API 14.3 Flow Conditioner Performance Test for the

CPA 50E Flow Conditioner

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Abstract

Over the last several years, research has shown that by improving on the flow conditioners used in natural gas metering applications, measurement is improved and installation cost can be reduced. The new standard developed for orifice meters (AGA-3/API 14.3 and ISO 5167 - 2) addresses the question of flow conditioner testing to ensure the meter performance when subjected to various flow perturbations.

This paper reviews testing carried out by Southwest Research Inc. and the NOVA Research and Technical Centre performed on the CPA 50E flow conditioner in accordance with AGA-3 and ISO 5167 - 2. These tests meet the requirements of the standard for approval of type.

Introduction

Orifice metering is one of the most commonly used metering technology in the gas production and transmission industry. This is due to the low installation and maintenance cost, and the low uncertainty which can be achieved using these meters.

Another significant advantage orifice meters have over most other technologies is the ability to use the meters without having them *proved* or *calibrated* (Note that there is a requirement to calibrate the instrumentation measuring pressure, differential pressure and temperature, but not to flow prove the meters themselves). This feature is achieved by precisely defining the geometry of the meter, so that each meter reacts similarly to the flow of gas. This is referred to as *dynamic similarity*.

In order to ensure that the meters have the property of dynamic similarity, orifice meters should conform to the industry standard for these devices, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids*, referred to as AGA Report No. 3, or API 14.3.

A key factor in maintaining dynamic similarity is the velocity profile of the gas as it enters the meter. The orifice equation was developed using a *fully developed* velocity profile. This is considered to be the profile of the gas after travelling through a long length of uniform straight pipe. Unfortunately, it is generally not possible to arrange the piping upstream of a meter so that there is enough straight pipe to achieve fully developed flow. The 2000 version of the standard results from testing done at a number of recognized facilities. The intent of these tests was to provide installation requirements, including the piping upstream of the meter so that the results are the same as those obtained from a long uniform upstream pipe.

A key aspect of the upstream installation is a flow conditioner, which modifies the flow as it passes through the meter. A.G.A-3 provides three options for flow conditioners: 1) The user of the meter can opt for not using a flow conditioner (a bare tube); 2) A tube bundle flow straightener of specific design can be used (the details for this can be found in the standard); or 3) A flow conditioner, which passes a series of tests can be used. These tests are outlined in the standard. This third option is the subject of this paper.

The reason that someone using an orifice meter would use this third option is that it there are several flow conditioners on the market that easily outperform the tube bundle flow straightener. The testing for the 2000 version of the standard has shown that the installation requirements for the tube bundle, in the previous version of the standard, do not allow sufficient flow development to reproduce the long uniform length of pipe used in developing the standard. Because of this, many existing meter installations do not meet the new standard. It is possible, however, by the simple act of replacing the tube bundle with another flow conditioner that the meter will again the standard, and be capable of measuring flow accurately.

CPA 50E Flow Conditioner

The CPA 50E Flow Conditioner consists of a steel plate 0.125D to 0.15D in thickness with a central circular hole and two rings of circular holes in concentric circles around the central hole. The spacing and design of the flow conditioner has been developed to produce a fully developed profile downstream of the conditioner. The holes account for about 50% of the area of the plate, and are sized such that the velocity profile a short distance downstream will be the same as the fully developed profile. The thickness of the plate also eliminates swirl which may exist upstream of the meter.

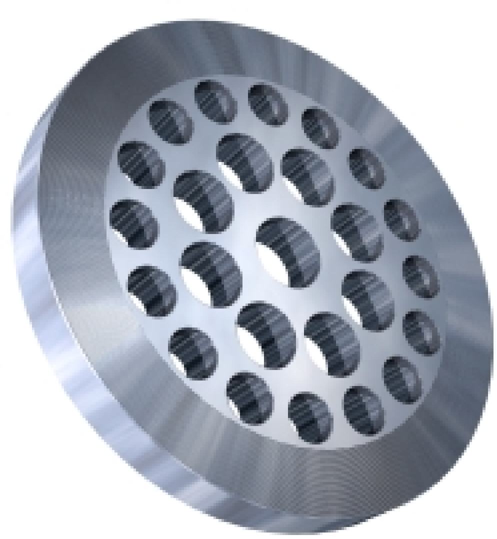


Figure 1 – CPA 50E Flow Conditioner

The design is patented and cannot be used without permission

Test Requirements

Detailed test requirements are outlined in the 2000 version of AGA-3 Appendix 2D (2). This Appendix outlines the range of pipe sizes, β ratios, and Renolds Numbers to be used (users are advised to refer to the published standard). The test requirements for approval of type are presented here in abbreviated form.

1. **Baseline Calibration** using a bare meter tube with a minimum of 70D upstream of the orifice plate, with less than 2 degrees of swirl upstream of the 70D tube. This test should be performed with the same orifice plates and β ratios that will be used for tests 2 to 5.
2. **Good Flow Conditions** with the flow conditioner downstream of the meter tube used in Test 1. This test is done to show how the flow conditioner affects the meter baseline.
3. **Two 90˚ Elbows Out of Plane –** This test will show how the flow conditioner handles this normal piping installation.
4. **Gate Valve Closed 50%** - This test shows how the flow conditioner handles highly asymmetric velocity profiles.
5. **High Swirl –** This test shows how the flow conditioner handles high swirl (min. 24˚ at 17D). The design of a device to generate this swirl is given in the standard.

In addition, there are requirements for testing different sizes to ensure scalability of the flow conditioner, and testing at multiple flow rates. These last two tests must be performed on the baseline calibration and at least one of the disturbance tests.

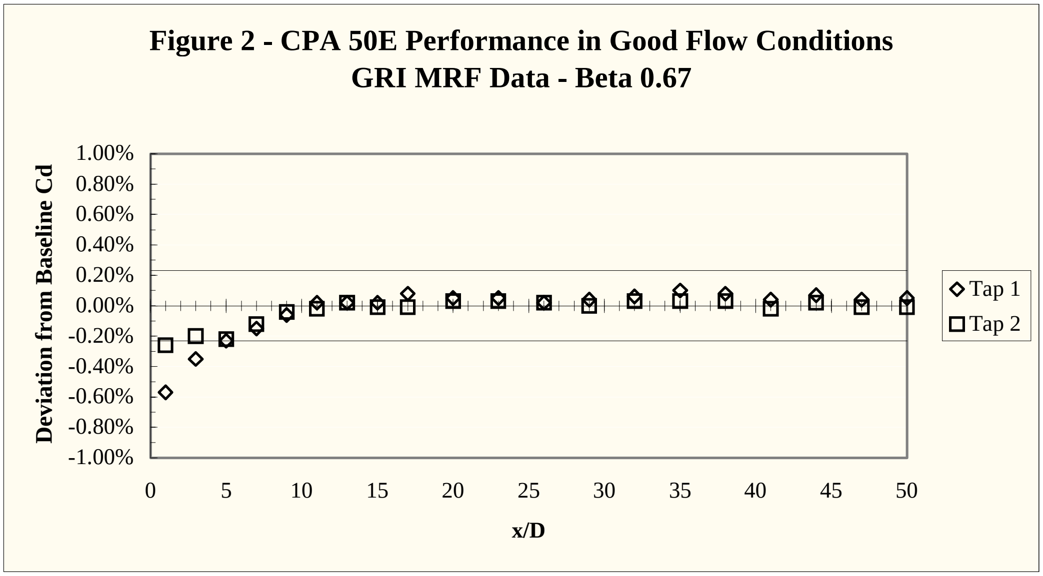
The performance that the flow conditioners must meet to pass these tests is very stringent. The threshold for acceptance is half the 95% confidence level in the RG equation at infinite Reynolds Number. This is slightly more than twice the repeatability for the SwRI facility, which means that it is close to the detectable limit for that facility.

Test Results

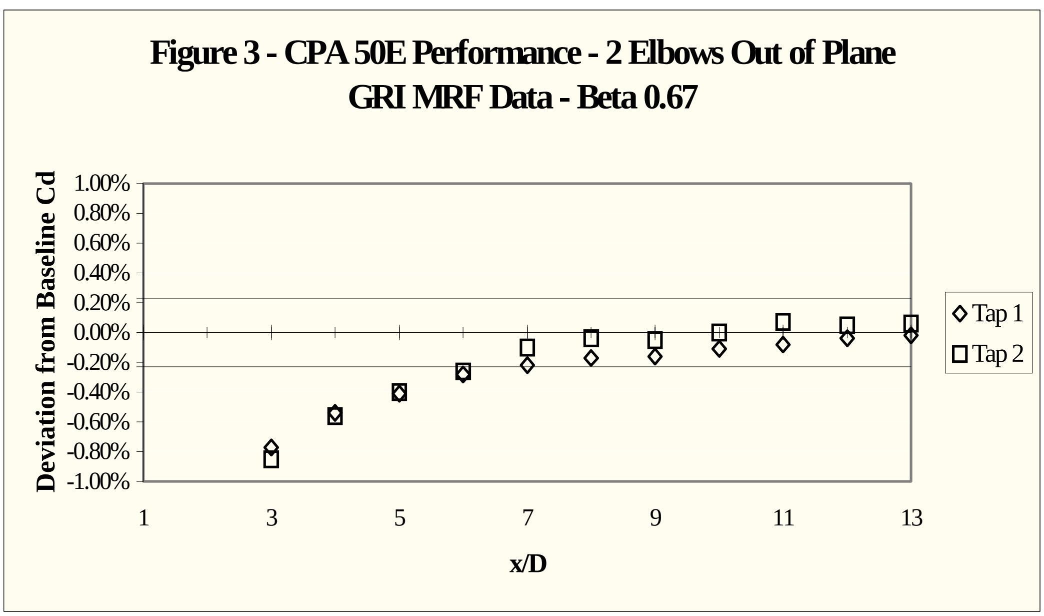
Southwest Research Institute – This testing was sponsored by GRI at the GRI Metering Research Facility (GRI MRF) at Southwest Research in San Antonio. The purpose was to provide data to support the development of the tests which later became part of AGA-3. Only a small portion of the data is included in this paper. For a complete report, please contact GRI.

Test 1 - Baseline Calibration - Southwest Research has done a baseline calibration on the meter used in the other tests. This calibration falls within the uncertainty of the overall data set used to develop the flow equation.

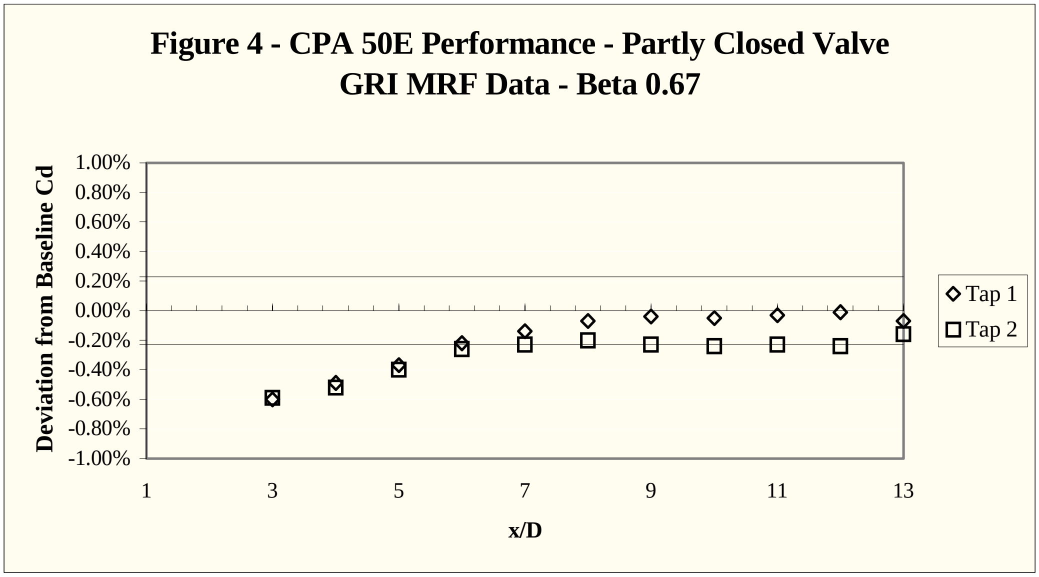
Test 2 - Good Flow Conditions - This test is performed to ensure that the flow conditioner does not alter the meter indication when place in a line with good flow conditions (already fully developed). Note that the results presented here are a subsection of the results presented in the full report developed by Southwest Research. These results are those for β = 0.67. The results for Test 2 are shown in Figure 2. Note that when the flow conditioner is very close to the orifice plate the reading is outside the limits set forth. However, after the flow conditioner is moved 5D or so from the plate, the measurement is within the specification.



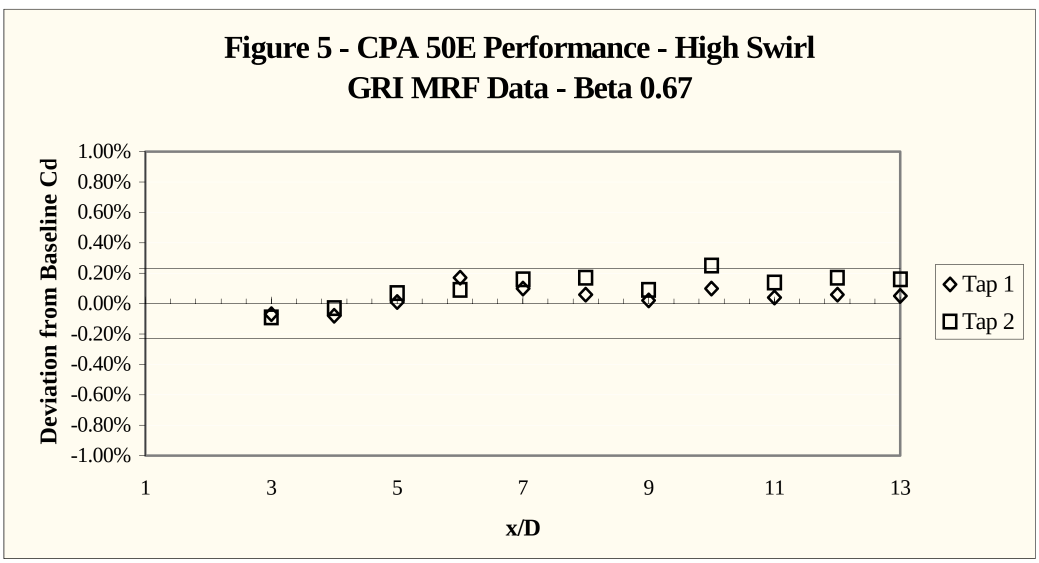
Test 3 – Two 90˚ Elbows Out of Plane – This test demonstrates the performance of the flow conditioner in this common piping installation. The results for a 17D meter run are shown in Figure 3. In this case, 7D is required so the reading is within the tolerance allowed**.** 29D and 45D meter runs were also tested, with similar results.



Test 4 - Gate Valve Closed 50% - The results are shown in Figure 4. Again, 7D is required to meet the specification.

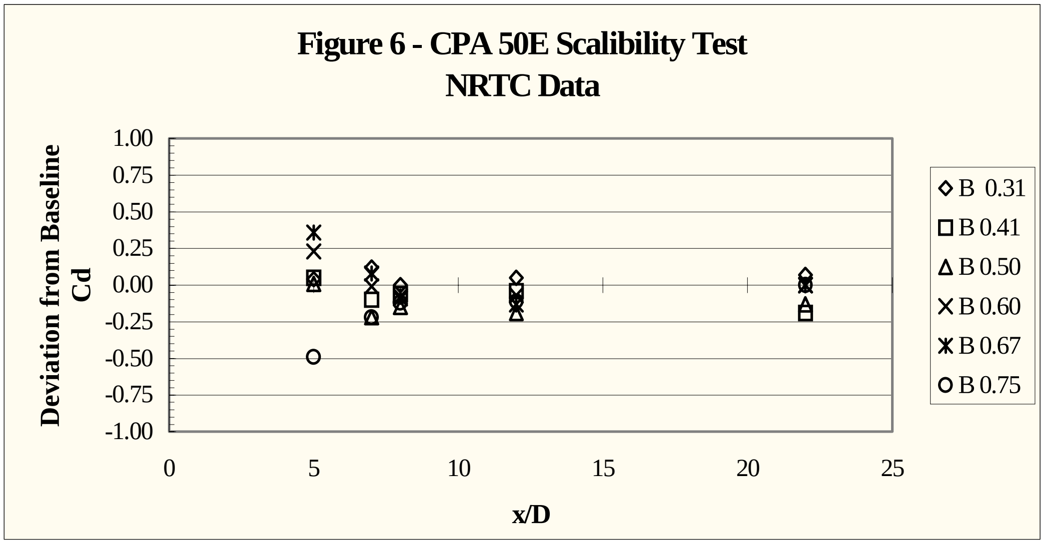


Test 5 - High Swirl – The results are shown in Figure 5. The flow conditioner meets the requirements 7D upstream of the orifice plate.



Scaling – Tests were carried out by the Nova Research & Technical Centre at TransCanada's Didsbury Test facility (testing sponsored by TransCanada Pipelines). As per the requirements of the standard, this testing was carried out on the baseline condition and on one other of the proscribed tests. In this case, Test 3 – Two 90˚ Elbows in

Perpendicular Planes, was repeated. The results are reported in detail in Reference 5. Results are shown in Figure 6.



Reynolds Number Sensitivity – Results reported by SwRI (3) for testing on 0.67β plates are at Re 2.7 x 10^6. Testing performed by NRTC (6) on air at 0.68 β plates at Re 1.7 x 10^5 and 1.0 x 10^5 give results as follows:

NTRC Testing on Two Elbows out of Plane on Air at Low Pressure

- 12D Meter Run
- CPA 50E Flow Conditioner 7D upstream of orifice plate

Beta Ratio	Reynolds Number	Deviation from Baseline Cd
0.68	170,000	-0.24
0.68	100,000	-0.08

This meets the requirements of the standard over a much larger range of Re than specified. This testing was conducted on 4-inch flow conditioners, as per the recommendation of the standard.

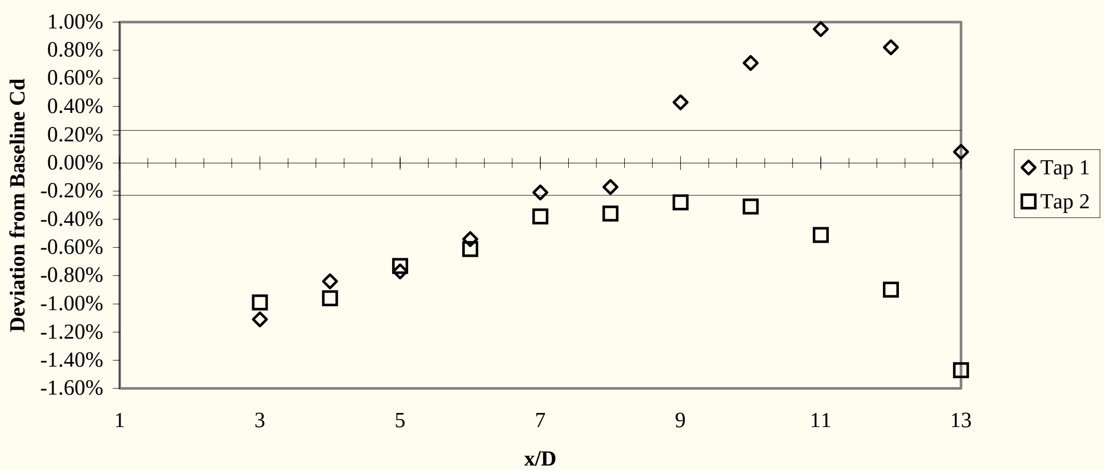
Flow Conditioner Application

The CPA 50E Flow Conditioner can be used as a retrofit in existing orifice meter applications, or as part of a new installation. Both of these uses of the flow conditioner will result in a good installation when some care is taken in the design of the facility. In general, the upstream portion of the piping should be such that strong swirl or highly asymmetric flow is not present. When these are unavoidable some additional meter tube between the flow conditioner and orifice plate is suggested.

Retrofit Installations – There are many meters installed in accordance with the former version of the standard. In these cases, the minimum length does not always give enough development downstream of the flow conditioner to meet the requirements of the new standard. Even though these installations may be grandfathered under the current revision some additional uncertainty is present.

For example, the 1991 version of AGA-3 Part 2, using figure 2.5 Partly Closed Valve Upstream of a Meter Tube, an overall length of 17D from the orifice plate upstream to the partly closed valve is required ($\beta = 0.75$). 7D is required from the straightening vane outlet to the orifice plate. The work done by Southwest Research at the GRI MRF (3) shows that this configuration results in much higher uncertainties than described in the previous version of the standard. This is illustrated by Figure 7

Figure 7 - 19 Tube Bundle Performance - Partly Closed Valve
GRI MRF Data - Beta 0.67



Under all of these installations using tube bundles and the minimum lengths specified in AGA-3 (1991), the situation can be corrected by installing a CPA 50E flow conditioner in place of the tube bundle.

Another example is a meter with no straightening vane or flow conditioner, downstream of two in-plane elbows. In this configuration, the previous version of the standard requires 17D between the last elbow and the orifice plate. Again, testing done by SwRI shows that this length of upstream pipe is not adequate to avoid high uncertainty. A flow conditioner such as the CPA 50E can also be used in this case, instead of substantially increasing the upstream length required.

These examples show how a CPA 50E flow conditioner can be used to retrofit existing meter runs to meet the new standard.

New Installations – When new meters are being installed, using a CPA 50E flow conditioner can reduce the amount of upstream pipe required to keep uncertainty as low as possible. Of course, flow conditioning is only one of many factors which affect overall meter performance.

Conclusions

The CPA 50E flow conditioner meets the requirement for approval of type in the 2000 version of AGA-3.

Existing meters designed to meet previous versions of the standard can be retrofitted to meet the new standard, in most cases at nominal cost, by installing a new flow conditioner.

Flow conditioning is an important aspect of orifice metering, but a flow conditioner cannot correct all problems associated with metering. The condition of the meter tube and orifice plate, as well as the condition and design of the secondary equipment are all factors which may also affect the quality and performance of the meter.

References

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4. Studzinski, W., Karnik, U., LaNasa, P., Morrow, T., Goodson, D., Hussain, Z. and Gallagher, J. 1997 "GRI report White Paper on Orifice Meter Installation Configurations with and without Flow Conditioners"
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