Types of Meters Commonly Used in the Natural Gas Industry

An Online Continuing Education Course for Engineers

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Definitions

- Beta Ratio - The ratio of an orifice to the inner diameter of meter piping.
- Chord - A measurement path across the flow profile used to calculate average velocity.
- Differential Pressure (DP) - The pressure difference across a restriction.
- Index - A mechanical or electronic register that records totalized flow.
- Inferential Meter - A meter type (e.g., turbine, ultrasonic, orifice) that infers volume from another variable like velocity or pressure.
- Interconnect - Physical points of connection between two pipeline systems where natural gas custody is exchanged from one company to another.
- K-Factor - A calibration constant (pulses per unit volume) for turbine meters.
- L&U or LAUF (Lost and Unaccounted for Gas) - This is a common metric that many companies use, quantified by the difference in deliveries and receipts less than what is stored in the pipeline. Measurement error and undocumented leaks/vents are all sources of LAUF.
- Turn-down - This is the ratio of the highest flow a meter can accurately measure to the lowest flow a meter can accurately measure.
- Orifice Plate - A thin plate with a hole that creates a measurable pressure drop for flow calculation.
- Positive Displacement Meter - A meter type (e.g., diaphragm, rotary) that measures actual trapped volumes of gas.
- Repeatability - The property of yielding the same measurement when the same input conditions are met.
- Spin Test - A diagnostic procedure for turbine meters to check the health of the meter.
- Standard Conditions - a defined pressure and temperature used to normalize gas volumes for comparison.
- Transducer - A device that converts electricity into acoustic signals.
- Uncertainty - The range in which the actual value lies relative to a measurement.

Introduction

A young engineer once asked me what my favorite type of meter was. He was likely just trying to make small talk, but it took me aback. Having a favorite meter is like having a favorite tool in your toolbox. Each tool serves a different purpose and is only useful in situations that require that purpose. You wouldn't use a sledgehammer for building a birdhouse, and just the same, you wouldn't use an ultrasonic meter (one of the most accurate and expensive types of flow meters) for measuring gas to your house.

There are two main types of volumetric flow meters: positive displacement and inferential. Positive displacement meters are meters that directly measure volume. Inferential meters are meters that do not directly measure volume but instead measure some other parameter and use that to infer what the volume is through a physical or empirical relationship. This course will cover two positive displacement meters: rotary meters and diaphragm meters, and three inferential meters: orifice meters, ultrasonic meters, and turbine meters. The sixth meter is a little different because it is not a volumetric flow meter at all, but rather a mass flow meter. It is the Coriolis meters.

In the natural gas industry, pipelines are often compared to toll roads. The natural gas moving through the pipeline is like the cars driving on the toll road, and the meters are the toll booths that let the toll authority know how much to bill people. Just as a toll booth needs to accurately know how many cars are entering and exiting the toll road, meters also need to be accurate. Most companies use the metric of LAUF or L&U (lost and unaccounted for gas) to quantify how accurately they are keeping track of gas in their pipeline system. To quantify it, they take the sum of all the receipts into their system, subtract all the deliveries out of their system, and subtract the amount of gas stored on the pipeline itself (referred to as line pack). If all gas stayed in the pipeline and all measurements were 100% accurate, this value should always be zero. In practicality, however, LAUF is almost never zero. There may be small unquantified leaks across the system, or someone may have blown down a section of pipe and not reported it properly for it to get documented in the LAUF metric. That is the gas loss side of LAUF. The other side is all about measurement error. No measurement can ever be 100% accurate. There is always uncertainty built into the meter. The trick is to utilize meters in the most advantageous situation to minimize error and know what factors can lead to introducing error unintentionally.

Rotary Meters

Rotary meters are a versatile type of flowmeter. A larger size rotary meter can feed an entire municipal gas supply to a small town. In contrast, smaller rotary meters are now the standard for restaurants, other businesses, and even residences (replacing the diaphragm meters, which used to be standard). You will also sometimes see rotary meters parallel to a higher throughput meter, such as an ultrasonic meter. Rotary meters are the first of the two positive displacement meters covered in this course. They directly measure a specific unit volume that, when multiplied by a frequency, yields a volumetric rate.

Figure 1 - A rotary meter supplying gas to my local grocery store. Source: Robert Noriega (self)

Rotary meters are typically comprised of two figure-eight impellers that fit together tightly and rotate when gas flows through them. The impeller lobes are offset by 90 degrees, which traps a known, fixed volume of gas as the impeller rotates. You measure the frequency at which the impellers spin, which allows you to calculate the flow rate.

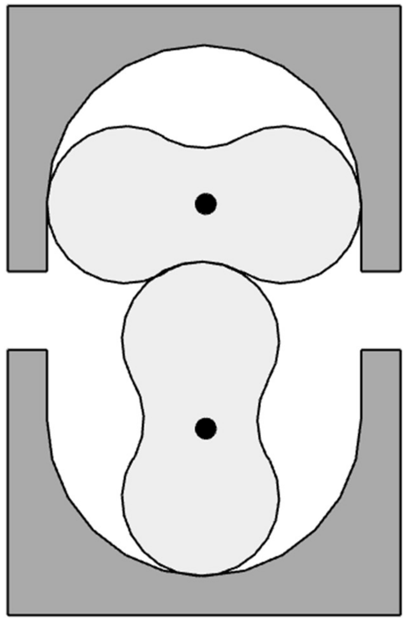

Figure 2 - A sectional drawing of a rotary meter showing the two figure-eight impeller lobes in a meter body. Source: Robert Noriega (self)

For maintenance, rotary meters are a mechanical device, which means there is a possibility of wear. To combat this, rotary meters are often installed with a lubricating system. During your inspection, check your lube oil reservoir and refill it as needed. Many operations and maintenance practices will require periodic differential pressure testing or flow proving to confirm the accuracy of the meter. Differential pressure testing involves comparing the differential pressure across the rotary meter at a given flow rate to a baseline. Excessive differential pressure can indicate an error in the meter. Flow proving can be accomplished via sonic nozzle testing or transfer proving. Due to increased greenhouse gas reduction efforts, sonic nozzle testing has largely fallen out of use. It involves blowing gas downstream of a rotary meter through a series of sonic nozzles that restrict the flow rate to a constant, known rate, which will typically be printed on the nozzles. Transfer proving involves bringing a calibrated meter and an air blower, and piping them up in series with the rotary meter. The blower will simulate flow rates at different levels of flow, and the technician will compare the flow rates indicated by the calibrated meter to the flow rates indicated by the rotary meter. In any case, whether transfer proving, sonic nozzle testing, or differential pressure testing, if excessive error is identified, the meter will need to be removed from service and sent to the manufacturer for recalibration. During the flow proving process, the rotary meter is removed from service and is unable to flow gas to the customer.

In terms of installation configurations, you need to make sure no solid debris can enter the rotary meter. This is accomplished by installing a filter or strainer upstream of the meter. In addition, you will need to have piping configurations that accommodate whatever flow proving method you choose to utilize.

Also, if your customer cannot allow for the downtime of flow proving, you may need to have bypass piping or a redundant meter to ensure the customer maintains flow even when flow proving. A final necessary precaution is some means to ensure the meter will not exceed the maximum flow rate for which the meter is sized. I've seen high gas velocity rip the insides out of a rotary meter when the flow limit was exceeded. This is typically accomplished with a sonic nozzle or orifice plate that is plumbed in series with the rotary meter. A sonic nozzle is preferable if space allows because it will lose less pressure than an orifice plate.

Diaphragm Meters

Of all the meters discussed in this course, this one has the highest likelihood of being within a hundred feet of you at this very moment. Diaphragm meters are the standard for residential gas measurement all over the world. They can measure the relatively low flow rates of domestic gas use with high accuracy. Still, they are typically only able to measure low flow rates and only at lower pressures (less than 100 psig). You won't typically find these transmission gas pipeline systems due to those constraints. Diaphragm meters share the classification of a positive displacement meter with rotary meters. They measure volume directly via the unit volume of their diaphragm chambers (similar to the unit volume of the trapped volume between the rotary meter impellers).

Figure 3 - A common diaphragm meter found at just about every residential property.
Source: Robert Noriega (self)

Diaphragm meters are composed of the actual diaphragm and a valve assembly that allows gas to either enter or exit the diaphragm chamber. The valve assembly allows gas to flow into the diaphragm or metering chamber until the diaphragm expands to its maximum volume. At this point, the valve assembly will shut off gas from entering and open the outlet side to allow gas to leave the meter. As gas cannot enter and leave the chamber at the same time, a single diaphragm meter chamber cannot supply a continuous flow of gas. To combat this, most diaphragm meters will have at least two chambers that work in sync to supply a constant stream of gas (i.e., one chamber will be intaking gas while the other chamber is exhausting gas). Each time the diaphragm reaches its maximum expansion, it will also trigger the index (visible via the number dials on the meter) to indicate the amount of gas that has flowed through the meter. Your gas company will periodically check this index to know how much gas to bill you for.

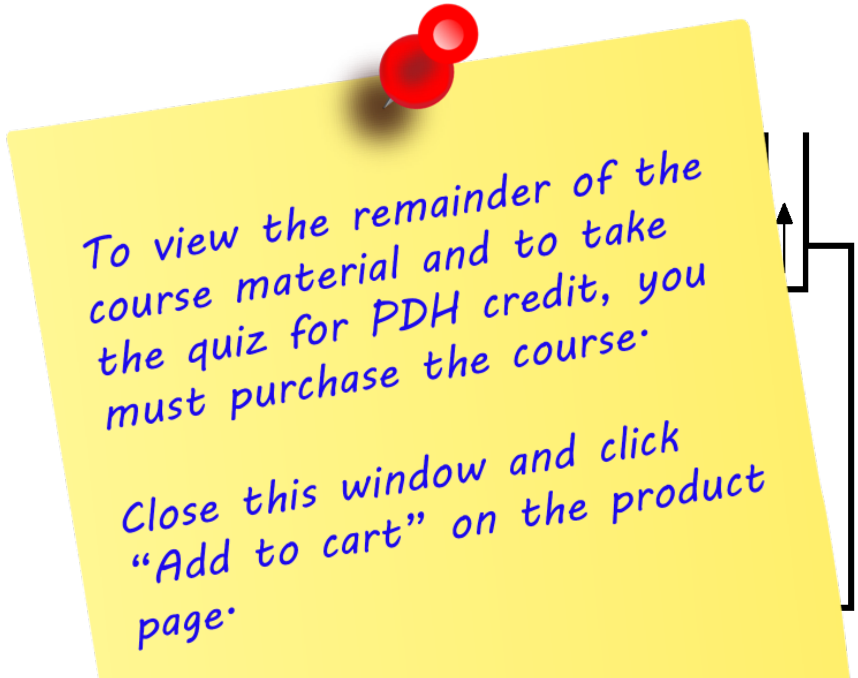

Figure 4 - A sim ... ***the meter through the valve assembly on one s*** ... ***maximum size, at which point the valve assembly shifts*** ... ***out of the meter. Source: Robert Noriega (self)***

As far as installation considerations, the main issue is pressure. These meters cannot withstand high pressures, so you must ensure that you regulate your pressure upstream of the diaphragm meter. Additionally, another key consideration is to make sure the meter is in an easily accessible location for the utility technician to be able to read the index and service the meter as needed.