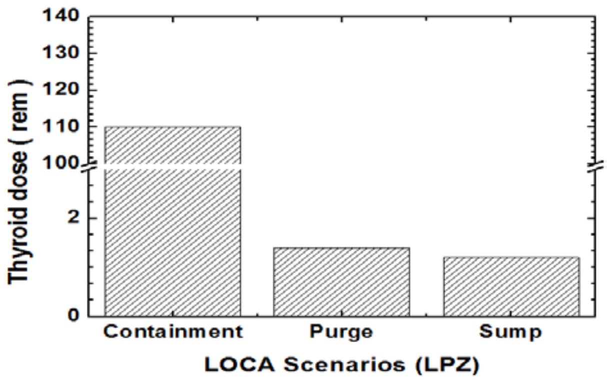

Fig. 4 Thyroid dose results in LPZ

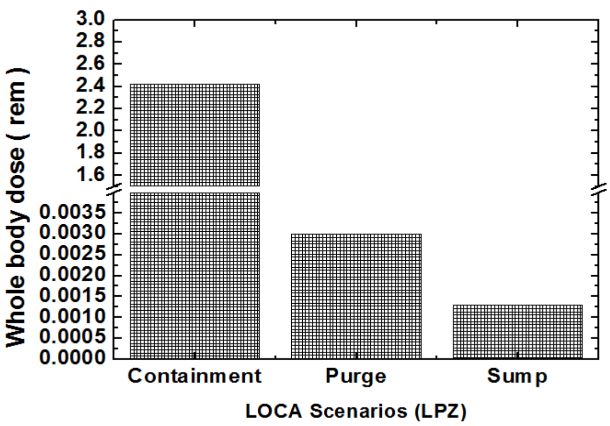

Fig. 5 Whole body dose results in LPZ

Table4. Safety margin/contributions in each scenario

Location	Safety Margin & Contributions
EAB (%)	Containment leakage (Margin / Contribution) - Thyroid : 30.00 / 98.50 - Whole body : 60.40 / 99.99 Containment purge (Margin / Contribution) - Thyroid : 99.20 / 1.11 - Whole body : 99.90 / 0.008 Sump leakage (Margin / Contribution) - Thyroid : 99.70 / 0.30 - Whole body : 99.99 / 0.002
LPZ (%)	Containment leakage (Margin / Contribution) - Thyroid : 63.3 / 97.6 - Whole body : 92 / 99.8 Containment purge (Margin / Contribution) - Thyroid : 99.5 / 1.3 - Whole body : 99.9 / 0.12 Recirculation Sump (Margin / Contribution) - Thyroid : 99.6 / 1.1 - Whole body : 99.9 / 0.08

4. CONCLUSIONS

LOCA dose analysis and offsite atmospheric dispersion factors are evaluated by RADTRAD code and PAVAN code. The main three leakage scenario are compared one another in the view of the safety margin and the contribution of radiation dose. The results of comparison show the strong effect of containment leakage scenario. From this study, 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. Thyroid dose safety margin is ranged from 30% to 63.3% in the case of containment leakage scenario.
d. Whole body dose safety margin is ranged from 60.4% to 92% in the same scenario.
e. Containment leakage scenario has very strong effect and the effect contribution is over 97%.
f. The purge leakage and the sump leakage has small fraction in the view of radiation dose effect and is below 2 %.
g. The maximum contribution of containment leakage scenario is over 99.9 %.

REFERENCES

[1] Final Safety Analysis Report.
[2] Seung Chan LEE, “LOCA Analysis Modeling with RADTRAD code, KNS Spring Meeting, May (2019).
[3] USNRC, “Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Reactors”, R. G. 1.195, May (2003).
[4] NUREG/CR-6604, “Simplified Model for RADionuclide Transport and Removal and Dos Estimation”, (2002).