Importance of measurement at points of supply and consumption

By C Gimson, Endress+Hauser Pyrotemp

This article focuses on some of the practical considerations when choosing the correct flow meter and why so often the user is disappointed in the final metering installation - thus undermining the effectiveness of any energy reduction campaign.

It can be reliably stated that experience in South African and international industrial environments has shown that significant savings (in excess of 20%) can be obtained in the normally energy conscious area of utilities consumption – this covers 'Water, Air, Gases, Electricity and Steam,' commonly collectively referred to as 'WAGES'.

Regardless of the energy management concept used, the 'key ingredient' to these strategies is the proper measurement of these media at the points of supply (eg compressors, boilers, water and gas incoming lines etc) and major points of consumption (eg factory departments' feeds, major points of usage, etc). It is important that whilst super accurate flow metering is not the number one essential (although it helps!) what is important is that all the metering points measure correctly over the full plant operating range and take into account the practical realities of the installations (eg pipework) and flow media conditions (eg cleanliness, quality, composition).

Looking through the user's eyes, choosing the correct flow meter for any particular measurement point can be a challenge. *Table 1* gives an example of just some of the common choices open to the user when starting to look at selecting a flow meter for any particular measuring requirement:

	Air	Water	Carbon Dioxide	Steam	
Vortex	•	•	•	•	Volumetric
Thermal	•		•		Mass
Magnetic		•			Volumetric
Differential Pressure	•	•	•	•	**
Turbine	•	•	•	•	Volumetric
Coriolis	•	•	•		Mass
Positive Displacement	•	•	•	•	Volumetric

Table 1: Meter technology /flow media.

*** Differential pressure is not itself a direct flow measuring principle but can be applied to both volumetric or mass flow measurement depending entirely on the configuration of the primary element (nozzle, orifice plate, pitot tube), ancillary equipment and calculation used.*

Table 1 also illustrates the initial problem of meter type selection, namely: 'Which meter is the correct one for my application?' The point here is that despite there being a wide range of possible flow meters for any one metering requirement, the achievable performance of each one varies considerably depending on the operating conditions under which each is required to work. Each meter type has considerably different measuring ranges, sensitivity to different process conditions, installation and media quality not to mention cost implications and simplicity of installation and usage. Before the meter type can be considered, the first steps of selection must be to spell out the application requirement in terms of performance requirements and then under what conditions the meter must operate. A common mistake is overlooking that this must be done at every measurement point in the system and in some cases, you may end up with different meter types on the same flow media around the total system. You should never assume that because you have successfully selected a particular meter type in a particular location that it will function just as well in another location -unless you know, irrevocably, that the requirements and operating conditions are truly similar.

(1)

The starting point must always be: 'What performance characteristics are the most important for your meter?' If you are measuring large values or are using your flow meter in a billing or accounting type application then accuracy is important. An energy management system normally involves reconciling supply with consumption over the factory layout so accuracy will be a requirement in all but the smallest of installations (a possible exception would be flow meters installed at a final point of consumption where the consumption is small relative to the overall consumption).

(2)

The next step to be considered is the operating conditions of the metering location: The required flow range including:

- Minimum flow rate
- Nominal flow rate
- Maximum flow rate

The common mistake here is to neglect the minimum flow rate. All flow meters have a minimum flow rate at which the meter accuracy falls away or even worse, the meter stops measuring altogether. If you have selected and sized the flow meter only considering the nominal and maximum flow rate values, there is a high risk that if there are times when the flows drop below the minimum threshold for that particular chosen meter, you will have errors when reconciling your consumptions with production. One example (case study) of the consequences of selecting a wrong meter type or size – was carbon dioxide flow in a brewery. Both meter types (in this case vortex and thermal mass) worked perfectly over a large part of the operation range but at the minimum threshold of the vortex meter, the latter stopped working whilst the thermal meter which is known for its lower flow range operation carried on working. In this example, the times that the vortex meter dropped out of range resulted in 11% errors over the total monitoring period. There was no metering defect, just the wrong selection due to not considering the lower flow rate.

A very important step and a very often misunderstood topic is the selection of the flow unit. In a consumption application such as steam, gas, water or compressed air distribution application, the flow unit of choice must be a mass flow unit (eg kilogram, or pound (lb)) rather than a volumetric unit (eg cubic metre m3 or cubic foot cf). An extremely common choice is what is referred to as a 'normalised' (Nm3), 'standardised' (Scf) or 'corrected' volume' unit. This is expressed as a volume unit but the media process conditions have been mathematically adjusted inside the flow meter or externally in a computer to a common set of 'reference' pressure and temperature conditions (eg 0ºC, 1013,25 mbara). This is totally acceptable so long as the reference conditions are the same for all the flow meters in the measuring system and are known (they can be different depending on the country of origin and industry). The point to understand that 1 Nm3 of air referenced to 0ºC and 1013,25 mbara is always numerically the same as 1,293 kg so it is actually a mass flow unit and as such meets the requirement for the measurement application. Confusing the m3 volumetric unit with Nm3 is one of the most common reasons for errors in a measuring system.

(3)
The quality of the measured medium:
Gas dryness, solids content, gas bubbles in liquid, cleanliness
The quality of the flow media can have a huge effect of the performance and reliability of the selected meter type. The most common problems in the utilities measurements are water dropout (steam and compressed air), oil breakout and dirt particles (compressors)

Some examples:

- A vortex meter that works under very wet and dirty conditions: The dirt collected over the bluff body has no effect but the relatively small dirt on the sensing paddle will affect or potentially even knock out the measurement.
- A thermal mass meter is affected significantly by water on the sensor elements – the meter should be installed with precautions knowing that the measured gas is saturated at times.
- A thermal meter with dirt particles stuck over the sensors – although the user considers his gas clean as far as his process is concerned, what is considered 'clean' or 'dry' by the user is not necessarily the same for the installed instrument so you should attempt to make sure that the actual conditions are known at the time of selection - the terms 'clean', 'dry' and 'good' are subjective terms and do not portray the full picture.

(4)
Process conditions
If you are using a volumetric flow meter such as a vortex, positive displacement (PD), turbine, a differential pressure orifice or pitot tube, the minimum to maximum pressure and temperature ranges needs to be known to accurately be able to size the flow meter in terms of mass flow rather than the range in volumetric units.

Meter selection summary

Generally speaking, the same criteria should be applied to all applications. At 'top level', it often appears that the choice of meter principle is open (ie any type will perform the required task):

- Do not rely on just specification sheets
- Speak to your supplier
  - o Tell them about your application and its requirements
  - o Give them all your known process conditions
  - o Based on the above, ask what their meter recommendation is and why
- The minimum and maximum flow rates of their selection
- What flow units have been used
  - o If 'corrected' or 'normalised' units used, what are the reference temperature and pressure conditions used
- All installation requirements

Coriolis Most installation friendly Most expensive In most cases, especially with installation conditions taken into account = most accurate Highest pressure drop Mass and volume flow (liquids) Volume flow (gas) ***Commonly used on:*** Carbon dioxide Fuel oil	**Vortex** Most robust Probably lowest cost for smaller pipes Best for wet gases Volumetric flow ***Commonly used on:*** Steam Compressed air Carbon dioxide Water Natural gas Biogas High pressure air	**Thermal** Gas flows only Lowest pressure drop Most installation sensitive Low flows Largest measuring range Mass flow Large range of pipe sizes possible ***Commonly used on:*** Compressed air Carbon dioxide Natural gas Biogas
Differential Pressure Orifice/ Pitot tube Requires knowledge to apply Relatively low flow range Volumetric and mass flow when temperature and pressure compensation applied Relatively low cost for large pipe sizes Can be used with wet and dirty gases with some precautions Bi-directional measurement possible ***Commonly used on:*** Steam Compressed air Carbon dioxide Biogas	**Magnetic Flow meter** Conductive liquids use only No pressure drop Direction al measurement possible Very wide pipe diameter range Able to handle unclean liquids Easily cleanable Wide flow range capability Volumetric flow ***Commonly used on:*** Water	**Other metering types** Positive displacement Turbine ***Commonly used on:*** Water Fuel oil Natural gas

Operational Requirements	Quality of Installation	Cost
Accuracy Repeatability Stability Maintenance Ease of installation	Gas quality Environment Process conditions Physical installation itself	Purchase Installation Maintenance

For the application gases and liquids most commonly found in the utilities department (boiler, compressor, bottling flow management), the following types are today's common choice.

Meter installation considerations

Having chosen the best flow meter type and size based on an assessment of the application requirements, flow ranges and process conditions and quality, we should be in a position to have a reasonable expectation of the metering performance but.... regardless of this initial work, care and attention to necessary detail, the next most common reason for non-performance is the quality of the physical pipework installation.

All flow meters normally leave the manufacturer with a calibration certificate that, of course, will give a pretty impressive statement of the meter performance that is probably in excess of what you actually need for your application. So why, you may ask, is that same meter – now, during your site diagnostics - not delivering its promised delivery in your installation?

An example of typical installation-induced error conditions is three flow meters all measuring the same flow but with one installed incorrectly - and as the flow increases, its error increases!

The starting point is to understand one of the realities of calibration, namely that all flow meters are normally calibrated under ideal installation and process conditions.

All meters calibrated on the rig enjoy the 'benefits' of a perfect pipework installation, controlled pressures and both room and flowing air temperatures not to mention the guarantee of being set up correctly! Different flow meter types, for both gases and liquids, will be affected to different degrees when some of those perfect conditions are not presented in the application.

Now in the 'real' world of the installation, there is unfortunately often a considerable gap between the calibration conditions and the operating conditions. As soon as you add practical entities such as pipe diameter changes, bends, valves, filters, etc, you start to distort the flow conditions inside the pipe that are presented to the meter.

It is not adequate on a plant schematic just to specify a point as a metering point due to the process requirements. Often meters are installed to suit the convenience of the user to allow easy access rather than considering what the meter itself requires. A working example could be a compressor house output. You will want to measure the flow output of the compressor or compressor bank but there will be a huge difference in performance if you mount the meter before or after the receiver, before or after the dryer if one is fitted, before or after the manifolds, etc. You must look at the features of the physical installation before selecting the installation point. The person responsible for the installation must have a copy of the installation manual and he or she must read it! The manual will have specific instructions and guidelines as to the need for straight pipe before and after the meter point relative to pipework bends, diameter changes and most critically, upstream valve locations.

The meter inlet diameter that matches the installation pipework may be a critical point – for example for a thermal flow cell meter this is critical but this can be easily compensated for in a vortex meter. For steam look out for low points that could trap water drop out and definitely do not mount a meter at that point no matter how convenient the location may be to the operator – this can result in water hammer (slugs of water travelling down the pipework) that is a well known destroyer of instrumentation!

Now the next 'reality check' is that manuals and specification sheets can possibly cover all the practical issues behind every application and installation so a manual will attempt to cover the general requirements for the meter type but there will be often gaps acknowledging the wide diversity of application and customer installation variations. For example, a manual may give you guidelines for guarding against pipework bends, pipe reductions/expansions or valves, etc, but what about a combination of such effects – a very common reality of installations?

It is very important that you should always treat the manual recommendations as a minimum requirement. If you have several disturbances, focus on the worst ones and always try to play safe by providing more than that recommended.

Gas meter installations are more sensitive than liquids and light gases such as helium and hydrogen are much more sensitive then heavier gases such as air and carbon dioxide.

Flow straighteners and flow conditioners

The last topic in this article addresses the use of flow straighteners and flow conditioners. Both terms are often used to mean the same thing but this is strictly speaking incorrect. A flow straightener is designed predominately to remove swirl from the flow stream. There are many designs available on the market with examples such as Zanker, Etoile and Tube bundle.

A very common commercially available flow conditioner available from most manufacturers is the flat plate perforated plate conditioner. Whilst predominantly a flow profile conditioner, it does offer a moderate protection against light swirl and its relatively simple design provides an economical and easy-to-install solution and so is a common choice.

The 'danger point' of simply relying on these types of devices to remove the effects of poor installation is that whilst these devices

can work, they are not guarantees of success and they come at a cost through extra introduced pressure drop. They also have installation requirements themselves in terms of upstream and downstream straight pipe requirements so they do not actually remove the need for clear pipework. A far better approach is to try to minimise, or preferably avoid, swirl in the first place.

To illustrate the power of straight pipework upstream of a flow meter in minimising disruptive affects to its performance relative to that of a perforated plate flow conditioner, an example reproduced on a flow rig showed that 16 diameters of upstream clear pipework was as effective as the perforated plate conditioner - the point being that the flow conditioner installation required 10 diameters of pipework upstream of the flow meter and introduced a significant pressure drop. The 16 pipe diameter alternative produced no discernible pressure drop, did not have any installation cost and was significantly lower in cost. In this case less was more!

Conclusion

No feature on flow meter installation would be complete without examples of people getting it very wrong. There are many examples – such as the valve being installed upstream of the flow meter, inadequate upstream pipework, mismatched flanges, slipped gaskets, unsealed cable glands, process temperature sensor not fitted in the pipework, meter pipework by pass configuration missing a necessary isolation valve… the list goes on. Decide for yourself how important it is for the user to read the manual!

Chris Gimson BSc Mphil CEng MIET has spent twenty years as technical director of E+H UK, six years project manager at E+H Flowtec Switzerland and two years seconded to E+H South Africa as energy management and flow consultant before moving permanently to South Africa in April 2011 as general manager of E+H Pyrotemp, the company's local temperature manufacturing division. This has given him extensive experience in the design, manufacturing, sales and service aspects of process instrumentation especially in the field of gas flow metering and energy management processes. He was the recipient of the 2011 SAIMC Negretti Award for his paper on 'Flow metering within energy monitoring' on which parts of this article are based. Enquiries: Email Chris.Gimson@pyrotemp.endress.com.

About the author