

## Use and Calibration of Field Meters

The three major uses for a field meter during servicing of a continuous water-quality monitor are (1) as a general check of reasonableness of monitor readings, (2) as an independent check of environmental changes during the service interval, and (3) to make cross-section surveys or vertical profiles in order to verify the representativeness of the location of the sonde in the aquatic environment. The field meter should not be used directly to calibrate the water-quality monitor nor in the computation of monitor records. With the exception of temperature, it is important not to give too much credence to meter-to-meter comparisons. Independent field measurements must be made before, during, and after servicing the monitor to document environmental changes during the service interval. Measurements are made at the monitoring site by locating calibrated field instruments as close to the sensor as possible and at 5-minute intervals, or more frequently if necessary.

Before site visits, all support field meters should be checked for operation and accuracy. Minimum calibration frequency for each type of meter is detailed in Anderson (2004) and Wilde and Radtke (2005). All calibrations must be recorded in instrument logbooks, along with all calibrations, measurements, results from USGS National Field Quality Assurance (NFQA) Program samples, and information about sensor replacements, instrument upgrades, or other periodic calibrations.

## Temperature

Proper certification and documentation for liquid-in-glass thermometers and thermistor thermometers are detailed in Radtke and others (2004). Thermometers must be calibrated or checked against a calibration thermometer, which is either certified by the National Institute of Standards and Technology (NIST) or certified by the manufacturer as NIST traceable (Radtke and others, 2004). Liquid-in-glass thermometers and thermistors must be accurate within  $\pm 0.2$  °C. For both thermistors and liquid-in-glass thermometers, an annual five-point calibration is required over the temperature range of 0 to 40 °C using a temperature-controlled water bath and an NIST-certified or NIST-traceable thermometer to ensure accurate temperature measurement. In addition, two-point calibration checks over the maximum and minimum expected annual temperature range must be made three or more times per year for thermistors and two or more times per year for liquid-in-glass thermometers. Calibrated thermometers and thermistors must be marked with the date of calibration.

## Specific Conductance

Proper calibration and documentation for specific conductance meters are detailed in Radtke and others (2005). Calibration and adjustments for multiparameter sensor systems are found in manufacturers' servicing manuals. Calibration standard solutions of known quality that bracket the expected full range of anticipated values are used to calibrate the specific conductance meter to the appropriate units for particular field conditions. Calibration is performed at the field site with calibration standard solutions that have been allowed to equilibrate to the temperature of the water being monitored. The USGS reports specific conductance compensated to 25 °C. Most meters have automatic temperature compensation circuits that permit readings in microsiemens per centimeter at 25 °C, but this should be verified by checking the manufacturer's instruction manual. The accuracy of the meter should be within 5 percent for specific conductance values less than or equal to 100  $\mu\text{S}/\text{cm}$ , or within 3 percent for specific conductance values greater than 100  $\mu\text{S}/\text{cm}$ . Specific conductance standards are available from the USGS National Field Supply Service (NFSS). Calibration standard solutions must be discarded after use as described by Wilde (chapters variously dated).

## Dissolved Oxygen

Proper calibration and documentation for DO meters are detailed in Lewis (2005). Calibration and adjustments for multiparameter sensor systems are provided in manufacturers' servicing manuals. The most commonly used DO sensors measure the partial pressure of DO by the flow of oxygen through a porous membrane and oxygen consumption at a cathode. The calibrated accuracy of DO meters should be

within the lesser of 5 percent or  $\pm 0.3$  mg/L. Meters must be calibrated to 100-percent DO saturation and checked with a zero DO solution to provide an indication of sensor-response linearity. Calibration of a DO meter at 100-percent oxygen saturation is made by adjusting the meter reading for air saturated with water vapor to a value obtained from a DO solubility table (<http://water.usgs.gov/software/dotables.html>; Lewis, 2005) generated from the equations of Weiss (1970). The DO solubility is based on the water temperature, the uncorrected barometric pressure, and salinity. A reliable pocket altimeter can be used to measure uncorrected (true) barometric pressure to the nearest 1 millimeter (mm) of mercury; a specific conductance meter can be used to measure salinity. The accuracy of a DO meter at 0.0 mg/L is verified by measuring the DO of a fresh solution of sodium sulfite, prepared as described by Lewis (2005). The zero-DO measurement also serves to ensure the integrity of the electrolyte solution, the membrane, and the retaining ring. Calibration and operation procedures differ among instrument types and makes, and the manufacturer's instructions must be followed closely.

## pH

A detailed description of the 10-step calibration process for pH meters, including a wide range of available equipment, is provided by Radtke and others (2003). Calibration and adjustments for multiparameter sensor systems are available in manufacturers' servicing manuals. Accuracy of field pH meters should be at least  $\pm 0.1$  pH unit. Two standard buffer solutions bracketing the expected range of environmental values are used to calibrate a pH electrode, and a third is used as a check for calibration range and linearity of electrode response. The pH-7 buffer is used to establish the null point, and a pH-4 or pH-10 buffer is used to establish the slope of the calibration line at the temperature of the solution. The slope of a pH electrode is temperature sensitive, but the pH slope for modern sensors usually is adjusted to the observed temperatures through automatic temperature compensation by use of the theoretical Nernst equation (Radtke and others, 2003). It is important that the temperatures of the buffers be as close as possible to the samples being measured. Immersing the pH buffer bottles in the aquatic environment for about 15 minutes allows the buffer temperature to equilibrate to the aquatic environment. Standard buffers of pH 4, 7, and 10 are readily available from the NFSS. Proper calibration of pH sensors does not ensure accurate pH measurements for low specific conductance waters. Consult the USGS National Field Manual for the recommended procedure when the specific conductance of the water sample is less than 100  $\mu\text{S}/\text{cm}$  (Busenberg and Plummer, 1987; Radtke and others, 2003).

## Turbidity

Proper calibration and documentation for turbidity meters are described by Anderson (2004). The three types of turbidity

calibrants are (1) reference turbidity solutions, (2) calibration turbidity solutions, and (3) calibration verification solutions and solids. Reference turbidity solution is a calibrant that is synthesized reproducibly from traceable raw materials by a skilled analyst. The reference standard is fresh user-prepared formazin, prepared as described by Anderson (2004) or American Public Health Association (1998). All other calibrants are traced back to this reference solution. Calibration of a turbidity instrument by using reference turbidity solutions should be done only in the laboratory.

Meters are calibrated using calibration turbidity solutions, which must be traceable and equivalent to the reference turbidity calibrants. Acceptable calibration turbidity solutions include commercially prepared formazin, stabilized formazin (such as StablCal™), and styrene divinylbenzene (SDVB) polymer standards (such as Amco AEPA-1™ Polymer). Calibration turbidity solutions for various ranges are available commercially. Formazin-based calibrants can be diluted by using a dilution formula; however, errors may be introduced during the dilution process, thus reducing the accuracy of the standard solution. Formazin-based calibrants also are temperature dependent, and accurate readings may be difficult to obtain during field conditions. Anderson (2004) suggests that the effect of thermal fluctuations can be minimized by calibrating the instrument at room temperature in an office laboratory using a reference or calibration turbidity solution. Instrument calibration can then be checked at the field site by using a calibration verification calibrant.

Calibration verification calibrants may include, but are not limited to, calibration turbidity solutions; however, calibration verification calibrants that are sealed or solid materials must not be used to adjust instrument readings (Anderson, 2004). Before placing the sensor in a calibration verification calibrant, the sensor must be cleaned, rinsed three times with turbidity-free water, and carefully dried. Turbidity-free water is prepared as described by Anderson (2004).