Spiking Effect in Steam Generator Tube Rupture Analysis at Uljin Units 3, 4

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1. Introduction

In order to evaluate the effects of the iodine spiking factor, the radiation dose of a steam generator tube rupture (SGTR) is calculated and reviewed. The RADTRAD code[1] is used for evaluating the radiation dose of a SGTR. The source terms and the inventory of the fission products at Uljin 3, 4 are calculated. The pre-existing iodine spike (PIS) and the event-generated iodine spike (GIS) are determined using the spiking factor (or spiking component). The spiking effect is reviewed in this study according to technical specifications (Tech. Spec.), dose limit, and the limiting condition of operation (LCO).

2. Methods and Results

To evaluate radiation dose, there are three important factors such as source terms, atmospheric dispersion factors (ADFs), and dose conversion factors (DCFs). The terms are based on Uljin 3, 4 FSAR[2].

2.1 Input Parameters for SGTR

Table 1 presents the basic input parameters of a SGTR. Generally, the core source term is calculated using the fuel gap activity, shown in Table 1. Therefore, the value is 10% of the inventory of fission products. Table 2 summarizes the inventory of fission products considering the spiking factor.
Table 3 and Table 4 present the flow rate in the following locations: the RCS, steam generator, and the environment. Table 5 shows the thyroid and whole body DCFs. The DCFs are important since the thyroid and whole body doses are calculated by multiplying the integral radioactive release (Ci) by DCFs.

Table 1. Basic Input Parameters for SGTR

Input parameters	Value	
Thermal Power	2871.3	Mwt
Fuel Gap Activity Fraction	0.1	
Fuel Failure rate	0.01	
Radial Peaking factor	2.0	
RCS Liquid Inventory	1.97E+5	ft^3
Iodine Escape rate	1.30E-8	sec^{-1}
Iodine spiking factor(GIS)	500	
GIS equilibrium time	1800	sec
PIS Dose Equivalent Concentration	60	uCi/gram
GIS Dose Equivalent Concentration	1.0	uCi/gram
Secondary Coolant concentration	0.1	uCi/gram
EAB	700	m
Breathing rate	3.47E-4	m^3/sec
Atmospheric Dispersion Factor	1.96E-4	sec/m^3

Table 2. Iodine Source Terms using Spiking Factors

Nuclide	1.0uCi /gram	RCS	Iodine	Iodine	1.0uCi /gram Appearance	Spiking	500uCi /gram
	D.E.I-131	mass	Activity	Removal	D.E. I-131	Factor	Iodine
	(uCi/gram)	(gram)	(Ci)	(min^{-1})	(Ci/min)		(Ci/min)
I-131	8.305E-01	1.97E+05	1.636E-01	1.002E-03	1.639E-04	500	0.0819
I-132	1.917E-01	1.97E+05	3.776E-02	5.965E-03	2.252E-04	500	0.1126
I-133	8.624E-01	1.97E+05	1.698E-01	1.497E-03	2.543E-04	500	0.1271
I-134	7.510E-02	1.97E+05	1.479E-02	1.412E-02	2.089E-04	500	0.1044
I-135	3.673E-01	1.97E+05	7.236E-02	2.690E-03	1.946E-04	500	0.0973

Table 3. RCS Release (RCS →SG)

RCS to Ruptured Steam Generator (Flow Rate)			
Time	Time	Flow rate	Flow rate
(sec)	(hours)	(cm^3/min)	(ft^3/min)
0	0	1462000	51.63004
445	0.123611	1215000	42.90732
465	0.129167	1454000	51.34753
1700	0.472222	1534000	54.1727
2800	0.777778	1426000	50.35871
3000	0.833333	1140000	40.25872
3500	0.972222	650500	22.97219
3590	0.997222	0	0
7200	2	0	0
28800	8	0	0

Table 4. Steam Release (SG→Environment)

Intact SGs to Environment (Steam Release)					
Time	Time	Flow rate	Flow rate	Partition Factor	Transfer Rate
(sec)	(hours)	(cm3/min)	(ft3/min)	(Iodine)	(ft3/min)
0	0	110800	3.912865	0.0001	0.000391287
2800	0.777778	26320	0.929482	0.01	0.00929482
3500	0.972222	48440	1.710642	0.01	0.017106425
7200	2	14750	0.520891	0.01	0.005208913
28800	8	6260	0.22107	0.01	0.002210698
Ruptured SG to Environment (Steam Release)					
Time	Time	Flow rate	Flow rate	Partition Factor	Transfer Rate
(sec)	(hours)	(cm3/min)	(ft3/min)	(Iodine)	(ft3/min)
0	0	30320000	1070.741	0.0001	0.107074069
465	0.129167	2076000	73.31325	0.01	0.733132481
1700	0.472222	0	0	0.01	0
7200	2	33520	1.183748	0.01	0.011837476

Table 5. Dose Conversion Factors[3, 4, 5]

Radio Isotope	Whole body ($rem.m^3$/Ci.sec)	Beta skin ($rem.m^3$/Ci.hr)	Thyroid (rem/Ci)
I-131	8.72e-4	1.14e+2	1.43e+4
I-132	5.13e-1	4.75e+2	2.69e+5
I-133	1.55e-1	2.65e+2	3.73e+3
I-134	5.32e-1	3.32e+2	5.60e+4
I-135	4.21e-1	4.64e+2	
Kr-85m	3.72e-2	1.67e+2	
Kr-85	5.25e-4	1.53e+2	
Kr-87	1.87e-1	1.11e+3	
Kr-88	4.64e-1	2.70e+2	
Kr-89	5.25e-1	1.15e+3	
Xe-131m	2.92e-3	5.43e+1	
Xe-133m	8.00e-3	1.13e+2	
Xe-133	9.33e-3	3.49e+1	
Xe-135m	9.92e-2	8.11e+1	
Xe-135	5.72e-2	2.12e+2	
Xe-138	2.81e-1	4.71e+2	

2.2 Assumptions

The following assumptions[2] are employed to assess SGTR offsite doses using RADTRAD code.

1. Radiation dose of a SGTR is calculated using the following two assumption:
   - GIS case: Iodine spiking at the start of an accident
   - PIS case: Iodine spiking at normal conditions
2. Dose equilibrium conditions are 1.0 uCi/gram in the primary coolant and 0.1 uCi/gram in the secondary coolant of the limiting condition of operation.
3. GIS spiking factor is 500.
4. In the PIS case, the dose equivalent I-131 concentration is 60 uCi/gram, according to the NPP technical specifications.
5. During the accident, the intact steam generator has the release rate of 0.6 gpm (2.27 L/ min).
6. The flashed condition is assumed to have a decontamination factor of 100.
7. Dose calculation includes the total release accumulation of the intact steam generator and the faulty steam generator.
8. In this study, the atmosphere dispersion factor is referenced from the FSAR.
9. The pathway between the system and environment has a decontamination factor of 1.
10. The continuous time is 8 hours (this time is sufficient to recover from the accident).

2.3 Results of RADTRAD Analysis

All data of Table 1 through to Table 5 are put into the data form of RADTRAD code.
On the basis of these data, the final results are shown in Table 6. Table 6 summarizes the RADTRAD results for a SGTR. In Table 6, the present study is verified in comparison with current FSAR results. The difference ranges from 0.6% to 4.2%. Ref. 1 considered correlation within 5% as an acceptable level in verification of RADTRAD code against other analyses (or other studies). The present results are thus in good agreement with the FSAR.

Table 6. Results of SGTR Analysis in Uljin 3, 4

Case	Offsite	Dose	FSAR	This work	Difference
GIS	EAB	Thyroid	1.89	1.97	4.2%
	EAB	Whole body	5.58e-2	5.8e-2	3.9%
PIS	EAB	Thyroid	7.85	7.9	0.6%
	EAB	Whole body	6.37e-2	6.49e-2	1.8%
GIS	LPZ	Thyroid	1.16e-1	1.17e-1	0.8%
	LPZ	Whole body	3.09e-3	3.12e-3	1.0%
PIS	LPZ	Thyroid	4.30e-1	4.33e-1	0.7%
	LPZ	Whole body	3.51e-3	3.6e-3	2.5%

2.4 Spiking Effect

Using the data in Table 1 through Table 5 and increasing the RCS concentration from 1 uCi/gram to 1000 uCi/gram, the RCS concentrations reached to the GIS limitation and the PIS limitation are calculated. Fig. 1 summarizes the sensitivity results of the spiking effect (GIS effect and PIS effect). From these results, in the case of only a fuel failure condition, the RCS concentration reached to the GIS limiting point is 807 uCi/gram. In the case of the spiked condition, the concentration points reached to the GIS limitation and the PIS limitation are 10 uCi/gram and 20.1 uCi/gram, respectively. From a comparison between the GIS case and fuel failure case (normal condition), the spiking effect is more than 80 times higher relative to the normal condition. In the case of the PIS case, the spiking effect is more than 40 times higher relative to the normal condition.

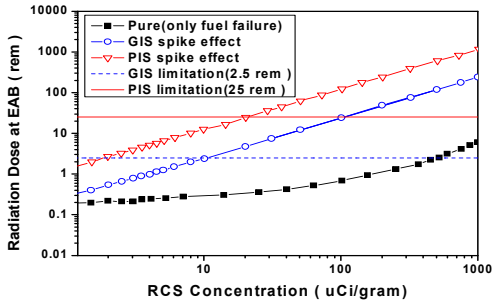

Fig. 1 Comparison between spiked condition and normal condition

3. Conclusions

In order to evaluate the spiking effect in a SGTR analysis, RADTRAD code is used and verified. From Ref. 1, correlation within 5% is deemed acceptable in the verification of RADTRAD against other analyses in complex accident scenarios. Comparing the RADTRAD analysis results with the FSAR results, the difference is within this range. Therefore, the RADTRAD code is applicable for use in evaluating a SGTR analysis of DBAs. In the spiking effect, the radiation doses of GIS and PIS are more than 80 times and 40 times higher, respectively, relative to the normal condition.

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