Analytical Investigation of APR1400 SBLOCA Using MARS-KS Code

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1. Introduction

Since the approval of operating license of SKN3, there have been licensing reviews on the SBLOCA of APR1400 including topical report on SPACE3.0/sEM and change of operating license on the change of core design and safety analysis code. In addition, the possibility of core uncovery and significant reheat due to loop seal clearing and reformation phenomena was considered as one of the safety issues by USNRC in the review of design certificate for APR1400. Therefore, it is needed to perform the independent audit calculation to review the results of safety analysis on APR1400 SBLOCA with changed codes and the raised issue explained above.

In this study, the transient behavior of APR1400 SBLOCA was analyzed with MARS-KS code. The thermal-hydraulic phenomena including loop seal clearance and reformation was observed so that its effect on core cooling capability and safety margin were identified.

2. Modeling

The MARS-KS1.4 code was used for the analysis[1]. Fig. 1 shows the nodalization of APR1400 simulating cold leg SBLOCA.

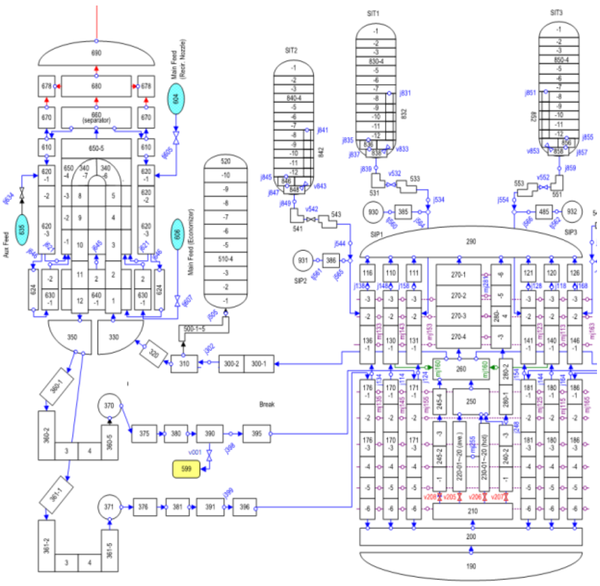

Fig. 1. Nodalization of APR1400 cold leg SBLOCA

The break occurred at 1A cold leg piping at pump discharge section. The break was modeled by connecting PIPE component 380 to TMDPVOL(time-dependent volume) component 599 by TRPVLV(trip valve) 001. Face 6 of PIPE 380 which means upper face was connected to TRPVLV 001 to simulate top slot break. The Henry-Fauske critical flow model was employed at the TRPVLV 001. The discharge coefficient and thermal non-equilibrium factor were 1.0 and 0.14, respectively.

The initial core power was 102% of nominal power. 120% of ANS-1973 was used as decay heat curve. The peak linear heat generation rate was set to 14.0 kW/ft and the axial power shape with peak power at 85% of active core height was applied.

For the conservative modeling, the CCFL parameters of the steam generator tubes and the uncertainties in the heat transfer model of critical heat flux and film boiling were applied same as SPACE 3.0/sEM[2]. Especially, the intercept and the slope of Wallis CCFL form, 0.553 and 2.765 were used as the conservative values in terms of the PCT obtained by the applicant's sensitivity study.

3. Analysis Results and Discussion

The spectrum of cold leg SBLOCAs including 0.5 ft^2, 0.35 ft^2, 0.1ft^2 and 0.05 ft^2 were simulated to obtain the limiting result in terms of PCT. As a result, the analysis result of 0.05 ft^2 break is shown in this study. Table 1 summarizes trip logics and calculation results

Table 1. Sequence of events

Event	Trip logics [sec]	Calculation results[sec]
Break	0.0	0.0
LPP trip	Pressuizer pressure < 125.0 kg/cm^2A	34.3
Turbine trip	LPP+0.1	34.4
Reactor trip	LPP+0.5	34.8
RCP trip	LPP+0.5	34.8
MFW isolation	LPP+10.0	44.3
SIP actuation	LPP+40.0	74.3

The transient was initiated by 0.05 ft^2 cold leg top slot break by triggering the TRPVLV 001. Fig. 2 and Fig. 3 show the pressure of primary and secondary system, and the break discharge flow rate respectively. The break discharge flow rate decreases until the RCS pressure drops to the secondary side pressure. After the rapid depressurization, the primary system pressure and break discharge flow rate remain at plateau period in saturated condition so that the RCS is cooled down by natural circulation. After the occurrence of loop seal clearance, the pressure decreases rapidly. The break flow rate sharply decreases and maintains low level at boil-off phase.

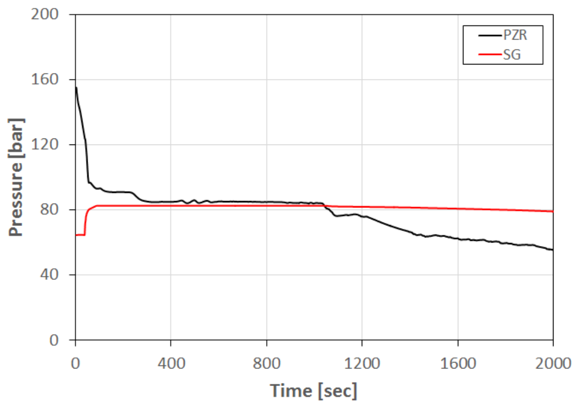

Fig. 2. Primary system pressure

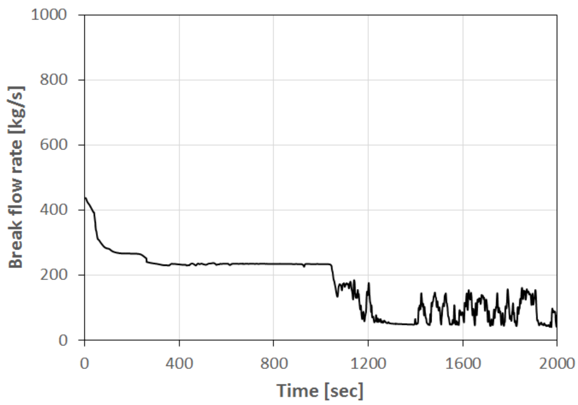

Fig. 3. Break discharge flow rate

The collapsed water levels of core and downcomer are plotted in Fig. 4. The core water level decreases continuously before loop seal clearance occurs. Once the loop seal clearing occurs, the core water level increases rapidly while downcomer water level decreases sharply.

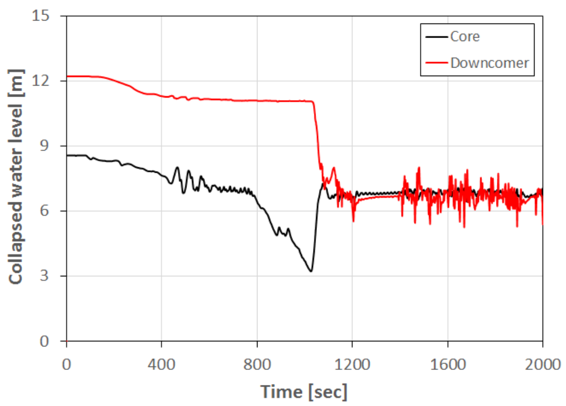

Fig. 4. Collapsed water level

Fig. 5 shows the cladding temperature at PCT node. In this figure, the result obtained by using conservative intercept(0.553) and slope(2.765) of Wallis CCFL form and using default values, 1.0 and 1.0 are compared each other. When the collapsed water level of core is at the minimum, the PCT, 905.7 K is observed just before the loop seal clearing when the conservative values of CCFL correlation were used. However, PCT is not observed when the default values of CCFL form were used. The core is cooled continuously after the occurrence of reheat. As a result, the safety margin is enough in spite of the core reheat prior to loop seal clearance with conservative model.

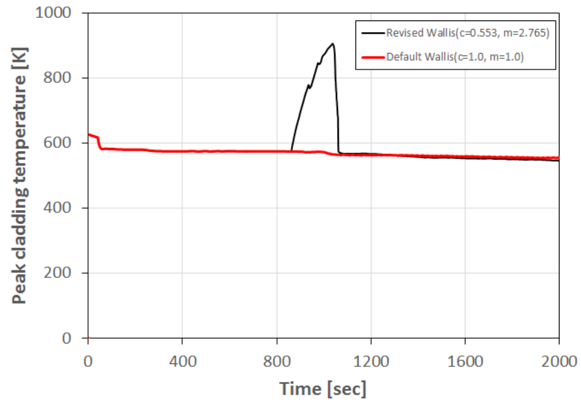

Fig. 5. Cladding temperature at PCT node

3. Conclusions

The cold leg piping break of 0.05 ft^2 for APR1400 was simulated with MARS-KS. The thermal-hydraulic behaviors with major parameters were investigated. The core cooling capability was identified with enough safety margin despite the PCT prior to the loop seal clearance.

ACKNOWLEDGEMENTS

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety (KOFONS), granted financial resource from the Nuclear Safety and Security Commission (NSSC), Republic of Korea (No. 1305002).

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[1] KINS, MARS Code Manual, Volume II: Input Requirements, KINS/RR-1282, Rev.1, 2016. 5.

[2] KHNP, SBLOCA Safety Analysis Evaluation Methodology for APR1400 Type Nuclear Power Plants Using the SPACE Code, TR-KHNP-0031, 2017. 3