The local resistance of gas—liquid two-phase flow through an orifice

D. K. Chen, Z. H. Chen, Z. S. Zhao and N. Zhuo*

The calculation of local resistance of gas–liquid two-phase flow through an orifice is a problem yet to be solved in engineering design. A new model allowing the calculation was developed. The calculation on which the model is based was verified by tests carried out on an air–water two-phase flow test bed and proved to be in good agreement with the experimental results. By comparing the results of the calculation with data from experiments on steam–water systems, the authors also found that, on the whole, this model fits the system of steam–water mixture, thus giving it a rather wide range of application. Moreover, the accuracy of the calculation can also meet the general requirements of engineering design.

Keywords: *gas–liquid two-phase flow, orifice, local resistance*

The orifice is one of the most commonly used elements in flow rate measuring and regulating. Because of its simple structure and reliable performance, the orifice is increasingly adopted in gas–liquid two-phase flow. Today, the technology of measuring flow rate of gas–liquid two-phase flow by orifice is becoming increasingly useful. In the straight pipes of two-phase flow with an orifice, the calculation of orifice resistance must inevitably be encountered while the accuracy of the calculation is an important factor in determining the economy and reliability of the design. There have been some investigations made on the theory and experiment of resistance characteristics of orifices[1–7] and some useful correlations have been obtained. However, some of them cover only a limited range, and the errors of some are far beyond the margin of tolerance, so they are not widely used in engineering design. The new model presented in this paper was developed to predict the local resistance during the two-phase flow through an orifice, and then corrected by measured data to ensure its wider application and accurate calculation.

Theoretical analysis

As shown in Fig 1, the loss of local resistance, $\Delta p_{1,4}$ in fluid through an orifice can be divided into two parts: loss $\Delta p_{1,3}$ occurs through the section of abrupt contraction, 1–3, and loss $\Delta p_{3,4}$ occurs through the section of uncontrolled expansion, 3–4. Hence,

$$\Delta p_{1,4} = \Delta p_{1,3} + \Delta p_{3,4} \tag{1}$$

For gas–liquid two-phase flow through an orifice, it is assumed that the liquid is incompressible fluid and the specific volume of mixture for any one cross-section between sections 1 and 4 is equal to the mean specific volume between the same sections. We define local resistance as follows:

$$\Delta p_{1,4} = (\xi_{1,4})_2 \frac{G_2^2 \bar{v}}{2g} \tag{2}$$

$$\Delta p_{1,3} = (\xi_{1,3})_3 \frac{G_3^2 \bar{v}}{2g} \tag{3}$$

$$\Delta p_{3,4} = (\xi_{3,4})_3 \frac{G_3^2 \bar{v}}{2g} \tag{4}$$

where $(\xi_{1,4})_2$ is the loss coefficient from section 1 to 4 based on the mass flux at the orifice plane 2; $(\xi_{1,3})_3$ and $(\xi_{3,4})_3$ are the loss coefficient of the sections of abrupt contraction and uncontrolled expansion, respectively; $\bar{v}$ is the mean specific volume of gas–liquid mixture, that is:

$$\bar{v} = x\bar{v}_g + (1+x)v_l$$

Substituting Eqs (2) to (4) into (1), we have

$$(\xi_{1,4})_2 = \{(\xi_{1,3})_3 + (\xi_{3,4})_3\}\left(\frac{A_2}{A_3}\right)^2 \tag{5}$$

which implies that the loss coefficient of an orifice can also be divided into two parts: the loss coefficient of the section

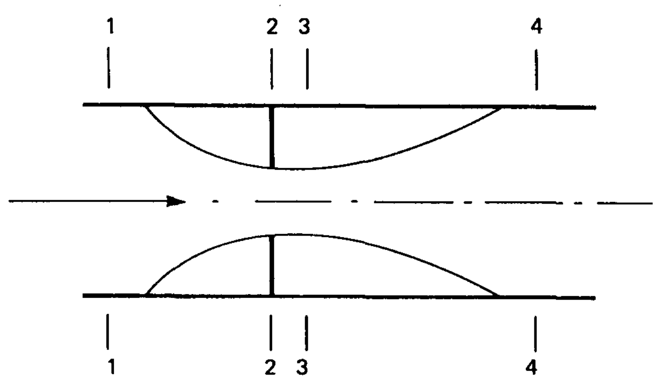

Fig 1 Sketch of gas–liquid two-phase flow passing through an orifice

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of abrupt contraction, $(\xi_{1,3})_3$, and the loss coefficient of the section of uncontrolled expansion, $(\xi_{3,4})_3$. Next, the two loss coefficients are discussed by means of the conservation of mass, energy and momentum. Before doing that we must define the two basic parameters: discharge coefficient μ and contraction coefficient ε.

The discharge coefficient μ is defined as

$$\mu=\frac{M}{M_r} \tag{6}$$

where M is the flow rate; M_r is the ideal frictionless mass flow rate through an orifice, based on the same maximum static pressure drop p_1-p_3 and with no presence of vena contracta.

The contraction coefficient ε is defined as

$$\varepsilon=\frac{A_3}{A_2} \tag{7}$$

On the assumption of steady flow with gravitation being ignored, the one-dimensional energy equation based on separated two-phase flow model can be written as

$$-\bar{v}\frac{dp}{dz}=\frac{dF}{dz}+\frac{d}{dz}\left[G^2\left\{\frac{v_l^2(1-x)^3}{(1-\Phi)^2}+\frac{v_g^3x^3}{\Phi^2}\right\}\right]\frac{1}{2g} \tag{8}$$

Integrating Eq (8) from section 1 to section 3, we have

$$p_1\bar{v}+\frac{KG_1^2}{2g}=p_3\bar{v}+\frac{KG_3^2}{2g}+(\xi_{1,3})_3\frac{\bar{v}^2G_3^2}{2g} \tag{9}$$

where

$$K=\frac{\bar{v}_g^2x^3}{\bar{\Phi}^2}+\frac{v_l^2(1-x)^3}{(1-\bar{\Phi})^2} \tag{10}$$

Under the ideal condition, integrating Eq (8) again from cross-section 1 to cross-section 3 and noting $G_3r=G_2r$ we have

$$p_1\bar{v}+\frac{KG_1^2r}{2g}=p_3\bar{v}+\frac{KG_2^2r}{2g}$$

From Eqs (6), (7), (9) and (10), we get the coefficient of local resistance for the abrupt contraction section:

$$(\xi_{1,3})_3=\frac{\varepsilon^2K(1-m^2)}{\bar{v}\mu^2}+\frac{K(\varepsilon^2m^2-1)}{\bar{v}} \tag{11}$$

where

$$m=\frac{A_2}{A_1}$$

To find the coefficient of local resistance for the uncontrolled expansion, we first integrate Eq (8) from section 3 to section 4, to obtain:

$$p_3\bar{v}+\frac{KG_3^2}{2g}=p_4\bar{v}+\frac{KG_4^2}{2g}+(\xi_{3,4})_2\frac{G_3^2\bar{v}^2}{2g} \tag{12}$$

Then, on the assumptions of steady flow with negligible friction between fluid and wall and negligible gravitation, the one-dimensional momentum equation based on the separated two-phase flow model can be written[8]

$$\frac{d}{dz}\left[\left\{\frac{v_l(1-x)^2}{1-\Phi}+\frac{v_gx^2}{\Phi}\right\}G^2A\right]\frac{1}{g}+\frac{dp}{dz}A=0$$

Integrating the above equation from section 3 to section 4, we obtain

$$p_3A_1+\frac{G_3^2A_3H}{g}=p_4A_1+\frac{G_4^2A_4H}{g} \tag{13}$$

where

$$H=\frac{v_l(1-x)^2}{1-\bar{\Phi}}+\frac{\bar{v}_gx^2}{\bar{\Phi}}$$

From Eqs (7), (12) and (13), we get

$$(\xi_{3,4})_3=\frac{2\varepsilon mH(\varepsilon m-1)}{\bar{v}}+\frac{K(1-\varepsilon^2m^2}{\bar{v}^2} \tag{14}$$

Substituting Eqs (7), (11) and (14) into Eq (5), the

Notation

A	Channel cross-sectional area, m^2
D	Tube diameter, m
d	Diameter of the hole of an orifice, m
F	Mechanical energy converted to internal energy
G	Mass flux, $kg/(m^2s)$
m	Ratio of cross-sectional area of an orifice to that of the tube
M	Mass rate, kg/s
n	Index
p	Pressure, kg/cm^2
Q	Volumetric flow rate, m^3/s
s	Velocity ratio
v	Specific volume, m^3/kg
x	Mass quality
Δp_{14}	Local resistance
ε	Contraction coefficient
μ	Discharge coefficient
ξ	Coefficient of local resistance
Φ	Void fraction
Φ^2_{lo}	Two-phase multiplier, which is defined as ratio of two-phase fractional pressure gradient to that of single-phase flow at the same total mass velocity and with the physical properties of the liquid phase

Superscripts

–	Mean value between sections 1 and 4

Subscripts

1	Steady section upstream of an orifice
2	Section of an orifice
3	Section of vena contracta
4	Steady section downstream of an orifice
6	Inlet of an orifice
7	Outlet of an orifice
g	Gas phase
l	Liquid phase
r	Ideal condition

coefficient of local resistance for an orifice becomes

$$(\xi_{1,4})_2=\frac{K(1-m^2)}{\mu^2\bar{v}^2}+\frac{2mH(\varepsilon m-1)}{\varepsilon\bar{v}} \tag{15}$$

which is mainly related to pressure p, mass quality x, mean void fraction $\bar{\Phi}$ and parameter m.

The discharge coefficient μ and the contraction coefficient ε can be calculated according to the correlations given by Benedict[9]. The mean specific volume $\bar{v}$ is defined as the arithmetical mean of the specific volume of the mixture at the inlet and outlet of an orifice, and is given by

$$\bar{v}=\frac{v_6+v_7}{2}$$

The mean void fraction $\bar{\Phi}$ is given by

$$\bar{\Phi}=\frac{1}{1+\bar{s}\left(\frac{\bar{v}_l}{\bar{v}_g}\right)\left(\frac{1-x}{x}\right)}$$

The mean velocity ratio $\bar{s}$ in the above correlation is calculated by

$$\bar{s}=\left(\frac{\bar{v}_g}{\bar{v}_l}\right)^n$$

in which the index n is to be determined by experiment.

Experimental details

Fig 2 is a sketch of the experimental apparatus. Tests were performed by using air and water.

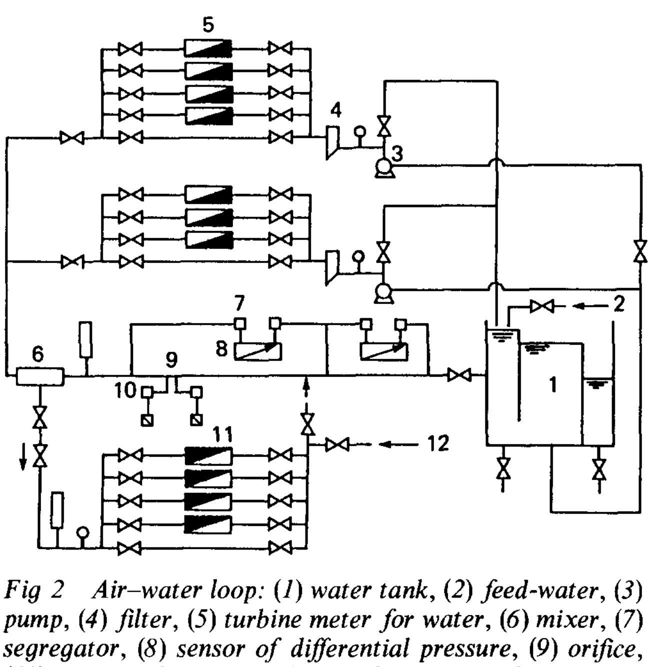

Fig 2 Air–water loop: (1) water tank, (2) feed-water, (3) pump, (4) filter, (5) turbine meter for water, (6) mixer, (7) segregator, (8) sensor of differential pressure, (9) orifice, (10) sensor of pressure, (11) turbine meter for air, (12) compressed air

The water pumped from the steady region of the water tank (1) flowed across the filter (4) to the region of single-phase measurement, then across the mixer (6) to the test section. The compressed air flowed across the region of single-phase measurement into the mixer (6), and, after mixing, the air and water flowed into the test section. The air–water mixture formed in the mixer flowed across the orifice (9), and, in turn, across the adjusting valve for back pressure, into the separated region of the water tank (1). The air was released to the atmosphere while the water was discharged into the steady region. The total length of the test section was 14 m, the length from the mixer to the orifice was 6 m, and the length from the orifice to the water tank 8 m.

The five different orifices in this experiment were measured, and their sizes are shown in Table 1. A total of 298 two-phase runs were performed at values of mass quality x between 0.002 14 and 0.836. The water rate Q' in the test varied between 2.72×10^{-5} and 5.59×10^{-3} m^3/s, and the air rate Q'' between 1.02×10^{-5} and 4.4×10^{-2} m^3/s. The orifice inlet pressure p_6 was maintained at 1 and 2 kgf/cm^2.

Results and analysis

The index n was determined by experiment. For each value of parameter m and pressure p the authors calculated the correlation, Eq (15), between $n=0$ and 1, at step 0.05. For every step the authors compared calculated $(\xi_{1,4})_2$ with measured $(\xi_{1,4})_2$, and calculated their mean square error σ. The calculated results are drawn in Fig 3 for six of the curves. When $n=0.55$, as illustrated in Fig 3, the mean square error σ is smallest; that is to say, the calculated value and measured value are the closest. This result has also been obtained by Cao[10] using a different approach. Fig 3 also indicates that parameter m and pressure p have no effect on index n.

Using $n=0.55$, curves of $(\xi_{1,4})_2$ versus x for the different orifices at different pressures were calculated from the correlation, Eq (15). Fig 4 shows only two of the curves and the corresponding experimental data. It can be seen that the calculated values agree basically with the measured values, and the coefficient of local resistance $(\xi_{1,4})_2$ of an orifice depends mainly on mass quality x, parameter m and pressure p. The higher the pressure, the larger is the coefficient of the local resistance. It is expected that the curve becomes a straight line parallel with the X-axis at the critical pressure.

The mean square errors of calculated curves are between 5.96% and 13.3%, and the average value of mean square error is about 10%. This is permissible in engineering.

Using $n=0.55$, the authors calculated the curves of $\bar{\Phi}_{lo}^2$ versus x for the different sizes of orifices at different pressures. Fig 5 shows only two of the curves and corresponding experimental data.

The calculated values, as shown in Fig 5, are in good agreement with the measured value. It is also known

Table 1 Orifice sizes

D (mm)	25.4		50.8		
d (mm)	13.71	15.85	22.38	27.36	31.62
m	0.2913	0.3894	0.1941	0.2902	0.3875

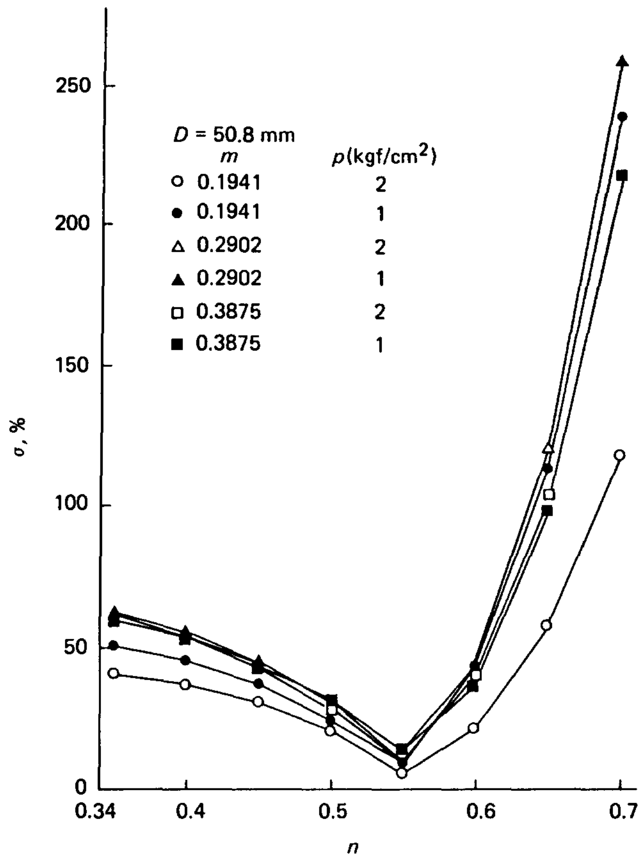

Fig 3 Index n *versus mean square error*

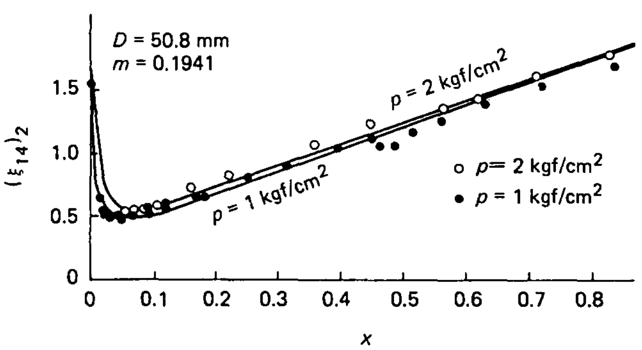

Fig 4 Coefficient of local resistance $(\xi_{1,4})_2$ *versus mass quality* x

from the calculation that the two-phase pressure drop multiplier Φ_{lo}^2 is almost unaffected by parameter m and only slightly affected by the mass flux. That means, the higher the pressure, the less steep is the curve. The curves will be parallel with the X-axis at the critical pressure.

As shown in Fig 5, the agreement between the results of experiment and the prediction of Simpson's correlation is fairly good. It implies that Simpson's correlation is not only applicable to an orifice inserted into a large diameter pipe but also to one inserted into a small diameter pipe. However, in the range of low mass quality x, the prediction of Simpson's correlation is on the high side (Fig 6). This point has also been made in Ref 7.

The model proposed was only tested in an air–water two-phase flow system; but what is of greater interest is whether the model can be used for steam–water two-phase flow systems. From a comparison made by the authors between the calculated value (on which the model was based) and the experimental data given by Kofaezen[2] and by Janssen[1] (Figs 7 and 8), it was found that they are in good agreement. That is to say, the model covers a rather wide range of application and can be used either for air–water two-phase flow systems or for steam–water two-phase flow systems.

Conclusion

From numerous experiments undertaken during the research, it was found that the calculated results based on the basic model of local resistance of an orifice proposed by the authors are in good agreement with the

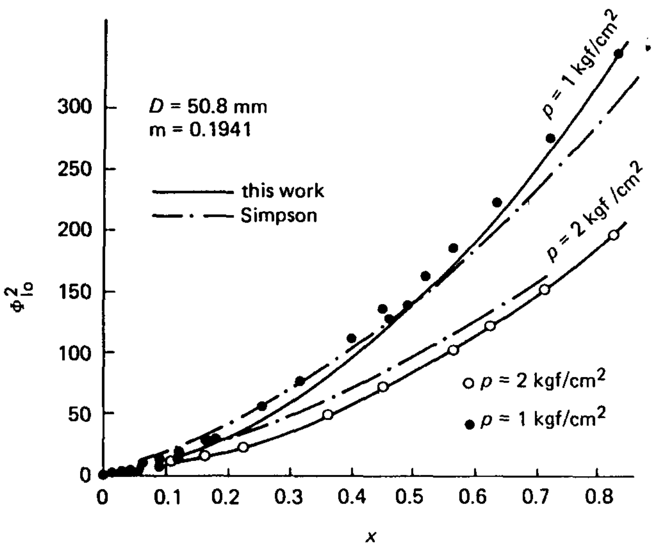

Fig 5 Two-phase multiplier Φ_{lo}^2 *versus mass quality* x

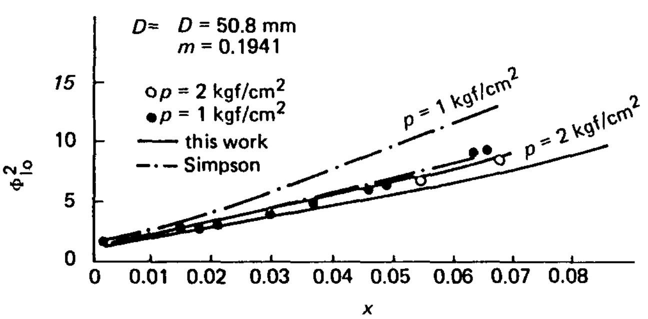

Fig 6 Two-phase multiplier Φ_{lo}^2 *versus mass quality* x

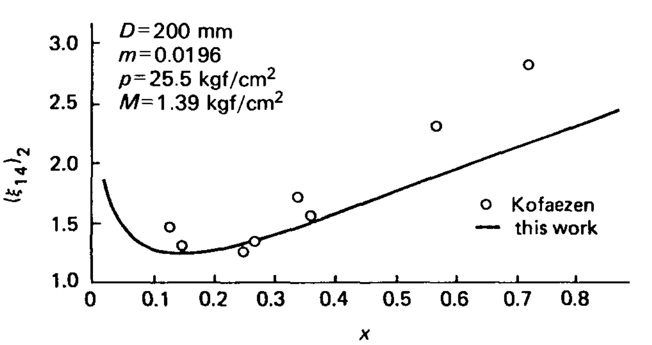

Fig 7 Comparison of values predicted by model and experimental data given by Kofaezen[2]

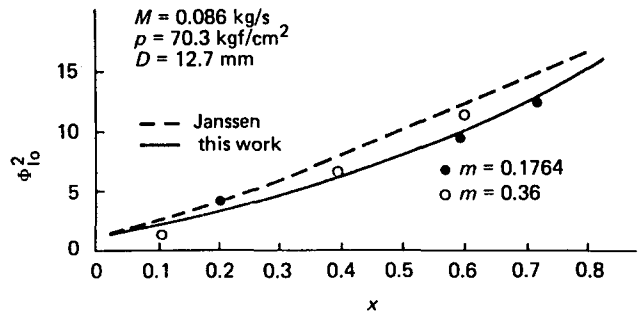

Fig 8 Comparison of values predicted by model and experimental data given by Janssen[1]

experimental results. Further, by comparing the calculated results with data obtained from experiments on steam–water systems by Kofaezen and Janssen, it was also found that, on the whole, this model fits the system of steam–water mixture.

Based on the experiments, the authors recommend index $n = 0.55$, which proved to be steady and unaffected by parameter m and pressure p. Through experiments and calculation, it was also found that the coefficient of local resistance depends mainly on mass quality x, pressure p, and parameter m, while pressure drop multiplier Φ_{lo}^2 depends mainly on mass quality x and pressure p.

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APPENDIX: Experimental data

$D=25.4$ mm			$m=0.2913$		
$P=2$ kgf/cm²			$P=1$ kgf/cm²		
Q' (m³/s)	Q'' (m³/s)	$\Delta P_{1,4}$ (kgf/cm²)	Q' (m³/s)	Q'' (m³/s)	$\Delta P_{1,4}$ (kgf/cm²)
12.1×10^{-5}	13.2×10^{-3}	0.468	9.70×10^{-5}	13.3×10^{-3}	0.309
12.0	14.3	0.493	9.99	15.2	0.408
10.2	14.8	0.534	7.43	15.6	0.376
9.97	17.0	0.735	7.54	17.0	0.457
11.2	19.5	1.13	7.55	18.3	0.532
9.82	18.3	0.881	7.11	17.0	0.429
9.65	19.4	1.03	7.27	18.5	0.544
9.61	20.1	1.12	7.10	18.7	0.530
9.46	20.9	1.14	7.06	18.8	0.547
7.26	16.2	0.549	4.42	14.9	0.269
7.19	17.8	0.706	8.68	14.4	0.350
6.93	19.2	0.842	8.59	15.3	0.368
7.32	21.1	1.13	8.49	16.7	0.450
6.90	21.4	1.12	8.47	17.7	0.533
6.75	21.4	1.14	4.38	20.3	0.553
12.0	12.9	0.421	4.40	19.5	0.502
11.0	13.5	0.411	4.41	16.9	0.349
9.83	13.8	0.423	4.46	14.3	0.229
9.79	14.2	0.457	12.1	12.1	0.294
9.60	15.5	0.568	12.0	13.8	0.393
9.45	16.5	0.654	12.0	15.1	0.479
9.57	20.1	1.13	10.5	16.7	0.522
6.93	18.3	0.736	7.63	13.4	0.285
6.70	21.5	1.11	7.55	15.1	0.400
22.7	12.8	0.661	7.50	18.0	0.532
21.2	13.1	0.655	7.44	18.3	0.539
19.6	13.0	0.616	24.3	11.9	0.480
19.1	13.1	0.611	17.6	9.82	0.257
20.2	13.5	0.671	13.9	8.50	0.169
17.8	13.5	0.612	17.6	11.0	0.317

D=25.4 mm			m=0.2913		
P=2 kgf/cm^2			P=1 kgf/cm^2		
Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)	Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)
18.4	14.9	0.794	13.9	9.26	0.186
15.6	13.2	0.532	17.5	12.4	0.403
15.6	14.1	0.656	16.1	12.3	0.384
16.6	15.0	0.758	15.9	13.4	0.448
12.9	12.9	0.481	15.8	14.2	0.504
12.1	13.8	0.471	12.1	12.4	0.319
27.4	8.20	0.357	12.1	14.2	0.406
26.6	11.0	0.549	12.1	15.2	0.464
25.6	12.0	0.629	11.6	16.0	0.518
24.0	11.9	0.578	83.4	2.13	0.500
22.7	12.2	0.583	68.0	3.45	0.472
100	2.76	0.783	58.8	4.49	0.445
94.0	3.67	0.883	32.1	8.02	0.339
91.5	4.38	0.931	31.7	9.71	0.458
40.9	3.25	0.248	26.4	10.4	0.431
39.6	4.42	0.260	26.3	11.0	0.473
39.4	5.46	0.306	24.5	11.5	0.459
38.0	7.43	0.388	28.8	9.37	0.376
32.6	7.16	0.318	20.5	9.61	0.304
			34.2	6.95	0.288
			33.9	8.02	0.361
			33.7	9.20	0.451
			33.6	9.44	0.467
			29.2	9.48	0.420
			33.4	8.68	0.402

D=25.4 mm			m=0.3894		
P=2 kgf/cm^2			P=1 kgf/cm^2		
Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)	Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)
108×10^{-5}	5.47×10^{-3}	0.573	82.8×10^{-5}	3.95×10^{-3}	0.332
88.7	6.81	0.537	70.5	5.21	0.343
86.2	7.53	0.531	59.1	6.79	0.305
81.7	8.31	0.505	50.7	8.26	0.269
73.9	9.55	0.483	40.4	10.7	0.263
68.8	10.4	0.468	47.7	8.70	0.275
60.2	11.9	0.483	39.2	11.0	0.285
55.1	12.9	0.506	35.8	11.9	0.272
49.2	14.1	0.537	34.9	12.3	0.285
44.7	15.1	0.554	33.4	12.7	0.285
58.7	12.0	0.489	35.3	12.2	0.298
45.2	14.6	0.537	33.8	12.6	0.286
33.9	17.6	0.611	24.9	15.3	0.295
30.0	18.7	0.663	21.8	16.5	0.333
25.9	20.2	0.742	27.4	14.6	0.292
19.5	22.8	0.816	15.9	19.6	0.379
16.7	24.1	0.816	14.5	20.5	0.379
14.5	24.9	0.795	12.7	21.9	0.389
13.6	25.4	0.789	10.9	22.6	0.386
11.7	25.9	0.758	10.1	22.9	0.380
15.3	24.6	0.805	8.61	23.6	0.376
13.5	25.4	0.784	7.95	23.9	0.375
11.9	26.0	0.763	7.32	24.0	0.372
10.2	26.4	0.716	6.78	24.4	0.360
10.7	27.5	0.721	6.09	24.9	0.365
9.93	27.1	0.715	5.40	25.3	0.360
9.05	27.3	0.700	4.76	25.5	0.365
8.21	27.8	0.685	4.02	26.2	0.367
7.45	28.1	0.685	2.75	27.0	0.379
6.30	28.7	0.679			
4.55	29.4	0.674			

D=50.8 mm			m=0.1941		
P=2 kgf/cm^2			P=1 kgf/cm^2		
Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)	Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)
163×10^{-5}	26.2×10^{-3}	1.47	266×10^{-5}	2.29×10^{-3}	0.802
150	29.4	1.53	187	13.5	0.659
133	32.6	1.57	137	20.9	0.664
111	35.1	1.42	120	24.4	0.685
68.2	35.2	0.886	102	28.7	0.742
46.4	35.2	0.695	82.8	33.6	0.806
23.9	35.4	0.524	193	11.7	0.749
16.5	35.6	0.475	104	28.0	0.769
10.3	35.6	0.407	68.5	37.4	0.840
8.06	35.6	0.392	52.2	41.6	0.840
5.41	35.5	0.376	34.2	46.2	0.834
2.77	35.3	0.356	26.9	49.0	0.835
			19.6	51.3	0.834
			16.2	52.7	0.832
			13.0	55.6	0.839
			10.8	55.6	0.801
			8.09	55.2	0.759
			5.36	55.1	0.717
			2.72	54.9	0.666
			126	24.0	0.730
			105	28.6	0.764
			84.8	34.6	0.809
			69.9	38.2	0.825
			49.6	43.7	0.831
			153	19.2	0.677
			174	14.9	0.752
			16.1	55.6	0.827
			14.7	56.5	0.823

D=50.8 mm			m=0.2902		
P=2kgf/cm^2			P=1 kgf/cm^2		
Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)	Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)
559×10^{-5}	2.89×10^{-3}	1.31	400×10^{-5}	4.11×10^{-8}	0.665
250	35.0	1.12	302	11.8	0.523
431	13.3	1.08	252	16.1	0.437
371	18.9	0.975	226	19.9	0.436
356	21.3	0.926	200	26.5	0.496
294	29.1	1.07	186	29.5	0.512
250	35.2	1.13	173	32.6	0.537
205	34.8	0.788	159	35.7	0.570
175	35.1	0.596	133	42.3	0.633
146	35.1	0.477	148	38.7	0.610
103	34.7	0.360	121	47.4	0.666
52.7	35.0	0.252	67.1	53.8	0.504
35.6	35.1	0.223	51.3	54.3	0.429
26.0	35.2	0.190	31.3	54.8	0.332
17.8	35.3	0.178	23.7	54.8	0.296
14.0	35.0	0.157	17.6	54.5	0.271
10.1	35.4	0.150	13.1	54.8	0.247
5.33	35.0	0.134	7.68	55.0	0.230
5.32	35.2	0.138	19.1	54.7	0.286
2.73	35.1	0.123	13.1	54.9	0.250
			10.6	54.7	0.244
			8.07	54.5	0.239
			5.37	54.6	0.222
			2.79	54.4	0.207

$D=50.8$ mm			$m=0.3875$		
$P=2$ kgf/cm^2			$P=1$ kgf/cm^2		
Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)	Q' (m^3/s)	Q'' (m^3/s)	$\Delta P_{1,4}$ (kgf/cm^2)
554×10^{-5}	17.4×10^{-3}	1.03	330×10^{-5}	19.0×10^{-3}	0.369
462	25.3	0.829	294	25.4	0.381
361	35.1	0.698	254	33.2	0.385
296	34.5	0.511	231	38.2	0.403
252	34.5	0.405	209	42.3	0.412
216	34.8	0.334	182	50.2	0.452
187	35.2	0.264	137	55.2	0.374
161	34.7	0.213	85.6	55.3	0.254
138	34.8	0.201	42.0	55.2	0.172
114	35.2	0.170	31.3	55.8	0.147
85.9	35.4	0.155	21.2	56.0	0.126
56.1	35.5	0.118	21.0	55.7	0.136
31.6	35.5	0.0950	16.9	55.9	0.119
25.2	35.6	0.0895	13.3	55.8	0.112
19.3	35.7	0.0833	10.9	55.8	0.110
11.9	35.7	0.0723	8.14	55.4	0.107
10.3	36.0	0.0711	5.42	55.5	0.101
8.05	35.6	0.0641	2.75	55.5	0.0961
7.85	35.8	0.0689	8.22	56.7	0.0933
5.40	35.5	0.0661			
5.27	35.8	0.0666			
2.79	35.3	0.0616			