

Dealing with the Highs and Lows of Flow

Choosing a flow meter that measures both

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In February of 2014 due to severe drought conditions the Federal Bureau of Reclamation informed central California farmers that they would receive no irrigation water from the lakes, canals and reservoirs under the Bureau's control. Last year (2013) the farmers were only given 20% of their normal allocation of water. California officials who oversee the state's water holdings also released information that no water will be available to the farmers for irrigation. Residential users will also see severe cuts.

This is significant since about 33 percent of the fruits and vegetables produced in the United States are grown on these central California farms, translating to \$44 Billion a year industry. Water restrictions will also impact the beef and dairy industries with higher feed prices which in turn will lead to higher prices for consumers at market checkout lines. The result is that water is becoming a much more valuable commodity every year, in California and elsewhere, so the measurement of water has also become a big business opportunity.

Specifically, the low flow conditions are being scrutinized to improve the overall accuracy of water measurement in systems. Low flow measurement can be used to identify water systems leaks or water theft. This article will outline what is being used to measure water today, and what can be expected from those instruments when measuring at low flows with an explanation of their overall measurement performance and reliability in those conditions.

Many types of devices are used today for water flow measurement. These include Turbine, Compound, paddle wheel, ultrasonic and magnetic flowmeters as well as Positive Displacement (PD) meters or differential pressure (DP) meters and many more iterations! With the exception of PD and DP meters the other meters mentioned all have one thing in common, they directly measure flowing velocity!¹ From the velocity measurement a volumetric measurement is calculated based on the cross sectional area of the meter section. For our purpose, we will focus our attention on those velocity measurement devices.

Every customer desires the most accurate reporting over the widest range of measurement; for a meter this is referred to as turndown. Turndown is a ratio that is generally considered a range of measurement that stays within stated accuracy specification and can be determined by dividing the highest flow by the lowest flow possible. If the high flow to be measured is 1000 GPM and the low flow to be measured is 10 GPM the desired turndown is said to be 100:1 or better. If the high flow is 100 and the low flow is 10 the desired turndown is 10:1 or better. Flow meter users should select

¹some compound meters have PD meters for the low flow sections but will be considered velocity type for this paper

a meter that will cover the needed flow range with the necessary accuracy! This is referred to as %usable turndown+.

Flow meters all have a turndown ratio; this can be specified as 10:1 or given as a range of measurement, 1-100 GPM or a velocity span such as .3 FPS to 20 FPS. Of importance is if that range is really %usable+ for the flow measurement being made. A flow meter may have a turndown of 100:1 however because a flow meter can register 1200 GPM doesn't mean there will ever be flows of 1200 GPM. In a nominal four inch pipe, the velocity at 1200 GPM is 30.6 feet per second and at 1000 GPM the velocity is 25.5 feet per second. These are not realistic velocities in the water distribution or irrigation industry since pumping costs and friction losses would be too high. This is where velocity enters the discussion.

For example, consider a flow meter that can register flows between 1200 GPM and 12 GPM with a stated accuracy of .5% of the measured value. This is actually a typical range and accuracy stated on either a four inch ultrasonic or magnetic flow meter. In comparison, a four inch Turbine meter may have an accuracy of 1.5% of measured value with maximum occasional flow of 1200 GPM and a normal or continuous flow of 1000 GPM.²

Typically, the highest flow in a 4 inch pipe would probably be 300 GPM or possibly as high as 450 GPM. The equivalent velocities are about 7.5 to 10 feet per second. This %usable Turndown+ is closer to a nominal 25:1 or 30:1 and not the 100:1 which manufacturers state the meters to be capable of.

At the desired low flow rate of 12 GPM the velocity equates to 1/3 of a foot per second. This and even lower flow rates are being scrutinized today for leaks and theft in water systems.

The next important factor for consideration is the accuracy statement of the instrument. Accuracy statements such as 0.5% of measured value for a magnetic flow or ultrasonic flow meter and 1.5% of measured value for a turbine meter are common. For these meter types the accuracy statement is of measured value, which means as the flow goes lower or higher within the specified flow range, the accuracy will not change. For example, a stated accuracy of 0.5% is +/- 1/2 gallon at 100 GPM or +/- 5 gallons at 1000 GPM.³

Other mechanical meters such as a paddle wheel meters have stated accuracies based on the maximum published range of the meter, such as 1% of maximum range. A typical range for a paddle wheel meter is a flow rate of 12 GPM to 783 GPM in a four inch pipe equating to a velocity of .3 to 20 feet per second. With this specification, the error at 12 GPM could be as high as 7.83 gallons (1% of the maximum range) or 65% of

² Mechanical meters normally have a high or maximum flow rate of 20-25% over the continuous flow rate. The mechanical meters cannot sustain long use at the maximum flow rates or they will be damaged.

³ (An exception is meters which include a zero stability statement, this adds an additional error at low flows and is discussed later in the paper)

the measured value. When accuracy is stated as a function of maximum measuring range, the error will vary, becoming much more significant in lower flow conditions.

The measurement range has an impact on the choice of instrument. Turndown is not an issue if flow is steady at 250 GPM as long as the instrument can measure the 250 GPM. Accuracy based upon maximum range and accuracy based on measured value can be viewed as equal if the instrument will always be operating near the upper range; sometimes an inexpensive paddle wheel meter will do the job as well as a more expensive DP meter! The lesson here is match the meter to the application for optimal performance.

As mentioned earlier, water is more valuable today than ever before. Where water is not as plentiful as it once was, less will be allotted for irrigation and personal use. A flow meter may not be the most expensive component in the water system, though it is sometimes critical as the only method of registering water usage. If the meter is over reporting water consumption, the possibility exists for the end user not to receive all the water which they are allotted or they could be billed for water they have not received. Conversely, if the meter is under reporting, a greater amount of water is distributed than is being allotted or billed for. The goal is to select the proper meter with the best accuracy over the widest % usable turndown.

The matrix below shows several types of the water meters previously mentioned that are typically used to measure water flow. All are velocity type meters, and all of them require a full pipe for correct measurement. These all come in sizes up to 6 inch. Some are mechanical meters which require extra components such as filter baskets to trap contaminants to limit any damage while in use. Mechanical meters also require extra maintenance to ensure proper metering. Operations such as visual blade inspection, recalibration due to wear, and cleaning the buildup of deposits on blades and other parts, are additional expenses to be considered.

Typically high flow rates in a 4 inch pipe are 400 GPM or 10.5 feet per second. This flow rate is used in the matrix for the upper flow, all meters are capable of measuring this flow rate, the pressure drop is acceptable with all meters and the velocity is somewhat typical. The low flow rates are based on an error not greater than 1.5%, which are typically accepted errors for these types of meters.⁴ Cross over errors were not taken into account for the compound meter. The paddle wheel error is based upon the accuracy statement of: 1% of the maximum range. (783 GPM, based upon 20 FPS maximum in a 4 inch ID pipe.)

⁴ See AWWA Standards for Cold Water Turbine Meters and Standards for Compound Meters

Table 1 Nominal Flow Measurement Performance Characteristics by Meter Type

Meter Type	Usable Turndown	High Flow GPM	Low Flow GPM	Accuracy low flow	Accuracy High Flow	Velocity Low Flow	Upstream / Downstream straight run requirement	Filter / Strainer required	Pressure loss 400 GPM
Turbine	67:1	400	6	1.50%	1.50%	0.31FPS	5D	yes	2.5 PSI
Compound	20:1	400	20	1.50%	1.50%	0.52 FPS	5 D	yes	7.5 PSI
Magnetic traditional full bore	27:1	400	15	1.50%	>.2%, < .5%	0.39 FPS	5 up 3 down	no	0.027 PSI
Ultrasonic / Not clamp on	12:1	400	33	1.50%	0.50%	1.3 FPS	10 up 5 down	no	0.027 PSI
KROHNE WATERFLUX	89:1	400	4.5	1.50%	0.21%	0.12 FPS	0 up 0 down	no	.99 PSI
Paddle Wheel	36:1	400	11	65.00%	1.90%	.3 FPS	10 up 5 down	no	

Clearly, as displayed in the matrix in Table 1, the majority of the meters available today are capable of fairly high usable turn downs, with acceptable low flow accuracy. The non-mechanical electronic meters such as the magnetic flow meters and the ultrasonic inline meters have excellent low flow measurement accuracy when compared to their mechanical counterparts. The electronic meters have no moving parts therefore requiring less maintenance. The electronic meters have low pressure drop and do not require filters, strainers or anything else to clean the water prior to registering flow totals. The pressure drop is miniscule, normally the same as the pipe in which the meter is installed. The electronic type meters deserve attention for the measurement of low flow and high flow of water.

Keep in mind that magnetic flow meter accuracy statements vary greatly by manufacturer. The majority are from .2% up to 1% of the measured value with an additional zero stability error which affects the low flow accuracy of the meter. The smaller this additional error specification is, the better the low flow performance of the meter.

In the table above, KROHNE WATERFLUX stands out as the most accurate choice of the electronic type meters over the entire range of measurement. The WATERFLUX can be powered by a battery or line power, requires no maintenance, has very little pressure loss and has no upstream or downstream straight run requirements.

KROHNE WATERFLUX is the clear choice for measurement of Low Flow, High Flow and all the in-between flows too!