FUNDAMENTAL PRINCIPLES OF ROTARY METERS

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INTRODUCTION

Natural gas measurement today is accomplished using two different classes of gas meters. These are inferential type meters, which include orifice and turbine meters, and positive displacement meters, which include diaphragm and rotary displacement meters. The inferential type meters are so-called because rather than measuring the actual volume of gas passing through them, they "infer" the volume by measuring some other aspect of the gas flow and calculating the volume based on the measurements. The positive displacement type meters are so-called because they measure the actual volume of gas displaced through them.

The rotary positive displacement meter has been in existence for over 75 years. Its reliability, rangeability, long-term accuracy, and ease of installation, maintenance, and testing have made this meter a favorite among gas utilities for billing purposes in industrial and commercial applications. Rotary meters have also gained popularity in the production and transmission markets.

This paper will present basic operating principles of rotary gas meters, accuracy and rangeability, installation of meters, maintenance and testing, meter instrumentation, and finally, a brief glimpse at the industry trends in rotary gas metering.

PRINCIPLES OF OPERATION

The lobed impeller type rotary meter consists of two figure-eight shaped impellers, positioned at 90° from each other, which rotate in opposite directions inside a cylinder of fixed volume (Figure 1). Gas flowing through the meter causes the impellers to turn, creating a measurement chamber bounded by the impeller, cylinder, and head plates. This known volume is then discharged and another identical volume of gas is trapped by the other impeller, cylinder, and head plates. Gas is alternately trapped and discharged four times for each impeller revolution.

The displaced gas per revolution is multiplied by the number of impeller revolutions to determine the volume of gas passed by the meter. A gear reduction system is used to totalize the displaced volume for instrument drives and counter readouts in engineering units (i.e., cubic feet).

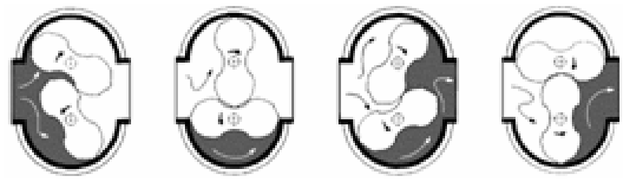

FIGURE 1. ROOTS Rotary Positive Displacement Operating Principle

POSITION 1. As the bottom impeller rotates in a counterclockwise direction towards a horizontal position, gas enters the space between the impeller and cylinder.

POSITION 2. At the horizontal position, a definite volume of gas is contained in the bottom compartment

POSITION 3. As the impeller continues to turn, the volume of gas is discharged out the other side.

POSITION 4. The top impeller, rotating in opposite direction, has closed to its horizontal position confining another known and equal volume of gas.

SIZING OF METERS

The sizing of a rotary meter is simply the selection of the appropriate capacity meter for the given flow conditions. The actual flow rate should not exceed the rated capacity of the meter. Line pressure and line temperature should be considered.

Applying the basic gas laws, the following formula may be used to size a rotary meter:

$$\mathbf{Q_s = Q_d \times F_p \times F_t}$$

where:

Q_s = Standard or corrected volume

Q_d = Displaced or uncorrected volume

F_p = Pressure correction factor =

$$\frac{\text{Gauge Pressure + Atmospheric Pressure}}{\text{14.73 psia}}$$

F_t = Temperature Correction Factor =

$$\frac{520°R}{460°R + \text{Gas Temperature}}$$

ACCURACY AND RANGEABILITY

The accuracy of a meter is defined as the degree to which a meter correctly measures the volume of gas passing through it. Accuracy is determined by comparing the volume registered by the meter with a known volume registered by a connected proving device.

The accuracy of a rotary meter is built-in through the careful machining of its components and cannot be adjusted. Since the volume of the measurement chamber does not change, the only factor that can affect accuracy is an increase in internal friction within the meter, which allows gas to slip through the clearances. A typical accuracy curve is depicted in Figure 2.

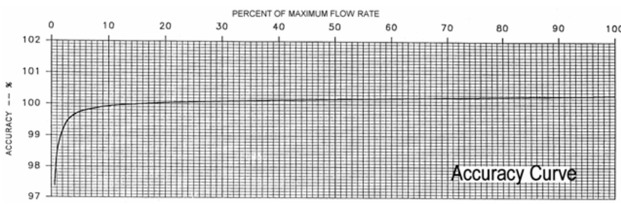

FIGURE 2. Typical Accuracy Curve

The rangeability of a meter is defined as the meter's maximum rated capacity divided by a selected "minimum capacity." Assuming that a meter "runs" at 100% accuracy, minimum capacity is determined to be the point where the meter's accuracy moves above or below a specified tolerance (usually ± 1% or ± 2%) from the 100% accuracy point.

Newer designs of rotary meters, using lighter materials, have greatly improved rangeability by reducing start rates and, thus, pushing the lower end (knee) of the accuracy curve to the left.

INSTALLTION

Proper installation in accordance with the manufacturer's recommendations is necessary to ensure optimal performance for any rotary gas meter. For the most satisfactory operation, rotary meters should be placed where they have the best chance of remaining uncontaminated.

Prior to meter installation, the line should be cleaned of pipe dope, weld slag, liquids, sand, valve grease, or other debris. The meter should not be installed at the low point in the piping system, where liquids or particulate matter tend to collect, or behind a lubricated valve whose grease could block the impellers and cause the meter to stop. If particulate matter is in the gas stream, a suitable strainer, screen, or filter should be used.

Particular care should be exercised in installing the meter with proper support. Piping connected to the meter should be supported to prevent strains on the meter cylinder. Placing one or two flexible couplings in the system can eliminate possible piping strain.

Proper leveling of the meter is important during installation and will maximize meter life and efficiency. Leveling not only reduces the possibility of meter body stress due to flange misalignment, but also may prevent overfilling of oil chambers that may be reading low on one end due to improper leveling.

Where a meter may be subject to possible over-speeding because of sudden pressure drops or flow surges, a restricting orifice should be installed downstream of the meter in accordance with the manufacturer's recommendation. A properly sized orifice plate or nozzle will protect a meter from damage due to over-speed by restricting the gas flow to 120% (typically) of the meter's rated capacity.

Most manufacturers recommend installing the meter using a bypass loop. This allows for easy maintenance or testing without the interruption of service, as well as a smooth, controlled start-up of the meter. Typical piping arrangements are shown in Figure 3.

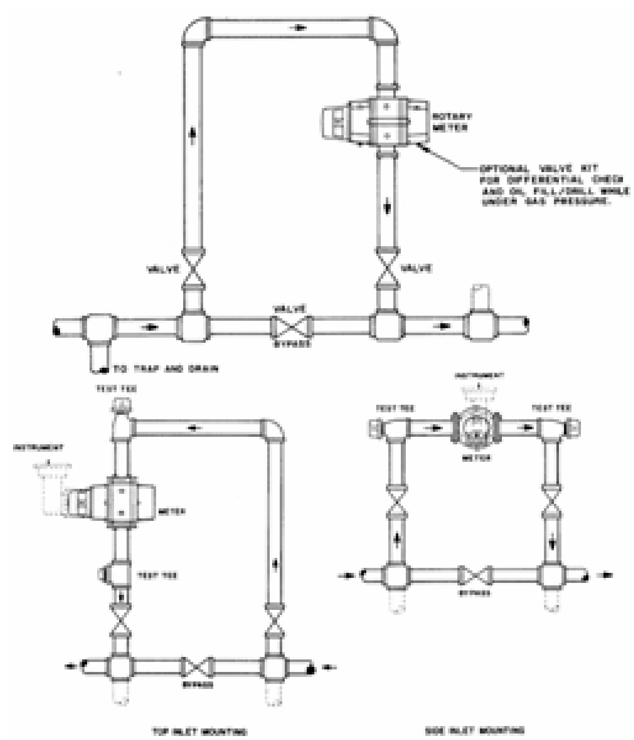

FIGURE 3. Typical Piping Arrangements

MAINTENANCE AND TESTING

Very little field maintenance is required for rotary meters if care and proper installation procedures are followed. A periodic check and maintenance of the proper oil levels is all that is needed under normal operating conditions. The interval between checks can vary substantially and may be dependent on utility requirements and/or the condition (cleanliness) of the gas. Oil, which may have become discolored because of dirt or emulsified due to water, should be changed. A normal or typical time interval is once every 3 to 5 years.

In addition to the visual check of the oil level and condition, a differential rate test may be performed on the rotary meter. The differential rate test is an accurate and acceptable method of comparing the performance of a rotary meter to its original, manufactured or installed, performance.

This test is based on the premise that the differential pressure between the meter inlet and outlet will not change substantially - over 50% of its original reading - unless the meter parts wear or become dirty, given that the pressure, temperature, specific gravity, and flow rate, as initially tested, remain relatively unchanged. For an accurate baseline curve, the differential pressure should be checked and plotted for several gas flow rates (at least three between 25% and 100% of capacity).

As with the oil level check, the recommended frequency of a differential test is subjective. However, experience has shown that a five-year interval is usually more than adequate. If the test indicates an increase in differential pressure over 50% from the initial test, the meter should be checked for the causes of increased resistance. Possible causes may be worn bearings, build-up of deposits on impellers, casings, or mechanical parts, incorrect oil or volume of oil, or out-of-time impellers. Usually, the meter may be brought back into specification with a simple flushing of the cylinder, which removes dust and materials collected on the impeller and cylinder surfaces.

METER INSTRUMENTATION

The volume of gas that has passed through a meter and has been measured must be totalized and registered. This may be done with an index. The simplest type of index is a mechanical counter, which provides uncorrected volumes at line conditions. A counter is used when the line pressure is low and temperature is assumed to be at base conditions. Gas volumes at constant pressures and temperatures other than base conditions may be corrected by applying fixed-factor multipliers to the index reading.

Where gas temperatures vary significantly, affecting the volume of the gas, a temperature compensated index may be used. The mechanical temperature compensator, or TC, corrects the volume counter to a standard volume at a base temperature of 60°F. In addition to the corrected readout, the index also contains an uncorrected readout. As with the counter, a fixed-factor multiplier may be applied to correct the volume of gas at a constant pressure other than base pressure.

On an Instrument Drive (ID) unit, a spur gear reduction with the proper gear ratio rotates a drive dog. One revolution of the drive dog represents a certain displaced volume - either the uncorrected volume registered with a counter or the temperature corrected volume registered with a TC.

Rotary meters may also be equipped for automated meter reading (AMR). Pulsers generate either high- or low-frequency pulses that represent volumetric information for remote data collection units.

Because gas volumes are subject to the effects of pressure as well as temperature according to Charles' and Boyle's laws, instrumentation may be used to compensate for these effects. With fluctuating pressures and temperatures, it is desirable to use instrumentation which corrects the volume measured at line conditions to base conditions. This instrumentation may be mechanical or electronic and may be integrally mounted, remotely mounted or mounted atop an instrument mounting plate, which is part of the instrument drive unit.

Today, rotary meters are available with integral electronic temperature and/or pressure correction. This design innovation combines the high accuracy of the rotary meter with the increased measurement accuracy, great flexibility, and economy of electronic volume correctors. With integral instrumentation, the elimination of gearing, bearings, seals, and shafts has improved the combined accuracy of meter and instrument.

RECENT DEVELOPMENTS AND INDUSTRY TRENDS

The last two decades have brought about many changes in the rotary gas measurement business. Increased customer demands, as well as changes in government regulations have driven these changes. The most significant of these is the replacement of the long-used mechanical corrector by electronic correction devices. Advances in electronic technology have made it possible to provide cost effective electronic gas volume correction, resulting in increased measurement accuracy, better long-term stability, quicker calibration and elimination of the mechanical gear reduction system.

Significant improvements in rotary meters have been realized in the last few years because of improvements in manufacturing techniques and the manufacturing equipment's ability to hold closer tolerances. Better machinability has lead to improved rangeability. Additionally, new designs for high capacity meters have reduced the sizes and weights of once necessarily foot-mounted, cast iron meters, and made them line-mounted aluminum meters.

Many utilities are using rotary meters with prefabricated meter sets to reduce field labor installation costs and times. Quick-change rotary meter conversion kits, designed to eliminate the need for field welding, pipe cutting, and other costly field exercises, are based upon existing meter pipe sizes and flange dimensions to provide faster, less expensive change-outs of other types of meters.

SUMMARY

Rotary positive displacement gas meters have been in use for more than 75 years. In that time, they have become the preferred method of measurement for industrial and commercial gas loads. The rotary meter is designed to measure gas with a very high degree of accuracy and reliability over time. They also offer the unique-to-rotary-meters differential testing capability, which reduces the need to shut down for testing and lowers the whole-life cost of ownership. Advancements in technology continue to improve meter performance making rotary gas meters a vital element in gas measurement today.