Conductivity Sparks Solutionsfor Challenging Process Applications

Recent advances have improved and expanded applications in process industries

‘Conductivity measurement is ideal for a broad range of applications throughout all process industries.’By J. Kevin Quackenbush [1]

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Conductivity as a measurement technique has proven itself in applications ranging from controlling water purity to measuring the strength of the strongest, most aggressive industrial acids. Any application where water is heated, cooled, purified or conditioned is a candidate to benefit from the accuracy and affordability of a conductivity measurement approach. Recent advances in sensing technology have contributed to using conductivity for traditionally difficult measurements of aqueous concentrations of acids, bases and salts. An understanding of how conductivity measurement works and today’s conductivity capabilities can prove invaluable for your next concentration measurement challenge.

Connecting with Conductivity

Every binary solution, whether it is water, milk, or acid, is comprised of ions, most of which exhibit electrical conductivity. When the ion concentration increases or decreases, so can the conductivity. This usually provides a reliable means to measure the concentration by weight of the solution. For example, let’s look at water, the most abundant solution on earth. The typical ion in water is salt (NaCl). As the concentration of salt increases, so will the detectable conductivity. Because the same premise applies to other binary solutions, such as acids, bases or other salts, conductivity measurement is ideal for a broad range of applications throughout all process industries. Typical applications include condensate feed water for boilers, boiler blow-down, cooling towers, water for injection and rinse water, as well as acid and caustic concentration control, and heat exchanger leak detection.

The Real Measure

Two methods of sensing conductivity to accommodate a broad range of process conditions are contacting and electrodeless. A contacting conductivity sensor uses metal or graphite electrodes in direct contact with the fluid being measured. One electrode is excited by a high frequency AC signal, the resistance is then measured across the two electrodes and converted to conductivity. Electrodeless conductivity sensing uses multiple toroids that work together as sender-receiver. One set of toroids is energized by the analyzer, creating an induced current in the liquid, and the other toroids sense the field created. As the conductivity varies, the size of the sensed signal varies proportionally. Contacting conductivity (CC) sensors offer low detection limits and are usually used in applications with clean fluids, such as water. Where the measured value is typically less than 10 microsiemens per centimeter, CC should be considered. These “pure water” applications range from steam condensate and feed water for boilers and turbines, to “ultra pure” water (less than one microsiemen/cm resistivity – RS) for semiconductor processing. While CC/RS sensors are typically more accurate for precise and sensitive measurement (below 10 microsiemens/cm), they do have an inherent problem - sensor coating. The electrode surfaces must be maintained in pristine condition to provide accurate measurements. Anything that coats, fouls or otherwise contaminates them, adds resistance, which lowers the displayed conductivity value. Contaminates can include mineralization, oils, even bubbles. To assure accurate measurement, the CC/RS sensors must be inspected, cleaned and calibrated routinely. The maintenance schedule depends on the application and how often and seriously the sensors become coated, or how critical the measurement. It may be every couple of days, every week, every two weeks, but the consequences of neglect could be grave. It’s a lot easier and less costly to plan frequent maintenance and/or replace a contacting conductivity sensor than a turbine or boiler. Alternatively, electrodeless conductivity (EC) requires far less maintenance and is typically unaffected by coatings, such as chemical films and algae growth. The two most common EC configurations are insertion (invasive), which is immersed in the liquid flow, and flow-through, which is installed in, and becomes a section of, the process pipeline. The surface or material of an EC sensor is not critical to making the measurement. Instead, a field develops around the sensor head, and that field is what detects the resistance of the solution passing through. EC sensors can be used in applications with conductivity ranging from approximately five microsiemens to two million microsiemens (2,000 millisiemens). Newer, large bore insertion and flow-through EC sensors can operate at a minimum full scale range of zero to 50 microsiemens/cm with demonstrated measurement capability at or below approximately five microsiemens/cm. Electrodeless conductivity technology is predominant for demanding applications, such as acids and other aggressive materials and process conditions with temperatures up to 411&#176F and pressures to 300 psi+.

Advances in Conductivity Measurement

While conductivity measurement is a mature and established technology, recent

advances in system capabilities and materials have improved and expanded applications in process industries ranging from chemical to food and pharmaceutical. For instance, the Measurements & Instruments Division of Invensys Process Systems introduced Foxboro sensors made from PEEK, a thermo-plastic material proven to be compatible with the widest array of process solutions. Invensys- Foxboro also pioneered the used of virgin PEEK (P-oxyphenylene p-oxyphenylene p-carbooxyphenylene), which is FDA compliant and 3A approved for its sanitary sensors. For standard industrial sensors, the company uses glass-filled PEEK (polyetheretherketone), along with other alternate sensor materials for non-standard applications. These include PVDF (polyvinylidenedifluoride), PCTFE (polychlorotrifluoroethylene), Noryl, as well as borosilicate glass, glass-filled Teflon, virgin polypropylene, and several other thermoplastic materials. For sanitary applications, Invensys has developed a Foxboro electrodeless conductivity flow-through sensor that is appropriate for the full gamut of applications and allows the process to be automated. One example of how this improves operations and reduces costs is beer processing. As beer passes through a pipeline, the conductivity loop will display a product value of perhaps 3,500 microsiemens. At the end of the bottling cycle, the line is flushed out with a clean-in-place (CIP) solution. With the flow-through sensor in place as an integral part of the pipeline, it immediately recognizes the change in conductivity of the CIP solution, which is commonly sodium hydroxide (NaOH). The system automatically switches to the correct curve (e.g. NaOH at 50&#176C) and accurately measures conductivity during the CIP cycle. The converse happens as the arrival of the rinse water causes the conductivity to drop sharply. Again the correct curve is automatically applied (e.g. Dilute NaCl) and the system continues to measure the rinse cycle. When the conductivity rises to the predetermined level of beer, the process starts all over again. The completely automated conductivity loop is the cornerstone to automating the valve switching network to improve production efficiency and quality control, while reducing material waste and maintenance costs.
The sanitary flow-through design also allows in-line calibration while the process is running, which is critical for sanitary applications. In addition to not having to stop the process, the process line does not have to be opened to access the sensor, thus eliminating the need to have to recertify the process line as sanitary.

Conductive Solution

Following are two applications where conductivity sensing proved to be the cost effective solution. Sulfuric acid is one of the most important industrial chemicals worldwide. The highly corrosive properties of this clear and colorless fluid are critical in applications ranging from the production of fertilizers to removing oxides from iron and steel. But there is a subtler, more delicate side of sulfuric acid, and that is precise production. A variation of 0.1 percent in acid strength could corrode profits by increasing production and material costs, compromising quality and violating emissions standards. Producing sulfuric acid involves precisely combining sulfur, air and water. A major international chemical processing company accomplishes this by passing air through an oleum tower where it combines with sulfur trioxide (SO_3) and moisture to form sulfuric acid mist particles at 99+ percent strength. While the typical strength is in the 99.6 to 99.2 percent range, the

company needs the ability to measure up to 99.9 percent. A Foxboro conductivity measurement loop proved to be the solution. The system includes electrodless sensors and an intelligent analyzer that together measure acid strength by sensing changes in electrical conductivity. The sensor is installed in-line in a sample loop of the sulfuric acid towers. The analyzer/sensor determines the conductivity and converts that to concentration by weight, then the analyzer sends data back to the plant control systems. Based on these measurements compared to preset conductivity limits, the control systems bring in water or acid to reduce or maintain strength. To meet the specific materials compatibility demands of this application, Invensys provided a PFA Teflon-coated toroid head, combined with a Carpenter 20 alloy wetted metal housing, and Viton O-rings. However, for even more demanding applications, such as high purity acid where no wetted metal is permitted, other sensor selections are required…and available. To take full advantage of the sensor's resistant material and innovative design, the company worked closely with Foxboro engineers to develop a custom curve set. While the analyzer came programmed from the factory to handle the 99.5 percent to 93 percent range, the custom curve set allowed accurate measurement of 99.85-plus percent. With sulfuric acid, the higher the strength, the greater the profitability. This company has found that the reliability and robustness of both the sensor and analyzer have allowed them to consistently produce high quality, and highly profitable, sulfuric acid. The second example involves automating production of a high-value organic solvent. As part of the process, the high-value solvent separates from a salt concentrated by product. A critical step in the process is draining the heavier aqueous salt solution layer while leaving the lighter solvent. This was traditionally done by qualified technicians who would observe the fluids emptying the tank, relying on sight and individual experience to try to stop the flow at the right moment, to avoid losing the revenue rich chemical. However, even seconds of delay could result in the loss of thousands of dollars worth of profits quickly down the drain. The solution to this balancing act proved to be the Foxboro 871FT flow through sensor. The saltwater byproduct has a high ionic concentration, which exhibits a strong conductivity compared to the organic compound that exhibits negligible conductivity. The non-invasive sensors measure the ionic content of the liquids, and instantly signals when a sudden and significant change in conductivity occurs. This triggers a signal that shuts the drain. The result is greater process efficiency, reduced maintenance costs and reduced worker interaction with chemicals.

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