Performance of Full-bore Vortex Meters for Measurement of Liquid Flows

API TECHNICAL REPORT 2577
FIRST EDITION, JULY 2018

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Introduction

This technical report documents performance characteristics of several commercially available vortex meters for liquid flows. Although vortex meters are available in full-bore and reduced-bore designs, performance verification and characterization were limited to full-bore liquid vortex meters only, due to the inadequacy of test data available in the public domain for reduced-bored designs and lack of funding to develop a field test database for hydrocarbon liquids. Vortex meter test results reported in this document are of nominal 2-in. (50-mm) and 4-in. (100-mm) meter sizes. Five vortex meter vendors participated in the laboratory and field tests with hydrocarbon liquid of 4-in. (100-mm) meters, while only three manufacturers participated in the 2-in. (50-mm) tests. Since the flow rate through 2-in. (50-mm) vortex meters is relatively low, its use in field trials with hydrocarbon fluids was not possible, as it would delay and limit the normal operation of the field meter. Therefore, 2-in. (50-mm) vortex meter tests were limited to performance verification at the laboratory test facility with water only.

The baseline performance of each meter was established under controlled flowing conditions of the laboratory test facility, where the test fluid was water. Commercially available 4-in. (100-mm) vortex meters output may have a manufactured pulse, where the pulse output is used during proving of the meter to establish the meter factor and repeatability of the meter factor. Also, due to time variations of shed vortices that result from hydrodynamic instability and current limitations of the available sensor technology, the raw pulse signal of vortex meters require time averaging. The reference flow rate at the proving facility was established by a Small Volume Prover (SVP), also referred to as Captive Displacement Prover (CDP), because proving of field meters for hydrocarbon fluids was performed by portable proving systems that used SVP. The time of the proving run of a SVP normally used to calibrate 4-in. (100-mm) meters was inadequate for the time-averaged proving run required for the flow rate range of the liquid vortex meters. The laboratory proving setup duplicated the portable field proving system. In order to achieve repeatable meter factors (MF) and laboratory and field proving of vortex meters, the MF of the meter being tested was established by utilizing the transfer proving method. The master meter (MM) for the transfer proving was the liquid turbine meter, whose MF was established by the SVP. At the proving facility, the MM, meter being tested, and SVP, were installed in series.

In the field, the performance of the vortex meter for hydrocarbon flows were established against the field flowmeter as the master meter, after the field meter was flow calibrated by the portable proving system. Therefore, variations in flow rate and properties of hydrocarbon fluids for vortex meter were limited as vortex meter could only be tested for the flow rates and properties of the hydrocarbon fluids for which the field meter were being calibrated. Vortex meter proving and performance data for hydrocarbon liquids presented in this technical report are limited. While developing this report, there was no significant test data available in literature or in the public domain for vortex meters that characterized the performance of vortex meters with hydrocarbon liquid flows indicating the precision and uncertainty.

Members of the API Working Group were assigned to evaluate the performance characteristics of liquid vortex meters, document the response of vortex meters for hydrocarbon liquids, and to develop this Technical Report to examine the current use of liquid vortex meters. Therefore, individuals who use flowmeters can make an informed decision before selecting liquid vortex meters, to determine if the performance characteristics of the vortex meter can adequately meet the required measurement uncertainty when applied.

The Work Group appreciates the support of Coastal Flow and participating vendors that donated vortex meters for this study.

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Performance of Full-bore Vortex Meters for Measurement of Liquid Flows

1 Scope

This technical report provides:

— documentation of performance characteristics of full-bore liquid vortex meters for measuring liquid hydrocarbon flows of different API gravity under the field operating conditions and under a controlled environment in a laboratory test facility with water as the proving fluid.

— limited laboratory proving facility test results using water as the calibration fluid of several and 2 in. (50 mm) and 4 in. (100 mm) commercially available full-bore vortex meters that are typically installed for non-custody transfer liquid installations.

— typical performance of full-bore 4-in. (100-mm) liquid vortex meters for liquid hydrocarbon measurement and to provide guidance in selecting liquid vortex meters for custody transfer measurement.

2 References

— API *Manual of Petroleum Measurement Standards (MPMS) Chapter 4*

— ASME *Measurement of Fluid*

— *Flow in Pipes Using Vortex Flowmeters (MFC 6-2013), Appendix A*

— International Organization of Legal Metrology (OIML) D 25 Report*, Vortex meters used in measuring systems for fluids,* 2010

3 Terms, Definitions, and Abbreviations

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

3.1
accuracy
The extent to which the results of a calculation or the readings of an instrument approach the true value.

3.2
bias
Any influence on a result that produces an incorrect approximation of the true value of the variable being measured. Bias is the result of a predictable systematic error.

3.3
calibration
A set of operations which establish, under specified conditions, the relationship between the values indicated by a measuring device and the corresponding known values indicated when using a suitable measuring standard.

3.4
compensation
The adjustment of the measured value to reference conditions (e.g. pressure compensation).

3.5
flowing density
The density of the fluid at actual flowing temperature and pressure.

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3.6
metering or measurement system
A combination of primary, secondary or tertiary measurement components, or a combination thereof, necessary to determine the flow rate.

3.7
performance
The response of a measurement device to influence parameters such as operating conditions, installation effects, and fluid properties.

3.8
range of uncertainty
The range or interval within which the true value is expected to lie with a stated degree of confidence.

3.9
verification
The process or procedure of comparing an instrument to a reference standard to ensure its indication or registration is in satisfactorily close agreement, without making an adjustment.

3.10
uncertainty
The amount by which an observed or calculated value may depart from the true value.

3.11 Abbreviations

CDP	Captive Displacement Prover
LPG	Liquified Petroleum Gas
MF	meter factor
MM	master meter
NGL	Natural Gas Liquids
SVP	small volume prover

4 Field of Application

Vortex meters are commonly used in the petroleum industry for different applications including and limited to measurement of upstream and downstream liquids, steam, measurement in midstream applications, and chemical and other fluids in process plants.

Vortex meters are used in some allocation measurement applications and some are used to measure produced water.

Vortex meters essentially have no moving parts with relatively more relaxed mechanical tolerance for the primary element (vortex shedder) and require relatively low maintenance compared to other alternative flow measurement devices for similar application.

5 Test Matrix for Full-bore Vortex Meter

It was decided by the members of the API Working Group (WG) for the liquid vortex meter standard to conduct field tests of 4-in. (100 mm) ANSI 600 vortex meters to document its performance for hydrocarbon fluids. Experimental study to document the performance of liquid vortex meters were conducted in two phases: 1) baseline performance characteristics of each vortex meter were documented by testing vortex meters with water as the calibration fluid; and 2) field testing of the vortex meter with hydrocarbon fluids of different API gravities was conducted in the field with

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