Transactions of the Korean Nuclear Society Spring Meeting
Jeju Korea, May 17-19, 2017

Study for Thermal Hydraulic and Radiological Effects on Main Steam Line Break in Westinghouse type Nuclear Power Plants

Seung-Chan Lee*, Duk-Joo Yoon
Korea Hydro Nuclear Power Electricity Co., KHNP Central Research Institute, Yuseong-daero 1312 boen-gil, Yuseong-gu, Daejeon 305-343 Korea.
**Corresponding author: eitotheflash@khnp.co.kr*

1. Introduction

In the DBA(design Basic Accident), in the secondary side of the system in NPP, the best confined case is MSLB(Main Steam Line Break). Some fission products are released from the pipe of the main steam line. Specially, FSAR (Final Safety Report) includes radiation dose results of DBAs (Designed Basis Accidents). In this case, the radiological sequence is affected by the condition of the various thermal hydraulic phenomena. In this study, some checking study results are introduced using LOFTRAN calculation results. LOFTRAN code is developed by Westinghouse company to estimate the various non-LOCA thermal hydraulic phenomena for the Westinghouse type NPP. Some results of LOFTRAN code used as input data for calculation of MSLB radiation dose. In this process, some sensitivity results are generated from various dose calculations. Of course, key parameters of radiation dose effect will be introduced through the reflection of various thermal hydraulic conditions such as primary RCS pressure, leak flow rate between primary and secondary side, steam generator's level and liquid volumes and so on. In addition, the sensitivity results are shown regard to Iodine spiking in Main Steam Line Break [1, 2, 3].

2. Methodology and Strategy

Generally speaking, MSLB is affected by Iodine spiking phenomena. Iodine behavior is very complex in calculating the radiation dose. This study is based on Fig. 1 and Fig. 2. [1, 2].

2.1 Application of LOFTRAN code

In this study, LOFTRAN code is used for achieving the key parameters such as the 1th side pressure, steam line break flow, 2th side pressure and SG steam flow out discharge and so on. The input information is based on Westinghouse methods for MSLB. Fig. 1 shows the LOFTRAN solution sequence. For using LOFTRAN , Westinghouse SAS 12.2 are used. Base input deck is used as the example solutions. This method is to make strategy for Westinghouse type MSLB radiation dose analysis.

From Fig. 1, LOFTRAN code can generate some information as like a steam flow through safety valves from each SG during time step, a summation of all steam flow from each SG from time zero, SG pressure, a computed DNBR, and a steam enthalpy and so forth.

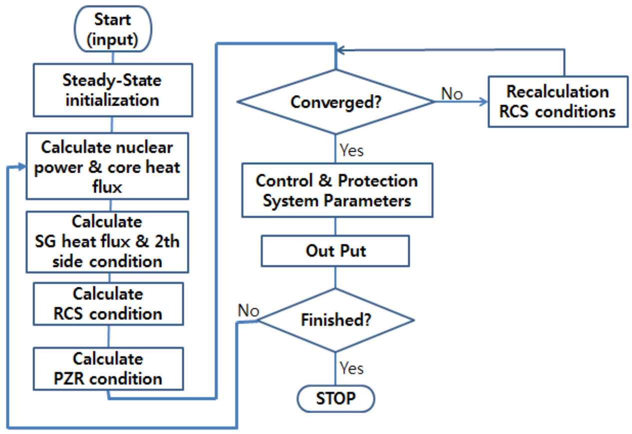

Fig. 1 Block Diagram of LOFTRAN Solution Sequence.

2.2 Radiological Analysis for MSLB

MSLB is the limiting case in the 2th side system of NPP.

Generally speaking, the ruptured position is located on the steam pipe passed through the steam generators. The ruptured pattern is bulletin break style. Radiation dose calculation is made by the work frame in Fig. 2.

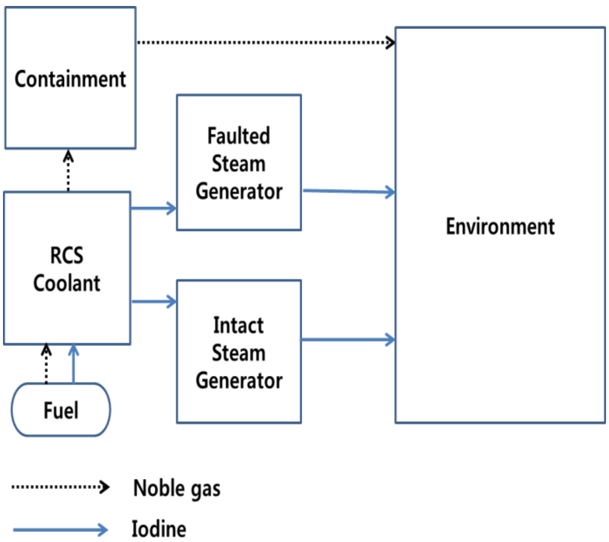

Fig. 2 Main Steam Line Break Radiological Analysis Concept.

In this case, Iodine spiking is very important.

MSLB is strongly sensitive in the case of the leakage between primary coolant and secondary coolant and also a radiation dose rate is strongly impacted in Iodine spiking phenomena [1].

This phenomena is generated from the rapidly pressure change. The reason why a MSLB is selected in this study is the very unstable pressure phenomena. The analysis input parameters of MSLB are shown in Table 1.

From Table 1, PIS (Pre Iodine Spiking) means that Iodine spiking effect is in the starting point before a general accident of MSLB.

Another one, GIS (coincident event-Generated Iodine Spiking) means that Iodine spiking effect is in the beginning after MSLB immediately.

Table 1. Input Parameters for MSLB

Input parameters	Value
Fuel Failure	
-Gap Activity ratio	0.1
-Cladding Failure ratio	0.02
-Radial Peaking Factor(radius)	1.65
Iodine Spiking from Accident	
-RCS Liquid Inventory	1.97E+05 kg
-Iodine Escape Ratio	1.38E-08
-Spiking Factor (PIS case)	500
-Spiking Factor (GIS case)	0.01
-Fuel Failure Ratio	
Dose Equivalent Iodine	0.01
-RCS(PIS case)	60 uCi/g
-RCS(GIS case)	1.0 uCi/g
-Secondary Coolant	0.01 uCi/g
Time during Accident	
-Equilibrium time	1800 sec
-Initial time	7200 sec
-Later time	28800 sec
Exclusion Area Boundary	700 m
Breathing rate	3.47E-4 m^3/sec
Atmospheric Dispersion Factor	1.96E-4 sec/m^3

2.3 Analysis Basics

RADTRAD software is used to implement the phenomena of Iodine spiking effect.

So many conditions are made from RCS concentration based on TS (Technical Specification).

Analysis categories are consisted of four items. These items are below:

a. Spiking effect application
b. Steam flow analysis
c. DNBR estimation
d. Source term generation & dose calculation

In this chapter, the methods of each item are explained. The spiking effect is calculated by the spiking factor and then the escape rate of each fission product is calculated by combination between the source term and steam flow analysis results.

RADTRAD software is designed to calculate offsite dose. Calculation procedure is below:

a. Modeling each compartment
b. Modeling each pathway
c. Generating source term information
d. Making exhalation rate for each fission product per unit time
e. Generating accumulation and timing files
f. Link to fission product library file and editing library files
g. Link to dose conversion information
h. Making input of timely atmospheric dispersion factors
i. Generating the analysis execute file
j. Generating output of calculated results.

Here, dose conversion factors are based on ICRP 30, FGR11 (Federal Guidance Report No. 11) and FGR12.

The external dose conversion factor of deposition effect caught the value of soil surface model in FGR12.

And also the radioactive submersion modeling is made from FGR12 [5, 6].

The some assumptions of the analysis are used as followings [4]:

a. MSLB is calculated using the following two cases:
   - GIS : Iodine spiking at the start of an accident
   - PIS : Iodine spiking before an accident conditions
b. 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.
c. GIS spiking factor is 500.
d. In the PIS case, the dose equivalent I-131 concentration is 60 uCi/gram, according to NPP technical specifications.
e. During the accident, the intact steam generator has the release rate of 0.5 gpm.
f. The flashed condition is assumed to have a decontamination factor of 100.
g. Dose calculation includes the total release accumulation of the intact steam generator and the faulted steam generator.
h. In this study, the atmosphere dispersion factor is referred from the FSAR.
i. The pathway between the system and environment has a decontamination factor of 1.

The continuous time is 2 hours in EAB[4, 5, 6] from FSAR referred from the RG(Regulatory Guide 1.4, 1.195)

2.4 Sensitivity Analysis

The sensitivity analysis is carried out using the data of Lee et al. [1].

To check the radiation dose effect, the specific activity for LCO is estimated using the limit criteria written on the Technical Specification. The first estimation started from the general criteria 1.0uCi/gram. And the specific concentration of the 1-th coolant increase up to 100 uCi/gram. In this process, when the radiation dose result is beyond the criteria, the value is the new limit criteria of FSAR. The values are compared with the values of the other accident conditions such as Table 2.

Table 2. Accident Case for the limit criteria of MSLB

Category of accident	Effective radiation dose limit [rem]
LOOP(GIS)	2.5
LOOP(PIS)	25
LOOP_ADV(GIS)	2.5
LOOP-ADV(PIS)	25

Here LOOP is the mean of Loss of Offsite Power.
The pre-existing iodine spike (PIS) and the event-generated iodine spike (GIS) are determined using the spiking factor 500. The spiking effect is reviewed in this study according to technical specifications (Tech. Spec.), dose limit, and the limiting condition of operation (LCO).

2.5. LOFTRAN Modeling

In order to thermal hydraulic analysis for MSLB, LOFTRAN code is used. MSLB accident has a major weight in modeling steam generator's geometric input because the main phenomena are focused on the 2-th side systems of NPP.
LOFTRAN code has the flexible modeling condition in making a SG geometric modeling.
Here, the user has the ability to model new and different steam generators without having to change the LOFTRAN coding. This option is selected by setting SGTYPE=0. In this study, domestic newly replaced SG condition is reflected by this method. The main geometric parameters are calculated from FSAR of Westinghouse type NPP using reference date. And Master lists are selected in the options of steam flow mode, aux feed water flow mode, main-steam flow mode, and some SG mode modification.

3. Results and Discussions

3.1. LOFTRAN Results

LOFTRAN code has carried out some works. Fig. 3, Fig. 4 and Fig. 5 are resulted from the thermal hydraulic analysis. These results are limiting conditions in radiation dose calculations. The reason is because the conditions make the maximum steam break flow rate. From Fig. 3, any fuels are not experienced from DNBR. This shows that the fuel claddings are safe and peak cladding temperature is less than the criteria of fuel temperature's tolerance. Minimum DNBR is 1.72 and it is more than the criteria 1.21.
Fig. 4 is the difference of pressure between intact SG and faulted SG. When the difference is maximum value, a steam break flow rate in SG is the maximum value.
In the accident of MSLB, the steam break flow rate cause the linearly increase in the radiation dose. Fig. 5 is the worst condition resulted from the condition of Fig. 4.

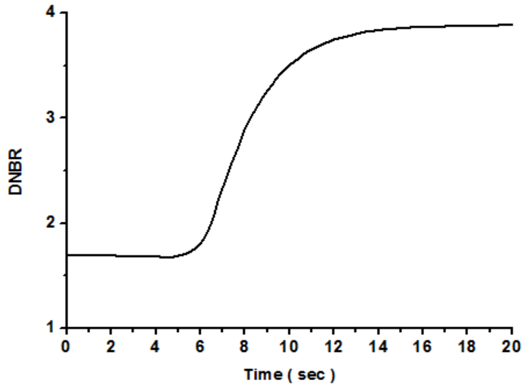

Fig. 3 Computed DNBR in Main Steam Line Break from LOFTRAN code.

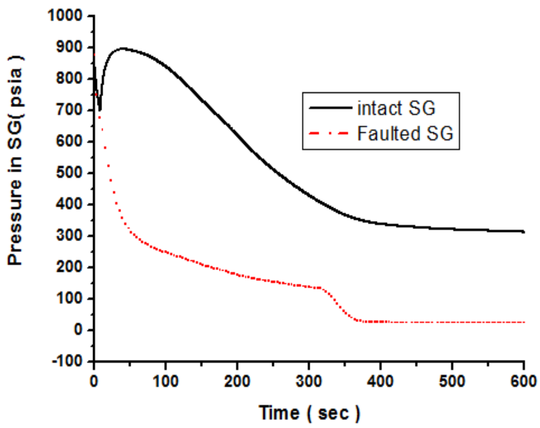

Fig. 4 Comparison of Pressure between Steam Generators during time steps(From LOFTRAN).

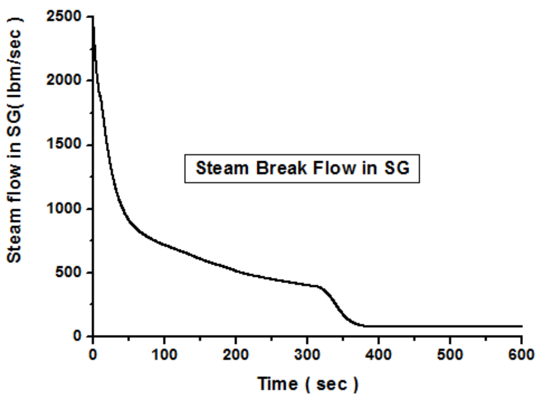

Fig. 5 Steam Break flow rate on the broken position in MSLB(From LOFTRAN).

3.1. Radiation Dose Results

In this study, the main purpose is the only sensitivity results. Because of that, the TEDE is selected. The reason of the TEDE selection is only one value and the comparison between radiation dose values is very easy.
From the worst conditions of LOFTRAN analysis, some radiation dose is calculated.
Table 3 presents the reached limit concentration of each cases of a MSLB.

Table 3. Estimation Results in Each Case

Category of accident	Dose limit [rem]	TS Limitation Approach Concentration [uCi/gram]
LOOP(GIS)	2.5	8.9
LOOP(PIS)	25	13.1
LOOP_ADV(GIS)	2.5	2.3
LOOP-ADV(PIS)	25	4.2

Table 3 shows that the 1-th specific activity concentration in Technical Specification is in the most severe condition as the case of LOOP(Loss of Offsite Power) plus ADV(Atmospheric Dump Valve) opening plus GIS(Event-Generated Iodine Spike).
From the results of Table3, in the current Technical Specification, 2.3times of Iodine concentration criteria is the dose limit concentration in EAB (Exclusion Area Boundary). These results are the same comparing with the dose estimation trend of NUREG-1431 and NUREG-1432.
For LCO in Technical Specification, analysis results of Hanul site show that the most sensitive case is the LOOP plus ADV plus GIS and in the case, the dose limit margin is about 103% in LCO.
Table 4 presents the timely steam flow rate is changed during accident time steps.
This is result from the LOFTRAN code results such ad Fig. 3, Fig. 4 and Fig. 5.

Table 4. Steam Release from Faulted SG and intact SG

Sequence hours	Faulted SG	Intact SG
0.0~0.196	290.133	20.5025
0.196~0.5	30.6302	20.5025
0.5~1.389	40.1536	20.5025
1.389~2.0	70.6765	20.5025
2.0~3.639	70.3152	0.0
3.639~8.0	0.0	0.0

4. Conclusions

In order to evaluate the radiation dose effect in thermal hydraulic analysis conditions, LOFTRAN code is used and some sensitivity results are generated. And also Westinghouse type NPP is selected and the Westinghouse methodology is basic on the whole dose calculation. In MSLB, DNBR is more than 1.75. In the steam release case, the faulted SG is superior to the intact SG. The difference is more than 10 times. In radiation dose calculations, the worst condition is the case of the maximum difference pressure between intact SG and faulted SG.
Technical Specification limiting value is selected for some sensitivity analysis of MSLB. From the results, the case of LOOP plus ADV plus GIS is the most severe case and the dose limit margin is about 103% in LCO.

REFERENCES

[1] Seung Chan Lee et al, Spiking Effect in Steam Generator Tube Rupture Analysis at Hanul site, Transaction of the Korean Nuclear Society Autumn Meeting, Oct. 27-28, 2011.
[2] Seung Chan Lee, Radiation Dose Effects into LCO in Technical Specification by Iodine, Transactions of the Korean Nuclear Society Spring Meeting, May 06-08, 2015.
[3] NUREG 1431.
[4] Final Safety Analysis Report, Kori 1,2.
[5] Federal Guidance Report No. 11.
[6] Federal Guidance Report No. 12.