Cold-Leg Small Break LOCA Analysis of APR1400 Plant Using a SPACE/sEM Code

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1. Introduction

The Small Break Loss-of-Coolant Accident (SBLOCA) evaluation methodology (EM) for APR1400, called sEM, is now being developed using SPACE code. SPACE/sEM is to set up a conservative evaluation methodology in accordance with appendix K of 10 CFR 50. Major required and acceptable features of the evaluation models are described as below.

- Fission product decay : 1.2 times of ANS97 decay curve
- Critical flow model : Henry-Fauske Moody two-phase critical flow model
- Metal-Water reaction model : Baker-Just equation
- Critical Heat Flux (CHF) : B&W, Barnett and Modified Barnett correlation
- Post-CHF : Groeneveld 5.7 film boiling correlation

A series of test matrix is established to validate SPACE/sEM code in terms of major SBLOCA phenomena, e.g. core level swelling and boiling, core heat transfer, critical flow, loop seal clearance and their integrated effects. The separated effect tests (SETs) and integrated effect tests (IETs) are successfully performed and these results shows that SPACE/sEM code has a conservatism comparing with experimental data. Finally, plant calculations of SBLOCA for APR1400 are conducted as described below.

- Break location sensitivity : DVI line, hot-leg, cold-leg, pump suction leg.
- Break size spectrum : $0.4ft^2$~$0.02ft^2$(DVI) $0.5ft^2$~$0.02ft^2$(hot-leg, cold-leg, pump suction leg)

This paper deals with break size spectrum analysis of cold-leg break accidents. Based on the calculation results, emergency core cooling system (ECCS) performances of APR1400 and typical SBLOCA phenomena can be evaluated.

2. Steady State Calculation

Nodalization of APR1400 plant is presented in Fig. 1. The core is modeled by 2 channels, e.g. average core, hot core, and each channel has 20 volumes in axial direction. The downcomer (DC) is divided by 6 channel. The each channel of the core and DC is connected by cross flow FACEs. The upper guide structure (UGS) has 2 channels and each channel is divided by 4.

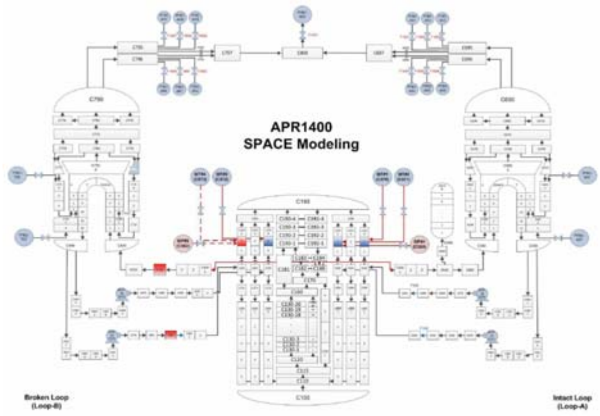

Fig. 1. Nodalization of APR1400

Secondary system has 2 SGs, 4 steamlines and 3 main steam safety valves (MSSVs) in each steamline. ECCS has 4 safety injection tanks (SITs) and 2 safety injection pumps (SIPs) based on a single failure assumption.

Major target operation variables are set up based on design data of Shin-Kori unit 3 and 4, which are the first commercial plants of APR1400. Steady state calculation results are presented in Table. I. Reactor power is set as 102% of a nominal power. Core bypass fraction is about 3%. All parameters of steady state are well predicted.

Table I: Steady state calculation results

Parameter	Target	Calculated
Reactor Power [MWt]	4,062.66	4,062.66
Reactor vessel flow rate [kg/s]		
Core flow Key alignment bypass Baffle-Barrel bypass CEA guide tube flow UGS to upper plenum	20,361.26 101.93 527.93 277.07 379.00	20,363.52 100.983 526.75 281.1 382.128
Core bypass rate [%]	3.0	2.99
Hot channel flow	83.95	84.42
Avg channel flow	20,277.31	20,279.1
Hot leg flow rate	10,495.63	10,495.65
Cold leg flow rate	5,247.81	5,247.81
PZR pressure [MPa]	15.51	15.51
Core inlet temp.[^{o}C]	290.6	290.41
Core outlet temp.[^{o}C]	325.3	325.15

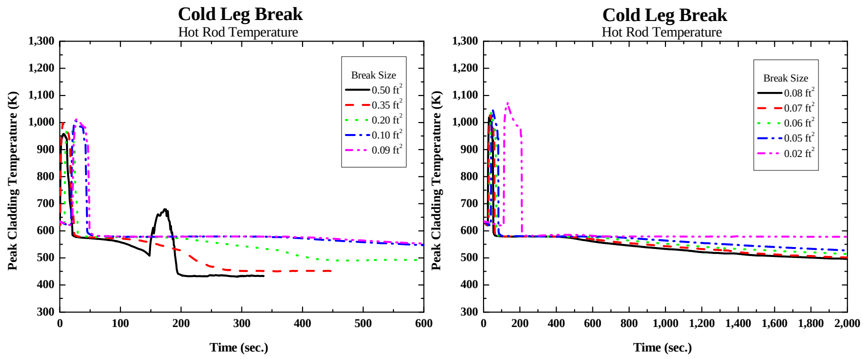

Fig. 2. Peak cladding temperature of the hot rod in break size spectrum

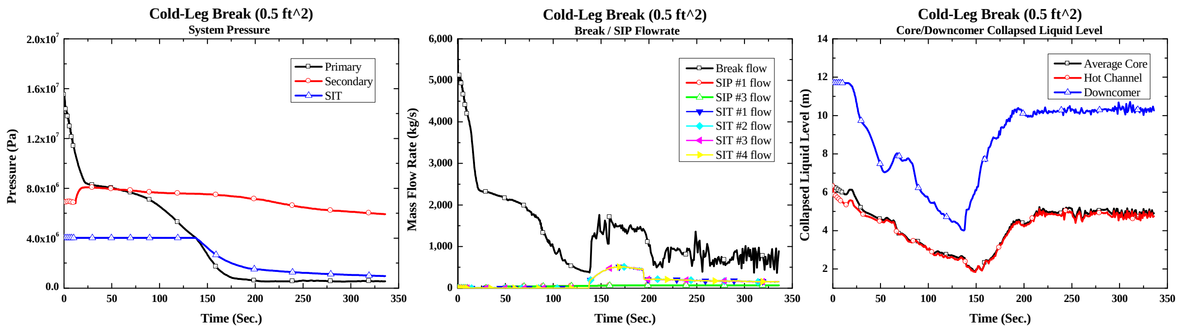

Fig. 3. Major parameter behavior in 0.5ft^2 break case
(left : system pressure, middle : break and SIPs flow rate, right : core and downcomer level)

3. Transient Calculation

The cold-leg break is initiated at zero time. Reactor trip and reactor coolant pumps (RCPs) trip signal are generated from a low pressurizer pressure (LPP) trip. If the pressurizer pressure is lower than 1555 psia, LPP trip signal is generated. This condition is most limiting assumption, called harsh environment. Safety injection actuation signal (SIAS) turns to be on by LPP signal with 40 sec delay time.

Fig. 2 shows the peak cladding temperature (PCT) of the hot rod in break size spectrum. From 0.5ft^2 case to 0.02ft^2 case, blow-down PCTs are observed with all cases and maximum value is 1074K in 0.02ft^2 case, which is a minimum break size. In 0.02ft^2 case, break flow rate is smaller than the other cases. It means that depressurization of the primary system by break is slower than the others hence LPP signal is also delayed. Therefore a full core power is maintained due to delayed LPP trip and the maximum blow-down PCT are predicted in smallest break size. After LPP trip, all blow-down PCTs are rapidly quenched due to reactor trip.

The boil-off PCT occurs only in 0.5ft^2 case. At around 60 sec, accumulated steam in loop seal is discharged into the break location and then DC level is temporarily recovered as shown in Fig. 3. After the loop seal clearance, the core level is continuously decreased by decay heat of the core. At 150 sec, minimum core level is observed and cladding temperature is increased to 690K.
4 SITs starts to inject into the DC and the DC level is rapidly recovered and then the core level is recovered due to the recovered hydraulic head of DC. The quenching of core boil-off is finished at 190 sec.

4. Conclusions

Cold-leg SBLOCA analysis for APR1400 is performed using SPACE/sEM code under harsh environment condition. SPACE/sEM code shows the typical SBLOCA behaviors and it is reasonably predicted. Although SPACE/sEM code has conservative models and correlations based on appendix K of 10 CFR 50, PCT does not exceed the requirement (1477 K). It is concluded that ECCS in APR1400 has a sufficient performance in cold-leg SBLOCA.

REFERENCES

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