McCrometer V-Cone Meters Tested in Accordance with

API 5.7 "Testing Protocol for Differential Pressure Flow Measurement Devices"

And Subsequently Further Tested to Meet the Additional Requirements of

API 22 "Testing Protocol" Section 2 – "Differential Pressure Flow Measurement Devices" (a Revision of API 5.7)

A Summary

By

Dr R.J.W. (Bob) Peters May 2006

API 5.7"Testing Protocol for Differential Pressure Flow Measurement Devices"
Published January 2003

The American Petroleum Institute Manual of Petroleum Measurement Standards, Chapter 5.7 (API 5.7) specifies a testing protocol for differential pressure flow measurement devices. The protocol was written to apply to all flow measurement devices that measure single-phase fluid flow based on the detection of a differential pressure created in the fluid flow stream. This standard was published in January 2003 "to supply industry with a comparable description of the capabilities of these devices for the measurement of single-phase fluid flow when they are used under similar operating conditions."
A laboratory traceable to NIST or an equivalent national or international standard is required. McCrometer chose to undertake the tests of the Wafer V-Cone, in accordance with API 5.7 at CEESI, The results of the API 5.7 tests were presented in a joint paper by McCrometer and CEESI at Flomeko 2004 [1] in Guilin, China on the 14th to 17th September, 2004

McCrometer chose to undertake the tests of the Standard V-Cone, in accordance with API 5.7 at Southwest Research Institute, in San Antonio Texas and Utah State University. The results of the API 5.7 tests were presented in a joint paper by McCrometer and Southwest Research Institute at The North Sea Flow Measurement Workshop in St Andrews, Scotland on the 26th to 28th October, 2004 [2].

API 22 "Testing Protocol" – Section 2 "Differential Pressure Flow Measurement Devices" Published August 2005

This standard is a revision of API 5.7 [2] and was published in August 2005 "to supply industry with a comparable description of the capabilities of these devices for the measurement of single-phase fluid flow when they are used under similar conditions".
A laboratory traceable to NIST or an equivalent national or international standard is required. McCrometer chose to undertake the additional tests of the Wafer V-Cone and the Standard V-Cone, to bring the previous testing regime into compliance with the additional requirements of API 22.2, at CEESI, as the initial tests of the Wafer V-Cone meters to API 5.7 had been performed there. The results of these Wafer V-Cone tests will be presented in a joint paper by McCrometer and CEESI, at The Fluid Flow Measurement 6^{th} International Symposium in Queretaro, Mexico on the 16^{th} to 18^{th} May, 2006[3].

When the Standard V-Cone testing report is completed in May 2006, a paper will be presented in a joint paper at the next appropriate conference.

KEY ELEMENTS AND CONCLUSIONS FROM THESE PAPERS

FLOMEKO 2004,CHINA

The 12th International Conference on Flow Measurement

September 14-17,2004 Guilin,China

Testing the Wafer V-Cone Flowmeters in accordance with API 5.7 "Testing Protocol for Differential Pressure Flow Measurement Devices" in the CEESI Colorado Test Facility

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Dr Richard Steven – Multiphase Meter Development Manager, McCrometer
Steve Caldwell – Vice President, CEESI
Bill Johansen – Engineering Manager, CEESI

7. Conclusions for the Testing of the Wafer V-Cone Meter

7.1 Water and air tests were performed on 4 Wafer V-Cone meters for McCrometer. One 2 inch Wafer V-Cone with a beta of 0.45 and three 4" Wafer V-Cone meters with beta ratios of 0.45, 0.5, and 0.65 were tested.

7.2 Testing was performed using compressed air on all of the Wafer V-Cone meters at a line pressure of 87 psia to establish baseline performance. These tests revealed that the characteristic curves of all of the Wafer V-Cone meters were very similar. The similarity of the characteristic curves indicates that the expansibility equation used with the Wafer V-Cone meter is correct.

7.3 Testing was performed at a significantly higher air pressure on all 4 Wafer V-Cone meters. The high pressure test results were compared to the low pressure test results and uncertainty bounds. The 4" 0.45 and 0.65 beta ratio Wafer V-Cone meter test results show no differences between the high pressure and baseline meter performance. The 2" 0.45 beta ratio and 4" 0.5 beta ratio test results show slight differences between the high pressure and baseline test results.

7.4 Liquid testing was performed on the 4" 0.65 and 0.45 beta ratio Wafer V-Cone meters as well as the 2" 0.45 beta ratio Wafer V-Cone meter. The liquid testing was performed using water. The differences between the liquid flow tests and the baseline tests performed on those meters along with the uncertainties associated with those differences are shown in Figure A1. The 4" 0.65 and 0.45 beta ratio Wafer V-Cone meter test results show no differences between the liquid flow and baseline meter performance. The 2" 0.45 beta ratio Wafer V-Cone meter test results show a difference between the liquid flow and air flow baseline test results of 1.93%±0.644%.

7.5 Non-standard testing was performed on the 4" 0.45 beta ratio Wafer V-Cone meter to determine the sensitivity of the Wafer V-Cone meter to asymmetric velocity profiles and swirl. Tests were conducted with a swirl generator at 0D, double out-of-plane elbows at 0D, a half-open gate valve at 3.1D, and a half-open gate valve at 0D. The differences between these tests and the baseline test results on the 4" 0.45 beta ratio Wafer V-Cone meter along with the uncertainty associated with the differences is shown in Figure A1. The only test showing a significant statistical difference between the test results and the baseline data is the Half-Open Gate Valve at 0D. These results indicate that the Wafer V-Cone exhibits a high degree of insensitivity to installation effects.

7.6 Noise measurements were made during all of the low pressure air testing performed on the four Wafer V-Cone meters. It was not possible to differentiate between the background noise in the test area and the noise produced by the Wafer V-Cone meters.

7.7 In conclusion the McCrometer Wafer V-Cone meter in these tests met the claims made by the manufacturer and exhibited an exceptional ability to operate effectively downstream of flow disturbances.

NORTH SEA FLOW MEASUREMENT WORKSHOP 2004

In

St Andrews, Scotland

From the 26th to 28th October, 2004

"Tests of the V-Cone Flow Meter at Southwest Research Institute® and Utah State University in Accordance with the New API Chapter 5.7 Test Protocol"

Authors:
Dr. Darin L. George – Senior Research Engineer, Southwest Research Institute
Mr. Edgar B. Bowles – Fluid Systems Engineering Manager, Southwest Research Institute
Ms. Marybeth Nored – Research Engineer, Southwest Research Institute
Dr. R.J.W. Peters – Flow Measurement Technology Manager, McCrometer
Dr. Richard Steven – Multiphase Development Manager, McCrometer

Conclusions

- The tests of the V-Cone Flow Meter according to API Chapter 5.7 demonstrated the V-Cone Flow Meter performance high-pressure gas at the MRF and in water at Utah State University. The test results showed good meter repeatability, resulting in a small measurement uncertainty in the calibrated discharge coefficient. In addition, the tests showed the excellent agreement between the MRF, the Utah State University Water Research Laboratory and the McCrometer water laboratory.
- The V-cone Flow Meter met the claims of the manufacturer as a ±0.5% device over a large Reynolds number range. The expansibility equation supplied for the meter was effective over the full range of test pressures, differential pressures and meter line sizes.

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- Non-standard Test 2 demonstrated that two, 90º out-of-plane elbows could be placed on the inlet of the meter with a maximum shift in the discharge coefficient of no more than ±0.15%. A flow with a swirl angle up to 30º at the inlet to the V-cone flow meter will produce similar results, with a minimal change (±0.15%) in the calibrated discharge coefficient. When a half moon orifice plate is placed at 5D upstream of the meter, the shift in the discharge coefficient can be expected to be no more than ±0.5%, within the tolerance claimed by the manufacturer.
- The Acoustic Noise Test indicated that there was no significant noise from the meter, but no conclusive noise level could be determined for the meter due to the background noise of the test facility.

FLUID FLOW MEASUREMENT

6^{TH} INTERNATIONAL SYMPOSIUM

MAY 16^{TH} TO 18^{TH} , 2006, QUERETARO MEXICO

TESTING THE WAFER V-CONE FLOWMETERS IN ACCORDANCE WITH API 22 "TESTING PROTOCOL" SECTION 2 – "DIFFERENTIAL PRESSURE FLOW MEASUREMENT DEVICES" IN THE CEESI COLORADO TEST FACILITY

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CEESI

Steve Caldwell – Vice President
CEESI

8. Conclusions for the Testing of the Wafer V-Cone Meters in Air

8.1 Air tests were performed on 4 Wafer V-Cones - One 2 inch Wafer V-Cone with a beta of 0.45 and three 4" Wafer V-Cones with betas of 0.45, 0.5, and 0.65.

8.2 Testing was performed using compressed air on all of the Wafer V-Cones at a line pressure of 87 psia to establish baseline performance. These tests revealed that the characteristic curves of all of the Wafer V-Cones were very similar. The similarity of the characteristic curves indicates that the expansibility equation used with the Wafer V-Cone is correct.

8.3 During the baseline test for the 4" line size with the 0.65 Beta insert, the lowest Reynolds number range tested was 93 962. At the time of the test, it would have taken exceedingly long to cover the low end of the range, so the decision was made to move on to other testing. Due to the shape of the Cd vs. Reynolds number curve, this has a significant effect on the calculation of the Mid Cd. In Table 2, the results are first shown with the installation effects test values over the entire Reynolds number range from 50 000 to 500 000. This shows that there is a significant difference between the Mid Cd values of each installation effects test from the baseline test. Due to the non-linearity of the Cd vs. Reynolds number curve, the proper way to compare Mid Cd values is to compare the installation effects tests over the same range that the baseline test was run.

These results, limiting the installation effects Reynolds number range from 90 000 to 500 000, are at shown as a separate section at the bottom of Table 2.

8.4 The conclusions for the half-moon disturbance tests are as follows:
2” 0.45 Meter.

There is no statistical difference from the baseline test when
Half Moon Plate 5D Upstream
Half Moon Plate 1D Downstream
Half Moon Plate 5D Upstream and 1D Downstream

4” 0.45 Meter

There is no statistically difference from the baseline test when
Half Moon Plate 5D Upstream
Half Moon Plate 2D Downstream
It is concluded that there would be no statistical difference if there is
Half Moon Plate 5D Upstream and 1D Downstream

4” 0.50 Meter

There is no statistically difference from the baseline test when
Half Moon Plate 5D Upstream
Half Moon Plate 1D Downstream
Half Moon Plate 5D Upstream and 1D Downstream

4” 0.65 Meter

Restricted Re range of 90,000 to 500,000
There is no statistically difference from the baseline test when
Half Moon Plate 5D Upstream
Half Moon Plate 2D Downstream
It is concluded that there would be no statistical difference if there is
Half Moon Plate 5D Upstream and 1D Downstream

8.5 Noise measurements were made during all of the low pressure air testing performed on the four Wafer V-Cone meters. It was not possible to differentiate between the background noise in the test area and the noise produced by the Wafer V-Cone meters. 8.5 Noise measurements were made during all of the low pressure air testing performed on the four Wafer V-Cone meters. It was not possible to differentiate between the background noise in the test area and the noise produced by the Wafer V-Cone meters.

8.6 In conclusion the McCrometer Wafer V-Cone meter in these tests exhibited an exceptional ability to operate effectively downstream of extreme flow disturbances. McCrometer will now advise their customers of the Upstream and Downstream straight pipe requirements between such disturbances and the Wafer V-Cone Meter to achieve the claimed uncertainty.

R.J.W.P 3rd May, 2006