

ABB Measurement Products Flowmeters for minimizing energy

Measurement made easy

Selecting flowmeter technologies to minimize annual energy costs

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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 that several technologies would work for a particular application, minimizing energy costs can help narrow the selection. This article discusses ways to assess the energy costs associated with a particular flowmeter technology.

Flowmeter technologies

The pie chart of Figure 1 indicates 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--orifice plates, nozzles, wedges, Venturi's, 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.

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

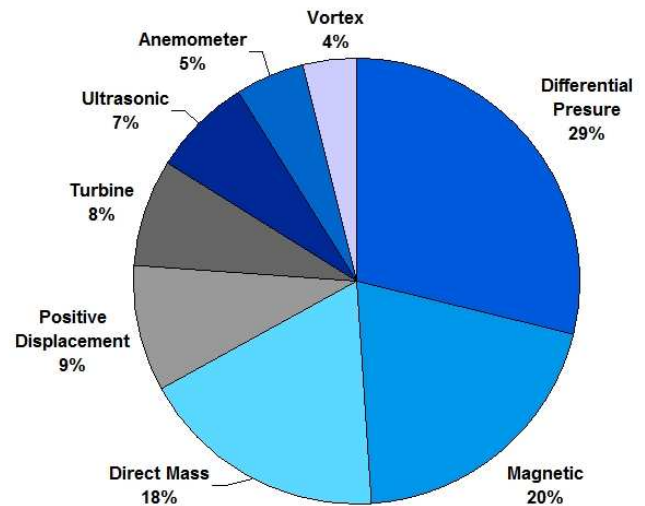


Figure 1. Flowmeter technologies in the process industries.

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. On the other hand, Coriolis flowmeters (and thermal probes for gas) directly measure mass flow rate. Currently at 18% of the market, they are steadily increasing market share.

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. Obviously 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.

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 properly.

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 cut the need for top-up pumping or compression as well as environmental impact. In the case of steam boilers, which are expensive, the ability to retrofit existing flowmeters with those having low pressure losses can boost the

effective boiler capacity.

By selecting flowmeters with low pressure losses, engineers can

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

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

1. Coriolis
2. Orifice/Nozzle
3. Turbine
4. Vortex
5. Venturi
6. Averaging Pitot tube
7. Electromagnetic/
Ultrasonic (negligible PPL)

PPL



	Magnetic	Vortex Swirl	Thermal Mass	Coriolis	DP Orifice	Wedge	VA
Liquids							
Conductive	Green	Green	Red	Green	Green	Green	Green
Non conductive	Red	Green	Red	Green	Green	Green	Green
High solids	Green	Red	Red	Yellow	Yellow	Green	Red
Pulsating flow	Green	Red	Red	Yellow	Yellow	Yellow	Red
High viscosity	Green	Yellow	Red	Green	Yellow	Green	Yellow
Gases							
Dry/clean	Red	Green	Green	Green	Green	Green	Green
Moist	Red	Yellow	Yellow	Yellow	Green	Green	Green
Corrosive	Red	Yellow	Yellow	Yellow	Yellow	Green	Yellow
Contaminated	Red	Green	Yellow	Yellow	Yellow	Green	Red
Steam	Red	Green	Red	Yellow	Green	Green	Green

Figure 2. Selection of flowmeter technologies depends on the application. Red, no. Green, yes. Yellow, maybe.

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

Examples of energy usage

Calculation of energy usage per unit of time depends on the product of the permanent pressure loss (PPL) and the volumetric flow rate Q divided by the mechanical efficiency (ME) of the system in decimal.

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

$$\text{Power} = (0.118 \text{ PPL} * Q) / \text{ME}$$

The system mechanical efficiency ME is the product of the decimal efficiencies of the electric motor and that of the pump or compressor. Boilers also have an associated system efficiency. The following analyses assume a system efficiency of 0.70 for nitrogen and water and 0.90 for the boiler. Lower system efficiencies obviously require more power to make up for the pressure losses in the process.

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

Nitrogen, water, and steam serve as representative gases and liquids for a great many materials common to chemical plants. Below are calculations of the savings possible for an orifice, averaging pitot, vortex, and magmeter (liquids only) flowmeters using these fluids as examples.

Example 1. Nitrogen gas

- 4-inch line
- Normal flow: 1500 SCFM
- Pressure: 50 psig
- Flow at 50 psig (64.7 psia)= $1500 / [64.7 / 14.7] = 341 \text{ CFM}$
- ME: 70 percent

Technology	PPL in. H ₂ O	Power Watts	70% ME Watts	Annual \$ cost
Orifice	54	2173.8	3104	2719.10
Ave. pitot	2.8	112.7	160	140.16
Vortex	27.2	1094.4	1563	1369.19

Orifice beta = 0.65 for all the examples.

Example 2. Liquid water

- 4-inch line
- Average flow: 26.74 CFM
- ME: 70 percent

Technology	PPL in. H ₂ O	Power Watts	70% ME Watts	Annual \$ cost
Orifice	64.1	202.3	288	252.29
Ave. pitot	7.5	23.7	33	28.91
Vortex	25.6	80.8	115	100.74
Magma meter	0	0	0	0

Example 3. Steam

- 4-inch line
- Density = 0.1495 lbs per cubic foot = 6.68 cu ft /lb
- Flow = 125 lbs/min * 6.68 cu ft/lb) = 835 CFM
- Boiler efficiency: 90%

Technology	PPL in. H ₂ O	Power Watts	90% Eff Watts	Annual \$ cost
Orifice	83.7	8247	9163	8026.78
Ave. pitot	5.23	515.3	572.6	501.60
Vortex	47.12	4643	5159	4519.28

Obviously a process system may have several flowmeters and other pressure reduction devices served by a pump, compressor, or boiler, leading to much higher costs than indicated here. But 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.

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