Evaluation of Early Termination of Containment Spray and Safety Injection Pumps after LOCA to address USNRC Bulletin 2003-01

Chang Hyun KIM* and Sang Yeol KIM
Korea Hydro & Nuclear Power Co., Ltd., 25-1 Jang-dong, Yuseong-gu, Daejeon, Republic of Korea
**Corresponding author: chkim@khnp.co.kr*

1. Introduction

USNRC bulletin 2003-01[1] requires that the utilities evaluate and implement compensatory measures to reduce potential risk of emergency recirculation sump blockage due to post-accident debris. The bulletin directs utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. Possible interim compensatory measures included in the bulletin are procedural modifications such as early termination of containment spray and/or safety injection pumps. These procedural modifications are intended to do the following: (a) Reduce the flow rate to the sump when containment recirculation begins; (b) Reduce the differential pressure across the emergency sump screen if there is a build-up of debris; and (c) Provide a modest time delay to the start of containment recirculation during small breaks.

These actions would be part of the Loss of Coolant Accident (LOCA) Guidelines and plant specific evaluations should be performed to implement compensatory measures related to the early termination of containment spray and safety injection pumps. In the present paper, the effects of the early termination of containment and safety injection pumps on the long term cooling have been evaluated using a licensed LOCA analysis method for the domestic nuclear power plants.

2. Analysis Method

For plant specific evaluations, Kori Unit 3&4 and Ulchin Unit 3&4 are adopted as reference plants of domestic Westinghouse 3-loop and OPR 1000 plants, respectively. RELAP5/MOD3[2] and CONTEMPT4[3] code package are used to evaluate the long-term cooling behavior of the reactor coolant system and containment after a LOCA.

Nuclear power plants have two trains of forced cooling to carry out the containment safety function. Each train includes one spray pump and two reactor containment fan coolers (RCFCs). For the evaluation of early termination of containment spray, it is assumed that all spray pumps are terminated at 10 min. after initiation of a LOCA and containment cooling is subsequently performed only by RCFCs. Sensitivity studies are performed according to the number of RCFCs operated.

For the evaluation of early termination of safety injection pumps, four cases are analyzed for each reference plant. The purpose of this evaluation is to investigate the emergency procedure change to terminate one train of High Pressure Safety Injection (HPSI) and/or Low Pressure Safety Injection (LPSI), assuming each pump is terminated at 10 min. after initiation of a LOCA. The analysis cases are summarized in Table 1.

Table 1. Analysis cases of early termination of safety injection pumps (each pump is terminated at 10 min. after LOCA)

Case	1	2	3	4
HPSI Flow	2 train Max.	Termination of one-train only	Termination of all pumps	Termination of all pumps
LPSI Flow	2 train Max.	Termination of all pumps	Termination of one-train only	Termination of all pumps

3. Results and Discussion

3.1 Early termination of containment spray pumps

Early termination of all the containment spray pumps leaves the Reactor Containment Fan Coolers (RCFCs) as the only active containment heat removal system. Figure 1 and 2 show the containment pressure and temperature after a LOCA for Westinghouse 3-loop plant. All the spray pumps are terminated at 10 min. after initiation of the LOCA. The results show that the RCFCs will maintain the containment pressure and temperature control if three of the four RCFCs are operated. For the implementation of this early termination of the spray pump adequate time to start idle spray pumps should be secured. The results demonstrate that there is adequate time to start the idle spray pumps and maintain the pressure and temperature below the Equipment Qualification (EQ) limit curve (dashed lines in Figs 1 and 2). Analysis results for OPR-1000 plants show the same results as obtained for the Westinghouse 3-loop plant. Containment pressure and temperature are effectively controlled if three of the four RCFCs are operated.

This action will reduce the flow through the emergency sump screen at the time of containment recirculation and post-containment recirculation operations. Therefore implementation of early termination of containment spray in the Emergency Operation Procedure (EOP) is recommended in order to reduce potential risk of post-accident debris blockage.

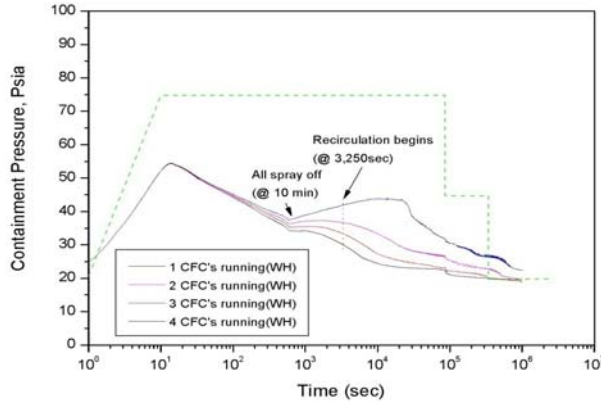

Fig. 1. Containment pressures after all sprays are terminated at 10 min. (Westinghouse 3-Loop Plant).

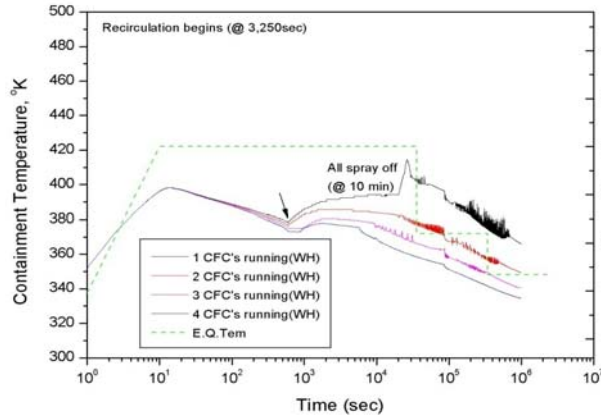

Fig. 2. Containment temperatures after all sprays are terminated at 10 min. (Westinghouse 3-Loop Plant).

3.2 Early termination of safety injection pumps

A series of analyses are performed to determine the rise in core temperature due to early termination of High Pressure Safety Injection (HPSI) and/or Low Pressure Safety Injection (LPSI) pumps. It is assumed that one HPSI and/or LPSI pumps are secured at approximately 10 min after initiation of a Large Break LOCA. As shown in Figs 3 and 4, the core temperature could be maintained in a safe level if one HPSI or LPSI pumps provides core cooling water.

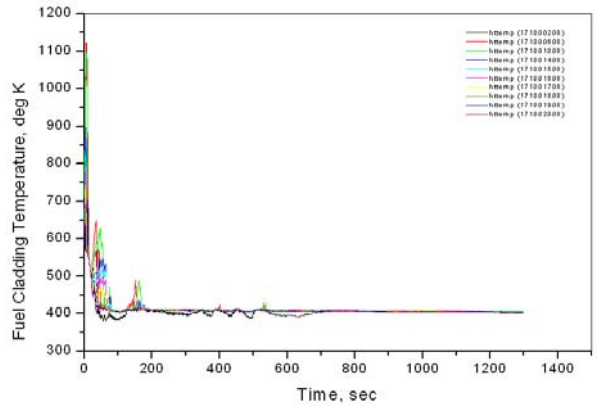

Fig. 3. Core temperatures when only one of HPSI pumps is operated (Case 2 : OPR-1000 Plant).

The strategy of early termination of one HPSI or LPSI pump before recirculation alignment may be beneficial to reduce potential risk of sump blockage. However, this action requires revision of the safety injection stop criteria of the current Emergency Operation/Procedure Guideline (EOG/EPG) and re-analysis of the LOCA as it does not account for an interruption in LPSI flow due to a single failure. Additionally this action adds some operator burden and opportunity for human error. Therefore it is determined that the strategy of early termination of safety injection is not beneficial to reduce the risk of sump blockage.

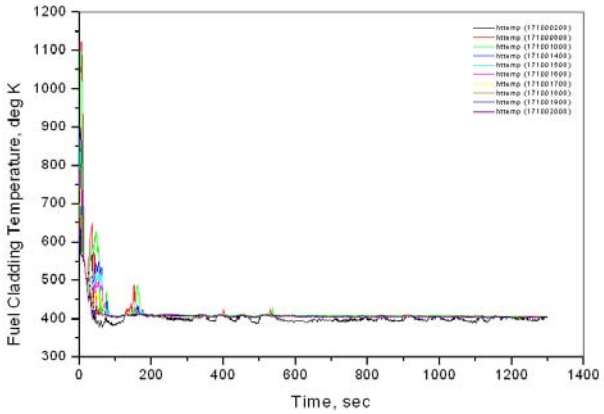

Fig. 4. Core temperatures when only one of LPSI pumps is operated (Case 3 : OPR-1000 Plant).

3. Conclusions

A plant specific evaluation of early termination of containment spray and safety injection pumps after a loss of coolant accident has been performed to address USNRC bulletin 2003-01. Early termination of the containment spray pump offers the advantage of reducing the potential risk of post-accident debris blockage. Early termination of the safety injection pump also has the advantage of reducing the risk but it is not recommend as it would require revision of the safety injection stop criteria and the licensing basis for a LOCA analysis. Therefore steps for early termination of containment spray pump will be added in the Emergency Operation Procedure (EOP) in order to reduce potential risk of post-accident debris blockage.

REFERENCES

[1] USNRC, Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized Water Rectors," June 2003.
[2] Information System Lab, "RELAP5/MOD3.3 Code Manual," NUREG/CR-5535-Rev.1, June 2002.
[3] USNRC, "CONTEMPT-LT/028 A Computer Program for Predicting Containment Pressure Temperature Response to a Loss-of-Coolant Accidents," NUREG/CR-0255, 1979.