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Measurement of Local Two-phase Flow Parameters in the Downcomer Boiling Condition

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1. Introduction

To investigate the thermal hydraulic behavior in the downcomer region of the APR1400, a test program for the downcomer boiling has been progressed in the reflood phase of a postulated LBLOCA. For this, the test facility was designed as a one side heated rectangular test section which adopts a full-pressure, full-height, and full-size downcomer-gap approach, but with the circumferential length reduced 47.08-fold. The test consisted of two-phases: (I) visual observation and acquisition of the global two-phase flow parameters and (II) measurement of the local two-phase flow parameters.
The Phase-I test showed that 1) occurrence of countercurrent subcooled boiling flow, 2) the creation of a distinct bubble boundary layer whose thickness varied dramatically with the applied heat flux, 3) small channel average void fraction and thus the reduction of the hydraulic head for the core reflood was not too severe in the present test condition, 4) subcooling of 4.3–5.5^{o}C at the bottom of the test section[1]. A typical behavior of two phases in the downcomer boiling flow condition is characterized in Fig.1. However, the information on the internal flow structure of two-phase flow which is required for the evaluation and development of thermal hydraulics models in best estimation codes, are still lack in the Phase-I. And thus, measurement of local two-phase flow parameters such as a local void fraction, a local bubble velocity, a local liquid velocity, a local liquid temperature was tried in the Phase-II. In the present paper, the data of the Phase-II test was presented.

2. Test Facility

The DOBO test facility is designed to simulate the downcomer region below the cold leg in the late reflood phase of the postulated LBLOCA, in which the ECC injection from the SIT is terminated. During this period, most of the parameters in the primary system reaches quasi-steady state, and hence the DOBO facility is designed for a steady-state operation. The test facility was designed by adopting full pressure, full height scaling approach. It also has the same gap size of downcomer with that of the APR1400, however the width is reduced. The scaling ratio of cross sectional area is 1/47. Fig.1 shows the geometrical comparison of the reactor vessel of

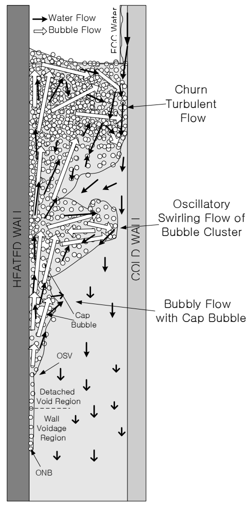


Fig. 1. Illustration of a Typical Downcomer Boiling Phenomena Observed in the Phase-I Test.

the APR1400 and test section of the DOBO facility (Details are found in the reference [1]).

Several kinds of instrumentations are installed for the measurement of boundary mass and energy flows. Especially,local five conductance probes and local BDFT(Bidirectional flow Tube) are installed at five elevations along test section for the measurement of local two-phase flow parameters in the Phase-II test. The instrumentation locations for the test sections are shown in

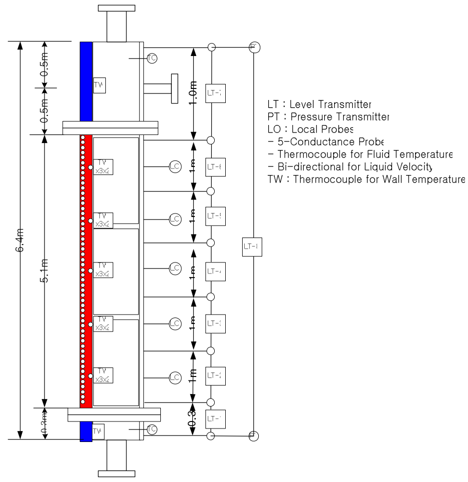
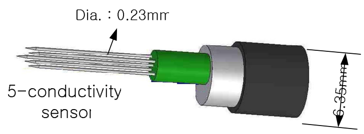
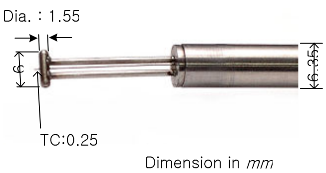


Fig. 2. Schematics of the DOBO Facility



(a) 5-concuctance probe



(b) Local BDFT with a thermocouple

Fig. 3. Schematics of 5-conductance and local BDFT

Fig.2. And the local 5-conductance probe and local BDFT are shown in Fig.3(a),(b), respectively.

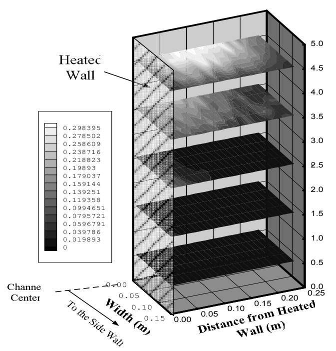
3. Experimental Results

A total of four tests were performed in the reflood flow condition. Phase-II tests were performed by following flow conditions of the Phase-I test which had been already performed. In the present paper, test matrix of R2-1 was presented and its flow condition was summarized in the table 1.

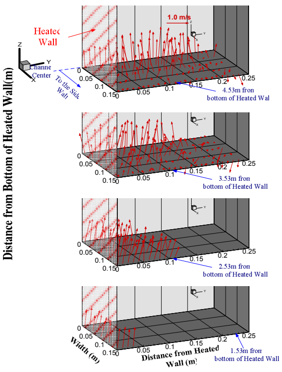
Fig. 4(a) shows the local void fraction at each elevation of the test section. At the lower part where the boiling is initiated, steam is concentrated near the wall. As goes upward, the void profile becomes wide and a distinct bubbly boundary layer was developed. However, at the two highest regions, center peaking of void profile was found. Fig.4(b) shows a plot of 3-dimensional bubble velocity. At the highest two elevations, the profile of the bubble velocity follows that of the void fraction. In the opposite side of the heated wall, the bubble velocity is very low or negative since the upward bubble motion is suppressed by the downward liquid. Fig.4(c) shows the temperature distribution of a liquid phase. It shows that the distributions of water temperature coincided with those of a local void fraction. In addition, the temperature of water phase increases as goes downward due to the increased saturation temperature resulted by hydrostatic head. Fig.4(d) shows the distribution of an axial water velocity. It shows well that the water goes upward due to the interfacial friction of bubble phases in the high void fraction region which is located adjacent heated wall, however, it goes downward in the lower void fraction and wall region.

Table 1 Summary of Experimental Conditions

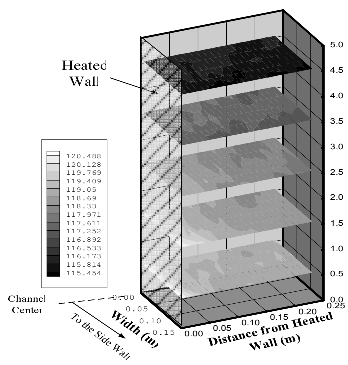
Parameter	T_{ECC} (^oC)	P_{sys} (kPa)	W_{ECC} (kg/s)	Q'' (W/cm^2)
R2-1	110.7	158.5	1.33	70.5



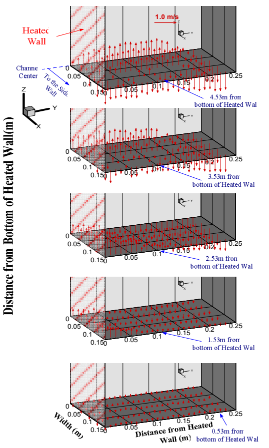
(a) void fraction



(b) 3-D bubble velocity



(a) liquid temperature



(b) liquid velocity

Fig. 4 Propagation of Local Two-phase Flow Parameters (R2-1)

4. Conclusion

The local two phase flow parameters such as a void fraction, a bubble velocity, a liquid velocity and a liquid temperature were measured successfully in the downcomer boiling condition. The data can be used for the development of downcomer boiling models.

Acknowledgment

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REFERENCES

[1]B.J.Yun, D.J.Euh and C.-H. Song, "Investigation of the Downcomer Boiling Phenomena During the Reflood Phase of a Postulated Large-Break LOCA in the APR1400," *Nuclear Technology*, Vol.156 pp.56-68 (2006).