Analysis of the MSLB M/E Release for Framatome NPPs using RELAP5/MOD3.3

Jeong Kwan Suh [a*], Dong Soo Song [a], Jae Yong Lee [a], Seung Jong Oh [b]
[a] *KHNP Central Research Institute, 1312-70 Yuseongdae-Ro, Yuseong-Gu, Daejeon 305-343, Korea*
[b] *KINGS, 1456-1 Shinam-Ri, Seosaeng-Myeon, Ulju-Gun, Ulsan 689-882, Korea*
[*] *Corresponding author: jksuh@khnp.co.kr*

1. Introduction

KHNP is planning to refurbish Framatome nuclear power plants (NPPs) with replacement of steam generator (RSG) and power uprating (PU). The environmental qualification (EQ) envelop curve in current Framatome NPPs FSAR should be modified according to the refurbishment. An analysis of the mass and energy (M/E) release following a main steam line break (MSLB) outside containment was done using LOFTRAN-COMPARE code [1]. However, the analysis results for the steam bunker with LOFTRAN-COMPARE code showed too high temperature of 209.05 °C as the generic limit of EQ temperature is 182.2 °C.

To address this issue, we have used RELAP5-COMPARE code, and took account recommendations of the standard review plan [2] in this study. There is a significant difference between two codes in simulating the superheating by the heat transfer to steam from the uncovered portion of the SG tubes. The calculation results of M/E release following a MSLB using RELAP5/MOD3.3 are presented, and compared with those of the LOFTRAN.

2. MSLB Modeling and Major Assumptions

2.1 Event Descriptions

A steam line break results in an increased steam flow rate of one or more SGs. The increased steam flow causes an increase in the heat extraction rate from the reactor coolant system (RCS), and reduces primary coolant temperature and pressure. Because the negative moderator temperature and Doppler fuel temperature reactivity coefficients are characteristics of PWR core designs, the core power will inherently seek a higher level which corresponds the steam load demanded, assuming no intervention of control, protection, or engineered safeguard systems.

The rate at which the plant approaches the new power level that matches the steam flow greatest when the moderator temperature coefficients (MTC) are the more negative, which corresponds to End-Of-Life(EOL) conditions.

Steam line break occurring outside containment may result in significant release of high energy fluid to the subcompartment which could possibly results in high temperatures and pressures.

2.2 MSLB Modeling

There are many factors that influence the quantity and rate of the M/E release from the steam line. To encompass these factors, a spectrum of cases is analyzed that vary the initial power level, the break type, the break area and the single failure.

There are two types of pipe ruptures that are considered. First is a double-ended guillotine rupture in which the steam pipe is completely severed and the ends of the break displace from each other. The other postured break type is a split rupture in which a hole opens at some point on the side of the steam pipe but does not result in a complete severance of the pipe.

Figure 1 shows the RELAP5 nodalization for the Framatome NPP which simulates all the above break spectra.

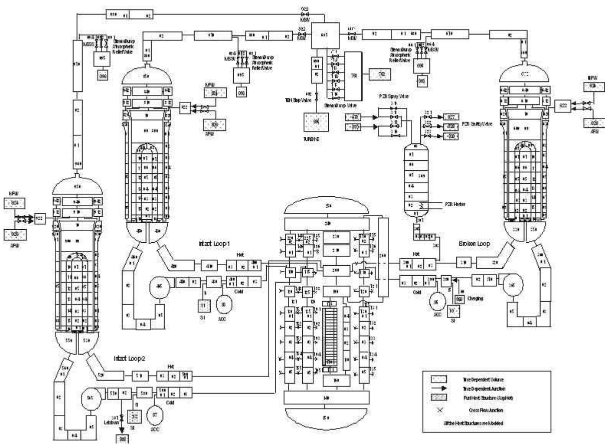

Fig. 1. RELAP5 nodalization for the Framatome NPP

2.3 Major Assumptions

The conservative initial conditions for the power levels, RCS average temperature, SG fluid mass, MFW/AFW flow rate, FW enthalpy, shutdown margin, MTC, and entrainment are assumed as summarized in table 1. The assumptions for the values of SG fluid mass, MFW/AFW flow rate, and the modeling methodology of entrainment are different between the codes of RELAP5 and LOFTRAN.

The worst transient in SLB is defined as follows.

- Main steam line pipe break
- Upstream of the MSL isolation valves
- Discharge of the whole content of the SG
- Power excursion (from HZP)
- 0% tube plugging for steam generator
- Worst single failure

The calculated initial conditions for the Framatome NPP RSG are shown in table 2.

Table 1: Conservative initial conditions

Parameter	LOFTRAN	RELAP5	Ref.
Core power	Max.	Max.	
RCS avg. temp.	Max.	Max.	
S/G level	Min.	Max.	Diff.
MFW flow rate	Min.	Max.	Diff.
AFW flow rate	Min.	Max.	Diff.
FW enthalpy	Max.	Max.	
Shutdown margin	Min.	Min.	
MTC	Max.	Max.	
Entrainment	Not assume	Min.	Diff.

Table 2: Calculated initial conditions

Parameter	Unit	Set value	Calculated
Rx power	MWt	2958	2958
PRZ pressure	MPa	15.86	15.86
PRZ level	%	67	66.8
RCS flow	Kg/s	4088	4088
RCS Tavg	K	583.4	583.3
S/G pressure	MPa	6.1	6.07
S/G level	%	67	66.8
S/G Stm. flow	Kg/s	555	554.7
FW Temperature	K	496	496

3. Analysis Results

Figure 2 shows the mass flow rate following a MSLB outside containment. The initial mass flow rate calculated by RELAP5 is larger than that of LOFTRAN. Although the break size is similar in the two codes, the characteristics of break modeling of the codes caused this difference.

Figure 3 shows the enthalpy release following a MSLB outside containment. The initial enthalpy release is similar between the two codes as the initial conditions are similar. However, after the MSLB, the enthalpy release calculated by LOFTRAN is larger than that of RELAP5. This behavior shows that the LOFTRAN over predicts the superheating by the heat transfer to steam from the uncovered portion of the SG tubes.

Figure 4 shows the temperature of steam bunker following a MSLB calculated by RELAP5-COMPARE. The peak temperature is below the generic limit of EQ temperature (182.2 °C).

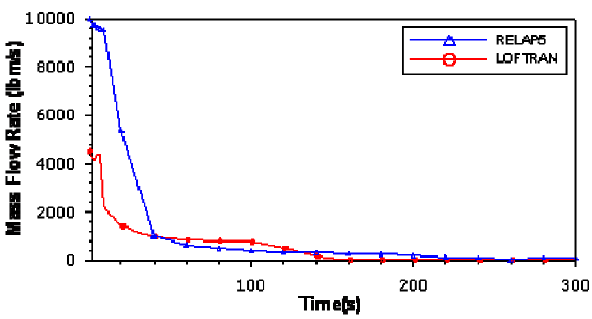

Fig. 2. Mass flow rate (RELAP5, LOFTRAN)

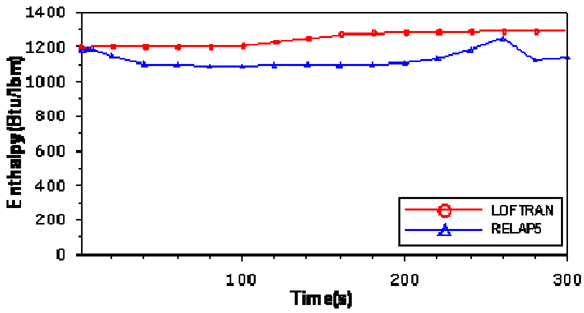

Fig. 3. Enthalpy release (RELAP5, LOFTRAN)

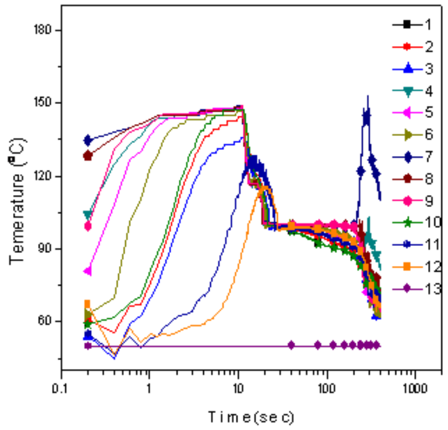

Fig. 4. Temperature of steam bunker (COMPARE)

4. Conclusions

The MSLB M/E release outside containment for the Framatome NPP has been analyzed using RELAP5/MOD3.3 and COMPARE code. The initial conditions are conservatively assumed, and simulate the RSG and PU. The calculated results of M/E release by RELAP5/MOD3.3 has been compared those of LOFTRAN. The enthalpy release calculated by LOFTRAN shows the over prediction of steam superheating. The transient behavior of the steam bunker temperature for MSLB using the RELAP5-COMPARE is appropriate for the Framatome NPP RSG.

REFERENCES

[1] Dong Soo Song, et al., “Relaxation of Pressure and Temperature during HELBA for Subcompartment”, Transactions of the KNS Spring Meeting, Taebaek, Korea, May 26-27, 2011.

[2] “Mass and Energy Release Analysis for Postulated Secondary System Pipe Ruptures”, NUREG-0800 6.2.1.4, Revision 2, U.S. NRC, March 2007.

[3] Cheol Woo Kim, et al., “Application of KIMERA Methodology to APR1400 M/E Analysis”, Transactions of the KNS Autumn Meeting, Jeju, Korea, October 21-22, 2010.

[4] “RELAP5/MOD3.3 Code Manual”, NUREG/CR-5535, Revision 1, December 2001.