# Investigation on Applicability of Downcomer Boiling Phenomena by Drift Flux Approach used in RELAP codes

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## 1. Introduction

The downcomer boiling phenomena at the late reflood period is issued recently. In late reflood period, the injection water flow-rate is small compared to the refill and early reflood period due to the termination of large cooling water source, such as the Safety Injection Tanks (SITs)[1]. At this situation, the reactor vessel wall is still in a high temperature and injected water is partly vaporized at the reactor vessel near wall surface. Some of system codes (e.g. RELAP, TRACE) predict this generated steam prevents the penetration of safety injection water into core and eventually degradates the core cooling capability. In this concern, KAIST performed a separate effect test on the downcomer boiling phenomena based on the APR1400 lower downcomer annulus geometry at late reflood period. In this paper, the predictability of downcomer boiling phenomena is examined based on the experiment performed at KAIST using the RELAP3.3 codes

## 2. Experimental Facilities and Results

The test facility models the APR1400 lower downcomer with rectangle geometry[2]. The major parameters including the gap size, reactor vessel wall thickness are scaled down based on the APR1400 configuration. After the initial wall temperature reaches to the assumed reflood condition (~300℃), the cooling water (~95℃) is injected into the downcomer during ~30sec until the bottom of cold leg is filled with water, and the transient data is gathered. Test results show that the void generation is observed in the near wall surface, but it does not propagates to the bulk liquid. In the wall surface region, the water and the steam are uprising co-currently and the bulk liquid flows down, and overall internal circulation is formed. The steam and water velocities at the near wall surface are ~0.8m/sec and ~0.4m/sec, respectively. No sudden level drop and transient is observed.

## 3. Base Case Analysis Results

In the vertical geometry, RELAP code uses the drift flux approach to obtain the interfacial drag force. The basic form of drift flux formation is showed below;

$$F_i = C_i |v_R| v_R \quad (1)$$

$$v_R = C_1 v_g - C_0 v_f \quad (2)$$

The applicable interfacial drag coefficient ($C_i$) and the void distribution coefficient ($C_0$) are determined based on the mass flow-rate and the hydraulic diameter. In APR1400 and experimental facility geometry ($D_H$ > 20cm), Kataoka-Ishii/churn-turbulent correlation are used. The base case analysis results show that the near wall vapor velocity is underestimated as ~0.4m/sec and therefore the steam is trapped at the downcomer. This inappropriate prediction induces the sudden collapsed level drop. In addition, the wall temperature behavior is far beyond the actual temperature.

## 4. Sensitivity Studies

First of all, the inaccurate wall temperature prediction is mainly due to the Chen correlation characteristics. This correlation is used at the transition boiling condition and is very sensitive to the mass flow-rate. But RELAP code does not consider the water flow-rate at the near wall surface and/or internal circulation. In addition, the degree of superheating of wall temperature is also important factors for vapor generation. To adjust the wall temperature behaviors, the Weismann heat transfer correlation, which is used in the core reflood condition, is used in this case. Results shows that the wall temperature behavior is relatively well predicted (Fig 1).

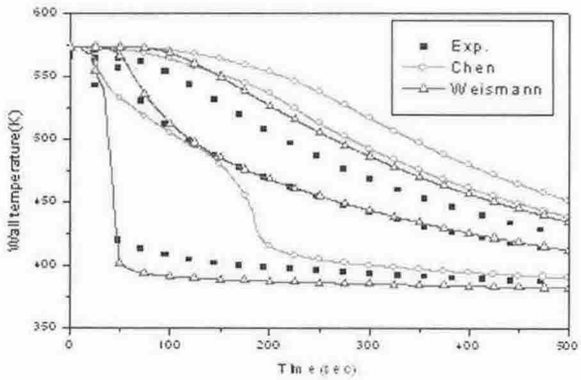


Figure 1. Wall temperature behaviors

To evaluate the effect of hydraulic aspects of downcomer boiling, this Weismann correlation will be used below sensitivity studies.

*4.1 Interfacial Drag Coefficient*

The interfacial drag coefficient used in RELAP code is originally developed on the flowing circular pipe with small hydraulic diameter. So these correlation might not be applicable to the large hydraulic and annulus geometry with circulation flow existing. To estimate the appropriate drag coefficient range in reactor vessel annulus geometry, some correlations used in the RELAP code are evaluated. EPRI and Bestion correlation is compared to the original Kataoka-Ishii correlation. The results show that both Bestion and EPRI correlation show a gradual decrease of water level and no sudden level drop results. In respect to the vapor velocity, Bestion correlation shows an un-physical fast vapor velocity (~10m/sec) rather than the ~2.5m/sec of EPRI correlation So, applicable range of interfacial drag coefficient is ranging between EPRI and Kataoka-Ishii correlation ~$10^3$ .

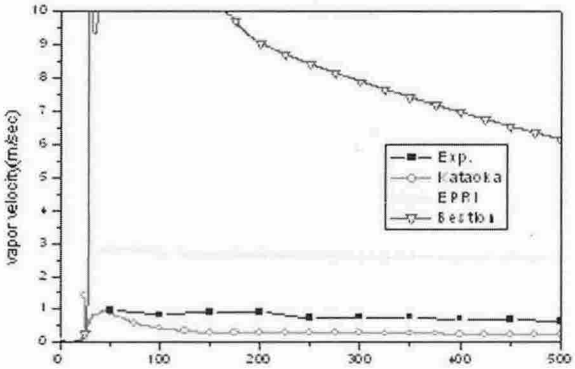


Figure 2. Vapor velocity vs. interfacial drag coeff.

### *4.2 Void Distribution Coefficient*

Drift flux approach considers the channel void distribution as one of key factors for determining the interfacial force. And is implemented as $C_0$ parameter (Eq. 2). But experimental condition for this approach is that the void is well distributed in the channel and limit this factor between 1.0 ~1.3. However, the experimental results show that the void is asymmetrically distributed in the channel. Simplified calculation based on the $C_0$ definition show that the $C_0$ of experimental result is ~5.0. So, the applicability of drift flux approach at this asymmetry condition is examined with varying $C_0$ range as 1, 2, and 5, respectively. Results show that RELAP code well predict the overall system behavior including void fraction, vapor velocity when the $C_0$ is ~5.0. So, the asymmetry geometry condition results can be implemented by the appropriate consideration of $C_0$ parameters.

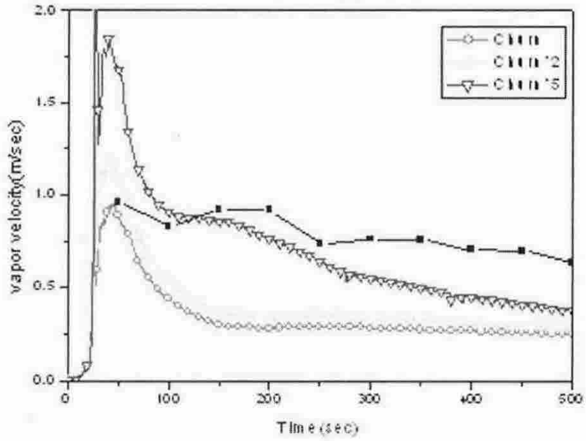


Figure 3. Vapor velocity vs. void distribution coeff.

## 5. Conclusions

The predictability of downcomer boiling behavior is examined with RELAP code based on the KAIST experiments. Results show that transition wall heat transfer correlation has a some shortcoming in respect to the wall vapor generation/temperatures at downcomer boiling condition. In the hydraulic concerns, the two approaches, interfacial drag coefficient/void distribution coefficient, can resolve the code inaccuracy. More evaluation can be made after the detailed experimental data is provided.

## ACKNOWLEDGEMENT

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## REFERENCES

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[2] D.W.Lee & H.C. No et. al, An experimental study and numerical simulation by RELAP5 for the downcomer boiling of APR1400 under LBLOCA, Proceeding of KNS meeting May, 2004.