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MARS-KS Condensation Assessment Results on very Small Break LOCA

Joosung KIM, and Kwangwon SEUL
Korea Institute of Nuclear Safety, 19 Gueseong, Yuseong, Daejeon, Korea, 305-338
kjsung@kins.re.kr, k130kik@kins.re.kr

1. Introduction

This paper presents the MARS-KS steam generator condensation sensitivity assessment results on the very small break LOCA experiment performed in RD-14M test facility. The specific experiment, B9802, was modeled and assessed for the MARS-KS prediction capability of condensation in the steam generator.

The B9802 SBLOCA test has 3 mm inlet header break, and it was performed to provide data on the influence of condensation rates in the steam generators on primary loop response under conditions where such sensitivity is expected. The break was represented by a 3 mm orifice installed in the drain line from header to an inventory tank. Once the break valve was opened, single phase liquid was discharged through the orifice, changing to two phase flow when the inlet header pressure reached saturation. Since this test had a very small break area, no ECC, no pump ramp, and no secondary pressure ramp were initiated.

2. MARS-KS Nodalization and System Model

In modeling the primary-side nodalization, volume, length, flow area and elevation change of each MARS-KS pipe component resembles the RD-14M test facility, as closely as possible. The pipe component is adopted for heated section model because the pipe horizontal stratified criterion works for low- and moderate viscosity liquids, including water, at least in small diameter pipes up to 5 cm. In the heat structure, the seven fuel rods are combined into a single fuel rod heat structure and these fuel pins generate heat corresponding to each channel power. The power distribution in the axial direction is assumed to be uniform. The break is modeled by the trip valve attached at inlet header 8. The improved critical flow model is adopted instead of original RELAP5 critical flow model developed by Ransom and Trapp.

The steam generator secondary side includes only those components within the steam generator. Figure 1 shows the RD-14M test facility and steam generator nodalization. For the steam generator condensation sensitivity study, two different steam generator control volume size, 8 and 16 u tube nodes, are simulated and compared. The steam outlet pressure and the feedwater flowrates and temperatures measured from the experiments are used for boundary condition.

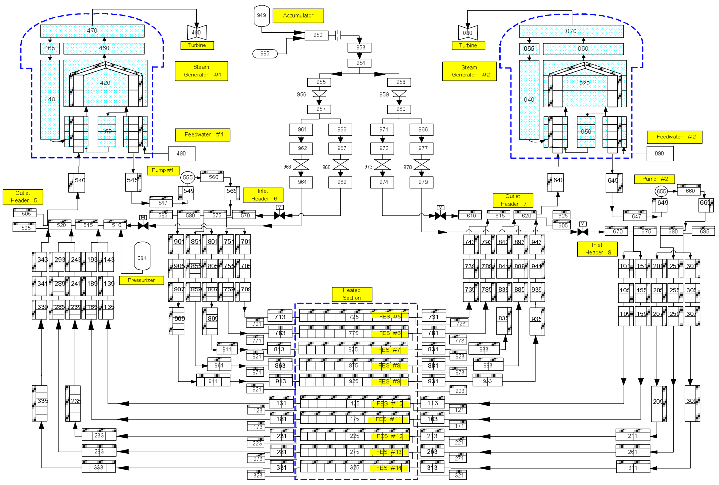

Fig. 1 MARS-KS Nodalization for RD-14M Facility

3. Results

The steady state run was performed to initialize the reactor conditions to correspond to the test initial conditions. The calculated values of the major parmeters are in good agreement with the experiment data as shown in table 1.

Table 1 Selected Variables Comparison for Initialization

Variable Description	Exp.	Cal. U tube node number		units
		8	16	
Primary side				
Pump 1/2 Flow	18.3/18.2	18.3/18.3	18.3/18.3	Kg/s
U-tube1 In/Out Temp	301.8/260.9	302.7/262.9	301.9/261.5	°C
U-tube2 In/Out Temp	301.8/262.6	302.5/262.9	301.3/262.0	°C
Secondary side				
FW 1/2 Flowrate	2.09/1.97	2.1/2.1	2.1/2.1	Kg/s
FW 1/2 Temp	187.63	187.6	187.6	°C
STM 1/2 Flowate	1.93/1.91	1.99/2.12	1.94/2.1	Kg/s
Recirculation Ratio	≈ 6	7.3	6.3	

After the break opened, the primary system pressure rapidly decreased due to the sudden discharge of the inventory mass. After then, the pressure relatively and slowly decreased since the power supply and reactor coolant pumps are still operated. The header pressures are typically well predicted in both cases. The header pressure of the more fine nodes case, however, shows more closed to measured data in all headers.

In order to achieve better understanding and assess the steam generator condensation sensitivity on very small break LOCA, the results of calculation with two different u tube node size is compared. Figure 2 implies the steam generator void fraction transient comparison. The u tube inlet void variations resulting from voiding in the channel is well predicted in the simulation. The voiding is condensed and collapsed in the u tube by secondary side heat removal. Although the u tube outlet void fraction shows good agreement to experiment results while the heat is fully removed, the timing of oscillation is earlier than measured. When the break flow discharge coefficient is adjusted to 0.65, the timing of oscillation goes closer to experiment. In this case, the inlet void fraction is calculated lower than other results. The more assessment of the heat removal from steam generator surface to environment is needed. Figure 3 shows the average void fraction varying along the u tube distance from 900 seconds to 1000 seconds. The void fraction at the middle location, top of the u tube, is highly calculated than those with sixteen nodes case, because the large heat transfer area is assumed in this region. Overall heat transfer area from primary to secondary side is approximately same each other. The small control volume size of the u tube shows the better prediction of condensation, therefore this paper suggest that the control volume size sensitivity study should be performed to have better accurate results when the steam condensation significantly affected on the system response.

The FES sheath temperature calculation is often the most significant parameter in safety analyses. Figure 4 provides outlet FES temperature comparison of channel 13. In this test, the initial FES temperature is maintained until 1000 seconds when the channel flow rate began to oscillate. The full removal of the FES bundle heat makes the FES temperature maintain the initial temperature since the primary loop flow rate has almost normal circulation. A delayed FES temperature increase and power trip initiation is predicted due to high channel flow rate which is contributed by less break discharge flow rate.

5. CONCLUSIONS

The capability of MARS-KS code to simulate the steam condensation during the very small break LOCA condition was assessed. Through sensitivity assessment results of B9802 SBLOCA test, the small control volume size of the steam generator shows the better prediction of condensation. The calculation of break discharge flow rate which finally determines the u tube flow rate also important point in order to properly predict the steam condensation behavior. Therefore, this paper suggests that the control volume size and break flow discharge sensitivity studies should be performed to have better accurate results when the steam condensation significantly affected on the system response.

REFERENCES

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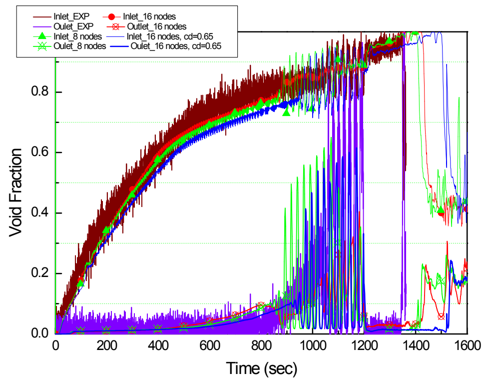

Fig. 2 Steam Generator Void Fraction

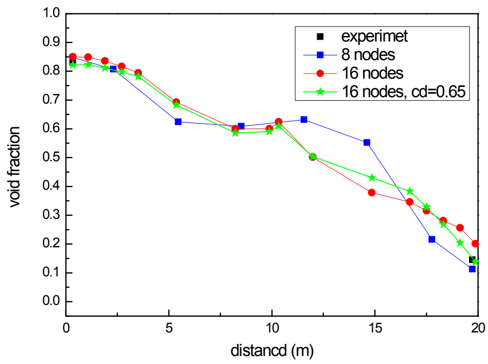

Fig. 3 Void Fraction along U Tube

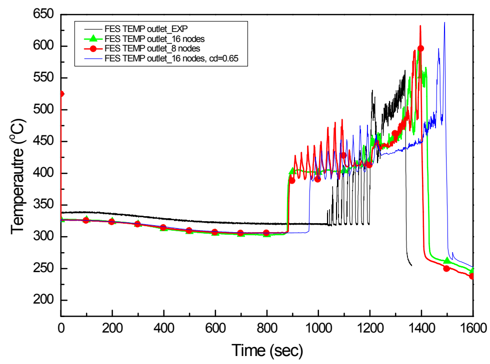

Fig. 4 Channel 13 Outlet Temperature