

## Simulation of DOBO Tests using SPACE code

Kwi Seok Ha, Jong-Hyuk Lee, Seungwook Lee, Changwon Lee, and Dong-Jin Euh  
Korea Atomic Energy Research Institute, Deadeok-daero, 989-111, Yuseong-gu, Daejeon, 34057, Rep. of Korea  
ksha@kaeri.re.kr

**\*Keywords : Downcomer boiling, Direct Vessel Injection, SPACE.**

### 1. Introduction

APR (Advanced Power Reactor) 1400 has two kinds of safety injection systems which composes of the high-pressure safety injection system (HPSI) and the special Safety Injection Tank (SIT) which has the fluidic device and the plant adopts the direct vessel injection (DVI) system. Under the LBLOCA (Large Break Loss of Coolant Accident) situation, the ECC (Emergency Core Cooling) water through the fluidic device plays a role of the low-pressure safety injection of the existing power plant. However, the duration of the ECC water injection time through the fluidic device is short because of the limited inventory of SITs. Thus, only HPSI flow is available in the late reflood phase of the LBLOCA and the DVI is more efficient way to save the injected water.

In the simulation of the LBLOCA for the APR1400 there was some boiling in the downcomer region in the late reflood phase due to the wall heat transfer from the core barrel. This affects the reflood flow rate for cooling of core because it reduces the coolant head in the downcomer, which can induce the core reheating. This paper is to evaluate the predictability of SPACE [1] code for the downcomer boiling phenomenon.

### 2. Description of DOBO test [2]

The DOBO tests were conducted to investigate the downcomer boiling in the late reflood phase. The test facility was constructed according to the volume scaling law of which scaling ratio is 1/48, however, the gap size of the downcomer is the same as the original size of APR1400. As shown in the Fig. 1, the test section is designed with a slab geometry that simulates the high-temperature wall of a reactor vessel from the cold leg to the flow skirt. However, its length was extended by 1.3 m to allow installation of a single DVI nozzle at the top of the test section and to drain water at the bottom, but there is no heat input to this region. The width, depth, and total height of the test section are 0.3, 0.25, and 6.4 m, respectively. Only one of the four side walls (which has a length of 5.1 m) simulates a high-temperature reactor vessel wall.

Total of four tests were performed in the reflood flow conditions which is summarized in Table I. However, the actual mass flow rate in the test was 10% lower than the ideally scaled one.

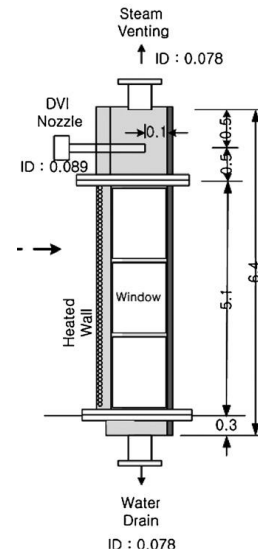


Fig. 1. Outline of the DOBO facility

Table I. Summary of the Experimental Conditions

Run	$T_{ECC}(^{\circ}C)$	$P_{sys}(kPa)$	$W_{ECC}(kg/s)$	$Q''(kW/m^2)$
R1	110.1	162.8	1.22	50.2
R2	110.2	161.4	1.16	69.7
R3	109.6	166.5	1.20	82.1
R4	109.5	170.8	1.20	91.1

### 3. SPACE modeling for DOBO tests

Two kinds of calculation model were used to simulate the DOBO tests. The first one is the single channel model (Fig. 2(a)) and the other one is the double channel model (Fig. 2(b)). Double channel model is the same as the single channel model except number of flow channels in the test section. the test section in the double channel model is divided into the heated channel and the unheated channel which have the same flow area. The pressure boundary conditions were applied to both ends (100, 140) and the ECC water is injected into the outlet of the test section (300-24). Test section is axially divided into 20 nodes which has the same length and the power is equally imposed to each node of heat structure (300-01 to 300-20)

The tests were carried out under the quasi-steady state condition. In order to obtain steady state condition in the calculation the subcooled liquid is first injected into the test section through DVI nozzle (130) increasing to the target value from 0 second to 300

seconds and after that constant flow rate is maintained. From 400 seconds to 500 seconds the power is imposed into the heat structure of the test section and it gradually increases to the target value and after that the constant heat power is maintained like Fig. 3.

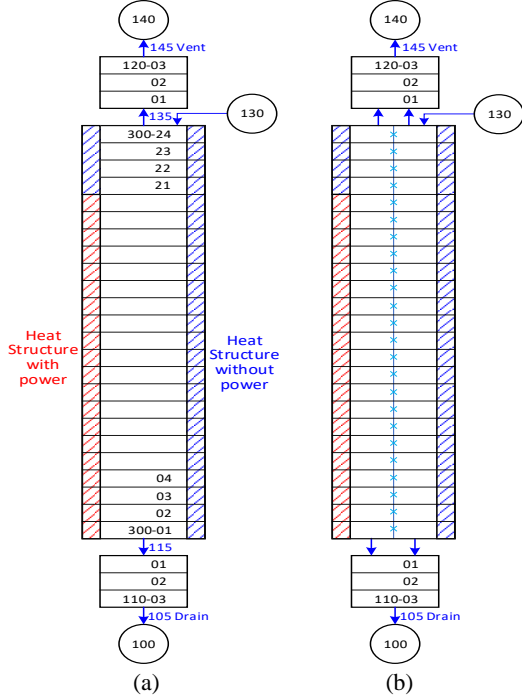


Fig. 2. Nodalization for SPACE calculation

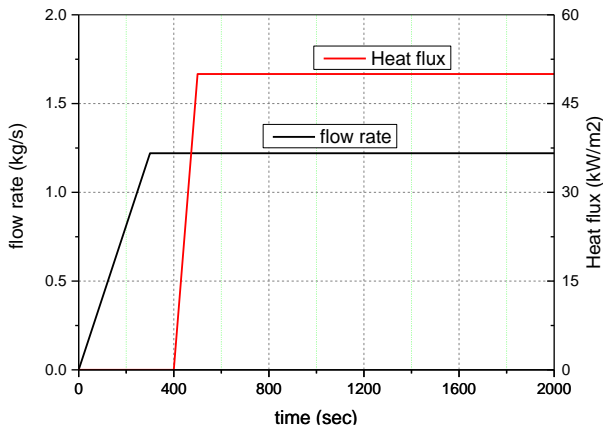


Fig. 3. Process of liquid injection and power imposing

#### 4. Calculation results

Difference among tests is the heat flux and thus the void fraction is gradually increased as the powers are increased as shown in the Figs. 4 and 5. Void fractions using single channel model are much higher than those of double channel model. Figure 6 shows the velocity distribution in the test section when the double channel model is used and the ECC water is injected into the 23-th node of channel 2(Unheated side). Much amount of the cold liquid goes down and some amount of the liquid is moved to the channel 1(Heated side) and goes

up and the liquid is heated in the heated side. However, the liquid when using single channel model has no choice but to go down and the liquid temperature is continually increased.

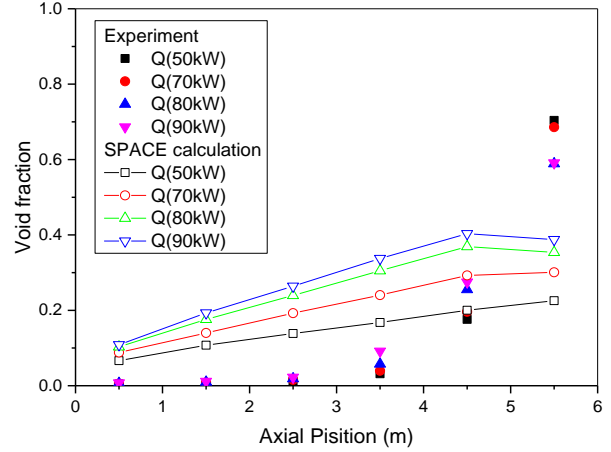


Fig. 4. Comparison of void fractions using single chn. model

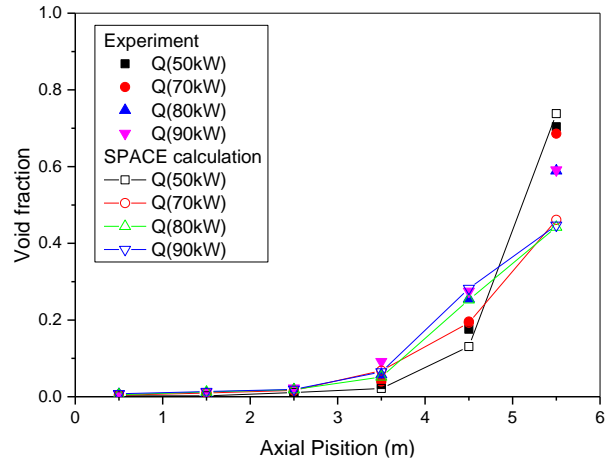


Fig. 5. Comparison of void fractions using double chn. model

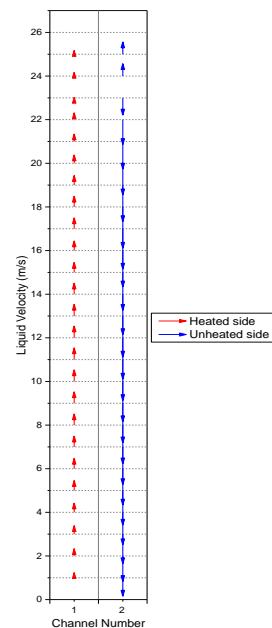


Fig. 6. Velocities in double channel model

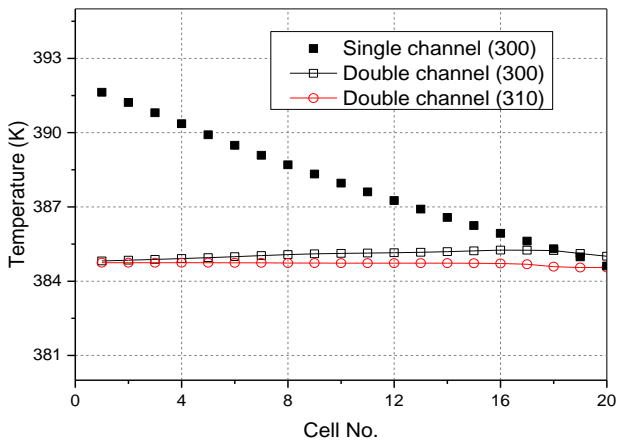


Fig. 6. Temperature distribution along axial length.

Fig. 6 shows the temperature distributions and the temperature of the unheated side (310) in the double channel increases slightly and in the upper region of the heated side (300) it approaches to the saturation temperature. But, in the single channel model the liquid temperature is continually increased as the liquid goes down. In the lower part of the test section the liquid temperature is significantly different depending on the channel modeling.

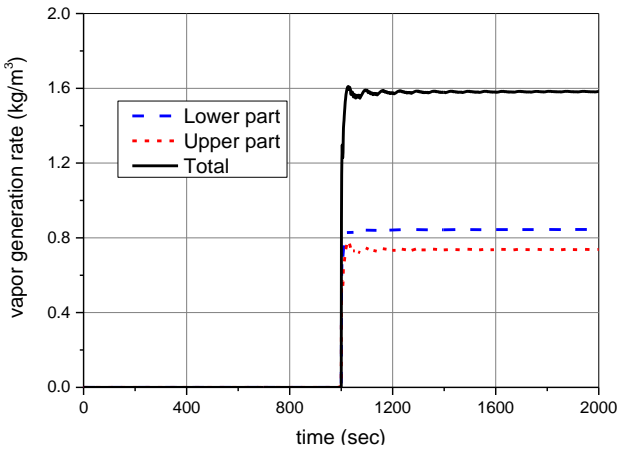


Fig. 7. Vapor generation rate in Single channel model.

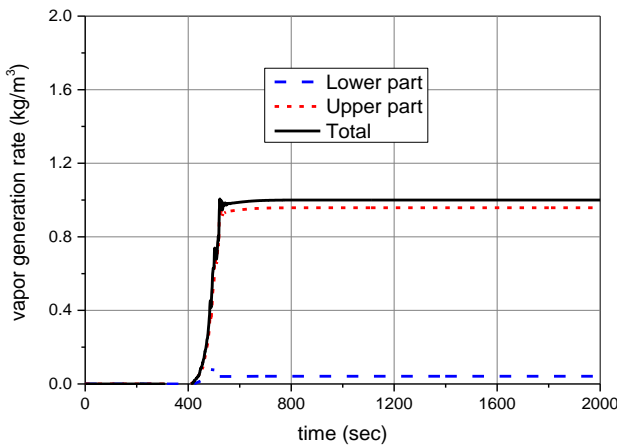


Fig. 8. Vapor generation rate in Double channel model.

The vapor generation rate in the lower part of the test section is very small in the double channel model compared with the rate of single channel model, as shown in Figs. 7 and 8. The results of double channel model show that the multi-dimensional flow behavior significantly affects the vapor generation and these results are more agreed with the experimental data.

## 5. Conclusion

Two kinds of modeling method were applied to simulate DOBO tests. The phenomena of the downcomer boiling can't be exactly predicted by single channel model and the double channel model gives more exact void fraction and subcooling of liquid. The main cause of the over-prediction for void fraction in the single channel model is due to the higher temperature of fluid.

However, the downcomer is generally modeled with single channel model in the real plant simulations. The single channel model is worth in the view point of conservative approach in terms of hydrostatic head and subcooling.

## ACKNOWLEDGEMENT

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20224B10200020).

## REFERENCES

- [1] S. J. Ha, et al., Development of the SPACE code for nuclear power plants, Nuclear Engineering and Technology, Vol. 43, No. 1, pp. 45-62, 2011.
- [2] D. J. Euh, et al., Performance evaluation of the safety analysis codes for subcooled boiling in a nuclear reactor downcomer during the late reflood phase of an LBLOCA, Nuclear Technology, Vol. 164, pp. 369-383, 2008.