Low permanent pressure loss in process systems can equal high savings for operators
Selecting flowmeter technologies to minimize energy costs

Choosing a flowmeter with a low permanent pressure loss can reduce pump or compressor work requirements and increase steam boiler capacities – thereby trimming annual energy costs

by: Greg Livelli – Senior Vice President, Global Product Group Flow Measurement, ABB Inc.

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

The pie chart of Fig. 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 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.

Fig. 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 reduce 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 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 fluid density, the square of the fluid velocity \((V_f)^2\), 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/Ulasonic (negligible PPL)

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 above equation becomes:

\[
\text{Power} = \frac{0.118 \text{ PPL} \times Q}{\text{ME}}
\]

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 CFM
- ME: 70%

<table>
<thead>
<tr>
<th>Technology</th>
<th>Flow SCFM</th>
<th>Flow SCFM</th>
<th>PPL in. water</th>
<th>Power watts</th>
<th>ME 70% watts</th>
<th>Annual cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice (\beta=0.65)</td>
<td>1500</td>
<td>341</td>
<td>54</td>
<td>2172.8520</td>
<td>3104</td>
<td>$2,719.10</td>
</tr>
<tr>
<td>Averaging pitot</td>
<td>1500</td>
<td>341</td>
<td>2.8</td>
<td>112.664</td>
<td>160</td>
<td>$140.16</td>
</tr>
<tr>
<td>Vortex</td>
<td>1500</td>
<td>341</td>
<td>27.2</td>
<td>1094.4736</td>
<td>1563</td>
<td>$1,369.19</td>
</tr>
</tbody>
</table>

\(\beta\) is the ratio of the orifice hole diameter to the pipe inside diameter.

**Example 2: Liquid water**

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

<table>
<thead>
<tr>
<th>Technology</th>
<th>Ave. flow gpm</th>
<th>Ave. flow CFM</th>
<th>PPL in. water</th>
<th>Power watts</th>
<th>ME 70% watts</th>
<th>Annual cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice (\beta=0.65)</td>
<td>200</td>
<td>26.74</td>
<td>64.1</td>
<td>202.25601</td>
<td>288</td>
<td>$252.29</td>
</tr>
<tr>
<td>Averaging pitot</td>
<td>200</td>
<td>26.74</td>
<td>7.5</td>
<td>23.664</td>
<td>33</td>
<td>$28.91</td>
</tr>
<tr>
<td>Vortex</td>
<td>200</td>
<td>26.74</td>
<td>25.6</td>
<td>80.776192</td>
<td>115</td>
<td>$100.74</td>
</tr>
<tr>
<td>Magmeter</td>
<td>200</td>
<td>26.74</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>$0</td>
</tr>
</tbody>
</table>

**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%

<table>
<thead>
<tr>
<th>Technology</th>
<th>Ave. flow lbs/hr</th>
<th>Ave. flow CFM</th>
<th>PPL in. water</th>
<th>Power watts</th>
<th>Boiler 90% watts</th>
<th>Annual cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice (\beta=0.65)</td>
<td>7500</td>
<td>833</td>
<td>83.7</td>
<td>8227.2078</td>
<td>9141</td>
<td>$8,007.52</td>
</tr>
<tr>
<td>Averaging pitot</td>
<td>7500</td>
<td>833</td>
<td>5.23</td>
<td>514.0776</td>
<td>571</td>
<td>$500.20</td>
</tr>
<tr>
<td>Vortex</td>
<td>7500</td>
<td>833</td>
<td>47.12</td>
<td>4631.6132</td>
<td>5146</td>
<td>$4,307.90</td>
</tr>
</tbody>
</table>
The chart in Fig. 3 compares the annual costs for energy to overcome the permanent pressure losses associated with individual flowmeter technologies discussed in the examples. 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.

![Fig. 3: Annual energy costs for various flowmeter technologies and fluids based on the examples discussed. Selecting a flowmeter for minimum energy favorably affects pump and compressor sizing as well as boiler capacity.](image)

**About the author**

Greg Livelli is Senior Vice President, Global Product Group Flow Measurement for ABB Inc. Based in Warminster, Pa., he has more than 20 years experience in the design and marketing of flowmetering equipment. Mr. Livelli earned an MBA from Regis University and a bachelor’s degree in Mechanical Engineering from New Jersey Institute of Technology. Mr. Livelli can be reached at greg.livelli@us.abb.com or 215 674-6641.

**Contact us**

To find your local ABB contact visit:
www.abb.com/contacts

For more information visit:
www.abb.com/measurement

**ABB Inc.**
**Process Automation**
125 E. County Line Road
Warminster
PA 18974
USA
Tel: +1 215 674 6000
Fax: +1 215 674 7183

**Note**

We reserve the right to make technical changes or modify the contents of this document without prior notice. With regard to purchase orders, the agreed particulars shall prevail. ABB does not accept any responsibility whatsoever for potential errors or possible lack of information in this document.

We reserve all rights in this document and in the subject matter and illustrations contained therein. Any reproduction, disclosure to third parties or utilization of its contents in whole or in parts – is forbidden without prior written consent of ABB.

**Copyright© 2015 ABB**
All rights reserved