A case for insertion paddlewheel flow sensors

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This fluid velocity measuring device is simple, relatively inexpensive to buy and maintain, and creates no head loss/pressure drop.

More than thirty years ago, when insertion paddlewheel technology was first introduced as an economical alternative to traditional flow sensing technologies, it met with some skepticism. How could such a simple concept for measuring fluid velocity have been overlooked for so long? Since that time, in spite of all the available liquid flow sensing technologies, insertion paddlewheels have steadily gained in popularity.

This technology has typical linearity and repeatability of ±1% and 0.5% of range, respectively, and can accurately measure flows over a range of 0.3 to 20 ft/s. Some insertion paddlewheels come with NIST traceable test certificates *(Fig.1)*. Though other methods may have greater inherent accuracies, the repeatability of the open cell paddlewheel is more than satisfactory for indicative measurements.

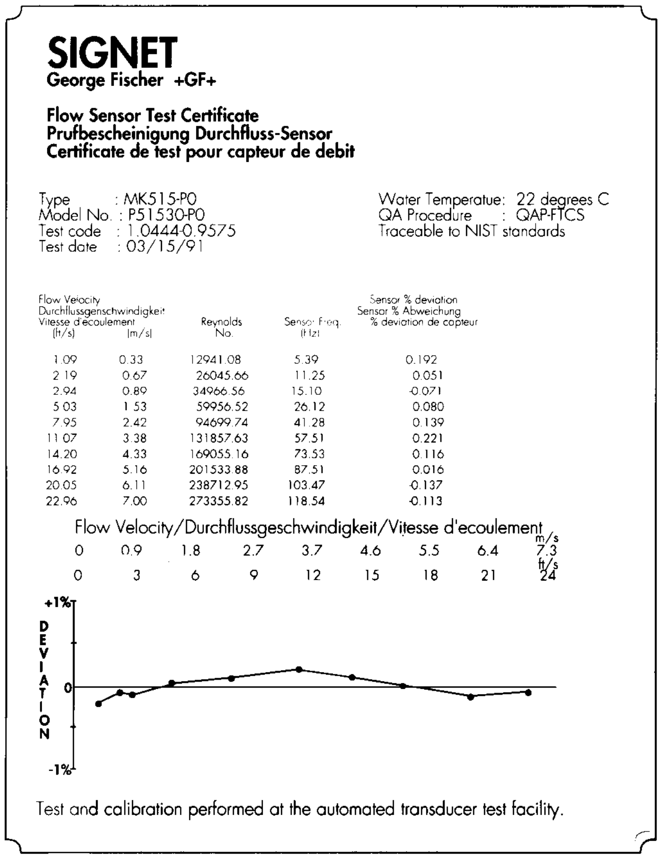
In recent years, companies have been looking at various ways to help them obtain more feedback from their processes, cut production costs, bill ultra-pure water usage to various departments, and cut the overall cost of water and chemical consumption by improving the efficiencies of their processes. Insertion paddlewheels offer companies a way to monitor, record, and control more flow sensing points within their facility for their dollar.

One of the obvious advantages of this technology is its low initial cost, which is often the same whether the pipe size is 2-in. or 36-inch. In addition, insertion paddlewheels are known for creating no head loss/pressure drop. Thus they can often be used in gravity flow and/or low pressure applications unsuitable for other flow technologies, including in-line turbines, vortex shedding, positive displacement, and differential pressure sensors.

The simple design concept of an insertion paddlewheel allows for an easy initial installation with basic hand tools, ensuring minimal system downtime and labor costs. This simple insertion concept also holds true for rapid removal and re-installation of sensors. For those applications that cannot easily be shut down, such as HVAC or municipal water, hot-tap insertion paddlewheels eliminate the need for downtime even during the initial installation.

The maintenance cost for insertion paddlewheels is much less than that for full-bore mechanical flow sensors. It starts with the easy removal of the sensor from the tee, saddle, or weld-on pipe fitting. If it's not a hot or wet-tap style sensor, the fluid flow is first shut off, the sensor is removed, a plug or cap is put in its place, and the flow is turned back on. The sensor, including the rotor, axle, bearings and "O" rings, can be easily rebuilt in the field within a few minutes. Better still, the parts and labor costs to rebuild it are a fraction of those for an in-line turbine flow sensor.

One of the greatest advantages of insertion paddlewheel flow sensors is the wide range of pipe sizes that are covered by just a few part numbers. For example, plastic insertion paddlewheels that use customized pipe fittings take three sensor



SIGNET
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Flow Sensor Test Certificate
Prufbescheinigung Durchfluss-Sensor
Certificate de test pour capteur de debit

Type : MK515-P0
Model No. : P51530-P0
Test code : 1.0444-0.9575
Test date : 03/15/91

Water Temperatue: 22 degrees C
QA Procedure : QAP-FTCS
Traceable to NIST standards

Flow Velocity / Durchflussgenschwindigkeit / Vitesse d'ecoulement (ft/s)	(m/s)	Reynolds No.	Sensor Freq. (Hz)	Sensor % deviation / Sensor % Abweichung / % deviation de capteur
1.09	0.33	12941.08	5.39	0.192
2 19	0.67	26045.66	11.25	0.051
2.94	0.89	34966.56	15.10	-0.071
5 03	1 53	59956.52	26.12	0.080
7.95	2.42	94699.74	41.28	0.139
11 07	3.38	131857.63	57.51	0.221
14.20	4.33	169055.16	73.53	0.116
16.92	5.16	201533.88	87.51	0.016
20.05	6.11	238712.95	103.47	-0.137
22.96	7.00	273355.82	118.54	-0.113

Test and calibration performed at the automated transducer test facility.

Fig. 1: Many insertion paddlewheel flow sensors come standard with a NIST (National Institute of Standards and Technologies) traceable test certificate showing linearity curve vs specification over the entire range of the sensor. The certificate also documents the fluid temperature, fluid velocity, Reynolds number, and sensor frequency.

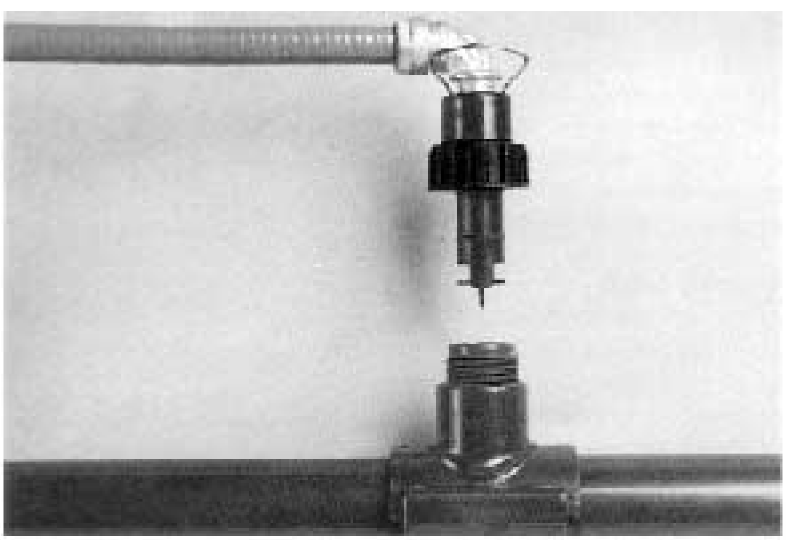


FIG. 2: This low-flow sensor is a Hall-effect type paddlewheel sensor with a low flow detection of 0.3 ft/sec in pipe diameters ranging from 0.5 in. to 36 inch. Shown is a SIGNET® 2535.

sizes to cover pipes ranging from 0.5 to 36 in.–one sensor for 0.5 through 4 in. (*Fig. 2*), a second for 5 thru 8 in., and a third for 10 in. and greater. However, there are adjustable insertion paddlewheels made of metal that use standard off-the-shelf external pipe fittings with a 1.5-in. F-NPT connection–one size sensor fits plastic or metal pipes 1.5 in. thru 36 inch. This reduces spares inventories for both replacement parts and complete meters.

How they work

An insertion-type paddlewheel flow system is comprised of three parts: an installation pipe fitting that rigidly positions the sensor, the paddlewheel flow sensor that produces the raw flow signal, and some sort of instrumentation (a two-wire transmitter, an electronic flowmeter, or a controller) that processes the raw flow signal.

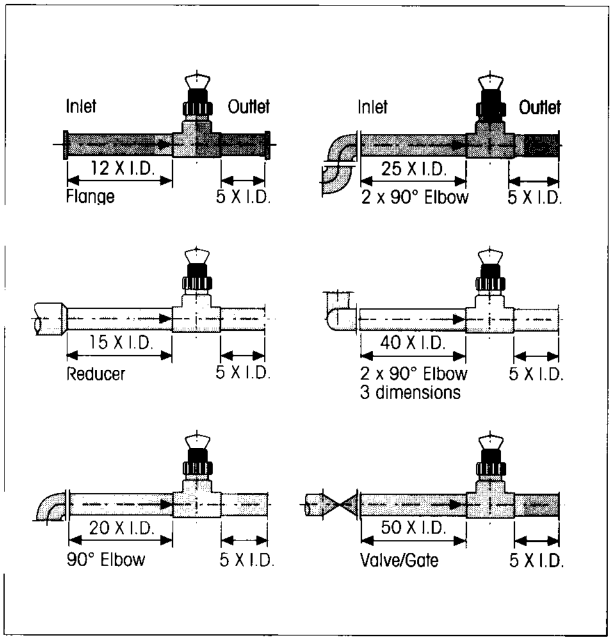
Insertion paddlewheel flow sensors use a velocity sensing technology. Like any velocity-sensitive fluid flow sensor, they require a full pipe during flow measurement, and there must be adequate up- and downstream straight runs to ensure a fully developed turbulent flow profile (*Fig. 3*). Their design and standard calibration is for water-like fluids with a Reynolds number >4500 (*Fig. 4*).

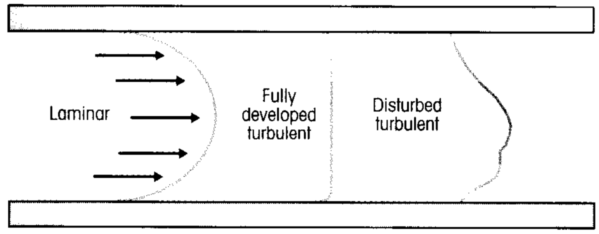
Insertion paddlewheels use a multi-bladed paddlewheel rotor to sense fluid movement. The rotor typically is inserted at the critical position where the local fluid velocity is also the average velocity. As the rotor spins at a speed proportional to fluid velocity, a raw signal is generated, from which an inferred velocity and volume measurement can be obtained.

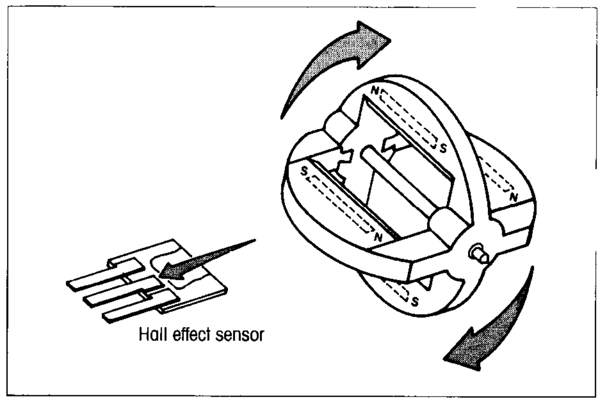
There are several methods used to sense the paddlewheel movement. Let's look at some of the more common ones.

One method uses a coil in the body of the sensor and a magnet embedded in each rotor blade of the paddlewheel. As the fluid movement spins the rotor near the sensing coil, a raw voltage and frequency is generated proportional to the RPM of the rotor and, hence, the fluid's velocity.

A second method uses a coil wound







(clockwise from top left)
FIG. 3: Typically, to insure that the inlet flow conditions are adequate, the sensor must be located in a straight run of pipe with at least 10 pipe diameters of uninterrupted straight pipe upstream of the sensor, and at least five diameters of uninterrupted straight pipe downstream.

FIG. 4: Velocity sensitive liquid flow sensors, including insertion paddlewheels, must have full pipes to work correctly, and are designed/calibrated for fully developed turbulent flow profiles with Reynolds numbers greater than 4500.

FIG. 5: This low-flow sensor incorporates a permanent magnet in each rotor blade. Fluid flow causes the paddlewheel rotor to spin past the Hall-Effect switch embedded in the sensor body that produces an open-collector pulse proportional to the flow rate. Shown is a SIGNET® 2535.

around a magnet inside the flow sensor body. As the stainless steel rotor blades spin near the coil-and-magnet assembly, they generate a voltage and frequency proportional to the fluid velocity.

A third method uses a Hall-effect switch *(Fig. 5)* embedded in the body of the flow sensor. A paddlewheel rotor with magnets spins past the Hall-effect switch, which turns on and off, producing an open collector pulse.

The first two methods need no outside power. The Hall-effect switch requires a small dc current.

Installation

Depending on the style of the particular sensor, the installation pipe fitting will often be a customized design that allows the sensor to be easily installed into the process; such a fitting will not only provide a liquid seal, but also ensure that the sensor is predictably inserted into the flow profile.

Another method uses what is called an adjustable insertion paddlewheel. As mentioned earlier, this type of sensor uses standard off-the-shelf fittings. With this approach, the quality of the installation rests a bit more on the shoulders of the installer, who must calculate and set the sensor position and insertion depth.

With either approach, the inlet flow conditions must be taken into consideration prior to fitting and sensor installation.

Summary

In many applications, insertion paddlewheel sensors may be a better choice than in-line configurations. The pipe size may be too large for other technologies, the flow velocity may vary over a wide range, or the process may be one that cannot be shut down. With only a modest intrusion into the flow stream, the open-cell paddlewheel delivers good accuracy with virtually no pressure drop, making it well suited for gravity and low-flow applications.

About the author

Rick Hines, SIGNET flow project manager, has been with the company since 1978. Highlights during his tenure include positions as service manager and production manager, and implementing a Technical Services department responsible for application engineering and creating technical documentation for field support. ∎

For more information...

The author, Rick Hines, will be available to answer any questions you may have about this article. He can be reached at (800) 854-4090 on during normal business hours.