APPENDIX A. BUBBLE RISE VELOCITY IN STILL WATER

When air bubbles are entrained in water, a net upward force (i.e. buoyancy) is exerted on them. Buoyancy is the vertical force caused by the pressure difference between the upper and lower surfaces of the bubble. The buoyant force counteracts the pressure force and equals the weight of displaced liquid.

In still water, many researchers investigated the rise velocity of an individual air bubble in still water (e.g. CLIFT et al. 1978, COMOLET 1979b). Small air bubbles (i.e. $d_{ab} < 1$ mm) act as rigid spheres. Surface tension imposes the shape of small bubbles but the motion of these bubbles is dominated by the balance between the viscous drag force and the buoyant force. For very small bubbles (i.e. $d_{ab} < 0.1$ mm) the bubble rise velocity u_r is given by Stokes' law (e.g. STREETER and WYLIE 1981) :

$$u_r = \frac{2}{9} * \frac{g * (\rho_w - \rho_{air})}{\mu_w} * d_{ab}^2 \qquad (d_{ab} < 0.1 \text{ mm}) \quad \text{(A-1)}$$

where u_r is the bubble rise velocity, g is the gravity acceleration, ρ_w is the water density, ρ_{air} is the air density, μ_w is the dynamic viscosity of water and d_{ab} is the bubble diameter. For small rigid spherical bubbles (i.e. $0.1 < d_{ab} < 1$ mm), the rise velocity is best fitted by (COMOLET 1979a) :

$$u_r = \frac{g * \rho_w}{18 * \mu_w} * d_{ab}^2 \qquad (0.1 < d_{ab} < 1 \text{ mm}) \quad \text{(A-2)}$$

where σ is the surface tension between air and water. When the fluid viscosity may be neglected (i.e. $d_{ab} > 1$ mm), COMOLET (1979b) showed that the bubble rise velocity can be estimated as :

$$u_r = \sqrt{\frac{2.14 * \sigma}{\rho_w * d_{ab}} + 0.52 * g * d_{ab}} \qquad (d_{ab} > 1 \text{ mm}) \quad \text{(A-3)}$$

Discussion

The velocity of a single bubble rising in still water was calculated using the above equations and the measured water properties (Table 2-2). The results collapse almost into one curve showing little difference in rise velocity for the investigated water solutions (Fig. A-1). Quantitative values are summarised in Table A-1. They suggest smaller rise velocities of very-small air bubbles ($d_{ab} < 0.1$ to 0.5 mm) in saltwater and seawater than in freshwater.

CHANSON (1997) discussed specifically the bubble rise velocity in a non-hydrostatic pressure distribution. He reviewed also the effects of turbulence on the rise velocity. Most studies suggested that high-level of turbulence would retard the bubble rise resulting in smaller rise velocities than in still water.

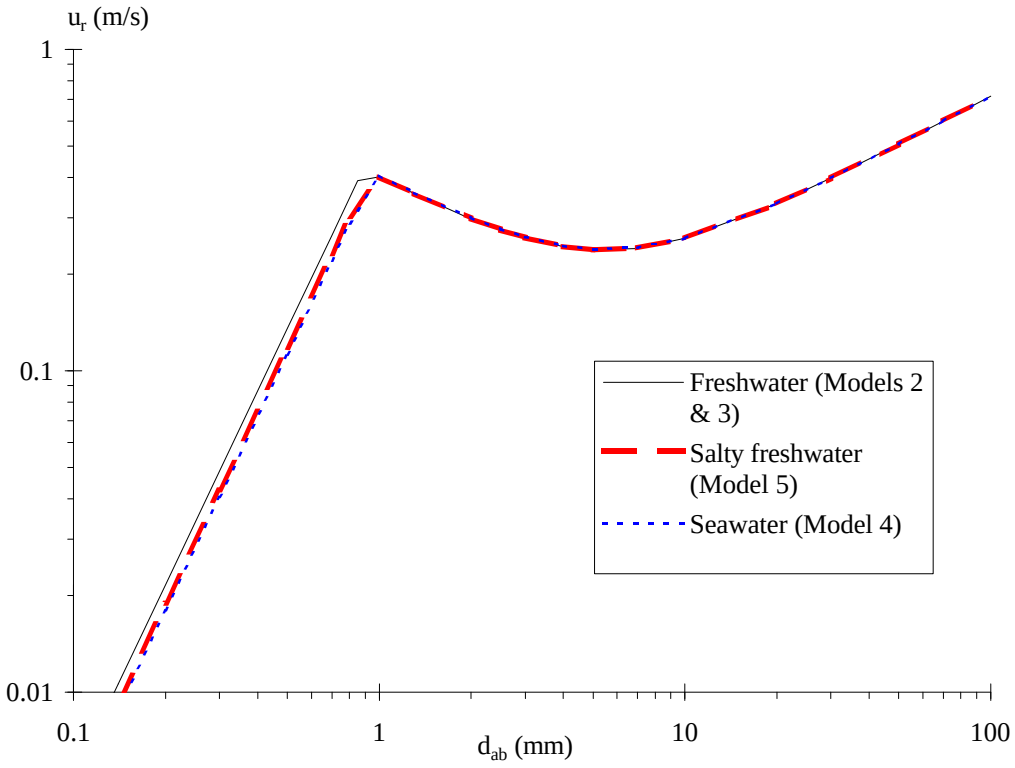
Table A-1 - Calculated rise velocity of individual air bubble in freshwater, salty freshwater and seawater

d_{ab} (mm)	u_r (m/s)		
	Freshwater Models 2 & 3	Saltwater Model 5	Seawater Model 4
(1)	(2)	(3)	(4)
0.1	0.0054	0.0047	0.0045
0.5	0.135	0.118	0.112
1	0.402	0.402	0.405
2	0.297	0.298	0.299
5	0.238	0.238	0.239
10	0.258	0.258	0.259
20	0.331	0.331	0.332

Note : Based upon measured fluid properties reported in Table 2-2

Fig. A-1 - Bubble rise velocity of a single bubble in freshwater, salty freshwater and seawater

Legend : solid line = freshwater, long-dashed line = salty freshwater, short-dashed line = seawater



APPENDIX B. EXPERIMENTAL DATA : VOID FRACTIONS AND BUBBLE COUNT RATES

Table B-1 - Summary of air-water flow measurements in vertical circular plunging jets

Run	V_1	Fr_1	$\frac{x-x_1}{r_1}$	$\frac{Y_{Cmax}}{r_1}$	C_{max}	$\frac{Y_{Fmax}}{r_1}$	$\frac{F_{max}*r_1}{V_1}$	Remarks
	m/s							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Model 1								Freshwater.
BM35_1	3.5	7.22	1.67	1.08	0.23	1.07	0.32	
			2.51	1.18	0.16	1.12	0.23	
			4.18	1.18	0.08	1.19	0.16	
BM4_2	4.1	8.41	1.65	1.11	0.36	1.05	0.38	
			2.48	1.20	0.23	1.09	0.29	
			4.13	1.25	0.19	1.14	0.23	
BM44_2	4.4	9.00	1.64	1.11	0.39	1.06	0.42	
			2.46	1.17	0.27	1.08	0.34	
			4.11	1.27	0.19	1.17	0.26	
Model 2								Freshwater
Cir_2	2.42	7.07	1.67	*1.22*	*0.21*	*1.15*	*0.32*	
			2.51	*1.24*	*0.11*	*1.19*	*0.18*	
			4.19	1.38	0.06	1.32	0.11	
Cir_4	3.04	8.81	1.65	1.09	0.33	1.01	0.40	
			2.47	1.12	0.22	1.04	0.30	
			4.11	1.24	0.13	1.14	0.18	
Cir_5	3.18	9.20	1.64	1.10	0.36	1.02	0.40	
			2.46	1.14	0.22	1.04	0.32	
			4.10	1.25	0.15	1.10	0.24	
Cir_6	3.46	9.98	1.63	1.12	**0.53**	1.03	**0.45**	
			2.45	1.05	**0.42**	1.05	0.25	
			4.09	1.29	**0.31**	1.10	0.20	
Model 4								Seawater
Sea_2	2.46	7.19	1.67	*1.13*	*0.15*	*1.08*	*0.21*	
			2.51	*1.05*	*0.07*	*1.25*	*0.11*	
			4.18	1.24	0.06	1.19	0.10	
Sea_4	2.87	8.34	1.65	1.13	0.22	1.08	0.28	
			4.13	1.31	0.10	1.16	0.13	
Sea_5	3.13	9.07	1.64	1.17	0.24	1.08	0.32	
			2.46	1.17	0.16	1.09	0.19	
			4.11	1.23	0.11	1.18	0.17	
Sea_6	3.36	9.70	1.64	1.18	0.25	1.08	0.31	
			2.46	1.13	0.18	1.06	0.30	
			4.09	1.26	0.11	1.21	0.17	
Model 5								Salty freshwater
Salt_5	3.12	9.04	1.64	1.14	0.32	1.07	0.40	
			2.46	1.17	0.16	1.09	0.25	
			4.11	1.22	0.12	1.09	0.20	
Model 3								Freshwater
Run-1	1.79	7.09	1.69	1.07	0.04	1.04	0.05	
			2.51	1.10	0.03	1.04	0.05	
			4.20	1.13	0.02	0.95	0.04	
Run-2	2.16	8.46	1.66	1.15	0.11	1.15	0.11	
			2.48	1.12	0.06	1.09	0.09	
			4.14	1.18	0.03	1.06	0.05	
Run-3	2.30	9.00	1.65	1.17	0.12	1.11	0.14	
			2.47	1.17	0.08	1.08	0.10	
			4.12	1.17	0.04	0.99	0.07	
Run-4	2.49	9.74	1.65	1.43	0.23	1.32	0.17	
			2.46	1.39	0.19	1.29	0.15	
			4.10	1.36	0.10	1.18	0.10	

Notes :

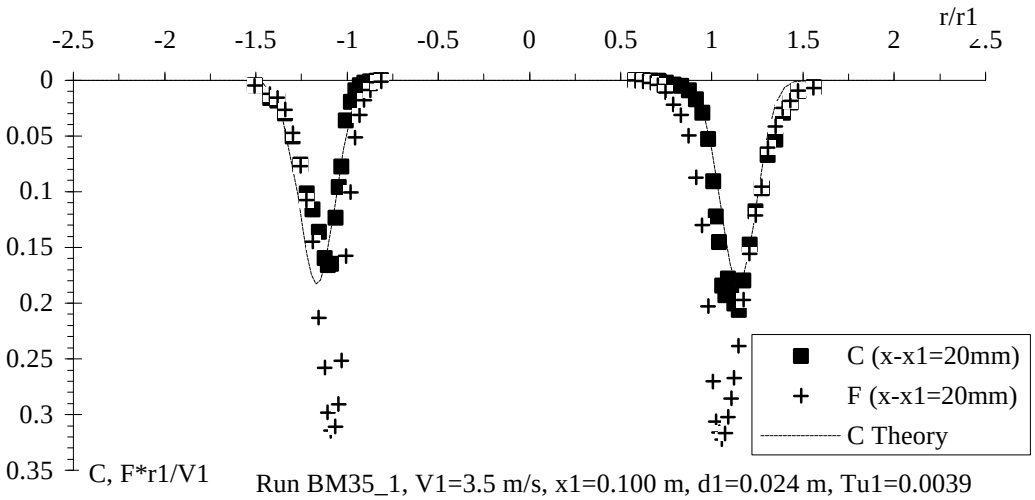
Bold data : very-suspicious experimental data;

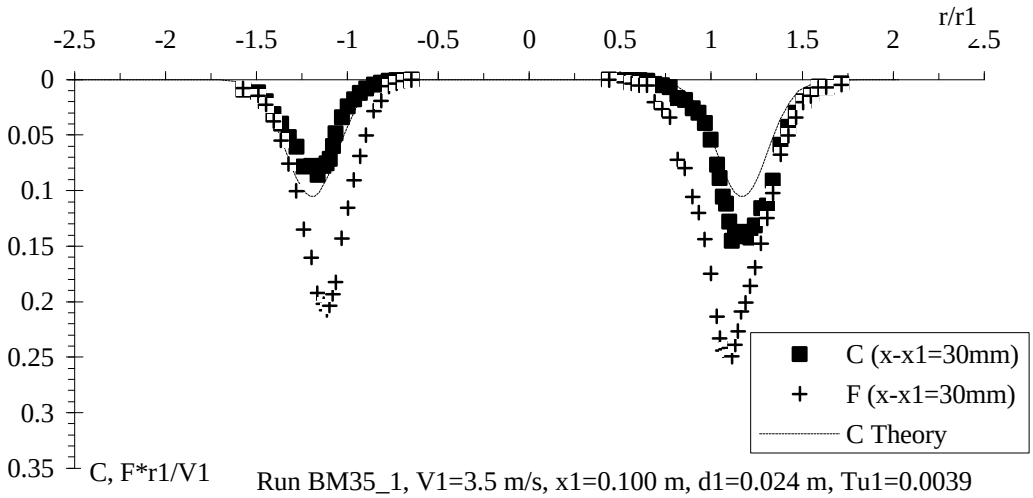
Italic data : doubtful data.

B.1 Model 1, d_0 = 25 mm, x_1 = 100 mm, Freshwater

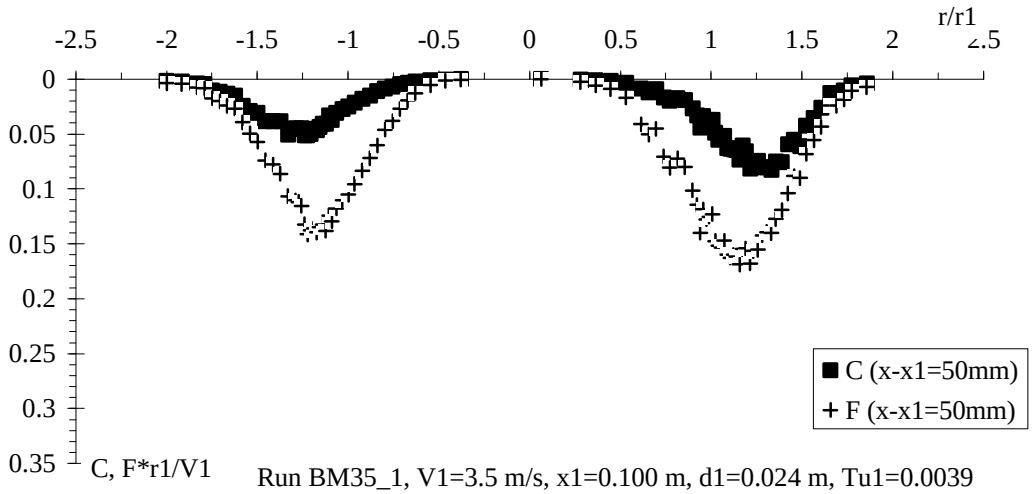
Location :	University of Queensland (Australia)
Date :	Sept. 1998 to March 1999
Experiments by :	B. BOLDEN and T. McGIBBON
Data processing by :	H. CHANSON
Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.025 m. Nozzle design : 1/2.16 contraction ratio (elliptical profile) located at the end of a 3.5 m long circular PVC pipe. Nozzle construction : aluminium. Receiving pool : height : 1.8 m, width : 0.3 m, length : 3.6 m. Water supply: constant head tank. Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.35 mm). Scanned at 2 kHz for 180 s.
Water solution :	Freshwater (tap water).
Comments :	Low turbulence inflow conditions. Quasi-uniform velocity profiles measured at 5 mm below nozzle for nozzle velocities ranging from 1 to 5 m/s. Probe built at the University of Queensland. Electronics: air bubble detector reference AS25240 (CHANSON 1988, CUMMINGS 1996).

Run BM35_1



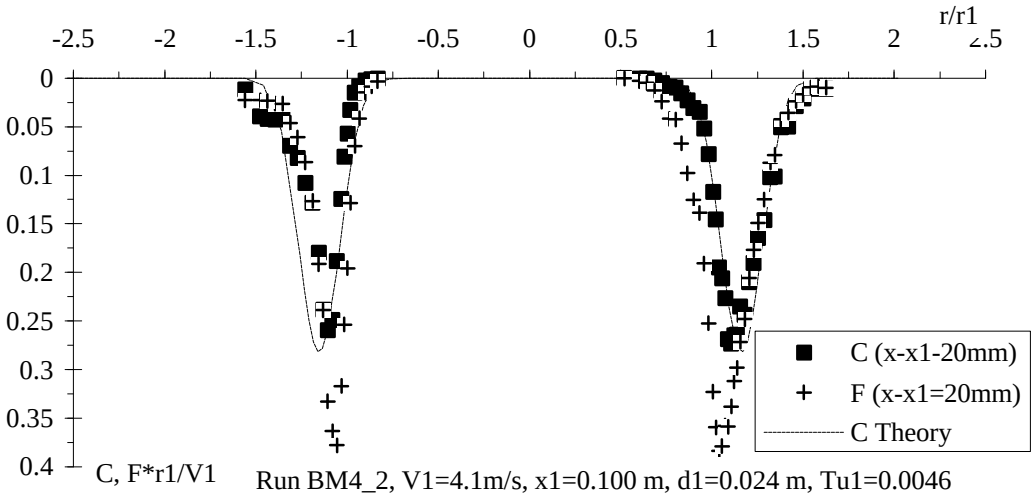


Run BM35_1, V1=3.5 m/s, x1=0.100 m, d1=0.024 m, Tu1=0.0039

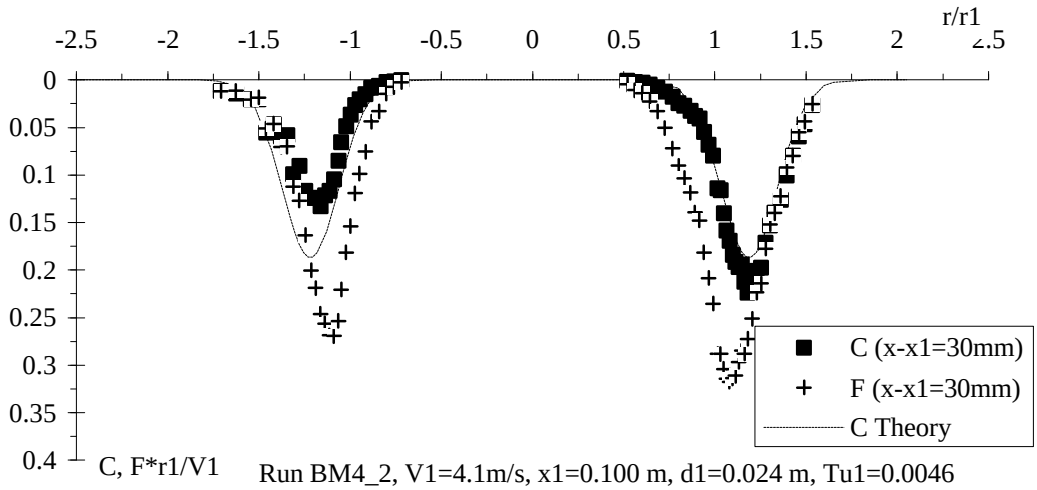


Run BM35_1, V1=3.5 m/s, x1=0.100 m, d1=0.024 m, Tu1=0.0039

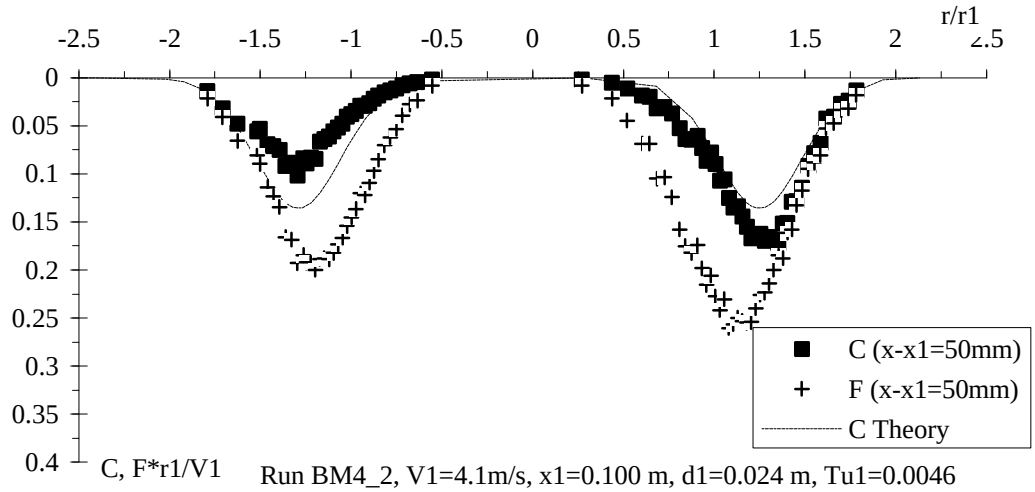
Run BM4_2



Run BM4_2, V1=4.1m/s, x1=0.100 m, d1=0.024 m, Tu1=0.0046

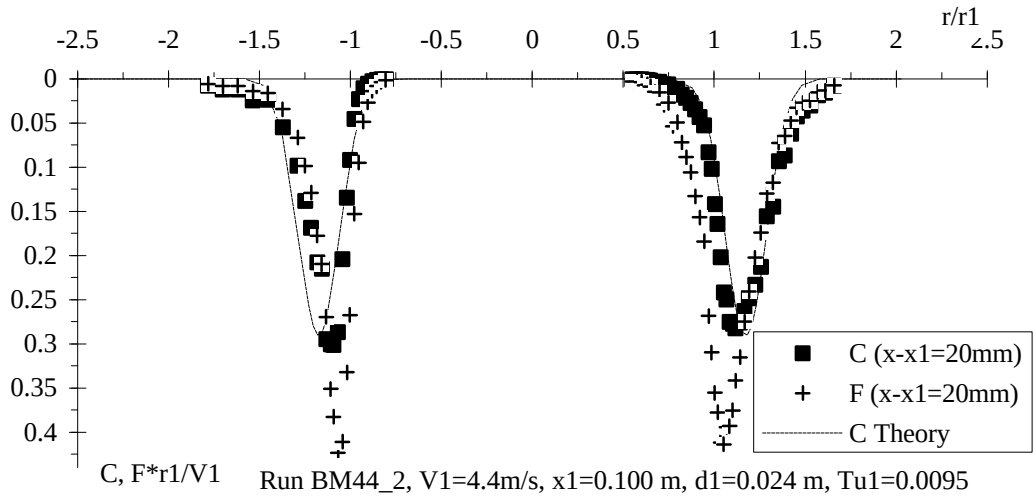


Run BM4_2, V1=4.1m/s, x1=0.100 m, d1=0.024 m, Tu1=0.0046

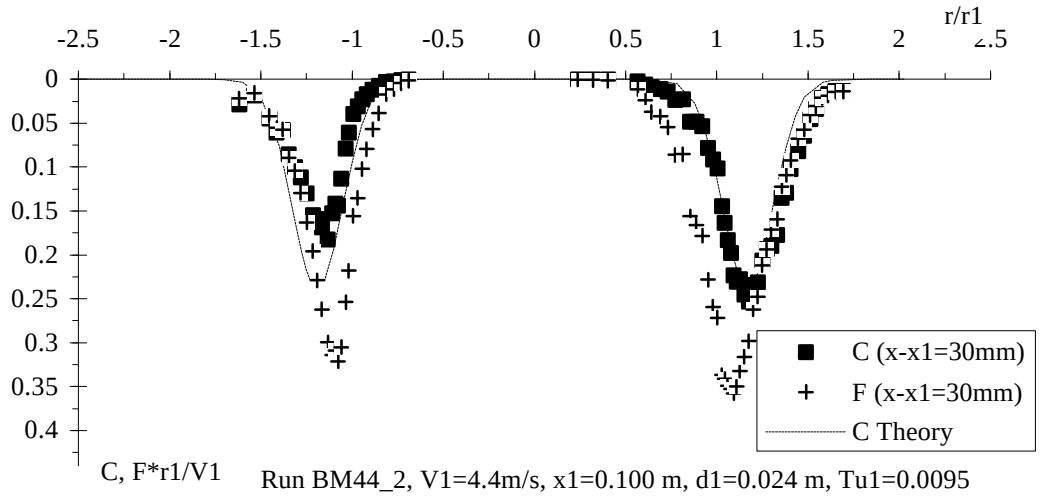


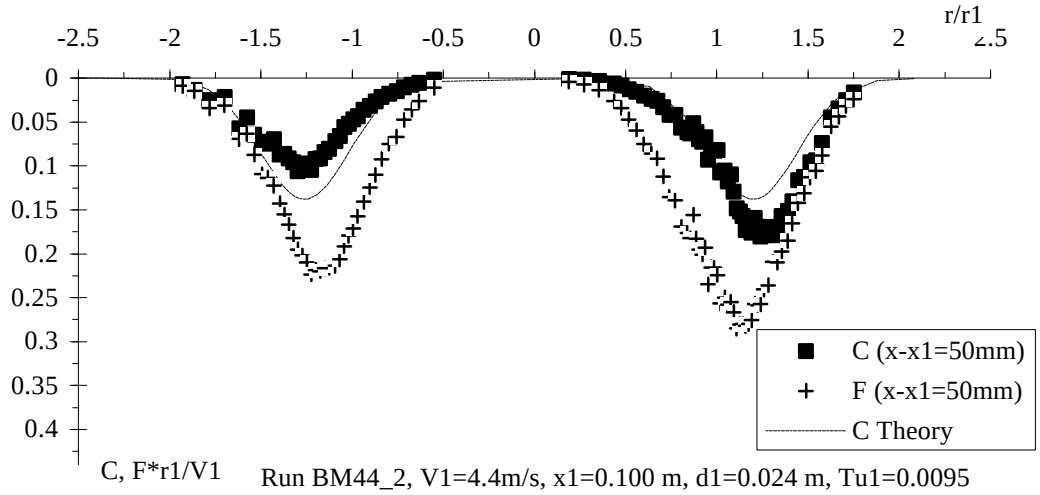
Run BM4_2, V1=4.1m/s, x1=0.100 m, d1=0.024 m, Tu1=0.0046

Run BM44_2



Run BM44_2, V1=4.4m/s, x1=0.100 m, d1=0.024 m, Tu1=0.0095

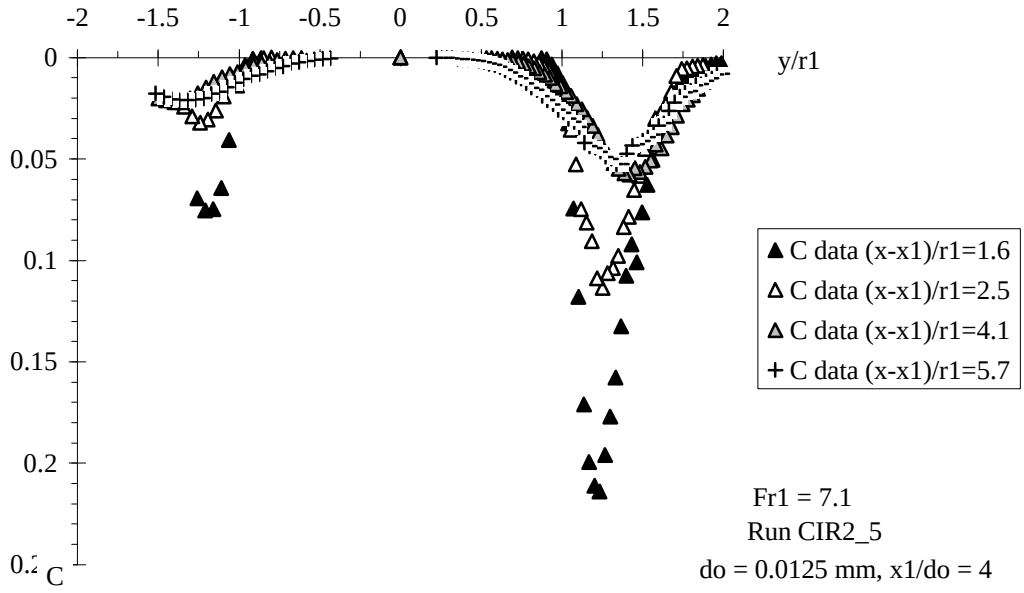




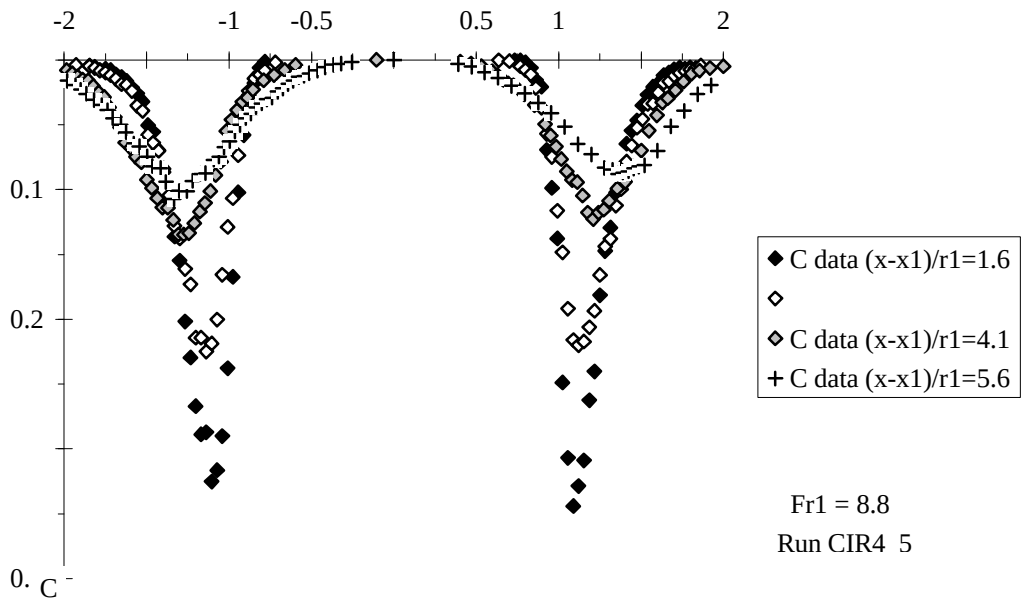
B.2 Model 2, d_0 = 12.5 mm, x_1 = 50 mm, Freshwater

Location :	Toyohashi University of Technology (Japan)
Date :	Jan. 2001 to Nov. 2001
Experiments by :	IWATA, A. HOQUE and KIDA
Data processing by :	A. HOQUE and H. CHANSON
Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0125 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Water supply: pump(s). Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Electronics analog output. Scanned for 300 s.
Water solution :	Freshwater (tap water).
Comments :	Kanomax™ conductivity probe system.

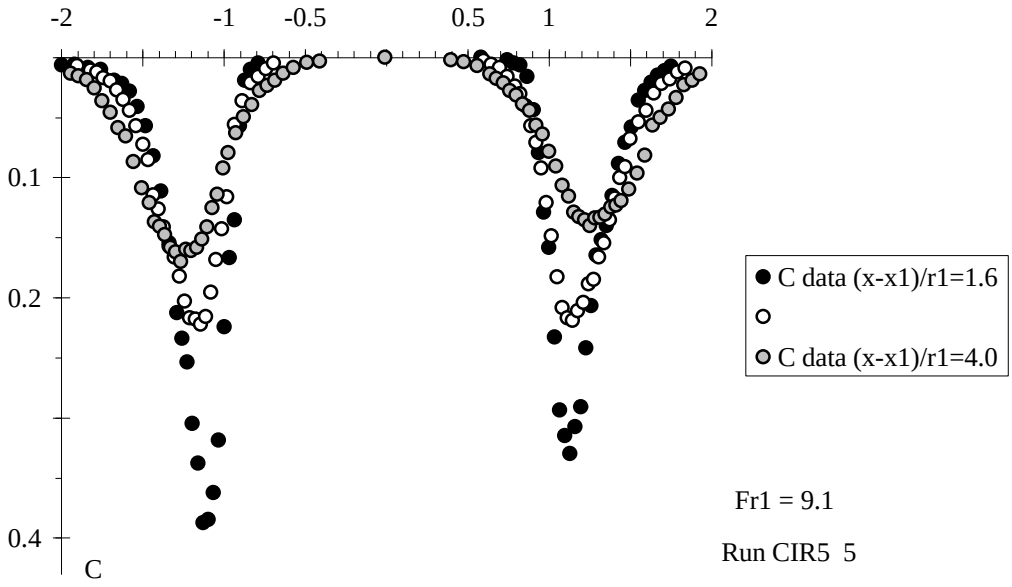
Run Cir_2



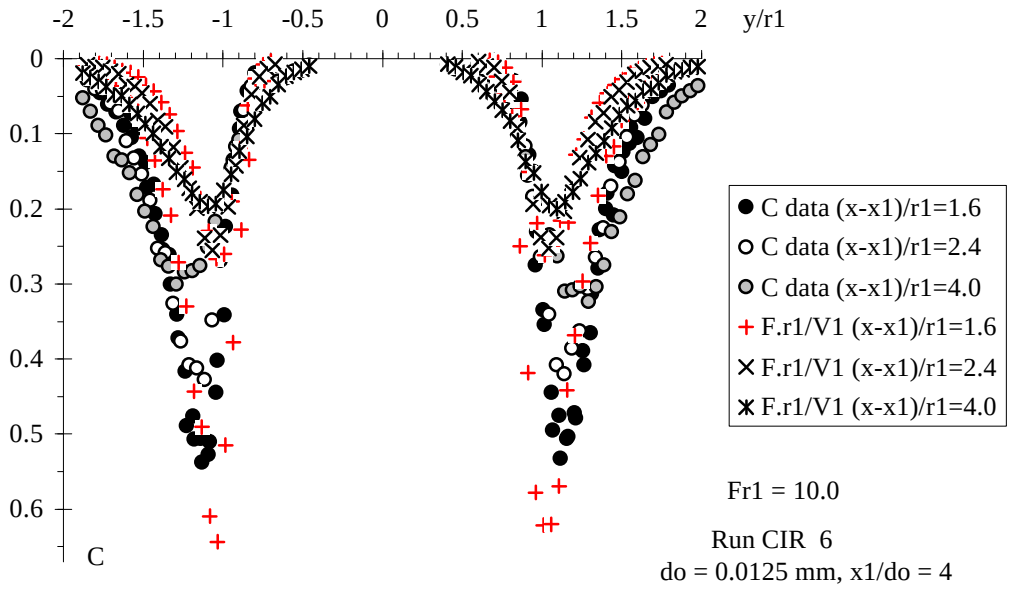
Run Cir_4



Run Cir_5



Run Cir_6

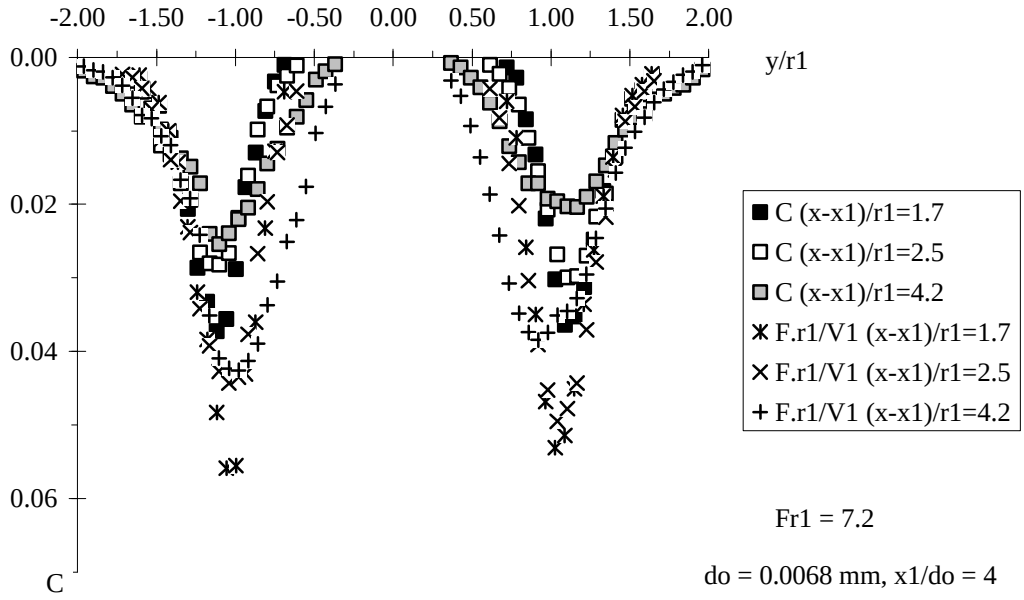


B.3 Model 3, d_0 = 6.83 mm, x_1 = 0.0273 mm, Freshwater

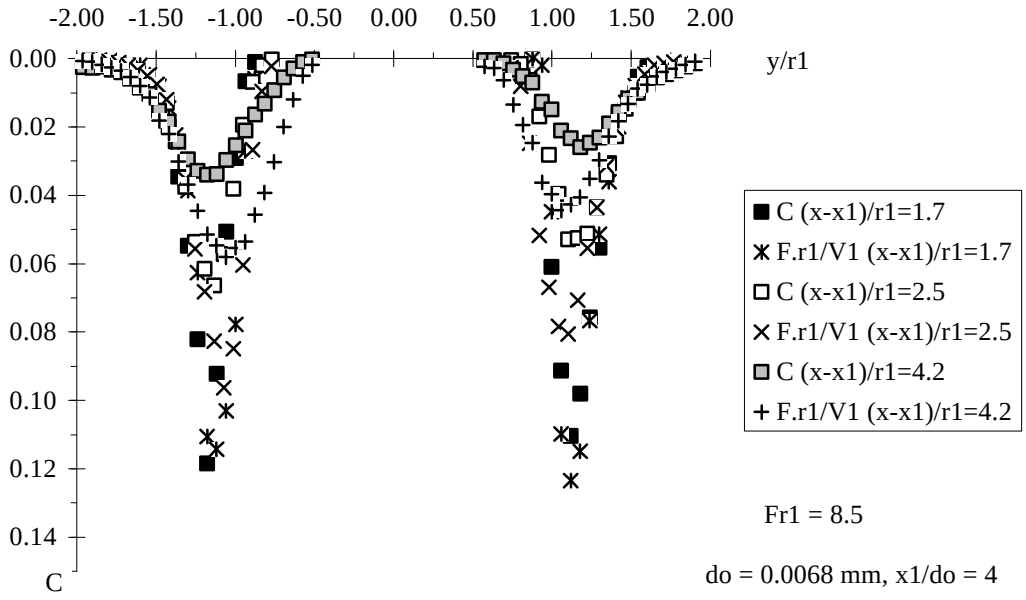
Location :	Toyohashi University of Technology (Japan)
Date :	Oct. 2001 to Nov. 2001
Experiments by :	IWATA and KIDA
Data processing by :	H. CHANSON

Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0273 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Water supply: pump(s). Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Electronics analog output. Scanned for 300 s.
Water solution :	Freshwater (tap water).
Comments :	Kanomax™ conductivity probe system.

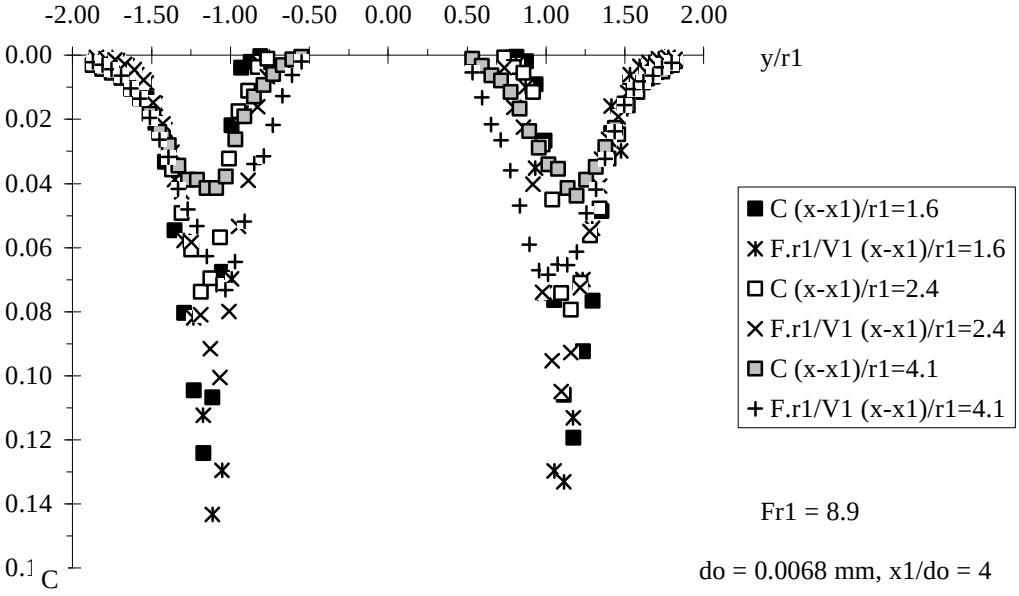
Run Run-1



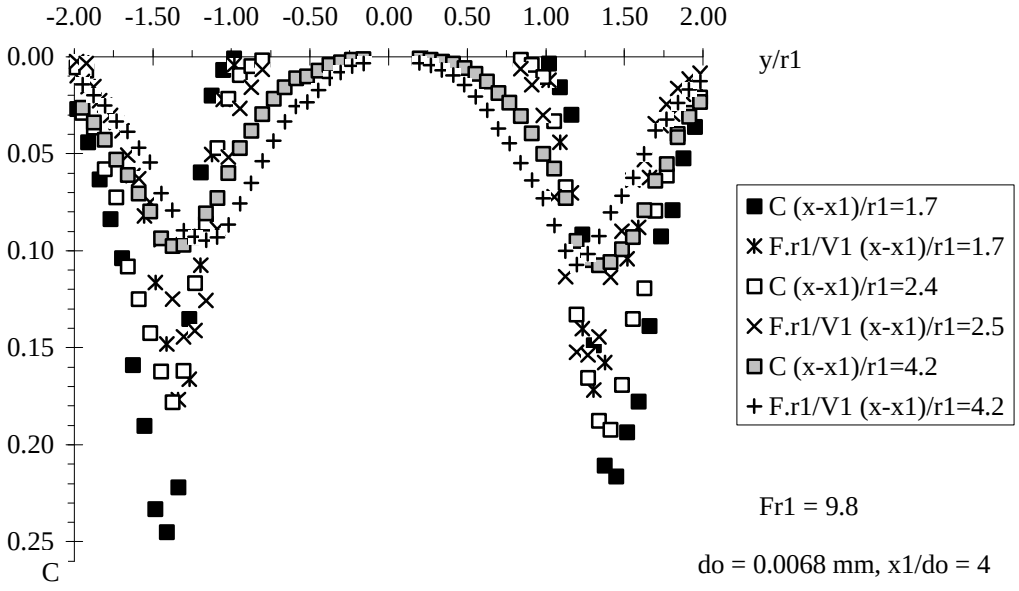
Run Run-2



Run Run-3



Run Run-4

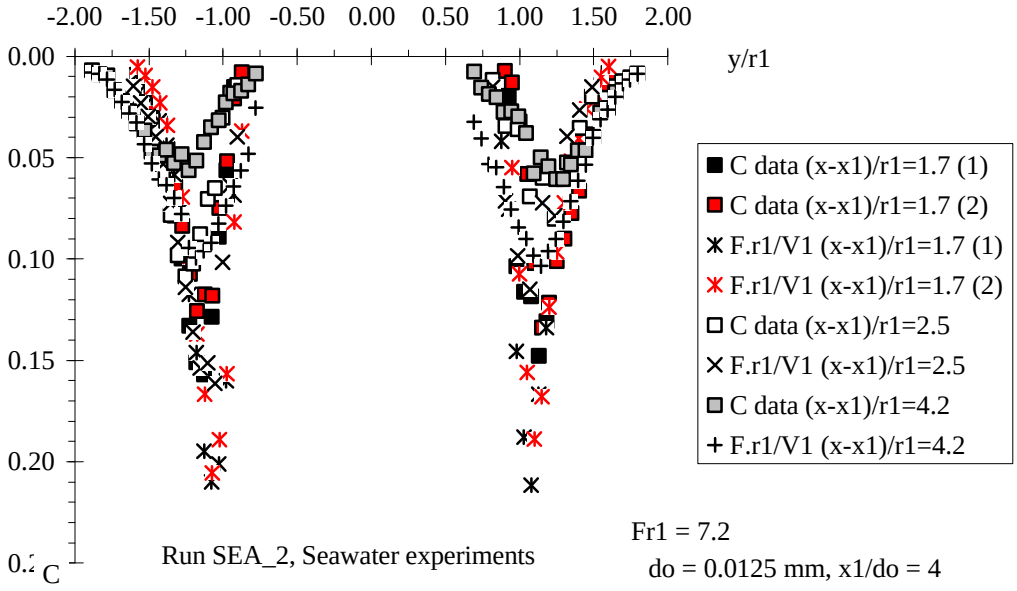


B.4 Model 4, d_0 = 12.5 mm, x_1 = 50 mm, Seawater

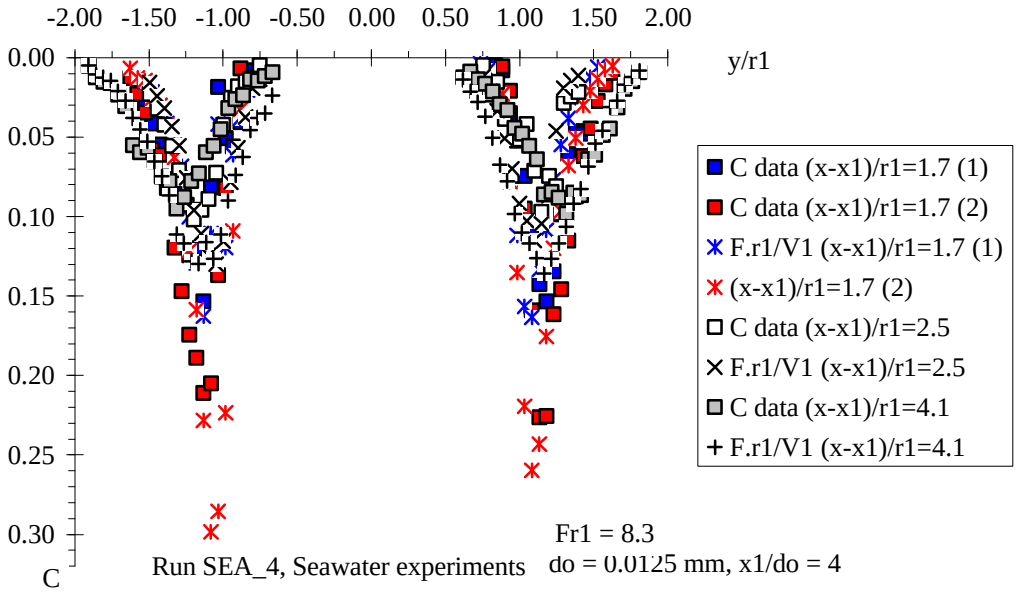
Location :	Toyohashi University of Technology (Japan)
Date :	Oct. 2001 to Nov. 2001
Experiments by :	IWATA and KIDA
Data processing by :	H. CHANSON

Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0125 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Water supply: pump(s). Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Electronics analog output. Scanned for 40 s.
Water solution :	Seawater collected off breaker zone by a group of surfers on the Enshu coast, Pacific Ocean (Terasawa beach) and once from a fishing boat off Akabane harbour.
Comments :	Very clear seawater. Seawater sediment coarse material was filtered prior to experiments. Kanomax™ conductivity probe system.

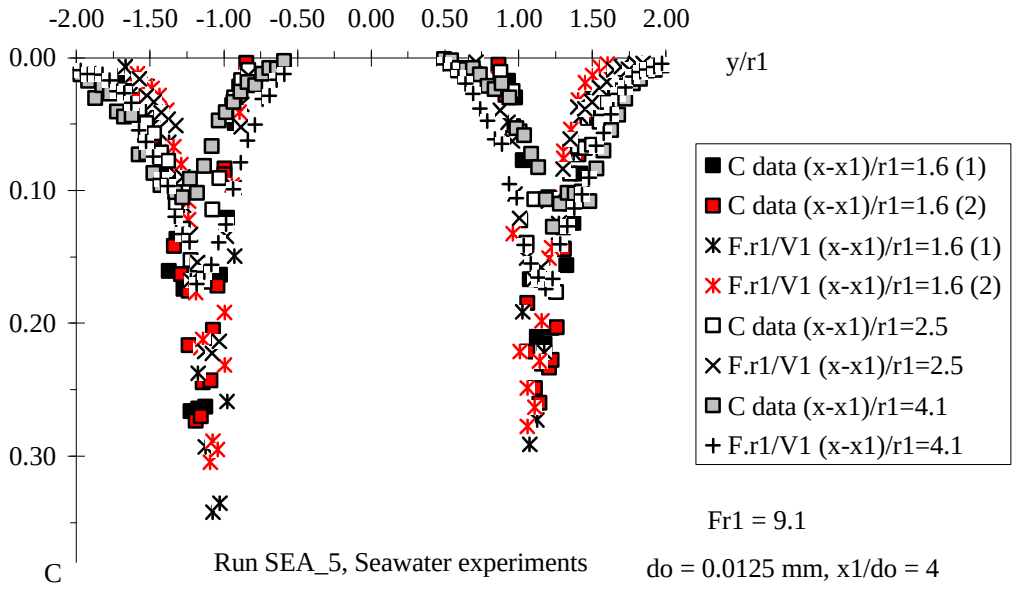
Run Sea_2



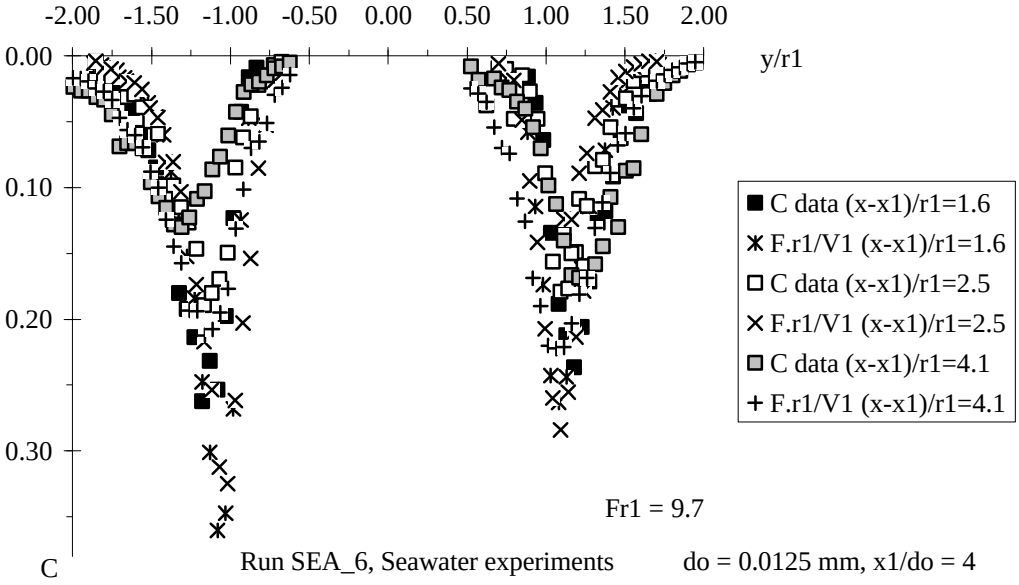
Run Sea_4



Run Sea_5



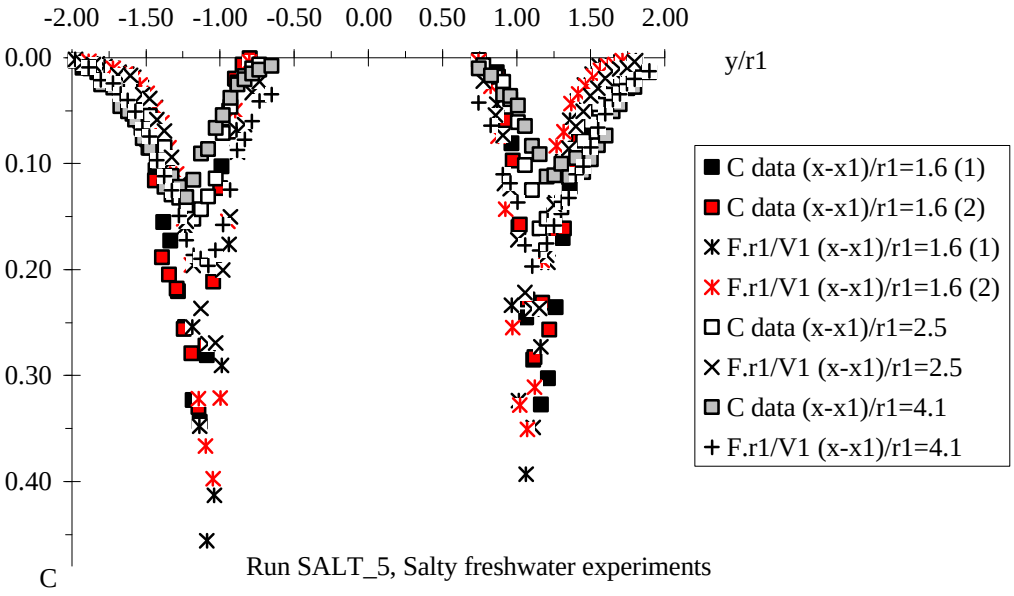
Run Sea_6



B.5 Model 5, d_o = 12.5 mm, x_1 = 50 mm, Salt freshwater

Location :	Toyohashi University of Technology (Japan)
Date :	Nov. 2001
Experiments by :	IWATA and KIDA
Data processing by :	H. CHANSON
Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0125 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Water supply: pumps. Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Electronics analog output. Scanned for 300 s.
Water solution :	Salty freshwater (see App. D).
Comments :	tap water plus 3.45% per weight of sodium chloride (NaCl) with a 99.5% quality. Salt contained at least 99.5% of NaCl, less than 5 ppm of phosphate (PO_4), less than 0.002% of sulphate (SO_4) and less than 0.005% of potassium. Kanomax™ conductivity probe system.

Run Salt_5


-2.00 -1.50 -1.00 -0.50 0.00 0.50 1.00 1.50 2.00
0.00
0.10
0.20
0.30
0.40
y/r1
C data (x-x1)/r1=1.6 (1)
C data (x-x1)/r1=1.6 (2)
F.r1/V1 (x-x1)/r1=1.6 (1)
F.r1/V1 (x-x1)/r1=1.6 (2)
C data (x-x1)/r1=2.5
F.r1/V1 (x-x1)/r1=2.5
C data (x-x1)/r1=4.1
F.r1/V1 (x-x1)/r1=4.1
C
Run SALT_5, Salty freshwater experiments

APPENDIX C. EXPERIMENTAL DATA : CHORD TIME DATA ANALYSIS

C.1 Presentation

The bubble chord time is defined as the time spent by the bubble on the probe tip. In Models 2, 4 and 5, bubble chord times were measured on the jet diameter through the centreline. The chord time data were calculated from the raw probe signal scanned at 25 kHz for 2.625 seconds at eight different locations, per cross-section (paragraph C.2), selected next to the location of maximum void fraction and maximum bubble frequency. The signal was processed using a single threshold technique and the threshold was set at about 15-20% of the air-water voltage range. A incomplete sensitivity analysis was conducted with thresholds between 10 and 30% of the voltage range. The results showed little effect of the threshold on the chord time results. Time-variations of the water voltage during the scan period (i.e. 2.625 sec.) was sometimes noted. Data sets were rejected when the water voltage variations exceeded 10% of the air-water voltage range during a scan.

Chord time results are presented in terms of pseudo bubble chord length ch_{ab} defined as :

$$ch_{ab} = V_1 * t_{ch} \qquad \text{(C-1)}$$

where t_{ch} is the bubble chord time and V_1 is the jet impingement velocity. Observed impact velocities for each experiment are summarised in Table C-1 (paragraph C.4).

Although the pseudo bubble chord length ch_{ab} is not equal to the real chord length because the local air-water velocity V is less or equal than the impingement velocity V_1, the experiments of CUMMINGS and CHANSON (1997b) and BRATTERG and CHANSON (1998) in the developing flow region of two-dimensional plunging jets showed that most entrained bubbles were advected in the high-velocity shear region where $V_1/2 < V < V_1$ typically. A re-analysis of data from CHANSON and BRATTBERG (1996) and CUMMINGS and CHANSON (1997b) shows that Equation (C-1) provides a correct estimate of chord size distribution shape and that it overestimates the chord sizes by about 10 to 30% (paragraph 5.1).

Pseudo-bubble chord length distributions are presented in paragraph C.3. A summary table is shown in paragraph C.4 and it includes means and standard deviations of pseudo-chord sizes.

C.2 Locations of chord time recordings

At each cross-section, bubble chord times were recorded at 8 locations next to the maximum void fraction and bubble count rate. At each location, the data include the measured void fraction, bubble count rate, number of detected bubbles, mean pseudo-chord length and standard deviation of pseudo-chord size.

Run	Q_w	x_1	Water	V_1	$x-x_1$	Probe position	C	F	Nb of bubbles	Mean $t_{ch}*V_1$	Std $t_{ch}*V_1$
	L/s	mm		m/s	mm			Hz		m	m
	DATA			REFERENCE							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Sea_6	0.393	50	Seawater	3.36	25	r < 0	0.107	57.7	271	0.004552	0.006544
Sea_6	0.393	50	Seawater	3.36	25	r < 0	0.127	67.2	327	0.005079	0.006877
Sea_6	0.393	50	Seawater	3.36	25	r < 0	0.120	84.3	349	0.004265	0.004987
Sea_6	0.393	50	Seawater	3.36	25	r < 0	0.120	79.3	330	0.004251	0.005555
Sea_6	0.393	50	Seawater	3.36	25	r > 0	0.116	105.4	526	0.003906	0.004765
Sea_6	0.393	50	Seawater	3.36	25	r > 0	0.154	99.9	391	0.004539	0.006861
Sea_6	0.393	50	Seawater	3.36	25	r > 0	0.160	89.0	301	0.005391	0.007325
Sea_6	0.393	50	Seawater	3.36	25	r > 0	0.150	83.3	328	0.005157	0.007183

Sea_2	0.277	50	Seawater	2.46	25	r < 0	0.042	26.9	92	0.004673	0.005613
Sea_2	0.277	50	Seawater	2.46	25	r < 0	0.050	38.0	151	0.003388	0.003675
Sea_2	0.277	50	Seawater	2.46	25	r < 0	0.051	41.6	152	0.003433	0.004033
Sea_2	0.277	50	Seawater	2.46	25	r < 0	0.046	45.6	189	0.002672	0.00263
Sea_2	0.277	50	Seawater	2.46	25	r > 0	0.041	42.1	186	0.002121	0.00219
Sea_2	0.277	50	Seawater	2.46	25	r > 0	0.047	45.5	189	0.002623	0.002837
Sea_2	0.277	50	Seawater	2.46	25	r > 0	0.049	40.7	124	0.003635	0.004256
Sea_2	0.277	50	Seawater	2.46	25	r > 0	0.049	33.8	115	0.003335	0.003128
Sea_5	0.3535	50	Seawater	3.13	10	r < 0	0.233	105.1	439	0.006169	0.007294
Sea_5	0.3535	50	Seawater	3.13	10	r < 0	0.240	147.3	501	0.004559	0.004674
Sea_5	0.3535	50	Seawater	3.13	10	r < 0	0.176	166.7	706	0.004097	0.003849
Sea_5	0.3535	50	Seawater	3.13	10	r < 0	0.203	86.6	319	0.006148	0.007357
Sea_5	0.3535	50	Seawater	3.13	10	r > 0	0.175	137.8	609	0.00527	0.005266
Sea_5	0.3535	50	Seawater	3.13	10	r > 0	0.243	136.1	521	0.004465	0.004788
Sea_5	0.3535	50	Seawater	3.13	10	r > 0	0.230	112.7	399	0.007119	0.008542
Sea_5	0.3535	50	Seawater	3.13	10	r > 0	0.217	82.8	293	0.00969	0.012165
Sea_5	0.3535	50	Seawater	3.13	15	r < 0	0.116	60.8	280	0.005275	0.006008
Sea_5	0.3535	50	Seawater	3.13	15	r < 0	0.148	81.8	364	0.004401	0.005162
Sea_5	0.3535	50	Seawater	3.13	15	r < 0	0.144	96.3	444	0.004993	0.006251
Sea_5	0.3535	50	Seawater	3.13	15	r < 0	0.121	102.3	429	0.003402	0.00407
Sea_5	0.3535	50	Seawater	3.13	15	r > 0	0.105	102.7	465	0.003678	0.004137
Sea_5	0.3535	50	Seawater	3.13	15	r > 0	0.149	102.5	401	0.003633	0.004195
Sea_5	0.3535	50	Seawater	3.13	15	r > 0	0.140	90.5	388	0.00492	0.006908
Sea_5	0.3535	50	Seawater	3.13	15	r > 0	0.122	70.7	309	0.005442	0.007188
Sea_4	0.336	50	Seawater	2.87	25	r < 0	0.072	43.1	197	0.004875	0.005381
Sea_4	0.336	50	Seawater	2.87	25	r < 0	0.089	54.7	220	4.48E-03	0.005799
Sea_4	0.336	50	Seawater	2.87	25	r < 0	0.089	64.1	231	0.003739	0.004525
Sea_4	0.336	50	Seawater	2.87	25	r < 0	0.086	72.7	330	0.003118	0.003552
Sea_4	0.336	50	Seawater	2.87	25	r > 0	0.064	65.4	304	0.002711	0.003184
Sea_4	0.336	50	Seawater	2.87	25	r > 0	0.085	61.9	250	0.003428	0.004113
Sea_4	0.336	50	Seawater	2.87	25	r > 0	0.089	56.2	223	0.004792	0.006041
Sea_4	0.336	50	Seawater		25	r > 0	0.082	48.2	192	0.005219	0.007055
Sea_5	0.356	50	Seawater	3.13	25	r < 0	0.091	53.8	204	0.007037	0.010336
Sea_5	0.356	50	Seawater	3.13	25	r < 0	0.104	64.3	235	0.004085	0.004635
Sea_5	0.356	50	Seawater	3.13	25	r < 0	0.095	73.1	358	0.004118	0.005263
Sea_5	0.356	50	Seawater	3.13	25	r < 0	0.062	80.8	259	0.002545	0.002759
Sea_5	0.356	50	Seawater	3.13	25	r > 0	0.097	76.3	306	0.003275	0.004107
Sea_5	0.356	50	Seawater	3.13	25	r > 0	0.103	72.3	96	0.003676	0.003713
Sea_5	0.356	50	Seawater	3.13	25	r > 0	0.127	57.5	213	0.005414	0.007194
Sea_5	0.356	50	Seawater	3.13	25	r > 0	0.096	40.7	188	0.00495	0.006084
CIR_4	0.349	50	**Freshwater**	3.04	25	r < 0	0.191	156.8	307	0.004994	0.005428
CIR_4	0.349	50	**Freshwater**	3.04	25	r < 0	0.198	169.0	335	0.005021	0.00517
CIR_4	0.349	50	**Freshwater**	3.04	25	r < 0	0.185	181.1	349	0.004745	0.00486
CIR_4	0.349	50	**Freshwater**	3.04	25	r < 0	0.168	177.2	356	0.004128	0.003938
CIR_4	0.349	50	**Freshwater**	3.04	25	r > 0	0.188	163.4	333	0.004683	0.004889
CIR_4	0.349	50	**Freshwater**	3.04	25	r > 0	0.194	156.8	311	0.004925	0.005343
CIR_4	0.349	50	**Freshwater**	3.04	25	r > 0	0.208	145.5	262	0.006146	0.006207
CIR_4	0.349	50	**Freshwater**	3.04	25	r > 0	0.178	127.8	264	0.005088	0.005065
CIR_5	0.361	50	**Freshwater**	3.18	25	r < 0	0.212	160.9	312	0.005361	0.005516
CIR_5	0.361	50	**Freshwater**	3.18	25	r < 0	0.231	191.5	402	0.004651	0.005538
CIR_5	0.361	50	**Freshwater**	3.18	25	r < 0	0.224	196.3	365	0.004752	0.004696
CIR_5	0.361	50	**Freshwater**	3.18	25	r < 0	0.208	207.9	382	0.004772	0.00458
CIR_5	0.361	50	**Freshwater**	3.18	25	r > 0	0.204	202.9	390	0.004371	0.004493
CIR_5	0.361	50	**Freshwater**	3.18	25	r > 0	0.218	197.3	359	0.006054	0.006425
CIR_5	0.361	50	**Freshwater**	3.18	25	r > 0	0.242	184.7	359	0.005009	0.00489
CIR_5	0.361	50	**Freshwater**	3.18	25	r > 0	0.208	157.9	318	0.005884	0.007156
CIR_5	0.359	50	**Freshwater**	3.18	15	r < 0	0.261	133.0	261	0.008107	0.009381
CIR_5	0.359	50	**Freshwater**	3.18	15	r < 0	0.328	191.2	323	0.0074	0.007675
CIR_5	0.359	50	**Freshwater**	3.18	15	r < 0	0.328	250.0	452	0.00557	0.005565
CIR_5	0.359	50	**Freshwater**	3.18	15	r < 0	0.257	272.6	578	0.004644	0.004295
CIR_5	0.359	50	**Freshwater**	3.18	15	r > 0	0.199	245.1	510	0.003857	0.003233
CIR_5	0.359	50	**Freshwater**	3.18	15	r > 0	0.293	262.7	539	0.005092	0.004887
CIR_5	0.359	50	**Freshwater**	3.18	15	r > 0	0.306	210.6	384	0.00686	0.007776
CIR_5	0.359	50	**Freshwater**	3.18	15	r > 0	0.274	140.4	294	0.007756	0.009156
CIR_5	0.354	50	**Freshwater**	3.18	10	r < 0	0.289	112.2	218	0.010162	0.0116
CIR_5	0.354	50	**Freshwater**	3.18	10	r < 0	0.348	154.9	265	0.01154	0.013937
CIR_5	0.354	50	**Freshwater**	3.18	10	r < 0	0.389	237.0	410	0.007336	0.007173
CIR_5	0.354	50	**Freshwater**	3.18	10	r < 0	0.311	283.6	561	0.004809	0.003981
CIR_5	0.354	50	**Freshwater**	3.18	10	r > 0	0.286	271.3	569	0.004659	0.003737

CIR_5	0.354	50	**Freshwater**	3.18	10	r > 0	0.379	251.4	467	0.006882	0.006404
CIR_5	0.354	50	**Freshwater**	3.18	10	r > 0	0.355	177.3	308	0.011599	0.013418
CIR_5	0.354	50	**Freshwater**	3.18	10	r > 0	0.292	116.3	201	0.010878	0.011602
CIR_6	0.394	50	**Freshwater**	3.46	25	r < 0	0.252	191.1	334	0.00677	0.00774
CIR_6	0.394	50	**Freshwater**	3.46	25	r < 0	0.272	222.5	399	0.007301	0.008641
CIR_6	0.394	50	**Freshwater**	3.46	25	r < 0	0.285	252.7	469	0.005961	0.006178
CIR_6	0.394	50	**Freshwater**	3.46	25	r < 0	0.255	268.9	529	0.005026	0.005001
CIR_6	0.394	50	**Freshwater**	3.46	25	r > 0	0.262	255.1	496	0.005296	0.00556
CIR_6	0.394	50	**Freshwater**	3.46	25	r > 0	0.269	237.7	446	0.005971	0.006507
CIR_6	0.394	50	**Freshwater**	3.46	25	r > 0	0.267	209.1	394	0.007421	0.008507
CIR_6	0.394	50	**Freshwater**	3.46	25	r > 0	0.254	191.2	354	0.007365	0.008934
CIR_2	0.275	50	**Freshwater**	2.42	25	r < 0	0.101	61.4	103	0.005445	0.00593
CIR_2	0.275	50	**Freshwater**	2.42	25	r < 0	0.120	75.7	153	0.004968	0.004579
CIR_2	0.275	50	**Freshwater**	2.42	25	r < 0	0.123	88.0	183	0.004439	0.003945
CIR_2	0.275	50	**Freshwater**	2.42	25	r < 0	0.116	97.1	216	0.003681	0.003132
CIR_2	0.275	50	**Freshwater**	2.42	25	r > 0	0.116	96.0	185	0.004347	0.003841
CIR_2	0.275	50	**Freshwater**	2.42	25	r > 0	0.127	91.3	193	0.004246	0.00364
CIR_2	0.275	50	**Freshwater**	2.42	25	r > 0	0.126	83.1	193	0.00481	0.005359
CIR_2	0.275	50	**Freshwater**	2.42	25	r > 0	0.116	67.0	145	0.004565	*0.004268*
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r < 0	0.290	86.1	258	0.011091	0.013746
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r < 0	0.349	130.1	327	0.009144	0.011037
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r < 0	0.362	183.2	526	0.006885	0.007012
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r < 0	0.276	213.7	654	0.004544	0.004256
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r > 0	0.242	190.7	613	0.004679	0.004599
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r > 0	0.241	113.1	363	0.006596	0.008047
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r > 0	0.225	68.8	254	0.00867	0.011158
Salt_5	0.367	50	*Salty freshwater*	3.12	10	r > 0	0.149	38.4	127	0.009067	0.011091
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r < 0	0.149	59.4	179	0.006235	0.007221
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r < 0	0.161	85.7	274	0.005971	0.007842
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r < 0	0.167	118.6	377	0.0043	0.005053
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r < 0	0.125	145.2	552	0.003672	0.003537
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r > 0	0.100	125.0	487	0.003087	0.003161
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r > 0	0.151	129.5	388	0.004465	0.005231
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r > 0	0.159	101.8	272	0.006349	0.007919
Salt_5	0.367	50	*Salty freshwater*	3.12	15	r > 0	0.117	65.7	32	0.004917	0.005271
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r < 0	0.105	44.3	169	0.005468	0.008585
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r < 0	0.126	64.1	221	0.004554	0.006386
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r < 0	0.133	87.6	342	0.004148	0.005489
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r < 0	0.101	106.2	384	0.002837	0.003396
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r > 0	0.102	97.2	416	0.003713	0.004941
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r > 0	0.133	82.9	290	0.006466	0.008955
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r > 0	0.129	53.3	208	0.006211	0.007233
Salt_5	0.367	50	*Salty freshwater*	3.12	25	r > 0	0.078	27.6	127	0.006047	0.006523
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r < 0	0.143	103.7	272	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r < 0	0.145	122.3	321	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r < 0	0.134	133.4	350	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r < 0	0.125	78.5	206	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r > 0	0.132	129.3	339	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r > 0	0.145	123.5	324	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r > 0	0.147	108.1	284	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	5.5	r > 0	0.130	82.4	216	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r < 0	0.110	94.0	247	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r < 0	0.108	104.6	275	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r < 0	0.101	106.0	278	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r < 0	0.103	82.1	216	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r > 0	0.104	106.0	278	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r > 0	0.110	103.1	271	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r > 0	0.106	92.9	244	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	8.2	r > 0	0.095	105.6	277	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r < 0	0.094	94.1	247	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r < 0	0.093	76.0	200	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r < 0	0.093	80.5	211	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r < 0	0.087	91.2	239	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r > 0	0.091	85.6	225	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r > 0	0.098	80.5	211	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r > 0	0.101	76.0	200	--	--
Run_3	0.0805	27.3	**Freshwater**	2.32	13.7	r > 0	0.091	66.6	175	--	--

C.3 Pseudo-bubble chord length histograms

Pseudo-bubble chord length distributions are presented in sub-paragraphs C.3.1, C.3.2 and C.3.3. Each histogram describes all bubbles detected across the shear layer width (i.e. 8 locations) at depths ($x - x_1$) = 10, 15 and 25 mm. Flow conditions at each measurement location are summarised in paragraph C.2. In the following paragraphs, each table presents the normalised pseudo-chord length probability distribution function at a cross-section where the histogram data represent the probability of chord length in 0.5 mm intervals : e.g., the probability of a chord length from 2.0 to 2.5 mm is represented by the data labelled 2.0. The last data (i.e. > 10) indicates the probability of chord lengths exceeding 10 mm.

C.3.1 Model 2, d_o = 12.5 mm, x_1 = 50 mm, Freshwater

Location :	Toyohashi University of Technology (Japan)
Date :	Nov. 2001
Experiments by :	IWATA and KIDA
Data processing by :	S. AOKI and H. CHANSON
Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0125 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Raw signal scanned at 25 kHz for 2.625 s at 8 different locations per cross-section.
Data processing :	Single threshold set at about 15-20% of the air-water voltage range.
Water solution :	Freshwater (tap water).
Comments :	

$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function	$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Run Cir_2				**Run Cir_5**			
25	0	63	0.046	10	0	102	0.034
	0.5	100	0.073		0.5	182	0.061
	1	125	0.091		1	198	0.066
	1.5	162	0.118		1.5	182	0.061
	2	105	0.077		2	187	0.062
	2.5	106	0.077		2.5	182	0.061
	3	87	0.063		3	162	0.054
	3.5	69	0.050		3.5	120	0.040
	4	74	0.054		4	128	0.043
	4.5	57	0.042		4.5	126	0.042
	5	45	0.033		5	110	0.037
	5.5	41	0.030		5.5	88	0.029
	6	38	0.028		6	82	0.027
	6.5	42	0.031		6.5	71	0.024
	7	31	0.023		7	75	0.025
	7.5	27	0.020		7.5	67	0.022
	8	22	0.016		8	62	0.021
	8.5	18	0.013		8.5	58	0.019
	9	17	0.012		9	61	0.020
	9.5	15	0.011		9.5	51	0.017
	>10	127	0.093		>10	705	0.235
Run Cir_4				15	0	142	0.043

25	0	122	0.048		0.5	285	0.085
	0.5	252	0.100		1	281	0.084
	1	255	0.101		1.5	251	0.075
	1.5	215	0.085		2	236	0.071
	2	198	0.079		2.5	203	0.061
	2.5	145	0.058		3	196	0.059
	3	135	0.054		3.5	165	0.049
	3.5	145	0.058		4	154	0.046
	4	83	0.033		4.5	115	0.034
	4.5	95	0.038		5	110	0.033
	5	89	0.035		5.5	118	0.035
	5.5	71	0.028		6	102	0.031
	6	75	0.030		6.5	83	0.025
	6.5	53	0.021		7	76	0.023
	7	53	0.021		7.5	80	0.024
	7.5	63	0.025		8	59	0.018
	8	53	0.021		8.5	54	0.016
	8.5	45	0.018		9	64	0.019
	9	36	0.014		9.5	34	0.010
	9.5	20	0.008		>10	533	0.160
	>10	314	0.125	25	0	163	0.056
Run Cir_6					0.5	241	0.083
25	0	135	0.039		1	293	0.101
	0.5	296	0.087		1.5	236	0.082
	1	274	0.080		2	217	0.075
	1.5	273	0.080		2.5	210	0.073
	2	236	0.069		3	174	0.060
	2.5	219	0.064		3.5	109	0.038
	3	185	0.054		4	132	0.046
	3.5	147	0.043		4.5	123	0.043
	4	135	0.039		5	103	0.036
	4.5	117	0.034		5.5	85	0.029
	5	114	0.033		6	84	0.029
	5.5	114	0.033		6.5	69	0.024
	6	100	0.029		7	52	0.018
	6.5	92	0.027		7.5	47	0.016
	7	70	0.020		8	39	0.014
	7.5	61	0.018		8.5	47	0.016
	8	59	0.017		9	44	0.015
	8.5	53	0.015		9.5	32	0.011
	9	51	0.015		>10	387	0.134
	9.5	46	0.013				
	>10	644	0.188				

C.3.2 Model 4, d_o = 12.5 mm, x_1 = 50 mm, Seawater

Location :	Toyohashi University of Technology (Japan)
Date :	Nov. 2001
Experiments by :	IWATA and KIDA
Data processing by :	S. AOKI and H. CHANSON
Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0125 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Raw signal scanned at 25 kHz for 2.625 s at 8 different locations per cross-section.
Data processing :	Single threshold set at about 15-20% of the air-water voltage range.

Water solution :	Seawater collected off breaker zone by a group of surfers on the Enshu coast, Pacific Ocean (Terasawa beach) and once from a fishing boat off Akabane harbour.
Comments :	Very clear seawater. Seawater sediment coarse material was filtered prior to experiments.

$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function	$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Run Sea_2				**Run Sea_5**			
25	0	166	0.139	10	0	364	0.096
	0.5	180	0.150		0.5	360	0.095
	1	149	0.124		1	338	0.089
	1.5	109	0.091		1.5	261	0.069
	2	99	0.083		2	244	0.064
	2.5	66	0.055		2.5	196	0.052
	3	78	0.065		3	189	0.050
	3.5	58	0.048		3.5	164	0.043
	4	51	0.043		4	151	0.040
	4.5	36	0.030		4.5	131	0.035
	5	31	0.026		5	118	0.031
	5.5	21	0.018		5.5	93	0.025
	6	26	0.022		6	93	0.025
	6.5	15	0.013		6.5	84	0.022
	7	7	0.006		7	88	0.023
	7.5	6	0.005		7.5	70	0.018
	8	14	0.012		8	68	0.018
	8.5	14	0.012		8.5	62	0.016
	9	7	0.006		9	60	0.016
	9.5	12	0.010		9.5	42	0.011
	>10	53	0.044		>10	612	0.162
Run Sea_4				15	0	373	0.121
25	0	259	0.133		0.5	407	0.132
	0.5	266	0.137		1	360	0.117
	1	238	0.122		1.5	257	0.083
	1.5	171	0.088		2	192	0.062
	2	137	0.070		2.5	156	0.051
	2.5	106	0.054		3	146	0.047
	3	90	0.046		3.5	110	0.036
	3.5	66	0.034		4	100	0.032
	4	67	0.034		4.5	108	0.035
	4.5	60	0.031		5	81	0.026
	5	66	0.034		5.5	71	0.023
	5.5	44	0.023		6	67	0.022
	6	37	0.019		6.5	54	0.018
	6.5	26	0.013		7	45	0.015
	7	41	0.021		7.5	52	0.017
	7.5	24	0.012		8	41	0.013
	8	26	0.013		8.5	34	0.011
	8.5	18	0.009		9	39	0.013
	9	21	0.011		9.5	30	0.010
	9.5	16	0.008		>10	357	0.116
	>10	168	0.086	25	0	226	0.122
Run Sea_6					0.5	260	0.140
25	0	395	0.140		1	216	0.116
	0.5	410	0.145		1.5	155	0.083
	1	287	0.102		2	138	0.074
	1.5	205	0.073		2.5	110	0.059
	2	185	0.066		3	70	0.038
	2.5	140	0.050		3.5	89	0.048
	3	111	0.039		4	61	0.033
	3.5	99	0.035		4.5	38	0.020

4	111	0.039	5	58	0.031
4.5	91	0.032	5.5	41	0.022
5	58	0.021	6	38	0.020
5.5	49	0.017	6.5	33	0.018
6	63	0.022	7	23	0.012
6.5	47	0.017	7.5	27	0.015
7	62	0.022	8	15	0.008
7.5	35	0.012	8.5	22	0.012
8	37	0.013	9	18	0.010
8.5	26	0.009	9.5	19	0.010
9	32	0.011	>10	202	0.109
9.5	32	0.011			
>10	348	0.123			

C.3.3 Model 5, d_o = 12.5 mm, x_1 = 50 mm, Salt freshwater

Location :	Toyohashi University of Technology (Japan)
Date :	Nov. 2001
Experiments by :	IWATA and KIDA
Data processing by :	S. AOKI and H. CHANSON
Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0125 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Raw signal scanned at 25 kHz for 2.625 s at 8 different locations per cross-section.
Data processing :	Single threshold set at about 15-20% of the air-water voltage range.
Water solution :	Salty freshwater (see App. D).
Comments :	tap water plus 3.45% per weight of sodium chloride (NaCl) with a 99.5% quality. Salt contained at least 99.5% of NaCl, less than 5 ppm of phosphate (PO_4), less than 0.002% of sulphate (SO_4) and less than 0.005% of potassium.

$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function	$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Run Salt_5				**Run Salt_5**			
10	0	280	0.090	25	0	293	0.136
	0.5	281	0.090		0.5	274	0.127
	1	246	0.079		1	222	0.103
	1.5	214	0.069		1.5	198	0.092
	2	167	0.053		2	113	0.052
	2.5	154	0.049		2.5	129	0.060
	3	137	0.044		3	99	0.046
	3.5	108	0.035		3.5	98	0.045
	4	103	0.033		4	76	0.035
	4.5	96	0.031		4.5	61	0.028
	5	90	0.029		5	65	0.030
	5.5	81	0.026		5.5	39	0.018
	6	80	0.026		6	37	0.017
	6.5	75	0.024		6.5	54	0.025
	7	69	0.022		7	28	0.013
	7.5	63	0.020		7.5	23	0.011
	8	56	0.018		8	23	0.011
	8.5	60	0.019		8.5	22	0.010
	9	48	0.015		9	16	0.007

	9.5	45	0.014	9.5	32	0.015
	>10	669	0.214	>10	255	0.118
15	0	339	0.132			
	0.5	308	0.120			
	1	231	0.090			
	1.5	195	0.076			
	2	181	0.071			
	2.5	135	0.053			
	3	132	0.052			
	3.5	108	0.042			
	4	101	0.039			
	4.5	78	0.030			
	5	70	0.027			
	5.5	61	0.024			
	6	56	0.022			
	6.5	52	0.020			
	7	57	0.022			
	7.5	39	0.015			
	8	33	0.013			
	8.5	27	0.011			
	9	28	0.011			
	9.5	25	0.010			
	>10	305	0.119			

C.3.4 Model 3, d_o = 6.8 mm, x_1 = 25 mm, Freshwater (tap water)

Location :	Toyohashi University of Technology (Japan)
Date :	20 Jan. 2002
Experiments by :	KIDA, S. AOKI, A. HOQUE
Data processing by :	S. AOKI
Experiment characteristics :	Vertical circular plunging jet. Jet diameter at nozzle : 0.0068 m. Nozzle design : sharp edges (1/1 contraction ratio) located at the end of a 1.2 m long circular PVC pipe. Nozzle construction : PVC. Receiving pool : height : 0.75 m, width : 0.1 m, length : 2 m. Cross-flow : none.
Instrumentation :	Single-tip conductivity probe (inner electrode : Ø = 0.10 mm). Raw signal scanned at 25 kHz for 2.625 s at 8 different locations per cross-section.
Data processing :	Single threshold set at about 15-20% of the air-water voltage range.
Water solution :	Freshwater (see App. D).
Comments :	Tap water.

$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function	$x - x_1$ (mm)	ch_{ab} Interval (mm)	Nb of bubbles	Probability distribution function
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Run Run_3				**Run Run_3**			
5.5	0	95	0.0462	13.7	0	72	0.0434
	0.5	181	0.0879		0.5	164	0.0988
	1	183	0.0889		1	195	0.1175
	1.5	177	0.0860		1.5	168	0.1012
	2	198	0.0962		2	158	0.0952
	2.5	180	0.0875		2.5	153	0.0922
	3	132	0.0641		3	107	0.0645
	3.5	125	0.0607		3.5	111	0.0669
	4	103	0.0500		4	95	0.0572
	4.5	103	0.0500		4.5	70	0.0422
	5	90	0.0437		5	66	0.0398
	5.5	76	0.0369		5.5	57	0.0343
	6	58	0.0282		6	55	0.0331

	6.5	50	0.0243	6.5	35	0.0211
	7	43	0.0209	7	25	0.0151
	7.5	33	0.0160	7.5	18	0.0108
	8	30	0.0146	8	24	0.0145
	8.5	24	0.0117	8.5	14	0.0084
	9	28	0.0136	9	16	0.0096
	9.5	20	0.0097	9.5	8	0.0048
	>10	129	0.0627	>10	49	0.0295
8.2	0	97	0.0500			
	0.5	195	0.1005			
	1	196	0.1010			
	1.5	174	0.0897			
	2	193	0.0995			
	2.5	166	0.0856			
	3	157	0.0809			
	3.5	131	0.0675			
	4	94	0.0485			
	4.5	110	0.0567			
	5	63	0.0325			
	5.5	64	0.0330			
	6	44	0.0227			
	6.5	30	0.0155			
	7	38	0.0196			
	7.5	25	0.0129			
	8	21	0.0108			
	8.5	22	0.0113			
	9	27	0.0139			
	9.5	16	0.0082			
	>10	77	0.0397			

C.4 Summary

Table C-1 - Measured means and standard deviations of pseudo chord length ch_{ab}

Run	V_1	Fr_1	$\frac{x-x_1}{r_1}$	Nb of bubbles	Mean ch_{ab}	Std ch_{ab}	Remarks
	m/s				mm	mm	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model 2							Freshwater
Cir_2	2.42	7.07	4.19	1371	4.48	5.89	
Cir_4	3.04	8.81	4.11	2517	4.92	7.00	
Cir_5	3.18	9.20	1.64	2999	7.54	14.11	
			2.46	3341	5.79	10.78	
			4.10	2887	5.07	8.67	
Cir_6	3.46	9.98	4.09	3421	6.27	11.04	
Model 3							Freshwater.
Run_3	2.32	9.07	1.65	2058	3.83	7.78	
			2.47	1940	3.47	6.66	
			4.12	1660	3.36	5.98	
Model 4							Seawater
Sea_2	2.46	7.19	4.18	1198	3.08	4.58	
Sea_4	2.87	8.34	4.13	1947	3.90	8.31	
Sea_5	3.13	9.07	1.64	3787	5.56	13.40	
			2.46	3080	4.39	8.77	
			4.11	1859	4.29	8.20	
Sea_6	3.36	9.70	4.09	2823	4.58	9.18	
Model 5							Salty freshwater
Salt_5	3.12	9.04	1.64	3122	6.75	13.61	
			2.46	2561	4.50	7.56	

4.11	2157	4.60	8.94	

Notes :

Nb of bubbles : number of samples (column 5);

Mean ch_{ab} : mean pseudo-bubble chord length (column 6);

Std ch_{ab} : standard deviation of pseudo-chord length (column 7).

APPENDIX D. SALT COMPOSITION

Plunging jet experiments in Model 5 were conducted with salty freshwater. The water solution was made of tap water ([1]) plus 3.45% per weight of sodium chloride (NaCl) with a 99.5% quality. The following table lists the composition of the sodium chloride (column 2) used to prepare the salty freshwater solution. The next column (column 3) gives the average ion concentration in the saltwater solution (Model 5). For comparison, column 4 presents the average concentrations of major ions in seawater (RILEY and SKIRROW 1965, Open University Course Team 1995). All numbers are concentrations by weight.

Composition	Sodium Chloride NaCl used in Model 5	Average concentration in salty freshwater (Model 5)	Average concentration in seawater
(1)	(2)	(3)	(4)
Sodium Chloride (NaCl)	> 99.5%	34.5 ppt	29.536 ppt ([a])
Phosphate (PO_4)	< 5 ppm	< 0.17 ppt	0.02-0.08 ppm ([b])
Sulfate (SO_4)	< 0.002%	< 0.69 ppm	2.649 ppt ([a])
Nitrogen compounds (as N)	< 0.001 %	< 0.345 ppm	--
Potassium (K)	< 0.005%	< 1.725 ppm	0.380 ppt ([a])
Copper (Cu)	< 2 ppm	< 0.069 ppm	0.001-0.02 ppm ([b])
Magnesium (Mg)	< 0.002 %	< 0.69 ppm	1.272 ppt ([a])
Calcium (Ca)	< 0.002%	< 0.69 ppm	0.400 ppt ([a])
Barium (Ba)	< 0.001%	< 0.345 ppm	0.01-0.06 ppm ([b])
Lead (Pb)	< 2 ppm	< 0.069 ppm	~ 0.005 ppm ([b])
Iron (Fe)	< 2 ppm	< 0.069 ppm	0.01-0.1 ppm ([b])

Notes :

Concentrations by weight (1 ppt = 1 g per kg);

([a]) : reference : Open University Course Team (1995);

([b]) : reference : RILEY and SKIRROW (1965).

[1] as in Models 2 and 3.