QUALIFICATION OF A FLOW CONDTIONING DEVICE ACCORDING TO THE NEW API 14.3 PROCEDURE

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Abstract: The new AGA 3/API 14.3 standard on concentric square edged orifice meters suggests that, if installation effects can be shown to be less than about 0.23%, there is no need to apply any additional uncertainty to that of the basic discharge coefficient. This suggestion has revived interest in flow conditioners that can assure this performance without the need for long straight upstream lengths of pipe.

A feature of the new standard is that it specifies performance acceptance tests for evaluating other flow conditioners, which were not included in the previous versions of the document. In this paper we will review this procedure and show results for a device that has been qualified in this manner.

INTRODUCTION

The latest API 14.3 revision is altering the specification of the commonly used 19-tube bundle flow straightener to such an extent that it can no longer be easily made from standard tubing. However, the standard allows other flow conditioners to be qualified for use by meeting certain type approval requirements. In anticipation of these changes, Daniel has qualified a non-proprietary flow conditioner to make it available to the industry.

API TYPE APPROVAL REQUIREMENTS

These have not yet been adopted and are subject to change, but the basic philosophy described below will no doubt be followed. The description of these tests as currently drafted for the new standard is quoted below.

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 for all line sizes and Reynolds Number (Re) values. The flow conditioner performance test contains the following common elements:

Test 1: Baseline Calibration, evaluating performance of test facility

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

Test 3: Two 90^0 Elbows in Perpendicular Planes, testing of flow conditioner performance in handling combination of a modest swirl (up to 15^0 swirl angle) and a non-symmetrical velocity profile

Test 4: Gate Valve 50% Closed, evaluating flow conditioner performance in strongly non-symmetrical velocity profile

Test 5: High Swirl, assessing flow conditioner performance in flows with high swirl angle (over 25^0), representative of headers

The facility baseline has to meet the acceptance criteria specified below. The results of Tests 2 - 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 diameter-ratio (b) and *Re*.

D 1. Baseline Calibration - A baseline calibration should be performed using the same beta ratio range of orifice plates that will be used in the type approval tests.

a) The baseline should be performed using a meter tube with a minimum straight upstream meter tube length of 70Dn, where Dn is the nominal pipe diameter. There must be swirl-free (less than 2^0 swirl angle) flow at the entrance to the meter tube.

b) Baselines using large pipe diameters (>16-inch) may prove to be difficult to perform due to space limitations in most laboratories. An alternative baseline configuration of a minimum of 45Dn and an oversized Sprenkle flow conditioner is acceptable. The oversized Sprenkle design must conform to that specified in NIST Technical Note 1264.

c) To prove that the mechanical baseline configuration is valid, the baseline C_D values should lie within the 95% confidence interval for the Reader-Harris/Gallagher (RG) equation.

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

D 2. Type Approval Test, which approves use of a tested flow conditioner for any type of upstream installation, any line size, and any Re. Such a broad approval of the flow conditioner applications requires performance of the Tests 1 to 5 within the following prescribed parameter ranges:

(2.1) $10^4 \leq Re \leq 5 \times 10^5$ and Re $\geq 10^6$
(2.2)   D $\leq$ 4" and D $\geq$ 8"

The following selection of tests <u>must be performed</u>:
a) <u>Disturbance</u>
   Tests 1 to 5 at one pipe diameter and one Re range selected from (2.1) and (2.2).
b) <u>Scaling</u>
   Tests 1 and one of Tests 3 to 5 conducted at two pipe sizes [preferably at one pipe size as in a)] selected from two prescribed diameter ranges at the Re as in the tests a) or at the Reynolds number chosen from the second range.
c) <u>Reynolds Number Sensitivity</u>
   Tests 1 and one of the tests 2 to 5 conducted preferably at one of the pipe sizes used in b) and at two Reynolds numbers, one selected from the range Re $\geq 10^6$ and the other from the lower Re range such that their ratio is greater than about 7. Preferably one of the selected Reynolds number should be as used in a) or b). If the selected Reynolds number in a) is equal or larger than 3×10^6 and the manufacturer or user of flow conditioner is seeking an approval for applications in the range Re$\geq 3 \times 10^6$, then the test c) can be skipped.
d) <u>Orifice β ratio</u>
   If it is known that 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. However, if swirl is not removed by the flow conditioner, it would be misleading and erroneous to rely on a single value of β to gauge the 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 flow conditioner performance tests be performed for a single value of β=0.67. If the 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 flow conditioner at β=0.40 and β=0.67, then Test 3 and Test 5 will have to be performed for a complete range of β values between β=0.20 and β=0.75.

In all performance tests, the use of a flow conditioner is restricted to those locations within the meter run where the ΔC_D of the tested flow conditioner are within one half of the uncertainty limits $\pm 2s$ of RG equation.

ZANKER PLATE DESIGN

In 1959, while at BHRA, Zanker developed a flow conditioner designed to produce fully developed flow in a short pipe length. It consists of a graded resistance perforated plate followed by a section of rectangular honeycomb to reduce turbulence and remove swirl, as shown in Figure 1. Results were made more generally available at an NEL conference in 1960 and published in 1962 [Ref. 1]. In 1980, the Zanker straightener was included in ISO 5167, the international standard on pressure differential devices.
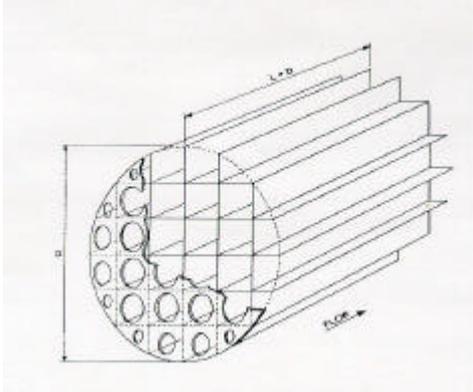
Figure 1. Original Zanker Plate

Figure 2. Profiler™ flow conditioner

A substantial body of work has appeared on flow conditioners. A significant advance was made by Mitsubishi in 1973 [Ref. 2] when they showed that a deep perforated plate (depth = hole diameter) removed swirl. Laws did much to improve the performance and understanding of flow conditioners. In 1992 she published work [Ref. 3] which basically confirmed that a deep Zanker perforated plate performed well and did not need the honeycomb to remove swirl.

Because this body of information has been in the public domain for such a long time and is thus free of any proprietary encumbrances or patent restrictions, Daniel decided to qualify the "Modified Zanker" or Profiler™ flow conditioner for the new standard.

The design used for the testing is shown in Figure 2. It is identical to that described in Reference 3.

EXPERIMENTAL SETUP

The orifice meter used for this investigation was a nominal 100mm (4") run, with β = 0.67. An orifice flange union (OFU) was used as the plate holder and seven spool pieces were fabricated in order to place the flow conditioner at 7.5D, 12D, 17D, 22D and 29D upstream of the orifice plate. Plate cleanliness was maintained throughout the test to retain the same plate surface finish.

The test was conducted in the Flow Research Laboratory of Daniel Industries in Houston, Texas. The flowing fluid was water and the flow rate was determined by the dynamic-weighing method. A schematic of the test flow facility and instrumentation is shown in Figure 3. The differential pressure was monitored with a single-leg 100" (2540mm) mercury manometer. Each setup was calibrated for a number of flow rates, covering a 3:1 Reynolds Number range. Preliminary investigations established that, for any calibration, the value of the discharge coefficient at a given flow rate repeated to within ±0.1% for a collection time of 80 seconds or more for dynamic weighing. Therefore, weight of water collected varied from 14000 lbs. to 4000 Lbs. The least significant digit on the timing display was 0.001 sec, and the smallest division on the weigh scale was 0.9kg (2 lb.). The elapsed time of each run is determined with a Daniel timer to an accuracy of ±1 millisecond. It is actuated by a preset totalizer start and stop mechanism. By allowing sufficient time and accumulating a large weight at each flow rate, the inherent inaccuracies of the switching system are reduced to a negligible error. In the dynamic weighing method, timer switches are actuated by settings on the weigh scale. All temperatures are monitored with temperature transducers that are calibrated against certified

thermometers. The temperature at the manometer is monitored and appropriate corrections are applied to the manometer reading. The flowing fluid temperature is monitored to apply the density correction for the discharge coefficient computation.
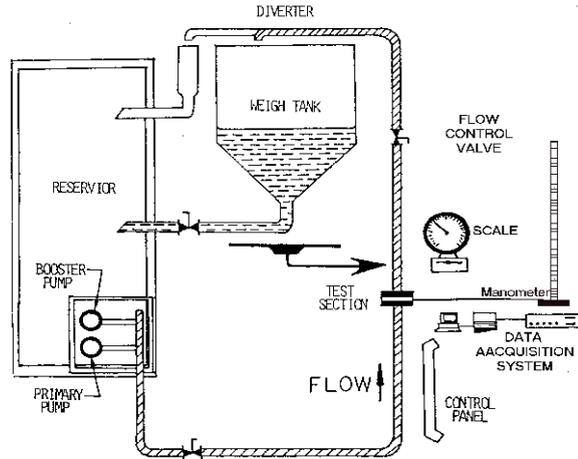

Figure 3. Schematic of test rig.

The orifice meter tube was plumbed in a horizontal position with the appropriate disturbance, conditioner plate, and straight pipe lengths upstream, and 5 pipe diameters downstream of the meter. A sufficient time is allowed to achieve the steady state flow rate before acquiring data at any given flow rate. During a timed interval, at least 30 differential pressure readings are recorded. The differential pressure used for the computation of the flow coefficient is the average of those 30 readings. Temperatures and pressures are recorded during each flow test period and proper corrections are incorporated in the calculation. For the weighing method, volume is determined from the weight of water collected and the water density corrected for the temperature of the flowing water. The flow rate is calculated from the volume of water collected and the time of collection.

RESULTS

a) Baseline

The results are shown in detail in Figure 4. Note that measurements are made for three tap locations and four Reynolds Numbers (from 3 to $8*10^5$). This is more than required for type approval; one tapping and one Reynolds number would be sufficient. The baseline calibration agrees very well with API 14.3 and qualifies the Daniel flow laboratory to perform the type test. Note that the standard does not demand an "accredited facility" to perform type testing but accepts a satisfactory baseline calibration.
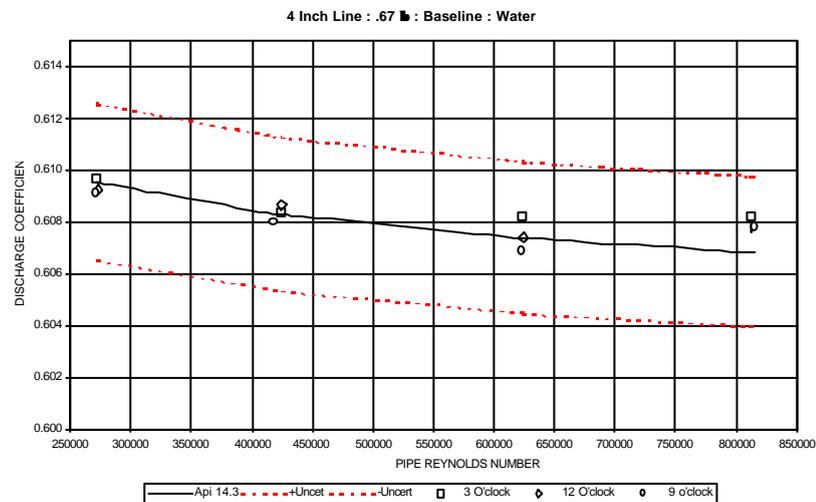

Figure 4.

b) Good Flow Conditions

The results shown in Figure 5 plot deviations of C_D from baseline conditions (in %) against the distance of the flow conditioner from the orifice plate (in pipe diameters). Apart from the measurement at 3D, all results are within tolerance; even at 3D the average of the 3 tapping locations is in tolerance. At greater distances from the orifice (17D), ΔC_D tends to zero.
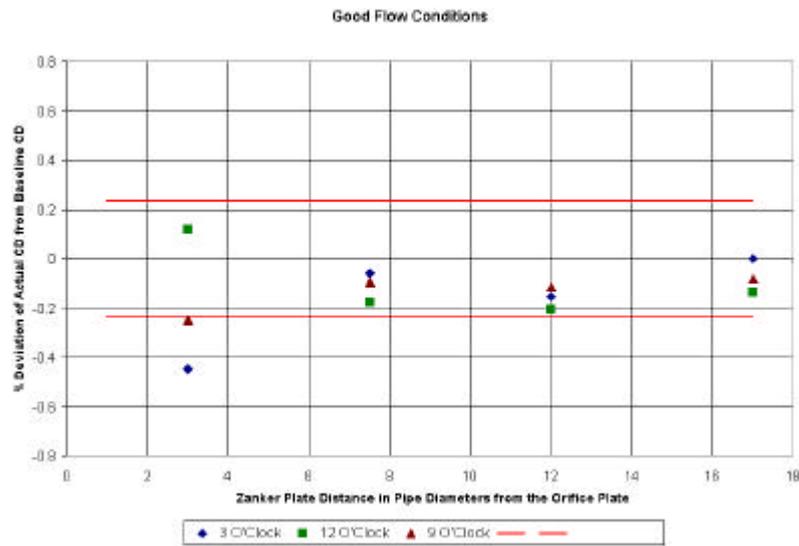

Figure 5.

c) Two 90° Elbows in Perpendicular Planes

Results were taken for three different flanged meter tube lengths (17, 29 and 45D) and are shown for 17D (Figure 6). As the meter tube gets longer, the distance between the conditioner and disturbance increases for the same distance between the conditioner and orifice plate. All the results are in tolerance; at greater distances from the orifice (29D), ΔC_D tends to zero.
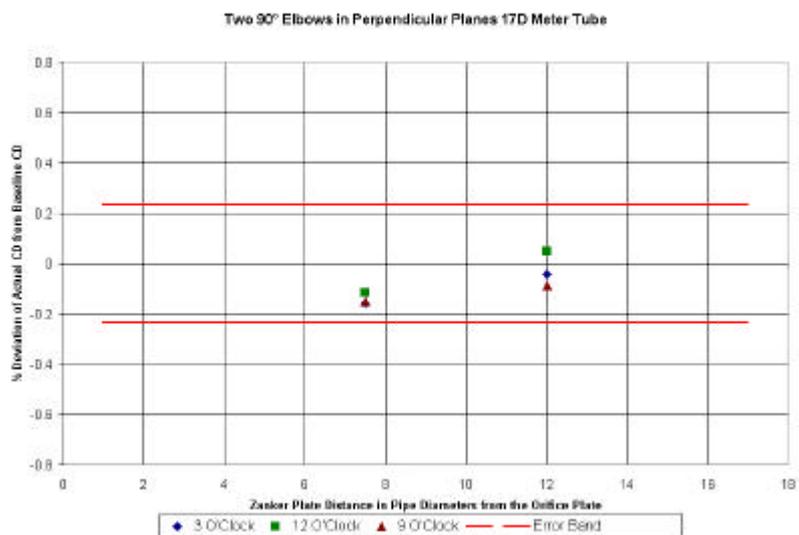
Figure 6.

d) 50% Closed Gate Valve

Results were taken for three different meter tube lengths and are shown for 17D (Figure 7) and 29D (Figure 8). As the meter tube gets longer, the distance between the conditioner and disturbance increases for the same distance between the conditioner and orifice plate.
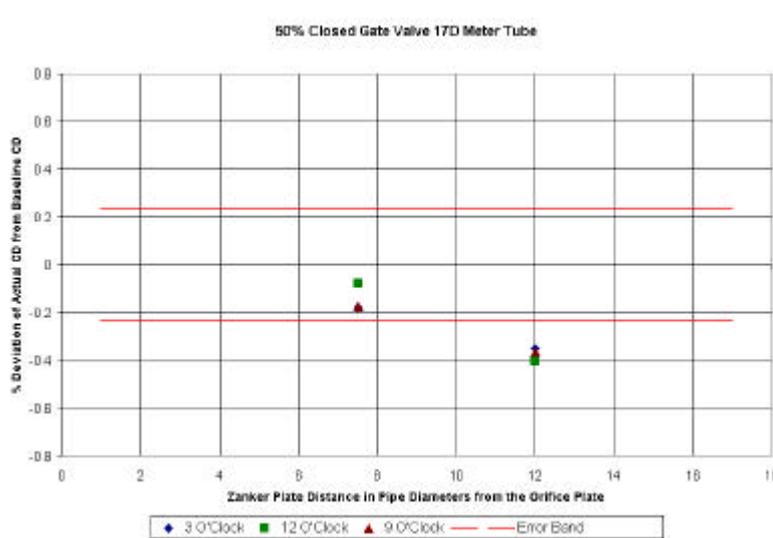
Figure 7

Figure 8

All results are within tolerance except the 17D meter tube with the conditioner 12D from the orifice plate. The problem is that the conditioner is only 5D (=17-12) from the disturbance and the 50% closed gate valve produces a jetting asymmetric flow. The conditioner cannot be used at 12D in a 17D meter tube, but is fine for all other positions tested.

e) High Swirl ($> 25^{o}$)

There is little guidance in 14.3 either on how to produce the swirl or on where and how to measure the swirl angle. We have used eight blades set at 45° to the axis, welded into the 4" pipe as shown in the photograph (Figure 9).

A three-holed Pitot tube has been used to find the swirl angle (results shown in Figure 10). The maximum swirl near the wall is 32°, which is more arduous than required.
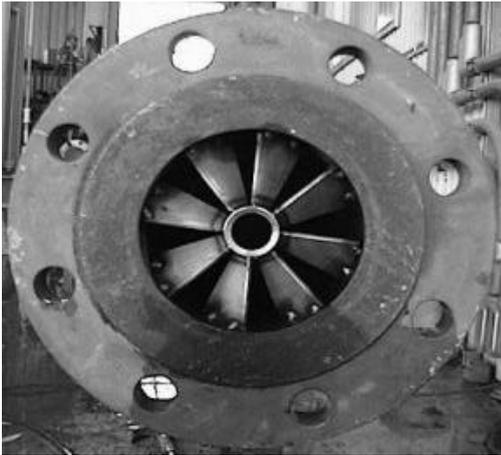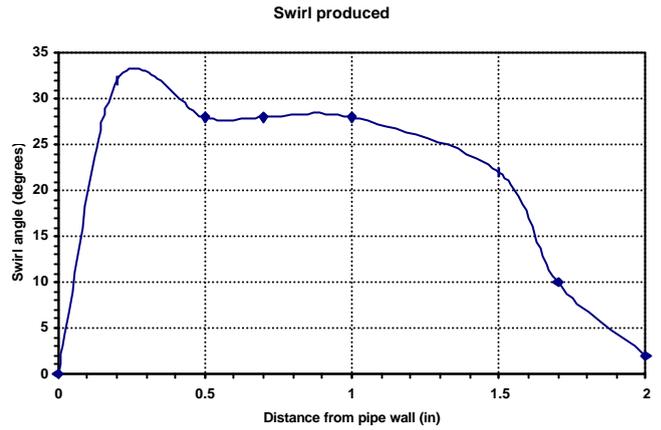
Figure 9.

Figure 10.

Results were taken with $\beta = 0.67$ for three different meter tube lengths and are shown for 17D (Figure 11). Despite some scatter at 7.5D, all the points are within tolerance.
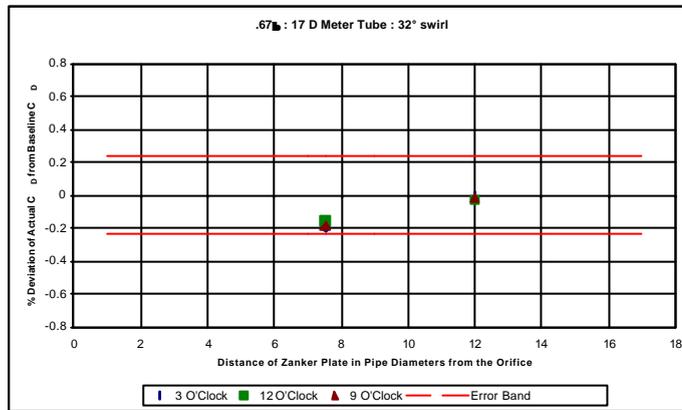

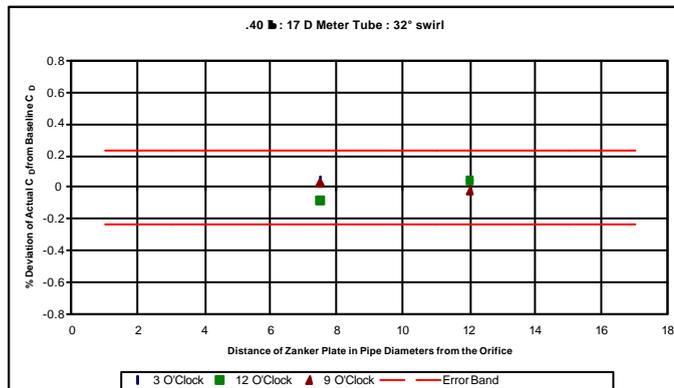**Figure 11**.

f) High Swirl, with $\beta = 0.4$

Figure 12.

Results were taken with $\beta = 0.4$ for three different meter tube lengths and are shown for 17D (Figure 12). All results are within tolerance; there is no significant difference between the $\beta = 0.4$

and β = 0.67 orifice plates. Hence, the flow conditioner does remove swirl and it is sufficient to test with β = 0.67.
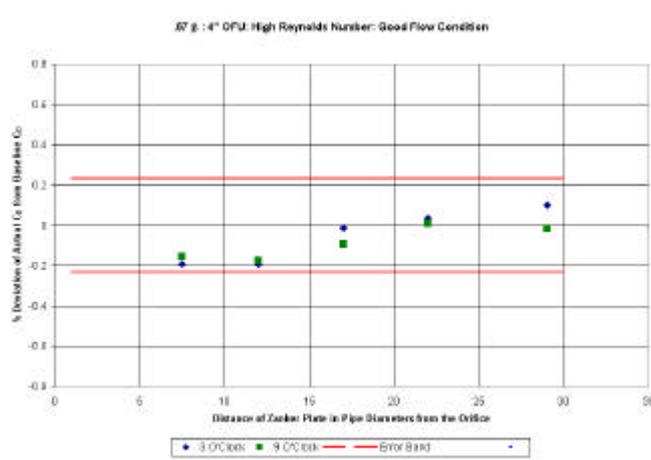
g) Reynolds Number sensitivity

Figure 13

Results are shown with β = 0.67 and good flow (Figure 13) for the same pipe work tested in water at the Daniel flow lab, but tested in high pressure gas at CEESI with Re = $1 - 3.2*10^{6}$. All the results are in tolerance; at greater distances from the orifice (29D), ΔC_D tends to zero. Because testing exceeded Re of $3*10^{6}$, the conditioner can be used up to infinite Re.

h) Scaling

The 8" orifice was tested with disturbance produced by a 50% closed gate valve. Results were taken with β = 0.67 for three different meter tube lengths and are shown for 17D (Figure 14) and 29D (Figure 15). These results agree with those for the 4" orifice given in d) above.
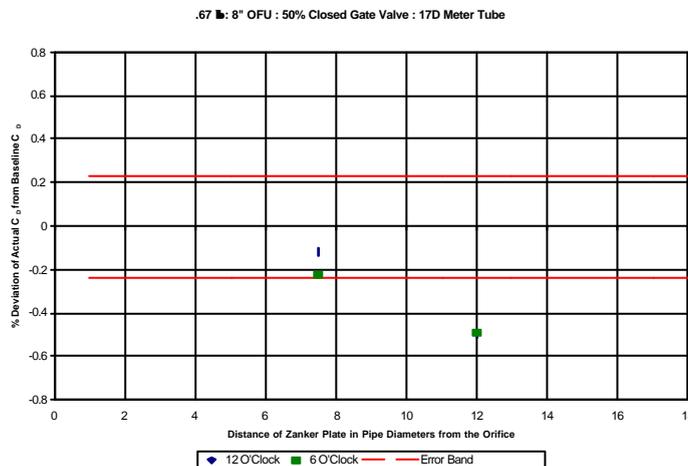

Figure 14.

DISCUSSION

The same 4" orifice meter and meter tube were calibrated at Daniel in water and at CEESI in high pressure air. The results of both calibration are shown together in Figure 16 and exhibit excellent agreement between the labs and the RG equation.

The 8" water, 4" water, and 4" high pressure air tests all used the flow conditioner in fully developed flow. The results for all three tests are shown together in Figure 17 where they basically fall onto a single curve.
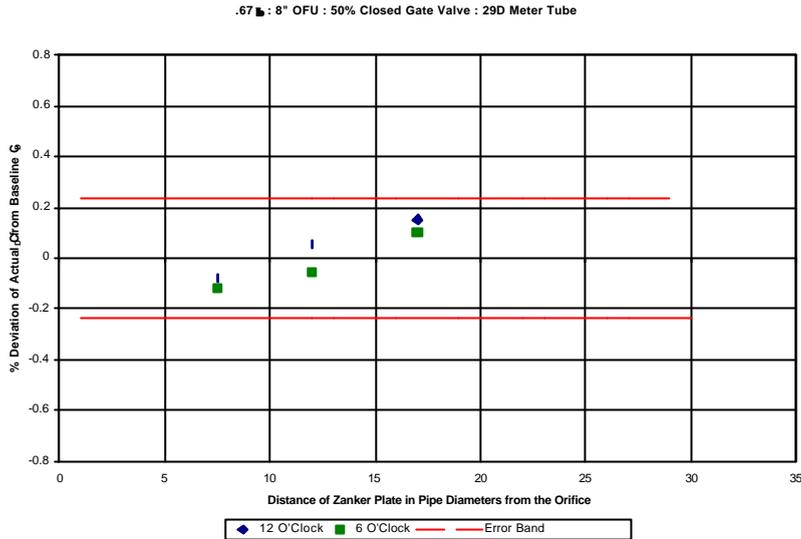
.67 ▶ : 8" OFU : 50% Closed Gate Valve : 29D Meter Tube

Figure 15.

API 14.3 does not ask for pressure loss measurements. However, because of their practical significance, the loss coefficient K has been measured, and defined as:

$K = \Delta p / \frac{1}{2} \rho V^2$ where Δp = pressure loss, ρ = fluid density, V = fluid velocity The conditioner has K = 2.8. This can be reduced significantly by chamfering the inlet edge of the holes, but this would require re-testing to check on the performance.

The NIST TN 1264 is not too specific on the design of any oversized Sprenkle plate, it just gives some details of the plates used in the reported testing. ISO 5617 at least gives general information on the design of Sprenkle plates and the oversize should be one nominal pipe size.
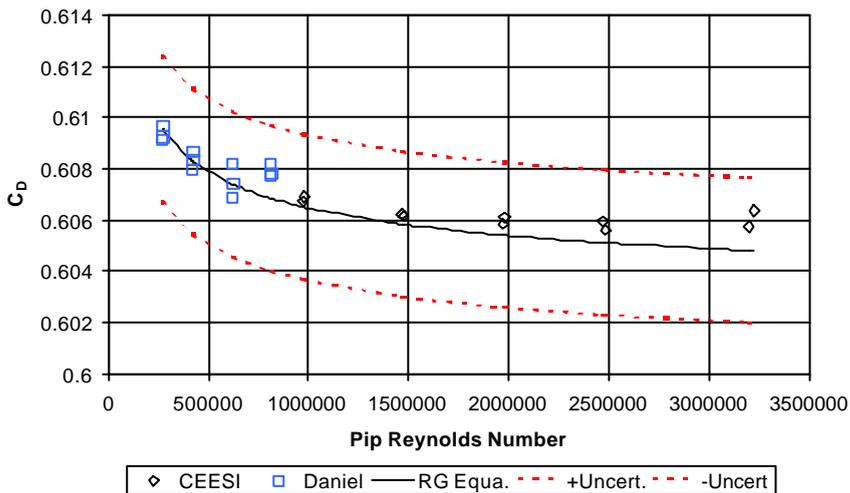
4' OFU : .67▶:Ceesi & Daniel Baselines
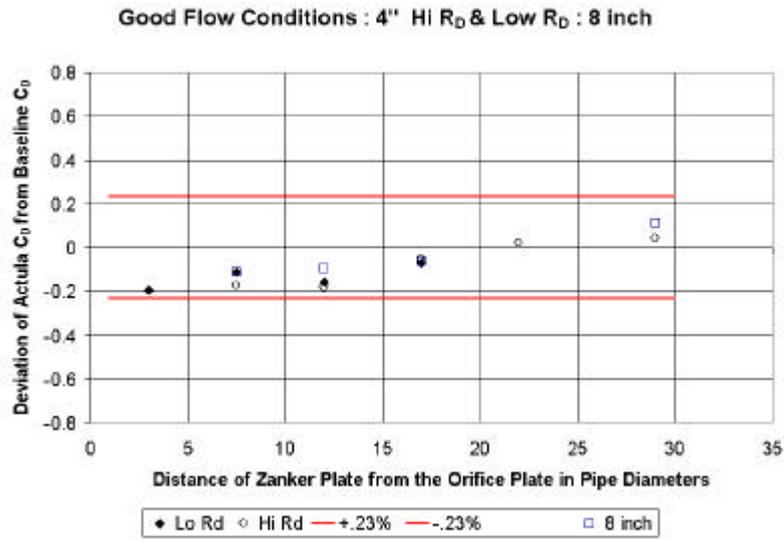

Figure 16.

Figure 17.

CONCLUSIONS

The exact process of obtaining type approval for a flow conditioner has not yet been finalized. Hopefully these results and this discussion will help achieve this approval.

The use of three pairs of taps, which is not part of the type approval, shows that they are not always all in tolerance although the average normally is.

The High Swirl Test requires better definition: how to produce the swirl, how to measure the swirl angle, and where to measure the swirl angle.

The tests indicate that it has been possible to qualify the Modified Zanker Profiler™ flow conditioner under the API 14.3 standard type approval. This mean that users will continue to have access to reasonably priced, non-proprietary flow conditioners for orifice meter installations.

A simple recommendation would be to use a 17D meter tube with this new conditioner placed 7.5D from the orifice plate, as this arrangement passed all tests.

The conditioner can be used with ∃ up to 0.67, with any disturbance, in any pipe size, and with no upper limit on Reynolds Number.

REFERENCES

[1] Zanker, K.J., The Development of a Flow Straightener for use with Orifice-Plate Flowmeters in Disturbed Flows, Flow Measurement in Closed Conduits, NEL, 1960.
[2] Akashi, Koichiro; Watanabe, Hisao; Koga, Kenichi, of Mitsubishi,
    U.S. Patent 3840051, Straightener April 14, 1973.
[3] Laws, E.M.; Quazzane, A., Effect of Plate Depth on the Performance of a Zanker Flow Straightener, Flow Measurement Instruments, Volume 3, No. 4, 1992.