Eijkelkamp
Soil & Water

EC-probe for soil conductivity measurements

Manual

Meet the difference

Eijkelkamp Soil & Water
Nijverheidsstraat 30, 6987 EM
Giesbeek, the Netherlands

T +31 313 880 200
E info@eijkelkamp.com
I www.eijkelkamp.com

M-1401E

Contents

On these operating instructions

☞ **If the text follows a mark (as shown on the left), this means that an important instruction follows.**

If the text follows a mark (as shown on the left), this means that an important warning follows relating to danger to the user or damage to the apparatus.The user is always responsible for its own personal protection.

Text **Italic indicated text indicates that the text concerned appears in writing on the display(or must be typed).**

Introduction

The standard EC-probe set for soil conductivity measurements consists of an EC-probe and an earth resistivity meter. It is used to measure electric resistivity of the soil, which is an indicator of soil salinity. The EC-probe can be operated at a depth of up to 110 cm.

Salinization means an increased salt concentration of the soil. The occurrence of salt in rooted soil impedes the water absorption of plants, causing drying out despite soil humidity. This in turn leads to a decrease in crop production. Salinization often occurs in irrigation areas, or in ecosystems affected by salt water such as lagoons. Salinization is also the result of salt strewn on the roads in winter.
The salt concentration of soil moisture depends on the total amount of salt and of the soil humidity. These salts may have been deposited by irrigation water, capillary rise of shallow groundwater in semi-arid areas, seawater flooding, and weathering of source material or by soil pollution. Nutrient salts originating from the decomposition of organic material or from the application of fertilisers also contribute to the soil salt content. Dissolved salts largely effectuate electric conductivity of the soil. Since the conductivity is measured on the soil as it is, the measured value also stands for “bulk soil conductivity“. Only after extraction of the pore water (by soil moisture sampling, centrifuging or displacement) one can measure the EC of pore water alone. Although of course there is a relation between bulk soil conductivity and pore water conductivity one cannot apply a simple formula to convert one value to the other.

Using the EC-probe and the earth resistivity meter for measurements of the electric conductivity of humid soil proves to be a quick, easy and relatively cheap method to determine the salt content of the soil. The set is particularly suitable for use in irrigation projects and ecohydrologic research.

1. EC and earth resistivity

The salt content of water can be quantified as the concentration of dissolved salt, expressed in terms of [g/l] or [ppm]. The measure of salt content is called ‘Electrical Conductivity’ (EC), expressed in terms of [mS/cm], [mS/m] or [mmho/cm]. Usually, the EC is used to determine the salt content.

The EC of the soil depends on the total amount of salt in the soil, moisture content, the type of salt and the temperature. In addition, it is affected by the structure and texture of the soil.

- Moisture content. Since the majority of the minerals have an insulating quality, completely dry soil does not conduct electricity. The occurrence of salt in completely dry soil is of no relevance to plants as they are not capable of absorbing undissolved salt. Upon moistening of the soil, salt dissolves in water; molecules split into ions and the soil itself becomes electrically conductive. A very low level of soil humidity is correlated to a high level of salt concentration. An increase of moisture content leads to a decrease of salt concentration and consequently of the soil’s EC.
- Salt content. An increase of dissolved salts in the soil humidity causes an increasing number of ions and thus the electrical conductivity rises. The relation is not linear as an increasing ion concentration causes restricted ion movement.

- Type of salt. The following ions mostly contribute to soil moisture conductivity: sodium, potassium, calcium, magnesium, ammonium, chloride, sulphate, (bi)carbonate and nitrate. The effects of univalent, and bivalent or trivalent ions to conductivity are not identical. The ion's diameter also affects its mobility: the larger the ion, the less its mobility (and consequently the lower level of EC).
- Temperature. An increase in temperature leads to an increase of the ion's kinetic energy in the soil solution, a lower viscosity of the water and consequently to a higher EC.

The electrical resistivity is the reciprocal quantity of electrical conductivity. A high level of EC indicates a low level of resistivity. The earth resistivity of the soil equals the theoretical resistivity of a column of soil, expressed in [Ω.cm].

Soil properties and conditions show considerable spatial variability. As a result, the earth resistivity varies per location and per type of soil. Indicative earth resistivity values for various types of soils are listed in the table alongside.

Soil type	Earth resistivity [Ω.cm]
Gravel	40.000 - 200.000
Coarse gravel	40.000 - 200.000
Humus	1.000 - 4.000
Clay	500 - 2.000
Silty clay	3.000 - 5.000
Lime	20.000 - 300.000
Loam	3.000 - 10.000
Slate	30.000 - 70.000
Loess	3.000 - 10.000
Marshy ground	1.000 - 3.000
Marl	1.000 - 10.000
Silt	1.000 - 2.000
Silt (fine)	2.000 - 10.000
Peat	8.000 - 12.000
Sand	10.000 - 500.000

2. Description

The standard EC-probe set for soil conductivity measurements consists of a EC-probe with detachable handle, an earth resistivity meter, a single gouge auger, a bent spatula and a solid carrying bag (see figure on page 1).

EC-probe.

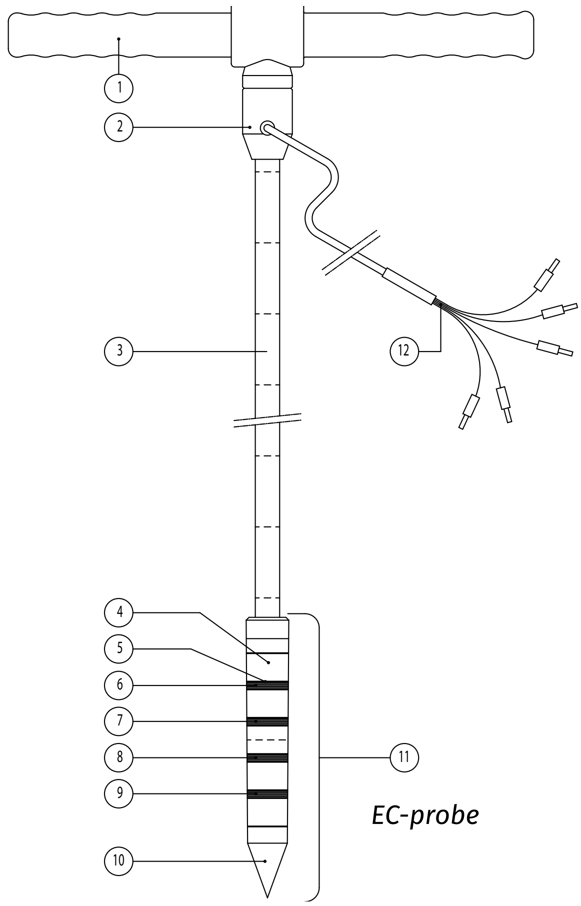
The EC-probe (see figure) measures 110 cm. It consists of a stainless steel rod (3) with a probe (11), a revolving upper part (2) with a detachable handle (1). The rod has a 10-cm calibration.

The probe measures 20 cm. Its diameter increases from 30 mm at the top to 28 mm at its base. This assures a tight contact with the wall of the borehole.

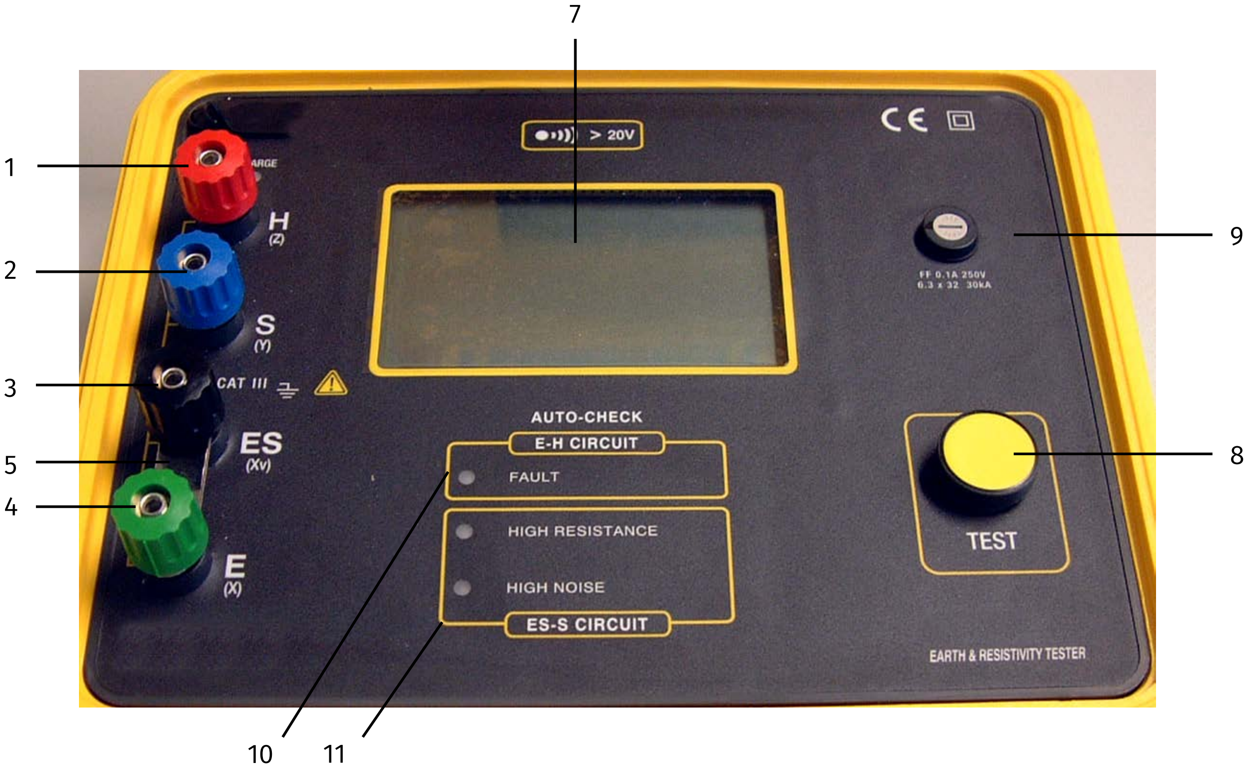
The probe contains four ring-shaped electrodes (6, 7, 8, 9), spaced 25 mm apart. The electrodes are separated by sealing rings (5) and insulation rings (4). The outer electrodes (6, 9) are current electrodes, the inner (7, 8) are measuring electrodes. The probe's cone (10) holds a temperature sensor.

Every electrode is connected to a live wire (see table). The temperature sensor is connected to the grey wire. The wires (12) emerge at the revolving upper part of the probe. The banana plugs ensure easy connection to the earth resistivity meter.

Electrode (no. in drawing)	Live wire (colour)
6	Green
7	White
8	Brown
9	Yellow



EC-probe



<u>Earth resistivity meter.</u>
The earth resistivity meter consists of a watertight, shockproof housing with a control panel, held in a carrying case. It is powered by 8 1.5 V LR 14 batteries or rechargeable cells of the same size, NiMH or NiCd. For safety reasons it holds a 0,1 A – 250V – fuse as well.

On the control panel 4 power points (1, 2, 3, 4) connect to the EC-probe electrodes. A removable metal junction strip (5) is positioned between the power points. Measuring starts by pushing the “Test” button (8). The digital display (7) shows the resistivity values (to 2000 Ohm) and the battery condition.

To check proper functioning of the meter, five indicators are available (see paragraph 7.1). They blink when the wires are not connected properly or when the batteries are low:

(7) : Batteries are low (indicated on large display).
(7) : The “minus” sign in the large display indicates reversal of the measurement conditions. Opposite direction of the current.
(10) : E-H Circuit: “FAULT” : if the current circuit resistance is too high or if the fuse (9) is defective
(11) : ES-S Circuit:
“HIGH RESISTANCE” : means that the measurement is liable to be over-affected by the resistance in the S-ES voltage circuit.
“HIGH NOISE” : if there is too much interference in the S-ES voltage circuit, it means that the electronics saturated and the measurement is no longer valid.

<u>Gouge auger.</u>
The single gouge auger of the set (see picture on page 1) measures 120 cm. The auger body is half-cylindrical with parallel-running cutting edges. Its operational depth is 50 cm. The outer diameter is 24 mm, somewhat narrower than the probe’s diameter. The synthetic handle is detachable allowing easy stowing away of the gouge. The gouge auger is made from iron-manganese steel (not stainless steel, non-toxic). For ecological reasons, the auger body is unvarnished.

3. Safety

Prior to augering check for cables, tubes and pipes (inquire at your municipality or other relevant organisations). Use the utility probe to safely check the spot for augering. If necessary, select another spot.

Insert and remove the EC-probe vertically without rotating it. Revolving may cause the sealing and insulation rings to turn in different directions, which could undo a current wire and damage the EC-probe.

Always use specified spare parts for maintenance. Eijkelkamp Soil & Water cannot be held responsible for accidents resulting from repairs carried out by others than authorised mechanics.

Prior to opening the battery compartment, disconnect all wires to the probe.

Replace the batteries simultaneously. Never mix batteries and accumulators.

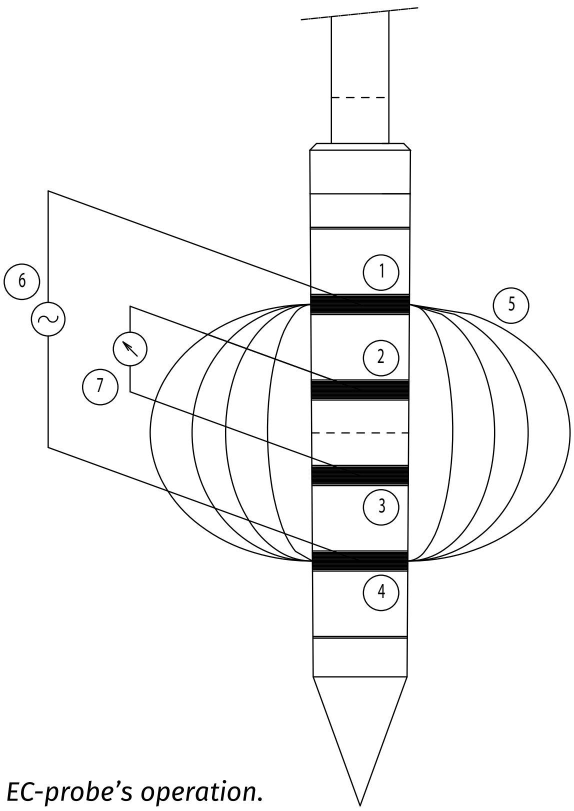
4. Methodology

Measurement of the soil resistivity using four electrodes is based on the Wenner-method, applied by Rhoades & Van Schilfgaarde (1976) for the development of an EC-probe. See the figure alongside for its operation.

The power source (6), i.c. the earh resistivity meter, generates an alternating current between the two current electrodes (1, 4) thereby creating an electric field. Its strength depends on the strength of the current and the distance between the four electrodes. Resistivity of the soil causes decreased voltage between the current electrodes. The earth resistivity meter (7) measures a potential difference between the measuring electrodes (2, 3). The quotient of the registred potential difference and the strength of the current equals the resistivity. The EC-probe establishes the resistivity in an elliptic volume of 80 cm^3 of soil around the probe (paragraph 5.2).

Since the EC is susceptible to temperature, the temperature of the soil is read by the sensor located in the EC-probe's cone. This enables an adjustment of the measured resistivity value and EC to a standard temperature (paragraph 5.3).

The resistivity is converted to electrical conduction of the soil (EC_s = bulk soil conductivity) and possibly to earth resistivity (paragraph 5.4), using an empirical constant or 'cell constant' that is determined by the distance between, and the shape of, the electrodes.



EC-probe's operation.

The EC-probe reads the EC_s directly in the field in the layer(s) of interest, regardless the moisture level. However in a laboratory environment, usually the soil salt content is expressed in terms of the EC of the saturation extract (EC_e). The saturation extract is obtained in a laboratory analysis by adding water to a soil sample until it is fully saturated and subsequently by determining the EC of the extract (this requires laboratory experience and a probe that resist the use in a mud). In other cases a diluted extract is used (e.g. $EC_{1:1}$ or $EC_{1:2}$ or $EC_{1:5}$). Meaning 1 part of dried/sieved soil with 1, 2 or 5 parts of water. The more diluted extracts can be measured with a standard water EC probe. It is not possible to convert EC's found with one method to an EC according to another method (e.g. convert bulk soil measurements to $EC_{1:5}$ measurements). Consult literature to determine which method suits your field of work best (horticulture, irrigation, forestry, etc.).
The EC is expressed in [mS/cm] at 25°C.

The EC_s value which refers to the soil itself and not to a solution, can be converted to the EC_e through a calibration curve. A calibration curve is established by determining the EC_s on various locations in the field and by taking samples from the same soil, whereupon the EC_e can be determined in a laboratory (paragraph 5.5).
Having determined the calibration curve, it can be applied in all soils with a similar texture and a similar water retaining qualities at field capacity. Subsequently, the field EC_e can be established, provided that during calibration and measuring the moisture content is similar. It is possible then to establish the EC_e directly in the field.

If possible, the EC_e can be used to establish the total quantity of dissolved salt in the soil. This can be realised by vaporising down a soil water sample, or by utilising the existing relationship between EC_e and the salt content (paragraph 5.6).

5. Use of the EC-probe

5.1 Pre-conditions

☞ **It is crucial to base the measurements of soil salinity and the calibration of soil samples on similar moisture content values.**

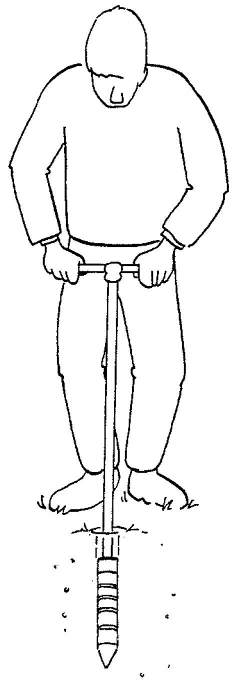
- ❑ To obtain values that can be well compared it is recommended to carry out EC measurements when the moisture content is at field capacity. This will be at two or three days after irrigation or heavy rainfall. (Rhoades et al. (1976) developed an alternative method, which permits to establish the EC_s based on different moisture content values).

- ❑ The 25-mm distance between the electrodes permits measuring within 15-cm depth intervals. This facilitates determining the EC of separate soil layers. The measuring volume being relatively small (80 cm^3), it is imperative to carry out repetitive measurements to average out the natural variability of the soil.

- ❑ If establishment of the EC_s is carried out in a soil volume that is smaller than the volume through which the electric field passes, it will occur that the field is truncated, which in turn will affect the measurements. The resistivity will increase and the calculated EC will appear to be lower than it is in reality. Therefore, it is crucial to have a soil volume that is sufficiently large to measure resistivity. For comparable reasons, it is not advised to measure the EC of groundwater in observation pipes.

- ❑ The relation between ion concentration and EC is not linear, consequently the different EC values (EC_e, $EC_{1:1}$ or $EC_{1:2}$ or $EC_{1:5}$) cannot be compared at random.

5.2 Measuring earth resistivity



1. Attach the handles to the gouge auger and to the EC-probe.

Prior to augering check for cables, tubes, pipes, larger stones or debris (inquire at your municipality or other relevant organisations). Use the utility probe to safely check the spot for augering. If necessary, select another spot.

2. Use the gouge to auger to a chosen depth (and not deeper!) in order to carry out resistivity measurements with the EC-probe.

   2.1 Push the gouge auger vertically into the soil without rotating it. Take a sample of max. 50 cm. Should you encounter any resistance, take a shorter sample or rotate the auger a full circle.

   2.2 Rotate the auger a full circle without pressing down to cut off the sample (this will facilitate hoisting the auger, and prevents loss of sample). Hoist the full gouge auger, gently rotating it.

   2.3 Use the bent spatula (rounded side up) to remove the sample from the auger body. If necessary, use this sample as a reference sample to establish the calibration curve (see paragraph 5.5 make a profiel description), or to examine the proper moisture content.

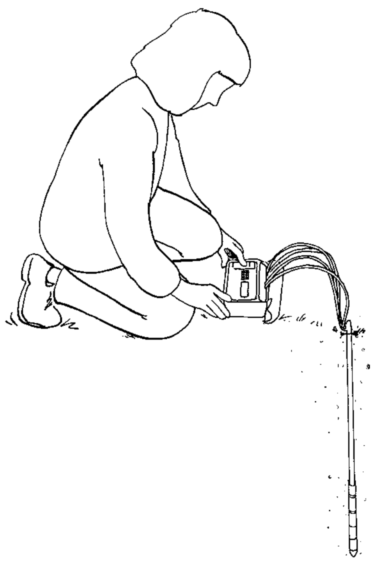
3. Insert the EC-probe vertically, and without rotating it, into the pre-augered borehole (see figure). To obtain optimum results the probe should be in full contact with the soil. For immediate temperature adjustment, the probe's cone should well touch the soil.

Insert and remove the EC-probe vertically without rotating it. Revolving may cause the sealing and insulation rings to turn in different directions, which could undo a current wire and damage the EC-probe.

4. Make sure the junction strips between the power points E-ES and S-H (see photo, page 4) of the earth resistivity meter are removed. If not, remove the strips.

5. Attach the four banana plugs of the EC-probe to the power points of the earth resistance meter according to the scheme below:

Wire	Power point
Yellow	E
Brown	ES
White	S
Green	H
Grey	Do not connect



Make sure the instrument is well-connected. Check the indicators. See paragraph 7.1 for how to act in the case of a failure.

6. Start measuring. Push the "Test" (measure) button of the earth resistivity meter, hold it down until the measuring value shows on the display. Check the failure indicators again. If necessary, correct the situation and repeat measuring. Upon releasing the button, the instrument switches off immediately. Take down the measured resistivity. This will be the measured resistivity at the prevailing temperature: $R_t(\Omega)$.

7. Next, determine the temperature correction factor (next paragraph).

5.3 Establishing the temperature correction factor

1. Remove the EC-probe banana plugs from the power points on the earth resistivity meter.

2. Replace the junction strips between power points E-ES and S-H.

3. Connect the yellow and grey EC-probe banana plugs to the power points on the earth resistivity meter according to the scheme below:

Wire	Powerpoints
Yellow	ES
Grey	S

4. Push the 'Test' (measure) button on the earth resistivity meter and make sure the measuring value on the display is completely stable. This may take 1 to 3 minutes from the moment of insertion of the EC-probe into the borehole (depending on the difference in temperature between the probe and the soil). Note the measuring value.

5. Divide this value by 1000 to obtain the temperature correction factor (f_t). If needed, read the appendix to find the corresponding soil temperature.

☞ **Example: The temperature correction factor for a measuring value of 1247 comes to 1.247.**
(The corresponding temperature is 15.0 °C).

6. Remove the wires from the earth resistivity meter. Hoist the EC-probe vertically, without rotating it.

7. Repeat the above, starting from step 2 for each new resistivity measurement.

5.4 Calculating EC_s and earth resistivity

1. Upon measuring the resistivity (paragraph 5.2) and determining the temperature correction factor (paragraph 5.3), the soil electrical conductivity can be calculated according the formula below:

$$EC_s = k * f_t / R_t$$

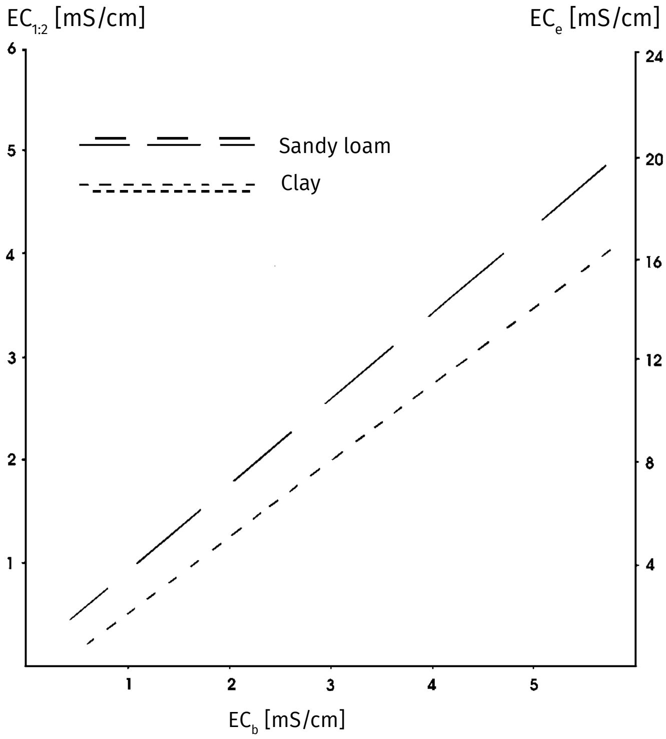
Where
EC_s : Soil electrical conductivity in [mS/cm] or [mmho/cm] at 25°C.
: NB 1 mS/cm = 1mmho/cm.
k : The empirically established constant or 'cell constant' [cm^{-1}] The cell constant of the Eijkelkamp Soil & Water EC-probe comes to 17.5 cm^{-1}.
f_t : Temperature correction factor for converting the measured EC_s to the EC_s at 25°C.
R_t : Measured resistivity at the prevailing temperature in [Ω].

2. If needed, calculate the earth resistivity by determining the reciprocal of the EC_s, i.e.(1/ EC_s). The unit of earth resistivity is [kΩ.cm].

*Example: At a measured resistivity of 503 Ω and a temperature correction factor of 1.247, the EC_s is calculated as follows: EC_s = 17.5 * 1.247 / 503 = 0.04mS/cm at 25°C. (The earth resistivity equals: 1 / 0.04 = 25 kΩ.cm).*

5.5 Determining the calibration curve

The EC_s depends on the structure and texture of the soil, the moisture content and the salt content of the soil moisture. To convert the EC_s to the standard EC_e, a calibration curve is constructed, see figure alongside.
It is essential that measuring be carried out at a constant moisture content. A calibration curve should be constructed for each type of soil (see Van Hoorn 1980 for calibration curves for various types of soils). Proceed as follows:



1. Use a gouge auger to pre-bore a hole where the EC_s will be measured (see paragraph 5.2, step 2).

2. Take samples at a desired depth from the soil material in the gouge auger.

3. Determine the EC_s at the same depth.

4. Repeat steps 1-3 until a sufficient number of measurements are available to construct a calibration curve.

5. Have the samples analysed for the EC_e (if needed, an alternative EC can be determined, such as the $EC_{1:2}$).

6. Construct the calibration curve; plot out the EC_s on the x-axis, and the EC_e (or an alternative EC) on the y-axis. Apply linear regression.

7. Use the resulting calibration curve to convert all EC_s measurements of this type of soil to $EC_{e.}$

8. Repeat steps 1-7 for differing types of soils. It may not always be necessary to construct a calibration curve for each type of soil. Generalised calibration curves can be used for soil types with identical water retaining qualities and textures (Rhoades 1978, 1981).

Eventually, the relation between EC_s and EC_e can be determined in an alternative way. To this purpose the clay content and the percentage of soil moisture content in the field should be estimated vis-à-vis the situation at field moisture capacity. Application of this method demands ample experience. Therefore, this method is not described here (for more information, see for example Rhoades 1992).

5.6 Salt content

The relation between electrical conductivity of the soil and the total salt content cannot be determined directly; a soil solution always consists of several types of salt ions. The effect of univalent ions on conductivity is not identical to that of bivalent or trivalent ions. The ion's diameter affects its mobility in water as well.

There are several methods to determine the salt content in [g/l] or [meq/l]:

- Vaporising. Reduce the soil solution by vaporising and determine the weight of the remaining salts. This will cause partial loss of salts, such as bicarbonates.
- The relation between EC and the salt content. The literature on this subject mentions several connections (see USDA 1954). This method tends to be more accurate than the method mentioned above.
- Conversion. The salt content can be approximated by multiplying the EC by a conversion factor (see literature, for example USDA 1954) This method is sufficiently accurate in most cases.

6. Applications

The earth resistivity meter is applied to determine the electrical conductivity of the soil to a depth of 110 cm. Its operational depth allows salt content measurements in rooted soil, below furrows, or in separate soil layers. The EC-probe set is used in measuring, monitoring, and surveying the soil salinity in the following areas of investigation:

- Problems of salinization in irrigation.
- Composition and quality of groundwater in ecohydrologic research and drinking-water collection.
- Salinization research in nature preservation.
- Soil assessment for various types of crops.
- Measuring of salinization caused by the application of manure salts.
- Measuring the salt content in road verges after strewing in winter.
- Civil engineering: monitoring the salt content of fill-material.

7. Troubleshooting

7.1 Error indicators

- "-" sign (opposite direction of the current).
  This indicator displays a negative value resulting from faulty connection of the wires; H and E (green and yellow wire) or E and S (yellow and white wire). Connect the banana plugs properly. See the table in paragraph 5.2.

- Circuit E-H failure
  This indicator shows that the voltage between power points E and H exceeds the max. 30- Volt output voltage. It indicates that:
  - the E – H circuit has too high a resistance;
  - the interference resistance in the E – H circuit is too high;
  - a fuse has blown.

  Check the EC-probe, the current wires, the connections and the fuse. To check the fuse: short circuit the E and H poles, the junction strip (5) (see photo on page 4) should be removed. If the red led blinks, replace the fuse (see paragraph 8.1).

- Measuring-circuit ES-S failure.
  This indicator displays a resistance of over 50 kΩ, indicating that the measurement is affected by resistance of the ES – S circuit. The indicator will keep blinking if the resistance decreases to below 50 kΩ during measuring.

Check the probe, the wires and the connections.

- ❒ Measuring-circuit ES-S interference.
  This indicator shows interference voltage in the measuring circuit. Noise exceeds 13 V_{peak} between power points ES and E, and impedes measuring.
  Select another spot for measuring the EC.

- ❒ Low battery indicator [– +]
  The low battery indicator blinks. It indicates that the earth resistivity meter batteries are low, allowing a small number of measurements. Replace the batteries as soon as possible.

- ❒ The display indicates "1- - -"
  Resistivity exceeds the measuring range (over 2000 Ω). Check the connections.

7.2 Miscellaneous

- ❒ Although no measuring takes place, the rechargeable batteries of the earth resistivity meter discharges rapidly. Rechargeable batteries, as opposed to alkaline batteries, contain less energy and discharge although no measuring takes place.
- ❒ Augering with the gouge auger is strenuous. Take a shorter sample, or cut off the sample by rotating the auger a full circle and continue augering.
- ❒ Loss of sample during augering. If this is the result of too often cutting off the sample, thereby loosing cohesion, then take a shorter sample. Loss of sample could also be the result of changing to a less cohesive type of soil.

8. Maintenance

8.1 Earth resistivity meter

⚠ **Always use specified spare parts for maintenance. Eijkelkamp Soil & Water cannot be held responsible for accidents resulting from repairs carried out by others than authorised mechanics.**

- ❒ Clean the instrument using a moistened cloth. Never use alcohol, paraffin or other hydrocarbon-based products.

☞ **Prior to opening the battery compartment, disconnect all wires to the probe.**

- ❒ Replace the batteries when (almost) empty. Remove the four screws on the bottom of the housing. Then remove the shell + front panel assembly of the yellow housing. Then undo the two screws closing the battery compartment cover. Take out the 8 cells and replace them (check polarity). Close the battery compartment.

⚠ **Replace the batteries simultaneously. Never mix batteries and rechargeable batteries.**

Note: It is possible to replace the batteries by rechargeable cells (1.2 V - 2 Ah or above, NiCd or NiMH, of same size): Remove the plug under the batteries and set the switch to the position: NiCd / NiMH.
Replace the plug. Insert the 8 rechargeable cells

- ❒ Then in both cases:

- ❒ Replace the battery cover, and screw in the two screws closing the battery compartment cover.
  Replace the shell + front panel assembly in the yellow housing then tighten the four captive screws under the housing

- ❐ To check the fuse continuity, short circuit the H and E terminals and make a measurement. If the FAULT indicator light flashes, it means that the fuse has blown. The fuse is on the front panel. Using a screwdriver, turn the screw through a quarter turn and take out the support containing the fuse. Replace the fuse (FF 0.1 A - 250 V – 6.3 x 32 - 30 kA). Replace the support and screw it back.

- ❐ When stowing away the earth resistivity meter, remove the batteries and keep the instrument stored under appropriate conditions. Charge the batteries prior to use.

8.2 Gouge auger and EC-probe

- ❐ It is recommended to keep the equipment in good condition by rinsing it upon use.

- ❐ Clean the gouge augers and EC-probe after use with running water and dry them well. Stow away the equipment in the carrying bag.

- ❐ The gouge auger body needs no whetting, proper use keeps it sharp-edged. Under normal conditions oxidation is not detrimental to the auger and will vanish upon use.

9 Technical specifications

9.1 Earth resistivity meter

Reference conditions

Temperature	23°C ± 3K
Relative humidity	Between 45% and 55%
Supply voltage	9.5 V ± 0.2 V
Auxiliary resistances RH, RS, RES and RE	Zero
Spurious voltage (Ac and DC)	Zero
Serial inductances	Zero
Electric field	< 1 V/m
Magnetic field	< 40 A/m

Metrological properties

Voltage detection

Measurement range:	20 to 250 VAC between the H and E terminals or between the S and E terminals.
Frequency:	DC at 450 Hz

Resistance

Measurement range:	0 to 2000 Ω		
Rating (Ω)	0.00 - 19.99	20.0 - 199.9	200 - 1999
Resolution (Ω)	0.01	0.1	1
Intrinsic error	±2% ±1 pt	±2% ± 1pt	±2% ±3 pt
Measuring current	10 mA	1 mA	0.1 mA
No load voltage	$\leq 42\ V_{peak}$	$\leq 42\ V_{peak}$	$\leq 42\ V_{peak}$
Response time:	4 to 8 seconds		

When the unit is locked on the second rating, the characteristics are as follows:

Rating (Ω)	0.0 – 199.9
Resolution	0.1 Ω
Intrinsic error	±2% ±1 pt
Measuring current	1 mA
No load voltage	$\leq 42\ V_{peak}$

Power supply

The equipment power supply is obtained from 8 x 1.5 V LR 14 batteries or rechargeable cells of the same size, NiMH or NiCd.

	(8 LR14 cells)	(8 x1,2 V, 2 Ah cells)
Battery charge life	4500	1180
average in continuous	measurements	measurements
operation*	15 s	15 s
	or 18 h 45	or 4 h 45

* at the rating consuming most power

The load limit of the power supply is indicated by the display.

The capacity after this display is approximately 50 measurements of which only 20 are with rechargeable cells.

Environmental parameters

Climatic

Nominal range of use:
- from -10°C to +55°C
- from +20% to +90 % HR without condensation

Storage (without battery or rechargeable cell but with battery depending on model):
- 40 to +70 °C
- from +20% to 90 % HR without condensation

Construction specifications
Overall dimensions of the unit (LxWxH):

273 x 247 x 127 mm
273 x 280 x 127 mm, with handle extended.

Weight: 2.85 kg

Compliance with international standards

Electrical safety as per EN 61010-1 + A2 (ed. 95), EN 61557 (ed. 97).
Dual insulation
Pollution level 2
Installation category III
Maximum operating voltage: 30 V rms

Electromagnetic compatibility: as per NF EN 61326 (ed. 98).

Mechanical protection: The resistivity meter (14.01.14) has succesfully undergone all the required mechanical tests (vibration / rigidity / resistance to impact / free fall) and therefore meets all the requirements of the standards NF EN 61557 and NF EN 61010-1.

Variations in operating range

Influence quantities	Operating range limits	Typ. measurement variations	Max. measurement variations
Temperature	-10 to +55°C	(0.% ±1 pt)/10 °C	(1% ±1 pt)/10°C
Relative humidity	20 to 90% RH	1% ±3 pt	2% ±5 pt
Supply voltage	7.5 to 13 V	0.5% ±1 pt/V	1% ±1 pt/V
Rvoltage (RS + RX + RES)	50 kΩ	-0.6%/10 kΩ ±2 pt	-1%/10 kΩ ±4 pt
Rcurrent (RH + RX + RE)	Calibr. 1...30 kΩ (1) 2...30 kΩ 3...50 kΩ	0,5%/10 kΩ ±1 pt	1%/10 kΩ ±2 pt
Resistance into the 4k rods (RH = RS = RES = RE)	Calibr. 1...15 kΩ (1) 2...15 kΩ 3...25 kΩ	(0.% ±0,3 Ω)/10 kΩ 0.%/10 kΩ 0.5%/10 kΩ	(1% ±0.6 Ω)/10 kΩ 1%/10 kΩ 1%/10 kΩ
DC voltage in series with Rx	0 to 20 V (2)	-	Negligible
Spurious voltages AC in series with H (50 Hz, 60 Hz) or their harmonics	0 to3 Vrms or 0 to 32.5 Vpeak at 16,67, 50, 60 or 400 Hz	1% ±1 pt	2% ±2 pt
AC spurious voltages in series with S (50 Hz 60 Hz or their harmonics	0 to 9 Vrms or 0 to 13 Vpeak at 16,67, 50, 60 or 400 Hz	0.2 % ± 1 pt	0.5 % ± 2 pt
Inductance in series with H and S	0 to 13 mH	-	Negligible

(1) Beyond 3 kΩ, the unit switches to calibr. 2.
(2) Risk of flashing HIGH RESISTANCE indicator light flashing beyond 4.5 V.

9.2 EC-probe

Dimensions : Length 110 cm, width 30 mm (top) to 28 mm (base)
Spacing of electrodes : 25 mm (centre to centre)
Cell constant : 17.5 cm^{-1}

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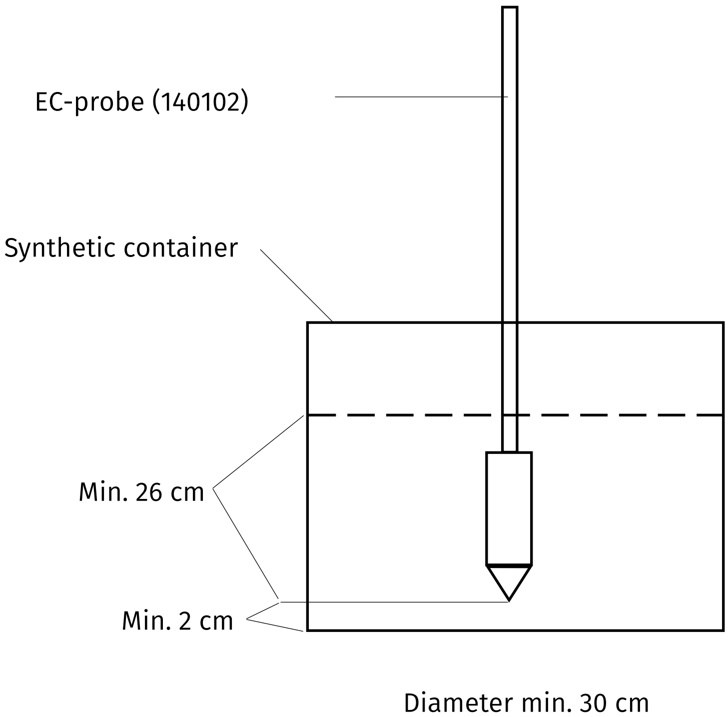
Appendix 1 Temperature correction factor and corresponding soil temperatures.

To obtain the temperature correction factor f_t, the value read on the earth resistivity meter display should be divided by 1000.

°C	f_t	°C	f_t	°C	f_t
3,0	1,709	22,0	1,064	29,0	0,925
4,0	1,660	22,2	1,060	29,2	0,921
5,0	1,613	22,4	1,055	29,4	0,918
6,0	1,569	22,6	1,051	29,6	0,914
7,0	1,528	22,8	1,047	29,8	0,911
8,0	1,528	23,0	1,043	30,0	0,907
9,0	1,448	23,2	1,038	30,2	0,904
10,0	1,411	23,4	1,034	30,4	0,901
11,0	1,375	23,6	1,029	30,6	0,897
12,0	1,341	23,8	1,025	30,8	0,894
13,0	1,309	24,0	1,020	31,0	0,890
14,0	1,277	24,2	1,016	31,2	0,887
15,0	1,247	24,4	1,012	31,4	0,884
16,0	1,218	24,6	1,008	31,6	0,880
17,0	1,189	24,8	1,004	31,8	0,877
18,0	1,163	25,0	1,000	32,0	0,873
18,2	1,157	25,2	0,996	32,2	0,870
18,4	1,152	25,4	0,992	32,4	0,867
18,6	1,147	25,6	0,988	32,6	0,864
18,8	1,142	25,8	0,983	32,8	0,861
19,0	1,136	26,0	0,979	33,0	0,858
19,2	1,131	26,2	0,975	34,0	0,870
19,4	1,127	26,4	0,971	35,0	0,829
19,6	1,122	26,6	0,967	36,0	0,815
19,8	1,117	26,8	0,964	37,0	0,801
20,0	1,112	27,0	0,960	38,0	0,788
20,2	1,107	27,2	0,956	39,0	0,775
20,4	1,102	27,4	0,953	40,0	0,763
20,6	1,097	27,6	0,950	41,0	0,750
20,8	1,092	27,8	0,947	42,0	0,739
21,0	1,087	28,0	0,943	43,0	0,727
21,2	1,082	28,2	0,940	44,0	0,716
21,4	1,078	28,4	0,936	45,0	0,705
21,6	1,073	28,6	0,932	46,0	0,694
21,8	1,068	28,8	0,929	47,0	0,683

Appendix 2 Calibrating a soil conductivity meter

Already for years we sell a soil conductivity meter for direct use in the soil. But does it work correctly? A calibration procedure has been developed to check the probe-typical value K (cel-constant). This procedure allows end-users and service-technicians to check the accuracy of the meter-probe combination.



Follow the procedure described below:

Calibration 1:

- ❒ Position the probe according to the drawing in a plastic bucket with a diameter larger or equivalent to 30 cm.
- ❒ Fill the plastic bucket with 30 cm of tap water.
- ❒ Determine with a well calibrated good quality EC/T° meter for water the EC value of the water in the bucket. It is absolutely essential that the measurements are correctly temperature compensated ! So do not forget to stick the temperature probe in the water too ! Attention: The conductivity measured must be expressed in milliS/cm: . . . . mS/cm. For the calibration procedure this value will be the EC value in the formula below.
- ❒ Now determine the EC but with the soil salinity meter 14.01:
  Connect the banana plugs to the four connectors on the meter while accurately respecting the colours and writings on the cables. The metal junction strips on the meter should be left open.
  Note: The grey cable is not connected.
  Push the “Test” button on the meter and write down the value . . . .
- ❒ Now the temperature correction factor has to be determined:
  Disconnect all cables and close the junction strips.
  Connect the yellow and grey cables to the indicated plugs.
  Push the “Test” button and write down this value . . . .
  Divide this value by 1000 . . . . This will be temperature correction factor ft in the formula below.

Calibrations 2 and 3:

- ❒ The above mentioned calibration procedure should be repeated two more times but with increasing NaCl salt concentrations ! We suggest you add NaCl (kitchen salt) untill approximately 1.5 mS/cm and 4 mS/cm are measured with the water EC meter. Other values are however acceptable too.

- ❒ To check the K value of the probe 14.01 put the gathered data of measurement 1 in the formula:

  EC = k * ft/Rt

  EC = The value obtained with the calibrated <u>water</u> EC meter
  ft = temperature correction factor obtained with the 14.01 probe connected to the earth resistivity meter (140114).
  Rt = Measured resistivity with the earth resistivity meter (14.01.14)

- ❒ Now calculate the value K resulting from calibration 1 ....
- ❒ Now calculate the value K resulting from calibration 2 ....
- ❒ Now calculate the K-value resulting from calibration 3 ....
- ❒ Determine the average value of calibrations 1, 2 and 3: ....
- ❒ Compare this with the value of a new probe K = 17.5 cm^{-1}
- ❒ If the value obtained is within ± 2% of the original celconstant we suggest you continue to do measurements with the equipment based on the original K-value of 17.5 cm^{-1}
- ❒ If the value is ± 2-20% from the original 17,5% (so between 14 and 21 cm^{-1}) we suggest you start working with the newly obtained K value.
- ❒ If the value is more than ±20% from the original 17,5 cm^{-1} we suggest to have the equipment recalibrated by Eijkelkamp Soil & Water.