Improvement and Evaluation for Henry-Fauske Critical Flow Model of SPACE Code

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1. Introduction

The Henry-Fauske critical flow model applied to the SPACE code does not predict the break flow conservatively compared to the critical flow model of the RELAP5 code. The break flow rate is one of the highly important phenomena in accident analysis. The SPACE code applies a counter current flow limiting(CCFL) model to compensate for the non-conservatism of these critical flows. This causes a problem with excessive calculation time. To solve these problems, we add the same Henry-Fauske critical flow model as RELAP5 to the SPACE code. In this study, to verify this, we perform verification calculations on LOFT L9-3 which is a representative integral effect test(IET).

2. Experimental evaluation

Henry-Fauske critical model applied to existing SPACE codes will predict lower critical flow rates over the period of transition from subcooled liquid to two-phase fluid compared to RELAP5 critical flow models assuming a non-equilibrium(Ne) factor of 0.14 and discharge coefficient of 1.0.

2.1 Overview of LOFT L9-3 Experiments

The LOFT L9-3[1] experimental purpose is to provide experimental data to developers of analysis codes for ATWS analysis, evaluate alternative methods of reaching long-term shutdown without inserting control rods after ATWS, and verify the applicability of point kinetics model or transients. In addition, the experimental data provided is used to determine the behavior characteristics of the primary system due to loss of main feedwater flow rate on the secondary side of the steam generator and to determine the two-phase and overcooling flow characteristics released through PORV and SRV at high pressure. The LOFT L9-3 experimental device is a 50MWt pressurized light water reactor designed at a scale of 1/60 based on a 4-Loop Westinghouse-type nuclear power plant. The schematic diagram is shown in Fig. 1.

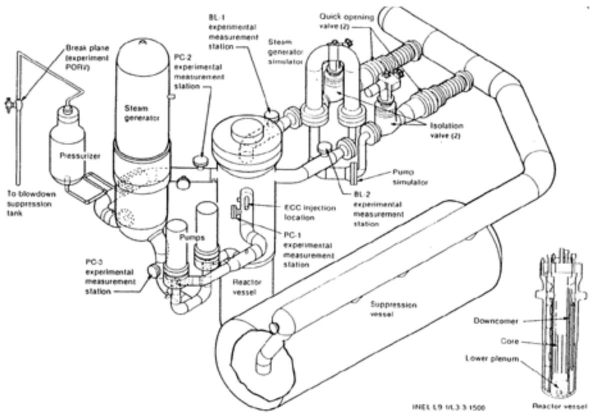

Fig. 1. LOFT Facility Schematic

2.2 Experimental Conditions

The LOFT L9-3 experimental conditions begin at normal conditions, such as core power of 48.7MWt, cold leg temperature of 557.0K, hot leg temperature of 576.4K, pressurizer pressure of 14.98MP, and steam generator pressure of 5.61MPa. The key steady-state initial conditions of the experiment are shown in TableⅠ.

Table I: Initial value of experiment

Parameter	Experiment	SPACE
Mass flow rate(kg/s)	467.6	467.63
Hot leg pressure(MPa)	14.98	14.95
Cold leg temperature(K)	557.0	555.04
Hot leg temperature(K)	576.4	574.56
Power level(MWt)	48.7	48.7
PZR Liquid temperature(K)	615.2	614.78
PZR Pressure(MPa)	14.98	14.98
SG Liquid level(m)	3.15	3.19
SG Pressure(MPa)	5.61	5.55
SG Mass flow rate(kg/s)	25.7	25.6

2.3 LOFT L9-3 Evaluation Results

Fig. 2. shows the discharge flow rate through PORV and SRV during the transient. The main feedwater stops, the pressure gradually rises, and after 67.3 seconds the MSCV of the steam generator closes, reaching the opening set point of the PORV. At 100 seconds when the pressurizer pressure reaches its maximum, the discharge flow rate is maximum, and after that, the PORV and SRV are repeatedly opened and closed. We compare the results with the existing Henry-Fauske critical flow model using the newly added Henry-Fauske critical flow model in the simulation with SPACE code for discharge of coolant through the PORV and the SRV. Overall, the opening points are similar, but there are some differences in the amount of discharge. When using the newly added Henry-Fauske critical flow model, we can confirm that the maximum discharge flow rate is higher and conservatively predicted.

Fig. 3. Shows the pressure change of the pressurizer. The new Henry-Fauske critical flow model shows more similar results to experimental results than existing models. Initially, the main feedwater to the steam generator is interrupted, causing the pressurizer pressure to rise just like the experiment. The pressure that was decreasing due to the operation of the pressurizer spray system gradually increases again after the spray system stops. The increased pressure is reduced again in 55 seconds by the operation of the spray system. The MSCV of the steam generator closes at 67.3 seconds, resulting in a rapid increase in pressure as shown in the experimental results. The pressure then reaches the open setting of the pressurizer PORV, which opened at 73.8 seconds, but continue to rise, somewhat different from the experimental value trend. The rising pressure decreases at 90 seconds, but without the complement of the steam generator's main feedwater, the pressure rises again and reaches a maximum pressure slightly higher than the experimental results at 103 seconds. Subsequently, the pressure s reduced due to the operation of the PORV, SRV, and pressurizer spray systems of the steam generator, and after 120 seconds, the rise and fall are repeated near 15.5MPa to 16MPa.

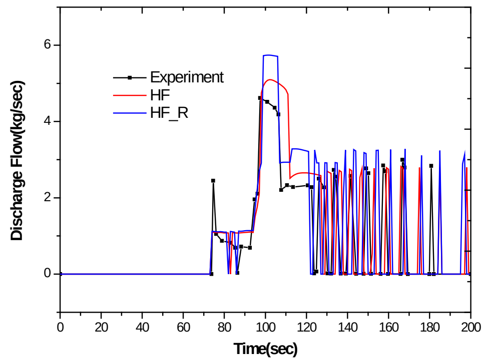

Fig. 2. Discharge flow rate

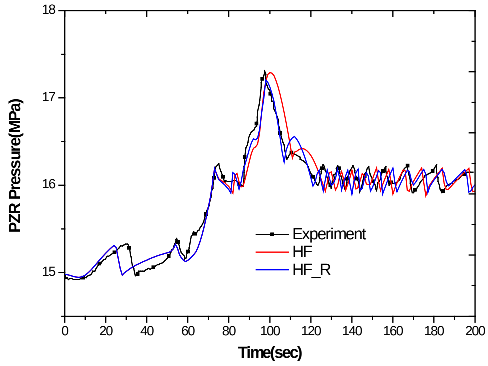

Fig. 3. Pressure change of the pressurizer.

3. Conclusions

An analysis of the Henry-Fauske critical flow model of existing SPACE code and the same conservative Henry-Fauske critical flow model as RELAP5 is performed on LOFT L9-3. As a results, the conservative Henry-Fauske critical flow model was evaluated to conservatively predict the critical flow rate than the previous Henry-Fauske critical flow model. A new Henry-Fauske critical flow model with RELAP5-level conservatism will be used in the future to develop SPACE methodologies for OPR1000-type and WH 3-loop type nuclear power plants.

REFERENCES

[1] NUREG/CR-3427 'Experiment Analysis and Summary Report for LOFT ATWS Experiments L9-3 and L9-4'.