Assessment of Pressurizer Transients using the SPACE Code

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1. Introduction

The Korean nuclear industry has been developing a thermal-hydraulic analysis code for the safety analysis of PWRs(pressurized water reactors). The new code is named SPACE(Safety and Performance Analysis Code for Nuclear Power Plant). In this paper, in an effort to assess the ability of the SPACE code to predict transients involving the pressurizer, two pressurizer transients are calculated and results are compared to either experiment results or to RETRAN calculations. For a stand-alone pressurizer experiment, The MIT pressurizer experiment was selected. For the plant calculation, Ulchin units 3&4 were selected and a simple hypothetical transient was used to test the applicability of the SPACE code pressurizer model.

2. Description of the SPACE Code

2.1 General Description of the SPACE Code

The SPACE code is an advanced thermal hydraulic analysis code capable of two-fluid, three-field analysis. The SPACE code can be used in LBLOCA, SBLOCA and in Non-LOCA analyses of PWRs.

2.2 Modeling Pressurizer in SPACE

In the SPACE code, the PWR pressurizer is modeled using several types of hydro dynamic components. The pressurizer volume itself is modeled using the PRZR component, which is similar to the PIPE component with the added features of pressurizer heater and a level calculation function. The pressurizer spray is modeled using the TFBC component. Pressurizer safety valves and relief valves are modeled using VALV or TFBC components.

Because the SPACE code calculates three-field (including droplet) for all cells and faces, no special governing equation is needed for the pressurizer. The heat transfer coefficient between the vapor and the liquid is calculated from a models and correlations package. The user has the option to change the heat transfer coefficient by entering a multiplier for the droplet heat transfer to simulate the pressurizer spray. The user may also input the heat transfer coefficient for the liquid and vapor phase to model the heat transfer at the liquid and vapor interface in the pressurizer.

3. MIT Pressurizer Experiment

3.1 Description of the MIT Pressurizer Experiment

In the early 1980s, MIT performed a series of pressurizer experiments. The transients considered included 5 sets of insurge and outsurge tests. The initial pressure for the pressurizer ranged from 0.7~0.9MPa. More detailed information on the MIT pressurizer tests can be found in the references [1]. In this paper, only an insurge to a partially-full tank is analyzed.

3.2 SPACE Nodalization

The MIT pressurizer was modeled using one pressurizer component, one heat structure group and one TFBC(Temporal Face Boundary Condition) component as shown in Fig.1. A pressurizer component(c110) with 10 cells was used to model the primary tank. The initial water level was modeled by changing the vapor void fraction of each cell in the pressurizer. The heat structure (h110-1) was used to model heat loss to the environment. The TFBC component was used to model the flow boundary condition to the pressurizer.

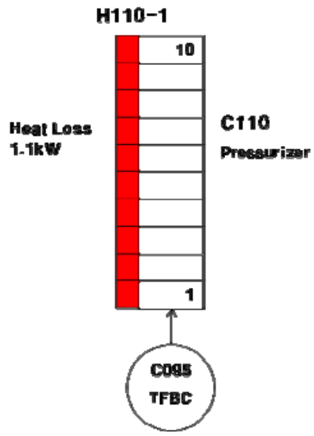

Fig. 1. SPACE Nodalization diagram for the MIT pressurizer.

3.3 Calculation results

The SPACE calculation for an “insurge to a partially-full tank” was performed. The initial pressurizer water level is 0.35m (1/3 of the primary tank). The initial water level is modeled by setting the vapor void fraction to 0.0 for the lower 3 cells for C110 and to 0.6666 for the 4th cell. The remaining cells have a void fraction of 1.0. The insurge begins at t=20sec and stops at about t=86sec. The insurge water is subcooled.

However, the insurge water does not immediately mix with the saturated liquid already present in the pressurizer. Therefore, the pressurizer pressure increases rapidly during the insurge. The pressure decreases after the insurge stops. This pressure decrease occurs due to the heat loss to the pressurizer wall and the mixing of cool insurge water and the saturated water initially present in the pressurizer. The results are shown in Fig. 2. Case 1 and case 2 used different heat transfer coefficients for the liquid-vapor interface. Case1 used heat transfer coefficient from models & correlations. Case 2 assumed no heat transfer at the liquid-vapor interface. Case2 show better agreement with the experiment results. The SPACE code under-predicted the pressure rise during the insurge and over-predicted the pressure decrease after the insurge stopped. However, the general trend is identical to than in the experiment.

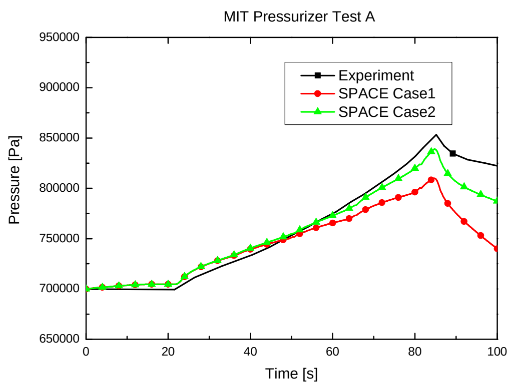

Fig. 2. Pressure vs. time for the MIT Pressurizer test : insurge into a partially filled pressurizer.

4. PWR Plant Calculation

4.1 Plant Nodalization and Transient Scenario

For the plant calculation, Ulchin units 3&4 were selected as the reference plant. The Ulchin units 3&4 are CE-type plant with two steam generators and four reactor coolant pumps. Its thermal output is 2815MWt. The steady-state input nodalization is shown in Fig. 3.

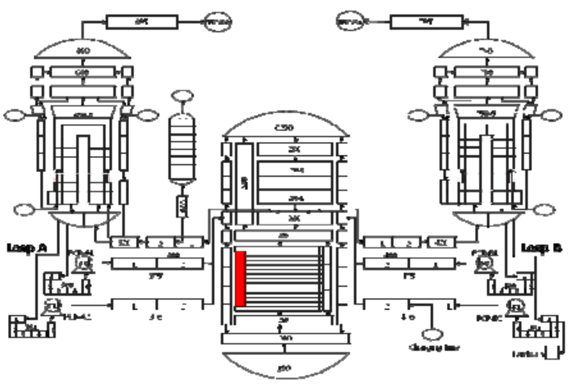

Fig. 3. SPACE Nodalization for Ulchin unit 3&4 Basedeck.

A simple hypothetical transient scenario was created for this paper. The transient scenario is shown in the table below. The control systems, such as steam generator level control, pressurizer level control, and steam dump were not modeled.

Event	Time
RCP Trip	0.0 sec
Reactor Trip	3.0 sec
End of Calculation	100.0 sec

4.2 Calculation Results

The transient scenario was calculated with the SPACE code and the RETRAN code. In the early part of the transient, the RCS pressure increases as a result of a RCP trip, leading to reduced heat removal to the secondary side. After the reactor trip, primary heat generation is reduced and the primary pressure decreases. The SPACE code and RETRAN results show a similar trend, with SPACE showing a slightly higher peak pressure.

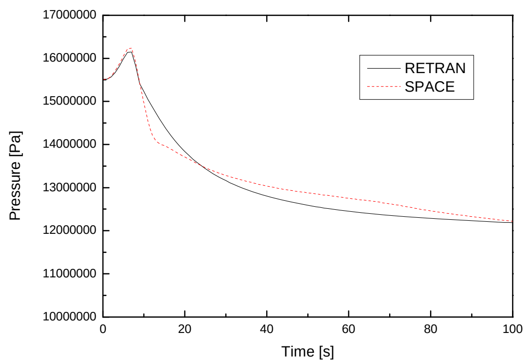

Fig. 4. Pressure vs. time for Ulchin 3&4 Plant Transient

5. Conclusions

To assess the ability of the SPACE code to predict transients involving a pressurizer, two pressurizer transients were calculated and results were compared to experimental results or RETRAN calculations. The MIT pressurizer experiment and Ulchin units 3&4 plant hypothetical transient were selected for use in this study. The results show that the SPACE code pressurizer model can predict pressure trends correctly.

REFERENCES

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