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The Study for Dose Effect Analysis of Control Rod Ejection Accident

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1. INTRODUCTION

In the final safety analysis report(FSAR), various kinds of design basic accidents(DBA) are introduced. The one of the DBAs is control rod ejection accident (REA).

The specific characteristic of REA is that the reactivity explosion is much more than any other scenario cases.

Because of that, the fuel failure may be appealed from the accident in short duration.

In the case of REA, the rod system error makes its position to be changed into the region out of original position. The duration time is within 1 sec. During this time, the break of reactivity balance in core cause the thermal power's rapid increase until Doppler feedback and moderator temperature feedback are appeared.

At that time, the fuel enthalpy is in excess of the regulation limit or some fuels experience DNB in core.

These kinds of fuels are assumed failed state.

Because of that, the dose estimation related to safety analysis is needed.

In this study, the dose effect analysis in REA is introduced and specific modeling is established.

The concept of REA modeling is introduced in the view of RADTRAD input. In this study, REA modeling, offsite atmospheric dispersion factor, dose estimation, and safety margin are estimated regulatory guide 1.183(R.G. 1.183) and 1.23(R.G. 1.23). The calculation of offsite atmospheric dispersion factor is carried out by PAVAN code [1-5].

2. METHODOLOGY

2.1. REA analysis Concept

The design basis rod ejection accident is analyzed using a conservative set of assumptions and as-built design inputs. The input values of the critical design inputs are conservatively selected to make an appropriate prudent safety margin against large uncertainties in facility parameters. In order to simulate the radioactive material transport, atmospheric dispersion factor are calculated using meteorological data during more than 2 years. The REA analysis is performed using the guidance in Regulatory Guide 1.183 and its Appendix H.

In this analysis, the RADTRAD 3.03 is used to calculate the potential radiological consequences of the REA.

The validation and verification (V&V) of the RADTRAD code is addressed.

The REA dose is determined by summing the results from the containment leakage (iodine and noble gas), the primary to secondary leakage (iodine and noble gas) and the secondary liquid iodine leakage.

RG 1.183, Appendix H, Section 3, the following two release cases are introduced:

• Containment Leakage Release: 100% of the activity released from the fuel is assumed to be
released instantaneously and homogeneously throughout the containment atmosphere and available for release to the environment.

• Secondary System Release: 100% of the activity released from the fuel is assumed to be completely dissolved in the primary coolant (i.e., Reactor Coolant System [RCS]) and available for release to the environment through the secondary system. No additional release paths other than containment leakage and secondary side releases are required to be considered per RG 1.183, Appendix H.

Licensed thermal power level of 2,815 MWt is used and multiplied by factor of 1.02.

In this analysis, the thermal power level of 2,872 MWt (2,815X1.02) providing a 2% safety margin for power uncertainty.

In fission product release, noble gas of 100% and iodine of 50% are assumed from fuel inside to the containment atmosphere. In this case, the fuel failure is 1.0% [1-5].

2.2. Offsite Dispersion Factor Modeling

In REA modeling, the main 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 pathways, fission products release 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.

In PAVAN code, the necessary meteorological data is about recently 4 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, 200,000 data set over 4 years 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.

2.3. REA Analysis Modeling by RADTRAD code

REA analysis modeling is carried out by RADTRAD code. RADTRAD code is licensed and designed by US NRC.
Fig.1 shows the frame of REA modeling concept including the containment leakage model and RCS to secondary system leakage model.
Dotted lines are the containment leakage frame and solid lines are RCS to secondary system leakage frame.
In the environment component of Fig.1, radioactive material's dispersion behavior is used. This behavior can be simulated by the offsite dispersion factor using PAVAN code calculation.

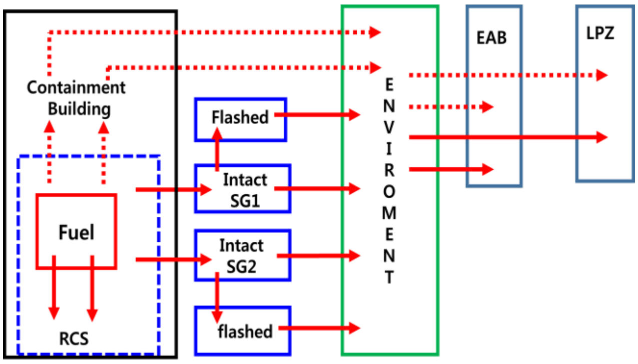

Fig. 1 REA modeling concept in RADTRAD code

The fission products released from the core is assumed to mix instantaneously and homogeneously in the containment volume. The design inputs for the transport in the primary containment are shown in Table 1.
During the first 24 hours the containment is assumed to leak at its maximum technical specification leak rate and at 50% of this leak for duration residual time of the accident.

2.4. Containment Design Input Parameters of REA Analysis

Table 1 show the initial leak rate range 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. Decontamination factors include natural deposition and mixing phenomena in the free volume of containments. The containment design input parameters for REA analysis are shown in Table1.

Table1. Range of containment design parameters for REA 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 - Natural deposition : 0~10 Iodine Decontamination Factor - Iodine by deposition : 100
Containment internal Volume (cubic feet)	Free volume : 2.727e+06
RCS to Secondary System leakage (gpm)	RCS to SG tube : 0.5 ~ 1.0

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. Here, the iodine and the noble gases leak from core to containment building atmosphere and go through the containment leak pathway into environment.

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
RCS to Secondary System leakage (gpm)	RCS to SG tube : 1.0
Removal rate or Decontamination Factors	Natural deposition removal rate - Unsprayed region : 5.50 Iodine Decontamination Factor - Iodine by deposition : 100
Offsite Dispersion Factors (sec/cubic meter)	EAB : 5.700e-04 (0~2hours) LPZ : 3.631e-05(0~8hours) 2.377e-05(8~24hours) 1.250e-05(24~96hours) 4.100e-06(96~720hours)

3.2. Parameters of the RCS to Secondary System Leakage Model

The iodine and the noble gases leak from RCS to SG tube and go through the SG MSSV into environment. In the SG to environment pathway, iodine directly goes from SG to environment.
In this time, RCS to SG leak rate is 1.0 gpm and SG to environment leak rate is dependent on flashing fraction.

3.3. Results from Dose Calculation EAB and LPZ in REA Analysis

Table 3 shows the final results of REA analysis. According to R.G. 1.183, the dose limit is 6.3 rem at TEDE. In this study, the results of EAB are 1.74. The results of LPZ are 1.13 rem.

The both of EAB and LPZ are meet the dose criteria with the safety margin of 60% ~ 85.3% in TEDE.

Table3. Calculation results of REA analysis

Location	Results of REA analysis
EAB : TEDE (rem)	Containment leakage model : 1.7 RCS to SG goes to environment leakage model : 0.04 Total : 1.74
LPZ : TEDE (rem)	Containment leakage model : 1.1 RCS to SG goes to environment leakage model : 0.03 Total : 1.13
Dose Criteria: TEDE (RG 1.183) (rem)	EAB & LPZ : 6.3

4. CONCLUSIONS

REA analysis modeling is carried out by RADTRAD code. And offsite atmospheric dispersion factor is calculated by PAVAN. The main pathways as the containment leakage model and the RCS to SG through the environment leakage model are selected and simulated.

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

a. Offsite atmospheric dispersion factor of EAB is 5.700e-04 sec/cubic meter in EAB.
b. Offsite atmospheric dispersion factor of LPZ is ranged 4.100e-06 ~ 3.631e-05.
c. The safety margin of TEDE is ranged from 60% to 85.3%.
d. The confined case is containment leakage model because of release time and of release amount.
e. The maximum contribution of containment leakage model is over 70%.

From some conclusions we know that the contribution of containment leakage model is stronger than RCS through SG to environmental release model in REA dose effect analysis.

REFERENCES

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