The American Gas Association defines the orifice meter as the complete measuring unit consisting of a primary and a secondary measurement device.

The orifice meter body, tube and orifice plate are considered the primary measuring device. This primary device is equipped with pressure taps that allow for the hook-up of a secondary device to sense the output signal of the primary orifice meter. The secondary device is some type of recorder or datalogger that allows for the recording of the events (i.e. signal levels and changes) that are created in the primary device.

For many years, the most widely used secondary device of the natural gas industry has been the circular chart recorder. The repeatability and accuracy are important factors when determining the volume of natural gas that is moved through a given measurement point within a given time frame.

Like all compressed fluids, natural gas will flow from the point with a higher static pressure to the point with a lower static pressure. Static pressure is commonly known as the pressure exerted against the walls of the pipe and is most commonly measured in pounds per square inch gauge (PSIG) or pounds per square inch absolute (PSIA). As natural gas flows through it, this pressure will continue to decrease as the gas flows further downstream in the piping and the fluid is less and less compressed. Many conditions affect the flow of the fluid from one point to another in a pipeline — the quality of the inside surface of the pipe, amount and type of sediment in the pipe, length and bends in the pipe, and temperature. These and others are all factors that will influence volumetric measurement.

As discussed earlier, the primary device is normally a meter tube complete with an orifice plate assembly. When fluid is compressed on the upstream side of the orifice plate, it seeks the lower pressure side and must pass through the “bore” of the plate. The bore is an orifice that is somewhat smaller than the internal diameter of the pipeline. As fluid moves downstream and strikes the orifice plate, pressure increases on the upstream side as it is “funneled” through the small bore in the center of the plate. The result is a pressure drop from the high pressure (upstream) side to the low pressure (downstream) side of the plate. The difference in pressure when comparing the two sides results in “differential pressure.” As flow velocity increases from one side to the other, so does the “DP.”

When a secondary device, such as the circular chart recorder, is connected to the high and low pressure ports of the primary orifice meter, the differential pressure is recorded. In addition to measuring and recording “DP,” the chart recorder can also be configured to measure and record static pressure and temperature. Combining these three measurement variables with other known factors, standardized gas volumes can be determined.

The equation used to calculate this is as follows:

\[ Q_h = C' \sqrt{H_w P_f} \]

Where:

- \( Q_h \) = flowrate in cubic feet per hour
- \( C' \) = meter coefficient or orifice flow constant
- \( H_w \) = differential pressure, in inches of water column
- \( P_f \) = static pressure in psi

An orifice flow meter records the variables of the flow equation for a specified period of time. Integration of these variables recorded on the charts are used to calculate the gas volume flowed within that given time period. The specific gravity of the fluid and temperature are also factored into the calculation when determining flow volumes.

**ORIFICE METER TYPES**

**MERCURY METER**

One of the earliest devices used to record the pressure drop across an orifice plate is a mercury meter (See Fig.1). While there are several manufacturers and configurations of mercury meters, they all employ the same basic principle of the mercury manometer. With links to several health and environmental concerns, the mercury meter use has been, and continues to be, in declined.
The bellows differential pressure sensor (See Fig. 2) is the successor to the mercury sensor. A bellows meter utilizes a type of “spring balance.”

The unit consists of a high pressure housing and low pressure housing, each containing a bellows that is connected with a stem. These two chambers are isolated from each other by a center plate. As pressure is applied to both sides, the bellows senses the pressures and if the pressure on one side is higher than the other, the side with the higher pressure is displaced and moved in the direction of the side that has the lower pressure. The stem that connects the two bellows together converts this movement to a shaft that drives the recorder's movement assembly mechanism, transmitting the difference of the two sides into the recorder case where it can be recorded as historical data. The DP sensor contains a “range spring” that allows for proper sizing in regards to the amount of differential pressure the unit will see.

**Fill fluids within the bellows**

Bellows “fill” is a clean, virtually incompressible fluid that allows for the displacement from one side of the DP sensor to the other, supporting the walls of bellows internally and providing a clean lubricating fluid for the internals. Valves and stops within the bellows allow for over-range protection.

**Pulsation dampening**

High fluctuation of the differential pressure in an orifice meter can be controlled by the pulsation dampener. An adjustable integral needle valve is used to regulate the rate at which liquid is transferred from the high pressure side of the bellows to the low pressure side or vice versa. Also note that the more a unit is dampened the slower it will indicate any event changes on the chart.

**Temperature Compensation**

Most bellows type orifice meters have built in temperature compensation. While most fill fluid's volume varies little with pressure, they will undergo some change with temperature variation. Adding two additional convolutions to the high pressure bellows that are not connected to the bellows stem gives that added space which acts as an reservoir to absorb changes in liquid volumes without affecting the properties of the measuring bellows.

**Range Springs**

The basic range of the bellows unit is determined by the range spring which is constructed of materials that exhibit good linear characteristics as force is applied to them. Material selected must have good elastic properties and remain stable over a wide range of temperatures and pressure changes.

**Torque tube**

A method must be provided for converting the bellows' linear motion into a rotary motion for a shaft that drives the recording mechanism linkage. The bell is a sealed system and conveying this motion outside the bellows assembly unit without leakage is done by a torque assembly.

**Static Pressure**

The device used to measure the static pressure and convert it to a mechanical motion in most orifice meters is the helical Bourdon tube (Fig. 3). The pressure element's span is determined by the wall thickness, the number of winds, and the material used. Helical pressure elements have been made from many types of material as long as the material selected is compatible with the process and can maintain its linear and repeatability qualities. Monel, 316 stainless steel, and 316L stainless steel are the most common helical pressure element materials used in the field today.

**Temperature sensing**

Today's most common temperature sensors are hermetically sealed, filled systems (Fig. 4). The sensing bulb, capillary, and spiral Bourbon tube that are filled...
with a hydrocarbon fluid or mercury, pre-loaded with a set pressure (depending on range), and then sealed. As the temperature increases the pressure will increase causing the spiral Bourbon tube to try to straighten. This causes the arm connected to it to move the linkage connected to the recorder mechanism.

CONCLUSION

Orifice flow meters for decades have proven their reliability and accuracy.

Technological improvements have occurred such as retrofit kits that will allow electronic flow integrators and electronic data loggers that can be installed into existing mechanical chart recorder. These units increase the accuracy of the meter and also eliminate the need to have the charts manually integrated.

The developments of EFM (Electronic Flow Meter) and its capabilities have reduced the market share of the mechanical orifice chart meters.

Along with these enhancements that are available for the orifice meters and the current environmental limitation that some EFM have, mechanical orifice chart meters are proven and effective solutions for many flow measurement applications and will continue into the next century.