The Importance of Mass Flow Measurement and the Relevance of Coriolis Technology

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Why is Mass Flow Measurement important within process industries and what are the strengths of Coriolis Flow Meters and Controllers? Measurement of the flow of a fluid, either liquid or gas, is commonly a critical parameter in many processes. In most operations this can be linked to the basic "recipe" of the process – knowing that the right fluid is at the right place and the right time. Equally, it can be linked to asset management, keeping the fluid in motion or even simple tank balancing. Some applications, however, require the ability to conduct accurate flow measurements to such an extent that they influence product quality, Health & Safety, and ultimately can make the difference between making a profit or running at a loss.

In other cases, the inaccurate measurement of flow, or even the failure to take such measurements, can cause serious or even disastrous results. With most liquid and gas flow measurement instruments, the flow rate is determined inferentially by measuring the fluids velocity or the change in kinetic energy. Velocity depends on the pressure differential that is forcing the fluid through a pipe or conduit. Because the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. The basic relationship for determining the liquid's flow rate in such cases is:

$Q = V \times A$

where

Q = fluid flow through the pipe

V = average velocity of the flow

A = cross-sectional area of the pipe

Other factors that affect liquid flow rate include the liquid's viscosity and density, and the friction of the liquid in contact with the pipe.

With the many variations of flowmeter technology available it can be very hard for an operator to make a decision on which technology is right for the application. Industry experts claim that a majority of flowmeters in the field are selected incorrectly. An important and perhaps overlooked question, is what the instrument is supposed to do versus what is it able to do? When selecting a flowmeter technological improvements can sometimes get overlooked through historical knowledge of what has been possible in the past – in a way, experience working against you.

Direct mass flow measurement is an important development across industry as it eliminates inaccuracies caused by the physical properties of the fluid, not least being the difference between mass and volumetric flow. Mass is not affected by changing temperature and pressure. This alone makes it important method of fluid flow measurement. Volumetric flow remains valid, in terms of accuracy, provided that the process conditions and calibration reference conditions are adhered to. Volumetric measuring devices, such as variable area meters and turbine flow meters, are unable to distinguish temperature or pressure changes.

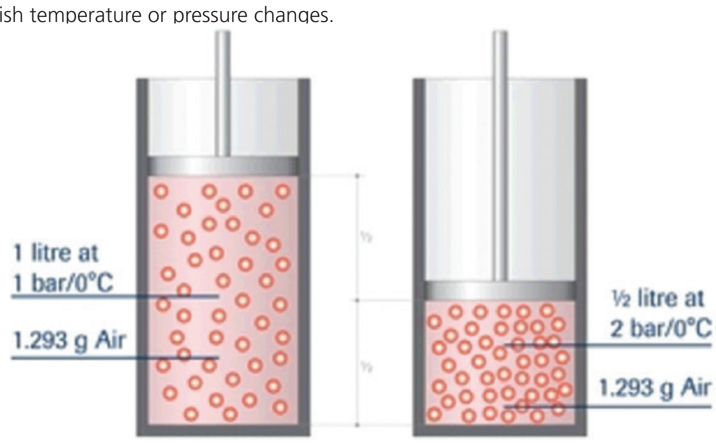

Figure 1 : Difference of mass of gas by volume with changing conditions

One method of Mass Flow measurement employs the phenomenon of Coriolis force. This force is a deflection of moving objects when they are viewed in a rotating reference frame. Coriolis force is proportional to the rotation rate and the centrifugal force is proporti onal to its square.

This long understood principle is all around us in the physical world; the flow of water down the sink, the Earth's rotation and its effect on the weather. The principle, and mathematical formula developed back in the 1800's, was further developed during the 1970's and then applied to the measurement of fluid flow. The operating principle is basic but very effective. A tube, or tubes, with a known mass is energised by a fixed vibration. When a fluid passes through the tube(s) the mass will change, the tube(s) will twist and the inlet and outlet sections will result in a phase shift. This phase shift can be measured and a linear output derived proportional to flow. As this principle simply measures whatever is within the tube it can be directly applied to any fluid flowing through it, liquid or gas. Furthermore, in parallel with the phase shift in frequency between inlet and outlet it is also possible to measure the actual change in frequency. This change in frequency is in direct proportion to the density of the fluid – and a further signal output can be derived. Having measured both the mass flow rate and the density it is, interestingly, therefore possible to derive the volume flow rate.

The Coriolis principle, applied as a mass flow meter, therefore has its place within fluid measurement and control within the traditional Process Industry. Perhaps more importantly though, the additional features of the technology allow for an extension of the accuracy and precision into other, more non-traditional, applications.

Take, for example, filling and dosing applications across a great many industries and the replacement of both weighing scales and the gravimetric method. Traditionally, the dosage of mass/volume was achieved by using a shut-off valve with a weighing scale/balance. The weighing scale is located under a valve outlet nozzle and, after a zeroing procedure once the vessel being filled is in position, the valve will open. The weighing scale will send a signal to the PLC or control unit and, once the batch has been reached, the valve will close. Multiple dosing, building up a recipe, is achieved by moving the vessel to the next dosing point in line and repeating the process. The alternative solution of simultaneous mass flow dosing/filling significantly reduces the amount of time needed, and the loss of volatiles, whilst increasing productivity, quality and repeatability.

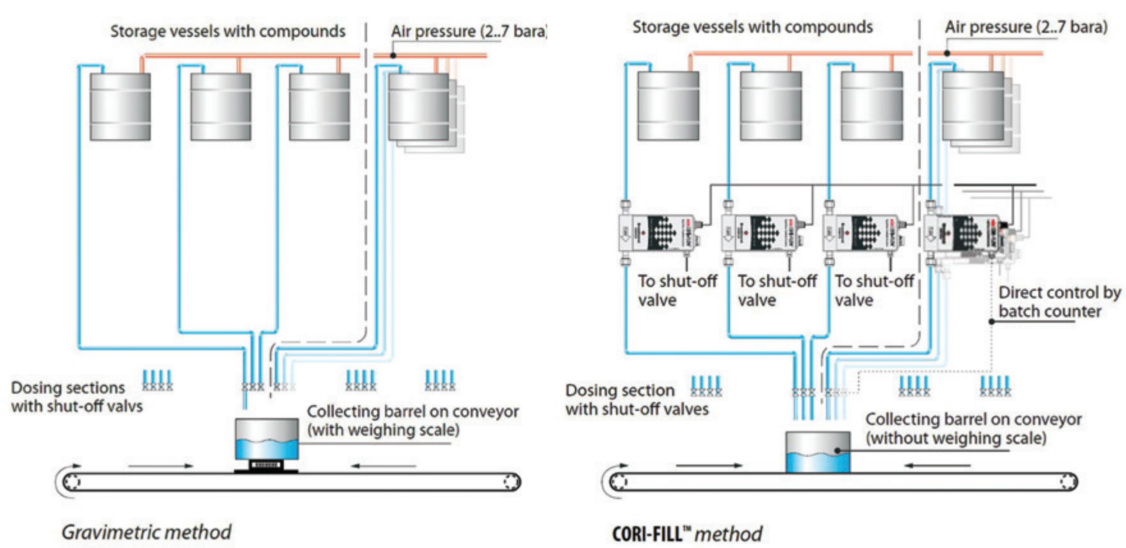

Figure 2 : How Coriolis technology can help with process improvement

Another example of process improvement has been seen within the field of specialist chemicals. The customer was unaware that low to ultra-low flow control was possible with a Coriolis instrument resulting in the raw ingredient being mixed with water to create a carrier volume. This higher volume was then metered and dosed into the main product flow. The process added cost to the production method and, as the dilution step added variability to the concentration of the additive, product quality was often compromised with a resulting additional cost of re-work. Furthermore, the final process step saw the bulk material being heated and stirred to evaporate the added water to reduce volume and increase concentration. The energy requirement to do so was significant and the operational stock-holding was high. Further complications were added by the need for the "dosing system" to handle multiple additive doses with stringent cleaning needed between batches resulting in yet more wastage and high additional cost.

By understanding the extended capabilities of Coriolis instruments it was possible to establish that the concentrated raw ingredient could be added via a highly accurate low flow Coriolis Flow Meter directly coupled and controlling a precision pump. This solution ensured that the costly addition and removal of the water could be eliminated and that very close tolerances on the dosage rate, and hence final product quality, could be maintained. The inclusion of multiple synchronous injection points eliminated the costly clean-down process and the reduction of working process volume also reduced the stock holding inventory further reducing operational costs. Re-producible product quality has been increased, productivity has been increased, wastage has been reduced, energy consumption has been reduced and operational costs have also been dramatically reduced.

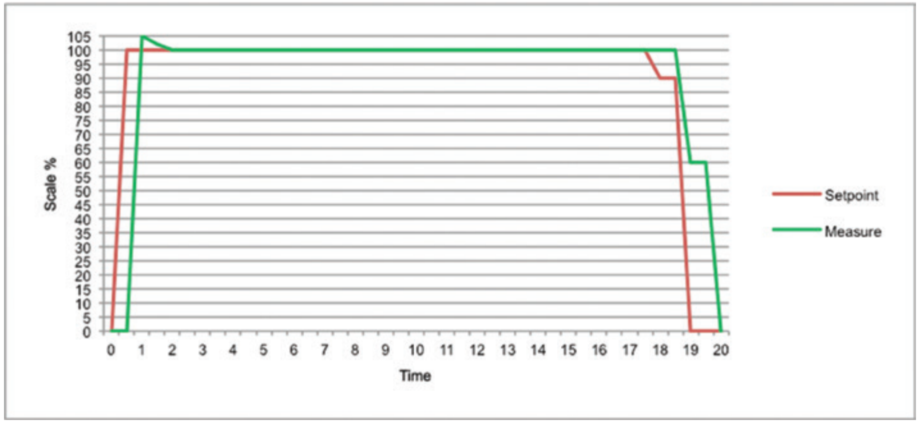

Figure 3 : Flow Rate profile of the meter for the example application

Although currently configured for control via the client DCS the Coriolis flow meter can, if needed, be "paired" with the main process line flow meter to act in master/slave mode. Standard on-board firmware can be utilised to immediately match the required dosage rate to any variability within the main flow line. This facility eliminates any time lag in process response and further enhances the very tight tolerances on product quality. A host of secondary benefits have also been utilised within the solution. The density of the concentrated natural raw ingredient is measured, recorded and trended thereby allowing tracking of the natural innate variability and further fine-tuning of the control process. The pump steering signal is utilised for condition monitoring and as a preventative maintenance tool. This, together with dry-running protection, will ensure less emergency break-down and catastrophic down-time.

A further example illustrating where Coriolis flow technology can benefit the customer has been seen with the dosing of performance chemicals within the Oil & Gas Industry. The traditional method of chemical injection, a piston pump with check valves on the inlet and outlet, is tried and tested and works well for quite long periods of time. However, on occasion the check valves can foul and begin to "pass". Also, out-gassing or entrained air can cause an air-lock within the piston chamber that is simply compressed/decompressed in situ rather than pumped. In each of these cases the pump appears to be still working but there is no actual transfer of chemical into the pipeline. The only way to verify actual flow has been via a graduated gauge and a stop-watch; an empirical measurement but time consuming.

Another issue with the traditional method of injection is actually changing the flow rate. This can only be done manually by changing the stroke length of the piston – a process that is "trial and error" and only verifiable using the graduated gauge as above. Fine tuning of injection rates, for example to compensate for day/night changes in temperature across a field, is virtually impossible as the labour required to do so is prohibitive. This results in the injection rate being set for worst case thereby resulting in overdosing during normal conditions – a very expensive waste.

Modern communications networks now allow for technology to arrive at diffuse production fields. The Coriolis flow system can be installed at each injection point and real-time monitoring, control and logging of injection rates can be achieved. This allows for remote checking of flow rates, remote instantaneous re-setting of those flow rates, on-board auto-alarm for status checking (for example, empty tank alarm and pump protection shut down), density change alarm, single point totalisation, multi-point (total field) totalisation for cost per barrel calculations and pump steering signal monitoring as a guide to preventative maintenance. In short, a very powerful tool within field management.

With these applications it can be seen that Coriolis Flow Technology can be a benefit to the user especially when the extended product capabilities are employed. Process improvement, cost reduction, real-time measurement and greater accuracy can all be achieved.

About the Author

Ashley Buck has been working for Bronkhorst for just over 4 years. He started as internal sales engineer, then moved to product management in 2013. Ashley has been in the process industry for 18 years, and has experience of working with all types of instrumentation.