Application of Alternative Source Term for Locked Rotor Event of Kori unit 1

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1. Introduction

Alternative source term(AST) rule was made in 2000 based on the extensive research after TMI-2 incident. The base is that conventional TID-14844 source term is overly and unrealistically conservative. AST has been widely applied in US plants and moreover new plants such as US-EPR also uses AST for design certification in US.

This study is to get insight on the effect of AST application to Korean plants and thus ultimately seeks to increase safety margins for operating margins.

Radiological consequence analyses are performed for Locked Rotor Event(LRA) of the Kori Unit1 using AST(Regulatory Guide 1.183) and TID-14844 source terms. The focus of this study is to obtain most limiting parameters for AST and TID cases. Table 1 shows the comparison of TID with AST for PWRs. LRA is selected since it is most limiting with respect to radiological consequences of operating Westinghouse type plants.

SRP(Standard Review Plan) 6.5.2. Rev.02. methodology is used to calculate inventory of Iodine inside the containment [1-3].

Table 1. Comparison of TID with AST for PWRs

	TID	AST
Core fractions released into containment	Noble gases (Xe,Kr) – 100% Iodine - 50%, half of this amount plates out, thus 25% Solids – 1%	Noble gases – 100% Iodine - 40% Cesium – 30% 95% CsI Tellurium – 5% 4.85% elemental IBarium – 2% 0.15% organic I Others – 0.02 to 0.2% Solids – Treated as aerosol. The entire source term except elemental iodine, organic iodine, and the noble gases is treated as solids.
Rate of release	Released Instantaneously	Released over 1.8 hours Gap: 30s – 0.5h Early In-Vessel: 0.5-1.8h
Iodine chemical and physical form	91% inorganic vapor 4% organic vapor 5% aerosol	4.85% inorganic vapor 0.15% organic vapor 95% aerosol
Accidents Analyzed	Offsite, All CR, LOCA	Offsite, All CR, All
Dose Limits CR Offsite – LOCA	30 Rem Thyroid (SRP 6.4 limit; 50 in RG 1.195) 5 Rem WB 300 Rem Thyroid 25 Rem WB	5 Rem TEDE 25 Rem TEDE

2. Methods and Results

2.1 General Description of the Event

This LRA analysis postulates the instantaneous seizure of a RCP(Reactor Coolant Pump) rotor, where the reactor is tripped on the subsequent low flow signal. Following the trip heat stored in fuel rods continues to pass into the core coolant, causing the coolant to expand. At the same time, heat transfer to the shell side of the steam generator is reduced, first because the reduced flow results in a decreased tube side film heat transfer coefficient, and then because the primary reactor coolant in the tubes cools down while the shell side temperature increase (turbine steam flow is reduced to zero upon plant trip). The effect cause the expansion of reactor coolant, the reduced heat transfer in the SG(Steam Generator), and the pressure increase throughout the RCS(Reactor Coolant System)[2,3].

The insurgence into the pressurizer causes a pressure increase, which in turn actuates the spray system, opens PORV(Power-Operated Relief Valve). The SG PORVs are designed for reliable operation in course of the accident.

2.2 Analytical Assumptions

Followings are assumptions used for calculating radiological consequence of LRA for Kori Unit 1.

(a) Core inventory is based on a DBA power level of 1,758 Mwt, which is 102% of the Rated Thermal Power.
(b) 65% of the fuel is damaged and failed during the initiation of LRA.
(c) No fuel melts following the postulated LRA.
(d) 5% of the core inventory of noble gases and iodines are released from the fuel gap, excluding I-131 and Kr-85, where 8% and 10% are respectively released. The other fractions of nuclide groups contained in the fuel gap are detailed in Regulatory Guide 1.183.
(e) Iodines are 97% particulates and 3% organic
(f) The activity released from the fuel and from either the gap or from fuel pellets is assumed to be rapidly mixed with reactor coolant within the vessel.
(g) SG PORV release finishes at 8 hours after which core residual heat can be removed by auxiliary feed-water system

2.3 Release Rates and Partitioning Fractions

RCS(Reactor Coolant System) activity is released to the secondary coolant by primary-to-secondary leak rate. The design leak rate of Kori Unit 1 is 0.175 gpm per intact SG(total 0.35 gpm) and 0.5 gpm for the SG with a failed PORV.

Release to the environment is related with steam from intact SG PORVs and direct release from the SG with a failed PORV. R.G. 1.183 states that amount of activity released to environment should be based on partitioning fraction between the liquid and gas states of water. The partitioning fraction of iodine is 0.01 from R.G. 1.183. Nuclides from core other than iodine are Cs, Rb, and Noble gases. For these nuclides, partitioning fraction is 0.0055[3, 4].

2.4 Dose Calculation

The revised dose conversion Factor from U.S. Federal Guidance Report 11&12 are used. RADTRAD 3.03 includes these DCFs in code package database. All the dose calculations are at the EAB(Exclusion Area Boundary) 700m of Kori Unit 1 for worst-two hours [4,5].

To verify this calculation, calculations are done for US plants. Table 2 shows our calculation is correct within 1 %.

Table 2. Verification of the accuracy of this Calculation for Braidwood plants

Items (Dose)	Excelon's Calulations	This Calculations
Whole body	0.1454	0.1453
Thyroid	28.7	28.7
TEDE	1.42	1.43

The focus of these calculations is to obtain most limiting parameters for AST and TID cases. Therefore, radiological consequences for diverse parameter cases of LRA of Kori Unit 1 are performed using AST and TID source terms [1-3]. Table 3-1 and 3-2 show the results.

Table 3-1. Conditions for LRA analysis for Kori Unit 1

Case No.	Base of the parameters	Fuel failure (%)	R.G. 1.25	Part. fraction	Type* (Iodine)	Source term	Leak Rate**
1	FSAR	100	No	0.01	E	TID	1.00
2	FSAR	100	Yes	0.01	E	TID	1.00
3	FSAR	65	Yes	0.01	E	TID	0.35
4	FSAR	65	Yes	0.01	P	AST	1.00
5	FSAR	65	Yes	0.01	P	AST	1.00
6	FSAR	65	Yes	0.01	E	TID	1.00
7	FSAR	65	Yes	1.00	E	TID	1.00
8	FSAR	65	Yes	1.00	P	AST	1.00
9	FSAR	100	Yes	0.01	P	AST	1.00
10	FSAR	100	Yes	0.01	P	AST	1.00

* : E(elemental), P(particulate)

**: Primary to secondary leak rate (gpm)

Table 3-2. Results of calculation for LRA for Kori Unit 1

Case No.	Whole Body (rem)	Thyroid (rem)	TEDE (rem)	Source Term
1	0.45	10.7	-	TID
2	5.7	90	7.6	TID
3	3.91	20	-	TID
4	0.64	5.34	0.805	AST
5	0.64	5.41	0.808	AST
6	0.542	17.5	1.179	TID
7	1.04	134	5.22	TID
8	0.54	14.01	0.89	AST
9	0.98	8.22	1.239	AST
10	0.98	8.31	1.243	AST

The results of this study show that the partitioning fraction and the primary-to-secondary leak rates are more limiting and sensitive.

3. Conclusion

Radiological consequence analyses are performed for Kori unit 1 rocked rotor event using TID and AST methodology. Radiological consequence for AST calculation is very small compared with TID methodology. The minimum reduced dose for AST is about 50% of TID values.

It is concluded that AST source term is very effective to increase operating margin for limiting design basis events of Korean plants.

REFERENCES

[1] US. NRC Regulatory Guide 1.183, "Alternative Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors", July 2000.

[2] "RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation", NUREG/CR-6604(April, 1998), Supplements 1(June 1999) and 2(October, 2002).

[3]FSAR Kori Unit 1.

[4] American Nuclear Society ANS/ANSI-18.1-1999, "American National Standard Radioactive Source Term for Normal Operation of Light Water Reactors", 1999.

[5]U.S. Federal Guidance Report No. 11 & No. 12.(1988-1993).