Conditioning Orifice Plate Technology; Taking the Standard to a New Level of Capability

Conditioning Orifice Plates, the 1595 Conditioning Orifice Plate and the 405C Compact Conditioning Orifice Plate, are differential pressure producers used to measure rate of fluid flow in a pipe. Conditioning Orifice Plate Technology is based on the same Bernoulli streamline energy equation and as a result follows the same Discharge Coefficient versus Reynolds Number relationship as standard orifice plates. Standard orifice plates are typically specified and installed according to one of three standards; AGA Report Number 3, ASME MFC 3M or ISO 5167. Although the Conditioning Orifice Plate was designed as closely as possible to these standards, there are four areas of departure. These differences allow greater flexibility in installation and better performance over a wide variety of conditions, including:

- Superior performance.
- Installation in short straight pipe run, tight fit applications.
- Improved performance in wet gas applications by allowing condensate to pass and preventing the “damming” affect suffered by standard orifice plates. None of the three standards provide allowances for drain vent holes in the orifice plate.

Figure 1: 3051SFC Conditioning Orifice Flowmeter

The conditioning orifice plate varies from the existing orifice plate standards in four ways:

- Plate thickness
- Orifice / Beta
- Piping Requirements
- Accuracy

Figure 2: 1595 Conditioning Orifice Plate

Figure 3: Standard Orifice Plate

Conditioning Orifice Plate

Table 1 depicts a comparison between conditioning orifice plate technology and standard orifice plate technology, highlighting the deviations from the standards. These deviations allow for a more flexible installation as straight pipe requirements are reduced in some cases by as much as 96%.

Table 1: The Conditioning Orifice Plate as compared to the orifice plate standards.

Category	1595 and 405C Conditioning Orifice Plate Technology			
Total Straight Pipe Run Requirements	**1595 and 405C**	**ASME MFC 3M**	**AGA Report Number 3**	**ISO 5167**
Upstream (In Pipe Diameters)	2	Up to 54	Up to 95	Up to 60
Downstream (In Pipe Diameters)	2	5	4.2	7
Flow Conditioners	Not Required. All three standards sometimes require flow conditioners to shorten required straight pipe run.			
Pressure Taps				
Flange Taps	Complies with all three standards.			
Corner Taps	Complies with ASME and ISO. Corner taps not included in AGA Report Number 3.			
D and D/2	In development.			
O-Plate Thickness				
2” to 4”	Complies with all three Standards.			
6”	Compliant to ASME MFC 3M and ISO 5167. Thicker than AGA Report Number 3.			
8” to 24”	Complies with all three Standards.			
Beta	Area of 4 holes = Area of same ß for standard orifice of all three standards. (1)			
All other plate dimensions (Including angle of bevel, bore thickness (e), etc.)	Complies with all three Standards.			
Surface Finish	Complies with all three Standards.			
Discharge Coefficient Uncertainty	Follows ISO 5167. (2)			
Expansion Factor	Follows ISO 5167.			

(1) At Schedule Standard
(2) Follows ISO 5167 with a bias shift – The bias is determined in a calibration flow lab and factored into the DP bore calculation.

Plate Thickness

Table 2 depicts the plate thicknesses of Conditioning Orifice Plates and the thickness ranges for standard orifice plates as dictated by the three standards. The plate thicknesses for the 1595 and 405C Conditioning Orifice Plates fall within the values provided in all three standards with one exception, the AGA Report Number 3 standard for the 6" line. In the cases of non-compliance, the important aspect as pertaining to plate thickness is that the Conditioning Orifice Plates are thicker than the standard orifice plates. This helps prevent plate deflection under higher flow rates and leads to a more accurate flow measurement.

Table 2: Plate Thickness

			ASME MFC 3M		AGA Report Number 3		ISO 51767	
Line Size	1595 Conditioning Orifice Plate	405C Compact Conditioning Orifice Plate	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
2 in (50.8 mm)	0.125 in (3.2 mm)	0.125 in (6.4 mm)	0.120 in (3.1 mm)	0.180 in (4.6 mm)	0.115 in (2.9 mm)	0.130 in (3.3 mm)	0.008 in (0.2 mm)	0.125 in (3.2 mm)
3 in (76.2 mm)	0.125 in (3.2 mm)	0.125 in (6.4 mm)	0.120 in (3.1 mm)	0.180 in (4.6 mm)	0.115 in (2.9 mm)	0.130 in (3.3 mm)	0.012 in (0.3 mm)	0.158 in (4.0 mm)
4 in (101.6 mm)	0.125 in (3.2 mm)	0.125 in (6.4 mm)	0.120 in (3.1 mm)	0.180 in (4.6 mm)	0.115 in (2.9 mm)	0.130 in (3.3 mm)	0.017 in (0.4 mm)	0.206 in (5.2 mm)
6 in (152.4 mm)	**0.250 in (6.4 mm)**	**0.250 in (6.4 mm)**	0.120 in (3.1 mm)	0.275 in (7.0 mm)	0.115 in (2.9 mm)	0.192 in (4.9 mm)	0.026 in (0.7 mm)	0.310 in (7.9 mm)
8 in (203.2 mm)	0.250 in (6.4 mm)	0.250 in (6.4 mm)	0.120 in (3.1 mm)	0.275 in (7.0 mm)	0.115 in (2.9 mm)	0.319 in (8.1 mm)	0.036 in (0.9 mm)	0.413 in (10.5 mm)
10 in (254.0 mm)	0.250 in (6.4 mm)		0.120 in (3.1 mm)	0.500 in (12.7 mm)	0.115 in (2.9 mm)	0.319 in (8.1 mm)	0.044 in (1.1 mm)	0.520 in (13.2 mm)
12 in (304.8 mm)	0.250 in (6.4 mm)		0.183 in (4.6 mm)	0.500 in (12.7 mm)	0.175 in (4.4 mm)	0.398 in (10.1 mm)	0.053 in (1.3 mm)	0.620 in (15.8 mm)
14 in (355.0 mm)	0.350 in (8.9 mm)		0.183 in (4.6 mm)	0.500 in (12.7 mm)	0.175 in (4.4 mm)	0.398 in (10.1 mm)	0.058 in (1.5 mm)	0.683 in (17.3 mm)
16 in (406.4 mm)	0.350 in (8.9 mm)		0.183 in (4.6 mm)	0.500 in (12.7 mm)	0.175 in (4.4 mm)	0.500 in (12.7 mm)	0.067 in (1.7 mm)	0.783 in (19.9 mm)
18 in (457.2 mm)	0.350 in (8.9 mm)		0.183 in (4.6 mm)	0.500 in (12.7 mm)	0.175 in (4.4 mm)	0.500 in (12.7 mm)	0.075 in (1.9 mm)	0.883 in (22.4 mm)
20 in (508.0 mm)	0.350 in (8.9 mm)		0.183 in (4.6 mm)	0.500 in (12.7 mm)	0.240 in (6.1 mm)	0.505 in (12.8 mm)	0.083 in (2.1 mm)	0.984 in (25.0 mm)
24 in (609.6 mm)	0.500 in (12.7 mm)		0.245 in (6.2 mm)	0.500 in (12.7 mm)	0.240 in (6.1 mm)	0.562 in (14.3 mm)	0.100 in (2.5 mm)	1.184 in (30.1 mm)

NOTE

The values that are in **Bold** reflect the deviation from the standards.

Conditioning Orifice Plate

Orifice / Beta

The most obvious difference between standard orifice plates and the Conditioning Orifice Plates is four holes versus a single hole. These four holes are placed tangent to the pipe wall, leaving a metal section of the plate in the center of the pipe. This causes the flow to condition itself as it is forced through the four holes thereby removing the requirement for a flow conditioner. Because of this phenomenon, Conditioning Orifice Plates provide superior performance in short straight pipe run and tight fit applications.

Standard orifice plates are sized to a beta from 0.1 to 0.75, beta = d/D, where "d" is the bore size and "D" is the internal diameter of the pipe/meter tube. The 1595 and 405C Conditioning Orifice Plates are designed with 2 standard bore sizes, one for high flow rates and one for low flow rates. These standard bore sizes are fixed and do not change with pipe schedule. We refer to the two different bore sizes as betas because the sum of the area of the four bores is equivalent to the area of a bore "d" in the standard equation "beta = d/D" for a schedule standard pipe. In a schedule standard pipe, the bores equal betas of 0.4 and 0.65. The fixed bores or beta ratios make it easier to specify and order while reducing inventory.

Also a concern for orifice plate is centering. The orifice must be centered or conditions may arise that negatively affect accuracy. The 405C Compact Conditioning Orifice Plate is supplied with a centering ring and assures a centered plate to within 1/32". If the orifice plate, whether it is a Conditioning Orifice Plate or a standard orifice plate, is not centered, there can be as much as 5% degradation in accuracy.

Piping Requirements

Standard orifice plates require significant straight pipe to assure an accurate flow measurement while conditioning plate technology requires only 4 diameters of straight pipe. This equates to significant savings in pipe material costs and allows flexibility in determining flowmeter placement. There are dramatic savings to be obtained when purchasing pipe, in some cases there is up to a 96% reduction in straight pipe requirements.

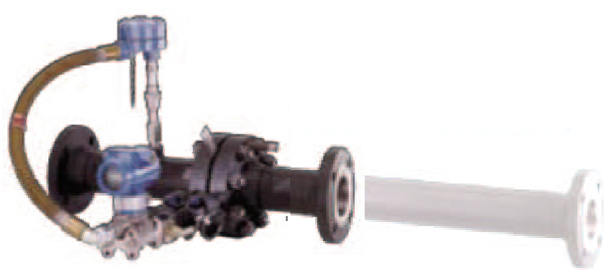


Figure 4: Conditioning Orifice Plates can reduce piping requirements by as much as 96%

Table 3 demonstrates that the 1595 and 405C Conditioning Orifice Plates require just 2 diameters upstream and downstream. The values in *Italics* are the reduction in pipe requirements if a Conditioning Orifice Plate is used instead of a standard orifice plate. The **(Bold)** values in the tables reflect the straight pipe requirement if a flow conditioner is installed.

Table 3: Straight pipe required in pipe diameters

	Beta = 0.4	Conditioning Orifice Plate	ASME MFC 3M	AGA Report Number 3	ISO 5167
Upstream	Single 90 Degree Bend	2	14 *86%*	16 *88%*	16 *88%*
Upstream	Single Tee	2	14 *86%*	9 *78%*	9 *78%*
Upstream	Two or more Bends in the same plane	2	18 **(17)** *89%* ***(88%)***	10 *80%*	10 *80%*
Upstream	Two or more Bends in a different plane	2	36 **(19)** *94%* ***(89%)***	50 **(29)** *96%* ***(93%)***	50 **(30)** *96%* ***(93%)***
Upstream	Reducer	2	10 *80%*	6 *67%*	5 *60%*
Upstream	Valve	2	12 *83%*	21 *90%*	12 *83%*
Downstream		2	5 *60%*	3.2 *38%*	6 *67%*

	Beta = 0.65	Conditioning Orifice Plate	ASME MFC 3M	AGA Report Number 3 [(1)]	ISO 5167 [(1)]
Upstream	Single 90 Degree Bend	2	22 *91%*	44 **(29)** *95%* ***(93%)***	44 **(30)** *95%* ***(93%)***
Upstream	Single Tee	2	22 *91%*	44 **(29)** *95%* ***(93%)***	36 **(30)** *94%* ***(93%)***
Upstream	Two or more Bends in the same plane	2	32 **(22)** *94%* ***(91%)***	44 **(29)** *95%* ***(93%)***	44 **(30)** *95%* ***(93%)***
Upstream	Two or more Bends in a different plane	2	54 **(25)** *96%* ***(92%)***	95 **(29)** *98%* ***(93%)***	60 **(30)** *97%* ***(93%)***
Upstream	Reducer	2	12 *83%*	11 *82%*	12 *83%*
Upstream	Valve	2	16 *88%*	35 **(29)** *94%* ***(93%)***	18 *89%*
Downstream		2	5 *60%*	4.2 *48%*	7 *71%*

[(1)]The piping requirements specified are for Beta = 0.67.

NOTE

The values in *Italics* reflect the reduction in straight pipe requirements.
The values in **(Bold)** reflect the piping requirements if a 19-tube bundle flow straightener is used.

Accuracy

The innovative technology and design of the Conditioning Orifice Plate enables multiple benefits without compromising performance. The Conditioning Orifice Plate follows the discharge coefficient of the ISO 5167-2:2003(E) with a bias. This bias is determined at the time of manufacture and factored into the bore calculation. With just 4 diameters (2 up and 2 down) of straight piping, the discharge coefficient uncertainty (U_{Cd}) follows the uncertainty of the standard orifice plate when installed according to the relevant standard. This has been verified in independent test laboratories. Results can be found in the *Rosemount 405 Compact Orifice Flowmeter Series and 1595 Conditioning Orifice Plate Flow Test Data Book and Flow Handbook*, part number 00821-0100-4810.

Tables 4 - 6 and Equation 1 depict the discharge coefficient uncertainties for all orifice plates according to typical standards. Graphs 1 and 2 illustrate the discharge coefficient uncertainties, comparing the standard orifice plates (with sufficient straight pipe run) against the Conditioning Orifice Plate (with 2 diameters of straight pipe run immediately after a flow disturbance). The end result is that the Conditioning Orifice Plate rivals the performance of the standard orifice plates while virtually eliminating straight pipe run requirements. With sufficient straight run, the accuracy curve of the Conditioning Orifice Plate would follow the ISO 5167 standard.

Table 4: Conditioning Orifice Technology Discharge Coefficient Uncertainty

Beta	Reynolds Number < 10,000	Reynolds Number > 10,000
0.4	U_{Cd} = 1.0%	U_{Cd} = 0.5%
0.65	U_{Cd} = 1.25%	U_{Cd} = 0.75%

Table 5: AMSE MFC-3M – 1989 Discharge Coefficient Uncertainty (Section 7.3.2.1)

R_D	0.2 < Beta (b) < 0.6	0.6 < Beta (b) < 0.75
$10{,}000 < R_D < 10^8$	U_{Cd} = 0.60%	U_{Cd} = (β)%
$2{,}000 < R_D < 10{,}000$	U_{Cd} = (0.6 + β)%	

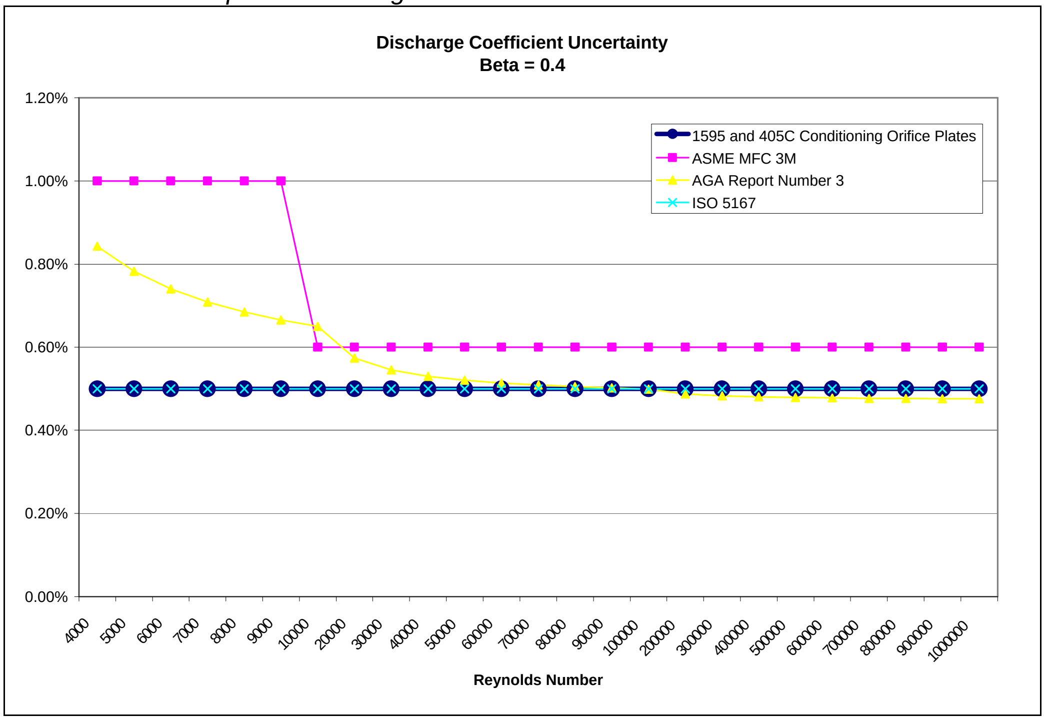
Table 6: ISO 5167-2:2003(E) Discharge Coefficient Uncertainty (Section 5.3.3.1)

Beta (b)	Reynolds Number < 10,000	Reynolds Number > 10,000
0.2 < β < 0.5	U_{Cd} = 0.5%	U_{Cd} = 0.5%
0.5 < β < 0.6	U_{Cd} = 1.0%	U_{Cd} = 0.5%
0.6 < β < 0.75	U_{Cd} = (1.667 * β)%	U_{Cd} = (1.667 * β - 0.5)%

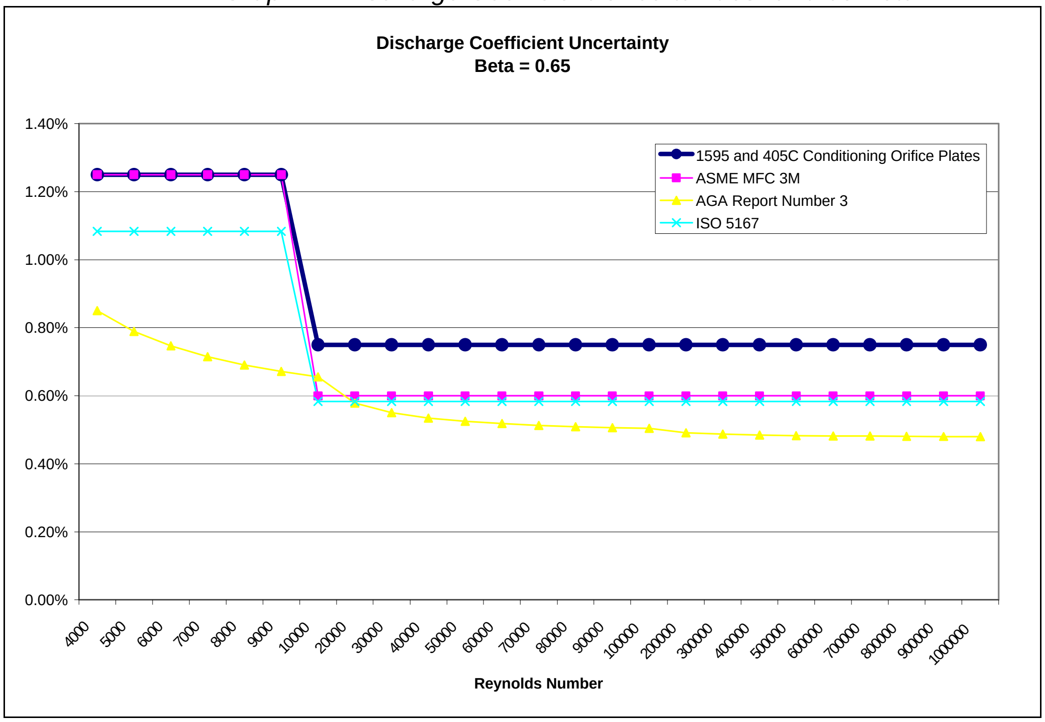
Equation 1: AGA Report Number 3 Discharge Coefficient Uncertainty (Section 1.12.4.1 in Part 1)

$$U_{Cd} = \left[0.5600 - 0.2550 * b + 1.9316 * b^{8}\right] * \left[1 + 0.7895 * \left(\frac{4000}{\mathrm{Re}_D}\right)^{0.8}\right] \%$$

Graph 1: Discharge Coefficient Uncertainties for 0.4 Beta



Graph 2: Discharge Coefficient Uncertainties for 0.65 Beta



Conditioning Orifice Plate

Summary

The Conditioning Orifice Plate is a revolutionary innovative technology based on the most common differential primary element in the industry. While not complying with the standards of AGA Report Number 3, ASME MFC 3M or ISO 5167, it is designed based on those standards and provides superior performance in short straight pipe run, tight fit applications with upstream flow disturbances.

- Requires 2 diameters upstream of a flow disturbance and 2 diameters downstream.
    - Decreased straight runs can lower installed cost.
    - Provides flexibility of flowmeter placement and design.
- Compact design reduces installation costs as compared to standard orifice plates.
- Highly accurate and repeatable primary elements.
- Simplified ordering and reduction in inventory, only two betas to choose; one for high flows, one for low flows.
- Suitable for most gas, liquid and steam applications.

Whether compliance to a standard is required or if it is not required, Emerson Process Management has the flowmeter to fit the application.

Figure 5: The Emerson Process Orifice Offering

Emerson Process Management.

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