Badger Meter

Differential Pressure Flow Metering: Problem Solver for Chemical Processing Industry (CPI) Applications

IND-WP-02899-EN-01 (July 2018)

White Paper

CONTENTS

INTRODUCTION

Flow measurement is a critical aspect of plant operation in the Chemical Processing Industry (CPI). Users choosing equipment to meter the flow of liquid or gas processes must consider a wide range of factors to arrive at an optimal solution. Experience has shown there are significant differences between meter technologies, with each type of device having its own advantages and disadvantages for processing facilities.

In modern chemical plants, personnel need to make faster and better decisions by capturing, managing and analyzing the right data at the right time. These facilities rely heavily on flow processes, and thus accurate and reliable measurement techniques are vital to the efficiency and safety of their operations

Most chemical processing plants have two primary flow measurement challenges: accuracy and cost. The goal is to correctly match the right flow meter to the right application to achieve the best performance for the lowest purchase price and total cost of ownership (See Fig. 1).

Figure 1: Most chemical processing plants have two primary flow measurement challenges: accuracy and cost.

UNDERSTANDING DP TECHNOLOGY

Differential Pressure (DP) flow measurement is often overlooked as a solid performer among flow meter technologies. This is especially true when looking into the measurement of fluids in chemical and petrochemical applications. The fact is that when combined with today's advanced pressure transmitter capabilities, DP technology outperforms many other flow measurement solutions.

First, a little history is in order. Most of us have heard of Bernoulli and the principle he developed. The basis for all DP flow measurement devices, Bernoulli's principle states that an increase in the velocity of a fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy. The principle was first published in his book, Hydrodynamica, in 1738. Another interesting note is that Clemens Herschel, an American hydraulic engineer, invented the Venturi in 1886. The Herschel Venturi was the first large-scale, accurate device for measuring water flow. The elements discussed here are based on both of these early accomplishments (See Fig. 2).

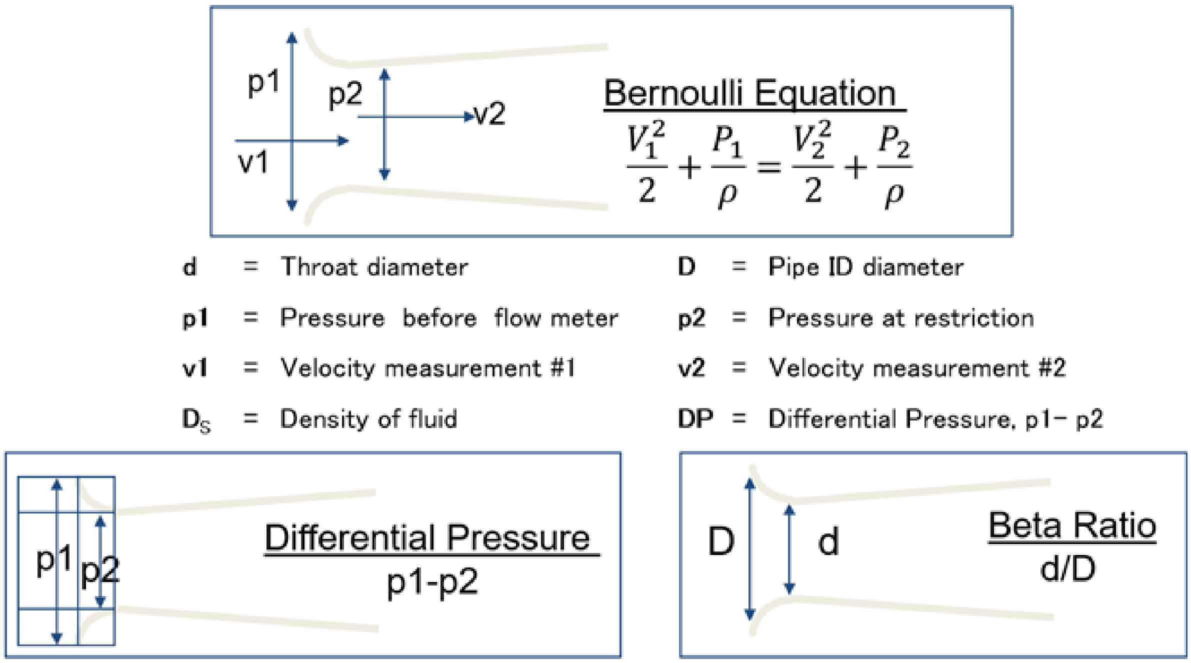

Figure 2: Bernoulli's principle, the basis for all DP flow measurement devices, states that an increase in the velocity of a fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy.

Differential Pressure flow meters measure the pressure differential across the meter and extract the square root. They have a primary element that causes a change in kinetic energy, creating differential pressure in the pipe, and a secondary element measuring the differential pressure and providing a signal or read-out converted to the actual flow value.

DP-style meters are versatile instruments, which employ a proven, well-understood measuring technology that does not require moving parts in the flow stream. The meters are not greatly affected by viscosity changes.

COMMON METER CONFIGURATIONS

Most CPI users are familiar with orifice plate-based flow measurement. The following are some of the higher-performing techniques that are available for differential pressure flow measurement. Each approach has its place when optimizing flow measurements in plant processes (See Fig. 3).

Figure 3: Each DP approach has its place when optimizing flow measurements in plant processes.

Venturi

Venturi meters are a tried-and-true performer. These devices, whether they employ the classical Herschel designs, low-loss designs or insertion configurations, are one of the oldest precision methods of flow measurement. Venturi meters work simply by reducing the pipe diameter and measuring the pressure directly before the reduction (high pressure) and then again in a segment of the reduction diameter (low pressure). By comparing the difference in these two pressures, one can take the square root of this difference and equate it to the flow rate in the pipeline. Of course, there are calculations that will aid in compensating for everything from thermal expansion of materials to the possibility of more than one phase of fluid being present. The venerable Venturi is very repeatable in its designed range and can be manufactured out of practically any material required. The meter also can be sized for very low permanent pressure drop, making it a fit for some supercritical fluids and other pressure-sensitive fluids.

A Venturi element is best used in flows over 75-100K Reynolds Number in applications that have a relatively straight section of pipe to place them in. Some versions are flow characterized from years of empirical data, and therefore do not require calibration. However, in critical measurement applications, one might want to pay a little more to have the unit tested and certified. This technology is used on fluids from water to steam and gas with very good results. It is not uncommon to have Venturi meters last for decades in the absence of corrosion or other deleterious events.

Typical core applications for Venturi meters include water, vapor, steam, gas, liquefied natural gas (LNG), chemicals and some slurries.

Cone Meter

One of the more advanced DP technologies is the Cone meter. Although it does not replace the Venturi in some applications, this design provides a considerable improvement in more difficult applications. If you look at the basic Cone meter design, you can see that it is simply an inverse Venturi. The Beta ratio (ratio of area between the differing diameters) controls the amount of differential pressure generated for a given flow rate, just like most other head-producing devices. The major difference here is that the cone interacts with the core velocity first and then re-proportions the flow around the cone. By doing so, a couple of very positive attributes come forward.

First, because the Cone meter is a contoured element, and inserted into the high-velocity core flow, the majority of the flow is redirected away from the beta edge as it passes to the low-pressure zone. The angled deflection of the flow, coupled with the vena contracta condition and the vortices recirculating at the point of separation, force the flow away from the critical beta edge. This greatly decreases wear on the cone and the pipeline as the low-pressure zone draws the flow to the center of the pipe slightly downstream of the beta edge.

Secondly, the need for straight pipe diameters in front of and behind the meter is greatly reduced. In some cases, the straight pipe requirement can be eliminated. This makes the Cone meter very useful when retrofitting into an existing piping network where straight runs are few and far between.

A further benefit is that a Cone meter will give high performance over a much greater range. The meter shows a linear (after square root) flow response in flow ranges that generate Reynolds Numbers of approximately 5-6 k and higher.

Typical core applications for Cone meters include steam, gas, critical fluids, low-viscosity liquids and multi-phase flow.

Wedge Meter

Another advanced DP technology is the wedge meter. This creative design was originally developed for the mining industry to measure slurry flows. It quickly was adopted for use where other contaminants caused either wear or plugging of ports and geometry on other DP devices. The Wedge meter is akin to a segmental orifice, but one that's on steroids. A segmental orifice still has a small restriction in the line around the opening. The Wedge meter does not. The wedge design allows solids and particulates to be swept through the opening with ease. It also enables measurements with Reynolds Numbers down in the laminar range to 500 as a minimum.

In difficult environments, it is common to use remote seal technology to isolate pressure transmitters from the process. The Wedge meter takes this in stride and can be offered with large open ports for the seals to attach. Standard taps are available if appropriate for the application. The Wedge meter also benefits from a partial redirection of the flow that protects the edge of the restriction to some degree. When coupled with a hard facing compound on the wedge portion of the meter, it is extremely resistant to wear.

Typical core applications for Wedge meters include high-viscosity fluids, slurries, corrosive fluids, contaminated air/gas, multiphase flow, etc.

Averaging Pitot Tube

Averaging Pitot Tubes can also be a problem solver for certain applications. These meters work a little bit differently than other DP devices as they actually measure impact pressure into an upstream port rather than a pressure field upstream of a restriction. The impact pressure is then compared to the static pressure. Averaging Pitot Tubes do not use a Beta ratio per se, but do relate to the internal diameter of the pipe. This element, like the Venturi, must be in a Reynolds Number range greater than 75K to provide an optimal linear response.

Applications for trending flow are very repeatable and can be used for controlling or monitoring of many gasses and liquids. Some particularly great applications are air for burner intakes, clean gasses, sour gasses, petroleum vapors, ventilation air, steam, oxygen, etc. These elements can be used in square or rectangular ducting as well. It is not uncommon to see several Averaging Pitot Tube devices in an array all plumbed together for an averaging effect on large pipes or ductwork. This can be a very affordable way to measure physically large applications.

Typical core applications for Averaging Pitot Tubes include air, water, clean liquids and clean gasses.

SHARED DESIGN CHARACTERISTICS

All differential pressure flow meters can be employed for compensated mass flow with the addition of temperature and static pressure measurement. Most flow computers have compensation algorithms already in place that are based on the latest AGA and API standards, real gas laws, and other methods. Some multivariable transmitters have built-in flow equations, making them a combination transmitter/flow computer.

There are numerous attributes associated with DP meters: no moving parts, accuracies that rival turbine meters without the need for maintenance, temperature and pressure options galore, and service ranges from vacuum to many thousands of pounds per square inch. Materials of construction primarily limit temperatures with these devices. Care must be taken to orient the electronics appropriately for extremes in temperature (See Fig. 4).

	Typical Accuracy	**Repeatability**	**Typical Turndown**	**Main Benefits**
Venturi	+/- 0.75 - 1%	0.1%	12:1	Low permanent pressure drop, stable, no need for primary element calibration, extremely long life
Cone	+/- 0.5%	0.1%	20:1	Excellent turndown, little to no straight pipe required, high accuracy and repeatability
Wedge	+/- 0.5 - 3%	+/- 0.2%	10:1	Handles viscous fluids, slurries (and other non-Newtonian fluids), and is suitable for other abrasive applications
Averaging Pitot	+/- 0.75%	0.1%	17:1	Great for characterizing clean flow, repeatable, low cost, hot tap version available, lowest permanent pressure drop

Figure 4: Attributes of common DP flow meter designs.

The materials of construction for DP meters are very flexible. Most companies can manufacture out of whatever material best suits the application. Often times, it will be up to the end user to determine the materials most compatible with their processes. After all, the end user should know more about their process than can be compiled in a compatibility book or understood by a vendor.

If desired, most DP meter elements can be flow tested along with their respective transmitters for ultimate performance. Some meter designs can have transmitters directly mounted to the element with suitable manifolding to allow for future calibration checks and service.

SUMMARY

Differential Pressure meters can be the best solution for some of today's most difficult flow measurement applications. Their fixed geometry will last for years. When combined with advanced differential pressure transmitters, they provide very good rangeability without the complexity that is common with old school analog transmitters. When used with a multivariable transmitter, DP meters are easily installed and durable in nature. This technology is a proven problem solver with versions that are specific to different measurement tasks.

ABOUT BADGER METER

Badger Meter is an innovator in flow measurement and control products, serving water utilities, municipalities, and commercial and industrial customers worldwide. The company's products measure water, oil, chemicals, and other fluids, and are known for accuracy, long-lasting durability and for providing valuable and timely measurement data. For more information, visit www.badgermeter.com.

Control. Manage. Optimize.

www.badgermeter.com

The Americas | Badger Meter | 4545 West Brown Deer Rd | PO Box 245036 | Milwaukee, WI 53224-9536 | 800-876-3837 | 414-355-0400

México | Badger Meter de las Americas, S.A. de C.V. | Pedro Luis Ogazón N°32 | Esq. Angelina N°24 | Colonia Guadalupe Inn | CP 01050 | México, DF | México | +52-55-5662-0882

Europe, Eastern Europe Branch Office (for Poland, Latvia, Lithuania, Estonia, Ukraine, Belarus) | Badger Meter Europe | ul. Korfantego 6 | 44-193 Knurów | Poland | +48-32-236-8787

Europe, Middle East and Africa | Badger Meter Europa GmbH | Nurtinger Str 76 | 72639 Neuffen | Germany | +49-7025-9208-0

Europe, Middle East Branch Office | Badger Meter Europe | PO Box 341442 | Dubai Silicon Oasis, Head Quarter Building, Wing C, Office #C209 | Dubai / UAE | +971-4-371 2503

Slovakia | Badger Meter Slovakia s.r.o. | Racianska 109/B | 831 02 Bratislava, Slovakia | +421-2-44 63 83 01

Asia Pacific | Badger Meter | 80 Marine Parade Rd | 21-06 Parkway Parade | Singapore 449269 | +65-63464836

China | Badger Meter | 7-1202 | 99 Hangzhong Road | Minhang District | Shanghai | China 201101 | +86-21-5763 5412

Switzerland | Badger Meter Swiss AG | Mittelholzerstrasse 8 | 3006 Bern | Switzerland | +41-31-932 01 11