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The Effects of Flow Conditioners and Tap Location on Orifice Flowmeter Performance

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CROSS-REFERENCE CHART

Figure No.	Beta Ratio 0.43	0.55	0.67	0.73	Flow Cond.*	Table No.	Test Config	Tap Location** 3:00	6:00	9:00	12:00
6	X				ZAN	2	FIG. 3			X	
7		X			ZAN	3	FIG. 3			X	
8			X		ZAN	4	FIG. 3			X	
9				X	ZAN	5	FIG. 3			X	
10	X	X	X	X	ZAN	SUMM.	FIG. 3			X	
11	X				ET1	6	FIG. 3			X	
12		X			ET1	7	FIG. 3			X	
13			X		ET1	8	FIG. 3			X	
14				X	ET1	9	FIG. 3			X	
15	X	X	X	X	ET1	SUMM.	FIG. 3			X	
16	X				FT6	10	FIG. 3			X	
17		X			FT6	11	FIG. 3			X	
18			X		FT6	12	FIG. 3			X	
19				X	FT6	13	FIG. 3			X	
20	X	X	X	X	FT6	SUMM.	FIG. 3			X	
21	X				FT1	14	FIG. 3			X	
22		X			FT1	15	FIG. 3			X	
23			X		FT1	16	FIG. 3			X	
24				X	FT1	17	FIG. 3			X	
25	X	X	X	X	FT1	SUMM.	FIG. 3			X	
26	X				FT1	18	FIG. 4			X	
27		X			FT1	19	FIG. 4			X	
28			X		FT1	20	FIG. 4			X	
29				X	FT1	21	FIG. 4			X	
30	X	X	X	X	FT1	SUMM.	FIG. 4			X	
31	X				IT1	22	FIG. 4			X	
32		X			IT1	23	FIG. 4			X	
33			X		IT1	24	FIG. 4			X	
34				X	IT1	25	FIG. 4			X	
35	X	X	X	X	IT1	SUMM.	FIG. 4			X	
36				X	---	26,27	FIG. 4	X		X	
37				X	---	28,29	FIG. 4		X		X
38	X				---	30,31	FIG. 4	X		X	
39	X				---	32,33	FIG. 4		X		X
40				X	IT1	34,35	FIG. 4	X		X	
41				X	IT1	36,37	FIG. 4		X		X
42	X				IT1	38,39	FIG. 4	X		X	
43	X				IT1	40,41	FIG. 4		X		X
44				X	FT2	42,43	FIG. 4	X		X	
45	X				FT2	44,45	FIG. 4	X		X	
46				X	FT4	46,47	FIG. 4	X		X	
47	X				FT4	48,49	FIG. 4	X		X	

*See Table 1 for details
**As seen when looking downstream

LIST OF FIGURES

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LIST OF FIGURES (continued)

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THE EFFECTS OF FLOW CONDITIONERS AND TAP LOCATION ON ORIFICE FLOWMETER PERFORMANCE

ABSTRACT

Current research is being conducted to provide information which will be used to improve the existing industry standards for proper installation of orifice meters. This research includes experimental investigation of a Zanker, an etoile, and several tube bundle flow conditioners at various positions relative to the orifice plate. Also included are the effects of pressure tap location, both with and without flow conditioning, as reflected in determination of discharge coefficients.

Of the flow conditioners tested at approximately 11 pipe diameters upstream of the orifice plate, the Zanker flow conditioner resulted in discharge coefficients most similar to baseline values. There was only a slight difference in orifice meter performance when a flanged or an in-line tube bundle flow conditioner was used at the tested location upstream of the orifice plate. The effect of pressure tap location was found to be significant with the 0.73 beta ratio plate. Recommendations for future research, as a result of these findings, are included.

Key words: discharge coefficient; etoile; flow conditioner; flow disturbance; flow measurement; gas; orifice flowmeter; tap location; tube bundle; Zanker

INTRODUCTION

In recent years, much research has been devoted to improving flow measurement accuracy of the orifice flowmeter. Various piping configurations upstream of the orifice flowmeter can induce swirl in the flow that causes a shift in discharge coefficient [1,2,3]. Using a flow conditioner upstream of the meter can remove swirl[4,5], but the proper location of the flow conditioner relative to the orifice plate remains a question. The locations are specified in the standards such as AGA Report No. 3, ANSI/API 2530[6], and ISO 5167[7]; however, the guidelines provided in these standards do not adequately address this problem. Work has been done to determine both the type of flow conditioner and its location relative to the orifice plate that will result in discharge coefficients similar to baseline values[3,8-12].

Most recent work completed at the National Institute of Standards and Technology, Boulder, Colorado (NIST-B), has been done using an in-line flow conditioner with 19 concentric tubes (figure 1). The published results [11,12] indicate that for flow conditions in this facility, a good location of the in-line tube bundle for all beta ratios tested is between 13 and 17 pipe diameters upstream of the orifice plate. The beta ratio of an orifice plate is the ratio between the orifice diameter and the inner diameter of the meter tube. If placed closer to the orifice plate, the flow conditioner caused a negative shift in the discharge coefficient. Research was conducted at NIST-B with various piping configurations upstream of the flow conditioner. When the in-line tube bundle is located 17 pipe diameters upstream of the orifice plate, the measured discharge coefficient is within 0.3% of the baseline discharge coefficient at the same Reynolds number for all beta ratios tested. This result was consistent regardless of whether the flow conditioner was preceded by a long, straight, upstream section or a disturbance such as a tee or two, out-of-plane elbows located 19 pipe diameters upstream of the orifice plate. The question was raised that perhaps a different type of flow conditioner would produce similar or better results. For that reason, the following four alternate flow conditioners were tested: a Zanker; an etoile; a flanged, 7 tube bundle; and a flanged, 19 tube bundle of similar construction to the in-line, 19 tube bundle. These flow conditioners are illustrated in figures 2a through 2d. Because previous work had determined that an upstream tee resulted in the greatest shift in the discharge coefficient[11], the tee was placed 19 pipe diameters upstream of the orifice plate for the testing of the four flow conditioners (figure 3).

Another objective of this research was to determine the difference in orifice meter performance when using either the flanged or the in-line, 19 tube bundle flow conditioner. Prior to conducting these tests, the system configuration was modified so that the distance between the tee and the orifice plate was reduced to 17 pipe diameters (figure 4). This configuration more accurately reflects the minimum allowable overall distance between the disturbance and the orifice plate as specified by AGA Report No.3, ANSI/API 2530[6] when a flow conditioner is used (for a beta ratio of 0.75 and a partially closed valve disturbance). The flow conditioners were placed directly downstream of the disturbance because it was previously determined that this was an acceptable location for the in-line tube bundle in this system[11].

The next aim of the research conducted at NIST-B was to determine the effect, if any, of pressure tap location (flange taps) on determining the orifice discharge coefficient. These tests were conducted with and without an in-line tube bundle flow conditioner located directly downstream of the tee, as shown in figure 4. In addition, concern had been expressed that flow conditioners of the same basic type could be significantly different from one to another. Using the same configuration, tests were conducted using two other flanged, 19 tube bundle flow conditioners, one with a hexagonal pattern, figure 2e, and the other a round pattern with tubes of slightly larger diameter. Table 1 lists all the flow conditioners and their salient features.

Table 1. Flow conditioner codes, descriptions, and measurements.

Identification	Name	Number Tubes/ Blades	Pattern: In-line (I) Flanged (F)	Dimension mm (in) Length	OD	Tube ID
IT1	tube bundle	19	round-I	254 (10)	97 (3.8)	15 (0.6)
FT1	tube bundle	19	round-F	254 (10)	95 (3.7)	15 (0.6)
FT2	tube bundle	19	hex-F	254 (10)	95 (3.7)	16 (0.64)
FT4	tube bundle	19	round-F	254 (10)	101 (4)	18 (0.7)
FT6	tube bundle	7	round-F	340 (13.4)	100 (3.9)	32 (1.3)
ET1	etoile	8	star-F	311 (12.3)	102 (4)	--- ---
ZAN	Zanker	32 holes	perf. plate with honeycomb-F	108 (4.3)	102 (4)	--- ---

EXPERIMENTAL PROGRAM

The facility at NIST-B is a 100 mm (4 inch) nitrogen gravimetric system with an operating pressure of about 4 MPa (580 psia). The orifice flowmeter consists of three sections: approach, upstream, and downstream. Two approach pieces were used during the course of this research. One approach section used is 8 pipe diameters in length and has an internal surface roughness of 0.76 μm (30 μin) Ra, the absolute mean deviation value of the surface finish measurement. This piping configuration is shown in figure 3. The other approach section is 6 pipe diameters in length with an internal surface roughness of 2.5 μm (100 μin) Ra and was used as shown in figure 4. The upstream section, 11 pipe diameters long, has a surface roughness of 3.8 μm (150 μin) Ra. The downstream section is 16 pipe diameters in length. All sections were pinned at the flanges to insure proper alignment.

The 4 inch orifice discharge coefficient baseline values used for comparison in this report were described in detail by Sindt et al.[11]. In brief, for each of the beta ratios of 0.43, 0.55, 0.67, and 0.73, data were obtained in at least two baseline configurations. For these baseline configurations, the orifice plate was preceded by either 56 pipe diameters of straight pipe, figure 5a, an oversized Sprenkle flow conditioner and 46 diameters of straight pipe, figure 5b, or 46 diameters of straight pipe, figure 5c. All meter tube configurations included the 3.8 μm (150 μin) Ra upstream section. These data were fitted to a curve which relates orifice discharge coefficient to pipe Reynolds number for each beta ratio. The same fitting routine was used for all subsequent experimental data.

Portions of this research include complete data sets. A typical data set contains at least four data points, taken at each of four flow rates, for all four beta ratios. For each beta ratio, half of the data were taken on one day and the other half on another to include the effects of any daily variability. For each data point, the pressure drop across the orifice plate was measured at the flange pressure taps located at the 9 o'clock position, as viewed from upstream (figure 3). The flow rates used extended over a pipe Reynolds number range of $0.5\text{-}1.5 \times 10^6$.

The data sets for the other portions of the research in this report include data points obtained when using only the largest and smallest beta ratios. Because the configuration and flow conditioner (in-line tube bundle) used for the tap location tests had been investigated thoroughly in previous work[11], we decided to limit this testing to the 0.43 and 0.73 beta ratio plates with two data points at each flow rate. The flow rates using these two plates covered the entire pipe Reynolds number range. The use of these two orifice plates was also deemed sufficient for tests to determine the effect of variations in the dimensions of the flanged, 19 tube bundle flow conditioner, but four data points were obtained at each flow rate.

The percentage of the shift in orifice meter discharge coefficients caused by either upstream piping configurations or flow conditioners at selected Reynolds numbers was computed as follows:

$$\Delta C(\%) = \frac{(C_t - C_b)\,x100}{C_b}, \tag{1}$$

where C_b is the discharge coefficient that was experimentally determined with the baseline configurations and C_t is the discharge coefficient calculated for the various test configurations.

The first tests involved alternate flow conditioners, and a complete data set was taken for each flow conditioner. A complete data set is defined as four data points taken at each of four flow rates, for all four orifice plate beta ratios. The data sets were taken over a two-day period to include the effects of daily variability. The tee was located 19 pipe diameters upstream of the orifice plate as shown in figure 3. AGA Report No. 3, ANSI/API 2530[6] specifies that the minimum allowable distance between the flow conditioner and the orifice plate is approximately 7 pipe diameters with a 0.75 beta ratio orifice plate. Tests at this facility and others[3,8-11] have shown that placing the flow conditioner 7 pipe diameters upstream of the orifice plate results in a negative shift of the discharge coefficient for a variety of working fluids and meter sizes. In an effort to find a better location, the initial tests of the alternate flow conditioners were conducted with the downstream end of the flow conditioner located 11 pipe diameters upstream of the orifice plate. An exception was the Zanker flow conditioner, figure 2a. Because of its design, the flange must be on the upstream side; therefore, the distance between the outlet of the Zanker flow conditioner and the orifice plate was 10 pipe diameters. Because these tests showed a consistent negative shift of the discharge coefficients with the use of each of the flow conditioners, no tests were conducted with the flow conditioners located closer to the orifice plate.

For the second portion of the research, the tee was located 17 pipe diameters upstream of the orifice plate (figure 4). This was accomplished by installing the shorter approach section of the flowmeter. A complete set of data was gathered using the flanged, round pattern, 19 tube flow conditioner [FT1], and the in-line, 19 tube flow conditioner [IT1], figures 1 and 2d. For these tests, the flow conditioner was placed at the outlet of the tee so that its downstream end was 15 pipe diameters upstream of the orifice plate.

The piping configuration shown in figure 4 was used in the pressure tap location study. For these tests the discharge coefficients were determined both with and without the in-line, 19 tube flow conditioner located at the tee outlet. Because the configuration and flow conditioner (IT1) used for the tap location tests had been previously investigated[11], a reduced data set was taken. Only the 0.43 and 0.73 beta ratio orifice plates were used, and only two data points were taken at each flow rate. The pressure drop across the orifice plate was measured at four locations: 12, 3, 6, and 9 o'clock, as viewed from upstream of the orifice.

Because these tests indicated a pressure tap location influence, subsequent tests were modified to include the determination of the discharge coefficients at the 3 o'clock tap location in addition to those from the 9 o'clock tap location. With measurements at the two tap locations and the same piping configuration (figure 4), two other flanged, 19 tube bundle flow conditioners of slightly different design [FT2, FT4] were located at the tee outlet and tests were conducted with the 0.43 and 0.73 beta ratio orifice plates.

To complement the flow measurement work being done with various flow conditioners, a pitot-static probe was used to characterize the velocity profiles downstream of each flow conditioner. For these measurements, the orifice plate was removed and the probe apparatus was located in its place. The velocity profile work was preliminary; however, a general description of the profiles are mentioned in this report.

TEST RESULTS

<u>Alternate Flow Conditioners:</u>

Data for the Zanker flow conditioner are shown in tables 2-5. Figures 6-9 show the orifice discharge coefficients at various pipe Reynolds numbers for each of the beta ratios. For a pipe Reynolds number of 1.25×10^6, the difference between the discharge coefficients calculated from the measured data and that of the baseline is shown in figure 10. Using the Zanker flow conditioner 10D upstream of the orifice plate results in discharge coefficients within -0.15% of baseline for each beta ratio.

Data taken with the etoile flow conditioner located 11D upstream of the orifice plate are recorded in tables 6-9 and the discharge coefficients are shown in figures 11-14. The shift in discharge coefficient is shown in figure 15. The discharge coefficients are at least 0.25% below baseline values for all beta ratios tested.

Tables 10-13 contain the data taken while using the flanged, 7 tube bundle [FT6] located at 11D, and the discharge coefficient data are displayed in figures 16-19. The percent shift in discharge coefficient when using this flow conditioner is shown in figure 20. Once again, the discharge coefficients with this flow conditioner were lower than baseline values for all beta ratios tested.

The last flow conditioner tested at the 11D upstream location was the flanged, 19 tube bundle [FT1] and the data are in tables 14-17. Figures 21-24 and figure 25 display the discharge coefficient data and the percent shift in discharge coefficient, respectively. With this flow conditioner, the discharge coefficient with the 0.43 beta ratio is similar to the baseline value, but there was a negative shift with the larger beta ratios.

In summary, when a tee disturbance is located 17 pipe diameters upstream of the orifice plate, placing any of the four flow conditioners about 11 pipe diameters upstream of the orifice plate returns the discharge coefficient within -0.5% of the baseline value, at a pipe Reynolds number of 1.25×10^6.

Velocity profiles were measured downstream of these flow conditioners at the orifice meter location and the results were somewhat varied. All were symmetric, but those downstream of the tube bundle and etoile flow conditioners were flatter, while the profiles downstream of the Zanker flow conditioner were slightly more peaked than a theoretical reference turbulent velocity profile at an equivalent Reynolds number.

In-line vs. Flanged Tube Bundle Flow Conditioners:

The data taken with the flanged, 19 tube bundle flow conditioner [FT1] located 15 pipe diameters (15D) upstream of the orifice plate are recorded in tables 18-21 and are illustrated in figures 26-29. The percent differences between these discharge coefficients and the baseline values are shown in figure 30. Tables 22-25 contain the data taken when the in-line tube bundle was located 15 pipe diameters upstream of the orifice plate. The data are plotted in figures 31-34 and figure 35 shows the percent change in discharge coefficient from baseline.

The discharge coefficients with the flanged flow conditioner were slightly above baseline except for the 0.55 beta ratio plate. The largest shift in discharge coefficient occurred with the 0.67 beta ratio plate, but it was only about +0.25%. The results for the in-line flow conditioner were marginally better. The largest shift was -0.2% which occurred with the 0.55 beta ratio plate. Though the velocity profiles in the plane of the orifice plate were asymmetric, placing either of these flow conditioners 15 pipe diameters upstream of the orifice plate resulted in discharge coefficients close to baseline values.

Pressure Tap Location:

Only the 0.43 and 0.73 beta ratio plates were used for the pressure tap location testing. Data were taken simultaneously at the 3 and 9 o'clock positions, as were the data for the 6 and 12 o'clock positions. Therefore, the 3 and 9 o'clock discharge coefficient data will be plotted together, as will the 6 and 12 o'clock data.

Tables 26-29 contain the data taken at each of the pressure taps with a 0.73 beta ratio orifice plate installed and no flow conditioner. Figures 36 and 37 show the discharge coefficients computed at each location. Tables 30-33 list the data obtained at the four tap locations while using the 0.43 beta ratio plate and no flow conditioner. The plots of the discharge coefficients are shown in figures 38 and 39.

As expected, the discharge coefficients for the 0.73 beta ratio plate shifted away from the baseline because no flow conditioner was installed. The effect of tap location was significant, especially at the 6 and 12 o'clock positions (figure 37). At a pipe Reynolds number of 1.1×10^6, the discharge coefficient from the 6 o'clock position showed a +0.7% shift from baseline, while the coefficient for the 12 o'clock position showed a -0.36% shift from baseline. Figures 38 and 39 indicate that the shift from baseline when using the 0.43 beta ratio orifice plate without a flow conditioner was very substantial, however there was little difference between results for different pressure tap locations.

The in-line tube bundle was installed at the outlet of the tee and the tests to determine pressure tap location effects were repeated. The data for the 0.73 beta ratio plate are in tables 34-37 and are plotted in figures 40 and 41. Tables 38-41 contain the data for the 0.43 beta ratio plate, and figures 42 and 43 show those data.

The discharge coefficients for the 0.43 beta ratio plate resulted in values similar to baseline as shown previously in figure 31 for this piping configuration and flow conditioner location. The discharge coefficients at the 6 and 12 o'clock positions indicated a slight downward shift; however, all points are within the scatter shown in figure 31. No dependence on tap location was observed for these specific tests.

The discharge coefficients for the 0.73 beta ratio plate with the flow conditioner installed showed a tap location dependency. The discharge coefficients were near baseline values at the 9 and 6 o'clock tap locations as previously seen with this configuration in figure 34. The discharge coefficients at the 3 and 12 o'clock positions, however, were below baseline. At a pipe Reynolds number of 1.1×10^6, the difference between the discharge coefficients at the 3 and the 9 o'clock positions was about 0.75% (figure 40). The disparity between discharge coefficients at the various tap locations for the 0.73 beta ratio plate seemed as great when the flow conditioner was installed as when it was not. Because of the apparent influence of tap location on discharge coefficient for the 0.73 beta ratio plate, determination of the discharge coefficient at the 3 o'clock position was added to the test plan for subsequent research work.

Other Tube Bundle Flow Conditioners:

Two flanged, 19 tube bundle flow conditioners, one with a hexagonal tube pattern [FT2] and one with a round concentric pattern [FT4] were placed at the outlet of the tee disturbance which was located 17 pipe diameters upstream of the orifice plate. The round pattern conditioner had tubes of larger diameter, thinner walls, and rougher surface finish than those in the flow conditioners referred to previously in this paper.

Data taken with the hexagonal-pattern flow conditioner and the 0.73 beta ratio orifice plate are located in tables 42 and 43 and are plotted in figure 44. Data for the 0.43 beta ratio and the same flow conditioner are in tables 44 and 45 and are displayed in figure 45.

Data obtained when using the round-pattern flow conditioner and the 0.73 and 0.43 beta ratio orifice plates are found in tables 46-49. Data for the 0.73 beta ratio are displayed in figure 46 and those for the 0.43 beta ratio are in figure 47.

Figure 45 indicates that for the 0.43 beta ratio plate the hexagonal-pattern flow conditioner resulted in discharge coefficients similar to baseline values. Figure 47 shows that the discharge coefficients using the round-pattern flow conditioner with the 0.43 beta ratio plate are shifted slightly downward. In both cases, pressure tap location had very little impact on the discharge coefficient.

This is not the case with the 0.73 beta ratio plate. Figure 44 shows that when the hexagonal-pattern flow conditioner was used, the discharge coefficients using the 9 o'clock taps were slightly higher than baseline value, while those using the 3 o'clock taps fell nearly 1.0% lower.

Using the round-pattern flow conditioner yielded similar results. The 9 o'clock tap location yielded slightly higher discharge coefficients than baseline, and the discharge coefficients at the 3 o'clock tap location were lower than baseline and showed more data scatter.

CONCLUSIONS AND RECOMMENDATIONS

Previous work at this facility showed that a tee disturbance upstream of the orifice plate resulted in a larger shift in discharge coefficient than either a single- or double-elbow disturbance at the same location[11]. Additional work is needed to determine whether the same is true for other upstream disturbances such as valves and reducers.

With a tee installed 19 pipe diameters upstream of the orifice plate and the various flow conditioners located 10 to 11 pipe diameters upstream of the orifice plate, discharge coefficients were within -0.5% of the baseline value for all beta ratios tested. The Zanker flow conditioner produced somewhat better results than the others; discharge coefficients were within -0.2% of baseline values for all beta ratios.

Should these results prompt additional interest in the Zanker flow conditioner, future research could include several possibilities. The Zanker flow conditioner could be tested in other line sizes and at different locations relative to the orifice plate. Because the velocity profile downstream of the Zanker flow conditioner is quite distinctive from those downstream of other flow conditioners, pressure tap location tests should also be included.

The tee was installed 17 pipe diameters upstream of the orifice plate, and comparative data were taken with a flanged, 19 tube bundle [FT1] and an in-line, 19 tube bundle flow conditioner [IT1] placed directly downstream of the tee. The discharge coefficients with the flanged tube bundle flow conditioner were higher than baseline except when the 0.55 beta ratio plate was used. The largest shift in coefficient, +0.25%, occurred when the 0.67 beta ratio plate was used. When the in-line flow conditioner was used, all discharge coefficients were at or slightly below baseline value. The largest error, -0.2%, occurred when the 0.55 beta ratio plate was used. Figures 30 and 35 would indicate that the in-line flow conditioner performed slightly better in this test configuration.

Discharge coefficients were computed using the pressure differential across the flange taps at 3, 6, 9, and 12 o'clock for the 0.43 and 0.73 beta ratio orifice plates. These tests were conducted with the tee located 17 pipe diameters upstream of the orifice plate, with no flow conditioner and with an in-line tube bundle flow conditioner placed directly downstream of the tee. When the 0.43 beta ratio plate was used, the computed discharge coefficient showed no dependence upon pressure tap location. When the 0.73 beta ratio plate was used, there was a dependence on pressure tap location both with and without a flow conditioner (figures 40, 41, 44, 46).

The results for various types of flanged, 19 tube bundle flow conditioners were beta ratio dependent. When the 0.43 beta ratio plate was used, installing the hexagonal-pattern flow conditioner [FT2] at the outlet of the tee resulted in discharge coefficients similar to baseline values. When the round-pattern tube bundle, with larger rougher tubes [FT4], was placed at the tee outlet, the computed discharge coefficient showed a -0.3% shift from baseline. Because of the obvious dependence of pressure tap location when using the 0.73 beta ratio plate, it is difficult to determine the performance characteristics of these flow conditioners when this orifice plate is used. If we consider the discharge coefficients at the 9 o'clock tap location, the flow conditioners performed comparably.

The results from the pressure tap location study, including the flow conditioner comparison work, were very compelling. Future work should include additional measurement of pressure tap location effects when the system is in a baseline piping configuration (figures 5a, 5b, 5c), particularly with larger beta ratio orifice plates. It would also be interesting to examine the relationship between flow conditioner position and tap location.

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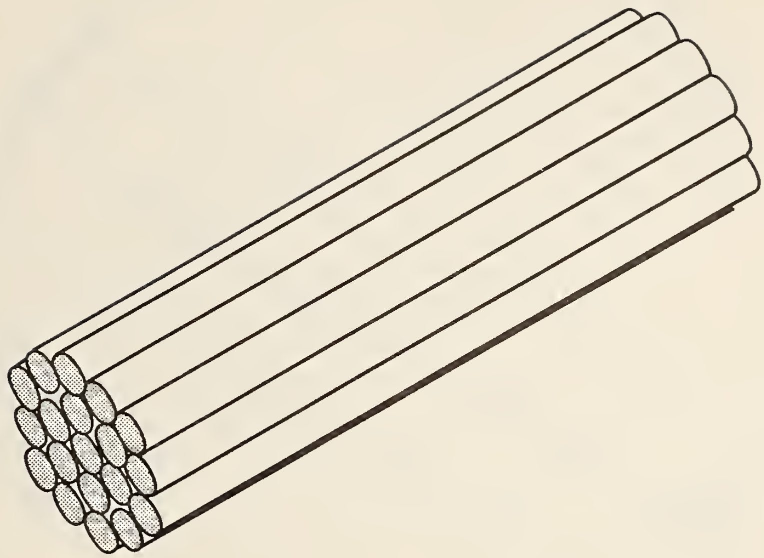

Figure 1. In-line, tube bundle flow conditioner.

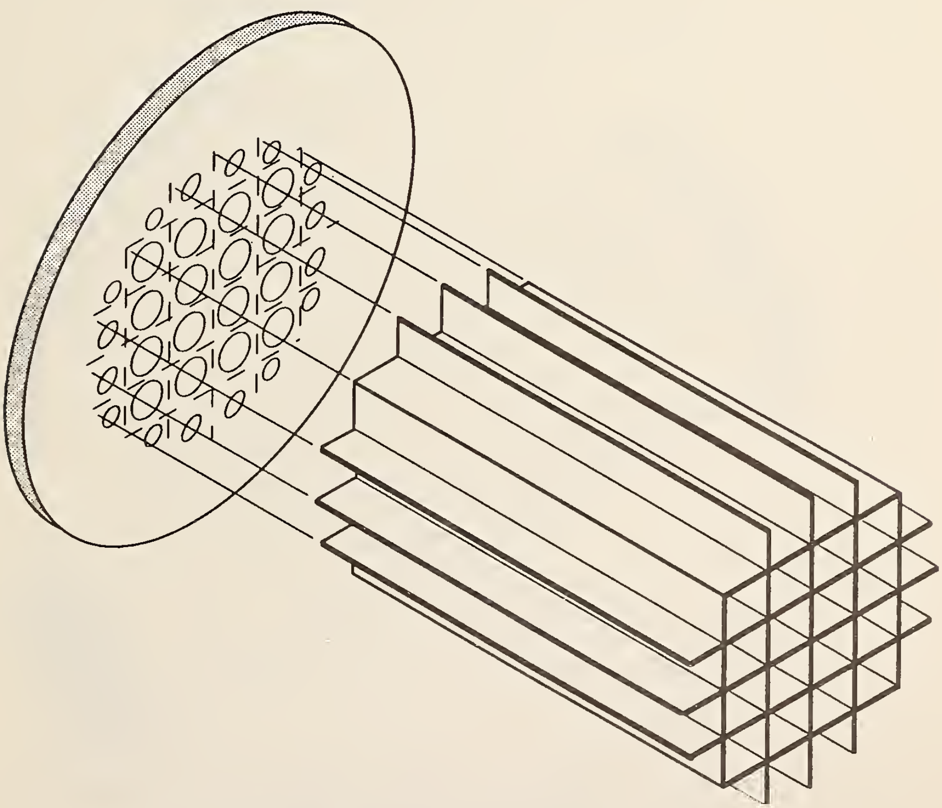

Figure 2a. Zanker flow conditioner.

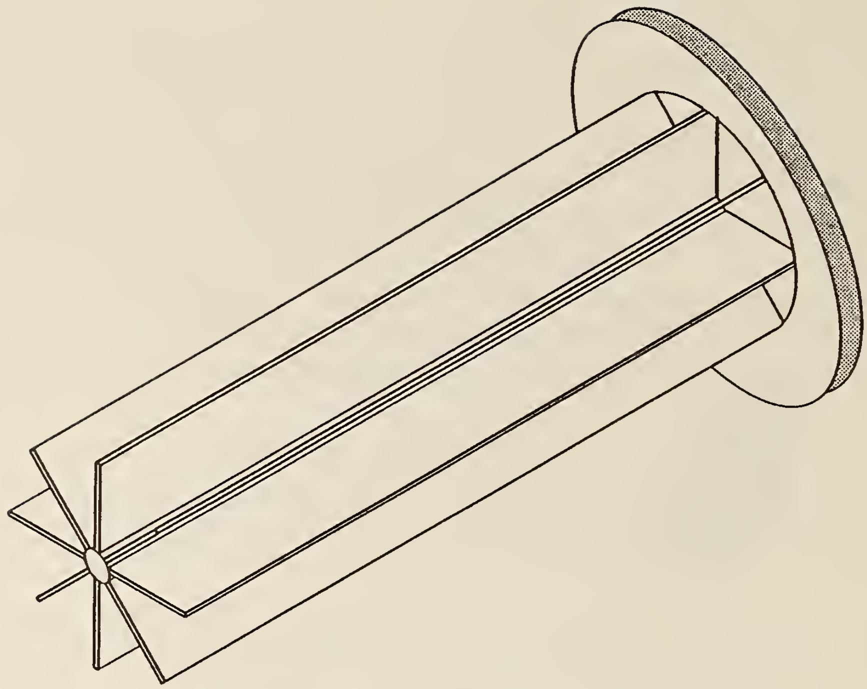

Figure 2b. Etoile flow conditioner.

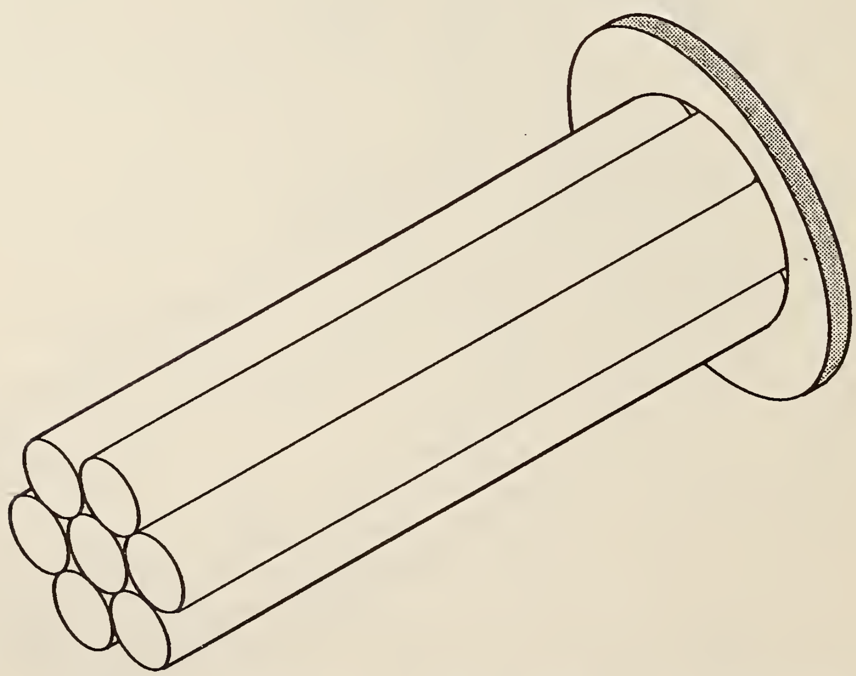

Figure 2c. Flanged, 7 tube bundle flow conditioner.

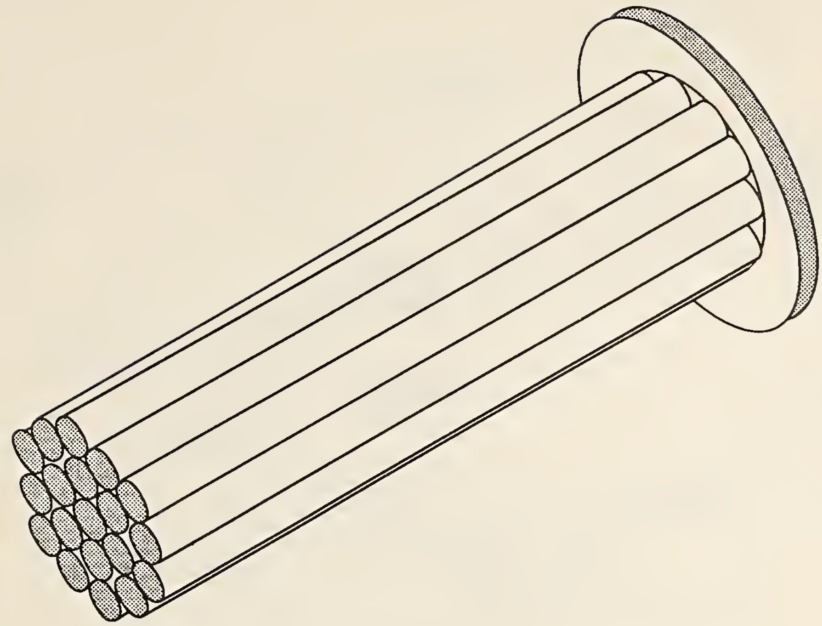

Figure 2d. Flanged, 19 tube bundle flow conditioner (round).

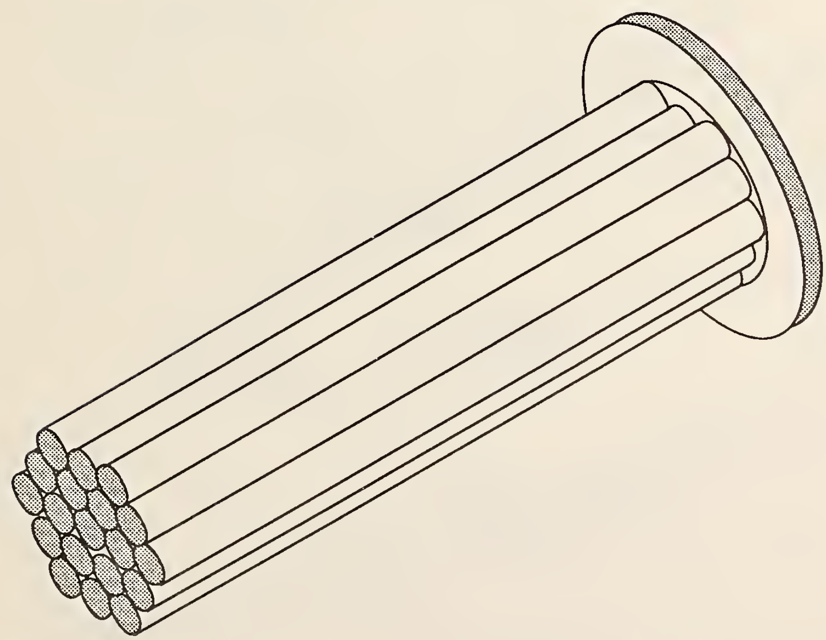

Figure 2e. Flanged, 19 tube bundle flow conditioner (hexagonal).

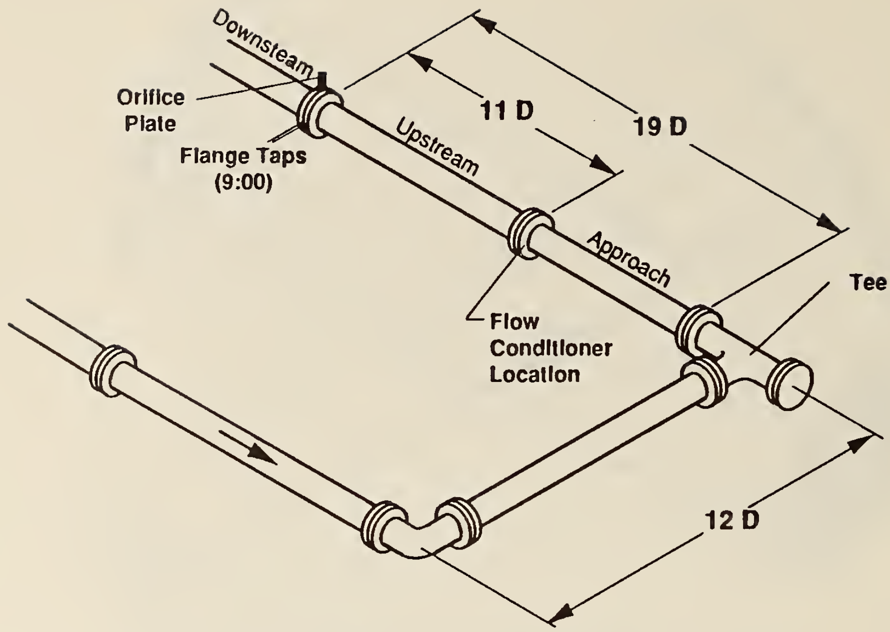

Figure 3. Test configuration with a tee 19 pipe diameters upstream of the orifice plate.

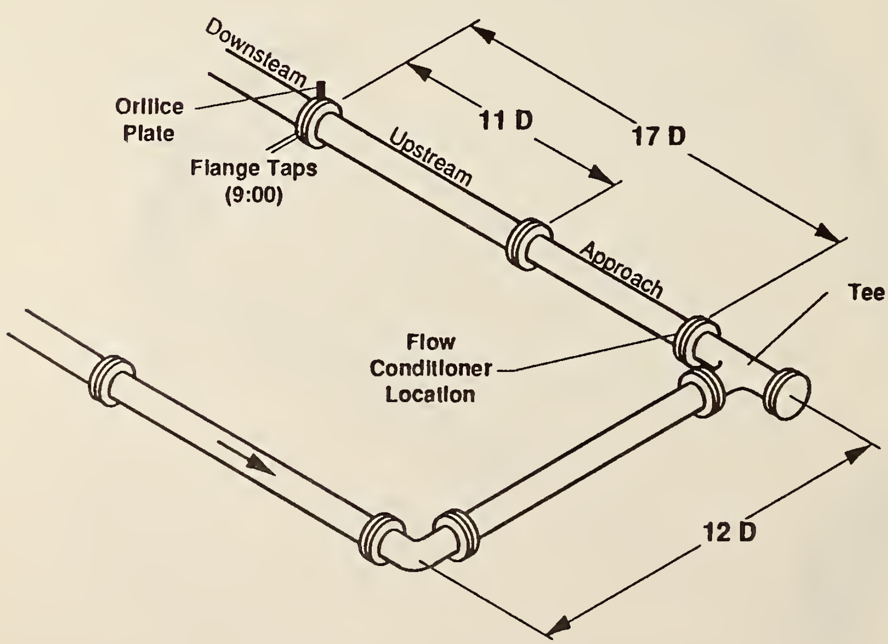

Figure 4. Test configuration with a tee 17 pipe diameters upstream of the orifice plate.

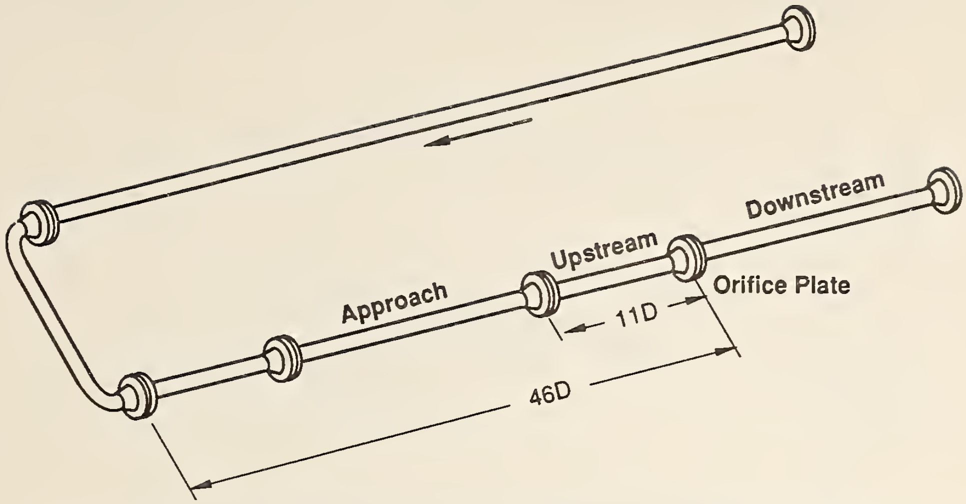

Figure 5a. Four-inch orifice meter, 56 pipe diameters of straight pipe.

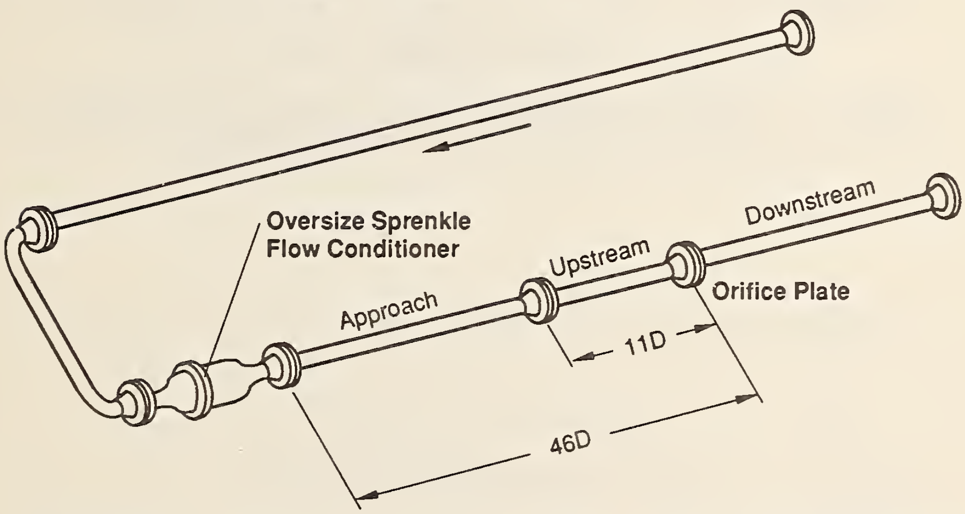

Figure 5b. Four-inch orifice meter, 6-inch Sprenkle at 46 pipe diameters.

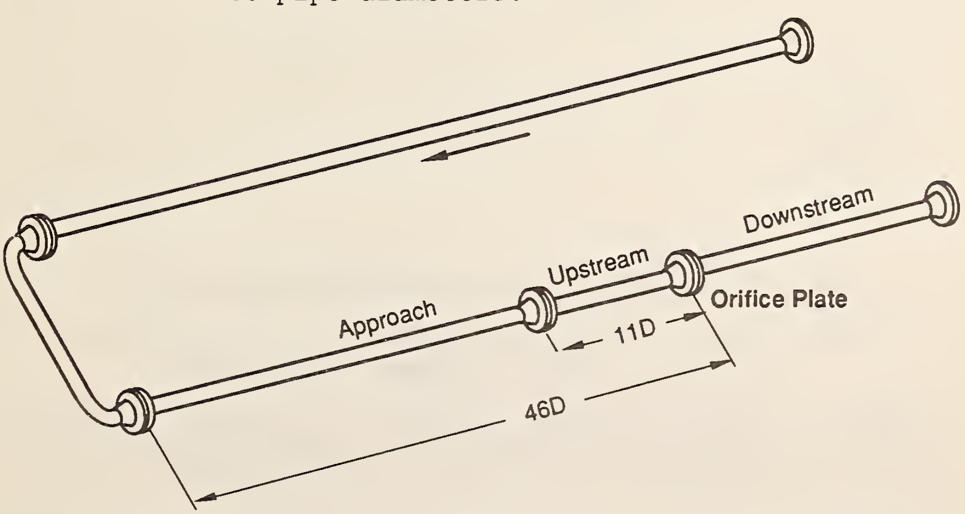

Figure 5c. Four-inch orifice meter, 46 pipe diameters of straight pipe.

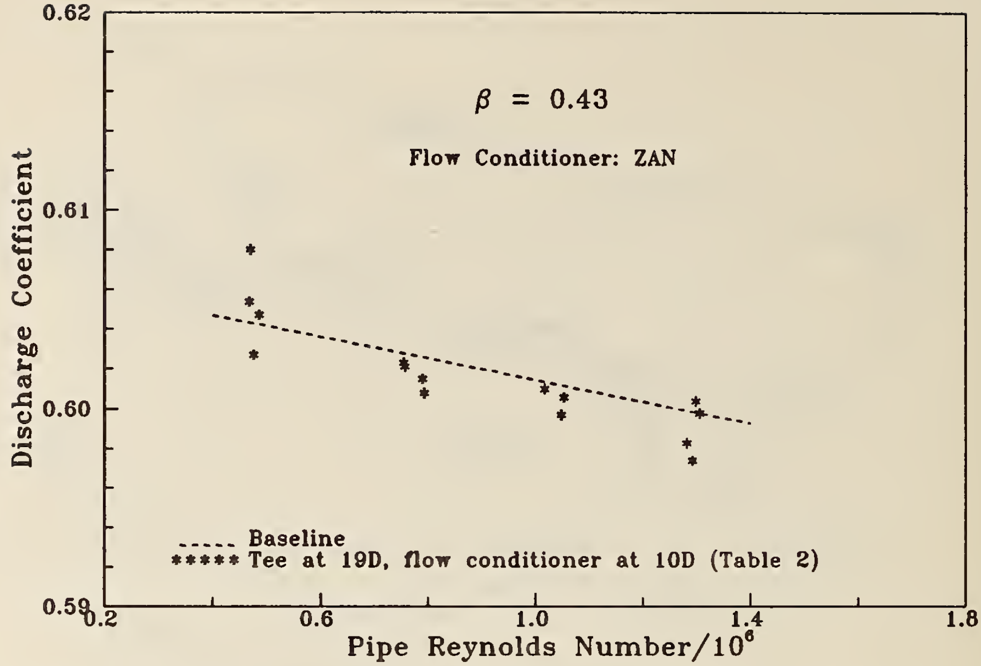

Figure 6. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 19D and a Zanker flow conditioner at 10D.

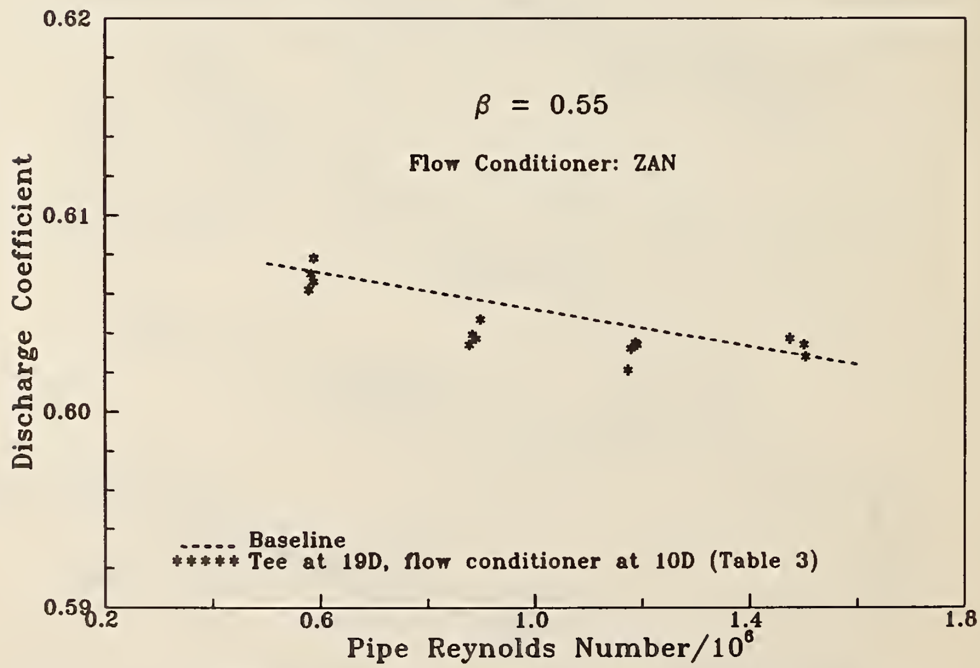

Figure 7. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio plate with a tee at 19D and a Zanker flow conditioner at 10D.

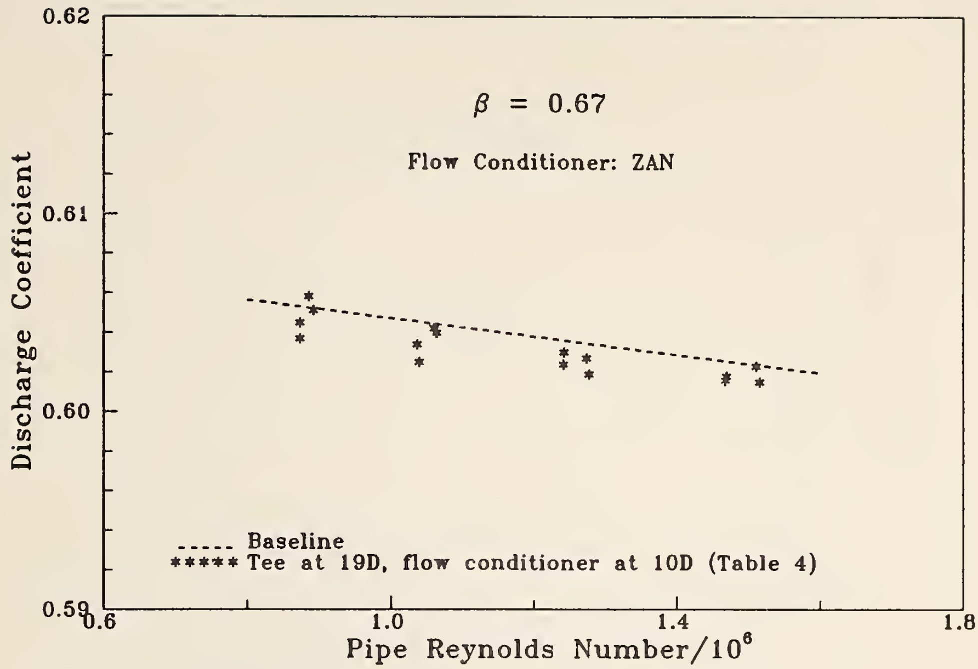

Figure 8. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio plate with a tee at 19D and a Zanker flow conditioner at 10D.

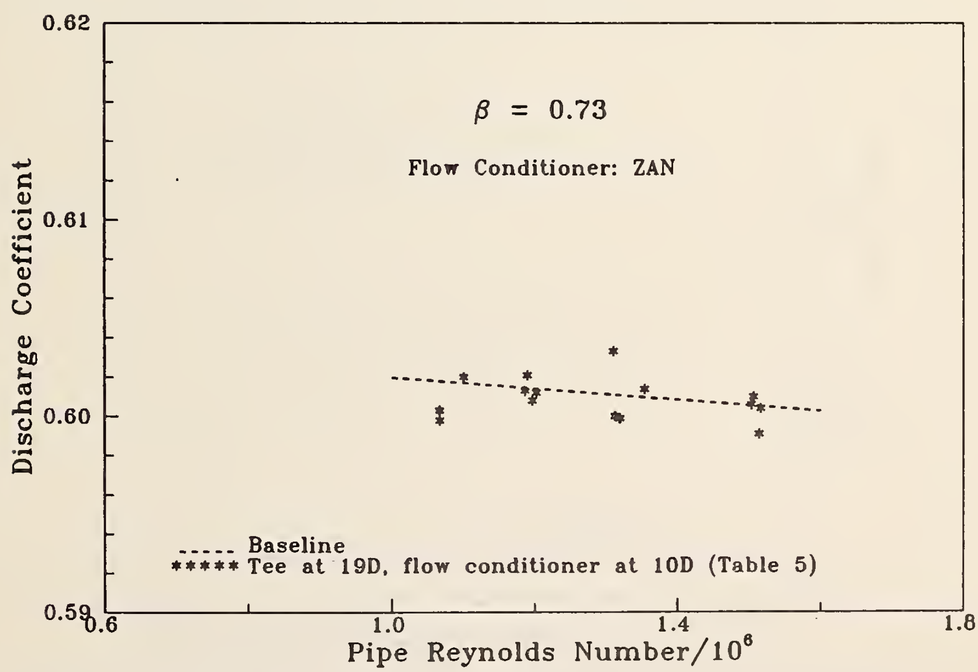

Figure 9. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 19D and a Zanker flow conditioner at 10D.

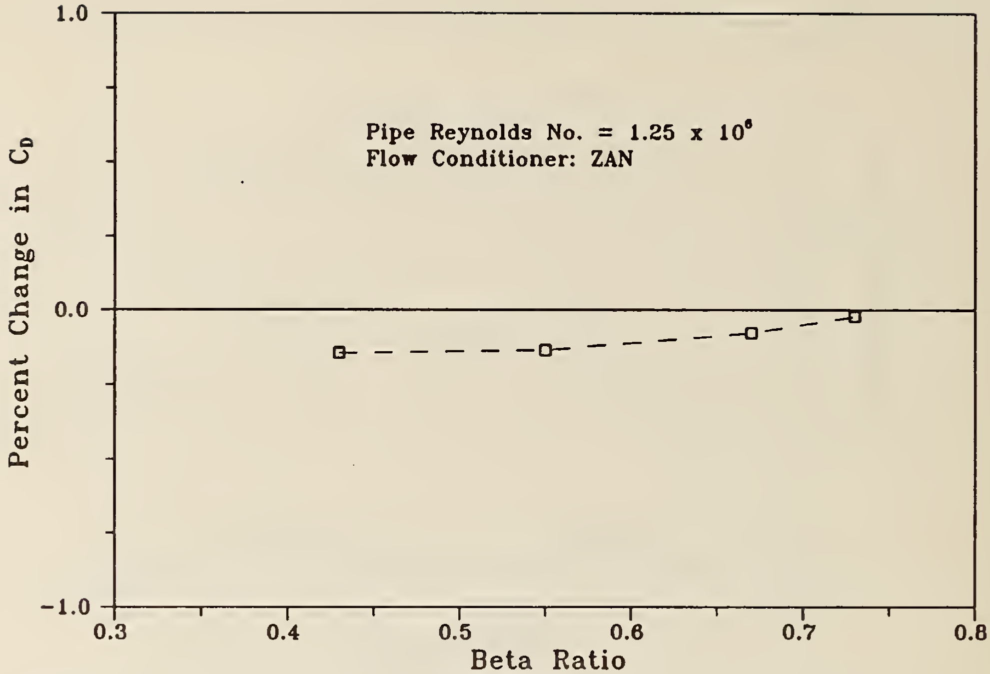

Figure 10. Percent change in discharge coefficient vs. beta ratio with a Zanker flow conditioner at 10D and a tee at 19D.

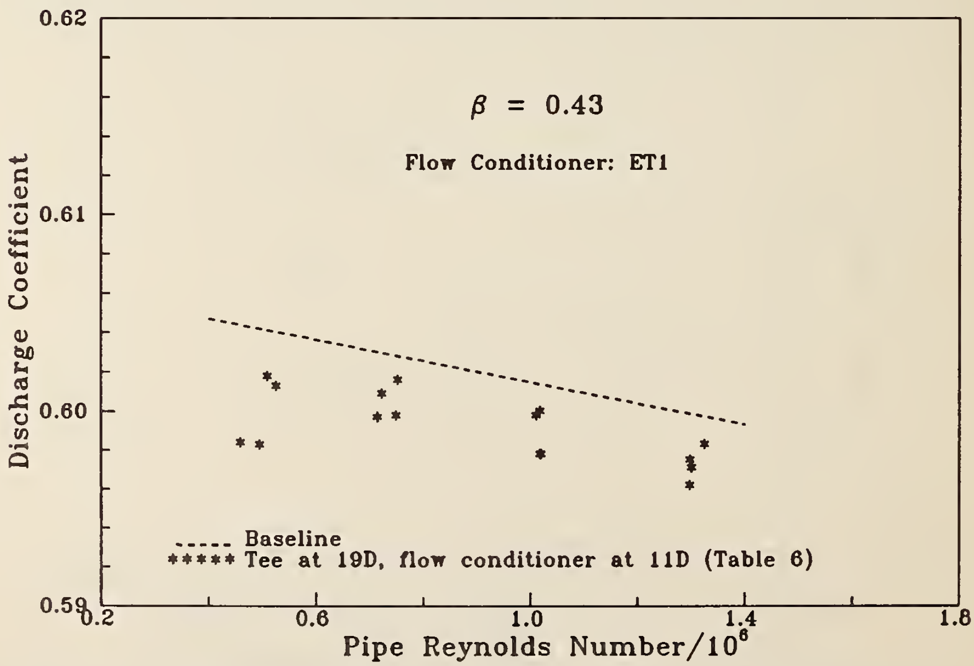

Figure 11. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 19D and an etoile flow conditioner at 11D.

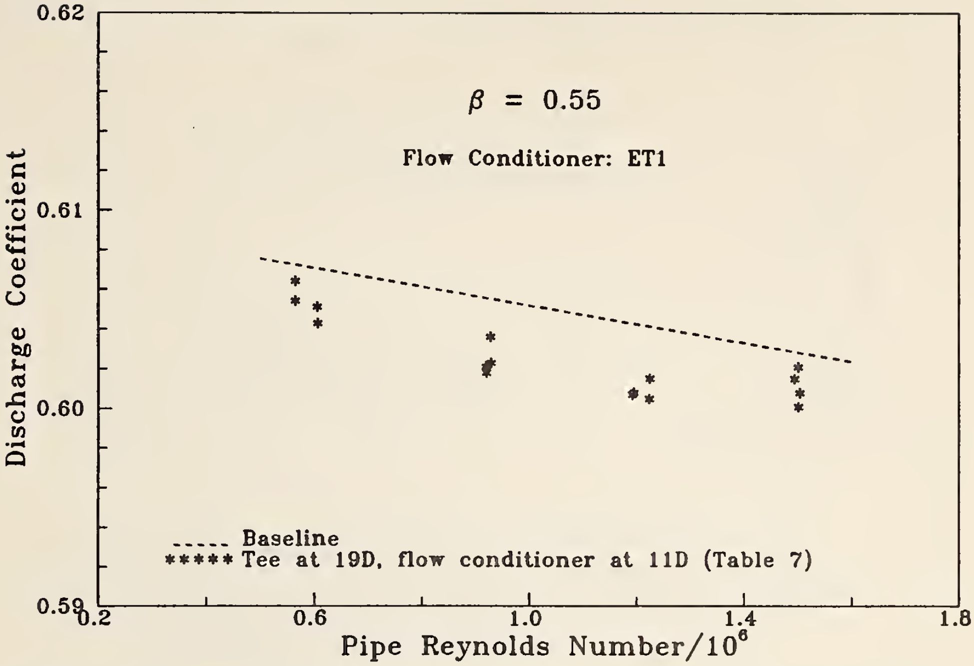

Figure 12. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio plate with a tee at 19D and an etoile flow conditioner at 11D.

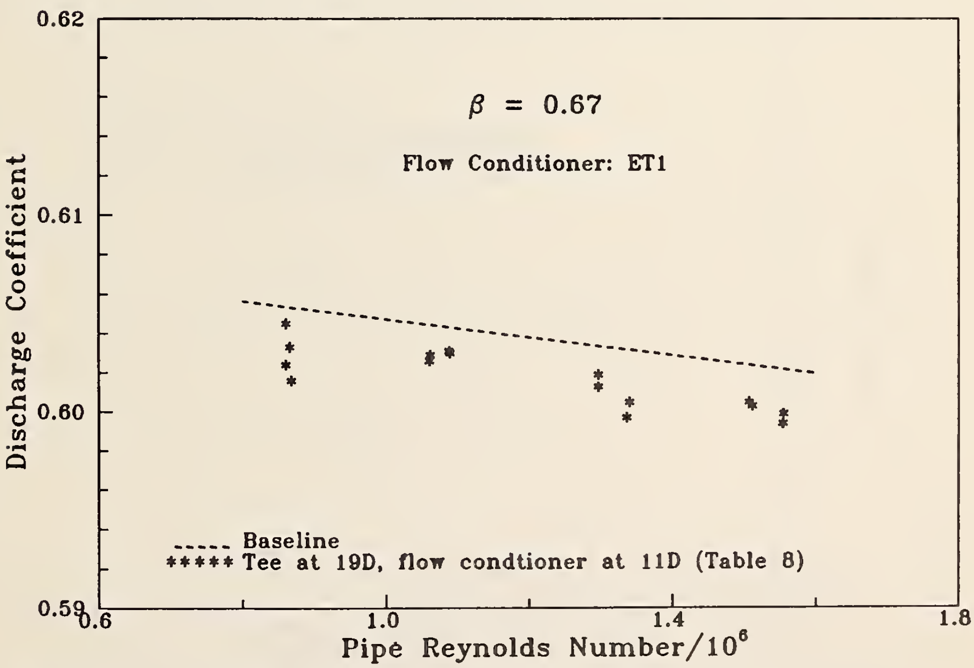

Figure 13. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio plate with a tee at 19D and an etoile flow conditioner at 11D.

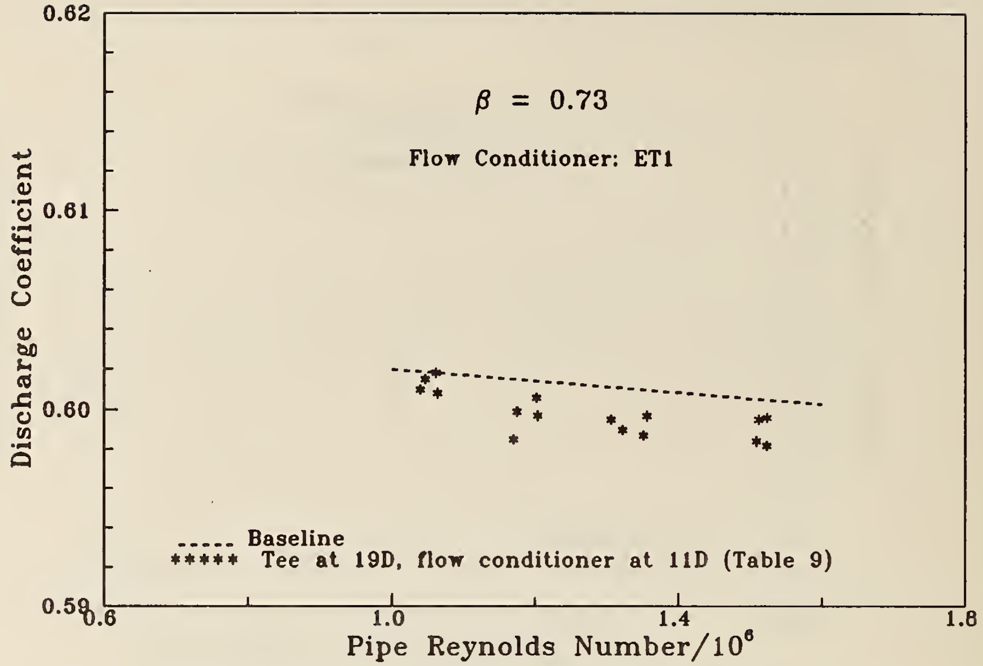

Figure 14. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 19D and an etoile flow conditioner at 11D.

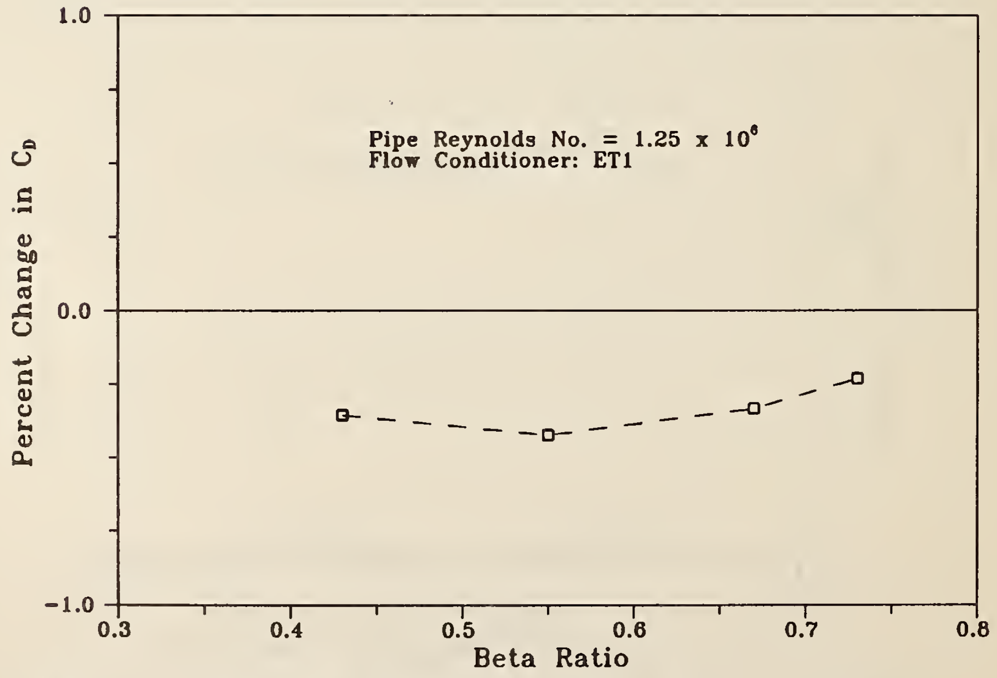

Figure 15. Percent change in discharge coefficient vs. beta ratio with an etoile flow conditioner at 11D and a tee at 19D.

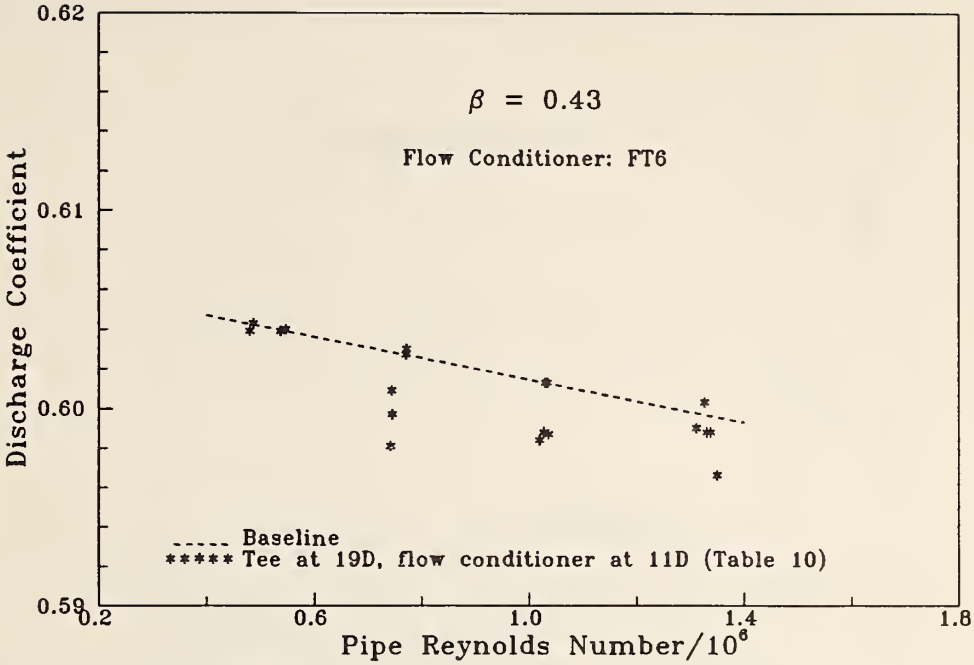

Figure 16. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 19D and a flanged, 7 tube bundle flow conditioner at 11D.

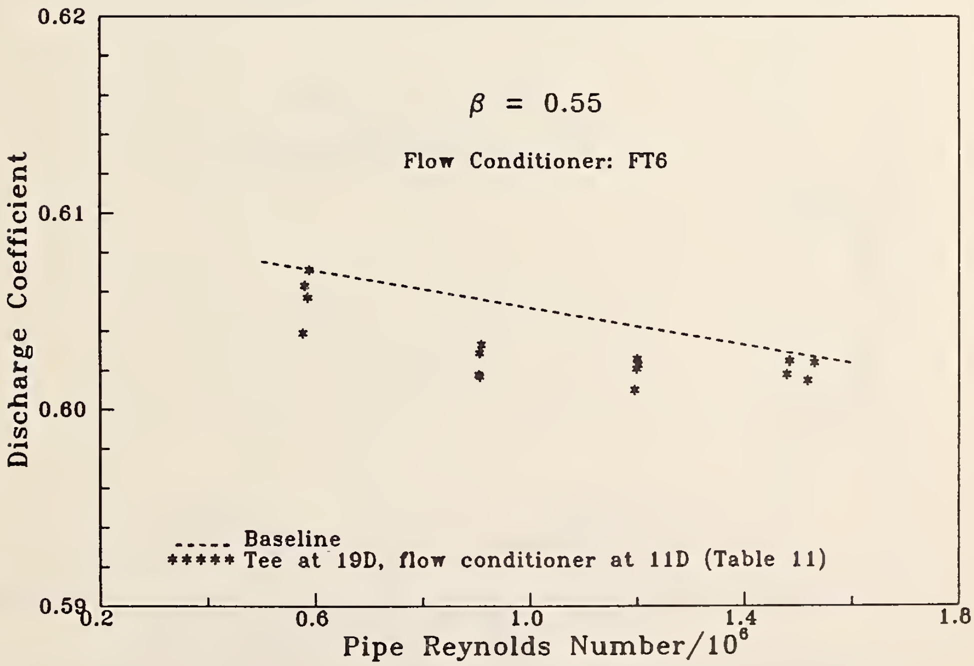

Figure 17. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio plate with a tee at 19D and a flanged, 7 tube bundle flow conditioner at 11D.

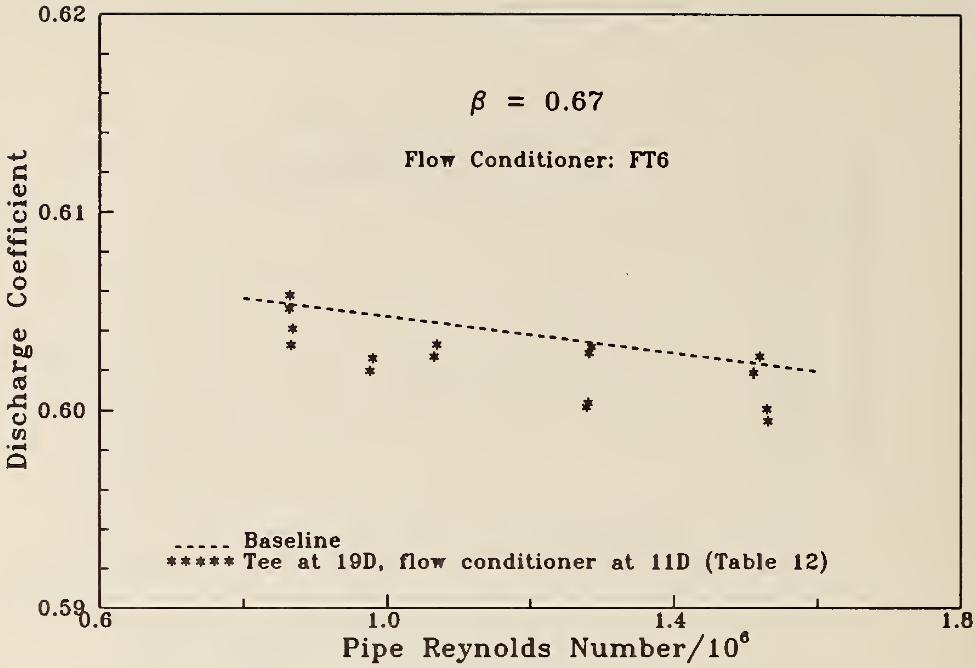

Figure 18. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio plate with a tee at 19D and a flanged, 7 tube bundle flow conditioner at 11D.

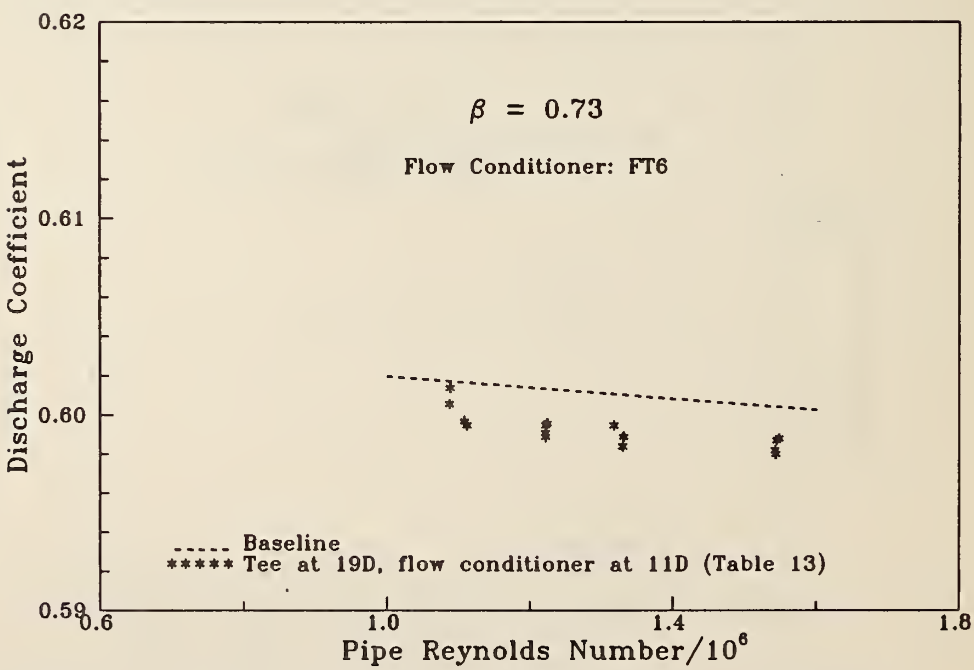

Figure 19. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 19D and a flanged, 7 tube bundle flow conditioner at 11D.

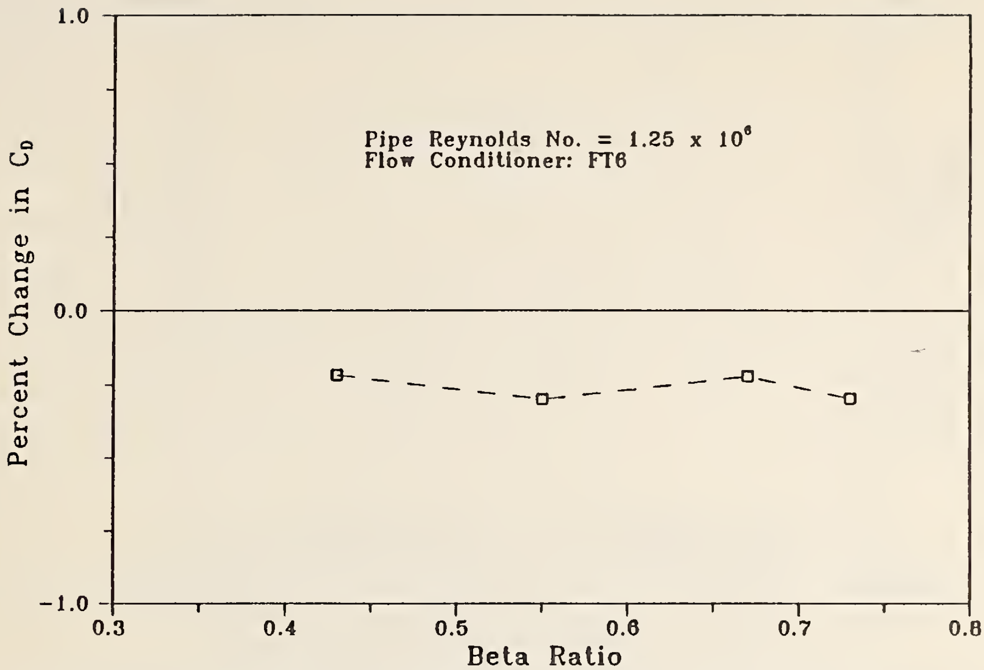

Figure 20. Percent change in discharge coefficient vs. beta ratio with a flanged, 7 tube flow conditioner at 11D and a tee at 19D.

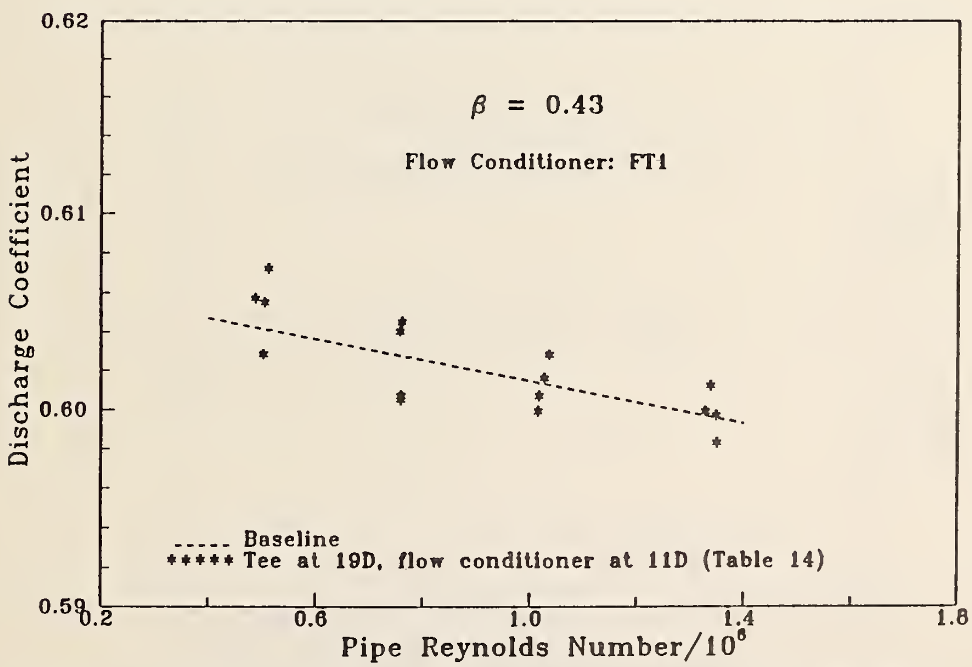

Figure 21. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 19D and a flanged, 19 tube bundle flow conditioner at 11D.

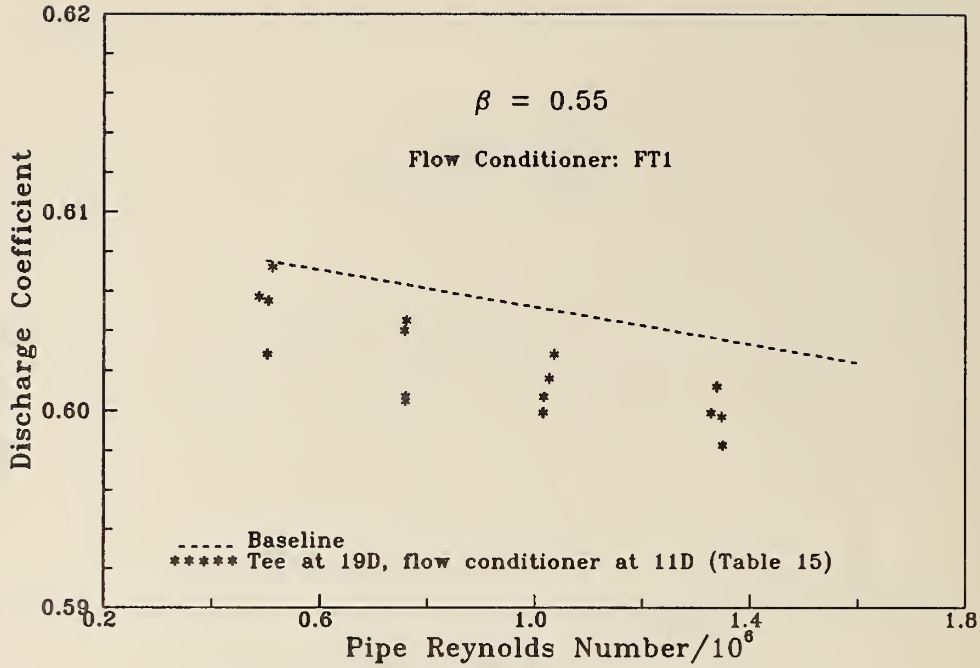

Figure 22. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio plate with a tee at 19D and a flanged, 19 tube bundle flow conditioner at 11D.

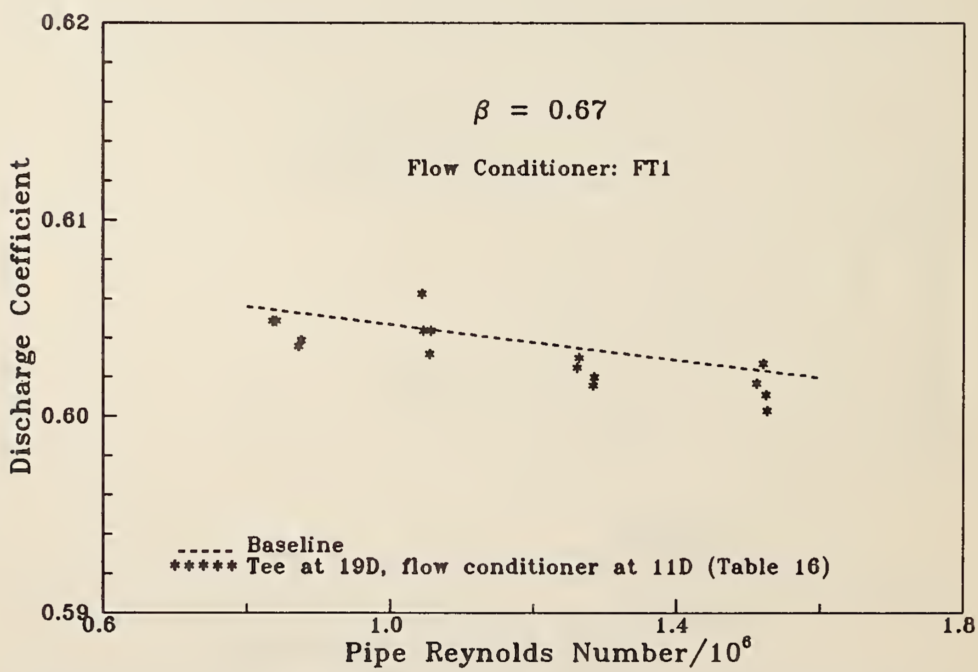

Figure 23. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio plate with a tee at 19D and a flanged, 19 tube bundle flow conditioner at 11D.

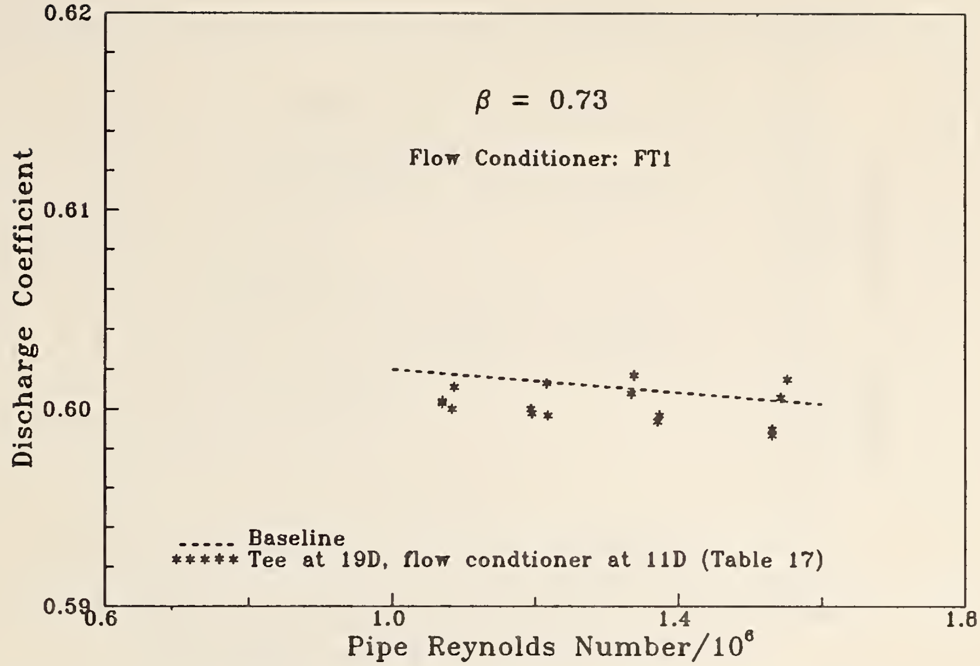

Figure 24. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 19D and a flanged, 19 tube bundle flow conditioner at 11D.

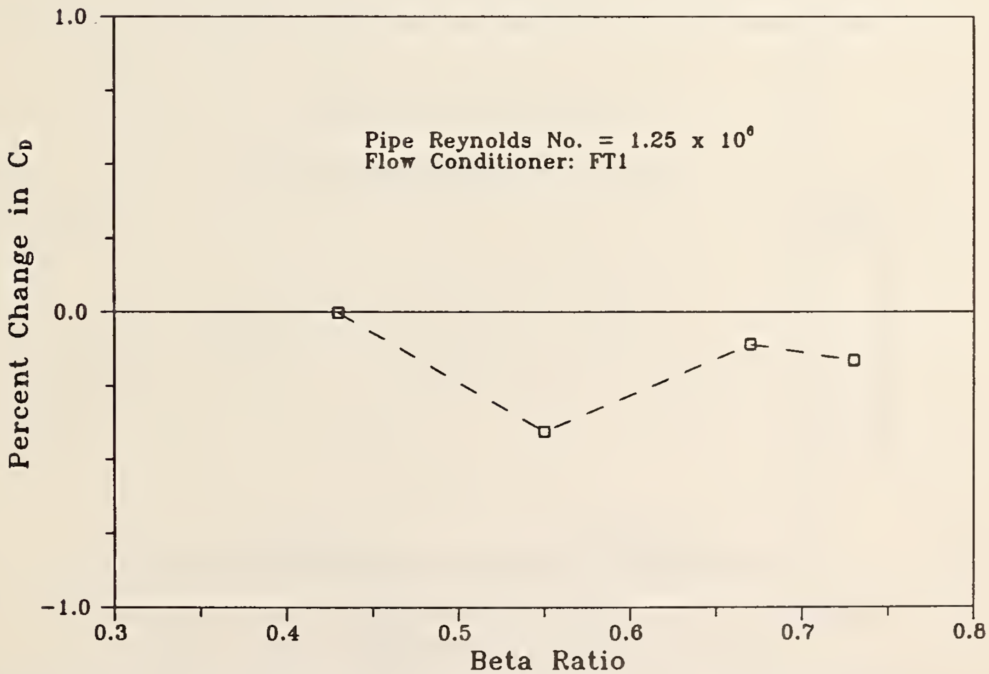

Figure 25. Percent change in discharge coefficient vs. beta ratio with a flanged, 19 tube flow conditioner at 11D and a tee at 19D.

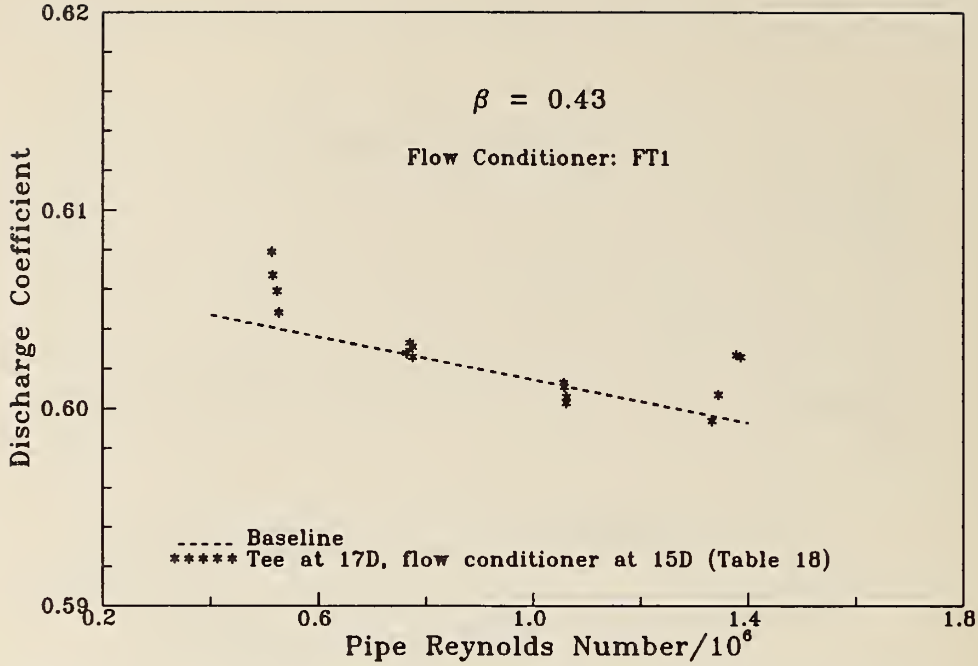

Figure 26. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D and a flanged, 19 tube bundle flow conditioner at the outlet of the tee.

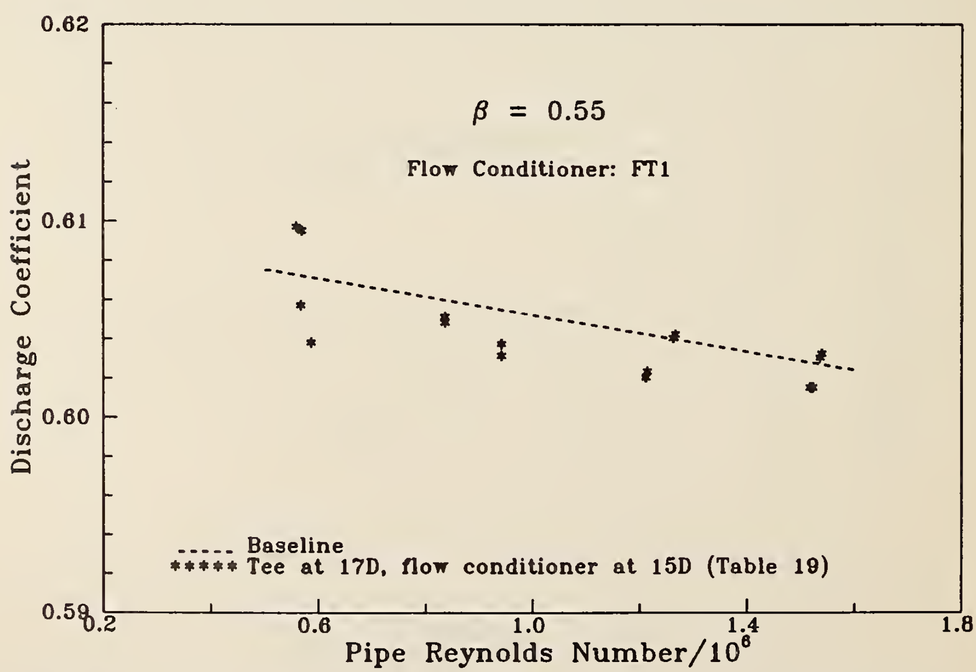

Figure 27. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio plate with a tee at 17D and a flanged, 19 tube bundle flow conditioner at the outlet of the tee.

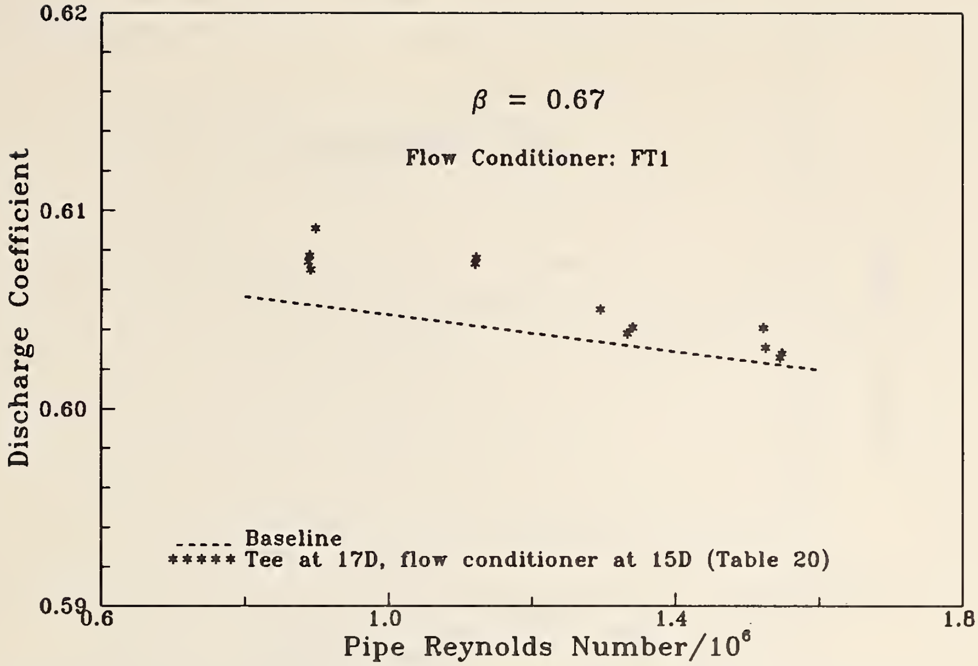

Figure 28. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio plate with a tee at 17D and a flanged, 19 tube bundle flow conditioner at the outlet of the tee.

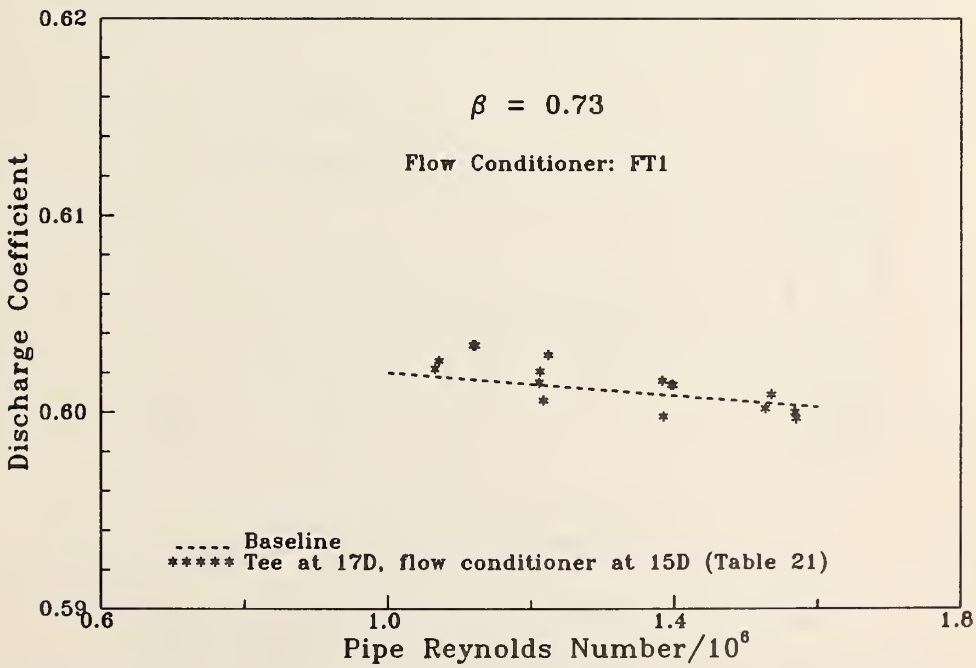

Figure 29. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D and a flanged, 19 tube bundle flow conditioner at the outlet of the tee.

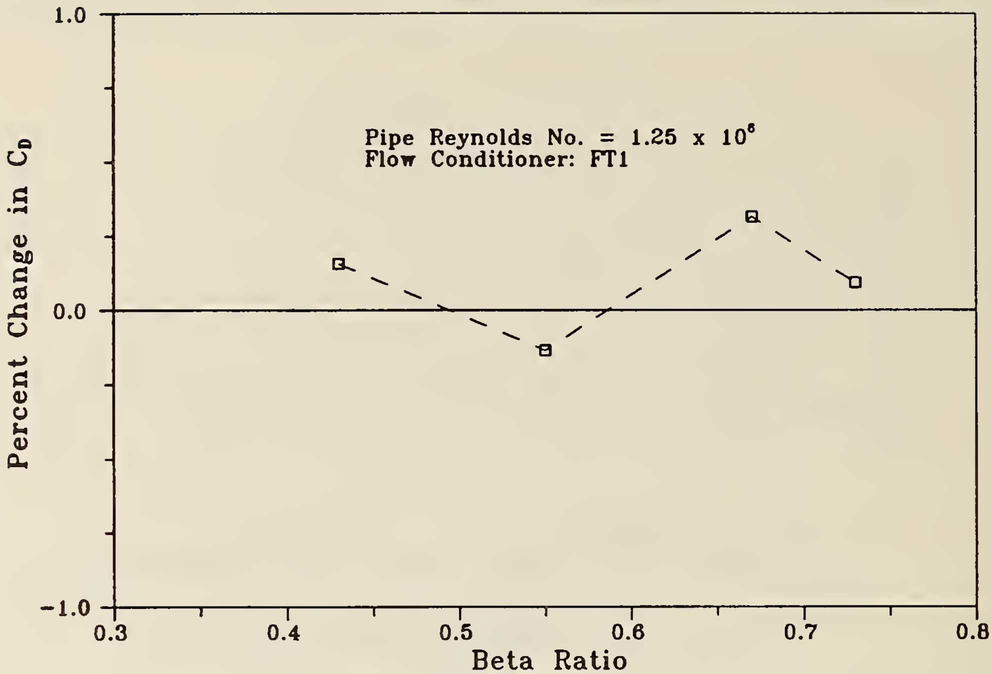

Figure 30. Percent change in discharge coefficient vs. beta ratio with a tee at 17D and a flanged, 19 tube bundle flow conditioner at the outlet of the tee.

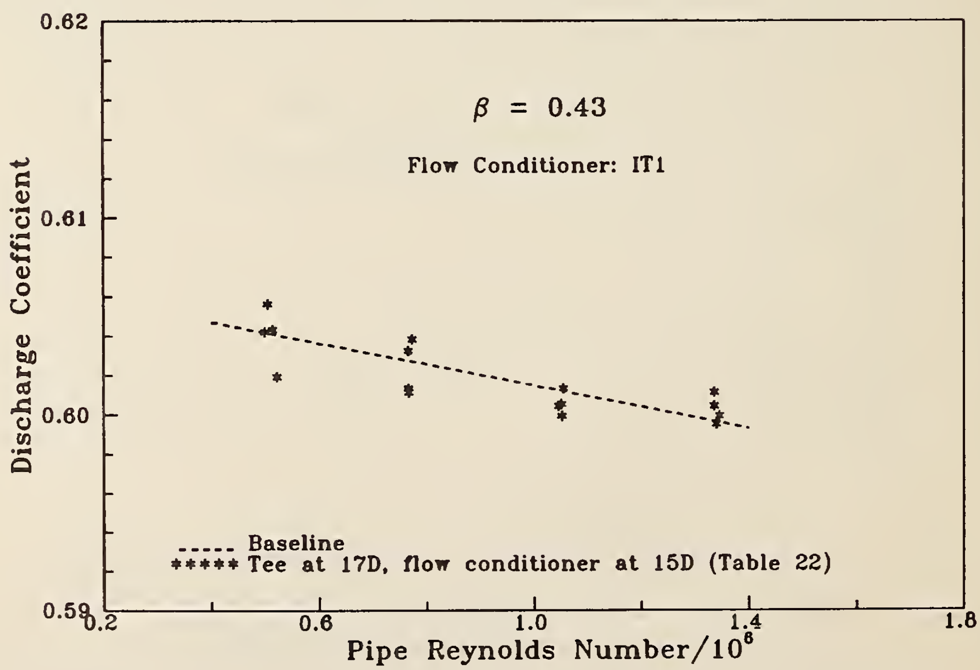

Figure 31. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D and an in-line, 19 tube bundle flow conditioner at the outlet of the tee.

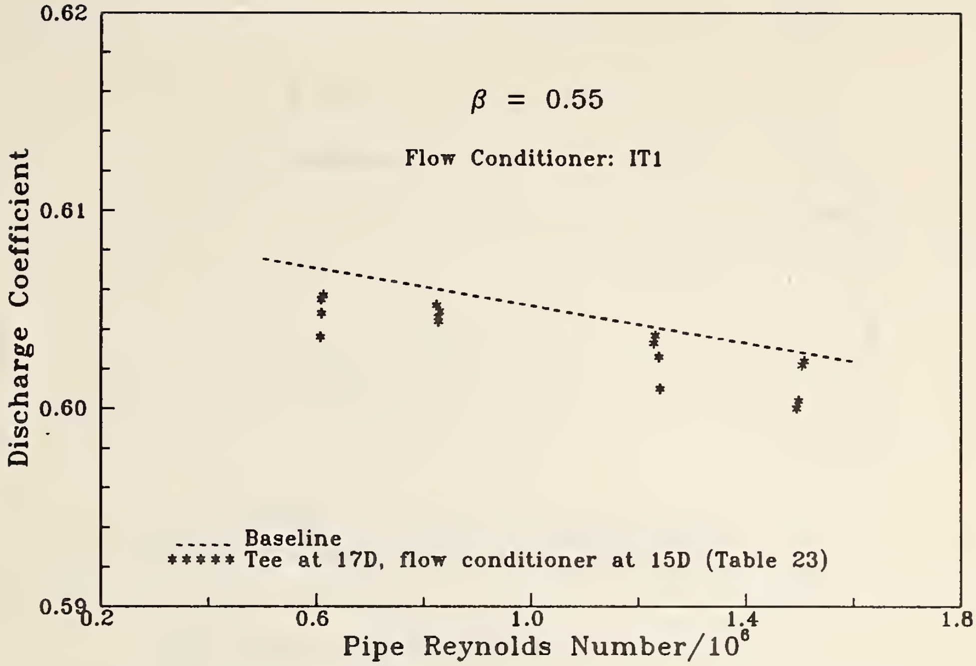

Figure 32. Discharge coefficient vs. Reynolds number for the 0.55 beta ratio plate with a tee at 17D and an in-line, 19 tube bundle flow conditioner at the outlet of the tee.

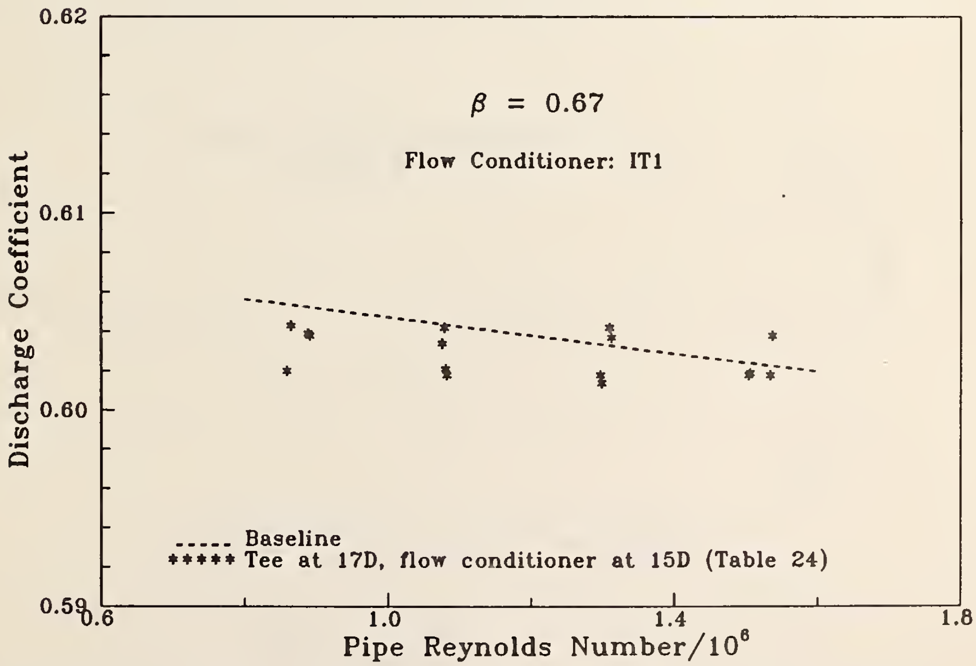

Figure 33. Discharge coefficient vs. Reynolds number for the 0.67 beta ratio plate with a tee at 17D and an in-line, 19 tube bundle flow conditioner at the outlet of the tee.

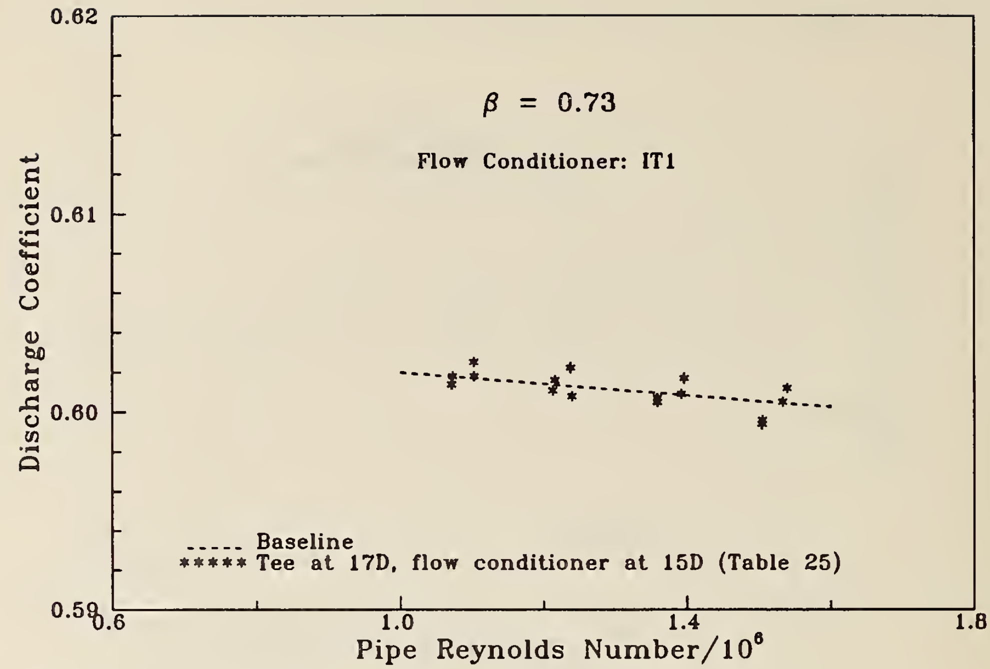

Figure 34. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D and an in-line, 19 tube bundle flow conditioner at the outlet of the tee.

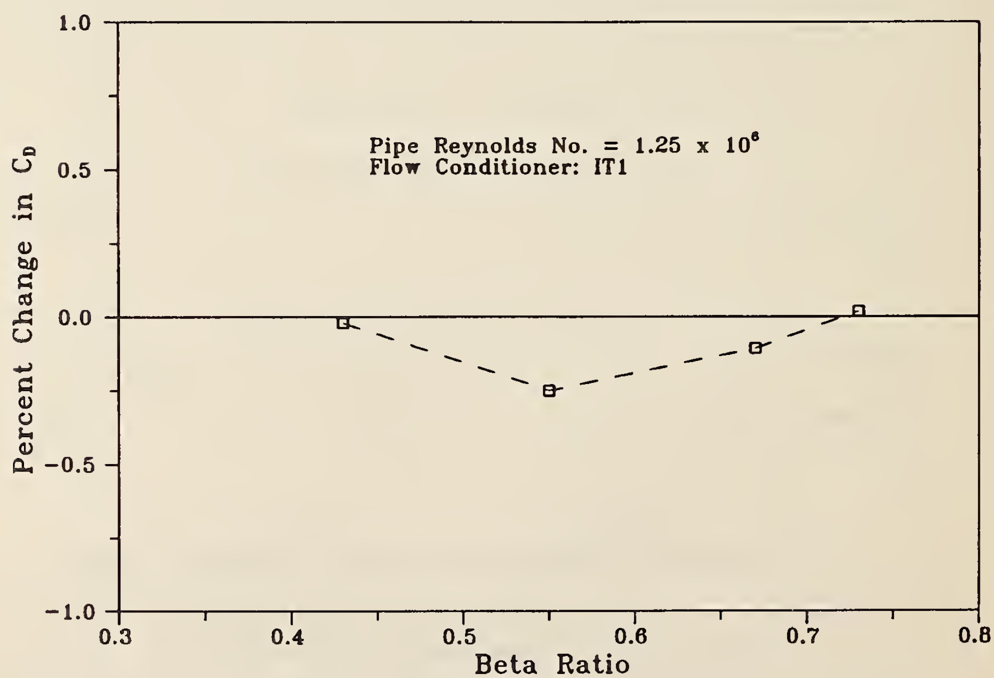

Figure 35. Percent change in discharge coefficient vs. beta ratio with a tee at 17D and an in-line, 19 tube bundle flow conditioner at the outlet of the tee.

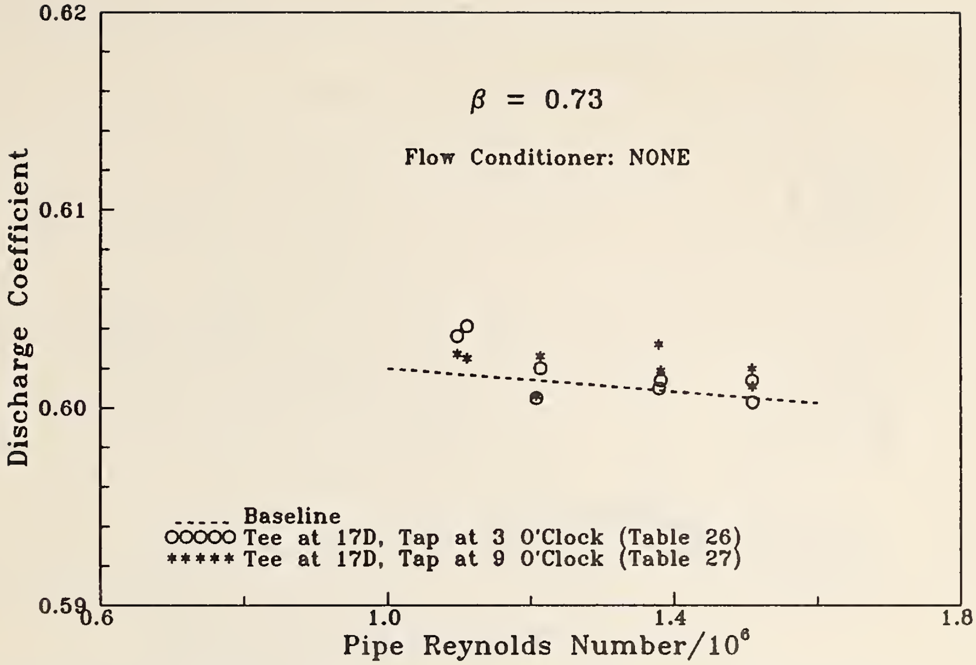

Figure 36. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D, no flow conditioner, and flange pressure taps at 3 and 9 o'clock.

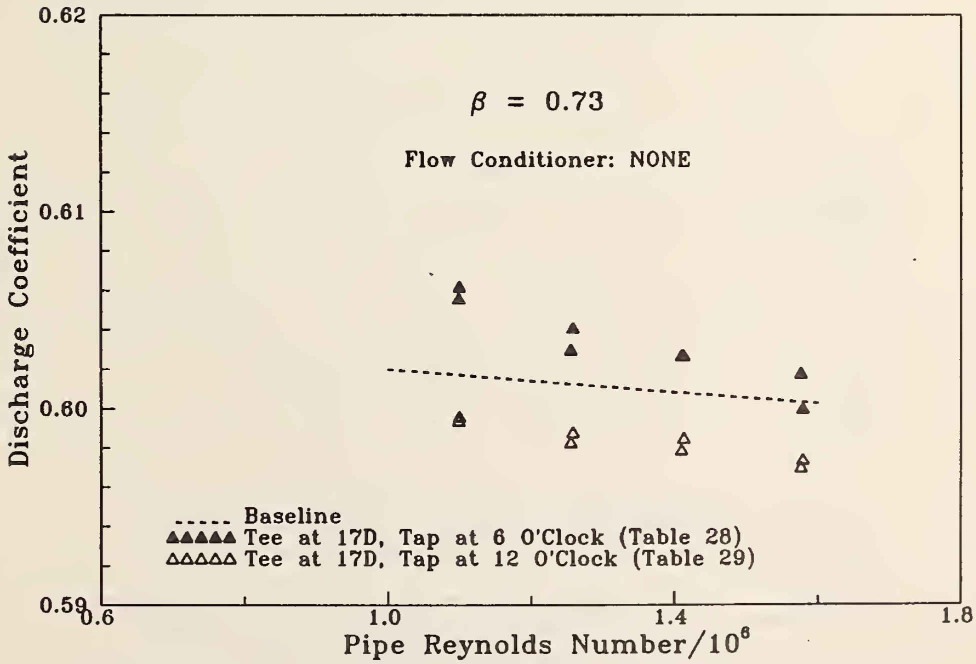

Figure 37. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D, no flow conditioner, and flange pressure taps at 6 and 12 o'clock.

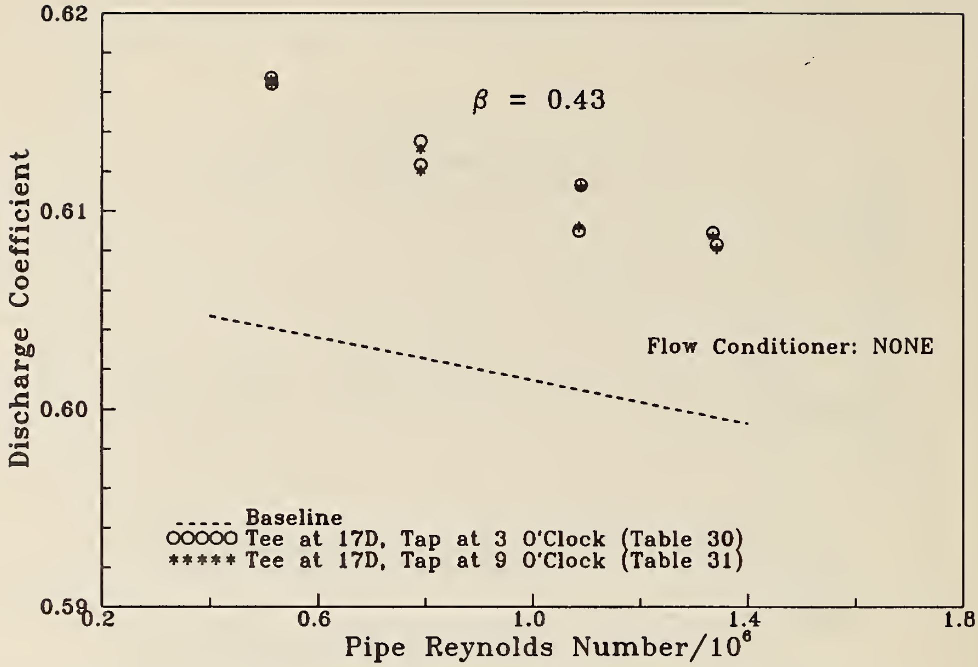

Figure 38. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D, no flow conditioner, and flange pressure taps at 3 and 9 o'clock.

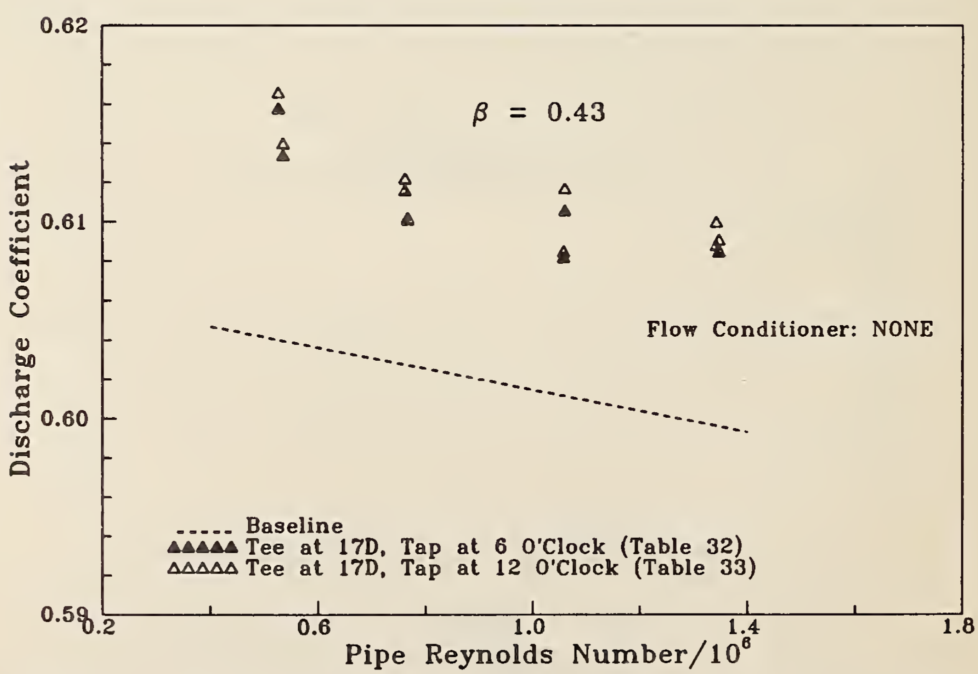

Figure 39. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D, no flow conditioner, and flange pressure taps at 6 and 12 o'clock.

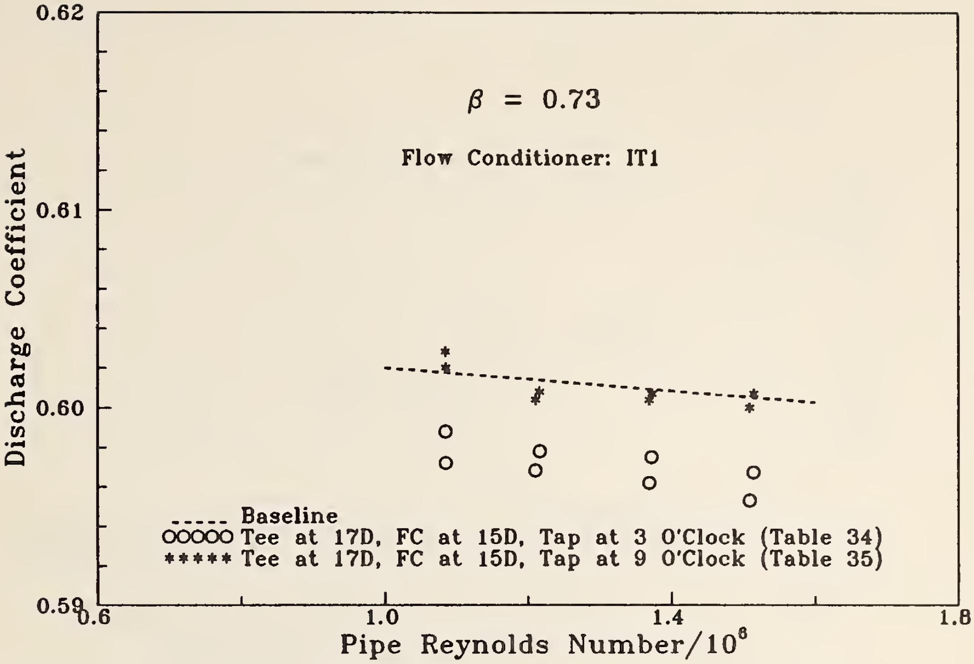

Figure 40. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D, an in-line, 19 tube bundle flow conditioner at the tee outlet, and flange pressure taps at 3 and 9 o'clock.

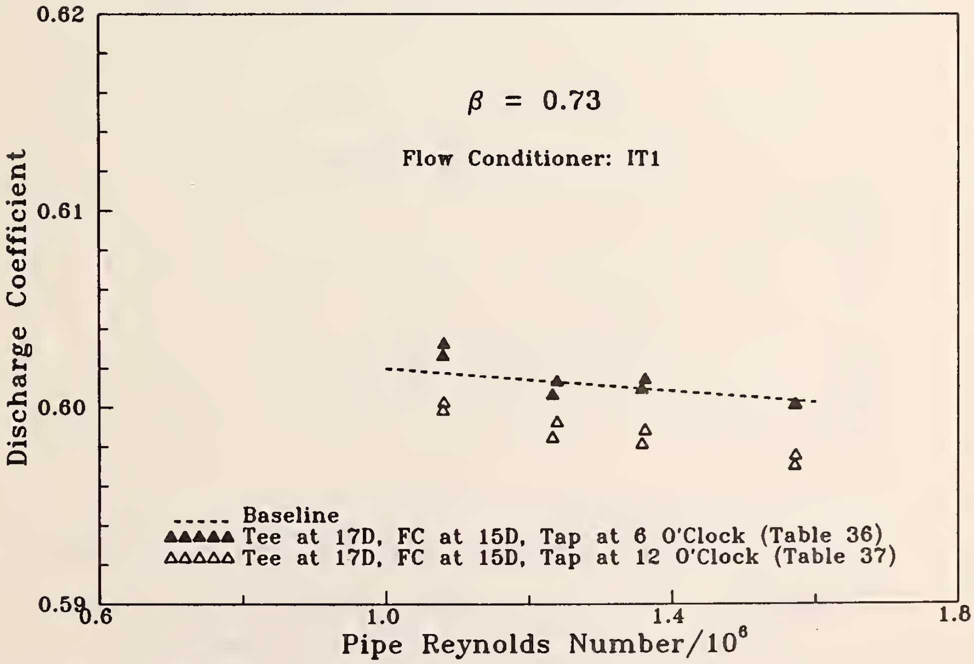

Figure 41. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D, an in-line, 19 tube bundle flow conditioner at the tee outlet, and flange pressure taps at 6 and 12 o'clock.

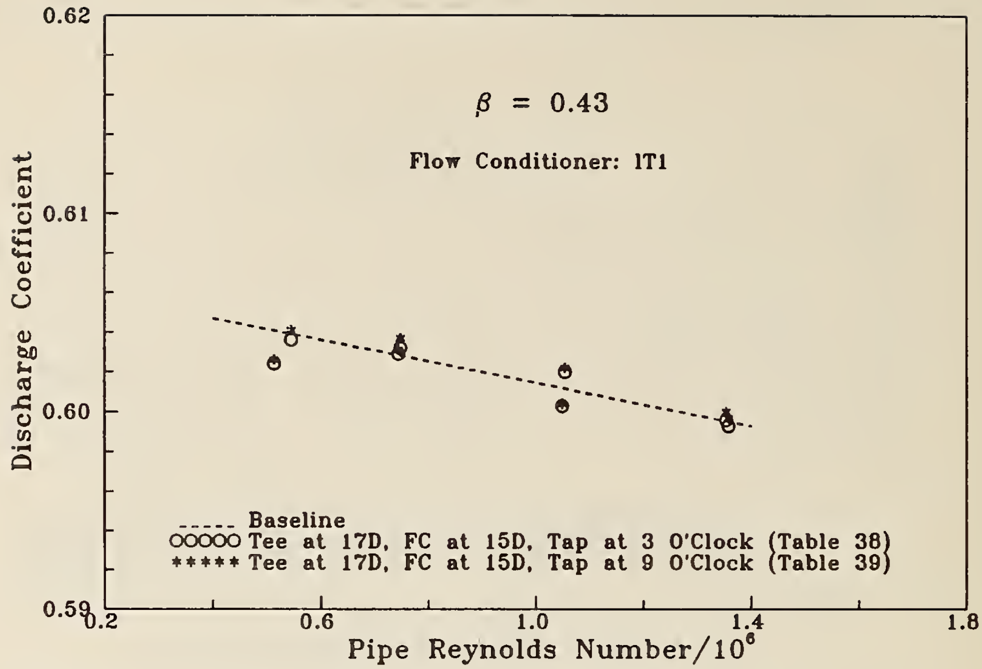

Figure 42. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D, an in-line, 19 tube bundle flow conditioner at the tee outlet, and flange pressure taps at 3 and 9 o'clock.

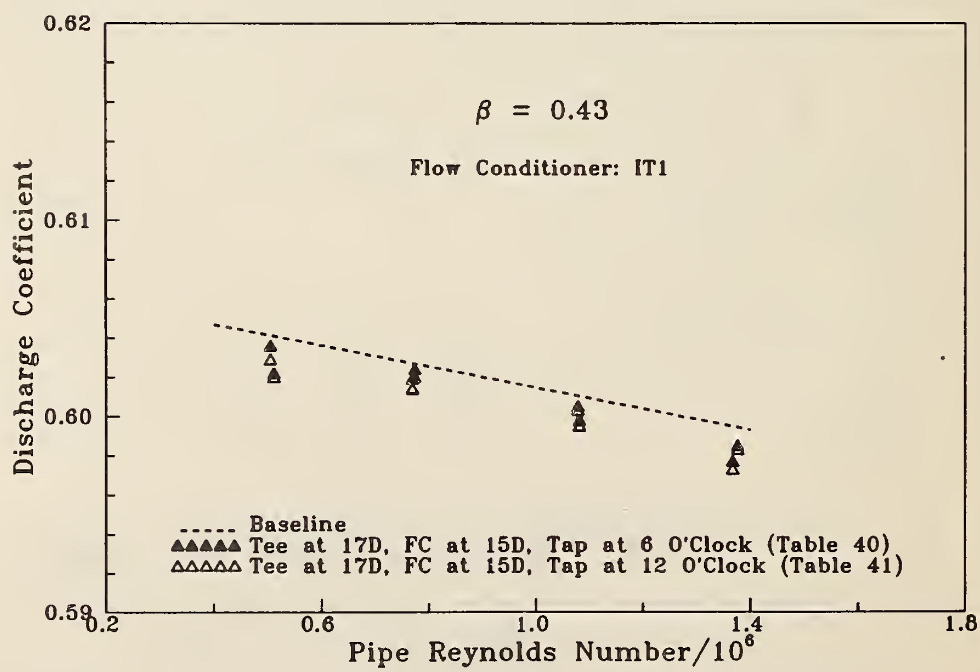

Figure 43. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D, an in-line, 19 tube bundle flow conditioner at the tee outlet, and flange pressure taps at 6 and 12 o'clock.

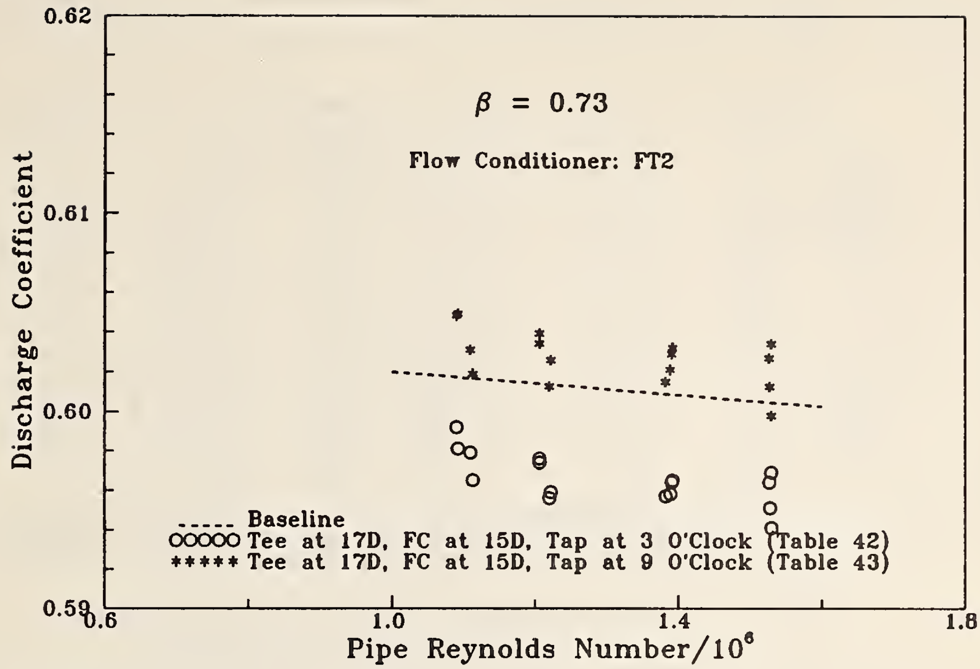

Figure 44. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D, a flanged, 19 tube bundle flow conditioner (hex) at the tee outlet, and flange pressure taps at 3 and 9 o'clock.

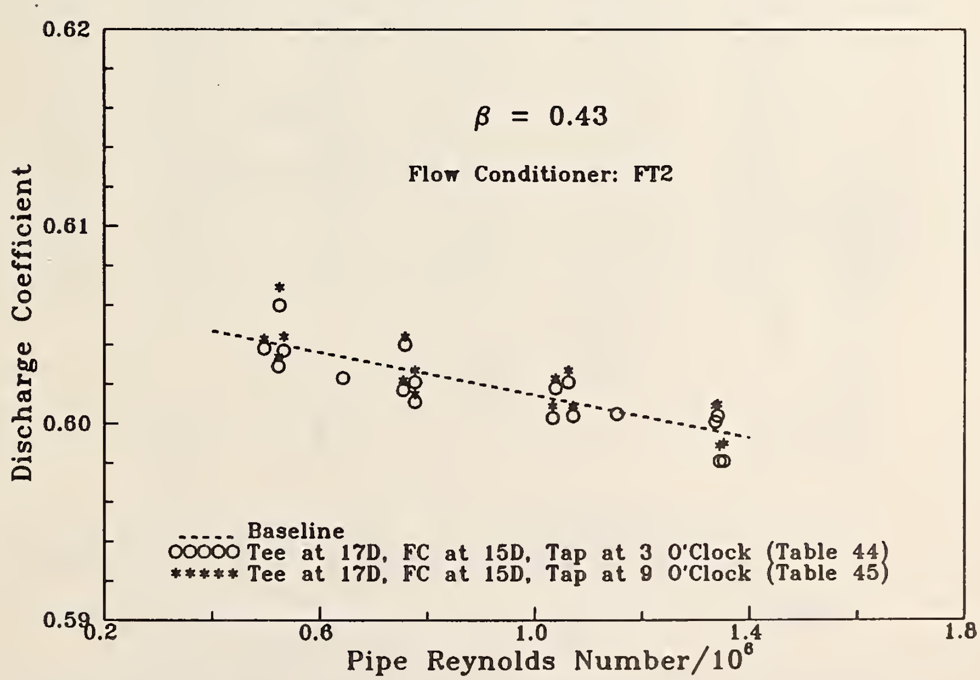

Figure 45. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D, a flanged, 19 tube bundle flow conditioner (hex) at the tee outlet, and flange pressure taps at 3 and 9 o'clock.

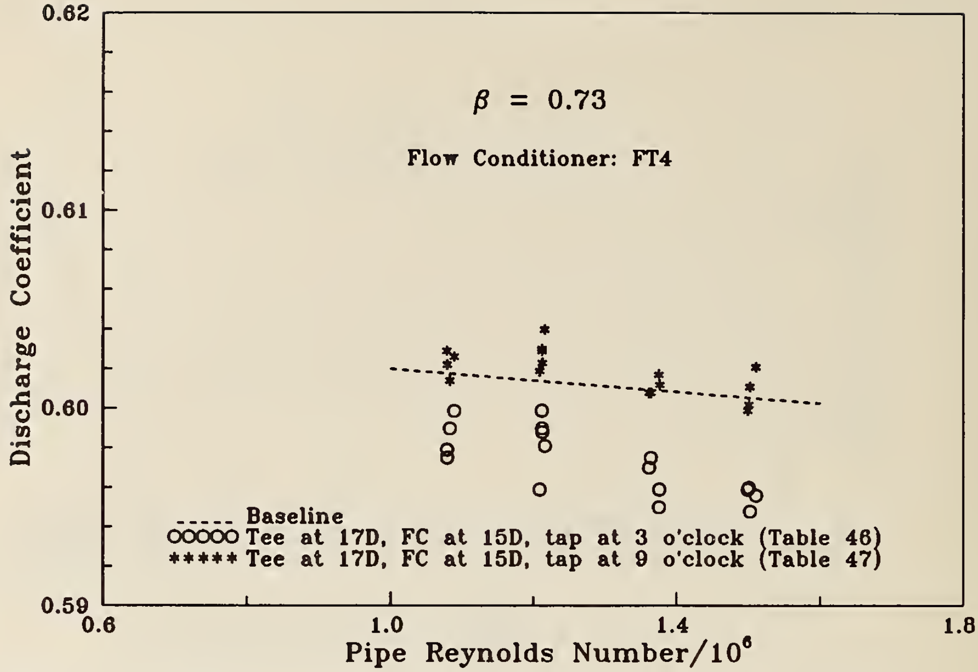

Figure 46. Discharge coefficient vs. Reynolds number for the 0.73 beta ratio plate with a tee at 17D, a flanged, 19 tube bundle flow conditioner (round) at the tee outlet, and flange pressure taps at 3 and 9 o'clock.

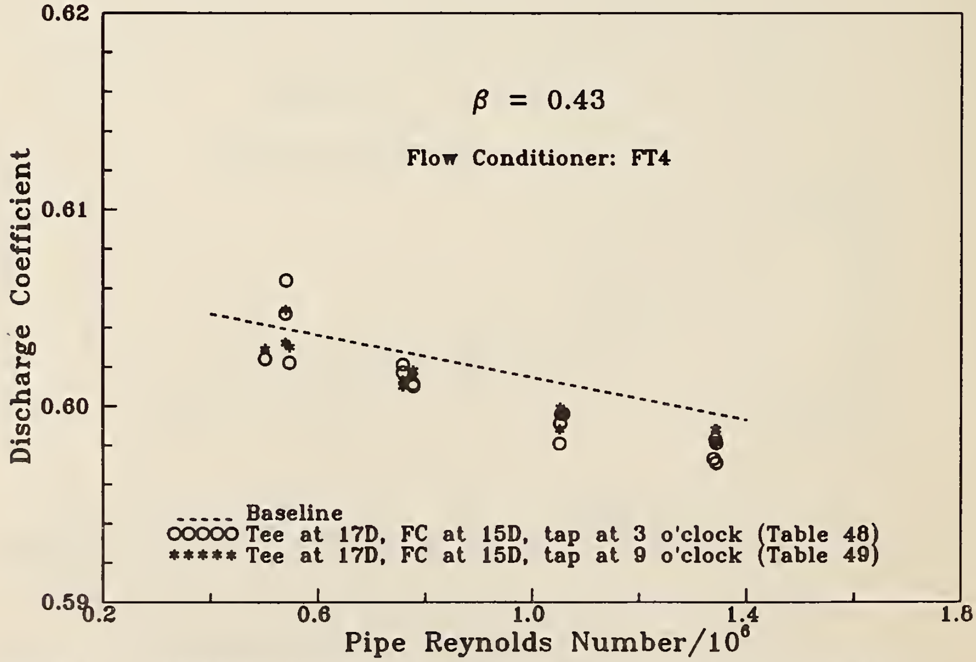

Figure 47. Discharge coefficient vs. Reynolds number for the 0.43 beta ratio plate with a tee at 17D, a flanged, 19 tube bundle flow conditioner (round) at the tee outlet, and flange pressure taps at 3 and 9 o'clock.

Table 2. Measured and calculated quantities for 0.43 beta ratio, tee at 19D, ZAN at 10D.

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	CY2
43031490- 1	3.8857	287.94	45.81	16.365	1.1629	0.7888	0.6015	0.6020
43031490- 2	3.8745	288.01	45.67	16.624	1.1690	0.7929	0.6008	0.6014
43031490- 3	3.7976	287.50	44.85	29.730	1.5496	1.0534	0.6006	0.6016
43031490- 4	3.7904	287.62	44.74	29.585	1.5419	1.0480	0.5997	0.6007
43031490- 5	4.0065	288.57	47.13	5.550	0.6909	0.4673	0.6054	0.6056
43031490- 6	3.9981	288.69	47.01	5.588	0.6954	0.4702	0.6080	0.6082
43031490- 7	3.6474	287.06	43.14	46.633	1.9048	1.2985	0.6004	0.6020
43031490- 8	3.6495	287.39	43.11	45.868	1.8819	1.2818	0.5983	0.5999
43031690- 1	3.6170	287.31	42.74	47.683	1.9156	1.3056	0.5998	0.6015
43031690- 2	3.6149	286.66	42.82	46.854	1.8930	1.2922	0.5974	0.5991
43031690- 3	3.9582	288.30	46.61	5.841	0.7017	0.4752	0.6027	0.6029
43031690- 4	3.9959	288.50	47.02	6.020	0.7179	0.4857	0.6047	0.6049
43031690- 6	3.7876	287.48	44.73	27.745	1.4959	1.0170	0.6010	0.6019
43031690- 8	3.8533	287.93	45.43	15.154	1.1154	0.7569	0.6021	0.6026
43031690- 9	3.8483	287.96	45.37	15.071	1.1120	0.7547	0.6023	0.6028

Table 3. Measured and calculated quantities for 0.55 beta ratio, tee at 19D, ZAN at 10D.

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	CY2
44031390- 1	3.8773	287.91	45.72	7.004	1.3011	0.8827	0.6039	0.6041
44031390- 2	3.8687	287.88	45.62	6.935	1.2923	0.8769	0.6034	0.6037
44031390- 3	3.9877	288.42	46.93	2.950	0.8596	0.5817	0.6070	0.6070
44031390- 4	4.0170	288.50	47.26	2.976	0.8677	0.5869	0.6078	0.6079
44031390- 5	3.5659	286.29	42.29	21.672	2.1991	1.5034	0.6028	0.6035
44031390- 7	3.7334	287.19	44.14	12.863	1.7310	1.1785	0.6032	0.6036
44031390- 8	3.7147	287.41	43.88	12.889	1.7245	1.1737	0.6021	0.6025
44031590- 1	3.7087	287.29	43.83	13.199	1.7480	1.1901	0.6034	0.6038
44031590- 2	3.7049	287.24	43.79	13.124	1.7424	1.1865	0.6035	0.6039
44031590- 3	3.5461	286.33	42.05	21.652	2.1939	1.5001	0.6034	0.6041
44031590- 4	3.9395	287.88	46.46	2.936	0.8523	0.5779	0.6062	0.6063
44031590- 5	3.9399	288.15	46.42	3.024	0.8651	0.5861	0.6066	0.6066
44031590- 6	3.8087	287.76	44.93	7.329	1.3212	0.8974	0.6047	0.6049
44031590- 7	3.8032	287.82	44.86	7.226	1.3087	0.8889	0.6037	0.6039
44031590- 8	3.5464	286.13	42.09	20.828	2.1536	1.4733	0.6037	0.6044

Table 4. Measured and calculated quantities for 0.67 beta ratio, tee at 19D, ZAN at 10D.

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	CY2
45031490- 2	3.6803	287.37	43.48	5.692	1.8242	1.2422	0.6030	0.6032
45031490- 3	3.6728	287.35	43.39	5.707	1.8228	1.2414	0.6024	0.6026
45031490- 4	3.7979	287.58	44.84	2.783	1.3010	0.8843	0.6058	0.6059
45031490- 5	3.7915	287.47	44.78	2.838	1.3113	0.8916	0.6051	0.6052
45031490- 6	3.7415	287.34	44.21	4.102	1.5636	1.0640	0.6040	0.6041
45031490- 7	3.7425	287.20	44.24	4.061	1.5570	1.0599	0.6042	0.6043
45031590- 1	3.5935	287.17	42.48	8.687	2.2221	1.5154	0.6015	0.6017
45031590- 2	3.5951	286.99	42.53	8.600	2.2151	1.5113	0.6023	0.6025
45031690- 1	3.8122	287.91	44.95	3.885	1.5309	1.0395	0.6025	0.6026
45031690- 2	3.8061	287.67	44.92	3.846	1.5248	1.0360	0.6034	0.6035
45031690- 3	3.8422	287.94	45.30	2.700	1.2854	0.8724	0.6045	0.6046
45031690- 4	3.8389	287.83	45.28	2.709	1.2853	0.8726	0.6037	0.6038
45031690- 5	3.6830	287.57	43.48	6.052	1.8772	1.2776	0.6019	0.6020
45031690- 6	3.6801	287.13	43.51	5.978	1.8691	1.2735	0.6027	0.6029
45031690- 7	3.5660	286.72	42.23	8.187	2.1519	1.4696	0.6018	0.6021
45031690- 8	3.5700	286.54	42.30	8.153	2.1484	1.4679	0.6016	0.6018

Table 5. Measured and calculated quantities for 0.73 beta ratio, tee at 19D, ZAN at 10D.

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	CY2
46031390- 1	3.6679	287.11	43.37	3.987	1.9226	1.3102	0.6033	0.6034
46031390- 2	3.6426	286.69	43.14	4.292	1.9833	1.3534	0.6014	0.6015
46031390- 4	3.7371	287.27	44.17	2.783	1.6173	1.1009	0.6020	0.6021
46031390- 5	3.7015	287.26	43.75	3.279	1.7475	1.1900	0.6021	0.6021
46031390- 6	3.7003	287.24	43.74	3.271	1.7426	1.1867	0.6013	0.6013
46031490- 1	3.6166	286.99	42.78	5.461	2.2193	1.5138	0.5991	0.5992
46031490- 2	3.6209	286.74	42.88	5.438	2.2218	1.5163	0.6004	0.6005
46031590- 1	3.7704	287.48	44.53	3.309	1.7685	1.2026	0.6012	0.6013
46031590- 2	3.7521	287.41	44.32	3.293	1.7591	1.1968	0.6008	0.6009
46031590- 3	3.8031	287.66	44.89	2.595	1.5701	1.0669	0.6003	0.6004
46031590- 4	3.7981	287.76	44.81	2.608	1.5711	1.0674	0.5998	0.5999
46031590- 5	3.5599	286.63	42.17	5.432	2.2047	1.5062	0.6010	0.6012
46031590- 6	3.5680	286.45	42.29	5.401	2.1998	1.5033	0.6006	0.6007
46031590- 7	3.6898	287.12	43.63	4.067	1.9364	1.3193	0.5999	0.6000
46031590- 8	3.6710	287.51	43.35	4.057	1.9282	1.3127	0.6000	0.6001

Table 6. Measured and calculated quantities for 0.43 beta ratio, tee at 19D, ET1 at 11D.

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	CY2
43041090- 1	3.7005	286.86	43.80	46.321	1.9037	1.2976	0.5975	0.5991
43041090- 2	3.6796	286.63	43.59	48.265	1.9416	1.3245	0.5983	0.6000
43041090- 3	3.9763	288.14	46.85	6.684	0.7515	0.5090	0.6018	0.6020
43041090- 4	3.9657	288.31	46.69	7.159	0.7758	0.5253	0.6013	0.6015
43041090- 5	3.7961	287.64	44.81	27.827	1.4968	1.0172	0.6000	0.6009
43041090- 6	3.7937	287.38	44.82	27.424	1.4859	1.0104	0.5998	0.6008
43041090- 7	3.8510	287.76	45.43	14.944	1.1067	0.7514	0.6016	0.6021
43041090- 8	3.8488	287.87	45.39	14.904	1.1015	0.7477	0.5998	0.6003
43041190- 1	3.7730	287.41	44.57	28.249	1.4987	1.0193	0.5978	0.5987
43041190- 2	3.7700	287.46	44.53	28.182	1.4964	1.0176	0.5978	0.5988
43041190- 3	3.6499	287.32	43.12	47.354	1.9090	1.3005	0.5971	0.5988
43041190- 4	3.6528	287.27	43.17	47.205	1.9040	1.2972	0.5962	0.5979
43041190- 5	3.9554	288.49	46.54	5.542	0.6780	0.4589	0.5984	0.5986
43041190- 6	3.9483	288.37	46.48	6.433	0.7297	0.4941	0.5983	0.5985
43041190- 7	3.8844	287.93	45.80	13.721	1.0635	0.7215	0.6009	0.6014
43041190- 8	3.8764	287.96	45.70	13.523	1.0525	0.7140	0.5997	0.6001

Table 7. Measured and calculated quantities for 0.55 beta ratio, tee at 19D, ET1 at 11D.

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	CY2
44041090- 1	3.7852	287.62	44.68	13.226	1.7591	1.1956	0.6008	0.6012
44041090- 2	3.7798	287.33	44.66	13.152	1.7534	1.1927	0.6007	0.6011
44041090- 1	3.9564	288.38	46.57	3.225	0.8926	0.6043	0.6051	0.6052
44041090- 2	3.9612	288.40	46.62	3.259	0.8967	0.6070	0.6043	0.6044
44041090- 3	3.6493	286.47	43.26	21.401	2.2026	1.5037	0.6008	0.6015
44041090- 4	3.6568	286.52	43.34	21.339	2.1989	1.5009	0.6001	0.6008
44041090- 5	3.8693	287.38	45.72	7.652	1.3552	0.9207	0.6018	0.6020
44041090- 6	3.8640	287.54	45.63	7.648	1.3542	0.9197	0.6021	0.6023
44041190- 1	3.9210	288.12	46.20	2.828	0.8329	0.5645	0.6054	0.6055
44041190- 2	3.9291	288.31	46.26	2.808	0.8318	0.5635	0.6064	0.6064
44041190- 3	3.6690	286.63	43.47	21.127	2.1986	1.5000	0.6021	0.6028
44041190- 4	3.6655	286.28	43.48	20.960	2.1879	1.4941	0.6015	0.6022
44041190- 5	3.7863	287.03	44.79	13.805	1.7986	1.2242	0.6005	0.6010
44041190- 6	3.7759	287.58	44.57	13.886	1.8024	1.2253	0.6015	0.6019
44041190- 7	3.8867	287.35	45.93	7.746	1.3678	0.9292	0.6023	0.6026
44041190- 8	3.8518	287.65	45.46	7.786	1.3674	0.9286	0.6036	0.6039

Table 8. Measured and calculated quantities for 0.67 beta ratio, tee at 19D, ET1 at 11D.

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	CY2
45040990- 1	3.6336	287.01	42.98	9.091	2.2805	1.5552	0.5999	0.6001
45040990- 2	3.6436	287.15	43.08	9.085	2.2802	1.5542	0.5994	0.5996
45040990- 3	3.7484	286.98	44.35	6.528	1.9622	1.3363	0.5997	0.5999
45040990- 4	3.7423	287.01	44.27	6.559	1.9677	1.3401	0.6005	0.6007
45040990- 5	3.8755	287.66	45.74	2.647	1.2761	0.8663	0.6033	0.6034
45040990- 6	3.8716	287.54	45.72	2.669	1.2773	0.8675	0.6016	0.6017
45040990- 7	3.8176	287.29	45.12	4.231	1.6019	1.0892	0.6030	0.6032
45040990- 8	3.8123	287.34	45.05	4.228	1.6002	1.0880	0.6031	0.6032
45041190- 1	3.7165	287.07	43.96	6.167	1.9037	1.2967	0.6013	0.6015
45041190- 2	3.7150	286.89	43.97	6.143	1.9021	1.2962	0.6019	0.6021
45041190- 3	3.8014	287.23	44.94	4.028	1.5587	1.0602	0.6026	0.6027
45041190- 4	3.7933	287.06	44.87	4.036	1.5599	1.0616	0.6029	0.6030
45041190- 5	3.8345	287.55	45.28	2.634	1.2647	0.8593	0.6024	0.6025
45041190- 6	3.8340	287.44	45.29	2.620	1.2656	0.8601	0.6045	0.6045
45041190- 7	3.5935	286.73	42.55	8.643	2.2140	1.5116	0.6003	0.6006
45041190- 8	3.5932	286.47	42.59	8.567	2.2059	1.5069	0.6005	0.6008

Table 9. Measured and calculated quantities for 0.73 beta ratio, tee at 19D, ET1 at 11D.

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	CY2
46040990- 1	3.6970	286.73	43.78	4.278	1.9891	1.3563	0.5997	0.5998
46040990- 2	3.6938	286.80	43.73	4.267	1.9822	1.3514	0.5987	0.5988
46040990- 3	3.6020	286.67	42.66	5.445	2.2103	1.5091	0.5984	0.5985
46040990- 4	3.6028	286.62	42.68	5.443	2.2146	1.5122	0.5995	0.5997
46040990- 5	3.7941	287.29	44.84	2.459	1.5292	1.0401	0.6010	0.6010
46040990- 6	3.7878	287.31	44.77	2.491	1.5391	1.0468	0.6015	0.6016
46040990- 7	3.7439	287.29	44.25	3.187	1.7264	1.1749	0.5999	0.6000
46040990- 8	3.7435	287.11	44.27	3.173	1.7191	1.1705	0.5985	0.5986
46041090- 1	3.6967	287.29	43.69	3.988	1.9176	1.3058	0.5995	0.5996
46041090- 2	3.6824	287.33	43.51	4.116	1.9427	1.3230	0.5990	0.5991
46041090- 3	3.7301	287.28	44.08	3.338	1.7656	1.2018	0.6006	0.6007
46041090- 4	3.7296	287.37	44.06	3.361	1.7685	1.2035	0.5997	0.5998
46041090- 5	3.6353	286.91	43.02	5.494	2.2342	1.5239	0.5996	0.5998
46041090- 6	3.6327	286.08	43.12	5.480	2.2287	1.5233	0.5982	0.5984
46041090- 7	3.8207	287.36	45.15	2.540	1.5614	1.0615	0.6018	0.6018
46041090- 8	3.8165	287.35	45.10	2.563	1.5651	1.0641	0.6008	0.6008

Table 10. Measured and calculated quantities for 0.43 beta ratio, tee at 19D, FT6 at 11D.

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	CY2
43040490- 1	3.9202	288.78	46.07	15.562	1.1400	0.7714	0.6030	0.6035
43040490- 2	3.9179	288.87	46.03	15.551	1.1386	0.7703	0.6027	0.6032
43040490- 3	3.8499	288.28	45.33	28.436	1.5254	1.0344	0.6013	0.6022
43040490- 4	3.8436	287.95	45.31	28.176	1.5182	1.0304	0.6013	0.6023
43040490- 5	3.9928	289.24	46.85	7.698	0.8095	0.5467	0.6040	0.6043
43040490- 6	3.9895	289.22	46.81	7.427	0.7947	0.5367	0.6039	0.6041
43040490- 7	3.6983	287.34	43.70	48.180	1.9487	1.3268	0.6003	0.6020
43040490- 8	3.6959	287.51	43.64	47.390	1.9268	1.3114	0.5990	0.6006
43040690- 1	3.6344	288.18	42.80	51.709	1.9862	1.3506	0.5966	0.5984
43040690- 2	3.6675	288.32	43.17	49.523	1.9590	1.3311	0.5988	0.6006
43040690- 3	3.6737	287.91	43.31	49.784	1.9672	1.3379	0.5988	0.6005
43040690- 4	3.9817	289.37	46.69	5.962	0.7108	0.4799	0.6039	0.6041
43040690- 5	3.9720	289.51	46.55	6.135	0.7206	0.4865	0.6043	0.6045
43040690- 6	3.7861	288.39	44.56	28.747	1.5143	1.0273	0.5988	0.5997
43040690- 7	3.7952	288.41	44.66	28.285	1.5028	1.0193	0.5984	0.5993
43040690- 8	3.8718	288.91	45.48	14.799	1.0956	0.7416	0.5981	0.5986
43040690- 9	3.8829	288.90	45.61	14.805	1.1003	0.7447	0.5997	0.6002
43040690- 10	3.8756	288.24	45.64	14.671	1.0978	0.7443	0.6009	0.6014
43040690- 11	3.8760	288.09	45.67	14.649	1.0974	0.7442	0.6009	0.6014
43040690- 12	3.8058	287.31	44.98	28.830	1.5233	1.0359	0.5987	0.5996

Table 11. Measured and calculated quantities for 0.55 beta ratio, tee at 19D, FT6 at 11D.

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	CY2
44040490- 1	3.8411	288.36	45.21	7.493	1.3362	0.9059	0.6029	0.6031
44040490- 2	3.8358	288.38	45.15	7.509	1.3340	0.9045	0.6018	0.6020
44040490- 3	3.9519	289.04	46.40	3.043	0.8664	0.5857	0.6057	0.6058
44040490- 4	3.9501	289.24	46.34	3.067	0.8713	0.5887	0.6071	0.6072
44040490- 5	3.7015	287.36	43.73	21.918	2.2472	1.5299	0.6024	0.6031
44040490- 6	3.6953	287.71	43.60	21.726	2.2306	1.5174	0.6015	0.6022
44040490- 7	3.8416	288.10	45.26	13.121	1.7686	1.1999	0.6026	0.6030
44040490- 8	3.8318	287.74	45.21	13.168	1.7699	1.2019	0.6023	0.6027
44040590- 1	3.8760	288.47	45.61	7.491	1.3424	0.9096	0.6033	0.6035
44040590- 2	3.8742	288.44	45.59	7.480	1.3378	0.9065	0.6017	0.6019
44040590- 3	3.9917	289.14	46.85	2.946	0.8540	0.5769	0.6039	0.6040
44040590- 4	3.9881	289.17	46.81	2.961	0.8592	0.5804	0.6063	0.6064
44040590- 5	3.6380	287.69	42.92	21.004	2.1799	1.4840	0.6025	0.6032
44040590- 6	3.6376	287.71	42.92	20.895	2.1715	1.4782	0.6018	0.6025
44040590- 7	3.7630	288.15	44.33	13.335	1.7598	1.1949	0.6010	0.6014
44040590- 8	3.7578	288.03	44.29	13.379	1.7653	1.1990	0.6021	0.6025

Table 12. Measured and calculated quantities for 0.67 beta ratio, tee at 19D, FT6 at 11D.

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	CY2
45040590- 1	3.9254	288.63	46.16	3.379	1.4470	0.9794	0.6026	0.6027
45040590- 2	3.9217	288.69	46.11	3.365	1.4416	0.9757	0.6020	0.6021
45040590- 3	3.9413	288.85	46.31	2.635	1.2828	0.8677	0.6041	0.6041
45040590- 4	3.9365	288.78	46.27	2.629	1.2792	0.8655	0.6033	0.6033
45040590- 5	3.8126	288.06	44.93	5.943	1.8864	1.2804	0.6004	0.6005
45040590- 6	3.8065	288.21	44.83	5.941	1.8835	1.2781	0.6002	0.6004
45040590- 7	3.6688	287.50	43.32	8.788	2.2494	1.5315	0.5995	0.5997
45040590- 8	3.6687	287.98	43.24	8.789	2.2498	1.5299	0.6001	0.6003
45040690- 1	3.6497	286.54	43.25	8.533	2.2267	1.5199	0.6027	0.6030
45040690- 2	3.6442	287.23	43.07	8.519	2.2173	1.5110	0.6019	0.6022
45040690- 3	3.7510	287.08	44.36	5.968	1.8872	1.2849	0.6032	0.6033
45040690- 4	3.7418	287.27	44.22	5.964	1.8827	1.2814	0.6029	0.6031
45040690- 5	3.8599	287.79	45.54	2.623	1.2726	0.8638	0.6058	0.6059
45040690- 6	3.8547	287.83	45.47	2.628	1.2715	0.8630	0.6051	0.6052
45040690- 7	3.8076	287.42	44.98	4.088	1.5729	1.0693	0.6033	0.6034
45040690- 8	3.8048	287.48	44.94	4.070	1.5670	1.0652	0.6027	0.6028

Table 13. Measured and calculated quantities for 0.73 beta ratio, tee at 19D, FT6 at 11D.

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	CY2
46040590- 1	3.7797	288.37	44.48	4.105	1.9600	1.3299	0.5984	0.5985
46040590- 2	3.7778	288.04	44.52	4.096	1.9600	1.3309	0.5989	0.5990
46040590- 3	3.6619	287.81	43.19	5.691	2.2752	1.5480	0.5988	0.5989
46040590- 4	3.6615	288.04	43.14	5.682	2.2721	1.5450	0.5987	0.5989
46040590- 5	3.8540	288.12	45.41	2.782	1.6334	1.1079	0.5997	0.5998
46040590- 6	3.8538	288.40	45.36	2.811	1.6403	1.1119	0.5995	0.5996
46040590- 7	3.8144	288.25	44.92	3.429	1.8012	1.2219	0.5989	0.5990
46040590- 8	3.8116	288.23	44.89	3.427	1.8006	1.2216	0.5991	0.5991
46040690- 1	3.6445	287.96	42.96	5.707	2.2695	1.5438	0.5980	0.5982
46040690- 2	3.6407	287.73	42.95	5.689	2.2663	1.5426	0.5982	0.5983
46040690- 3	3.7849	288.47	44.53	3.455	1.8021	1.2224	0.5995	0.5996
46040690- 4	3.7783	288.11	44.51	3.461	1.8035	1.2244	0.5996	0.5997
46040690- 5	3.8165	288.33	44.93	2.699	1.6048	1.0885	0.6014	0.6014
46040690- 6	3.8120	288.38	44.86	2.708	1.6041	1.0879	0.6006	0.6006
46040690- 8	3.7097	288.47	43.64	4.091	1.9415	1.3180	0.5995	0.5996

Table 14. Measured and calculated quantities for 0.43 beta ratio, tee at 19D, FT1 at 11D.

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	CY2
43032090- 1	3.7557	287.21	44.40	49.445	1.9830	1.3497	0.5983	0.5999
43032090- 2	3.7503	286.84	44.40	48.996	1.9786	1.3479	0.5997	0.6014
43032090- 3	4.0411	288.54	47.54	6.415	0.7462	0.5045	0.6055	0.6057
43032090- 4	4.0217	288.69	47.29	6.610	0.7575	0.5121	0.6072	0.6074
43032090- 5	3.8411	287.93	45.29	28.370	1.5266	1.0361	0.6028	0.6037
43032090- 6	3.8345	287.63	45.26	27.942	1.5117	1.0269	0.6016	0.6026
43032090- 7	3.8891	288.21	45.81	15.112	1.1229	0.7612	0.6045	0.6050
43032090- 8	3.8799	287.99	45.74	14.992	1.1167	0.7575	0.6040	0.6045
43032390- 1	3.8628	288.22	45.49	15.325	1.1194	0.7591	0.6005	0.6010
43032390- 2	3.8607	288.26	45.46	15.341	1.1201	0.7595	0.6007	0.6012
43032390- 3	3.8016	287.81	44.84	27.774	1.4978	1.0174	0.6007	0.6016
43032390- 4	3.8007	287.66	44.86	27.706	1.4942	1.0153	0.5999	0.6008
43032390- 5	3.9679	288.74	46.64	6.540	0.7428	0.5024	0.6028	0.6030
43032390- 6	3.9855	288.96	46.81	6.080	0.7210	0.4873	0.6057	0.6059
43032390- 7	3.7221	287.61	43.93	48.715	1.9676	1.3384	0.6012	0.6029
43032390- 8	3.7152	287.49	43.87	48.189	1.9514	1.3279	0.5999	0.6016

Table 15. Measured and calculated quantities for 0.55 beta ratio, tee at 19D, FT1 at 11D.

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	CY2
44032290- 1	3.8919	288.93	45.71	3.082	0.8668	0.5865	0.6067	0.6068
44032290- 1	3.8398	287.86	45.28	13.024	1.7570	1.1928	0.6007	0.6011
44032290- 2	3.8315	287.73	45.21	12.990	1.7541	1.1913	0.6010	0.6014
44032290- 3	3.6579	287.84	43.13	21.944	2.2176	1.5087	0.5982	0.5989
44032290- 4	3.6589	287.64	43.18	21.889	2.2218	1.5123	0.5997	0.6004
44032290- 5	4.0044	288.75	47.07	3.146	0.8858	0.5989	0.6048	0.6049
44032290- 6	3.9990	288.87	46.99	3.185	0.8935	0.6039	0.6068	0.6069
44032290- 7	3.9921	289.03	46.88	3.163	0.8896	0.6011	0.6070	0.6071
44032290- 8	3.8724	288.28	45.60	7.023	1.2981	0.8800	0.6025	0.6027
44032290- 9	3.8637	288.49	45.46	6.901	1.2851	0.8708	0.6026	0.6028
44032690- 1	3.7603	288.13	44.30	13.290	1.7580	1.1938	0.6016	0.6020
44032690- 2	3.7567	287.91	44.29	13.215	1.7540	1.1918	0.6019	0.6023
44032690- 3	3.6282	287.49	42.84	22.118	2.2355	1.5228	0.6027	0.6034
44032690- 4	3.6311	287.64	42.85	22.034	2.2294	1.5180	0.6021	0.6028
44032690- 5	3.9233	288.75	46.12	3.304	0.8991	0.6084	0.6051	0.6052
44032690- 6	3.9273	288.89	46.14	3.343	0.9046	0.6119	0.6050	0.6051
44032690- 7	3.8704	288.43	45.55	7.506	1.3444	0.9110	0.6039	0.6041
44032690- 8	3.8314	288.41	45.09	7.441	1.3314	0.9028	0.6037	0.6040

Table 16. Measured and calculated quantities for 0.67 beta ratio, tee at 19D, FT1 at 11D.

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	CY2
45032090- 1	3.8194	287.73	45.06	3.898	1.5401	1.0461	0.6044	0.6045
45032090- 2	3.8124	287.69	44.99	3.862	1.5364	1.0438	0.6063	0.6064
45032090- 3	3.8490	288.06	45.36	2.504	1.2392	0.8408	0.6049	0.6050
45032090- 4	3.8479	288.07	45.34	2.476	1.2323	0.8360	0.6049	0.6050
45032090- 5	3.7246	287.48	43.99	5.834	1.8574	1.2638	0.6030	0.6032
45032090- 6	3.7237	287.47	43.98	5.817	1.8530	1.2608	0.6025	0.6027
45032090- 7	3.7153	287.48	43.87	8.470	2.2345	1.5205	0.6027	0.6030
45032090- 8	3.6954	287.17	43.69	8.419	2.2191	1.5115	0.6017	0.6019
45032390- 1	3.8844	288.31	45.73	3.941	1.5569	1.0552	0.6032	0.6033
45032390- 2	3.8780	288.10	45.69	3.931	1.5575	1.0562	0.6044	0.6045
45032390- 3	3.9097	288.22	46.05	2.689	1.2921	0.8756	0.6039	0.6040
45032390- 4	3.8958	288.29	45.87	2.680	1.2866	0.8720	0.6036	0.6037
45032390- 5	3.7657	287.52	44.47	5.992	1.8892	1.2847	0.6020	0.6021
45032390- 6	3.7588	287.42	44.40	5.990	1.8865	1.2833	0.6016	0.6018
45032390- 7	3.6328	287.29	42.93	8.765	2.2394	1.5261	0.6003	0.6006
45032390- 8	3.6348	287.23	42.96	8.717	2.2371	1.5247	0.6011	0.6014

Table 17. Measured and calculated quantities for 0.73 beta ratio, tee at 19D, FT1 at 11D.

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	CY2
46032290- 1	3.7570	287.96	44.29	3.437	1.7930	1.2181	0.5997	0.5998
46032290- 2	3.7495	287.65	44.25	3.405	1.7885	1.2160	0.6013	0.6014
46032290- 3	3.7929	287.97	44.71	2.700	1.6004	1.0867	0.6011	0.6012
46032290- 4	3.7828	287.86	44.61	2.700	1.5955	1.0839	0.6000	0.6001
46032290- 5	3.6519	287.02	43.20	5.645	2.2765	1.5520	0.6015	0.6016
46032290- 6	3.6478	287.42	43.08	5.621	2.2650	1.5428	0.6006	0.6007
46032290- 7	3.7789	287.68	44.59	4.089	1.9690	1.3382	0.6017	0.6018
46032290- 8	3.7563	287.88	44.29	4.107	1.9638	1.3344	0.6008	0.6009
46032690- 1	3.8089	287.91	44.91	3.267	1.7607	1.1956	0.5998	0.5999
46032690- 2	3.8015	287.94	44.82	3.264	1.7583	1.1940	0.6000	0.6000
46032690- 3	3.8362	288.47	45.14	2.608	1.5784	1.0700	0.6003	0.6004
46032690- 4	3.8343	288.28	45.15	2.605	1.5778	1.0701	0.6004	0.6005
46032690- 5	3.6355	287.94	42.85	5.606	2.2504	1.5311	0.5990	0.5992
46032690- 6	3.6360	287.78	42.88	5.601	2.2491	1.5308	0.5987	0.5989
46032690- 7	3.7201	287.77	43.88	4.390	2.0162	1.3710	0.5994	0.5995
46032690- 8	3.7158	287.48	43.88	4.397	2.0187	1.3737	0.5997	0.5998

Table 18. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, FT1 at 15D.

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	CY2
43090590- 1	4.0485	286.02	48.10	14.913	1.1393	0.7749	0.6026	0.6031
43090590- 2	4.0502	285.89	48.14	14.870	1.1391	0.7750	0.6031	0.6035
43090590- 3	3.9885	285.54	47.47	28.413	1.5575	1.0614	0.6003	0.6012
43090590- 4	3.9869	285.59	47.44	28.449	1.5588	1.0621	0.6006	0.6015
43090590- 5	4.1335	286.73	48.97	6.366	0.7573	0.5137	0.6079	0.6081
43090590- 6	3.9063	285.07	46.57	48.677	2.0294	1.3859	0.6026	0.6042
43090590- 7	3.8702	285.26	46.11	48.602	2.0181	1.3782	0.6027	0.6043
43090690- 1	3.8228	287.56	45.14	48.052	1.9787	1.3445	0.6007	0.6023
43090690- 2	3.8247	288.17	45.05	47.610	1.9638	1.3324	0.5994	0.6010
43090690- 3	3.9263	288.26	46.24	29.151	1.5600	1.0569	0.6013	0.6023
43090690- 4	3.9098	288.06	46.08	29.283	1.5603	1.0578	0.6011	0.6021
43090690- 5	3.9620	288.66	46.59	15.093	1.1286	0.7636	0.6028	0.6033
43090690- 6	3.9917	288.52	46.96	15.181	1.1373	0.7695	0.6033	0.6038
43090790- 1	4.0740	288.52	47.94	6.937	0.7783	0.5260	0.6048	0.6051
43090790- 2	4.0609	288.58	47.77	6.631	0.7618	0.5149	0.6067	0.6069
43090790- 3	4.0635	288.57	47.80	6.842	0.7732	0.5226	0.6059	0.6062

Table 19. Measured and calculated quantities for 0.55 beta ratio, tee at 17D, FT1 at 15D.

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	CY2
44083090- 1	3.9774	285.36	47.37	5.976	1.2255	0.8356	0.6051	0.6053
44083090- 2	3.9786	285.23	47.41	5.974	1.2252	0.8356	0.6048	0.6050
44083090- 3	4.0921	286.27	48.57	2.679	0.8367	0.5684	0.6095	0.6096
44083090- 1	3.8027	285.02	45.34	21.138	2.2499	1.5386	0.6032	0.6039
44083090- 2	3.8005	285.60	45.21	21.181	2.2483	1.5354	0.6030	0.6037
44083090- 3	3.9259	285.62	46.71	13.864	1.8509	1.2620	0.6040	0.6044
44083090- 4	3.9366	285.76	46.81	13.932	1.8581	1.2663	0.6042	0.6046
44083090- 5	4.0981	286.92	48.52	2.592	0.8228	0.5581	0.6097	0.6098
44090790- 1	3.8980	287.58	46.02	13.157	1.7841	1.2111	0.6020	0.6024
44090790- 2	3.8965	286.91	46.13	13.132	1.7853	1.2139	0.6023	0.6027
44090790- 3	3.7878	287.29	44.77	21.145	2.2300	1.5168	0.6015	0.6022
44090790- 4	3.7998	286.75	45.00	21.126	2.2348	1.5219	0.6015	0.6022
44090790- 5	3.9845	288.07	46.96	3.016	0.8649	0.5858	0.6038	0.6039
44090790- 6	3.9853	288.18	46.95	2.816	0.8383	0.5677	0.6057	0.6058
44090790- 7	3.9571	287.36	46.76	7.786	1.3870	0.9414	0.6037	0.6039
44090790- 8	3.9552	287.53	46.71	7.817	1.3876	0.9414	0.6031	0.6034

Table 20. Measured and calculated quantities for 0.67 beta ratio, tee at 17D, FT1 at 15D.

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	CY2
45083190- 1	3.7629	285.61	44.76	8.544	2.2667	1.5486	0.6028	0.6030
45083190- 2	3.7660	285.08	44.89	8.473	2.2597	1.5458	0.6026	0.6028
45083190- 3	3.8656	285.44	46.02	6.149	1.9529	1.3331	0.6038	0.6040
45083190- 4	3.8651	285.25	46.04	6.203	1.9628	1.3405	0.6041	0.6042
45083190- 5	4.0080	286.13	47.59	2.632	1.3074	0.8895	0.6077	0.6078
45083190- 6	4.0061	286.14	47.57	2.667	1.3190	0.8973	0.6091	0.6092
45090590- 1	3.9770	285.04	47.42	4.171	1.6421	1.1205	0.6073	0.6074
45090590- 2	3.9687	285.27	47.28	4.195	1.6452	1.1221	0.6076	0.6077
45090590- 3	3.9997	285.55	47.60	2.616	1.3028	0.8877	0.6074	0.6075
45090590- 4	4.0017	285.65	47.61	2.640	1.3079	0.8909	0.6070	0.6071
45090590- 5	3.9105	285.30	46.58	5.714	1.8977	1.2951	0.6050	0.6052
45090590- 6	3.9090	284.83	46.65	5.693	1.8956	1.2953	0.6050	0.6052
45090590- 7	3.8240	284.46	45.69	8.074	2.2274	1.5249	0.6031	0.6033
45090590- 8	3.8202	284.37	45.66	8.027	2.2239	1.5230	0.6041	0.6043

Table 21. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, FT1 at 15D.

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	CY2
46083090- 1	3.8723	284.64	46.24	4.196	2.0247	1.3847	0.5998	0.5999
46083090- 2	3.8671	284.94	46.12	4.180	2.0243	1.3835	0.6016	0.6017
46083090- 3	3.7650	284.04	45.06	5.489	2.2868	1.5683	0.6000	0.6001
46083090- 4	3.7693	283.88	45.14	5.492	2.2883	1.5699	0.5997	0.5998
46083090- 5	3.9461	284.74	47.11	2.680	1.6430	1.1224	0.6034	0.6035
46083090- 6	3.9410	284.60	47.07	2.666	1.6377	1.1192	0.6034	0.6034
46083090- 7	3.9144	284.35	46.80	3.207	1.7897	1.2242	0.6029	0.6030
46083090- 8	3.9095	284.94	46.63	3.217	1.7824	1.2175	0.6006	0.6007
46090690- 1	3.9071	287.74	46.10	3.255	1.7874	1.2127	0.6021	0.6021
46090690- 2	3.9064	287.78	46.09	3.256	1.7857	1.2115	0.6015	0.6016
46090690- 3	3.9454	288.28	46.46	2.504	1.5739	1.0660	0.6022	0.6022
46090690- 4	3.9405	288.22	46.41	2.528	1.5819	1.0716	0.6026	0.6027
46090690- 5	3.7902	287.39	44.78	5.368	2.2577	1.5353	0.6009	0.6010
46090690- 6	3.7904	288.14	44.65	5.357	2.2498	1.5271	0.6002	0.6003
46090690- 7	3.8443	287.94	45.32	4.392	2.0565	1.3957	0.6014	0.6016
46090690- 8	3.8426	287.76	45.34	4.403	2.0594	1.3983	0.6014	0.6016

Table 22. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, IT1 at 15D.

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	CY2
43110990- 1	3.9287	284.91	46.87	28.068	1.5388	1.0510	0.6005	0.6015
43110990- 2	3.9277	284.36	46.96	28.028	1.5374	1.0515	0.5999	0.6008
43110990- 3	4.0621	286.02	48.26	6.744	0.7660	0.5209	0.6019	0.6021
43110990- 4	4.0532	286.01	48.15	6.139	0.7329	0.4985	0.6042	0.6044
43110990- 5	3.9898	285.21	47.54	14.802	1.1307	0.7711	0.6038	0.6043
43110990- 6	3.9846	285.12	47.50	14.591	1.1211	0.7648	0.6032	0.6037
43110990- 7	3.8516	284.07	46.09	45.730	1.9494	1.3354	0.6004	0.6019
43110990- 8	3.8435	283.87	46.03	45.593	1.9474	1.3348	0.6011	0.6026
43111490- 1	3.9614	288.47	46.61	15.220	1.1309	0.7655	0.6013	0.6018
43111490- 2	3.9590	288.95	46.50	15.328	1.1331	0.7661	0.6011	0.6016
43111490- 3	3.8285	287.52	45.21	48.133	1.9794	1.3450	0.5999	0.6015
43111490- 4	3.8269	287.83	45.14	47.951	1.9729	1.3396	0.5995	0.6011
43111490- 5	3.9129	288.48	46.04	28.755	1.5437	1.0454	0.6004	0.6014
43111490- 6	3.9106	288.47	46.01	29.176	1.5567	1.0543	0.6013	0.6022
43111490- 7	4.0643	289.64	47.61	6.689	0.7610	0.5130	0.6043	0.6045
43111490- 8	4.0608	289.43	47.61	6.414	0.7467	0.5037	0.6056	0.6058

Table 23. Measured and calculated quantities for 0.55 beta ratio, tee at 17D, IT1 at 15D.

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	CY2
44111390- 1	3.8153	284.52	45.58	20.080	2.1881	1.4980	0.6004	0.6010
44111390- 2	3.8134	284.15	45.62	19.944	2.1804	1.4941	0.6000	0.6007
44111390- 3	3.9062	284.26	46.72	13.324	1.8104	1.2388	0.6026	0.6030
44111390- 4	3.9026	284.40	46.65	13.458	1.8133	1.2404	0.6010	0.6014
44111390- 1	4.1360	285.86	49.17	3.083	0.8944	0.6079	0.6036	0.6036
44111390- 2	4.1523	286.18	49.30	3.109	0.9025	0.6128	0.6057	0.6058
44111390- 3	4.0820	285.59	48.58	5.770	1.2191	0.8297	0.6049	0.6051
44111390- 4	4.0810	285.62	48.56	5.684	1.2104	0.8237	0.6052	0.6054
44111590- 1	3.9260	287.91	46.30	13.481	1.8164	1.2316	0.6037	0.6041
44111590- 2	3.9255	288.43	46.20	13.495	1.8144	1.2288	0.6033	0.6038
44111590- 3	3.9971	288.60	47.01	6.004	1.2228	0.8271	0.6046	0.6048
44111590- 4	3.9960	288.76	46.97	6.022	1.2237	0.8274	0.6044	0.6045
44111590- 5	3.8193	287.58	45.09	20.759	2.2207	1.5089	0.6024	0.6031
44111590- 6	3.8169	287.42	45.09	20.639	2.2134	1.5046	0.6022	0.6028
44111590- 7	4.0757	289.56	47.77	3.213	0.9029	0.6087	0.6055	0.6056
44111590- 8	4.0756	289.23	47.82	3.220	0.9033	0.6095	0.6048	0.6049

Table 24. Measured and calculated quantities for 0.67 beta ratio, tee at 17D, IT1 at 15D.

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	CY2
45110990- 1	3.7988	284.01	45.47	8.197	2.2413	1.5366	0.6038	0.6040
45110990- 2	3.7930	284.21	45.36	8.248	2.2385	1.5340	0.6018	0.6021
45110990- 3	3.9592	284.56	47.30	2.651	1.2998	0.8882	0.6039	0.6040
45110990- 4	3.9614	284.66	47.31	2.665	1.3035	0.8904	0.6038	0.6039
45110990- 5	3.8768	284.57	46.31	5.899	1.9186	1.3123	0.6037	0.6039
45110990- 6	3.8742	284.99	46.20	5.891	1.9165	1.3096	0.6042	0.6044
45110990- 7	3.9346	284.59	47.00	3.927	1.5782	1.0786	0.6042	0.6043
45110990- 8	3.9298	284.84	46.89	3.932	1.5753	1.0761	0.6034	0.6035
45111490- 1	3.8784	289.27	45.50	6.039	1.9182	1.2972	0.6018	0.6020
45111490- 2	3.8747	287.70	45.73	5.986	1.9132	1.2987	0.6014	0.6015
45111490- 3	3.9654	288.67	46.63	2.583	1.2702	0.8593	0.6020	0.6021
45111490- 4	3.9648	288.43	46.66	2.585	1.2762	0.8638	0.6043	0.6044
45111490- 5	3.9340	288.31	46.32	4.115	1.5976	1.0822	0.6018	0.6019
45111490- 6	3.9326	288.40	46.29	4.103	1.5954	1.0805	0.6021	0.6022
45111490- 7	3.7960	288.09	44.73	8.211	2.2183	1.5059	0.6019	0.6021
45111490- 8	3.7977	288.61	44.66	8.226	2.2181	1.5038	0.6018	0.6020

Table 25. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, IT1 at 15D.

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	CY2
46111390- 1	4.0551	284.88	48.39	2.534	1.6166	1.1025	0.6025	0.6026
46111390- 2	4.0445	284.53	48.33	2.540	1.6156	1.1029	0.6018	0.6019
46111390- 3	3.8676	284.19	46.26	5.147	2.2484	1.5395	0.6012	0.6014
46111390- 4	3.8660	285.33	46.04	5.170	2.2453	1.5331	0.6005	0.6006
46111390- 5	3.9772	284.19	47.58	3.232	1.8096	1.2374	0.6022	0.6023
46111390- 6	3.9740	284.13	47.55	3.259	1.8125	1.2396	0.6008	0.6009
46111390- 7	3.9289	284.00	47.04	4.159	2.0394	1.3960	0.6017	0.6018
46111390- 8	3.9288	284.01	47.03	4.146	2.0335	1.3919	0.6009	0.6010
46111590- 1	3.9531	288.17	46.57	3.253	1.7947	1.2158	0.6016	0.6017
46111590- 2	3.9488	288.08	46.54	3.245	1.7900	1.2129	0.6011	0.6012
46111590- 3	3.9811	288.95	46.76	2.529	1.5850	1.0714	0.6014	0.6015
46111590- 4	3.9830	288.84	46.80	2.530	1.5870	1.0730	0.6018	0.6018
46111590- 5	3.8412	288.06	45.27	5.145	2.2171	1.5043	0.5994	0.5995
46111590- 6	3.8399	288.07	45.25	5.147	2.2178	1.5048	0.5996	0.5997
46111590- 7	3.9000	288.50	45.88	4.140	2.0059	1.3586	0.6005	0.6006
46111590- 8	3.9006	288.57	45.88	4.137	2.0058	1.3584	0.6007	0.6008

Table 26. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, no flow conditioner, flange taps at 3:00.

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	CY2
46112790- 1	3.9172	287.36	46.29	4.210	2.0345	1.3815	0.6014	0.6015
46112790- 2	3.9159	286.91	46.36	4.186	2.0286	1.3791	0.6010	0.6011
46112790- 3	3.9606	286.89	46.89	3.198	1.7858	1.2134	0.6020	0.6020
46112790- 4	3.9555	287.93	46.64	3.216	1.7819	1.2078	0.6005	0.6005
46112790- 5	3.8455	286.67	45.56	5.101	2.2176	1.5097	0.6003	0.6004
46112790- 6	3.8440	287.33	45.43	5.110	2.2201	1.5090	0.6014	0.6015
46112790- 7	3.9790	287.51	46.99	2.603	1.6176	1.0972	0.6036	0.6037
46112790- 8	3.9782	286.97	47.08	2.653	1.6357	1.1110	0.6041	0.6042

Table 27. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, no flow conditioner, flange taps at 9:00.

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/m³)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10⁶)	C	CY2
46112790- 1	3.9172	287.36	46.29	4.203	2.0345	1.3815	0.6019	0.6020
46112790- 2	3.9159	286.91	46.36	4.156	2.0286	1.3791	0.6032	0.6033
46112790- 3	3.9606	286.89	46.89	3.190	1.7858	1.2134	0.6026	0.6026
46112790- 4	3.9555	287.93	46.64	3.214	1.7819	1.2078	0.6006	0.6007
46112790- 5	3.8455	286.67	45.56	5.088	2.2176	1.5097	0.6011	0.6012
46112790- 6	3.8440	287.33	45.43	5.099	2.2201	1.5090	0.6020	0.6021
46112790- 7	3.9790	287.51	46.99	2.611	1.6176	1.0972	0.6027	0.6027
46112790- 8	3.9782	286.97	47.08	2.666	1.6357	1.1110	0.6025	0.6026

Table 28. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, no flow conditioner, flange taps at 6:00.

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/m³)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10⁶)	C	CY2
46120490- 1	3.9617	285.98	47.07	3.387	1.8481	1.2585	0.6041	0.6042
46120490- 2	3.9593	287.15	46.83	3.421	1.8490	1.2556	0.6030	0.6030
46120490- 3	3.8316	286.91	45.35	5.566	2.3168	1.5765	0.6018	0.6019
46120490- 4	3.8295	286.48	45.40	5.597	2.3180	1.5790	0.6000	0.6002
46120490- 5	3.9090	286.19	46.40	4.350	2.0750	1.4132	0.6027	0.6028
46120490- 6	3.9053	286.54	46.29	4.348	2.0721	1.4100	0.6027	0.6028
46120490- 7	4.0006	286.57	47.42	2.562	1.6169	1.0989	0.6056	0.6056
46120490- 8	3.9918	286.22	47.38	2.558	1.6166	1.0998	0.6062	0.6062

Table 29. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, no flow conditioner, flange taps at 12:00.

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/m³)	Dif Press (kPa)	Flow Rate (kg/s)	Pipe Re No. (÷10⁶)	C	CY2
46120490- 1	3.9617	285.98	47.07	3.447	1.8481	1.2585	0.5988	0.5989
46120490- 2	3.9593	287.15	46.83	3.474	1.8490	1.2556	0.5983	0.5984
46120490- 3	3.8316	286.91	45.35	5.653	2.3168	1.5765	0.5970	0.5972
46120490- 4	3.8295	286.48	45.40	5.645	2.3180	1.5790	0.5974	0.5976
46120490- 5	3.9090	286.19	46.40	4.411	2.0750	1.4132	0.5985	0.5986
46120490- 6	3.9053	286.54	46.29	4.417	2.0721	1.4100	0.5979	0.5980
46120490- 7	4.0006	286.57	47.42	2.613	1.6169	1.0989	0.5994	0.5995
46120490- 8	3.9918	286.22	47.38	2.613	1.6166	1.0998	0.5996	0.5996

Table 30. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, no flow conditioner, flange taps at 3:00.

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	CY2
43112790- 1	3.9812	287.04	47.11	29.315	1.6045	1.0895	0.6113	0.6123
43112790- 2	3.9772	287.53	46.97	29.499	1.6014	1.0862	0.6090	0.6100
43112790- 3	4.1255	288.38	48.57	6.280	0.7596	0.5132	0.6167	0.6169
43112790- 4	4.1537	288.63	48.85	6.283	0.7616	0.5141	0.6164	0.6166
43112790- 5	3.8955	286.67	46.15	45.593	1.9728	1.3422	0.6083	0.6098
43112790- 6	3.8906	287.56	45.94	45.434	1.9666	1.3352	0.6089	0.6104
43112790- 7	4.0189	287.79	47.42	15.335	1.1674	0.7909	0.6135	0.6140
43112790- 8	4.0155	287.55	47.42	15.382	1.1671	0.7912	0.6123	0.6128

Table 31. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, no flow conditioner, flange taps at 9:00.

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	CY2
43112790- 1	3.9812	287.04	47.11	29.327	1.6045	1.0895	0.6112	0.6121
43112790- 2	3.9772	287.53	46.97	29.486	1.6014	1.0862	0.6092	0.6101
43112790- 3	4.1255	288.38	48.57	6.282	0.7596	0.5132	0.6166	0.6168
43112790- 4	4.1537	288.63	48.85	6.283	0.7616	0.5141	0.6164	0.6166
43112790- 5	3.8955	286.67	46.15	45.616	1.9728	1.3422	0.6081	0.6096
43112790- 6	3.8906	287.56	45.94	45.461	1.9666	1.3352	0.6087	0.6102
43112790- 7	4.0189	287.79	47.42	15.353	1.1674	0.7909	0.6131	0.6136
43112790- 8	4.0155	287.55	47.42	15.396	1.1671	0.7912	0.6120	0.6125

Table 32. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, no flow conditioner, flange taps at 6:00.

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	CY2
43120490- 1	3.8886	286.35	46.13	45.781	1.9770	1.3462	0.6085	0.6100
43120490- 2	3.8876	286.29	46.13	45.402	1.9698	1.3415	0.6088	0.6104
43120490- 3	3.9799	286.57	47.18	27.772	1.5550	1.0571	0.6082	0.6091
43120490- 4	3.9716	286.04	47.17	27.604	1.5561	1.0594	0.6106	0.6116
43120490- 5	4.1009	287.24	48.49	6.593	0.7764	0.5262	0.6158	0.6160
43120490- 6	4.1020	287.35	48.48	6.859	0.7890	0.5346	0.6134	0.6136
43120490- 7	4.0290	286.74	47.73	14.395	1.1288	0.7666	0.6101	0.6106
43120490- 8	4.0244	286.73	47.68	14.154	1.1212	0.7615	0.6116	0.6121

Table 33. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, no flow conditioner, flange taps at 12:00.

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	CY2
43120490- 1	3.8886	286.35	46.13	45.695	1.9770	1.3462	0.6091	0.6106
43120490- 2	3.8876	286.29	46.13	45.236	1.9698	1.3415	0.6100	0.6116
43120490- 3	3.9799	286.57	47.18	27.752	1.5550	1.0571	0.6085	0.6094
43120490- 4	3.9716	286.04	47.17	27.518	1.5561	1.0594	0.6117	0.6126
43120490- 5	4.1009	287.24	48.49	6.576	0.7764	0.5262	0.6166	0.6168
43120490- 6	4.1020	287.35	48.48	6.847	0.7890	0.5346	0.6140	0.6142
43120490- 7	4.0290	286.74	47.73	14.395	1.1288	0.7666	0.6102	0.6106
43120490- 8	4.0244	286.73	47.68	14.128	1.1212	0.7615	0.6122	0.6127

Table 34. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, IT1 at 15D, flange taps at 3:00.

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	CY2
46112890- 1	3.9797	287.74	46.96	3.246	1.7855	1.2104	0.5968	0.5968
46112890- 2	3.9757	287.83	46.90	3.270	1.7939	1.2159	0.5978	0.5978
46112890- 3	3.8676	286.51	45.85	5.162	2.2247	1.5147	0.5967	0.5968
46112890- 4	3.8602	286.87	45.70	5.173	2.2183	1.5091	0.5953	0.5954
46112890- 5	3.9219	287.37	46.34	4.205	2.0216	1.3726	0.5975	0.5976
46112890- 6	3.9200	287.34	46.33	4.203	2.0162	1.3691	0.5962	0.5963
46112890- 7	3.9965	287.46	47.21	2.572	1.5988	1.0844	0.5988	0.5988
46112890- 8	3.9958	287.86	47.13	2.597	1.6010	1.0848	0.5972	0.5973

Table 35. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, IT1 at 15D, flange taps at 9:00.

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	CY2
46112890- 1	3.9797	287.74	46.96	3.206	1.7855	1.2104	0.6004	0.6005
46112890- 2	3.9757	287.83	46.90	3.237	1.7939	1.2159	0.6008	0.6008
46112890- 3	3.8676	286.51	45.85	5.094	2.2247	1.5147	0.6007	0.6008
46112890- 4	3.8602	286.87	45.70	5.093	2.2183	1.5091	0.6000	0.6001
46112890- 5	3.9219	287.37	46.34	4.160	2.0216	1.3726	0.6007	0.6008
46112890- 6	3.9200	287.34	46.33	4.145	2.0162	1.3691	0.6004	0.6005
46112890- 7	3.9965	287.46	47.21	2.537	1.5988	1.0844	0.6028	0.6029
46112890- 8	3.9958	287.86	47.13	2.556	1.6010	1.0848	0.6020	0.6020

Table 36. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, IT1 at 15D, flange taps at 6:00.

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	CY2
46120390- 1	4.0003	285.97	47.53	2.483	1.5882	1.0810	0.6033	0.6034
46120390- 2	4.0208	286.63	47.65	2.486	1.5894	1.0798	0.6027	0.6028
46120390- 3	3.9179	286.01	46.54	4.045	2.0001	1.3626	0.6015	0.6016
46120390- 4	3.9118	286.31	46.41	4.041	1.9947	1.3580	0.6010	0.6011
46120390- 5	3.8176	285.68	45.40	5.516	2.3018	1.5713	0.6002	0.6003
46120390- 6	3.8194	285.48	45.46	5.513	2.3025	1.5725	0.6002	0.6003
46120390- 7	3.9414	286.77	46.68	3.326	1.8138	1.2331	0.6007	0.6008
46120390- 8	3.9321	286.01	46.71	3.338	1.8197	1.2395	0.6014	0.6014

Table 37. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, IT1 at 15D, flange taps at 12:00.

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	CY2
46120390- 1	4.0003	285.97	47.53	2.508	1.5882	1.0810	0.6003	0.6003
46120390- 2	4.0208	286.63	47.65	2.508	1.5894	1.0798	0.5999	0.6000
46120390- 3	3.9179	286.01	46.54	4.080	2.0001	1.3626	0.5989	0.5990
46120390- 4	3.9118	286.31	46.41	4.078	1.9947	1.3580	0.5982	0.5983
46120390- 5	3.8176	285.68	45.40	5.573	2.3018	1.5713	0.5971	0.5972
46120390- 6	3.8194	285.48	45.46	5.561	2.3025	1.5725	0.5976	0.5977
46120390- 7	3.9414	286.77	46.68	3.350	1.8138	1.2331	0.5985	0.5986
46120390- 8	3.9321	286.01	46.71	3.361	1.8197	1.2395	0.5993	0.5994

Table 38. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, IT1 at 15D, flange taps at 3:00.

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	CY2
43112890- 1	3.9791	287.31	47.03	28.346	1.5530	1.0539	0.6020	0.6029
43112890- 2	3.9739	287.96	46.86	28.415	1.5477	1.0487	0.6003	0.6013
43112890- 3	3.8783	286.93	45.90	48.332	1.9966	1.3578	0.5993	0.6009
43112890- 4	3.8804	287.13	45.89	48.042	1.9914	1.3536	0.5996	0.6012
43112890- 5	4.0925	288.39	48.18	6.626	0.7595	0.5134	0.6024	0.6027
43112890- 6	4.0897	288.51	48.12	7.447	0.8063	0.5449	0.6036	0.6038
43112890- 7	4.0239	287.84	47.47	14.152	1.1037	0.7476	0.6032	0.6036
43112890- 8	4.0232	288.07	47.42	14.057	1.0989	0.7440	0.6029	0.6034

Table 39. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, IT1 at 15D, flange taps at 9:00.

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	CY2
43112890- 1	3.9791	287.31	47.03	28.326	1.5530	1.0539	0.6022	0.6031
43112890- 2	3.9739	287.96	46.86	28.411	1.5477	1.0487	0.6004	0.6013
43112890- 3	3.8783	286.93	45.90	48.260	1.9966	1.3578	0.5997	0.6013
43112890- 4	3.8804	287.13	45.89	47.983	1.9914	1.3536	0.6000	0.6016
43112890- 5	4.0925	288.39	48.18	6.622	0.7595	0.5134	0.6026	0.6029
43112890- 6	4.0897	288.51	48.12	7.436	0.8063	0.5449	0.6041	0.6043
43112890- 7	4.0239	287.84	47.47	14.129	1.1037	0.7476	0.6037	0.6041
43112890- 8	4.0232	288.07	47.42	14.049	1.0989	0.7440	0.6031	0.6035

Table 40. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, IT1 at 15D, flange taps at 6:00.

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	CY2
43120390- 1	4.0310	286.91	47.72	15.041	1.1394	0.7735	0.6024	0.6029
43120390- 2	4.0293	287.01	47.68	14.917	1.1333	0.7692	0.6019	0.6024
43120390- 3	3.8857	285.62	46.22	49.134	2.0175	1.3763	0.5985	0.6001
43120390- 4	3.8824	286.01	46.12	48.806	2.0058	1.3671	0.5977	0.5993
43120390- 5	3.9698	285.96	47.17	29.555	1.5843	1.0788	0.6005	0.6015
43120390- 6	3.9699	286.23	47.12	29.838	1.5890	1.0813	0.5998	0.6008
43120390- 7	4.1137	287.53	48.59	6.494	0.7548	0.5111	0.6022	0.6024
43120390- 8	4.1116	287.71	48.53	6.320	0.7458	0.5048	0.6036	0.6038

Table 41. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, IT1 at 15D, flange taps at 12:00.

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	CY2
43120390- 1	4.0310	286.91	47.72	15.063	1.1394	0.7735	0.6020	0.6025
43120390- 2	4.0293	287.01	47.68	14.941	1.1333	0.7692	0.6014	0.6019
43120390- 3	3.8857	285.62	46.22	49.171	2.0175	1.3763	0.5983	0.5999
43120390- 4	3.8824	286.01	46.12	48.878	2.0058	1.3671	0.5973	0.5989
43120390- 5	3.9698	285.96	47.17	29.576	1.5843	1.0788	0.6003	0.6013
43120390- 6	3.9699	286.23	47.12	29.869	1.5890	1.0813	0.5995	0.6004
43120390- 7	4.1137	287.53	48.59	6.499	0.7548	0.5111	0.6020	0.6022
43120390- 8	4.1116	287.71	48.53	6.335	0.7458	0.5048	0.6029	0.6031

Table 42. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, FT2 at 15D, flange taps at 3:00.

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	CY2
46120790- 1	3.9697	286.84	47.00	3.300	1.7985	1.2220	0.5959	0.5959
46120790- 2	3.9684	286.79	47.00	3.292	1.7951	1.2198	0.5956	0.5956
46120790- 3	3.8637	286.97	45.72	5.336	2.2491	1.5297	0.5941	0.5943
46120790- 4	3.8591	287.05	45.65	5.315	2.2467	1.5278	0.5951	0.5952
46120790- 5	3.9862	286.86	47.20	2.693	1.6335	1.1097	0.5979	0.5980
46120790- 6	3.9864	286.53	47.26	2.714	1.6371	1.1130	0.5965	0.5966
46120790- 7	3.9173	285.79	46.57	4.278	2.0378	1.3891	0.5958	0.5959
46120790- 8	3.9088	287.17	46.22	4.297	2.0347	1.3824	0.5957	0.5958
46121090- 1	3.8433	286.22	45.61	5.278	2.2444	1.5296	0.5969	0.5970
46121090- 2	3.8346	286.24	45.51	5.278	2.2403	1.5269	0.5964	0.5966
46121090- 3	3.8933	285.84	46.28	4.305	2.0400	1.3907	0.5964	0.5965
46121090- 4	3.8936	285.70	46.30	4.306	2.0412	1.3920	0.5965	0.5966
46121090- 5	3.9704	286.38	47.10	2.587	1.6026	1.0901	0.5992	0.5992
46121090- 6	3.9686	286.36	47.08	2.606	1.6052	1.0920	0.5981	0.5982
46121090- 7	3.9413	286.07	46.81	3.196	1.7710	1.2060	0.5976	0.5976
46121090- 8	3.9409	286.11	46.80	3.200	1.7713	1.2061	0.5974	0.5975

Table 43. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, FT2 at 15D, flange taps at 9:00.

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	CY2
46120790- 1	3.9697	286.84	47.00	3.227	1.7985	1.2220	0.6026	0.6027
46120790- 2	3.9684	286.79	47.00	3.229	1.7951	1.2198	0.6013	0.6013
46120790- 3	3.8637	286.97	45.72	5.236	2.2491	1.5297	0.5998	0.5999
46120790- 4	3.8591	287.05	45.65	5.205	2.2467	1.5278	0.6013	0.6015
46120790- 5	3.9862	286.86	47.20	2.647	1.6335	1.1097	0.6031	0.6031
46120790- 6	3.9864	286.53	47.26	2.665	1.6371	1.1130	0.6019	0.6020
46120790- 7	3.9173	285.79	46.57	4.189	2.0378	1.3891	0.6021	0.6022
46120790- 8	3.9088	287.17	46.22	4.215	2.0347	1.3824	0.6015	0.6016
46121090- 1	3.8433	286.22	45.61	5.165	2.2444	1.5296	0.6034	0.6035
46121090- 2	3.8346	286.24	45.51	5.170	2.2403	1.5269	0.6027	0.6028
46121090- 3	3.8933	285.84	46.28	4.213	2.0400	1.3907	0.6029	0.6030
46121090- 4	3.8936	285.70	46.30	4.211	2.0412	1.3920	0.6032	0.6033
46121090- 5	3.9704	286.38	47.10	2.539	1.6026	1.0901	0.6048	0.6048
46121090- 6	3.9686	286.36	47.08	2.547	1.6052	1.0920	0.6049	0.6050
46121090- 7	3.9413	286.07	46.81	3.135	1.7710	1.2060	0.6034	0.6034
46121090- 8	3.9409	286.11	46.80	3.130	1.7713	1.2061	0.6039	0.6040

Table 44. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, FT2 at 15D, flange taps at 3:00.

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	CY2
43120790- 2	3.9686	286.14	47.12	28.588	1.5613	1.0627	0.6021	0.6030
43120790- 3	4.0128	287.18	47.46	14.478	1.1177	0.7585	0.6040	0.6045
43120790- 4	4.0098	287.11	47.43	14.457	1.1124	0.7550	0.6017	0.6022
43120790- 5	3.8814	285.48	46.20	46.320	1.9642	1.3404	0.6004	0.6019
43120790- 6	3.8782	285.43	46.17	46.085	1.9575	1.3361	0.6001	0.6016
43120790- 7	3.9590	285.78	47.07	29.194	1.5726	1.0714	0.6004	0.6014
43120790- 8	4.0983	287.59	48.39	6.118	0.7330	0.4964	0.6038	0.6040
43120790- 9	4.0982	287.72	48.37	6.812	0.7723	0.5228	0.6029	0.6031
43120790- 1	3.9388	286.18	46.76	34.066	1.6937	1.1531	0.6005	0.6016
43120790- 2	4.0136	287.26	47.45	10.476	0.9478	0.6430	0.6023	0.6026
43121090- 1	4.0376	286.95	47.79	15.224	1.1447	0.7769	0.6011	0.6016
43121090- 2	4.0371	287.22	47.74	15.216	1.1457	0.7771	0.6021	0.6026
43121090- 3	3.8989	285.40	46.42	47.242	1.9810	1.3519	0.5981	0.5997
43121090- 4	3.8760	285.58	46.12	47.026	1.9699	1.3441	0.5981	0.5996
43121090- 5	4.1107	287.29	48.60	7.011	0.7862	0.5327	0.6037	0.6039
43121090- 6	4.1109	287.57	48.55	6.769	0.7752	0.5249	0.6060	0.6063
43121090- 7	3.9767	286.40	47.17	27.367	1.5275	1.0389	0.6018	0.6027
43121090- 8	3.9779	286.42	47.18	27.212	1.5197	1.0335	0.6003	0.6012

Table 45. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, FT2 at 15D, flange taps at 9:00.

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	CY2
43120790- 2	3.9686	286.14	47.12	28.534	1.5613	1.0627	0.6027	0.6036
43120790- 3	4.0128	287.18	47.46	14.462	1.1177	0.7585	0.6044	0.6048
43120790- 4	4.0098	287.11	47.43	14.433	1.1124	0.7550	0.6022	0.6027
43120790- 5	3.8814	285.48	46.20	46.219	1.9642	1.3404	0.6010	0.6026
43120790- 6	3.8782	285.43	46.17	45.958	1.9575	1.3361	0.6009	0.6024
43120790- 7	3.9590	285.78	47.07	29.145	1.5726	1.0714	0.6009	0.6019
43120790- 8	4.0983	287.59	48.39	6.107	0.7330	0.4964	0.6043	0.6045
43120790- 9	4.0982	287.72	48.37	6.802	0.7723	0.5228	0.6034	0.6036
43121090- 1	4.0376	286.95	47.79	15.204	1.1447	0.7769	0.6015	0.6020
43121090- 2	4.0371	287.22	47.74	15.189	1.1457	0.7771	0.6027	0.6032
43121090- 3	3.8989	285.40	46.42	47.100	1.9810	1.3519	0.5990	0.6006
43121090- 4	3.8760	285.58	46.12	46.892	1.9699	1.3441	0.5989	0.6005
43121090- 5	4.1107	287.29	48.60	6.993	0.7862	0.5327	0.6044	0.6047
43121090- 6	4.1109	287.57	48.55	6.751	0.7752	0.5249	0.6069	0.6071
43121090- 7	3.9767	286.40	47.17	27.322	1.5275	1.0389	0.6023	0.6032
43121090- 8	3.9779	286.42	47.18	27.163	1.5197	1.0335	0.6009	0.6018

Table 46. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, FT4 at 15D, flange taps at 3:00.

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	CY2
46121290- 1	3.8673	284.96	46.12	5.085	2.2103	1.5106	0.5956	0.5957
46121290- 2	3.8676	285.45	46.04	5.061	2.2004	1.5020	0.5948	0.5949
46121290- 3	3.9576	285.49	47.11	3.213	1.7831	1.2157	0.5981	0.5982
46121290- 4	3.9557	286.93	46.82	3.241	1.7789	1.2086	0.5959	0.5960
46121290- 5	3.9879	286.06	47.36	2.527	1.5852	1.0789	0.5979	0.5980
46121290- 6	3.9894	286.03	47.39	2.531	1.5856	1.0792	0.5975	0.5975
46121290- 7	3.9268	286.94	46.48	4.232	2.0252	1.3764	0.5959	0.5960
46121290- 8	3.9093	286.24	46.40	4.227	2.0195	1.3752	0.5950	0.5951
46040891- 1	3.9301	286.66	46.57	4.120	2.0056	1.3640	0.5975	0.5976
46040891- 2	3.9093	285.44	46.54	4.089	1.9958	1.3617	0.5970	0.5971
46040891- 3	3.8350	286.77	45.42	5.121	2.2026	1.4993	0.5959	0.5961
46040891- 4	3.8384	285.73	45.64	5.080	2.1994	1.5009	0.5960	0.5962
46040891- 5	3.9675	285.83	47.16	2.545	1.5903	1.0832	0.5990	0.5991
46040891- 6	3.9688	286.47	47.06	2.578	1.6014	1.0891	0.5999	0.6000
46040891- 7	3.9373	285.98	46.78	3.216	1.7798	1.2123	0.5988	0.5989
46040891- 8	3.9360	286.45	46.68	3.226	1.7812	1.2119	0.5990	0.5991
46040891- 9	3.9357	286.44	46.67	3.216	1.7811	1.2119	0.5999	0.6000

Table 47. Measured and calculated quantities for 0.73 beta ratio, tee at 17D, FT4 at 15D, flange taps at 9:00.

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	CY2
46121290- 1	3.8673	284.96	46.12	4.974	2.2103	1.5106	0.6021	0.6023
46121290- 2	3.8676	285.45	46.04	4.955	2.2004	1.5020	0.6011	0.6013
46121290- 3	3.9576	285.49	47.11	3.151	1.7831	1.2157	0.6040	0.6041
46121290- 4	3.9557	286.93	46.82	3.177	1.7789	1.2086	0.6019	0.6019
46121290- 5	3.9879	286.06	47.36	2.486	1.5852	1.0789	0.6029	0.6030
46121290- 6	3.9894	286.03	47.39	2.491	1.5856	1.0792	0.6022	0.6023
46121290- 7	3.9268	286.94	46.48	4.157	2.0252	1.3764	0.6012	0.6013
46121290- 8	3.9093	286.24	46.40	4.135	2.0195	1.3752	0.6017	0.6018
46040891- 1	3.9301	286.66	46.57	4.075	2.0056	1.3640	0.6008	0.6009
46040891- 2	3.9093	285.44	46.54	4.038	1.9958	1.3617	0.6008	0.6009
46040891- 3	3.8350	286.77	45.42	5.053	2.2026	1.4993	0.5999	0.6001
46040891- 4	3.8384	285.73	45.64	5.010	2.1994	1.5009	0.6002	0.6003
46040891- 5	3.9675	285.83	47.16	2.524	1.5903	1.0832	0.6014	0.6015
46040891- 6	3.9688	286.47	47.06	2.556	1.6014	1.0891	0.6026	0.6026
46040891- 7	3.9373	285.98	46.78	3.178	1.7798	1.2123	0.6023	0.6024
46040891- 8	3.9360	286.45	46.68	3.183	1.7812	1.2119	0.6030	0.6030
46040891- 9	3.9357	286.44	46.67	3.184	1.7811	1.2119	0.6029	0.6030

Table 48. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, FT4 at 15D, flange taps at 3:00.

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	CY2
43121190- 1	4.0143	286.67	47.57	14.503	1.1157	0.7580	0.6017	0.6022
43121190- 2	4.0102	286.73	47.51	14.503	1.1157	0.7579	0.6021	0.6026
43121190- 3	3.8728	286.71	45.88	47.474	1.9741	1.3433	0.5981	0.5996
43121190- 4	3.8744	286.64	45.91	47.286	1.9717	1.3419	0.5983	0.5999
43121190- 5	3.9596	285.75	47.08	28.324	1.5469	1.0540	0.5996	0.6005
43121190- 6	3.9578	286.13	46.99	28.630	1.5539	1.0578	0.5996	0.6005
43121190- 7	4.0911	287.53	48.32	7.198	0.7958	0.5390	0.6047	0.6050
43121190- 8	4.0984	287.48	48.42	7.161	0.7966	0.5396	0.6064	0.6066
43121290- 1	3.9839	286.51	47.24	28.345	1.5462	1.0513	0.5981	0.5990
43121290- 2	3.9812	286.64	47.18	28.353	1.5482	1.0523	0.5991	0.6000
43121290- 3	4.1404	287.42	48.93	6.197	0.7400	0.5011	0.6024	0.6026
43121290- 4	4.1158	287.61	48.60	7.438	0.8078	0.5469	0.6022	0.6024
43121290- 5	3.8808	285.34	46.21	46.971	1.9675	1.3432	0.5971	0.5987
43121290- 6	3.8858	286.48	46.07	47.028	1.9664	1.3386	0.5973	0.5988
43121290- 7	4.0210	286.42	47.69	15.232	1.1439	0.7775	0.6011	0.6016
43121290- 8	4.0181	286:61	47.62	15.268	1.1440	0.7773	0.6010	0.6015

Table 49. Measured and calculated quantities for 0.43 beta ratio, tee at 17D, FT4 at 15D, flange taps at 9:00.

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	CY2
43121190- 1	4.0143	286.67	47.57	14.538	1.1157	0.7580	0.6010	0.6014
43121190- 2	4.0102	286.73	47.51	14.540	1.1157	0.7579	0.6013	0.6018
43121190- 3	3.8728	286.71	45.88	47.358	1.9741	1.3433	0.5988	0.6004
43121190- 4	3.8744	286.64	45.91	47.209	1.9717	1.3419	0.5988	0.6004
43121190- 5	3.9596	285.75	47.08	28.307	1.5469	1.0540	0.5997	0.6007
43121190- 6	3.9578	286.13	46.99	28.619	1.5539	1.0578	0.5997	0.6007
43121190- 7	4.0911	287.53	48.32	7.235	0.7958	0.5390	0.6032	0.6034
43121190- 8	4.0984	287.48	48.42	7.195	0.7966	0.5396	0.6049	0.6051
43121290- 1	3.9839	286.51	47.24	28.280	1.5462	1.0513	0.5988	0.5997
43121290- 2	3.9812	286.64	47.18	28.278	1.5482	1.0523	0.5999	0.6008
43121290- 3	4.1404	287.42	48.93	6.187	0.7400	0.5011	0.6029	0.6031
43121290- 4	4.1158	287.61	48.60	7.418	0.8078	0.5469	0.6030	0.6033
43121290- 5	3.8808	285.34	46.21	46.818	1.9675	1.3432	0.5981	0.5996
43121290- 6	3.8858	286.48	46.07	46.888	1.9664	1.3386	0.5982	0.5997
43121290- 7	4.0210	286.42	47.69	15.200	1.1439	0.7775	0.6018	0.6023
43121290- 8	4.0181	286.61	47.62	15.241	1.1440	0.7773	0.6015	0.6020

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11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

Current research is being conducted to provide information which will be used to improve the existing industry standards for proper installation of orifice meters. This research includes experimental investigation of a Zanker, an etoile, and several tube bundle flow conditioners at various positions relative to the orifice plate. Also included are the effects of pressure tap location, both with and without flow conditioning, as reflected in determination of discharge coefficients.

Of the flow conditioners tested at approximately 11 pipe diameters upstream of the orifice plate, the Zanker flow conditioner resulted in discharge coefficients most similar to baseline values. There was only a slight difference in orifice meter performance when a flanged or an in-line tube bundle flow conditioner was used at the tested location upstream of the orifice plate. The effect of pressure tap location was found to be significant with the 0.73 beta ratio plate. Recommendations for future research, as a result of these findings, are included.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

discharge coefficient; etoile; flow conditioner; flow disturbance; flow measurement; gas; orifice flowmeter; tap location; tube bundle; Zanker

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