Steam Metering

Choosing the right flowmeter to achieve targeted energy savings
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With fuel prices rising and legislation to control carbon emissions tightening, the importance of finding new ways to save energy consumption is climbing up the agenda for many steam-using organisations.

Some of today’s most cost effective energy saving schemes rely on motivating people to think about how they can better manage their energy consumption. By making an organisation’s individual departments or cost centres accountable for their energy, the impetus for saving is placed with the user.

Some companies are finding that such monitoring and targeting schemes can produce savings of up to 5% of their energy bill.

The first step in making users pay for the energy they use is to measure their actual consumption. The more accurate the metering, the better the control over consumption. In addition to the more obvious energy costs, such as gas and electricity, steam is one utility where significant savings can be made by eliminating wasteful consumption.

It is vital to choose a flowmeter type that takes into account all the needs of metering steam – a relatively slow flowing, high temperature fluid with varying density, often feeding variable demand and with entrained moisture that can damage unsuitable meter types.

Meter accuracy is another significant factor in the equipment selection process, but turndown, which is the ratio of the maximum and minimum flow rates the meter can measure, is often even more important. It is sensible to choose the flowmeter that offers the largest possible turndown. The chances of ending up with a flowmeter that cannot cover actual flow rate are therefore greatly reduced.

Very often, greater energy efficiency achieved as a result of installing steam metering can help recoup the cost of installation within just two years. However, it is essential to choose the right flowmeter for the job.

1.0 Executive Summary
2.0 Carbon and energy reduction is a UK priority

Britain is the first country in the world to set legally binding carbon budgets that will cut UK emissions by 34% by 2020 and at least 80% by 2050. Some of those savings will be realised by developing low-carbon technologies for energy generation, but energy efficiency improvements will have a huge role to play, according to the Department of Energy and Climate Change (DECC).

Virtually every organisation in the country will have to reduce its energy consumption and carbon footprint, with regulatory and tax incentives being applied to make sure this happens. For example, England’s National Health Service (NHS) carbon reduction strategy calls for a cut in the NHS’s 2007 carbon footprint of 10% by 2015. This will require the current level of growth of emissions to not only be curbed, but the trend to be reversed and absolute emissions reduced. Meanwhile, the biggest industrial emitters are subject to the European Union’s Emissions Trading Scheme and more modest energy users will be feeling the pinch from the UK Government’s CRC Energy Efficiency Scheme.

In other words, as the Government gets serious about climate change, businesses and other organisations are being asked to bear the brunt of the changing regulatory environment in their energy bills. On average, DECC expects UK domestic energy bills to be 1% higher in 2020 than today, while non-domestic energy bills for medium-sized consumers will be 26% higher as a result of climate change and energy policies.

However, the impact of climate change and energy policies on energy prices is higher than their impact on bills, expected to be 24% and 43% on gas and electricity prices respectively for medium-sized non-domestic consumers. The impact on bills is lower because policies to improve energy efficiency will help businesses to reduce energy consumption, lessening the overall bill impact.

In other words, improving energy efficiency is a key way to keep fuel bills rising more slowly than fuel prices. This is clearly important against the backdrop of soaring fuel prices in recent times. Between Q2 2011 and Q2 2012, average industrial prices in real terms, including Climate Change Levy (CCL) rose by 4.5% for electricity and by 6.4% for gas.

For most steam-using organisations, finding ways to improve the efficiency of their steam systems must be a growing priority.

**You can’t control what you can’t measure**
Accurate measurement is an essential prerequisite in any successful control scheme, and energy management is no exception. This effectively puts metering equipment at the heart of any effort to monitor and target energy consumption. According to the Carbon Trust, automatic monitoring and targeting (M&T) equipment typically helps organisations to reduce their energy costs by around 5%.

First for Steam and Energy Solutions
M&T schemes relate energy consumption data to a range of factors, including the weather and production figures, to help organisations understand how energy is being used within their buildings and processes. Most importantly, it will identify any signs of avoidable waste or other opportunities to reduce consumption.

Data collection may be manual, automated, or a mixture of the two. Once an M&T scheme has been set up, its routine operation should be neither time-consuming nor complex. Ideally the data will accumulate regularly and provide the information to underpin all the organisation’s energy management activities.

As well as spotting waste, M&T can provide a reliable measure of the success of any energy saving initiatives, which can otherwise be tricky to untangle from external factors such as the weather or changes in production levels. It also helps to highlight promising areas for further investigation, making it easier to focus on the most fruitful areas. The feedback from M&T can be used to raise staff awareness and encourage the spread of best practice.

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**Why measure steam flow rates?**

Measuring steam use accurately under all load conditions provides vital information on usage and associated costs that can improve efficiency in four key areas:

**Plant efficiency**
- Is idle machinery switched off?
- Is plant loaded to optimum efficiency?
- Identify cleaning and / or maintenance needs
- Identify major steam users
- Highlight peak steam usage times
- Indicate whether working practices are satisfactory

**Energy efficiency**
- Monitor the results of energy saving schemes
- Compare the efficiency of various pieces of plant

**Process control**
- Confirm if the correct quantity of steam at the right pressure and temperature is being supplied

**Costing**
- Cost steam as a raw material
- True cost of individual product lines can be established
- Relate steam energy costs to total plant efficiency
- Check individual plant performance
- Charge for steam usage
3.0 Ensuring steam metering accuracy

Metering steam flow reliably and accurately involves a number of technical differences to other types of fluid flow metering. For example, many steam meters measure volumetric flow, which needs to be implemented with the physical properties of steam in mind to ensure that the flow rate is measured accurately.

Changes in the system during normal operations can result in considerable differences between actual pressure and temperature and a meter’s design parameters. Therefore, accurate steam metering often means measuring temperature and pressure, as well as flow.

While temperature and pressure in most steam systems are relatively constant, this is not the case in many applications.

The importance of density compensation. In this example a simple non-compensated meter is set for 6 bar g. The actual pressure in the system varies through the day and unless this is allowed for, by the end of the day, very significant errors can arise. This is typical of many steam systems.
3.1 Temperature, erosion and velocity considerations

Other steam properties also need to be taken into consideration. For example, the high temperatures associated with steam flow measurement can affect the accuracy and longevity of metering electronics.

Also, in poorly designed systems, wet steam can cause inaccurate readings and can damage flow sensing elements through erosion. For this reason it is recommended that steam conditioning equipment such as separators and traps are fitted in the system.

Steam pipework is often designed with a bigger bore than other fluids to keep the overall velocity down in order to limit erosion. This can reduce the performance of many flowmeters that only achieve their optimum accuracy at higher velocities.

3.2 Specifying turndown

Steam use often varies considerably, perhaps with the weather in the case of space heating applications, or production schedules in the case of process steam. This means that many meters will be called on to provide accurate measurements over a wide range of flows. To meet the possible flow range parameters it is important to specify a meter with as large a turndown as possible.

Turndown is a measure of a flowmeter’s effective operating range, expressed as the ratio of the maximum and minimum flow rates the meter can measure and still meet its specified level of accuracy. High turndown is good insurance against future changes in demand. Whether flow rates increase or decrease, a high turndown meter is more likely to meet changing requirements than a low turndown device, avoiding the cost of meter replacement.

This graph shows a typical demand curve for a distributed steam system with a high start-up load and variable demand through the day. A flowmeter, with a 4:1 turndown is sized on the peak load of 1000 kg/h would lose or at best record with a significant error any flow rates below 250 kg/h.
3.3 Specifying accuracy

The way in which accuracy of meters is specified can also affect a flowmeter’s performance in a particular installation.

There are two ways that a flowmeter’s accuracy can be specified. These are % of Full Scale Deflection (FSD) and % of reading. The two are very different and it is important to understand the difference as many manufacturers use the % FSD specification to make their accuracy statements look better. To see how this works consider the two following examples:

Example 1: % of FSD

Full flow = 1000kg/h, Accuracy stated as +/-1% of FSD.
When reading full flow (1000kg/h) the actual error may be +/-10kg/h so the actual flow may be between 990 and 1010kg/h = a 1% error.
When reading 10% flow (100kg/h) the actual error may still be +/-10kg/h so the actual flow may be between 90 and 110kg/h = a 10% error!

Example 2: % of reading

Full flow = 1000kg/h, Accuracy stated as +/-1% of reading.
When reading full flow (1000kg/h) the actual error may be +/-10kg/h so the actual flow may be between 990 and 1010kg/h = a 1% error.
When reading 10% flow (100kg/h) the actual error may +/-1kg/h so the actual flow may be between 99 and 101kg/h = a 1% error.

It is clear that at lower flow rates a meter with an accuracy specified as % of reading will be more accurate than a meter with an accuracy specified as % of FSD.

3.4 Available installation space

As well as the physical properties of steam, there are other important considerations that need to be taken into account regarding the application and installation of metering systems.

For example, the pipework used to distribute steam often follows complex, tortuous routes and it can be difficult to find the straight runs of pipe required by many meters to allow a turbulent-free flow into the meter for accurate results. It is important therefore, to select a meter that can fit within the upstream and downstream straight pipe runs available. The length of unobstructed pipework before and after a meter is usually expressed in terms of the number of pipe diameters of pipeline needed.
Different flowmeter types need longer or shorter unobstructed, straight pipe lengths upstream and downstream to achieve their specified accuracy.
4.0 A wide variety of flowmeter types

The properties of steam mean that some types of meter that are commonly used for other fluids are not generally appropriate for steam metering. Of the technologies that are suitable, it’s often a question of picking the right technology with each one’s pros and cons influencing the best choice in each application.

4.1 Coriolis flowmeters
Coriolis flowmeters directly measure mass flow rate. They have one or more bent, straight, or U-shaped vibrating tubes in the fluid stream. When fluid is passed through the tubes, a twisting motion is introduced and the resonant frequency changes. It is the combination of the amount of twist and the resonant frequency that indicates mass flow rate.

The chief advantage of Coriolis flowmeters is that they measure mass flow rate directly, without the need for accessories to measure temperature or pressure.

4.2 Orifice plate flowmeters
Orifice plates measure the pressure drop in the steam as the flow passes through a precise circular orifice in a plate spanning the width of the pipe. The differential pressure across the plate can be used to calculate the flow. Correct sizing and installation of orifice plates is absolutely essential, but a properly designed system can achieve a turndown of between 4:1 and 5:1.

4.3 Pitot tube flowmeters
Pitot tubes can be cost-effective for large-bore pipes. They enable users to calculate velocity based on the pressure generated in an open-ended tube facing the flow. Because a simple Pitot tube only samples a single point, accurate placement of the nozzle is critical. Averaging Pitot tubes have a number of upstream tubes to sense various velocity pressures across the pipe, which are then averaged to give a representative flow rate.

4.4 Turbine flowmeters
Turbine meters have a multi-bladed rotor mounted at right angles to the flow and suspended in the fluid stream on a free-running bearing. The speed of rotation is proportional to the volumetric flow rate of the steam. In larger pipelines, turbines can be projected into the flowing medium through a conventional or ‘hot tapped’ side connection to save money. They offer a typical turndown of 10:1 and ±0.5% accuracy, although leading-edge instruments can offer 25:1 and still maintain ±2% accuracy.

4.5 Variable area flowmeters
A variable area flow meter, often called a rotameter, consists of a vertical, tapered bore tube with the small bore at the lower end and a float that moves freely in the fluid. When fluid passes up through the tube, the float’s position depends on the upward force of the fluid and the mass of the float, so it effectively indicates the flow rate.
4.5.1 Spring-loaded in-line variable area (SILVA) flowmeters
These meters use a spring as the balancing force, rather than the weight of the float. This makes the meter independent of gravity, allowing it to be used in any plane, even upside-down.

Also, the flow area between the float and the tube can be designed to increase as the spring moves so that the differential pressure across the meter is directly proportional to flow. Crucially, this means that either the displacement of the spring or the differential pressure across the meter is linear in proportion to flow.

If using the displacement principle, SILVA meters offer turndowns of 25:1 at normal steam velocities and accuracy of ±2%. If using differential pressure, the turndown may be up to 100:1 and accuracy of ±1% can be achieved.

4.5.2 Target variable area (TVA) flowmeters
TVA flowmeters operate in a similar way to SILVA meters. However, rather than measuring differential pressure, they measure the force caused by the deflection of a cone using high quality strain gauges. The higher the flow of steam, the greater the force. This removes the need for differential pressure transmitters.

TVA meters are generally accurate to ±2% over a turndown of 50:1.

4.6 Ultrasonic flowmeters
Ultrasonic flowmeters measure the time it takes an ultrasonic pulse to travel back and forth across a pipe at an angle. The pulse moves quicker when travelling with the flow than when it travels against it. The difference between these times is proportional to the flow rate.

These meters are especially suitable for measuring flow in large pipes. As with Coriolis meters, they have a relatively high initial cost.

4.7 Vortex shedding meters
When a non-streamlined or ‘bluff’ body is placed in a fluid flow, regular vortices are shed from the rear of the body. These vortices can be detected, counted and displayed. The rate of vortex shedding is proportional to the flow rate across a range of flows.

These meters are best suited to fluids with high velocities up to 80 ms-1.
5.0 Which meters suit which steam applications?

The physical properties of steam and the characteristics of different applications within steam systems make the use of many types of meter inappropriate.

Some types of meter offer very limited turndown ratios of 4 or 5:1, such as orifice plates and Pitot tubes. However, these simple, rugged and low cost meters can still be extremely useful for steam users. Orifice plates are commonly used where the flow rate remains fairly constant, or where trending information is more important than precise measurements, such as on the steam main from the boiler. Meanwhile, Pitot tubes are sometimes used to get a preliminary indication of the steam flow rate, perhaps to see which other meter might be the best permanent solution.

The high turndown ratio achievable with meters in other fluids may be impossible to realise with steam. For example, vortex meter manufacturers often quote a turndown ratio of 25:1, but this is typically in applications where the top velocity of the fluid approaches 75m/s. Steam may contain water droplets that could cause serious damage at such high speeds, so steam pipework is generally sized to produce a maximum recommended velocity of 35m/s, giving vortex meters a practical turndown ratio closer to 12:1.

Some vortex meters try to overcome the problem by restricting the bore of the pipe and speeding up the flow through the meter. However, great care must be taken when using this approach with steam. Condensate in steam lines must be able to drain freely. In a horizontal line, anything that creates obstructions such as a concentrically reduced bore in the pipe will stop that from happening.

Similarly, the sharp edges of an orifice in an orifice plate or the precise shape of the bluff body in a vortex meter is critical to maintain accuracy, so any erosion may be problem. In contrast, it’s only the cross-sectional area of the float in an in-line variable area meter that affects the reading, so erosive wear is not generally an issue.

SILVA flowmeters are often used in the float-displacement mode for metering the steam supply to individual processes or to track the output of small boilers. The differential pressure mode is usually preferred for metering boiler houses and large plants, where it’s easier to justify the added cost of the differential pressure cell.

Frequently, pipework considerations limit the use of certain meters. For example, orifice plates and vortex shedding meters must all be installed in the middle of lengthy runs of unobstructed, straight pipework to give good results and that may simply be impractical.

This is not a problem for SILVA and TVA meters.
Table: Comparison of meter types when used to measure steam flow

<table>
<thead>
<tr>
<th>Type of meter</th>
<th>Superheated steam?</th>
<th>Saturated steam?</th>
<th>Wet steam?</th>
<th>Turndown ratio*</th>
<th>Accuracy*</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Orifice plate</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>4:1</td>
<td>±3%</td>
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<tr>
<td>Turbine</td>
<td>Yes</td>
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<td>No</td>
<td>10:1/25:1</td>
<td>±2%</td>
<td>Low</td>
</tr>
<tr>
<td>SILVA</td>
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<td>Yes</td>
<td>Yes</td>
<td>25:1/100:1</td>
<td>±2%/1%</td>
<td>Medium</td>
</tr>
<tr>
<td>TVA</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>50:1</td>
<td>±2%</td>
<td>Medium</td>
</tr>
<tr>
<td>Vortex shedding</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>12:1</td>
<td>±2%</td>
<td>Medium</td>
</tr>
<tr>
<td>Pitot tubes</td>
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<td>Yes</td>
<td>No</td>
<td>4:1</td>
<td>±5%</td>
<td>Low</td>
</tr>
<tr>
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<td>Yes</td>
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<td>±2%</td>
<td>High</td>
</tr>
<tr>
<td>Coriolis</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>50:1 / 100:1</td>
<td>±0.1 – 1%</td>
<td>High</td>
</tr>
</tbody>
</table>

* In steam applications
6.0 The Spirax Sarco metering portfolio

Spirax Sarco offers a range of flowmeter types designed to suit the needs of any steam-using organisation.

6.1 Orifice plate flowmeter
The Spirax Sarco M410 orifice plate flowmeter can be supplied as a tab handled plate that can be located between existing flanges or fitted in its own carrier with integral pressure tappings. It offers a competitive solution for installations that need a rugged, cost effective flowmeter with low installation cost and a turndown of not more than 4:1.

The meter’s accuracy is ±3% of reading (equivalent to ±1.5% full scale deflection at 50% of rated maximum flow). Turndown is 4:1. Requires up to 30 pipe diameters of unobstructed, straight piping upstream and five diameters downstream.

6.2 ILVA spring loaded variable area flowmeter
Using the well-established spring loaded variable area principle, the Spirax Sarco ILVA (In Line Variable Area) Meter features a specifically shaped cone that moves within a fixed orifice, maintaining a near linear differential pressure with respect to flow. This unique feature enables accurate measurement right down to 1% of maximum flow. The addition of a temperature and/or pressure sensor and a flow computer provides a highly accurate measurement of mass flow and energy.

The ILVA requires only six pipe diameters of unobstructed, straight piping upstream and three diameters downstream. It has a quoted accuracy of ±1% of reading, down to 5% maximum flow and 0.1% FSD to 1% of maximum flow. Turndown is 100:1.

6.3 TVA spring loaded in-line variable area flowmeter
The Spirax Sarco TVA flowmeter is a stand-alone unit that integrates a flow sensing device, temperature sensor, connection accessories and flow computer into a compact unit, eliminating the need for additional external equipment. The TVA uses a profiled stainless steel cone with a large, smooth surface area plated in hard chromium to resist erosion from wet steam, for a long and reliable operational life with recalibration rarely needed.

The TVA offers ±2% of reading from 100% to 10% maximum flow rate; ±0.2% of FSD from 20% to 2% maximum flow rate. Turndown is 50:1. The meter requires only six pipe diameters of unobstructed, straight piping upstream and three diameters downstream.

6.4 RIM10 rotor insertion flowmeter
The Spirax Sarco RIM10 rotor insertion flowmeter for steam, gas and liquids is a turbine meter that incorporates a temperature and pressure sensor to provide compensated mass flow readings for liquids, gas and steam. This provides error-free readings accurate to ±1.5% with liquids and ±2% with gas and steam over an exceptional turndown among turbine meters of 25:1.

It can be rapidly fitted directly into operational pipework using hot-tapping techniques without waiting for a shutdown. This versatile meter caters for high pressure flow up to 137.8 bar g and temperatures up to 400°C and needs only 10 straight pipe diameters upstream and five downstream.
The importance of turndown: Brewery identifies energy saving opportunities

A UK brewery that operates three 11,000 kg/h boilers supplying steam to process and space heating applications was working to cut its energy consumption since the introduction of the Climate Change Levy. However, its efforts were being seriously hampered by the limitations of the existing steam meters.

A meter had been fitted to each boiler to monitor its output and two more meters were positioned on the steam mains on the factory floor. These units were vortex flowmeters that could not provide the utilities team with the information that they needed to make a case for energy saving investments.

When the steam flow rate dropped to below about 25% of its maximum, the meters would read zero. This meant they couldn’t measure the base loads at weekends. After testing some energy saving ideas on one of the boilers, the brewery found it impossible to tell from the readings which upgrade was the most efficient. This made it very difficult to justify investing any more in upgrading the other boilers.

By replacing the old meters with five Spirax Sarco SILVA flowmeters, the brewery was able to accurately quantify the benefits of each energy-saving idea on one boiler. It was then able to make an informed decision whether to make similar changes to the other boilers.

References

1 “Estimated impacts of energy and climate change policies on energy prices and bills”, July 2010, Department of Energy & Climate Change


4 Energy Trends and Quarterly Energy Prices, September 2011, Department of Energy & Climate Change