Conductivity of Water

DOC316.52.93084

Based on ISO standard 7888:1985

1. Introduction

Conductivity of water allows measuring ionic constituents of all types of water including surface waters, process waters in water supply and treatment plants.

2. Principle

Conductivity is the ability of a solution, a metal or a gas - in brief all materials - to pass an electric current. In solutions the current is carried by cations and anions whereas in metals it is carried by electrons. How well a solution conducts electricity depends on a number of factors:

- Concentration of ions
- Mobility of ions
- Valence of ions
- Temperature

All substances possess some degree of conductivity. In aqueous solutions the level of ionic strength varies from the low conductivity of ultrapure water to the high conductivity of concentrated chemical samples.

Conductivity may be measured by applying an alternating electrical current (I) to two electrodes immersed in a solution and measuring the resulting voltage (U). During this process, the cations migrate to the negative electrode, the anions to the positive electrode and the solution acts as an electrical conductor.

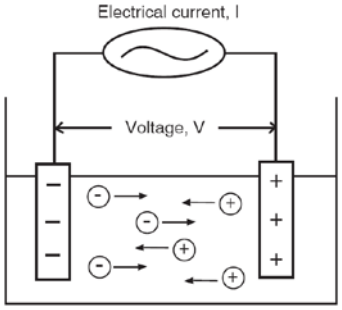


Figure 1: Migration of ions in solution

The resistance of the solution (R) can be calculated using Ohm's law as shown below. The resistance unit is [Ohms] or [Ω].

$$R = \frac{U}{I} [\Omega] \qquad \text{(Eq. 1)}$$

Where:

U = voltage [V]
I = current [A]
R = resistance of the solution [Ω]

The conductance (G) is defined as the reciprocal of the electrical resistance (R) of a solution between two electrodes. It is measured in Siemens [S] which equals [Ω^{-1}].

$$G = \frac{1}{R} \quad [S] \qquad \text{(Eq. 2)}$$

The conductivity meter measures the conductance, and displays the reading converted into conductivity.

The cell constant (K) is the ratio of the distance (d) between the electrodes to the area (a) of the electrodes.

$$K = \frac{d}{a} \quad [m^{-1}] \qquad \text{(Eq. 3)}$$

Where:

K = cell constant [m^{-1}]
a = effective area of the electrodes [m^2]
d = distance between the electrodes [m]

Commonly, K is expressed in [cm^{-1}] instead of [m^{-1}], because the cell dimension is expressed in [cm^{-1}].

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Electricity is the flow of electrons. This indicates that ions in solution will conduct electricity. Conductivity is the ability of a solution to pass current. The conductivity reading of a sample will change with temperature. The conductivity (κ) is defined as:

$$\kappa = G \times K \qquad [S/m] \qquad (Eq.\ 4)$$

Where:

G = conductance [S]
K = cell constant [m^{-1}]

Usually the cell constant K is expressed in [cm^{-1}], the conductivity κ is expressed in [S/cm^{-1}], or even in a more convenient unit such as [mS/cm^{-1}] or [$\mu S/cm^{-1}$].

Definitions:

- **Calibration:** Determination of the cell constant required converting conductance readings into conductivity results
- **Standard solution:** A solution of known conductivity that is used to calibrate the conductivity measuring chain
- **Reference temperature:** Conductivity readings are often referenced to a specific temperature (typically 20 °C or 25 °C) for comparative purposes
- **Automatic temperature correction:** Algorithms for automatic conversion of sample conductivity to a reference temperature

3. Electrode

Conductivity sensor: Intellical™ CDC401. The range of conductivity for this electrode is 0.01 µS/cm - 200 mS/cm, see section **6 Results** for additional specifications.

The temperature compensation law is valid for a conductivity range from 60 to 1000 µS/cm.

4. Application default settings

This application has been optimized with the following settings:

Name	Default parameter	Unit
Application		
Name	Water Conductivity	
Sample		
Name	Water ?[1]	
Amount	100	[mL]
QC		
Name	QC Sample	
Electrode		
Type	Conductivity	
Recommended electrode	CDC401	
Temp. compensation	Natural water 25 °C	
Method: Conductivity		
Active	Yes	
Max. stability time	150	[s]
Stability criterion	1	[%/min]
Stirring speed	20	[%]
Result 1 (R1) name	Conductivity	
R1 hide	No	
R1 QC min.	0	[uS/cm]
R1 QC max.	9999	[uS/cm]

[1] "?" in the name, indicates that the sample name will be automatically incremented with a number for each analysis

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Remarks on settings:

Sample amount

The sample amount of 100 mL is given as an indication. The sample volume must be sufficient to allow the conductivity sensor to be immersed in the solution being measured.

Temperature compensation

For **Natural Water**, the instrument is set to compensate the temperature at 25 °C in a measurement range between 0 to 35 °C, using the *"Natural Water Standards ISO/DIS_7888".* The conductivity range is about 60 to 1000 µS/cm.

For other types of temperature compensation such as **German drinking water regulation**, **Linear temperature compensation** or **No temperature compensation**, contact a Hach/Hach Lange application support engineer.

5. Procedure

5.1. Conductivity electrode calibration

If an electrode calibration is required, refer to section **8 Appendix: conductivity electrode calibration**.

5.2. Sample analysis

To avoid sample contamination, take a sample in a polyethylene bottle (not glass) and proceed to measurement as soon as possible to avoid gas exchange, such as CO_2, or biological activity. You can reduce biological activity by keeping the sample below 4 °C and in obscurity.

In **Direct measurement** (called by the application) the *Natural Water temperature compensation* is applied. For **Live measurement** there is no temperature compensation applied.

5.3. Electrode cleaning

For electrode cleaning recommendations, refer to the CDC401 conductivity probe user manual (DOC022.53.80022).

6. Results

Performance is directly linked to that of the CDC401 conductivity sensor:

	CDC401
Type of sensor	Standard Intellical™ Conductivity Probe - CDC401 Graphite, 4-pole conductivity probe
Cell constant	0.40 cm^{-1} ± 10%
Conductivity Range	0.01 µS/cm to 200.0 mS/cm
Accuracy	± 0.5% of the reading
Conductivity resolution	0.0 to 19.99 µS/cm: 0.01 µS/cm 20.0 to 199.9 µS/cm: 0.1 µS/cm 200 to 1999 µS/cm: 1 µS/cm 2.00 to 19.99 mS/cm: 0.01 mS/cm 20.0 to 200.0 mS/cm: 0.1 mS/cm
Operating Temperature range	-10 to 110 °C (14 to 230 °F)
Temperature accuracy	± 0.3 °C (± 0.54 °F)
Minimum sample depth	45 mm (1.77 in.)
Conductivity response time	> 99% in 30 s between KCl 0,01 D and KCl 1D
Temperature response time	95% of the response in 30 s between 5 and 40 °C

7. Bibliography

- *Water quality - Determination of electrical conductivity,* International standard **ISO 7888 (1985);** EPA method number 310.1
- User manual for conductivity probe models *CDC40101, CDC40103, CDC40105, CDC40110, CDC40115 and CDC40130*, DOC022.53.80022, Hach Company (2010)

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8. Appendix: conductivity electrode calibration

8.1. Electrode and standards

Conductivity sensor: Intellical™ CDC401

Cell constant K [cm^{-1}]	Conductivity range
K=0.4	0.01 µS/cm - 200 mS/cm

The temperature compensation law is valid for a conductivity range from 60 to 1000 µS/cm.

Conductivity standards:

Standard type	Description
KCl_1D	1D KCl, 111.3 mS/cm – 25 °C
KCl_0_1D	0.1D KCl, 12.85 mS/cm – 25 °C
KCl_0_01D	0.01D KCl, 1408 µS/cm – 25 °C
KCl_0_1M	0.1M KCl, 12.88 mS/cm – 25 °C
KCl_0_01M	0.01M KCl, 1413 µS/cm – 25 °C
KCl_0_001M	0.001M KCl, 146.93 µS/cm – 25 °C
NaCl_18mSPerCm	NaCl, 18 mS/cm – 25 °C
NaCl_1000uSPerCm	NaCl, 1000 µS/cm – 25 °C
NaCl_0_05Percent	NaCl, 0.05%, 1015 µS/cm – 25 °C
NaCl_25uSPerCm	NaCl, 25 µS/cm – 25 °C

8.2. Electrode calibration settings

Name	Default parameters	Unit
Application		
Name	Water Conductivity	
Electrode		
Type	Conductivity	
Recommended electrode	CDC401	
Calibration frequency	180	[Days]
Stirring speed	20	[%]
Calibration mode	Fixed	
Standard	0.01M KCl	
Min. cell constant	0.3	[cm-1]
Max. cell constant	0.5	[cm-1]
Temp. compensation	Natural water 25 °C	

8.3. Electrode calibration procedure

Calibrate the electrode with the KCl 0.01M standard or with another one selected from the available standard list. It is better to calibrate at 25 °C but if standard solution is not at 25 °C, an automatic temperature compensation is applied to correct the calibration computation (max. range: 0 to 50 °C). Choose a standard with a conductivity value as close as the conductivity of the sample you want analyzed.

According to ISO 7888-1985, 3 standards can be used: 0.1M, 0.01M and 0.001M KCl. Sensor calibration must be run at least every 6 months.

In the calibration process, the measurement is displayed without temperature compensation. When stability is reached, the temperature compensation of the standard is applied at the measurement temperature to compare both results and to determine the cell constant.

8.4. Calibration result

The calibration of the conductivity electrode is a one point-calibration. At the end of the analysis the resulting cell constant is returned.

The calibration should be accepted if the value of the cell constant is between 0.3 and 0.5 cm^{-1}, respectively the **Min. cell constant** and **Max. cell constant** parameters. See section **6 Results** for additional information on electrode performance.

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