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7		X			2a, 2b	Baseline
8			X		3a, 3b, 3c	Baseline
9				X	4a, 4b, 4c	Baseline
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11		X			6	Fig. 1a
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13				X	8	Fig. 1a
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Orifice Meter Performance Downstream of a Tube Bundle Flow Conditioner, Elbows, and a Tee

Charles F. Sindt, Michael A. Lewis, and James A. Brennan

System pipe configurations can produce large flow disturbances that significantly affect the accuracy of orifice meters. Flow conditioners such as the tube bundle are frequently used to remove the effect of upstream disturbances. The flow conditioner can also influence measurement accuracy if improperly located relative to the orifice plate in the orifice meter. Tests were conducted in a 3.8 μm (150 μin) Ra surface finish pipe with a tube bundle flow conditioner located at four different positions upstream of an orifice plate. The resulting orifice discharge coefficients are shown for the tube bundle flow conditioner at each of the locations. Changes in the orifice discharge coefficient for orifice plates downstream of three flow disturbances consisting of elbows or a tee were measured. For most of the configurations tested, installing a tube bundle flow conditioner immediately downstream of the disturbances reduced these changes in the discharge coefficient from as much as 2 percent to less than 0.2 percent. Recommendations for future research needs are suggested.

Key words: discharge coefficient; flow conditioner; flow disturbances; flow measurement; gas; orifice meter; tube bundle

INTRODUCTION

Most meter installations have some form of flow disturbance upstream of the meter. The disturbance may be a valve, an elbow, a tee, a header, or other piping elements. The parameters for acceptable orifice meter installations downstream of a flow disturbance are specified in standards such as ANSI/API 2530[1] and ISO 5167[2]. These standards define the minimum upstream distances between the orifice plate and the upstream disturbance in installations with no flow conditioner. For installations with a flow conditioner the standards specify the minimum distance between the upstream disturbance and the flow conditioner as well as the distance from the flow conditioner to the orifice plate. These required distances from the orifice plate are functions of the type of disturbance; the beta ratio; the type of pressure taps; and the location of a flow conditioner, if used. Effects of the flow conditioner location on the orifice meter in undisturbed flow have been measured and reported[3,4]. The work reported by Smith[3] included the effects of the location on the orifice discharge coefficient when using flow conditioners such as the Sprenkle, Zanker, and two types of tube bundles. A literature review of flow conditioner effects is included in NIST Technical Note 1330[4]. That report also covers the previous work performed at the National Institute of Standards and Technology, Boulder, Colorado (NIST-B) that was sponsored by the Gas Research Institute (GRI), Chicago, Illinois. The test results reported in Technical Note 1330 are for the tube bundle and the Sprenkle flow conditioner in a 4-inch orifice meter with an upstream tube of 0.76 μm (30 μin) Ra surface roughness. This surface roughness is smoother than that of most commercial meters. Therefore, tests with the tube bundle were repeated using a meter with an upstream tube surface roughness of 3.8 μm (150 μin). The test results indicate the effect of the increased surface roughness in reducing the flow conditioner influence was less than 0.3 percent with the flow conditioner located at seven pipe diameters and was less than 0.1 percent in most other cases.

If no flow conditioner is used, the ANSI/API 2530[1] standard requires a longer upstream straight pipe between the disturbance and the orifice plate than it does if a flow conditioner is installed. For example, the distance from two close-spaced, out-of-plane elbows to the orifice plate must be 35 pipe diameters without a flow conditioner and 15 pipe diameters if a tube bundle flow conditioner is used. However, for an orifice beta ratio of 0.75, this standard specifies that a flow conditioner can be placed no closer than seven pipe diameters upstream of the orifice plate. Tests reported here and by others[3,4] show that an in-line tube bundle located at seven pipe diameters upstream of the orifice plate in a 4-inch orifice meter can decrease the orifice discharge coefficient by as much as 1.2 percent. The location of the flow conditioner that resulted in a much smaller change to the orifice discharge coefficient depended on the beta ratio and was between 15 and 20 pipe diameters upstream of the orifice plate. Depending on the type of disturbance, this is more than the total length between the disturbance and the orifice plate specified in the current standard[1]. Moving the flow conditioner to 15 pipe diameters upstream of the orifice plate and maintaining the specified distance between the flow conditioner and the upstream disturbance would require eight more pipe diameters of overall meter length, as the current standard also specifies eight pipe diameters between the disturbance and the flow conditioner outlet.

The potential requirement for increasing the overall length between an upstream disturbance and the orifice plate would be an impractical modification to many existing installations. For this reason, a program to determine the minimum practical length of pipe required between the disturbance and the flow conditioner was conducted by NIST-B. The program included testing the effects of three upstream disturbances: (1) two elbows in plane at 12 pipe diameters apart, (2) a tee, and (3) two out-of-plane elbows butt-welded together. Both the tee and the out-of-plane elbows were 12 diameters downstream of an elbow. The test results indicate that an in-line tube bundle placed immediately downstream of the disturbance and 17 pipe diameters upstream from the orifice plate resulted in negligible flow measurement error with the tee and less than 0.2 percent error in most of the other cases.

EXPERIMENTAL PROGRAM

Three test configurations were used to produce the baseline orifice discharge coefficients. The meter configuration for these tests included at least 46 pipe diameters of straight upstream length and were composed of an approach section, an upstream section, and a downstream section, as shown in figures 1a, 1b, and 1c. The approach section was 34 pipe diameters long and had an internal surface roughness of 2.3 μm (90 μin) Ra. The internal surface roughness of the 11 pipe diameters long upstream section was 3.8 μm (150 μin) Ra. The downstream section was 16 pipe diameters long. Four orifice beta ratios of 0.43, 0.55, 0.67, and 0.73 were tested with and without a 6-inch Sprenkle flow conditioner located at 46 pipe diameters upstream of the orifice plate (the configurations shown in figures 1a and 1b). A few tests were conducted using the beta ratio plates of 0.67 and 0.73 with 56 pipe diameters of straight pipe upstream of the orifice plate (configuration 1c).

The flow conditioner used for the tests was a 19-tube, circular pattern, in-line unit, as illustrated in figure 2. This type of flow conditioner is held in the pipe with a set screw positioned at the center of the tube bundle. The set screw was located at the top of the horizontal meter tube. The flange pressure taps were located at the 9 o'clock position looking in the direction of flow.

The first objective of the test program was to determine the flow conditioner location where the calculated orifice discharge coefficient was equivalent to the discharge coefficient at the baseline. Four flow conditioner locations upstream of the orifice plate were selected. The closest was at seven pipe diameters because this is the minimum distance allowed[1] when using a beta ratio of 0.75. The other locations were approximately 11, 17, and 27 pipe diameters. Data were taken using the meter with 46 pipe diameters of straight upstream pipe (the configuration shown in figure 1a) and with four orifice plates with beta ratios of 0.43, 0.55, 0.67, and 0.73. With the flow conditioner at 27 pipe diameters and the beta ratios of 0.67 and 0.73, a second test configuration used an oversized (6-inch) Sprenkle flow conditioner at 46 pipe diameters upstream of the orifice plate (the configuration shown in figure 1b).

The second objective of the program was to test configurations to determine the minimum lengths required between the orifice plate, the tube bundle, and the disturbance for maintaining accurate flow measurement. The flow conditioner location tests reported here and those reported by McFaddin[4] suggest that a distance of 15 to 20 pipe diameters is the best compromise for the distance between the in-line tube bundle flow conditioner and the orifice plate to prevent the flow conditioner from degrading the flow measurement. Therefore, to keep the overall length to a minimum, the test plan started with the flow conditioner located immediately downstream of the disturbances, which were located 19 pipe diameters upstream of the orifice plate. The meter approach section used for the flow conditioner location study was replaced with a shorter section to obtain the 19 pipe diameters. The downstream flange of this piece was pinned to the upstream section to ensure alignment. The internal surface roughness of this piece was 0.76 μm (30 μin) Ra. The flow conditioner used for these tests was the same in-line, circular pattern, 19 tube unit used for the flow conditioner location study.

The first upstream disturbance test configuration used two long radius elbows in plane which turned the same direction and were spaced 12 pipe diameters apart. This configuration is shown in figure 3. The next test configuration placed a tee 12 pipe diameters downstream of a long radius elbow as is shown in figure 4. Figure 5 shows the third configuration, which consisted of two out-of-plane long radius elbows butt-welded together and spaced 12 pipe diameters downstream of a third long radius elbow.

Two upstream sections of different interior surface roughness were used in the test program. The data for the two elbows in plane were taken using a 0.76 μm (30 μin) Ra upstream section. A 3.8 μm (150 μin) Ra upstream section was used with the two out-of-plane elbows. Both sections were used with the tee. Flow was measured using all three configurations, with and without the flow conditioner installed, and using orifice plates with beta ratios of 0.43, 0.55, 0.67, and 0.73.

TEST RESULTS

Baseline Data

The baseline data used for the 3.8 μm (150 μin) Ra upstream tube in the three configurations shown by figure 1 are presented in tables 1a through 4c for the four beta ratio plates. The plotted data are shown in figures 6 through 9. Data for each configuration are plotted with a different symbol so that it can be observed separately from the others; a straight line fitted to all of the data is also shown on the plots.

The baseline data used for the 0.76 μm (30 μin) Ra upstream tube were taken from NIST Technical Note 1330 by McFaddin et al.[4]. The measured data for each beta ratio plate using the two baseline configurations (tables B1 through B8 of the referenced technical note) were combined and fitted with a straight line. These resulting curves serve as the baselines used in this study.

Flow Conditioner Location Tests

The flow conditioner location tests using the 0.76 μm (30 μin) Ra upstream pipe were reported in NIST Technical Note 1330[4]. The flow conditioner location tests reported here are for the 3.8 μm (150 μin) Ra upstream pipe. All of the tests on location of the flow conditioner were taken for the configuration shown in figure 1a; that is, no flow conditioner at the elbow and 46 pipe diameters of straight pipe from the last elbow to the orifice plate, with two exceptions. The two exceptional cases were with the flow conditioner located at 27 pipe diameters with the two beta ratios of 0.67 and 0.73. With these two beta ratios and the tube bundle at 27 pipe diameters, additional data were taken in the configuration shown in figure 1b. The data taken with the flow conditioner located at 7 pipe diameters upstream of the orifice plate and 37 pipe diameters downstream from the elbow are presented in tables 5 through 8. The data for the four beta ratios are compared to the baseline in figures 10 through 13. Tables 9 through 12 contain the data for the four beta ratios with the flow conditioner located at 11 pipe diameters; the discharge coefficients are compared to the baseline in figures 14 through 17. The graphs for the flow conditioner located at 17 pipe diameters upstream of the orifice plate are shown in figures 18 through 20 and the data are in tables 13 through 15. No data were taken with the 0.43 beta ratio plate and the flow conditioner located at 17 or 27 pipe diameters, because previous measurements[4] indicated very little effect at these locations. Figures 21 through 23 and tables 16 through 18 present the data with the flow conditioner located at 27 pipe diameters. The data for the in-line tube bundle located at 27 pipe diameters with the 6-inch Sprenkle at 46 pipe diameters are given in tables 19 and 20 and are shown in figures 24 and 25 for the two beta ratios of 0.67 and 0.73. In these data there appears to be a difference which needs additional investigation.

To calculate the differences in the orifice discharge coefficient, the data at each flow conditioner location and beta ratio were fitted to a straight line over the flow range tested. The percent difference at selected Reynolds numbers was calculated as follows:

$$\Delta C(\%) = \frac{(C_t - C_b) \times 100}{C_b}, \qquad (1)$$

where C_t is the calculated discharge coefficient for the test configuration and C_b is the calculated discharge coefficient for the baseline configuration.

Figures 26 through 28 show the difference in the orifice discharge coefficient between the baseline and the configuration with the flow conditioner at the four test locations when using the 3.8 μm (150 μin) Ra and 0.76 μm (30 μin) Ra upstream sections. Curves are shown for a pipe Reynolds number of 1.6 x 10^6 for the beta ratios of 0.55, 0.67, and 0.73.

For all beta ratios there is a difference of less than 0.2 percent in the change of the orifice discharge coefficient between the two upstream pipes, except when the flow conditioner is located at seven pipe diameters from the orifice plate for the beta ratios of 0.55 and 0.67. Also, at a beta ratio of 0.73, the change in discharge coefficient with the flow conditioner at 11 and 27 pipe diameters is 0.3 percent between the smoother and the rougher upstream pipe. But with the Sprenkle flow conditioner upstream of the meter run the change in the discharge coefficient was within 0.2 percent of that with the smoother upstream section. The location of the flow conditioner which minimizes the shift in the orifice discharge coefficient is between 15 and 20 pipe diameters from the orifice plate for both of the upstream pipe roughnesses tested.

As noted above, with the flow conditioner placed 27 pipe diameters upstream of the 0.73 beta ratio orifice plate, there was a significant difference in the discharge coefficient when the 6-inch Sprenkle was used at the elbow and when it was not used. The data when the 6-inch Sprenkle was used are in better agreement with the data using the 0.76 μm Ra upstream pipe. More data points were taken without the 6-inch Sprenkle to reduce the possibility that one anomalous data set was causing the disagreement. There is some scatter in these data, but the scatter does not overlap the data taken when using the 6-inch Sprenkle, so we conclude that the difference measured is valid.

Inlet Disturbance Tests

Measurements were made with and without the flow conditioner installed for each of the three disturbances. Data were taken with the two elbows in plane using the 0.76 μm (30 μin) Ra upstream section. Data with no flow conditioner are presented in tables 21 through 24 and the data with the in-line tube bundle placed at the discharge of the second elbow are presented in tables 25 through 28. Figures 29 through 32 show the orifice discharge coefficient versus the pipe Reynolds number. The difference between the calculated discharge coefficients determined from the measurements with and without the flow conditioner and the baseline meter is shown at a pipe Reynolds number of 1.25 x 10^6 in figure 33. With the two elbows in plane, the calculated discharge coefficient was below the baseline for all beta ratios. With the 0.43 and 0.55 beta ratio plates, installing the flow conditioner did not improve the flow measurement. With a beta ratio of 0.67 the flow conditioner almost restored the orifice discharge coefficient to the baseline value and with a beta ratio of 0.73 it reduced the shift from -0.7 percent to -0.2 percent.

Orifice discharge coefficients were determined using the 0.76 μm (30 μin) Ra and the 3.8 μm (150 μin) Ra upstream pipes with the tee 19 pipe diameters from the orifice plate. The data measured using the 0.76 μm (30 μin) Ra upstream pipe with and without the flow conditioner are presented in tables 29 through 32 and tables 33 through 36, respectively. Figures 34 through 37 show plots of the data. Similar data for the 3.8 μm (150 μin) upstream pipe are given in tables 37 through 44 and figures 38 through 41. Figure 42 shows the change in the orifice discharge coefficient versus the beta ratio at a Reynolds number of 1.25 x 10^6 for both upstream pipes with the tee at 19 pipe diameters.

The tee introduces very large fluctuations in the orifice differential pressure; these fluctuations are accompanied by large errors in the flow measurement, especially at the lower beta ratios. These pressure fluctuations are apparently caused by a moving swirl produced by the tee, as measurements made with a pitot tube reveal highly fluctuating stagnation pressures, which indicate swirl. The tube bundle flow conditioner placed 17 pipe diameters upstream of the orifice plate at the discharge of the tee restored the orifice discharge coefficient to the baseline value over the Reynolds number range tested, 0.5×10^6 to 1.5×10^6, except with the smooth pipe and the 0.73 beta ratio orifice plate. For this configuration the shift was still less than 0.5 percent and was actually greater with the flow conditioner than for the configuration without it. With the 3.8 μm (150 μin) Ra upstream pipe, the data in figure 42 show a small positive change in the discharge coefficient with no flow conditioner. However, the curve in figure 42 with no flow conditioner is deceptive because it does not show the scatter in the measured orifice discharge coefficient that is apparent in figure 41. Therefore, the discharge coefficient may not be predictable without the flow conditioner.

The two out-of-plane elbows butt-welded together were tested using the 3.8 μm (150 μin) Ra upstream pipe. Data for this configuration without the flow conditioner are in tables 45 through 48 and data for the configuration with the flow conditioner at the exit of the second elbow are in tables 49 through 52. Figures 43 through 46 show these data. The change in orifice discharge coefficient versus the beta ratio at the Reynolds number of 1.25×10^6 is presented in figure 47.

With the beta ratios of 0.43 and 0.55, use of the flow conditioner removed nearly all of the shift of the orifice discharge coefficient produced by the two elbows. The data taken with 0.43 beta ratio plate and the flow conditioner show slightly less shift than was previously reported[5]. This is a result of our having taken additional data since that paper was written, and of a better resolution of the conditioned coefficient value. Without a flow conditioner the shift in the orifice discharge coefficient reversed sign between the beta ratio of 0.67 and the beta ratio of 0.73, which is the response previously observed with swirl present[6]. With the 0.67 beta ratio plate the flow conditioner had no effect, but at a beta ratio of 0.73 the flow conditioner almost restored the discharge coefficient to the baseline value.

CONCLUSIONS

Tests of the orifice meter at NIST-B show that the best compromise for the location of the tube bundle in our 4-inch meter was 17 pipe diameters upstream of the orifice plate, as this location produced the smallest average flow measurement deviation for all beta ratios from the baseline measurement[4]. This was true for both roughnesses of upstream pipes (0.76 μm and 3.8 μm Ra). Using the in-line tube bundle at 17 pipe diameters upstream of an orifice plate also significantly reduced the shift in flow measurement caused by flow disturbances immediately upstream. The test results reported here show that placing the flow conditioner at the discharge of two out-of-plane elbows butt-welded together reduces the shift in the orifice discharge coefficient within 0.3 percent of the baseline installation as the worst case. When the flow disturbance was a tee, the flow conditioner located at the discharge of the tee removed most of the change in the orifice discharge coefficient, which was larger than 2.75 percent. The flow conditioner located at the discharge of two elbows in plane widely spaced was only helpful at the beta ratio of 0.67 and higher where it did reduce the effect of the disturbance to less than 0.25 percent. However, at 0.43 and 0.55 beta ratio the shift from the baseline discharge coefficient was less than 0.25 percent with or without the flow conditioner.

RECOMMENDATIONS

This research was conducted with a 4-inch orifice meter, so the effect of meter tube size was not measured and is unknown at this time. Some of the work reported by others was conducted in larger sizes and did include tests with a 19-tube flow conditioner[3]. The effect of location of the flow conditioner relative to the orifice plate and to upstream disturbances needs to be measured in larger and smaller meter sizes.

The only flow conditioner used in our tests was the in-line tube bundle. Tests using other flow conditioners have been reported[3,4]. These tests were limited in scope and did not evaluate the effectiveness of the flow conditioner downstream of a disturbance. More extensive tests need to be conducted to determine whether other types of flow conditioners located closer to the orifice plate will remove the effects of disturbances when placed close to the disturbance.

Tests should be run with flow conditioners close to the disturbance and the disturbance closer to the orifice plate to determine if the overall length can be further reduced to accommodate shorter field installations. Some of this testing is included in the 1990 program.

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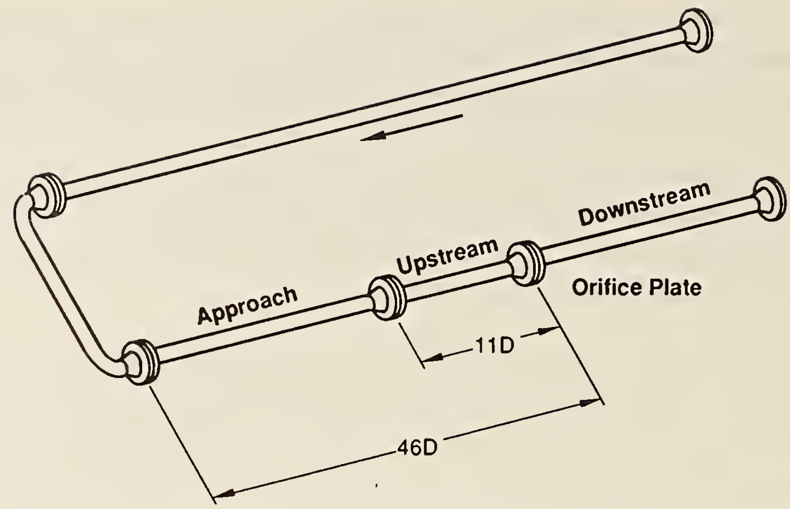

Figure 1a. Four-inch orifice meter, 46 pipe diameters of straight pipe upstream.

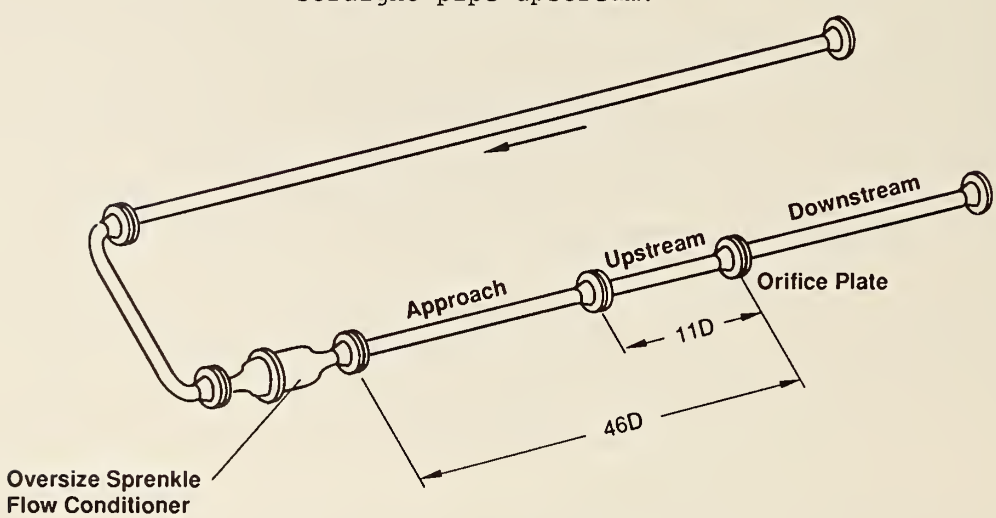

Figure 1b. Four-inch orifice meter, 6-inch Sprenkle at 46 pipe diameters.

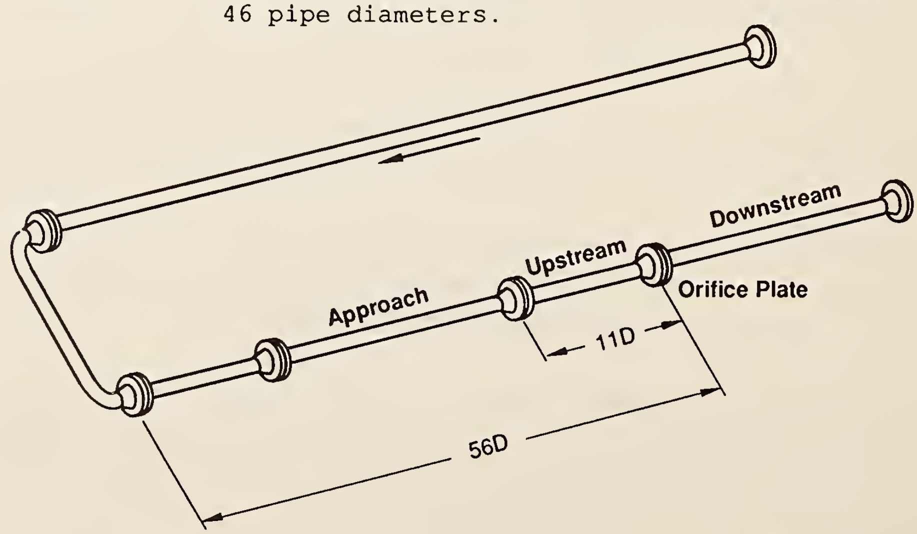

Figure 1c. Four-inch orifice meter, 56 pipe diameters of straight pipe upstream.

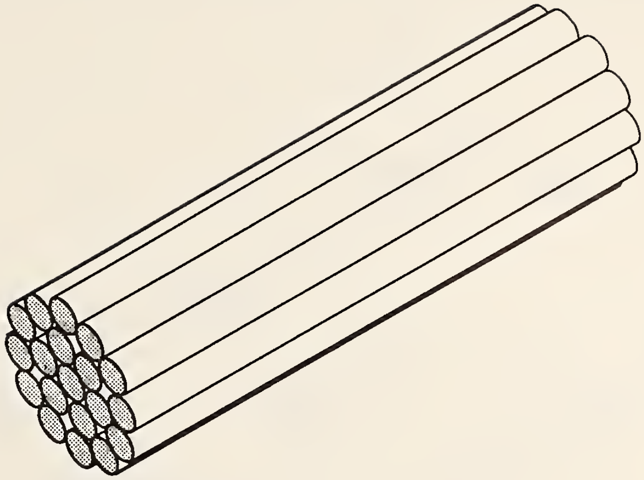

Figure 2. In-line tube bundle.

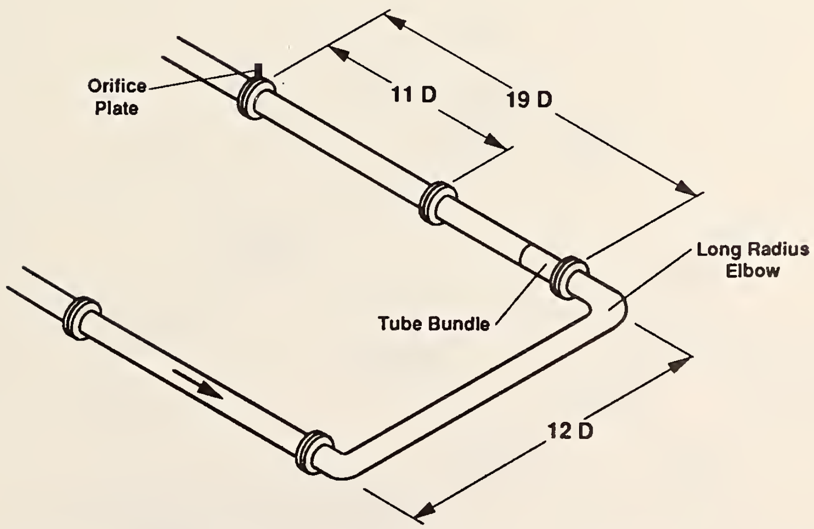

Figure 3. Test configuration with two elbows in plane at 19 pipe diameters from the orifice plate.

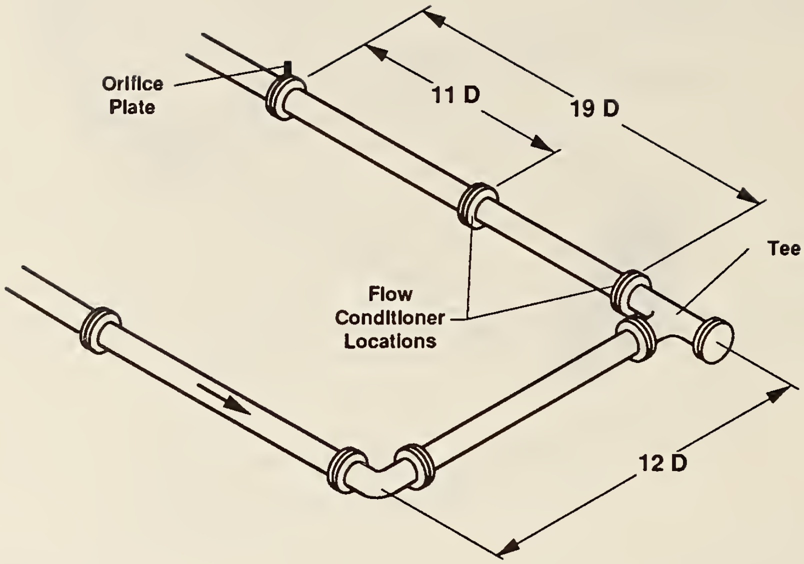

Figure 4. Test configuration with a tee at 19 pipe diameters from the orifice plate.

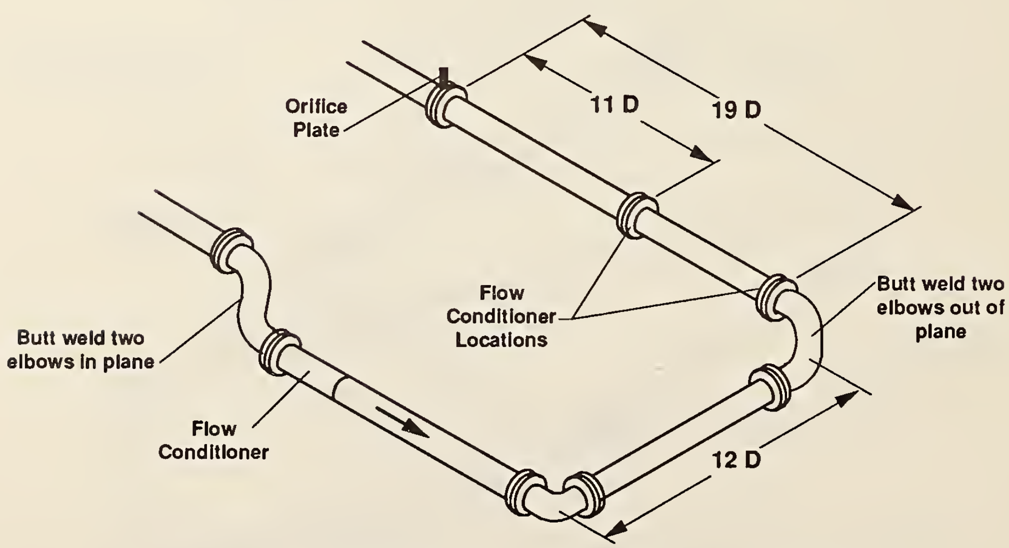

Figure 5. Test configuration with two elbows out-of-plane at 19 pipe diameters from the orifice plate.

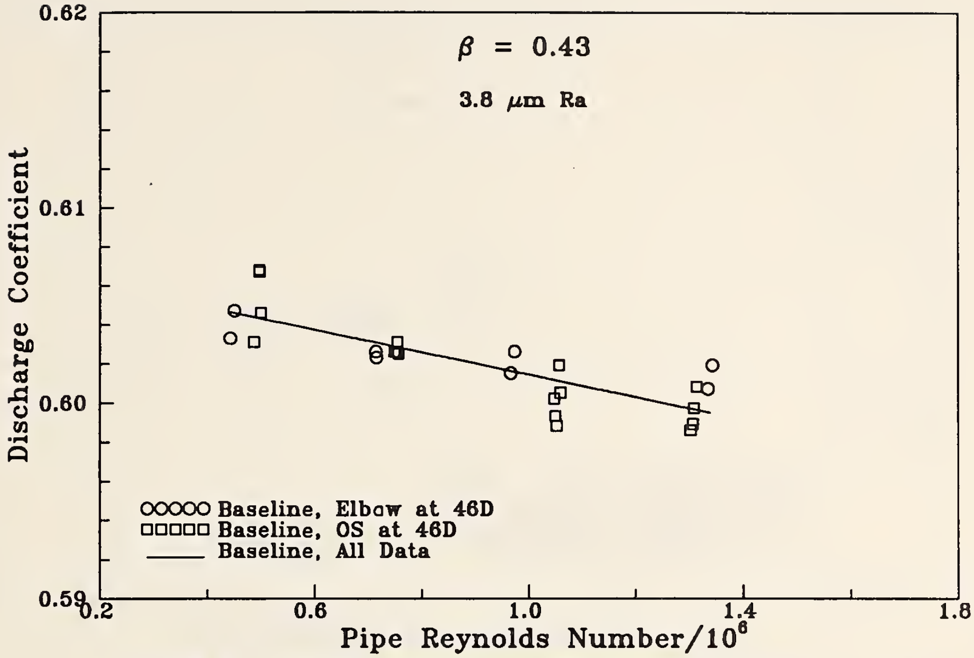

Figure 6. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio orifice plate, baseline data.

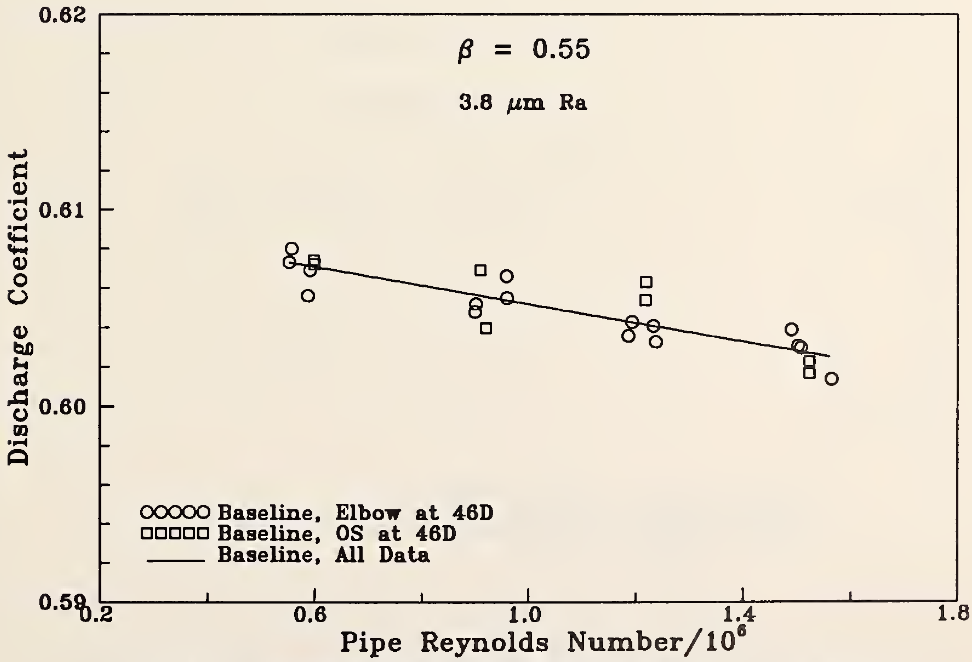

Figure 7. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate, baseline data.

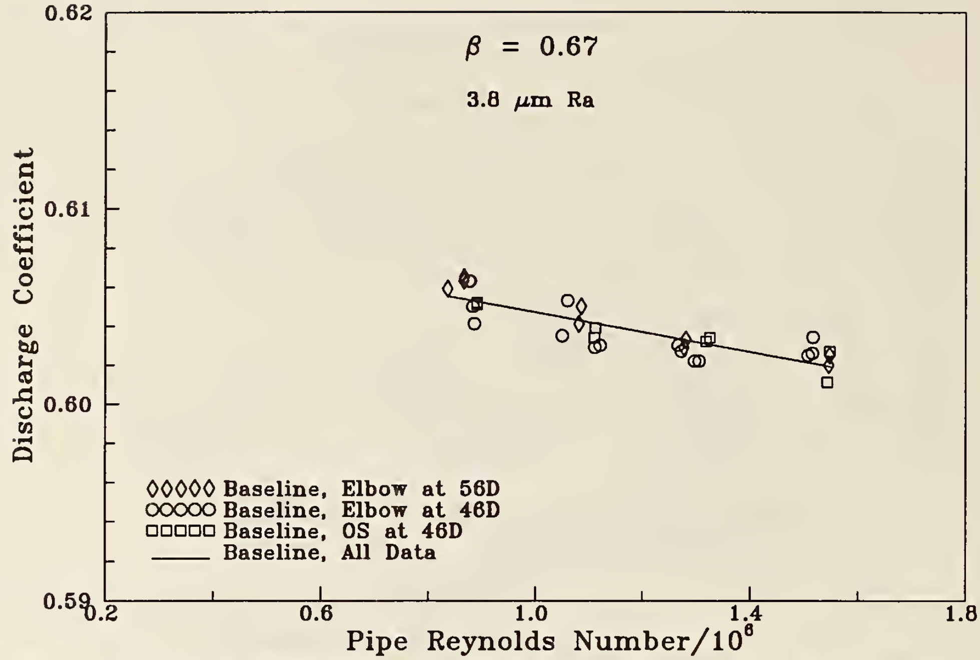

Figure 8. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plate, baseline data.

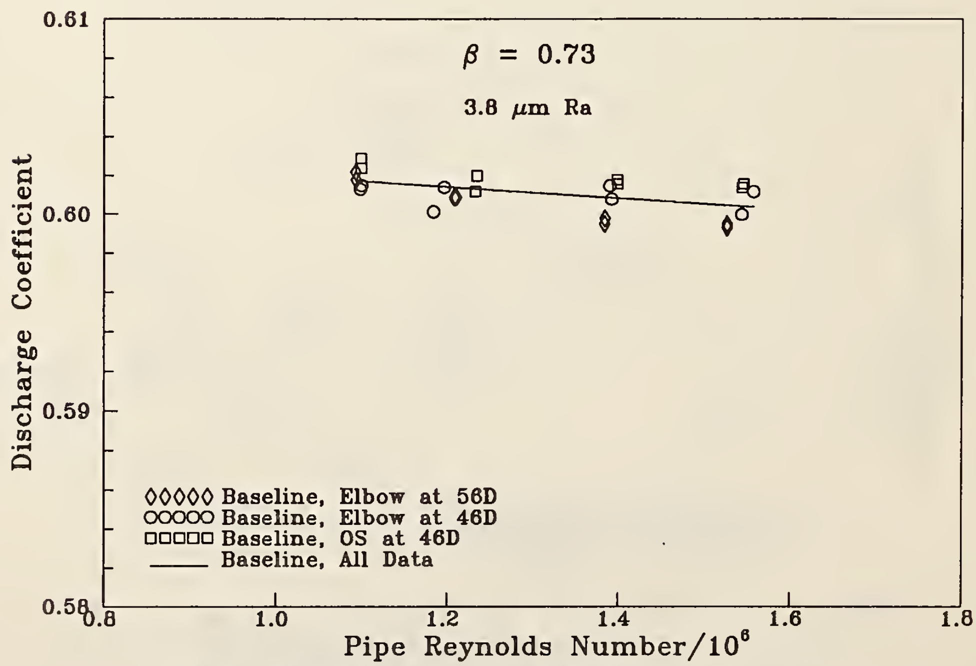

Figure 9. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio orifice plate, baseline data.

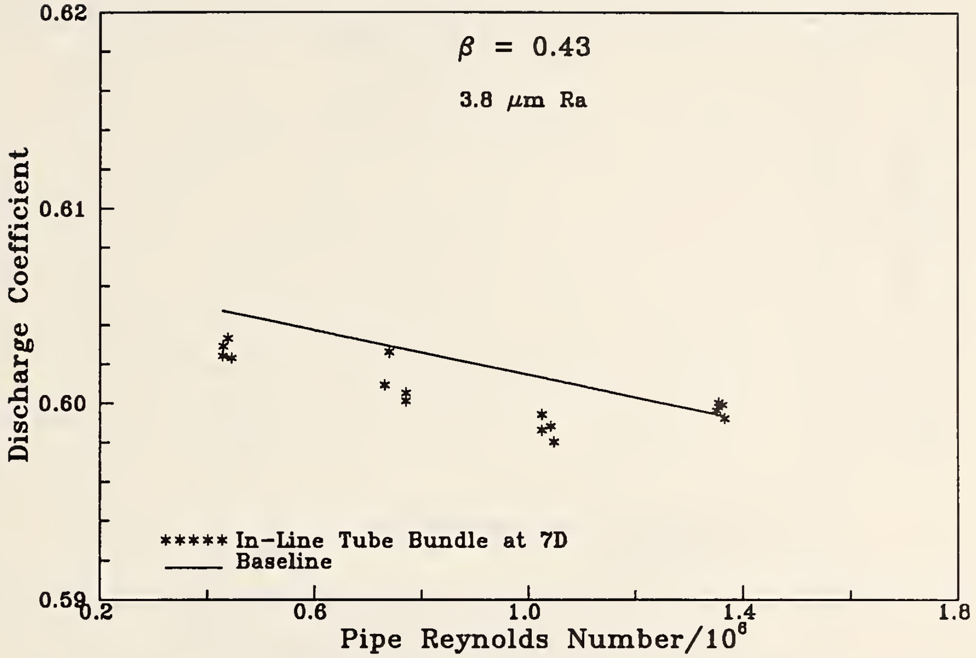

Figure 10. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio orifice plate with the in-line tube bundle at 7 pipe diameters.

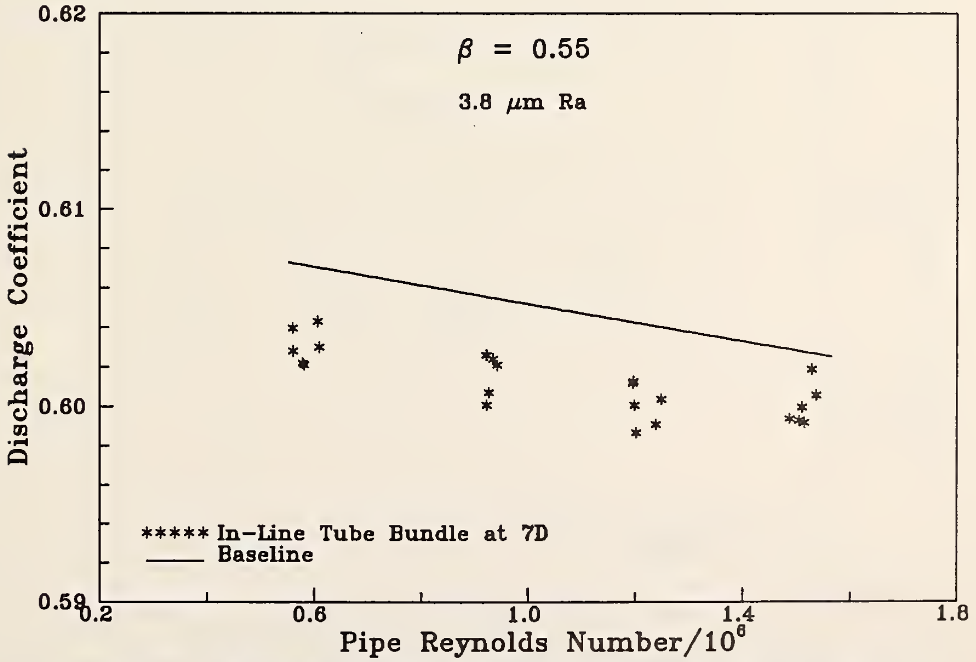

Figure 11. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate with the in-line tube bundle at 7 pipe diameters.

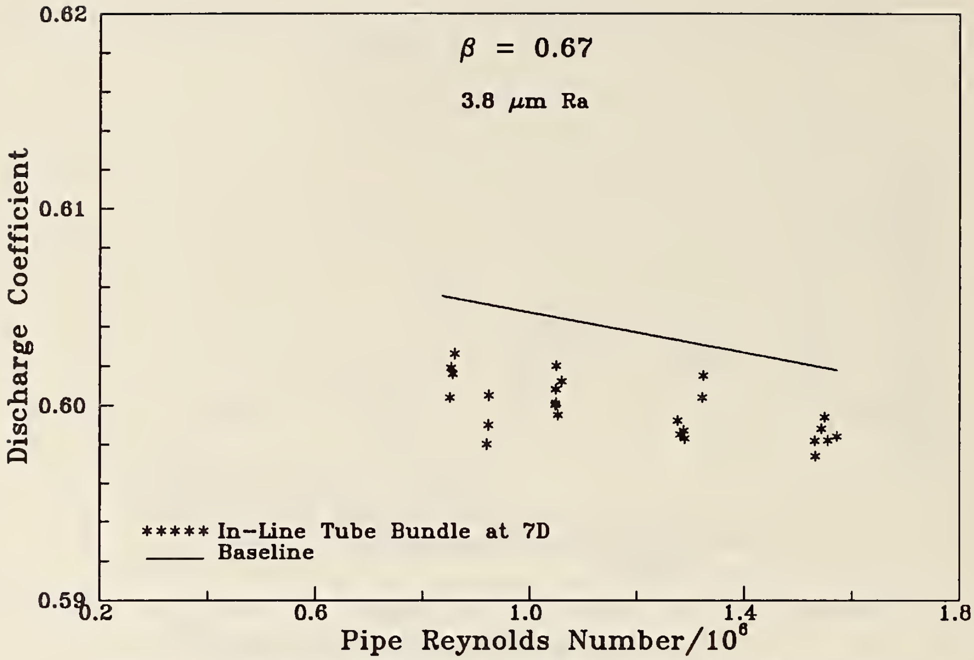

Figure 12. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plote with the in–line tube bundle ot 7 pipe diameters.

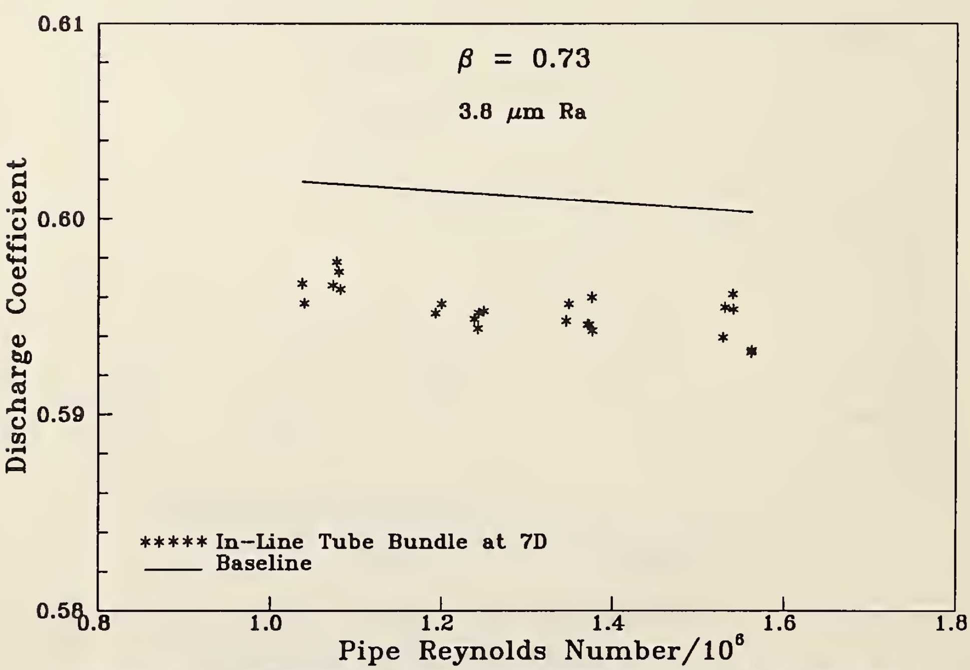

Figure 13. Discharge coefficient vs. Reynolds number for the 0.73 beto ratio orifice plate with the in–line tube bundle ot 7 pipe diometers.

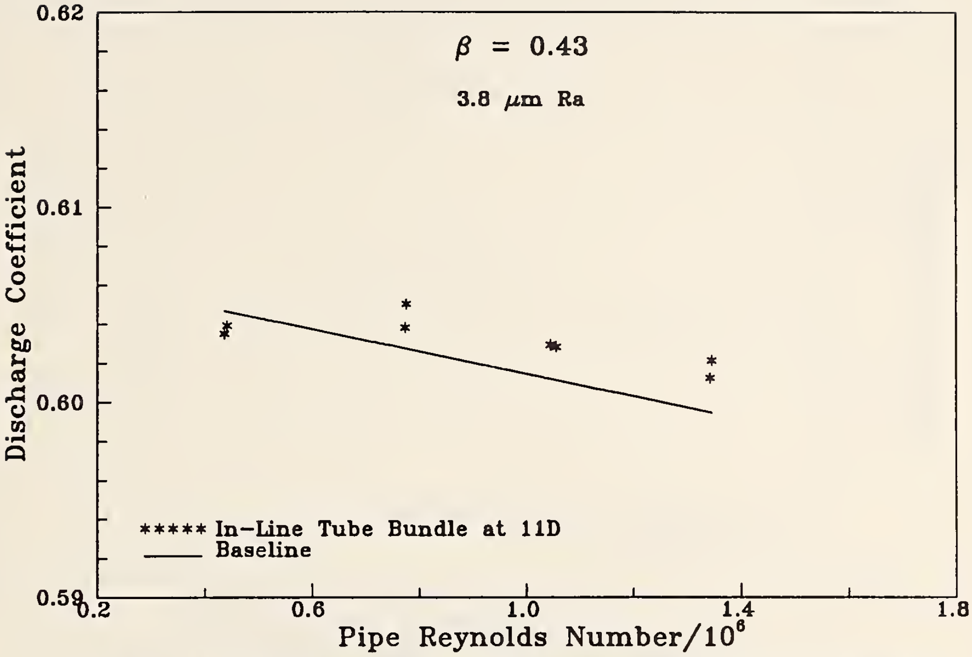

Figure 14. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio orifice plate with the in-line tube bundle at 11 pipe diameters.

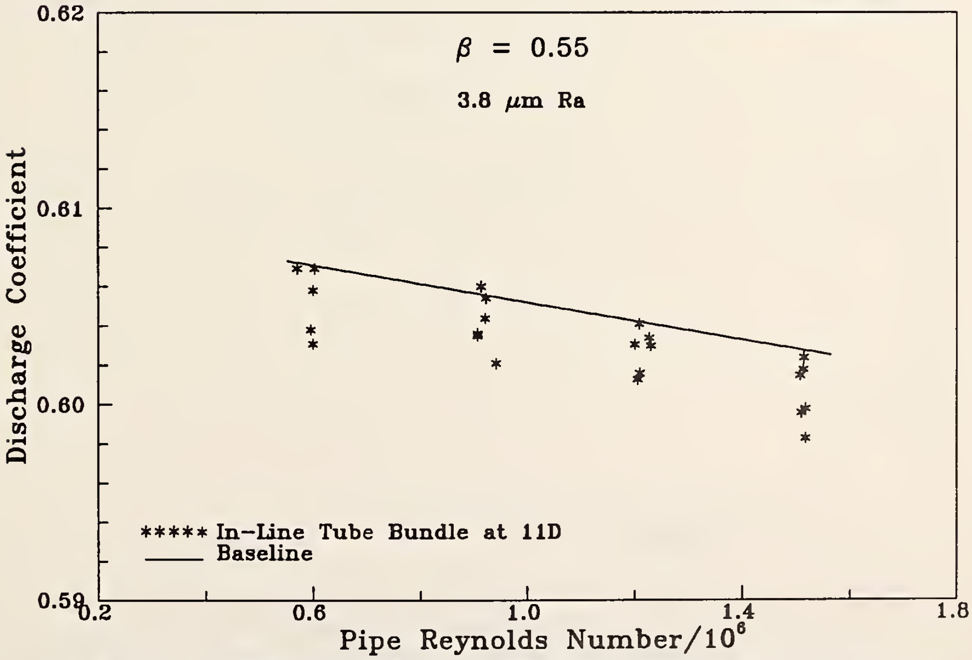

Figure 15. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate with the in-line tube bundle at 11 pipe diameters.

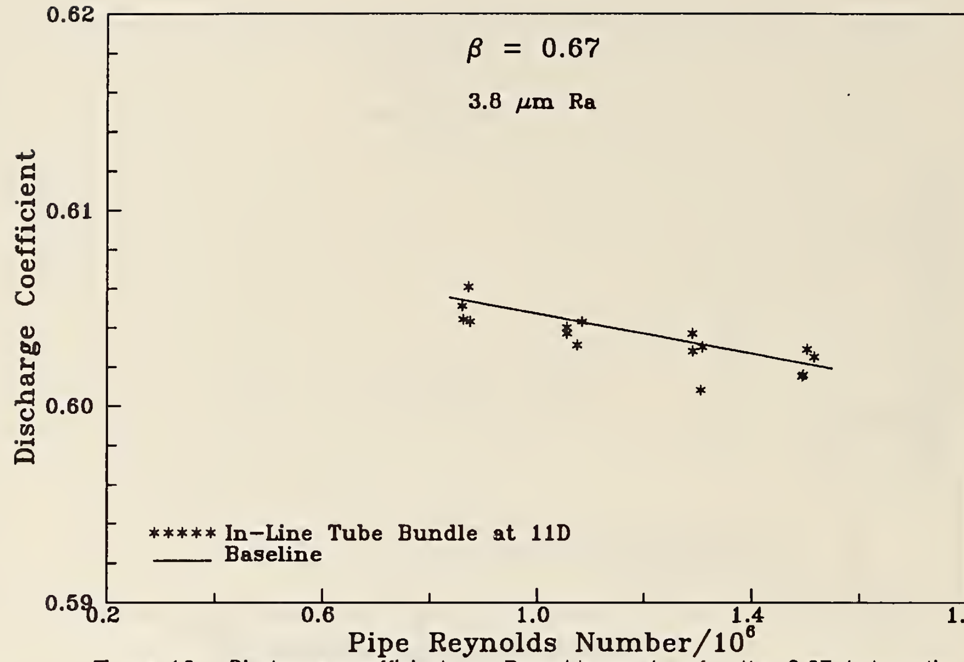

Figure 16. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plate with the in–line tube bundle at 11 pipe diameters.

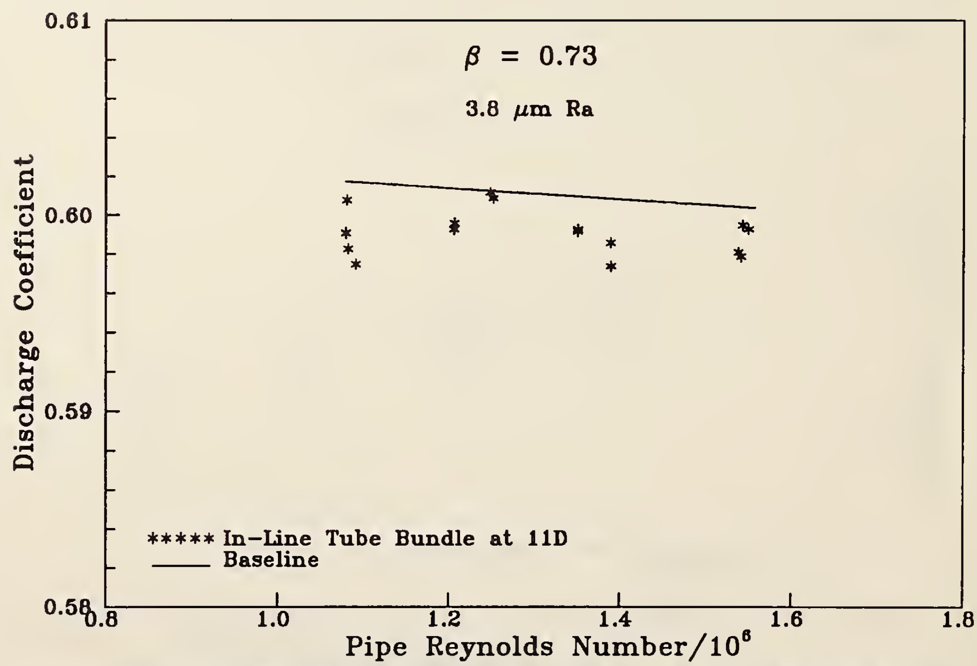

Figure 17. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio orifice plate with the in–line tube bundle at 11 pipe diameters.

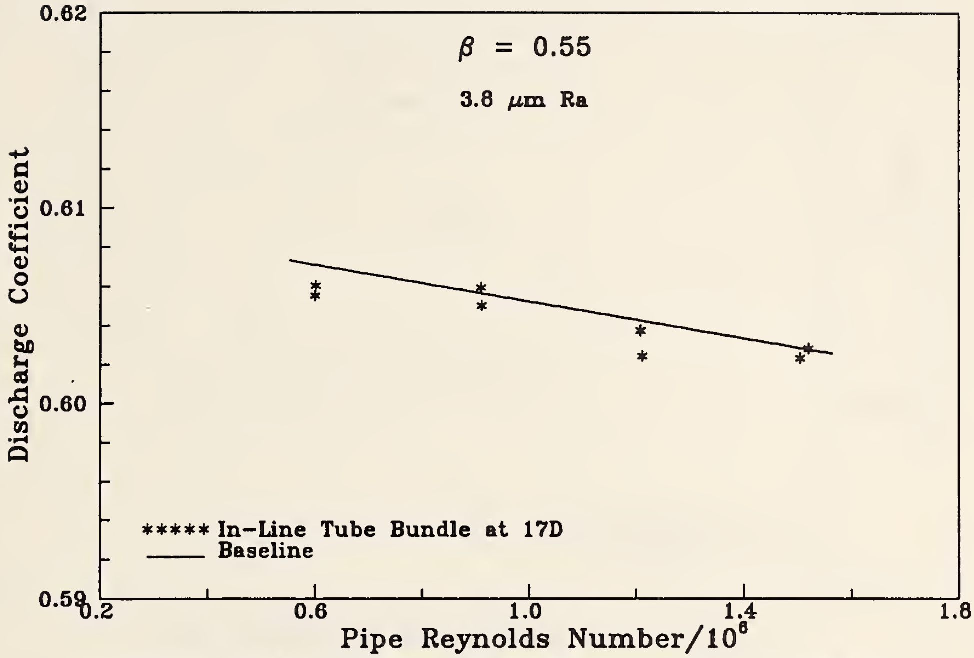

Figure 18. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate with the in-line tube bundle at 17 pipe diameters.

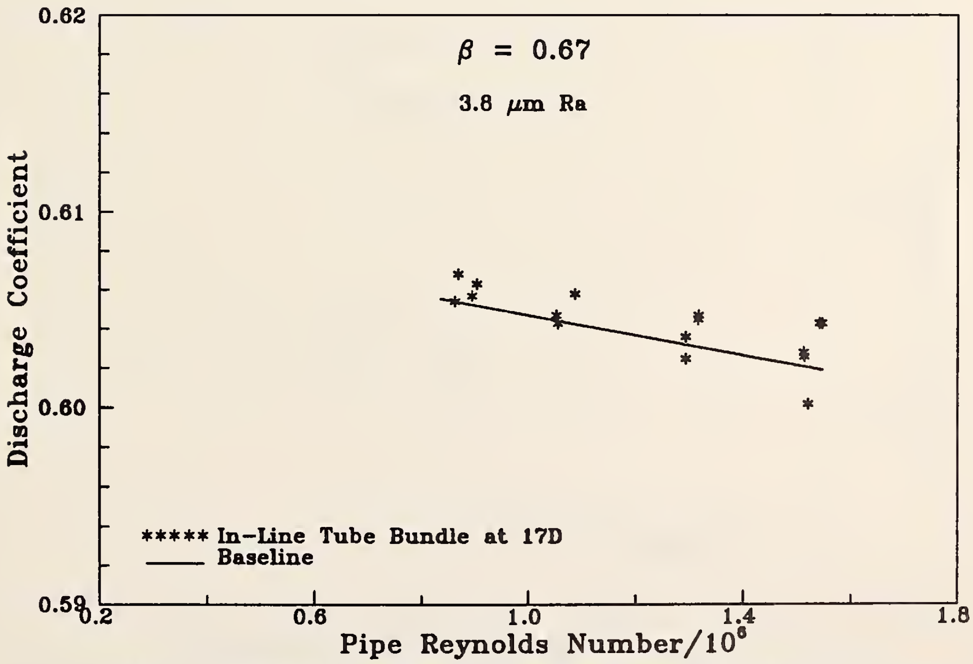

Figure 19. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plate with the in-line tube bundle at 17 pipe diameters.

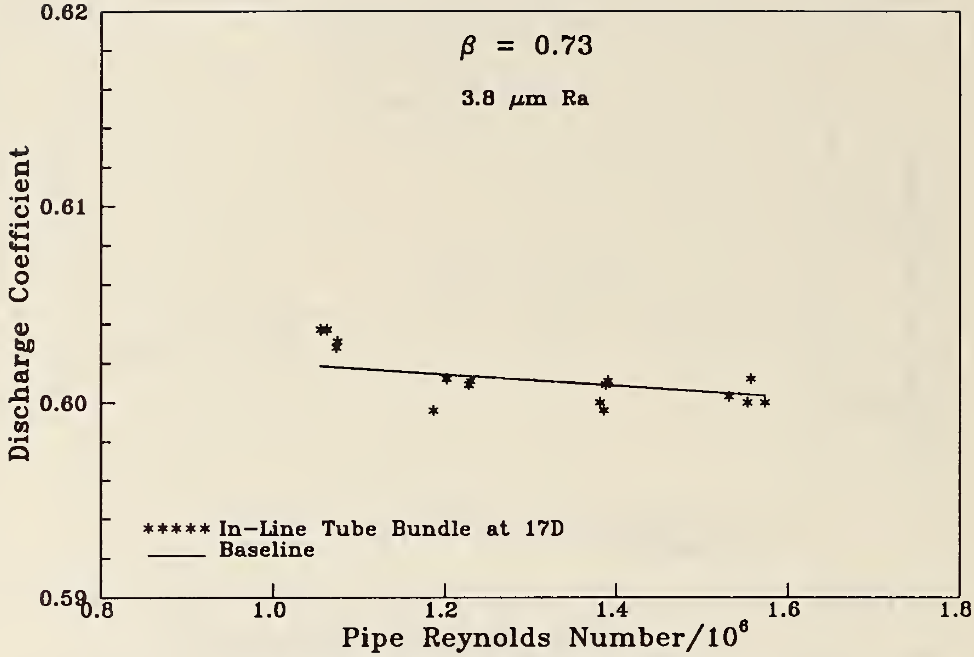

Figure 20. Dischorge coefficient vs. Reynolds number for the 0.73 beto rotio orifice plote with the in-line tube bundle ot 17 pipe diometers.

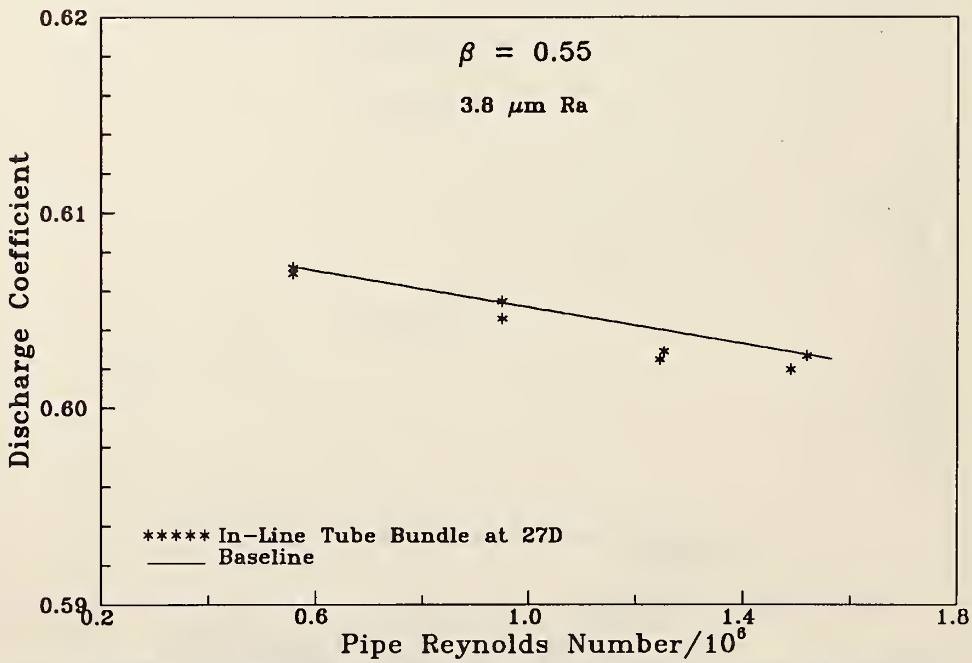

Figure 21. Dischorge coefficient vs. Reynolds number for the 0.55 beta rotio orifice plate with the in-line tube bundle at 27 pipe diameters.

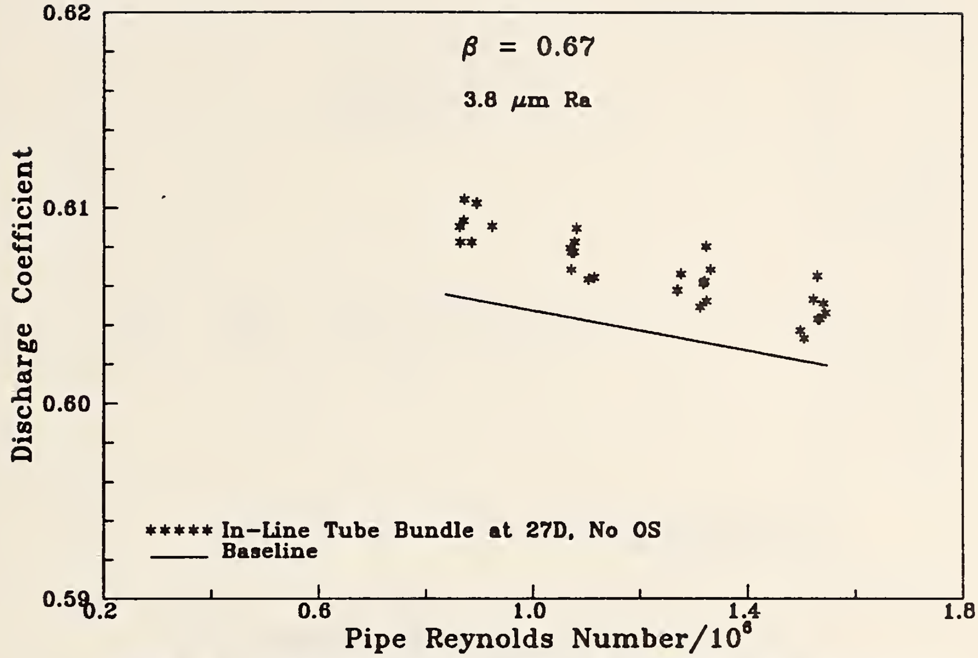

Figure 22. Discharge coefficient vs. Reynolds number for the 0.67 beto rotio orifice plote with the in-line tube bundle at 27 pipe diometers.

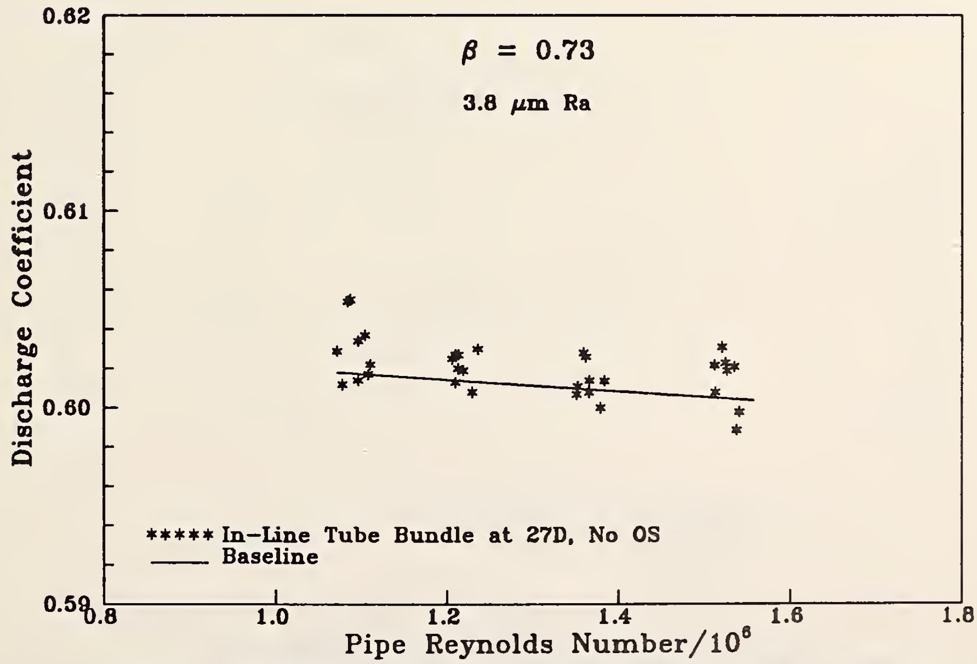

Figure 23. Dischorge coefficient vs. Reynolds number for the 0.73 beto rotio orifice plote with the in-line tube bundle ot 27 pipe diometers.

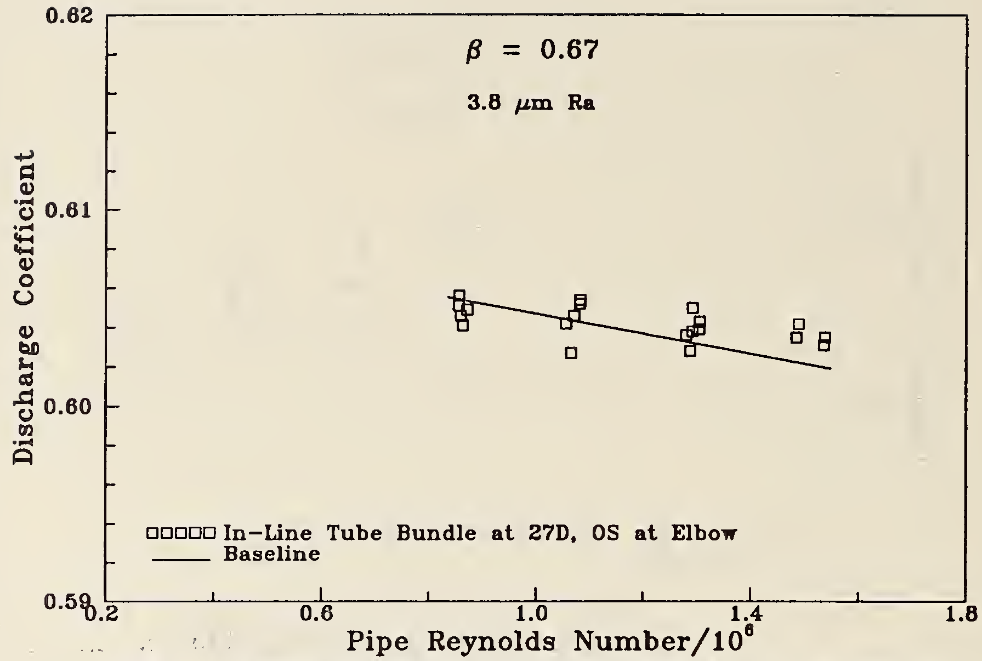

Figure 24. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plate with the in–line tube bundle at 27 pipe diameters and the 6–inch Sprenkle at 46 pipe diameters.

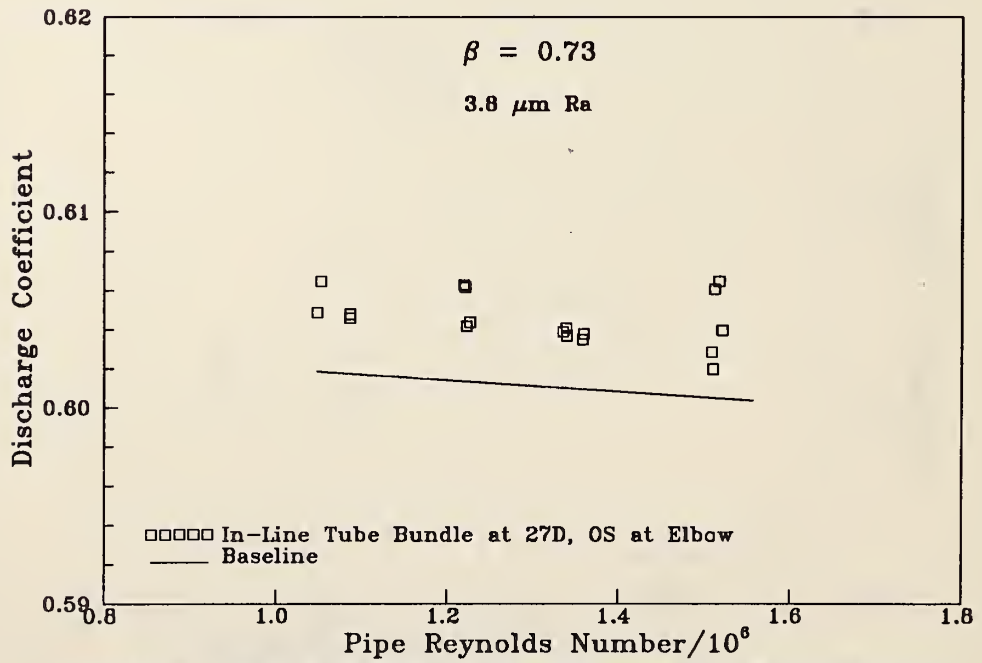

Figure 25. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio orifice plate with the in–line tube bundle at 27 pipe diameters and the 6–inch Sprenkle at 46 pipe diameters.

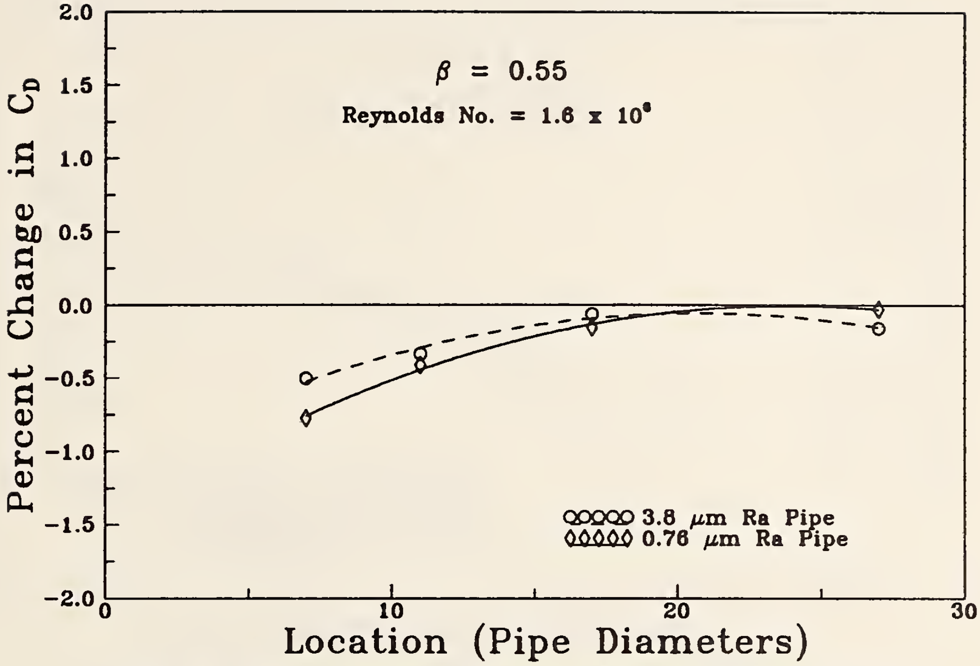

Figure 26. Percent change in the orifice discharge coefficient vs. flow conditioner location for the 0.55 beta ratio orifice plate.

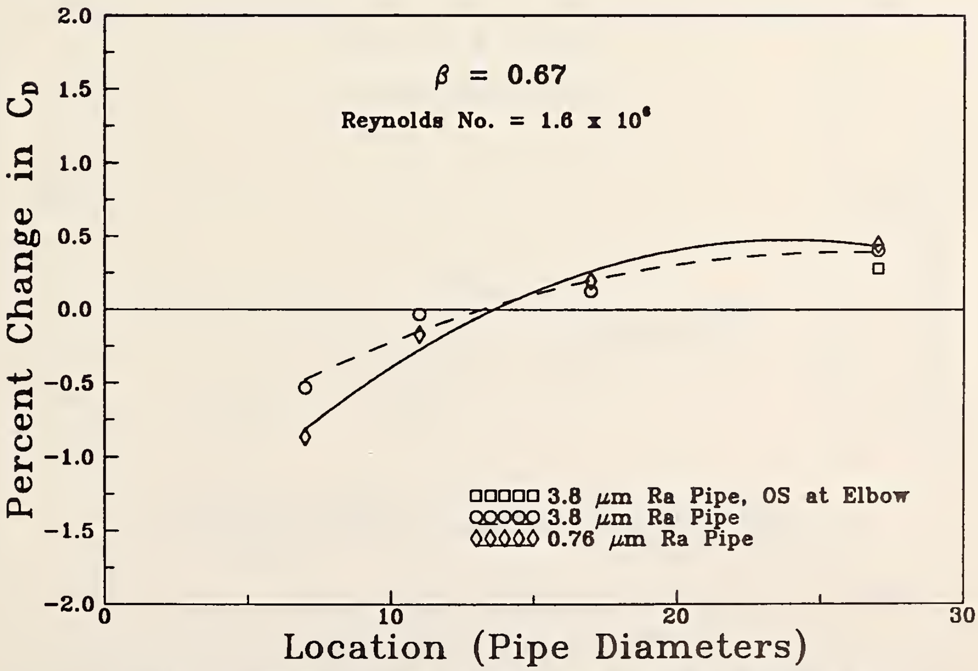

Figure 27. Percent change in the orifice discharge coefficient vs. flow conditioner location for the 0.67 beta ratio orifice plate.

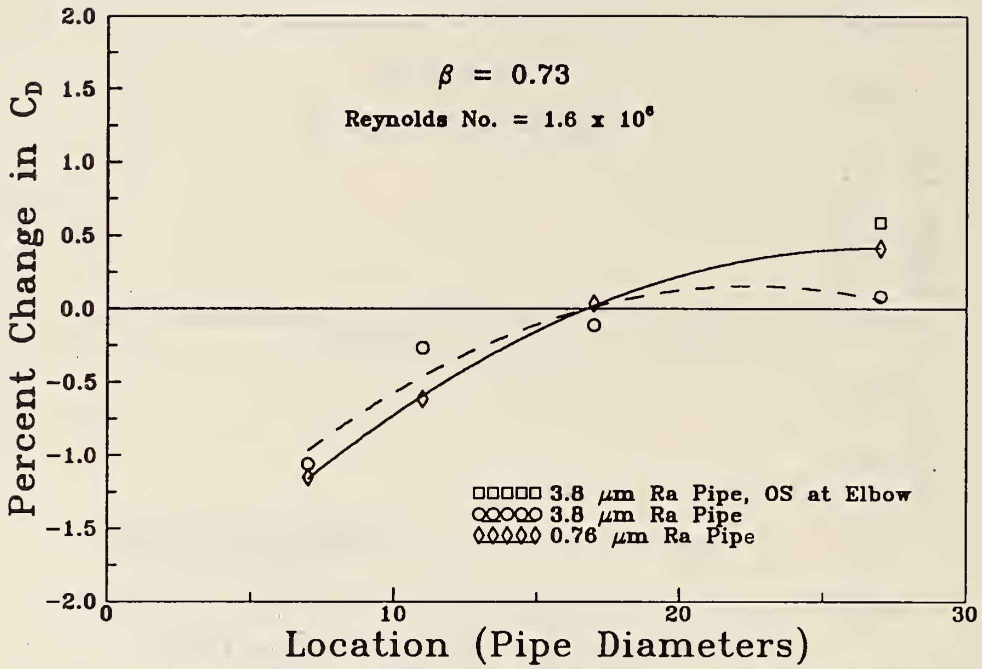

Figure 28. Percent change in the orifice discharge coefficient vs. flow conditioner location for the 0.73 beta ratio orifice plate.

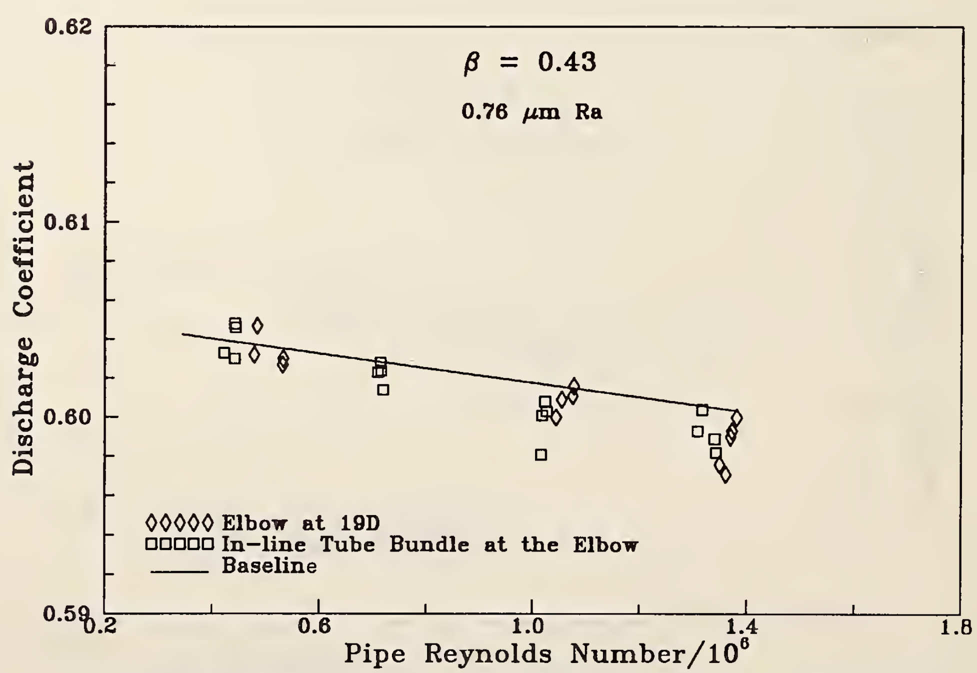

Figure 29. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio orifice plate at 19 pipe diameters from two elbows in plane.

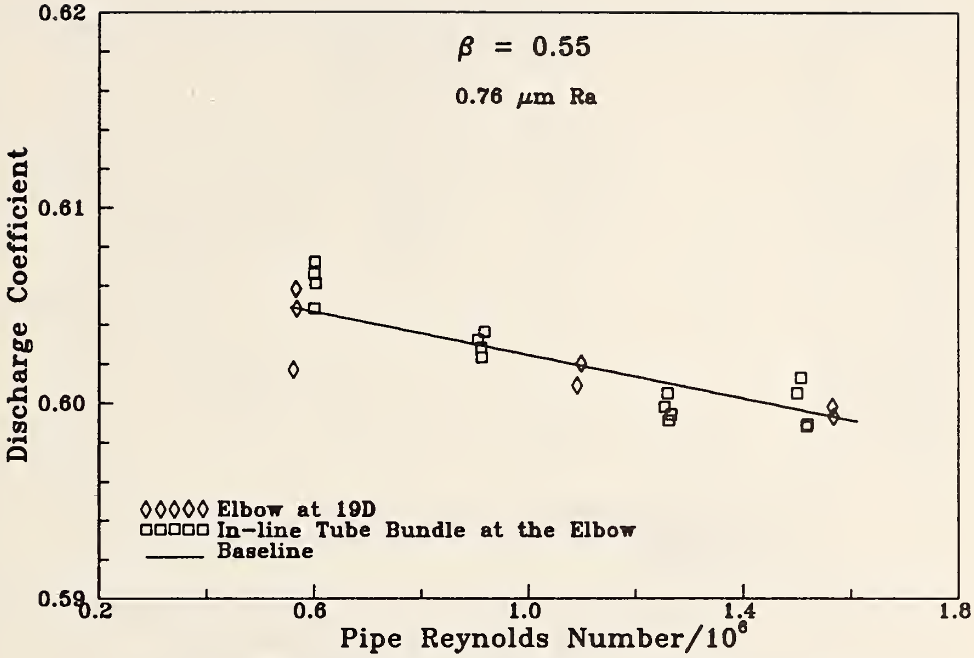

Figure 30. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate at 19 pipe diameters from two elbows in plane.

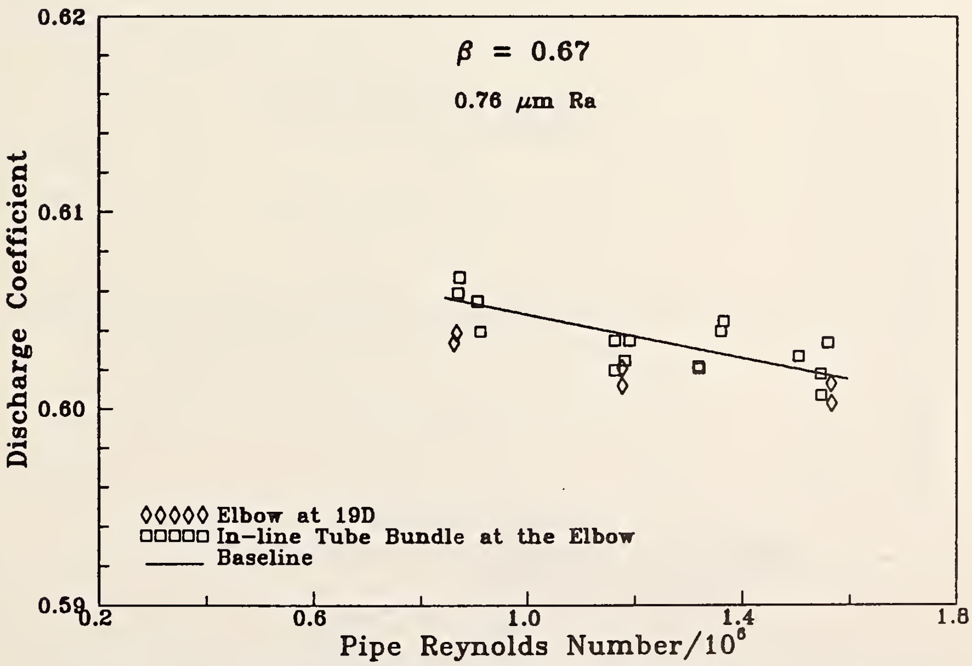

Figure 31. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plate at 19 pipe diameters from two elbows in plane.

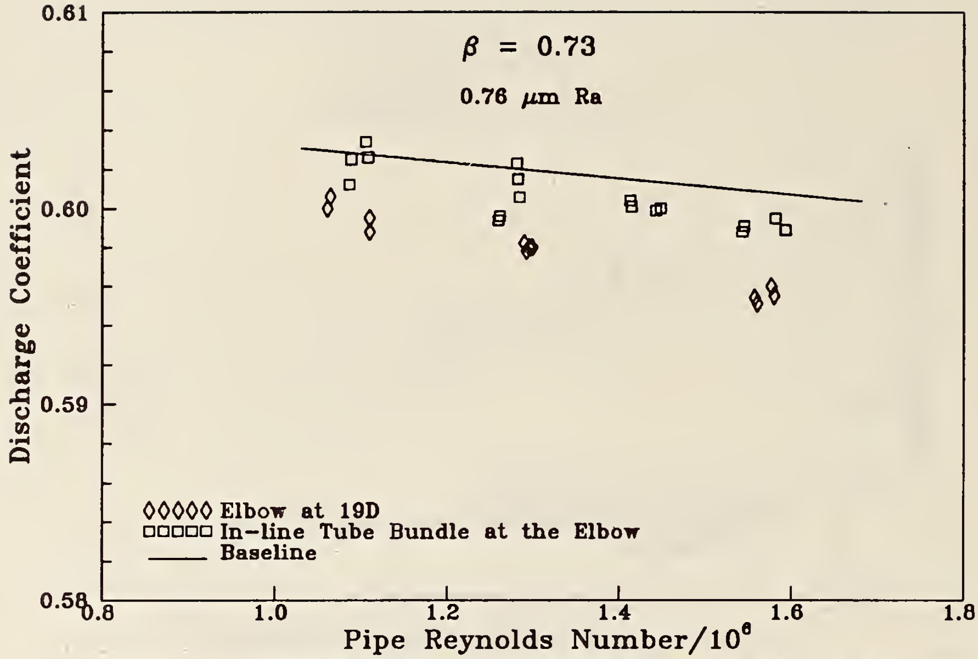

Figure 32. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio orifice plate at 19 pipe diameters from two elbows in plane.

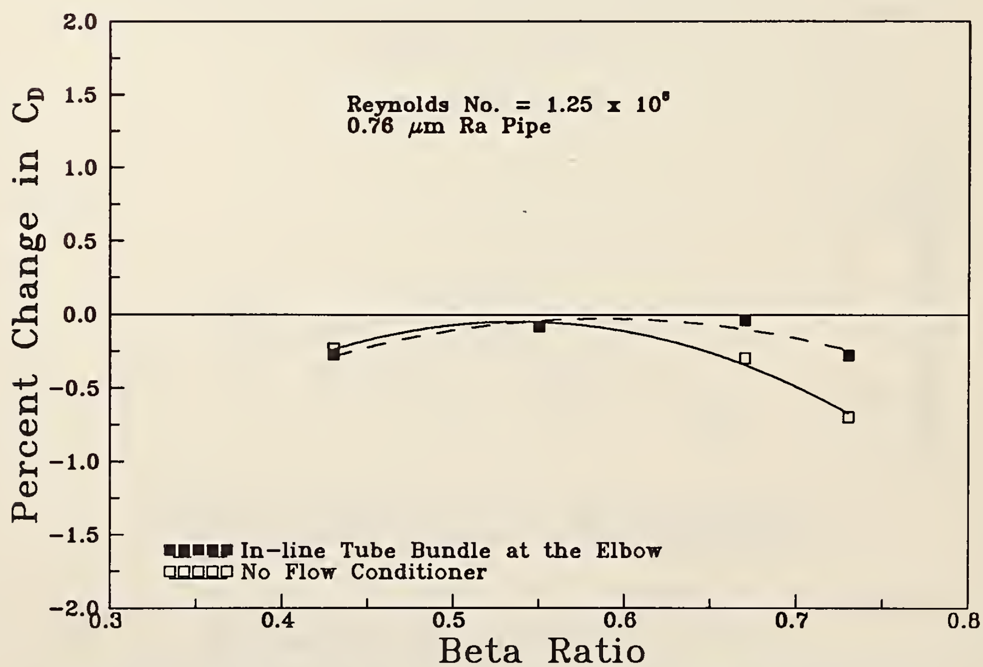

Figure 33. Percent change in the orifice discharge coefficient vs. beta ratio for the orifice plate 19 diameters from two elbows in plane.

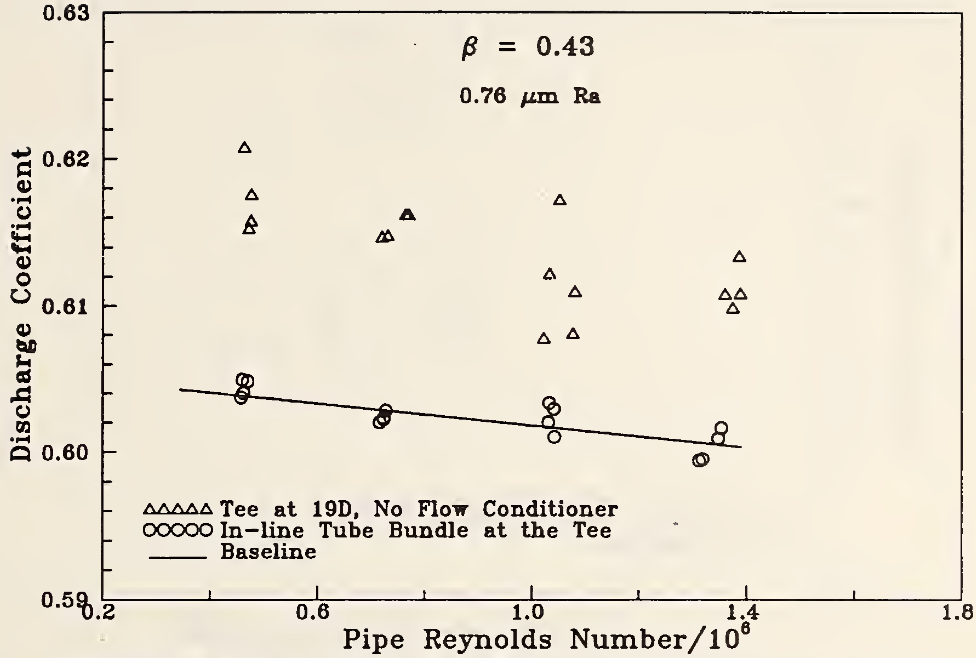

Figure 34. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio orifice plate at 19 pipe diameters from a tee and with the 0.76 μm upstream pipe.

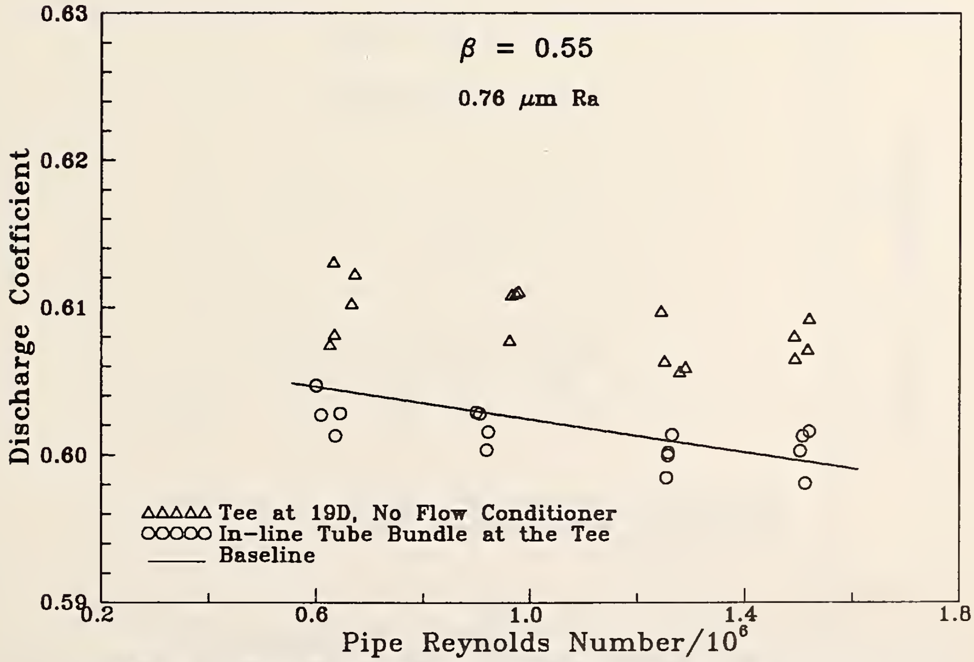

Figure 35. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate at 19 pipe diameters from a tee and with the 0.76 μm upstream pipe.

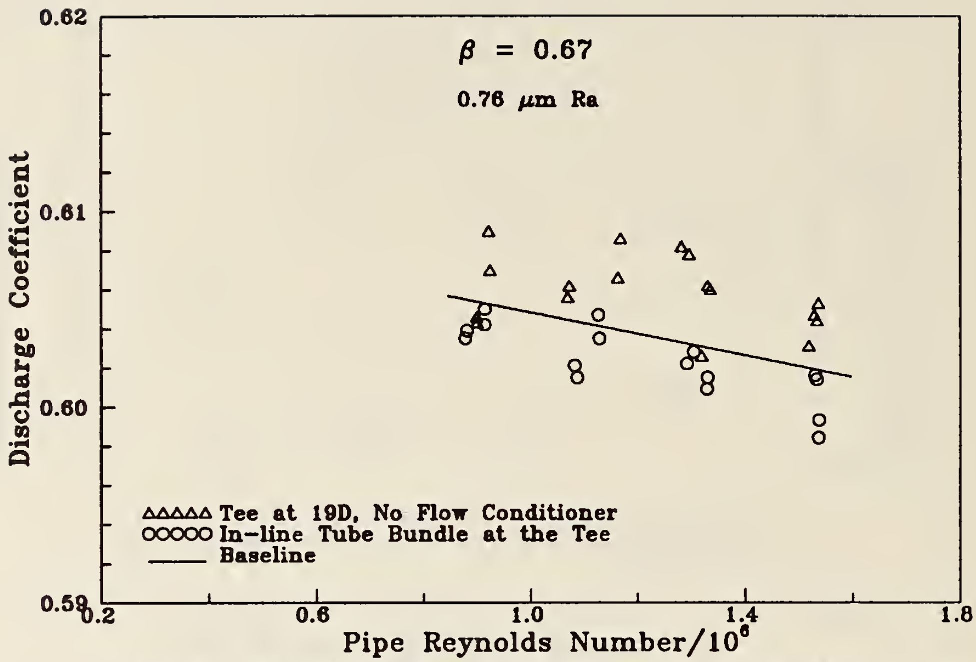

Figure 36. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plate at 19 pipe diameters from a tee and with the 0.76 μm upstream pipe.

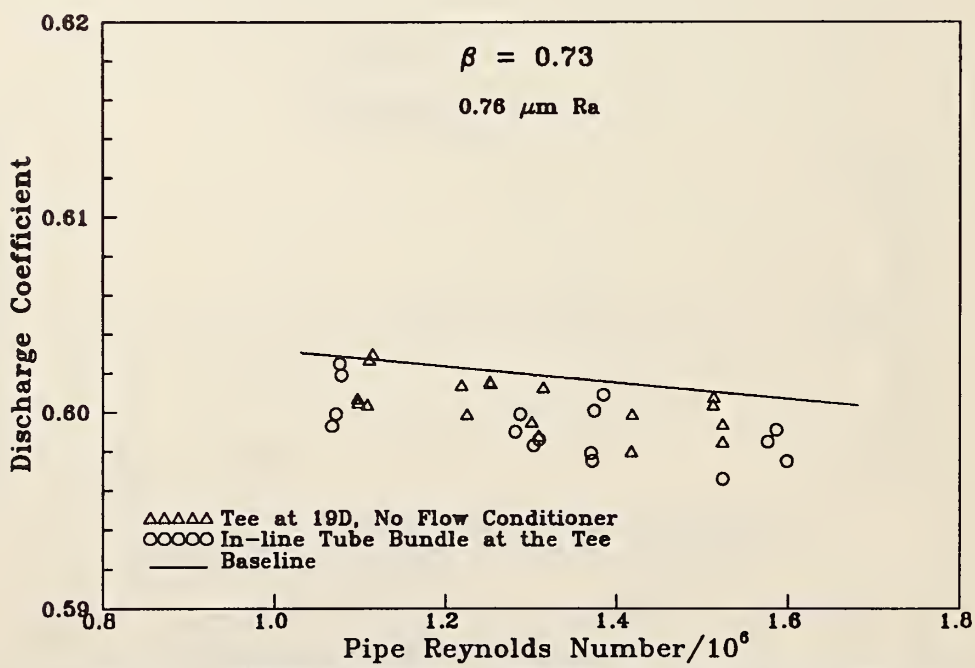

Figure 37. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio orifice plate at 19 pipe diameters from a tee and with the 0.76 μm upstream pipe.

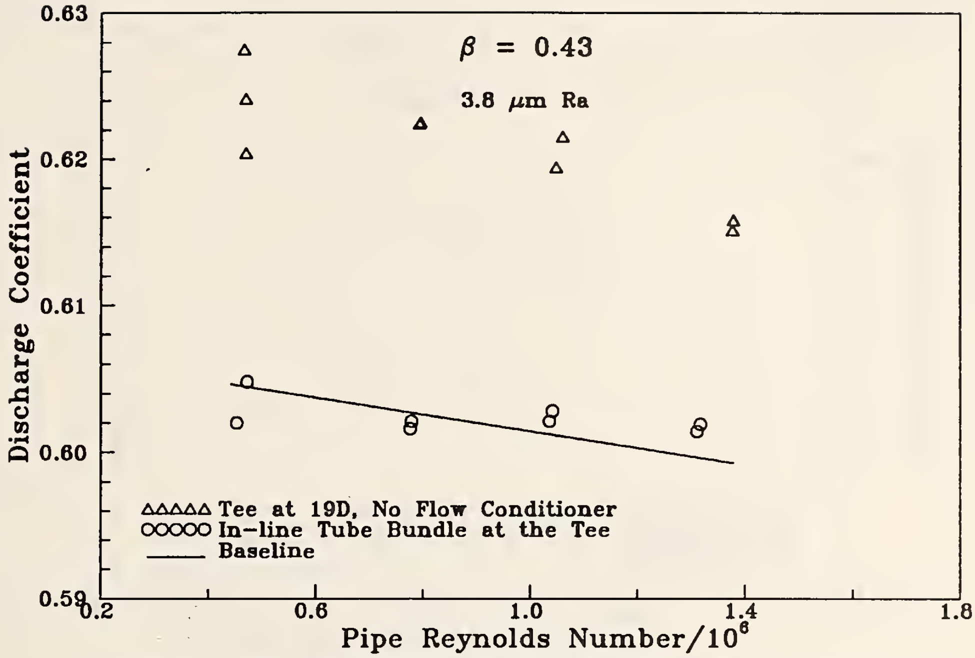

Figure 38. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio orifice plate at 19 pipe diameters from a tee and with the 3.8 μm upstream pipe.

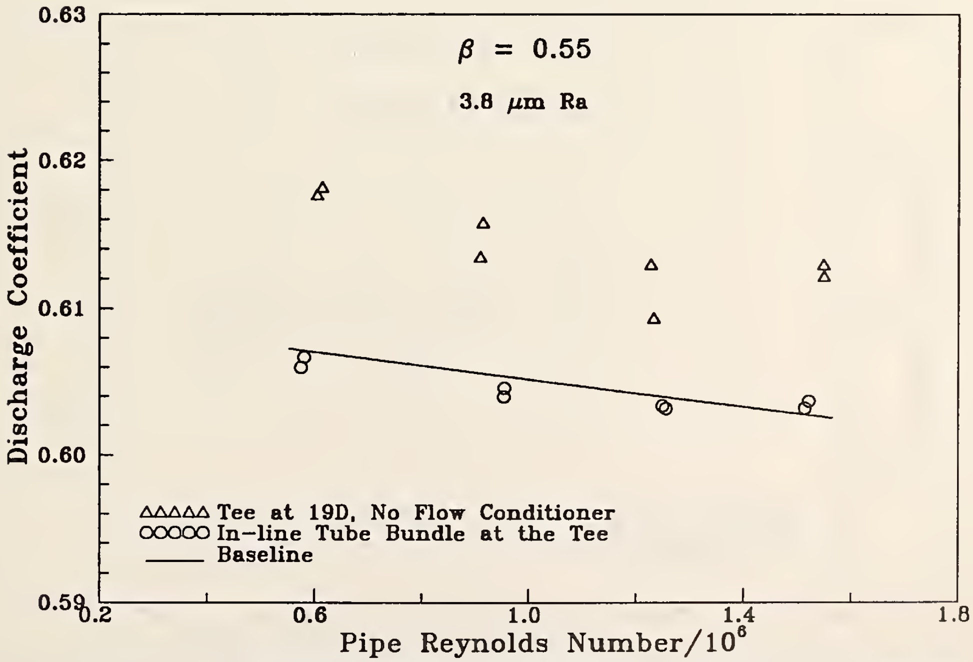

Figure 39. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate at 19 pipe diameters from a tee and with the 3.8 μm upstream pipe.

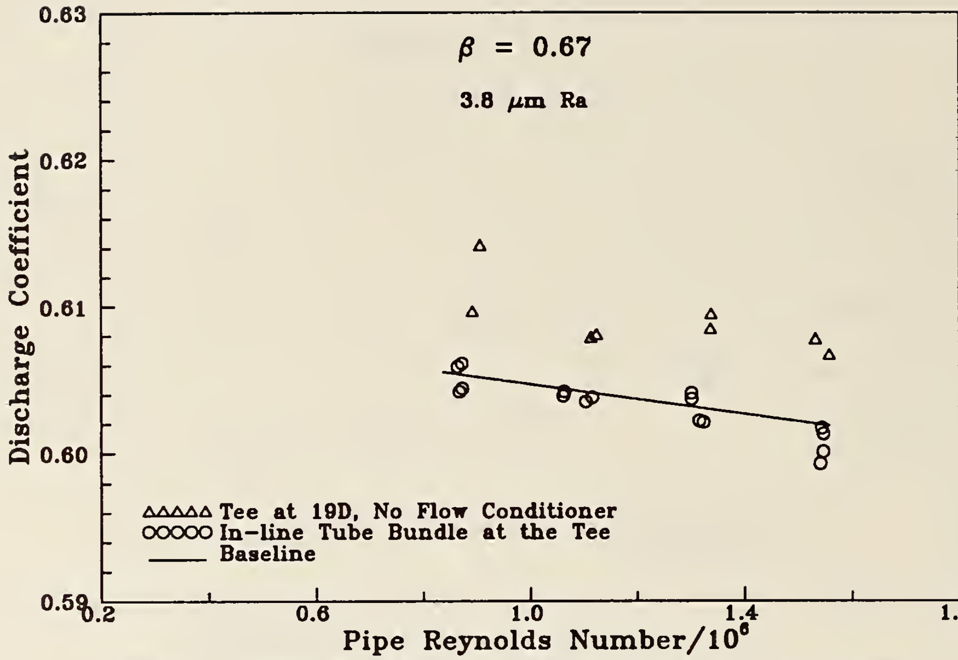

Figure 40. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio orifice plate ot 19 pipe diameters from o tee ond with the 3.8 μm upstreom pipe.

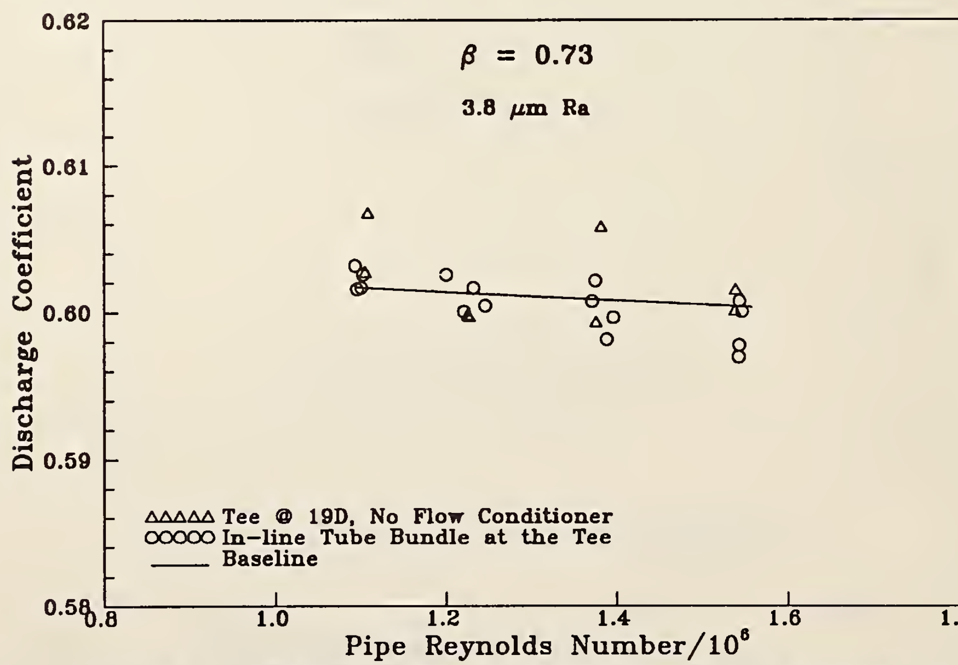

Figure 41. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio orifice plate at 19 pipe diameters from o tee and with the 3.8 μm upstreom pipe.

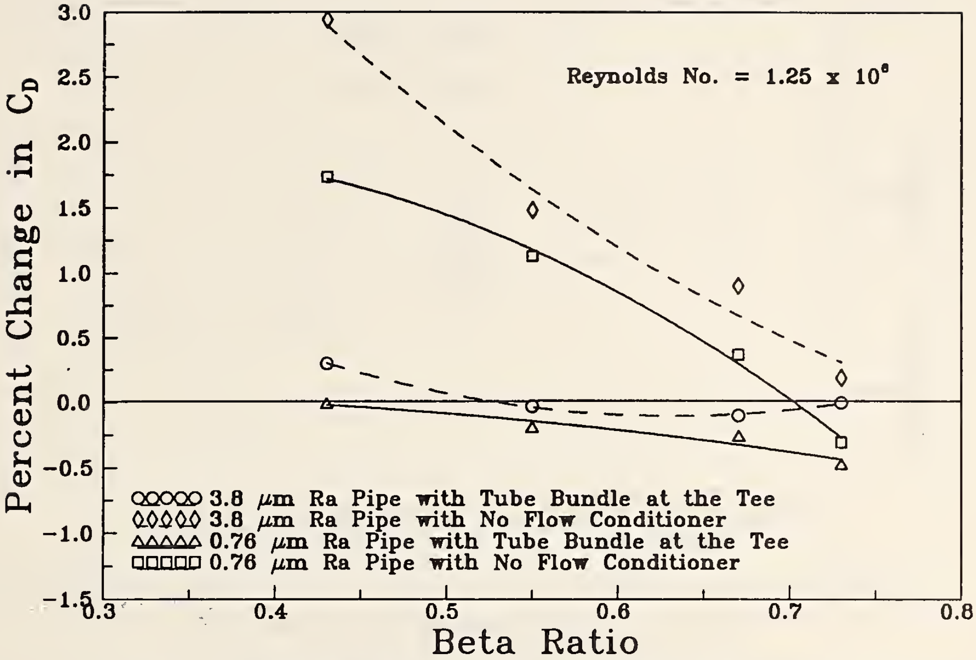

Figure 42. Percent change in the orifice discharge coefficient vs. beta ratio for the tee at 19 pipe diameters from the orifice plate.

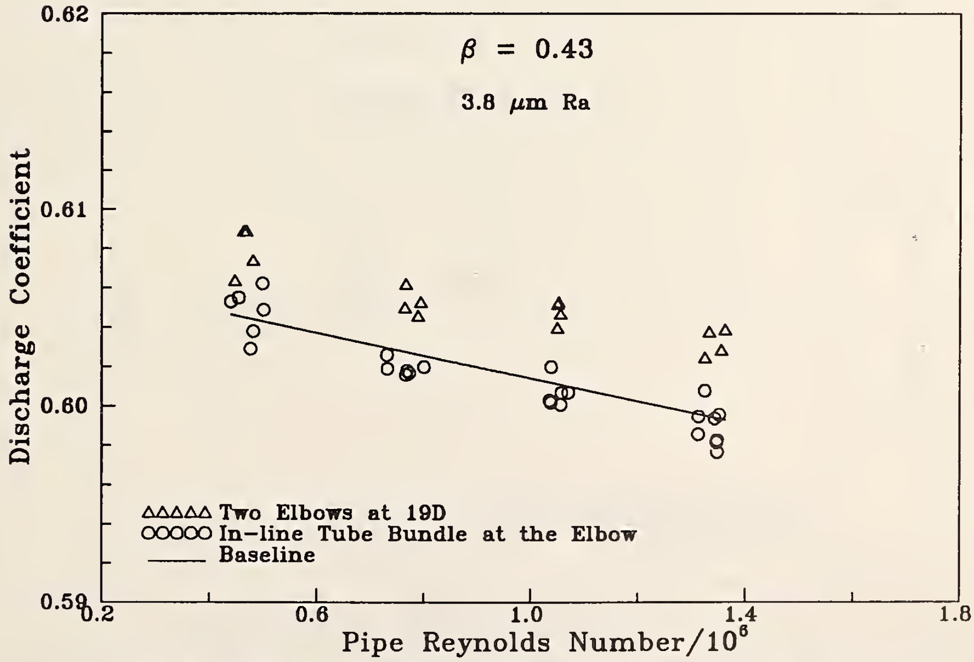

Figure 43. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio orifice plate at 19 pipe diameters from two elbows out-of-plane.

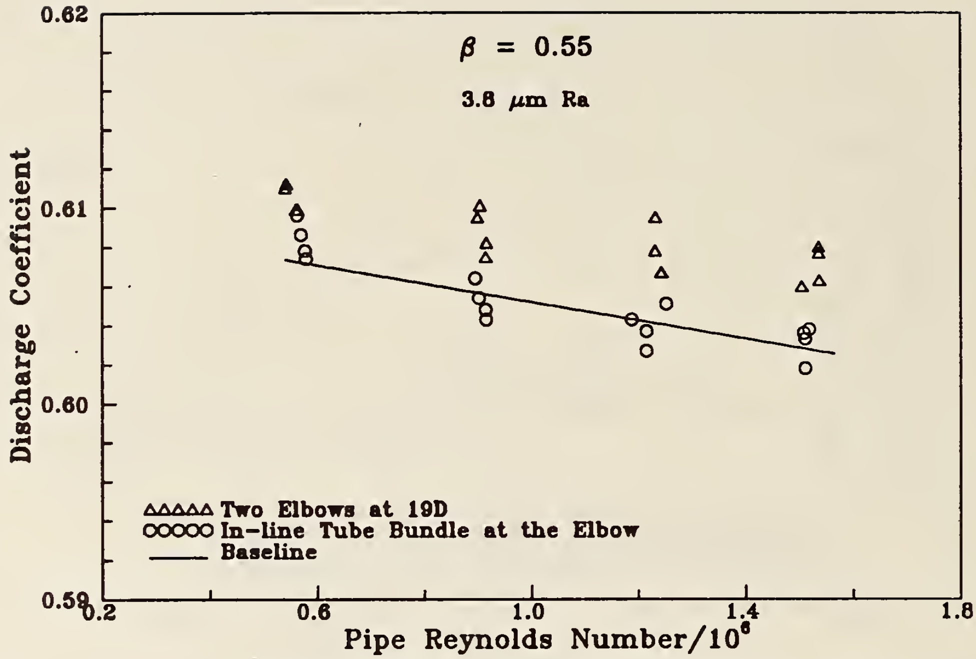

Figure 44. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio orifice plate at 19 pipe diameters from two elbows out-of-plane.

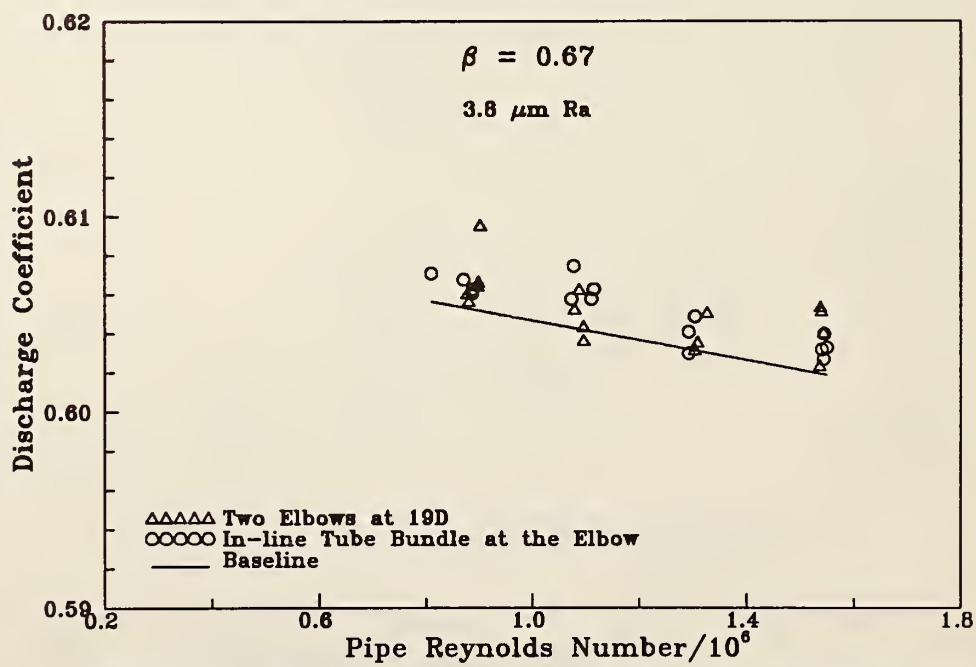

Figure 45. Dischorge coefficient vs. Reynolds number for the 0.67 beto rotio orifice plote ot 19 pipe diameters from two elbows out-of-plone.

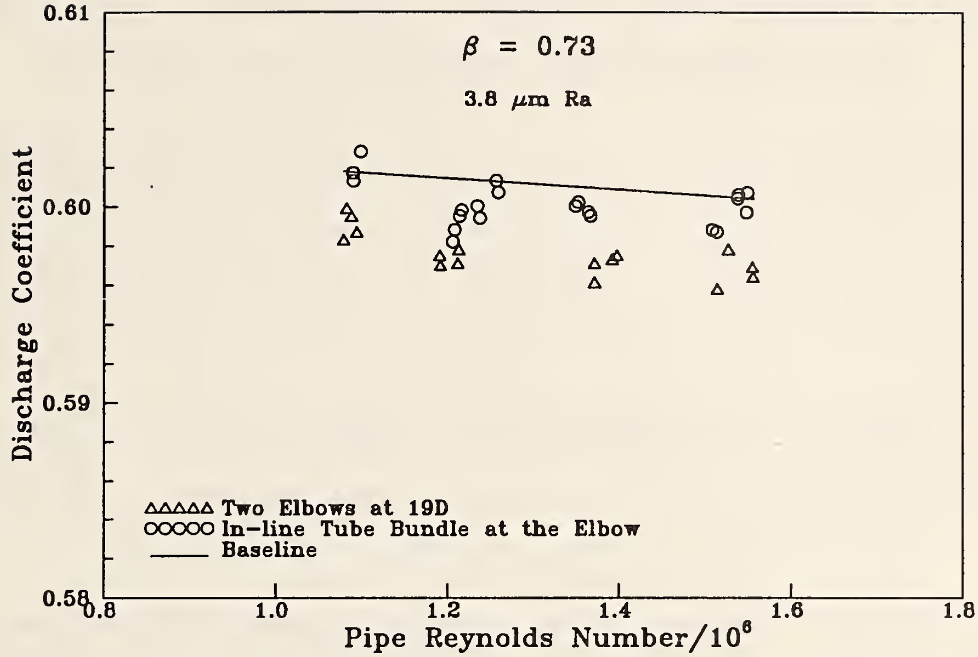

Figure 46. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio orifice plate at 19 pipe diameters from two elbows out-of-plane.

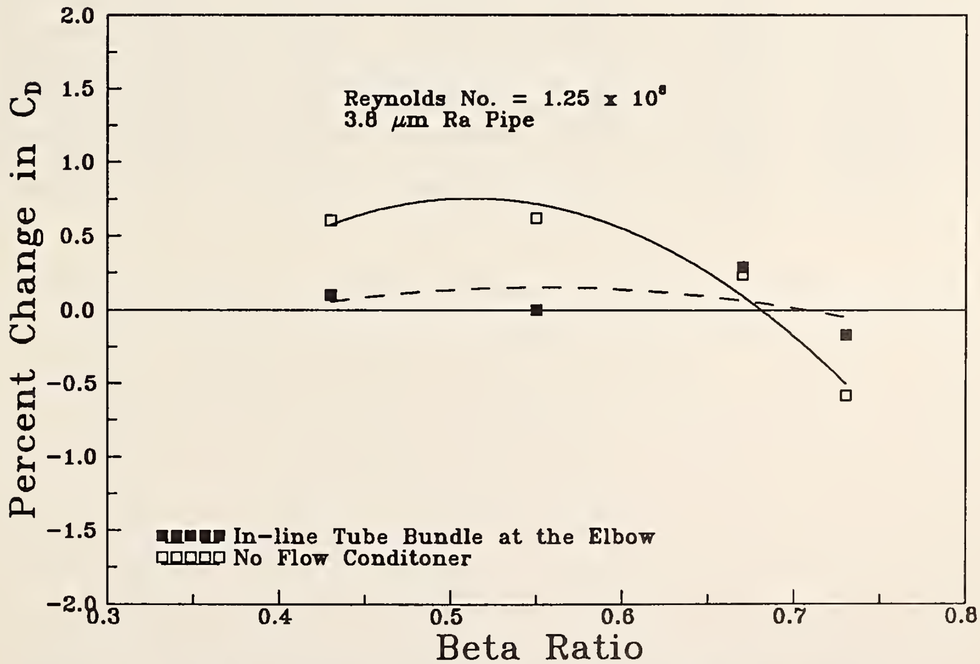

Figure 47. Percent change in the orifice discharge coefficient vs. beta ratio for two elbows out-of-plane at 19 pipe diameters from the orifice plate.

Table 1.a. Measured and calculated quantities for the beta ratio of 0.43 with the 3.8 μm upstream pipe and 46 pipe diameters of straight pipe upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
43050389- 1	3.7800	287.89	44.57	48.332	1.9763	1.3425	0.6019	0.6036
43050389- 2	3.7730	287.68	44.52	47.914	1.9627	1.3341	0.6007	0.6023
43050389- 3	4.0826	289.35	47.89	4.956	0.6556	0.4422	0.6033	0.6035
43050389- 4	4.0496	289.42	47.48	5.147	0.6670	0.4500	0.6047	0.6048
43050389- 5	3.8726	288.72	45.52	25.059	1.4379	0.9737	0.6026	0.6035
43050389- 6	3.8703	288.57	45.52	24.745	1.4262	0.9662	0.6015	0.6023
43050389- 7	3.9226	288.92	46.08	13.378	1.0562	0.7144	0.6026	0.6030
43050389- 8	3.9166	288.89	46.01	13.440	1.0575	0.7154	0.6023	0.6027

Table 1.b. Measured and calculated quantities for the beta ratio of 0.43 with the 6-inch Sprenkle 46 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
43042390- 1	4.0545	289.42	47.54	6.234	0.7369	0.4971	0.6067	0.6069
43042390- 2	4.0345	289.60	47.27	6.252	0.7358	0.4963	0.6068	0.6070
43042390- 3	3.7342	287.38	44.11	46.548	1.9198	1.3064	0.5989	0.6005
43042390- 4	3.7275	287.50	44.02	46.390	1.9132	1.3016	0.5986	0.6002
43042390- 5	3.8085	287.79	44.93	29.862	1.5498	1.0526	0.5988	0.5998
43042390- 6	3.8125	287.68	44.99	30.013	1.5593	1.0594	0.6005	0.6015
43042390- 7	3.8129	287.78	44.98	29.767	1.5562	1.0570	0.6019	0.6029
43042390- 8	3.8698	288.23	45.57	15.091	1.1156	0.7564	0.6025	0.6030
43042390- 9	3.8671	288.38	45.52	15.032	1.1138	0.7549	0.6031	0.6036
43042490- 1	3.7679	286.72	44.63	46.089	1.9272	1.3130	0.6008	0.6024
43042490- 2	3.7624	286.97	44.52	46.060	1.9207	1.3079	0.5997	0.6013
43042490- 3	4.0151	288.16	47.30	6.048	0.7198	0.4873	0.6031	0.6033
43042490- 1	3.8144	287.49	45.05	29.353	1.5422	1.0482	0.6002	0.6012
43042490- 2	3.8255	287.54	45.17	29.485	1.5455	1.0502	0.5993	0.6003
43042490- 3	3.8918	288.18	45.84	14.839	1.1097	0.7523	0.6026	0.6031
43042490- 4	3.8860	288.18	45.77	14.712	1.1042	0.7486	0.6026	0.6031
43042490- 5	4.0122	288.82	47.15	6.368	0.7393	0.4997	0.6046	0.6048

Table 2.a. Measured and calculated quantities for the beta ratio of 0.55 with the 3.8 μm upstream pipe and 46 pipe diameters of straight pipe upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44050389- 1	3.9783	288.92	46.73	7.180	1.3348	0.9023	0.6052	0.6054
44050389- 2	3.9954	288.93	46.93	7.133	1.3325	0.9005	0.6048	0.6050
44050389- 3	4.1054	289.42	48.14	2.970	0.8717	0.5877	0.6056	0.6057
44050389- 4	4.1067	289.48	48.14	3.001	0.8781	0.5919	0.6069	0.6070
44050389- 5	3.9190	288.29	46.15	12.697	1.7617	1.1936	0.6043	0.6047
44050389- 6	3.9139	288.38	46.07	12.602	1.7517	1.1866	0.6036	0.6040
44050389- 7	3.6938	287.39	43.64	23.047	2.2984	1.5647	0.6014	0.6022
44050389- 8	3.7305	288.04	43.96	20.645	2.1922	1.4895	0.6039	0.6046
44102589- 1	4.0569	288.14	47.80	2.615	0.8172	0.5530	0.6073	0.6074
44102589- 2	4.0527	288.17	47.75	2.655	0.8240	0.5576	0.6080	0.6081
44102589- 3	3.6886	286.78	43.67	21.201	2.2109	1.5075	0.6030	0.6037
44102589- 4	3.6864	286.16	43.75	20.941	2.1997	1.5022	0.6031	0.6038
44102589- 5	3.8298	286.97	45.32	13.694	1.8125	1.2333	0.6041	0.6045
44102589- 6	3.8242	287.17	45.22	13.871	1.8198	1.2377	0.6033	0.6037
44102589- 8	3.9145	287.55	46.22	8.107	1.4139	0.9597	0.6066	0.6068
44102589- 9	3.9151	287.47	46.25	8.137	1.4143	0.9601	0.6055	0.6058

Table 2.b. Measured and calculated quantities for the beta ratio of 0.55 with the 6-inch Sprenkle 46 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44042390- 3	3.8806	287.53	45.83	13.214	1.7943	1.2185	0.6054	0.6058
44042390- 4	3.8832	287.56	45.85	13.197	1.7961	1.2196	0.6063	0.6067
44042390- 5	4.0500	288.70	47.62	3.082	0.8857	0.5985	0.6074	0.6075
44042390- 6	4.0414	288.83	47.49	3.108	0.8880	0.6000	0.6072	0.6073
44042390- 7	3.9393	288.25	46.39	7.295	1.3442	0.9106	0.6069	0.6071
44042490- 1	3.9007	287.86	46.01	7.574	1.3574	0.9208	0.6040	0.6042
44042490- 2	3.6656	287.06	43.36	21.887	2.2356	1.5237	0.6023	0.6030
44042490- 3	3.6605	287.11	43.29	21.948	2.2349	1.5232	0.6017	0.6025

Table 3.a. Measured and calculated quantities for the beta ratio of 0.67 with the 3.8 μm upstream pipe and 46 pipe diameters of straight pipe upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
45050289- 1	3.7063	288.22	43.64	8.400	2.2188	1.5073	0.6025	0.6028
45050289- 2	3.7284	288.26	43.90	8.442	2.2311	1.5151	0.6026	0.6029
45050289- 3	3.8914	288.75	45.74	4.379	1.6407	1.1107	0.6029	0.6030
45050289- 4	3.8893	288.74	45.72	4.459	1.6554	1.1207	0.6030	0.6031
45050289- 5	3.8481	288.38	45.29	5.782	1.8756	1.2715	0.6027	0.6029
45050289- 6	3.8351	288.68	45.09	5.757	1.8681	1.2657	0.6030	0.6031
45050289- 7	3.9556	288.97	46.46	2.661	1.2961	0.8763	0.6063	0.6064
45050289- 8	3.9348	288.91	46.22	2.685	1.2986	0.8784	0.6063	0.6064
45082989- 1	3.8527	286.81	45.62	3.927	1.5577	1.0600	0.6053	0.6054
45082989- 2	3.8492	286.95	45.55	3.885	1.5436	1.0501	0.6035	0.6036
45082989- 3	3.6286	285.98	43.09	8.482	2.2184	1.5167	0.6034	0.6036
45082989- 4	3.7554	286.46	44.52	6.053	1.9008	1.2961	0.6022	0.6023
45082989- 5	3.7565	286.34	44.56	6.126	1.9130	1.3048	0.6022	0.6024
45082989- 6	3.9022	287.12	46.15	2.705	1.2995	0.8831	0.6050	0.6050
45082989- 7	3.8988	287.14	46.11	2.732	1.3035	0.8858	0.6041	0.6042

Table 3.b. Measured and calculated quantities for the beta ratio of 0.67 with the 3.8 μm upstream pipe and 56 pipe diameters of straight pipe upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
45051790- 1	3.8566	287.26	45.59	5.782	1.8834	1.2801	0.6033	0.6035
45051790- 2	3.8560	287.39	45.56	5.770	1.8794	1.2770	0.6029	0.6030
45051790- 3	3.9672	287.74	46.81	2.570	1.2785	0.8668	0.6063	0.6064
45051790- 4	3.9717	287.86	46.85	2.571	1.2798	0.8674	0.6065	0.6066
45051790- 8	3.7262	286.62	44.15	8.688	2.2692	1.5472	0.6025	0.6027
45051790- 9	3.7241	286.76	44.10	8.697	2.2674	1.5455	0.6020	0.6023
45051790-10	3.9226	287.57	46.32	4.063	1.5933	1.0813	0.6041	0.6042
45051790-11	3.9208	287.48	46.31	4.082	1.5992	1.0856	0.6050	0.6051
45051790-12	3.9713	287.87	46.84	2.395	1.2338	0.8363	0.6059	0.6060

Table 3.c. Measured and calculated quantities for the beta ratio of 0.67 with the 6-inch Sprenkle 46 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
45051690- 1	3.8949	287.20	46.05	4.311	1.6360	1.1117	0.6039	0.6040
45051690- 2	3.8986	287.16	46.10	4.297	1.6330	1.1097	0.6034	0.6036
45051690- 3	3.7136	286.82	43.97	8.727	2.2705	1.5475	0.6027	0.6030
45051690- 4	3.7138	286.42	44.03	8.685	2.2607	1.5424	0.6011	0.6014
45051690- 5	3.8244	286.79	45.29	6.151	1.9358	1.3178	0.6032	0.6033
45051690- 6	3.8342	286.73	45.41	6.194	1.9460	1.3247	0.6034	0.6036
45051690- 8	3.9429	287.61	46.55	2.737	1.3135	0.8911	0.6052	0.6053
45051690- 9	3.9468	287.61	46.60	2.737	1.3138	0.8913	0.6051	0.6052

Table 4.a. Measured and calculated quantities for the beta ratio of 0.73 with the 3.8 μm upstream pipe and 46 pipe diameters of straight pipe upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46050289- 1	3.8813	288.41	45.68	3.212	1.7653	1.1962	0.6014	0.6014
46050289- 2	3.8562	288.50	45.37	3.183	1.7476	1.1843	0.6001	0.6002
46050289- 3	3.8915	288.63	45.76	2.707	1.6218	1.0982	0.6013	0.6014
46050289- 4	3.8966	288.50	45.84	2.706	1.6235	1.0997	0.6015	0.6016
46050289- 5	3.7055	287.41	43.77	5.631	2.2875	1.5570	0.6012	0.6013
46050289- 6	3.6874	287.51	43.54	5.584	2.2673	1.5433	0.6000	0.6001
46050289- 7	3.7804	288.06	44.55	4.424	2.0466	1.3897	0.6015	0.6016
46050289- 8	3.7795	288.21	44.51	4.456	2.0507	1.3919	0.6008	0.6009

Table 4.b. Measured and calculated quantities for the beta ratio of 0.73 with the 3.8 μm upstream pipe and 56 pipe diameters of straight pipe upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46051790- 1	3.9302	287.76	46.37	2.630	1.6115	1.0930	0.6022	0.6022
46051790- 2	3.9333	287.53	46.45	2.628	1.6112	1.0934	0.6018	0.6019
46051790- 3	3.7514	286.92	44.40	5.361	2.2409	1.5263	0.5993	0.5994
46051790- 4	3.7515	286.61	44.45	5.344	2.2392	1.5264	0.5995	0.5996
46051790- 5	3.8251	287.08	45.25	4.331	2.0346	1.3840	0.5998	0.5999
46051790- 6	3.8200	287.20	45.16	4.341	2.0346	1.3837	0.5995	0.5996
46051790- 7	3.8923	287.23	46.02	3.239	1.7779	1.2080	0.6009	0.6010
46051790- 8	3.8896	287.23	45.99	3.255	1.7814	1.2105	0.6009	0.6010

Table 4.c. Measured and calculated quantities for the beta ratio of 0.73 with the 6-inch Sprenkle 46 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46051690- 1	3.8589	287.08	45.64	3.392	1.8129	1.2327	0.6012	0.6013
46051690- 2	3.8578	287.07	45.64	3.394	1.8156	1.2346	0.6020	0.6021
46051690- 3	3.7876	286.74	44.86	4.418	2.0532	1.3985	0.6018	0.6019
46051690- 4	3.7873	286.81	44.84	4.426	2.0540	1.3988	0.6016	0.6017
46051690- 5	3.8948	287.23	46.05	2.661	1.6171	1.0987	0.6029	0.6030
46051690- 6	3.8940	287.16	46.05	2.666	1.6175	1.0992	0.6024	0.6025
46051690- 7	3.7039	287.08	43.80	5.526	2.2685	1.5454	0.6016	0.6018
46051690- 8	3.7029	286.66	43.86	5.497	2.2632	1.5434	0.6014	0.6015

Table 5. Measured and calculated quantities for the beta ratio of 0.43 with the in-line tube bundle at 7 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
43050889- 1	3.9887	289.22	46.80	14.143	1.0945	0.7393	0.6026	0.6030
43050889- 2	3.9807	289.34	46.69	13.935	1.0821	0.7308	0.6009	0.6014
43050889- 3	3.9087	288.67	45.96	27.878	1.5140	1.0249	0.5986	0.5996
43050889- 4	3.9061	288.66	45.93	27.794	1.5132	1.0245	0.5994	0.6003
43050889- 5	4.1318	289.95	48.35	4.647	0.6376	0.4292	0.6029	0.6030
43050889- 6	4.1098	289.98	48.09	4.653	0.6357	0.4280	0.6024	0.6025
43050889- 7	3.8163	287.91	45.00	49.991	2.0104	1.3650	0.5992	0.6008
43050889- 8	3.8107	288.09	44.90	49.285	1.9966	1.3551	0.6000	0.6016
43050989- 1	3.8528	288.74	45.28	29.569	1.5463	1.0473	0.5980	0.5990
43050989- 2	3.8440	288.83	45.17	29.270	1.5384	1.0418	0.5988	0.5997
43050989- 3	3.9182	289.23	45.97	15.755	1.1403	0.7708	0.6001	0.6006
43050989- 4	3.9035	289.32	45.78	15.785	1.1399	0.7705	0.6005	0.6011
43050989- 1	4.1488	289.98	48.55	4.991	0.6615	0.4452	0.6023	0.6025
43050989- 2	4.1553	289.91	48.64	4.808	0.6509	0.4380	0.6033	0.6034
43050989- 3	3.8413	288.22	45.24	49.439	2.0069	1.3612	0.5999	0.6015
43050989- 4	3.8318	288.10	45.15	48.816	1.9912	1.3511	0.5996	0.6012

Table 6. Measured and calculated quantities for the beta ratio of 0.55 with the in-line tube bundle at 7 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
44050489- 1	4.0638	289.32	47.67	3.259	0.9046	0.6103	0.6030	0.6031
44050489- 2	4.0442	289.35	47.43	3.225	0.8998	0.6072	0.6043	0.6044
44050489- 3	3.7285	287.47	44.03	21.404	2.2194	1.5101	0.6000	0.6006
44050489- 4	3.7413	288.09	44.08	21.366	2.2161	1.5053	0.5993	0.6000
44050489- 1	3.8806	288.44	45.67	13.234	1.7726	1.2011	0.5987	0.5991
44050489- 2	3.8687	287.96	45.61	13.106	1.7671	1.1989	0.6001	0.6005
44050489- 3	3.9339	288.64	46.26	7.699	1.3635	0.9229	0.6001	0.6003
44050489- 4	3.9429	288.64	46.37	7.745	1.3706	0.9275	0.6007	0.6009
44051189- 1	4.0865	289.33	47.93	2.951	0.8621	0.5815	0.6021	0.6022
44051189- 2	4.0636	289.37	47.66	2.934	0.8572	0.5783	0.6022	0.6023
44051189- 3	3.7074	287.64	43.75	21.906	2.2466	1.5283	0.6019	0.6026
44051189- 4	3.7122	287.84	43.78	22.263	2.2596	1.5363	0.6006	0.6013
44051189- 5	3.9513	288.62	46.47	7.807	1.3815	0.9349	0.6024	0.6026
44051189- 6	3.9460	288.50	46.43	7.948	1.3928	0.9429	0.6021	0.6024
44051189- 7	3.8817	288.48	45.67	13.020	1.7662	1.1966	0.6013	0.6017
44051189- 8	3.8871	288.35	45.76	12.979	1.7647	1.1959	0.6012	0.6016
44102589- 1	3.9315	287.49	46.44	7.558	1.3592	0.9225	0.6026	0.6028
44102589- 2	3.9366	287.59	46.48	7.566	1.3605	0.9231	0.6026	0.6028
44102589- 3	4.0574	288.21	47.80	2.714	0.8280	0.5602	0.6040	0.6041
44102589- 4	4.0543	288.17	47.77	2.731	0.8287	0.5607	0.6028	0.6029
44102589- 5	3.7032	286.83	43.84	20.826	2.1821	1.4875	0.5994	0.6000
44102589- 6	3.6892	286.81	43.68	21.687	2.2220	1.5150	0.5992	0.5999
44102589- 7	3.8272	287.03	45.28	14.041	1.8195	1.2378	0.5991	0.5996
44102589- 8	3.8230	286.94	45.25	14.223	1.8344	1.2483	0.6004	0.6008

Table 7. Measured and calculated quantities for the beta ratio of 0.67 with the in-line tube bundle at 7 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45050889- 1	3.8667	288.26	45.53	6.260	1.9529	1.3240	0.6015	0.6017
45050889- 2	3.8592	288.27	45.44	6.270	1.9488	1.3214	0.6004	0.6006
45050889- 3	3.9753	288.94	46.70	2.570	1.2671	0.8565	0.6016	0.6016
45050889- 4	3.9624	288.98	46.54	2.591	1.2721	0.8600	0.6026	0.6026
45050889- 5	3.9241	288.77	46.12	3.895	1.5512	1.0497	0.6020	0.6021
45050889- 6	3.9355	288.74	46.26	3.887	1.5491	1.0482	0.6008	0.6009
45050889- 7	3.7096	288.03	43.71	8.897	2.2712	1.5436	0.5988	0.5991
45050889- 8	3.7212	287.42	43.95	8.867	2.2758	1.5488	0.5994	0.5997
45050989- 1	4.0159	289.01	47.16	2.522	1.2623	0.8528	0.6019	0.6020
45050989- 2	3.9993	288.92	46.98	2.531	1.2589	0.8508	0.6004	0.6005
45050989- 3	3.9907	288.51	46.95	3.905	1.5651	1.0589	0.6012	0.6013
45050989- 4	3.9630	288.53	46.45	3.865	1.5484	1.0479	0.6000	0.6001
45050989- 5	3.8911	288.33	45.81	5.971	1.9026	1.2893	0.5983	0.5984
45050989- 6	3.8937	288.30	45.84	5.936	1.8992	1.2871	0.5987	0.5989
45050989- 7	3.7158	288.02	43.79	9.218	2.3120	1.5712	0.5984	0.5986
45050989- 8	3.7319	287.86	44.01	8.982	2.2872	1.5547	0.5982	0.5984
45042790- 1	3.8784	288.29	45.67	3.970	1.5521	1.0520	0.5995	0.5996
45042790- 2	3.8514	288.05	45.39	3.961	1.5471	1.0497	0.6001	0.6003
45042790- 3	3.7877	287.84	44.67	6.001	1.8842	1.2800	0.5985	0.5987
45042790- 4	3.7652	287.79	44.41	5.985	1.8785	1.2766	0.5992	0.5994
45042790- 5	3.6369	287.47	42.95	8.922	2.2489	1.5318	0.5974	0.5977
45042790- 6	3.6277	287.27	42.87	8.884	2.2450	1.5300	0.5982	0.5984
45042790- 7	3.8547	288.32	45.38	3.069	1.3566	0.9198	0.5980	0.5981
45042790- 8	3.8321	288.43	45.09	3.096	1.3606	0.9225	0.5990	0.5991
45042790- 9	3.8321	288.22	45.13	3.080	1.3613	0.9234	0.6005	0.6006

Table 8. Measured and calculated quantities for the beta ratio of 0.73 with the in-line tube bundle at 7 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46050489- 1	3.8230	288.32	45.01	4.378	2.0277	1.3753	0.5960	0.5961
46050489- 2	3.8186	288.25	44.97	4.369	2.0198	1.3702	0.5946	0.5947
46050489- 3	3.7091	287.74	43.76	5.609	2.2637	1.5395	0.5962	0.5963
46050489- 4	3.7214	287.05	44.02	5.579	2.2612	1.5402	0.5954	0.5955
46050489- 5	3.8595	288.24	45.45	3.559	1.8321	1.2423	0.5944	0.5945
46050489- 6	3.8439	288.33	45.25	3.602	1.8420	1.2489	0.5953	0.5954
46050489- 7	3.9015	288.48	45.91	2.640	1.5934	1.0793	0.5973	0.5973
46050489- 8	3.9039	288.53	45.92	2.659	1.5971	1.0816	0.5964	0.5964
46051189- 1	3.8889	288.66	45.73	2.638	1.5910	1.0773	0.5978	0.5978
46051189- 2	3.8862	288.65	45.70	2.626	1.5839	1.0726	0.5966	0.5967
46051189- 3	3.7989	288.26	44.73	4.432	2.0282	1.3762	0.5943	0.5944
46051189- 4	3.7958	288.51	44.65	4.415	2.0234	1.3721	0.5946	0.5947
46051189- 5	3.8400	288.18	45.23	3.541	1.8245	1.2376	0.5949	0.5950
46051189- 6	3.8389	288.02	45.25	3.564	1.8316	1.2429	0.5952	0.5952
46051189- 7	3.6673	287.43	43.31	5.872	2.2934	1.5617	0.5933	0.5935
46051189- 8	3.6806	287.58	43.45	5.856	2.2934	1.5609	0.5932	0.5934
46042690- 1	3.8636	287.94	45.55	2.474	1.5325	1.0399	0.5957	0.5958
46042690- 2	3.8479	288.11	45.34	2.466	1.5286	1.0370	0.5967	0.5967
46042690- 3	3.7401	287.42	44.18	4.266	1.9817	1.3483	0.5957	0.5958
46042690- 4	3.7325	287.35	44.10	4.263	1.9767	1.3452	0.5948	0.5949
46042690- 5	3.6320	287.44	42.89	5.664	2.2437	1.5285	0.5940	0.5941
46042690- 6	3.6274	286.92	42.92	5.629	2.2433	1.5302	0.5955	0.5956
46042690- 7	3.7699	287.55	44.51	3.321	1.7537	1.1924	0.5952	0.5953
46042690- 8	3.7612	287.29	44.45	3.356	1.7633	1.1998	0.5957	0.5958

Table 9. Measured and calculated quantities for the beta ratio of 0.43 with the in-line tube bundle at 11 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
43052589- 1	4.0096	288.39	47.20	15.262	1.1465	0.7757	0.6050	0.6055
43052589- 2	4.0088	288.44	47.18	15.212	1.1421	0.7727	0.6038	0.6043
43052589- 3	3.8380	287.80	45.27	47.747	1.9802	1.3445	0.6021	0.6037
43052589- 4	3.8433	287.44	45.40	47.481	1.9743	1.3416	0.6012	0.6028
43052589- 5	4.1497	289.02	48.74	4.835	0.6542	0.4412	0.6039	0.6041
43052589- 6	4.1289	289.15	48.47	4.764	0.6470	0.4364	0.6035	0.6037
43052589- 7	3.9517	287.94	46.59	28.663	1.5566	1.0551	0.6028	0.6038
43052589- 8	3.9435	287.91	46.50	28.129	1.5406	1.0445	0.6029	0.6038

Table 10. Measured and calculated quantities for the beta ratio of 0.55 with the in-line tube bundle at 11 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44052489- 1	3.9832	288.24	46.91	7.310	1.3511	0.9148	0.6060	0.6062
44052489- 2	3.9784	288.28	46.85	7.263	1.3405	0.9076	0.6035	0.6037
44052489- 3	3.9810	288.24	46.89	7.254	1.3403	0.9075	0.6036	0.6038
44052489- 4	3.7272	286.79	44.13	21.313	2.2155	1.5099	0.5996	0.6002
44052489- 5	3.7377	287.32	44.17	21.154	2.2154	1.5077	0.6015	0.6022
44052489- 6	3.8926	287.78	45.92	12.925	1.7695	1.2007	0.6031	0.6035
44052489- 7	3.8759	287.64	45.75	13.087	1.7802	1.2086	0.6041	0.6045
44052489- 8	4.1092	288.64	48.33	3.074	0.8887	0.6002	0.6058	0.6059
44052489- 9	4.1087	288.77	48.30	3.096	0.8933	0.6032	0.6069	0.6070
44101989- 2	3.9477	287.32	46.66	7.849	1.3872	0.9417	0.6021	0.6023
44101989- 3	3.9466	287.47	46.62	7.857	1.3873	0.9415	0.6021	0.6023
44101989- 4	3.8598	287.19	45.64	13.214	1.7794	1.2096	0.6016	0.6020
44101989- 5	3.8608	286.94	45.69	13.104	1.7722	1.2054	0.6013	0.6017
44101989- 6	3.6777	286.15	43.65	21.788	2.2232	1.5184	0.5983	0.5990
44101989- 7	3.6857	286.60	43.67	21.705	2.2251	1.5179	0.5998	0.6005
44101989- 8	4.0805	287.81	48.14	3.044	0.8798	0.5956	0.6038	0.6039
44101989- 9	4.0775	287.89	48.09	3.096	0.8857	0.5995	0.6031	0.6031
44102489- 1	3.8572	286.88	45.66	13.577	1.8082	1.2301	0.6030	0.6034
44102489- 2	3.8561	287.18	45.60	13.540	1.8057	1.2276	0.6034	0.6038
44102489- 3	3.7017	286.67	43.85	21.367	2.2220	1.5153	0.6024	0.6031
44102489- 4	3.7061	285.92	44.03	21.217	2.2160	1.5139	0.6018	0.6025
44102489- 8	4.0027	287.20	47.33	7.358	1.3602	0.9231	0.6054	0.6056
44102489- 9	4.0051	287.38	47.33	7.353	1.3574	0.9208	0.6044	0.6046
44102489-10	4.1207	287.89	48.60	2.741	0.8431	0.5704	0.6069	0.6070

Table 11. Measured and calculated quantities for the beta ratio of 0.67 with the in-line tube bundle at 11 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45052489- 1	3.7874	287.39	44.74	8.263	2.2280	1.5152	0.6025	0.6028
45052489- 2	3.7683	287.68	44.47	8.162	2.2088	1.5014	0.6029	0.6031
45052489- 3	4.0172	288.39	47.29	2.586	1.2887	0.8718	0.6061	0.6062
45052489- 4	4.0087	288.42	47.18	2.624	1.2929	0.8747	0.6043	0.6044
45052489- 5	3.9628	288.14	46.69	3.857	1.5584	1.0557	0.6040	0.6041
45052489- 6	3.9672	288.11	46.75	3.857	1.5586	1.0559	0.6037	0.6038
45052489- 7	3.8798	287.72	45.78	5.871	1.9003	1.2898	0.6028	0.6030
45052489- 8	3.8834	287.49	45.87	5.823	1.8971	1.2884	0.6037	0.6039
45072489- 1	3.9871	287.33	47.12	2.522	1.2682	0.8605	0.6051	0.6052
45072489- 2	4.0226	287.43	47.53	2.521	1.2720	0.8625	0.6044	0.6045
45072489- 3	3.8463	286.90	45.53	6.038	1.9219	1.3076	0.6030	0.6031
45072489- 4	3.8507	286.66	45.63	6.031	1.9164	1.3046	0.6008	0.6010
45072489- 5	3.7372	286.57	44.29	8.106	2.1920	1.4945	0.6016	0.6018
45072489- 6	3.7365	286.09	44.36	8.057	2.1870	1.4929	0.6015	0.6018
45072489- 7	3.9090	286.80	46.29	4.016	1.5808	1.0750	0.6031	0.6032
45072489- 8	3.9043	286.92	46.21	4.072	1.5938	1.0836	0.6043	0.6044

Table 12. Measured and calculated quantities for the beta ratio of 0.73 with the in-line tube bundle at 11 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46052589- 1	3.7105	286.86	43.92	5.542	2.2609	1.5409	0.5979	0.5981
46052589- 2	3.7188	287.33	43.94	5.527	2.2588	1.5376	0.5981	0.5982
46052589- 3	3.8089	287.67	44.95	4.438	2.0449	1.3894	0.5974	0.5975
46052589- 4	3.7943	287.57	44.80	4.431	2.0439	1.3892	0.5986	0.5987
46052589- 5	3.9144	287.98	46.15	2.628	1.5966	1.0826	0.5983	0.5984
46052589- 6	3.9089	287.88	46.10	2.678	1.6088	1.0912	0.5975	0.5976
46052589- 7	3.9019	287.78	46.03	3.252	1.7779	1.2063	0.5996	0.5996
46052589- 8	3.9033	287.89	46.03	3.256	1.7779	1.2059	0.5993	0.5993
46072589- 1	3.8473	286.89	45.54	4.104	1.9855	1.3509	0.5993	0.5994
46072589- 2	3.8393	286.82	45.46	4.108	1.9844	1.3505	0.5992	0.5993
46072589- 3	3.9396	287.08	46.61	2.571	1.5891	1.0795	0.5991	0.5991
46072589- 4	3.9211	287.13	46.38	2.574	1.5908	1.0808	0.6008	0.6009
46072589- 5	3.7126	285.96	44.10	5.533	2.2689	1.5498	0.5993	0.5995
46072589- 6	3.7172	286.52	44.06	5.503	2.2621	1.5429	0.5995	0.5996
46072589- 7	3.8722	286.99	45.82	3.464	1.8355	1.2482	0.6012	0.6013
46072589- 8	3.8511	286.82	45.60	3.502	1.8402	1.2522	0.6009	0.6009

Table 13. Measured and calculated quantities for the beta ratio of 0.55 with the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44101989- 1	3.6757	286.76	43.53	21.248	2.2070	1.5052	0.6023	0.6030
44101989- 3	3.8436	287.25	45.43	13.154	1.7775	1.2084	0.6037	0.6041
44101989- 4	3.8400	287.06	45.43	13.255	1.7804	1.2110	0.6024	0.6028
44101989- 5	3.6704	286.63	43.48	21.653	2.2286	1.5205	0.6028	0.6035
44101989- 7	4.0868	288.06	48.17	3.071	0.8864	0.5997	0.6055	0.6056
44101989- 8	4.0899	288.14	48.19	3.083	0.8892	0.6014	0.6060	0.6061
44101989- 9	3.9585	287.58	46.74	7.278	1.3435	0.9114	0.6050	0.6052
44101989-10	3.9545	287.62	46.68	7.253	1.3424	0.9105	0.6059	0.6061

Table 14. Measured and calculated quantities for the beta ratio of 0.67 with the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45072689- 1	3.8993	287.16	46.11	4.096	1.6006	1.0877	0.6058	0.6059
45072689- 2	3.8946	287.25	46.04	4.097	1.5997	1.0868	0.6058	0.6059
45072689- 3	3.6755	286.52	43.56	8.737	2.2670	1.5470	0.6043	0.6045
45072689- 4	3.6805	285.69	43.76	8.617	2.2567	1.5430	0.6043	0.6046
45072689- 5	3.8170	286.82	45.19	6.127	1.9343	1.3168	0.6045	0.6047
45072689- 6	3.7946	286.92	44.91	6.174	1.9361	1.3180	0.6047	0.6048
45072689- 7	3.9248	287.42	46.37	2.764	1.3183	0.8950	0.6057	0.6058
45072689- 8	3.9243	287.46	46.36	2.813	1.3311	0.9036	0.6063	0.6063
45082289- 1	3.6154	286.06	42.92	8.656	2.2248	1.5210	0.6002	0.6004
45082289- 2	3.6117	285.70	42.94	8.497	2.2132	1.5145	0.6026	0.6028
45082289- 3	3.6171	285.66	43.01	8.459	2.2109	1.5130	0.6028	0.6030
45082289- 4	3.7407	286.87	44.28	6.042	1.8983	1.2933	0.6036	0.6037
45082289- 5	3.7265	286.38	44.19	6.055	1.8950	1.2928	0.6025	0.6027
45082289- 6	3.8754	287.06	45.85	2.611	1.2763	0.8677	0.6068	0.6069
45082289- 7	3.8707	287.20	45.77	2.602	1.2700	0.8632	0.6054	0.6055
45082289- 8	3.8198	287.10	45.18	3.952	1.5525	1.0561	0.6043	0.6044
45082289- 9	3.8162	286.86	45.18	3.915	1.5461	1.0524	0.6047	0.6048

Table 15. Measured and calculated quantities for the beta ratio of 0.73 with the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46072689- 1	3.8273	286.83	45.32	3.396	1.8070	1.2299	0.6011	0.6012
46072689- 2	3.8218	286.67	45.28	3.388	1.8035	1.2281	0.6009	0.6010
46072689- 3	3.6337	286.00	43.15	5.806	2.3016	1.5734	0.6000	0.6001
46072689- 4	3.6691	286.44	43.50	5.468	2.2437	1.5315	0.6003	0.6004
46072689- 5	3.7760	286.49	44.76	4.371	2.0326	1.3855	0.5996	0.5997
46072689- 6	3.7614	286.71	44.55	4.391	2.0366	1.3877	0.6009	0.6010
46072689- 7	3.8638	286.90	45.74	2.551	1.5778	1.0733	0.6028	0.6029
46072689- 8	3.8750	287.06	45.84	2.551	1.5805	1.0746	0.6031	0.6032
46082289- 1	3.8300	287.11	45.30	2.516	1.5616	1.0621	0.6037	0.6038
46082289- 2	3.8198	287.04	45.19	2.485	1.5504	1.0548	0.6037	0.6038
46082289- 3	3.5788	285.97	42.50	5.739	2.2756	1.5567	0.6012	0.6013
46082289- 4	3.5946	285.61	42.75	5.692	2.2683	1.5528	0.6000	0.6001
46082289- 5	3.7035	286.23	43.94	4.449	2.0368	1.3904	0.6011	0.6012
46082289- 6	3.6843	286.18	43.72	4.423	2.0223	1.3810	0.6000	0.6001
46082289- 7	3.7694	286.91	44.61	3.224	1.7426	1.1867	0.5996	0.5997
46082289- 8	3.7672	286.48	44.66	3.281	1.7636	1.2023	0.6012	0.6013

Table 16. Measured and calculated quantities for the beta ratio of 0.55 with the in-line tube bundle at 27 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44102489- 1	3.9072	287.54	46.14	8.013	1.3997	0.9502	0.6046	0.6048
44102489- 2	3.9055	287.62	46.10	7.995	1.3998	0.9501	0.6055	0.6058
44102489- 3	4.0438	288.28	47.62	2.675	0.8245	0.5578	0.6069	0.6070
44102489- 4	4.0421	288.36	47.59	2.676	0.8248	0.5579	0.6072	0.6073
44102489- 5	3.6710	286.98	43.43	20.908	2.1859	1.4900	0.6020	0.6027
44102489- 6	3.6650	286.02	43.52	21.535	2.2233	1.5193	0.6027	0.6034
44102489- 7	3.8026	287.12	44.97	14.145	1.8302	1.2452	0.6025	0.6029
44102489- 8	3.8016	287.13	44.96	14.307	1.8417	1.2530	0.6029	0.6034

Table 17. Measured and calculated quantities for the beta ratio of 0.67 with the in-line tube bundle at 27 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
45082389- 1	3.8480	287.38	45.47	4.057	1.5900	1.0805	0.6089	0.6090
45082389- 2	3.8431	287.23	45.43	4.044	1.5837	1.0767	0.6077	0.6078
45082389- 3	3.9101	287.56	46.17	2.595	1.2845	0.8719	0.6104	0.6105
45082389- 4	3.9101	287.62	46.16	2.601	1.2837	0.8713	0.6093	0.6094
45082389- 5	3.7781	286.79	44.74	5.773	1.8743	1.2766	0.6066	0.6067
45082389- 6	3.7706	286.68	44.67	5.724	1.8622	1.2688	0.6057	0.6059
45082389- 7	3.6175	285.75	43.00	8.774	2.2581	1.5449	0.6046	0.6048
45082389- 8	3.6184	286.24	42.93	8.655	2.2402	1.5308	0.6043	0.6046
45082889- 1	3.8280	286.62	45.36	6.090	1.9431	1.3232	0.6080	0.6082
45082889- 2	3.8296	286.66	45.37	6.091	1.9377	1.3194	0.6062	0.6064
45082889- 3	3.8324	286.67	45.40	6.075	1.9355	1.3179	0.6061	0.6063
45082889- 4	3.9537	287.17	46.76	2.662	1.3044	0.8858	0.6082	0.6083
45082889- 5	3.9607	287.32	46.81	2.694	1.3175	0.8942	0.6102	0.6103
45082889- 6	3.9698	287.34	46.92	2.696	1.3193	0.8954	0.6102	0.6102
45082889- 7	3.6977	286.55	43.82	8.602	2.2593	1.5412	0.6051	0.6054
45082889- 8	3.6988	286.49	43.84	8.545	2.2493	1.5346	0.6043	0.6045
45082889- 9	3.8997	286.94	46.16	4.202	1.6233	1.1037	0.6063	0.6064
45082889-10	3.8857	286.67	46.04	4.283	1.6372	1.1140	0.6064	0.6065
45102389- 1	3.6379	286.59	43.10	8.557	2.2401	1.5291	0.6065	0.6068
45102389- 2	3.6406	286.45	43.16	8.504	2.2300	1.5227	0.6053	0.6056
45102389- 3	3.7612	287.24	44.46	6.235	1.9408	1.3207	0.6062	0.6064
45102389- 4	3.7676	287.13	44.55	6.304	1.9556	1.3310	0.6068	0.6070
45102389- 5	3.9030	287.24	46.14	2.918	1.3585	0.9229	0.6090	0.6091
45102389- 7	3.8742	287.05	45.84	4.011	1.5854	1.0779	0.6082	0.6083
45102389- 8	3.8776	287.21	45.85	3.976	1.5774	1.0720	0.6077	0.6078
45050990- 2	3.8393	287.94	45.26	4.020	1.5765	1.0700	0.6079	0.6080
45050990- 3	3.8652	287.83	45.59	4.023	1.5800	1.0723	0.6068	0.6069
45050990- 4	3.8727	287.87	45.67	2.582	1.2714	0.8627	0.6090	0.6091
45050990- 5	3.8604	287.98	45.51	2.610	1.2743	0.8646	0.6082	0.6083
45050990- 6	3.6417	286.97	43.08	8.396	2.2065	1.5047	0.6033	0.6035
45050990- 7	3.6364	287.14	43.00	8.332	2.1974	1.4979	0.6037	0.6039
45050990- 8	3.7273	287.68	43.98	6.249	1.9283	1.3114	0.6049	0.6050
45050990- 9	3.7341	287.48	44.10	6.338	1.9455	1.3236	0.6052	0.6054

Table 18. **Measured and calculated quantities for the beta ratio of 0.73 with the in-line tube bundle at 27 pipe diameters upstream of the orifice plate.**

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46082389- 1	3.7923	286.98	44.87	3.358	1.7904	1.2187	0.6019	0.6020
46082389- 2	3.7834	286.97	44.77	3.325	1.7820	1.2132	0.6027	0.6027
46082389- 3	3.7269	287.02	44.09	4.211	1.9838	1.3513	0.6007	0.6008
46082389- 4	3.7298	286.92	44.14	4.208	1.9855	1.3527	0.6011	0.6012
46082389- 5	3.6366	286.52	43.10	5.507	2.2482	1.5349	0.6021	0.6023
46082389- 6	3.6317	285.58	43.20	5.411	2.2301	1.5261	0.6019	0.6020
46082389- 7	3.8364	287.09	45.38	2.678	1.6121	1.0964	0.6034	0.6035
46082389- 8	3.8470	287.07	45.51	2.706	1.6236	1.1042	0.6037	0.6038
46082889- 1	3.6363	286.31	43.13	5.579	2.2515	1.5379	0.5989	0.5990
46082889- 2	3.6451	285.50	43.37	5.530	2.2512	1.5406	0.5998	0.5999
46082889- 3	3.7459	286.70	44.37	4.373	2.0302	1.3836	0.6014	0.6015
46082889- 4	3.7334	286.33	44.28	4.363	2.0213	1.3790	0.6000	0.6001
46082889- 5	3.8513	286.84	45.60	2.735	1.6281	1.1078	0.6017	0.6018
46082889- 6	3.8816	286.62	46.00	2.568	1.5834	1.0776	0.6012	0.6013
46082889- 7	3.8538	286.92	45.62	3.265	1.7781	1.2096	0.6013	0.6014
46082889- 8	3.8657	286.63	45.81	3.255	1.7813	1.2125	0.6020	0.6021
46102389- 1	3.7216	286.97	44.03	4.297	2.0050	1.3660	0.6014	0.6015
46102389- 2	3.7252	287.10	44.06	4.302	2.0046	1.3652	0.6008	0.6009
46102389- 3	3.6368	285.91	43.20	5.345	2.2125	1.5128	0.6008	0.6009
46102389- 4	3.6425	285.69	43.31	5.297	2.2104	1.5120	0.6022	0.6023
46102389- 5	3.8257	287.22	45.23	2.704	1.6116	1.0959	0.6014	0.6015
46102389- 6	3.8305	287.09	45.31	2.761	1.6323	1.1103	0.6022	0.6023
46102389- 7	3.7895	287.11	44.82	3.445	1.8158	1.2357	0.6030	0.6031
46102389- 8	3.7921	287.32	44.81	3.439	1.8074	1.2293	0.6008	0.6009
46050990- 1	3.8222	287.76	45.10	3.279	1.7757	1.2060	0.6025	0.6026
46050990- 2	3.8318	287.44	45.26	3.280	1.7797	1.2095	0.6027	0.6028
46050990- 3	3.7434	287.58	44.19	4.236	1.9987	1.3593	0.6028	0.6029
46050990- 4	3.7553	287.53	44.34	4.241	2.0028	1.3620	0.6026	0.6027
46050990- 5	3.8291	287.88	45.15	2.583	1.5781	1.0714	0.6029	0.6030
46050990- 6	3.8819	287.74	45.80	2.588	1.5974	1.0842	0.6054	0.6055
46050990- 7	3.9078	287.73	46.11	2.585	1.6022	1.0871	0.6055	0.6056
46050990- 8	3.6670	286.78	43.42	5.398	2.2349	1.5242	0.6023	0.6025
46050990- 9	3.6610	287.41	43.24	5.394	2.2324	1.5203	0.6031	0.6033

Table 19. Measured and calculated quantities for the beta ratio of 0.67 with the in-line tube bundle at 27 pipe diameters upstream of the orifice plate and with the 6-inch Sprenkle at 46 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45050890- 1	3.7890	287.76	44.70	5.996	1.9009	1.2915	0.6038	0.6040
45050890- 2	3.7821	287.83	44.61	5.987	1.9010	1.2915	0.6050	0.6052
45050890- 3	3.7789	287.79	44.58	5.996	1.8949	1.2875	0.6028	0.6029
45050890- 4	3.8801	288.46	45.66	2.610	1.2689	0.8597	0.6046	0.6047
45050890- 5	3.8762	288.46	45.61	2.641	1.2748	0.8638	0.6041	0.6042
45050890- 6	3.8263	288.05	45.09	4.166	1.5954	1.0827	0.6054	0.6055
45050890- 7	3.8261	287.98	45.10	4.161	1.5941	1.0820	0.6052	0.6053
45050890- 8	3.6327	287.70	42.86	8.835	2.2584	1.5375	0.6035	0.6037
45050890- 9	3.6298	287.59	42.84	8.824	2.2552	1.5358	0.6031	0.6034
45050890-10	3.7731	287.40	44.57	5.899	1.8819	1.2800	0.6036	0.6037
45050890-11	3.8201	287.88	45.05	3.981	1.5557	1.0563	0.6042	0.6043
45050890-12	3.8589	288.25	45.44	2.690	1.2859	0.8719	0.6049	0.6050
45051090- 1	3.7964	287.77	44.78	6.103	1.9197	1.3042	0.6039	0.6040
45051090- 2	3.7912	287.36	44.79	6.087	1.9190	1.3050	0.6043	0.6045
45051090- 3	3.8666	287.86	45.60	4.028	1.5705	1.0658	0.6027	0.6028
45051090- 4	3.8629	287.73	45.58	4.041	1.5776	1.0710	0.6046	0.6047
45051090- 5	3.8973	288.19	45.91	2.566	1.2626	0.8559	0.6051	0.6052
45051090- 6	3.8951	287.93	45.93	2.560	1.2624	0.8563	0.6056	0.6056
45051090- 7	3.6815	287.44	43.48	8.156	2.1882	1.4898	0.6042	0.6045
45051090- 8	3.6804	287.63	43.44	8.135	2.1816	1.4846	0.6035	0.6037

Table 20. Measured and calculated quantities for the beta ratio of 0.73 with the in-line tube bundle at 27 pipe diameters upstream of the orifice plate and with the 6-inch Sprenkle at 46 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46050890- 1	3.7422	287.56	44.18	5.215	2.2312	1.5176	0.6065	0.6067
46050890- 2	3.7359	287.83	44.06	5.209	2.2253	1.5126	0.6061	0.6062
46050890- 3	3.8573	287.63	45.53	3.292	1.7986	1.2214	0.6062	0.6063
46050890- 4	3.8517	287.59	45.47	3.286	1.7960	1.2198	0.6063	0.6063
46050890- 5	3.8862	287.82	45.84	2.432	1.5517	1.0529	0.6065	0.6065
46050890- 6	3.8862	287.80	45.84	2.423	1.5450	1.0484	0.6049	0.6049
46050890- 7	3.7858	287.43	44.72	4.055	1.9703	1.3398	0.6037	0.6038
46050890- 8	3.7826	287.26	44.71	4.045	1.9687	1.3393	0.6041	0.6042
46050890- 9	3.7550	287.55	44.33	4.062	1.9640	1.3356	0.6039	0.6040
46050890-10	3.6428	287.49	43.01	5.413	2.2337	1.5212	0.6040	0.6041
46051090- 1	3.8300	287.93	45.15	2.642	1.6008	1.0867	0.6048	0.6049
46051090- 2	3.8235	287.66	45.13	2.640	1.5993	1.0864	0.6046	0.6047
46051090- 3	3.7236	287.67	43.94	4.246	1.9988	1.3594	0.6038	0.6039
46051090- 4	3.7139	286.93	43.95	4.227	1.9934	1.3583	0.6035	0.6036
46051090- 5	3.6383	287.48	42.96	5.376	2.2175	1.5104	0.6020	0.6022
46051090- 6	3.6353	286.79	43.04	5.323	2.2119	1.5091	0.6029	0.6031
46051090- 7	3.7541	287.27	44.37	3.394	1.7969	1.2228	0.6042	0.6043
46051090- 8	3.7511	287.54	44.29	3.424	1.8037	1.2267	0.6044	0.6045

Table 21. **Measured and calculated quantities for the beta ratio of 0.43 with two elbows in plane at 19 pipe diameters upstream of the orifice plate.**

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 4.4445 cm (1.7498 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
43021087- 1	3.9541	289.05	46.43	29.067	1.5602	1.0545	0.6009	0.6018
43021087- 2	3.9463	289.68	46.22	28.782	1.5469	1.0440	0.6000	0.6009
43021087- 3	3.8360	288.33	45.16	49.987	2.0078	1.3612	0.5971	0.5988
43021087- 4	3.8318	290.09	44.81	49.840	1.9986	1.3494	0.5976	0.5992
43021087- 5	4.1393	287.40	48.92	5.722	0.7141	0.4835	0.6047	0.6049
43021087- 6	4.1466	286.32	49.21	5.567	0.7045	0.4782	0.6032	0.6034
43021187- 1	3.9837	288.05	46.95	29.802	1.5906	1.0773	0.6016	0.6025
43021187- 2	3.9852	287.96	46.99	29.690	1.5870	1.0751	0.6011	0.6021
43021187- 3	3.9022	287.02	46.17	49.647	2.0328	1.3815	0.6000	0.6017
43021187- 4	3.9016	288.97	45.82	49.836	2.0257	1.3702	0.5990	0.6006
43021187- 5	3.9022	287.94	46.01	49.529	2.0243	1.3727	0.5993	0.6009
43021187- 6	4.1994	287.81	49.55	6.916	0.7879	0.5326	0.6030	0.6033
43021187- 7	4.1933	287.88	49.47	6.905	0.7862	0.5314	0.6027	0.6029

Table 22. **Measured and calculated quantities for the beta ratio of 0.55 with two elbows in plane at 19 pipe diameters upstream of the orifice plate.**

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 5.7137 cm (2.2495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44021087- 1	3.9580	288.59	46.55	10.774	1.6232	1.0983	0.6020	0.6023
44021087- 2	3.9547	289.36	46.38	10.754	1.6157	1.0912	0.6009	0.6012
44021087- 3	4.1127	286.87	48.70	2.713	0.8364	0.5672	0.6048	0.6049
44021087- 4	4.1100	289.40	48.20	2.741	0.8323	0.5610	0.6017	0.6018
44021087- 5	4.1186	288.52	48.46	2.728	0.8380	0.5660	0.6058	0.6058
44021087- 6	3.7519	287.17	44.36	22.943	2.3033	1.5676	0.5993	0.6000
44021087- 7	3.7503	286.27	44.50	22.677	2.2952	1.5655	0.5998	0.6005

Table 23. **Measured and calculated quantities for the beta ratio of 0.67 with two elbows in plane at 19 pipe diameters upstream of the orifice plate.**

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45021187- 1	3.9490	288.06	46.54	4.835	1.7365	1.1765	0.6021	0.6022
45021187- 2	3.9497	287.27	46.69	4.818	1.7337	1.1768	0.6012	0.6013
45021187- 3	3.7722	289.22	44.25	9.077	2.3136	1.5664	0.6003	0.6005
45021187- 4	3.7701	288.72	44.31	9.002	2.3094	1.5655	0.6013	0.6015
45021187- 5	4.0190	286.44	47.67	2.537	1.2765	0.8675	0.6039	0.6039
45021187- 6	4.0215	288.59	47.30	2.556	1.2755	0.8624	0.6034	0.6035

Table 24. Measured and calculated quantities for the beta ratio of 0.73 with two elbows in plane at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 7.6177 cm (2.9991 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
46021087- 1	3.9764	289.81	46.55	2.765	1.6452	1.1097	0.5988	0.5989
46021087- 2	3.9694	289.12	46.59	2.747	1.6421	1.1095	0.5995	0.5996
46021087- 3	3.7516	290.65	43.78	5.879	2.3122	1.5605	0.5951	0.5953
46021087- 4	3.7645	287.29	44.49	5.797	2.3178	1.5768	0.5960	0.5961
46021087- 5	3.9227	287.33	46.36	3.766	1.9133	1.2990	0.5980	0.5981
46021087- 6	3.9173	288.59	46.07	3.776	1.9091	1.2923	0.5978	0.5979
46021187- 1	3.9841	288.97	46.79	2.504	1.5742	1.0638	0.6006	0.6007
46021187- 2	3.9803	288.29	46.87	2.481	1.5667	1.0605	0.6000	0.6001
46021187- 3	3.9136	288.68	46.01	3.798	1.9141	1.2955	0.5980	0.5981
46021187- 4	3.8951	288.35	45.85	3.767	1.9036	1.2897	0.5982	0.5983
46021187- 5	3.7627	286.09	44.67	5.776	2.3161	1.5802	0.5955	0.5956
46021187- 6	3.7578	289.94	43.97	5.808	2.3041	1.5575	0.5954	0.5955

Table 25. Measured and calculated quantities for the beta ratio of 0.43 with two elbows in plane upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 4.4445 cm (1.7498 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
43081088- 1	4.0643	289.19	47.70	4.953	0.6542	0.4414	0.6030	0.6032
43081088- 2	4.0575	289.59	47.54	4.553	0.6265	0.4224	0.6033	0.6035
43081088- 3	3.8781	288.41	45.64	27.928	1.5149	1.0263	0.6003	0.6013
43081088- 4	3.8728	288.39	45.58	27.520	1.5021	1.0178	0.6001	0.6010
43081088- 5	3.7566	287.93	44.29	49.221	1.9764	1.3424	0.5982	0.5998
43081088- 6	3.7658	287.82	44.41	48.795	1.9729	1.3403	0.5989	0.6005
43081088- 7	3.9682	288.61	46.67	13.236	1.0574	0.7152	0.6024	0.6029
43081088- 8	3.9615	288.62	46.59	13.451	1.0632	0.7192	0.6014	0.6018
43081188- 1	3.9179	288.42	46.11	13.177	1.0484	0.7099	0.6023	0.6027
43081188- 2	3.9221	288.34	46.17	13.316	1.0556	0.7149	0.6028	0.6032
43081188- 3	3.8326	287.57	45.25	27.826	1.5068	1.0234	0.6008	0.6017
43081188- 4	3.8302	287.56	45.22	27.684	1.4957	1.0160	0.5981	0.5990
43081188- 5	4.0144	289.21	47.11	5.034	0.6571	0.4436	0.6046	0.6047
43081188- 6	4.0068	289.26	47.01	5.006	0.6548	0.4421	0.6048	0.6050
43081188- 7	3.7162	287.22	43.93	47.211	1.9347	1.3171	0.6004	0.6020
43081188- 8	3.7172	287.24	43.94	46.765	1.9224	1.3085	0.5993	0.6010

Table 26. Measured and calculated quantities for the beta ratio of 0.55 with two elbows in plane upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 5.7137 cm (2.2495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
44080588- 1	3.9360	288.64	46.29	7.528	1.3561	0.9176	0.6036	0.6038
44080588- 2	3.9197	288.62	46.10	7.509	1.3489	0.9129	0.6023	0.6025
44080588- 3	3.8229	287.73	45.11	14.587	1.8550	1.2596	0.6005	0.6010
44080588- 4	3.8331	288.07	45.17	14.476	1.8470	1.2530	0.5998	0.6003
44080588- 5	4.0801	289.26	47.87	3.105	0.8899	0.6002	0.6066	0.6067
44080588- 6	4.0762	289.31	47.82	3.117	0.8919	0.6015	0.6072	0.6072
44080588- 7	3.6799	287.47	43.46	21.505	2.2143	1.5071	0.6013	0.6020
44080588- 8	3.6828	287.43	43.50	21.345	2.2041	1.5003	0.6005	0.6012
44081088- 1	3.8108	287.23	45.05	14.763	1.8614	1.2656	0.5994	0.5998
44081088- 2	3.8082	287.09	45.04	14.672	1.8546	1.2615	0.5991	0.5996
44081088- 3	4.0090	288.55	47.16	3.151	0.8873	0.6000	0.6048	0.6049
44081088- 4	3.9990	288.77	47.00	3.176	0.8912	0.6024	0.6061	0.6062
44081088- 5	3.9437	287.97	46.50	7.387	1.3448	0.9113	0.6028	0.6031
44081088- 6	3.9205	287.84	46.24	7.320	1.3358	0.9058	0.6032	0.6034
44081088- 7	3.6887	286.90	43.66	21.804	2.2257	1.5168	0.5988	0.5995
44081088- 8	3.6972	286.15	43.88	21.675	2.2252	1.5191	0.5989	0.5996

Table 27. Measured and calculated quantities for the beta ratio of 0.67 with two elbows in plane upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
45080488- 1	3.6952	286.31	43.83	8.849	2.2848	1.5592	0.6034	0.6036
45080488- 2	3.7109	285.65	44.13	8.665	2.2627	1.5463	0.6018	0.6020
45080488- 3	3.8975	287.22	46.08	4.724	1.7116	1.1627	0.6035	0.6036
45080488- 4	3.8782	286.94	45.90	4.750	1.7090	1.1619	0.6020	0.6022
45080488- 5	3.8162	286.81	45.19	6.557	1.9989	1.3605	0.6040	0.6042
45080488- 6	3.8225	287.26	45.18	6.605	2.0079	1.3650	0.6045	0.6047
45080488- 7	3.9735	287.71	46.89	2.591	1.2840	0.8703	0.6059	0.6060
45080488- 8	3.9955	287.69	47.16	2.588	1.2884	0.8731	0.6067	0.6068
45081188- 1	3.7987	286.26	45.07	5.025	1.7461	1.1903	0.6035	0.6036
45081188- 2	3.7829	287.12	44.74	5.021	1.7361	1.1812	0.6025	0.6027
45081188- 3	3.6026	286.48	42.70	9.010	2.2655	1.5471	0.6007	0.6009
45081188- 4	3.6244	285.89	43.06	8.379	2.2011	1.5049	0.6027	0.6029
45081188- 5	3.7179	289.22	43.61	6.478	1.9461	1.3183	0.6022	0.6023
45081188- 6	3.7273	290.12	43.58	6.527	1.9525	1.3197	0.6021	0.6023
45081188- 7	3.8391	289.79	44.94	2.957	1.3419	0.9065	0.6055	0.6056
45081188- 8	3.8476	289.26	45.14	2.987	1.3484	0.9120	0.6040	0.6041

Table 28. Measured and calculated quantities for the beta ratio of 0.73 with two elbows in plane upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 7.6177 cm (2.9991 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
46080488- 1	3.8567	288.08	45.45	3.692	1.8890	1.2811	0.6023	0.6024
46080488- 2	3.8671	287.89	45.60	3.715	1.8926	1.2839	0.6006	0.6007
46080488- 3	3.8653	288.19	45.53	3.705	1.8917	1.2824	0.6015	0.6016
46080488- 4	3.8015	287.58	44.88	4.761	2.1233	1.4427	0.5999	0.6000
46080488- 5	3.8094	287.58	44.97	4.788	2.1319	1.4484	0.6000	0.6001
46080488- 6	3.7308	287.52	44.05	5.569	2.2721	1.5453	0.5991	0.5992
46080488- 7	3.7278	287.54	44.01	5.564	2.2688	1.5430	0.5988	0.5989
46080488- 8	3.9166	288.09	46.15	2.701	1.6309	1.1052	0.6034	0.6034
46080488- 9	3.9087	288.03	46.07	2.723	1.6341	1.1077	0.6026	0.6027
46080588- 1	3.8357	287.94	45.22	3.625	1.8587	1.2613	0.5996	0.5997
46080588- 2	3.8378	288.22	45.20	3.624	1.8575	1.2596	0.5994	0.5995
46080588- 3	3.6591	287.01	43.29	5.903	2.3203	1.5814	0.5995	0.5996
46080588- 4	3.6699	284.11	43.90	5.839	2.3213	1.5932	0.5989	0.5990
46080588- 5	3.9005	288.13	45.96	2.636	1.6054	1.0881	0.6025	0.6026
46080588- 6	3.8956	288.03	45.92	2.637	1.6016	1.0858	0.6012	0.6012
46080588- 7	3.7808	287.50	44.65	4.596	2.0814	1.4148	0.6001	0.6002
46080588- 8	3.7825	287.48	44.67	4.575	2.0782	1.4127	0.6004	0.6005

Table 29. Measured and calculated quantities for the beta ratio of 0.43 and the 0.76 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 4.4445 cm (1.7498 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
43100588- 1	3.9279	288.25	46.26	26.697	1.5089	1.0221	0.6078	0.6086
43100588- 2	3.9026	287.88	46.02	29.580	1.5927	1.0801	0.6110	0.6120
43100588- 3	3.8980	287.96	45.96	29.674	1.5867	1.0759	0.6081	0.6091
43100588- 4	4.0854	289.08	47.97	5.401	0.6987	0.4715	0.6153	0.6155
43100588- 5	4.0738	289.18	47.81	5.510	0.7051	0.4757	0.6158	0.6160
43100588- 6	3.9908	288.54	46.95	13.193	1.0800	0.7305	0.6148	0.6152
43100588- 7	3.9733	288.77	46.70	12.884	1.0644	0.7197	0.6147	0.6152
43100588- 8	3.7803	287.68	44.61	48.108	2.0013	1.3598	0.6108	0.6125
43100588- 9	3.7772	286.84	44.72	49.814	2.0394	1.3886	0.6109	0.6126
43100688- 1	4.0994	289.13	48.12	5.107	0.6864	0.4630	0.6208	0.6210
43100688- 2	4.1055	289.12	48.20	5.450	0.7061	0.4762	0.6176	0.6178
43100688- 3	3.9286	287.67	46.37	27.260	1.5501	1.0514	0.6172	0.6181
43100688- 4	3.9102	287.67	46.15	26.839	1.5222	1.0327	0.6122	0.6131
43100688- 5	3.8158	287.37	45.09	49.032	2.0400	1.3866	0.6134	0.6151
43100688- 6	3.7966	287.03	44.92	48.752	2.0190	1.3737	0.6099	0.6116
43100688- 7	3.9703	288.00	46.80	14.361	1.1277	0.7639	0.6162	0.6167
43100688- 8	3.9600	288.22	46.64	14.628	1.1362	0.7694	0.6162	0.6167

Table 30. Measured and calculated quantities for the beta ratio of 0.55 and the 0.76 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 5.7137 cm (2.2495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44093088- 1	3.7151	287.48	43.87	20.428	2.1925	1.4916	0.6081	0.6088
44093088- 2	3.7228	286.83	44.07	20.429	2.1920	1.4935	0.6066	0.6072
44093088- 3	3.8282	287.98	45.13	14.793	1.8842	1.2786	0.6057	0.6061
44093088- 4	3.8423	288.04	45.28	14.982	1.9004	1.2891	0.6060	0.6065
44093088- 5	4.0261	288.70	47.34	3.390	0.9260	0.6258	0.6075	0.6076
44093088- 6	4.0416	288.84	47.49	3.398	0.9370	0.6329	0.6131	0.6132
44093088- 7	4.0754	288.91	47.88	3.444	0.9397	0.6344	0.6082	0.6083
44093088- 8	3.9293	288.21	46.28	8.334	1.4442	0.9783	0.6111	0.6113
44093088- 9	3.9430	288.32	46.42	8.227	1.4370	0.9730	0.6110	0.6112
44100688- 1	3.9499	288.01	46.56	8.060	1.4242	0.9650	0.6109	0.6111
44100688- 2	3.9434	288.03	46.48	8.096	1.4191	0.9615	0.6078	0.6081
44100688- 3	3.8760	287.62	45.75	13.919	1.8422	1.2504	0.6064	0.6068
44100688- 4	3.8617	287.70	45.57	13.688	1.8334	1.2445	0.6098	0.6102
44100688- 5	3.7357	286.68	44.25	20.868	2.2299	1.5196	0.6093	0.6100
44100688- 6	3.7420	287.23	44.23	21.001	2.2286	1.5166	0.6072	0.6079
44100688- 7	4.0509	288.25	47.71	3.773	0.9851	0.6663	0.6103	0.6104
44100688- 8	4.0373	288.48	47.51	3.836	0.9945	0.6723	0.6123	0.6124

Table 31. Measured and calculated quantities for the beta ratio of 0.67 and the 0.76 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45100588- 1	3.8289	287.35	45.24	6.233	1.9568	1.3299	0.6062	0.6063
45100588- 2	3.8168	287.82	45.02	6.243	1.9421	1.3186	0.6026	0.6028
45100588- 3	3.9237	287.94	46.26	3.971	1.5778	1.0695	0.6056	0.6057
45100588- 4	3.9154	287.98	46.16	3.994	1.5820	1.0724	0.6062	0.6063
45100588- 5	3.7385	287.32	44.18	8.449	2.2460	1.5282	0.6047	0.6049
45100588- 6	3.7225	287.06	44.03	8.391	2.2286	1.5176	0.6031	0.6033
45100588- 7	3.9765	288.13	46.86	2.797	1.3298	0.9004	0.6043	0.6044
45100588- 8	3.9458	288.13	46.49	2.807	1.3276	0.8993	0.6046	0.6047
45100588- 9	3.8334	287.85	45.21	6.304	1.9666	1.3349	0.6060	0.6062
45101188- 1	3.8473	287.56	45.43	5.868	1.9075	1.2954	0.6078	0.6079
45101188- 2	3.8249	287.59	45.15	5.764	1.8862	1.2812	0.6082	0.6084
45101188- 3	3.7143	287.27	43.90	8.562	2.2563	1.5358	0.6053	0.6056
45101188- 4	3.7206	287.27	43.97	8.545	2.2524	1.5331	0.6044	0.6046
45101188- 5	3.8786	287.79	45.76	4.721	1.7138	1.1628	0.6066	0.6067
45101188- 6	3.8663	287.83	45.60	4.748	1.7213	1.1680	0.6086	0.6087
45101188- 7	3.9319	287.92	46.36	2.912	1.3600	0.9219	0.6090	0.6091
45101188- 8	3.9372	288.16	46.38	2.940	1.3624	0.9229	0.6070	0.6071

Table 32. Measured and calculated quantities for the beta ratio of 0.73 and the 0.76 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 7.6177 cm (2.9991 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46092988- 1	3.8509	286.30	45.69	3.492	1.8392	1.2528	0.6015	0.6016
46092988- 2	3.8733	286.44	45.93	3.473	1.8392	1.2520	0.6016	0.6017
46092988- 3	3.7325	288.02	43.99	5.335	2.2266	1.5125	0.6004	0.6005
46092988- 4	3.7442	288.12	44.11	5.322	2.2285	1.5132	0.6008	0.6009
46092988- 5	3.9706	288.44	46.73	2.719	1.6381	1.1085	0.6004	0.6005
46092988- 6	3.9396	288.85	46.29	2.737	1.6422	1.1106	0.6027	0.6028
46092988- 7	3.9590	288.88	46.51	2.742	1.6487	1.1146	0.6030	0.6031
46092988- 8	3.8433	288.08	45.29	3.913	1.9377	1.3143	0.6013	0.6014
46092988- 9	3.8555	287.70	45.50	3.891	1.9286	1.3092	0.5988	0.5989
46092988-10	3.8447	288.53	45.22	3.868	1.9197	1.3007	0.5995	0.5996
46101188- 1	3.7072	286.95	43.87	5.418	2.2368	1.5239	0.5994	0.5995
46101188- 2	3.7199	287.34	43.95	5.432	2.2388	1.5235	0.5985	0.5986
46101188- 3	3.8890	287.69	45.90	2.693	1.6166	1.0969	0.6007	0.6007
46101188- 4	3.8716	287.63	45.70	2.707	1.6169	1.0976	0.6005	0.6006
46101188- 5	3.7695	287.45	44.52	4.632	2.0857	1.4181	0.5999	0.6000
46101188- 6	3.7681	287.12	44.56	4.647	2.0832	1.4176	0.5980	0.5981
46101188- 7	3.8436	287.51	45.39	3.396	1.8032	1.2248	0.5999	0.6000
46101188- 8	3.8359	287.56	45.29	3.352	1.7936	1.2183	0.6014	0.6015

Table 33. Measured and calculated quantities for the beta ratio of 0.43 and the 0.76 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 4.4445 cm (1.7498 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
43100488- 1	3.8024	287.17	44.96	46.401	1.9375	1.3177	0.5995	0.6011
43100488- 2	3.8088	287.37	45.00	45.974	1.9291	1.3113	0.5994	0.6010
43100488- 3	4.1297	289.02	48.50	5.218	0.6778	0.4572	0.6037	0.6039
43100488- 4	4.0922	289.22	48.02	5.356	0.6838	0.4612	0.6040	0.6042
43100488- 5	3.9206	288.11	46.20	27.642	1.5236	1.0324	0.6033	0.6042
43100488- 6	3.9044	287.70	46.08	28.390	1.5365	1.0424	0.6010	0.6020
43100488- 7	3.9743	288.34	46.79	13.626	1.0749	0.7275	0.6028	0.6032
43100488- 8	3.9671	288.50	46.68	13.532	1.0689	0.7232	0.6022	0.6027
43101288- 1	3.9094	288.63	45.97	13.727	1.0685	0.7233	0.6023	0.6027
43101288- 2	3.8934	288.56	45.80	13.507	1.0574	0.7160	0.6020	0.6024
43101288- 3	3.9934	289.28	46.85	5.427	0.6808	0.4596	0.6049	0.6051
43101288- 4	3.9990	289.44	46.88	5.672	0.6961	0.4697	0.6048	0.6049
43101288- 5	3.8401	288.04	45.26	28.652	1.5345	1.0410	0.6029	0.6038
43101288- 6	3.8262	287.83	45.13	28.212	1.5183	1.0306	0.6020	0.6030
43101288- 7	3.7318	287.59	44.05	49.558	1.9893	1.3527	0.6016	0.6033
43101288- 8	3.7348	287.61	44.08	49.225	1.9809	1.3469	0.6009	0.6026

Table 34. Measured and calculated quantities for the beta ratio of 0.55 and the 0.76 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 5.7137 cm (2.2495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44100388- 1	3.9846	288.50	46.88	7.156	1.3294	0.8993	0.6029	0.6032
44100388- 2	4.0186	288.20	47.34	7.187	1.3384	0.9057	0.6028	0.6030
44100388- 3	4.0927	288.84	48.10	3.221	0.9027	0.6094	0.6027	0.6028
44100388- 4	4.0731	288.95	47.85	3.120	0.8892	0.6003	0.6047	0.6048
44100388- 5	3.8836	287.75	45.82	14.440	1.8630	1.2641	0.6014	0.6019
44100388- 6	3.8822	287.76	45.80	14.345	1.8528	1.2571	0.6002	0.6007
44100388- 7	3.7434	287.21	44.25	21.129	2.2150	1.5074	0.6013	0.6020
44100388- 8	3.7561	287.63	44.33	21.076	2.2105	1.5026	0.6003	0.6010
44101288- 1	3.6847	287.49	43.51	21.869	2.2226	1.5126	0.5981	0.5988
44101288- 2	3.6931	286.54	43.77	21.598	2.2281	1.5197	0.6016	0.6023
44101288- 3	3.8718	288.28	45.59	7.739	1.3604	0.9220	0.6016	0.6019
44101288- 4	3.8585	288.25	45.44	7.735	1.3549	0.9185	0.6004	0.6006
44101288- 5	3.7575	287.83	44.32	14.797	1.8457	1.2539	0.5985	0.5990
44101288- 6	3.7683	287.96	44.42	14.760	1.8502	1.2565	0.6000	0.6005
44101288- 7	3.9532	288.82	46.46	3.638	0.9409	0.6362	0.6013	0.6015
44101288- 8	3.9550	288.97	46.45	3.728	0.9547	0.6453	0.6028	0.6029

Table 35. Measured and calculated quantities for the beta ratio of 0.67 and the 0.76 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45100488- 1	3.9629	288.59	46.61	2.685	1.2979	0.8780	0.6035	0.6036
45100488- 2	3.9686	288.51	46.69	2.695	1.3022	0.8810	0.6039	0.6040
45100488- 3	3.9387	288.23	46.39	4.152	1.6048	1.0869	0.6015	0.6016
45100488- 4	3.9308	288.26	46.29	4.116	1.5980	1.0823	0.6021	0.6022
45100488- 5	3.7341	287.52	44.09	8.725	2.2603	1.5372	0.5993	0.5996
45100488- 6	3.7350	287.48	44.11	8.734	2.2585	1.5361	0.5984	0.5987
45100488- 7	3.8491	287.48	45.46	6.306	1.9581	1.3300	0.6015	0.6017
45100488- 8	3.8499	287.46	45.47	6.304	1.9562	1.3288	0.6009	0.6011
45101188- 1	3.8548	287.83	45.47	6.048	1.9219	1.3043	0.6028	0.6030
45101188- 2	3.8349	287.59	45.27	5.957	1.9015	1.2914	0.6022	0.6024
45101188- 3	3.8987	287.97	45.96	4.443	1.6612	1.1263	0.6047	0.6048
45101188- 4	3.9006	287.91	46.00	4.472	1.6641	1.1284	0.6035	0.6036
45101188- 5	3.9457	287.94	46.52	2.893	1.3492	0.9144	0.6050	0.6051
45101188- 6	3.9389	287.99	46.43	2.904	1.3487	0.9140	0.6042	0.6043
45101188- 7	3.7345	286.61	44.25	8.548	2.2489	1.5328	0.6014	0.6016
45101188- 8	3.7390	287.02	44.23	8.531	2.2470	1.5299	0.6016	0.6018

Table 36. Measured and calculated quantities for the beta ratio of 0.73 and the 0.76 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.368 cm (4.082 in), 0.76 μm Ra   Orifice Diameter = 7.6177 cm (2.9991 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46092988- 1	3.8250	289.08	44.90	4.355	2.0245	1.3702	0.5979	0.5980
46092988- 2	3.8346	289.00	45.03	4.357	2.0265	1.3716	0.5975	0.5976
46092988- 3	3.6653	287.42	43.29	6.080	2.3472	1.5980	0.5975	0.5977
46092988- 4	3.7420	282.53	45.05	5.216	2.2141	1.5242	0.5966	0.5968
46092988- 5	3.8651	286.09	45.90	3.664	1.8807	1.2815	0.5990	0.5991
46092988- 6	3.8500	286.02	45.73	3.698	1.8888	1.2874	0.5999	0.6000
46092988- 7	3.9441	286.71	46.73	2.522	1.5765	1.0716	0.5999	0.6000
46092988- 8	3.9013	286.47	46.26	2.524	1.5679	1.0669	0.5993	0.5994
46100388- 1	3.9411	288.34	46.40	2.558	1.5892	1.0760	0.6025	0.6026
46100388- 2	3.9710	288.43	46.73	2.558	1.5934	1.0782	0.6019	0.6020
46100388- 3	3.8312	287.38	45.27	4.335	2.0380	1.3849	0.6009	0.6010
46100388- 4	3.8322	287.86	45.19	4.292	2.0236	1.3735	0.6001	0.6002
46100388- 5	3.7233	286.58	44.12	5.832	2.3267	1.5862	0.5991	0.5992
46100388- 6	3.7243	286.74	44.11	5.773	2.3126	1.5760	0.5985	0.5987
46100388- 7	3.8549	288.10	45.42	3.874	1.9214	1.3031	0.5983	0.5984
46100388- 8	3.8420	287.81	45.32	3.910	1.9293	1.3095	0.5986	0.5987

Table 37. Measured and calculated quantities for the beta ratio of 0.43 and the 3.8 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
43091389- 1	3.7488	286.49	44.44	48.485	2.0213	1.3782	0.6158	0.6175
43091389- 2	3.7474	286.50	44.42	48.513	2.0191	1.3767	0.6151	0.6168
43091389- 3	4.1024	287.62	48.44	5.198	0.6942	0.4700	0.6204	0.6205
43091389- 4	4.1238	287.76	48.67	4.973	0.6885	0.4659	0.6275	0.6277
43091389- 5	3.9223	286.68	46.47	27.165	1.5593	1.0605	0.6215	0.6224
43091389- 6	3.9238	286.83	46.46	26.758	1.5420	1.0483	0.6194	0.6203
43091389- 7	3.9894	287.22	47.17	15.005	1.1683	0.7929	0.6224	0.6229
43091389- 8	3.9860	287.10	47.15	15.085	1.1716	0.7954	0.6225	0.6230
43091389- 9	4.1303	287.97	48.70	5.109	0.6942	0.4695	0.6241	0.6243

Table 38. Measured and calculated quantities for the beta ratio of 0.55 and the 3.8 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44091389- 1	3.9463	287.12	46.68	7.076	1.3470	0.9149	0.6158	0.6161
44091389- 2	3.9472	287.43	46.63	7.071	1.3408	0.9100	0.6135	0.6137
44091389- 3	3.8476	286.84	45.55	13.389	1.8124	1.2333	0.6094	0.6099
44091389- 4	3.8444	287.03	45.48	13.169	1.8065	1.2287	0.6130	0.6134
44091389- 5	3.6688	285.98	43.57	21.697	2.2677	1.5496	0.6122	0.6129
44091389- 6	3.6684	285.92	43.58	21.613	2.2662	1.5489	0.6130	0.6137
44091389- 7	4.0559	287.41	47.93	3.013	0.8932	0.6054	0.6177	0.6178
44091389- 8	4.0596	287.38	47.97	3.099	0.9071	0.6149	0.6182	0.6183

Table 39. Measured and calculated quantities for the beta ratio of 0.67 and the 3.8 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY$_2$
45091289- 1	3.8879	286.62	46.07	4.330	1.6510	1.1235	0.6081	0.6082
45091289- 2	3.8840	286.72	46.01	4.262	1.6363	1.1133	0.6079	0.6080
45091289- 3	3.8042	286.16	45.16	6.202	1.9611	1.3374	0.6095	0.6097
45091289- 4	3.8020	285.99	45.16	6.204	1.9583	1.3360	0.6085	0.6087
45091289- 5	3.6607	285.70	43.52	8.761	2.2780	1.5579	0.6067	0.6070
45091289- 6	3.6807	285.77	43.75	8.399	2.2402	1.5314	0.6078	0.6081
45091289- 7	3.9308	286.83	46.55	2.691	1.3116	0.8916	0.6097	0.6098
45091289- 8	3.9361	286.69	46.63	2.734	1.3331	0.9065	0.6142	0.6143

Table 40. Measured and calculated quantities for the beta ratio of 0.73 and the 3.8 μm upstream pipe with a tee at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY$_2$
46091289- 1	3.8813	286.29	46.05	2.661	1.6277	1.1086	0.6068	0.6069
46091289- 2	3.8793	286.65	45.96	2.687	1.6234	1.1047	0.6028	0.6029
46091289- 3	3.7645	285.87	44.73	4.244	2.0231	1.3813	0.6059	0.6060
46091289- 4	3.7665	286.58	44.64	4.324	2.0177	1.3752	0.5994	0.5995
46091289- 5	3.6634	286.04	43.50	5.480	2.2508	1.5380	0.6016	0.6017
46091289- 6	3.6649	284.86	43.72	5.442	2.2431	1.5372	0.6002	0.6004
46091289- 7	3.8255	286.05	45.43	3.364	1.7967	1.2253	0.5999	0.6000
46091289- 8	3.8222	286.08	45.39	3.375	1.7987	1.2266	0.5998	0.5999

Table 41. Measured and calculated quantities for the beta ratio of 0.43 and the 3.8 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY$_2$
43101789- 1	3.9388	287.12	46.59	15.607	1.1464	0.7787	0.6021	0.6027
43101789- 2	3.9254	287.36	46.39	15.602	1.1427	0.7759	0.6016	0.6021
43101789- 3	3.8669	287.07	45.75	28.278	1.5319	1.0416	0.6028	0.6038
43101789- 4	3.8636	286.86	45.74	28.013	1.5227	1.0359	0.6021	0.6030
43101789- 5	4.0769	287.92	48.08	5.158	0.6689	0.4527	0.6020	0.6021
43101789- 6	4.0787	287.98	48.09	5.546	0.6969	0.4716	0.6048	0.6050
43101789- 7	3.7534	286.32	44.52	46.197	1.9308	1.3170	0.6019	0.6035
43101789- 8	3.7506	285.78	44.58	45.644	1.9189	1.3106	0.6014	0.6030

Table 42. **Measured and calculated quantities for the beta ratio of 0.55 and the 3.8 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.**

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
44101789- 1	4.0423	287.61	47.73	2.839	0.8491	0.5754	0.6060	0.6061
44101789- 2	4.0610	287.77	47.92	2.878	0.8576	0.5808	0.6067	0.6068
44101789- 3	3.6704	285.56	43.66	21.415	2.2241	1.5214	0.6037	0.6044
44101789- 4	3.6712	286.07	43.59	21.327	2.2161	1.5140	0.6032	0.6039
44101789- 5	3.8043	286.76	45.06	14.151	1.8350	1.2496	0.6034	0.6038
44101789- 6	3.8045	286.21	45.15	14.241	1.8422	1.2561	0.6032	0.6036
44101789- 8	3.9105	286.72	46.32	8.026	1.4023	0.9538	0.6040	0.6043
44101789- 9	3.9107	286.90	46.29	8.044	1.4047	0.9550	0.6046	0.6048

Table 43. **Measured and calculated quantities for the beta ratio of 0.67 and the 3.8 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.**

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
45090789- 1	3.8565	287.47	45.55	3.990	1.5660	1.0639	0.6042	0.6043
45090789- 2	3.8613	287.28	45.64	3.964	1.5618	1.0615	0.6039	0.6040
45090789- 3	3.6233	285.81	43.06	8.907	2.2600	1.5459	0.6001	0.6004
45090789- 4	3.6317	286.25	43.08	8.887	2.2552	1.5407	0.5993	0.5996
45090789- 5	3.7656	286.99	44.55	6.247	1.9319	1.3154	0.6022	0.6024
45090789- 6	3.7707	287.22	44.58	6.329	1.9445	1.3232	0.6021	0.6022
45090789- 7	3.9221	287.56	46.31	2.580	1.2732	0.8641	0.6059	0.6059
45090789- 8	3.9244	287.50	46.35	2.611	1.2777	0.8673	0.6042	0.6042
45090889- 1	3.6742	286.67	43.52	8.781	2.2622	1.5432	0.6017	0.6020
45090889- 2	3.6829	285.56	43.81	8.726	2.2606	1.5462	0.6013	0.6015
45090889- 3	3.8907	287.09	46.02	4.259	1.6245	1.1042	0.6035	0.6036
45090889- 4	3.8898	287.02	46.03	4.344	1.6414	1.1159	0.6038	0.6039
45090889- 5	3.8260	286.92	45.28	5.991	1.9119	1.3011	0.6037	0.6038
45090889- 6	3.8273	286.88	45.31	5.976	1.9114	1.3008	0.6041	0.6043
45090889- 7	3.9535	287.09	46.77	2.596	1.2839	0.8720	0.6061	0.6062
45090889- 8	3.9550	287.52	46.71	2.625	1.2866	0.8729	0.6044	0.6045

Table 44. Measured and calculated quantities for the beta ratio of 0.73 and the 3.8 μm upstream pipe with a tee upstream of the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
46090789- 1	3.6572	286.58	43.33	5.561	2.2604	1.5426	0.6008	0.6009
46090789- 2	3.6575	284.98	43.61	5.519	2.2560	1.5456	0.6001	0.6002
46090789- 3	3.8134	286.63	45.18	3.404	1.8085	1.2317	0.6017	0.6018
46090789- 4	3.8139	286.63	45.19	3.494	1.8286	1.2455	0.6005	0.6006
46090789- 5	3.7594	286.82	44.51	4.294	2.0174	1.3743	0.6022	0.6023
46090789- 6	3.7576	286.49	44.54	4.281	2.0105	1.3707	0.6008	0.6009
46090789- 7	3.8672	287.12	45.74	2.644	1.6075	1.0929	0.6032	0.6032
46090789- 8	3.8688	287.12	45.76	2.695	1.6215	1.1024	0.6026	0.6027
46090889- 1	3.8871	286.95	46.01	3.174	1.7645	1.1998	0.6026	0.6026
46090889- 2	3.8789	287.01	45.90	3.321	1.7954	1.2207	0.6001	0.6001
46090889- 3	3.6821	286.59	43.63	5.592	2.2599	1.5418	0.5970	0.5971
46090889- 4	3.6904	286.63	43.72	5.572	2.2613	1.5424	0.5978	0.5979
46090889- 5	3.7733	286.48	44.73	4.408	2.0358	1.3877	0.5982	0.5983
46090889- 6	3.7691	286.94	44.60	4.457	2.0494	1.3955	0.5997	0.5998
46090889- 7	3.8957	287.25	46.05	2.655	1.6120	1.0952	0.6016	0.6016
46090889- 8	3.8951	287.12	46.07	2.676	1.6189	1.1002	0.6017	0.6017

Table 45. Measured and calculated quantities for the beta ratio of 0.43 with two elbows out-of-plane at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
43110189- 1	3.9490	287.81	46.59	14.982	1.1306	0.7666	0.6062	0.6067
43110189- 2	3.9498	287.99	46.56	15.000	1.1288	0.7651	0.6050	0.6055
43110189- 3	3.8836	287.57	45.85	28.639	1.5466	1.0501	0.6040	0.6050
43110189- 4	3.8871	287.39	45.93	28.506	1.5471	1.0509	0.6052	0.6061
43110189- 5	4.0530	288.44	47.70	5.796	0.7126	0.4819	0.6074	0.6076
43110189- 6	4.0554	288.47	47.73	5.468	0.6940	0.4692	0.6089	0.6090
43110189- 7	3.7643	287.05	44.53	49.293	2.0015	1.3626	0.6039	0.6056
43110189- 8	3.7701	286.69	44.66	48.683	1.9886	1.3549	0.6029	0.6046
43110889- 1	3.9798	288.44	46.84	5.092	0.6607	0.4471	0.6064	0.6066
43110889- 2	3.9879	288.58	46.91	5.441	0.6864	0.4643	0.6089	0.6091
43110889- 3	3.6999	287.32	43.72	48.049	1.9574	1.3328	0.6038	0.6054
43110889- 4	3.7102	286.88	43.91	47.353	1.9435	1.3245	0.6025	0.6042
43110889- 5	3.8784	287.75	45.76	16.207	1.1626	0.7891	0.6046	0.6052
43110889- 6	3.8826	287.94	45.78	16.420	1.1718	0.7949	0.6053	0.6059
43110889- 7	3.8260	287.36	45.21	28.996	1.5486	1.0527	0.6053	0.6063
43110889- 8	3.8223	287.12	45.21	29.205	1.5524	1.0560	0.6047	0.6057

Table 46. Measured and calculated quantities for the beta ratio of 0.55 with two elbows out-of-plane at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
44103189- 1	3.7401	287.36	44.19	21.489	2.2564	1.5354	0.6077	0.6084
44103189- 2	3.7437	286.75	44.33	21.323	2.2524	1.5349	0.6080	0.6087
44103189- 3	4.0953	288.13	48.26	2.442	0.7984	0.5400	0.6110	0.6111
44103189- 4	4.0933	288.23	48.22	2.467	0.8022	0.5425	0.6112	0.6113
44103189- 5	3.9782	287.66	46.96	7.009	1.3327	0.9037	0.6101	0.6103
44103189- 6	3.9742	287.66	46.91	6.961	1.3259	0.8991	0.6095	0.6097
44103189- 7	3.8812	287.60	45.82	13.389	1.8132	1.2310	0.6078	0.6082
44103189- 8	3.8842	287.31	45.91	13.284	1.8127	1.2316	0.6095	0.6099
44110889- 1	3.7571	287.78	44.32	14.115	1.8277	1.2422	0.6067	0.6072
44110889- 2	3.7576	287.39	44.39	14.089	1.8276	1.2433	0.6067	0.6072
44110889- 3	3.8520	287.88	45.43	7.472	1.3477	0.9147	0.6075	0.6078
44110889- 4	3.8515	287.91	45.42	7.484	1.3500	0.9162	0.6082	0.6084
44110889- 5	3.9626	288.41	46.64	2.726	0.8277	0.5603	0.6099	0.6100
44110889- 6	3.9637	288.45	46.65	2.755	0.8323	0.5634	0.6099	0.6100
44110889- 7	3.6313	287.18	42.93	21.271	2.2067	1.5042	0.6060	0.6067
44110889- 8	3.6152	286.96	42.77	22.221	2.2525	1.5365	0.6063	0.6071

Table 47. Measured and calculated quantities for the beta ratio of 0.67 with two elbows out-of-plane at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
45103189- 2	3.8506	287.57	45.46	6.198	1.9532	1.3267	0.6051	0.6053
45103189- 3	3.7344	287.16	44.15	8.548	2.2613	1.5396	0.6052	0.6055
45103189- 4	3.7377	287.38	44.16	8.534	2.2602	1.5379	0.6054	0.6057
45103189- 5	3.9336	287.41	46.48	4.012	1.5891	1.0787	0.6053	0.6054
45103189- 6	3.9383	287.53	46.51	4.064	1.6025	1.0874	0.6063	0.6064
45103189- 7	3.9857	287.58	47.06	2.738	1.3303	0.9021	0.6096	0.6097
45103189- 8	3.9839	287.47	47.06	2.742	1.3250	0.8988	0.6067	0.6068
45103189- 9	3.9838	287.57	47.04	2.735	1.3227	0.8970	0.6065	0.6066
45110789- 1	3.9470	287.57	46.60	2.666	1.2978	0.8805	0.6057	0.6058
45110789- 2	3.9481	287.85	46.57	2.650	1.2945	0.8776	0.6061	0.6062
45110789- 3	3.9053	287.44	46.13	4.190	1.6137	1.0957	0.6037	0.6038
45110789- 4	3.9062	287.19	46.19	4.170	1.6126	1.0956	0.6044	0.6045
45110789- 5	3.7066	286.54	43.93	8.639	2.2631	1.5437	0.6041	0.6044
45110789- 6	3.7079	286.62	43.93	8.613	2.2532	1.5366	0.6024	0.6026
45110789- 7	3.8287	287.39	45.23	6.045	1.9180	1.3037	0.6032	0.6034
45110789- 8	3.8258	287.23	45.23	6.080	1.9245	1.3087	0.6036	0.6037

Table 48. Measured and calculated quantities for the beta ratio of 0.73 with two elbows out-of-plane at 19 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
46110189- 2	3.7977	287.08	44.92	4.320	2.0158	1.3717	0.5971	0.5972
46110189- 3	3.8031	287.07	44.99	4.329	2.0159	1.3717	0.5961	0.5962
46110189- 4	3.7250	287.28	44.02	5.448	2.2438	1.5274	0.5978	0.5979
46110189- 5	3.7064	287.38	43.79	5.423	2.2252	1.5148	0.5958	0.5960
46110189- 6	3.8931	287.41	46.00	2.644	1.6019	1.0879	0.5995	0.5995
46110189- 7	3.8935	287.58	45.97	2.684	1.6116	1.0941	0.5987	0.5988
46110189- 8	3.8613	287.40	45.62	3.222	1.7540	1.1917	0.5970	0.5971
46110189- 9	3.8605	287.50	45.59	3.218	1.7537	1.1912	0.5975	0.5975
46110789- 1	3.8671	287.31	45.71	3.323	1.7854	1.2133	0.5978	0.5979
46110789- 2	3.8669	287.46	45.68	3.328	1.7840	1.2118	0.5971	0.5972
46110789- 3	3.9077	287.47	46.16	2.606	1.5943	1.0824	0.5999	0.6000
46110789- 4	3.9082	287.53	46.15	2.604	1.5892	1.0788	0.5983	0.5983
46110789- 5	3.6990	287.26	43.72	5.719	2.2853	1.5562	0.5964	0.5965
46110789- 6	3.6992	287.18	43.73	5.696	2.2834	1.5553	0.5969	0.5971
46110789- 7	3.7905	287.31	44.80	4.464	2.0468	1.3922	0.5973	0.5974
46110789- 8	3.7925	286.87	44.89	4.477	2.0526	1.3976	0.5975	0.5976

Table 49. Measured and calculated quantities for the beta ratio of 0.43 with two elbows out-of-plane and the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 4.4437 cm (1.7495 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
43110289- 1	3.7763	286.88	44.70	49.001	1.9787	1.3475	0.5977	0.5993
43110289- 2	3.7839	287.13	44.75	48.863	1.9789	1.3467	0.5982	0.5999
43110289- 3	3.9573	287.58	46.73	16.504	1.1804	0.8007	0.6020	0.6025
43110289- 4	3.9688	287.78	46.83	15.409	1.1412	0.7737	0.6017	0.6022
43110289- 5	3.9197	287.48	46.30	27.937	1.5297	1.0384	0.6020	0.6029
43110289- 6	3.9134	287.35	46.25	29.827	1.5764	1.0705	0.6007	0.6017
43110289- 7	3.7978	287.28	44.89	48.903	1.9872	1.3516	0.5996	0.6012
43110289- 8	3.8013	286.79	45.01	48.586	1.9794	1.3478	0.5983	0.6000
43110289- 9	4.0947	288.30	48.22	6.260	0.7416	0.5014	0.6049	0.6051
43110289-10	4.0927	288.43	48.17	6.176	0.7378	0.4987	0.6062	0.6064
43110989- 1	3.8604	287.78	45.54	28.526	1.5285	1.0375	0.6002	0.6011
43110989- 2	3.8622	287.90	45.54	28.435	1.5264	1.0358	0.6003	0.6013
43110989- 3	3.9277	288.13	46.28	13.987	1.0811	0.7326	0.6019	0.6023
43110989- 4	3.9307	288.02	46.33	13.891	1.0793	0.7316	0.6026	0.6031
43110989- 5	3.7539	287.31	44.36	46.761	1.9285	1.3123	0.5986	0.6002
43110989- 6	3.7417	287.52	44.18	49.075	1.9747	1.3432	0.5994	0.6011
43110989- 7	4.0238	288.53	47.34	5.913	0.7128	0.4821	0.6038	0.6040
43110989- 8	4.0216	288.66	47.29	5.817	0.7056	0.4770	0.6029	0.6031
43030890- 1	3.9133	287.82	46.16	15.431	1.1340	0.7692	0.6018	0.6023
43030890- 2	3.9451	288.06	46.50	15.274	1.1320	0.7671	0.6016	0.6021
43030890- 3	3.8148	287.59	45.04	29.851	1.5564	1.0576	0.6007	0.6017
43030890- 4	3.8207	287.52	45.12	29.764	1.5539	1.0560	0.6001	0.6011
43030890- 5	4.0598	288.67	47.74	5.199	0.6732	0.4549	0.6055	0.6057
43030890- 6	4.0704	288.86	47.83	4.872	0.6519	0.4403	0.6053	0.6054
43030890- 7	3.6912	287.32	43.62	48.076	1.9461	1.3252	0.6008	0.6024
43030890- 8	3.6920	287.18	43.65	47.327	1.9275	1.3129	0.5995	0.6011

Table 50. Measured and calculated quantities for the beta ratio of 0.55 with two elbows out-of-plane and the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 5.7142 cm (2.2497 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
44110389- 1	3.8921	287.31	46.00	13.189	1.7879	1.2146	0.6027	0.6031
44110389- 2	3.8908	287.32	45.98	13.164	1.7889	1.2152	0.6037	0.6041
44110389- 3	3.9769	287.91	46.90	7.346	1.3505	0.9152	0.6043	0.6045
44110389- 4	3.9770	287.75	46.93	7.317	1.3492	0.9147	0.6048	0.6050
44110389- 5	4.0796	288.32	48.04	2.833	0.8534	0.5770	0.6078	0.6079
44110389- 6	4.0829	288.31	48.08	2.854	0.8565	0.5791	0.6074	0.6075
44110389- 7	3.7410	286.37	44.37	21.020	2.2142	1.5104	0.6018	0.6024
44110389- 8	3.7430	286.43	44.38	20.829	2.2110	1.5079	0.6036	0.6042
44110989- 1	3.9097	288.02	46.09	7.226	1.3301	0.9019	0.6054	0.6056
44110989- 2	3.9126	287.98	46.13	7.083	1.3198	0.8949	0.6064	0.6066
44110989- 3	4.0170	288.37	47.29	2.794	0.8419	0.5696	0.6086	0.6086
44110989- 4	4.0172	288.42	47.28	2.717	0.8316	0.5625	0.6096	0.6096
44110989- 5	3.6796	286.74	43.57	21.468	2.2253	1.5176	0.6038	0.6045
44110989- 6	3.6834	287.14	43.55	21.344	2.2165	1.5101	0.6033	0.6040
44110989- 8	3.8123	287.05	45.10	14.124	1.8393	1.2515	0.6051	0.6055
44110989- 9	3.8296	287.53	45.22	12.749	1.7474	1.1873	0.6043	0.6047

Table 51. Measured and calculated quantities for the beta ratio of 0.67 with two elbows out-of-plane and the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 6.9840 cm (2.7496 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. ($\div 10^6$)	C	CY_2
45110389- 1	3.9838	287.89	46.98	2.689	1.3098	0.8876	0.6061	0.6062
45110389- 2	3.9865	287.50	47.09	2.680	1.3094	0.8881	0.6063	0.6063
45110389- 3	3.9350	287.49	46.48	4.273	1.6428	1.1149	0.6063	0.6064
45110389- 4	3.9356	287.36	46.51	4.261	1.6410	1.1141	0.6063	0.6064
45110389- 5	3.7344	286.46	44.27	8.596	2.2657	1.5452	0.6040	0.6042
45110389- 6	3.7356	286.18	44.34	8.540	2.2570	1.5404	0.6032	0.6034
45110389- 7	3.8631	287.02	45.71	5.950	1.9182	1.3044	0.6049	0.6051
45110389- 8	3.8559	286.90	45.64	5.946	1.9163	1.3036	0.6049	0.6051
45110389- 9	3.9267	287.29	46.41	4.246	1.6350	1.1103	0.6058	0.6059
45112189- 1	3.8843	287.48	45.88	4.019	1.5861	1.0772	0.6075	0.6076
45112189- 2	3.8822	287.82	45.79	4.024	1.5812	1.0729	0.6058	0.6059
45112189- 3	3.6701	287.23	43.38	8.863	2.2748	1.5498	0.6033	0.6035
45112189- 4	3.6724	287.27	43.40	8.809	2.2663	1.5437	0.6027	0.6029
45112189- 5	3.7969	287.34	44.86	5.962	1.8996	1.2918	0.6041	0.6042
45112189- 6	3.7976	287.53	44.84	5.997	1.9014	1.2925	0.6030	0.6032
45112189- 7	3.9212	287.98	46.23	2.272	1.1960	0.8109	0.6071	0.6071
45112189- 8	3.9141	288.02	46.14	2.626	1.2841	0.8706	0.6068	0.6069

Table 52. Measured and calculated quantities for the beta ratio of 0.73 with two elbows out-of-plane and the in-line tube bundle at 17 pipe diameters upstream of the orifice plate.

Pipe Diameter = 10.366 cm (4.081 in), 3.8 μm Ra   Orifice Diameter = 7.6197 cm (2.9999 in)

Run ID	Pressure (MPa)	Temperature (K)	Density (kg/m^3)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10^6)	C	CY_2
46110689- 1	3.8702	287.00	45.80	4.082	1.9889	1.3525	0.6002	0.6003
46110689- 2	3.8685	286.83	45.80	4.063	1.9836	1.3494	0.6000	0.6001
46110689- 3	3.9608	287.22	46.83	2.585	1.6042	1.0892	0.6017	0.6017
46110689- 4	3.9603	287.38	46.80	2.597	1.6061	1.0900	0.6013	0.6013
46110689- 5	3.7512	287.00	44.38	5.507	2.2758	1.5498	0.6007	0.6008
46110689- 6	3.7488	286.93	44.36	5.515	2.2734	1.5485	0.5997	0.5998
46110689- 7	3.8996	286.93	46.16	3.486	1.8484	1.2568	0.6013	0.6014
46110689- 8	3.8937	286.91	46.09	3.512	1.8524	1.2595	0.6007	0.6008
46112189- 1	3.8759	287.53	45.77	2.681	1.6180	1.0988	0.6028	0.6028
46112189- 2	3.8689	288.03	45.60	2.664	1.6071	1.0901	0.6017	0.6018
46112189- 3	3.6721	287.24	43.40	5.550	2.2592	1.5390	0.6006	0.6007
46112189- 4	3.6712	287.29	43.38	5.554	2.2586	1.5384	0.6004	0.6005
46112189- 5	3.8128	287.14	45.09	3.457	1.8154	1.2349	0.6000	0.6001
46112189- 6	3.8145	287.79	45.00	3.499	1.8230	1.2381	0.5994	0.5995
46112189- 7	3.7624	287.08	44.50	4.294	2.0082	1.3671	0.5995	0.5996
46112189- 8	3.7652	286.91	44.56	4.265	2.0037	1.3646	0.5997	0.5998
46030890- 1	3.6220	286.36	42.95	5.432	2.2165	1.5141	0.5987	0.5989
46030890- 2	3.6220	287.12	42.83	5.428	2.2126	1.5087	0.5988	0.5989
46030890- 3	3.7798	287.59	44.62	3.358	1.7744	1.2062	0.5982	0.5983
46030890- 4	3.7838	287.42	44.70	3.389	1.7888	1.2164	0.5998	0.5998
46030890- 5	3.7774	287.59	44.59	3.389	1.7862	1.2143	0.5995	0.5996
46030890- 6	3.7727	287.22	44.60	3.359	1.7759	1.2084	0.5988	0.5988

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System pipe configurations can produce large flow disturbances that significantly affect the accuracy of orifice meters. Flow conditioners such as the tube bundle are frequently used to remove the effect of upstream disturbances. The flow conditioner can also influence measurement accuracy if improperly located relative to the orifice plate in the orifice meter. Tests were conducted in a 3.8 μm (150 μin) Ra surface finish pipe with a tube bundle flow conditioner located at four different positions upstream of an orifice plate. The resulting orifice discharge coefficients are shown for the tube bundle flow conditioner at each of the locations. Changes in the orifice discharge coefficient for orifice plates downstream of three flow disturbances consisting of elbows or a tee were measured. For most of the configurations tested, installing a tube bundle flow conditioner immediately downstream of the disturbances reduced these changes in the discharge coefficient from as much as 2 percent to less than 0.2 percent. Recommendations for future research needs are suggested.

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