IMPORTANCE OF THE PROPER ORIENTATION OF ORIFICE PLATES

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ABSTRACT

Is the proper orientation of an orifice plate with a bevel important? The importance depends upon whether gas is being bought or sold. Volumetric gas rates were measured at two meter tube pressure levels using orifice plate bore sizes from 1/2- through 1-1/4-inch in two 3-inch commercial meter tubes in series. The orifice plates were tested in the correct orientation with the sharp edge upstream and then reversed with the bevel upstream. The differences in the calculated gas rates for proper and improper orifice plate orientation are significant.

DISCUSSION OF GAS MEASUREMENT

A meter tube and orifice plate are presently the accepted method for measuring gas rates in most oil and gas field applications. There are numerous variables involved in the calculation of gas rates because gas is compressible, and its in situ volumetric rate is affected by pressure, temperature and gas composition. The many factors that can be included in the orifice flow constant reveal the complexity of accurate gas measurement calculations. Only 6 of the 11 factors are used for most calculations. The most important factor is the basic orifice factor since it is based on the bore ID of the orifice plate. Another factor which will effect the calculated gas rate significantly for a low gas gravity is the specific gravity factor. The other factors that are included in nearly all gas measurement calculations are the flowing temperature factor and the pressure and temperature base factors. The super-compressibility factor should be included at higher line pressures. The above six factors, which include the super-compressibility factor, were used in the gas measurement calculations in this paper.

The derivation of the basic orifice factor has a discharge coefficient based on a sharp-edged orifice and an infinite Reynolds number for the gas flow through the orifice. The value of the Reynolds number becomes asymptotic to the infinite value at high gas flow velocities; therefore, there is little error in this assumption in most instances.

The specifications for orifice plates are rigid in terms of all dimensions including commercially perfect flatness and a square sharp-edged bore that will not reflect appreciably a beam of light. The bevel angle for the thicker plates must have an angle of 45 degrees or less to the face of the plate. The bore ID is drilled at 68 oF. All plates with a bevel must be stamped "inlet" on the sharp-edged side or "outlet" on the beveled side. This requirement emphasizes the importance of properly installing an orifice plate.

TEST UNIT AND INSTRUMENTATION

The valve test skid unit[1] in Fig. 1 was not designed or built for a laboratory project. The unit was fabricated for conducting gas throughput tests in the field, and the instrumentation is typical oil field measurement equipment. High quality pressure gauges, bellows type orifice meters and a flow computer were installed on the test unit. The gas measurement system was the same as can be found on many oil and gas leases.

The orifice meters were calibrated at the test site by instrument technicians to eliminate any change in calibration from transportation to and installation on the test unit. Complete gas analyses were conducted regularly during the test period. The gas source was a plant delivering 89 percent methane with gas specific gravity of 0.601 which remained relatively constant. The gas was dry with no liquids ever detected in the system during the tests.

The upstream and downstream commercial 3-inch meter tubes had strightening vanes and ball orifice fittings with flange taps. The straightening vanes prevent swirl in the gas flow stream entering the orifice. The ball orifice fitting in Fig. 2 allows an orifice plate change without having to isolate the fitting and bleedoff the pressure. There is no interruption of the gas rate through the meter tube and orifice fitting while changing an orifice plate. A ball-orifice fitting ensures proper centering of the orifice in the meter tube. The upstream orifice meter on a 2.899-inch ID meter tube had a 0-100 inches of water differential bellows, and the downstream orifice meter on a 2.897-inch ID meter tube had a 0-200 inches of water differential bellows. The same orifice bore size could be used in the upstream and downstream orifice fittings for most tests by doubling the differential range of the downstream meter because of the lower downstream pressure.

The test unit is a closed loop because there is no branching between the upstream and downstream meter tubes. The gas rate passing through the upstream orifice must exit the system through the downstream orifice at the same gas rate at stabilized flow conditions. All flowing pressures, temperatures and gas rates were stabilized before the orifice-meter chart readings were recorded. The tests reported in this paper were conducted to verify the gas measurement equipment before initiating the valve test program. The piping was ideal for checking the difference between the proper and improper installation of orifice plates with two meters in series in a closed loop. The orifice plates were new and the orifice meters had been calibrated immediately before beginning the verification tests to prove the measurement system.

TEST RESULTS

The test results of these measurement verification tests are tabulated in Table 1. A chart from the upstream orifice meter is shown in Fig. 3. The actual chart in Fig. 3 is a pressure recorder chart for a 0-1500 psi pressure element. The differential reading must be corrected for a 0-100 inches of water differential bellows element. For example, a 1343-unit reading would represent approximately 89.5 inches of water. The range of the pressure element in the upstream orifice meter was 0-1500 psi.

Reasonably accurate gas measurement with a meter tube and orifice plate cannot be expected unless the recommendations and specifications outlined in AGA Report No. 3 or the ANSI/API 2530 for orifice metering of natural gas are followed[2,3]. The metering equipment on the test unit in Fig. 1 complied with the gas measurement recommendations and the specifications. The recommended beta ratio for flange taps is between 0.15 and 0.70 where the beta ratio is the orifice bore ID divided by the meter tube ID. The beta ratio for the tests in this paper ranged from over 0.172 to 0.431. Very low pressure differentials in inches of water were avoided because the accuracy of gas measurement is less at very low pressure differentials across the orifice plate. The differential recordings for these tests are given in Table 2. The lowest readings were 24 inches of water for the 0-100 inches of water differential bellows and 44 inches of water for the 0-200 inches of water bellows. The upstream orifice meter pressure ranged from 705 to 795 psig and the downstream pressure ranged from 360 to 390 psig during the verification tests in this paper. The flowing meter tube pressures were recorded downstream of the orifice plate.

The calculated percent error in Table 2 is based on the correct measured gas rates using the following equation:

$$\% \text{ Error} = \frac{\text{Correct } q_{gsc} - \text{Incorrect } q_{gsc}}{\text{Correct } q_{gsc}} \text{ X } 100$$

where the correct qgsc is the measured gas rates with the sharp-edged side of the orifice plate upstream and the beveled side downstream. The correct daily gas rate in the above equation is the average of the two tests for each orifice bore size with the proper plate orientation. If the percent error is calculated on the basis of the incorrect measured gas rates with the bevel upstream, the error percentage is greater. For example, a 20 percent error in Table 2 would represent a 25 percent shortage in actual gas sales if these gas rates are based on a measurement with the bevel upstream.

To illustrate the economic impact from an improperly installed orifice plate, assume that the measured daily gas production from a small gas field is 240 Mscf/D. The orifice plate is installed with the bevel upstream and the error in measurement is 20 percent on the basis of the actual correct gas production of 300 Mscf/D. The gas is sweet with a Btu content in excess of 1200 and sells for $2.00/Mscf at the wellhead. Over a period of 30 days the buyer recieves 9000 Mscf of gas worth $18,000 but pays only $14,400 for this gas production. The seller is loosing $3600 per month or $43,200 per year because of an inexcusable mistake.

CONCLUSIONS

Efforts to verify gas measurement on the test skid unit confirmed the old adage "measure a fluid once and you have a measurement but measure a fluid twice and you have an argument". There is no doubt on the basis of these simple tests that balancing the gas flow through a pipeline network is a difficult problem.

Although there are apparent inconsistencies in the results from these tests, a trend exists that indicates a greater error in measurement with the bevel upstream for the smaller bore ID orifice plates.

Extremely accurate measurement of gas production in the field is not easy under the best conditions. The loss in revenue can exceed 30 percent based on the results in Table 2 from incorrect measurements by improperly installing an orifice plate with the bevel upstream.

Abrasive fluid which includes sand or debris in gas will erode the sharp edge of an orifice plate and result in low gas measurement. For this reason the seller should inspect all orifice plates on a regular basis and replace those with a rounded upstream edge on the orifice bore ID.

REFERENCES

1. Winkler H.W. and Camp G.F.: "Dynamic Performance Testing of Single-Element Unbalanced Gas-Lift Valves," ***SPE Production Engineering*** (August 1987) 183-190.

2. ***Orifice Metering of Natural Gas - Gas Measurement Committee Report No. 3***, American Gas Association, Arlington, VA (1972).

3. ***Orifice Metering of Natural Gas - ANSI/API 2530***, American National Standard Institute, Arlington, VA (1978).

Table 1

Test No.	Upstream Orifice Meter: Orifice Bore ID inches	Upstream: Plate Orientation	Upstream: Q_{gsc} Mscf/D	Downstream Orifice Meter: Orifice Bore ID inches	Downstream: Plate Orientation	Downstream: Q_{gsc} Mscf/D
1	0.500	Correct	411.7	0.500	Correct	421.4
2	0.500	Bevel Up	331.0	0.500	Correct	419.8
3	0.500	Correct	408.9	0.500	Bevel Up	321.6
4	0.500	Correct	297.4	0.500	Correct	295.8
5	0.500	Bevel Up	242.4	0.500	Correct	295.5
6	0.500	Correct	298.1	0.500	Bevel Up	225.0
7	0.750	Correct	903.9	0.750	Correct	918.3
8	0.750	Bevel Up	748.9	0.750	Correct	913.0
9	0.750	Correct	910.2	0.750	Bevel Up	694.3
10	0.750	Correct	585.5	0.750	Bevel Up	426.1
11	0.750	Bevel Up	489.6	0.750	Correct	573.3
12	0.750	Correct	592.3	0.750	Correct	573.5
13	1.000	Correct	1703.9	1.000	Correct	1732.4
14	1.000	Bevel Up	1456.1	1.000	Correct	1739.1
15	1.000	Correct	1701.1	1.000	Bevel Up	1367.6
16	1.000	Correct	1142.4	1.000	Correct	1138.9
17	1.000	Bevel Up	972.9	1.000	Correct	1126.8
18	1.000	Correct	1141.0	1.000	Bevel Up	915.8
19	1.250	Correct	2542.5	1.250	Correct	2608.3
20	1.250	Bevel Up	2165.0	1.250	Correct	2616.5
21	1.250	Correct	2562.6	1.250	Bevel Up	2200.1
22	1.250	Correct	1571.3	1.250	Correct	1527.1
23	1.250	Bevel Up	1320.7	1.250	Correct	1518.8
24	1.250	Correct	1568.2	1.250	Bevel Up	1284.8

Table 2

Test Nos.	Orifice Bore ID inches	Upstream Orifice Meter Approximate h_w: Correct in.H_2O	Upstream: Bevel Up in.H_2O	Upstream: Error %	Downstream Orifice Meter Approximate h_w: Correct in.H_2O	Downstream: Bevel Up in.H_2O	Downstream: Error %
1-3	0.500	85	55	19.3	195	114	23.5
4-6	0.500	44	29	18.6	96	56	23.9
7-9	0.750	93	63	17.4	184	106	24.2
10-12	0.750	39	26	16.9	73	40	25.7
13-15	1.000	89	65	14.5	193	120	21.2
16-18	1.000	40	29	14.8	84	55	19.2
19-21	1.250	91	65	15.2	172	123	15.8
22-24	1.250	34	24	15.9	62	44	15.6

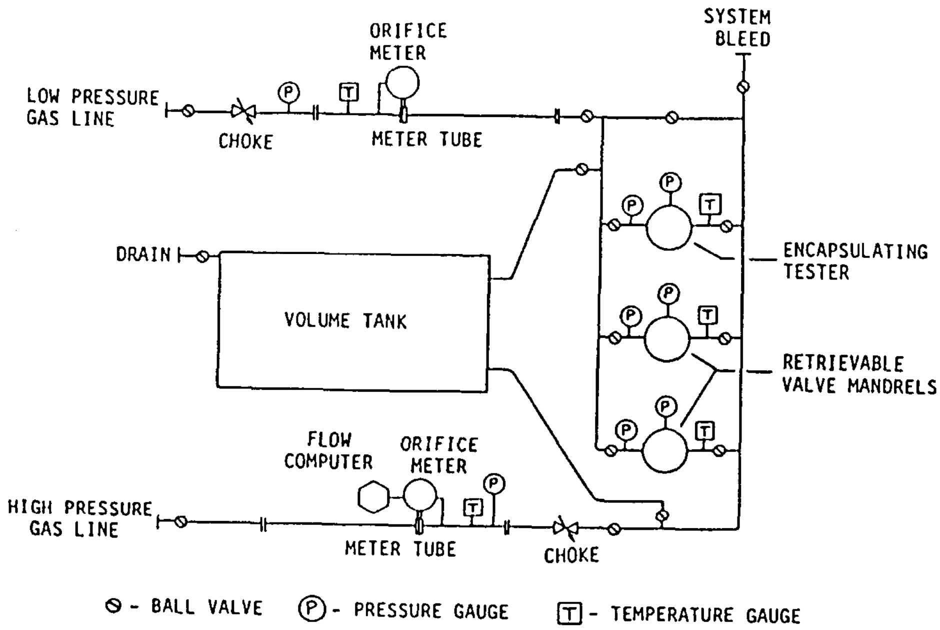

Figure 1 — Valve test skid unit

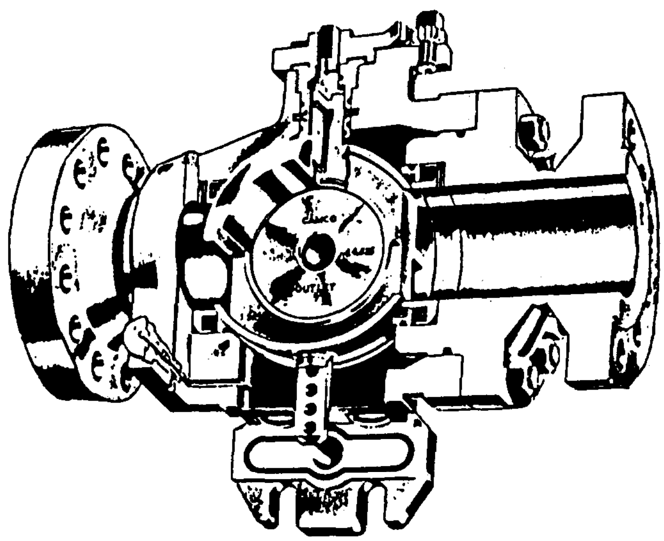

Figure 2 — Ball-orifice fitting

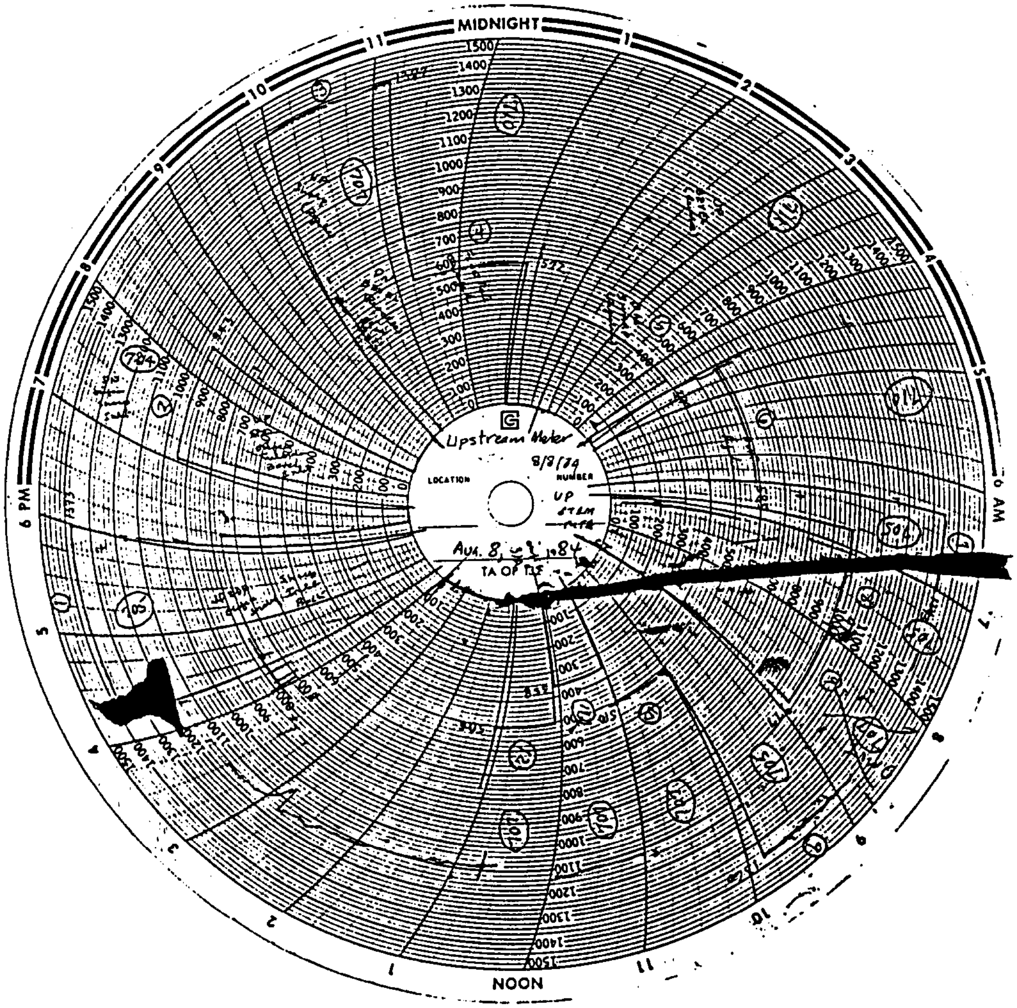

Figure 3 — Upstream orifice meter chart