An Overview of Conductivity Measurement Technology

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Although conductivity measurement systems cannot necessarily tell you what is in the water you use every day, it can certainly tell you how much corrosive scale is building up in a boiler, how much dissolved solid content is removed by a filter, and how many conductive particles are accumulating in a rinse tank.

Conductivity controllers protect valuable capital equipment, ensure high product quality and keep production processes running efficiently. It may be the single most important component in some manufacturing organizations. It may be one of the least understood measurements as well.

Basic Conductivity Theory

The chemistry of conductivity measurement is complicated, but the basic principles are textbook knowledge. Pure water (H_2O) has a very high resistance to electrical current flow, and conversely very low conductive properties. Anything added to pure water reduces the resistance and increases the conductance. Resistance on Ohms is inversely proportional to conductivity, in mhos, which is the same as Siemens. To measure the resistance of a wire, a fixed DC voltage is applied by attaching two electrodes to the ends. The resistance of the wire causes a drop in the applied voltage which is used by the meter to calculate the resistance. The resistance of the wire is determined by its diameter and length. This measurement will always be the same because the modules in the wire don't change and are fixed in a pattern that makes electron exchange easy when a voltage is applied across the ohmmeter leads. Conductive solutions have a similar reaction to an applied voltage, but the path of the electrons is not so orderly.

Most chemical molecules disassociate easily in the presence of water, starting a string of actions and reactions that release positive and negatively charged ions into the solution. Different chemicals initiate ionic transfer at very specific levels and the unique characteristics of many chemicals are well known. When voltage is applied across two electrodes, positively charged ions in the solution attract electrons from the negative electrode. At the same time, negatively charged ions in the solution donate electrons to the positive electrode. As electrons randomly disperse through the solution, current begins to flow through the circuit. The voltage drop caused by the solution's resistance is measured and becomes the basis for calculating conductivity. Heat increases ionic mobility, which reduces resistance and increases conductivity. But the change in conductivity caused by temperature fluctuations needs to be isolated from the change caused by subtraction or addition of actual material from the water. Accurate temperature sensing and compensation is key to meaningful conductivity measurement.

Conductivity Measurement

Measuring resistance in a conductive solution is not as simple as measuring resistance in a piece of wire. The obvious first challenge is to rearrange the components of the measurement sensor to adapt to a liquid media. Conductivity sensor electrodes consist of two plates of carefully measured size, and are spaced a fixed distance apart. The size and spacing define the cell constant. A 1.0 cell constant has two plates 1 cm^2 placed 1 cm apart. The solution bridges the two surfaces and becomes the object of the measurement.

Laboratory sensors are made of glass and elemental metals and are designed for use off-line. They require periodic maintenance and careful handling. Industrial applications require rugged sensors, able to withstand wider ranges of temperature and pressure, and must be able to be installed on-line in piping systems.

Type 316 stainless steel is widely used for the electrode material as it offers the best performance over the broadest range of applications.

The natural process of electrolysis is an unavoidable by-product of applying direct current to a solution. It erodes the material of the sensor and adds chemically to the solution. Many industrial systems combat electrolysis by applying a square wave rather than a direct current. But, the physical construction of a conductivity cell and the chemistry of the solution create a capacitive effect that must also be minimized. Applying a square wave to a capacitive circuit causes the waveform to be distorted so it becomes very difficult to determine the optimum measurement with an acceptable degree of accuracy. Applying a sine wave substantially resolves this problem, since the gradual slope is less impacted by the capacitive effect than the square wave.

The Signet 9050 Intelek-Pro™ Conductivity Controller has adopted the more costly sine wave method, thus optimizing electrolysis prevention and signal quality.

The frequency of the sine wave combined with the capacitance of the solution directly control the shape of the output signal. As the solution varies in conductivity, a fixed frequency will result in signal degradation as a result of the impedance mismatch. Many systems on the market use a fixed frequency or switch between several frequencies based on the sensor cell constant. The resulting performance is optimized within a narrow range and suffers increasingly large errors at the extremes of the range.

The Signet 9050 incorporates an algorithm which continuously adjusts the frequency of the applied sine wave as the conductivity of the solution changes. This design approach insures that the system delivers optimum accuracy across the entire range.

Applications

The other half of a conductivity system is the controller which takes the signal from the sensor and translates it into working outputs that solve real needs in a wide variety of applications.

Features to look for include:

- dual channel capability
- wide dynamic range
- ease of use
- versatility in assigning control parameters.

Water treatment systems use two channels working in complement to provide "percent reject" data to monitor system performance. In some dual channel instruments, the cell constants must be the same or within a specified proximity to each other. The Signet 9050 allows independent dual channel measurement which can monitor two different sites simultaneously, regardless of their relative ranges.

In boilers and HVAC systems, conductivity measurement and control prevents scaling in pipes and optimizes water refresh rates. It is important that relays are not restricted in their function. They may be required to work at high alarms, low alarms, or pulsed to drive metering pumps. In addition to these function options, the 9050 also allows relays to respond to temperature rather than conductivity values, adding another dimension to the control possibilities.

Analog outputs such as 4 to 20 mA signals are frequently used to drive chart recorders required by regulatory agencies. The span of the current output should be user definable, so the best resolution for a specific application can be obtained. The bottom line for anyone in the market for a conductivity measurement system:

1) Look for accurate and economical sensors that work with versatile, reliable controllers that can be tailored to meet your requirements;

2) Don't settle for equipment that tries to force you to adapt your application to the controller.

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