A Flow Meter Primer

INTRODUCTION

The purpose of this paper is to provide the reader with a brief, simplified overview of some of the more common types of liquid flow meters, their pros and cons, and their most common applications. The Specifier/User should understand that for each measurement application there may be several solutions. Conversely for whichever metering solution selected, there are often performance tradeoffs. Examples of some of these performance factors include: required minimum measureable flow, accuracy (measurement uncertainty), turndown ratio, pressure drop & recovery and process conditions/properties just to name a few of the more common ones. The importance of each factor to the end user will be weighted by how critical that factor is to the overall measurement application.

Finally, it should be noted that that the performance of ALL flow meters can be negatively impacted by improper meter installation. Installation factors whcich are beyond the scope of this paper include: electrical installation, piping configuration and environmental influences. These factors are usually within the control of the engineer or installer and can therefore be quantified or minimized. Remember, the closer the adherence to the manufacturer's recommended installation guidelines, the better will be the instrument's performance.

FLOW METERS

Coriolis Mass Flow Meters

PRINCIPLE of OPERATION:

These meters work based on the Coriolis principle a result of the conservation of energy. This is measured when a process fluid is redirected through a pair of curved vibrating tubes. The twisting moment that develops in the tubes as a result of the mass flow of the process is a function of the mass or process moving through the pipes. The tubes are vibrated at their natural resonant frequency or a harmonic thereof and this allows the meter to also determine very accurately the process density. These meters are the only liquid meters that measure the **mass flow rate** of the process liquid directly without inferring it based on velocity or pressure.

APPLICATIONS: Custody transfer, expensive fluids, critical process measurements requiring precise dosing. i.e. batch control

PROS:

1. Very accurate & repeatable. (excellent for custody transfer applications)
2. High turndown (100:1)or more
3. Multivariable measurement (flow rate, density, temperature, viscosity)
4. Measures mass flow directly
5. Low maintenance

CONS:

1. Be prepared to pay for the benefits
2. Requires careful installation
3. Sophisticated meter

Differential Pressure Meter (used with a primary element)

PRINCIPLE of OPERATION:

Differential pressure is one of the oldest and most common forms of measuring flow. Also referred to as the square law density dependant method, it is basically a differential pressure transmitter measuring the pressure drop or differential created across a flow restriction in the process piping. The square root of the measured differential pressure is proportional to the flow velocity. The flow restriction, called the primary element, may be any one of an Orifice Plate, a Venturi tube, a Pitot tube or any of the many variations of these.

APPLICATIONS: Steam, multi-phase processes in oil & gas

PROS:

1. Very well known and understood
2. User can accurately calculate the meter's operational parameters (pressure differential / flow) in advance before installation
3. Can be used on almost any process fluid
4. Versatile & used in many applications

CONS:

1. Limited accuracy and turndown although smart D/P transmitters are improving this
2. Installation can be complex
3. Impulse lines (line connecting to process piping) may require heat tracing in cold climates

Electro-Magnetic Flow Meter

PRINCIPLE of OPERATION:

Full bore electromagnetic flow meters commonly referred to as mag meters, work on Faraday's Law of electromagnetic induction. This is the same operating principle as a bicycle generator. The faster one pedals the brighter the light generated. This same principle applies to mags. The greater the flow velocity the greater the signal generated in the sensor which is then converted and displayed as flow rate in the transmitter. Every mag meter is comprised of two components, the sensor tube that is located in the pipe and the transmitter. The transmitter can either be integrally mounted on the sensor or remotely mounted on a wall. Mag meters are restricted to measuring conductive fluids only and require external power (24VDC or 120VAC) to operate.

APPLICATIONS: Water and Waste Water, conductive chemicals

PROS:

1. Will measure virtually any conductive fluid or slurry, limited only by the process fluids' minimum conductivity
2. A very low pressure drop
3. High accuracy, high turndown ratio and excellent repeatability if installed properly
4. Wide range of materials of construction & process piping connections.

CONS:

1. Process fluid must be conductive
2. Heavy in larger sizes & prohibitively expensive
3. Can be affected by coating and build up in the pipe and on the measurement electrodes
4. Can be sensitive to the meter's electrical grounding
5. Pipe must be broken Breaking the pipe is required for installation in existing applications

Paddlewheel Flow Meters

PRINCIPLE of OPERATION:

As the name implies, paddle wheel meters consist of a paddle wheel inserted perpendicularly into a process stream. The number of rotations of the paddlewheel are directly proportional to the velocity of the process.

APPLICATIONS: Flow indication & transmission of clean fluids

PROS:

1. Relatively inexpensive
2. Technically simple to install, check and fix
3. Operates without external power BUT requires external power to display & transmit

CONS:

1. 5% accuracy under good conditions
2. Sensitive to flow profile
3. Mechanical devices that can be high maintenance often require replacing frequently
4. Requires breaking the pipe although hot tap are available

Positive Displacement Meters

PRINCIPLE of OPERATION:

These meters work by mechanically metering very accurately, discreet quantities of the process liquid. This is much like a PD pump in reverse. Whereas a PD pump pump a certain amount of flow based on the rotational speed of the impeller; the rotational speed of a PD meter's 'impellor' is a function of the process flow. An internally coupled counter, either electronic or mechanical accurately monitors the measuring element's rotations to ensure a very accurate volumetric recording of the flow total.

APPLICATIONS: Custody transfer, non-abrasive, clean fluids

PROS:

1. Highly accurate, excellent for custody transfer applications
2. Process Powered, no external power required
3. Mechanical meter enables easier field repair
4. Well suited for loading docks

CONS:

1. Expensive
2. Mechanical meter can result in higher maintenance costs
3. Great for providing a flow total only, extra equipment required to transmit a signal
4. Transmitting an analog flow signal requires add on electronics
5. Meter assemblies can be large heavy

Rotameters

PRINCIPLE of OPERATION:

Rotameters consist of a tapered tube (usually glass) that houses a precisely weighted plug. The flow or a stream proportional to the flow is directed through the rotameter tube and the plug rises proportionally as a function of the flow rate.

APPLICATIONS: Flow indication where external power in NOT required

PROS:

1. Great for on-site indication of flow
2. Easy to install and understand
3. Inexpensive

CONS:

1. Pressure constrained although there are metal tube instruments available for high pressure
2. Relatively difficult to transmit a signal
3. Glass can become coated in some applications
4. High pressure drop w/ little recovery

UltraSonic 'Doppler' Flow Meters

PRINCIPLE of OPERATION:

The Doppler flow meters work by transmitting an ultrasonic beam of a precise, known frequency upstream into an on-coming process stream and then measuring the frequency of the reflected beam. Any measured frequency shift is a result of process flow and is directly proportional and linear to the process' velocity.

APPLICATIONS: Limited use on liquid processes with entrained solids or gases. (i.e. sewage)

PROS:

1. Will measure virtually any fluids that contain bubbles or particulates for the transmitted sound to reflect off of.
2. Easy to install on existing installations or retrofits, no need to break the pipe.
3. High accuracy, high turndown ratio, excellent repeatability

CONS:

1. Will not work on clean , homogeneous process fluids (see Time of Flight)

2. Relatively expensive

Ultra Sonic 'Time of Flight' Flow Meters

PRINCIPLE of OPERATION:

These flow meters transmit precise, timed, sound pulses up and down the pipe through the process stream. The meter's electronics measure the time elapsed for the sound to travel upstream and downstream and then calculates the travelling time difference. That time difference is directly proportional and linear to the velocity of the measured fluid.

APPLICATIONS: Any Clean, homogeneous fluid.

PROS:

1. Will measure any clean, homogeneous process fluid
2. No need to break the pipe
3. Non-obstructive=low pressure drop
4. High accuracy, high turndown ratio, excellent repeatability
5. Can be mounted on any clean, round, straight pipe
6. Very cost effective for large pipes (4" and up)

CONS:

1. Process fluids MUST be clean and free of bubbles and particulate matter
2. Accurate pipe dimensions must known (i.e. ID , wall thickness, pipe material, etc.)
3. Sensitive to process composition & temperature

Vortex Meters

Vortex meters operate based on the frequency with which vortices (called Karmen Vortices) are shed from a bluff body (as opposed to a streamlined one) that is inserted in the process stream perpendicular to the direction of flow.

APPLICATIONS: Steam, clean, non-viscous liquids

PROS:

1. Great for measuring steam and many gases
2. Better than 1% accuracy
3. No moving parts

CONS:

1. Sudden drop to zero when flow drops below the minimum measureable flow range
2. Not suited for viscous fluids
3. Requires breaking the pipe or hot tap in some cases
4. Higher pressure drop than mags.

SUMMARY

In conclusion, one can see that there are many types of flow meters and as often as not, more than one type of flow meter to satisfy the application. It is wise to remember that the decision-making process should include, in addition to a comparison spread sheet of the hard specifications, a column valuing the non-tangible factors. These difficult to quantify, intangibles can influence the degree of success of an installation. They include:

1. Acceptance of the technology
2. Technical ability of the onsite support personnel
3. Support ability of the supplier
4. "Spook Factor" pre-conceived often irrational (false) notions about the meters' source or technology

When selecting a method of flow metering, paying careful attention to application guides & limitations noted above will ensure a successful flow installation.