ABB MEASUREMENT & ANALYTICS | TECHNICAL PUBLICATION

ABB Measurement & Analytics
Flowmeter technologies



Our extensive portfolio of flowmeter technologies

Selecting flowmeter technologies to minimize annual energy costs.

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Measurement made easy

Introduction

Rate of fluid flow constitutes an important measurement in the processing industries. Selecting an appropriate technology for a flow measurement application can be a daunting task. In the case where several technologies would work for a particular application, minimizing energy costs can help narrow the selection further. This publication outlines ways to assess the energy costs associated with a particular flowmeter technology.

Flowmeter technologies

Figure 1 shows the variety of flowmeter technologies available and their representation in the processing industries. Many of the technologies shown (electromagnetic, vortex, turbine, ultrasonic and anemometer) actually measure the flow velocity of the fluid in the pipe. Multiplying the measured average velocity by the cross-sectional area of the meter or pipe results in volumetric flow rates. Flowmeters based on differential pressure (for example, orifice plates, nozzles, wedges, Venturis and pitot tubes) introduce a restriction in the flow. The unrecoverable pressure loss caused by the restriction is a measure of the volumetric flow rate.

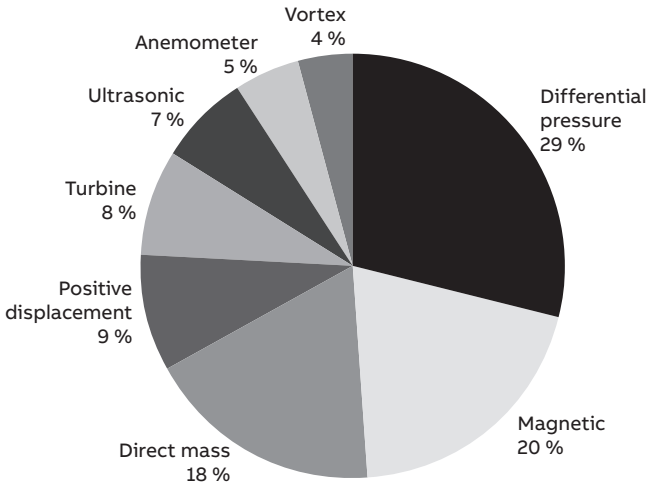


Figure 1 Flowmeter technologies in the process industries

Positive displacement flowmeters are true volumetric flow devices, measuring the actual fluid volume that passes through a meter body with no concern for velocity. These flowmeters capture a specific volume of fluid and pass it to the outlet. The fluid pressure moves the mechanism that empties one chamber as another fills.

If the application requires a measure of the mass flow rate, volumetric flowmeters must be supplemented with additional information, such as fluid density, pressure and/or temperature. Some multivariable flowmeters and transmitters incorporate an additional sensor to provide this information. Alternatively, Coriolis flowmeters (and thermal probes for gas) measure mass flow rate directly. Currently at 18 % of the market, their market share is increasing steadily.

Figure 2 shows the applicability of certain flowmeter technologies to various liquid and gas conditions. Green indicates the technology will generally work while red rules it out. Yellow indicates that the flowmeter technology will sometimes work if certain conditions are met. Clearly, more than one technology can apply for a given set of fluid conditions. These are the cases when basing the selection on minimizing energy can further narrow the choices.

	Magnetic	Vortex/Swirl	Thermal mass	Coriolis	DP orifice	Wedge	VA
Liquids							
Conductive							
Non conductive							
High solids							
Pulsating flow							
High viscosity							
Gases							
Dry/Clean							
Moist							
Corrosive							
Contaminated							
Steam							

Figure 2 Flowmeter technology applicability

Why minimize energy?

Many flowmeter technologies introduce pressure loss into a system. Pressure losses equate to energy losses and costs. Valves, pipe friction, reducers, expanders and measuring devices such as flowmeters all increase the Permanent Pressure Loss (PPL) in the system. Some flowmeters require upstream reducers and downstream expanders to operate correctly.

For new processes, engineers often consider PPL when designing a system because it's important in sizing the pump (liquids), compressor (gases) or boiler (steam) to meet process conditions and to deliver the desired pressure and / or flow. For operating processes, PPL leads directly to the need for compensating energy, which can equate to significant increased annual operating costs. By minimizing pressure losses in a process, engineers can reduce the need for top-up pumping or compression as well as lowering the environmental impact. In the case of steam boilers, which are expensive, the ability to retrofit existing flow points with meters having low pressure losses can increase the effective boiler capacity.

By selecting flowmeters with low pressure losses, engineers can:

- reduce pumping/compressing costs
- increase capacity
- minimize compressor, pump or boiler size.

The amount of pressure lost in a flowmeter depends on three factors: the density of the fluid, the square of the fluid velocity (Vf)2 and the degree of obstruction to fluid flow (Kmeter). The following list roughly ranks the magnitude of the Kmeter factor for various flowmeters, from greatest pressure loss to lowest.

1 Coriolis
2 Orifice
3 Nozzle
4 Turbine
5 Vortex
6 Venturi
7 Averaging pitot tube
8 Electromagnetic / Ultrasonic



Replacing an orifice plate with an averaging pitot tube, for example, can reduce the PPL (and therefore the energy requirement) by a factor of 20. ABB averaging pitot tubes offer minimal irrecoverable pressure losses as well as being economical and simple to install.

Examples of energy usage

Calculation of energy usage depends on the PPL, volumetric flow rate (Q) and the mechanical efficiency (ME) of the system (in decimal). The general equation is:

Energy/Time = Power = (PPL * Q) / ME.

The system mechanical efficiency ME is the product of the efficiencies of the electric motor and that of the pump or compressor. Boilers also have an associated system efficiency. The following analysis assume a system efficiency of 70 % for nitrogen and water and 90 % for the boiler. Lower system efficiencies obviously require more power to make up for the pressure losses in the process.

Incorporating units of measurement (make-up power in watts, PPL in inches of water and Q in CFM), the above equation becomes:

Power = (0.118 PPL * Q) / ME

The annual cost can then be calculated by multiplying the energy by the local electricity cost ($ per kwh) and the number of operating hours in a year (8,760 total hours per year). The examples below assume a cost per kwh of $0.10, which is close to the national average (in 2010). However, electric rates differ by state and by residential, commercial and industrial end uses. They can range from 6 cents to 25 cents per kwh.

Overleaf are examples of annual costs for a single flowmeter nitrogen, water and steam.

...Examples of energy usage

Example 1 – Nitrogen

- 4 inch line
- Normal flow: 1500 SCFM
- Pressure: 50 psig
- Flow at 50 psig (64.7 psia) = 1500 / [64.7 / 14.7] = 341 CFM
- ME: 70 %

Flow meter technology	Flow (SCFM)	Flow (CFM)	PPL (in. H_2O)	Power (W)	ME 70 % (W)	Annual cost
Orifice (β = 0.65)	1500	341	54	2172.8520	3104	$2,719
Averaging pitot	1500	341	2.8	112.6664	160	$140
Vortex	1500	341	27.2	1094.4736	1563	$1,369

Table 1 Annual cost calculations – nitrogen

Example 2 – Water

- 4 inch line
- Average flow: 200 gpm = 26.74 CFM
- Pressure: 100 psig
- ME: 70 %

Flow meter technology	Flow (SCFM)	Flow (CFM)	PPL (in. H_2O)	Power (W)	ME 70 % (W)	Annual cost
Orifice	200	26.74	64.1	202.25601	288	$252
Averaging pitot	200	26.74	7.5	23.6649	33	$28
Vortex	200	26.74	25.6	80.776192	115	$100
Magmeter	200	26.74	0	0	0	$0

Table 2 Annual cost calculations – water

Example 3 – Steam

- 4 inch line
- Flow = 7500 lbs/hour = (125 lbs/min * 6.66 cu ft/lb) = 832.5 CFM
- Temperature = 290 °F
- Pressure: 50 psig
- Boiler efficiency: 90 %

Flow meter technology	Flow (SCFM)	Flow (CFM)	PPL (in. H_2O)	Power (W)	ME 70 % (W)	Annual cost
Orifice (β = 0.65)	7500	833	83.7	8227.2078	9141	$8,007
Averaging pitot	7500	833	5.23	514.0776	571	$500
Vortex	7500	833	47.12	4631.6132	5146	$4,507

Table 3 Annual cost calculations – steam

Figure 3 is a comparison of the annual energy costs incurred in overcoming the PPL associated with the individual flowmeter technologies detailed in the above examples. Selecting a flowmeter for minimum energy favorably affects pump and compressor sizing as well as boiler capacity. Clearly, a process system may have several flowmeters and other pressure reduction devices and be served by a pump, compressor or boiler; leading to much higher costs than indicated here. However, lowering PPL can lead to lower electricity bills by minimizing the pump and/or compressor size or work. Lowering PPL can also be a low-cost method of expanding steam boiler capacities.

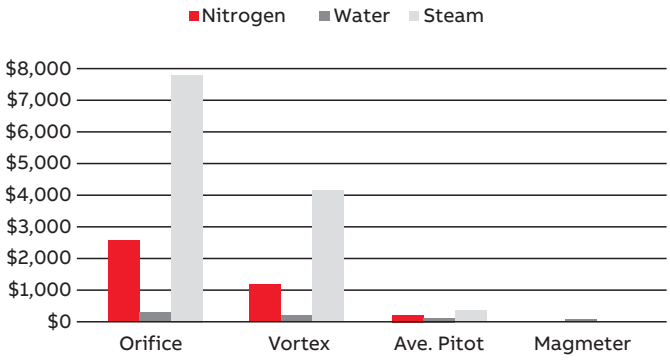


Figure 3 Annual energy costs for various flowmeter technologies and fluids

Measuring the emissions

By following the discussion so far, we have minimized the consumption of energy caused by monitoring and measuring the process flow rate. Now, we must consider the measurement of greenhouse gases produced.

Differential pressure (DP) measurement for emissions flow monitoring is not only the economical choice, but also the technically correct choice as proven by the many successful installations worldwide that are using averaging pitot meters to measure the flow of exhaust gas.

Averaging pitot meters:

- can be installed in stacks with diameters of up to 10 metres
- are available in partial (half diameter) insertion models for large diameter stacks when end support is not possible
- are able to measure volumetric or compensated mass flow with integral temperature measurement
- can be manufactured in exotic materials enabling them to be resistant to corrosive and hot gases (up to 600 °C [1112 °F])
- can be fitted with air purge systems for dirty gases
- comply with most Environmental Agency requirements and regulations

Figure 5 shows a typical set-up using an averaging pitot tube installed across the stack with end support and an air purge unit to ensure the ports in the pitot tube do not become blocked.



Figure 4 Typical stack

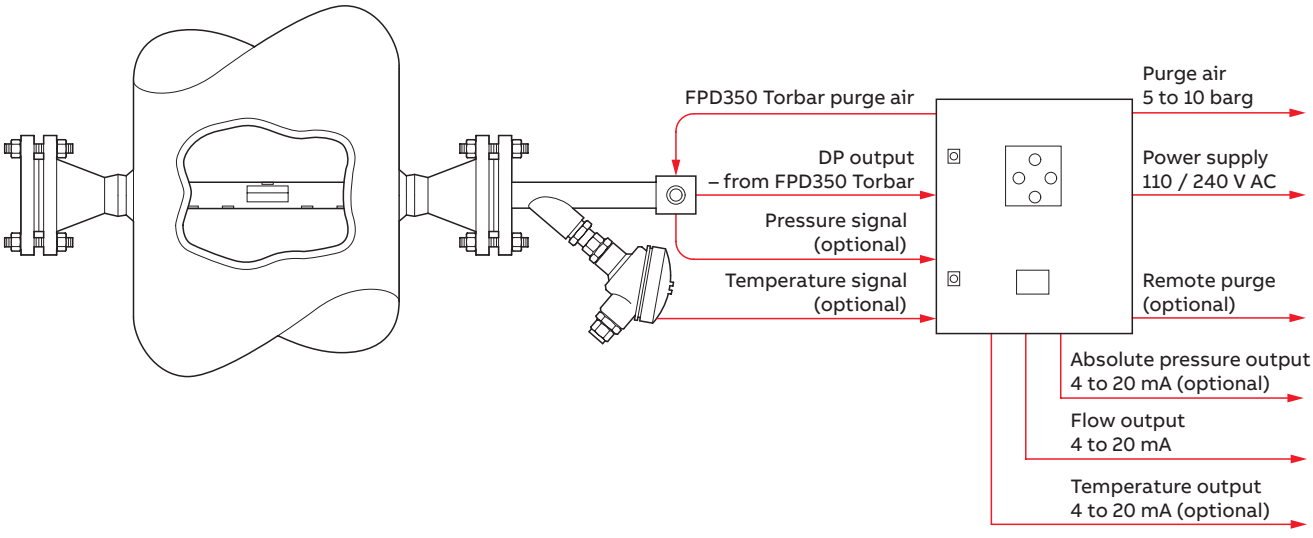


Figure 5 Typical averaging pitot tube installation

...Measuring the emissions

What is required to measure emissions?

Fig. 6 is an example of a continuous emissions measurement system for measuring nitrogen oxides (NOX), sulphur dioxide (SO2) and oxygen (O2) emissions from a stack.

Pressure and temperature sensors and a flow meter (pitot tube with differential pressure gauge) are installed in the stack (see Fig. 7). In this system, the results from the various sensors are transmitted to an analyzer that continuously measures each component of the flue gas. The analyzer then transmits the measured values to a computer or Distributed Control System (DCS) that performs temperature and pressure compensation, stores data, generates the appropriate written forms and periodically transmits the measured values and equipment status to the regulatory authorities. An uninterruptible power supply is used frequently and continuous emission monitoring systems are housed in an air-conditioned analysis room or analysis chamber.

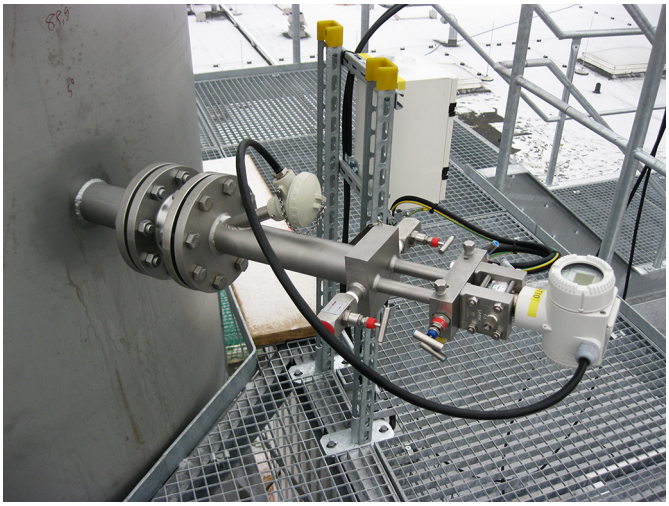


Figure 7 FPD583 installed in a stack

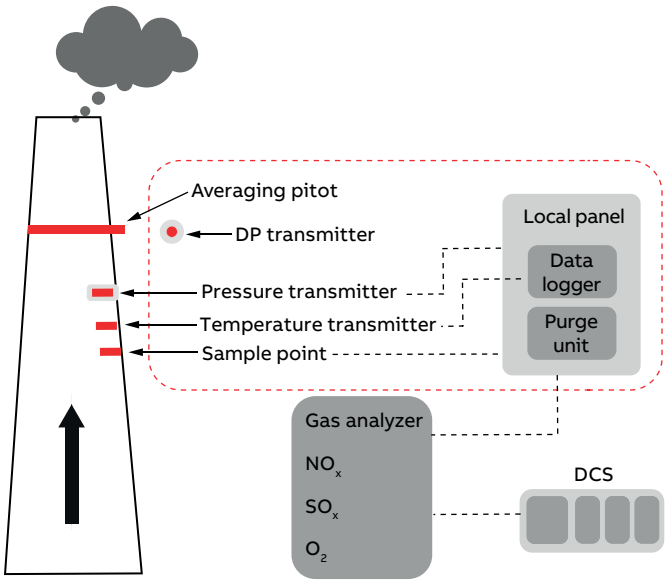


Figure 6 Typical Continuous Emissions Monitoring System (CEMS)

Notes

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