RELAP5 Modeling Method for SIT Equipped with Fluidic Device

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1. Introduction

One of the advanced safety features of APR1400 is the SIT (Safety Injection Tank) equipped with fluidic device. The device has a role of extending SIT flow to the later part of a LBLOCA (Large Break Loss-Of-Coolant Accident) to compensate the lack of low head safety injection pumps. The SIT flow going through the device experiences two step flow resistance which increases as the vorticity inside the device increases.

In LBLOCA calculations using RELAP5/MOD3, SITs are usually modeled with the ACCUM component. However, the ACCUM component model regards a SIT as a lumped volume so that it can not be applied to the modeling of the SIT of APR1400.

As the fluidic device was a kind of newly adopted safety equipment, a full scale test facility, VAPER (Valve Performance Test Rig) was built and various tests were performed by KAERI [1,2]. Utilizing the results of VAPER tests, a simple and practical RELAP5 modeling method was suggested in this paper.

2. VAPER Tests and Modeling Method

2.1 VAPER Tests

VAPER is a full scale test facility for the SIT of APR1400. It has a water tank pressurized with air to ~4 MPa and a fluidic device is installed at the bottom of the tank. At the discharge pipe, a quick opening valve is installed and the discharged water and gas are collected into a stock tank which is at the atmospheric condition.

Various kinds of tests were conducted in the facility. Through Test-II(b)-C-H-1, the design specifications of fluidic device were determined and FD-II(b)-C-1 ~ FD-II(b)-C-5 were conducted to show not only the performance of the fluidic device but also the repeatability of tests. The effect of stand pipe length was investigated through FD-II(b)-HH-1 ~ FD-II(b)-HH-3 and two additional sets of tests were conducted with small changes in fluidic device design.

Significant parameters measured in the tests are tank level, pressure and temperature of gas, stand pipe level, and pressure drop across the fluidic device. The rate of water discharge was calculated using the measured tank water level and assumed water density. The rate of gas discharge was also estimated with the measured gas pressure assuming a polytropic gas expansion.

The peak water discharge rate was estimated to be ~1000 kg/sec and the tank emptied at ~170 seconds in cases the tank had been pressurized to ~4.2 MPa. Only one test, FD-II(b)-C-5 was initiated from ~2.1 MPa and it resulted in a lower water discharge rate and a longer tank depletion time as easily expected.

One of the most interesting results of VAPER tests is the air discharge which had occurred much earlier than the tank emptied. This early air discharge occurred as the stand pipe was depleted much faster than the tank. Air discharge was calculated to occur at ~100 seconds in case of FD-II(b)-C-1 ~ FD-II(b)-C-4.

2.2 Modeling Method

The noding used in RELAP5 modeling for VAPER is presented in Fig. 1. In this noding, the air and water volume above the top of stand pipe is modeled using one BRANCH component (C100) and one PIPE component (C110), respectively. The volumes inside (C130) and outside (C120) of stand pipe are modeled using separate PIPE components. The cylinder part of fluidic device including the vortex chamber is modeled using a SNGLVOL component and SNGLJUN components are used to connect it to 3 adjacent volumes.

The most important part of this modeling is how to model the flow resistance of fluidic device varying with the vorticity in the vortex chamber. The vorticity produced in the vortex chamber is inversely proportional to the magnitude of flow supplied through stand pipe. If the flow through stand pipe is high, the vorticity is low and vice versa. The flow through stand pipe is proportional again to stand pipe water level. Thus, the flow resistance through fluidic device should be a function of stand pipe level.

However, the K factor of fluidic device is not a simple function of stand pipe water level which rebounds after a rapid drop as shown in Fig. 4. On the other hand, tank water level drops consistently and gradually so that it is easy to express the K factor of fluidic device as a simple linear function of that parameter. The relation between tank water level and the K factor of fluidic device obtained from test data is presented with the assumed one in calculations in Fig. 2.

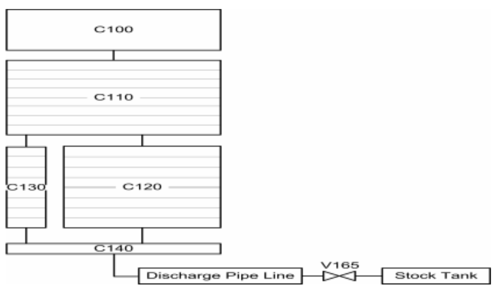

Fig. 1. RELAP5 noding for VAPER tests

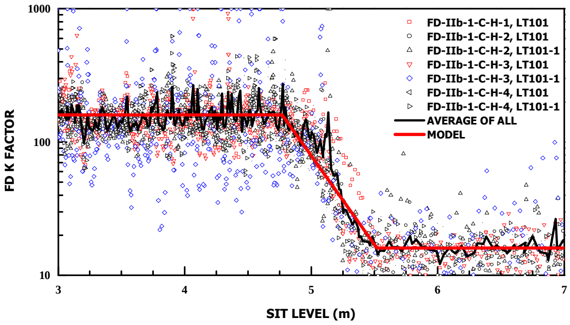

Fig. 2. FD K factor vs. tank level

3. Results and Conclusions

RELAP5/MOD3 simulations using the modeling method described above were conducted for FD-II(b)-C-1 ~ FD-II(b)-C-4 tests.

The calculated tank water level is compared with the measured data in Fig. 3. As seen in this figure, tank water level was predicted relatively well until the time of air discharge (~100 secs).

Fig. 4 contains the predicted and measured stand pipe water level. The overall behavior of stand pipe water level was also calculated well, but the rapid drop at ~35 secs and subsequent rebound were not predicted accurately. It was revealed from tentative calculations that the speed and depth of the rapid level drop is governed by the K factor of junction 125 which connect C120 to C140. However, the rebound of stand pipe level could not be predicted well even a higher K factor was imposed to junction 125.

The calculated water discharge rate shows a good agreement to test data as presented in Fig. 5. The calculated time of air discharge was also predicted well as shown in Fig. 6, but the peak air discharge rate was a little underestimated.

Calculations for other VAPER tests were also conducted. Though the results are not presented here, predictions are generally in good agreement with test data.

From these results, it is concluded that the SIT equipped with fluidic device can be modeled properly with the suggested RELAP5 modeling method.

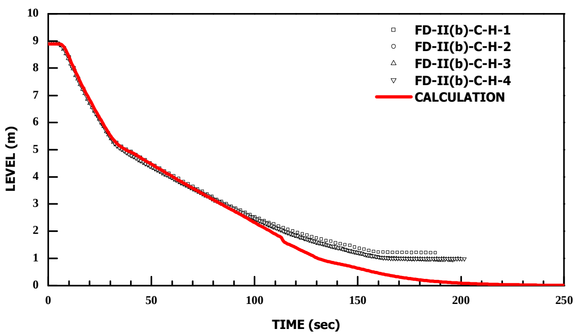

Fig. 3. Prediction of tank water level

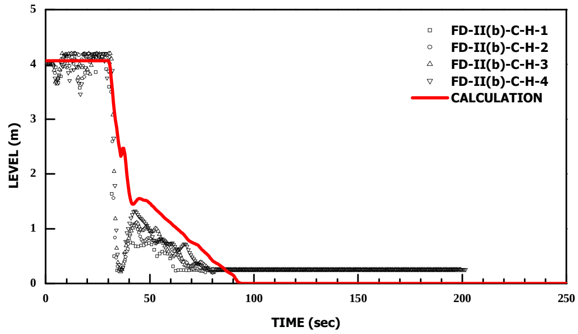

Fig. 4. Prediction of stand pipe water level

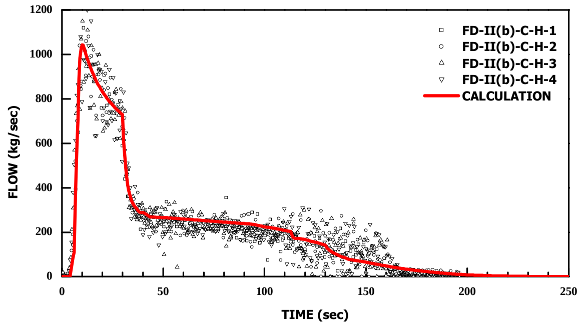

Fig. 5. Prediction of discharge water flow

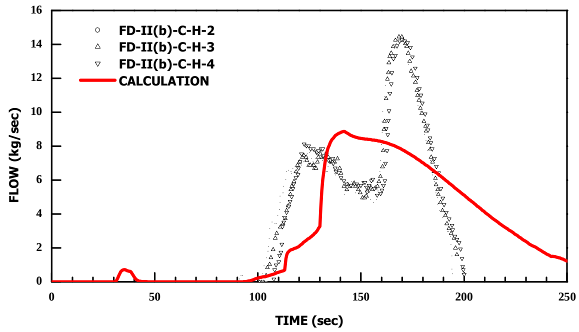

Fig. 6. Prediction of discharge air flow

REFERENCES

[1] KAERI, Performance Verification Test for APR1400 Fluidic Device, KHNP Report A03NJ02, 2005.
[2] KAERI, Fluidic Device Performance Test Using the VAPER Test Facility, VAPER-QLR-005, Rev.1, 2004.