Evaluation of Offsite Doses for Kori 3&4 Design Basis Accidents using RADTRAD Code

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1. Introduction

The RADTRAD code was developed by NRC to evaluate the doses for design basis accidents (DBAs) [1]. The code model estimates doses at offsite locations such as the exclusion area boundary (EAB), low population zone (LPZ) and in the control room. The code has two source terms options to describe fission products release from the RCS ; 1) those specified in TID-14844[2]. 2) those specified in NUREG-1465[3] as an alternative source terms. As radioactive material is transported through the containment, the user can account for sprays and natural deposition that may reduce the quantity of radioactive material. Material can flow between buildings, from buildings to environment, or into control rooms through high-efficiency particular air filters, piping, or other connectors. Also, the user can easily prepare and assess the offsite doses using graphic user interface (GUI). Hence it is anticipated that the code will be used to estimate attenuation of source terms as a result of modification for a facility or accident sequence.

In current Kori 3/4 FSAR, offsite doses for DBAs were performed by hand calculations. Because of hand calculations with using conservative assumptions and methodology, the offsite doses by some accidents are very close to their acceptance criteria. In order to improve the results of offiste doses for DBAs and simplify calculation procedures, the RADTRAD code is applied to assess the offsite doses for Kori 3/4 FSAR DBAs. The loss of coolant accident (LOCA), steam generator tube rupture (SGTR) and rod ejection accident (REA) are generally classified as the most limiting accidents from the offsite doses viewpoint. In this paper, the LOCA, SGTR and REA were estimated with RADTRAD code. The results were compared with the current Kori 3/4 FSAR and the applicability of RADTRAD was verified.

In section 2, the important data for offiste doses briefly described. In section 3, the LOCA, SGTR and REA offsite doses using RADTRAD were evaluated and the results were compared with current Kori 3/4 FSAR results. Finally section 4 summarizes the conclusions obtained in this study.

2. Important data

To evaluate the offsite doses, there are three important factors; 1) **Source terms**. Source terms are important to offsite doses since the source term determine how much radioactive material may be released to environment. The Kori 3/4 FSAR source terms, which are based on the TID-14844 are used to evaluate offsite doses for DBAs. Table 1 presents core source terms. 2) **Atmospheric dispersion factors (ADFs)**. The ADFs are important to offsite doses since radioactive material reach EAB, LPZ and control room in proportion to ADFs after the radioactive material release from nuclear power plant due to postulated accidents. Table 2 summarizes ADFs at EAB, LPZ and control room. Also the breathing rates are presented at Table 2. 3) **Dose conversion factors (DCFs)**. The DCFs are important since the thyroid and whole body doses are calculated by multiplying integral radioactive release (Ci) by DCFs. Table 3 presents thyroid and whole body DCFs.

Table 1. Core source terms

Isotope	Core Activity, Ci
I-131	8.00E+07
I-132	1.20E+08
I-133	1.70E+08
I-134	1.80E+08
I-135	1.50E+08
Kr-83m	9.90E+06
Kr-85m	2.20E+07
Kr-85	5.20E+05
Kr-87	4.10E+07
Kr-88	5.80E+07
Kr-89	7.20E+07
Xe-131m	5.60E+05
Xe-133m	2.30E+07
Xe-133	1.60E+08
Xe-135m	3.30E+07
Xe-135	3.40E+07
Xe-138	1.40E+08

Table 2. ADFs and breathing rates

Time period	ADFs, s/m^3			Breathing rate, m^3/s
	EAB	LPZ	Control room	
0 ~ 8 hr	6.42E-04	5.05E-05	6.82E-03	3.47E-04
8 ~ 24 hr	-	4.78E-06	2.52E-03	1.75E-04
1 ~ 4 days	-	1.83E-06	9.84E-04	2.32E-04
4 ~ 30 days	-	7.59E-07	4.14E-04	

3. RADTRAD evaluations

The various postulated accidents result in releases of radioactivity to environment. Among these, as a result of reviewing Kori 3/4 FSAR offiste doses, the LOCA, SGTR and REA are identified as the most limiting accidents from the offsite doses viewpoint. Hence, the detailed RATRAD evaluations were performed in this section.

Table 3. Dose conversion factors

Isotope	Whole body rem·m^3/Ci·sec	Beta-Skin rem·m^3/Ci·hr	Thyroid rem/Ci
I-131	8.72E-02	1.14E+02	1.49E+06

I-132	5.13E-01	4.75E+02	1.43E+04
I-133	1.55E-01	2.65E+02	2.69E+05
I-134	5.32E-01	3.32E+02	3.73E+03
I-135	4.21E-01	4.64E+02	5.60E+04
Kr-83m	2.40E-06	0.00E+00	-
Kr-85m	3.72E-02	1.67E+02	-
Kr-85	5.25E-04	1.53E+02	-
Kr-87	1.87E-01	1.11E+03	-
Kr-88	4.64E-01	2.70E+02	-
Kr-89	5.25E-01	1.15E+03	-
Xe-131m	2.92E-03	5.43E+01	-
Xe-133m	8.00E-03	1.13E+02	-
Xe-133	9.33E-03	3.49E+01	-
Xe-135m	9.92E-02	8.11E+01	-
Xe-135	5.72E-02	2.12E+02	-
Xe-138	2.81E-01	4.71E+02	-

3.1 Assumptions

Following assumptions are used to assess DBAs offsite doses using RADTRAD code.

1. Containment leakage rate of 0.1 volume %/day for the first 1 day and 0.05 volume %/day thereafter. (LOCA, REA)
2. Iodine removal by the containment spray until a decontamination factor of 100 achieved. (LOCA)
3. 100 % of the core noble gas and 25 % of the core iodine are immediately available for leakage from the containment. (LOCA)
4. 50 % of the iodine released from the RCS is assumed to plate out on the surfaces inside the containment. (LOCA, REA)
5. Pre-existing iodine spike of 60 μCi/g dose equivalent of I-131 is assumed. (SGTR)
6. 0.25 % of the core melt is assumed of which 100 % of the iodine and noble gases are released are released to the RCS. (REA)
7. 10 % of the fuel failure due to DNB is assumed. (REA)

3.2 RADTRAD analyses

Using important data in section 2 and assumptions, RADTRAD runs were performed to evaluate LOCA, SGTR and REA offsite doses. Table 4, 5 and 6 summarized the RADTRAD results for LOCA, SGTR and REA respectively and compared with current FSAR results. Ref. 1 considered a match within 5 % as acceptable in the verification of RADTRAD against other analyses in complex accident scenarios. The comparison results are within this limit.

Table 4 LOCA results using RADTRAD code

Release Path	Location	Dose Type	FSAR dose, rem	RADTRAD Dose, rem	Difference, %
Cont.	EAB	Thyroid	1.23E+02	1.19E+02	3.6
		Whole Body	2.57E+00	2.67E+00	3.7
	LPZ	Thyroid	2.35E+01	2.27E+01	3.6
		Whole Body	3.97E-01	4.05E-01	2.1
	CR	Thyroid	2.81E+01	2.78E+01	0.8
		Whole Body	1.05E+00	1.07E+00	2.5
		Beta skin	1.68E+01	1.72E+01	2.4
ECCS Leakage	EAB	Thyroid	4.79E+00	4.81E+00	0.4
		Whole Body	1.35E-02	1.37E-02	1.9
	LPZ	Thyroid	2.59E+00	2.59E+00	0.1
		Whole Body	3.78E-03	3.83E-03	1.2
Purge	EAB	Thyroid	1.42E+01	1.42E+01	0.1
		Whole Body	4.83E-03	4.82E-03	0.1
	LPZ	Thyroid	1.12E+00	1.12E+00	0.2
		Whole Body	3.80E-04	3.79E-04	0.1

Table 5. SGTR results using RADTRAD code

Case	Location	Dose Type	FSAR dose, rem	RADTRAD Dose, rem	Difference, %
PIS	EAB	Thyroid	96.5	9.56E+01	0.91
		Whole Body	1.82E-01	1.82E-01	0.27
	LPZ	Thyroid	7.74	7.93E+00	2.50
		Whole Body	1.46E-02	1.47E-02	0.82

Table 6. REA results using RADTRAD code

Release path	Location	Dose Type	FSAR dose, rem	RADTRAD Dose, rem	Difference, %
Cont.	EAB	Thyroid	19.970	20.013	0.22
		Whole Body	0.088	0.090	1.49
	LPZ	Thyroid	7.375	7.390	0.20
		Whole Body	0.0171	0.0169	0.95
SG	EAB	Thyroid	1.841	1.844	0.14
		Whole Body	4.37E-02	4.32E-02	1.23
	LPZ	Thyroid	0.1448	0.1450	0.14
		Whole Body	3.44E-03	3.39E-03	1.24

4. Conclusion

In order to verify the applicability of RADTRAD code, the offsite doses for Kori 3/4 LOCA, SGTR and REA were evaluated using RADTRAD code. From Ref. 1, a match within 5 % is acceptable in the verification of RADTRAD against other analyses in complex accident scenarios. Comparing the RADTRAD analyses results with FSAR results, the difference are within 5 %. Therefore, RADTRAD code is applicable to use evaluating offsite doses for DBAs.

REFERENCES

[1] RADTRAD: A Simplified Model for RADionuclide Transport and Removal And Dose Estimation, NUREG/CR-6604 Dec. 1997, Supplement 1 June 1999, Supplement 2 Oct. 2002.

[2] Calculation of Distance Factors for Power and Test Reactor Sites, TID-14844 1962.

[3] Accident Source Terms for Light Water Nuclear Power Plants, NUREG-1465 1995.