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About Conductivity

All aqueous solutions conduct electricity to some degree. The measure of a solution's ability to conduct electricity is called "conductance" and is the reciprocal of resistivity (resistance). Adding electrolytes such as salts, acids or bases to pure water increases conductance (and decreases resistivity).

A conductivity system measures conductance by means of electronics connected to a sensor immersed in a solution. The analyzer circuitry impresses an alternating voltage on the sensor and measures the size of the resulting signal, which is linearly related to the conductivity.

Because conductivity has a large temperature coefficient (as much as 4% per °C—see Fig. 1), an integral temperature sensor incorporated into its circuitry adjusts the reading to a standard temperature, usually 25°C (77°F).

Historically, the unit of conductivity measurement has been the "mho/cm" (a mho is the multiplicative inverse of an ohm).

A resistivity of 100 ohms x cm is equivalent to a conductivity of 1/100 mho/cm. The mho/cm unit of measurement is now being replaced in industry by an equal and interchangeable international unit called the "Siemen/cm." Conductivity is usually expressed in millionths of a Siemen, that is, in microSiemen/cm. Resistivity is still expressed in terms of Megohm (MΩ) x cm for high purity water – usually from 0.1 to 20 MΩ x cm.

RESISTIVITY

In high purity water, with conductivity typically less than 1 microSiemen/cm, the measurement is referred to as "resistivity" with units being MΩ x cm. Pure water has a resistivity of about 18.3 Megohm x cm at 25°C. One consideration that must be made when measuring solutions is the temperature coefficient of the conductivity of the water itself. To compensate accurately, a second temperature sensor and compensation network must be used. Specific sensors and analyzers are recommended for measurement in high purity water.

About Conductivity Sensors...

The contacting-type sensor usually consists of two electrodes, insulated from one another. The electrodes, typically 316 stainless-steel, titanium-palladium alloy or graphite, are specifically sized and spaced to provide a known "cell constant." Theoretically, a cell constant of 1.0 describes two electrodes, each being one square centimeter in area and spaced one centimeter apart (Fig. 3).

Cell constants must be matched to the analyzer for a given range of operation. For instance, if a sensor with a cell constant of 1.0 were used in pure water with a conductivity of 1 microSiemen/cm, the cell would have a resistance of 1,000,000 ohms. Conversely, the same cell in seawater might have a resistance of 30 ohms. Since the resistances are so different, it is difficult for ordinary instruments to accurately measure such extremes with only one cell constant.

In measuring the 1 microSiemen/cm solution, the cell would be configured with large electrodes spaced a small distance apart. This results in a cell resistance of approximately 10,000 ohms, which can be measured quite accurately. Using cells with different constants, the measuring instrument can operate over the same range of cell

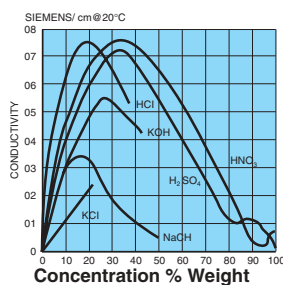


Figure 1
Conductivity vs. Concentration

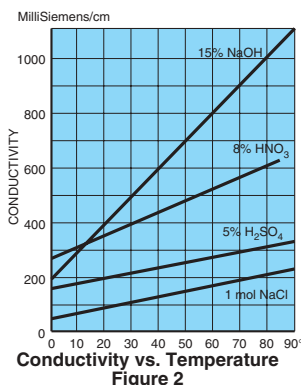
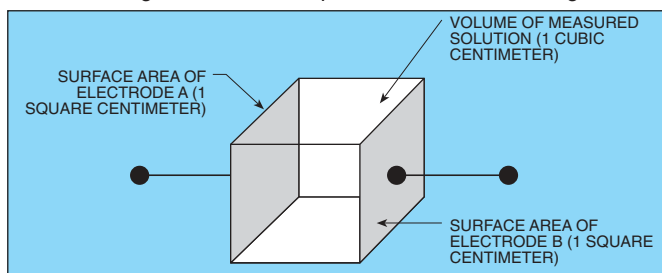


Figure 2
Conductivity vs. Temperature

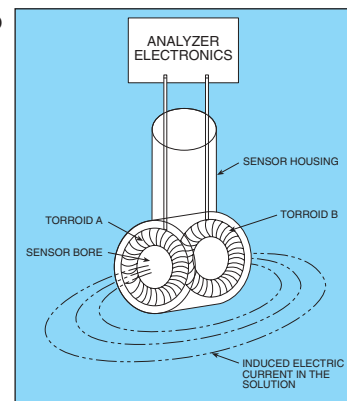


Theoretical Cell Constant of 1.0
Figure 3

resistance for both ultra-pure water and high conductivity seawater.

The electrodeless type of sensor operates by inducing an alternating current in a closed loop of solution and measuring its magnitude to determine conductivity (Fig. 4). The conductivity analyzer drives Torroid A, which induces the alternating current in the solution. This ac signal flows in a closed loop through the sensor bore and surrounding solution. Torroid B senses the magnitude of the induced current, which is proportional to the conductance of the solution. This signal is processed in the analyzer to display the corresponding reading.

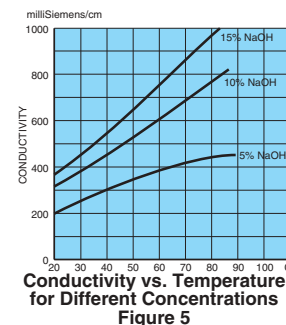
Since the electrodeless sensor has no electrodes, common problems facing contacting-type sensors are eliminated. Polarization, oily fouling, process coating or non-conducting electrochemical plating do not affect the performance of electrodeless sensors until gross fouling occurs.



Electrodeless Sensor
Figure 4

TEMPERATURE COMPENSATION

Conductivity measuring system accuracy is only as good as its temperature compensation. Since common solution temperature coefficients vary on the order of 1-3% per °C, measuring instruments with adjustable temperature compensation should be utilized. Solution temperature coefficients are somewhat non-linear and usually vary with actual conductivity as well (Fig. 5). Thus, calibration at the actual measuring temperature will yield the best accuracy.



Conductivity vs. Temperature for Different Concentrations
Figure 5

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