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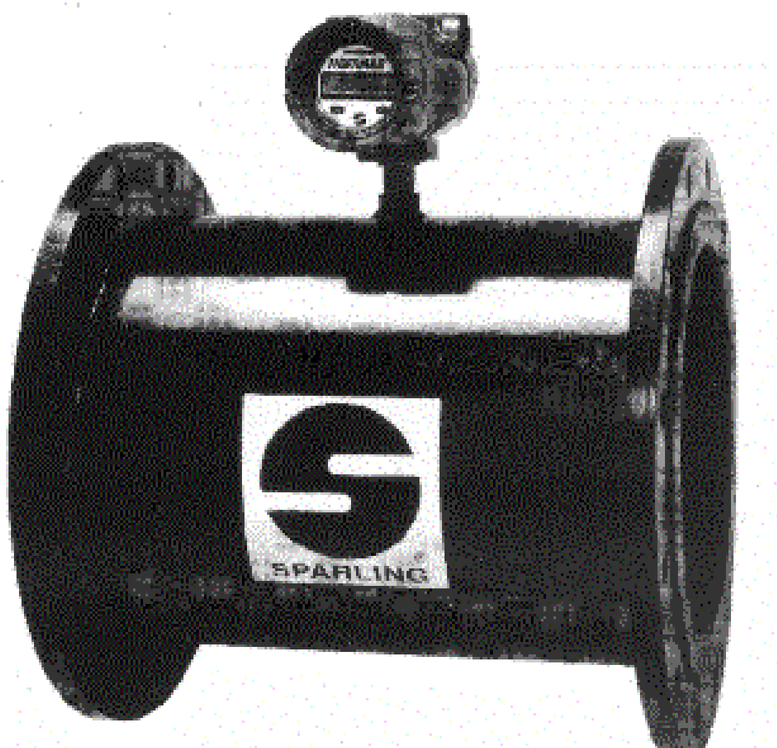
Ask Tom! Column

A Consumers' Guide to Full-Bore Magnetic Flowmeters

Guest article by David Spitzer PE and Walt Boyes

Magnetic flowmeters utilize Faraday's Law of Electromagnetic Induction to determine the velocity of a liquid flowing in a pipe. Faraday's Law forms the basis for electrical generation systems where wires travel through a magnetic field and produce a voltage.

In a typical physics class experiment to illustrate the phenomenon, a wire (conductor) connected across a galvanometer can be moved through the magnetic field of a horseshoe magnet and cause the galvanometer pointer to move. Moving the wire in the opposite direction will cause the pointer to move in the opposite direction due to the changing voltage polarity. Moving the wire faster will cause more voltage to be generated and the movement to move higher.



A TYPICAL MAGMETER (COURTESY SPARLING INSTRUMENTS, INC)

In magnetic flowmeters, a magnetic field is generated and channeled into the liquid flowing through the pipe. To accomplish this, the electromagnetic coils can be located outside of the pipe (flow tube), however the flow tube must be non-magnetic to allow penetration of the magnetic field into the liquid. Locating the coils internal to the flowmeter (closer to the liquid) can reduce the electrical power necessary to deliver the magnetic field, as well as reduce the size of the flowmeter and fabrication costs.

Following Faraday's Law, flow of a conductive liquid through the magnetic field will cause a voltage signal to be generated. This signal is sensed with electrodes located on the flow tube walls. When the coils are located externally, a non-conductive liner is installed inside the flow tube to electrically isolate the electrodes and prevent the signal from being shorted. For similar reasons, non-conductive materials are used to isolate the electrodes for internal coil designs.

The fluid itself is the conductor that will move (flow) through the magnetic field and generate a voltage signal at the electrodes. When the fluid moves faster, more voltage is generated. Faraday's Law states that the voltage generated is proportional to the movement of the flowing liquid. The transmitter processes the voltage signal to determine liquid flow.

The voltage signal will take the same general form as its electromagnetic excitation. When a magnetic flowmeter is excited by a sinusoidal magnetic field (AC waveform), the signal generated at the electrodes is also sinusoidal. In earlier designs, these signals were subject to a number of influences that affected measurement quality, including stray voltages in the process liquid, capacitive coupling between the signal and power circuits, capacitive coupling between interconnecting wiring, electrochemical voltage potential between the electrode and the process fluid, and inductive coupling of the magnets within the flowmeter. These flowmeters required a zero adjustment to compensate for these influences and the effect of electrode coating.

Turning the electromagnetic field on and off (DC waveform) causes the signal to resemble a square wave. When the electromagnetic field is on, the signal due to flow plus noise is measured. When the electromagnetic field is off, the signal due to only noise is measured. Subtracting these measurements cancels the effects of noise and eliminates the zero adjustment, reducing the abovementioned drift problems and improving performance. Waveforms other than those described above are also in use.

There is a perception within the instrumentation, systems, and automation community around the world, that magnetic flowmeters have become a commodity product. It has been said that magnetic flowmeters are pretty much equal, that their specifications are pretty much equal, and therefore their performance is pretty much equal. This has made it difficult for users and manufacturers alike to differentiate magnetic flowmeters. In order to compete, manufacturers have reduced prices and stifled new product development across the product niche. High development costs cannot be justified to develop innovative products in a market where the only differentiation is on price.

We discovered that manufacturer claims actually tend to support the perception that a magnetic flowmeter is a commodity item. These claims typically refer to claimed performance under ideal conditions, and are often simplifications intended to make things easy for the purchaser/specifier. So incredibly "easy" have things become that even the accuracy of the widely used analog output signal is often not stated or known. Yet this is important, since the analog output is the most commonly used to control the process.

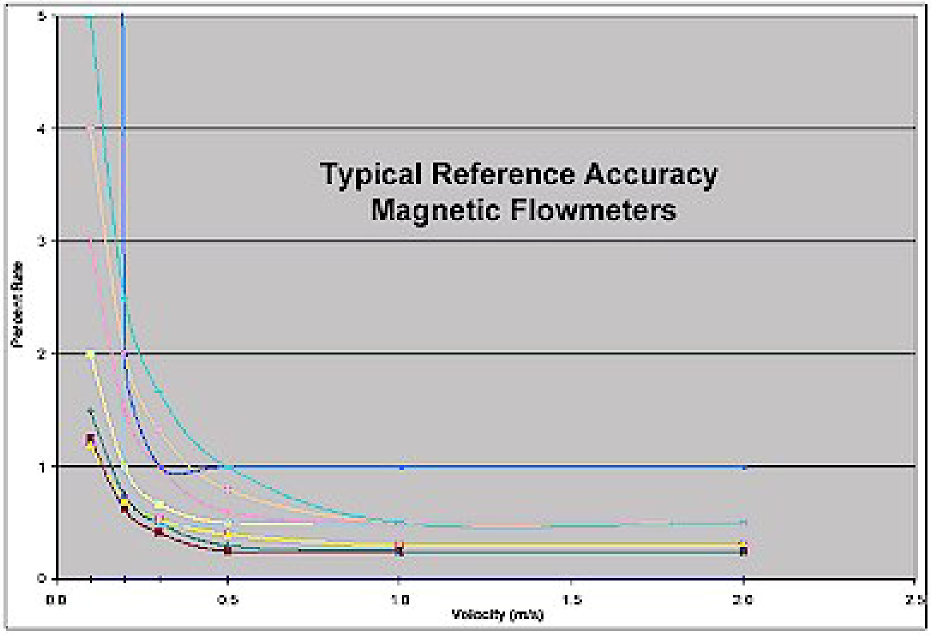
How we put together our study

Recent information we developed in the course of doing research for our newly released series of reports "Copperhill & Pointer's Competitive Intelligence Survey: Magnetic Flowmeters," challenges the perception that magnetic flowmeters are, or should be considered, a commodity product. Originally, we collected data on 43 companies worldwide who sell magnetic flowmeters. We found that 26 companies manufacture meters, with the remainder private-labeling them from one or more manufacturers. Since the study was completed, our list has expanded to over 50 companies worldwide, including companies in Eastern Europe, China, and India.

We asked the companies to participate in our research, and all but one agreed to provide product specifications. Their raw information was tabulated on over 120 data sheets that were developed specifically for this purpose. The types of magnetic flowmeters were further organized into categories (see sidebar). Within each category, each model was compared on the basis of its published performance specifications. If there appeared to be an omission or inconsistency in a published specification, we sought further clarification from the supplier .

How we analyzed the data

Tabulated and graphical performance data revealed significant differences between models and manufacturers of magnetic flowmeters . Some magnetic flowmeter performance was as much as 2-3 times worse than that of other flowmeters in the same category (see chart).



The calculations also illustrate much of the reason why magnetic flowmeters might be perceived as a commodity product. Magnetic flowmeter performance specifications are often intricate, and suppliers often simplify them to reflect performance under ideal conditions. So incredibly “simple” have things become that some suppliers cannot quantify the accuracy of the analog output signal. Yet this is important, since the analog output is the signal most commonly used to control the process.

What the data means

End-users and consulting engineers who know that several suppliers offer identical equipment (except for nameplate) will be able to better control whose equipment they purchase, and at what price. To simplify these relationships, the flowmeter categories were tabulated by supplier along with country of origin and/or source of manufacture.

To help select the best equipment for an application, they would also like to know which models perform better in a given category of magnetic flowmeters. To this end, within each category, each model was ranked in order of its calculated performance.

The results of the study

The report concludes, “Except for specialized applications, the operating conditions within which these flowmeters operate are similar within each design category. Similarly, while there are differences in the electronic features associated with different transmitters, flowmeter performance at reference conditions was found to vary widely. Differences were especially significant at low flow conditions that are commonly encountered in actual flowmeter operation.”

This series of reports is unique in providing this comparison data. We consider the results to be significant and expect that some buying patterns and marketing strategies may be altered as an outcome of our research.

Because of the dynamic changes in the flowmeter marketplace due to acquisitions, product additions and deletions, we intend to update this report as events warrant , and make it available as a consumers' guide utility on a continuing basis.

Magnetic Flowmeter Categories

- **Ceramic-lined** - Ceramic magnetic flowmeters have abrasion-resistant liners typically made of alumina ceramic instead of the typical elastomer linings usually found in magnetic flowmeters. They often permit higher temperature operation, and because their electrodes are typically part of the ceramic substrate, they tend not to offer a leak path between the electrode and liner.
- **Electrodeless** - So-called "electrodeless" magnetic flowmeters employ electrodes that are not in direct contact with the fluid. These electrodes are either embedded in the liner or located behind the liner, and are usually capacitatively-coupled to the flowing liquid.
- **Low flow** (under 12 mm/0.5inch) - Low flow magnetic flowmeters include sizes below 12 mm (0.5 inch) in diameter. Many have ceramic linings with embedded electrodes.
- **Medium flow** (12 mm/0.5 inch to 300-450 mm/12-18 inch) Medium flow magnetic flowmeters include flanged and wafer-style meters that are between 0.5 inch (12 mm) and 300-450 mm (12-18 inch) in diameter. A large number of magnetic flowmeter models fit into this category.
- **High flow** (over 300-450 mm/12-18 inch) - These magnetic flowmeters are larger in size, ranging to over 2 meters in diameter.
- **High-noise** - Many liquids, including slurries, produce signals that contain large amounts of noise. These magnetic flowmeters are designed to produce usable flow measurements even in high-noise environments.
- **Low-conductivity** - Traditionally, magnetic flowmeters could not be used for liquids having an electrical conductivity of less than about 5-20 uS. Several designs permit measurement of fluids with conductivities far less than the traditional level.
- **Partially-full** - Many conduits, especially in wastewater and storm water runoff applications, are only full part of the time. Partially-full magnetic flowmeters are designed to measure flow using both liquid velocity and liquid level to determine flow rate when the conduit is completely not full of liquid.
- **Fast response** - While many applications find the response time of traditional magnetic flowmeters suitable to the service, other applications require measurement where flow changes rapidly, or where the duration of the flow may be on the order of only a few seconds. Fast response magnetic flowmeters are designed to quickly respond during these short time periods.
- **Sanitary** - Sanitary magnetic flowmeters are designed and fabricated with materials and finishes that allow application in the food and pharmaceuticals industries where they may be cleaned in place (CIP) or steamed in place (SIP) to reduce or remove bacterial contamination.
- **Two-wire** - Traditionally, to generate a sufficient magnetic field, magnetic flowmeters required separate wiring to a source of power in addition to analog signal wiring. Two-wire, or loop-powered magnetic flowmeters are designed to operate on the power available from the loop power supply. Most two-wire designs run on available 4-20 mADC loop power, but some designs require higher power levels to operate over two wires.

About our author

David Spitzer has written a number of books on flow measurement and flow measuring devices, some of which are available through Amazon.com. These include:

- Flow Measurement: Practical Guides for Measurement and Control
- The Consumer Guide to Magnetic Flowmeters
- Industrial Flow Measurement

- The Consumer Guide to Coriolis Mass Flowmeters
- The Consumer Guide to Vortex Shedding and Fluidic Flowmeters
- Regulatory and Advanced Regulatory Control: Application Techniques

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Welcome to Ask Tom!, a monthly column by our resident water treatment guru, Tom Keenan of National Environmental Services Agency (NESA). Tom addresses the issues that bug you the most. And Tom knows!! With 35 years experience in providing environmental support services to public and private sector clients on a wide range of environmental issues.

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Guest articles for the **Ask Tom!** Column are always welcome, for more information please contact Tom Keenan directly at his email address: info@nesa.ie