A REVIEW OF THE 2000 REVISIONS TO ANSI 2530/API MPMS 14.3/AGA REPORT NO. 3 - PART2

Paul J. LaNasa

CPL & Associates

P.O. Box 801304, Houston, TX 77280-1304

ABSTRACT

Periodically, natural gas measurement standards are created or revised. In the period 1993 through 1999 Part 2 of ANSI 2530/API MPMS 14.3/AGA Report No 3 underwent revision. It is the intent of this paper to discuss the highlights of this revision.

BACKGROUND

The dictionary defines standard as "something established by authority, custom, or general consent as a model or example." In the natural gas industry, standards are established to provide uniformity of action with the hope this will improve efficiency and avoid differences. Natural gas measurement is one area of application for standards in the natural gas industry. Periodically, natural gas measurement standards are created or revised. In the period of 1993 through 1999 Part 2 of ANSI 2530/API MPMS 14.3/AGA Report No 3 has been revised. It is the intent of this paper to discuss the highlights of this revision.

ORIFICE PLATE REVISIONS

Two major orifice plate areas of concern are addressed in the 2000 revision of Part 2:

- Maximum allowable differential pressure across the orifice plate,
- Recommended 8 & 24-inch orifice plate thickness.

The maximum allowed differential pressure across the orifice plate is redefined in the new standard. The 1992 edition established an explicit maximum differential pressure of 200 inches of water column (iwc) for all orifice plates sizes except 8-inch. The 8-inch diameter by $^1/_8$ thick orifice plates were limited to 150 iwc. Although not identified in the 1992 revision, the 24-inch diameter by $^3/_8$ inch thick orifice plates experienced the same differential pressure limitation as the 8-inch diameter by $^1/_8$ inch thick orifice plates.

The revised differential pressures limits will vary and are now a function of:

- Plate thickness
- Plate material mechanical strength
- Acceptable expansion factor,Y, uncertainty.
- Maximum acceptable permanent pressure loss.

This revision can result in allowable differential pressures as high as 1000 iwc. Except for the additional expansion factor uncertainty, the influence of high differential pressures is archived in the Reader-Harris Gallagher coefficient of discharge calculation. The flange tapped coefficient of discharge database experienced differential pressures as high as 1300 iwc.

The recommended orifice plate thickness for 8-inch diameter orifice plates in the 1992 revision is $^1/_8$ of an inch and for the 24-inch diameter orifice plates is $^3/_8$ of an inch. Both the 8-inch diameter by $^1/_8$ thick orifice plate and the 24-inch by $^3/_8$ inch thick orifice plates were limited to 150 iwc in order to prevent excessive plate deflection. The 2000 revision has changed the recommended orifice plate thickness for 8-inch orifice plates to $^1/_4$ of an inch and the 24-inch orifice plate to $^1/_2$ of an inch. These changes can be achieved in some orifice plate holding devices without any modifications to the device provided the differential pressure tap hole tolerances and limits as specified are satisfied. Otherwise the orifice plate holding device has to be redrilled.

METER TUBE REVISIONS

Meter Tube Surface Roughness

Proper meter tube surface roughness is required to assure accurate measurement. New research data resulted in a revision in the surface roughness requirements. The new requirements establishes a minimum pipe wall roughness for all pipe sizes and allows pipes larger than 12-inch nominal pipe diameter to have a greater roughness than previous revisions.

The surface roughness requirement for 12-inch nominal pipe diameter and smaller is:

- 300 micro inches Ra when $\beta r < 0.6$
- 250 micro inches Ra when $\beta r \geq 0.6$
- Minimum Ra > 0.34 micro inches

The surface roughness requirement for greater than 12-inch nominal pipe diameter is:

- 600 micro inches Ra when $\beta r < 0.6$
- 500 micro inches Ra when $\beta r \geq 0.6$
- Minimum Ra > 0.34 micro inches

Irregularities such as grooves, scoring, or ridges resulting from seams, welding distortion, offsets, and the like that affect the tolerance in excess of that allowed by the Tolerances and Restrictions detailed in section 2.5.1.3

of the revision are not permitted. The existence of pits in the surface of the meter tube, although undesirable, are allowed provided their individual measurements do not exceed the surface roughness and/or diameter tolerance requirements of the meter tube and do not compromise the meter tube's pressure integrity. When these tolerances are exceeded, the irregularities must be corrected. The increase in the meter tube surface wall roughness requirement should not be interpreted as reducing the need to maintain clean meter tubes.

The 2000 revision states:

> "Due care shall be exercised to keep the meter tube interior clean and free from accumulation of dirt, ice, grit, grease, oil, free liquid and other extraneous materials, to the extent feasible. Damage and/or accumulation of extraneous materials in the meter tube may result in a greater uncertainty for the orifice plate coefficient of discharge, Cd(FT)."

The sections of the meter tube to which the orifice plate holder is attached or the adjacent pipe sections that constitute part of the meter tube, as defined, shall comply with inside surface requirements. However, due to the increased upstream meter tube length requirements and in keeping with the coefficient of discharge database lengths, the upstream meter tube section required to comply with the inside surface requirements shall be limited to the lengths shown in Meter Tube Length Tables or 17 published internal pipe diameters which ever is less. The piping roughness upstream of this length should not be greater than 600μin.

Flow Conditioners

The 2000 revision provides two changes to the 1992 flow conditioning section:

- It defines a 19 tube uniform concentric tube bundle flow straightener.
- It provides recognition and acceptance of the use of other flow conditioners.

In an effort to eliminate or reduce the potential for flow measurement bias in existing installations and to provide guidance for improved measurement accuracy in new installations, the 2000 revision provides construction requirements and installation recommendation for the 19 tube uniform concentric tube bundle flow straighteners cited in the installation effects research. Due to the significant (outside the designated uncertainty band) coefficient of discharge differences experienced from variations in the 1992 revision's straightening vane tube bundle construction, only those tube bundle flow straighteners meeting the 2000 criteria are specified to produce "no additional uncertainty" when installed as recommended. All other tube bundles should be considered as other flow conditioners.

It is not the intent of the 2000 revision to recommend any particular type of flow conditioner. However, the 2000 revision does recognize and accept the use of other types of flow conditioners. It requires that their use be based on technical performance data obtained from performance test(s). The 2000 revision provides a uniform criterion for evaluation of installation and/or flow conditioner performance (perturbation) test or tests. This test(s) is required by the 2000 revision to confirm the performance level that can be achieved by an orifice meter installation using a flow conditioner. Details of the performance test are given in Appendix 2-C & D of the revision. The performance test(s) will confirm the orifice meter diameter ratio, b, meter tube length, and flow conditioner location for which acceptable performance is obtainable.

Required Meter Tube Lengths

The most significant change in the 2000 revision has been to the required orifice meter tube lengths. The required orifice meter tube upstream lengths, both with flow conditioner and without flow conditioner (bare), have undergone significant revision. The required orifice meter tube downstream lengths remain unchanged. The upstream meter tube length revisions are the result of extensive research, both national and international, that has been underway since the mid 1980's. The 1992 revision indicated that the research was in progress and that revisions would occur when the research was concluded. All of the known data developed by researchers that met the acceptance criteria was utilized.

The research data compiled was carefully reviewed by an international group of experts from Canada, Japan, Western Europe and the United States. Only after this rigorous study of the data were the new meter tube lengths developed.

The required orifice meter tube lengths are divided into two categories:

- Meter tubes lengths without 19 tube concentric tube bundles (Bare meter tubes).
- Meter tubes lengths with 19 tube concentric tube bundles.

Meter Tubes Without the Uniform Concentric 19 Tube Bundle Flow Straightener (Bare meter tubes)

The bare meter tube consists of only straight pipe between the last pipe fitting and the orifice plate. The roughness of the pipe is the only agent that aids in the proper flow profile development. Any configuration not explicitly identified in the designated tables (See attached Table for more detail), the required lengths and the 1998 Uniform Concentric 19-Tube Bundle Straightener locations of the "any other configuration" classification should be followed.

Meter Tubes With Uniform Concentric 19 Tube Bundle Flow Straightener

The meter tube lengths utilizing the uniform concentric 19 tube bundle flow straightener have been revised. The research data segmented the meter tube lengths into the following two categories:

- $17D_i \leq$ Upstream Length $< 29D_i$
- Upstream Length $\geq 29\ D_i$

Where:

D_i = published internal pipe diameter

The recommended uniform concentric 19 tube bundle flow straightener location for $17D_i \leq$ Upstream Length $< 29D_i$ is designated as 12-13 D_i from the outlet of the flow straightener to the upstream face of the orifice plate. The recommended uniform concentric 19 tube bundle flow straightener location for Upstream Length $\geq 29\ D_i$ is designated as 12-13 D_i from the downstream end of the flow straightener to the upstream face of the orifice plate. (See attached table for more details.)

ORIFICE PLATE ECCENTRICITY

The 2000 revision removes the minimum limit on the high β ratio small diameter meter tube eccentricity tolerance. The 1992 revision had placed the minimum eccentricity tolerance for 2, 3, and 4-inch high β ratio orifice plates at 0.020 inches.

PULSATION ENVIRONMENT

The 2000 revision establishes for the first time a minimum pulsation threshold below which pulsation effects on orifice meter measurement is negligible. Accurate flow measurement with an orifice meter can be ensured only when the root mean square (rms) of the fluctuating differential pressure divided by the average differential pressure is less than or equal to 10%.

$$\Delta P_{rms} / \Delta P_{ave} \leq 0.10$$

This limit applies to:

- Single frequency flow pulsation with or without harmonics such as those generated by reciprocating compressors or closed relief or blow down valves,
- Broad band flow pulsation or noise such as generated by throttling valves.

Pulsation environments greater than the 10% limit given in the formula are not addressed.

Additionally, in order to avoid any resonance in the gauge line, the length of the gauge line should be as short as possible or should have lengths, l, specified according to the highest frequency, f, of concern from one of the following formulas:

$$0 \leq l_1 \leq 0.25a/(2\pi f)$$
$$l_2 = 2.5a/(2\pi f)$$
$$l_3 = 5.5a/(2\pi f)$$
$$l_4 = 8.5a/(2\pi f)$$
$$l_5 = 11.5a/(2\pi f)$$

Where :

a = speed of sound in the flowing fluid at operating conditions
f = frequency of pulsation levels
π = mathematical constant = 3.14159

The length of the gauge line determined from any of these formulas will ensure that no resonance and/or amplification of pressure pulsation exist in the gauge line. Both gauge lines should be of equal length and have no sudden changes of the internal diameter, especially for low pressure applications. In some cases, direct mount manifolds may reduce the effects of pulsation.

THERMOMETER WELLS

The thermometer wells must be located to accurately sense the flowing temperature of the fluid being measured. The wells may be placed on the downstream side of the orifice at the outlet of the downstream meter tube or no farther than four time the length of the downstream meter tube. If a flow conditioner is utilized, the thermometer well may be located upstream side of the orifice but no closer than 36 inches upstream of the flow conditioner. Thermometer wells exposed to the influences of the ambient environment may result in biased measurement.

Care should be taken to ensure that the temperature sensor indicates the flowing gas temperature and is not thermally coupled to the meter run pipe. Insulation of the meter tube can be required if the ambient temperature effects the accuracy of the flowing temperature measurement.

CONCLUSIONS

The 2000 revision of Part 2 of ANSI 2530/API MPMS 14.3/AGA Report No 3 represent the most comprehensive revision to the orifice meter's specification and installation requirements since 1955. Adherence to the 2000 revision's design specification and installation requirements will certainly improve measurement accuracy.

Paul J. LaNasa

TABLE - ORIFICE METER INSTALLATION REQUIREMENTS WITHOUT A FLOW CONDITIONER

Minimum straight unobstructed meter tube length from the upstream and downstream side of the orifice plate (in multiples of published internal pipe diameter, D_i)											
Diameter ratio β	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 $S \le 10D_i$	Two 90° elbows in the same plane, "S" configuration $10D_i < S \le 30D_i$	Two 90° elbows in perpendicular planes, $S < 5D_i$*	Two 90° elbows in perpendicular planes, $5D_i \le S \le 15D_i$	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 $S \ge 22D_i$	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	UL	DL
≤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 β ≤ 0.75	**44**	**44**	**44**	**95**	**44**	**44**	**44**	**44**	**13**	**145**	**4.5**

UL = Minimum meter tube length upstream of the orifice plate, UL, in published internal pipe diameter, D_i 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, DL, in published internal pipe diameters, D_i

S = Separation distance between piping elements in published 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.

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

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

TABLE A - ORIFICE METER INSTALLATION REQUIREMENTS WITH 1998 UNIFORM CONCENTRIC 19-TUBE BUNDLE FLOW STRAIGHTENER FOR METER TUBE UPSTREAM LENGTH OF $17D_i \leq UL < 29D_i$.

Diameter Ratio, β	Single 90° elbow $R/D_i = 1.5$	Two 90° elbows out of plane $S \leq 2Di$ $R/D_i = 1.5$	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	**	11-13	***	3.5
0.60	12-13	13.5-14.5	*	Not allowed	*	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 max range of β	**13** β≤0.67	**13.5-14.5** β≤0.67	**13** β≤0.54	**9.5** β≤0.47	**13** β≤0.54	**9.5** β≤0.46	**4.5**

NOTES:

Lengths shown under the UL2 column are the dimensions 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.

* - $13D_i$ allowed for up to $\beta = 0.54$

** - $9.5D_i$ allowed for up to $\beta = 0.47$

*** - $9.5D_i$ allowed for up to $\beta = 0.46$

S - Separation distance between elbows

UL1 = UL(Total upstream length) - UL2

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

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 B - ORIFICE METER INSTALLATION REQUIREMENTS WITH 1998 UNIFORM CONCENTRIC 19-TUBE BUNDLE FLOW STRAIGHTENER FOR METER TUBE UPSTREAM LENGTH OF UL ≥ 29D_i.

Diameter Ratio, β	Single 90° elbow R/D_i = 1.5	Two 90° elbows out of plane S ≤ 2Di 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	5-25	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	Not allowed	4.5
Recommended tube bundle location for max range of β	**14-16.5** β≤0.75	**12-12.5** β≤0.75	**12-13** β≤0.75	**11-12.5** β≤0.75	**13** β≤0.75	**13** β≤0.67	4.5

NOTES:

Lengths shown under the UL2 column are the dimensions 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.

S = Separation distance between elbows.

UL1 = UL – UL2

Note : The tolerance on specified lengths for UL, UL2 and DL is ±0.25D_i.