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North Sea FLOW Measurement Workshop 1995

Paper 11:

THE EFFECT OF SWIRL ON CORIOLIS MASS FLOWMETERS

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ABSTRACT

Coriolis mass flowmeters provide accurate mass flow measurement over a wide range of flow conditions. A preliminary investigation of a Micro Motion CMF200 (50 mm) meter was performed to assess the accuracy over a range of sensor inlet configurations. Various inlet configurations were tested, including: straight run, a single 90° long radius elbow, and two out-of-plane 90° long radius elbows. Testing was performed with water under each inlet condition from 0.76 kg/s (100 lbs_m/min) to 7.6 kg/s (1000 lbs_m/min), which corresponded to a Reynolds number range of 36,000 to 360,000.

The meter factor was established on water during the first calibration; subsequent testing was conducted with the same factor. The maximum average bias error over the range of inlet conditions and Reynolds numbers was 0.03%, indicating the meter was largely insensitive to inlet flow profiles.

TEST SETUP

Five data runs were performed on a CMF200 meter from 0.76 kg/s (100 lbs_m/min) to 7.6 kg/s (1000 lbs_m/min)[1]. The meter factor was established at 3.8 kg/s (500 lbs_m/min) on water[2] during test #1 (Figure 1). Each of the five data runs consisted of points spaced in 10% increments between 0.76 kg/s and 7.6 kg/s. A range of inlet conditions was tested with hot water at the following conditions:

Temperature = 50° C
Pressure = 5 bar
$\mu = 0.5$ cp
$\rho = 988$ kg/m^3

Table 1 shows a tabulation of the tests; Figure 1 shows the inlet configurations tested.

Table 1 – Test Matrix

Test No.	Reynolds Number	Inlet Configuration	Inlet Configuration Figure Number
1	36,000 to 360,000	Straight	1a
2	36,000 to 360,000	Single Elbow	1b
3	36,000 to 360,000	Double Elbow	1c
4	36,000 to 360,000	Single Elbow	1d
5	36,000 to 360,000	Double Elbow	1e

[1] The maximum mass flow was limited by the calibration facility – the maximum mass flow rate for the CMF200 is 12 kg/s (1600 lbs/min).

[2] Note: All data was collected digitally – IEEE488 and RS485. Errors were assessed based on these data.

Three basic inlet configurations were tested:

1) Straight run -- A 300 mm straight run of 2" pipe (6 diameters) was provided immediately upstream of the sensing element
2) Single 90° long radius elbow upstream of the 300 mm straight run
3) Two 90° elbows out-of-plane upstream of the 300 mm straight run

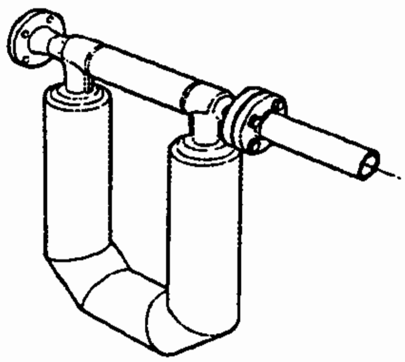

Figure 1a – Straight Inlet

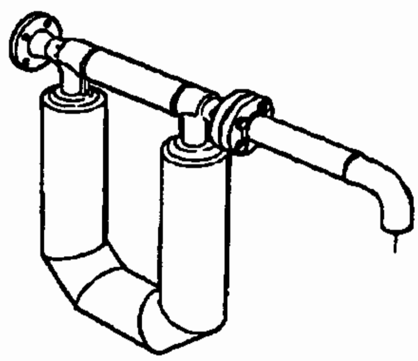

Figure 1b – Single 90° Elbow Parallel to Sensor Tube Plane

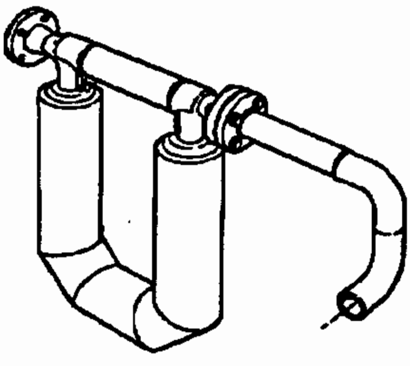

Figure 1c – Double Elbow. Elbow Closest to Sensor Parallel to Sensor Tube Plane.

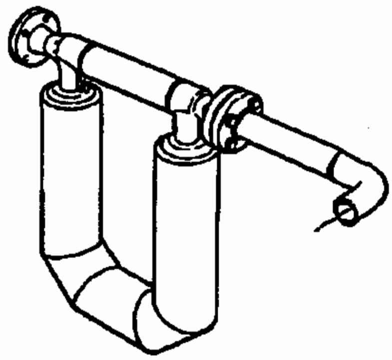

Figure 1d – Single 90° Elbow Perpendicular to Sensor Tube Plane

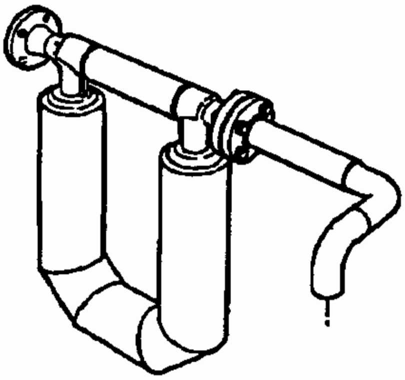

Figure 1e – Double Elbow. Elbow Closest to Sensor Perpendicular to Sensor Tube Plane.

In addition to the three basic inlet arrangements, it was theorized that the orientation of a 90° elbow next to the sensing element could have an affect on accuracy. Two additional tests were run to investigate the effect of the orientation of the 90° elbow next to the sensor. A total of five inlet configurations was tested, as shown in Figures 1 (a through e).

TEST RESULTS

Table 2 shows the average error from each calibration, corresponding to the conditions of Table 1 and Figure 1. Figure 2 shows each of the data runs, plotted versus Reynolds number. Figure 3 shows error versus mass flow rate.

Table 2 – Average Errors from Each Calibration

	Average Mass Flow Rate Error, %
1	+0.005%
2	+0.019%
3	+0.011%
4	+0.002%
5	+0.027%

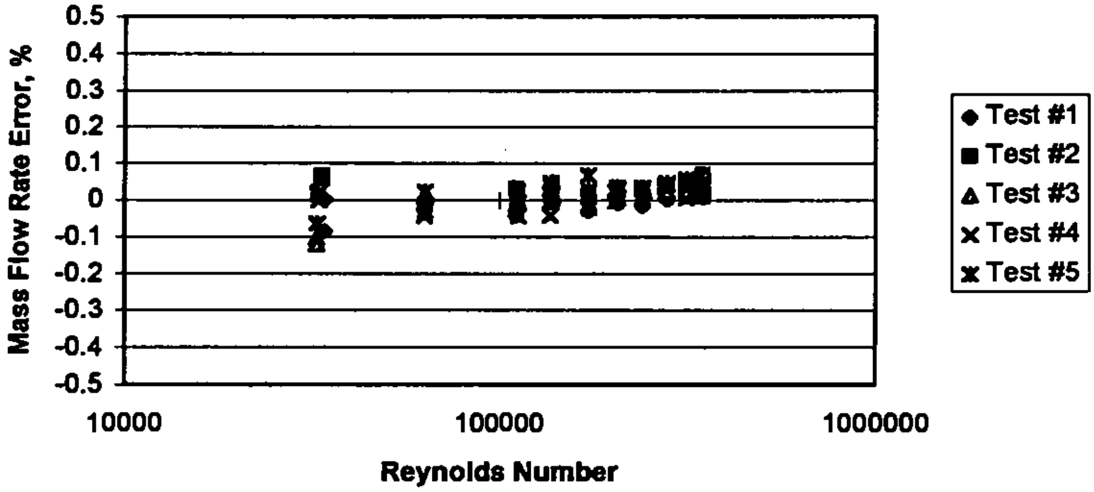

Figure 2 – Flow Rate Error vs. Reynolds Number for Each Inlet Configuration

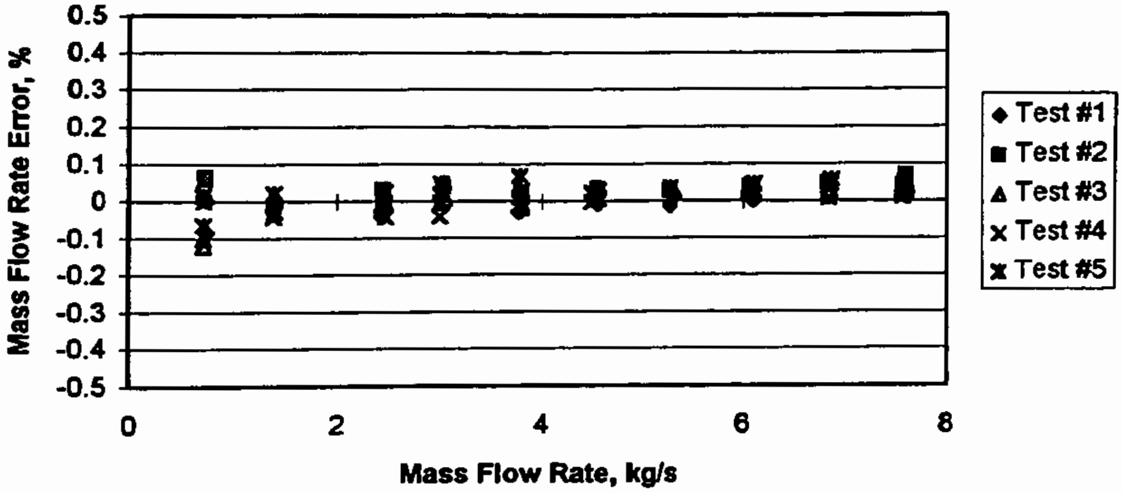

Figure 3 – Mass Flow Rate Error versus Mass Flow Rate

As can be seen, the effect of inlet configuration and swirl is very small over the 10:1 Reynolds number range. There is a slight non-linearity apparent at higher rates (less than 0.1%), and the effect of the zero can be seen at the 10:1 turndown point. However, these are typical Coriolis meter performance parameters; there is minimal additional effect due to the inlet configuration or swirl.

CONCLUSIONS

Coriolis flowmeters provide an accurate mass flow measurement over a wide range of inlet conditions. Testing at Micro Motion in Boulder, Colorado with water showed an average bias of only 0.03% among five different inlet configurations. Reynolds number varied from 36,000 to 360,000.

Additional testing needs to be performed to assess the effect of Reynolds number, especially below 30,000. Recent testing on gas suggests that there is little bias between water calibration and gas calibration (which are very high Reynolds numbers), at least within the measurement accuracy of the testing facilities. Additionally, liquid applications at higher Reynolds numbers will be limited due to pressure drop considerations.

This testing was performed under the described inlet conditions because it was felt they represented a relatively severe condition. Since little effect was determined, different configurations need to be addressed, especially shorter straight runs ahead of the sensor and short radius elbows.

Finally, the results presented here are based on the results of a single meter. Multiple meters of a common size need to be tested (50 mm size in this case), and Coriolis meters of different sizes and geometries need to be investigated.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.