TDS 3032A00
English
September 1995

# Magnetic Flowmeter Fundamentals


ROSEMOUNT® MEASUREMENT

FISHER-ROSEMOUNT™ Managing The Process Better.™

## INTRODUCTION TO MAGNETIC FLOWMETERS

The magnetic flowmeter is one of the most flexible and universally applicable flow measurement systems available. It provides completely obstructionless flow metering, is nearly insensitive to fluid properties, and is capable of measuring the harshest corrosive fluids. It installs like a conventional segment of process piping and has a pressure drop similar to an equivalent length of pipe. Magnetic flowmeters are ideally suited for measuring harsh chemicals, slurries, fluids with solids in suspension, and other extremely difficult-to-measure fluids. Their operating principles provide flow measurement with a signal that is inherently linear to the average volumetric flow rate—regardless of fluid temperature, pressure, density, viscosity, or direction. The only limitation is that the fluid must be electrically conductive and non-magnetic.

While magnetic flowmeters may be technically feasible for most fluids and offer many advantages, they are not necessarily the most cost-effective. For many clean, non-corrosive fluids other means of flow metering may be just as suitable at lower cost. Magnetic flowmeter accuracy, for example, may not outweigh the advantage of a simpler device with tolerable accuracy. Where no other measurement device will work, or will not work reliably with the necessary accuracy, the magnetic flowmeter is an obvious choice. Ideal fluid candidates generally fall into the categories of corrosive, viscous, or dirty fluids—particularly slurries. Magnetic flowmeters are widely used in the water and waste, pulp and paper, mining, chemical, and food industries.

## APPLYING FARADAY'S LAW TO FLOW MEASUREMENT

Faraday's Law of Electromagnetic Induction is the key principle applied to magnetic flowmeter operation. Working on the same principle as the electrical generator, Faraday's Law states that a voltage will be induced in a conductor moving through a magnetic field. The magnitude of the induced voltage is directly proportional to the velocity of the conductor, the length of the conductor, and the strength of the magnetic field. Figure 1 illustrates the principle applied to the elements of a flowmeter. In this figure **V** is the velocity of a conductive fluid in a nonconductive pipe flowing through an area having field strength **B**, and with the electrode contacts spaced at distance **D**. The conductive fluid along a line between the electrodes, the velocity, and the magnetic field are all at right angles to one another. Under these conditions, Faraday's Law is reduced to the following equation:

$$E = kBDV$$

In this equation the resulting electromotive force (emf) **E** is measured in volts, and **k** is an added proportionality constant.

Another calibration factor **Q** must be added to the basic equation to make it useful for flow measurement. Linear velocity is replaced by a volumetric flow rate as in the following equation:

$$Q = A \times V$$

The value **Q** is the volumetric flow rate, **A** is the cross sectional area of the pipe, and V is the fluid velocity. In Faraday's equation the k factor related the output to the induced emf. Incorporating both calibration factors k and Q produces the desired practical equation for a flow metering device:

$$E = \frac{kBDQ}{A}$$

To produce standardized meter performance, the factory calibration procedure measures flow Q and output E, and adjusts k electrically. These equations explain the simplicity of the flow metering principle, and the inherently linear relationship between fluid velocity and induced voltage.

## PRIMARY AND SECONDARY DEVICES

Most magnetic flowmeter systems are divided by function into a primary and secondary device. The pipe section with coils and electrodes, shown in Figure 1, makes up the primary device and is called the flowtube. The secondary device interprets the voltage generated at the electrodes, and transmits a standardized signal to the readout or control system. Various manufacturers refer to the secondary device as the transmitter or signal converter.

### Flowtube

The primary function of the flowtube is to produce a voltage proportional to the velocity of the fluid being measured. The field coils are energized by passing a current through them to develop the magnetic field. The process fluid functions as a moving conductor that induces a voltage in the fluid. The flush-mounted electrodes inside the flowtube are in direct electrical contact with the conductive process fluid, thereby picking up voltages present in the fluid. To prevent the voltage from being shorted, the fluid must be contained in an insulated material. This is accomplished by lining a metal flowtube with a nonconducting material such as PTFE or rubber.

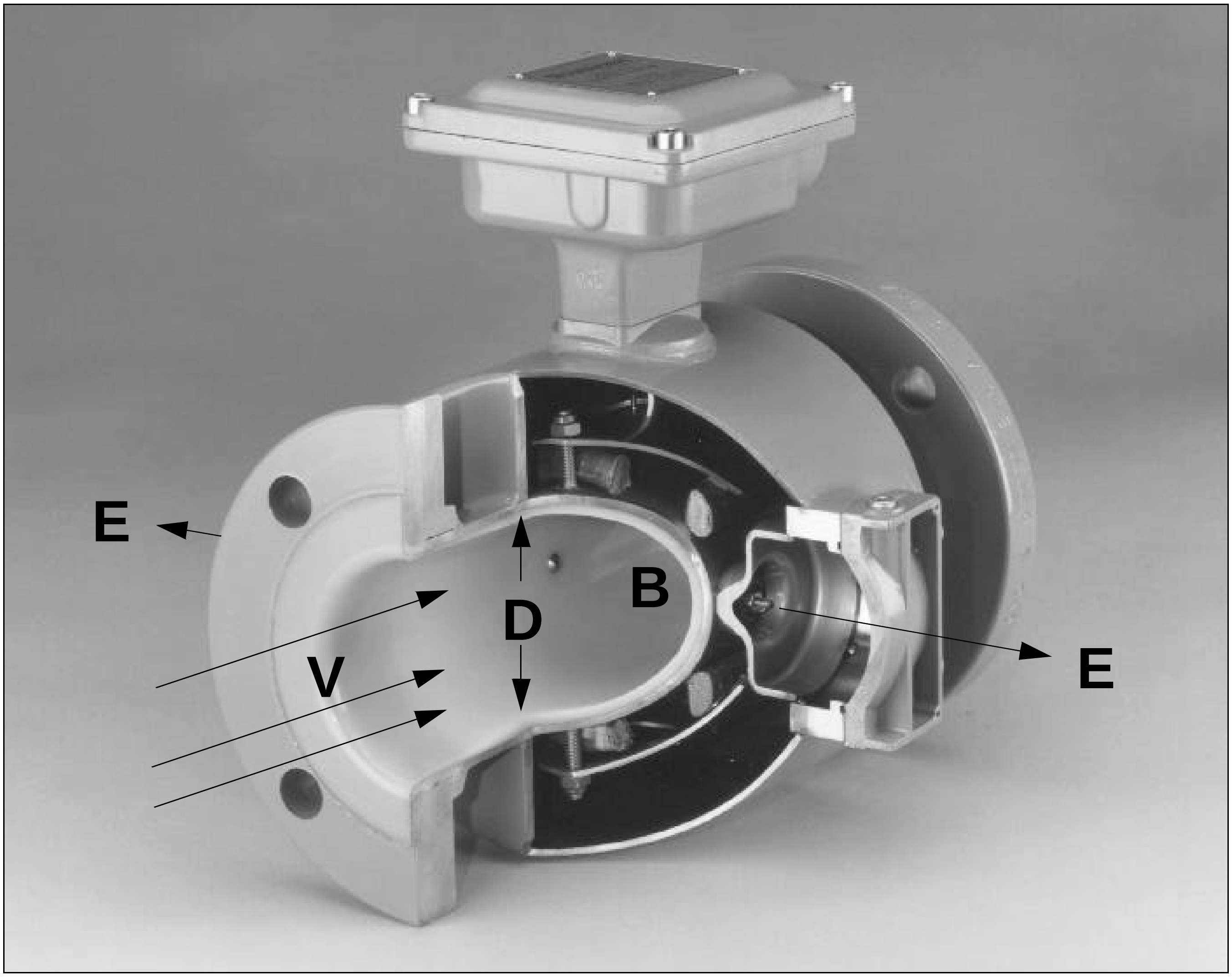



FIGURE 1. Cutaway View of the Model 8705 Magnetic Flowmeter Flowtube.

Flowtube liners, in addition to their nonmagnetic property, must be carefully selected for compatibility with the process fluid. Polyurethane and PTFE are the two most common liner materials; the different liner materails feature unique properties that may be more or less suitable for the process fluid or operating conditions of an application. Related flowtube components include mounting flanges, wiring, and housing. The housing protects the field coils, electrodes, and wiring from the environment. These components are shown in Figure 1.

## Transmitter

Signal conversion, conditioning, and transmission are the principal transmitter functions. The transmitter translates the flowtube output into a usable signal for process control or monitoring. The location of the transmitter varies between manufacturers. In most cases the preferred location for the transmitter is some distance from the flowtube. A remote site offers convenience and flexibility, as well as a more benign environment than that of the flowtube. In some cases the transmitter is mounted directly on the flowtube, making the transmitter an integral part of the flowtube package.

Because the flow signal is typically at a weak millivolt level, precautions are often necessary in specifying the type of cable and the number of conduits required between the flowtube and transmitter. These specification precautions are necessary to protect the signal from both internal and external interference. The allowable distance between the flowtube and transmitter depends on the fluid conductivity and flowmeter design.

## ELECTRICAL DESIGN

The practical application of Faraday's Law to industrial flow measurement has led to many fundamental design challenges. The greatest difficulties arise because the relatively small flow-induced voltage at the electrodes can be distorted by extraneous voltages.

Undesirable voltages, classified as noise, come from many sources. The following partial list describes the types of noise that must be considered.

- Electrochemical emf resulting from the electrolytic reaction between the metal electrode and the ion-conducting process fluid.
- Inductive coupling, referred to as quadrature voltage in ac designs, occurring with any conductor located within the magnetic field.
- Electrode circuit voltage resulting from capacitive coupling with the coil excitation circuits or other power circuits.
- Transmission losses resulting from lead resistance capacitive coupling in transmission cables.
- Stray voltages or current loops residing within the process fluid.

Because any noise component represents a measurement error when included with the electrode voltage, designers and manufacturers of magnetic flowmeters invest considerable effort to eliminate noise. Since the first industrial applications, efforts to deal with noise, while at the same time striving for higher accuracy, have led to an evolutionary change in the basic magnetic flowmeter design.

### Design Evolution

All magnetic flowmeters operate on the principle of electromagnetic induction. In the attempt to apply Faraday's Law to the development of a practical measurement instrument, manufacturers have recognized some common problems, and from these problems various design approaches have evolved. All designs must contend with the changing flux density of a magnetic field, and with the introduction and separation of unwanted noise on the flow signal. Attempts to eliminate these problems introduce terms such as zeroing, nulling, electrode loop, quadrature voltage, and phase detection to the terminology associated with magnetic flowmeters. These terms do not necessarily apply to all designs.

Early experiments to generate a magnetic field for a flow metering device involved either a permanent magnet, or electromagnetic coils driven by a constant dc current. However, in many of these experiments the electrochemical emf was so great that the voltage induced by flow was actually a minor portion of the electrode signal. In some cases it is possible to correct for the undesirable signal components, but as

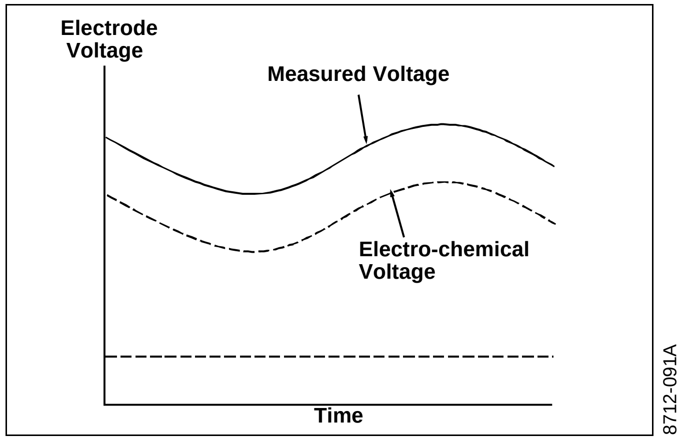



FIGURE 2. Signal Components.

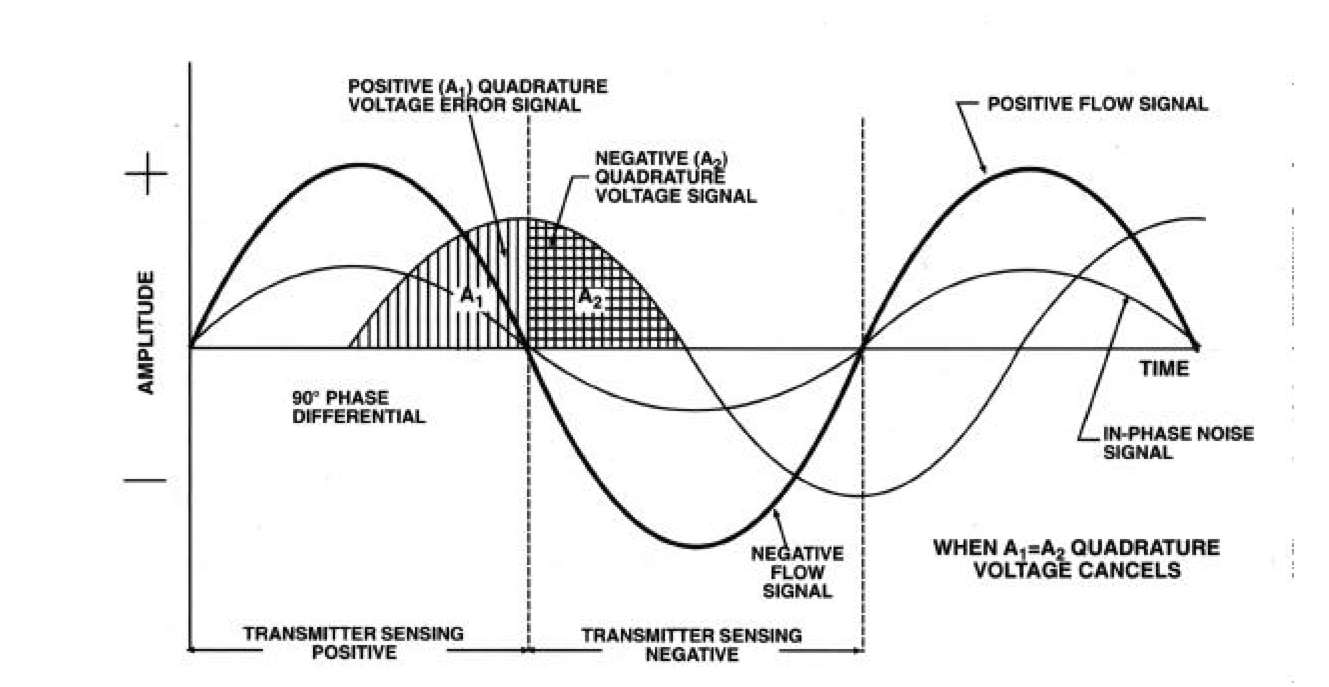
shown in Figure 2, most of the errors are quite unpredictable. Some factors affecting this unwanted voltage are fluid velocity, fluid chemistry, electrode material, films or deposits on the electrodes, and polarization of the electrodes from the low-level currents passing through them.

### ac-Driven Field Coils

Some manufacturers use field coils driven directly by ac line power. The intensity of the magnetic field produced varies sinusoidally, and as a result, the voltage induced at the electrodes is also sinusoidal. With this meter design, the amplitude of the ac electrode voltage is proportional to the fluid velocity. Since the unwanted electrochemical voltages vary much more slowly than the 60 Hz flow voltage, they can be detected and effectively filtered out.

Another unwanted voltage is produced by an electrode loop consisting of the electrodes, the lead wires, and the conductive fluid. Because the magnetic field fluctuates sinusoidally at 60 Hz, a voltage is also induced in any conductor located within the magnetic field, including the components of the electrode loop. This voltage is proportional to the rate of change of the magnetic field strength, and it is ideally 90 degrees out of phase with the flow signal—hence the name quadrature voltage. The quadrature voltage relationship to the flow signal is illustrated in Figure 3. Employing phase detection circuitry, quadrature voltage can be identified by a method called synchronous demodulation, and can be separated from the total voltage measured at the electrodes. Synchronous demodulation is performed at the transmitter, so protecting the quadrature relationship of the flow signal components is vital in order to avoid a phase shift in route to the transmitter. This explains the need for separate conduit and power-shielded, interconnecting cable in some systems.

Field coils driven directly by unregulated ac line voltage are subject to variations in field strength as the line voltage fluctuates. As a result, the electrode



8712-0922A

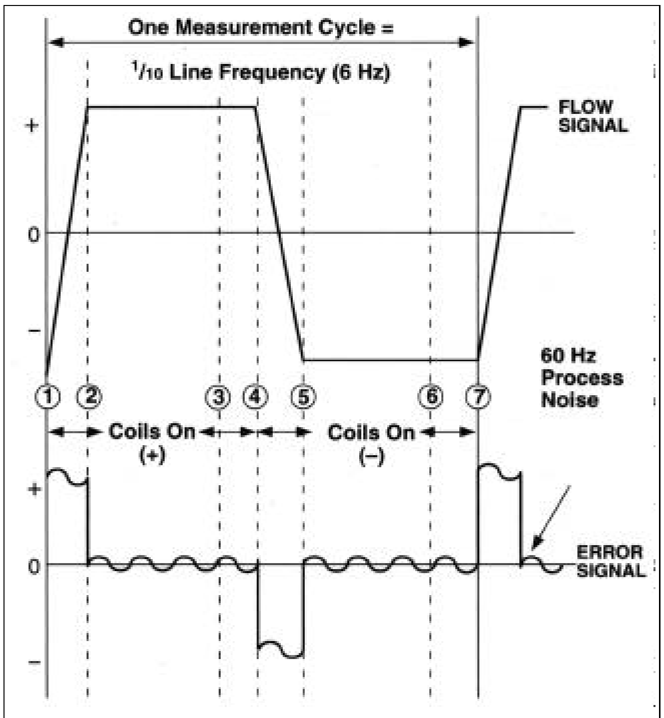
FIGURE 3. ac Magnetic Flowmeter Flow Signal.

signal also varies with line voltage, independent of flow velocity. Although this effect can be reduced by supplying a reference voltage to the transmitter circuitry, a significant inaccuracy is associated with this correction.

Another effect of the ac line voltage on the magnetic field is the characteristic form of the induced flow signal. The signal necessarily takes the same sinusoidal form as the ac voltage. Refer to the In-Phase Noise Signal shown in Figure 3. Unfortunately, this is the same form as the most prevalent source of stray signals in most environments. Representative of these stray signals is 50 and 60 Hz noise from flowmeter magnet coils, power lines, induction motors, welding equipment, and other voltages present in the process piping—including ground potentials. All this noise is picked up as a voltage at the electrodes, and it can be much stronger than the relatively weak flow signal. Having the same phase relationship as the noise, the flow signal cannot be detected by the phase-sensitive circuitry. Zeroing is necessary to separate this voltage from the actual flow signal. This is done by measuring the voltage at the electrodes under a no-flow condition, and adjusting a control to zero it out. Should these stray voltages change, as is typically the case, rezeroing would be required to maintain an accurate output.

## Pulsed dc Field Coils

Another design exhibits immunity to electrochemical noise of an ac design without the associated quadrature and other induced voltages inherent in an ac design. This design is most commonly referred to as pulsed dc. Pulsed dc systems excite, or power,




**EVENT SEQUENCE**

① Magnetic Field Transition Begins.
① –② Transients Present Due to Transition of Magnetic Field.
② –③ Magnetic Field and Flow Signal Stabilize.
③ –④ Flow Signal Sampled.
④ Magnetic Field Transition Begins.
④ –⑤ Transients Present Due to Transition of Magnetic Field.
⑤ –⑥ Magnetic Field and Flow Signal Stabilize.
⑥ –⑦ Flow Signal Sampled; Difference Taken from Previous Sample. Flow Rate Calculated.

8701-0265A

FIGURE 4. Pulsed dc Magmeter Flow Signal.

the magnet coils periodically with a low frequency square wave. With this design the flow signal is a dc pulse with an amplitude proportional to the velocity of the fluid conductor. There is no need to compensate for voltage and frequency variations on the ac power line. Although stray noise may be picked up along with the induced flow voltage at the electrodes, it is easily separated by measuring the pulse ON and pulse OFF voltage and subtracting the difference.

When the pulse is ON, both the desired flow signal and unwanted noise signals are present; but when OFF, only the noise is present. Figure 4 illustrates the events associated with the pulse ON and OFF sequence. In this sequence the circuitry samples and corrects for noise-induced voltage within the flowtube several times a second. The flow signal to the transmitter is also safe because it is immune to stray 50 and 60 Hz noise in the environment. Because the sinusoidal form of such noise does not interfere with the low frequency, pulse-shaped flow signal, coil drive and signal wires may share the same conduit and use standard cables. The issues of reference voltage, quadrature voltage, phase detection, and zero controls are not applicable to pulsed dc systems.

In summary, the later development of designs featuring pulsed dc coil excitation, in contrast to those driven directly by ac line power, have the following inherent advantages:

- **Automatic Zeroing**. Zeroing is accomplished several times a second, eliminating the need to zero the system under a no-flow condition that requires process shutdown.
- **Low Power Consumption**. The field coils are not continuously energized, reducing the power requirement of pulsed dc systems.
- **Simplified Installation**. Fewer electrical connections and conduit runs are required in comparison to most ac systems. In addition, special power-shielded cables are eliminated because the dc signal is immune to most of the noise sources that plague ac systems.

Nulling the loop voltage, however, is required regardless of the system design.

## Nulling Loop Voltage

A so-called electrode loop in the presence of a changing magnetic field in either an ac-driven or pulsed dc system can introduce an undesirable voltage on the flow signal. The loop formed in the flowtube's magnetic field consists of the process fluid, electrodes, and the electrode wiring. Because the electrode loop is not exactly at right angles to the flux lines of the flowtube's magnetic field, a flux linkage occurs. The linkage induces a voltage in the electrode loop that appears as an offset error at the meter output. Nulling this voltage is a one-time factory procedure accomplished under a no-flow condition. There are several approaches to nulling. One way is to orient the electrode loop mechanically so that its effective position is parallel to the lines of flux surrounding the flowtube. When correctly done, the resulting net flux through the loop is zero.

# INSTALLATION CONSIDERATIONS

Installation involves the physical orientation of the flowtube and transmitter with respect to the type of process fluid, adjacent piping, accessibility, electrical connections between the flowtube and transmitter, and good grounding practices. Installation should also be viewed from the standpoint of available design options and features that may simplify wiring procedures, provide remote transmitter mounting options, and affect serviceability.

## Flow Profile

Most studies indicate that the flow or velocity profile of a fluid passing through the flowtube of a well designed system has a minimal effect on measurement accuracy. The flow profile is typically characterized as either uniform or non-uniform laminar flow, or turbulent flow. The velocity of turbulent flow, as compared to laminar flow, varies erratically in magnitude and direction. To a magnetic flow measurement system this means different voltage potentials are developed in the area between the flowtube electrodes. Because the flow signal developed represents the sum of all voltages in this area, the total voltage potential is representative of the actual average flow profile or velocity. It is in fact the voltage potential averaging that makes magnetic flowmeters more tolerant to flow profile effects than other types of measurement devices. If good installation practices are followed, and the system design features a good magnetic flux distribution within the flowtube, any error caused by a non-uniform flow profile is negligible.

## Flowtube Orientation

The installed position of the flowtube, whether horizontal or vertical, does not affect measurement accuracy. This is technically true providing the flowtube is full at all times and the fluid is free of entrained air or gas. Since the equation applied to flow measurement accounts for the pipe diameter, the equation is not valid unless the pipe is full. The problem with air or gas in the fluid is not that it is physically harmful, but that it displaces fluid and has the same effect on measurement accuracy as a tube that is not completely full. A related problem is flowtube wall buildup that affects accuracy by effectively changing the diameter of the pipe. If electrode coating, often associated with pipe wall buildup, is a current or potential problem, the location or orientation of the flowtube should be planned to facilitate cleaning. Such coatings may be either conductive or insulating. Conductive coatings cause inaccurate outputs, while insulating coatings can prevent electrode contact with the process, creating erratic and unpredictable outputs.

## Vertical or Horizontal Mounting

When considering the suitability of a vertical or horizontal flowtube installation, the emphasis is on how best to ensure that the flowtube can be kept full as well as free of entrained air or gas. In a vertical installation the flow of process fluid should be upward. The vertical orientation is particularly recommended for slurries so that under no-flow conditions the solids will settle out of the flowtube. If a “bake-out” should occur, as may happen by flowtube coil heating when empty, there is less chance of baking-on an electrode coating that may not dissolve when the flowtube is again full. Flowtube baking is not generally associated with pulsed dc coils because they produce much less heat than ac-driven coils.

In a horizontal installation the fluid back pressure must be controlled to keep the flowtube full, or the flowtube may be located in a low section of piping that will be full even when flow stops. The electrode plane is also important for horizontal installations when entrained gas may be present. Since gas will favor the top of the tube, the electrode plane should also be horizontal. A vertical plane would expose the upper electrode to any air or gas at the top of the tube, affecting accuracy by tending to insulate the electrode from the process fluid.

## Adjacent Piping and Control Valves

Piping and valve restrictions that could influence the flow velocity profile and affect measurement accuracy are minimal. There is little evidence to support any significant problems, but some general recommendations have been noted. Guidelines address the flow profile past the electrodes and the need for a straight fluid “run” through this area. For flow upstream of the electrode plane the minimum straight run distance recommendation is five pipe diameters; for flow downstream it is two pipe diameters. In small pipe sizes the requirement may be satisfied inside the flowtube itself, because the electrode plane is in the center of the flowtube. Measurement accuracy has been maintained with two 90 degree elbows mounted near the flowtube inlet.

Other recommendations include the type and location of adjacent control valves and pumps. Butterfly valves are not recommended close to either end of the flowtube. Pumps and all other valves in general should be located, when possible, downstream of the flowtube.

## Electrical Connections

Electrical connections involve both the power and flow signal wires between the flowtube and transmitter. Although most systems are designed to be immune to stray electrical noise in “typical” installations, it is a standard practice to avoid close proximity to main power lines or heavy duty electrical equipment; all are fertile sources of unwanted noise. A good practice is to maintain a minimum of at least two feet from these troublesome areas, and more if possible. If the transmitter is mounted on the flowtube, the same guidelines apply.

## Remote Transmitters

Systems that allow the flexibility of a remote transmitter site also have cable protection, length, and type to consider. Steel conduit is recommended for all wiring. Some manufacturers specify separate conduit for power and signal wiring, as well as special cabling. These added specifications generally apply to ac-driven coil designs that have a sinusoidal flow signal susceptible to noise and phase shifting. Pulsed dc magnet coils produce a pulsed dc flow signal to avoid these problems, thus permitting coil drive and signal wires in the same conduit, and requiring no special type of cable.

## Cable Length

A maximum allowable cable length between the flowtube and a remote transmitter is normally specified. All cables have a certain impedance that is present in series with the input impedance to the transmitter. This becomes even more important when fluid conductivity is low, because it introduces an additional impedance in the electrode loop. In practice this means that the greater the conductivity, the greater the permissible cable length. The cable length recommended therefore takes into account the conductivity of the process fluid and attenuation of the relatively weak flow signal. It is typically specified between 50 and 1,000 feet.

## Grounding

Accurate flow measurement, and sometimes the safety of personnel, depends on proper system grounding. The primary objective is to reduce stray current and voltage that could otherwise interfere with the actual flow signal. Whether the process piping is conductive or not, the objective is the same. Symptoms of inadequate grounding may appear as a zero offset or flow signal drift. When the system is properly grounded with suitable straps or rings, the process fluid is held at a constant potential throughout the flowtube, and the flowtube is maintained at the same potential as the fluid. Part of this task involves locating a good earth ground that is normally connected to the flowtube housing. Locating a good earth ground is generally not a problem, but its suitability should never be assumed. It also is important to minimize the differences in ground potential between the flowtube and transmitter when planning a remote transmitter installation.

## MAGNETIC FLOWMETER APPLICATIONS

If a process fluid under consideration meets the conductivity requirement, it is a likely candidate for the application of a magnetic flowmeter. The fluid may be clean, dirty, or a slurry. It may be a valuable fluid where high accuracy is essential. And this accuracy can be maintained regardless of pressure, temperature, density, viscosity, or flow direction. Even variations in conductivity do not affect accuracy as long as the minimum conductivity threshold is maintained. The value of obstructionless flow measurement remains a constant advantage and may be a primary consideration in any application. Systems featuring interchangeable flowtubes and transmitters, and a remote transmitter location, offer the additional advantages of excellent maintainability and readout convenience.

As with any type of flow measurement instrument, construction materials must be compatible with the process fluid and operating temperature. Wear resistance is important for dirty or abrasive fluids, as is the material's reactive properties for corrosive or exotic fluids. Most manufacturers provide several flowtube liners and electrode materials to satisfy a variety of needs.

### Fluid Conductivity

The unit of measure for conductivity is microsiemens per centimeter. Minimum conductivity requirements may differ, but 5.0 microsiemens per centimeter is near the minimum conductivity limit. Below the minimum conductivity limit, electrode resistance can produce an error in the flow signal. Electrically, the resistance appears in series with the transmitter input impedance, and as fluid conductivity decreases, the internal circuit resistance increases. When the resistance increases to a certain point, the voltage drop across it is sufficient to produce an error at the transmitter input. Some typical conductivity values are alcohol at 0.2, hydrogen peroxide at 2.0, and water at 200.0. Variances in conductivity above the minimum threshold have little or no effect on measurement accuracy.

### Flowtube Liners

All flowtube liners are nonmagnetic and good insulators, a characteristic necessary to prevent distortion of the magnetic field. Liners rely on the strength of the basic flowtube construction material, typically ANSI 300 series stainless steel because it also is nonmagnetic. However, the strength of the tube cannot protect liners from separation from the wall of the tube or collapse in the presence of vacuum conditions. It is therefore important to avoid process conditions that could produce even temporary vacuum conditions. If these conditions cannot be eliminated, the manufacturer should be consulted for an evaluation of the limits that must be observed.

### Flowtube Electrodes

Although flowtube electrodes are mounted flush with the inside of the flowmeter, they are subject to wear, corrosion, and coating. To pick up the flow signal they must be electrically conductive and insulated from the flowtube.

### Electrode Coating

Electrode coating, caused by deposits from some process fluids, must be avoided to maintain flow measurement accuracy. Coating substances may be adhesive resins, fats, soaps, minerals, salts, and even organic deposits. Coating usually results in either an increase or decrease in electrode resistance, causing an error in the flow signal. When the conductivity of the coating is greater than the fluid, the result is a flow signal representing less than actual flow. When the opposite is true, the flow signal will initially increase, representing a greater than actual flow, and then become unpredictable. Sometimes a slight coating is acceptable if it has the same conductivity as the process fluid, but this is seldom the case. In severe cases a totally non-conductive coating can render the flowtube unusable. Several approaches are available to combat coating.

Correct flowtube sizing for optimum flow velocity, and altering the flow profile can minimize electrode coating. Obviously, if the velocity of a fluid containing suspended materials is sufficiently high, there is less chance for the materials to settle on the inside surface of the flowtube and electrodes. Keeping the velocity as high as possible thus keeps potential coating materials moving with the flow, and also provides scrubbing action for previously formed deposits. The benefit of cleaning action must be balanced by the possibility of increased liner wear, especially when the fluid contains abrasive particles. Another approach is to alter the flow profile or increase turbulence with pipe elbows or other flow conditioning devices. In this case too, abrasive particles can accelerate liner wear.

### Pipe Sizing

Selecting the correct flowtube size for a given application is as important as selecting the most appropriate electrode material and flowtube liner. Recommendations may vary, depending on the manufacturer, but sizing for maximum fluid velocities may range from 1 to 30 feet per second.

Velocities referenced in this discussion are guides based on general consensus. Manufacturer's recommendations, rather than material properties, should be followed. Although magnetic flowmeters can usually maintain specification accuracy during process flow surges, continuous operation above the recommended maximum may accelerate wear, or damage the flowtube if a severe hydraulic shock occurs.

Sizing for fluids without solids in suspension is normally straightforward, but even so-called clean fluids may require special considerations. Take the example of corrosive fluids. The resistant property of the electrode material may depend on a passive film build-up on the electrodes in the presence of the fluid. High fluid velocities in this application could accelerate corrosion by preventing this film build-up. For this reason the recommended fluid velocity for corrosive fluids is below ten feet per second. Slurries present other concerns.

The obstructionless flow characteristic of magnetic flowmeters is particularly attractive to otherwise difficult-to-measure slurries. Slurries, however, require careful sizing based on the solids in suspension and their abrasive quality. The problems associated with electrode coating have been previously discussed—essentially a trade-off between a flow fast enough to prevent coating and build-up, but slow enough to minimize wear. A flow rate of seven feet per second or greater is generally recommended for non-abrasive slurries. Abrasive slurries also require sufficient flow velocity to prevent coating, but a maximum should be set. A typical recommendation is between 7 and 14 feet per second.

## Summary

Magnetic flowmeter systems are one of the most accurate and versatile types of flow metering systems. They are commonly used in water and waste, pulp and paper, mining, chemical, and food industry applications because they can accomodate harsh corrosive fluids and fluids containing particles that render other systems ineffective.

A magnetic flowmeter system is comprised of two elements: the flowtube and the transmitter. Installation and effective use of a magnetic flowtmeter system requries consideration of many factors, includingwiring and cable length, groudning, adjacent process piping and valves, horizontal and vertical flow, and so forth. Selection of an appropriate magnetic flowmeter system requires consideration of the process fluid and its conductivity, flowtube liners, flowtube electrodes, and pipe sizing to maximize effectiveness. A manufacturer's guidelines are ususally the best guide int eh selection process.

*Cover Photo: 8712-001AB*

**Rosemount Inc.**
**Measurement Division**
8200 Market Boulevard
Chanhassen, MN 55317 USA
Tel (612) 949-7000
Telex 4310012
Fax (612) 949-7001

ROSEMOUNT™ MEASUREMENT

FISHER-ROSEMOUNT™ Managing The Process Better.™