Calibration Equations for the ECH_2O EC-5, ECH_2O-TE and 5TE Sensors

Decagon's ECH_2O EC-5, ECH_2O-TE, and 5TE (replaces ECH_2O-TE) probes are used in a variety of soil and soil-less media types, some of which require an adjustment to the probe calibration. To help with this, we provide this application note that includes calibration data from all media we have tested to date. If the media type that you are using does not appear in the calibration list, you may be required to conduct a calibration yourself or take advantage of Decagon's calibration service. Information on individual probe calibration can be found on our website in the application note section. To learn more about Decagon's calibration service, please email: support@decagon.com.

ECH_2O EC-5

All EC-5 calibration equations are given in two forms; the first can be used with the output from Decagon dataloggers, the second can be used with other non-Decagon dataloggers, such as those from Campbell Scientific.

Mineral Soil

According to our tests, a single calibration equation will generally suffice for all mineral soil types with electrical conductivities from 0.1 dS/m to 10 dS/m. Volumetric water content is given by

$$\theta = 8.50\text{x}10^{-4} * Raw - 0.48 \qquad (1)$$

where Raw is the output from the Decagon datalogger. If you are using a non-Decagon datalogger, VWC is given by

$$\theta = 11.9\text{x}10^{-4} * mV - 0.401 \qquad (2)$$

where mV is the output of the probe when excited at 2500 mV. Please note that the equation will reach maximum at ~60% volumetric water content (VWC) in pure water. To display data on a scale from 0 to 100%, VWC should be modeled with a quadratic equation (which would result in a 100% VWC in water), but a linear equation fits the mineral soil VWC range as well as the quadratic, and linear equations are easier to deal with, especially since mineral soil typically saturates at ~40 to 50% VWC.

Potting Soil

The following equations can be used to convert EC-5 output to water content in potting soil. We tested several types of potting soil at several salinities and found that VWC is given by

$$\theta = 1.30\text{x}10^{-3} * Raw - 0.696 \qquad (3)$$

for a Decagon datalogger, or

$$\theta = 2.11\text{x}10^{-3} * mV - 0.675 \qquad (4)$$

for a datalogger with 2500 mV excitation.

Rockwool

The EC-5 was calibrated in Grodan Master rockwool with solution electrical conductivities of 0.2, 1.0, 1.5, 2.0, and 4.5 dS/m. Volumetric water content can be calculated using

$$\theta = 6.28\text{x}10^{-7} * Raw^2 + 1.37\text{x}10^{-4} * Raw - 0.183 \qquad (5)$$

in a Decagon datalogger and

$$\theta = 2.63\text{x}10^{-6} * mV^2 - 5.07\text{x}10^{-4} * mv - 0.0394 \qquad (6)$$

for a datalogger with 2500 mV excitation.

Perlite

The EC-5 was calibrated in coarse perlite yielding the quadratic calibration function:

$$\theta = -1.30\text{x}10^{-7} * Raw^2 + 8.81\text{x}10^{-4} * Raw - 0.314 \qquad (7)$$

for Decagon dataloggers and

$$\theta = -2.36\text{x}10^{-7} * mV^2 + 1.14\text{x}10^{-3} * mV - 0.207 \quad (8)$$

for dataloggers using a 2500 mV excitation.

ECH_2O-TE

(Discontinued)

Mineral Soil

ECH_2O-TE probes output data in a digital form so there is only one output type ("Raw") regardless of datalogger. Like the EC-5, we found one calibration equation was adequate for all mineral soil types and salinities we tested (sand, sandy loam, silt loam, and clay; 0.1 to 7.3 dS/m).VWC is calculated using

$$\theta = 10.9\text{x}10^{-4} * Raw - 0.629 \quad (9)$$

where Raw is the raw water content output from the ECH_2O-TE.

Potting Soil

Similar to the EC-5, we tested the ECH_2O-TE in several types of potting soils with a range of solution electrical conductivities (3 to 14 dS/m). Volumetric water content in potting soil is calculated by

$$\theta = 10.4\text{x}10^{-4} * Raw - 0.499 \quad (10)$$

Rockwool

The ECH_2O-TE was calibrated in Grodan rockwool at solution electrical conductivities of 0.01, 4.1, and 8.1 dS/m. The following quadratic equation relates VWC to raw data:

$$\theta = 5.15\text{x}10^{-7} * Raw^2 + 1.41\text{x}10^{-4} * Raw - 0.160 \quad (11)$$

Perlite

The ECH_2O-TE was calibrated in coarse perlite yielding the quadratic calibration function:

$$\theta = -3.02\text{x}10^{-7} * Raw^2 + 1.22\text{x}10^{-3} * Raw - 0.503 \quad (12)$$

5TE

The 5TE sensor replaces the ECH_2O-TE sensor. It has incorporated two major changes: First, the electrical conductivity is measured using two stainless steel screws instead of long, gold conductors; second, sensor output is given in a form of dielectric units instead of "Raw". These changes require completely different calibration equations for the sensor. However, like the ECH_2O-TE, the calibration equations are the same for all dataloggers.

Dielectric units

To obtain actual dielectric units (ε_b), 5TE serial output ("Serial") must be divided by 50 (i.e. Serial = 375, ε_b= 7.5).

Mineral Soil

To calculate mineral soil VWC from sensor output, the Topp et al. (1980) equation can be used:

$$\theta\ (m^3/m^3) = 4.3\text{x}10^{-6} * \varepsilon_b^3 - 5.5\text{x}10^{-4} * \varepsilon_b^2 + 2.92\text{x}10^{-2} * \varepsilon_b - 5.3\text{x}10^{-2} \quad (13)$$

where ε_b is sensor output divided by 50 (*Serial*/50) or, to calculate VWC directly from the *Serial* output:

$$\theta\ (m^3/m^3) = 3.44\text{x}10^{-11} * Serial^3 - 2.20\text{x}10^{-7} * Serial^2 + 5.84\text{x}10^{-4} * Serial - 5.3\text{x}10^{-2} \quad (14)$$

Soilless Media Calibrations

Calibration equations for all soilless media were generating using laboratory methods outlined in our calibration application note (www.decagon.com/ag_research/literature/app_notes.php). We understand that this is not an exhaustive list of soilless media. It would be cost prohibitive to create calibrations for every media type. For other soilless media calibrations, please take advantage of our calibration service by contacting support@decagon.com for pricing and instructions.

Potting Soil
The 5TE was calibrated in Sunshine Potting soil (peat-perlite mix) and a peat potting soil with electrical conductivities ranging from 1 to 3 dS/m. The calibration equation is a quadratic:

$$\theta\ (m^3/m^3) = 1.80\times10^{-10} * Serial^3 - 8.23\times10^{-7} * Serial^2 + 1.45\times10^{-3} * Serial - 0.247 \qquad (15)$$

where *Serial* is the raw output from the sensor.

Rockwool
We used Grodan rockwool at 2 and 5 dS/m solution electrical conductivity for the calibration. Sensor readings were averaged from six locations in the rockwool slab. Variability in the pore size of the rockwool lead to standard deviation in the VWC measurement of ~5%. We believe the same variation due to insertion location can be expected for all rockwool slabs. Use the following equation to get VWC from *Serial* output:

$$\theta\ (m^3/m^3) = -6.71\times10^{-7} * Serial^2 + 1.31\times10^{-3} * Serial + 0.0266 \qquad (16)$$

Perlite
We tested the 5TE in coarse perlite at 1 and 2 dS/m solution EC. The VWC can be found using the following equation.

$$\theta\ (m^3/m^3) = -4.28\times10^{-7} * Serial^2 + 1.05\times10^{-3} * Serial - 0.0685 \qquad (17)$$

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