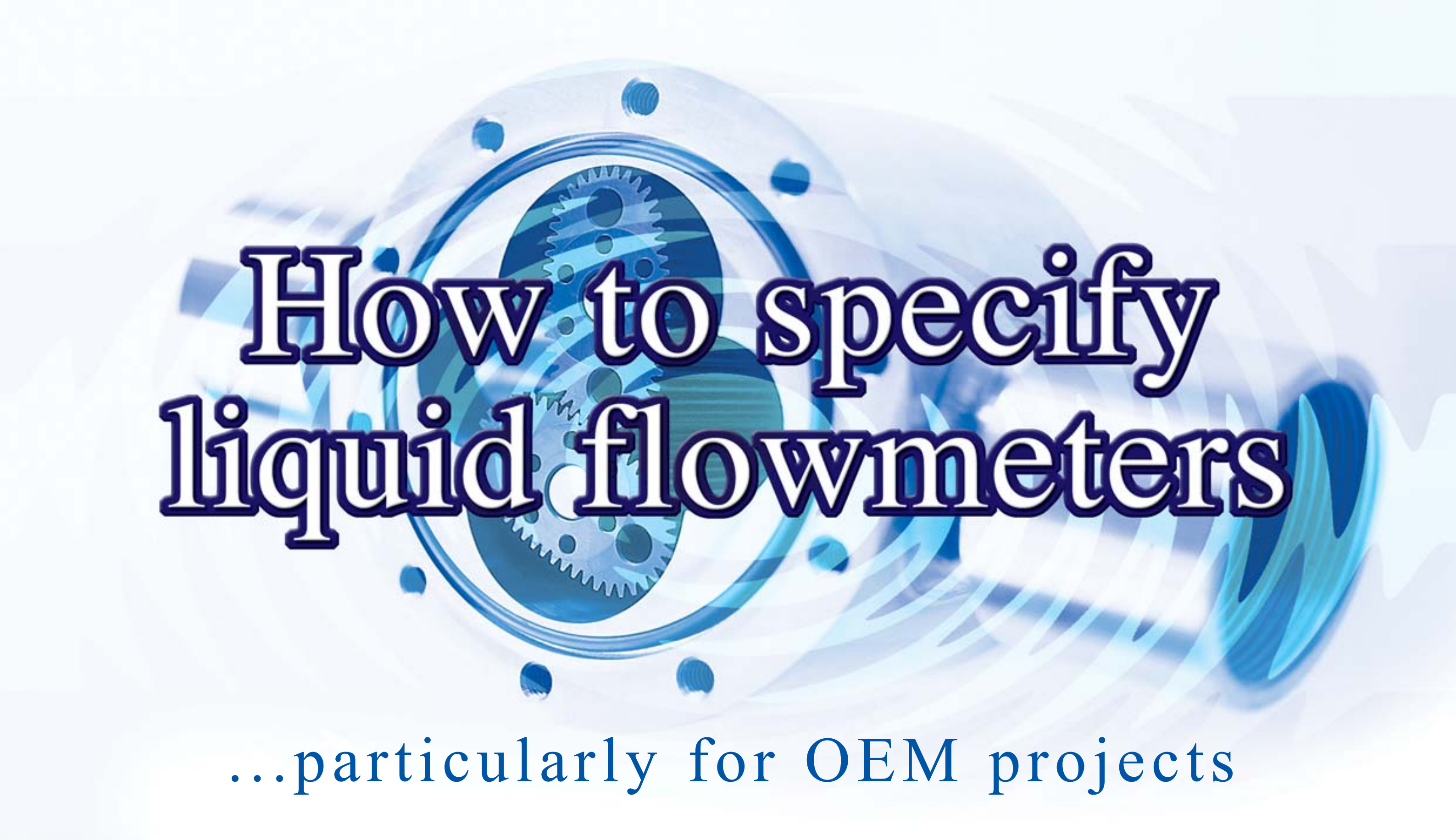


How to specify liquid flowmeters

...particularly for OEM projects

By Trevor Forster of Titan Enterprises Ltd, Dorset, UK

Accurate, reliable, cost effective flow measurement is more important today than it has ever been. The years have seen many styles and grades of flowmeter developed, because the first problem in meter specification is to define what the measurement has to achieve. Dispensing a volume of juice concentrate to within 2% is a different problem to knowing and alarming when the cooling water flow drops to 50% of the desired flow, with a system shutdown operating at 25%. Both are different to measuring whisky or beer or petrol delivery in a financial transaction. This article presents one view of the different techniques that can be used for liquid measurement: it does not include every type of flowmeter on the market, just some of the more familiar ones.

Cost of ownership is often an issue for end users and suppliers, but, for an OEM (original equipment manufacturer) maybe a better phrase should be “consequential costs of use”. The cost of ownership is not just its purchase price, but includes the cost of any breakdown in the warranty period; performance loss resulting from measurement uncertainty; and the power or equipment cost of running both the flowmeter and the fluid pressure drop it introduces. The cost of use for an OEM can also include any separate wiring needed, the positioning and space taken up in the equipment, including the straight line pipe requirements, the weight and the mounting arrangement, and any separate display or output interface.

Adding all these consequential costs to the function required can often lead to the choice of a simple mechanical vane or paddle wheel indicator, or a mechanical

totaliser - today this might include self-contained battery powered micro-electronics: think of the modern electronic gas meter, for example. The right flowmeter for the job is the one that will perform the task actually required, satisfactorily, at an acceptable fully installed cost.

Flowmeter Types

While all flowmeters can make use of the latest technology, the basic techniques are fairly well established. Flowmeters will be described falling into six broad groups:

- Differential pressure devices: (including variable area meters and mechanical flap devices),
- Inferential devices such as turbine meters, propeller meters
- Positive displacement meters, (including oval gear, nutating disc, oscillating piston)
- Fluidic devices, vortex meters
- Velocity measuring devices such as electromagnetic and ultrasonic,
- Mass flow measurement meters (Coriolis, thermal)

Each of these flowmeters has its own strengths and weaknesses: every different flowmeter style within these categories was developed for one particular OEM or customer application!

Differential Pressure

DP flow measurement is the original method, but not necessarily the best! It can be used for the most mundane, and the most critical duties. The Pitot tube uses the differential pressure generated by fluid impacting the open end of a tube facing the direction of flow, a second tapping at ninety degrees to the first measures the "static" pressure. Used on an aircraft this measures the airspeed: some years ago a maintenance engineer left some masking tape over the static pressure tappings on an aircraft Pitot tube: the flight engineer duly set his instruments to the ground static pressure. As the plane took off in poor weather, the instruments gave nonsensical readings: and the plane crashed. This highlighted the consequences of inadequate end user installation and maintenance procedures!

The most common method of using this principle is with an orifice plate, a hole in the bore of the pipe that creates an obstruction to flow: the square root of the pressure differential is proportional to the flow rate. This is where one of the problems with this type of device is encountered. If the pressure sensors have a 50:1 range the resulting flow range of the flowmeter is only 7:1, after the square root extraction.

It is often quoted that DP cells with orifice plates are the most popular form of flow measurement in the world today: but this is probably not so for OEMs. Not unless they buy the DP cell with integral orifice complete, calibrated, pressure tested and in one unit, but then it will most likely be too costly. Without the integral unit the technique involves too many connections and parts to assemble.

Techniques derived from DP principles

There are many places that OEMs would use other "DP devices": a classic is a V-notch weir or flume in an open channel, with a liquid level measuring device that can be a float or an ultrasonic level meter or similar. Flumes are available for such applications in the form of fibreglass moulds from specialist suppliers. Far more usual with OEMs are 'Variable Area' flowmeters that consist of a movable 'float' in a widening aperture, but in this case the differential pressure is used to balance the 'float' against a force. This is typically gravity as seen in a bench top glass tube laboratory VA meter, but some meters balance a float, flap or vane, against a spring, either in a metal or glass housing, or as an insertion device: this makes them orientation independent, but results in a higher operational pressure drop. The forces balancing the float are the mass, velocity and viscosity of the liquid. Simple visual devices are capable of ±1% accuracy, but ±5% is more likely. All such devices can have electronic 'bolt-on' analogue outputs these days, or alarm trips, driven by a magnet in the float or flap.

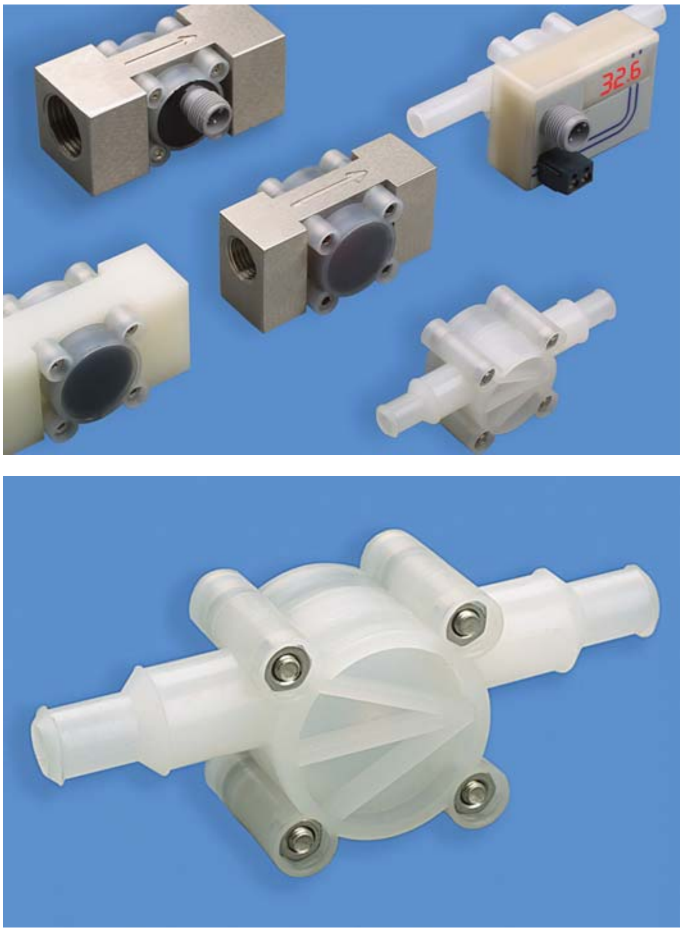
There are many specific designs: like metal bodied VA units for high pressure, using magnetically driven indicators, PTFE lined tubes for corrosive liquids, single alarm set point low flow switches for domestic water heaters. All tolerate any installation pipework format, and dirt in the liquid, since the aperture just opens further if the pressure is available. Some are really low cost and easy to troubleshoot: flow range is typically between 7:1 and 10:1, and a 1% device is possible.

Turbine and Propeller meters

A turbine meter is the most common and easiest to understand of all the different inferential meters. The axial turbine meter is basically a propeller in a pipe; with careful design the speed of the turbine is directly proportional to the flow rate. Accuracies of ±0.25% are achievable. They have many advantages: they are relatively small and are usually the same diameter as the pipe in which they are fitted, and pressure loss is quite low. Because of this tubular construction high pressures and temperatures are readily accommodated. All turbines are sensitive to viscosity changes and should be manufactured and calibrated with the final application in mind. They are only as good as their bearings and the smaller the axial turbine the more important the bearing

The Titan FT2 turbine flowmeter covers flow ranges from 0.01 to 160 LPM. With a PPS body and low inertia PVDF rotor, it operates up to 125C and 15 bar: the process fittings can be supplied in any material or specification: threads, hose barbs, flanges, fitted custom support brackets or tank connections.

characteristics, as the energy available to overcome the bearing friction is somewhat reduced - and the bearings, being smaller, are more sensitive to degradation.



The range of Pelton wheel based low flow metering sensors from Titan measure flows from 0.05 to 30 LPM. Units with built in battery powered LCD totalisers have been adapted for use in vending and drinks dispensing machines, and also to monitor beer flow totals in busy bars and clubs.

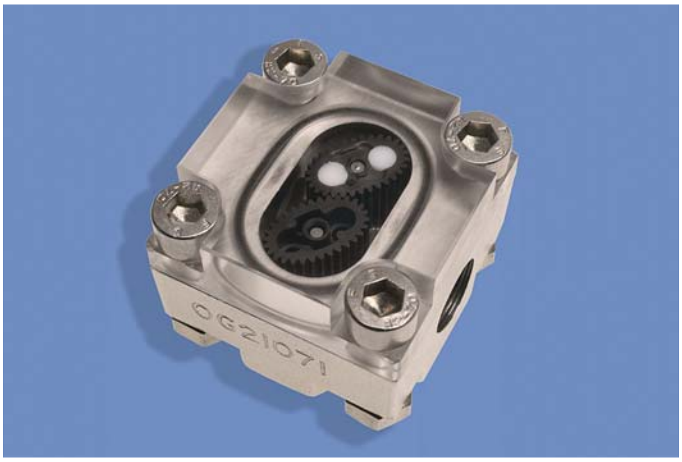
Pelton wheel or radial flow turbines are therefore better suited to low flows as the bearings can be very robust: the energy available from the liquid flow around this type of enclosed 'water wheel' is far greater than available with the axial device. They are particularly suited to OEM applications such as beverage dispensing or monitoring. A disadvantage of this type of meter is the relatively large body compared to the line size, greater pressure drop and reduced accuracy. Advantages however include low manufacturing costs, a larger dynamic range and the ability to meter very low flows, 10 mL/minute or lower.

Electronic outputs are provided either by a magnetic or optical pick off to count the rotation of the wheel or turbine. Pick-offs are moulded into the body housing: even the electronics for a totaliser or flowrate display can be housed within the meter body. Typically axial or Pelton wheel devices are produced in moulded modern engineering plastics, which are corrosion resistant and can be fitted with push-on fluid connectors, hose barbs or screw threads. Custom engineering of these connections allows them to incorporate panel or bulkhead mounting arrangements to suit the application, and the electrical wiring loom and terminations can be similarly customised.

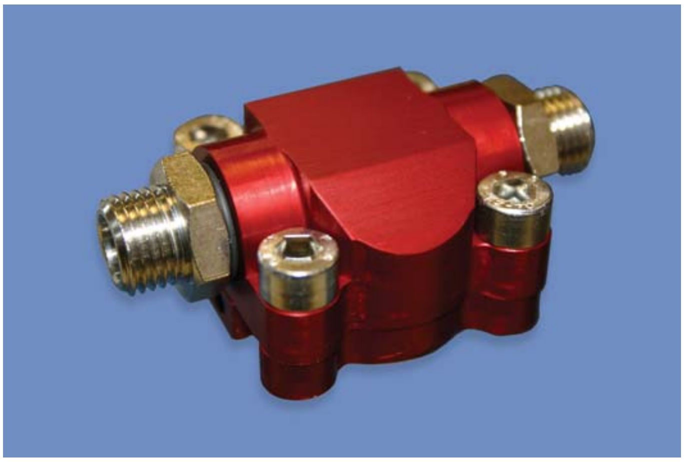
Positive Displacement meters

There are many different types of positive displacement meter, gear, oval gear, sliding vane, nutating disc, oscillating piston, helical screw and many more. All have the same basic mode of operation in that they take a discrete volume of liquid and pass it from the inlet to the outlet without loss or slippage.

The better types are capable of ±0.1% linearity over a wide flow range. By nature these devices perform better at higher viscosities as the increasing fluid thickness reduces the leakage rate even further and extends the useful operating range to lower flow rates. Globally the most common form of this device are likely to be domestic water meters and the meters found in petrol dispensing equipment. Because of the way these meters operate they often have a high-pressure drop, particularly with more viscous fluids, but some types including the oval gear design operate with a very low differential pressure, only millimetres of head in some cases.



The basic oval gear flowmeter system is available with a transparent lid to allow visual observation of the rotating gears as an immediate flow indication. Bodies can be made from stainless steel, aluminium or PEEK. Electronic flow sensing uses Hall effect detection of the rotation of a ceramic magnet embedded in the rotor.



Similar units have been custom engineered to be small and lightweight, using aluminium housings, for use on portable medical equipment and robot arms, in the latter case to monitor hydraulic oil flows to press tools.

They are very suitable for measuring oils, although some models are manufactured specifically for corrosive media: for example there is a version of an oval gear meter made from totally non-metallic plastic and ceramic components. In all cases the fluid should not contain any solid particles or stringy materials, as these would possibly jam the meshing gear or other mechanisms. The bodies for larger pipe sizes are very large, and housings suitable for high-pressure use become heavy. In the smaller sizes they are a very economic and accurate metering solution.

The output of these devices is a simple pulse, which defines the passage of a defined volume of liquid. They are therefore easy to interface with simple counting electronics. Several versions have integral electronic displays and transmitters, some being battery powered.

Fluidic and Vortex flowmeters

These flowmeters use the natural oscillations that can occur as fluids flow past an obstruction, such as make a flag flap on a flagpole. The sensing of these oscillations is fairly difficult, particularly if the pipeline itself has extraneous noise, so they are used on some specific flowmeter applications, and not typically by OEMs.

Ultrasonic and Electromagnetic flowmeters

In an ideal world the flowmeter would be a section of pipe with no intrusions and so no pressure drop. Two types of commercially available meter have come very close to this: electromagnetic and ultrasonic flowmeters both use full pipe bores, measure the liquid velocity and are inherently bi-directional.

Electromagnetic meters have good rangeability, are available in a wide range of pipe sizes, have low pressure loss, and power requirements are constantly being reduced as better magnetic and electronic techniques are being found. They will handle sewage, slurries and paper pulp. If the materials are selected carefully the "electrodes" are capable of handling very aggressive materials. They require the flowing liquid to be electrically conductive, but the lower limits on this are constantly decreasing. While prices are falling, they still tend to be expensive, and would only be used on slurries or such difficult liquids. Electromagnetic meters measure liquid flow velocity, averaged across the flow profile: they can tolerate some flow profile disturbance and retain reasonable accuracies.

The main type of ultrasonic flowmeter uses two or more transducers that fire a pulse of ultrasound at an angle both with and against the flow; the difference in time between the signals is effectively the flow rate. Multi-beam units are used for very large pipes and in most sizes they are available as clamp-on devices. Special designs are used in small lines, to increase the path length by several reflections, or the flow path is made to run along the pipe axis, as in the domestic gas meter. Suitable for cleaner liquids rather than slurries, this type of meter is currently forecast to show the greatest growth in the next ten years. The multi-path units are used to improve the flow profile averaging, across the pipe, and to correct for skew flow, which can produce large inaccuracies.

The original ultrasonic meters, introduced in around 1978, used one clamp-on transducer, and sensed reflected signals returned by particles or suspended solids in the flow, which shifted the transmitted frequency according to the Doppler effect. In a vibration free pipe, with a firmly clamped or bonded transducer, these units could achieve a reasonable flow indication or flow failure alarm, particularly for monitoring reasonable velocity slurry or sewage flows. Unfortunately, as the first clamp-on reasonably priced meter system introduced, the Doppler was sometimes applied to unsuitable applications, which led to a poor reputation: there are still some suitable applications today, alongside meters that measure flow noise or particle impact sounds.

Mass Flowmeters

Most mass flowmeters are Coriolis meters, using the fact that when a fluid is accelerated in a curve there is a reaction force at ninety degrees to the acceleration. If the resultant force or movement can be measured, the result is a mass flowmeter. This is different to all of the previously listed meters, as they have all been volumetric or velocity measurement devices, and often use an electronic package to convert velocity into volume flow, given the flowmeter dimensions. These Coriolis systems measure mass flow directly, separately measure the fluid density, and can then deduce volume flow. They are very accurate: with homogenous fluids accuracies of ±0.1% are often quoted, and calibrations that can achieve

0.01% are being discussed. The only restriction such meters commonly put to the flow is the bend in the pipe, although straight tube models are available. These meters are very expensive: but prices are falling. Some versions are very sensitive to errors induced by two-phase flow conditions, such as vapour included with the liquid. This is true for all types of flowmeter but the errors can have serious implications for mass flow meters that are designed to achieve the ultimate in accuracy.

Thermal mass flow systems commonly used for controlling low gas mass flows are now being introduced for liquids. The technique uses a measure of the power required to maintain a temperature increase in the flowing liquid down a bypass capillary, usually in a side flow path routed around an orifice in the main line. It is typically used with an integral flow controller such as a valve, to maintain a fixed flow dictated by an electronic input.

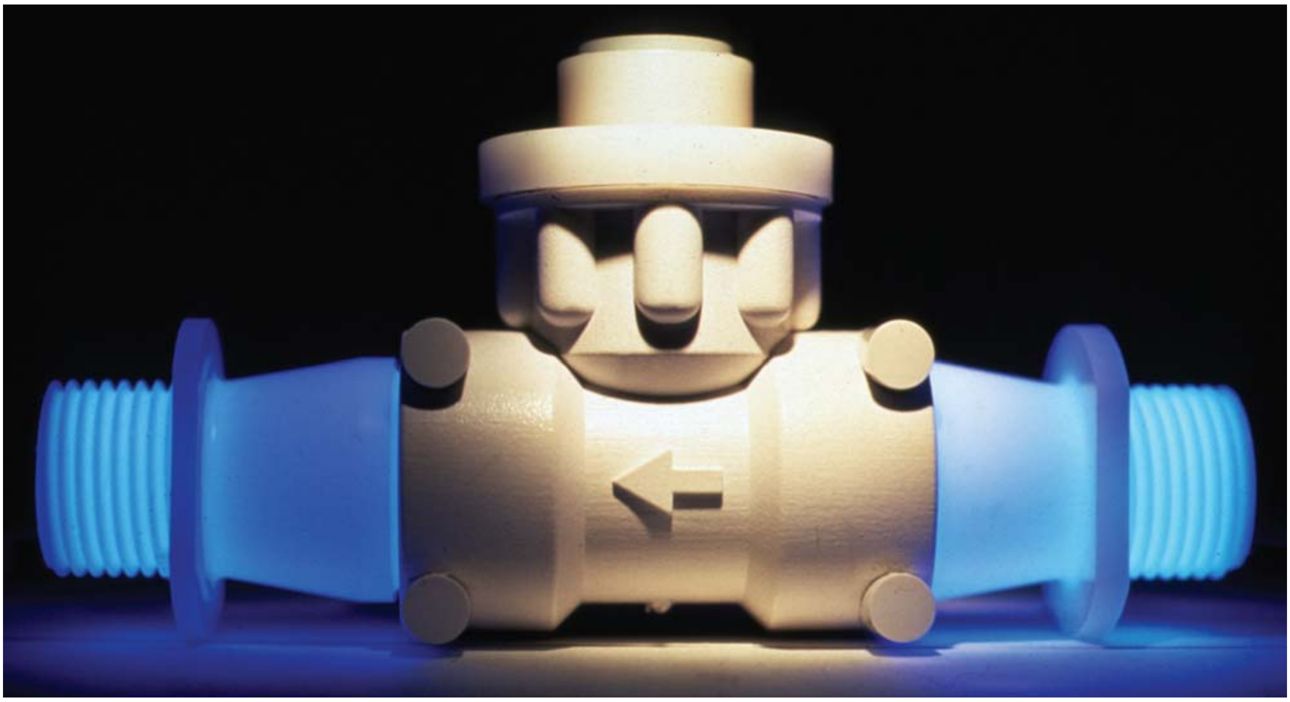
Flowmeter recommendations by duty required

The chart below gives a brief summary of the different types of meter and their suitability for various applications.

Key:

- Green: Suitable/good
- Yellow: Possible/ questionable
- Red: Unsuitable/poor

Meter requirement	Orifice plate	Averaging Pitot	Variable area	Spring loaded	Axial turbine	Pelton wheel	Insertion turbine	Oval gear	Gear	Helical screw	Electromagnetic	Ultrasonic	Coriolis	Thermal
Small water pipes	Yellow	Red	Green	Yellow	Red	Green	Red	Green	Red	Red	Green	Yellow	Green	Green
Large water pipes	Green	Green	Red	Green	Green	Red	Green	Red	Red	Red	Green	Green	Green	Red
Dirty water & slurries	Yellow	Red	Red	Yellow	Red	Red	Yellow	Red	Red	Red	Green	Yellow	Green	Red
Low viscosity fluids	Green	Green	Green	Green	Green	Green	Green	Green	Red	Red	Green	Green	Green	Green
High viscosity fluids	Yellow	Red	Red	Red	Red	Red	Red	Green	Green	Green	Red	Green	Green	Yellow
Very low flows	Red	Red	Green	Red	Red	Green	Red	Green	Green	Green	Green	Red	Red	Yellow
High accuracy	Red	Red	Red	Red	Green	Red	Red	Green	Green	Green	Green	Green	Green	Yellow
Pulsating flow	Red	Red	Red	Yellow	Red	Red	Red	Green	Green	Green	Yellow	Yellow	Yellow	Yellow
Contorted pipe work	Red	Red	Green	Red	Red	Yellow	Red	Green	Green	Green	Yellow	Yellow	Yellow	Green
Wide dynamic range	Red	Red	Red	Red	Red	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green
Low pressure loss	Red	Green	Yellow	Red	Yellow	Yellow	Green	Green	Red	Green	Green	Green	Green	Yellow
Low maintenance	Green	Green	Green	Green	Red	Red	Red	Yellow	Red	Yellow	Green	Green	Green	Green
Low purchase price	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Yellow	Red	Yellow	Yellow	Red	Yellow



The Titan FT2 flow sensor

Installation Effects

Having purchased a flowmeter it is very easy to compromise its performance with poor installation. With the exception of the positive displacement meters and small Pelton wheels, upstream and down stream pipe work configuration can drastically affect the meter performance. Two bends at ninety degrees to each other can stop a turbine meter at some flow rates, as the liquid can swirl at the same angle as the turbine blades and just slip past. Conversely if the swirl is in the opposite direction the meter will over register. Bends, valves, regulators, tees, pumps and almost anything else introduced into the pipe work will disturb the flow. Manufacturers specify the meter for ideal installations and any variation from this negates the performance characteristics.

Even when the pipework is perfect many applications are compromised with poor electrical installation. Signal wires should where possible be screened, routed away from and shielded from mains supplies, inverters, relays, solenoid valves, highly inductive loads and switching apparatus, as these can all modify the signals. Correct signal conditioning and protocol reduces these problems dramatically.

Footnote

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