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Experimental Study of Downcomer Boiling Phenomena in the LBLOCA Reflood Phase

B.J.Yun, D.J.Euh, Y.J.Youn, C.-H.Song
Korea Atomic Energy Research Institute, P.O.Box 105, Yuseong, Daejeon, 305-600, KOREA, bjyun@kaeri.re.kr

1. Introduction

Korean advanced power reactor(APR1400) adopts direct vessel injection(DVI) system instead of conventional cold leg injection(CLI). The performance of the new safety injection system depends on the thermal hydraulic phenomena in the downcomer during the transient. Safety analysis using best estimate codes show that the "downcomer boiling" is one of the important phenomena in the postulated LBLOCA, in the meanwhile, the codes showed different behavior for the key parameters for the APR1400 due to the difference of the thermal hydraulics models, especially such as interfacial friction and interfacial heat transfer in the downcomer. Fig. 1 shows typical thermal hydraulic phenomena in the LBLOCA reflood phase.

The downcomer boiling phenomena has not been an important issue in the previous CLI system. Sudo(1982) performed a separate effect test for the downcomer boiling phenomena in the slab geometry, in which the channel gap is 0.2m and its height is 6.5m. The test had been performed in a transient condition and it showed the possibility of the degradation of the hydro-static head arisen by the downcomer boiling. However, the channel size is different with the APR1400 and the local two-phase flow parameters were not generated. Thus, a separate effect test program for the downcomer boiling is being progressed at KAERI[1].

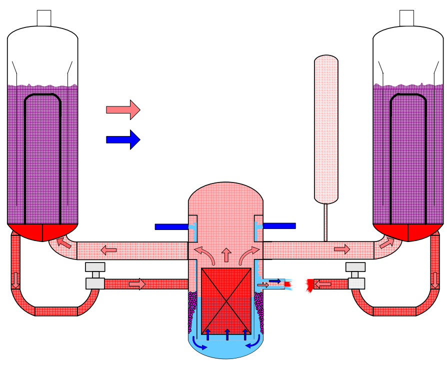

Fig. 1. Thermal Hydraulic Phenomena in the Annulus Downcomer of APR1400 under the LBLOCA Reflood Phase

In this paper, the experimental results obtained at the DOBO(Downcomer Boiling) facility were introduced.

2. Test Facility

To identify the phasic behaviour experimentally in the downcomer, DOBO (Downcomer Boiling) test facility is constructed to simulate lower downcomer region. 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 1/47.08. For simulating the heat release from the downcomer wall, one face among the four walls of test channel is heated by 207 cartridge heaters. The maximum available heat flux is 100 kW/m^2 which is the heat flux at the termination of ECC injection from SIT tanks.

For visual observation of phasic behaviour, transparent glasses are installed on the front and one side walls. The major instruments are two Coriolis mass flow meters for in- and out- flow measurements, eight SMART type differential pressure transmitters for the measurement of water level and axial average void fraction, two SMART type pressure transmitters for the test channel pressures and several K-type TCs for the measurements of fluid temperature.

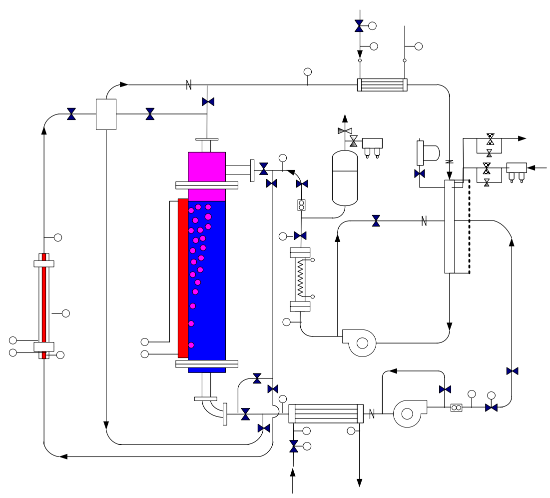

Fig. 2. Schematics of the DOBO Facility

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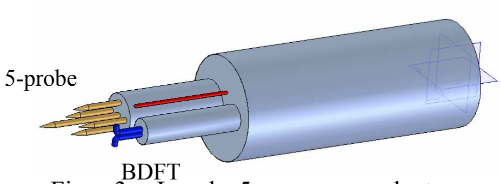

Fig. 3. Local 5-sensor conductance probe and bidirectional flow tube

For the measurement of local two phase flow parameters, five-sensor conductance probe and local bidirectional flow tube(BDFT) were applied on the measuring planes which are located at five elevations of test section. Fig.3 shows the schematics of the local probe which incorporates both probes. The local distributions of the two phase parameters on each measuring plane are obtained by traversing the probe,

3. Experiments

Four tests were performed in the reflood flow condition. The test conditions are summarized in the Table 1. In the test, the mass flow rates were 10% lower than the ideally scaled one. Fig.4 shows the axial distribution of the average void fraction according to the heat flux. Here, the axial void fraction was calculated from the reading of DPs. Where, the mixture level is maintained in the center of the pressure tab of the LT(Level Transmitter)-7 and thus the void fraction exceeds 0.4 for all the cases in the LT-7. As shown in the figure, the void fraction below the elevation of a 2.8m is negligible and a significant void fraction is found above it for all cases. It shows that an increase of the heat flux results in an increase of the void fraction above 2.8m in elevation. An overall void fraction of the test channel is less than 9% even for the maximum heat flux condition. This low void fraction is somewhat a different result from that of the best estimate code. The RELAP5 calculation showed more than 40% of a void fraction even in the middle region[2]. The 9% of void fraction results in the reduction of a 3% of the reflood flow rate.

Table 1. Experimental Condition

Parameter	T_{ECC} (°C)	P_{sys} (kPa)	W_{ECC} (kg/s)	Q'' (W/cm²)
R 1	110.1	162.8	1.22	5.02
R 2	110.2	161.4	1.16	6.97
R 3	109.6	166.5	1.20	8.21
R 4	109.5	170.8	1.20	9.11

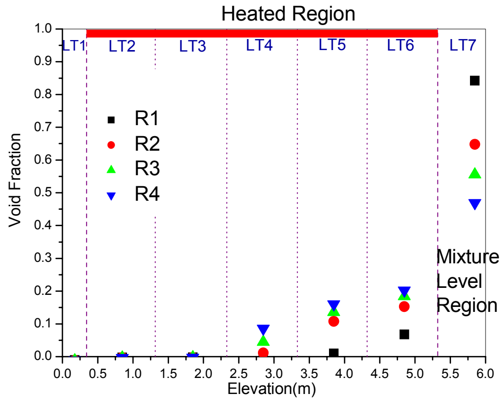

Fig. 4 Axial Void Fraction Distribution

From the test, the degree of the liquid subcooling at the bottom of the test section is in the range of 4.3 - 5.5 °C. Recently, the experimental study by applying the local probe of Fig.3 is being progressed to get information on the local two phase flow parameters such as local void fraction, bubble velocity, liquid velocity and so on.

4. Conclusion

The downcomer boiling test was performed in the reflood phase of postulated LBLOCA. In the test, the count-current subcooled boiling flow was observed. Since the test showed the channel average void fraction was small, the reduction of hydraulic head for the core reflood is not severe in the present test condition. And now, the measurement of local two phase flow parameters are tried to get local internal flow structure.

Acknowledgment

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REFERENCES

[1] B.J. Y D.J.EUH, Y.J.YOON and C.-H. SONG, "Downcomer Boiling Phenomena during Reflood Phase in the Postulated LBLOCA of the APR1400," NTHAS4, Japan (2004).

[2] S.W.Lee et al, 'RELAP 5 Calculation Results for the APR1400 under LBLOCA' Private communication, KHNP(2002)