



Engineering Technical Note

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Fluidic Oscillation Measurement for Natural Gas Applications

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ABSTRACT

Manufacturers of natural gas meters continue to improve their products and introduce new technologies to the industry. A new product, employing a not-so-new technology, is the fluidic oscillation meter. The technology currently is used in the water-metering field, but until recently, it has not been viable for use in distribution measurement for a medium such as natural gas. With improved electronics technology, it is now possible to detect the fluidic oscillation for natural flow, resulting in the development of fluidic meters for natural gas.

This Technical Note attempts to introduce the technology issues and concerns from a general perspective that goes into the development of a fluidic oscillation meter. Since some aspects of the meter design can be arbitrary at this point, further definitions or clarifications may be needed in the future.

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ABSTRACT

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1 INTRODUCTION

The Distribution Measurement Committee of the American Gas Association submits the following reference information for measuring natural gas with fluidic oscillation meters.

This is a compilation of information by experts in the field at the time of publication. It is not intended for use as a reference in contracts.

1.1 Task Group Scope

Develop an AGA Engineering Technical Note to address the following:

- Review the current state of fluidic oscillation metering technology.
- Share and disseminate operating experience with fluidic oscillation meters.
- Develop an understanding of the potential custody transfer applications and related business parameters.
- Identify technical issues or limitations and related research needs.

1.2 Engineering Technical Note Scope

This Technical Note is limited to fluidic oscillation meters for natural gas. Although references are made to fluidic oscillation meters for liquid flow applications, the general theme and the recommendations relate specifically to natural gas applications.

2 PRINCIPLE OF OPERATION

2.1 Introduction

Fluidic oscillation metering has been known in the process industry for many years, but because of relatively poor accuracy and limited dynamic range for gas applications, it has seen minimal use for custody-transfer metering. However, recent advancements in fluidic metering technology hold a viable custody-transfer measurement option for natural gas.

Current commercial applications of this technology include water measurement devices and natural gas measurement devices. See Appendix C for discussion of fluidic oscillation technology for water flow measurement.

Based on Bernoulli's Theory, a slow-moving high-pressure gas becomes a fast-moving low-pressure gas at the nozzle exit, forming a jet. The jet, once formed, can be controlled by the Coanda Effect using various structures and geometries. The meter is designed with a geometry experimentally determined to optimize the performance of the meter. Controlling the jet path enables formation of feedback nodes of pressure on either side of the jet. This provides a predictable oscillation of the jet.

The metrology of the meter is related to the mechanical design of the nozzle and the oscillation chamber. The jet oscillations are detected using appropriate sensing devices, which provide input to a register for data processing and/or maintenance. Each oscillation can be related directly, through a calibration, to a known volume of fluid passing through the meter.

2.2 Theory of Fluidic Oscillation Measurement

2.2.1 Oscillation Principle

The oscillation principle of a re-circulating fluidic oscillator is based on the formation of zones of different pressure on either side of the jet that will control the direction of the flow. The fluidic oscillations occur in the measuring chamber, but the formation of a conditioned gas jet is critical to the design of an accurate measurement device.

A re-circulating type fluidic oscillator can be described by the three main functions: the flow tranquilizer, the jet formation nozzle, and the oscillation chamber. As an example, see Figure 2.1.

2.2.2 Flow Tranquilizer

The condition of the flow at the inlet to a meter can vary due to piping configurations, such as elbows that create swirl, or having only a short length of pipe after a pressure regulator. To eliminate the effect of piping configurations on the meter performance, a flow-conditioning element should be placed before the nozzle to produce a repeatable (known) flow profile. An example of a flow tranquilizer is shown in Figure 2.2. This type of flow tranquilizer can be explained by its three main phases. In the initial phase (1), the flow impacts onto a perpendicular wall that has the effect of dividing it. In the next phase (2), the flow is presented with two equivalent paths with parallel walls to recondition the flow. The final phase of the conditioner

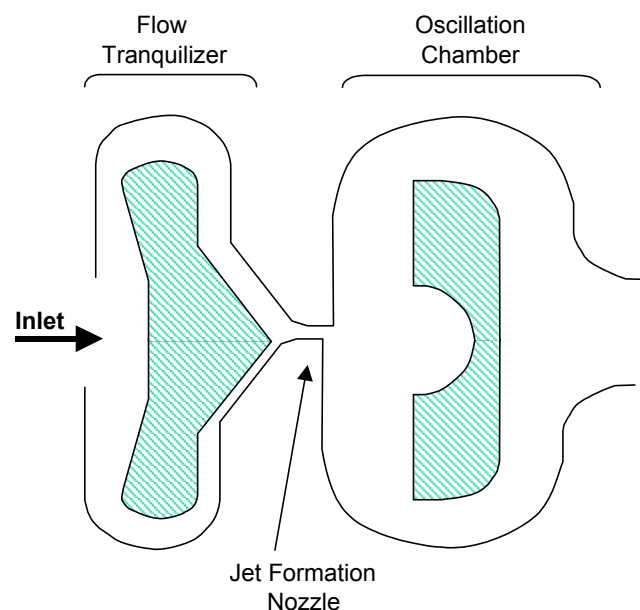


Figure 2.1

(3) is to combine the two paths and accelerate the flow, a function that is intended to eliminate any dissymmetry in the initial separation. These three phases are shown in Figure 2.2 where the velocity magnitude indicates the division, redevelopment of flows in the two conduits, and re-combination of the flow at the conditioner exit (3).

2.2.3 Jet Formation Nozzle

The acceleration of the fluid is a critical step in the fluidic oscillator. It is achieved by reducing the cross section presented to the flow and then quickly expanding the cross section by way of an oscillation chamber. The effect of this is to produce the formation of a distinct jet that will become unstable, and therefore, easily manipulated for the operation of the meter. The area of the fluidic oscillation device that provides the acceleration is called the nozzle. Bernoulli's Theory explains the jet formation by the conservation of energy as shown below:

$$P_1 + \frac{1}{2} \rho U_1^2 = P_2 + \frac{1}{2} \rho U_2^2 + \text{other energy} \quad (2.1)$$

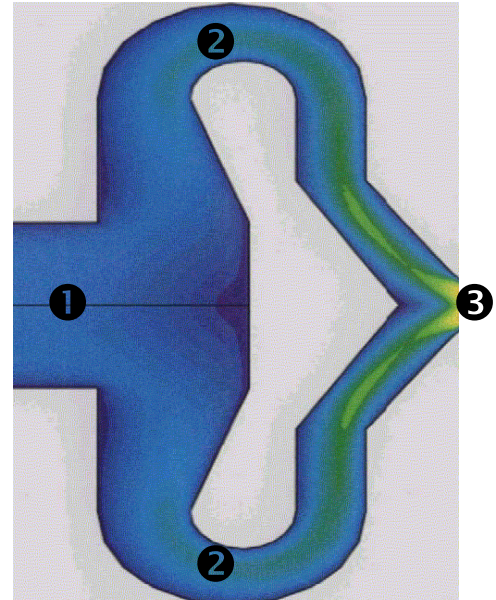


Figure 2.2

Where “other energy” refers to friction, magnetic, etc., which shall be neglected here. Simply stated, equation 2.1 shows that a slow-moving, high-pressure gas will turn into a high-speed, low-pressure gas. The pressure drop at the nozzle exit, therefore is, the key to the formation of the jet. The sudden expansion into a cavity has the additional effect of separating the jet from the boundaries.

2.2.4 The Coanda Effect

Consider a jet of fluid from a nozzle flowing into a body of relatively stationary fluid. The jet tends to carry some of the stationary fluid along with it. If a wall is placed near the nozzle and angled away from the direction of the jet, the stationary fluid, which is being carried along by the jet, will be removed from the space between the wall and the jet. This removal of fluid will create a low-pressure region between the wall and the jet. The resulting differential pressure across the jet will cause it to bend toward the wall. This phenomenon is known as the Coanda Effect.

2.2.5 Oscillation Chamber

In the oscillation chamber, an obstacle is located in the path of the jet. The function of this obstacle is to “control” the jet and ensure that the variation of static pressure on either side of the jet relates directly to the volume of gas cycled in the meter. The volume of gas for each “flip” of the jet is known because pressure nodes (P_1 and P_2) are formed in constrained areas on either side of the jet. The volume of gas necessary to cause a sufficient difference in pressure to flip the jet, therefore, is based on the constrained volumes of the two pressure nodes. See Figure 2.3.

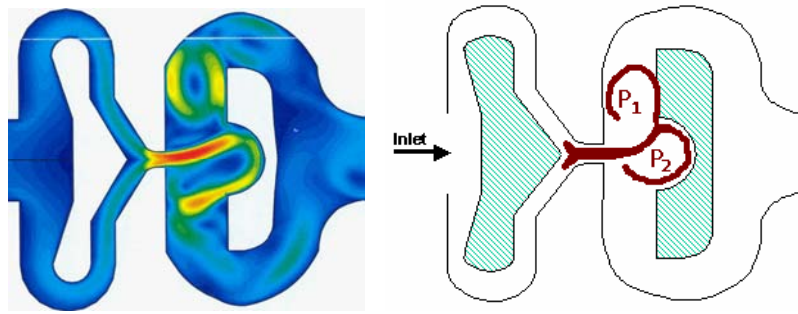


Figure 2.3

The design of the obstacle and the measuring chamber exploits the Coanda Effect to “bend” the jet, creating a propensity to follow the curved surfaces. The flow of the gas will cause re-circulation on one side of the chamber, an effect that increases the difference in pressure in the nodes on either side of the jet. Once the difference in pressure exceeds the “stiffness” of the jet, it will be forced toward the lower pressure zone, which is on the opposite side of the cavity. Re-circulation of the flow from the jet will again cause an increase in the static pressure in the node being created. This is the principle of oscillation in the meter.

The jet impinges on the obstacle, and the difference in pressure on either side of the jet causes the jet to bend to the side of the lowest pressure. Once in this position, the fluid is steered in a feedback path to create a pressure node. The pressure in the node will increase until it is greater in magnitude than the previously created node on the other side of the jet, which concurrently is evacuating from the chamber. The jet, therefore will, flip to the other side – an effect that will continue as long as gas is being supplied to create the pressure nodes.

2.2.6 Reynolds Number Relationship

The behavior of a fluidic meter can be characterized by the Reynolds Number. The Reynolds Number (Re) expression is shown below as a function of gas density (ρ), dynamic viscosity (μ), nozzle width (d), and gas velocity (U).

$$\text{Re} = \frac{\rho \cdot d \cdot U}{\mu} \quad (2.2)$$

Once a meter has been characterized in terms of a Meter Factor, in Meter Pulses per Volume Throughput, for a range of Reynolds Numbers, then by using interpolation techniques, predicted results can be calculated for a given pressure, flow rate, temperature and gas composition. For example, if the characterization of the meter was carried out on air, the different Reynolds Numbers could be tested by varying the air pressure in the meter. Typical characteristic curves in air are shown in Figure 2.4.

The oscillation principle relies on the formation of a jet of gas; therefore, there is a theoretical minimum flow rate at which this occurs. Below this theoretical minimum rate, the gas will simply diffuse into the measuring chamber, passing evenly by both sides of the obstacle.