Appendix A

Calibration of Instruments and Connecting Pipes

A.1 Pressure Transmitter Used to Measure Test Chamber Pressure

Endress+Hauser make pressure transmitter of model no. Cerabar SPMC71: A50CB20109C was mounted on the top of the test section to measure the air pressure. The pressure transmitter was factory calibrated and calibration results are shown in Table A.1.

Table A.1: Calibration data from pressure transmitter located at test section

% of span	Pressure input (bar)	Expected (Volts dc)	Actual (Volts dc)
100	10.0	5.0000	5.0005
75	7.5	4.0000	4.0007
50	5.0	3.0000	3.0001
25	2.5	2.0000	2.0003
0	0.0	1.0000	1.0001

A.2 Pressure Transmitter Used to Measure Phase Separators Pressure

Two Honeywell ST 3000 pressure transmitters of model no. STG140 were used in the experiment to measure the pressure of 1PH, and 2PH. Each pressure transducer was factory calibrated. Calibration results of both the pressure transmitters are shown in Table A.2 and Table A.3. The manufacturer calibrated the pressure transmitters with air at 26^0C temperature and with 69% humidity.

Table A.2:Calibration data from pressure transmitter located at 1PH

% of span	Pressure input (bar)	Expected (Volts dc)	Actual (Volts dc)
100	10.0	5.0000	4.9998
75	7.5	4.0000	4.0001
50	5.0	3.0000	3.0003
25	2.5	2.0000	2.0001
0	0.0	1.0000	0.9997

Table A. 3 : Calibration data from pressure transmitter located at 2PH

% of span	Pressure input (bar)	Expected (Volts dc)	Actual (Volts dc)
100	10.0	5.0000	5.0001
75	7.5	4.0000	4.0000
50	5.0	3.0000	2.9997
25	2.5	2.0000	1.9997
0	0.0	1.0000	0.9992

A.3 Water Mass Flow Meter

A mass flow meter operating on coriolis measuring principle was used in experiment to measure the water flow rate discharging from phase separator. The mass flow meter was installed at the downstream of the 1PH. The mass flow meter was factory calibrated with water. Calibration results of the mass flow meters are shown in Table A.4.

Table A. 4 : Calibration data from a mass flow meter located at downstream of 1PH

Flow (%)	Flow (kg/hr)	Duration (s)	Target mass (kg)	Measured mass (kg)	Deviation of reading (%)	Output (mA)
20.0	720.4	30.0	6.009	6.0116	0.028	7.20
34.7	1249.6	143.8	49.930	49.928	-0.003	9.55
50.0	1799.6	99.8	49.898	49.894	-0.007	12.00
74.3	2673.7	67.4	50.067	50.066	-0.002	15.88
100.1	3602.5	50.0	50.037	50.038	0.000	20.01

A.4 Calibration of Liquid Height

The objective was to calibrate the measured liquid height seen through the recording camera with respect to the actual height of the liquid in the glass tube. The calibration was done over the range of 2.25 mm to 59.00 mm of liquid height in the liquid level indicator as shown in Figure A.1.

A.5 Calibration of Connecting Pipes

The objective was to calibrate the connecting pipe for varying ΔP with fixed opening of the control valve located at the downstream of the branch. At each ΔP of 0.25, 0.50, 0.75, 1.00, 2.00, 3.00, 4.00 and 4.50 bar the variation in Fr_L within the operating range of ΔP is shown in Figure A.2.

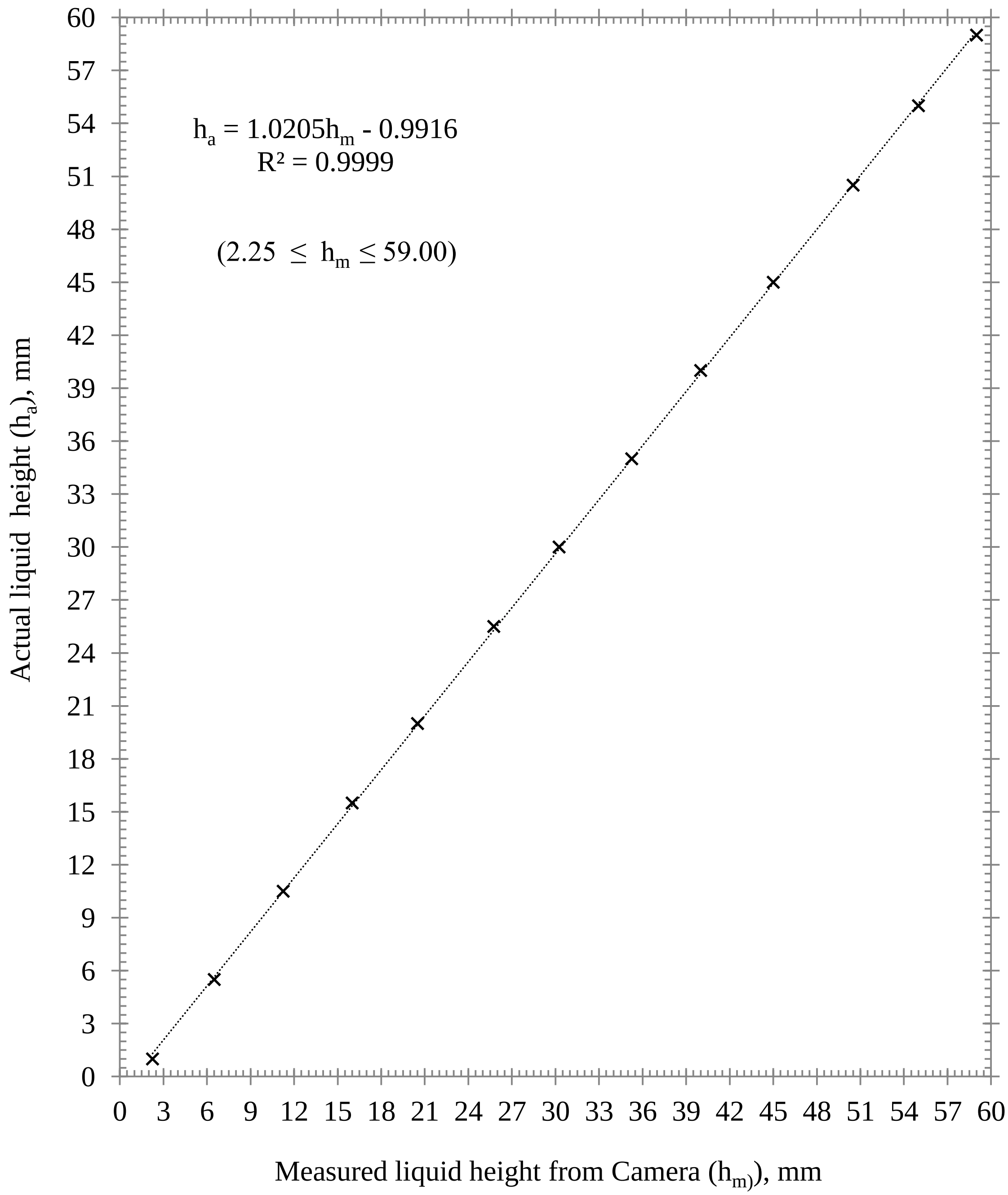
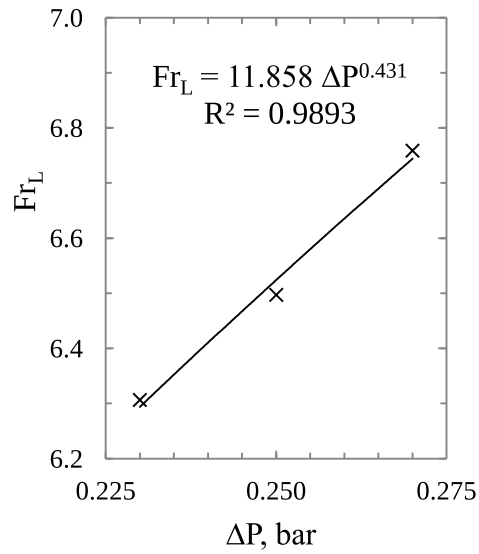
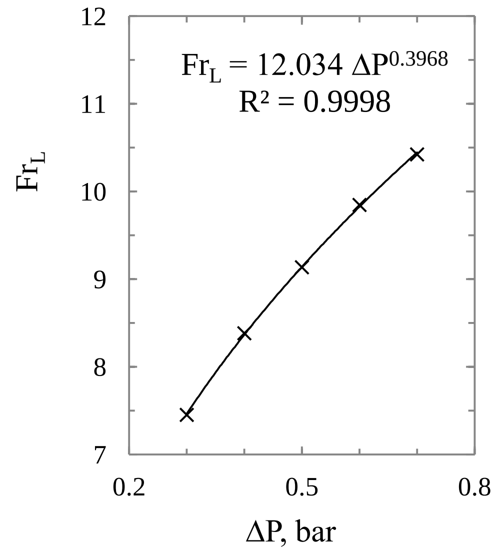


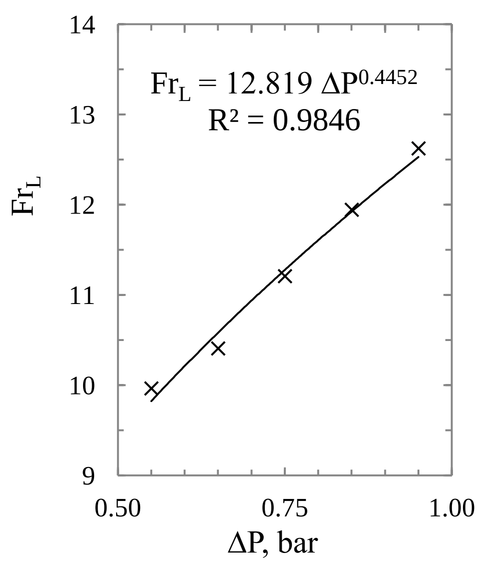
Figure A. 1 : Calibration of liquid height



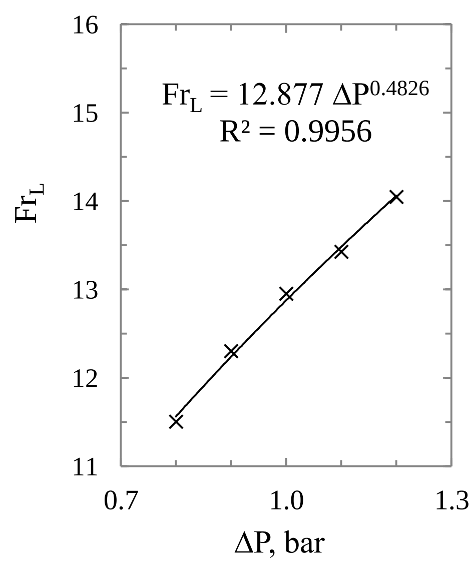
(a) For ΔP =0.25 bar



(b) For ΔP =0.50 bar

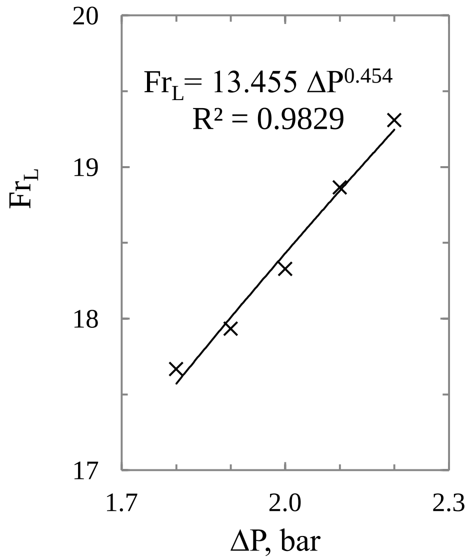


(c) For ΔP =0.75 bar

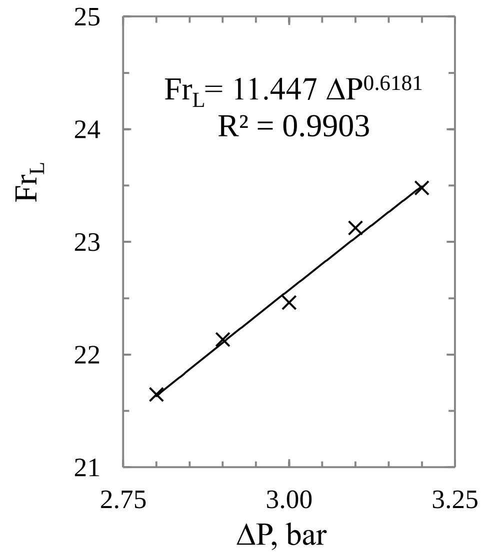


(d) For ΔP =1.00 bar

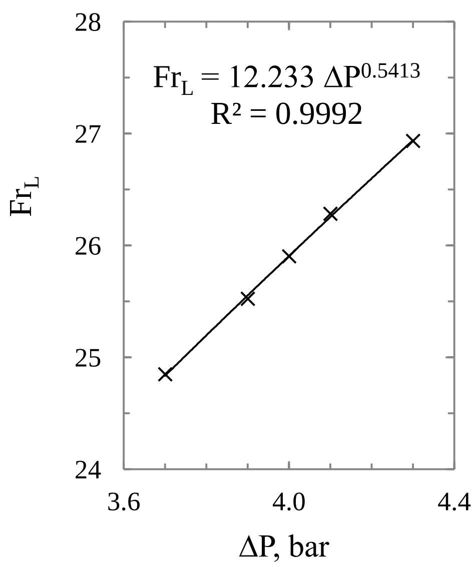
Figure A. 2 : Calibration of connecting pipes for varying ΔP



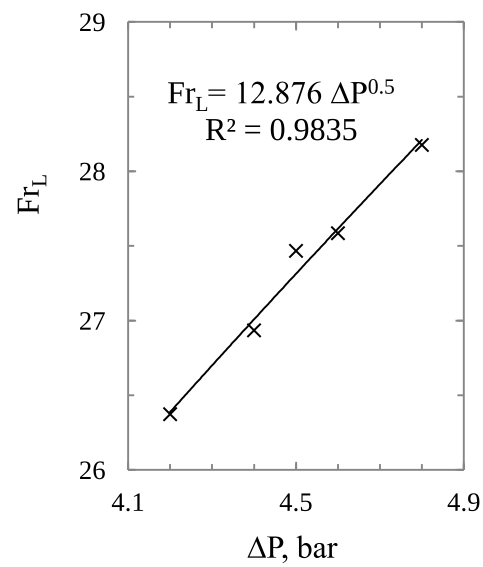
(e) For ΔP =2.00 bar



(f) For ΔP =3.00 bar



(g) For ΔP =4.00 bar



(h) For ΔP =4.50 bar

Figure A.2 : Calibration of connecting pipes for varying ΔP (cont.)

Appendix B

Estimation of Uncertainty

This appendix provides the measure of the reliability of the experimental results.

B.1 Experimental Uncertainty in the Data

Kline and McClintock (1953) and Moffat (1988) method was followed for estimation of experimental uncertainty for independent and dependent variables. All the uncertainties estimated are at “odds” of 20 to 1. The uncertainties include the accuracy of the calibrating device, the error in fitting an equation (for computer data reduction) to the calibration data, discrimination uncertainties in the measuring instruments and unsteadiness in the process.

If the result R is the function of an independent variable v_1, v_2,… v_n, each of which is normally distributed, then the relation between the interval for the variables wv_1, and the interval for the result wR, which gives the same odds for each of the variable and for the result is

$$wR = \pm\left[\left(\frac{\partial R}{\partial v_1} wv_1\right)^2 + \left(\frac{\partial R}{\partial v_2} wv_2\right)^2 + \ldots.. + \left(\frac{\partial R}{\partial v_n} wv_n\right)^2\right]^{1/2} \quad \text{(B.1)}$$

The relative uncertainty in the result is represented by:

$$\frac{wR}{R} = \pm\left[\left(\frac{\partial R}{\partial v_1}\frac{wv_1}{R}\right)^2 + \left(\frac{\partial R}{\partial v_2}\frac{wv_2}{R}\right)^2 + \cdots + \left(\frac{\partial R}{\partial v_n}\frac{wv_n}{R}\right)^2\right]^{1/2} \quad \text{(B.2)}$$

B.2 Uncertainty in P_{TC}

The instrument uncertainty of the pressure transmitter used to measure the air pressure in the test section and the uncertainty due to the fluctuation in the process was calculated as follows;

$$\frac{wP_{TC}}{P_{TC}} = \pm\sqrt{\left(\frac{wP_{TC,T}}{P_{TC}}\right)^2 + \left(\frac{wP_{TC,P}}{P_{TC}}\right)^2} \tag{B.3}$$

B.3 Uncertainty in P_{PH}

The instrument uncertainty of the pressure transmitter used to measure the pressure of the phase separators and the uncertainty due to fluctuation in the process was calculated as below;

$$\frac{wP_{PH}}{P_{PH}} = \pm\sqrt{\left(\frac{wP_{PH,T}}{P_{PH}}\right)^2 + \left(\frac{wP_{PH,P}}{P_{PH}}\right)^2} \tag{B.4}$$

B.4 Uncertainty in ΔP

Applying equation (B.2) to equation (B.5), the relative uncertainty for the pressure drop across the branches is calculated using equation (B.6).

$$\Delta P = (P_{TC} - P_{PH}) \tag{B.5}$$

$$\frac{\partial \Delta P}{\partial P_{TC}} = (1)$$

$$\frac{\partial \Delta P}{\partial P_{PH}} = (-1)$$

$$w\Delta P = \pm\left[\left(\frac{\partial \Delta P}{\partial P_{TC}}\ wP_{TC}\right)^2 + \left(\frac{\partial \Delta P}{\partial P_{PH}}\ wP_{PH}\right)^2\right]^{1/2}$$

$$\frac{w\Delta P}{\Delta P} = \pm\left[\left(\frac{\partial \Delta P}{\partial P_{TC}}\ \frac{wP_{TC}}{\Delta P}\right)^2 + \left(\frac{\partial \Delta P}{\partial P_{PH}}\ \frac{wP_{PH}}{\Delta P}\right)^2\right]^{1/2}$$

$$\frac{w\Delta P}{\Delta P} = \pm\left[\left(1\ \frac{1}{(P_{TC} - P_{PH})} wP_{TC}\right)^2 + \left(-1\ \frac{1}{(P_{TC} - P_{PH})} wP_{PH}\right)^2\right]^{1/2}$$

$$\frac{w\Delta P}{\Delta P} = \pm\left[\left(\frac{wP_{TC}}{(P_{TC} - P_{PH})}\right)^2 + \left(-\frac{wP_{PH}}{(P_{TC} - P_{PH})}\right)^2\right]^{1/2} \tag{B.6}$$

The uncertainty interval quoted by the manufacturer is ± 0.015 bar for the P_{TC} and ± 0.019 bar for the P_{PH}.

B.5 Uncertainty in ρ_G

Applying equation (B.2) to ideal gas law equation (B.7), the relative uncertainty for the density of air within the test section was calculated using equation (B.8).

$$\rho_G = \frac{P_{TC,abs}}{R_G T_G} \tag{B.7}$$

$$\frac{\partial \rho_G}{\partial P_{TC,abs}} = \left(\frac{1}{R_G T_G}\right)$$

$$\frac{\partial \rho_G}{\partial R_G} = \left(\frac{-P_{TC,abs}}{{R_G}^2 T_G}\right)$$

$$\frac{\partial \rho_G}{\partial T_G} = \left(\frac{-P_{TC,abs}}{R_G {T_G}^2}\right)$$

$$w\rho_G = \pm \left[\left(\frac{\partial \rho_G}{\partial P_{TC,abs}}\, wP_{TC,abs}\right)^2 + \left(\frac{\partial \rho_G}{\partial R_G}\, wR_G\right)^2 + \left(\frac{\partial \rho_G}{\partial T_G}\, wT_G\right)^2\right]^{\frac{1}{2}}$$

$$\frac{w\rho_G}{\rho_G} = \pm \left[\left(\frac{\partial \rho_G}{\partial P_{TC,abs}} \frac{wP_{TC,abs}}{\rho_G}\right)^2 + \left(\frac{\partial \rho_G}{\partial R_G} \frac{wR_G}{\rho_G}\right)^2 + \left(\frac{\partial \rho_G}{\partial T_G} \frac{wT_G}{\rho_G}\right)^2\right]^{1/2}$$

$$\frac{w\rho_G}{\rho_G} = \pm \left[\left(\frac{1}{R_G T_G} \frac{R_G T_G}{P_{TC,abs}}\, wP_{TC,abs}\right)^2 + \left(\frac{-P_{TC,abs}}{{R_G}^2 T_G} \frac{R_G T_G}{P_{TC,abs}} wR_G\right)^2 + \left(\frac{-P_{TC,abs}}{R_G {T_G}^2} \frac{R_G T_G}{P_{TC,abs}} wT_G\right)^2\right]^{1/2}$$

$$\frac{w\rho_G}{\rho_G} = \pm \left[\left(\frac{wP_{TC,abs}}{P_{TC,abs}}\right)^2 + \left(-\frac{wR_G}{R_G}\right)^2 + \left(-\frac{wT_G}{T_G}\right)^2\right]^{1/2}$$

The error in the characteristic gas constant is assumed negligible, $wR_G \simeq 0$.

$$\frac{w\rho_G}{\rho_G} = \pm\left[\left(\frac{wP_{TC,abs}}{P_{TC,abs}}\right)^2 + \left(-\frac{wT_G}{T_G}\right)^2\right]^{1/2} \quad (B.8)$$

The uncertainty interval quoted by manufacturer for T_G is $\pm 0.5\ ^0C$.

B.6 Uncertainty in Δρ

Applying equation (B.2) to the equation (B.9), the relative uncertainty for the Δρ was calculated using equation (B.10).

$$\Delta\rho = \rho_L - \rho_G \quad (B.9)$$

$$\frac{w\Delta\rho}{\Delta\rho} = \pm\left[\left(\frac{w\rho_L}{\Delta\rho}\right)^2 + \left(-\frac{w\rho_G}{\Delta\rho}\right)^2\right]^{1/2}$$

$$w\rho_L = 0 \text{ (negligible)}$$

$$\frac{w\Delta\rho}{\Delta\rho} = \pm\left[\left(-\frac{w\rho_G}{\Delta\rho}\right)^2\right]^{1/2} \quad (B.10)$$

B.7 Uncertainty in $\dot{m}_L$

The uncertainty quoted by the manufacturer for $\dot{m}_L$ is given below;

$$\%\ \text{Error in flow} = \pm\left(0.25 + \left(\frac{6 - \dot{m}_L}{14}\right) + \left(\frac{9}{1000 \times \dot{m}_L}\right)\right) \quad (B.11)$$

for $2.5 < \dot{m}_L < 6$

$$\%\ \text{Error in flow} = \pm\left(0.05 + \left(\frac{12 - \dot{m}_L}{30}\right) + \left(\frac{9}{1000 \times \dot{m}_L}\right)\right) \quad (B.12)$$

for $6 \leq \dot{m}_L < 12$

$$\%\ \text{Error in flow} = \pm\left(0.05 + \left(\frac{9}{1000 \times \dot{m}_L}\right)\right) \quad (B.13)$$

for $\dot{m}_L \geq 12$

B.8 Uncertainty in h_{OGE}

The uncertainty in measuring h_{OGE} was $\pm$ 0.25 mm due to minimum visualization accuracy of the human eye while reading the flat rule scale.

B.9 Uncertainty in Fr_L

Applying equation (B.2) to equation (B.14), the relative uncertainty for the Froude Number is calculated using equation (B.15).

$$Fr_L = \frac{4\,\dot{m}_L}{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L - \rho_G)}} \tag{B.14}$$

$$\frac{\partial Fr_L}{\partial \dot{m}_L} = \frac{4}{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L - \rho_G)}}$$

$$\frac{\partial Fr_L}{\partial g} = \frac{4\,\dot{m}_L}{\pi\sqrt{d^5\,\rho_L\,(\rho_L - \rho_G)}}\left(\frac{-1}{2g^{3/2}}\right)$$

$$\frac{\partial Fr_L}{\partial d} = \frac{4\,\dot{m}_L}{\pi\sqrt{g\,\rho_L\,(\rho_L - \rho_G)}}\left(\frac{-5}{2\,d^{7/2}}\right)$$

$$\frac{\partial Fr_L}{\partial \rho_L} = \frac{4\,\dot{m}_L}{\pi\sqrt{g\,d^5}}\left(-\frac{2\rho_L - \rho_G}{2\,\left(\rho_L(\rho_L - \rho_G)\right)^{3/2}}\right)$$

$$\frac{\partial Fr_L}{\partial \rho_G} = \frac{4\,\dot{m}_L}{\pi\sqrt{g\,d^5}}\left(\frac{\rho_L}{2\,\left(\rho_L(\rho_L - \rho_G)\right)^{3/2}}\right)$$

$$wFr_L = \pm\left[\left(\frac{\partial Fr_L}{\partial \dot{m}_L}\,w\dot{m}_L\right)^2 + \left(\frac{\partial Fr_L}{\partial g}\,wg\right)^2 + \left(\frac{\partial Fr_L}{\partial d}\,wd\right)^2 + \left(\frac{\partial Fr_L}{\partial \rho_L}\,w\rho_L\right)^2 + \left(\frac{\partial Fr_L}{\partial \rho_G}\,w\rho_G\right)^2\right]^{1/2}$$

$$\frac{wFr_L}{Fr_L} = \pm\left[\left(\frac{\partial Fr_L}{\partial \dot{m}_L}\frac{w\dot{m}_L}{Fr_L}\right)^2 + \left(\frac{\partial Fr_L}{\partial g}\frac{wg}{Fr_L}\right)^2 + \left(\frac{\partial Fr_L}{\partial d}\frac{wd}{Fr_L}\right)^2 + \left(\frac{\partial Fr_L}{\partial \rho_L}\frac{w\rho_L}{Fr_L}\right)^2 + \left(\frac{\partial Fr_L}{\partial \rho_G}\frac{w\rho_G}{Fr_L}\right)^2\right]^{1/2}$$

$$\frac{wFr_L}{Fr_L} = \pm\left[\left(\frac{4}{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L-\rho_G)}}\frac{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L-\rho_G)}}{4\,\dot{m}_L}w\dot{m}_L\right)^2 + \left(\frac{4\,\dot{m}_L}{\pi\sqrt{d^5\,\rho_L\,(\rho_L-\rho_G)}}\left(\frac{-1}{2g^{3/2}}\right)\frac{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L-\rho_G)}}{4\,\dot{m}_L}wg\right)^2 + \left(\frac{4\,\dot{m}_L}{\pi\sqrt{g\,\rho_L\,(\rho_L-\rho_G)}}\left(\frac{-5}{2\,d^{7/2}}\right)\frac{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L-\rho_G)}}{4\,\dot{m}_L}wd\right)^2 + \left(\frac{4\,\dot{m}_L}{\pi\sqrt{g\,d^5}}\left(-\frac{2\rho_L-\rho_G}{2\,\left(\rho_L(\rho_L-\rho_G)\right)^{3/2}}\right)\frac{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L-\rho_G)}}{4\,\dot{m}_L}w\rho_L\right)^2 + \left(\frac{4\,\dot{m}_L}{\pi\sqrt{g\,d^5}}\left(\frac{\rho_L}{2\,\left(\rho_L(\rho_L-\rho_G)\right)^{3/2}}\right)\frac{\pi\sqrt{g\,d^5\,\rho_L\,(\rho_L-\rho_G)}}{4\,\dot{m}_L}w\rho_G\right)^2\right]^{1/2}$$

$$\frac{wFr_L}{Fr_L} = \pm\left[\left(\frac{w\dot{m}_L}{\dot{m}_L}\right)^2 + \left(\frac{-1}{2}\frac{wg}{g}\right)^2 + \left(\frac{-5}{2}\frac{wd}{d}\right)^2 + \left(-\frac{(2\rho_L-\rho_G)\,w\rho_L}{2\rho_L(\rho_L-\rho_G)}\right)^2 + \left(\frac{1}{2}\frac{w\rho_G}{(\rho_L-\rho_G)}\right)^2\right]^{1/2}$$

The error in the density of liquid and error in gravitational acceleration was assumed negligible, $w\rho_L \simeq 0$ and $wg \simeq 0$.

$$\frac{wFr_L}{Fr_L} = \pm\left[\left(\frac{w\dot{m}_L}{\dot{m}_L}\right)^2 + \left(\frac{-5}{2}\frac{wd}{d}\right)^2 + \left(\frac{1}{2}\frac{w\rho_G}{(\rho_L - \rho_G)}\right)^2\right]^{1/2} \tag{B.15}$$

Vernier caliper was used to measure diameter of the branches having uncertainty interval of $\pm$0.01mm.

B.10 Sample Calculation for Estimation of Uncertainty in the Data

The sample calculation is shown for the set no. 1-1.1.

B.10.1 Uncertainty in P_{TC}

The atmospheric pressure was noted with the help of barometer as,

Barometer reading $= 29.52$ inches of mercury.

The atmospheric pressure in bar was calculated as,

1 bar = 29.9213 inches of mercury (Perry's Chemical Engineers' Handbook, 1999)

$$P_{atm} = \text{Barometer Reading} \times \frac{1.01325}{29.9213}$$

$$= 29.52 \times \frac{1.01325}{29.9213}$$

$$= 999.660 \times 10^{-3}\text{bar} \cong 1.00 \text{ bar}$$

The uncertainty in P_{TC} measurement by pressure transmitter was, $wP_{TC,T} = \pm$ 0.015 bar.

$$\frac{wP_{TC,T}}{P_{TC}} = \pm\left(\frac{0.015}{5.005} \times 100\right)$$

$$= \pm 299.700 \ \%$$

The uncertainty in P_{TC} measurement due to fluctuation in process was $wP_{TC,P}=$ ± 0.06 bar

$$\frac{wP_{TC,P}}{P_{TC}} = \pm \left(\frac{0.06}{5.005} \times 100\right)$$

$$= \pm 1.199 \ \%$$

The uncertainty in P_{TC} measurement due to uncertainty in pressure transmitter and fluctuation in process was calculated using equation (B.3):

$$\frac{wP_{TC}}{P_{TC}} = \pm \left(\left(\frac{wP_{TC,T}}{P_{TC}}\right)^2 + \left(\frac{wP_{TC,P}}{P_{TC}}\right)^2\right)^{1/2} \times 100$$

$$= \pm \left(\left(\frac{0.015}{5.005}\right)^2 + \left(\frac{0.06}{5.005}\right)^2\right)^{1/2} \times 100$$

$$= \pm 1.236 \ \%$$

$$wP_{TC} = \pm \left(\frac{1.236}{100} \times 5.005\right)$$

$$= \pm 61.862 \times 10^{-3} \text{ bar}$$

B.10.2 Uncertainty in $P_{TC,abs}$

Absolute gas pressure in test chamber was calculated as follows,

The measured test chamber was P_{TC} = 5.005 bar.

$$P_{Tc,abs} = P_{TC} + P_{atm}$$

= 5.005 + 1.00 = 6.005 bar

$wP_{atm} = 0$ (negligible)

∴ The uncertainty in $P_{TC,abs}$ measurement was, $wP_{TC,abs,T} = wP_{TC,T} = \pm$ 0.015 bar.

$$\frac{wP_{TC,abs,T}}{P_{TC,abs}} = \pm \left(\frac{0.015}{6.005} \times 100\right)$$

$$= \pm 249.792 \times 10^{-3} \%$$

The uncertainty in $P_{TC,abs}$ measurement due to fluctuation in process was

$wP_{TC,abs,P} = wP_{TC,P} = \pm$ 0.06 bar

$$\frac{wP_{TC,abs,P}}{P_{TC,abs}} = \pm \left(\frac{0.06}{6.005} \times 100\right)$$

$$= \pm 999.167 \times 10^{-3} \%$$

The uncertainty in $P_{TC,abs}$ measurement due to uncertainty in pressure transmitter and fluctuation in process was calculated as follows:

$$\frac{wP_{TC,abs}}{P_{TC,abs}} = \pm \left(\left(\frac{wP_{TC,abs,T}}{P_{TC,abs}}\right)^2 + \left(\frac{wP_{TC,abs,P}}{P_{TC,abs}}\right)^2\right)^{1/2} \times 100$$

$$= \pm \left(\left(\frac{0.015}{6.005}\right)^2 + \left(\frac{0.06}{6.005}\right)^2\right)^{1/2} \times 100$$

$$= \pm 1.023 \%$$

$$wP_{TC,abs} = \pm \left(\frac{1.023}{100} \times 6.005\right)$$

$$= \pm 61.431 \times 10^{-3} \text{ bar}$$

B.10.3 Uncertainty in P_{PH}

Absolute gas pressure in phase separator was calculated using equation (B.4),

The measured phase separator pressure was P_{PH} = 4.75 bar.

$$P_{PH,abs} = P_{TC,T} + P_{atm}$$

= 4.75 + 1.00

= 5.75 bar

The uncertainty in P_{PH} measurement by pressure transmitter was $wP_{PH,T}$= $\pm$0.019 bar

$$\frac{wP_{PH,T}}{P_{PH}} = \pm \left(\frac{0.019}{4.75} \times 100\right)$$

$$= \pm 0.400 \ \%$$

The uncertainty in P_{PH} due to fluctuation in the process was $wP_{PH,T}$= $\pm$0.02 bar.

$$\frac{wP_{PH,P}}{P_{PH}} = \pm \left(\frac{0.02}{4.75} \times 100\right)$$

$$= \pm 0.421 \ \%$$

The uncertainty in P_{PH} due to pressure transmitter and fluctuation in the process was calculated as follows:

$$\frac{wP_{PH}}{P_{PH}} = \pm\left(\left(\frac{wP_{PH,T}}{P_{PH}}\right)^2 + \left(\frac{wP_{PH,P}}{P_{PH}}\right)^2\right)^{1/2} \times 100$$

$$= \pm\left(\left(\frac{0.019}{4.75}\right)^2 + \left(\frac{0.02}{4.75}\right)^2\right)^{1/2} \times 100$$

$$= \pm 0.581\ \%$$

$$wP_{PH} = \pm\left(\frac{0.581}{100} \times 4.75\right)$$

$$= \pm 27.598 \times 10^{-3}\ \text{bar}$$

B.10.4 Uncertainty in ΔP

The pressure difference between across the branch was calculated using equation (B.6).

$$\Delta P = P_{TC} - P_{PH}$$

$$= 5.005 - 4.75$$

$$= 0.255\ \text{bar}$$

$$\frac{w\Delta P}{\Delta P} = \pm\left[\left(\frac{wP_{TC}}{(P_{TC} - P_{PH})}\right)^2 + \left(-\frac{wP_{PH}}{(P_{TC} - P_{PH})}\right)^2\right]^{1/2} \times 100$$

$$= \pm\left[\left(\frac{61.862 \times 10^{-3}}{0.255}\right)^2 + \left(-\frac{27.598 \times 10^{-3}}{0.255)}\right)^2\right]^{1/2} \text{X}\ 100$$

$$= \pm 26.653\ \%$$

$$w\Delta P = \pm\left(\frac{26.653}{100} \times \Delta P\right)$$

$$= \pm \left(\frac{26.653}{100} \times 0.255 \right)$$

$$= \pm 67.965 \times 10^{-3} \text{ bar}$$

B.10.5 Uncertainty in T_G

The gas temperature was noted down in the test section as,

T_G = 28.0 ^{0}C

= 28.0 + 273.15

= 301.15 K

The uncertainty of the thermometer was given as 1% of the Full Scale Deflection (FSD), and FSD was 50 ^{0}C, therefore uncertainty in gas temperature measurement was calculated as follows,

$$wT_G = \pm 1\% \text{ of FSD}$$

$$= \pm \left(\frac{1}{100} (50 + 273.15) \right)$$

$$= \pm 3.232 \text{ K}$$

$$\frac{wT_G}{T_G} = \pm \left(\frac{3.232}{301.15} \times 100 \right)$$

$$= \pm 10.73 \times 10^{-3} \%$$

B.10.6 Uncertainty in ρ_G

The gas constant was obtained from Perry's Chemical Engineers' Handbook (1999) as,

$R_G = 287.15$ kJ/kg. K

The density of gas obtained by treating the gas as ideal gas,

$$\rho_G = \left(\frac{P_{Tc,abs}}{R_G\, T_G}\right)$$

$$= \left(\frac{6.005\ \times\ 10^5}{287.15\ \times\ 301.15}\right)$$

$$= 6.944\ \text{kg/m}^3$$

The uncertainty in the density of gas was obtained using equation (B.8) as,

$$\frac{w\rho_G}{\rho_G} = \pm\left[\left(\frac{wP_{TC,abs}}{P_{TC,abs}}\right)^2 + \left(-\frac{wT_G}{T_G}\right)^2\right]^{1/2} \times\ 100$$

$$= \pm\left[\left(\frac{61.431\ \times 10^{-3}}{6.005}\right)^2 + \left(-\frac{3.23}{301.15}\right)^2\right]^{1/2} \times\ 100$$

$$= \pm\ 1.482\ \ \times 10^{-3}\ \%$$

$$w\rho_G = \pm\left(\frac{1.482\ \times 10^{-3}}{100}\ \times\ \rho_G\right)$$

$$= \pm\left(\frac{1.482\ \times 10^{-3}}{100}\ \times\ 6.944\right)$$

$$= \pm\ 102.910 \times 10^{-3}\ \text{kg/m}^3$$

B.10.7 Uncertainty in $\Delta\rho$

The density of liquid (at T_G = 28.0 ^{0}C) was obtained from Perry's Chemical Engineers' Handbook (1999) as,

ρ_L = 996.233 kg/m^3

The difference in density of liquid and gas was calculated as,

$$\Delta\rho = \rho_L - \rho_G$$

$$= 996.233 - 6.944$$

$$= 989.289 \text{ kg/ m}^3$$

The uncertainty in the $\Delta\rho$ was calculated using equation (B.10),

$$\frac{w\Delta\rho}{\Delta\rho} = \pm\left[\left(-\frac{w\rho_G}{\Delta\rho}\right)^2\right]^{1/2} \times 100$$

$$= \pm\left[\left(-\frac{102.910 \times 10^{-3}}{989.289}\right)^2\right]^{1/2} \times 100$$

$$= \pm 10.199 \times 10^{-3} \%$$

$$w\Delta\rho = \pm\left(\frac{\Delta\rho \times 10.199 \times 10^{-3}}{100}\right)$$

$$= \pm\left(\frac{989.289 \times 10.199 \times 10^{-3}}{100}\right)$$

$$= \pm 100.898 \times 10^{-3} \text{ kg/m}^3$$

B.10.8 Uncertainty in $\dot{m}_L$

The mass flow rate of liquid was measured by the flow meter as,

$$\dot{m}_{L,T} = 7.42 \text{ kg/min}$$

The uncertainty in mass flow measurement due to flow transmitter in percentage was calculated using equation (B.12) as,

$$\frac{w\dot{m}_{L,T}}{\dot{m}_L} = \pm\left(0.05 + \left(\frac{12 - \dot{m}_L}{30}\right) + \left(\frac{9}{1000 \times \dot{m}_L}\right)\right)$$

$$= \pm \left(0.05 + \left(\frac{12 - 7.42}{30}\right) + \left(\frac{9}{1000 \times 7.42}\right)\right)$$

$$= \pm\ 203.880 \times\ 10^{-3}\ \%$$

$$\therefore w\dot{m}_{L,T}\ =\ \pm\ \left(\frac{203.880\ \times\ 10^{-3}}{100} \times 7.42\right)$$

$$=\ \pm\ 15.128\ \times 10^{-3}\ \text{kg/min}$$

The mass flow rate was measured with the fluctuation of ± 0.1 kg/min in process,

$$\therefore w\dot{m}_{L,P} = \pm 0.1\ \text{kg/min}$$

The uncertainty due to the fluctuation in process was calculated as,

$$\frac{w\dot{m}_{L,P}}{\dot{m}_L} = \pm\left(\frac{0.1}{7.42} \times 100\right)$$

$$= \pm\ 1.348\ \ \%$$

The uncertainty in mass flow rate including the uncertainty of flow transmitter and uncertainty due to the fluctuation in process was calculated as follows,

$$\frac{w\dot{m}_L}{\dot{m}_L} = \pm\left(\sqrt{\left(\frac{w\dot{m}_{L,T}}{\dot{m}_L}\right)^2 + \left(\frac{w\dot{m}_{L,P}}{\dot{m}_L}\right)^2}\right) \times 100$$

$$\frac{w\dot{m}_L}{\dot{m}_L} = \pm\left(\sqrt{\left(\frac{203.880\ \times\ 10^{-3}}{100}\right)^2 + \left(\frac{1.348}{100}\right)^2}\right) \times 100$$

$$= \pm\ 1.36\ \%$$

$$w\dot{m}_L = \pm\ \left(\frac{1.36}{100}\ \times\ \dot{m}_L\right)$$

$$= \pm\left(\frac{1.36}{100} \times 7.42\right)$$

$$= \pm 100.912 \times 10^{-3}\ \text{kg/min}$$

B.10.9 Uncertainty in d

The uncertainty in the branch diameter of 9.0 mm was calculated as,

$$\frac{\text{wd}}{\text{d}} = \pm\left(\frac{0.01}{9.0} \times 100\right)$$

$$= \pm 0.111\ \%$$

B.10.10 Uncertainty in Fr_L

The uncertainty in the Froude number was calculated by using equation (B.15) for the calculated Fr_L = 6.58,

$$\frac{\text{wFr}_L}{\text{Fr}_L} = \pm\left[\left(\frac{\text{w}\dot{m}_L}{\dot{m}_L}\right)^2 + \left(\frac{-5}{2}\frac{\text{wd}}{\text{d}}\right)^2 + \left(\frac{1}{2}\frac{\text{w}\rho_G}{(\rho_L - \rho_G)}\right)^2\right]^{1/2} \times 100$$

$$= \pm\left[(1.36)^2 + \left(\frac{-5}{2} \times 0.111\right)^2 + \left(\frac{1}{2} \times 102.910 \times 10^{-3}\right)^2\right]^{\frac{1}{2}}$$

$$= \pm 1.389\ \%$$

$$\text{wFr}_L = \pm\left(\frac{1.389}{100} \times 6.58\right)$$

$$= \pm 91.396 \times 10^{-3}$$

Appendix C

Experimental Data

Table C.1 : Experimental data for single discharge

Series no. 1-1

P_{atm} = 1.00 bar

Set no.	T_G (ºC)	Activated line B1			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$
1-1.1	28.0	6.58	5.005	0.255	1.19
1-1.2	36.0	9.31	5.021	0.531	1.44
1-1.3	25.3	11.22	4.998	0.748	1.50
1-1.4	32.5	12.93	5.009	1.009	1.61
1-1.5	28.0	18.54	5.017	2.027	1.81
1-1.6	31.0	22.62	5.005	3.005	1.99
1-1.7	27.5	25.88	6.004	3.994	2.07
1-1.8	22.5	27.29	6.002	4.492	2.10

Series no. 1-3

P_{atm} = 1.00 bar

Set no.	T_G (ºC)	Activated line B3			
		$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$
1-2.1	28.5	6.52	4.999	0.249	1.03
1-2.2	36.0	9.08	5.000	0.500	1.23
1-2.3	25.5	11.23	5.000	0.750	1.37
1-2.4	32.5	12.96	5.014	1.014	1.56
1-2.5	28.5	18.53	5.016	2.026	1.90
1-2.6	31.0	22.57	5.004	2.994	2.04
1-2.7	28.0	25.89	5.996	3.996	2.18
1-2.8	24.5	27.30	6.002	4.492	2.26

Series no. 1-2

P_{atm} = 1.00 bar

Set no.	T_G (ºC)	Activated line B2			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$
1-3.1	28.0	6.53	5.000	0.250	1.27
1-3.2	36.0	9.14	5.009	0.509	1.52
1-3.3	25.5	11.23	5.000	0.750	1.61
1-3.4	32.5	12.88	4.992	1.002	1.69
1-3.5	28.0	18.44	5.014	2.004	1.97
1-3.6	31.0	22.69	5.028	3.018	2.25
1-3.7	27.5	25.90	5.999	3.999	2.37
1-3.8	22.5	27.35	6.013	4.513	2.48

Series no. 1-4

P_{atm} = 1.00 bar

Set no.	T_G (ºC)	Activated line B4			
		$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
1-4.1	28.5	6.37	4.996	0.236	1.42
1-4.2	36.0	9.16	5.001	0.511	1.53
1-4.3	25.8	11.25	5.002	0.752	1.67
1-4.4	32.5	12.95	5.012	1.012	1.76
1-4.5	29.0	18.44	5.003	2.003	2.07
1-4.6	31.0	22.65	5.000	3.010	2.26
1-4.7	27.5	25.88	5.992	3.992	2.35
1-4.8	23.5	27.32	6.001	4.501	2.49

Table C.1 : Experimental data for single discharge (cont.)

Series no. 1-5 P_{atm} = 1.00 bar					
Set no.	T_G (°C)	Activated line			
		B5			
		$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
1-5.1	28.5	6.57	5.004	0.254	1.21
1-5.2	36.0	9.08	5.001	0.501	1.29
1-5.3	25.5	11.27	5.005	0.755	1.44
1-5.4	32.5	12.92	5.007	1.007	1.46
1-5.5	29.0	18.54	5.016	2.026	1.78
1-5.6	31.0	22.60	4.999	2.999	1.92
1-5.7	27.5	25.88	6.002	3.992	2.04
1-5.8	23.5	27.31	5.997	4.497	2.07

Table C.2 : Experimental data for dual discharge

Series no. 2-1 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B1				B2			
		$Fr_{L,B1}$	P_{TC1} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC2} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$
2-1.1	27.5	6.57	5.004	0.254	1.24	6.53	4.990	0.250	1.16
2-1.2	32.0	9.15	5.012	0.512	1.44	9.01	5.003	0.493	1.24
2-1.3	25.0	11.24	5.001	0.751	1.61	11.30	5.000	0.760	1.32
2-1.4	31.5	12.84	4.996	0.996	1.70	12.97	4.996	1.016	1.41
2-1.5	31.0	18.43	5.018	1.998	2.02	18.42	4.995	1.995	1.63
2-1.6	30.5	22.57	4.995	2.995	2.25	22.57	5.005	2.995	1.80
2-1.7	28.5	25.92	6.002	4.002	2.33	25.85	5.993	3.983	1.92
2-1.8	25.0	27.40	6.023	4.523	2.36	27.37	6.005	4.515	2.03

Series no. 2-2 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B1				B3			
		$Fr_{L,B1}$	P_{TC1} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B3}$	P_{TC3} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$
2-2.1	24.0	6.60	5.007	0.257	1.13	6.52	5.000	0.250	1.00
2-2.2	34.0	9.03	4.995	0.495	1.41	9.00	4.981	0.491	1.23
2-2.3	24.0	11.36	5.020	0.770	1.53	11.28	5.008	0.758	1.34
2-2.4	31.8	13.30	5.050	1.070	1.67	12.85	4.997	0.997	1.50
2-2.5	32.0	18.42	4.994	1.994	1.90	18.43	4.997	1.997	1.78
2-2.6	31.3	22.60	5.020	3.000	2.10	22.50	4.987	2.977	2.07
2-2.7	29.0	25.99	6.010	4.020	2.27	26.06	6.031	4.041	2.15
2-2.8	25.5	27.31	5.995	4.495	2.33	27.28	5.985	4.485	2.26

Table C.2 : Experimental data for dual discharge (cont.)

Series no. 2-3 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B1				B4			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
2-3.1	25.0	6.46	4.995	0.245	1.19	6.51	4.999	0.249	1.31
2-3.2	33.0	9.20	5.018	0.518	1.41	9.02	5.003	0.493	1.62
2-3.3	24.5	11.27	5.006	0.756	1.53	11.29	5.009	0.759	1.67
2-3.4	31.5	13.19	5.011	1.051	1.70	12.32	5.002	0.912	1.81
2-3.5	32.0	18.37	5.003	1.983	1.99	18.43	5.006	1.996	2.04
2-3.6	31.0	22.67	5.035	3.015	2.22	22.72	5.015	3.025	2.26
2-3.7	28.5	25.93	6.006	4.006	2.33	25.96	6.003	4.013	2.38
2-3.8	25.5	27.32	5.997	4.497	2.36	27.32	5.996	4.496	2.43

Series no. 2-4 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B1				B5			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
2-4.1	27.5	6.51	4.999	0.249	1.10	6.58	5.005	0.255	1.18
2-4.2	32.0	9.11	5.006	0.506	1.33	9.12	5.007	0.507	1.35
2-4.3	25.0	11.23	5.000	0.750	1.44	11.23	5.000	0.750	1.46
2-4.4	31.5	12.88	5.002	1.002	1.64	12.91	5.007	1.007	1.61
2-4.5	29.5	18.37	4.995	1.985	1.87	18.44	5.003	2.003	1.89
2-4.6	30.0	22.63	5.007	3.007	2.02	22.60	5.001	3.001	2.04
2-4.7	28.1	25.95	6.003	4.013	2.16	25.96	6.004	4.014	2.15
2-4.8	24.5	27.33	6.011	4.501	2.22	27.36	6.012	4.512	2.18

Table C.2 : Experimental data for dual discharge (cont.)

Series no. 2-5 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B2				B3			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$
2-5.1	25.5	6.50	4.998	0.248	1.38	6.61	4.998	0.258	1.11
2-5.2	36.0	9.11	5.014	0.504	1.61	9.15	5.010	0.510	1.39
2-5.3	23.5	11.28	5.008	0.758	1.77	11.23	5.000	0.750	1.53
2-5.4	31.5	13.07	5.023	1.033	1.97	12.79	5.007	0.987	1.76
2-5.5	33.0	18.60	5.007	2.037	2.48	18.49	5.020	2.010	2.01
2-5.6	31.5	22.72	5.034	3.024	2.71	22.72	5.014	3.024	2.35
2-5.7	29.0	25.96	6.014	4.014	2.85	25.93	6.023	4.003	2.46
2-5.8	27.0	27.33	5.997	4.497	2.99	27.34	5.990	4.500	2.63

Series no. 2-6 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B2				B4			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
2-6.1	26.5	6.54	5.001	0.251	1.46	6.54	5.001	0.251	1.64
2-6.2	36.0	9.19	5.015	0.515	1.58	9.28	5.017	0.527	1.73
2-6.3	25.0	11.22	4.998	0.748	1.80	11.22	4.999	0.749	1.90
2-6.4	31.5	12.81	4.991	0.991	1.83	12.81	4.991	0.991	1.95
2-6.5	31.0	18.37	4.985	1.985	2.20	18.53	5.013	2.023	2.15
2-6.6	30.0	22.58	5.007	2.997	2.48	22.47	4.974	2.974	2.32
2-6.7	28.1	25.90	5.998	3.998	2.60	25.96	6.014	4.014	2.43
2-6.8	24.5	27.40	6.016	4.526	2.71	27.35	6.008	4.508	2.52

Table C.2 : Experimental data for dual discharge (cont.)

Series no. 2-7 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B2				B5			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
2-7.1	24.5	6.41	5.000	0.240	1.38	6.58	5.005	0.255	1.23
2-7.2	35.0	9.13	5.007	0.507	1.52	8.94	4.992	0.482	1.46
2-7.3	24.0	11.21	4.997	0.747	1.63	11.17	5.002	0.742	1.58
2-7.4	31.5	12.41	4.997	0.927	1.80	12.81	5.001	0.991	1.69
2-7.5	32.0	18.39	4.998	1.988	2.14	18.40	4.990	1.990	1.95
2-7.6	31.0	22.75	5.031	3.031	2.37	22.69	5.019	3.019	2.18
2-7.7	29.5	25.99	6.011	4.021	2.54	25.87	5.997	3.987	2.30
2-7.8	26.5	27.33	5.988	4.498	2.57	27.29	5.985	4.485	2.47

Series no. 2-8 P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B3				B4			
		$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
2-8.1	25.0	6.52	5.010	0.250	1.11	6.51	4.999	0.249	1.50
2-8.2	36.0	8.96	4.984	0.484	1.42	9.07	4.999	0.499	1.62
2-8.3	23.5	11.25	5.003	0.753	1.56	11.23	5.001	0.751	1.81
2-8.4	31.5	12.79	4.998	0.988	1.78	12.67	4.978	0.968	1.95
2-8.5	34.0	18.43	5.004	1.994	2.12	18.38	4.993	1.983	2.32
2-8.6	31.5	22.59	4.996	2.996	2.35	22.52	5.011	2.981	2.63
2-8.7	29.0	25.90	5.995	3.995	2.43	25.94	5.998	4.008	2.69
2-8.8	27.0	27.35	5.993	4.503	2.57	27.32	6.005	4.495	2.95

Table C.2 : Experimental data for dual discharge (cont.)

Series no. 2-9 P_{atm} = 1.00 bar									
Set no.	T_G (°C)	Activated lines							
		B3				B5			
		$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
2-9.1	23.5	6.60	4.997	0.257	1.00	6.53	5.001	0.251	1.12
2-9.2	35.5	9.17	5.012	0.512	1.25	9.20	5.007	0.517	1.38
2-9.3	23.5	11.20	4.996	0.746	1.34	11.20	4.996	0.746	1.46
2-9.4	31.8	12.86	4.999	0.999	1.53	12.96	4.995	1.015	1.66
2-9.5	32.5	18.46	4.994	2.004	1.78	18.41	4.992	1.992	1.92
2-9.6	31.5	22.70	5.020	3.020	2.04	22.45	4.977	2.967	2.10
2-9.7	29.0	25.67	5.980	3.930	2.15	25.90	5.996	3.996	2.18
2-9.8	26.5	27.37	6.010	4.510	2.26	27.38	6.014	4.514	2.27

Series no. 2-10 P_{atm} = 1.00 bar									
Set no.	T_G (°C)	Activated lines							
		B4				B5			
		$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
2-10.1	26.5	6.51	4.999	0.249	1.25	6.55	5.002	0.252	1.15
2-10.2	35.0	9.16	5.001	0.511	1.31	9.16	5.011	0.511	1.35
2-10.3	25.0	11.36	5.009	0.769	1.45	11.34	5.006	0.766	1.52
2-10.4	31.5	12.82	4.993	0.993	1.50	12.50	4.991	0.941	1.64
2-10.5	31.0	18.51	5.007	2.017	1.70	18.28	4.992	1.962	1.89
2-10.6	30.5	22.60	5.010	3.000	1.84	22.57	5.003	2.993	2.04
2-10.7	29.0	25.88	5.991	3.991	1.98	25.88	5.990	3.990	2.30
2-10.8	25.5	27.25	5.985	4.475	2.01	27.35	6.016	4.506	2.33

Table C.3 : Experimental data for triple discharge

Series no. 3-1 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B1				B2				B3			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$
3-1.1	20.5	6.48	4.997	0.247	1.21	6.49	4.998	0.248	1.24	6.54	5.002	0.252	1.03
3-1.2	28.5	8.92	4.992	0.482	1.53	9.15	5.022	0.512	1.38	9.52	5.022	0.562	1.34
3-1.3	23.0	11.11	4.993	0.733	1.67	11.25	4.994	0.754	1.52	11.36	5.010	0.770	1.53
3-1.4	31.0	12.74	5.030	0.980	1.81	12.66	4.997	0.967	1.69	13.07	5.042	1.032	1.73
3-1.5	30.5	18.39	4.989	1.989	2.19	18.49	5.004	2.014	2.03	18.46	5.007	2.007	2.04
3-1.6	31.5	22.47	4.992	2.972	2.36	22.65	5.010	3.010	2.28	22.63	5.005	3.005	2.32
3-1.7	29.0	25.82	5.992	3.972	2.59	25.88	5.989	3.989	2.45	26.04	6.014	4.034	2.40
3-1.8	27.5	27.37	6.008	4.508	2.68	27.31	5.999	4.489	2.54	27.37	6.009	4.509	2.54

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-2 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B1				B2				B4			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
3-2.1	20.0	6.54	5.002	0.252	1.21	6.62	5.009	0.259	1.13	6.63	5.000	0.260	1.50
3-2.2	29.5	9.02	5.005	0.495	1.47	8.98	4.990	0.490	1.24	9.11	5.007	0.507	1.76
3-2.3	21.0	11.23	5.002	0.752	1.64	11.28	5.009	0.759	1.38	11.20	4.997	0.747	1.90
3-2.4	30.3	12.86	5.009	0.999	1.79	12.92	5.019	1.009	1.55	12.84	4.997	0.997	1.90
3-2.5	29.5	18.60	5.020	2.040	2.04	18.39	4.991	1.991	1.77	18.42	4.997	1.997	2.15
3-2.6	31.0	22.72	5.026	3.026	2.25	22.83	5.009	3.049	1.92	22.60	4.990	3.000	2.32
3-2.7	27.5	25.90	5.998	3.998	2.36	25.83	5.990	3.980	2.11	25.87	5.999	3.989	2.52
3-2.8	27.5	27.40	6.018	4.518	2.51	27.33	6.007	4.497	2.34	27.36	5.994	4.504	2.60

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-3 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B1				B2				B5			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
3-3.1	19.5	6.54	5.002	0.252	1.30	6.56	5.004	0.254	1.10	6.49	4.998	0.248	1.18
3-3.2	31.0	9.11	5.006	0.506	1.44	9.03	4.995	0.495	1.18	9.11	5.006	0.506	1.44
3-3.3	21.5	11.22	5.000	0.750	1.67	11.27	5.007	0.757	1.27	11.22	5.000	0.750	1.52
3-3.4	31.5	12.93	5.010	1.010	1.79	12.70	4.993	0.973	1.38	12.80	4.979	0.989	1.72
3-3.5	28.0	18.37	4.997	1.987	2.07	18.34	5.000	1.980	1.61	18.44	5.005	2.005	2.01
3-3.6	31.5	22.28	5.000	2.930	2.22	22.32	5.000	2.940	1.80	22.63	5.006	3.006	2.12
3-3.7	26.5	25.91	6.004	4.004	2.36	25.86	5.998	3.988	1.89	25.90	6.001	4.001	2.36
3-3.8	27.5	27.32	6.001	4.491	2.48	27.35	6.001	4.501	2.00	27.30	6.005	4.485	2.64

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-4 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B1				B3				B4			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
3-4.1	21.5	6.49	4.998	0.248	1.19	6.49	4.998	0.248	1.09	6.47	4.996	0.246	1.59
3-4.2	28.0	9.62	5.066	0.576	1.53	9.46	5.005	0.555	1.39	9.23	5.023	0.523	1.76
3-4.3	24.5	11.25	5.003	0.753	1.56	11.34	5.006	0.766	1.53	11.22	4.998	0.748	1.87
3-4.4	28.5	12.85	5.009	0.999	1.84	12.78	4.998	0.988	1.76	12.85	4.999	0.999	1.90
3-4.5	30.5	18.38	5.016	1.986	2.13	18.39	4.989	1.989	2.09	18.47	5.008	2.008	2.32
3-4.6	28.3	22.59	5.002	3.002	2.42	22.59	5.002	3.002	2.29	22.60	5.004	3.004	2.55
3-4.7	25.3	25.94	6.015	4.015	2.53	25.93	6.011	4.011	2.49	25.87	6.004	3.994	2.72
3-4.8	27.5	27.37	6.009	4.509	2.62	27.34	5.998	4.498	2.63	27.34	5.998	4.498	2.80

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-5 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B1				B3				B5			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
3-5.1	23.0	6.52	5.000	0.250	1.13	6.60	5.002	0.257	0.98	6.50	4.998	0.248	1.18
3-5.2	29.0	8.95	4.976	0.486	1.27	9.40	5.046	0.546	1.20	8.83	4.989	0.469	1.32
3-5.3	23.8	11.26	5.005	0.755	1.47	11.17	4.992	0.742	1.34	11.22	4.999	0.749	1.55
3-5.4	31.0	12.88	5.002	1.002	1.73	12.75	5.002	0.982	1.42	12.94	5.002	1.012	1.66
3-5.5	30.0	18.44	4.993	2.003	2.02	18.43	5.000	2.000	1.70	18.42	4.997	1.997	2.07
3-5.6	31.5	22.54	4.996	2.986	2.22	22.66	5.002	3.012	2.01	22.59	5.006	2.996	2.36
3-5.7	25.0	25.90	6.004	4.004	2.33	25.90	6.003	4.003	2.09	25.92	6.010	4.010	2.27
3-5.8	27.5	27.36	6.005	4.505	2.42	27.34	6.000	4.500	2.23	27.26	5.993	4.473	2.64

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-6 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B1				B4				B5			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
3-6.1	19.5	6.49	4.998	0.248	1.16	6.66	5.013	0.263	1.25	6.54	5.002	0.252	1.21
3-6.2	30.0	9.03	5.006	0.496	1.41	9.18	5.016	0.516	1.34	9.03	5.006	0.496	1.35
3-6.3	24.5	11.26	5.005	0.755	1.50	11.17	4.992	0.742	1.39	11.22	4.999	0.749	1.55
3-6.4	28.5	13.04	5.020	1.030	1.64	12.84	4.998	0.998	1.45	12.83	4.996	0.996	1.72
3-6.5	29.0	18.60	5.011	2.041	2.10	18.47	5.000	2.010	1.64	18.50	5.008	2.018	2.15
3-6.6	28.3	22.47	4.995	2.975	2.30	22.57	4.998	2.998	1.79	22.47	4.995	2.975	2.30
3-6.7	26.0	25.90	6.011	4.001	2.33	25.98	6.013	4.023	1.87	25.91	6.013	4.003	2.33
3-6.8	27.5	27.35	6.002	4.502	2.45	27.33	5.995	4.495	1.90	27.34	6.000	4.500	2.47

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-7 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B2				B3				B4			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
3-7.1	24.5	6.67	5.003	0.263	1.63	6.60	4.997	0.257	1.20	6.68	5.004	0.264	1.64
3-7.2	28.0	8.95	4.976	0.486	1.72	8.86	5.024	0.474	1.56	8.86	5.024	0.474	1.73
3-7.3	24.8	11.30	5.011	0.761	1.92	11.36	5.009	0.769	1.70	11.31	5.011	0.761	1.90
3-7.4	28.0	12.81	4.993	0.993	2.08	13.05	5.011	1.031	1.95	12.94	5.014	1.014	2.04
3-7.5	30.5	18.29	5.005	1.965	2.51	18.46	5.006	2.006	2.46	18.46	5.007	2.007	2.49
3-7.6	28.5	22.62	5.018	3.008	2.82	22.63	5.000	3.010	2.60	22.60	5.004	3.004	2.78
3-7.7	25.0	25.85	5.998	3.988	3.05	26.03	6.009	4.039	2.80	25.85	5.998	3.988	2.92
3-7.8	27.5	27.35	6.003	4.503	3.16	27.43	5.999	4.529	3.00	27.36	6.004	4.504	3.09

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-8 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B2				B3				B5			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
3-8.1	24.5	6.37	4.997	0.237	1.38	6.57	5.004	0.254	1.06	6.60	5.007	0.257	1.21
3-8.2	28.0	9.56	5.048	0.568	1.80	9.05	4.999	0.499	1.34	8.75	4.989	0.459	1.38
3-8.3	24.3	11.19	5.005	0.745	1.83	11.14	4.997	0.737	1.56	11.20	4.996	0.746	1.58
3-8.4	28.0	12.90	4.997	1.007	1.89	12.90	5.017	1.007	1.67	12.96	5.017	1.017	1.81
3-8.5	30.5	18.39	4.989	1.989	2.28	18.44	5.002	2.002	2.01	18.30	5.017	1.967	2.07
3-8.6	28.5	22.63	5.010	3.010	2.60	22.62	5.007	3.007	2.26	22.37	5.003	2.953	2.27
3-8.7	25.0	25.90	6.002	4.002	2.74	25.91	6.006	4.006	2.37	25.86	6.003	3.993	2.41
3-8.8	27.0	27.35	6.002	4.502	2.91	27.36	6.007	4.507	2.57	27.37	6.001	4.511	2.50

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-9 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B2				B4				B5			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
3-9.1	20.5	6.48	4.997	0.247	1.46	6.50	4.999	0.249	1.45	6.73	5.009	0.269	1.18
3-9.2	29.5	9.12	5.018	0.508	1.58	9.10	4.995	0.505	1.59	9.59	4.992	0.572	1.44
3-9.3	22.5	11.29	5.009	0.759	1.86	11.24	4.993	0.753	1.62	11.33	5.006	0.766	1.49
3-9.4	31.0	12.95	5.004	1.014	1.83	12.99	5.030	1.020	1.67	13.06	5.011	1.031	1.81
3-9.5	30.0	18.52	5.000	2.020	2.11	18.38	4.987	1.987	1.87	18.61	5.022	2.042	2.07
3-9.6	31.0	22.61	5.001	3.001	2.37	22.61	5.002	3.002	2.01	22.61	5.002	3.002	2.30
3-9.7	25.5	25.94	6.013	4.013	2.48	25.92	5.999	4.009	2.07	25.87	6.014	3.994	2.38
3-9.8	27.0	27.37	6.010	4.510	2.60	27.42	6.006	4.526	2.12	27.28	5.999	4.479	2.53

Table C.3 : Experimental data for triple discharge (cont.)

Series no. 3-10 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B3				B4				B5			
		$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
3-10.1	25.0	6.49	4.997	0.247	1.11	6.57	5.004	0.254	1.34	6.48	4.996	0.246	1.18
3-10.2	28.5	9.08	4.983	0.503	1.37	9.47	5.056	0.556	1.56	9.35	5.009	0.539	1.44
3-10.3	23.5	11.24	5.002	0.752	1.56	11.11	4.993	0.733	1.67	11.22	4.999	0.749	1.55
3-10.4	31.5	12.85	5.007	0.997	1.76	12.96	5.015	1.015	1.76	12.91	5.016	1.006	1.81
3-10.5	30.5	18.55	4.998	2.028	2.09	18.50	5.006	2.016	2.01	18.37	5.015	1.985	2.01
3-10.6	31.3	22.61	5.001	3.001	2.37	22.51	5.000	2.980	2.29	22.62	5.003	3.003	2.21
3-10.7	25.0	25.78	5.990	3.970	2.52	25.87	5.994	3.994	2.43	25.89	6.010	4.000	2.36
3-10.8	27.0	27.37	6.000	4.510	2.68	27.31	5.989	4.489	2.58	27.35	6.004	4.504	2.50

Table C.4 : Experimental data for quadruple discharge

Series no. 4-1 P_{atm} = 1.00 bar																	
Set no.	T_G (ºC)	Activated lines															
		B1				B2				B3				B4			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$
4-1.1	29.0	6.52	4.999	0.249	1.38	6.52	4.999	0.249	1.46	6.43	5.001	0.254	1.25	6.51	4.998	0.247	1.59
4-1.2	36.0	9.08	5.000	0.500	1.64	9.00	4.990	0.490	1.49	9.24	5.012	0.496	1.56	9.09	5.012	0.494	1.67
4-1.3	25.5	11.27	4.995	0.755	1.87	11.23	5.000	0.750	1.69	11.30	5.000	0.751	1.70	11.23	5.000	0.763	1.90
4-1.4	32.0	12.78	4.975	0.985	1.79	12.84	4.995	0.995	1.86	12.86	4.998	0.982	1.95	12.86	4.999	0.963	2.04
4-1.5	27.0	18.45	5.009	2.009	2.25	18.48	5.016	2.016	2.37	18.37	4.990	2.017	2.37	18.48	5.014	2.041	2.52
4-1.6	28.6	22.53	5.009	2.989	2.65	22.61	5.005	3.005	2.65	22.62	5.007	3.002	2.71	22.61	5.005	3.008	2.89
4-1.7	22.5	25.89	5.994	4.004	2.68	25.85	5.992	3.992	2.85	25.84	5.990	4.010	3.00	25.85	5.992	4.001	3.09
4-1.8	27.5	27.36	6.007	4.507	2.91	27.43	5.998	4.528	3.05	27.36	6.005	4.493	3.11	27.43	5.998	4.498	3.26

Table C.4 : Experimental data for quadruple discharge (cont.)

Series no. 4-2 P_{atm} = 1.00 bar																	
Set no.	T_G (°C)	Activated lines															
		B1				B2				B3				B5			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
4-2.1	29.0	6.57	5.004	0.254	1.38	6.62	4.997	0.247	1.24	6.62	5.008	0.258	1.11	6.55	5.002	0.252	1.32
4-2.2	36.0	9.05	4.996	0.496	1.59	9.26	5.004	0.494	1.35	9.26	5.024	0.524	1.34	9.05	4.996	0.496	1.49
4-2.3	25.5	11.24	5.001	0.751	1.76	11.20	5.003	0.763	1.46	11.20	4.995	0.745	1.50	11.24	5.001	0.751	1.78
4-2.4	32.0	12.76	5.002	0.982	1.99	12.88	4.993	0.963	1.58	12.88	5.002	1.002	1.67	12.78	5.006	0.986	1.92
4-2.5	28.0	18.49	5.017	2.017	2.25	18.41	5.051	2.041	2.03	18.41	5.008	1.998	2.01	18.45	5.008	2.008	2.18
4-2.6	28.8	22.60	5.002	3.002	2.45	22.61	4.998	3.008	2.34	22.61	5.006	3.006	2.23	22.60	5.002	3.002	2.44
4-2.7	23.0	25.91	6.010	4.010	2.65	25.82	6.001	4.001	2.42	25.82	5.995	3.985	2.37	25.84	6.001	3.991	2.64
4-2.8	27.5	27.32	6.003	4.493	2.79	27.31	5.998	4.498	2.60	27.31	5.989	4.489	2.54	27.33	6.004	4.494	2.85

Table C.4 : Experimental data for quadruple discharge (cont.)

Series no. 4-3 P_{atm} = 1.00 bar																	
Set no.	T_G (ºC)	Activated lines															
		B1				B2				B4				B5			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
4-3.1	29.0	6.62	5.008	0.258	1.21	6.48	4.996	0.246	1.13	6.51	4.998	0.248	1.22	6.52	5.009	0.249	1.21
4-3.2	36.0	9.11	5.005	0.505	1.41	9.08	4.991	0.501	1.21	9.08	5.000	0.500	1.48	9.32	5.012	0.532	1.46
4-3.3	26.0	11.33	5.004	0.764	1.81	11.23	5.000	0.750	1.46	11.28	5.007	0.757	1.53	11.22	5.008	0.748	1.66
4-3.4	35.0	12.75	4.999	0.979	1.64	12.96	5.042	1.012	1.49	13.14	5.042	1.042	1.62	12.75	4.999	0.979	1.61
4-3.5	35.0	18.43	5.003	1.993	2.13	18.40	4.985	1.985	1.83	18.38	4.981	1.981	1.81	18.44	5.005	1.995	2.21
4-3.6	29.0	22.62	5.007	3.007	2.45	22.56	4.993	2.993	2.06	22.55	4.991	2.991	2.07	22.56	5.015	2.995	2.50
4-3.7	23.5	25.90	6.007	4.007	2.65	25.87	5.996	3.996	2.25	25.90	5.995	4.005	2.10	25.94	6.006	4.016	2.73
4-3.8	28.0	27.34	5.996	4.496	2.79	27.29	5.991	4.481	2.45	27.25	5.988	4.468	2.24	27.42	6.015	4.525	2.79

Table C.4 : Experimental data for quadruple discharge (cont.)

Series no. 4-4

P_{atm} = 1.00 bar

Set no.	T_G (ºC)	Activated lines															
		B1				B3				B4				B5			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
4-4.1	29.0	6.59	5.005	0.255	1.30	6.64	5.000	0.260	1.14	6.51	4.998	0.248	1.36	6.54	5.001	0.251	1.29
4-4.2	36.0	9.27	5.026	0.526	1.47	9.24	5.012	0.522	1.39	9.17	5.002	0.512	1.48	9.31	5.021	0.531	1.46
4-4.3	26.0	11.27	5.006	0.756	1.76	11.29	5.009	0.759	1.53	11.22	4.998	0.748	1.59	11.28	5.007	0.757	1.78
4-4.4	32.0	12.89	5.004	1.004	1.96	12.81	4.991	0.991	1.73	12.71	4.995	0.975	1.70	12.94	5.011	1.011	1.98
4-4.5	34.5	18.48	5.025	2.005	2.22	18.41	4.990	1.990	2.09	18.47	5.003	2.003	2.04	18.48	5.025	2.005	2.33
4-4.6	29.3	22.58	5.008	2.998	2.33	22.59	5.000	3.000	2.35	22.76	5.016	3.036	2.35	22.68	5.019	3.019	2.41
4-4.7	24.0	25.93	6.013	4.013	2.56	25.88	5.998	3.998	2.52	25.89	6.002	4.002	2.46	25.84	5.999	3.989	2.64
4-4.8	27.5	27.38	6.003	4.513	2.59	27.31	5.990	4.490	2.66	27.29	5.982	4.482	2.58	27.35	6.003	4.503	2.73

Table C.4 : Experimental data for quadruple discharge (cont.)

Series no. 4-5 P_{atm} = 1.00 bar																	
Set no.	T_G (ºC)	Activated lines															
		B2				B3				B4				B5			
		$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$	$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
4-5.1	28.0	6.57	5.004	0.254	1.69	6.66	5.002	0.262	1.23	6.35	4.994	0.234	1.45	6.62	5.008	0.258	1.26
4-5.2	37.0	9.08	5.010	0.500	1.77	9.01	5.001	0.491	1.56	9.09	5.001	0.501	1.56	9.19	5.005	0.515	1.58
4-5.3	26.0	11.23	4.999	0.749	1.94	11.21	4.997	0.747	1.73	11.21	4.996	0.746	1.73	11.26	5.004	0.754	1.72
4-5.4	32.0	12.57	4.981	0.951	2.06	12.76	4.982	0.982	1.95	12.71	4.975	0.975	1.84	12.58	4.984	0.954	1.72
4-5.5	27.5	18.45	4.998	2.008	2.60	18.49	5.007	2.017	2.43	18.55	5.011	2.031	2.24	18.48	5.025	2.015	2.18
4-5.6	29.2	22.55	5.001	2.991	2.79	22.66	5.015	3.015	2.74	22.54	5.000	2.990	2.52	22.69	5.031	3.021	2.47
4-5.7	24.5	25.84	6.007	3.987	3.14	25.97	6.005	4.025	3.02	25.91	6.008	4.008	2.72	25.89	6.011	4.001	2.62
4-5.8	27.5	27.40	6.009	4.519	3.31	27.45	6.005	4.535	3.14	27.25	5.970	4.470	2.83	27.26	5.993	4.473	2.73

Table C.5 : Experimental data for quintuple discharge

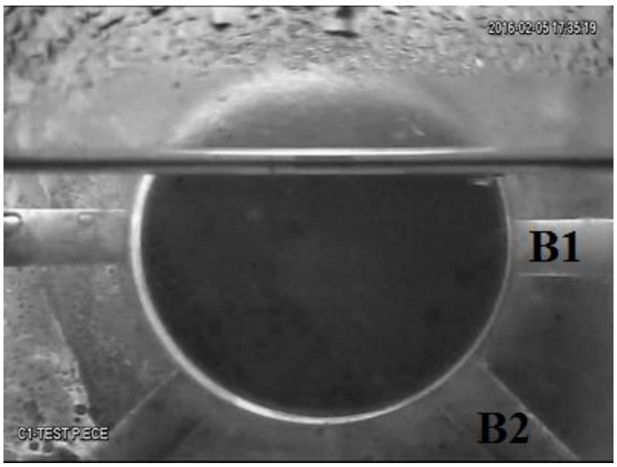
Series no. 5-1 P_{atm} = 1.00 bar													
Set no.	T_G (ºC)	Activated lines											
		B1				B2				B3			
		$Fr_{L,B1}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B1}}{d}$	$Fr_{L,B2}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B2}}{d}$	$Fr_{L,B3}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B3}}{d}$
5-1.1	27.5	6.47	4.995	0.245	1.41	6.49	4.997	0.247	1.41	6.62	5.008	0.258	1.28
5-1.2	35.5	9.08	5.001	0.501	1.79	9.09	5.002	0.502	1.46	9.07	4.999	0.499	1.48
5-1.3	24.8	11.24	5.002	0.752	1.87	11.15	4.998	0.738	1.69	11.24	5.002	0.752	1.70
5-1.4	32.0	12.85	4.977	0.997	2.04	13.08	5.003	1.033	1.92	12.88	5.002	1.002	1.95
5-1.5	27.0	18.34	5.002	1.982	2.33	18.29	5.000	1.970	2.37	18.67	5.030	2.060	2.37
5-1.6	30.0	22.50	5.030	2.980	2.53	22.34	4.945	2.945	2.65	22.72	5.027	3.027	2.80
5-1.7	25.0	25.87	6.014	3.994	2.77	25.73	5.996	3.956	2.91	25.87	5.986	3.996	2.97
5-1.8	27.5	27.28	5.998	4.478	2.85	27.07	6.009	4.409	3.05	27.23	5.992	4.462	3.14

Table C.5 : Experimental data for quintuple discharge (cont.)

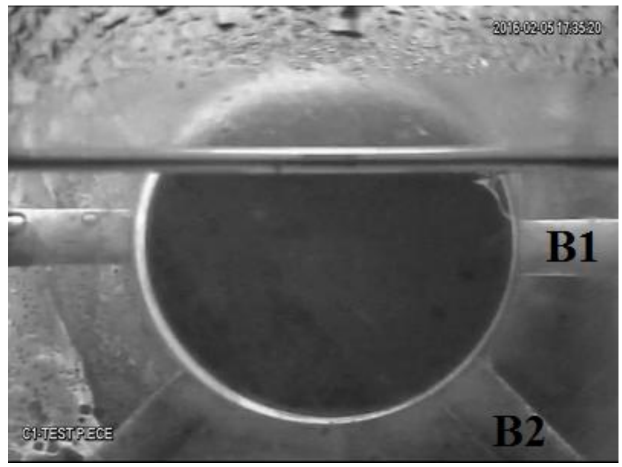
Series no. 5-1 (cont.) P_{atm} = 1.00 bar									
Set no.	T_G (ºC)	Activated lines							
		B4				B5			
		$Fr_{L,B4}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B4}}{d}$	$Fr_{L,B5}$	P_{TC} (bar)	ΔP (bar)	$\frac{h_{OGE,B5}}{d}$
5-1.1	27.5	6.62	4.998	0.258	1.42	6.67	5.003	0.263	1.46
5-1.2	35.5	9.04	4.995	0.495	1.50	9.13	5.007	0.507	1.69
5-1.3	24.8	11.22	4.999	0.749	1.73	11.24	5.002	0.752	1.75
5-1.4	32.0	13.08	5.003	1.033	1.84	12.85	4.977	0.997	1.98
5-1.5	27.0	18.35	4.994	1.984	2.26	18.42	4.992	2.002	2.27
5-1.6	30.0	22.87	5.058	3.058	2.60	22.27	5.000	2.930	2.50
5-1.7	25.0	25.89	6.001	4.001	2.75	25.79	6.003	3.973	2.88
5-1.8	27.5	27.11	6.003	4.423	2.86	27.28	5.998	4.478	2.96

Appendix D

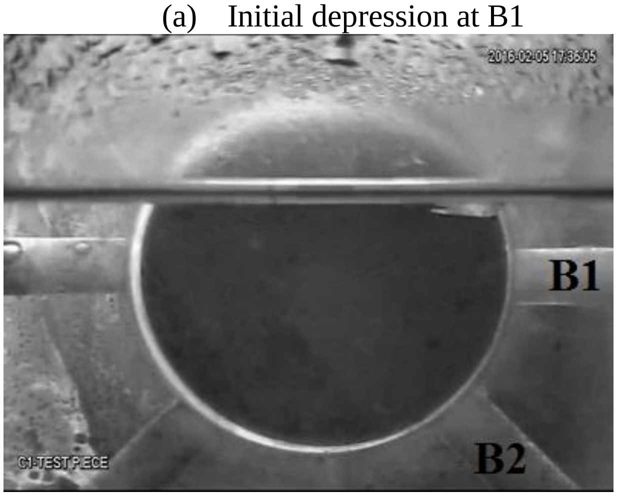
Images of Typical Gas Entrainment Phenomena for Dual, Triple, and Quadruple Discharge Conditions



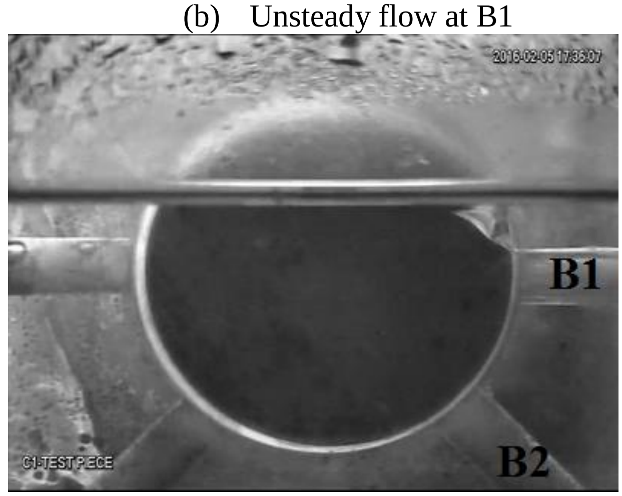
(a) Initial depression at B1



(b) Unsteady flow at B1

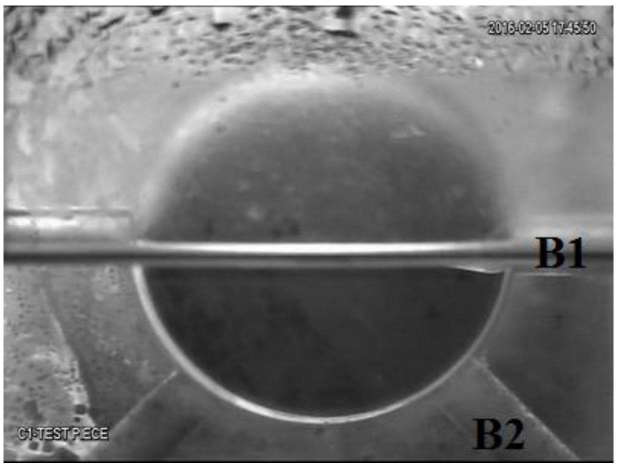


(c) Disappearance of unsteady flow at B1

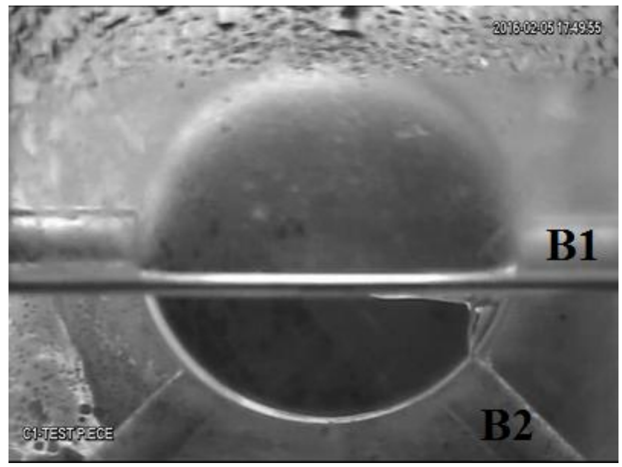


(d) Steady flow at B1

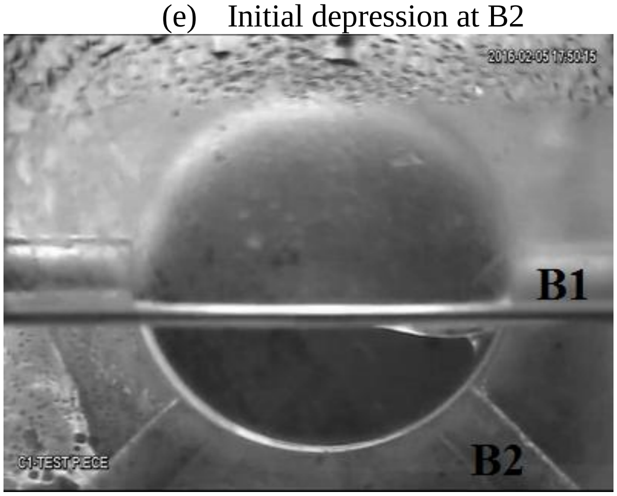
Figure D.1 : Gas entrainment phenomena of set no. 2-1.1



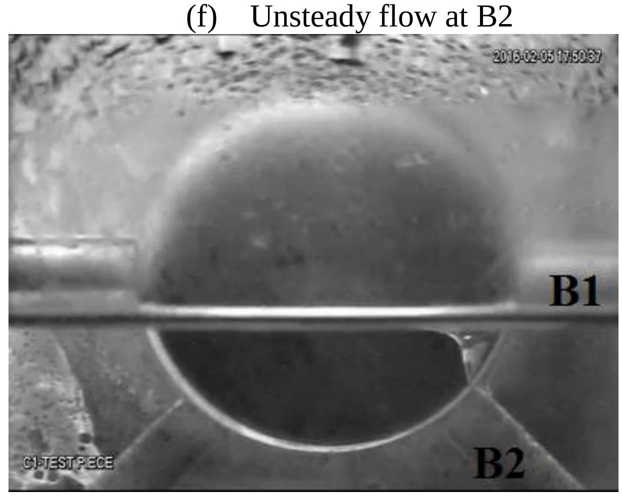
(e) Initial depression at B2



(f) Unsteady flow at B2

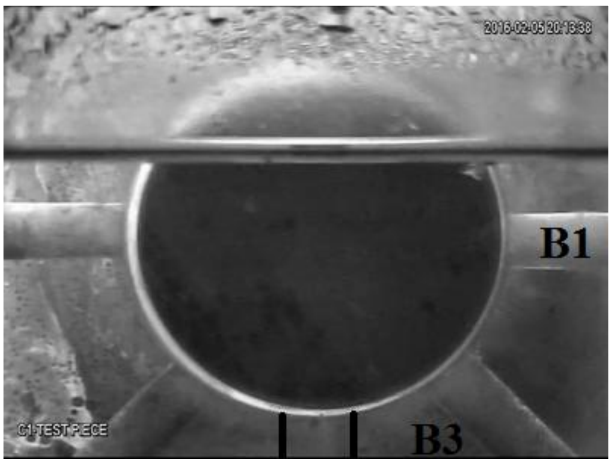


(g) Disappearance of unsteady flow at B2

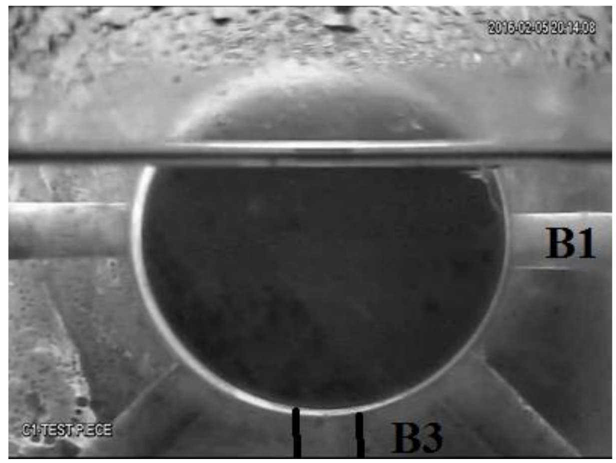


(h) Steady flow at B2

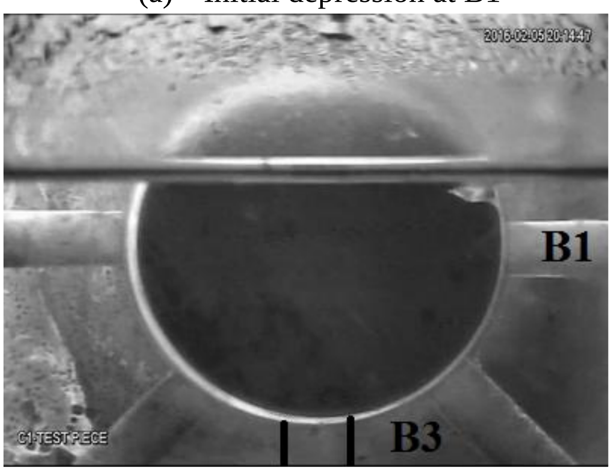
Figure D.1 : Gas entrainment phenomena of set no. 2-1.1 (cont.)



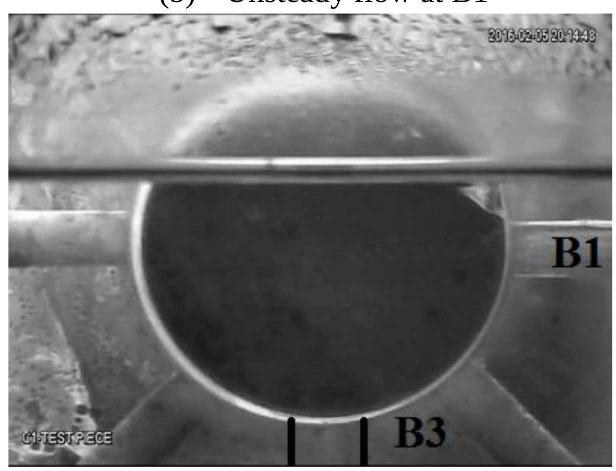
(a) Initial depression at B1



(b) Unsteady flow at B1

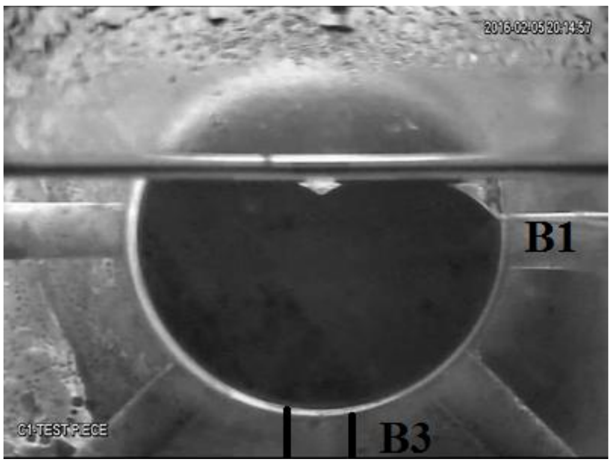


(c) Disappearance of unsteady flow at B1

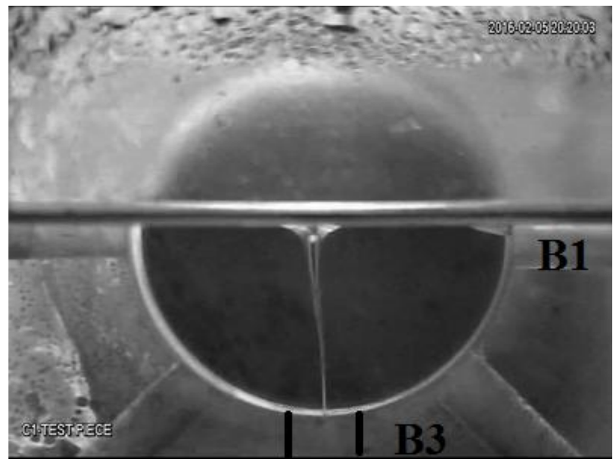


(d) Steady flow at B1

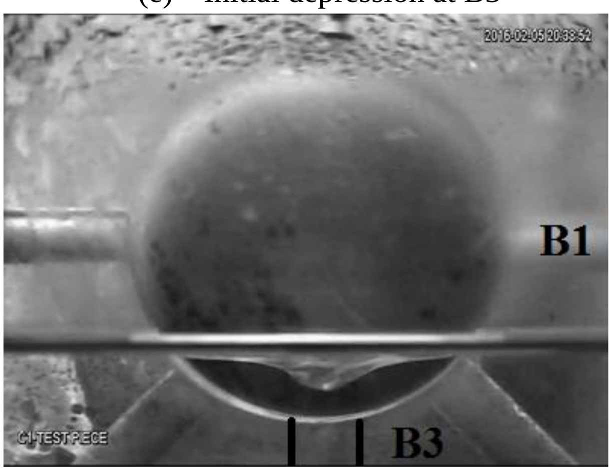
Figure D.2 : Gas entrainment phenomena of set no. 2-2.1



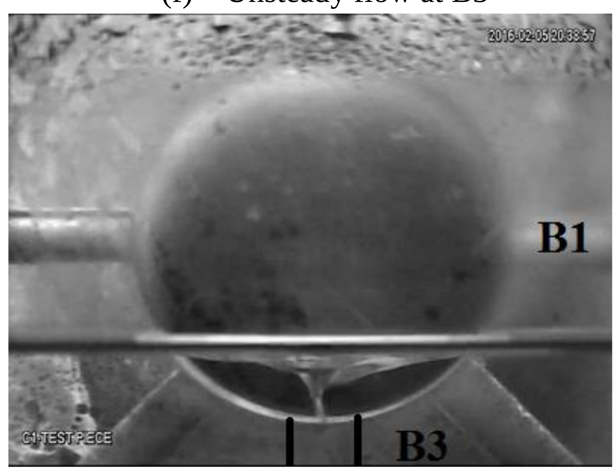
(e) Initial depression at B3



(f) Unsteady flow at B3

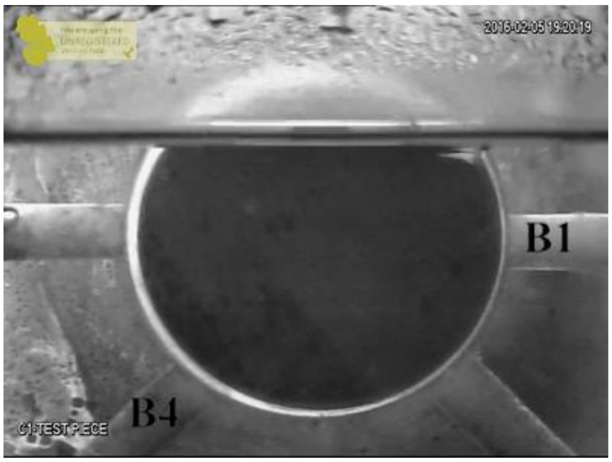


(g) Disappearance of unsteady flow at B3

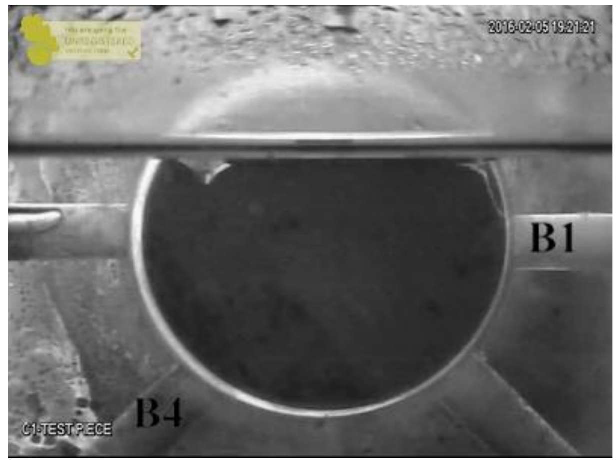


(h) Steady flow at B3

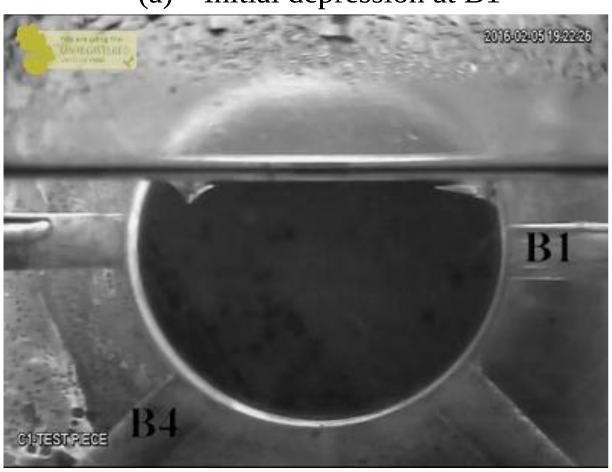
Figure D.2 : Gas entrainment phenomena of set no. 2-2.1 (cont.)



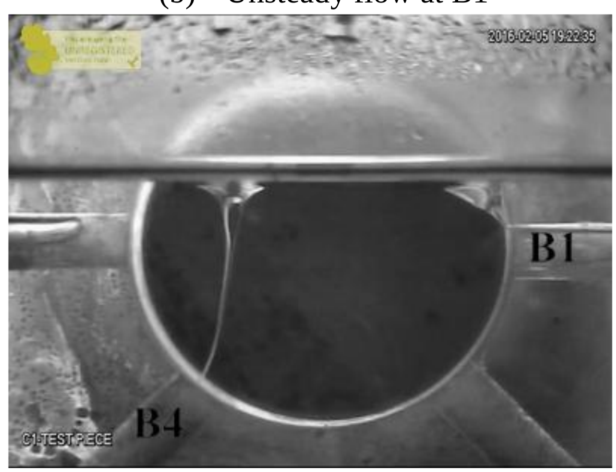
(a) Initial depression at B1



(b) Unsteady flow at B1

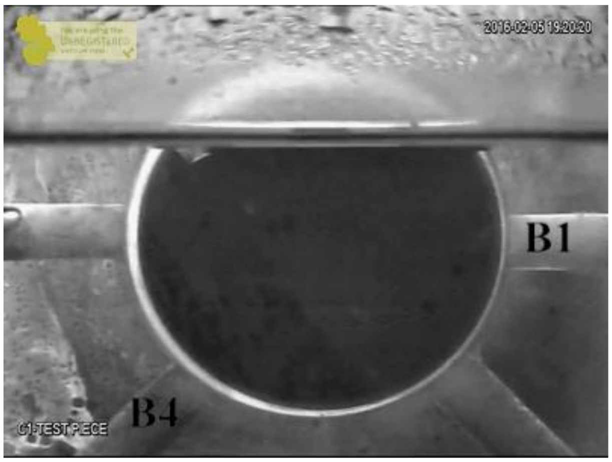


(c) Disappearance of unsteady flow at B1

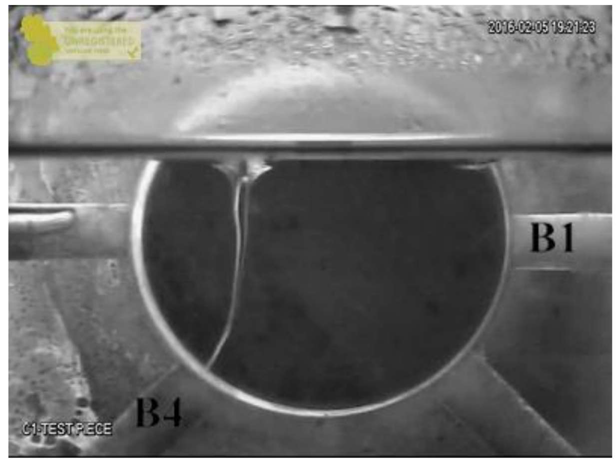


(d) Steady flow at B1

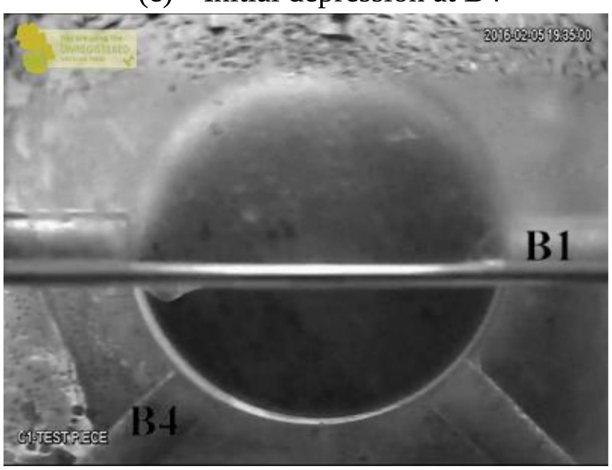
Figure D.3 : Gas entrainment phenomena of set no. 2-3.1



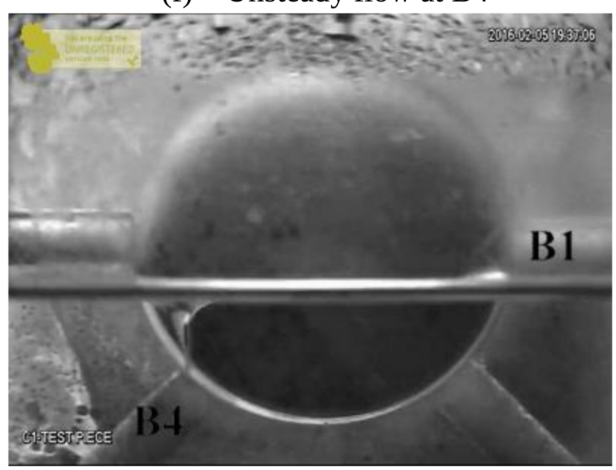
(e) Initial depression at B4



(f) Unsteady flow at B4

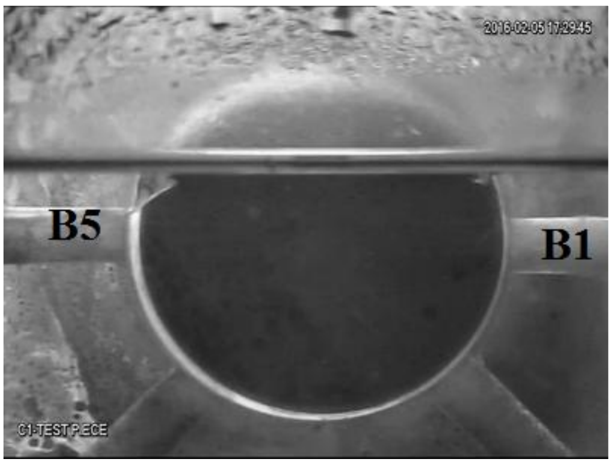


(g) Disappearance of unsteady flow at B4

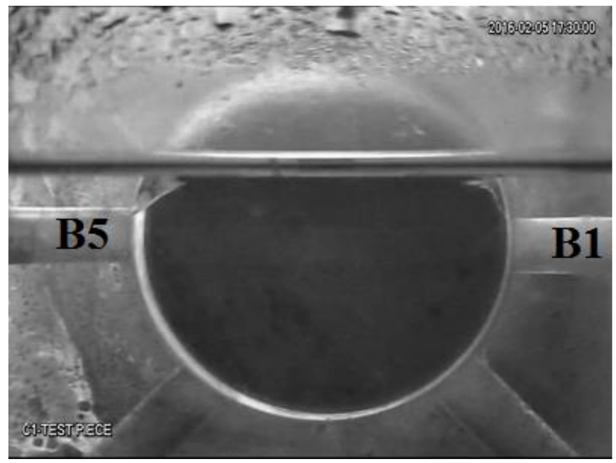


(h) Steady flow at B4

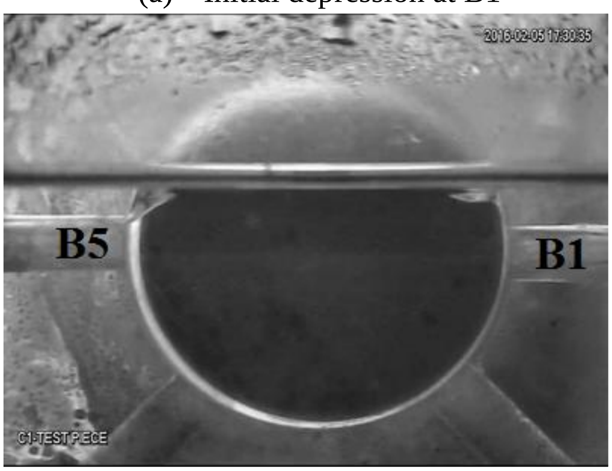
Figure D.3 : Gas entrainment phenomena of set no. 2-3.1 (cont.)



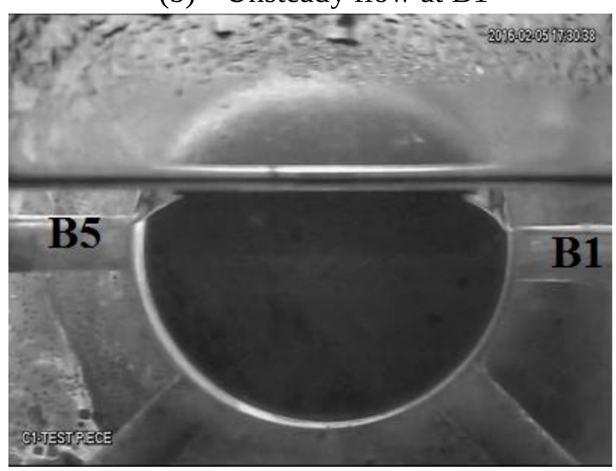
(a) Initial depression at B1



(b) Unsteady flow at B1

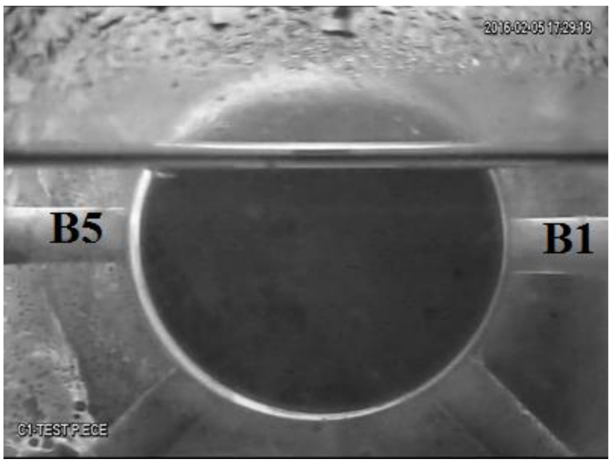


(c) Disappearance of unsteady flow at B1

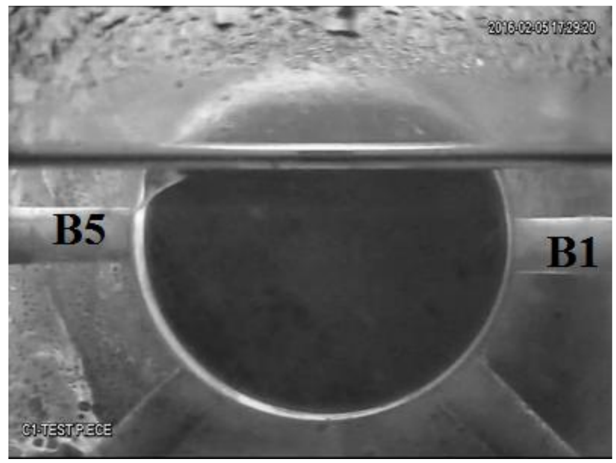


(d) Steady flow at B1

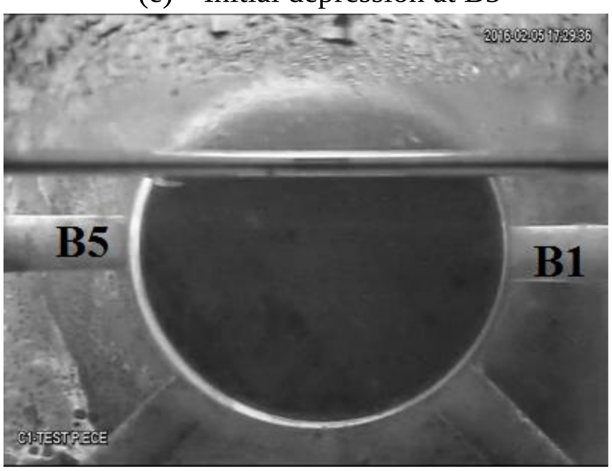
Figure D.4 : Gas entrainment phenomena of set no. 2-4.1



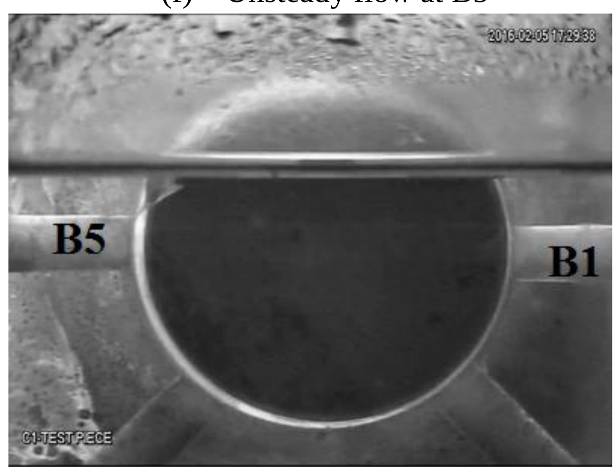
(e) Initial depression at B5



(f) Unsteady flow at B5

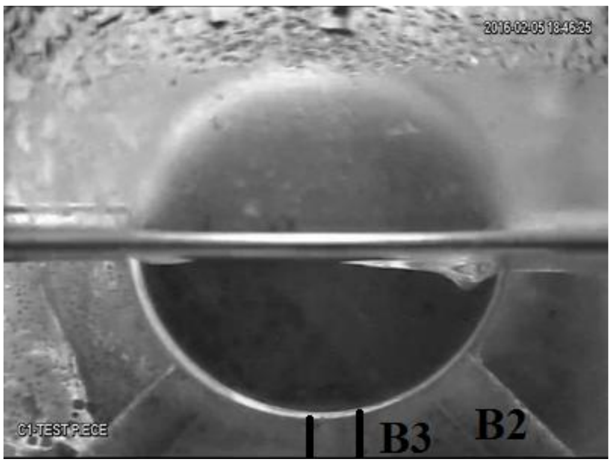


(g) Disappearance of unsteady flow at B5

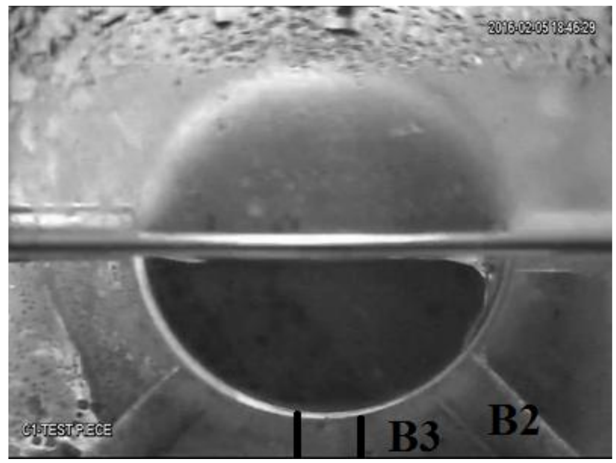


(h) Steady flow at B5

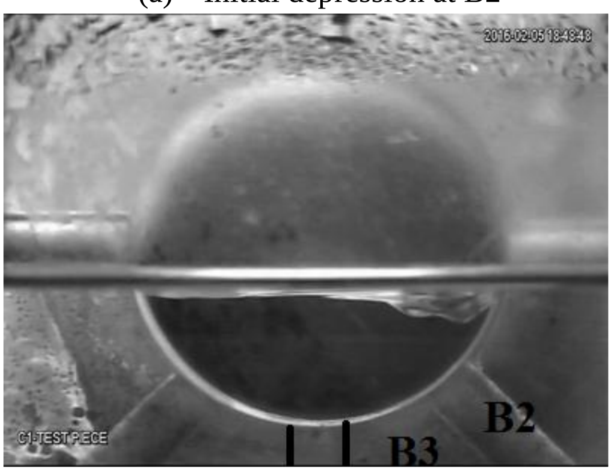
Figure D.4 : Gas entrainment phenomena of set no. 2-4.1 (cont.)



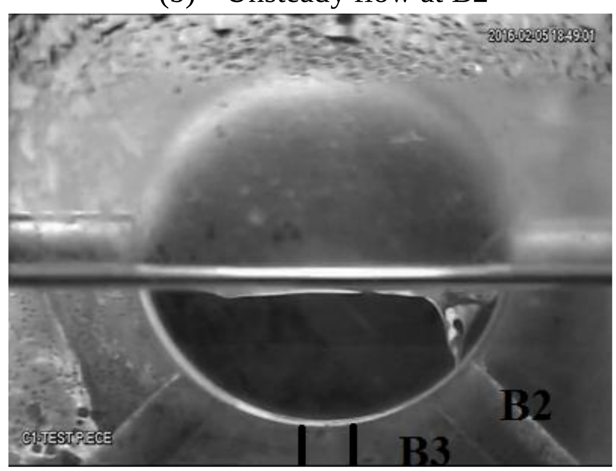
(a) Initial depression at B2



(b) Unsteady flow at B2

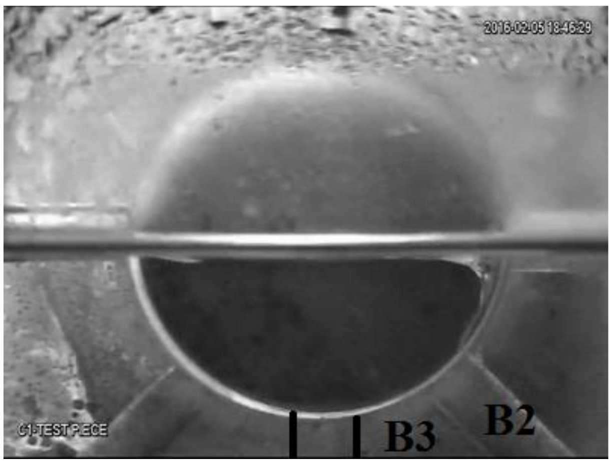


(c) Disappearance of unsteady flow at B2

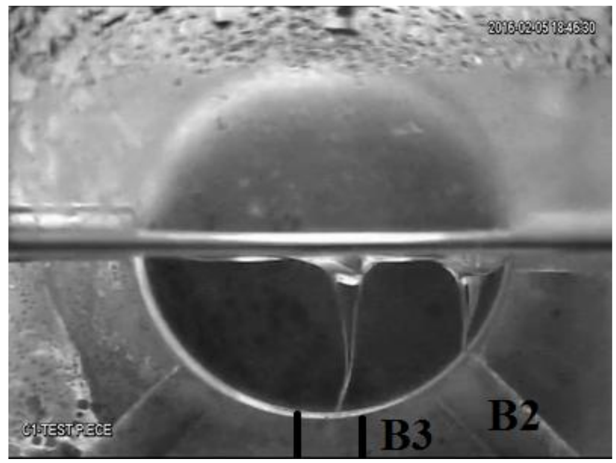


(d) Steady flow at B2

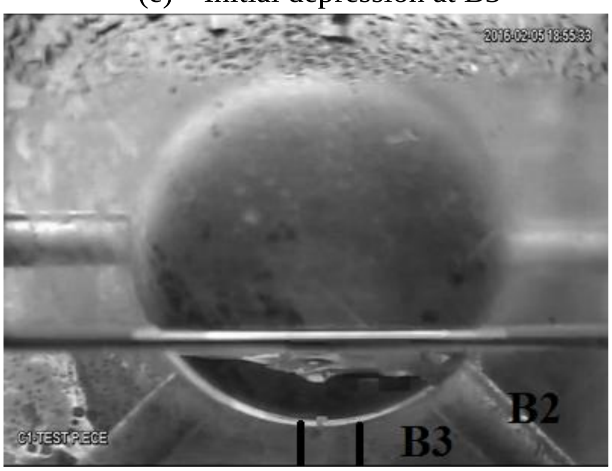
Figure D.5 : Gas entrainment phenomena of set no. 2-5.1



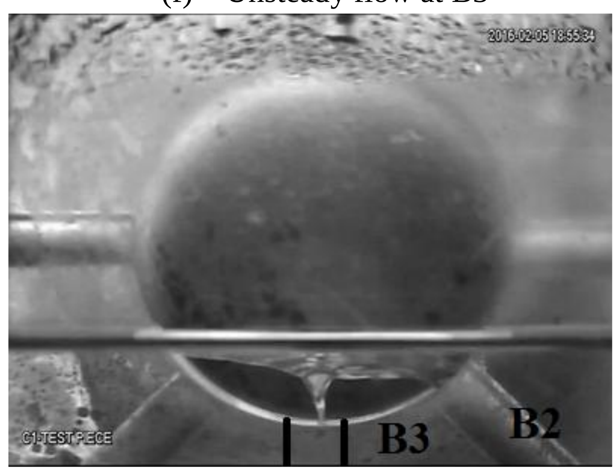
(e) Initial depression at B3



(f) Unsteady flow at B3

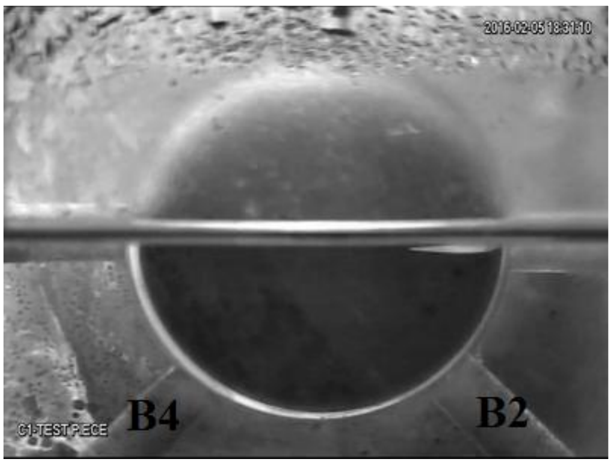


(g) Disappearance of unsteady flow at B3

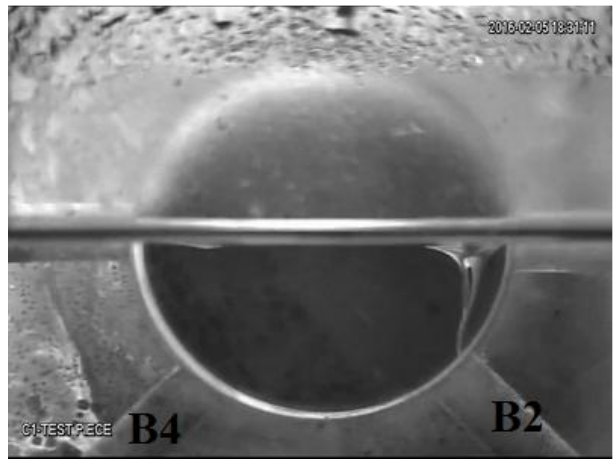


(h) Steady flow at B3

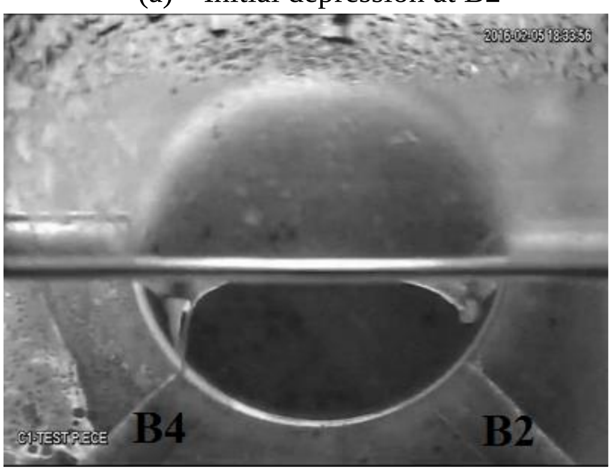
Figure D.5 : Gas entrainment phenomena of set no. 2-5.1 (cont.)



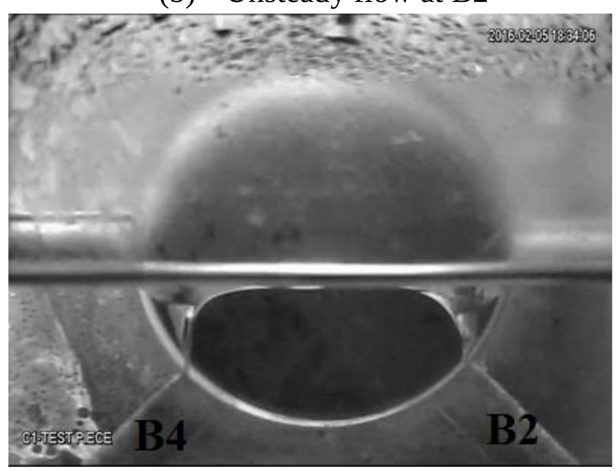
(a) Initial depression at B2



(b) Unsteady flow at B2

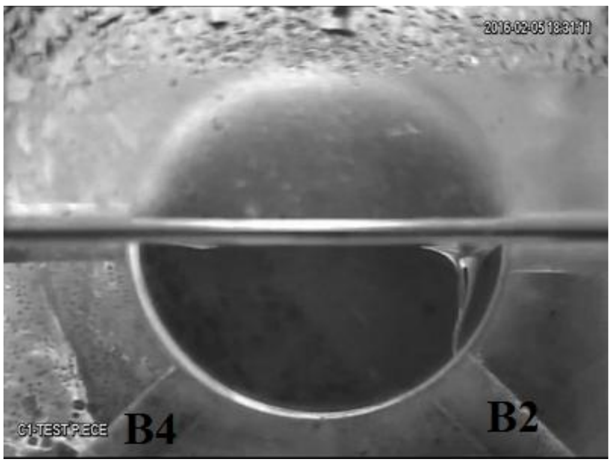


(c) Disappearance of unsteady flow at B2

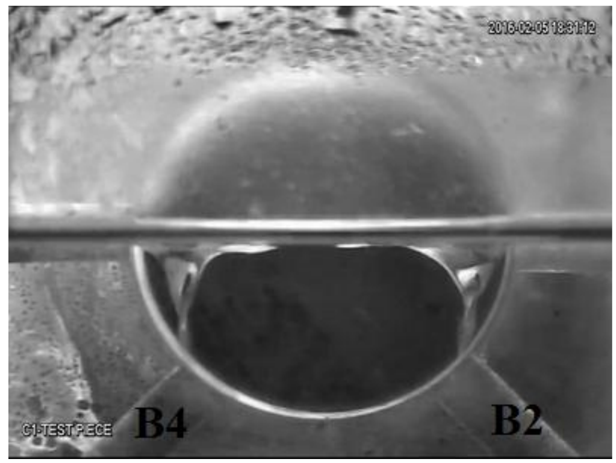


(d) Steady flow at B2

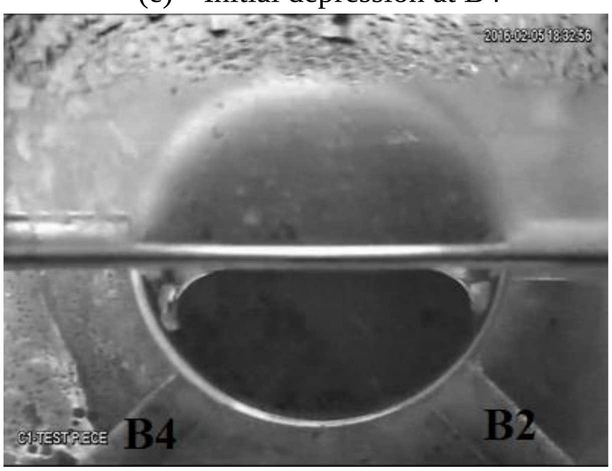
Figure D.6 : Gas entrainment phenomena of set no. 2-6.1



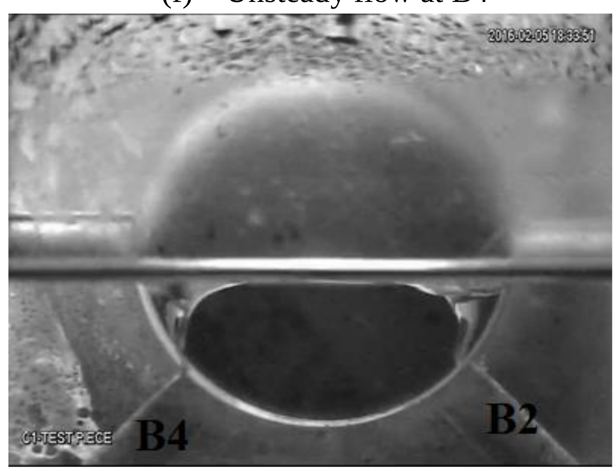
(e) Initial depression at B4



(f) Unsteady flow at B4

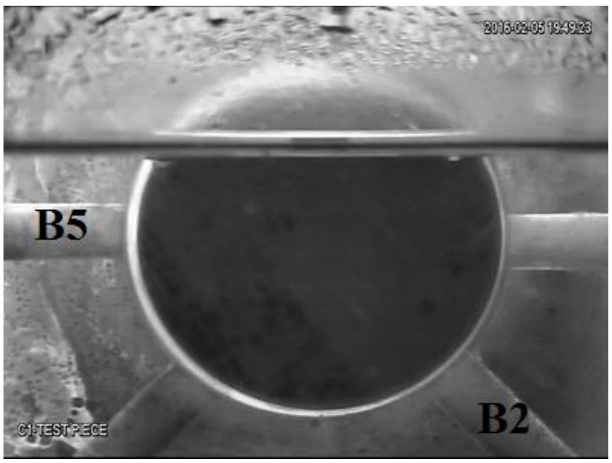


(g) Disappearance of unsteady flow at B4

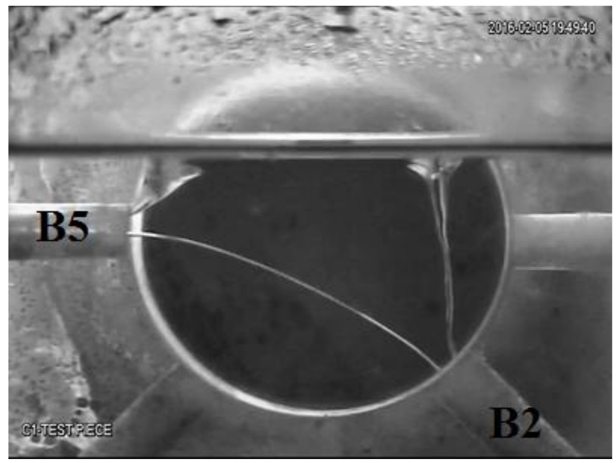


(h) Steady flow at B4

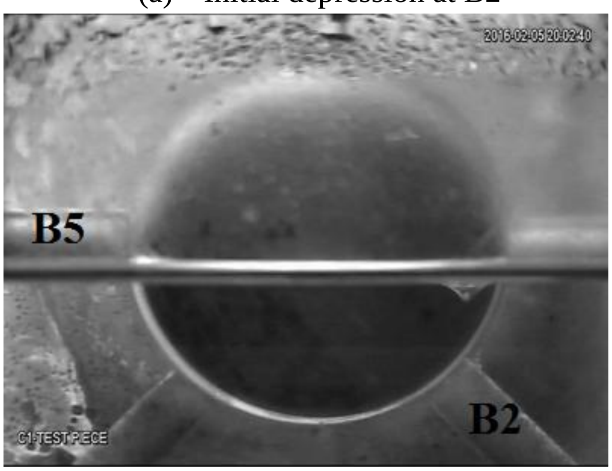
Figure D.6 : Gas entrainment phenomena of set no. 2-6.1 (cont.)



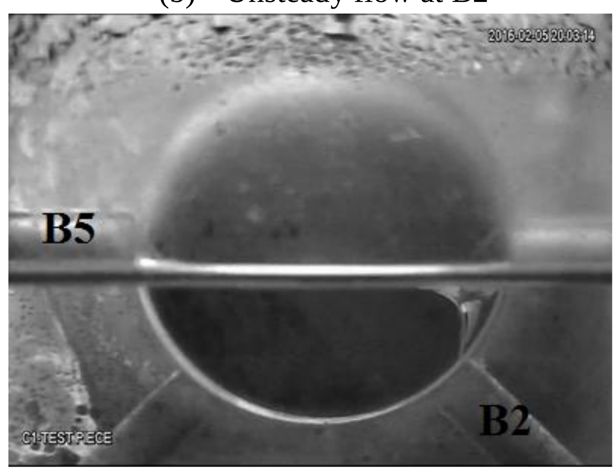
(a) Initial depression at B2



(b) Unsteady flow at B2

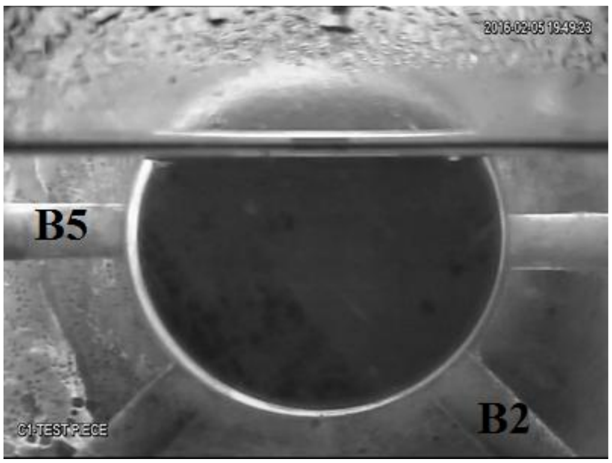


(c) Disappearance of unsteady flow at B2

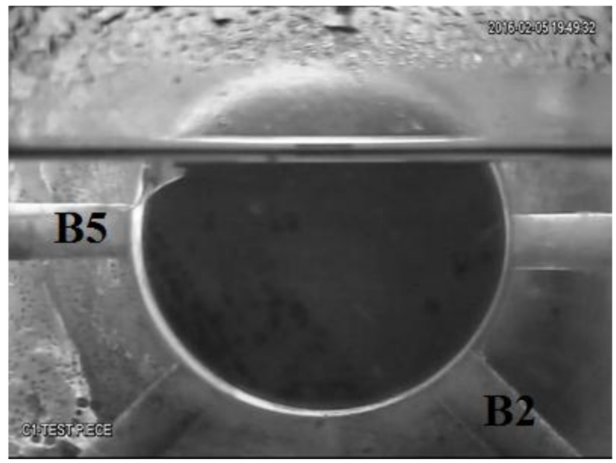


(d) Steady flow at B2

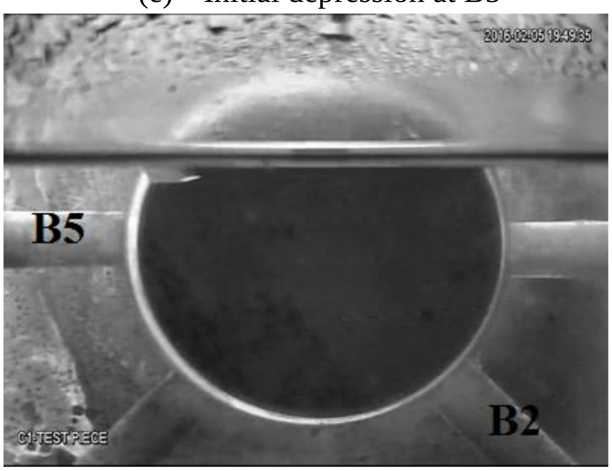
Figure D.7 : Gas entrainment phenomena of set no. 2-7.1



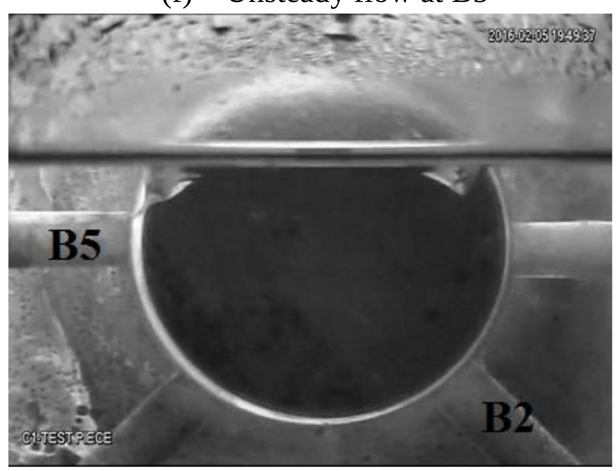
(e) Initial depression at B5



(f) Unsteady flow at B5

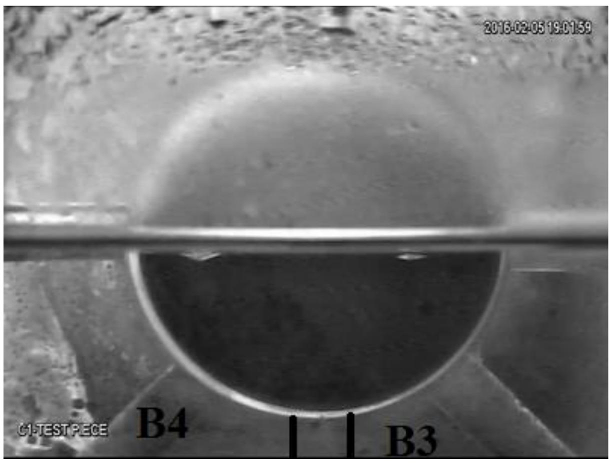


(g) Disappearance of unsteady flow at B5

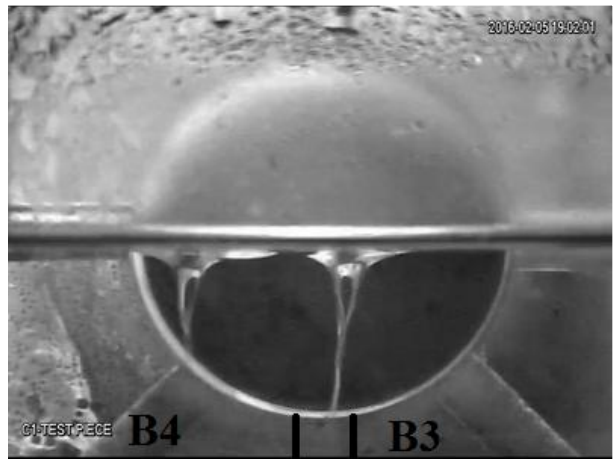


(h) Steady flow at B5

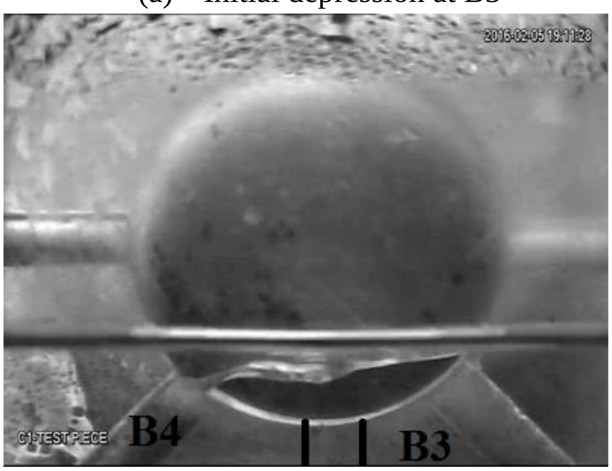
Figure D.7 : Gas entrainment phenomena of set no. 2-7.1 (cont.)



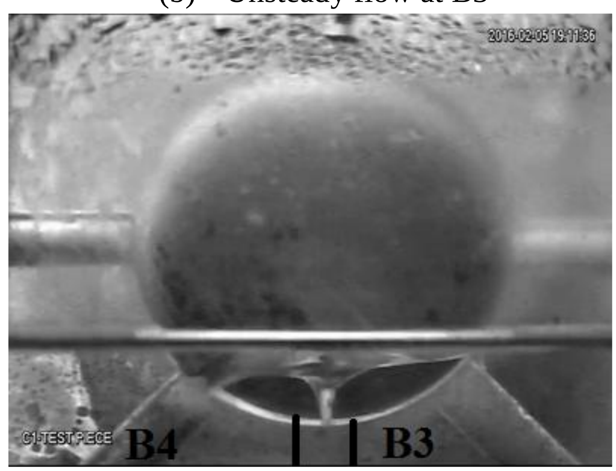
(a) Initial depression at B3



(b) Unsteady flow at B3

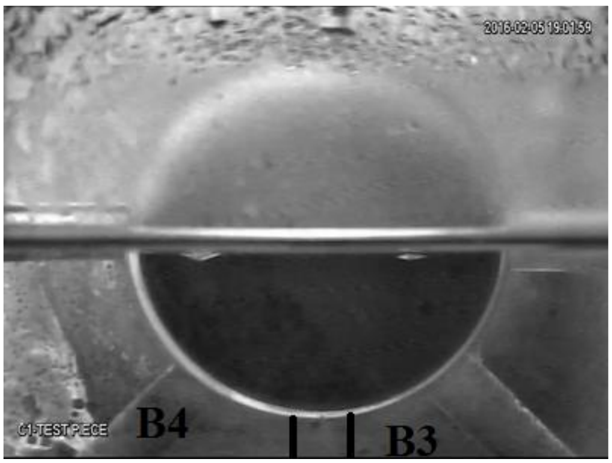


(c) Disappearance of unsteady flow at B3

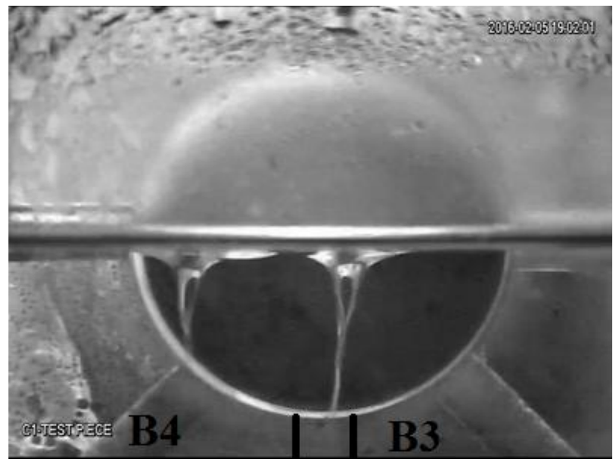


(d) Steady flow at B3

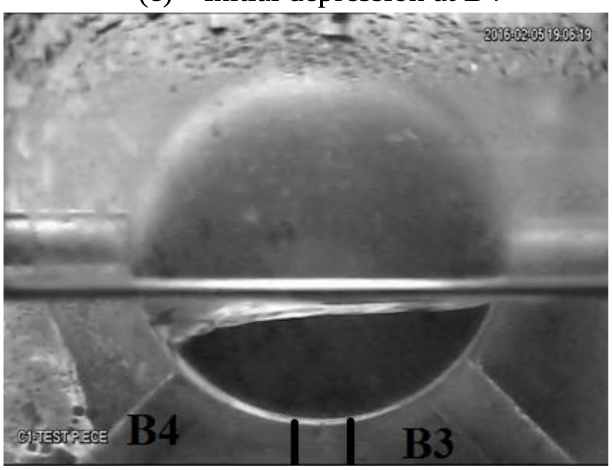
Figure D.8 : Gas entrainment phenomena of set no. 2-8.1



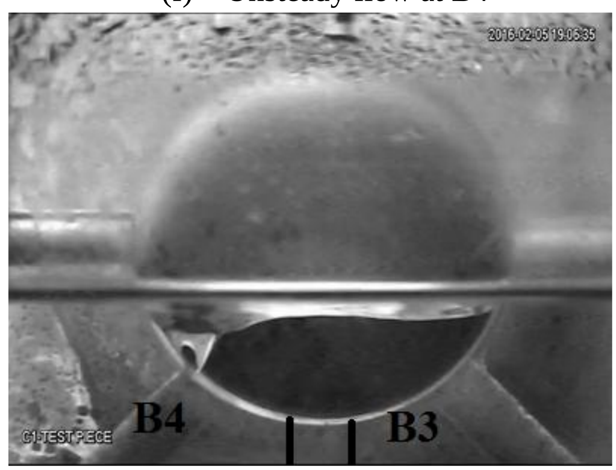
(e) Initial depression at B4



(f) Unsteady flow at B4

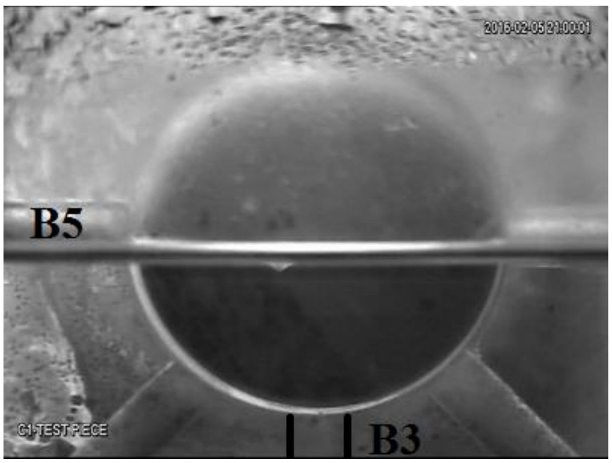


(g) Disappearance of unsteady flow at B4

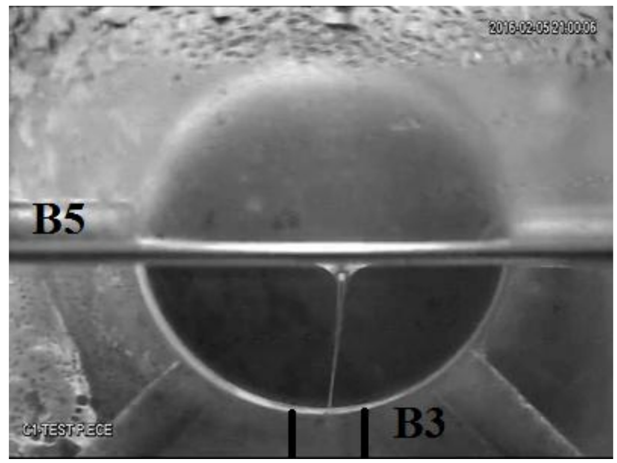


(h) Steady flow at B4

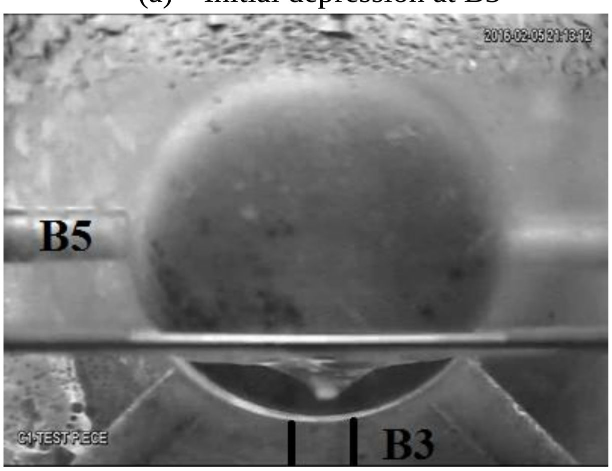
Figure D.8 : Gas entrainment phenomena of set no. 2-8.1 (cont.)



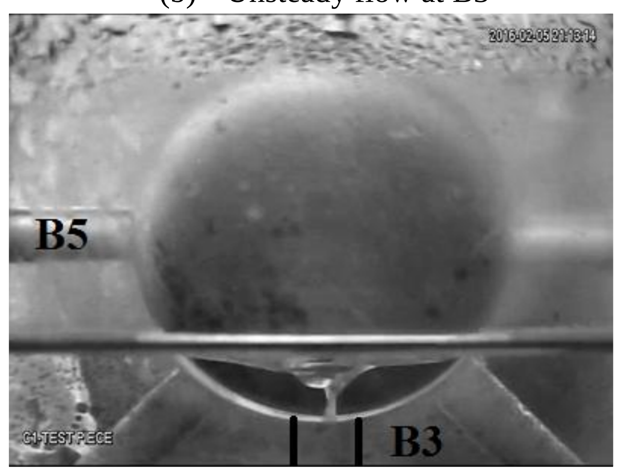
(a) Initial depression at B3



(b) Unsteady flow at B3

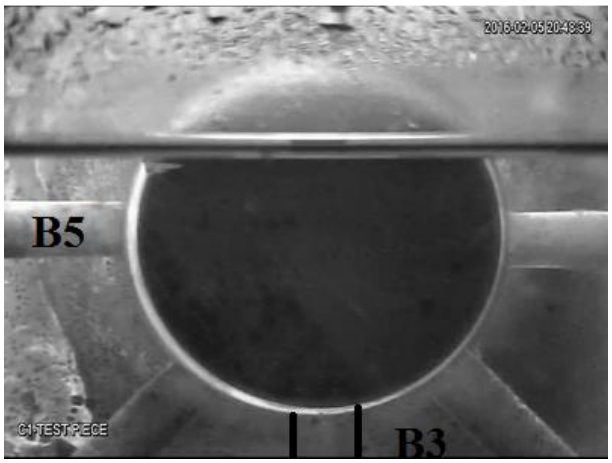


(c) Disappearance of unsteady flow at B3

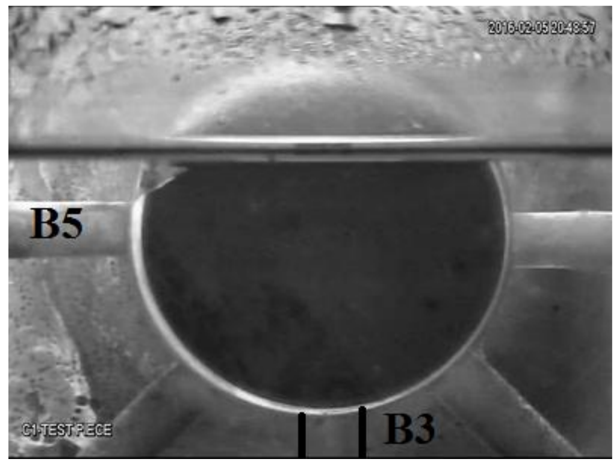


(d) Steady flow at B3

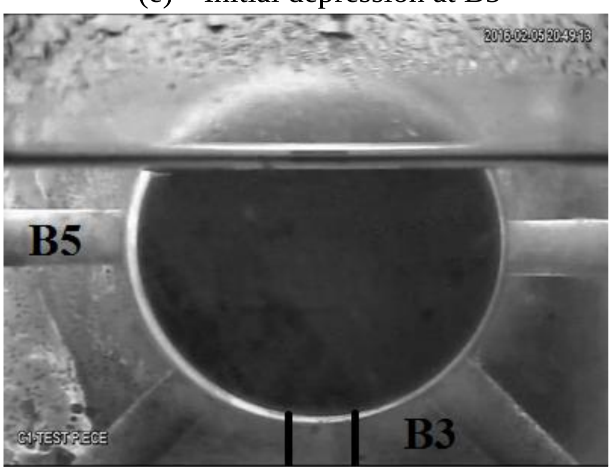
Figure D.9 : Gas entrainment phenomena of set no. 2-9.1



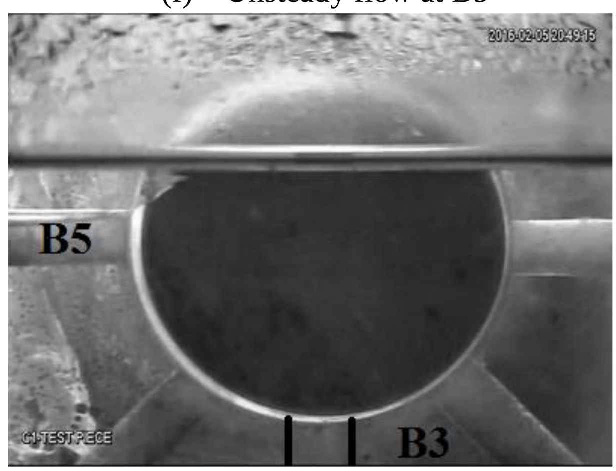
(e) Initial depression at B5



(f) Unsteady flow at B5

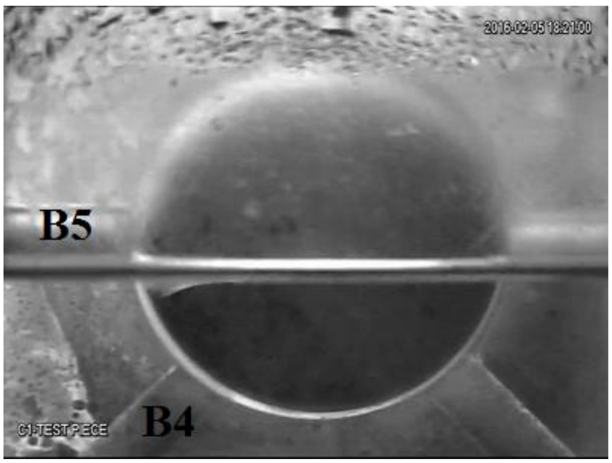


(g) Disappearance of unsteady flow at B5

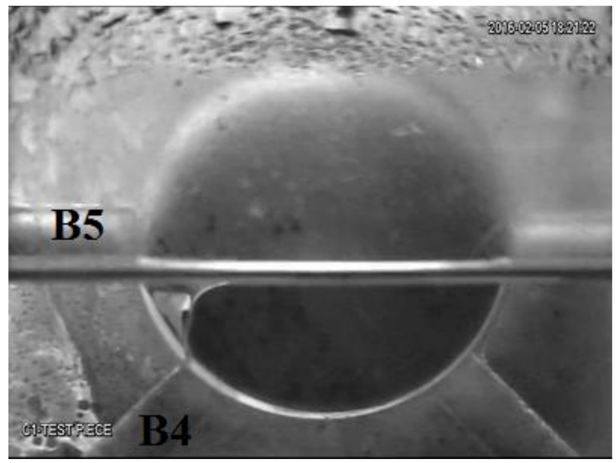


(h) Steady flow at B5

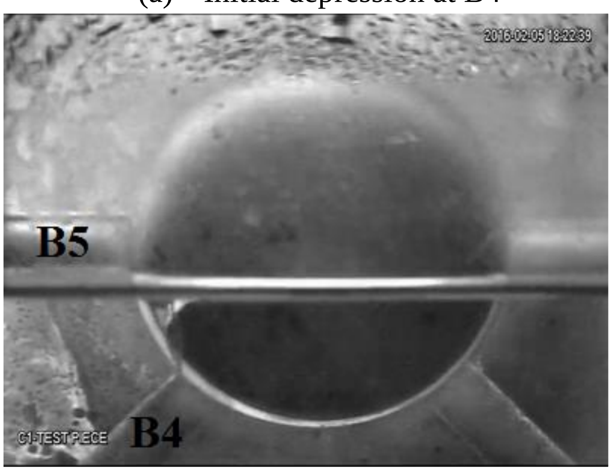
Figure D.9 : Gas entrainment phenomena of set no. 2-9.1 (cont.)



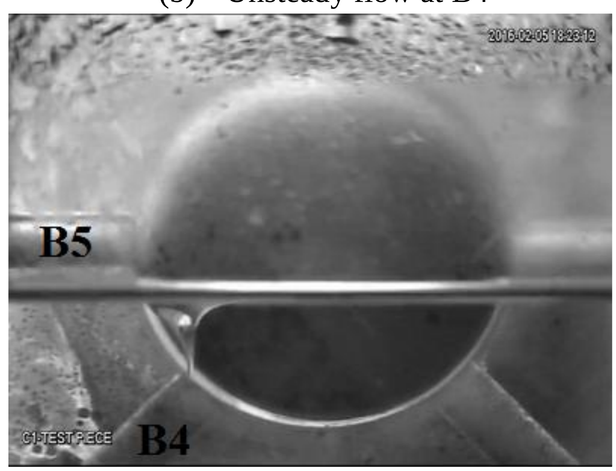
(a) Initial depression at B4



(b) Unsteady flow at B4

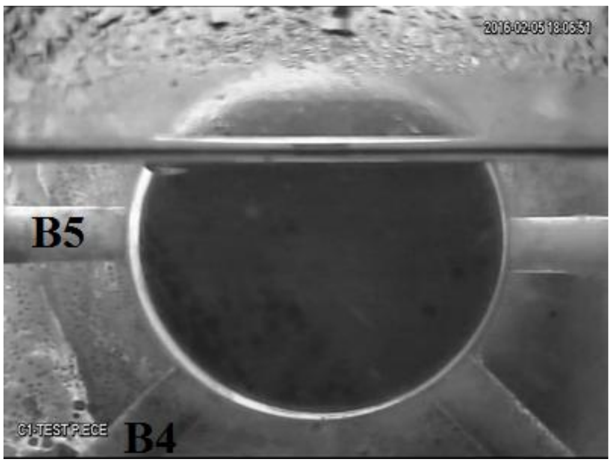


(c) Disappearance of unsteady flow at B4

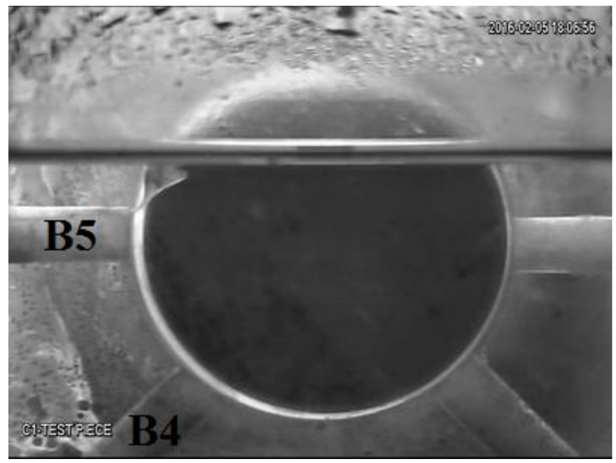


(d) Steady flow at B4

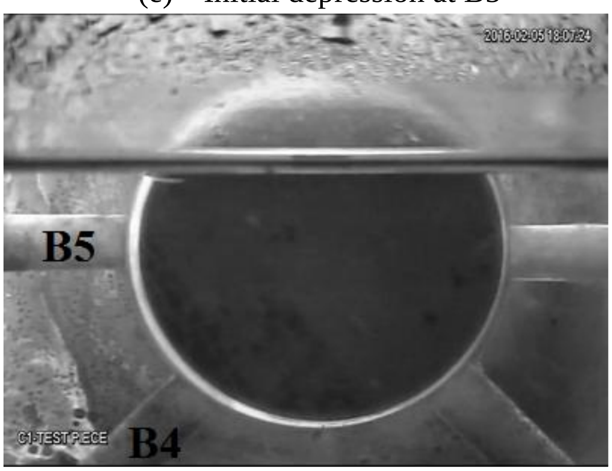
Figure D.10 : Gas entrainment phenomena of set no. 2-10.1



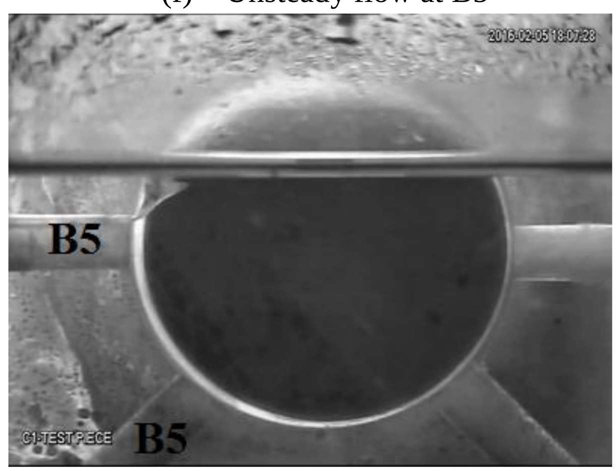
(e) Initial depression at B5



(f) Unsteady flow at B5

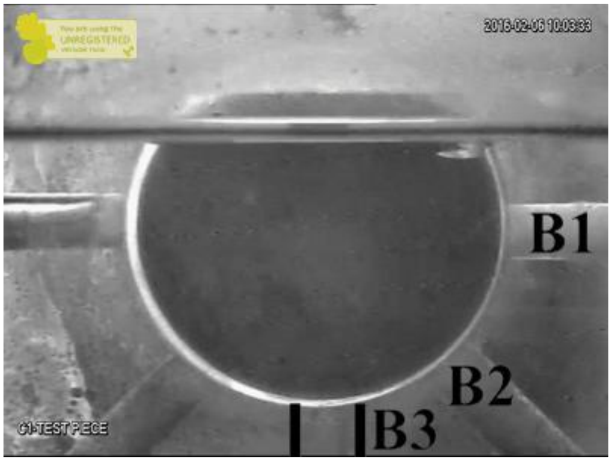


(g) Disappearance of unsteady flow at B5

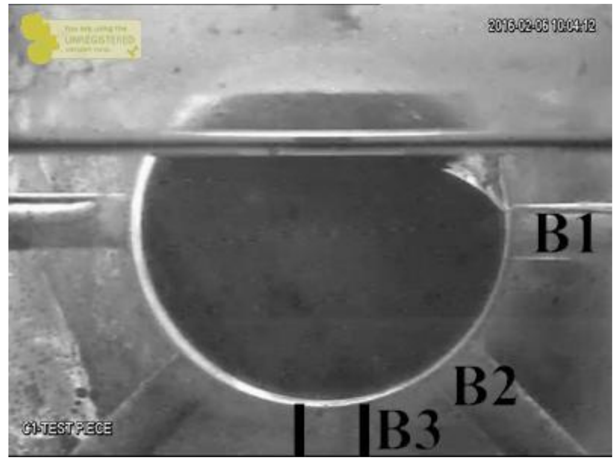


(h) Steady flow at B5

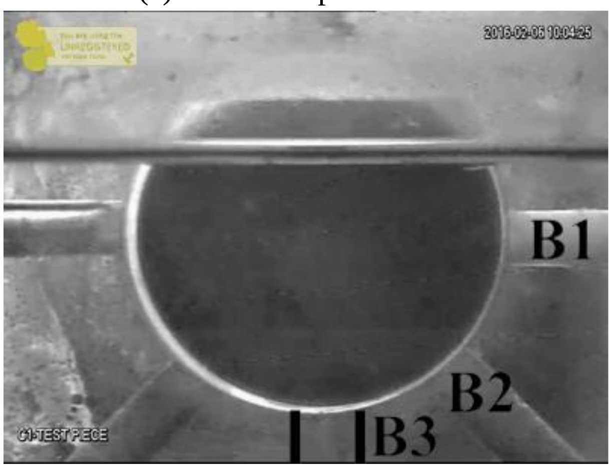
Figure D.10 : Gas entrainment phenomena of set no. 2-10.1 (cont.)



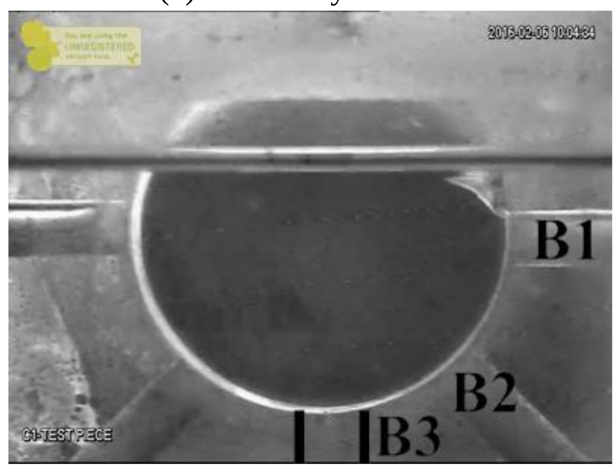
(a) Initial depression at B1



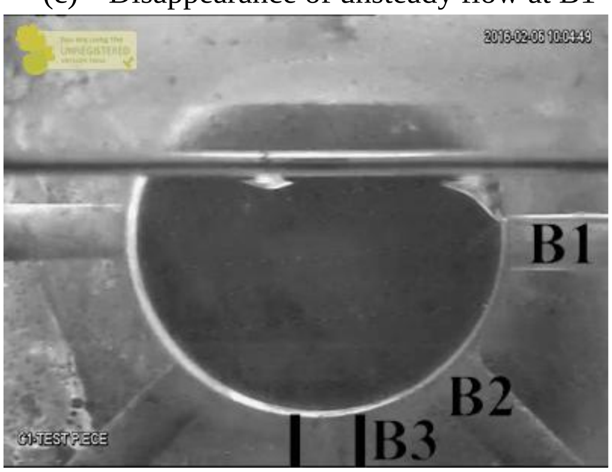
(b) Unsteady flow at B1



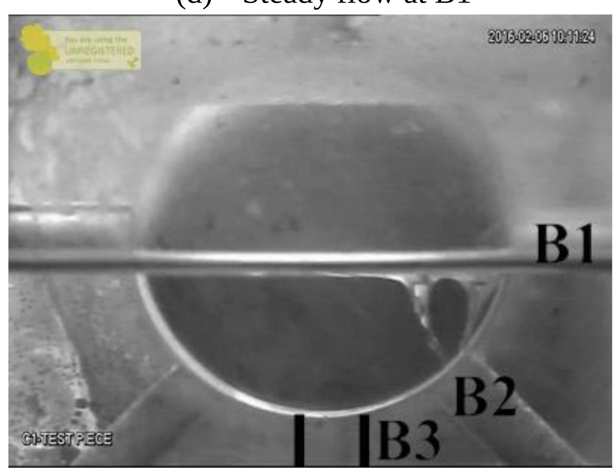
(c) Disappearance of unsteady flow at B1



(d) Steady flow at B1

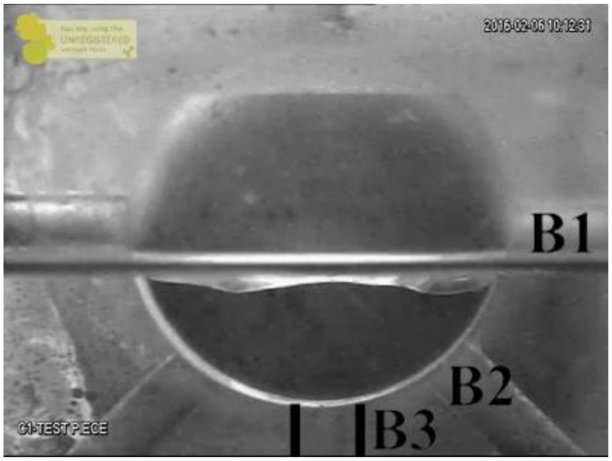


(e) Initial depression at B2

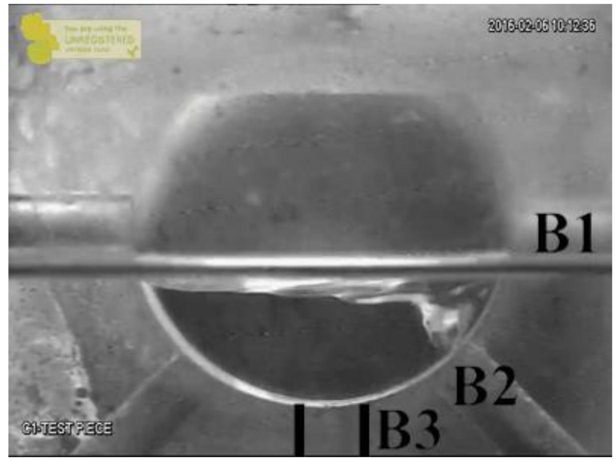


(f) Unsteady flow at B2

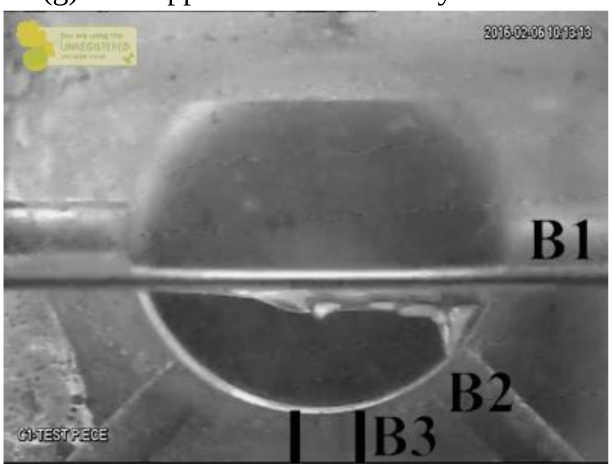
Figure D.11 : Gas entrainment phenomena of set no. 3-1.1



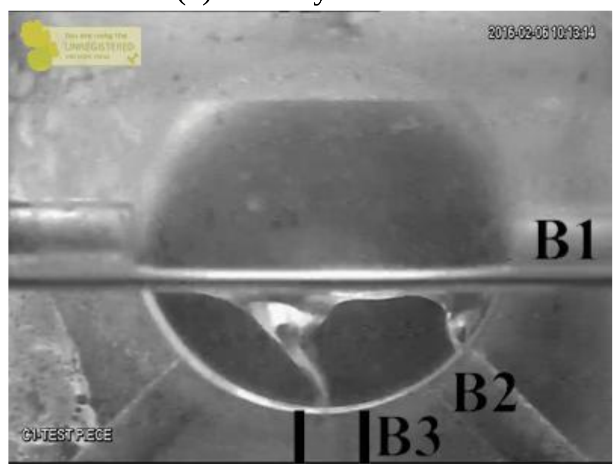
(g) Disappearance of unsteady flow at B2



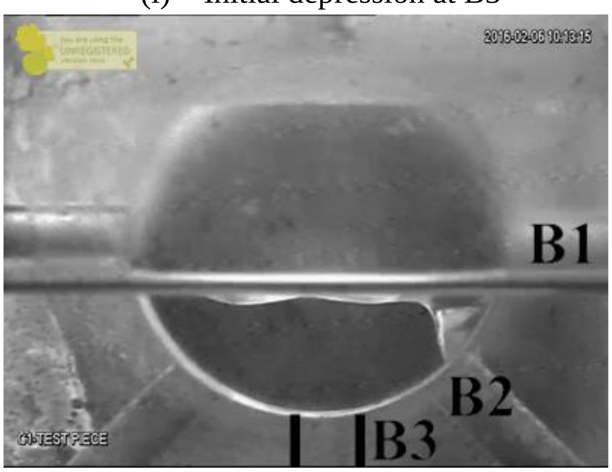
(h) Steady flow at B2



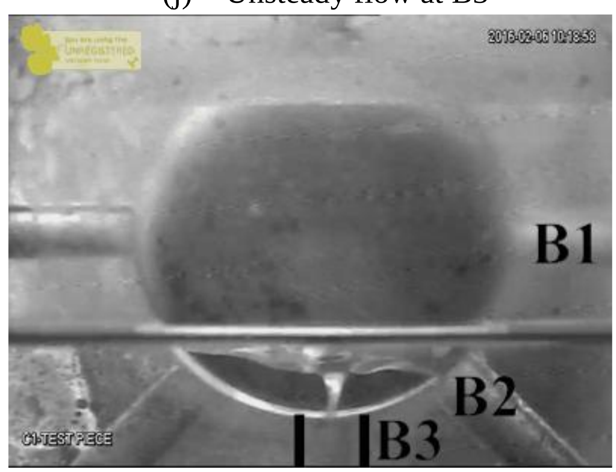
(i) Initial depression at B3



(j) Unsteady flow at B3

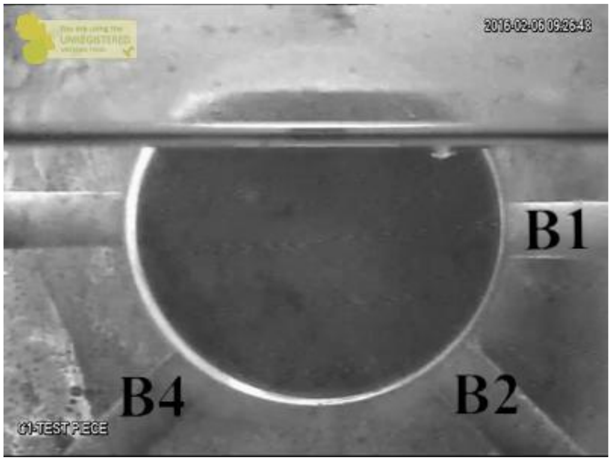


(k) Disappearance of unsteady flow at B3

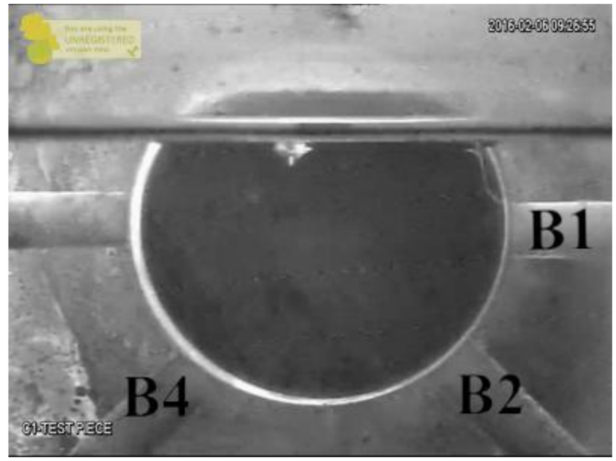


(l) Steady flow at B3

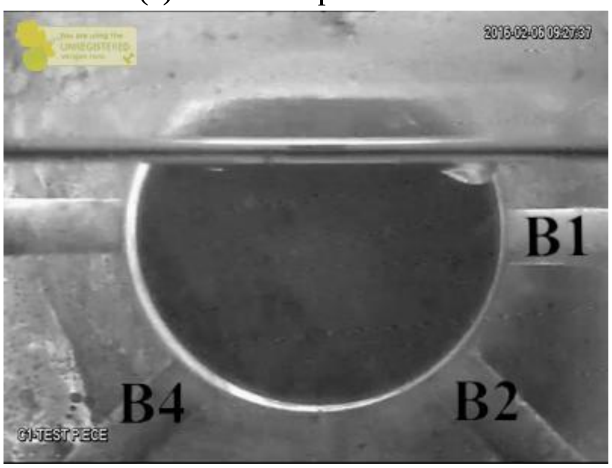
Figure D.11 : Gas entrainment phenomena of set no. 3-1.1 (cont.)



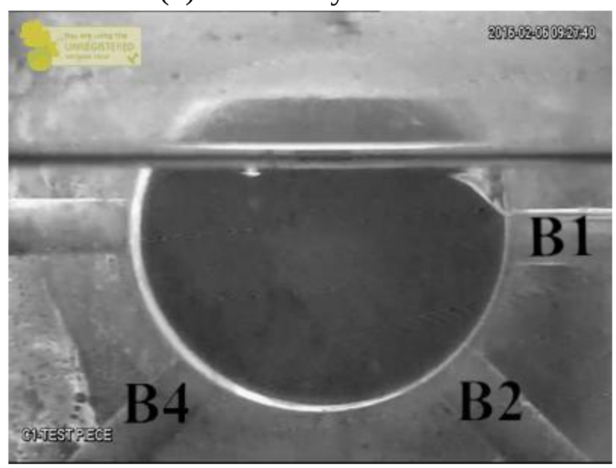
(a) Initial depression at B1



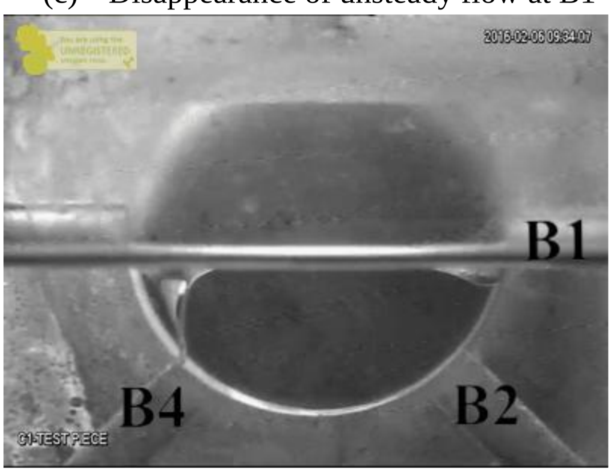
(b) Unsteady flow at B1



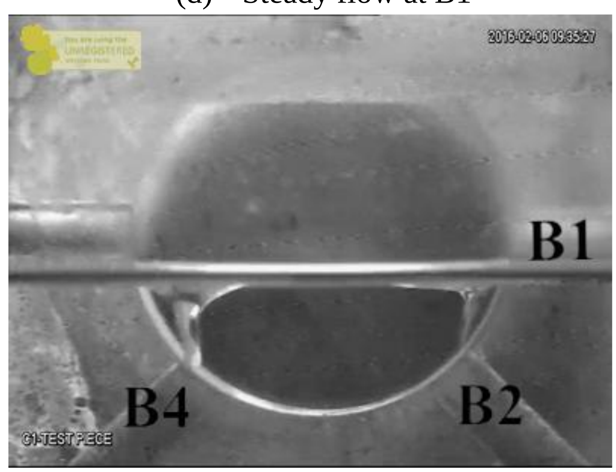
(c) Disappearance of unsteady flow at B1



(d) Steady flow at B1

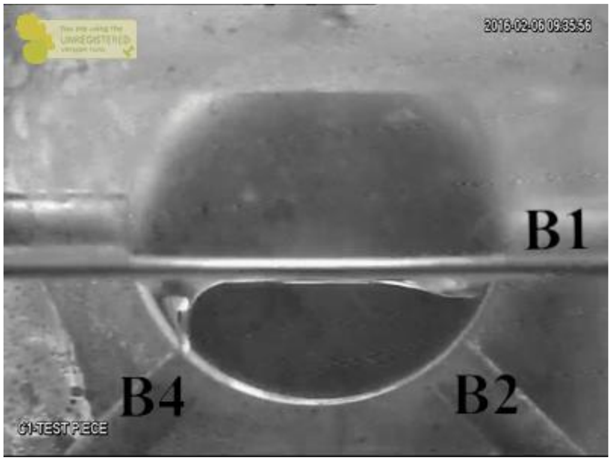


(e) Initial depression at B2

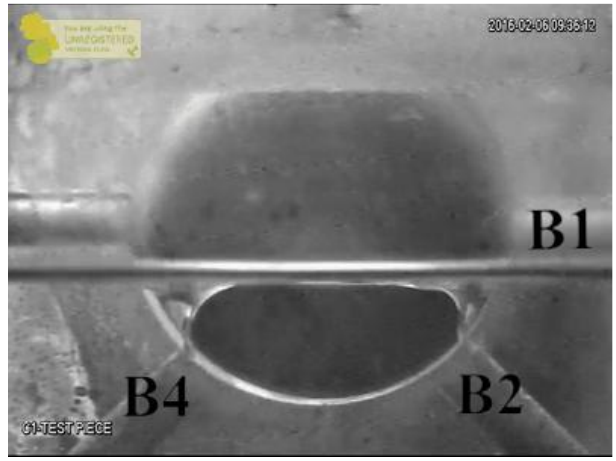


(f) Unsteady flow at B2

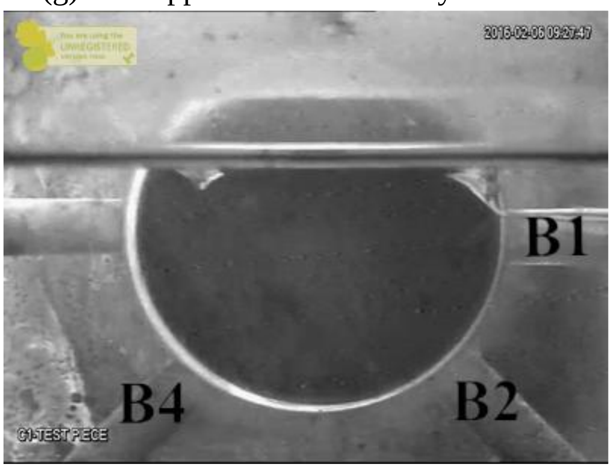
Figure D.12 : Gas entrainment phenomena of set no. 3-2.1



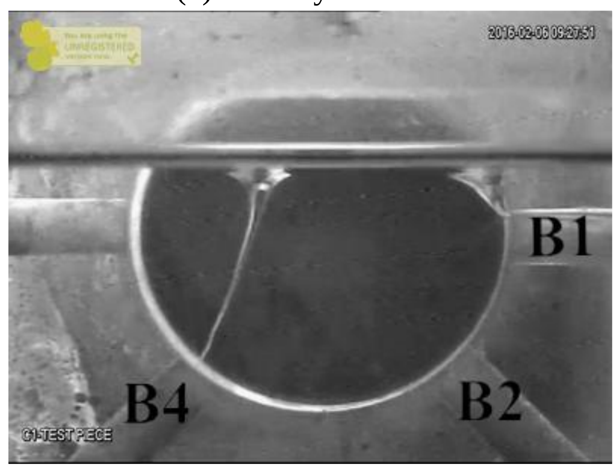
(g) Disappearance of unsteady flow at B2



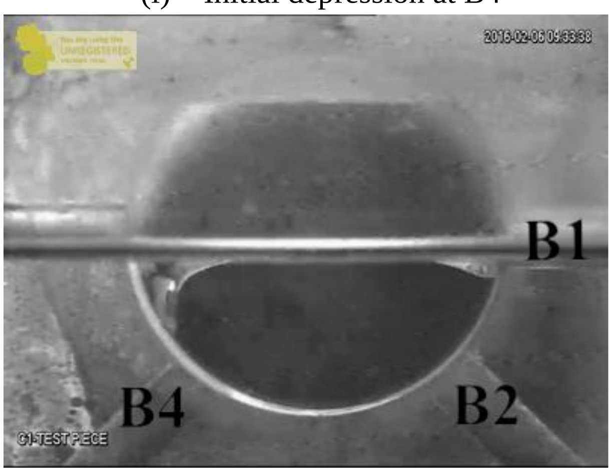
(h) Steady flow at B2



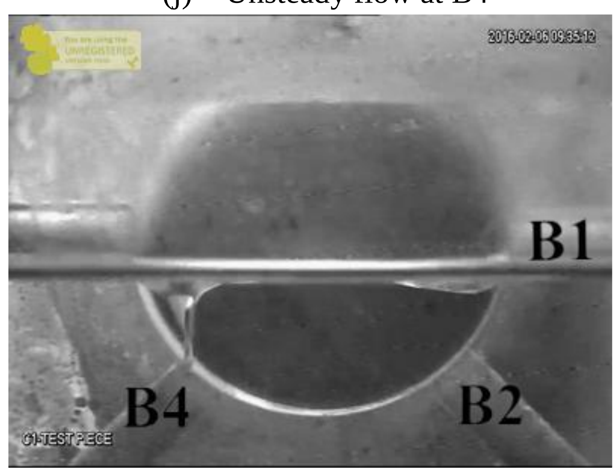
(i) Initial depression at B4



(j) Unsteady flow at B4

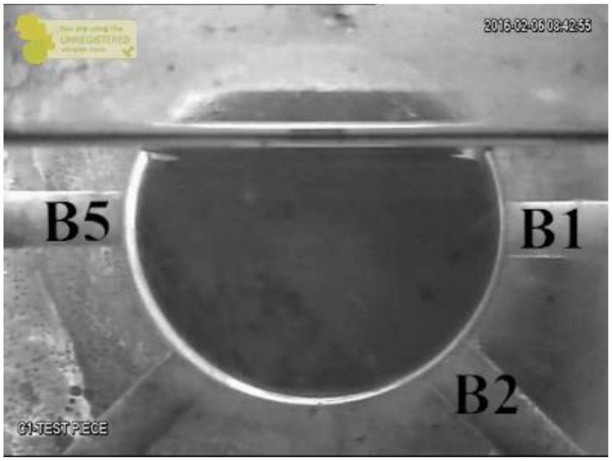


(k) Disappearance of unsteady flow at B4

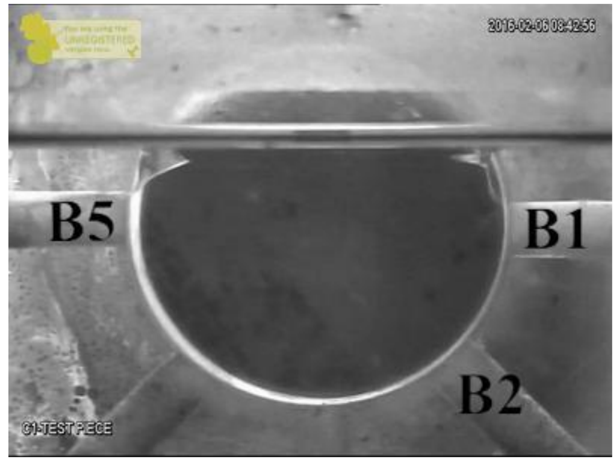


(l) Steady flow at B4

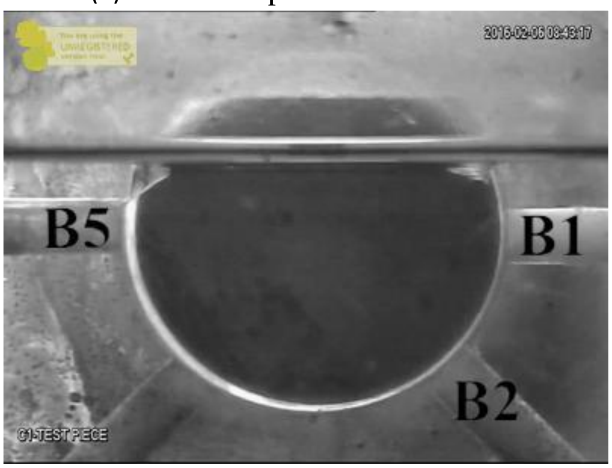
Figure D.12 : Gas entrainment phenomena of set no. 3-2.1 (cont.)



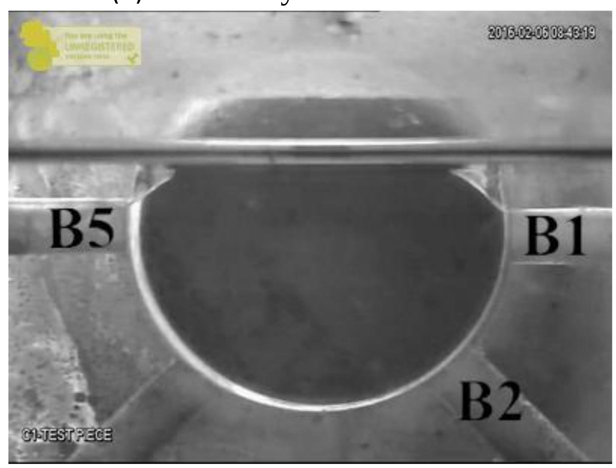
(a) Initial depression at B1 and B5



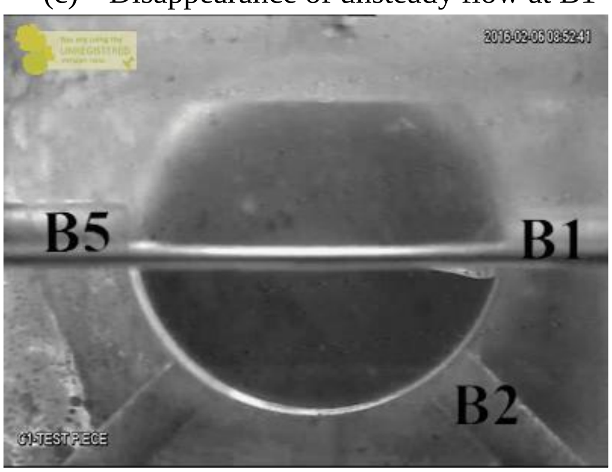
(b) Unsteady flow at B1 and B5



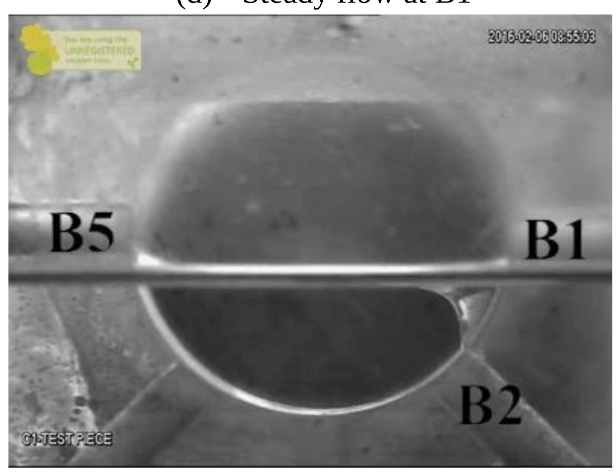
(c) Disappearance of unsteady flow at B1



(d) Steady flow at B1

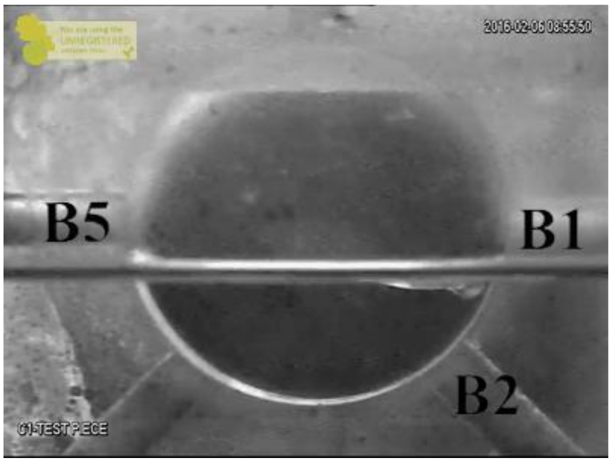


(e) Initial depression at B2

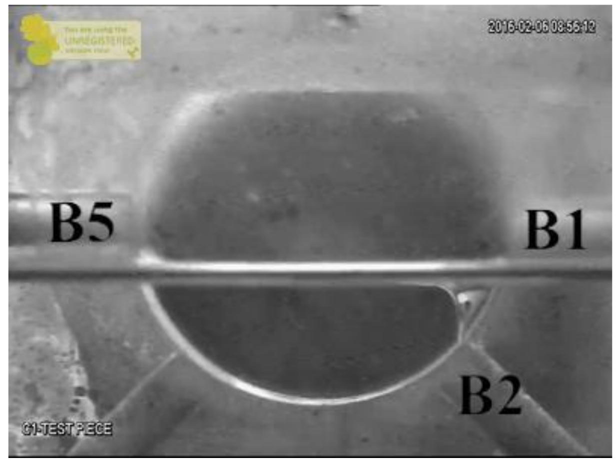


(f) Unsteady flow at B2

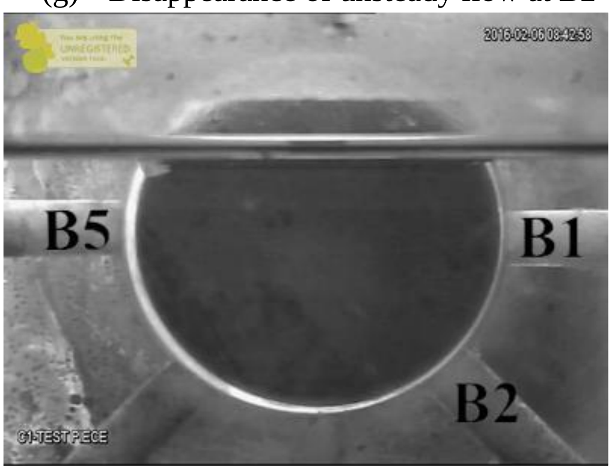
Figure D.13 : Gas entrainment phenomena of set no. 3-3.1



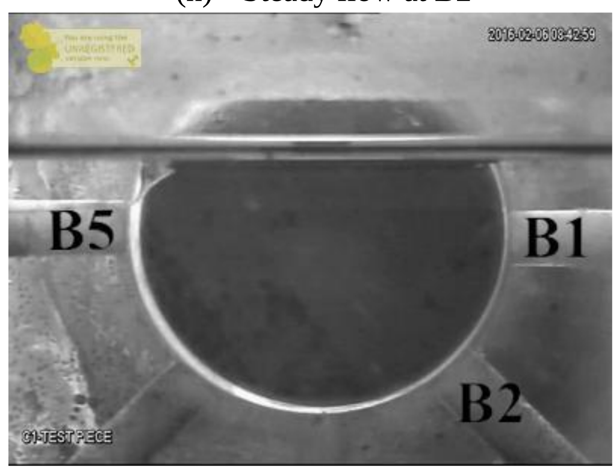
(g) Disappearance of unsteady flow at B2



(h) Steady flow at B2

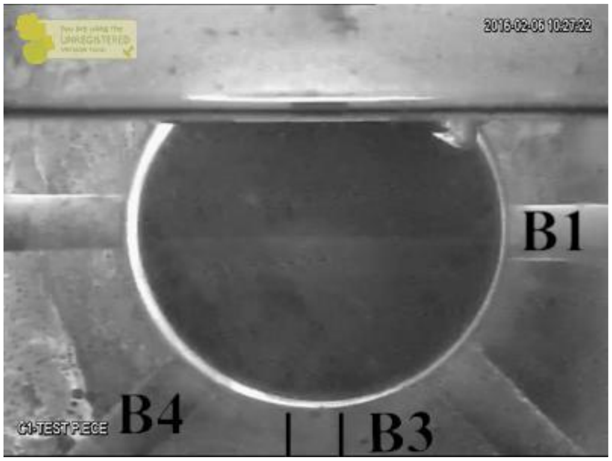


(i) Disappearance of unsteady flow at B5

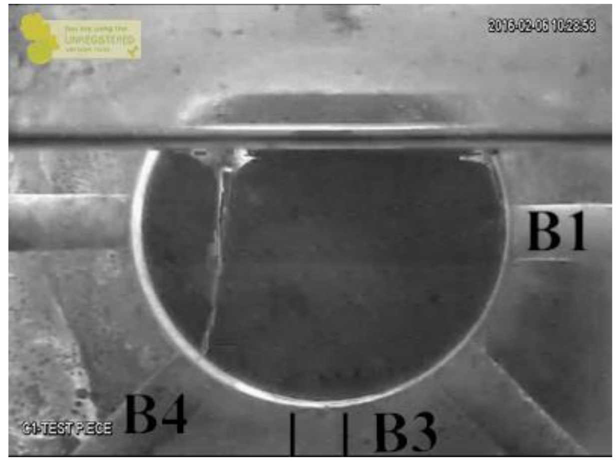


(j) Steady flow at B5

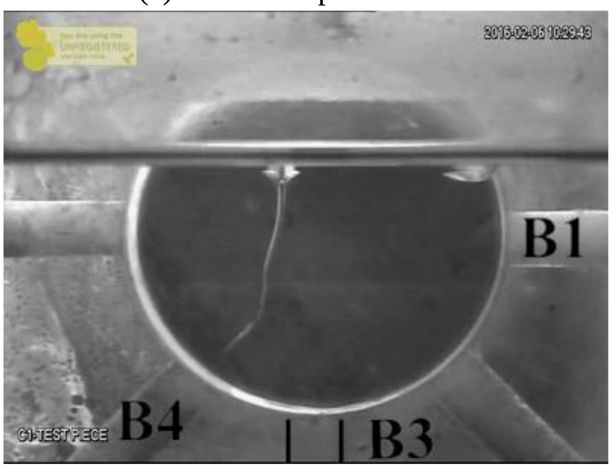
Figure D.13 : Gas entrainment phenomena of set no. 3-3.1 (cont.)



(a) Initial depression at B1

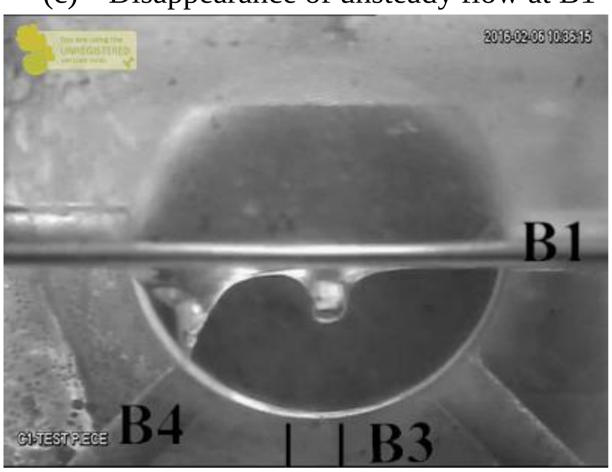


(b) Unsteady flow at B1

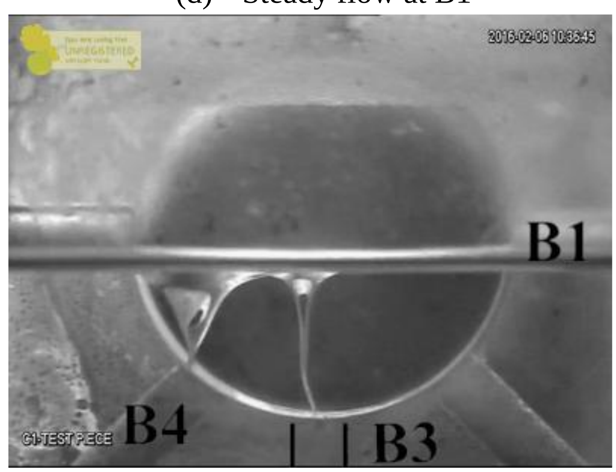


(c) Disappearance of unsteady flow at B1

(d) Steady flow at B1

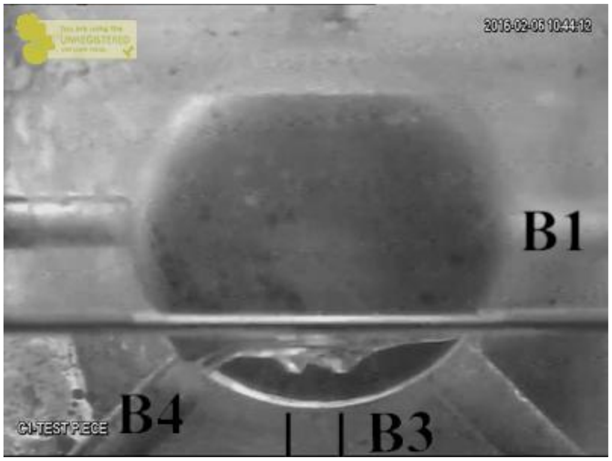


(e) Initial depression at B3

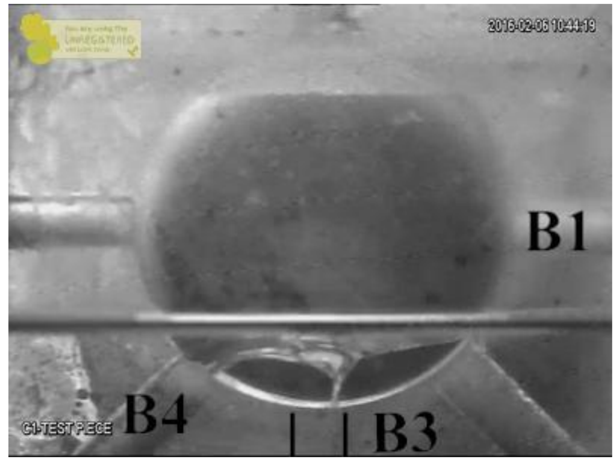


(f) Unsteady flow at B3

Figure D.14 : Gas entrainment phenomena of set no. 3-4.1



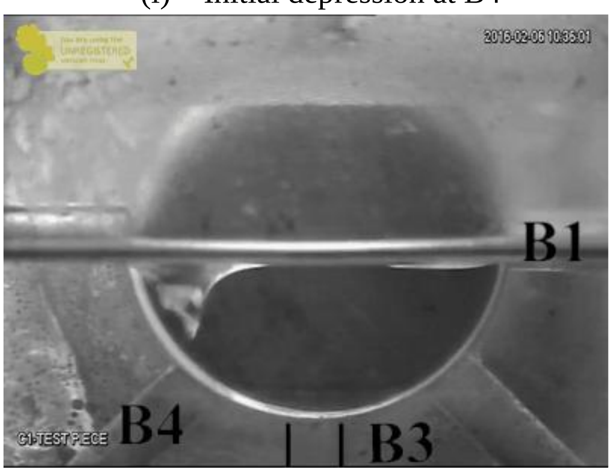
(g) Disappearance of unsteady flow at B3



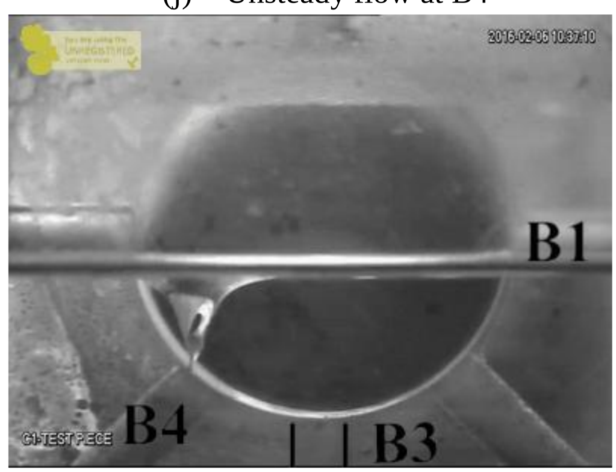
(h) Steady flow at B3

(i) Initial depression at B4

(j) Unsteady flow at B4

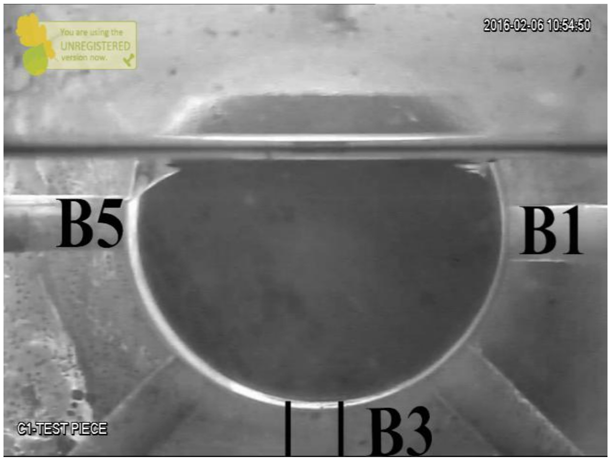


(k) Disappearance of unsteady flow at B4



(l) Steady flow at B4

Figure D.14 : Gas entrainment phenomena of set no. 3-4.1 (cont.)

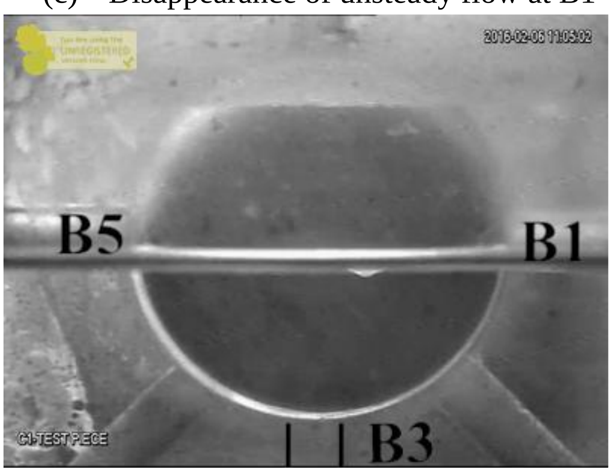


(a) Initial depression at B1

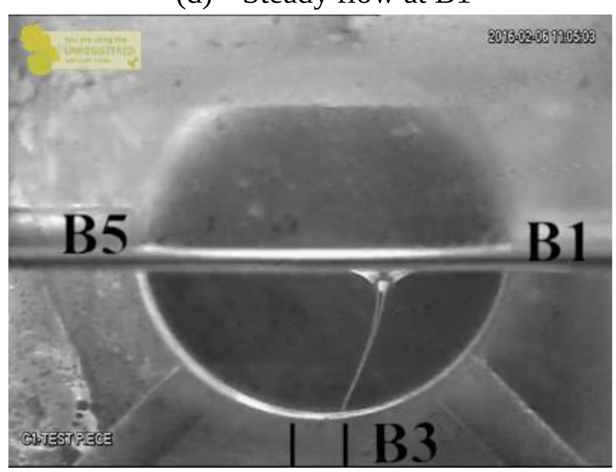
(b) Unsteady flow at B1

(c) Disappearance of unsteady flow at B1

(d) Steady flow at B1

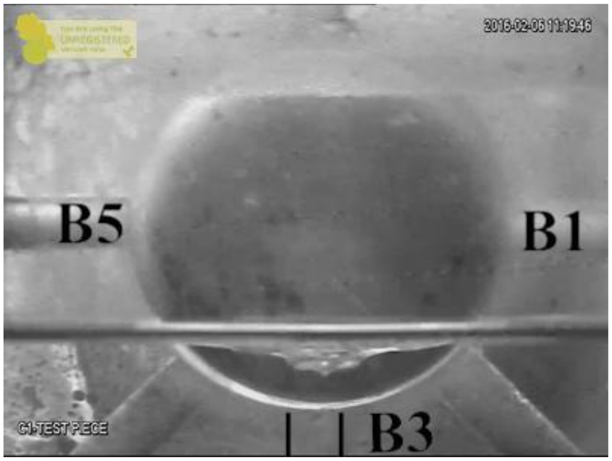


(e) Initial depression at B3

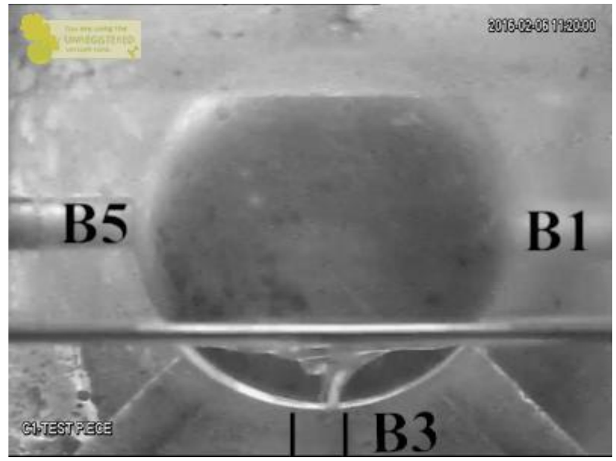


(f) Unsteady flow at B3

Figure D.15 : Gas entrainment phenomena of set no. 3-5.1



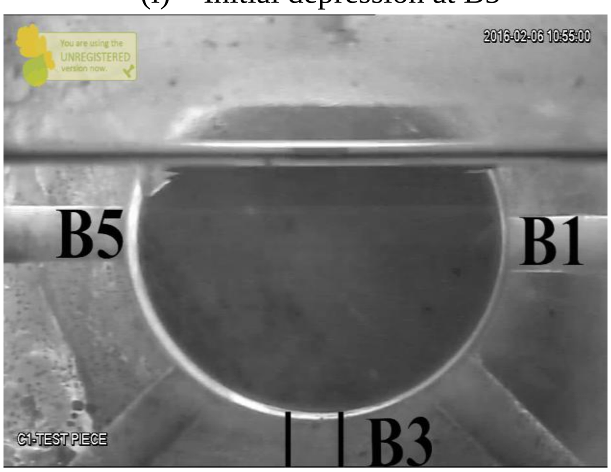
(g) Disappearance of unsteady flow at B3



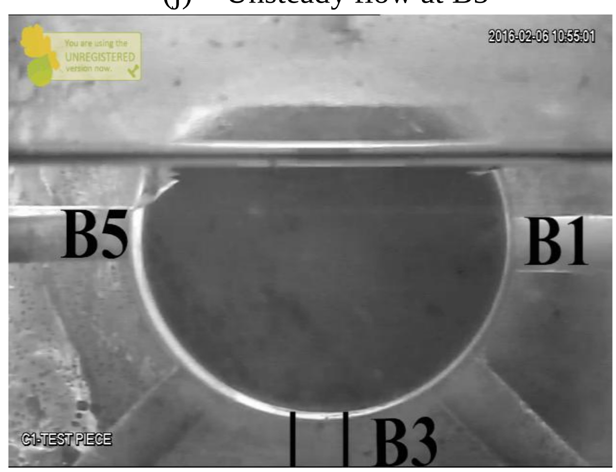
(h) Steady flow at B3

(i) Initial depression at B5

(j) Unsteady flow at B5

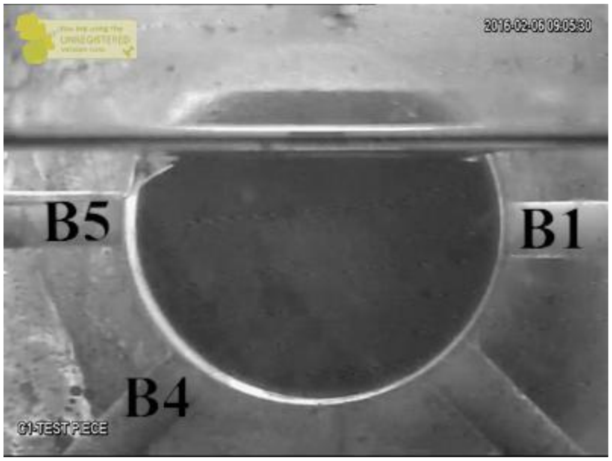


(k) Disappearance of unsteady flow at B5

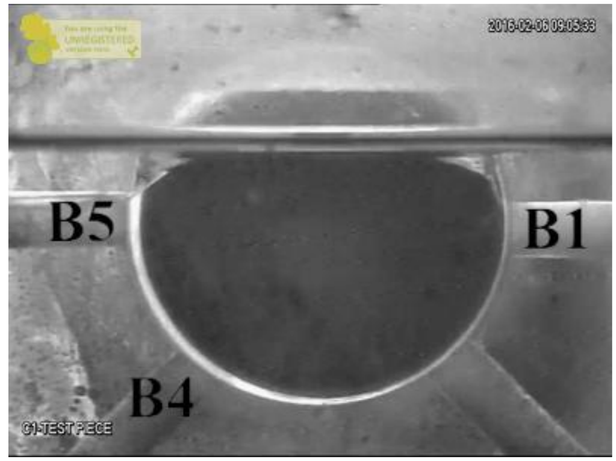


(l) Steady flow at B5

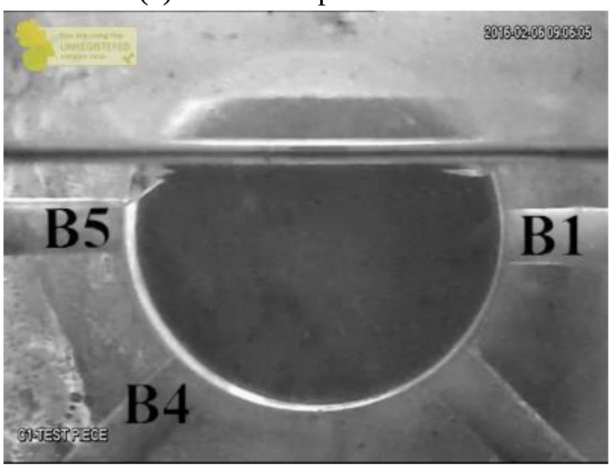
Figure D.15 : Gas entrainment phenomena of set no. 3-5.1 (cont.)



(a) Initial depression at B1

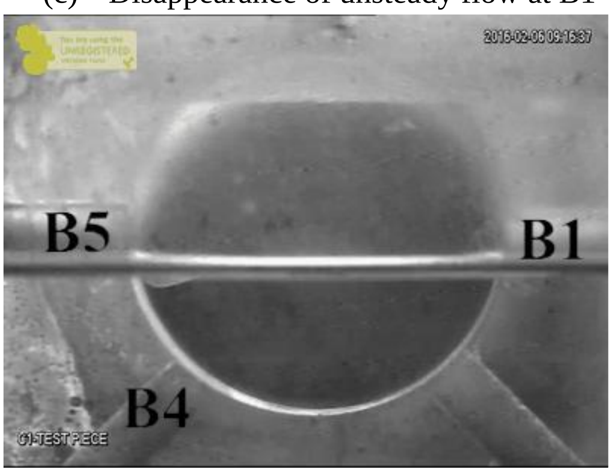


(b) Unsteady flow at B1

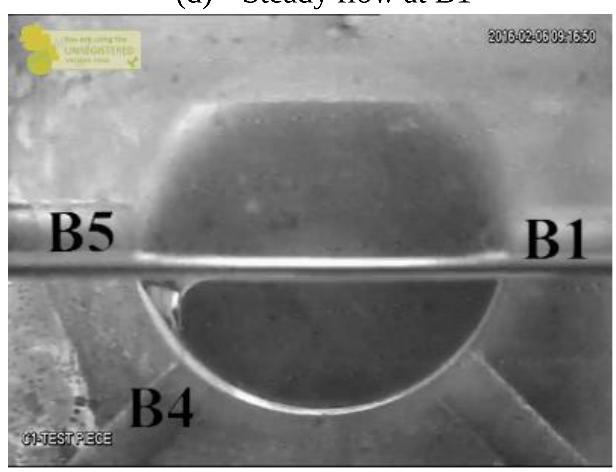


(c) Disappearance of unsteady flow at B1

(d) Steady flow at B1

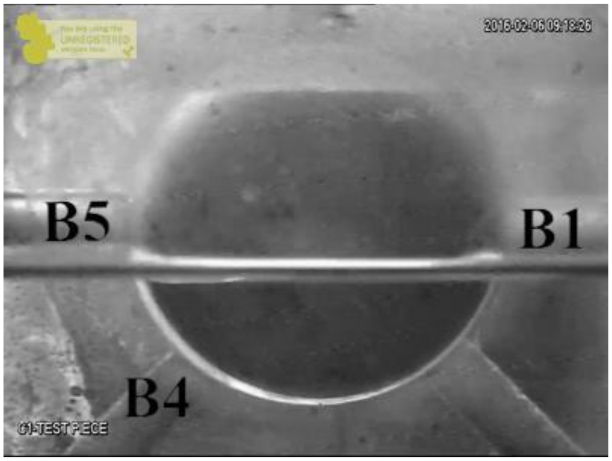


(e) Initial depression at B4

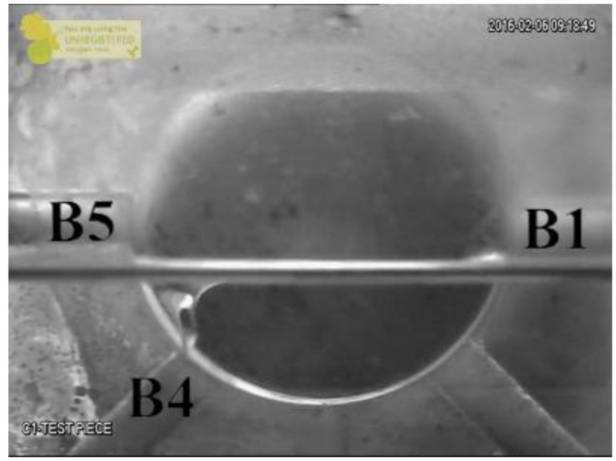


(f) Unsteady flow at B4

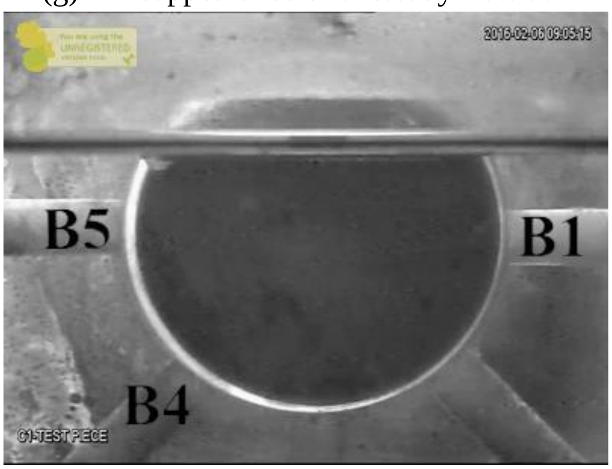
Figure D.16 : Gas entrainment phenomena of set no. 3-6.1



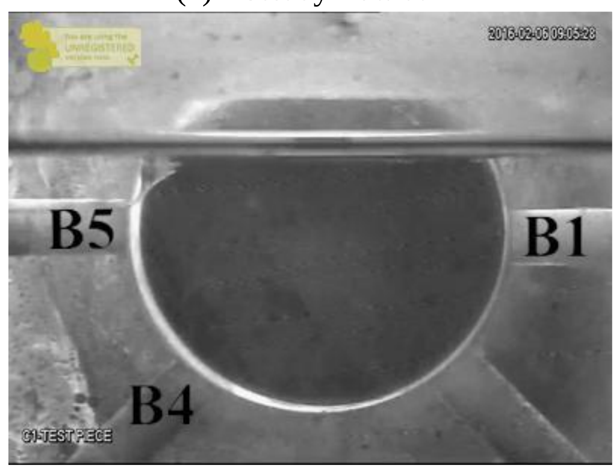
(g) Disappearance of unsteady flow at B4



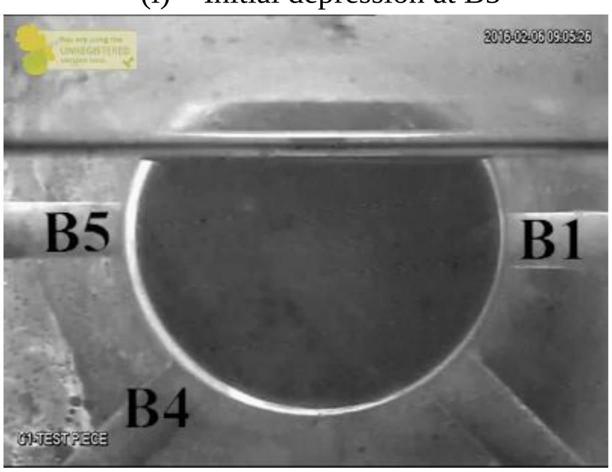
(h) Steady flow at B4



(i) Initial depression at B5



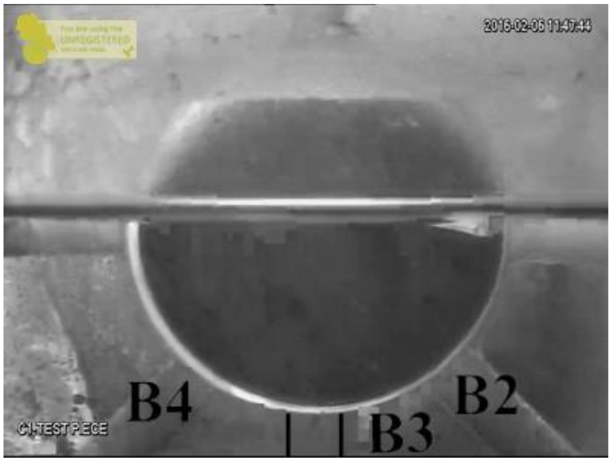
(j) Unsteady flow at B5



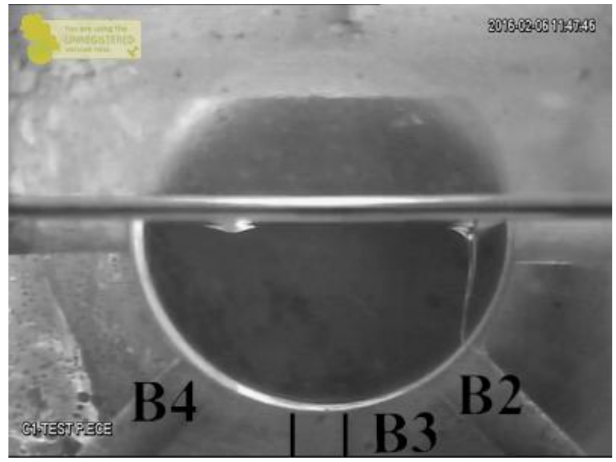
(k) Disappearance of unsteady flow at B5

(l) Steady flow at B5

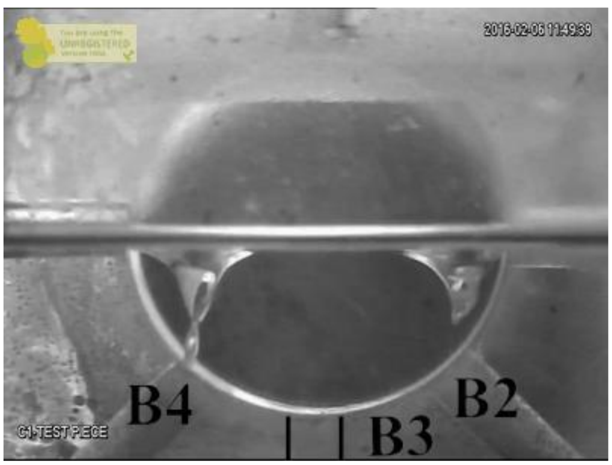
Figure D.16 : Gas entrainment phenomena of set no. 3-6.1 (cont.)



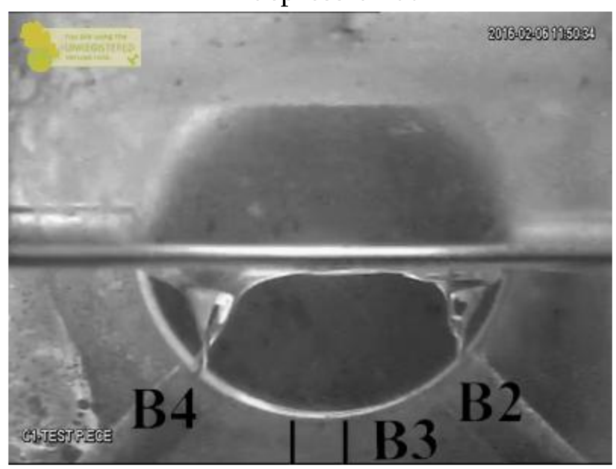
(a) Initial depression at B2



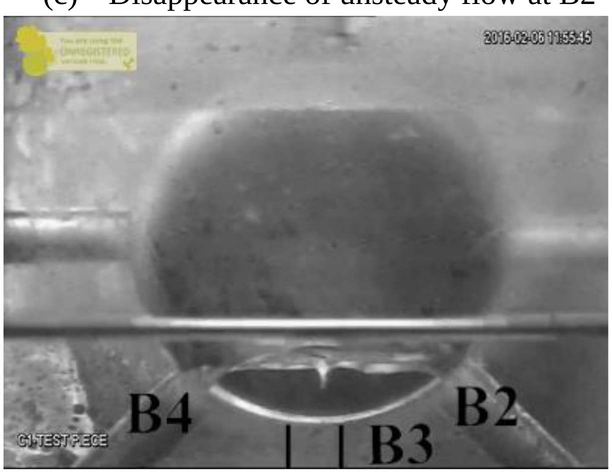
(b) Unsteady flow at B2 and Initial depression at B4



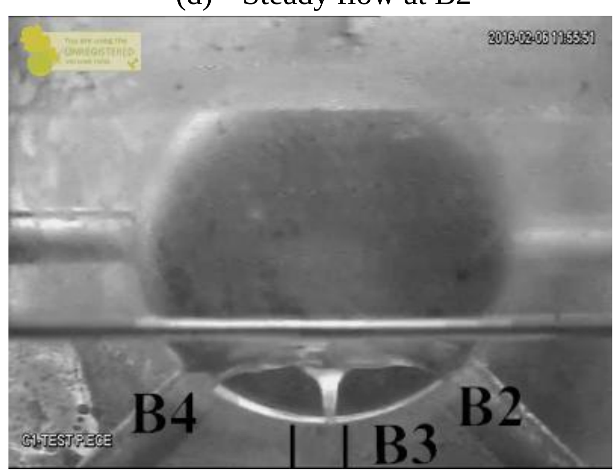
(c) Disappearance of unsteady flow at B2



(d) Steady flow at B2

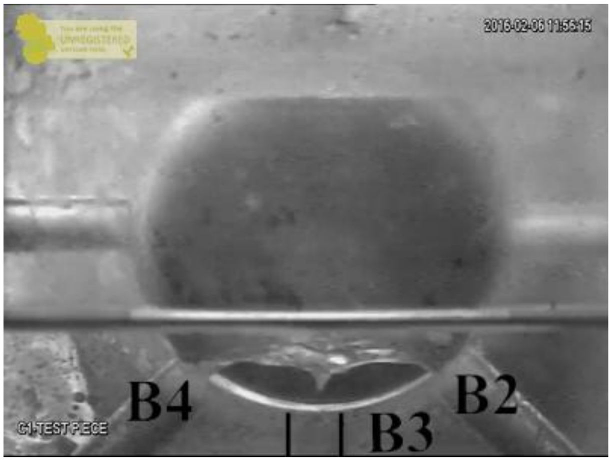


(e) Initial depression at B3

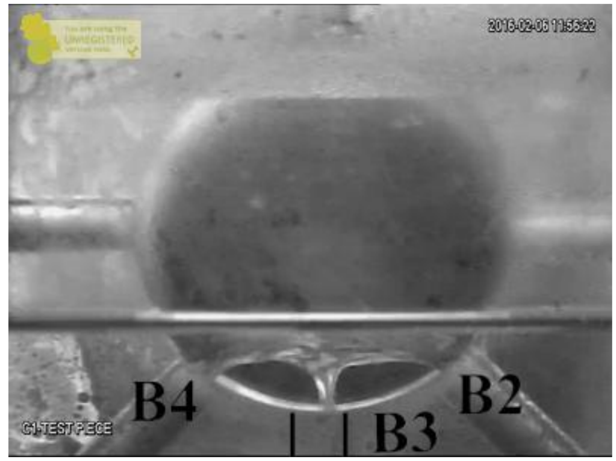


(f) Unsteady flow at B3

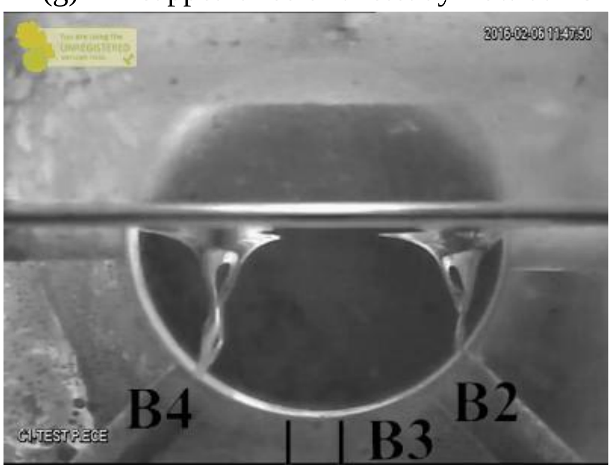
Figure D.17 : Gas entrainment phenomena of set no. 3-7.1



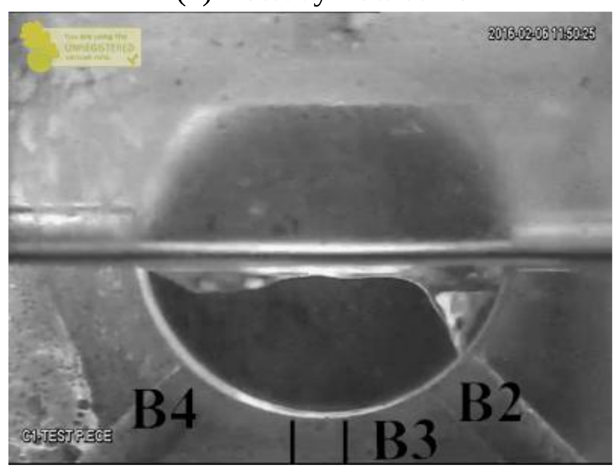
(g) Disappearance of unsteady flow at B3



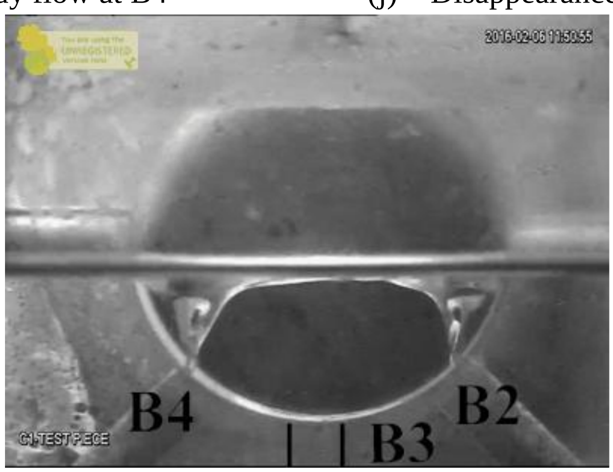
(h) Steady flow at B3



(i) Unsteady flow at B4



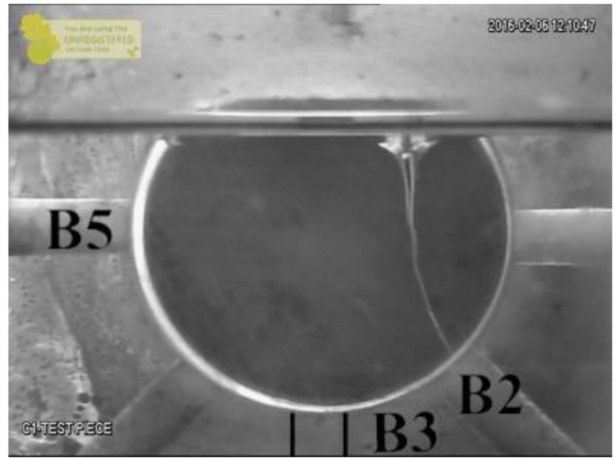
(j) Disappearance of unsteady flow at B4



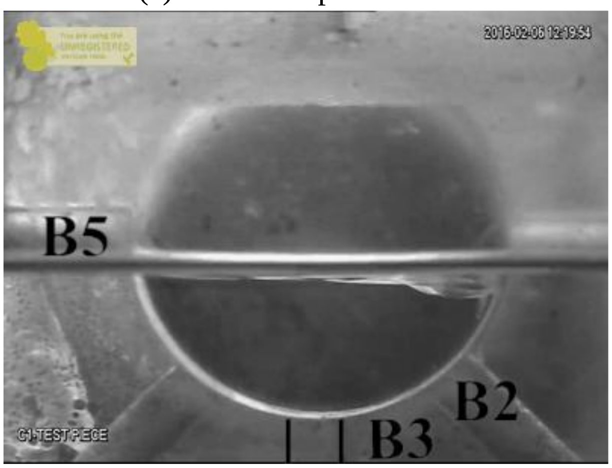
(k) Steady flow at B4

Figure D.17 : Gas entrainment phenomena of set no. 3-7.1 (cont.)

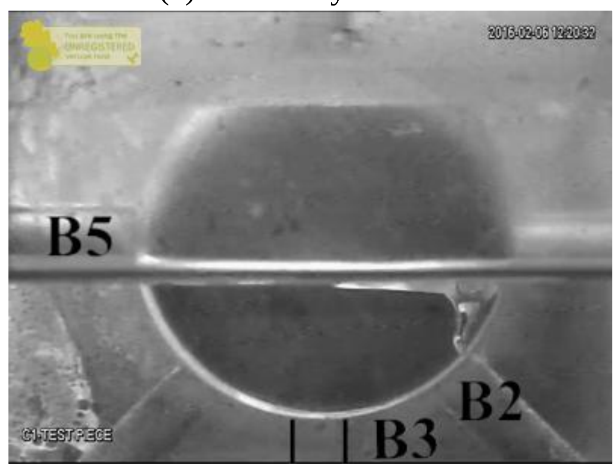
(a) Initial depression at B2



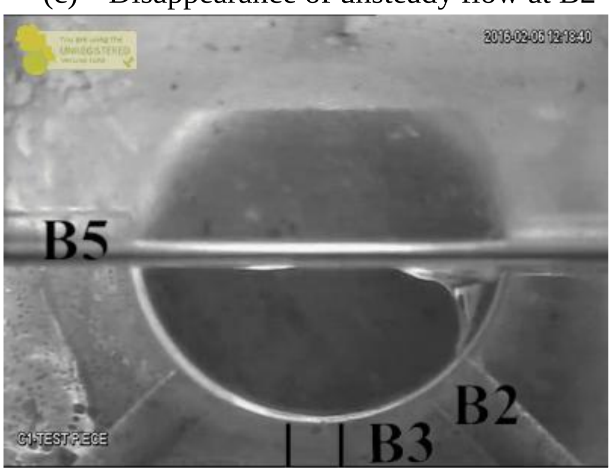
(b) Unsteady flow at B2



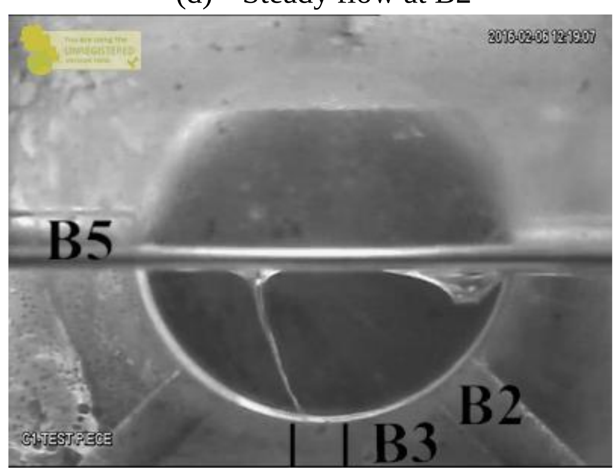
(c) Disappearance of unsteady flow at B2



(d) Steady flow at B2

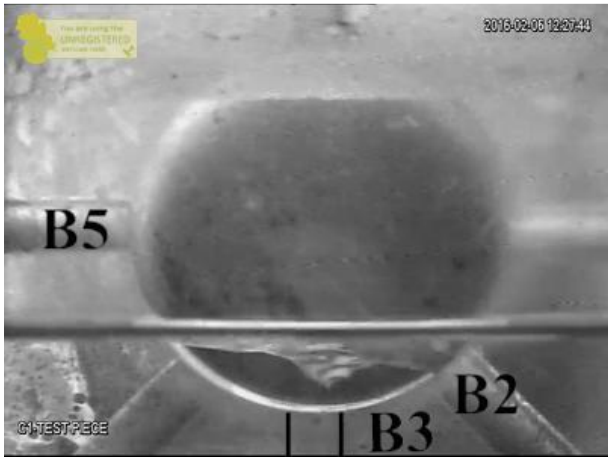


(e) Initial depression at B3

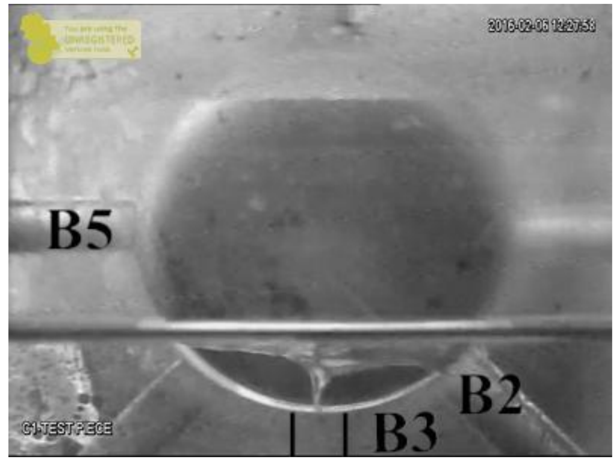


(f) Unsteady flow at B3

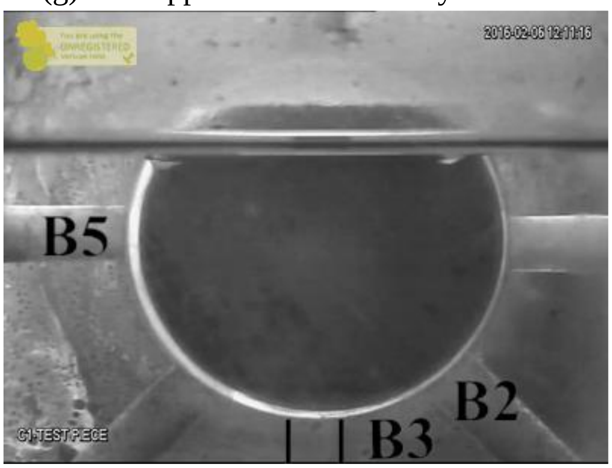
Figure D.18 : Gas entrainment phenomena of set no. 3-8.1



(g) Disappearance of unsteady flow at B3



(h) Steady flow at B3



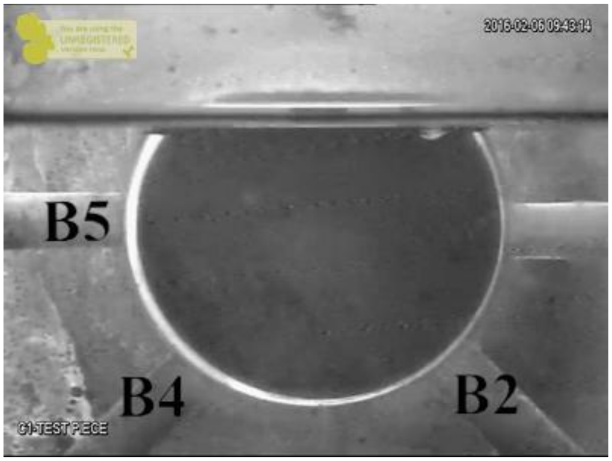
(i) Initial depression at B5

(j) Unsteady flow at B5

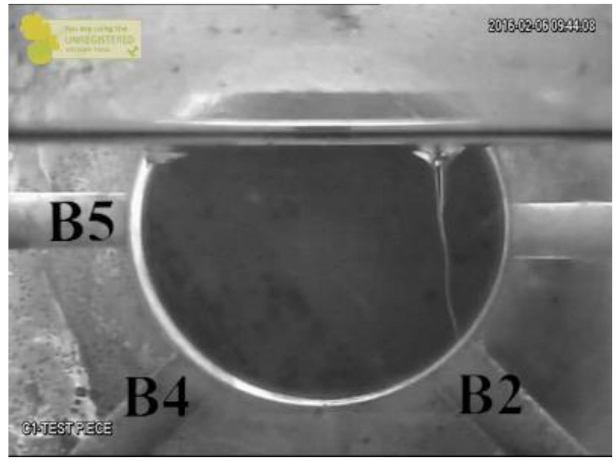
(k) Disappearance of unsteady flow at B5

(l) Steady flow at B5

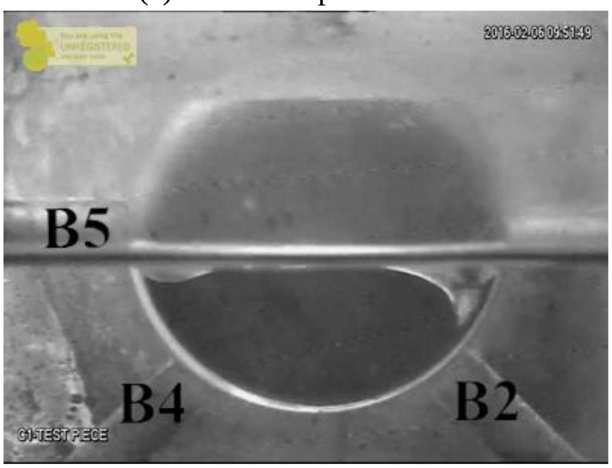
Figure D.18 : Gas entrainment phenomena of set no. 3-8.1 (cont.)



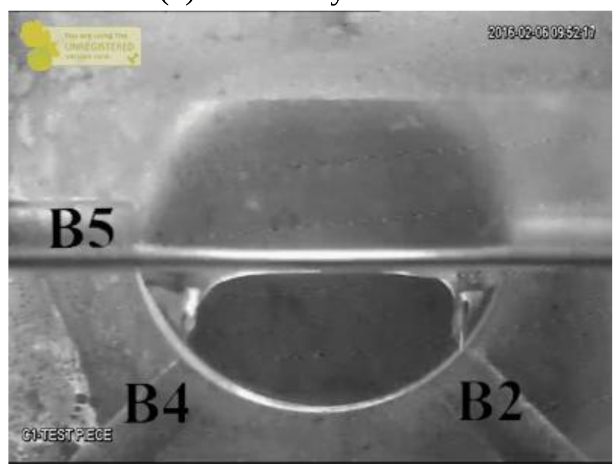
(a) Initial depression at B2



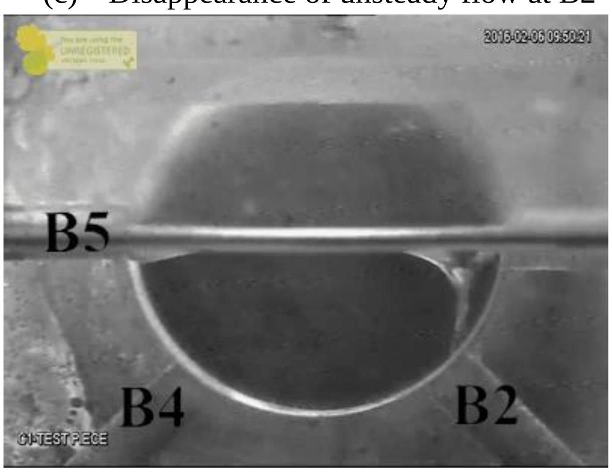
(b) Unsteady flow at B2



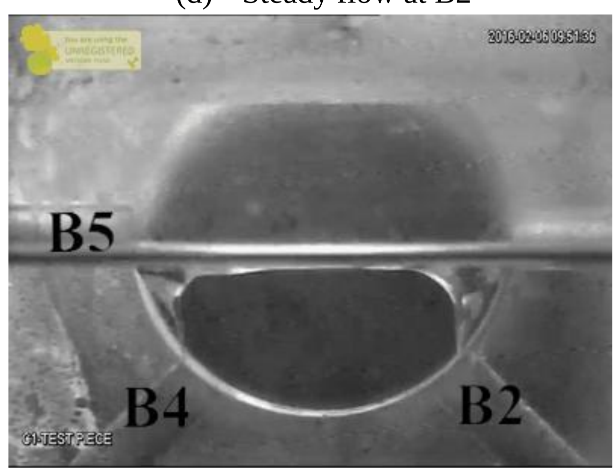
(c) Disappearance of unsteady flow at B2



(d) Steady flow at B2

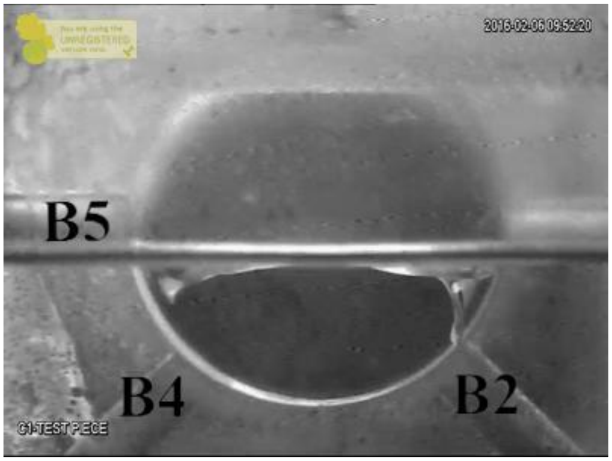


(e) Initial depression at B4

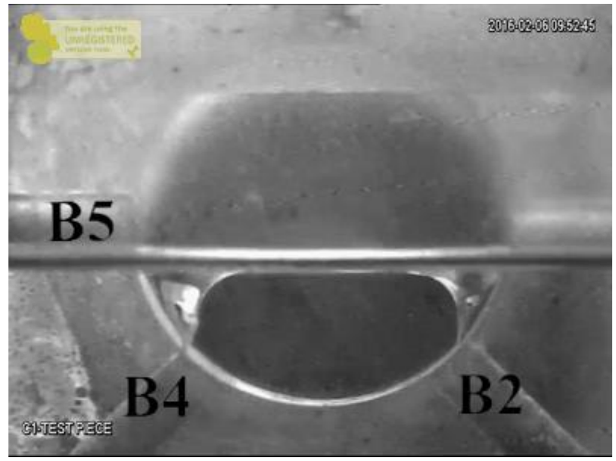


(f) Unsteady flow at B4

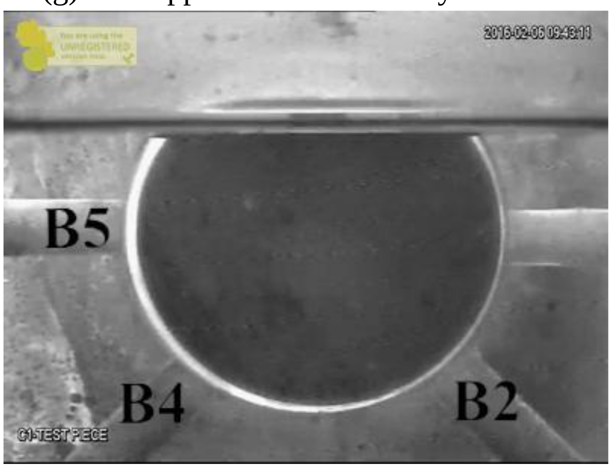
Figure D.19 : Gas entrainment phenomena of set no. 3-9.1



(g) Disappearance of unsteady flow at B4

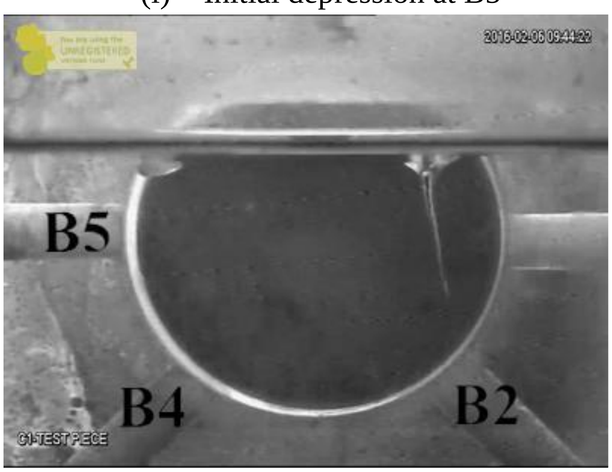


(h) Steady flow at B4

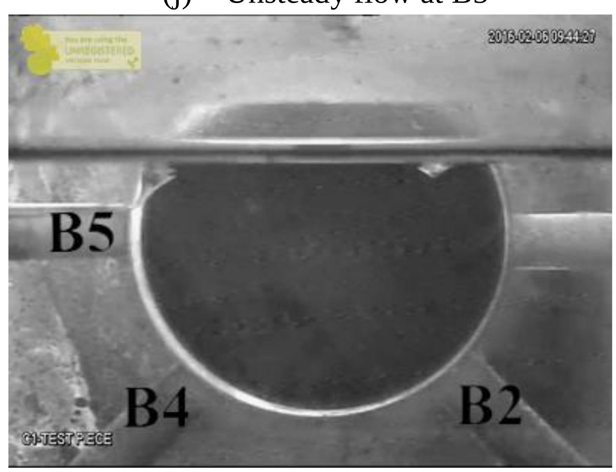


(i) Initial depression at B5

(j) Unsteady flow at B5

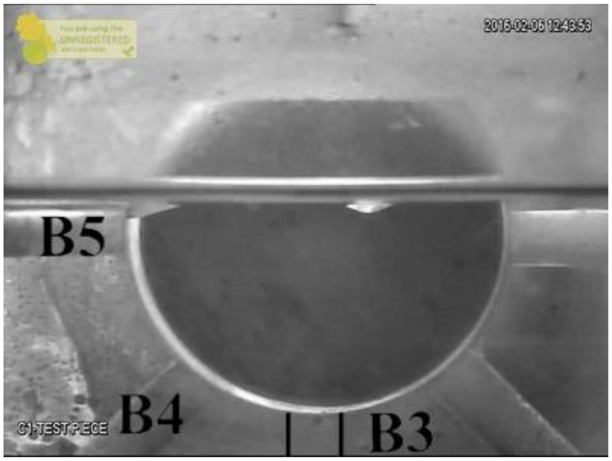


(k) Disappearance of unsteady flow at B5

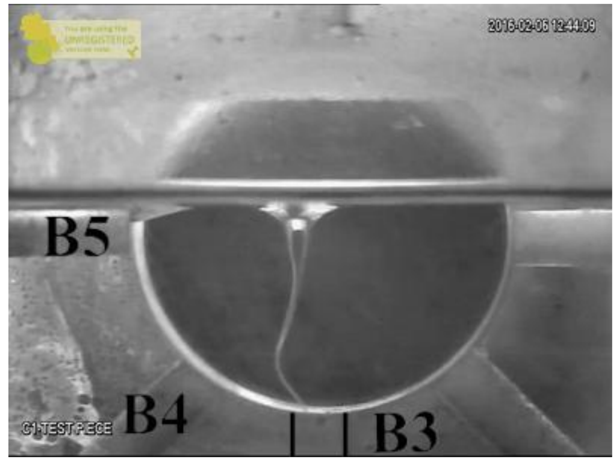


(l) Steady flow at B5

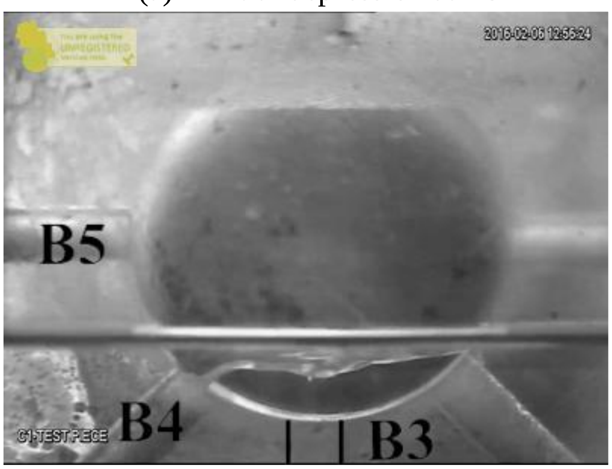
Figure D.19 : Gas entrainment phenomena of set no. 3-9.1 (cont.)



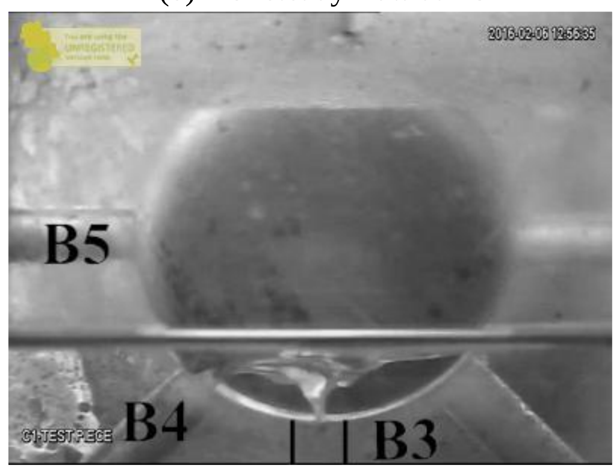
(a) Initial depression at B3



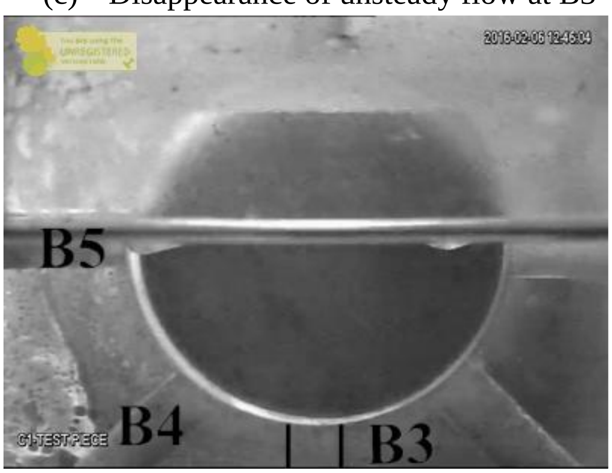
(b) Unsteady flow at B3



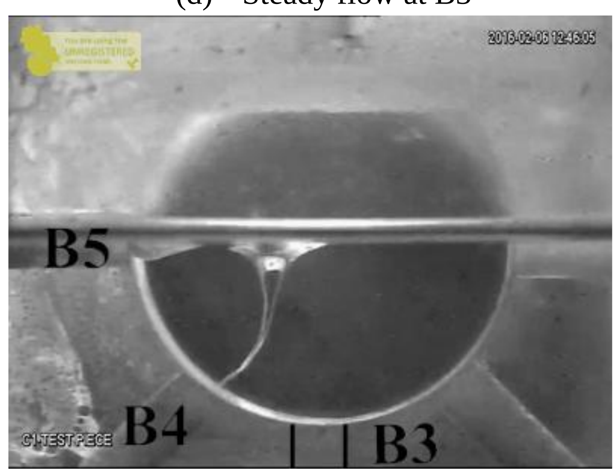
(c) Disappearance of unsteady flow at B3



(d) Steady flow at B3

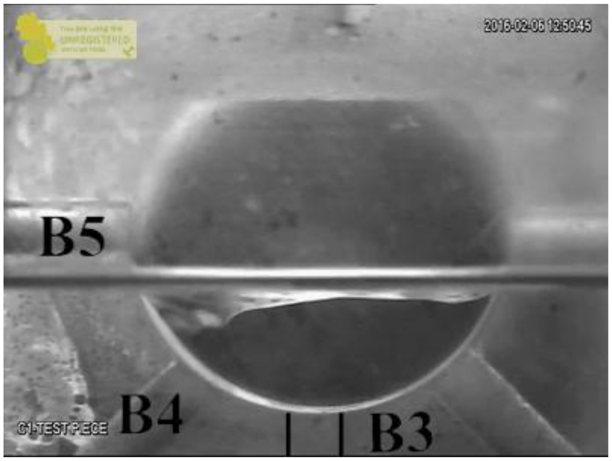


(e) Initial depression at B4

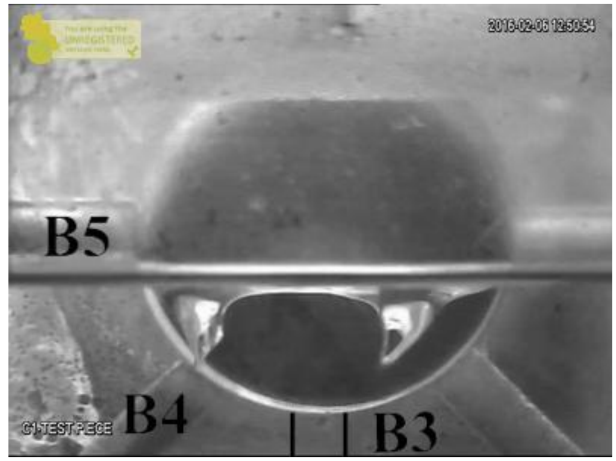


(f) Unsteady flow at B4

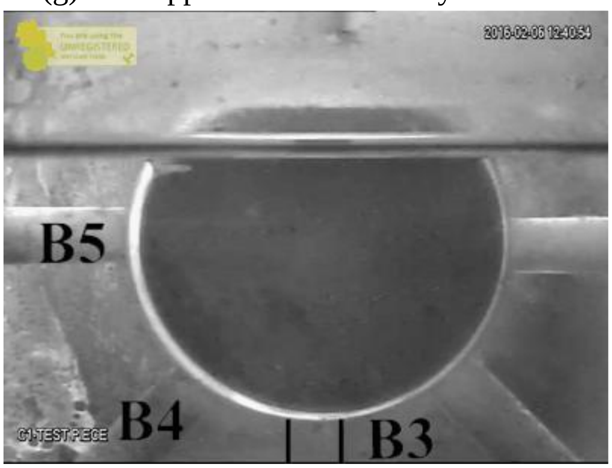
Figure D.20 : Gas entrainment phenomena of set no. 3-10.1



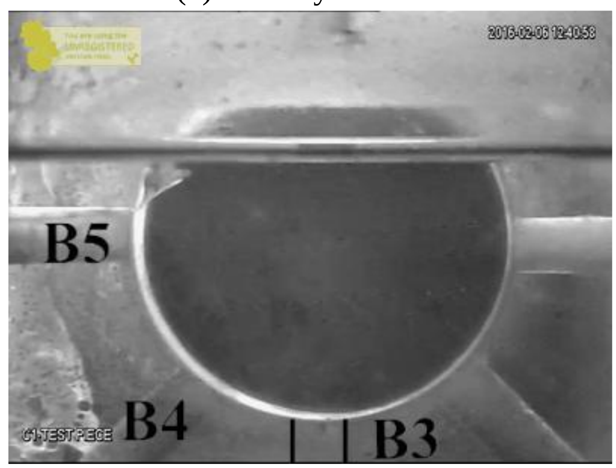
(g) Disappearance of unsteady flow at B4



(h) Steady flow at B4



(i) Initial depression at B5

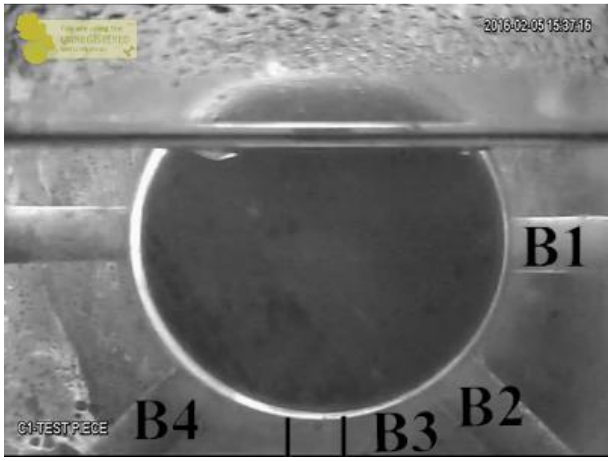


(j) Unsteady flow at B5

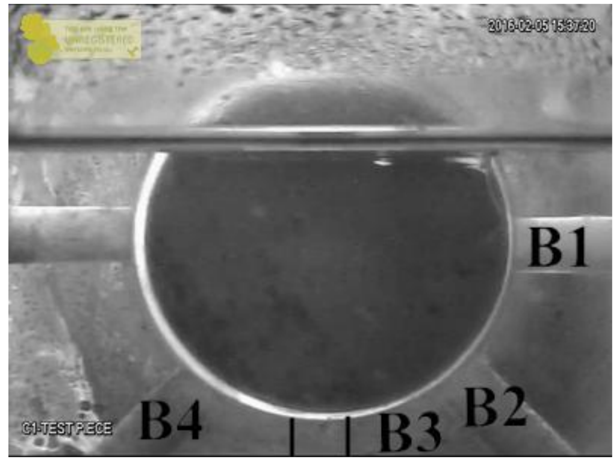
(k) Disappearance of unsteady flow at B5

(l) Steady flow at B5

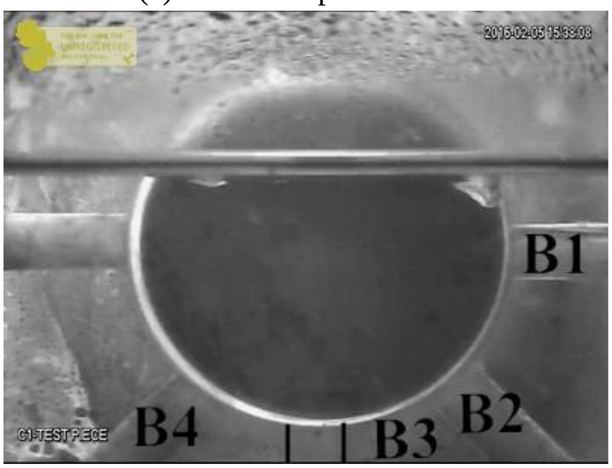
Figure D.20 : Gas entrainment phenomena of set no. 3-10.1 (cont.)



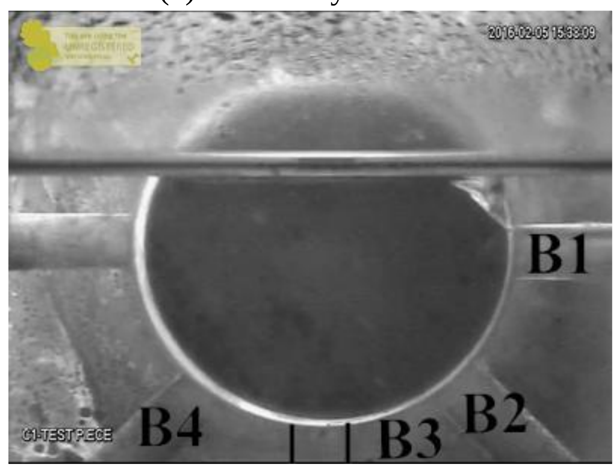
(a) Initial depression at B1



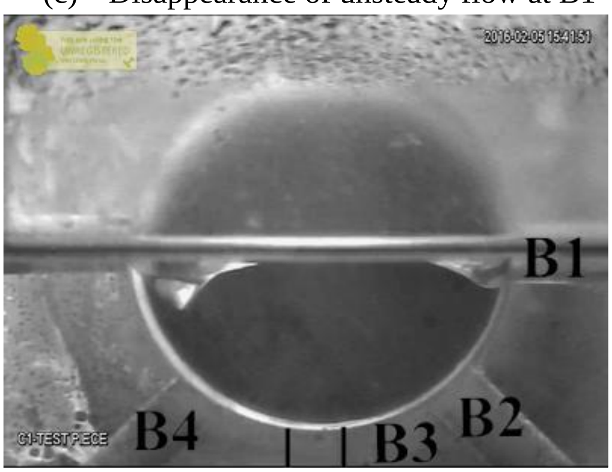
(b) Unsteady flow at B1



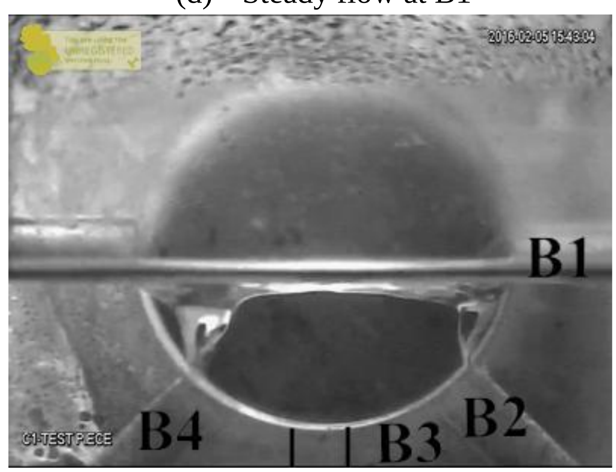
(c) Disappearance of unsteady flow at B1



(d) Steady flow at B1

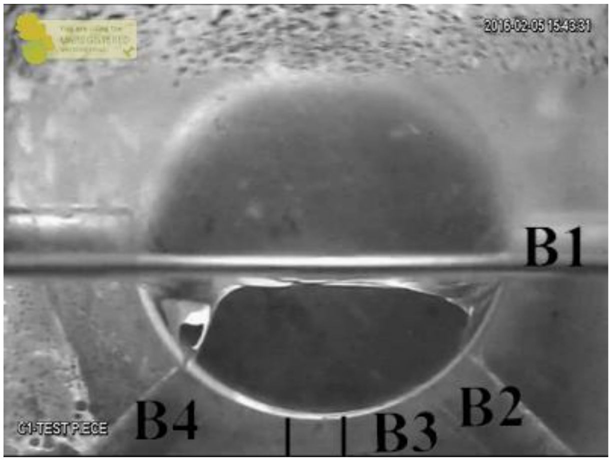


(e) Initial depression at B2

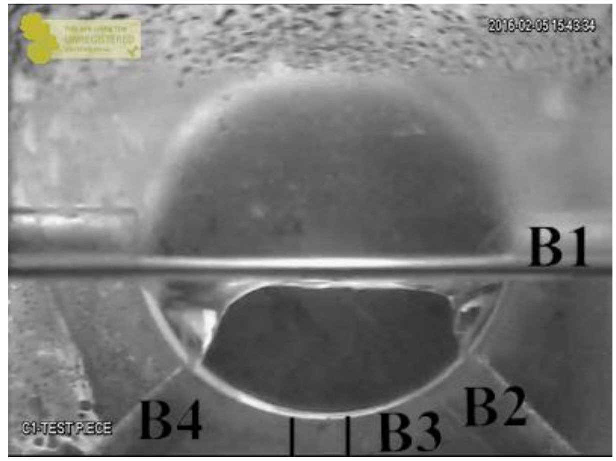


(f) Unsteady flow at B2

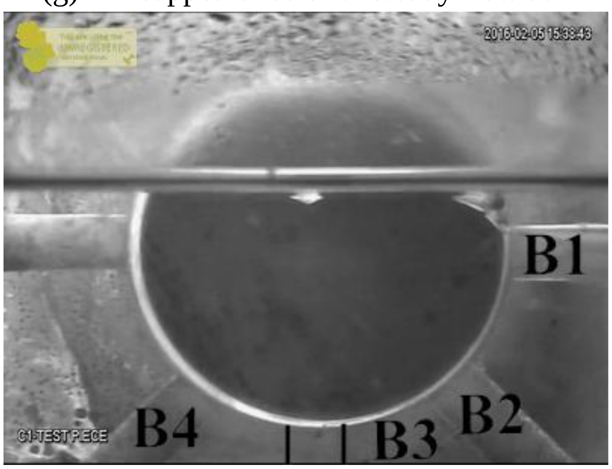
Figure D.21 : Gas entrainment phenomena of set no. 4-1.1



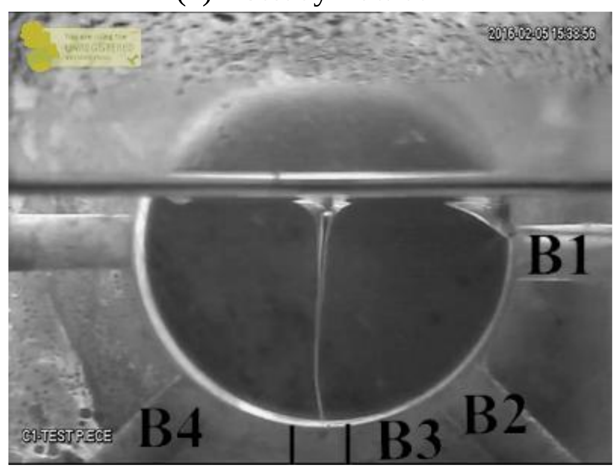
(g) Disappearance of unsteady flow at B2



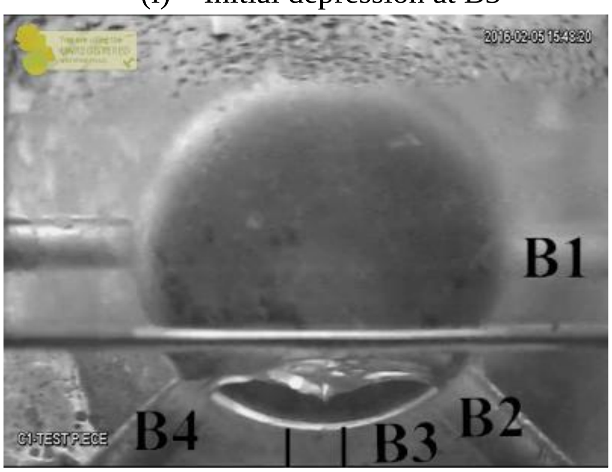
(h) Steady flow at B2



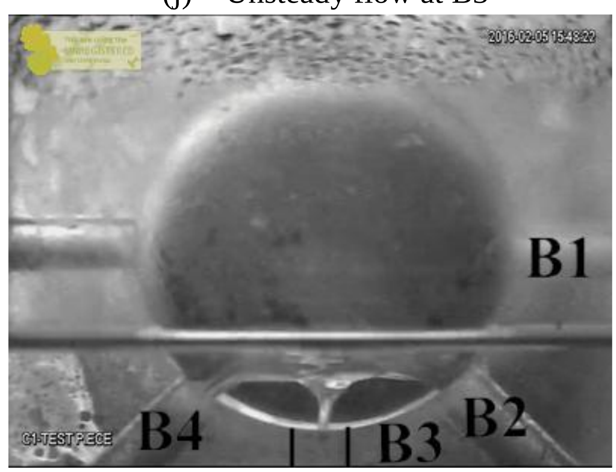
(i) Initial depression at B3



(j) Unsteady flow at B3

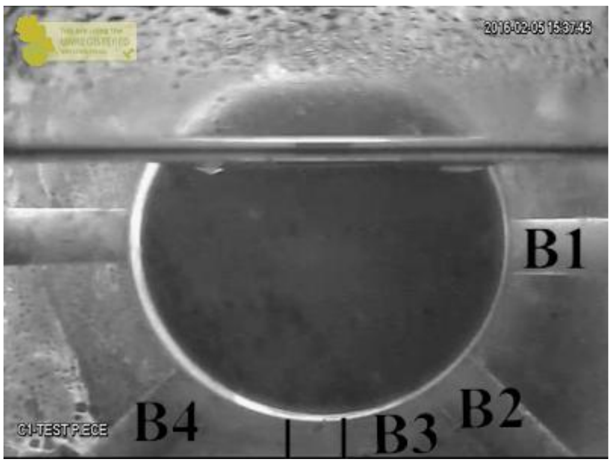


(k) Disappearance of unsteady flow at B3

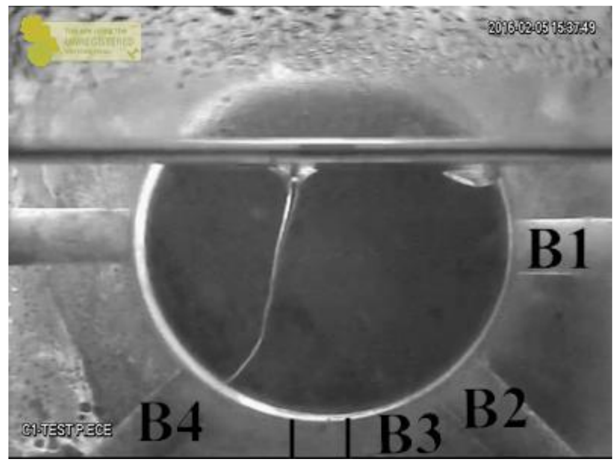


(l) Steady flow at B3

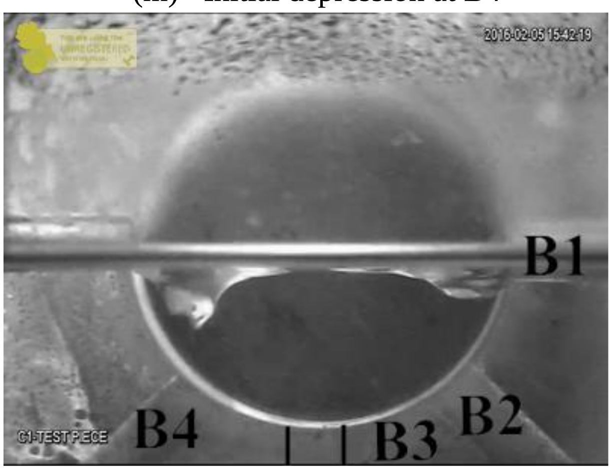
Figure D.21 : Gas entrainment phenomena of set no. 4-1.1 (cont.)



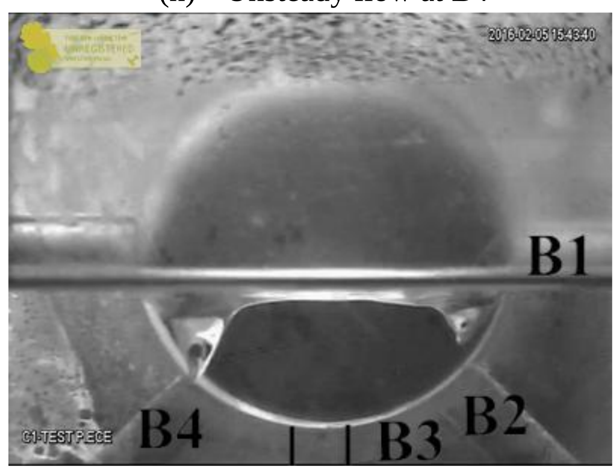
(m) Initial depression at B4



(n) Unsteady flow at B4

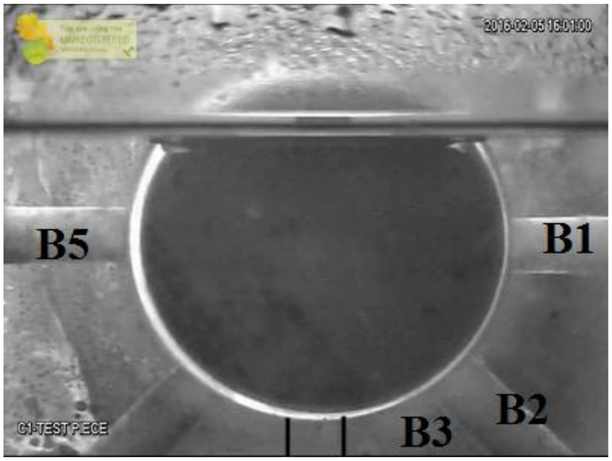


(o) Disappearance of unsteady flow at B4

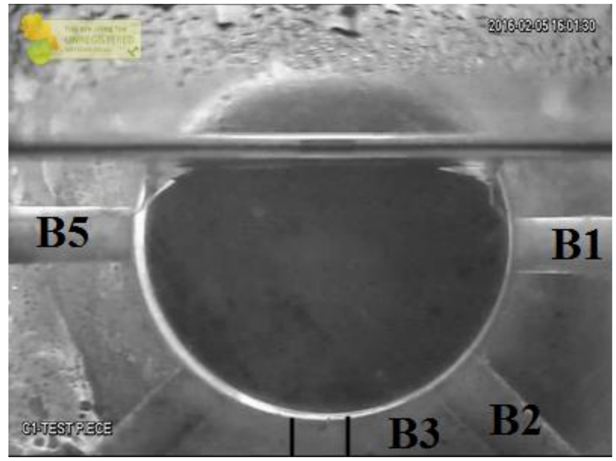


(p) Steady flow at B4

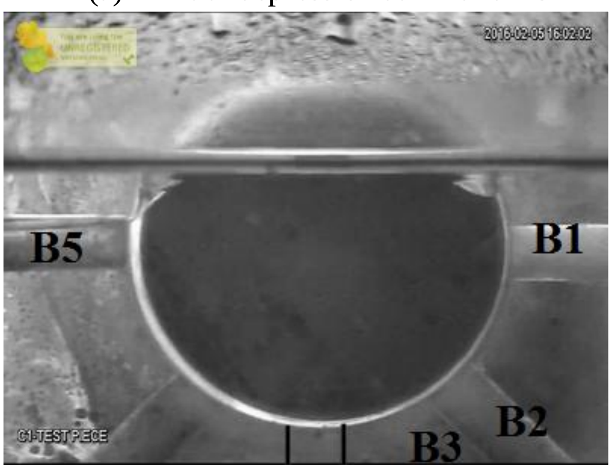
Figure D.21 : Gas entrainment phenomena of set no. 4-1.1 (cont.)



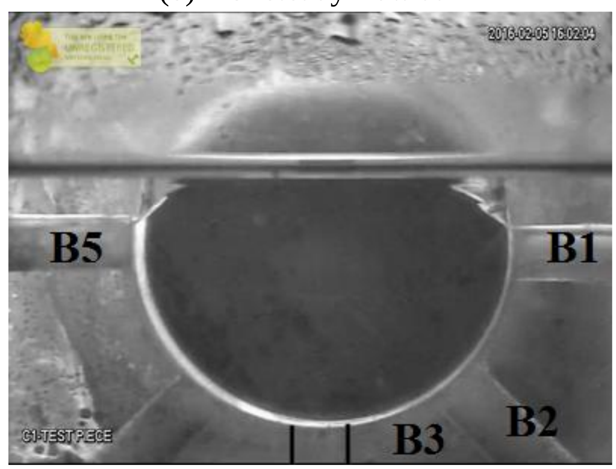
(a) Initial depression at B1 and B5



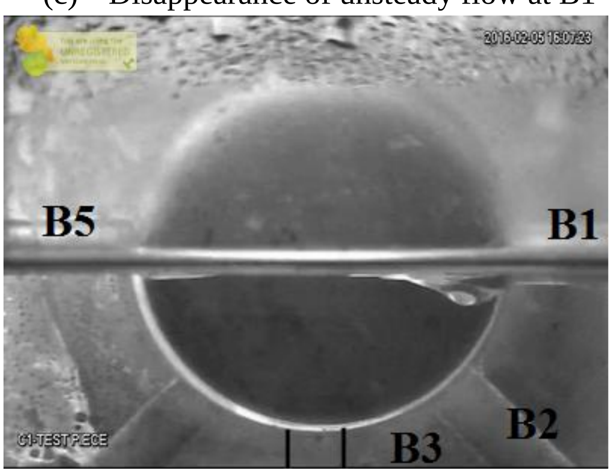
(b) Unsteady flow at B1



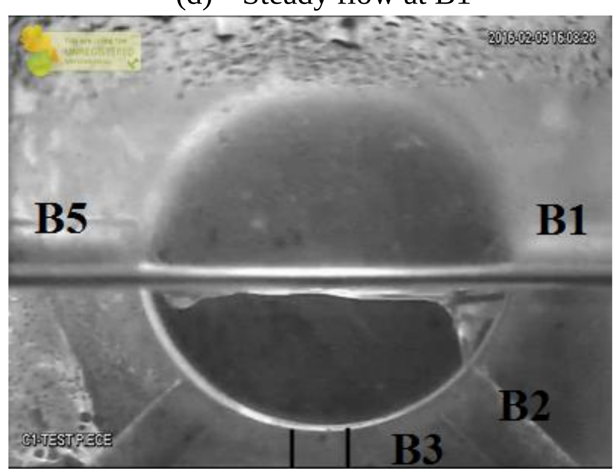
(c) Disappearance of unsteady flow at B1



(d) Steady flow at B1

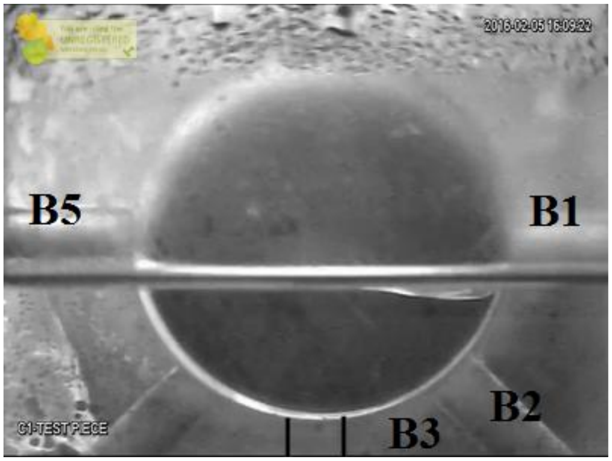


(e) Initial depression at B2

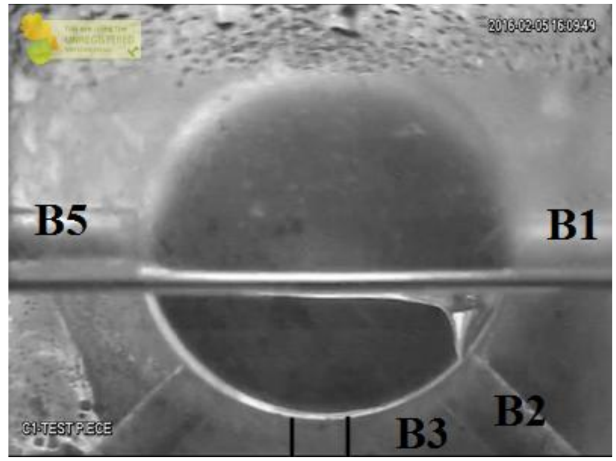


(f) Unsteady flow at B2

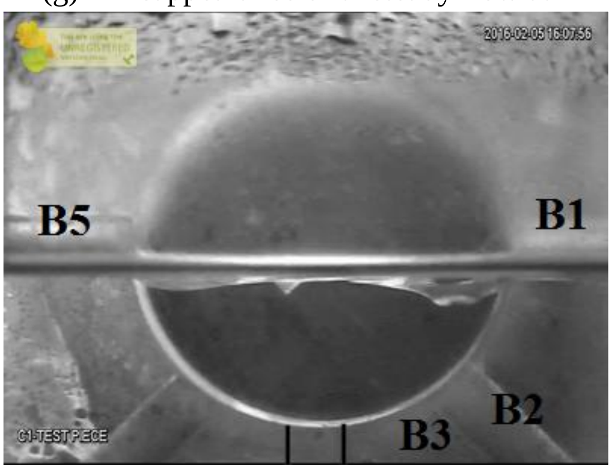
Figure D.22 : Gas entrainment phenomena of set no. 4-2.1



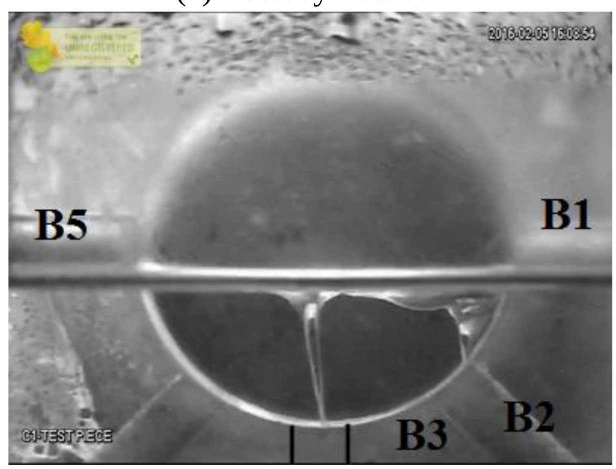
(g) Disappearance of unsteady flow at B2



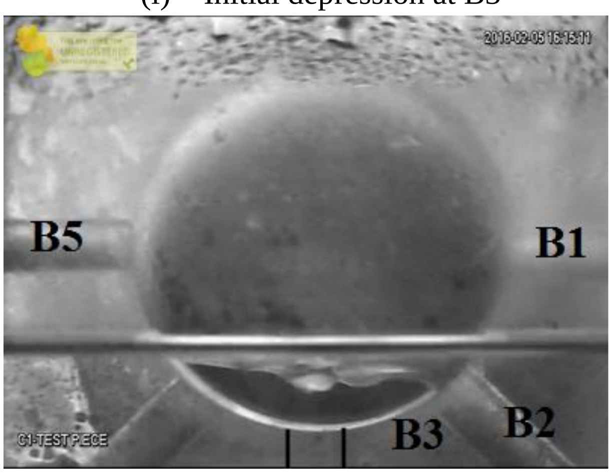
(h) Steady flow at B2



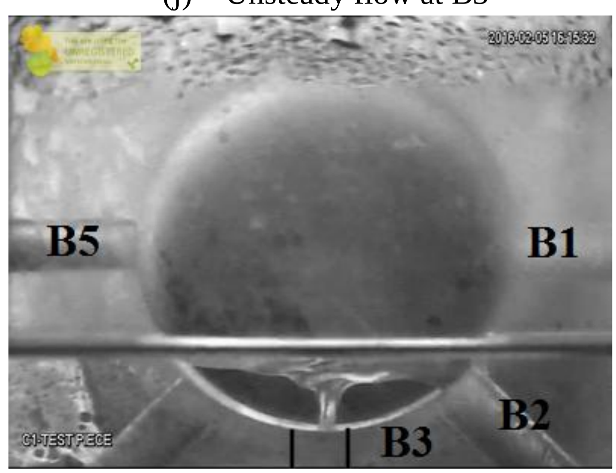
(i) Initial depression at B3



(j) Unsteady flow at B3

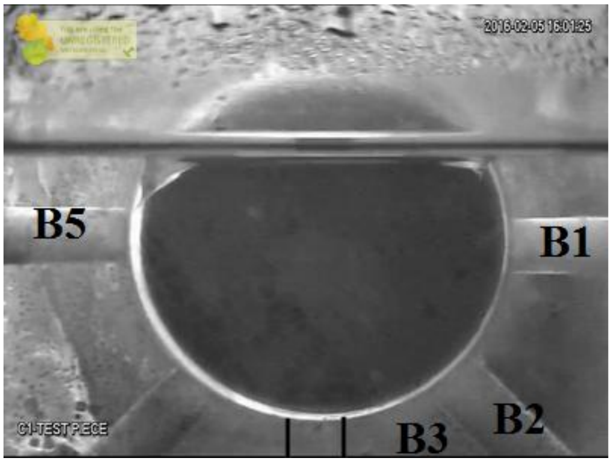


(k) Disappearance of unsteady flow at B3

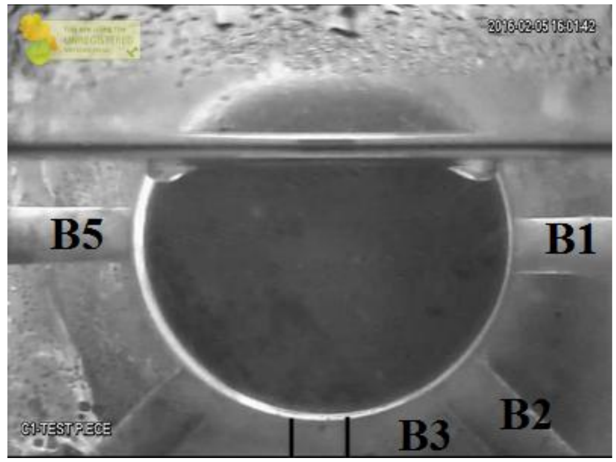


(l) Steady flow at B3

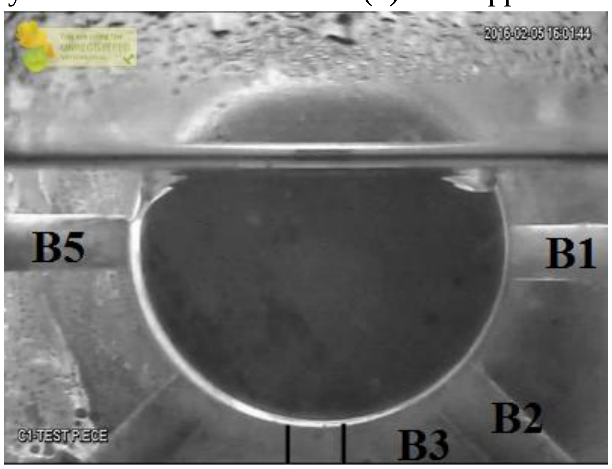
Figure D.22 : Gas entrainment phenomena of set no. 4-2.1 (cont.)



(m) Unsteady flow at B5

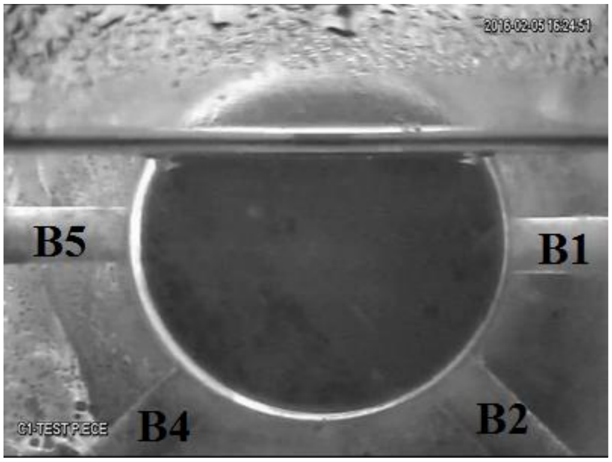


(n) Disappearance of unsteady flow at B5

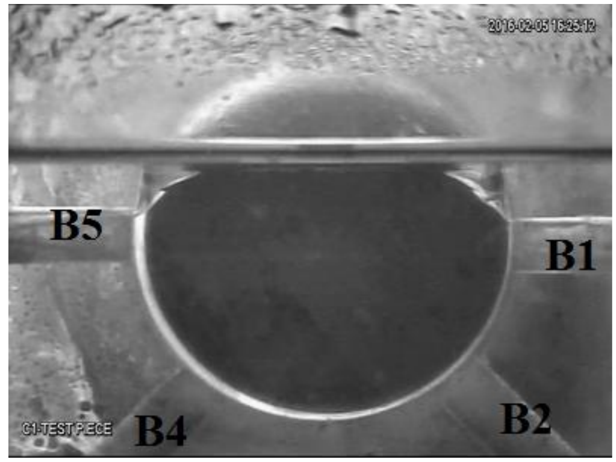


(o) Steady flow at B5

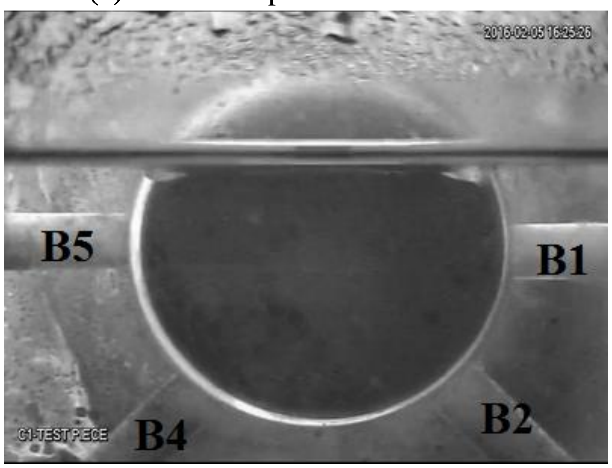
Figure D.22 : Gas entrainment phenomena of set no. 4-2.1 (cont.)



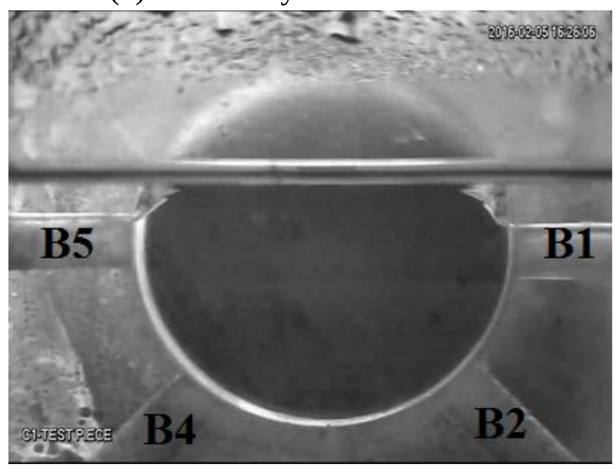
(a) Initial depression at B1 and B5



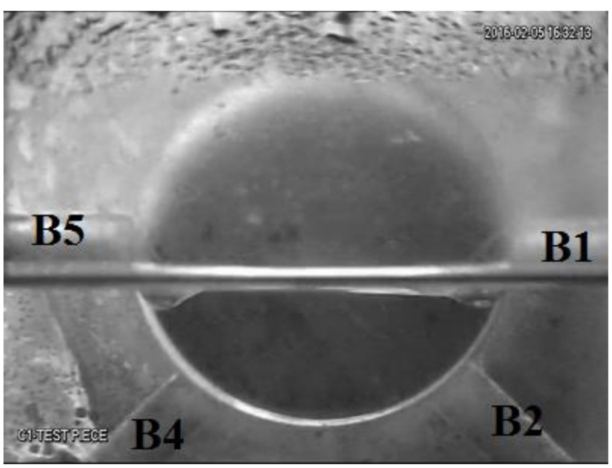
(b) Unsteady flow at B1 and B5



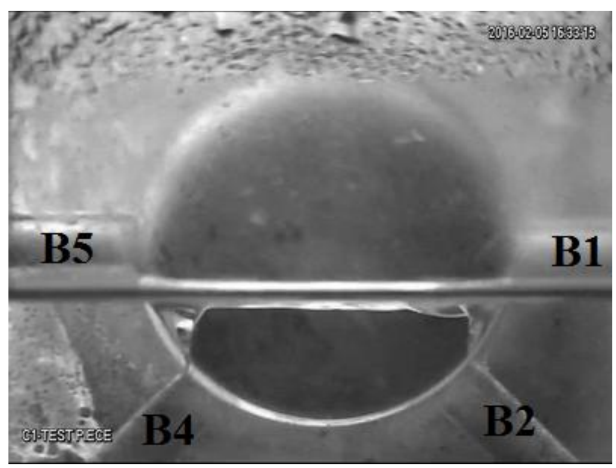
(c) Disappearance of unsteady flow at B1 and B5



(d) Steady flow at B1 and B5

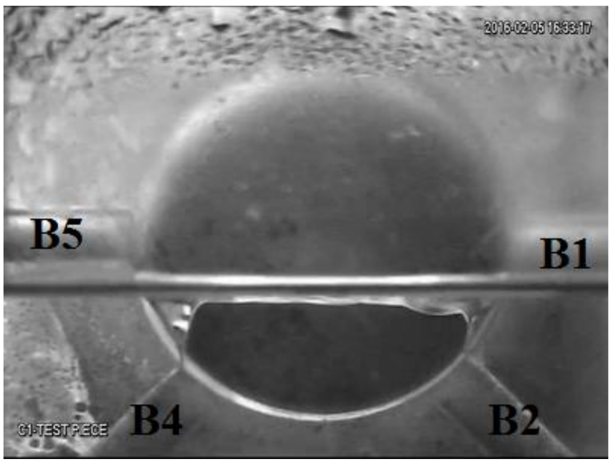


(e) Initial depression at B2 and B4

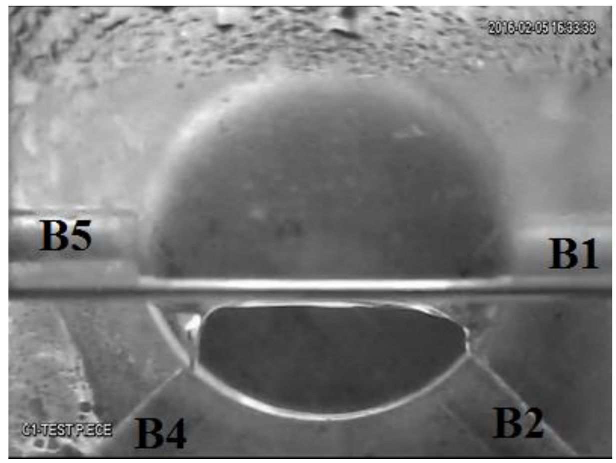


(f) Unsteady flow at B2

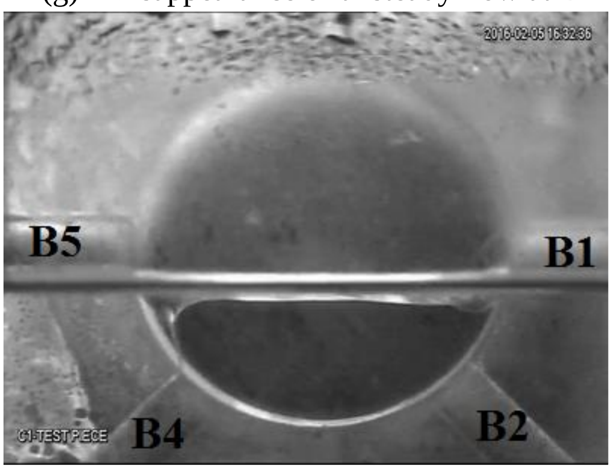
Figure D.23 : Gas entrainment phenomena of set no. 4-3.1



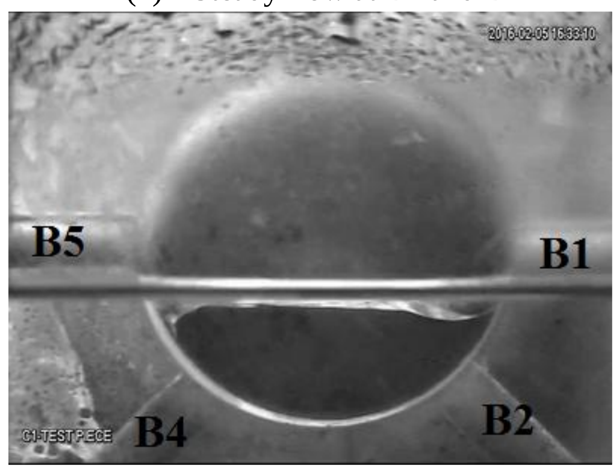
(g) Disappearance of unsteady flow at B2



(h) Steady flow at B2 and B4

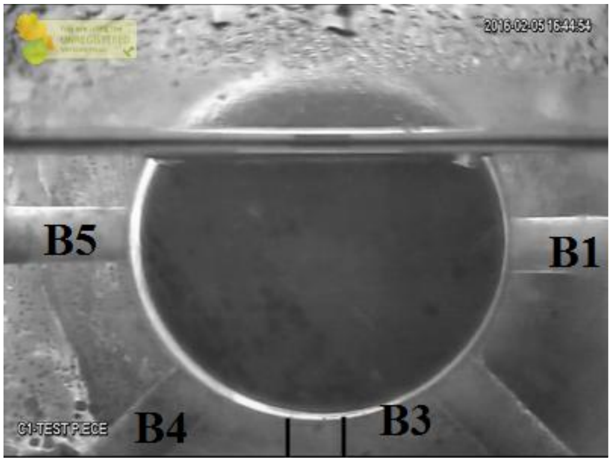


(i) Unsteady flow at B4

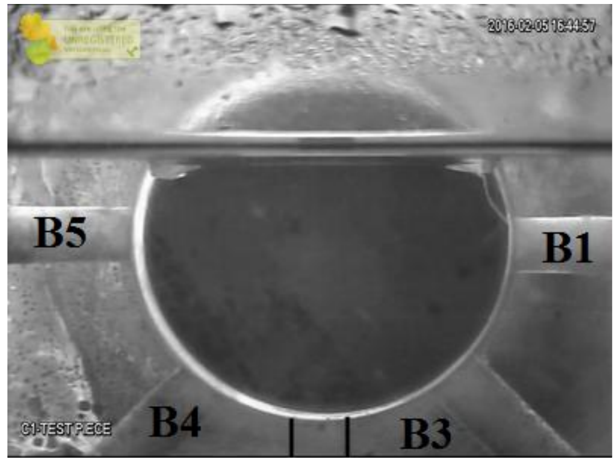


(j) Disappearance of unsteady flow at B4

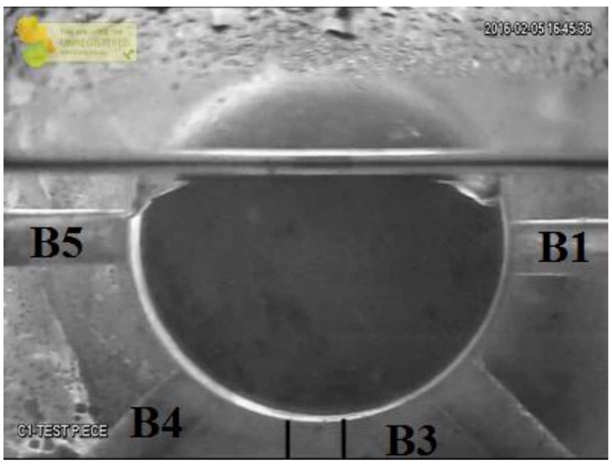
Figure D.23 : Gas entrainment phenomena of set no. 4-3.1 (cont.)



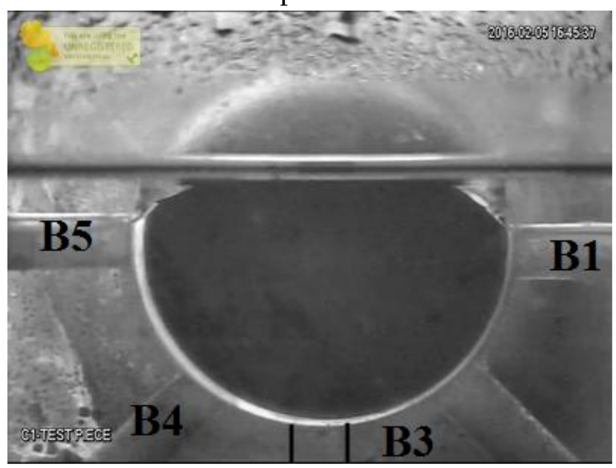
(a) Initial depression at B1



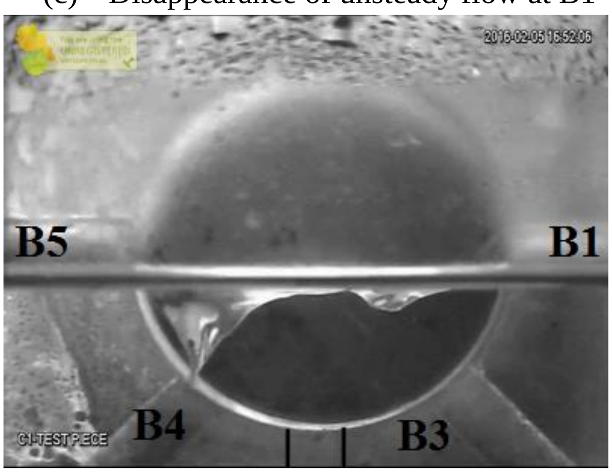
(b) Unsteady flow at B1 and Initial depression at B5



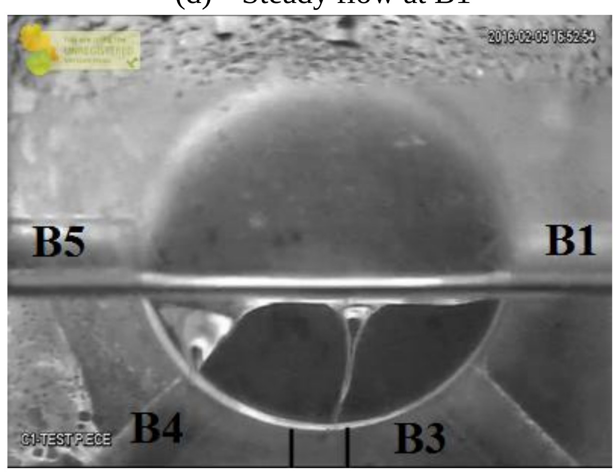
(c) Disappearance of unsteady flow at B1



(d) Steady flow at B1

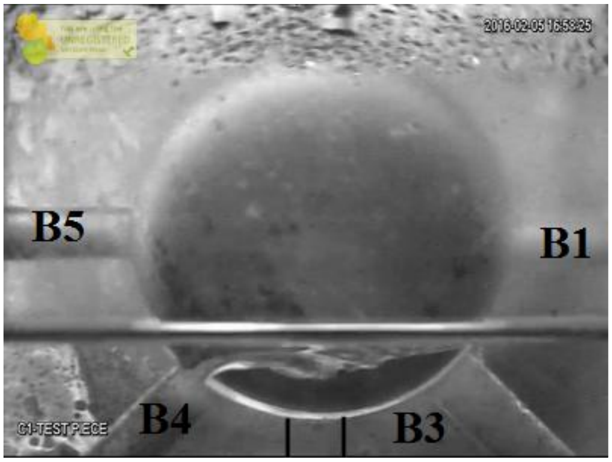


(e) Initial depression at B3

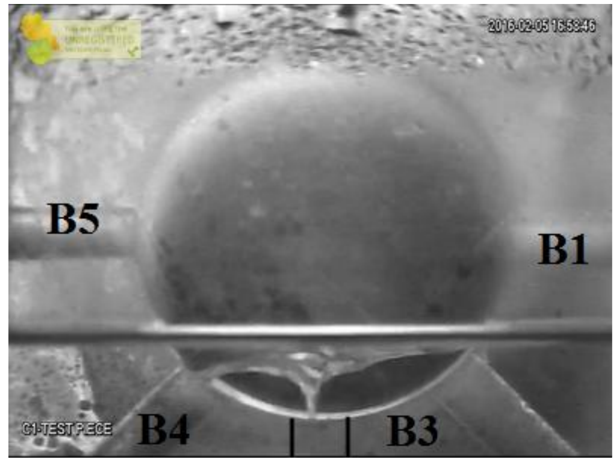


(f) Unsteady flow at B3

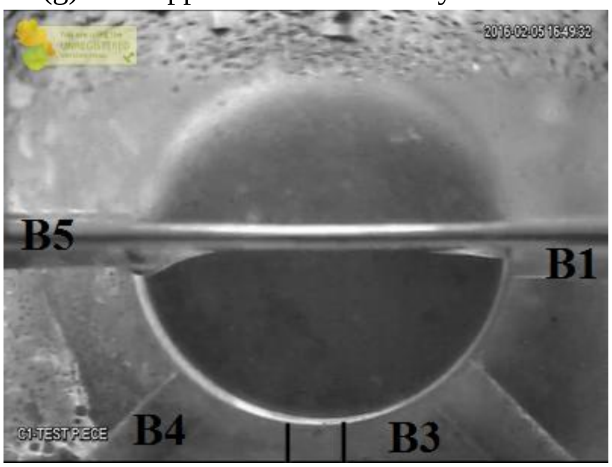
Figure D.24 : Gas entrainment phenomena of set no. 4-4.1



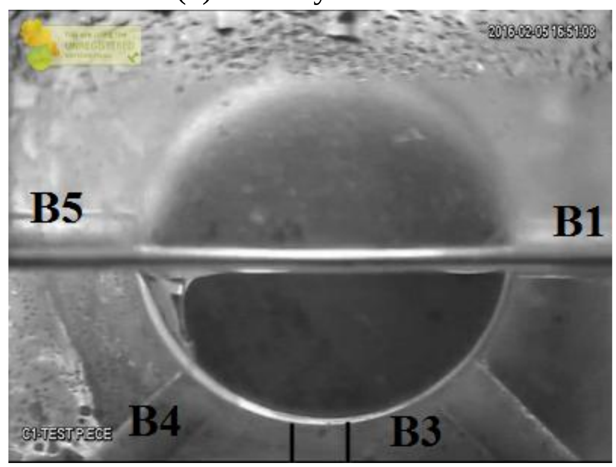
(g) Disappearance of unsteady flow at B3



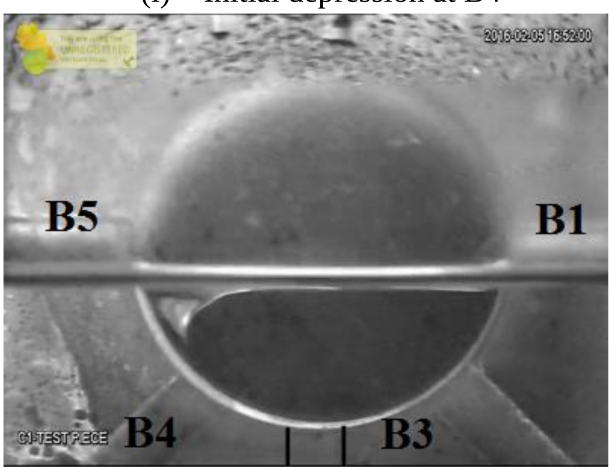
(h) Steady flow at B3



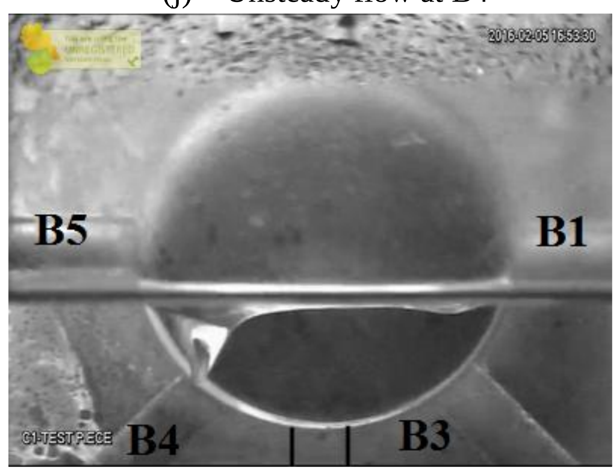
(i) Initial depression at B4



(j) Unsteady flow at B4

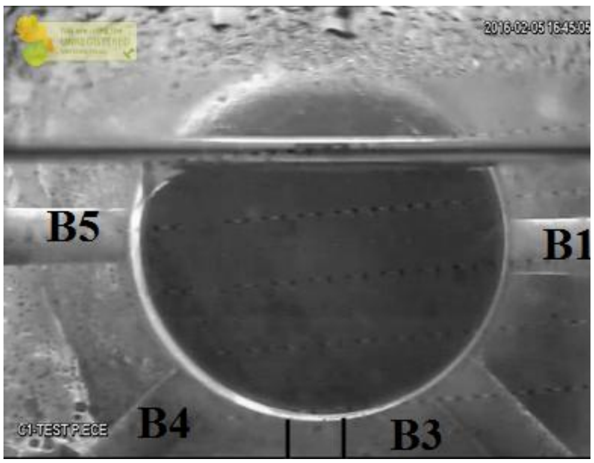


(k) Disappearance of unsteady flow at B4

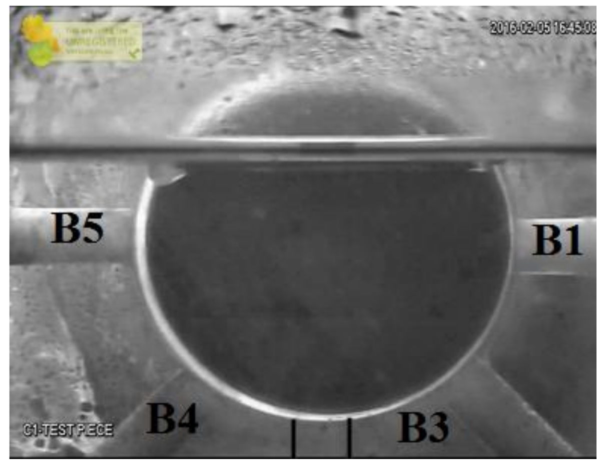


(l) Steady flow at B4

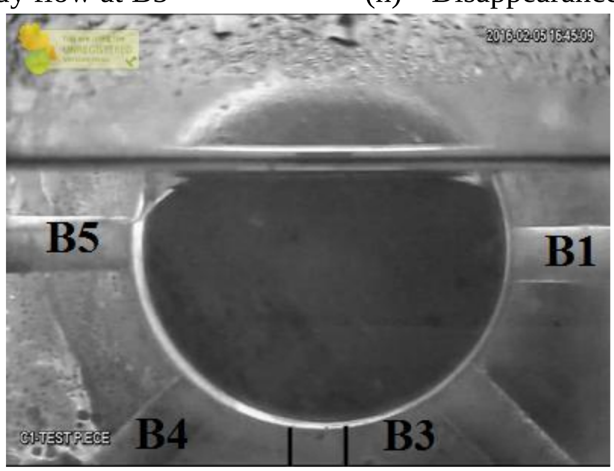
Figure D.24 : Gas entrainment phenomena of set no. 4-4.1 (cont.)



(m) Unsteady flow at B5

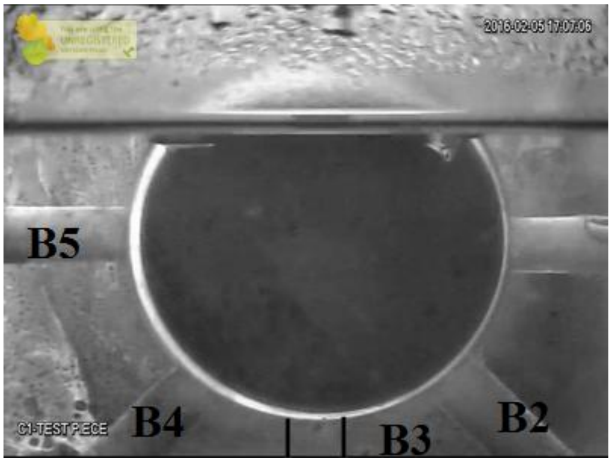


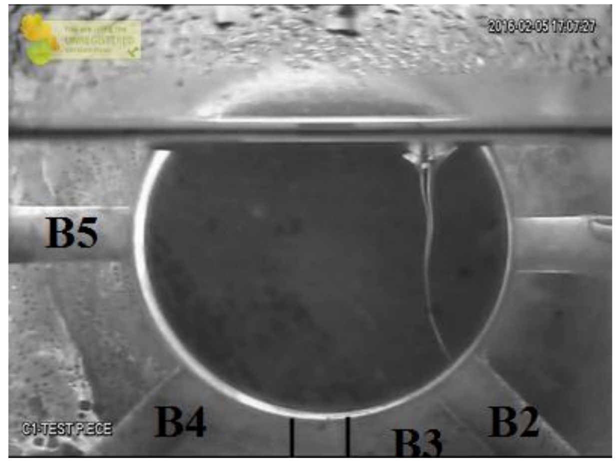
(n) Disappearance of unsteady flow at B5



(o) Steady flow at B5

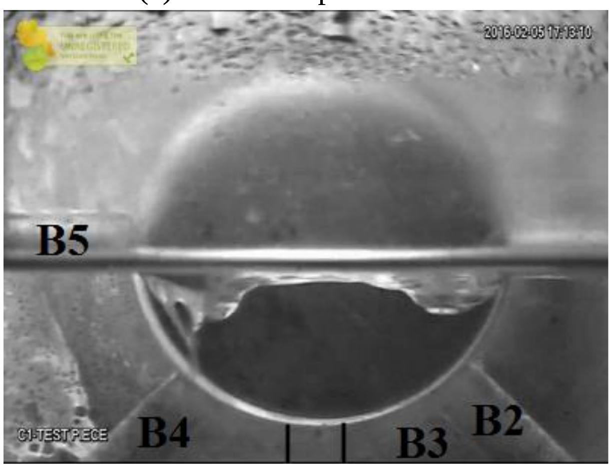
Figure D.24 : Gas entrainment phenomena of set no. 4-4.1 (cont.)

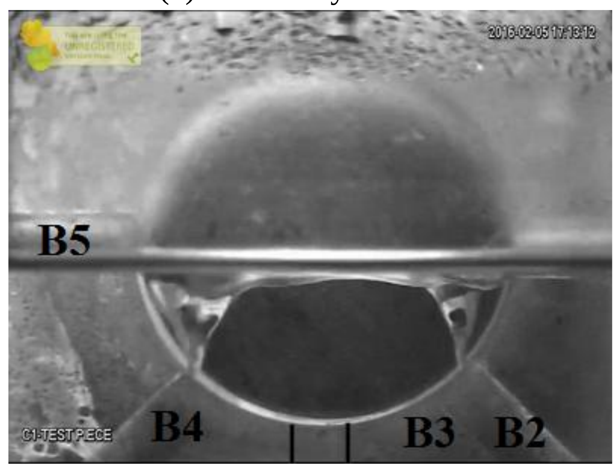




(a) Initial depression at B2

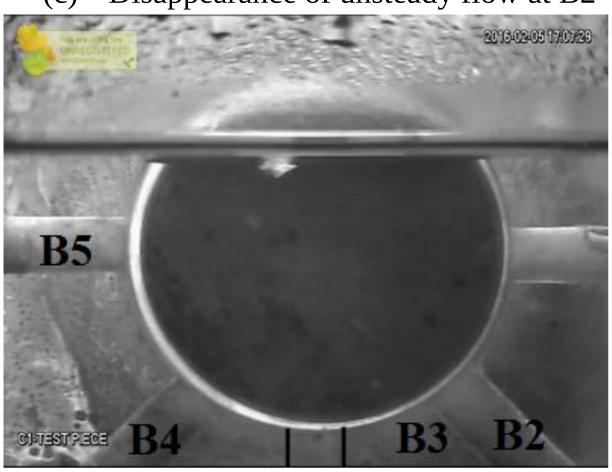
(b) Unsteady flow at B2

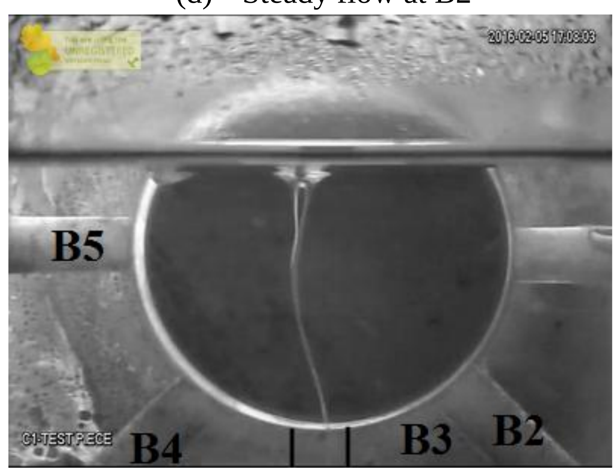




(c) Disappearance of unsteady flow at B2

(d) Steady flow at B2

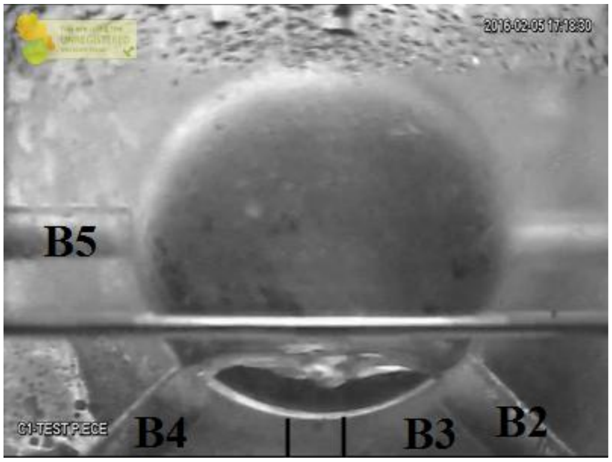




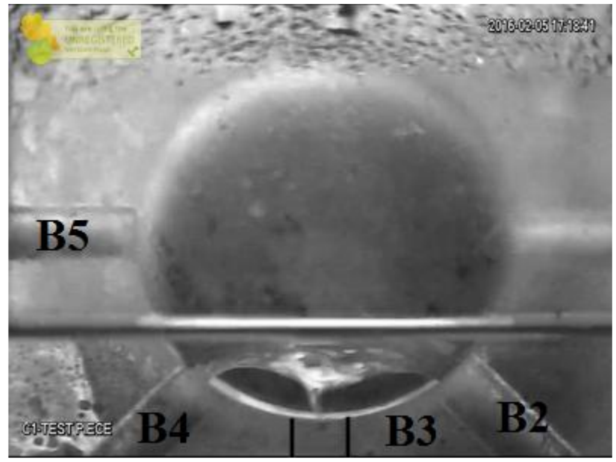
(e) Initial depression at B3

(f) Unsteady flow at B3

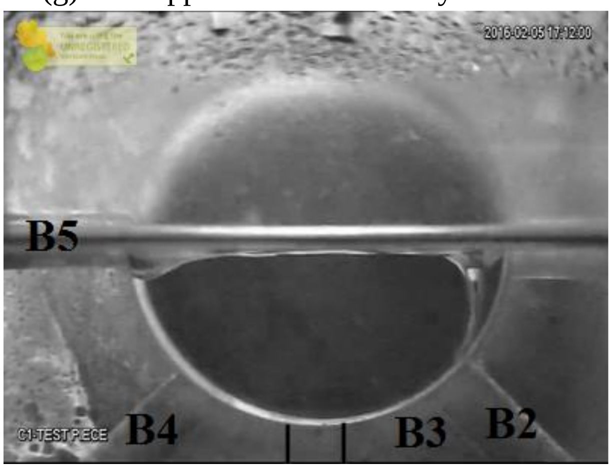
Figure D.25 : Gas entrainment phenomena of set no. 4-5.1



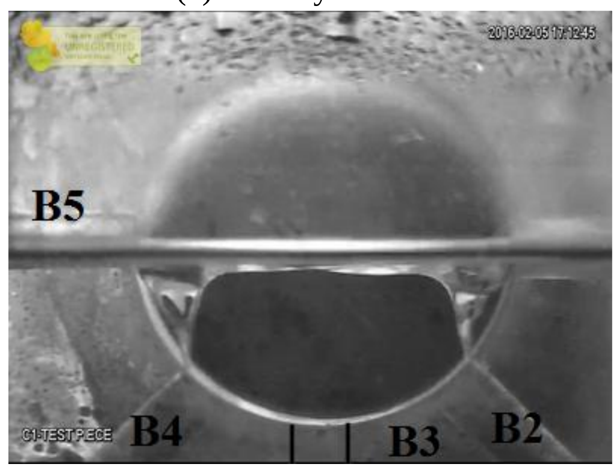
(g) Disappearance of unsteady flow at B3



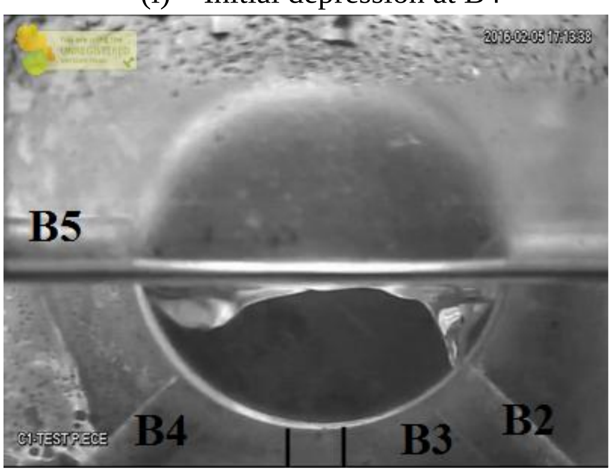
(h) Steady flow at B3



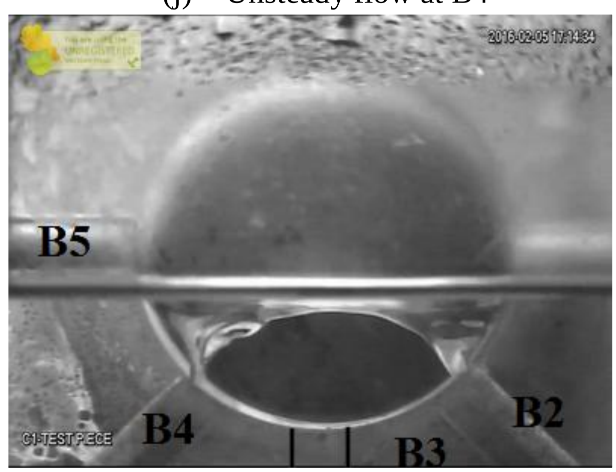
(i) Initial depression at B4



(j) Unsteady flow at B4

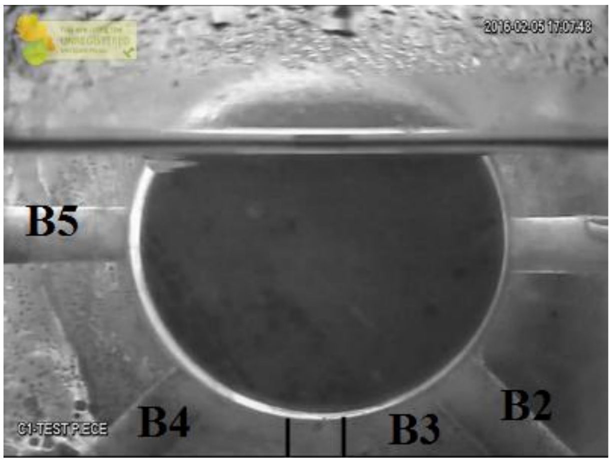


(k) Disappearance of unsteady flow at B4

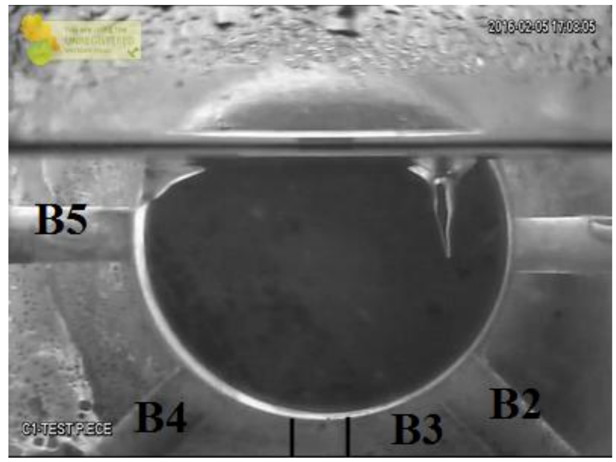


(l) Steady flow at B4

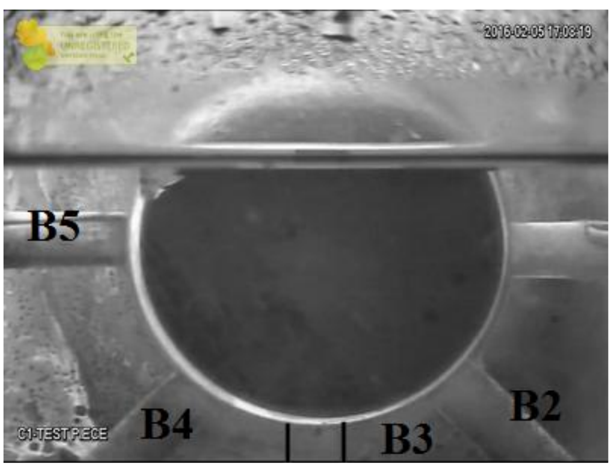
Figure D.25 : Gas entrainment phenomena of set no. 4-5.1 (cont.)



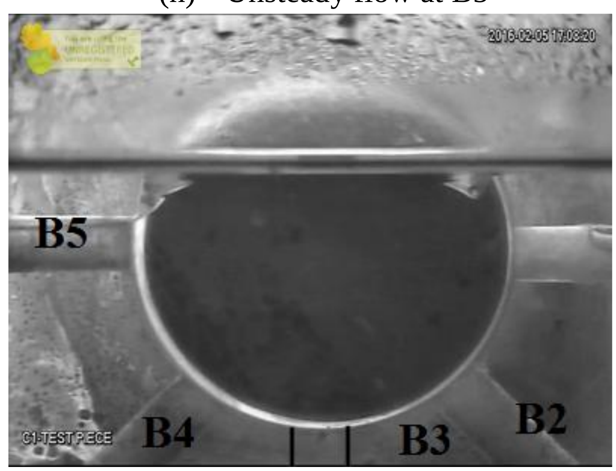
(m) Initial depression at B5



(n) Unsteady flow at B5



(o) Disappearance of unsteady flow at B5



(p) Steady flow at B5

Figure D.25 : Gas entrainment phenomena of set no. 4-5.1 (cont.)