Introduction to Metering

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Basics

Why do we meter?

We might as well get the obvious question out of the way at the very outset of this paper: why do we meter gas? There are certainly alternatives. For example, a distribution company could instead use a (seemingly now ubiquitous) subscription model. A customer might pay a fee for water heating, a fee for home heating, a fee for cooking, etc. Or they may pay a subscription for gas service to an entire home or facility, up to a specified flowrate. But this model, of course, doesn't account for the energy the customer actually uses.

Metering does this accounting and, in conjunction with other elements of a distribution system, allows each customer to be billed for the actual energy that they've used.

The obvious answer to why we meter is the one we've all heard and maybe repeated: it's the distribution company's cash register, although I'd argue that a meter is closer to a produce scale; the data it generates (in our case, totalized volume) is used with other data (gas quality, energy content, pressure, temperature, elevation, etc) to calculate the actual energy used and generate an accurate bill.

So, now that we've thought on *why* we meter, it's time to discuss *how* we meter.

Meter Types and Applications – Custody Transfer

Custody Transfer

We should probably begin a discussion of custody transfer meters by defining what we mean by custody transfer. As the term suggests, it's where the custody of the gas is transferred from one entity to another, for example, from a transmission company to a distribution company. In more basic terms, it's where gas is bought or sold, and meters used to measure at these locations are governed by industry standards and have accuracy standards to ensure proper billing.

Diaphragm

Probably the most universally recognized (and probably most numerous) meter type is the one that's probably on the side of your house, which is a diaphragm meter. The concept dates back well over 100 years and has proven to be very reliable and accurate. To oversimplify, they're basically operate just like a set of blacksmith's bellows. The chamber fills with gas to expand to a known volume, then gets forced back out as a measured quantity. Of course there's valves and linkages and gears and other things, but the basics are really just that expanding and contracting chamber.

Diaphragm meters have all sorts of reasons they've been so successful. First, they're a positive displacement meter, which uses a known volume chamber to measure, so there's less chance for gas to bypass the mechanism (assuming the mechanism isn't broken) and go unmetered. Second, they're all mechanical. There's no outside power or energy needed, aside from the pressure drop across the meter. Third, they've historically been very affordable, both in terms of acquisition cost and in terms of maintenance.

There are also come negatives. First, as mentioned above, they're mechanical. Unfortunately, that means the moving parts wear over time, which will eventually affect accuracy, and with positive displacement meters that tends to manifest as the meter slowing down, or measuring less gas than actually passes through them. Second, the fact that the diaphragms are made from rubber means that if the material wasn't properly stored, processed, and cured, it can change shape and size after the meter has been manufactured and installed in the field, meaning that our known-volume chamber has suddenly become an unknown-volume chamber. This usually manifests as shrinkage of the diaphragm, which in turn shows up as a fast meter.

Rotary

Probably the next most common meter type is rotaries. For the car guys out there, it's the inverse of a roots blower. It consists of a machined meter body in which rotate intermeshed figure-eight shaped rotors which, like diaphragms, are positive displacement meters. As the rotors rotate, they develop an effective seal against the body on both ends of the figure-eight and create a known-volume chamber. This meter type tend to be used on businesses from say, a McDonalds on the low end up to large industrial complexes on the high end.

Rotaries are advantageous for a variety of reasons. First, the accuracy is basically designed and machined into the meter. It's really not adjustable like the tangent on a diaphragm. Also, because there are small gaps between "sealing" surfaces, there's little to no wear occurring between the rotors and meter body, assuming clean gas conditions. In much the same vein, rotaries have a long history of being very reliable, again, assuming clean gas conditions. Additionally, rotaries tend to be affordable in comparison to some large capacity alternatives, both in relation to purchase and maintenance.

Some of the negatives relate to dirty gas conditions, in that if particulate gets into the meter, it can get into the gap between the rotors and the body and jam up the mechanism. The same condition can happen if the installation deforms the meter body. Unfortunately, in rotaries, this means that the flow of gas to the customer stops, requiring a truck roll.

Turbine

When we get to turbine meters, we depart from the arena of positive displacement meters and enter into what are referred to as inferential meters. Instead of directly measuring the volume of the gas moving through the meter, the meter instead measures some other parameter related to the gas flow which can be used to calculate the volume. In the instance of turbine meters, that parameter is gas velocity. And if you know the velocity and the area through which the gas is flowing, you can calculate a volume. The mechanism through which we measure the velocity is basically the back half of a jet engine (appropriately called the turbine). The gas runs into a very precisely machined and balanced fan, which causes the fan to spin at a rate that's proportional to the flow velocity and therefore, volume.

Positives of using turbine meters include being capable of passing very large volumes of gas and being able to continue allowing gas flow even if the mechanism binds.

Some negatives include cost, both in acquisition and maintenance. The meters themselves are expensive due to the required sensitivity and tight tolerances needed for the meter to function properly. The meters require periodic lubrication, which increases the cost of maintenance compared to, for example, a rotary. Additionally, turbines require lengths of straight pipe and potentially flow conditioning, so their installation requires a larger footprint.

Orifice

Where turbines measure velocity, orifice meters directly measure the differential pressure across a flow restriction. Basically, a very flat plate with a very precisely machined hole in exactly the middle is installed in the pipe to restrict the gas flow. On either side of the plate, the gas pressure is measured and the difference between the two pressures combined with the plate parameters and pressure, temperature, etc, usually using a flow computer, are used to calculate a volume.

Orifices are advantageous, like turbines, in that even if they stop working, gas flow to the customer isn’t stopped. Since the meter is just a hole in a piece of metal, there’s not really a way for the meter to stop flow. Additionally, there are no moving parts. The only wear the meter experiences is due to abrasives in the gas (if any), which can change the very precise shape of the orifice plate.

The large disadvantage of orifice meters is that they don’t perform well outside their designed flowrates, particularly with low flows. Unless there’s enough flow to create a differential pressure that’s within the accurate range of the pressure transducers, the meter won’t provide accurate measurement. Additionally, like turbines, they require straight pipe on both sides of the meter to produce accurate results.

Ultrasonic

Like turbine meters, ultrasonic meters measure gas velocity. They accomplish this by sending pulses of sound diagonally across the flow of gas, both in the upstream and downstream directions. The difference in time that it takes for both of these signals to make it across the flow is used within the meter electronics to calculate the flow velocity and therefore volume. At the large scale, these meters are used on large pipelines to measure huge quantities of gas, and in this instance, use multiple pairs of transducers to measure across several paths within the meter, in an effort to increase accuracy. On the low end, residential ultrasonic meters use a single measurement path in an effort to balance cost with accuracy and data gathering.

There are many advantages of using ultrasonic meters. One of the most compelling, especially on large pipeline meters, is the ability of the meter to use the data it generates to troubleshoot itself. The meter can tell the company when it’s having problems and in some cases, what the problems probably are. Hopefully, as smaller ultrasonics trickle down to residential size and we’re able to gather and analyze performance data, manufacturers can implement the same troubleshooting on these meters.

There are also disadvantages compared to other meter types. First, like turbines and orifice meters, ultrasonics require flow conditioning, whether that be straight pipe for pipeline meters or the built-in flow conditioning in smaller meters. Next, ultrasonic meters require power, whether that’s line power or battery power. Coupled with that, ultrasonics don’t function without electronics. That makes them smarter than legacy meters, but also introduces the possibility of new problems that distribution companies will need to learn to consider.

Coriolis

Compared to the other meters discussed so far, Coriolis meters operate a little differently. Instead of aiming to measure a volume flowrate, they measure a *mass* flowrate. Volume can then be calculated because the meter is also smart enough to be able to measure density. The meter measures the mass flowrate by splitting the flow into two parallel, horseshoe-shaped tubes. The meter vibrates these tubes at their natural frequency, but mass flowing through the tubes causes the frequency of the tubes to shift relative to each other. The meter uses this shift to calculate the mass flowrate. These meters are generally used in applications with relatively small pipe size, but relatively high pressure. For example, CNG fueling stations commonly use Coriolis meters to measure gas dispensed into vehicles.

One of the advantages of Coriolis meters is that they can operate at pressures higher than most meters. Additionally, they don’t take up much room or have large straight pipe requirements.

As for disadvantages, these meters are relatively expensive. They also usually require line power to be able to run the electronics and the mechanism that vibrates the measuring tubes.

Non-Custody Transfer Applications – Process Meters

We’ll finish off with metering that isn’t custody transfer, and doesn’t need to be as accurate as billing a customer or buying gas from a transmission company. This measurement would be used for data on how a distribution system is working, like how much gas is flowing through a particular transmission line and how to generally balance a distribution or transmission system. These meters, like pitot tubes, annubars, v-cones, conditioning orifice plates, and others, sacrifice some accuracy for drastically reduced complication to install. Annubars and pitot tubes only need a small hole drilled into existing piping to be installed. Others like conditioning orifice plates can be installed between existing flanges. And while there’s a tradeoff between accuracy and ease of install, they still generate valuable data for the operator of a gas system.