A Study of Reactor Vessel Downcomer Channel Model during SLB event

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1. Introduction

Non-LOCA safety analysis methodology is developed using SPACE code, developed to predict the thermal-hydraulic response of Nuclear Steam Supply System (NSSS) to the anticipated transients and the postulated accidents[1]. Since 2010, several nodalization schemes for the components such as steam generator and reactor vessel have been tested so far to find out optimized configuration for system model for Non-LOCA analysis.

In this paper, the flow behavior of borated water injected through a Direct Vessel Injection (DVI) nozzle during Steam Line Break (SLB) has been simulated using two different reactor vessel downcomer channel models; 2-channel downcomer model used as typical model for non-LOCA analysis and 6-channel downcomer model. The simulation results were also compared to experimental results[2].

2. Event Analysis

2.1 Description on SLB event

The primary system pressure and temperature decrease due to steam line break, resulting increase in heat transfer from primary system to secondary system. Due to the negative moderator temperature coefficient, positive reactivity is inserted into the core and core power increase. Reactor can be tripped by low steam generator pressure, low primary system pressure, low steam generator level, variable over power, or low DNBR. MSIVs are closed due to low steam generator pressure. Eventually, the affected steam generator is isolated by interrupting main feedwater supplied to the steam generators and closing all MSIVs. The pressurizer pressure decreases to the Safety Injection Actuation Signal (SIAS) setpoint. Also, the affected steam generator level decreases and Auxiliary Feedwater (AFW) is supplied for decay heat removal.

2.2 Initial conditions and assumptions

Fig. 1 and 2 show the 2-channel and 6-channel downcomer models for SLB event analysis, respectively. The DVI nozzle is located above the cold leg into the reactor vessel downcomer.

In order to assess the flow behavior of the borated water injected through DVI nozzle according to downcomer channel model for a steam line break event, the same initial conditions and assumptions are applied. The moderator temperature coefficient, fuel temperature coefficient, and boron reactivity are considered as the reactivity feedback tables.

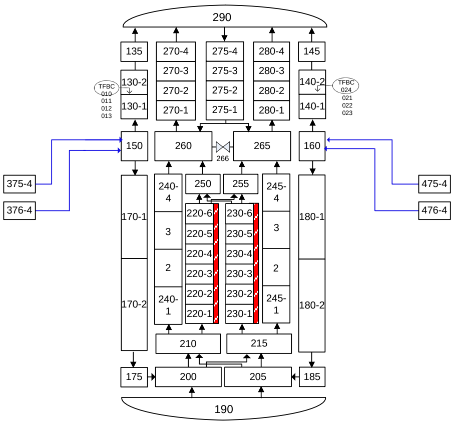


Fig. 1 2-channel downcomer model

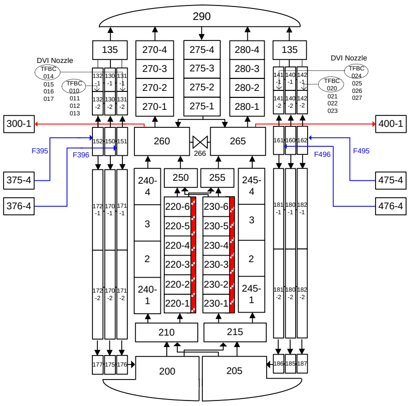


Fig. 2 6-channel downcomer model

3. Analysis Results

After break in steam line, excessive vapor discharged from the affected steam generator causes the decrease in reactor coolant temperature and system pressure. Consequently, power increases rapidly due to negative feedback effect of fuel and moderator, and then primary system pressure reaches safety injection actuation setpoint and borated water is injected through DVI nozzle.

Fig. 3 shows the comparison of boron mass fraction in RV for the 2-channel and 6-channel downcomer models. As shown in the figure, the almost all of the borated water injected through DVI is bypassed through the upper head region of reactor for 2-channel downcomer model. Therefore, the boron mass fraction of the upper head is higher than that of core inlet. But, the boron mass fraction of upper head region is not higher than that of core inlet for 6-channel downcomer model. This is because the borated water injected through DVI flows well to lower downcomer unlike that of 2-channel downcomer model. Consequently, the boron transport time to the core is delayed for the case of the 2-channel downcomer model compared to 6-channel downcomer model, and the total reactivity and the boron reactivity feedbacks have a significant difference between two models as shown in Fig. 4.

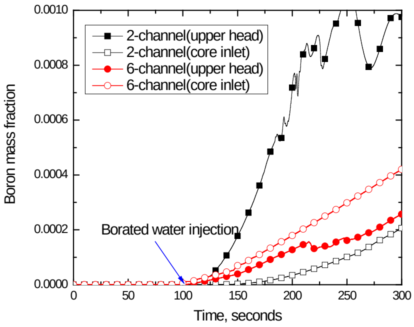


Fig. 3 Boron mass fraction

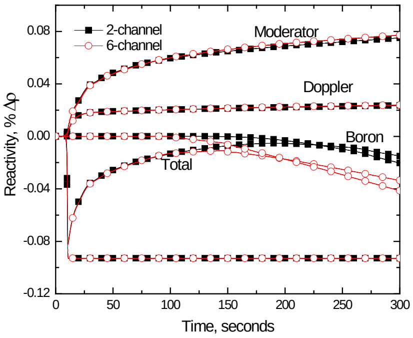
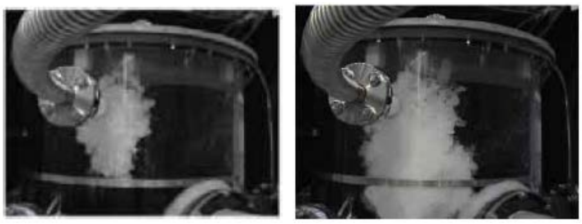
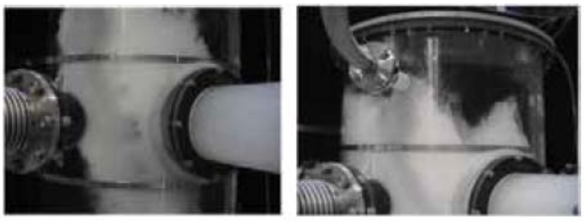


Fig. 4 Reactivity

Fig. 5 shows the behavior of the borated water in the downcomer visualized by experiment [2]. As shown in figures, the borated water injected through DVI flows well from the upper downcomer to the lower downcomer. The core bypass of the borated water does not occurred in the experiment. Therefore, the flow behavior of borated water in the experiment is similar to analysis result with 6-channel downcomer model.



after injection upper downcomer



lower downcomer steady-state

Fig. 5 Behaviors of borated water

4. Conclusions

In order to evaluate the 2-channel downcomer model using as typical model for non-LOCA analysis, a SLB with two different downcomer models is analyzed with SPACE code. The 6-channel downcomer model has shown a reasonable borated water delivery to the core rather than 2-channel model. The result was validated by an experiment performed by Ref. 2.

Based on the analysis, it is concluded that the 6-channel downcomer model is proper to simulate boron behavior in downcomer for steam line break accident.

Acknowledgment

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