

## A REVIEW OF API MPMS CHAPTER 14.3/AGA REPORT NO. 3 - PART 2

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### Introduction

This paper described the current contents of the United States orifice flow metering standard - American Petroleum Institute (API) Manual of Petroleum Measurement Standards (MPMS) Chapter 14.3, "Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids," Part 2, "Specification and Installation Requirements."<sup>[1]</sup> This document is also known as American Gas Association Report No. 3, Part 2.<sup>[2]</sup> As of the writing of this paper (i.e., May 2015), this standard was in its fourth edition, second printing. It was last revised in April 2000 and is in the process of being revised again. The revised document is currently in the ballot process at API and it is anticipated that the new version likely will be published by the end of 2015.

API MPMS, Chapter 14.3, includes four parts:

- Part 1: General Equations and Uncertainty Guidelines
- Part 2: Specification and Installation Requirements
- Part 3: Natural Gas Applications
- Part 4: Background, Development Implementation Procedure

The focus of this paper is Part 2 of the standard.

As a brief history of the development of API MPMS, Chapter 14.3, Part 2, research on orifice flow meters began in the U.S. around 1904. Thomas Weymouth published an ASME paper in 1912 describing results of a series of flow experiments dating to 1904 that he had performed on a flange tap orifice meter. Orifice meter research by what was known at the time as the National Bureau of Standards (NBS) (now known as the National Institute of Standards and Technology (NIST)) and others continued through the late 1920s. The *first* U.S. metering standard was produced by the American Gas Association in 1930...AGA Report No. 1 (which later evolved into API MPMS, Chapter 14.3 or AGA Report No. 3) for orifice flow meters. This followed publication of a preliminary report published in 1927 and revised in 1929.

AGA Report No. 2 was published in 1935. Key enhancements in Report No. 2 were improved orifice

coefficients based on a larger experimental dataset and the addition of supercompressibility factors for natural gas.

AGA Report No. 3 was first published in 1955 and incorporated an even larger experimental dataset than did Report No. 2. Report No. 3 was first revised in 1969, and subsequently revised again in 1985, 1992, and 2000. The API first adopted AGA Report No. 3 as a standard in 1975 and the American National Standards Institute (ANSI) first recognized the document as a national standard in 1977.

Much of the critical research related to the development of Part 2 of API MPMS, Chapter 14.3 is briefly described in Appendix 2-A of the standard. Appendix 2-A cites over 200 separate research studies performed on orifice flow meters between 1922 and 2000.

### Scope of the Standard

The scope of API MPMS, Chapter 14.3, Part 2 currently includes the following:

- Construction and Installation Requirements
- Symbols and Nomenclature
- Definitions
- Orifice Plate Specifications
- Meter Tube Specifications
- Installation Requirements
- Appendices
  - 2-A - Research Projects and Tests Conducted Between 1922 and 1999
  - 2-B - Orifice Meter Inspection Guidelines
  - 2-C - Specific Installation Calibration Test
  - 2-D - Flow Conditioner Performance Test
  - 2-E - Maximum Allowable Orifice Plate Differential Pressure
  - 2-F - Guidelines for Using High Differential Pressures for Measuring Natural Gas with Orifice Meters
- Addendum 1
- Addendum 2
- References

The following sections describe the principal contents of API MPMS, Chapter 14.3, Part 2.

**Construction and Installation Requirements (Section 2.1)**

This section notes that Part 2 includes the mechanical tolerances for the flow meter assembly required to ensure accurate flow measurement and the potential for measurement error associated with not maintaining the meter within the specified tolerances. This section also includes a “grandfather” clause, which essentially gives the flow meter operator/owner the discretion to decide whether or not to upgrade a given flow meter to the most current specifications whenever a new revision to Part 2 is published. If the operator chooses *not* to upgrade the meter to the latest specifications, additional flow measurement bias errors *may* result - possibly because of inadequate flow conditioning and upstream straight pipe length.

This section also provides cautionary guidance on diameter ratio (i.e., the ratio of the orifice bore diameter to the meter tube diameter,  $\beta_r$ ) limits, and maintenance and upkeep of the flow meter to help ensure accurate flow measurement. (Diameter ratio is also sometimes referred to as beta ratio.)

**Symbols and Nomenclature (Section 2.2)**

This section provides definitions for all parameters used in the equations, figures, and tables referenced in Part 2.

**Definitions (Section 2.3)**

This section provides definitions for the key terms referenced in Part 2, such as *orifice plate*, *meter tube*, *diameter ratio*, and *flow conditioner*, among others.

**Orifice Plate Specifications (Section 2.4)**

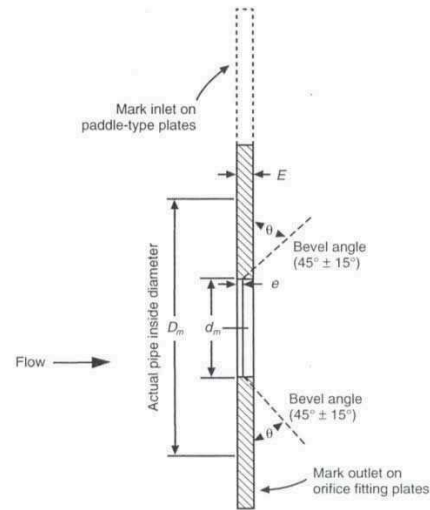
This section provides dimensional tolerances for the key components of an orifice flow meter assembly. This includes tolerances for the following:

- Orifice plate faces
- Orifice plate bore edges
- Orifice plate bore diameter ( $d_m$ ) and roundness ( $d_r$ )
- Orifice plate bore thickness ( $e$ )
- Orifice plate thickness ( $E$ )
- Orifice plate bevel angle ( $\theta$ )

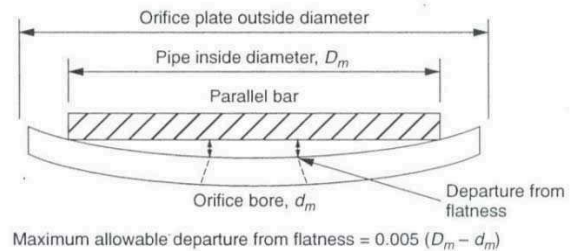
The symbols for orifice plate dimensions are shown in Figure 2-1 of Part 2.

The flatness of the orifice plate and the roundness of the bore in the plate are two critical parameters that influence the accuracy of the flow measurement. Allowable tolerances for both of these parameters are included in Section 2.4. Figure 2-2 illustrates the allowable departure

from flatness for the orifice plate. (Note that the figures and tables included in this paper were directly excerpted from API MPMS, Chapter 14.3, Part 2 (Fourth Edition)).



**Figure 2-1. Symbols for Orifice Plate Dimensions**



**Figure 2-2a. Orifice Plate Departure from Flatness (Measured at the edge of orifice bore and within inside pipe diameter)**

Orifice Bore Diameter, $d_m$ (inches)	Tolerance ( $\pm$ inches)
$\leq 0.250^a$	0.0003
0.251 – 0.375 <sup>a</sup>	0.0004
0.376 – 0.500 <sup>a</sup>	0.0005
0.501 – 0.625	0.0005
0.626 – 0.750	0.0005
0.751 – 0.875	0.0005
0.876 – 1.000	0.0005
$> 1.000$	0.0005 inch per inch of diameter

Note: <sup>a</sup>Use of diameters below 0.45 inch is not prohibited, but may result in uncertainties greater than those specified in AGA Report No.3, Part 1.

**Table 2-1. Roundness Tolerance for Orifice Plate Bore Diameter,  $d_m$**

There are also allowable tolerances for the orifice plate bore thickness,  $e$ , and the orifice plate thickness,  $E$ .

The *minimum* allowable bore thickness is specified as  $e \geq 0.01d_r$  or  $e > 0.005$  inches, whichever is larger, where  $d_r$  is the bore radius. The *maximum* allowable bore thickness is specified as  $e \leq 0.02D_r$ , where  $D_r$  is the actual meter tube inside radius, or  $e \leq 0.125d_r$ , whichever is

smaller; but  $e$  shall not be greater than the maximum allowable orifice plate thickness,  $E$ .

The minimum, maximum, and recommended values for orifice plate thickness,  $E$ , and allowable range of differential pressure across the orifice plate are provided in Table 2-3. Note that the maximum allowable differential pressure is limited to 1,000 inches of water column, which is the limit of the coefficient of discharge

database. The maximum allowable differential pressure for the recommended orifice plate thicknesses shown in Table 2-3 are for a maximum operating temperature of 150°F. Additional guidance of allowable differential pressure across the orifice plate is provided in Appendices 2-E and 2-F of Part 2. Guidance is also provided in Section 2.4 for estimating the permanent pressure loss across an orifice plate.

Nominal Pipe Size (NPS) (inches)	Published Inside Pipe Diameter (inches)	Orifice Plate Thickness, $E$ (inches)			Maximum Allowable $\Delta P$ ("H <sub>2</sub> O)	Maximum Allowable $\Delta P$ ("H <sub>2</sub> O)
		Minimum	Maximum	Recommended	Orifice Fitting	Orifice Flanges
2	1.687	0.115	0.130	0.125	1000	1000
	1.939	0.115	0.130	0.125	1000	1000
	2.067	0.115	0.130	0.125	1000	1000
3	2.300	0.115	0.130	0.125	1000	1000
	2.624	0.115	0.130	0.125	1000	1000
	2.900	0.115	0.130	0.125	1000	1000
	3.068	0.115	0.130	0.125	1000	1000
	3.152	0.115	0.130	0.125	1000	1000
4	3.438	0.115	0.130	0.125	1000	1000
	3.826	0.115	0.130	0.125	1000	1000
	4.026	0.115	0.130	0.125	1000	1000
	4.897	0.115	0.163	0.125	345	1000
6	5.187	0.115	0.163	0.125	345	1000
	5.761	0.115	0.192	0.125	345	1000
	6.065	0.115	0.192	0.125	345	1000
	7.625	0.115	0.254	0.250	1000	1000
	7.981	0.115	0.319	0.250	1000	1000
8	8.071	0.115	0.319	0.250	1000	1000
	9.562	0.115	0.319	0.250	570	1000
	10.020	0.115	0.319	0.250	570	1000
10	10.136	0.115	0.319	0.250	570	1000
	11.374	0.175	0.379	0.250	285	1000
	11.938	0.175	0.398	0.250	285	1000
	12.090	0.175	0.398	0.250	285	1000
12	14.688	0.175	0.490	0.375	465	1000
	15.000	0.175	0.500	0.375	465	1000
	15.025	0.175	0.500	0.375	465	1000
16	18.812	0.240	0.505	0.375	235	1000
	19.000	0.240	0.505	0.375	235	1000
	19.250	0.240	0.505	0.375	235	1000
20	22.624	0.240	0.505	0.500	360	1000
	23.000	0.240	0.562	0.500	360	1000
	23.250	0.240	0.562	0.500	360	1000
24	28.750	0.370	0.562	0.500	180	1000
	29.000	0.370	0.578	0.500	180	1000
	29.250	0.370	0.578	0.500	180	1000

Notes:

1. Maximum allowable differential pressure is limited to 1,000 inches of water column, which is the limit of the coefficient of discharge database. For further details on the limit of maximum allowable differential pressure, please refer to the text in 2.4.5.
2. Maximum allowable differential pressure is calculated for worst-case diameter ratio (typically  $\beta = 0.55 - 0.65$ ). Other diameter ratios may be able to go to higher differential pressures (see Appendix 2-E).
3. The maximum differential pressure applies to stainless steel plates at a maximum temperature of 150° F, and for the recommended plate thickness.
4. Maximum allowable differential pressure for other plate thicknesses refer to Appendix 2-E.
5. For single- or dual-chamber fittings, the orifice plate seal ring was assumed to deflect under axisymmetric conditions without plastic deformation. As such, the effect on the seal ring was not investigated.
6. Especially at very high differential pressures, the user should carefully consider the associated thermodynamic effects, such as temperature changes resulting from the Joule-Thompson effect as the stream passes through the orifice, and the limits on  $\Delta P/P_f$ , in particular, at low pressures. The sudden reduction of pressure will result in temperature and density changes.

**Table 2-3. Orifice Plate Thickness and Maximum Allowable Differential Pressure Based on the Structural Limit**

The allowable tolerance for the orifice plate bevel angle,  $\theta$ , (i.e., the angle between the bevel and the downstream face of the orifice plate) is  $45^\circ \pm 15^\circ$ . If a bevel is required, its minimum dimension, E minus e, measured along the axis of the bore, shall not be less than 0.0625 inch.

**Meter Tube Specifications (Section 2.5)**

The meter tube is defined as the straight length of pipe upstream of the orifice (of the same diameter), including the flow straightener/conditioner, if used; the orifice plate holder; and the similar downstream pipe beyond the orifice plate. The *upstream* section of the meter tube is defined as the length of straight pipe extending from the upstream face of the orifice plate to the nearest upstream change in cross-sectional area (not including flange fittings allowed by this standard) or change in axis of the pipe centerline.

Allowable tolerances are provided for the meter tube surface roughness. Guidance is also provided on where to measure surface roughness along the meter tube. Meter tube surfaces that are too hydrodynamically “smooth” or “rough” will result in a flow measurement bias error. Allowable tolerances for meter tube surface irregularities, such as grooves, gouges, scoring, or ridges resulting from seams, welding distortion, etc. are also provided. It is also required that the meter tube be kept clean and free from accumulation of dirt, ice, grit, grease, oil, free liquid, and other extraneous material. Otherwise, flow measurement bias errors may result.

Procedures are provided for measuring the meter tube diameter,  $D_m$ . Allowable tolerances are provided for both meter tube diameter and roundness - both upstream and downstream of the orifice plate. Tables 2-4 and 2-5 provide example meter tube internal diameter roundness tolerances.

Position	Meter Tube Internal Diameter Measurements (inches)				Mean, $D_m$
	A	B	C	D	
1-inch upstream plate	2.0696	2.0694	2.0694	2.0696	2.0695
Within one $D_m$	2.0700	2.0676	2.0671	2.0655	N/A
% deviation from mean $D_m$	0.024%	0.092%	0.116%	0.193%	N/A

**Table 2-4. Example Meter Tube Internal Diameter - Roundness Tolerances within the First Mean Tube Diameter Upstream of the Orifice Plate**

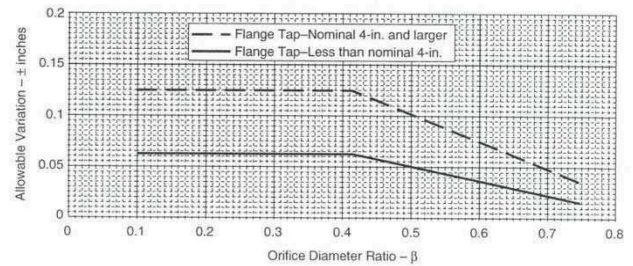
Position	Meter Tube Internal Diameter Measurements (inches)				Mean, $D_m$
	A	B	C	D	
1-inch upstream plate	2.0696	2.0694	2.0694	2.0696	2.0695
Within one $D_m$	2.0700	2.0676	2.0671	2.0655	N/A
Upstream check measurement	2.0621	2.0620	2.0613	2.0601	N/A

**Table 2-5. Example Meter Tube Internal Diameter - Roundness Tolerances - All Upstream Meter Tube Individual Internal Diameter Measurements**

Abrupt changes to the inside meter tube surface, such as shoulders, offsets, ridges, welding seams, etc., are, in

general, not allowed. Orifice plate gasket or sealing device tolerances are also provided in Part 2

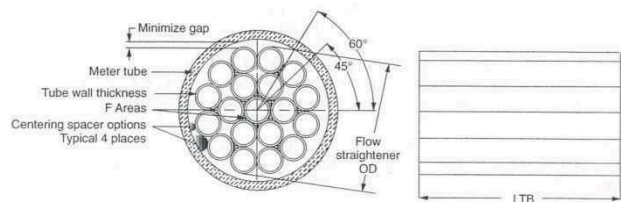
The various orifice configurations are discussed in this section. Orifice *flanges* and orifice *fittings*, along with associated inspection considerations, are discussed. Guidance is provided on the proper location and configuration (e.g., geometry) of pressure taps adjacent to the orifice plate. For instance, Figure 2-3 shows the allowable variations in pressure tap hole location for flange taps.



**Figure 2-3. Allowable Variations in Pressure Tap Hole Location**

Flow conditioning is also discussed in Section 2.5. A flow conditioner is a device placed upstream of the orifice plate that attempts to correct or eliminate flow field distortions created by the upstream piping configuration. Flow conditioners fall in one of two categories - flow *straighteners* and *isolating* flow conditioners (denoted as “*other*” flow conditioners in Section 2.5).

Flow *straighteners* are effective at reducing or eliminating swirl from the flow stream. However, they may not be capable of creating a flow condition (i.e., velocity profile) similar to that achieved for the flow experiments run to create the orifice plate coefficient of discharge dataset. If the flow field at an orifice inlet is substantially different than that for the flow experiments performed to create the orifice plate coefficient of discharge dataset, flow measurement bias errors can result. An example of a flow *straightener* is provided in Figure 2-4 in Section 2.5.



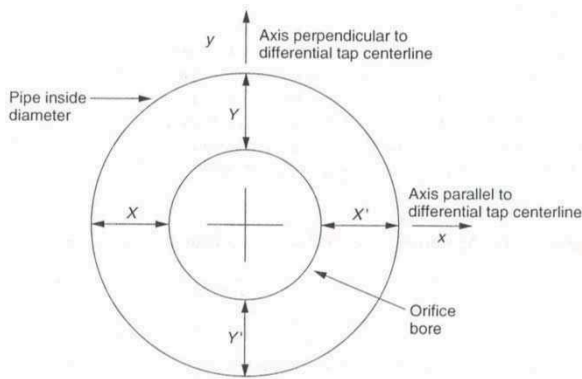
**Figure 2-4. 1998 Uniform Concentric 19-tube Bundle Flow Straightener**

*Isolating* flow conditioners are those that attempt to “isolate” the orifice plate from any adverse effects of flow distortions created by the upstream piping configuration. Isolating flow conditioners attempt to produce a fully-developed, axi-symmetric, swirl-free, turbulent velocity

profile immediately upstream of the orifice plate. Isolating flow conditioners typically use a perforated plate or grid configuration, and associated pressure drop, to redistribute the flow into the desired velocity profile downstream of the conditioner. Section 2.5 includes flow conditioner performance criteria and Appendix 2-D includes a test protocol to verify performance of “other” flow conditioner types besides flow straighteners.

**Installation Requirements (Section 2.6)**

Section 2.6 includes specifications for orifice plate bore eccentricity,  $\epsilon_x$ , and orifice plate perpendicularity - and how to measure these. Figure 2-5 shows a sample method for measuring the eccentricity. Table 2-6 shows the maximum tolerances for orifice plate bore eccentricity.



**Figure 2-5. Eccentricity Measurements (Sample Method)**

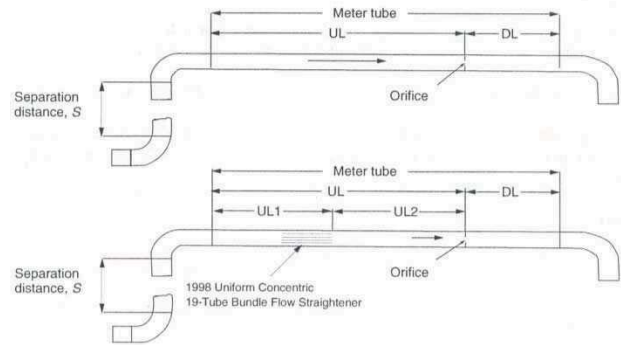
$\beta_m$	Meter Tube Inside Diameter (inches)					
	2.067	3.068	4.026	6.065	7.981	10.020
0.20	0.050	0.074	0.097	0.146	0.192	0.242
0.25	0.047	0.070	0.092	0.139	0.183	0.230
0.30	0.044	0.065	0.085	0.128	0.168	0.211
0.35	0.038	0.057	0.075	0.113	0.148	0.186
0.40	0.033	0.048	0.063	0.095	0.126	0.158
0.45	0.027	0.039	0.052	0.078	0.103	0.129
0.50	0.021	0.032	0.041	0.062	0.082	0.103
0.55	0.017	0.025	0.032	0.049	0.064	0.081
0.60	0.013	0.019	0.025	0.038	0.050	0.063
0.65	0.010	0.015	0.020	0.030	0.039	0.049
0.70	0.008	0.012	0.015	0.023	0.030	0.038
0.75	0.006	0.009	0.012	0.018	0.024	0.030

**Table 2-6. Maximum Tolerance of Orifice Plate Bore Eccentricity,  $\epsilon_x$ , in Inches**

Section 2.6 also provides extensive guidance on the minimum length of straight pipe required upstream and downstream of the orifice plate. For the reasons previously discussed, it is critically important that the upstream piping configuration produce an axi-symmetric, swirl-free, fully-developed, turbulent velocity profile at the inlet to the orifice plate in order to produce the most accurate flow measurement. Section 2.6 includes specifications for the minimum length of straight pipe required upstream of the plate - both with and without the inclusion of a flow conditioner. The recommended minimum upstream meter tube length varies depending on

the orifice diameter ratio,  $\beta_r$ , and the configuration of the piping element(s) immediately upstream of the meter tube. Figure 2-6 shows the orifice meter tube layout for flanged or welded inlet. This figure includes the critical length dimensions for the meter tube.

Table 2-7 presents the orifice meter length requirements for meter tubes without a flow conditioner and Tables 2-8a and 2-8b present the length requirements for meter tubes with a 1998 uniform concentric 19-tube bundle flow straightener.



**Figure 2-6. Orifice Meter Tube Layout for Flanged or Welded Inlet**

Other flow conditioners not specifically referenced in Section 2.6 can be flow tested per the performance verification test included in Appendix 2-D to demonstrate their performance characteristics for orifice meter applications.

Section 2.6 also discusses operation of orifice flow meters under pulsating flow conditions. Part 2 states that a pulsating differential pressure across the orifice plate,  $\Delta P$ , of up to 10% root mean square (a.k.a., RMS, which is a statistical measure of the magnitude of the variation in the  $\Delta P$ ) is acceptable. That corresponds to a square-root error (SRE) value of  $\sim 0.125\%$ . This applies to single frequency flow pulsations with or without several harmonics and to broad-band flow pulsations/noise. Any SRE above this threshold indicates that the pulsation is adversely affecting the orifice meter accuracy.

Part 2 also states...“Currently, *no* satisfactory theoretical or empirical adjustment for orifice measurement in pulsating flow applications exists that, when applied to custody transfer measurement, will maintain the measurement accuracy predicted by this standard. Arbitrary application of any correcting formula may even *increase* the flow measurement error under pulsating flow conditions. *The user should make every practical effort to eliminate pulsations at the source to avoid increased uncertainty in measurements.*”

Diameter ratio $\beta$	Minimum Straight Unobstructed Meter Tube Length from the Upstream Side of the Orifice Plate (in multiples of published internal pipe diameter, $D_i$ )										
	a. Single 90° elbow. b. Two 90° elbows in the same plane with $S > 30D_i$ . c. Two 90° elbows in perpendicular planes with $S > 15D_i$ .	Two 90° elbows in the same plane "S" configuration spacer $S \leq 10D_i$	Two 90° elbows in the same plane, "S" configuration $10D_i < S \leq 30D_i$	Two 90° elbows in perpendicular planes, $S < 5D_i^*$	Two 90° elbows in perpendicular planes, $5D_i \leq S \leq 15D_i$	Single 90° Tee used as an elbow but not as a header element	a. Single 45° elbow. b. Two 45° elbows in the same plane "S" configuration $S \geq 22D_i$	Gate valve at least 50% open	Concentric reducer	Any other configuration (catch all category)*	Downstream meter tube length
	UL	UL	UL	UL	UL	UL	UL	UL	UL	DL	
$\leq 0.20$	6	10	10	50	19	9	30	17	6	70	2.8
0.30	11	10	12	50	32	9	30	19	6	108	3.0
0.40	16	10	13	50	44	9	30	21	6	145	3.2
0.50	30	30	18	95	44	19	30	25	7	145	3.5
0.60	44	44	30	95	44	29	30	30	9	145	3.9
0.67	44	44	44	95	44	36	44	35	11	145	4.2
0.75	44	44	44	95	44	44	44	44	13	145	4.5
Recommended length for maximum range $\beta \leq 0.75$	44	44	44	95	44	44	44	44	13	145	4.5

UL = Minimum meter tube length upstream of the orifice plate in internal pipe diameter ( $D_i$ )(see Figure 2-6). Straight length shall be measured from the downstream end of the curved portion of the nearest (or only) elbow or of the tee or the downstream end of the conical portion of reducer or expander.

DL = Minimum downstream meter tube length in internal pipe diameters ( $D_i$ )(see Figure 2-6).

S = Separation distance between piping elements in internal pipe diameter ( $D_i$ ) measured from the downstream end of the curved portion of the upstream elbow to the upstream end of the curved portion of the downstream elbow.

\* These installations exhibit the strong effect of Reynolds number and pipe roughness on the recommended length due to the rate of swirl decay. The present recommendations have been developed for high Reynolds numbers and smooth pipes to capture the worst case.

Note: The tolerance on specified lengths for UL and DL is  $\pm 0.25D_i$ .

**Table 2-7. Orifice Meter Installation Requirements Without a Flow Conditioner**

Diameter Ratio, $\beta$	Single 90° elbow $R/D_i = 1.5$	Two 90° elbows out of plane $S \leq 2D_i$ $R/D_i = 1.5$	Single 90° tee used as an elbow but not as a header element	Partially closed valves (at least 50% open)	High swirl combined with single 90° Tee	Any fitting (catch-all category)	Downstream meter tube length
	UL2	UL2	UL2	UL2	UL2	UL2	DL
0.10	5 – 14.5	5 – 14.5	5 – 14.5	5 – 11	5 – 13	5 – 11.5	2.8
0.20	5 – 14.5	5 – 14.5	5 – 14.5	5 – 11	5 – 13	5 – 11.5	2.8
0.30	5 – 14.5	5 – 14.5	5 – 14.5	5 – 11	5 – 13	5 – 11.5	3.0
0.40	5 – 14.5	5 – 14.5	5 – 14.5	5 – 11	5 – 13	5 – 11.5	3.2
0.50	11.5 – 14.5	9.5 – 14.5	11 – 13	b	11 – 13	c	3.5
0.60	12 – 13	13.5 – 14.5	a	Not allowed	a	Not allowed	3.9
0.67	13	13 – 14.5	Not allowed	Not allowed	Not allowed	Not allowed	4.2
0.75	14	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	4.5
Recommended tube bundle location for maximum range of $\beta$	13 $\beta \leq 0.67$	13.5 – 14.5 $\beta \leq 0.67$	13 $\beta \leq 0.54$	9.5 $\beta \leq 0.47$	13 $\beta \leq 0.54$	9.5 $\beta \leq 0.46$	4.5

<sup>a</sup>  $13D_i$  allowed for up to  $\beta = 0.54$ .

<sup>b</sup>  $9.5D_i$  allowed for up to  $\beta = 0.47$ .

<sup>c</sup>  $9.5D_i$  allowed for up to  $\beta = 0.46$ .

S = Separation distance between elbows, measured as defined in Table 2-7.

UL1 = UL – UL 2 (see Figure 2-6).

Note 1: Lengths shown under the UL2 column are the dimensions shown in Figure 2-6, expressed as the number of published internal pipe diameters ( $D_i$ ) between the downstream end of the 1998 Uniform Concentric 19-Tube Bundle Flow Straightener and the upstream surface of the orifice plate.

Note 2: The tolerance on specified lengths for UL, UL2, and DL is  $\pm 0.25D_i$ .

Note 3: *Not allowed* means that it is not possible to find an acceptable location for the 1998 Uniform Concentric 19-Tube Bundle Flow Straightener downstream of the particular fitting for all values of UL.

**Table 2-8a. Orifice Meter Installation Requirements with 1998 Uniform Concentric 19-tube Bundle Flow Straightener for Meter Tube Upstream Length of  $17D_i \leq UL \leq 29D_i$**

	Single 90° elbow $R/D_i = 1.5$	Two 90° elbows out of plane $S \leq 2D_i$ $R/D_i = 1.5$	Single 90° Tee used as an elbow but not as a header element	Partially closed valves (at least 50% open)	High swirl combined with single 90° Tee	Any fitting (catch-all category)	Downstream meter tube length
Diameter Ratio, $\beta$	UL2	UL2	UL2	UL2	UL2	UL2	DL
0.10	5 – 25	5 – 25	5 – 25	5 – 13	5 – 23	5 – 13	2.8
0.20	5 – 25	5 – 25	5 – 25	5 – 13	5 – 23	5 – 13	2.8
0.30	5 – 25	5 – 25	5 – 25	5 – 13	5 – 23	5 – 13	3.0
0.40	5 – 25	5 – 25	5 – 25	5 – 13	5 – 23	5 – 13	3.2
0.50	11.5 – 25	9 – 25	9 – 23	7.5 – 15	9 – 19.5	11.5 – 14.5	3.5
0.60	12 – 25	9 – 25	11 – 16	10 – 17	11 – 16	12 – 16	3.9
0.67	13 – 16.5	10 – 16	11 – 13	10 – 13	11 – 13	13	4.2
0.75	14 – 16.5	12 – 12.5	12 – 14	11 – 12.5	14	<i>Not allowed</i>	4.5
Recommended tube bundle location for maximum range of $\beta$	13 $\beta \leq 0.75$	12 – 12.5 $\beta \leq 0.75$	12 – 13 $\beta \leq 0.75$	11 – 12.5 $\beta \leq 0.75$	13 $\beta \leq 0.75$	13 $\beta \leq 0.67$	4.5

$S$  = Separation distance between elbows, measured as defined in Table 2-7.  
 $UL1 = UL - UL2$  (see Figure 2-6).

Note 1: Lengths shown under the UL2 column are the dimensions shown in Figure 2.6 and as defined in Table 2-8a.

Note 2: The tolerance on specified lengths for UL, UL2, and DL is  $\pm 0.25D_i$ .

Note 3: *Not allowed* means that it is not possible to find an acceptable location for the 1998 Uniform Concentric 19-Tube Bundle Flow Straightener downstream of the particular fitting for all values of UL.

**Table 2-8b. Orifice Meter Installation Requirements with 1998 Uniform Concentric 19-tube Bundle Flow Straightener for Meter Tube Upstream Length of  $UL \geq 29D_i$**

### Addenda

Addendum 1 of API MPMS, Chapter 14.3, Part 2 provides an example of a measurement error analysis. Addendum 2 includes expanded data on the maximum allowable differential pressure across the orifice plate for 316 stainless steel, simply-supported orifice plates.

- American Gas Association Report No. 3, “Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids,” Part 2, “Specification and Installation Requirements,” Washington, D.C., Fourth Edition, April 2000, Second Printing, June 2003.

### Pending Revisions

A draft version of a new revision of the standard (i.e., Fifth Edition) was first balloted by the API Committee on Gas Fluids Measurement in 2011 and work on the revision has continued since. As of the date this paper was written (in May 2015), no publication date for the pending revision of the standard had been announced.

### Conclusions

This paper highlights some of the more important technical aspects of API, MPMS Chapter 14.3, Part 2, but for a complete treatment of the subject, the interested reader is strongly encouraged to refer to the standard in its entirety. Adherence to the requirements of this specification will help ensure that flow measurement accuracy using an orifice meter is optimized.



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### References

- American Petroleum Institute, Manual of Petroleum Measurement Standards, Chapter 14.3, “Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids,” Part 2, “Specification and Installation Requirements,” Washington, D.C., Fourth Edition, April 2000, Second Printing, June 2003.