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Verification of the SPACE Code for Separate Effects Tests

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1. Introduction

In order to assess applicability of SPACE as a system analysis code, various calculations for the phenomenological problems, the separate effects tests (SETs) and the integral effect tests (IETs) have been performed so far. The phenomenological problems are used to check whether the code shows quantitatively and qualitatively good agreement with the physics of each problem. Intensive study including comparison of SPACE predictions on wide variety of events with the results from SETs and IETs has been performed.

In this paper, simulation results for the evaluation of special process model, such as GE Level Swell test [1], Dukler's air/water flooding test [2] and HDU experiments [3], are presented.

2. Test Plan

A total of 22 developmental assessment calculations have been performed to assess whether the SPACE code meets properly the code requirements. Table 1 lists only 8 separate effects problems, which includes a brief description of the objective of each problem.

Table 1: Separate Effects Problems for the SPACE validation

SET Problems	Test Objectives
● Edwards Pipe	Vapor generation model, Choking model
● Marviken Test 15,20,22,24	Subcooled choking model
● Super Moby Dick	Internal choking model
● GE Level Swell	Single vapor choking model
● Dukler Air/Water Test	Countercurrent flow model, Interphase drag model
● Upper Core Support Plate Test	Countercurrent flow model, Interphase drag model
● Off-Take Test	Off-take model, Interphase drag model
● Pool Formation in Upper Plenum (UPTF Test 10B)	Interphase drag model, Entrainment/de-entrainment model

These are a collection of problems that have been performed by KEPCO E&C. In addition to these problems, various problems which contain the phenomenological problems, the SETs and the IETs, have been performed by other institutes, as a series of code validation effort.

3. Test Results

3.1 Critical Flow Model Test

In order to verify the critical flow model, the code was run to simulate GE Level Swell experiments. The tests were designed to measure transients in a large tank which was depressurized via a blowdown line and an orifice. The initial conditions for the test were a system pressure of 6.92MPa and a water level of 3.167m. In order to simulate the experiments, the test domain consists of 26 volumes and the initial liquid temperature is assumed to correspond to the saturation temperature. The outlet boundary is located at the top of the vessel and oriented vertically. The outlet junction is modeled using the abrupt area change model.

As shown in the figure 1, the analysis result at the beginning of the transient shows a tendency to depressurize rapidly. The omission of the wall heat capacity is considered to be the cause of this behavior. The pressure response of the vessel is also governed by flashing of water. The flashing produces a slow response to pressure changes, and most of the results are qualitatively in agreement with the physics of this problem.

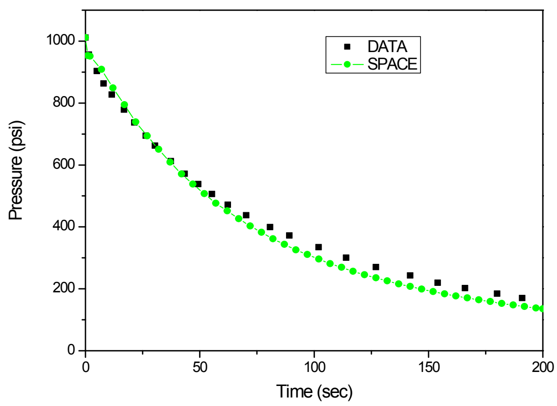

Figure 1 Pressure Variation at the Top of the Vessel

3.2 Countercurrent Flow Limitation (CCFL) Model Test

The CCFL model implemented in the SPACE code was assessed for Dukler's air/water flooding test, which was conducted to study the interaction between a falling liquid film and an upflowing gas in the core. The facility consists of a 0.051m diameter, 3.96m long, vertically oriented cylindrical plexiglass pipe, air injection and water drain nozzles installed on the pipe. The water is injected into the pipe from the upper section and the air blower pumps the air into the pipe from the lower section. The test geometry is modeled using the pipe and branch components. Three CCFL models were used for the test, but the one that appeared to be best for the test was a Wallis form. In order to determine optimal coefficients for the Wallis correlation, additional simulations were performed by changing the Wallis coefficients. The optimal constants were found to be 0.84 for the gas intercept and 1.0 for the slope. A comparison of the measured and calculated water downflow versus air flow injection rates for given liquid injection rates is shown in Figure 2. As shown in the figure, a good agreement with the data is observed. Thus the code is working properly with appropriate intercept and slope values input to the model.

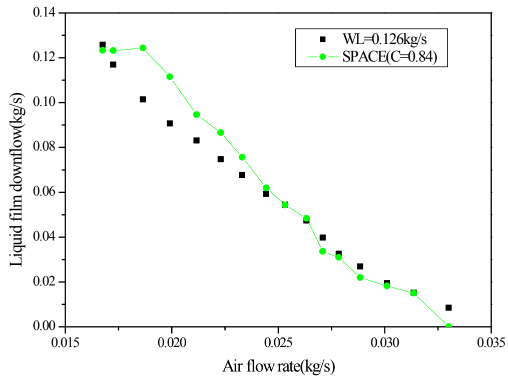

Figure 2 Liquid Downflow Rate Versus Air Flow Rate

3.3 Off-take Model Test

The off-take model implemented in the SPACE code was assessed to HDU experiments, which were conducted to investigate the off-take phenomena at the T-junction installed between the header and branch pipes. The test facility contains various branch pipes not only for three directions (top, side and bottom), but for arbitrary directions. The experiments about the onset of entrainment and branch quality only for three directions (top, side and bottom) were carried out by using air-water as working fluids under the conditions of about 20 °C temperature and of pressures up to 0.95 MPa.

The test geometry is modeled using the pipe and branch components. The off-take model is used at the junction of branch pipe connected to a horizontal pipe. On the whole, the off-take model in the SPACE predicts well the present experimental results such as the onset of off-take and the branch quality. A comparison of the Froude number versus the non-dimensional level in term of the ratio of inception height to branch diameter (h_b/d) at the onset of gas pull-through is shown in Figure 3. At the side branch, the calculated quality data are compared with the measured data in terms of the ratio of distance from the stratified liquid level to junction to inception height (h/h_b) as depicted in Figure 4. As shown in the figure, a good agreement with the data is observed.

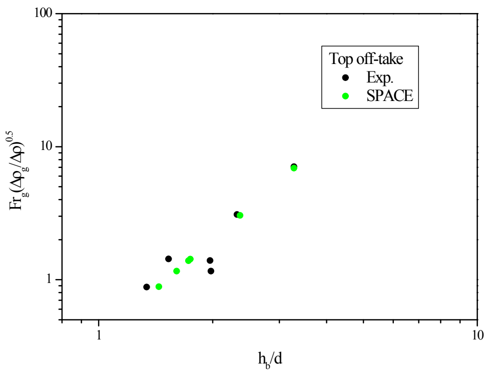

Figure 3 Onset of Entrainment at the Top Branch

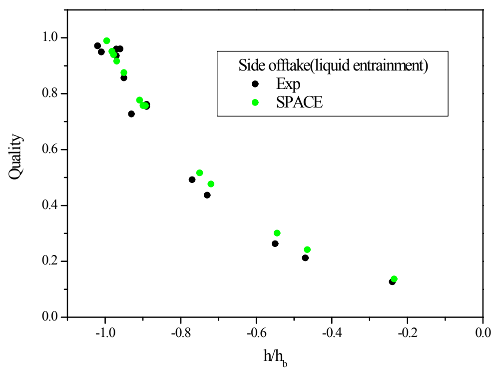

Figure 4 Discharge Flow Quality vs. Liquid Depth for the Side Branch

4. Conclusions

As an effort for verification, 22 developmental assessment calculations have been performed. Though only some results are shown here, most of the 22 test results agreed well with the measured data of each problem. It can be concluded that the SPACE code is applicable to the analysis of two phase thermal hydraulic phenomena that may be encountered during the nuclear power plant system transient events such as non-LOCA and LOCA.

Acknowledgment

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