Manual of Petroleum Measurement Standards

Chapter 22 TESTING PROTOCOLS

Section XX—Testing Protocol for Flow Conditioners for Orifice Meters

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Contents

Testing Protocol for Flow Conditioners for Orifice Meters

1 Scope

This testing protocol covers any flow conditioner used to create desired flow profiles for Concentric, Square-Edged Orifice Meters as used under API MPMS Chapter 14.3. This testing protocol defines the baseline testing and all influence testing that is necessary to determine the performance of a flow conditioner as well as how the data from the testing is to be reported and analyzed.

2 Normative References

API Manual of Petroleum Measurement Standards (MPMS), Chapter 14.3, Concentric, Square-Edged Orifice Meters, Part 1 – Equations and Uncertainty Guidelines

3 (ANSI 1/API 2530, A.G.A. Report No. 3, GPA 8185) [All sections] Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1
discharge coefficient (C_d)
The ratio of the actual flow rate through a primary device to the theoretical flow rate. The theoretical flow rate corresponds to the flow rate without any loss of energy due to friction.

3.1.1
discharge coefficient R-G (C_{dRG})
The discharge coefficient as determined from the Reader-Harris Gallagher equation from API MPMS Chapter 14.3.1.

3.1.2
discharge coefficient baseline (C_{dbase})
The discharge coefficient as determined from Test 1 (Baseline Test) of this standard.

3.1.3
discharge coefficient test (C_{dtest})
The discharge coefficient as determined from each of Tests 2-5 of this standard.

3.2
disturbance
Any installation upstream of a primary device which significantly alters either the flow profile or the amount of swirl in the pipe.

3.3
flow conditioner
Flow conditioners can be classified into two categories: flow straighteners or flow conditioners.

Flow straighteners are devices that effectively remove or reduce the swirl component of a flowing stream, but may have limited ability to produce the flow conditions necessary to accurately replicate the orifice plate coefficient of discharge database values. See API 14.3, Part 2, for installation requirements.

For the purposes of this standard, flow conditioners are devices that effectively remove the swirl component from the flowing stream while redistributing the stream to produce a pseudo fully developed flow profile and the flow conditions that accurately replicate the orifice plate coefficient of discharge database values.

3.4

meter tube

The straight sections of pipe, including all segments that are integral to the orifice plate holder, upstream and downstream of the orifice plate.

3.5

meter tube internal diameter (*D*)

The inside diameter of the upstream section of the meter tube computed at flowing temperature (T_f), as specified in 1.6.3 of API MPMS Ch.14.3.1/AGA Report No. 3, Part 1. The calculated meter tube internal diameter (*D*) is used in the diameter ratio and Reynolds number equations.

3.6

NIST primary standards

A device or object used as the reference in a calibration that is acknowledged to be of the highest metrological quality and that derives its measurement without reference to some other standard of the same quantity maintained by The National Institute of Standards and Technology (NIST).

3.7

Orifice diameter ratio (β)

The diameter ratio (β) is defined as the calculated orifice plate bore diameter (*d*) divided by the calculated meter tube internal diameter (*D*).

3.8

published meter tube internal diameter (D_i)

The inside diameter as published in standard handbooks for engineers.

3.9

Reynolds Number (Re_D)

The Reynolds number is the ratio of the inertial forces to the viscous forces of the fluid flow. This non-dimensional parameter is defined as, $\frac{rVD}{m}$, where V is the average axial velocity, r is the density of the fluid, m is the absolute viscosity of the fluid, and *D* is a characteristic length, which in most applications is the meter tube diameter for Re_D or bore diameter for Re_d.

3.10

scaling

Testing to determine if the flow conditioner performance changes as a function of the line size of the meter run.

3.11

test facility

A facility capable of performing assessments of flow meters and whose measurements are traceable to NIST (National Institute of Standards and Technology), other national standards bodies, or applicable regulatory agencies.

3.12

third party

A party that is neither the manufacturer of the device or the user of the device.

3.13

uncertainty

A parameter associated with the result of a measurement that characterizes the dispersion of the values that could be reasonably be attributed to the measurand, often expressed in terms of its variance or standard deviation. (ISO GUM)

3.2 Acronyms and Abbreviations

For the purposes of this document, the following acronyms and abbreviations apply.

C_d	Discharge coefficient
C_{dRG}	Discharge coefficient R-G
C_{dbase}	Discharge coefficient baseline
C_{dtest}	Discharge coefficient test
ΔC_d	The change in discharge coefficient from either the R-G equation or the baseline test
D	Measured or calculated meter tube internal diameter
D_i	Published meter tube internal diameter
f	Friction factor
Re_l	The lower Reynolds Number tested during type approval testing
Re_h	The higher Reynolds Number tested during type approval testing
R-G	Reader-Harris Gallagher
R_a	Absolute average roughness of meter tube
TD1	Application Test from Section 6.1
TD2	Type Approval Test from Section 6.1
UL	Meter tube length upstream of orifice plate in multiples of published internal pipe diameters
UL1	Meter tube length from exit of disturbance to upstream edge of flow conditioner
UL2	Meter tube length from flow conditioner exit to upstream edge of orifice plate in multiples of published internal pipe diameters
β	Orifice diameter ratio

4 Field of Application

The application for this testing protocol is limited to devices that are used in the measurement of hydrocarbon fluids in the petroleum, energy, and petrochemical industries. In addition, this protocol is limited to single phase, steady-state, Newtonian fluids.

The application of this testing protocol assumes that the installation of the flow conditioner in the field conforms to the test conditions used in this protocol.

5 Parameter Variations Affecting Device Performance

5.1 Orifice Diameter Ratio or Commonly Referred to as β Ratio

If it is known that an installation or a flow conditioner is successful in removing swirl from the downstream flow, then it is possible to limit the range of β-ratios used in the performance test. If swirl is not removed by the installation and/or flow conditioner, it would be misleading and erroneous to rely on a single value of β to gauge the installation or flow conditioner's performance. It is recommended that either Test 3 or Test 5 be performed first for β = 0.40 and β = 0.67. If the ΔC_D values for both values of β are negligible, or if ΔC_D varies approximately as $\beta^{3.0}$ to $\beta^{4.0}$, then it can be concluded that swirl in the meter tube is not a significant influence. In this case, it is recommended that the other installation or flow conditioner performance tests be performed for a single value of β = 0.67. If the installation or flow conditioner passes the test for β = 0.67, experience shows that it will also pass the test for lower values of β. If the flow conditioner passes the test for β = 0.67, it can also be tested at a higher value of β, if desired.

If swirl effects are not removed by the installation and/or flow conditioner at β = 0.40 and β = 0.67, Test 3 and Test 5 shall be performed for a complete range of β values between β = 0.20 and β = 0.75.

5.2 Meter Tube Length and Flow Conditioner Location

Some flow conditioners that were designed to comply with a particular flow meter standard may be retrofitted into existing meter tubes. In this case, the flow conditioner should be installed at the appropriate location, and its performance evaluated in a meter tube of the appropriate length. If the field meter tube was designed to comply with the API MPMS Chapter 14.3.2/AGA Report No. 3, Part 2, 1992 revision, Figure 5—"Partly Closed Valve Upstream of Meter Tube," the flow conditioner performance should be evaluated in a meter tube with an upstream length of $17D_i$, with the flow conditioner located at UL2 = $7.5D_i$ upstream of the orifice plate. If the field meter tube was designed to comply with the ISO 5167 standard, the flow conditioner performance should be evaluated in a meter tube with an upstream length of $45D_i$, with the flow conditioner located at UL2 = $22D_i$ upstream of the orifice plate. Alternatively, if the field meter tube is significantly longer than the minimum recommended length (e.g. some natural gas transmission companies have meter tubes with an upstream length of UL = $25D_i$ to $29D_i$, and install a tube bundle straightening vane at UL2 = $12D_i$ upstream of the orifice plate), the performance test should be performed with the same installation conditions.

The flow conditioner performance test can be performed for more than one meter tube length, and for more than one flow conditioner location, if desired.

6 Mandatory Tests

6.1 Objectives

The objective of performance tests for a flow conditioner is to prove that a tested device meets performance criteria within the specified tolerance limits for any type of piping installation upstream of the orifice meter at one line size and for a narrow range of Reynolds numbers (Test TD1) or for all line sizes and Reynolds numbers (Test TD2). This objective is broader than for a calibration test as in API 14.3.2 Annex C, which deals with a specific type of an upstream installation of interest to the user.

Both types of flow conditioner performance tests contain the following common elements.

— **Test 1**: Baseline Calibration—evaluating performance of the test facility.

— **Test 2**: Good Flow Conditions—test evaluating impact of flow conditioner on fully developed velocity profile.

— **Test 3**: Two 90-degree Elbows in Perpendicular Planes—testing of flow conditioner performance in handling a combination of a modest swirl (up to 15-degree swirl angle) and a nonsymmetrical velocity profile.

— **Test 4**: Gate Valve 50 % Closed—test evaluating flow conditioner performance in a strongly nonsymmetrical velocity profile.

— **Test 5**: High Swirl—test assessing flow conditioner performance in flows with high swirl angle (more than 25 degrees).

The facility baseline has to meet acceptance criteria specified below and the results of Tests 2 through 5 will be evaluated in terms of the normalized deviation (ΔC_d) between the measured discharge coefficient and the baseline discharge coefficient at the same β-ratio and Reynolds number.

There are two types of flow conditioner performance tests:

— **TD1:** *Application Test*. Approves the use of a flow conditioner for any type of upstream installation; just for the tested line size and a narrow range of Reynolds numbers associated with the tested β-ratio range and differential pressure range used. For these conditions, the five tests specified have to be performed.

— **TD2:** *Type Approval Test*. Approves use of a tested flow conditioner for any type of upstream installation, any line size, and any Reynolds number. Such a broad approval of the flow conditioner applications requires performance of Tests 1 through 5 within the parameter ranges prescribed in equations 1 and 3:

$$10^4 \le Re_l \le 10^6 \text{ and } Re_h \ge 10^6 \qquad \text{Equation 1}$$

a) for $\beta = 0.67 \rightarrow f\,(Re_l) - f\,(Re_h) \ge 0.0036$,

or b) for $\beta = 0.75 \rightarrow f\,(Re_l) - f\,(Re_h) \ge 0.0030$

where

Re_l is the low Reynolds number;

Re_h is the high Reynolds number;

f is the pipe friction factor obtained from (i) or (ii):

(i) the Colebrook-White equation

$$\frac{1}{\sqrt{f}} = 1.74 - 2log_{10}\left[6.3\,\frac{R_a}{D} + \frac{18.7}{Re_D\sqrt{f}}\right] \qquad \text{Equation 2}$$

(ii) the Moody diagram;

R_a is the absolute average roughness of meter tube.

$D_i \leq 4$ in. and $D_i \geq 8$ in. Equation 3

The following selection of tests shall be performed:

Test a) *Disturbance*. Tests 1 through 5 for one Reynolds number range and at one pipe diameter selected from Equation 1 and Equation 3. The full sequence of β-ratio selection is defined in Section 5.1 .

Test b) *Scaling*. Test 1, and one of the Tests 3 through 5, shall be conducted using two pipe sizes (preferably at one pipe size as in **Test a)** selected from two prescribed diameter ranges in Equation 3. Each pipe size test shall be conducted at the same Reynolds number (preferably the one as in **Test a)** or at a Reynolds number chosen from the prescribed ranges in Equation 1. To demonstrate scalability, the results from the two pipe sizes has to demonstrate that, in both cases, the flow conditioner meets the specified performance criteria for the same meter tube lengths, UL and $UL2$. Selection of β-ratio should follow the procedure described in Section 5.1.

Test c) *Reynolds Number Sensitivity*. Test 1, and one of Tests 2 through 5, shall be conducted, preferably at one of the pipe sizes used in **Test b)**, and at two Reynolds numbers selected for a chosen pipe diameter and pipe roughness, in such a way that the condition Equation 1 is fulfilled for β = 0.67 only; $\beta = 0.75$ may be used instead, if desired.

EXAMPLE A laboratory decides to use hydraulically smooth pipes, and selects $Re_h = 1.02 \times 10^6$. At the Reynolds number, Moody diagram gives $f(Re_h) = 0.0116$. The Reynolds number sensitivity test will be conducted at $\beta = 0.67$; thus, $f(Re_l) = f(Re_h) + 0.0036 = 0.0116 + 0.0036 = 0.0152$. This value of the friction factor corresponds to $Re_l = 2.31 \times 10^5$ for a smooth pipe at the Moody diagram. The tests can be conducted at the same facility, because $Re_h / Re_l = 4.4$ will not result in excessively high or low pressure differentials across the orifice plate.

The selection of two Reynolds numbers for **Test c)** requires use of an implicit formula or Moody diagram that may result in the ratio of Reynolds number even as low as 4 in facilities operating on liquids, and even higher than 10 in the facilities operating on high-pressure gas.

If the selected Reynolds number in **Test a)** is equal to or larger than 3×10^6, and the manufacturer or user of the flow conditioner is seeking an approval for applications in the range $Re >= 3 \times 10^6$, then the **Test c)** can be skipped.

In both types of performance tests, the use of the flow conditioner is restricted to those locations within the meter run where the ΔC_D of the tested flow conditioner was one-half of the uncertainty limits $\pm 2\sigma$ of Reader-Harris Gallagher (R-G) equation.

An installation and/or flow conditioner test should be performed for values of upstream meter tube length and/or flow conditioner location that are appropriate for the installation. If desired, a sliding or fixed position flow conditioner test can be performed for a range of flow conditioner locations for one or more upstream meter tube lengths.

6.2 Test 1: Baseline Calibration

A baseline (reference) calibration should be performed using the same orifice plates and β-ratios that will be used in the application or type approval test(s) (TD1 or TD2).

a) The baseline should be performed using a meter tube with a minimum straight upstream meter tube length of $70D_i$. There shall be swirl-free (less than 2 degree swirl angle) flow at the entrance to the $70D_i$ meter tube.

b) Baselines using large pipe diameters (16 in. and 24 in.) may prove to be difficult to perform because of space limitations in most laboratories. An alternative baseline configuration of a minimum of $45D_i$ and an oversized Sprenkle flow conditioner are acceptable. The oversized Sprenkle design has to conform to that specified in NIST Technical Note 1264, or to ISO 5167, and one NPS larger.

c) To prove that the mechanical baseline configuration is valid, the baseline C_d values should lie within the 95 % confidence interval for the R-G equation.

d) To minimize the effects of instrumentation bias errors, the same measuring equipment should be used in both the baseline test and Tests 2 through 5.

6.3 Test 2: Good Flow Conditions

This test is recommended to show that the installation or flow conditioner does not degrade the measurement performance of a meter tube under good (baseline) flow conditions. The upstream length of the meter tube or the flow conditioner location may be specified as appropriate for a retrofit installation. Otherwise, a sliding or fixed position flow conditioner test may be performed.

6.4 Test 3: Two 90-Degree Elbows in Perpendicular Planes

This test ensures that the installation or flow conditioner can remove normal amounts of swirl and provide good performance in a double out-of-plane elbow installation. The spacing between the exit plane of the first elbow and the entry plane of the second elbow should not exceed two pipe diameters. Since the out-of-plane elbows will produce swirl in the meter tube, the flow entering the first elbow should be swirl-free.

6.5 Test 4: Gate Valve 50% Closed

This test ensures that the installation or flow conditioner can accept a highly asymmetric profile of axial velocity without degradation of measurement performance. The 50 % closed valve should be the primary source of the velocity profile asymmetry. The velocity profile of the flow approaching the valve should be symmetric and swirl-free. In the flow conditioner performance tests, a full-bore gate valve was used. The gate was modified so that 50% of the flow area was blocked when the gate was lowered. The gate had to be raised to allow a sliding flow conditioner to enter the meter tube downstream of the valve.

For an evaluation of the performance of a flow conditioner at a fixed location, it is possible to substitute a segmented orifice plate mounted between two flanges for the gate valve. The segmented plate should block 50% of the flow through the meter tube. A segmented plate is employed in the high-level perturbation test described in the ISO 9951 standard for gas turbine meter installations. The open area of the plate should be adjacent to one of the orifice pressure tap pairs. The closed area of the plate should be adjacent to the pressure tap pairs on the opposite side of the orifice fitting.

6.6 Test 5: High Swirl

This test is recommended when the meter tube will be installed downstream of a header that may produce large axial swirl angles. The objective of the test is to prove that the flow conditioner is effective in high-swirl environments. The Chevron axial vane swirler is effective in generating a solid body type of rotation, with a linear distribution of swirl angle from near zero on the pipe centerline to a maximum value of 30 degrees near the pipe wall. The design of the Chevron swirler is as follows.

The basic design consists of a hub of 1.5 in. (38 mm) in diameter and 6 in. (152 mm) in length. The hub has a streamlined parabolic nose facing upstream and a blunt base [corner radius approximately 0.1

in. (2.5 mm)] facing downstream. The hub is supported and centered by struts from the stainless steel housing wall.

Ten vanes or blades are attached to the hub by shafts that pass through the housing wall and allow individual adjustment of each blade’s angle. Outside the housing, a protractor is fitted to each shaft. The vanes can be rotated by turning the shaft from outside the housing. The degree of rotation is read from the affixed vernier. The thickness of each blade 0.2 in. (5 mm) is milled to a tapered profile to streamline the flow when the blades are aligned in the axial direction.

The Chevron swirler used in the installation and/or flow conditioner performance tests verification has a nominal diameter of 6 inches. With reducer fittings attached to front and back, it performed well in tests with D_i = 4-in. pipe. For larger diameter pipe (8-in., 10-in., or 16-in.) it will be necessary to design and fabricate a larger diameter device. If another swirl-generating device is used in place of the Chevron swirler, the swirl-generator device should produce a swirl angle of at least ± 24 degrees at a distance of $17D_i$. Confirmation of the swirl angle is to be obtained by measurement using an appropriate technique; for example, a multi-hole Pitot tube. The setting of the vane angle on the swirler is not considered to be a measure of the swirl angle at the location of the meter.

7 Test and Calibration Facility Requirements

7.1 Test Facility Audit Process

The test facility performing the tests shall provide evidence that the tests are performed in accordance with requirements of this standard. This evidence shall be provided at the request of any user of the facility. Providing documentation that the tests were performed in accordance with the applicable test procedure is responsibility of the test facility. A manufacturer using a third-party test facility can request the system uncertainty of the testing facility to ensure the validity of the tests. The extent of the audit is determined by the user of the facility and shall be consistent with relevant national and/or international standards.

The test facility conducting the tests required in this protocol shall either provide the calculation details or be certified by a third party for the measurement uncertainty of each of the variables monitored and reported in the test results. All references used to establish the measurement uncertainty or performance specifications of the meter shall be traceable to national or internationally recognized standards. The system uncertainty of the calibration facility and each monitored variable included in the test report for establishing the performance of the meter shall include the measurement uncertainty with a 95% confidence interval. If requested by the user of the facility, the test facility shall provide the documentation of the procedure and calculation method used to establish the system uncertainty and frequency of verification, unless the performance uncertainty of the facility is certified and periodically verified by a nationally recognized third party. If the system uncertainty is certified by a third party, a copy of the valid certification would satisfy this requirement.

7.2 Test Facility Qualification

Test facility measurement systems for mass, length, time, temperature, and pressure shall be traceable to the NIST Primary Standards or applicable standards approved by regulatory agencies.

The test facility shall be able to determine values of the orifice discharge coefficient for orifice metering systems that meet the requirements of API MPMS Chapter 14.3.1 (2012), within the 95% confidence interval of the Reader-Harris Gallagher (R-G) equation.

7.3 Validity/Precision of Test Facility Results

If the test facility meets all the user requirements and any additional requirements defined in the testing protocol, then the results of the test shall be considered valid.

8 Uncertainty and Statistical Significance Analysis and Calculation

8.1 Test Facility and Calibration Facility Uncertainty

The uncertainty of the test facility and calibration facility instrumentation including the primary and secondary standards shall be verified by the baseline test and the performance of the test facility vs. the R-G equation. The uncertainty of the R-G equation shall be determined per API 14.3.1 Section 12.4.1.

8.2 Determination of Statistical Significance

For Test 1, the baseline test shall be deemed to be acceptable if the difference between the test discharge coefficient and the discharge coefficient calculated by the R-G equation is within the uncertainty limits of of the R-G equation.

For Tests 2-5, the test shall be deemed to be acceptable if the difference between the test discharge coefficient and the discharge coefficient determined during the respective baseline test is within half of the uncertainty limits of of the R-G equation.

9 Test Report

9.1 General

The raw data and test condition records of all tests, attested or certified by the test facility, if tests are performed at a third-party facility, shall be retained for future reference by the manufacturer of the device for verification if any of the reported results or computations is questioned at a later date. If a specific test report is not published in the public domain and is not available for verification of any claim, all claims based on that data will be deemed unverifiable.

To facilitate comparison between flow conditioners, all tests shall be reported in the following set format. The result of the tests should be reported in tabular form, including results of the baseline tests and all flow conditioner installation tests. The test report shall contain the following information.

9.2 Test Facility Information

— Name and location of the test facility

— Date and time of test

— Unique Test Identification Number

— Fluid(s) used

— Type of test installation or API 22.xx Test Number

— Meter tube ID at reference temperature (D_r) (inches)

— Orifice Diameter at reference temperature (d_r) (inches)

9.3 Flow Conditioner Information

— Name of the flow conditioner manufacturer

— Type/Name/Description of the flow conditioner

— Flow conditioner serial number and model number

— Nominal size of flow conditioner and piping

— Flow conditioner geometry and critical dimensions (drawing of the flow conditioner, may be separate attachment)

— Orientation of flow conditioner relative to orifice taps

9.4 Testing Results

For each test (Tests 1-5), the following information is required at a minimum:

— Mass flowrate as measured by the reference meter (pounds mass per second)

— Temperature measured downstream of orifice plate (°F)

— Static pressure measured at the orifice plate and tap location of static pressure measurement (psia)

— Differential pressure measured across the orifice plate (inches of water at 68°F)

— Beta corrected for flowing temperature (dimensionless)

— Density of fluid (pounds per cubic foot)

— Viscosity of fluid (centipoise)

— Isentropic Exponent (dimensionless)

— Pipe Reynolds Number (ReD) calculated for the test (dimensionless)

— Expansion factor calculated for the test (dimensionless)

— Uncertainty in R-G Equation discharge coefficient calculated for the test (%)

9.4.1 Test 1 (Baseline Test)

Additionally, the following information is required for Test 1 (baseline test):

— Discharge coefficient from test (Cd_{base}) (dimensionless)

— Discharge coefficient from R-G equation (Cd_{RG}) (dimensionless)

— Cd_{base} – Cd_{RG}

— Percent difference between Cd_{base} and Cd_{RG}

9.4.2 Test 2-5 (Flow Conditioner Installation Tests)

Additionally, the following information is required for Test 2-5 (Flow Conditioner Installation Tests):

— Statement that all flow conditioner installation testing was performed with the same facility equipment as the corresponding baseline test

— Distance from orifice plate to flow conditioner (UL2) (nominal Pipe Diameters)

— Distance from upstream disturbance to flow conditioner (UL1) (nominal Pipe Diameters)

— Discharge coefficient from test (Cd_{test}) (dimensionless)

— Discharge coefficient from corresponding baseline (Cd_{base}) (dimensionless)

— Cd_{test} – Cd_{base}

— Percent difference between Cd_{test} and Cd_{base}

9.5 Sample Meter Test Reporting Form

The following are example test reporting forms that may be used to report the test results.

9.5.1 Test 1 – Baseline Test

Test Facility Information	
Test Facility:	Date:
Location:	Time:
Fluid:	Test Number:
Meter Tube ID:	API 22.XX Test:
Orifice Diameter:	

Flow Conditioner Information	
Make:	Model:
Serial Number:	

Testing Results - Baseline Test							
Mass Flowrate	Temperature	Pressure	Differential Pressure	Beta @ Tf	Density	Viscosity	Isentropic Exponent
LBMS	°F	psia	"H20 @68	dim	lb/ft3	cP	dim

Expansion Factor	Pipe Reynolds Number	Discharge Coefficent	Discharge Coefficent	Diff	Diff	Uncertainty of R-G	In Tolerance?
dim	dim	From Test	R-G Equation		%	%	

9.5.2 Tests 2-5 (Flow Conditioner Installation Tests)

Test Facility Information

Test Facility:	Date:
Location:	Time:
Fluid:	Test Number:
Meter Tube ID:	API 22.XX Test:
Orifice Diameter:	

Flow Conditioner Information

Make:	Model:
Serial Number:	

Testing Results - Testing was performed with the same facility equipment as baseline test number:

Mass Flowrate	Temperature	Pressure	Differential Pressure	Beta @ Tf	Density	Viscosity	Isentropic Exponent
LBMS	°F	psia	"H20 @68	dim	lb/ft3	cP	dim
Expansion Factor	Pipe Reynolds Number	Discharge Coefficent	Discharge Coefficent	Diff	Diff	Uncertainty of R-G	In Tolerance?
dim	dim	From Test	Baseline		%	%	
UL2	UL1						
(Nominal Ds)	(Nominal Ds)						

Bibliography

The following documents are directly referenced in this recommended practice.

ISO 5167:2022 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements

ISO 9951:1993 Measurement of gas flow in closed conduits — Turbine meters

NIST Technical Note 1264 : Measurements of Coefficients of Discharge for Concentric Flange-Tapped Square-Edged Orifice Meters in Water Over the Reynolds Number Range 600 to 2,700,000 - 1989