Measurement of Subcooled Boiling Flow Characteristics in a Large Slab

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1. Introduction

A subcooled boiling phenomenon is an important safety concern in the downcomer of a nuclear reactor during a transient phase of a postulated accident. An experimental program has been performed to identify and quantify the phenomenon with a newly constructed test facility, "DOBO", which has slab geometry of a test section. This study's purpose is to generate experimental data in order to develop and validate a two-phase analysis code. Unlike the previous test, the water is supplied from the bottom of the test section in order to get clearer boundary conditions. The measured data can be divided into two categories: (I) global two-phase parameters such as pressure, temperature, flow rate, and water level, and (II) local two-phase parameters such as a void fraction and liquid/steam velocities.

2. Test Facilities and Experiments

2.1 Test Facilities

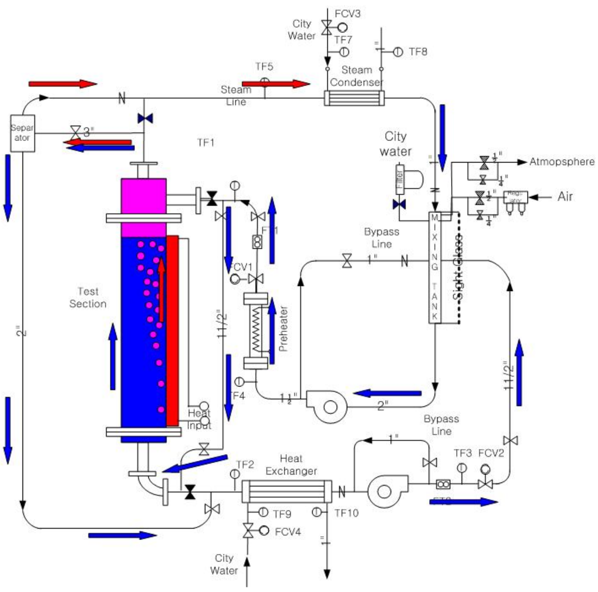


Fig. 1. Schematics and flow diagram of test facilities

The DOBO facility has a test section having a rectangular cross-section of 0.3m X 0.25m, and a height of 6.4m with fluid systems related to water supply, condensing, storaging, preheating and so on. Fig. 1 shows a schematic and flow diagram of the test facilities. The heat is generated by 207 cartridge heaters inserted in a side of a wall. The maximum available heat flux is 100 kW/m^2. The test section has a heating region of 5.1m and lower and upper unheated sections of 0.3m and 1.0m, respectively.

A separator is connected to the outlet pipe of the test section for the phase separation of the two-phase flow. The separated water and steam phases are respectively cooled and condensed by two heat exchangers. The temperature of the water in the storage tank is controlled by the heat removal rates of the heat exchangers. The circulating water is injected into the test section at the bottom of the test section and returned by two centrifugal pumps.

In the previous test, the water level was controlled to simulate the downcomer phenomenon during the late reflood phase of the LBLOCA. Since this study focuses on the test at the well-defined boundary conditions, the water is supplied from the bottom of the test section, which induces the co-current flow phenomenon and no free surface at the upper section.

2.2 Instrumentation

Global parameters such as pressure, temperature, and flow rate are measured at the test section and appropriate system position. Mass flow rates of the circulating water are measured by two Coriolis meters installed at the inlet and outlet pipes of the test section. The system pressure is measured at the top and bottom of the test section by two SMART-type pressure transmitters. Seven SMART -type DP (differential pressure) transmitters (LT-1 to LT-7) are axially spaced along the two pressure impulse taps of the pressure transmitters for measuring both the water level and the axial void fraction. An additional wide-range DP (LT-8) is installed to check the measured DP of the seven DP transmitters and to control the water level at the downcomer. The fluid temperatures are measured by several K-type thermo-couples. The accuracy of each instrument is described in Yun et al.[1]

Two types of local probes were specially developed to measure local two-phase parameters related to the flow dynamics. Steam parameters such as void fraction and bubble velocity are measured by a multi-sensor conductivity probe. Liquid velocity is measured by a BDFT (Bi-Directional Flow Tube). Five local probes are inserted at each mid-level between DP pressure tabs and traversed to a pre-defined position via a remote controlled two-directional moving system. Five local probes are used for a test. The data is acquired for 30 seconds with 20 kHz at 120 points on each measuring plane.

2.3 Test Conditions

The test condition is similar to the previous test, R2-1 that simulates the plant condition, except that the water injection is from the bottom. The C2-1a and -1b are the tests by using the conductivity probe and the BDFT, respectively. Table I summarizes the major boundary conditions.

Table I: Major boundary conditions

Tag	C2-1a	C2-1b	Comments
PT1 (kPa)	216.7	215.6	Lower Pressure
PT2 (kPa)	160.6	159.2	Top Pressure
LT8 (kPa)	54.31	54.40	DP between Top and Bottom
FT1 (kg/s)	1.287	1.311	Water Flow Rate
TFT1 (°C)	112.9	112.6	Inlet Temperature
TFT7 (°C)	114.1	114.1	Outlet Temperature
Power (kW)	110.4	109.6	
Heat Flux (kW/m^2)	72.2	71.6	

2.4 Results

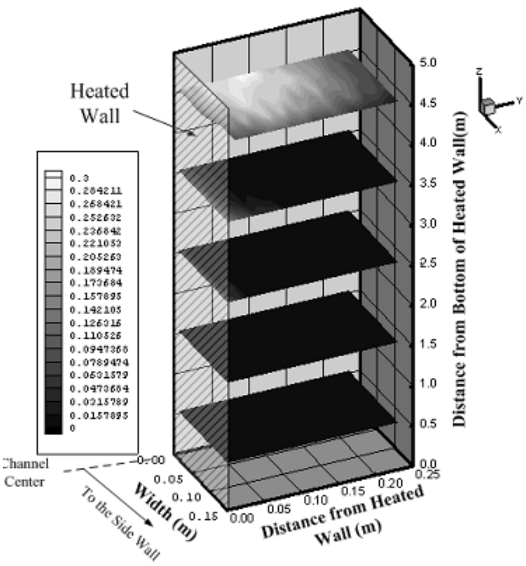
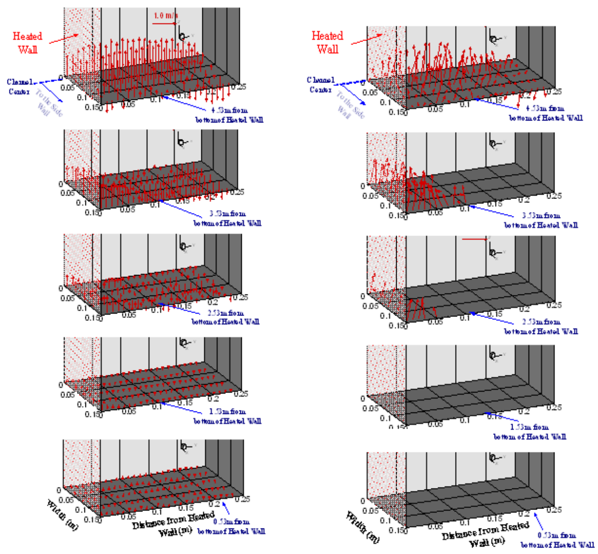


Fig. 2. Local distribution of void fraction (C2-1a)

Fig. 2 shows a local void fraction profile measured at five elevations in the test section. At the lower part where the boiling is initiated, steam is concentrated near the wall. As the generated steam flows upward, the void profile becomes wide and a distinct bubbly boundary layer was found. As flow goes upward, the peaking region is moved toward the bulk region, which forms a central peaking of the void fraction. Fig. 3 shows liquid and steam velocity profiles at each measuring plane, which are in accord with the void fraction profile.



(a) (b)

Fig. 3. Local distribution of liquid (a) and steam velocities (b) for C2-1a, b

3. Conclusions

To generate experimental data in order to validate a multi-phase flow analysis code, a subcooled boiling test was performed with a large slab shaped test section. Local two-phase parameters including a void fraction and bubble/liquid velocities were measured along with global variables such as an averaged void fraction from a DP. The experiments were performed under well-defined boundary conditions, which would be helpful for utilizing data in developing and/or validating two-phase analysis codes.

Acknowledgement

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REFERENCES

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