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Evaluation for Effect of Containment Pressure on LBLOCA of Framatome Plant

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1. Introduction

Nowadays, the large break LOCA (LBLOCA) analysis using the best-estimate (BE) methods to replace the old conservative evaluation method (EM) was performed by the licensee in several plants such as WH type Units, OPR1000 and APR1400. The licensee has used the combined analyses with a system thermal hydraulic code and a containment code in BE methods. The containment pressure was applied as the boundary condition in the LBLOCA analyses. The initial conditions of containment could change the containment pressure and then the containment pressure had a strong effect on the reflood phenomena for a LBLOCA. It could influence the following requirement: *2.Containment Pressure* in Appendix K to Part 50 - The containment pressure used for evaluating cooling effectiveness during reflood and spray cooling shall not exceed a pressure calculated conservatively for this purpose. Generally, the conservative initial conditions were also used in BE methods. Therefore, the sensitivity study for containment parameters is needed to identify the effect of containment pressure in a LBLOCA.

In this study, the combined analysis with MARS-KS code [1] and CONTAIN code [2] were performed to investigate sensitivities of important parameters to the containment pressure and to evaluate the effect of the containment pressure on LBLOCA. The CONTAIN code was used to calculate the containment pressure which was used as a boundary condition for MARS calculation. The calculation results from each code could interact every time step. The plant was selected the Framatome plants which the review for the power uprate has been conducted recently. Since the Framatome plants has a small margin on a peak cladding temperature (PCT) in a BE method, the effect of containment pressure could be more important than that of other plants.

2. Initial and Boundary Conditions

In this study, 100% double ended guillotine break was selected as the limiting case. The important input parameters and initial conditions for the emergency core cooling system (ECCS) were considered as the nominal values in BE methodology of FSAR [3]. Also, the initial conditions related to the containment were selected with referring FSAR as follows:

- Total core power : 2,900 *MWt*
- Total peaking factor, F_q : 2.5
- Net free volume : 50,400 m^3
- Containment initial pressure : 1.01 *bar*
- Containment initial temperature : 25 ^oC
- RWST temperature : 7 ^oC
- Spray total flowrate : 540 *kg/sec*
- Spray actuation time : 27 *sec*
- Heat transfer multiplier : 1.0(default)
- Passive heat sink : FSAR Table T-15.6.5-2

It was assumed to have a high spray flowrate and a low spray temperature to make the containment pressure conservatively underestimated. In this base case, the limiting PCT was determined as 1,170 K.

3. Sensitivity Study

The sensitivity study of the heat transfer rate, spray flowrate, passive heat sink area and the sump pool availability have been performed as follows:

Case 1 : Heat transfer multiplier = 0.5
Case 2 : Heat transfer multiplier = 4.0
Case 3 : A half of a spray flowrate
Case 4 : A decrease of 10% in passive heat sink area
Case 5 : Assumption for no sump pool

Among these cases, the spray flowrate and the passive heat sink area were related to the containment design and others had to do with CONTAIN modeling. In modeling of heat transfer structures in CONTAIN, the HMXMUL was used as the multiplier applied to the heat transfer correlations.

Fig. 1 and Fig. 2 show the containment pressure and the cladding temperature according to the heat transfer rate to the structures. As the heat transfer rate to structures was high, the removal of heat was generally high in the containment. As expected, the containment pressure increased with reduced heat transfer rate as shown in Fig. 1. At the blowdown phase, the cladding temperature was not greatly influenced by the containment pressure due to the critical flow. The peak cladding temperature occurred at the initiation of reflood phase and the peak cladding temperature of Case 02 was increased by about 20 K compared to that of Basecase. But, the peak cladding temperatures between Basecase and Case 01 were not different significantly. Also, the latest reflood quenching occurred in Case 02 that had the highest peak cladding temperature. The reflood quenching could be determined by the amounts of break flow and the safety injection flow. The low containment pressure resulted in the higher break flow and the reflood quenching delayed as shown in Fig. 2.

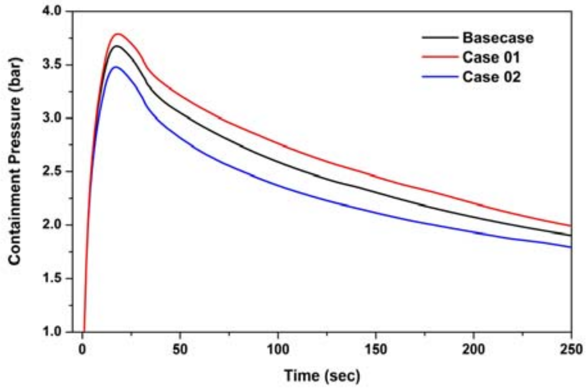

Fig. 1 Containment Pressure for Heat Transfer Multipliers

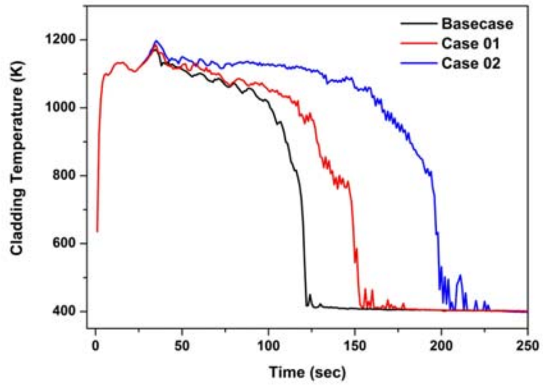

Fig. 2 Cladding Temperature for Heat Transfer Multipliers

Fig. 3 and Fig. 4 show the containment pressure and the cladding temperature for Case 03 ~ Case 05. In general, two spray pumps were assumed to be actuated to make a minimum containment pressure. If the single failure was considered as assumption of LBLOCA, the containment pressure could increase compared to the Basecase after operating one spray pump (Fig. 3). If the area of passive heat sink was reduced, the heat in containment could absorb less into the structure. Therefore, the peak of containment pressure increased compared to the basecase. The sump pool was related to the modeling of CONTAIN code such as aerosol settling. When the sump pool could not be considered, the containment pressure would be reduced somewhat. As shown in Fig. 4, the cladding temperature could show the similar results with Fig. 2. The minimum containment pressure was shown in Case 05 and then the peak cladding temperature occur at Case 05. In Case 3 and Case 4, the difference of peak cladding temperature was not significant with that of Basecase. The earliest reflood quenching occurred in Case 03 which the highest containment pressure showed in the reflood phase.

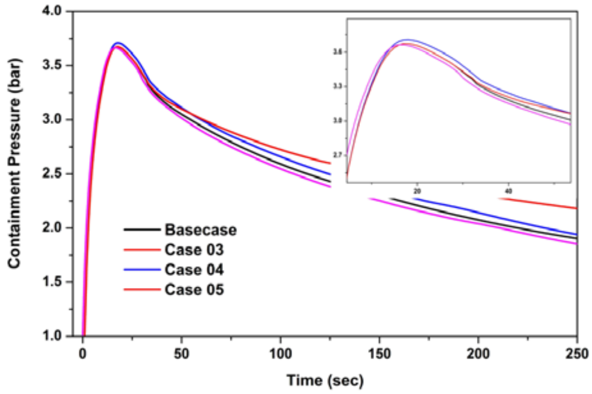

Fig. 3 Containment Pressure for Change of Parameters

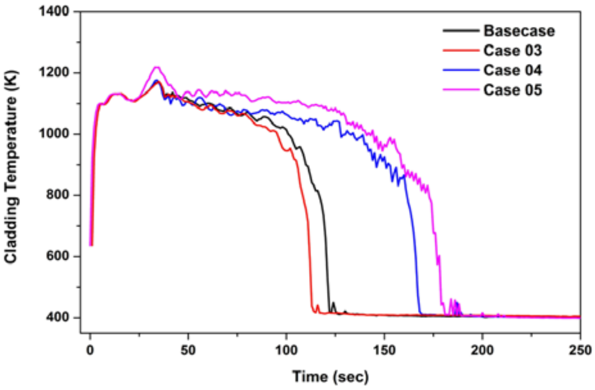

Fig. 4 Cladding Temperature for Change of Parameters

4. Conclusion

The LBLOCA calculation for Framatome plant was performed to identify the effect of the parameters in containment by the combined analysis with MARS-KS code and CONTAIN code. The increment of heat transfer to the structures resulted in the significant reduction of containment pressure. Also, the peak cladding temperature could show at the minimum containment pressure as expected. In further studies, the more detailed analysis for the combined analysis and the effect of parameters in containment would be needed to obtain the peak cladding temperature in LBLOCA.

REFERENCES

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[2] NRC, Code Manual for CONTAIN 2.0: A Computer Code for Nuclear Reactor Containment Analysis, NUREG/CR-6533, 1997.
[3] KSNP, ULCHIN 1&2 Final Safety Analysis Report, 2013.