FUNDAMENTAL PRINCIPLES OF ROTARY DISPLACEMENT METERS

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INTRODUCTION

The basic geometric configuration for rotary positive displacement meters was originally conceived for pumping water in the mid-1800's and was patented as a rotary blower in 1860 (US Patent 30,157). The original design used wood for the rotors and understandably had issues with excessive wear.

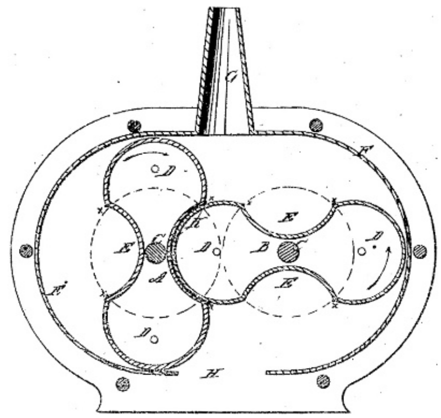

Figure 1. 1860 Patent Blower Configuration

The first rotary positive displacement gas meters that were based on the blower configuration were introduced in 1920 by the Dresser-Roots company. While the basic meter configuration is well established, changes in materials, manufacturing processes over the last 100+ years have improved the meter reliability, rangeability and long-term accuracy so that the meters are still a popular choice even with the introduction of newer technologies.

Positive displacement meters are notably different from inferential meters that are commonly used in the gas industry because positive displacement meters directly measure gas volumes. Orifice meters, turbine meters, ultrasonic meters, and Coriolis meters all infer the gas flow rate from other measurements associated with the gas flow. For example, pressure drop across the orifice plate is the primary measurement used by an orifice meter to compute the gas flow rate. The difference between these types of meters becomes more apparent when the operation of the rotary positive displacement is examined.

OPERATING PRINCIPLE

Figure 2 shows the sequence of positions of lobed impellers that result from differential pressure across the meter. The pressure difference is depicted by the colors with red being the high-pressure gas and blue being the low-pressure gas. The two impellers are connected by gears and rotate in opposite directions. The impellers are 90 degrees out of phase with each other as is apparent in positions two and four. Positions two and four also show the meter displacement volume(s) that are trapped between the lobes and the body of the meter: gas is trapped below the lobes at position two and above the lobes at position four.

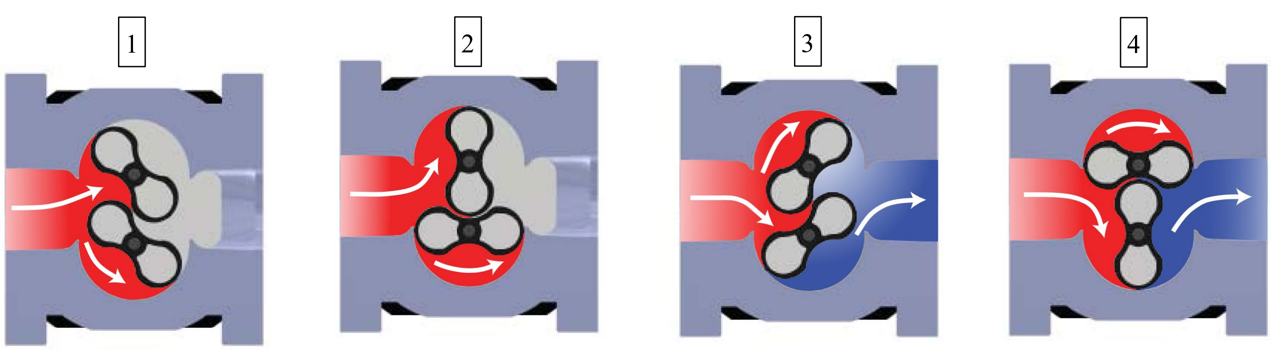

Figure 2. Rotation/Displacement Stages

There are no seals between the lobed impellers or between the lobed impellers and the meter case, but the small clearances (on the order of 0.001 inches) between the lobes and between the lobes and the meter body capture the gas from the inlet and release the gas at the outlet. The meter traps and releases gas four times for each revolution.

A cutaway of an example positive displacement rotary meter is shown in Figure 3. The cutaway shows the basic components including the readout module that is magnetically coupled to the meter output drive so that no rotating shaft seals are required. The meter body includes sight glass plugs to check the oil level for the gear system and differential test ports that can be used for measuring and monitoring the differential pressure across the meter.

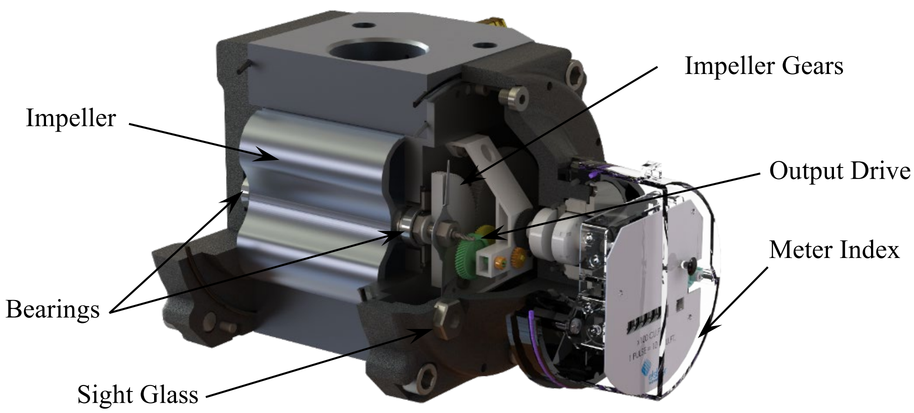

Figure 3. Example Mechanical Configuration of Rotary Meter

PERFORMANCE

Figure 4 shows an example meter performance curve for a rotary meter. Meter accuracy is defined as the ratio of the meter output to a known reference meter. The figure indicates excellent performance (approximately ±0.2%) between 20% and 100% of the rated meter capacity. For compliance with ANSI B109, Part 3 the initial meter accuracy must be within ±1% of 100% accuracy over the range from 10% to 100% of capacity. It is typical to limit the time at which the meter operates below 10% of capacity since the meter accuracy will decrease significantly as the percentage of gas flowing through the clearances becomes more significant as compared to the total gas flow.

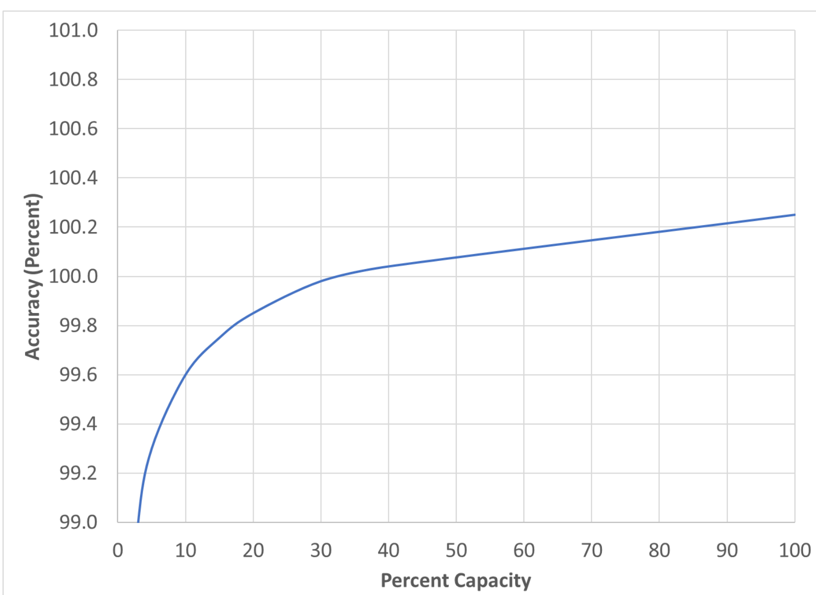

Figure 4. Example Performance Curve for Rotary Meter

The curve provided here is simply an illustration; the flow rate at which the accuracy starts to reduce significantly is dependent on the meter design and manufacturing accuracy. It is important to recognize that the shape of the accuracy curve is inherent to the meter design. The curve can be shifted up or down through gear changes on the output drive, but variation with flow cannot be mechanically adjusted. The accuracy curve may shift over time if the friction in the meter increases since an increase in friction will cause an increase in the amount of gas that slips through the mechanical clearances in the meter.

SIZING

The capacity of a rotary displacement meter is tied to the maximum acceptable rotational speed of the impellers. The published capacity of a rotary displacement meter is typically determined at a standard pressure and temperature condition like P_{std}=14.73 psia and T_{std}=60°F, however rotary meter designs that accommodate pressures over 1000 psia are available. To determine the capacity of the meter at actual flowing conditions (T_{flow}, P_{flow}) the gas laws can be applied as shown in the following equation (super compressibility can also be added for high pressure applications, or for a more accurate estimate).

$$Q_{std} = Q_{meter} \times \frac{459.67 + T_{std}}{459.67 + T_{flow}} \times \frac{P_{flow}}{P_{std}}$$

Q_{meter} is the actual flow rate (dial indication of the meter) and Q_{std} is the standard flow rate at the flowing conditions.

For example, a 3M meter (3,000 ft^3/hr) that operates at 75 psig (with an atmospheric pressure of 14.4 psia) and 70.4°F will have a standard flow capacity of approximately:

$$Q_{std} = 3{,}000 \times \frac{459.67 + 60}{459.67 + 70.4} \times \frac{75 + 14.4}{14.73} = 17{,}850\ SCFH$$

INSTALLATION

Rotary displacement meters can be configured so that they can be installed horizontally or vertically. Figure 5 shows an example horizontal installation of a rotary meter that includes a bypass, isolation valves, and a filter upstream of the meter. Because of the tight clearances in a rotary meter is important that there is no weld slag, or other debris introduced into the meter. Valves should be non-lubricated so that valve grease does not contaminate the meter. It typically recommended that the meter be installed vertically with flow downward so that and debris that does exist in the line will carry through the meter with less chance of doing harm.

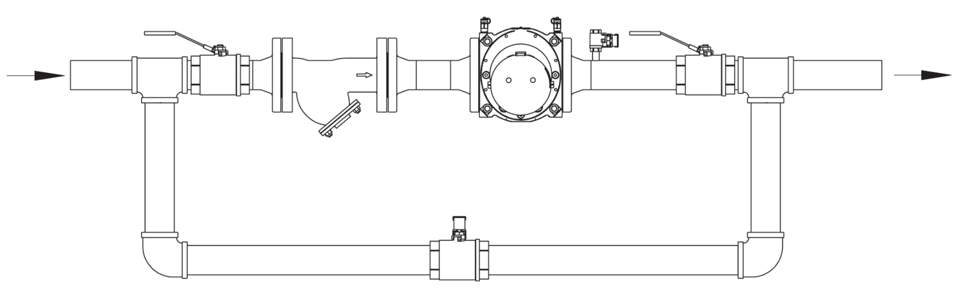

Figure 5. Horizontal Installation of Rotary Meter with a Bypass

Other suggested installation requirements include:

- The piping associated with the meter installation should be aligned properly to reduce any external stresses placed on the meter
- The assembly should be adequately supported to eliminate sag.
- The meter should never be installed such that condensate or debris could accumulate within the meter.
- The meter should be installed as level as possible so that the lubrication system will function properly.
- A restrictive orifice may be used downstream to prevent over-speeding of the meter.

Manufacturers typically provide installation guidelines that may include additional requirements.

The standard output from a rotary meter is most commonly a mechanical index that totalizes the actual flow at the operating condition. Rotary meters can be fitted with various types of AMR (Automated Meter Reading) devices. Mechanical or electronic volume correctors that account for the operating temperature and pressure when totalizing the flow can also be attached to the meter or may be an integral part of the meter design.

MAINTENANCE

The oil level and condition must be maintained for the meter to operate properly. If the oil becomes contaminated, meter friction will increase, and the accuracy will decrease (particularly at low flow rates). Once the oil is contaminated it should be drained and the meter should be flushed prior to refilling with oil. This process should return the meter to the near-factory condition. The frequency of the oil maintenance will be largely dependent on the operating conditions and the likelihood of contamination. Meter designs exist that extend the maintenance interval while maintaining the meter accuracy.

The condition of the meter can be assessed by comparing the pressure drop across the meter with a baseline pressure drop curve that was either measured at the time of installation or when the meter was initially characterized by the meter manufacturer. If the meter is operating at elevated pressure, it will be necessary to compare to a curve determined at similar conditions since the gas density will affect the pressure drop curve. Figure 6 shows an example pressure drop curve and an illustration of a shift in the pressure drop curve that could have resulted from increased friction caused by contamination. Once the meter is cleaned, it is expected that the pressure drop curve would return to close to the original baseline curve. The curve also illustrates the importance of ensuring that flow rate is recorded when making a pressure drop comparison.

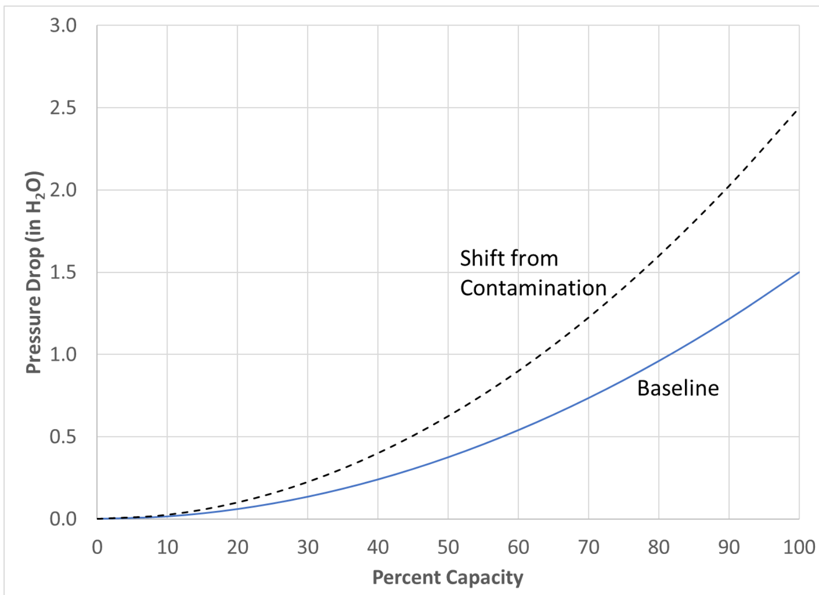

Figure 6. Example Pressure Drop Curve

SUMMARY

This paper has described the basic operation of rotary positive displacement meters and has included recommendations for installation and maintenance of the meters as well as equations for determining performance at various operating conditions. While rotary positive displacement meters are simple in concept and a mature measurement technology, the meters continue to improve through material selection, manufacturing methods and the integration of electronics.

REFERENCES

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