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VALVE POSITION MONITORING AND SMART DISCRETE CONTROLS

THE AUTHOR DESCRIBES THE TECHNOLOGICAL STEPS LEADING TO THE DEVELOPMENT OF MODERN CONTROL TRANSMITTERS, WHICH PRECISELY MONITOR AND CONTROL PROCESS VALVES IN CRITICAL SERVICE APPLICATIONS AND PROVIDE PREDICTIVE MAINTENANCE SIGNATURES THROUGH SLEW SPEED AND PRESSURE PROFILE DATA/GRAPHING.

BY JACK DiFRANCO, JR.

During the past century, the operation of process plants has transitioned through various stages of automation. Each stage has lasted several decades before being supplanted by a significant shift in technology.

Not surprisingly, the world of on/off valves has followed a similar pattern of technological change. The need for lower plant operating costs, greater efficiency and increased safety, coupled with improved downstream control devices and enhanced instrument diagnostics, has created markets for more advanced means of monitoring discrete valve position.

Background

In automated manufacturing and processing plants, position sensors help monitor and control production processes by confirming that critical activities are completed as intended. More specifically, their primary function is to detect the presence, or absence, of a moving object or "target."

Various industries utilize actuated valve systems. For example, in petrochemical plants, actuated valve systems control fluid flow during processing operations. On offshore oil platforms, they are a critical component of an emergency shutdown system (ESD). In these applications, it is desirable to know the exact status of the valve (i.e., open or closed) on a continuous basis.

Valve position indicators are electrical switching devices mounted directly on a valve actuator, or indirectly using non-contact remote feedback devices. They are employed with both rotary-actuated valves and linear-actuated valves and provide two basic switching options: non-contact and mechanical. Non-contact switches and proximity sensors enunciate position in the presence or absence of a target, either magnetic in the case of reed switches and Hall Effect sensors, or metal (ferrous or non-ferrous) for inductive or TTL sensors. Energized arms

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connected to a moving stem or shaft activate mechanical switches.

Some valve position indicators provide visual position information on a rotating dial or sliding scale. Other products feature a light-emitting diode (LED) indicator or both forms of feedback. The latest control monitors, in addition to position feedback LEDs, include output-state LEDs that provide visual indication of voltage to the solenoid. This confirms that power is being delivered by the I/O card to the device and assists in field diagnostics. Valve position indicators with position transmitters are also available. These devices provide continuous, signal-based information about a valve's open, closed or intermediate position.

One problem with valve position indicators is the potential for false-position feedback. Minor fluctuations in actuator pressure, seat wear inside the valve or external stresses on the switch package can cause misalignment between a signal trigger and a sensor or switch. This misalignment can cause the operator to get a false-position reading carrying the potential for nuisance trip alarms or, in critical service valves, a possible process shutdown.

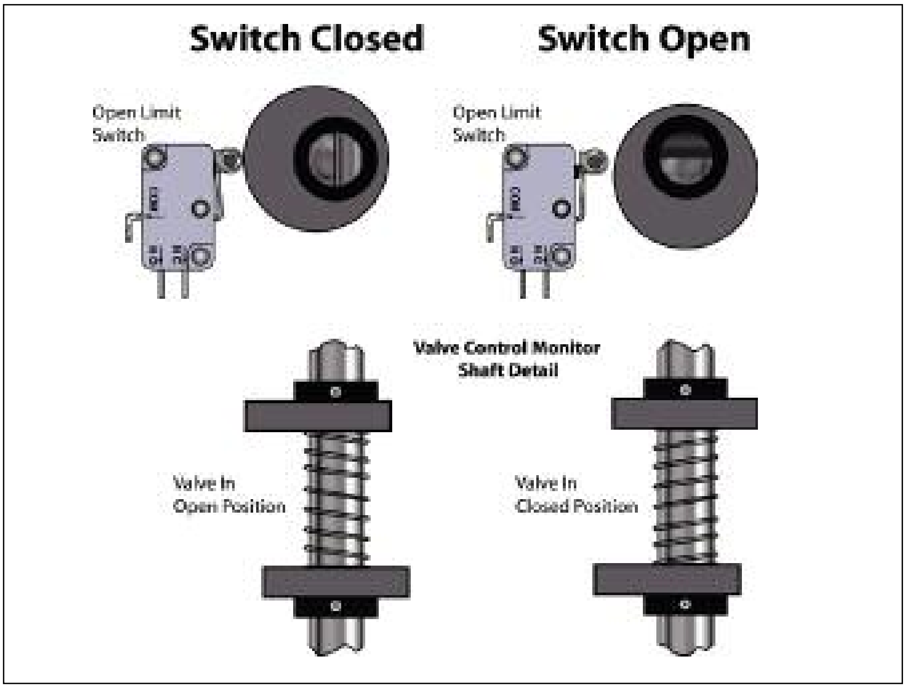

Figure 1—Mechanical limit switch

Technology Progress

Valve position feedback, while essential in most process operations, has traditionally been a straightforward affair. Typically, "0" is closed and "1" is open. Historically, the primary means for generating this discrete signal involved a trigger acting upon a mechanical magnetic proximity reed switch, or a ferrous target and proximity solid-state sensor.

Valve monitoring and control has progressed from early techniques where plant operators were required to manually turn valves to their proper positions, to today's state-of-the-art electronic controllers providing continuous feedback of valve position via an analog or digital signal.

Pneumatic actuators were the first solution allowing plant personnel to automatically open and close valves in the field. Subsequent advancements in process automation, such as the Distributed Control System (DCS) and Programmable Logic Controller (PLC), created the need for electrical feedback of valve position. The introduction of the "switchbox" added a visual display of valve position to the electrical feedback and helped reduce wiring costs.

Most recently, reductions in plant personnel and pressure for increased productivity have led to the adoption of digital bus communicating process control architectures and compatible on/off devices.

The progression of technology for valve position monitoring has included:

Mechanical limit switches

Mechanical limit switches were once regarded as the industry standard for valve position monitoring. This electromechanical switch determines the physical position of equipment by making direct physical contact with a target. For example, an extension on a valve shaft mechanically trips a limit switch as it moves from open to shut or shut to open. The switch provides an on/off output corresponding to the valve position. Normally, limit switches are used to provide full open or full shut indications (Figure 1).

Over the years, mechanical limit switches gained a reputation for poor repeatability and hysteresis as well as corrosion susceptibility. This discouraged their use in many newer automated valve positioning systems.

Reed switches

Reed switches are more reliable than mechanical switches due to their simplified construction and isolation from the surrounding environment. They are magnetically actuated switches typically manufactured with two ferromagnetic reeds (contact blades) sealed in a glass capsule. Commonly referred to as hermetically sealed switches, this design inherently prohibits the presence of "arcing" or "sparking" contacts in potentially explosive atmospheres and allows installation of the devices in a NEMA 4x enclosure in Class 1 Division 2 hazardous areas. In operation, the reeds are placed near the intended travel of the valve stem or control rod extension that is a permanent magnet. As the magnet approaches the reed switch, the switch makes (closed contact). When

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"We installed non-contact smart positioners and position transmitters several years ago and find the reliability and accuracy to be superior over mechanical feedback devices. The problem we had in the past is that our harsh environment caused mechanical feedback devices to fail prematurely. We have replaced our standard limit switch packages that included Tungsten reed elements and direct-acting solenoids with bifurcated switches with integrated, low-power solenoid valves. We have noticed a significant improvement with the reliability of these new devices in our digital I/O applications."

—**Steve Ducros, I/E Reliability, Chevron Chemical, Belle Chase, LA**

the magnet moves away, the switch breaks (open contact) (Figure 2).

Unlike a mechanical switch, the reed switch design requires no physical contact with the measurement target. This advantage led to the switch's adoption for a wide range of valve actuation solutions during recent decades.

Performance Issues

Despite advancements in switch technology, automation suppliers continue looking for new ways to address valve performance issues in process control. Corrosion resistance is a major consideration in today's low-voltage industrial applications. Humidity, hazardous chemicals and gases, as well as dirt and debris, all decrease the reliability and life expectancy of a switching device.

Corrosive environments

Mechanical limit switches have little protection against moisture, dust and corrosion, and with exposed contacts, are unsuitable for use in hazardous areas. Plus, as mechanical devices, they rely on multiple moving parts—making them subject to premature wear and failure.

Conventional reed switches are often misapplied in process valve applications. Manufacturers responded to the corrosion problem inherent in mechanical switches by packaging reed switches in hermetically sealed enclosures to protect their elements from hostile environments. They also improved the switch's mean time between failure (MTBF) in high- and low-current applications (0.01-3 amps) by utilizing either tungsten or rhodium element material (tungsten being the material of choice for high-current service while rhodium is the preferred material for low-current applications).

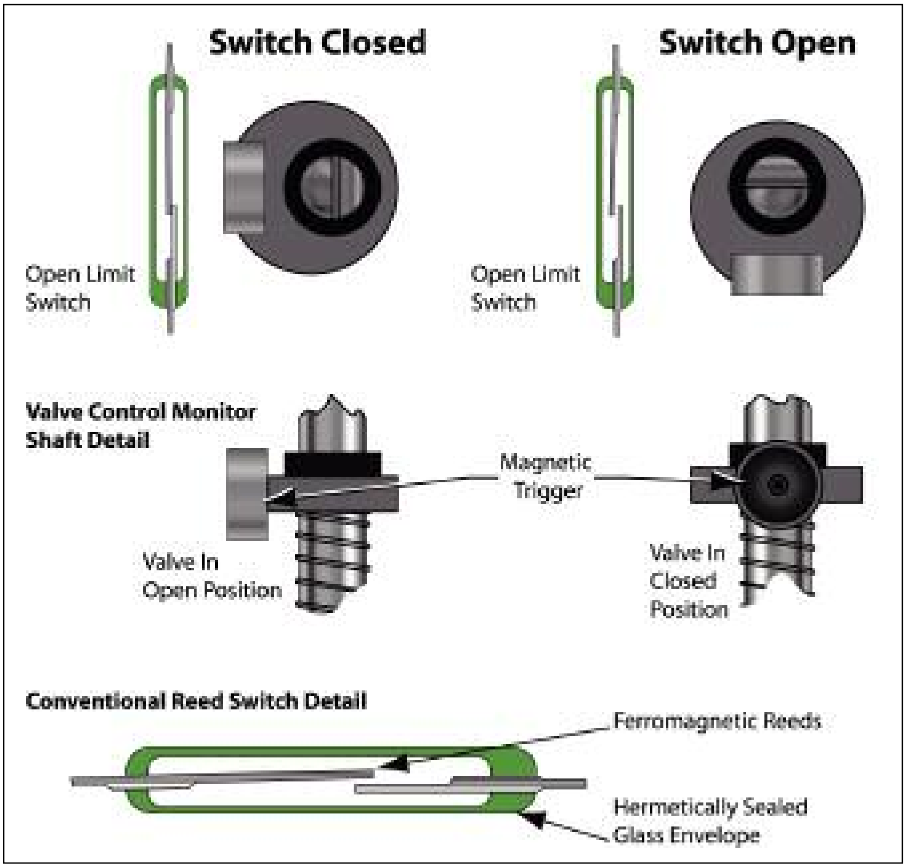

FIGURE 2—CONVENTIONAL REED SWITCH

Element oxidation

The reliability of reed switches came into question following the industry's adoption of digital technology. Even reed switches with tungsten elements can fail in low power applications (I <240mW) for discrete I/O.

As a reed switch opens and closes, it exposes a gap between the tungsten elements where oxidation can accumulate. This condition is most likely to occur in high-cycle applications. Before the advent of digital technology, current loads were sufficient to clean the switch contacts during each cycle. These higher currents were present in I/O loops prior to the use of HMIs to display process data, as control panels utilized small incandescent lights to confirm the position status of valves and other discrete I/O. These small bulbs pulled enough current through the switch elements to prevent the buildup of oxides.

Tungsten oxide buildup can increase the resistance of reed switch elements to the point where the host system can no longer accurately read whether the switch is open or closed. As a result, the operator receives an erroneous "open" valve position reading at all times. High temperature can also cause the oxidation to become sticky and freeze the switch in either the open or closed position.

Capacitor discharge

Reed switches are prone to failure in

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high voltage (120 VAC) applications using digital I/O—regardless of whether they include conventional, tungsten or rhodium elements. The switches have the potential to arc and weld shut while opening and closing. If the I/O channel has a capacitance value > .01μF there is enough charge potential to weld the switch contacts. The capacitance can be easily determined by measuring the capacitance of the I/O loop to earth ground.

Switch adjustment

For many end users, adjusting electromechanical switch settings for a given valve application is no easy task. That is because the characteristics of valve design and operation vary greatly between high-performance valves, such as metal-seated butterfly valves, and standard ball valves.

For instance, if metal-seated valves are set too loose, the switches do not provide accurate position feedback, which could lead to seat damage. If ball valves with soft seals are set too tight, the switches may create unnecessary nuisance alarms.

Design Improvements

The industry responded to the challenges of discrete valve control in the digital world by enhancing conventional reed switch designs and by developing solid-state proximity sensors immune to problems such as contact wetting arising in low-voltage applications.

Bifurcated reed switches

Increasingly, the valve industry is converting from valve position monitoring using conventional reed switches to equipment upgraded with bifurcated reed switches. These devices address the shortcomings of conventional reed switches in applications where ultra-low-power or capacitive discharge considerations apply. Bifurcated switches incorporate a two-pronged switch design creating a self-cleaning "snap action" movement that prevents contact oxide buildup and breaks non-resistive loads. This allows for a universal application of the switches in low-current and/or high-voltage digital I/O (Figure 3).

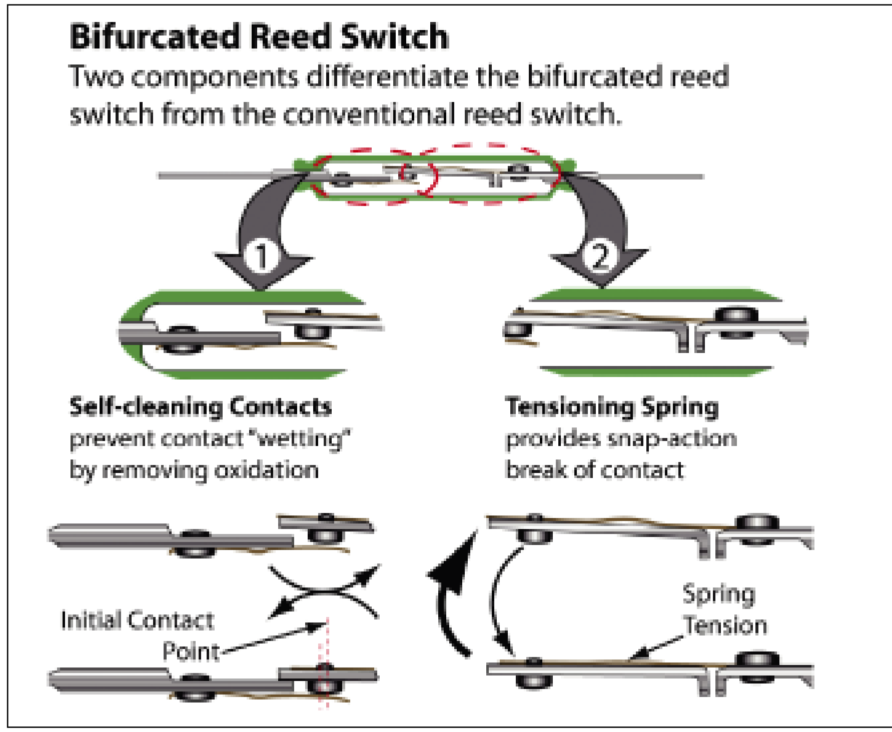

FIGURE 3—BIFURCATED REED SWITCH

Solid-state proximity sensors

Solid-state proximity sensors are primarily of three types: capacitive and inductive, which develop a bi-state output, and Hall Effect, which sense magnetic flux density developing a proportionally varying output voltage (Hall Effect sensors are discussed in the following section).

Inductive proximity sensors detect the position of metal targets via the disturbance of their electromagnetic field and work with virtually all metals, including non-ferrous metals. The sensor generates a high-frequency oscillation in an inductive coil creating the sensing magnetic field. As the metallic trigger moves into the sensing field, the oscillation is dampened. A detector monitors the oscillator's strength and triggers an output signal for feedback or other control actions.

Capacitive proximity sensors detect the position of a target via the disturbance of their electrostatic field and work with virtually all materials. The capacitance of the sensor is altered in the proximity of the trigger material. A detector monitors the capacitive charge and triggers an output signal for feedback or other control actions (Figure 4).

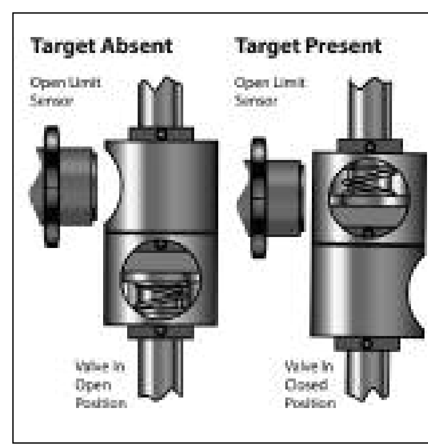

FIGURE 4—SOLID-STATE PROXIMITY SENSOR

Solid-state proximity sensors are an effective answer to the problems of element oxidation and capacitor discharge affecting reed switches. These sensors do not require physical contact with the target, and are unaffected by dust and dirt as long as target-sensing distances are not compromised. Plus, they have no moving parts to jam, wear or break.

Despite these advantages, solid-state sensors have a current leakage rate and voltage drop that can influence valve position readings. Care must be exercised in the selection of sensors and I/O

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cards to ensure compatibility of the I/O card's minimum current level to achieve its "off" state and the sensor's leakage current. Solid-state sensors also have difficulty handling high-current loads.

Non-contact Solution

Because of limitations inherent in their design, mechanical switches, reed switches and solid-state sensors cannot optimize valve performance in critical service applications where timely response to valve/actuator failure is essential. As a result, the valve equipment industry has developed a new breed of positioning devices that have changed the way valves are monitored and controlled.

Control transmitter

Today's control transmitters, utilizing advanced, microprocessor-based intelligence, provide reliable, consistent feedback on process valves—regardless of what position they are in. The transmitters elevate valve control performance to a new level by eliminating position blind spots during the stroke of a valve (Figure 5).

Digital control transmitters supply HART-enabled 4-20 mA continuous position feedback for both discrete rotary and linear valves. The transmitter design incorporates an integrated, low-power solenoid that reduces the power levels for actuation control to 5% of the energy required for operation of conventional solenoids (Figure 6).

Due to their precision measurements, control transmitters enable end users to establish the true open and closed positions for each category of valve in the plant. Accurate measurement of valve position also provides the precision data required for the use of advanced control strategies and predictive maintenance algorithms.

By delivering high-resolution valve position readings with continuous feedback to the operator, control transmitters eliminate many troublesome nuisance alarms—a key advantage for users faced with high maintenance costs on offshore rigs or at other unmanned facilities.

Hall Effect sensor

With the control transmitter, position sensing can be performed by non-contact means via an integrated Hall Effect sensor and magnet assembly detecting the proximity, presence or absence of a magnetic object using a critical distance. The sensor functions via an electrical potential developed across an axis transverse to an applied current flow in the presence of a magnetic field applied to the conductor (Figure 7).

FIGURE 5—TYPICAL APPLICATION/DIGITAL CONTROL TRANSMITTER

Hall Effect sensors used for valve positioning offer enhanced reliability in extreme environments. The sensor eliminates all mechanical contact between the actuator and the transmitter. As there are no moving parts involved within the sensor or magnet, typical life expectancy is improved compared to traditional electromechanical switches. Additionally, the sensor and magnet may be encapsulated in an appropriate protective material.

User Benefits

The evolution of discrete valve positioning, as evidenced by the development of "smart" control transmitters, is keeping pace with user demands for lower total cost of ownership, reduced maintenance, higher reliability and increased process uptime.

Greater versatility

Unlike conventional positioning devices, a control transmitter utilizing Hall Effect sensors provides feedback of valve position without the need for linkages, levers, or rotary and linear seals. This allows a remote sensor head assembly to be mounted a considerable distance from the electronics enclosure. The result: greater application versatility and improved safety for technicians performing maintenance work in the field.

The transmitter's remote mounting feature is particularly beneficial for high-vibration environments, such as power plants and compressor stations, which cause equipment wear and hysteresis in mechanical devices.

Higher reliability

The use of a robust, non-contact sensor and low-power solenoid enables a control transmitter to achieve a higher safety integrity level (SIL) rating than a conventional valve positioner. SILs are a measure of system performance: in low demand mode, SIL is a proxy for probability of failure on demand (PFD); in high demand/continuous mode, SIL is a proxy for failure rate. The higher the SIL number, the better the safety performance.

With an average PFD value of 6.61 x 10^{-3} and a safety failure fraction (SFF)

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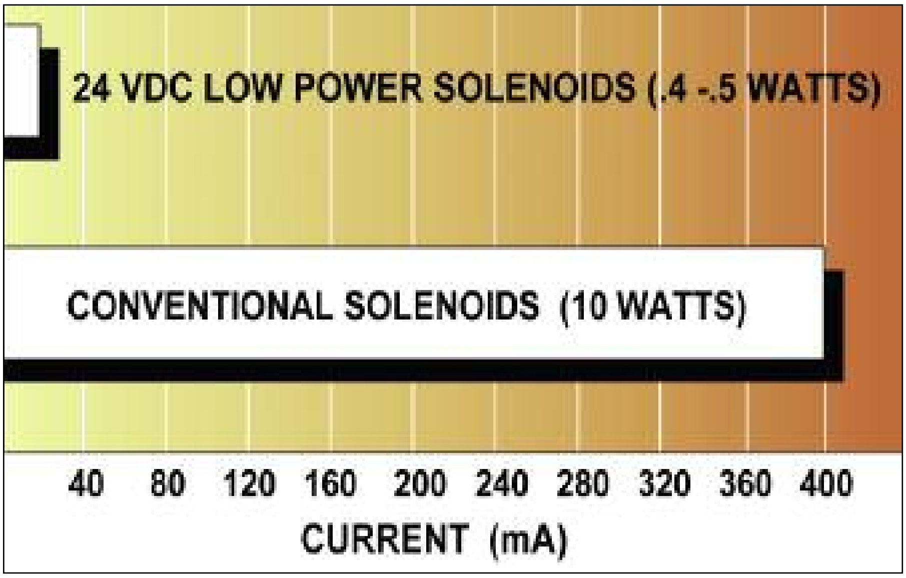

Figure 6—Low-power solenoid

value of 86.2%, control transmitters are a desirable alternative to positioners in emergency shutdown (ESD) and safety instrumented system (SIS) applications. This solution provides for a discrete output via the SIS to control an ESD solenoid with integrated partial stroke test functionality where calculations support an SIL3 application.

Easier calibration

Employing digital HART communications, control transmitters can read a remote signal for functions such as calibration, diagnostics, partial stroke testing, etc. The digital format eliminates the need for potentiometers used in analog positioners, removes the potential for human error when making calibration adjustments and provides a non-interacting zero and span consistent to every type of valve.

Control transmitter users can perform a single digital calibration, including auto-cal of zero and span, based on a uniform methodology for an entire population of valves. The user can determine what is open, and what is closed, for different style valves. This ensures the most accurate and reliable feedback possible.

Low cost-of-ownership

Control transmitters have a low cost-of-ownership thanks to precise positioning capabilities that can be customized by valve application, ease of calibration and service, and rich diagnostics for predictive maintenance signatures. New and enhanced digital devices now provide slew speed and pressure profile graphing for on/off applications.

Network compatibility

Control monitors and transmitters are also available that communicate via standard industrial protocols such as Foundation fieldbus, AS-I, Modbus, DeviceNet and Profibus. These devices combine the cost savings and increased diagnostic capabilities of networks with the advantages of these improved position sensors.

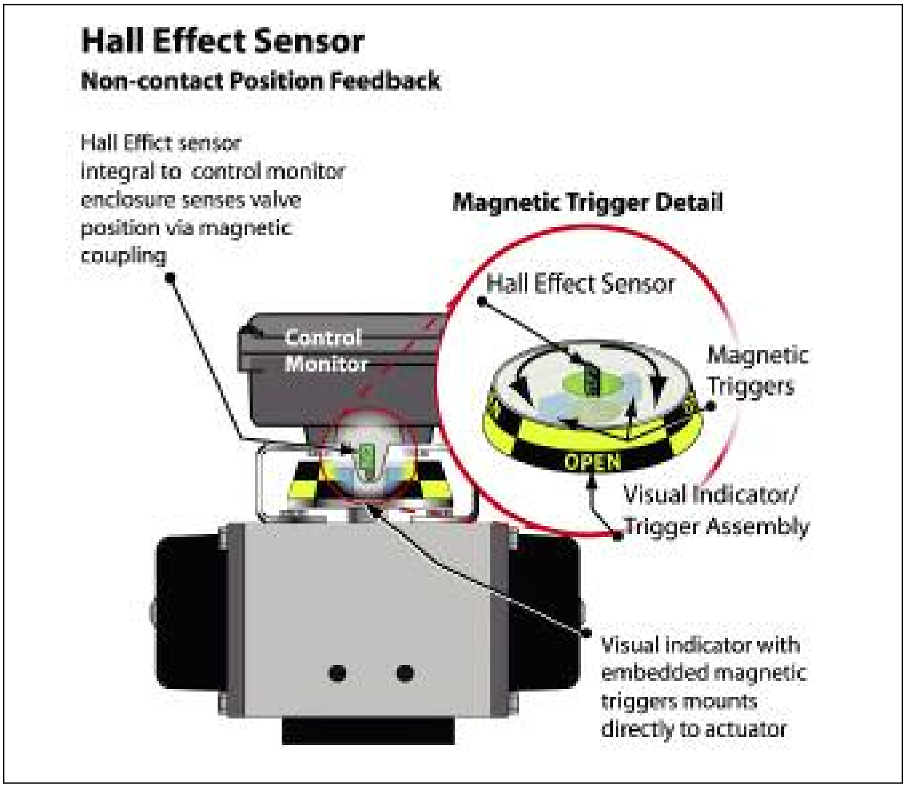

Figure 7—Hall Effect sensor

Conclusion

Today's intelligent control transmitters are versatile devices meeting a wide range of valve monitoring and control requirements. Whether it's a simple on/off function, hazardous or non-hazardous environment, or ESD system with partial stroke testing, digital position transmitters can handle virtually every control, monitoring and remote application in the plant. **VM**

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