

Instructions

accumet® Conductivity Cells Instruction Manual

Catalog Number	Compatible with accumet	Body Type	Nominal Cell-Constant cm ⁻¹	Cell Configuration	Ideal Range $\mu\text{S/cm}$
13-620-100	XL	Epoxy	1.0	Two Cell/ATC	10.0 to 2,000
13-620-101			0.1		0.5 to 200
13-620-102			10.0		1,000 to 200,000
13-620-155	Model 20-30-50, AB 30, AR 20-30-50-60	Glass	1.0	Two Cell	10.0 to 2,000
13-620-156		Glass	0.1		0.5 to 200
13-620-157		Glass	10.0		1,000 to 200,000
13-620-160		Epoxy	1.0		10.0 to 2,000
13-620-161		Epoxy	0.1		0.5 to 200
13-620-162		Epoxy	10.0		1,000 to 200,000
13-620-163		AB 30, AR 20-30-50-60, XL 20-30-50-60	Glass		1.0
13-620-164	Glass		10.0	1,000 to 200,000	
13-620-165	Epoxy		1.0	10.0 to 2,000	
13-620-166	Epoxy		10.0	1,000 to 200,000	
13-620-167	AP65	Epoxy	0.1	Two Cell/ATC	0.5 to 200
13-620-168			1.0		10.0 to 2,000
13-620-169			10.0		1,000 to 200,000
13-620-170			1.0	Four Cell/ATC	10.0 to 2,000
13-620-171			10.0		1,000 to 200,000

THEORY

Conductivity - Conductivity is defined as the ability of a substance to conduct electric current, with ions as the principal conducting agents. It is the reciprocal of the more commonly encountered term, resistivity. Conductivity offers a fast, reliable, nondestructive, inexpensive means of measuring the ionic content of a sample. The use of conductivity has the advantage of an almost direct relationship with impurities, especially at low concentration. Hence, a rising conductivity reading shows increasing impurities, or a generally increasing concentration in the case of a chemical stream (with some exceptions in concentrated solutions). Reliability and repeatability are excellent. The principle drawback of conductivity is that it is a nonspecific measurement; it cannot distinguish between different types of ions, giving instead a reading proportional to the combined effect of all ions present. Therefore it must be applied with some pre-knowledge of the solution composition or used in relatively pure (single solute) solutions to be successful.

Units of conductivity - The basic unit of resistance is the ohm. Conductance is the reciprocal of resistance, and its basic unit is the Siemen, formerly called mho. Specific conductance is commonly referred to as conductivity. Theoretically, conductivity is measured between the opposite faces of a 1-cm cube of the material. The units microsiemens/cm ($\mu\text{S/cm}$) and millisiemens/cm (mS/cm) are most commonly used to describe the conductivity of aqueous solutions. The corresponding terms for specific resistance (or resistivity) are ohm-cm ($\Omega\text{-cm}$), kilohm-cm ($\text{k}\Omega\text{-cm}$), and megaohm-cm ($\text{M}\Omega\text{-cm}$). Table 1 at the end of this manual lists some conversions between units.

Temperature effects - Conductivity has a substantial dependence on temperature. This dependence is usually expressed as a percent/ $^{\circ}\text{C}$ at 25°C . Ultrapure water has the largest dependence on temperature, at $5.2\%/^{\circ}\text{C}$. Ionic salts run about $2\%/^{\circ}\text{C}$, with acids, alkalis, and concentrated salt solutions are around $1.5\%/^{\circ}\text{C}$. Temperature variation causes frequent problems with conductivity

measurements when the solution under testing has a rapid varying temperature. The change in conductivity is instantaneous, since it is an electrical measurement. The thermistor, however, can have a response time of 15 seconds to several minutes. It is important to control the temperature since readings will continue to drift until the temperature has stabilized.

Polarization effects - When a DC voltage is applied across the electrodes of a conductivity cell, the ions present in the solution will be discharged onto the electrode. Ions will either accept or surrender electrons and change to the molecular form. Within a very short time, the flow of ions will virtually cease. Consequently the current will decrease to near zero. This is referred to as polarization, or a polarized state. Therefore, AC voltage is used for conductivity measurements. Polarization, however can take place during one half cycle of the AC current, resulting in the loss of current flow. This happens most often in samples that are high in conductivity.

CONDUCTIVITY CELLS

Construction - Simple conductivity sensors are constructed of an insulating material imbedded with platinum, graphite, stainless steel or other metallic pieces. These metal contacts serve as sensing elements and are placed at a fixed distance apart to make contact with a solution whose conductivity is to be determined. The length between the sensing elements, as well as the surface area of the metallic piece, determines the electrode cell constant, defined as length/area. In a two-cell unit, there are two sensing bands or plates. The cell constant is a critical parameter affecting the conductivity value produced by the cell and handled by the electronic circuitry.

The four-cell, or four band, conductivity cell consists of 4 bands along the measuring column. An AC voltage is applied across the two outermost bands (correcting bands), which causes a current flow through the measuring cell. Located between this pair of electrodes is a second pair of sensing bands. These sensing bands measure the voltage generated across the liquid. The measured voltage across the sensing bands is compared with the voltage measured by the correcting bands. Any difference between the measured voltages of the two pairs of bands (whether the conductivity of the solution changes or changes due to polarization or coating effects) initiates correcting action for the voltage across the correcting bands. The correcting action remains until the current through the cell generates a voltage across the correcting bands which equals the voltage between the sensing bands. Therefore, the four band conductivity cell can correct for any fouling or polarization, which may occur.

In order to produce a measuring signal acceptable to the conductivity meter, it is highly important that the user chose a conductivity electrode with a cell constant appropriate for the sample. Tables 2 and 3 located at the end of this manual list some typical conductivity values for various aqueous solutions.

Fisher accumet® Conductivity Cells

Cell Constant	Optimal Conductivity Range
0.1 cm ⁻¹	0.5 to 200 μS/cm
1.0 cm ⁻¹	10 to 2,000 μS/cm
10.0 cm ⁻¹	1,000 to 200,000 μS/cm

OPERATING INSTRUCTIONS

Installation - The conductivity cell should be placed into service as follows:

Prior to use, soak the conductivity cell in distilled or deionized water for 5 to 10 minutes. Connect the conductivity cell to the conductivity meter and follow the meter manual instructions for standardizing the cell for use at a given temperature. The cell constant value stated is nominal. It is only with standardization using a solution of known conductivity that an actual cell constant is calculated.

Note: When standardizing the conductivity cell, use a standard solution as close to the conductivity value of the sample as possible.

Sample measurement - Follow these steps for best results:

1. Rinse the conductivity cell sensing elements with distilled or deionized water between samples.
2. Best results will be obtained if the cell is rinsed with a small portion of sample before measurement.
3. Dip cell up and down in sample 2-3 times to completely wet surface.
4. Allow air bubbles to escape from conductivity cell side holes by tilting cell slightly.
5. It is important to control sample temperature since readings will continue to drift until the temperature has stabilized. A good rule of thumb is to allow 5 times the amount of time it takes for the thermistor to respond to allow the reading to stabilize. Any sudden dips or peaks should be ignored during this time.

Note: "Please ensure during measurement that, the side holes at the conductivity cell of the electrode are submersed in the measuring sample."

STORAGE

It is best to store the conductivity probe so that the electrodes are immersed in deionized water. If the conductivity probe is stored dry, it should be soaked in deionized water for 5 to 10 minutes to assure complete wetting of the electrodes.

CLEANING - For best results follow these procedures

The single most important requirement of accurate and reproducible results in conductivity measurement is a clean cell. A dirty cell will contaminate the solution and cause the conductivity to change. Grease, oil, fingerprints, and other contaminants on the sensing elements can cause erroneous measurements and sporadic responses.

1. For most applications, a hot solution of water with a mild lab. detergent can be used for cleaning.
2. A 1% dilute nitric acid may be used. Dip the cell in the 1% nitric acid and agitate for two to three minutes. Other dilute acids (e.g. sulfuric, hydrochloric, chromic) may be used for cleaning except for aqua regia. Rinse the cell several times with distilled or deionized water.

WARNING: Aqua regia will dissolve platinum.

3. When a stronger cleaning solution is needed, prepare a solution of concentrated hydrochloric acid mixed into 50% isopropanol. Dip the cell in the acid/alcohol solution and agitate. Rinse the cell several times with distilled or deionized water.
4. For lime and other hydroxide containing solutions, clean with a 5 - 10% solution of hydrochloric acid.
5. For solutions containing organic fouling agents (fats, oils, etc.), clean cell with acetone.
6. For algae and bacteria containing solutions, clean cell with a 10% chlorine bleach solution.

- Platinum conductivity cells of cell constant 1.0 **and** 10.0 are coated with platinum black before calibration. This coating is extremely important to cell operation, especially in solutions of high conductivity. Cells are platinized to avoid errors due to polarization. Cells should be inspected periodically and after each cleaning. If the black coating appears to be wearing or flaking off the cell or if the cell constant of any cell has changed by 50%, the cell should be cleaned and electrodes replatinized.

REPLATINIZING

Care should be taken when performing this procedure as the chemicals involved are potentially damaging to the conductivity cell.

- The platinum electrode should first be cleaned thoroughly in aqua regia, being careful not to dissolve the platinum. If cell remains too long in aqua regia, the platinum elements will dissolve completely.
- Prepare the solution of 0.025N HCl with 3% chloroplatinic acid (H_2PtCl_6) and 0.025% lead acetate.
- Connect the cell to a rheostat or 3 - 4 V battery to which a variable resistor has been connected.
- Immerse the cell in the chloroplatinic acid solution and electrolyze at 10mA/cm for 10 to 15 minutes.
- Reverse the polarity to the cell every 30 seconds until platinum electrodes are covered with a thin black layer.
- Disconnect the cell and save the platinizing solution. It may be conserved and reused many times and should not be discarded as it is expensive to make.
- Rinse the electrode with tap water for 1 to 2 minutes, followed by distilled or deionized water.

TABLE 1

CONDUCTIVITY/RESISTIVITY/TDS CONVERSIONS

CONDUCTIVITY (microsiemens/cm)	RESISTIVITY (ohms-cm)	TOTAL DISSOLVED SOLIDS (ppm)
0.056	18,000,000	0.0370
0.084	12,000,000	0.0554
0.167	6,000,000	0.1102
1.00	1,000,000	0.660
2.50	400,000	1.65
20.0	50,000	13.2
200	5,000	132
2000	500	1,320
20,000	50	13,200

NOTE: pm TDS = conductivity ($\mu S/cm$) x 0.66

TABLE 2

TYPICAL CONDUCTIVITY OF VARIOUS AQUEOUS SOLUTIONS AT 25°C

Material	Conductivity	Resistivity	Recommended Cell Constant
Purified Water	0.055 mS/cm	18 Megaohm-cm	0.1 cm ⁻¹
Power plant boiler water	0.055 - 1 mS/cm	1 - 18 Megaohm-cm	0.1 cm ⁻¹
Deionized water	0.1 - 10 mS/cm	0.1 - 10 Megaohm-cm	0.1 cm ⁻¹
Distilled water	0.5 mS/cm	2 Megaohm-cm	0.1 cm ⁻¹
Drinking water	0.3 - 1 mS/cm	1 Megaohm-cm	1.0 cm ⁻¹
0.01M KCl	1.4 mS/cm	0.7 kilohm-cm	1.0 cm ⁻¹
Ocean Water	53 mS/cm	Rarely Stated	10.0 cm ⁻¹
10% NaOH	355 mS/cm	Rarely Stated	10.0 cm ⁻¹
10% H ₂ SO ₄	432 mS/cm	Rarely Stated	10.0 cm ⁻¹
31% HNO ₃	865 mS/cm	Rarely Stated	10.0 cm ⁻¹

TABLE 3

COMMON CONVERSIONS FROM SPECIFIC CONDUCTANCE AND RESISTANCE AT 25°C

SPECIFIC CONDUCTANCE microsiemens/cm	SPECIFIC RESISTANCE Megaohm-cm	PARTS PER MILLION			GR./GAL. AS CaCO ₃
		AS ION	AS CaCO ₃	AS NaCl	
0.055	18.240	NONE	NONE	NONE	NONE
0.056	18.000	0.036	0.028	0.022	0.002
0.063	16.000	0.046	0.036	0.029	0.002
0.071	14.000	0.046	0.036	0.029	0.002
0.083	12.000	0.054	0.042	0.033	0.002
0.100	10.000	0.065	0.050	0.040	0.003
0.500	2.000	0.325	0.250	0.200	0.015
1.000	1.000	0.650	0.500	0.400	0.029
10.000	0.100	6.500	3.000	4.000	0.292
80.000	0.0125	52.000	40.000	32.000	2.340
625.000	0.0016	406.250	312.500	250.000	18.273
10,000.000	0.0001	6,500.000	5,000.000	4,000.000	292.398