Simulation of UPTF Test 20 by using MARS Multi-Dimensional Component

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1. Introduction

A multi-dimensional component in the thermal hydraulic system analysis code, MARS, was developed for a more realistic analysis of nuclear systems[1]. The governing equations and physical constitutive relationships are extended from those of 1-dimensional MARS components. As a preliminary assessment of multi-dimensional component of MARS, UPTF test 20 is simulated. UPTF test 20 is performed to evaluate the upper plenum injection phenomenon in the real PWR core scale by GIMENS. Takeuchi *et. al.* [2] have suggested a scaling law for the prediction of the parameters relating the upper plenum injection phenomenon by comparing the results of WCOBRA/TRAC and several upper plenum injection experiments, including UPTF test 20 and CCTF tests. During the analysis, Takeuchi *et. al.* used the 1-D like imaginary channel method. The scaling factor of CCTF facility is 0.091 and UPTF facility is 2.1. Based on these scaling factors, the prediction laws about the breakthrough flow area, downflow rate into the core, hot leg water carryover, and liquid level in the upper plenum are established. In this paper, a multi-dimensional component of MARS is used for the nodalization of core and upper plenum volumes of UPTF facility. The multi-dimensional MARS results are compared to both of WCOBRA/TRAC and experimental result of UPTF test 20.

2. UPTF Test 20 and MARS Nodalization

In this section UPTF facility for test 20 is explained. The initial and boundary conditions for the three phases of UPTF test 20 are summarized. The WCOBRA/TRAC results for the UPTF test 20 are summarized. MARS nodalization and simulation scheme is followed.

2.1 UPTF facility

UPTF facility is about 2.1 times larger than a usual UPI plant. This is a full scale simulation facility of 3900 MWth KWU 4-loop PWR. Each UPTF loop has a steam/water separator to simulate a steam generator and a variable resistance to simulate a reactor coolant pump. The upper plenum space consists of full-size internals. The fuel core is simulated by a steam/water injection system to set up the appropriate flow conditions in the reactor vessel. UPTF Test 20 consists of 3 phases. These phases simulate the thermal hydraulic conditions in a PWR with UPI during the reflood phase of a cold leg large break LOCA. The objective of the Test 20 was to investigate the steam/water UPI flow interaction in the upper plenum. Among the 4 loops, one loop is used to postulate the UPI system. A hutze is installed inside the hot leg of the loop for the injection of the UPI water. One loop is used to simulate the broken loop. Other two loops remain intact.

The system pressure equals 3.0 bar (36 psia) and the UPI rate equals 262 kg/s (576 lbm/s) of subcooled water by about 100 K (180 ^{o}F). Core simulation system injects the steam and water mixture. The boundary and initial conditions for the experiments are summarized in the **Table 1**.

2.2 WCOBRA/TRAC Results

The WCOBRA/TRAC results about UPTF test 20 are summarized for main important parameters. Down flow rate as a percentage of the available water amount are calculated. For the phase A, 89.0 % of the available water flows down through the core plate. For the Phase B and C, the percentages are 80.8 % and 88.2 %, respectively. The available water amount is the sum of the UPI injection water, steam condensation in upper plenum, and the core water injection. The condensation amount in the upper plenum is calculated as the difference between the steam in- and out-flow. The hot leg carryover flow as the percentage of the available water are 13.6 %, 20.7 %, and 8.7 % for the Phase A, B, C, respectively. The collapsed liquid level of the water pool is calculated as the ratio to the height from the hot leg center line from the upper tie plate. The ratios are 0.11, 0.10, and 0.09 for the phases, respectively.

2.3 MARS Nodalization

Figure 1 shows the multi-dimensional UPTF core nodalization and hot leg connection configuration. In this nodalization, the cold leg and downcomer region are ignored and not included. Instead, the drain water flow is controlled as the experimental value to keep the pressure of the UPTF core.

In the UPTF facility model, the dummy fuel region is the most important region for the proper simulation of the hydraulic behaviors of the UPI water in the upper plenum space. The lateral resistance factor for the dummy fuel region is decided as 38.4 (=0.3 x 16 x 8) with the assumption that 0.3 is the elemental resistance value for one fuel rod. 0.3 is the asymptotic form drag coefficient of a staggered rod in the cross flow situation at the turbulent region. As like the dummy fuel region model, lateral resistance factor for upper plenum region is decided as 0.6. It is assumed that 0.7083 core simulator pipes are spread in a core volume. The lateral resistance factor for core volume is decided as 0.21249.

Table 1. Boundary and initial conditions for the UPTF 20 Phase A, B, and C

Boundary		Phase A	Phase B	Phase C
ECC water	Flow	262	262	262
	Temp	305	305	305
	p	3.0	3.0	3.0
Drain water	Flow	270	270	270
Core simulator Steam	Flow	93	104	87
	Temp	474 K Duration average	463 K Duration average	459 K Duration average
	p	3.0	3.0	3.0
Core simulator Water	Flow	25	23	25
	Temp	110 ^{o}C = 383 K	110	110
	p	3.0	3.0	3.0
Plenum space	Temp	474	463	459
	p	3.0	3.0	3.0

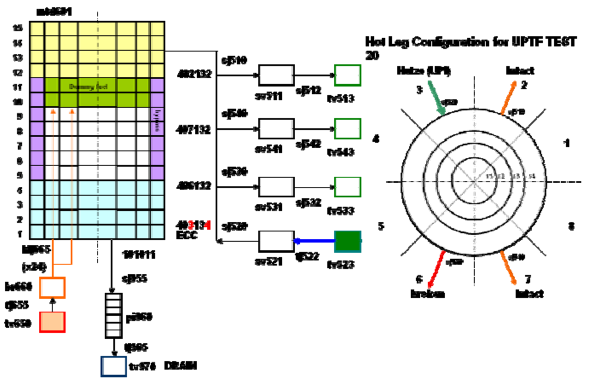

Figure 1. MARS multi-dimensional nodalization for the UPTF Test 20 facility

3. MARS Results

The results are plotted with the macroscopic view points in the figure 2 to 5. In addition, MARS results shows the location of the down flow occurring region in the upper plenum. The radial and peripheral trends of the collapsed water level of the UPI pool can be another result of the MARS multi-dimensional simulation.

4. Conclusions

MARS provides the macroscopic comparison parameters about UPTF test 20. The results show less down flow rate to the core and more hot leg carryover than the UPTF experiment.

REFERENCES

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[2] K.Takeuchi, M.E. Nissley, J.S. Spaargaren, S.I. Dederer, "Scaling effects predicted by WCOBRA/TRAC for UPI plant best estimate LOCA, Nuclear Engineering and Design, **186**, pp.257-278, 1998.

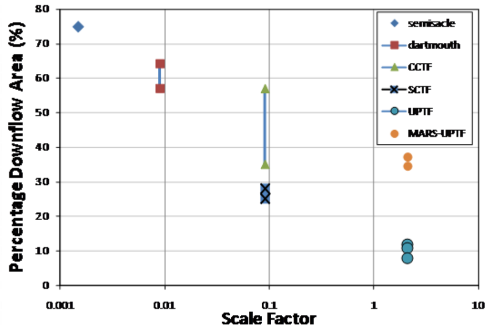

Figure 2. Down flow area and MARS prediction

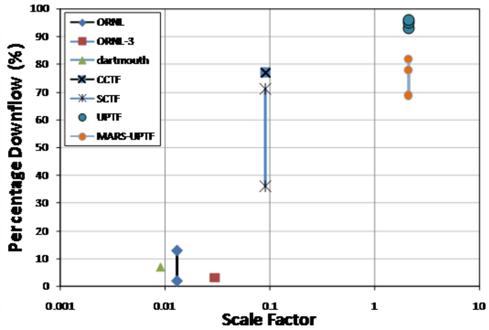

Figure 3. Down flow rate for the available liquid and MARS prediction

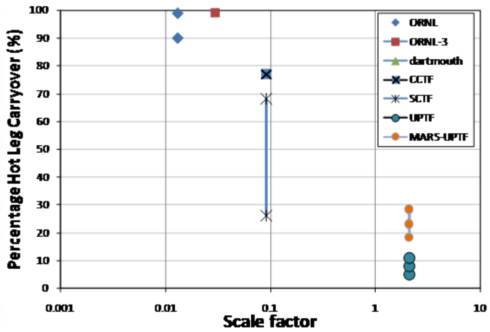

Figure 4. Hot leg carryover for the available liquid and MARS prediction

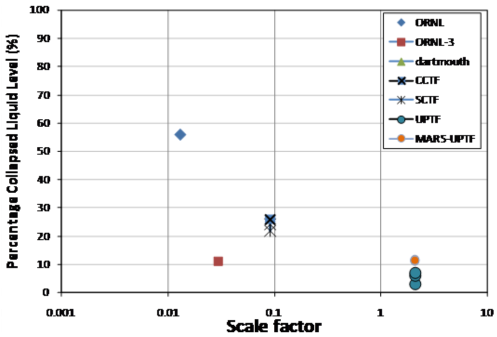

Figure 5. Collapsed level for the hot leg center level and MARS prediction