Differential Pressure Volumetric Flow

DPharp Digital Pressure Transmitters | EJA-E Series, EJX-A Series

Differential Pressure Flow is one of the oldest forms of measurement. The Egyptians began using simple flow devices to predict spring floods. Roman aqueducts used obstructions in the water with marks on the wall to measure the water flow to their cities. Even the Sumerians used flow devices to brew beer.

Of course, today, our understanding of differential pressure has advanced since these early users, but some things have remained the same. Differential pressure flow is a well-understood technology that quickly delivers an accurate and reliable signal. Even today, DP flow meters account for approximately 50% of the entire flowmeter market.

Volumetric versus Mass Flow

Volume is a physical quantity that measures the three-dimensional area occupied by a substance. Volumetric flow, or actual flow, measures the volume moving through a device per unit of time.

Mass is how much matter is in a substance and is often expressed in weight (grams, kilograms, tons, ounces, or pounds). Mass flow rate is the amount of a mass moving through an instrument per unit of time

For volumetric flow, a differential pressure transmitter using Bernoulli's principle can infer the flow rate through an obstruction in a pipe.

For mass flow, the differential pressure is one of several variables needed for a flow computer to calculate the mass flow.

Using Differential Pressure for Volumetric Flow

A differential pressure flow meter uses a variation of Bernoulli's principle to infer the flow rate in a pipe.   For our application of the principle, the velocity of the flow increases, and the pressure decreases as the flow moves through a restriction in the line; therefore, the pressure is higher before the restriction than after. Knowing this differential pressure, the flow rate can be determined. To further refine the equation, in turbulent flow (Re > 4000), the square root of the differential pressure across the restriction in the pipe is proportional to flow.

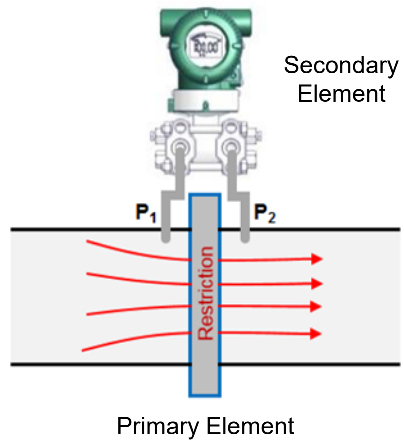
$$Q \propto \sqrt{P_1 - P_2}$$

Where:

Q = Flow Rate

P_1 = Before Restriction Pressure

P_2 = After Restriction Pressure



The above formula is the basis for measuring volumetric flow with differential pressure, but it is not practical. We need an easy-to-use form. We can make it more usable using mathematical principles beyond the scope of this FieldGuide. This formula can be broken down into different forms, but the easiest to use is the percentage calculation.

$$\%\Delta P = 100 \left[\frac{\%\ Flow}{100} \right]^2$$

The transmitter can use the Square Root function to generate an output matching the flow, or DCS/Controller can execute the calculation. Make sure you only enable one of the devices to do the calculation. If you enable both, you will be taken the square root of a square root, which infers nothing but a mess.

Example

For an illustration of how the formula works, we are going to use the following example:

An application has a volumetric flow of 0 to 200 GPM, corresponding to the differential pressure of 0 to 150 in H_2O.

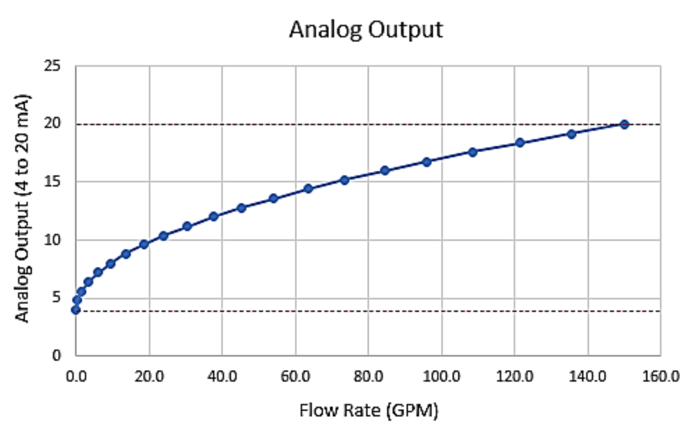
	LSL	USL	UOM
Flow Rate:	0	200	GPM
Differential Pressure:	0	150	inH_2O

The formula generates the percent of DP based on knowing the percent of Flow. I have broken down the % of flow rate into 5% increments. The simplified Bernoulli's formula can calculate the corresponding % of DP. Then, we can determine the pressure corresponding to a flow rate using the percentage.

	Flow Rate		Differential Pressure		Analog Output mA
	GPM	%	%	inH_2O	
1	0	0	0.0	0.0	4
2	10	5	0.3	0.4	4.8
3	20	10	1.0	1.5	5.6
4	30	15	2.3	3.4	6.4
5	40	20	4.0	6.0	7.2
6	50	25	6.3	9.4	8
7	60	30	9.0	13.5	8.8
8	70	35	12.3	18.4	9.6
9	80	40	16.0	24.0	10.4
10	90	45	20.3	30.4	11.2
11	100	50	25.0	37.5	12
12	110	55	30.3	45.4	12.8
13	120	60	36.0	54.0	13.6
14	130	65	42.3	63.4	14.4
15	140	70	49.0	73.5	15.2
16	150	75	56.3	84.4	16
17	160	80	64.0	96.0	16.8
18	170	85	72.3	108.4	17.6
19	180	90	81.0	121.5	18.4
20	190	95	90.3	135.4	19.2
21	200	100	100.0	150.0	20

When the transmitter measures 9.4 in H_2O (6.3 % of the DP Span), the formula says this equals 25% of Flow (50 GPM). Therefore, the transmitter will send an 8mA signal (25% of the 4 to 20mA signal).

If you generate an Analog Output versus Flow Rate graph of all points, it will look like this:



Digital Indicator

A feature of Yokogawa's differential pressure transmitter is the display being independent of the analog signal. This allows the display to be set up differently from the output. This is commonly used to give a local indication of flow while allowing the DCS/Controller to perform the square root function on the output.

Primary Element

The primary element is the restriction in the pipe that produces the differential pressure. Examples include different types of orifice plates, orifice bores, pitot tubes, averaging pitot tubes, flow nozzles, Venturi nozzles, Venturi tubes, Wedge Meters, or Cone Meters. The primary element must be sized to determine the Differential Pressure produced in an application. The calculated differential pressure will be used to calibrate the differential transmitter.

Conclusion

Differential Pressure Volumetric Flow is a well-understood technology. It offers advantages in ease of use and price compared to other flow technologies. The system accuracy depends on the primary element selected, but it can range from 0.5% to 1.5%. An appropriately selected DP flow system can provide good process control at a reasonable price compared to other flow technologies

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