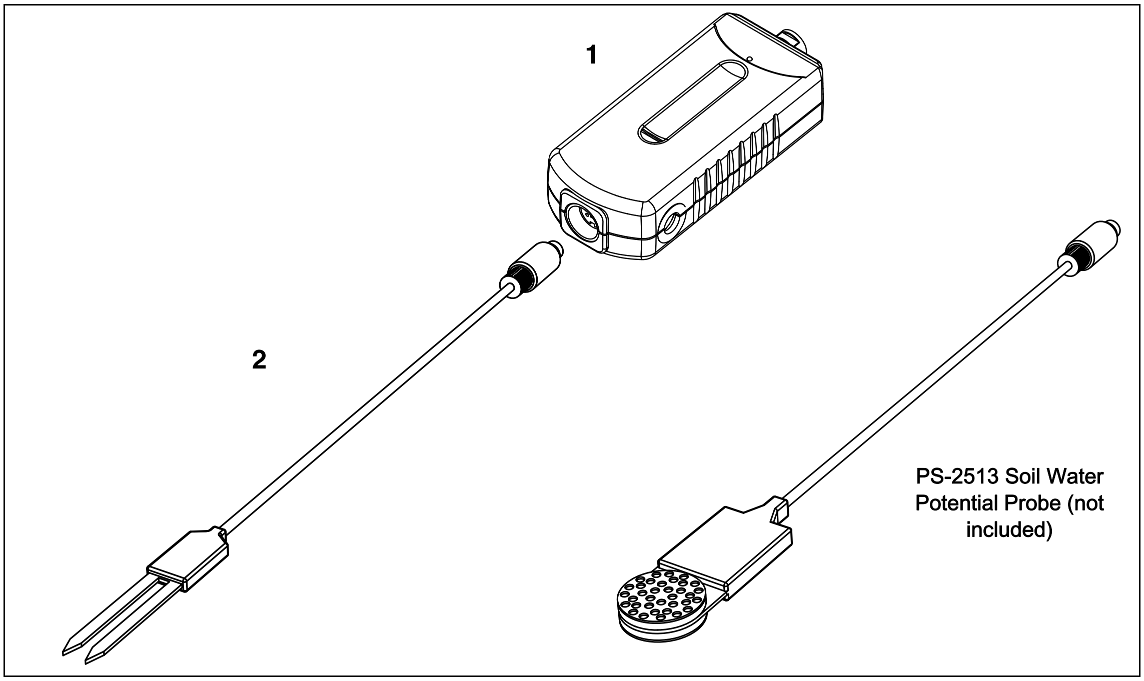
PASPORT Soil Moisture Sensor

PS-2163



Included Equipment	Part Number
1. PASPORT Soil Moisture Sensor	PS-2163
2. Soil Moisture Probe Cable Assembly	(See Technical Support)
Accessory Equipment	(See www.pasco.com for details)
PASPORT Soil Water Potential Probe (not included)	PS-2513*
Also Required*	
PASCO Interface	(See www.pasco.com for details)
PASCO Data Collection Software	(See www.pasco.com for details)

Introduction

The PASCO Model PS-2163 Soil Moisture Sensor works with a PASCO interface to collect soil moisture data. The sensor consists of the Soil Moisture Sensor box and the Soil Moisture Probe (cable assembly).

The sensor measures volumetric water content (VWC) percentage of a soil sample. Volumetric water content is the volume of soil water per unit of total volume. In simple terms, dry soil consists of solid material and air pockets. A typical volumetric ratio would be 55% solid material and 45% air pockets. As water enters the soil, the air pockets begin to fill with water. An example of 10% volumetric water content would be 55% solid material, 35% air pockets, and 10% water. The maximum volumetric water content would therefore be 45%. All the air spaces would be filled with water and the soil would be saturated.

About the Sensor

The Soil Moisture Probe uses capacitance to measure the dielectric permittivity of the surrounding soil. The volume of water in the total volume of soil most heavily influences the dielectric permittivity because the dielectric of water (80) is much greater than the other constituents of the soil (mineral soil, 4; organic matter, 4; air, 1). Thus, when the amount of water changes in the soil, the Soil Moisture Probe will measure a change in the capacitance (from the change in the dielectric permittivity) that can be directly correlated with a change in water content. Circuitry inside the Soil Moisture Probe changes the capacitance measurement into a proportional millivolt output.

The copper traces used to measure water content are sealed between two pieces of epoxy-impregnated fiberglass. The electromagnetic (EM) field generated by the traces travels through the fiberglass and into the soil surrounding the probe.

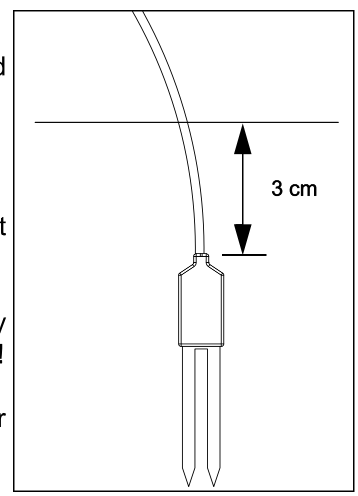
The Soil Moisture Probe averages the volumetric water content over the entire length of the probe, with a zone of influence about 2 cm around the probe. The zone of influence is with respect to the flat surface; there is little or no sensitivity at the edges of the probe. The electromagnetic field (EM) produced by the probe decreases with distance from the probe surface.

Installing the Soil Moisture Probe

When selecting a site for installation of the probe, it is important to remember that the soil adjacent to the probe's surface has the strongest influence on the sensor reading. Therefore, any air gaps or excessive soil compaction around the probe can profoundly affect the readings. Because the probe has a gap between its prongs, it is also important to consider the size of the media you are inserting the probe into. It is possible to get sticks, bark, roots, or other material stuck between the probe prongs, which will adversely affect readings. Finally, be careful when inserting the probe into dense soil, as the prongs will break if excessive sideways force is used when pushing them in.

Do not install the probe adjacent to large metal objects such as metal poles or stakes. This can attenuate the probe's electromagnetic field and adversely affect output readings.

When installing the probe, it is best to maximize contact between the probe and the soil.



Vertical Orientation

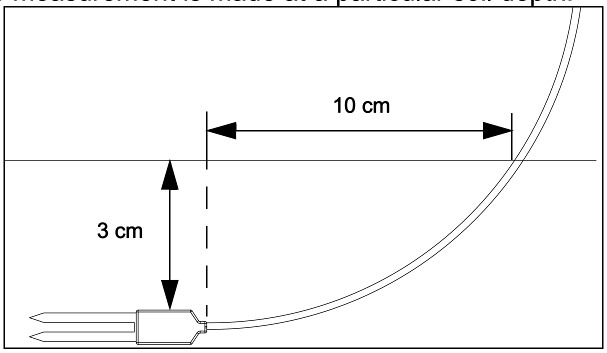
Insert the probe into the soil, making sure that the probe is completely buried at least 3 cm below the soil surface. The tip of each prong is sharp - *be careful!*

The probe may be difficult to insert into extremely compact or dry soil. Carefully loosen the soil before inserting the probe. **Never pound the probe into the soil!**

Make sure that there is good contact between the probe and the soil. Use your fingers and fist to tamp the soil down around the probe.

Horizontal Orientation

The probe can be oriented in any direction. However, orienting the flat side perpendicular to the surface of the soil will minimize the effects of downward water movement. The horizontal orientation of the probe makes sure that the soil moisture measurement is made at a particular soil depth.



Do not bend the cable too severely when putting the probe into the soil. Let about 10 cm of the cable nearest to the probe remain straight or gently curved as shown.

Make a narrow trench with a trenching shovel or garden spade. Place the probe into the narrow trench and completely cover the entire length with soil. Tamp down the soil along both sides of the probe with your fingers. Cover with more soil if needed. Repeat the process of tamping down the soil along both sides of the probe five to eight times.

Removing the Soil Moisture Probe

When removing the soil moisture probe from the soil, **do not pull it out of the soil by the cable!** Doing so may break internal components and make the probe unusable.

Setup

Hardware Setup

The following three steps can be performed in any order.

1. Connect the mini-DIN plug of the Soil Moisture Probe Cable Assembly to the front end of the Soil Moisture Sensor box.

2. Connect the Soil Moisture Sensor to a PASPORT-compatible interface.

3. If you will be using a computer, connect the PASPORT-compatible interface to the computer.

The mini-DIN plug on the Soil Moisture Cable Assembly fits into the sensor box in only one way.

Software Setup

Install the latest version of the PASCO data collection software first. Check the PASCO web site at:

www.pasco.com/software

Software Help

See the SPARKvue Help or PASCO Capstone Help for information about collecting, displaying, and analyzing data.

- In SPARKvue, select the **HELP** button (?) in any screen including the Home Screen.

- In PASCO Capstone, select **PASCO Capstone Help** from the **Help** menu, or press **F1**.

SPARKvue

1. Start the SPARKvue software program. If the sensor is connected and recognized by the software, the SPARKvue Home Screen will show the name of the sensor (Soil Moisture) and the list of its measurements.

2. Select a measurement such as VWC Potting Soil and click Show.

- A graph display opens with the selected measurement on the vertical axis and time on the horizontal axis.

3. Touch the **Start** button to begin collecting data. Later, touch the same button again to end data collection.


Start button

PASCO Capstone

1. Start the PASCO Capstone software program. Click Hardware Setup in the Tools palette and confirm that the sensor is recognized by the software. (Click Hardware Setup again to close the window.)

- The Capstone Home Screen shows choices for displaying data.

2. Select a display such as Graph & Digits.

- Page #1 changes to show two Digits displays and one Graph display. Each display has one or two <Select Measurement> menus.

3. Click the <Select Measurement> menu in one of the displays and select a choice from the menu. Repeat the process for the other <Select Measurement> menus in the other displays.

4. Select Record in the Controls Palette to begin collecting data. Later, select Stop to end data collection.

Calibration

The Soil Moisture Sensor comes pre-calibrated for three soil types: potting soil, mineral soil, and rockwool. The Soil Moisture Probe is insensitive to variation in texture and soil conductivity because it operates at a high frequency. Therefore, its calibrations should apply for all potting soil, mineral soil, and rockwool.

Rockwool is a green fibrous mat visually similar to fiberglass insulation used to grow greenhouse crops in hydroponics.

Other

If the type of soil or media that you are using does not appear in the Unit of Measure list, you may want to make measurements to create a soil specific calibration curve yourself, or take advantage of Decagon's calibration service.

The Soil Moisture Probe is built by Decagon Devices, Inc., 2365 NE Hopkins Ct., Pullman, WA 99163

Information on individual probe calibration can be found online at www.decagon.com/appnotes/echocal.pdf

Information on Decagon's calibration service can be found at www.decagon.com/echo/calibration.html.

See the User's Guides for the PASCO Data Collection Software for calibration instructions.

Creating a Calibration Curve

Volumetric Water Content (VWC) is the ratio of the volume of water per volume of bulk soil. One way to create a soil specific calibration curve is to match the voltage output from the Soil Moisture Probe to VWC values for several soil samples with different degrees of dryness, and then plot a graph of VWC versus probe output in millivolts (mV).

The basic process is to collect a measured volume of bulk soil, measure its mass, measure the probe reading in mV for the bulk soil, dry the soil to determine the amount of water that was in the soil, and calculate the ratio of the volume of water to the volume of bulk soil. Then, create a graph of VWC versus probe voltage and determine the “best fit” for the graph. If the graph is linear, determine the slope and y-intercept. If the graph is quadratic, determine the coefficients of each term. A *linear* calibration curve would have a formula of $y = mx + b$ where y is the VWC, m is the slope, x is the probe output in mV, and b is the y-intercept. Finally, create a calculation based on the formula for the soil specific calibration curve.

A *quadratic* calibration curve would have a formula of $y = ax^2 + bx + c$ where y is the VWC, x is the probe output in mV, and a, b, and c are coefficients.

Equipment: shovel and bulk soil container, calibration container, Soil Moisture Probe and PASCO Interface, volumetric soil sampler[1], soil drying containers with lids (e.g., baby food jars), scale or mass balance, drying oven.

Procedure:

1. Collect approximately 4 liters of bulk soil from the depth/location where you want to measure with the probe.
2. Air dry the soil (spread the soil in a thin layer and use a fan to move air over the soil.)
3. Remove large objects from the soil and break up large clods so the soil can fit through a 5 mm mesh.
4. Pack the soil into the calibration container at approximately the field bulk density.
5. Insert the Soil Moisture Probe fully into the soil. Connect the probe to the sensor and the sensor to the interface and use the sensor to make a measurement in millivolts (mV). Record the measurement.
6. Use the volumetric soil sampler to collect a sample near the probe. Place the soil sample into a drying container. Measure and record the mass of the soil sample plus the drying container and then replace the lid on the drying container*.
7. Wet the calibration soil by adding 200 to 300 milliliters of water to the soil as evenly as possible. Thoroughly mix the soil.
8. Repeat steps 3 through 7 until the soil approaches saturation. This generally yields five to seven calibration points.
9. Remove the lids from the drying containers. Dry the volumetric soil samples in a 105 C oven for 24 hours.
10. Remove the soil drying containers from the oven and replace the lids. Allow the containers to cool.
11. Measure and record the mass of the dry soil plus the container (without lid).

*Any water loss due to evaporation after sampling introduces error to the volumetric water content calculation.

Calculations:

1. Determine and record the volume of water by subtracting the dry soil mass from the "wet" (pre-dried) soil mass. Convert the mass difference into a volume based on the density of water (1 g/cm^3).

2. Calculate and record the volumetric water content by dividing the volume of water (cm^3) by the volume of the soil sample (cm^3).

Analysis:

1. Plot volumetric water content versus the sensor voltage output (in mV). Open a Table display and enter the values for sensor voltage output (x-axis) and volumetric water content (y-axis).

2. Open a Graph display and use the "Fit" function (PASCO Capstone) or the "Curve Fit" function (SPARKvue) to find the "best fit" for the plotted data. Record the slope and the y-intercept. (If the best fit is quadratic, record the coefficient, a, b, and c.)

3. Create a calculation for VWC based on the slope and the y-intercept (VWC = mx + b). Let "x" be the sensor voltage output.

[1] A volumetric soil sampler could be a 3 to 5 cm section of metal conduit or other small diameter (1.5 to 2.5 cm) metal or thin walled plastic tubing. Deburr both ends and sharpen one end for easy insertion into the soil. Measure its dimensions and calculate the volume,

$$V = \pi r^2 h$$

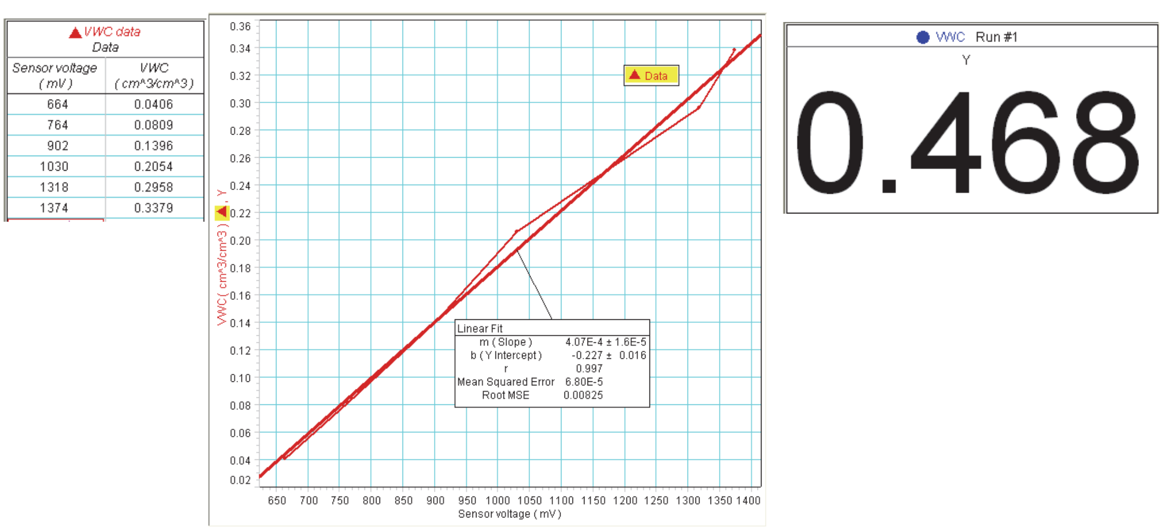
If the best fit is quadratic, create a calculation for VWC based on the coefficients, a, b, and c.

VWC = $ax^2 + bx + c$

where x is the sensor voltage output.

Sample Calibration Data

	Sensor voltage output (mV)	Sample volume (cm^3)	Mass of container + moist soil (g)	Mass of container + dry soil (g)	Volume of water (cm^3)	VWC (cm^3/cm^3)
1	664	15.31	94.836	94.215	0.621	0.0406
2	764	15.31	96.433	95.194	1.239	0.0809
3	902	15.31	96.923	94.785	2.138	0.1396
4	1030	15.31	101.979	98.834	3.145	0.2054
5	1318	15.31	100.402	95.873	4.529	0.2958
6	1374	15.31	101.060	95.886	5.174	0.3379



Experiment Suggestions

- Measure soil moisture over time.
- Evaluate soil moisture content for various species of plants to determine the optimal level of soil moisture.
- Examine soil moisture content in a greenhouse to determine the amount of irrigation.

Specifications (PS-2163)

Sensor Range	0 to 45% volumetric water content in soil
Accuracy	± 4%
Resolution	0.1%
Power	3 mA at 5 V DC
Operating Temperature	-40 to + 60 °C
Default Sample Rate	10 samples per second

PASCO Soil Water Potential Probe (PS-2513)

Introduction

In the engineering community, “soil suction” is used instead of soil water potential. Soil water potential is simply the negative of soil suction.

There are two basic parameters that describe the state of water in soil: one is soil water content, or the amount of water per unit of soil, and the other is soil water potential, or the energy state of the water in the soil. Water potential is often preferred over water content because it shows how water will move in a soil or from the soil to the plant. In an object comes into hydraulic contact with soil, the water potential of the object will come into equilibrium with the soil water potential.

The Soil Water Potential Probe uses a solid matric equilibration technique to measure the water potential of the soil. The probe has a static matrix - a porous ceramic disk - that is allowed to reach hydraulic equilibrium with the soil that is being measured. The probe measures the dielectric permittivity of the ceramic disk to determine its water potential and thereby the water potential of the soil.

Installing the Probe

Because it measures water potential, the probe needs good hydraulic contact with the surrounding soil. The preferred method for installing the probe is to take some native soil, wet it, and pack it in a ball around the entire probe, making sure that the moist soil is in contact with all surfaces of the ceramic disk. The probe and moist soil are then packed into the soil at the desired depth.

After the probe is installed, the hole that was excavated to bury the probe should be back-filled with care taken to re-pack the soil back to its native bulk density. Leave at least 15 cm of cable beneath the soil. Do not bend the cable in a tight radius as it leaves the probe. At least 10 cm of cable nearest the probe should remain in a straight line.

Removing the Probe

When removing the soil water potential probe from the soil, **do not pull it out of the soil by the cable!** Doing so may break internal components and make the probe unusable.

Handling and Care

For the probe to accurately measure water potential, the ceramic disks must readily take up water. If the ceramic disks are exposed to oils or other hydrophobic substances, then the ability of the disks to take up water can be compromised. As much as possible, minimize the exposure of the ceramic disks to skin oils, synthetic oils, or other hydrophopic compounds.

The probe consists of two engineered ceramic disks sandwiched between stainless steel screens and the probe's circuit board. The disks are brittle and can chip or crack if mishandled. Sharp trauma such as dropping the probe onto a hard surface can cause the ceramic to break. A cracked ceramic will cause a loss of accuracy.

Frozen Soil

Under frozen soil conditions, the probe cannot accurately measure the water potential of soil. However, the probe is unaffected by repeated freeze-thaw cycles, so the probe can remain in the soil year round.

Setup

Hardware Setup

The following three steps can be performed in any order.

1. Connect the mini-DIN plug of the Soil Water Potential Probe cable to the front end of the Soil Moisture Sensor box.

2. Connect the Soil Moisture Sensor to a PASPORT-compatible interface.

3. If you will be using a computer, connect the PASPORT interface to the computer's USB port.

The mini-DIN plug on the Soil Water Potential Probe cable fits into the sensor box in only one way.

Calibration

The Soil Water Potential Probe does not require any calibration by the user.

Software Help

See the SPARKvue Help or PASCO Capstone Help for information about collecting, displaying, and analyzing data.

- In SPARKvue, select the **HELP** button (?) in any screen including the Home Screen.

- In PASCO Capstone, select **PASCO Capstone Help** from the **Help** menu, or press **F1**.

Specifications (PS-2513)

Sensor Range	-10 to -50 kPa (pF 2 to pF 3.71)
Accuracy	± 5% from -10 to -50 kPa ± 20% of reading from -50 to -500 kPa
Resolution	1 kPa from -10 to -100 kPa 4 kPa from -100 to -500 kPa
Power	25 mA at 2 to 5 V DC
Operating Temperature	0 to + 50 °C
Default Sample Rate	10 samples per second

The probe's survival temperature is from -40 to +50 °C.

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: +1 916 462 8384 (worldwide)
800-772-8700 (U.S.)

Web: www.pasco.com

Email: support@pasco.com

Replacement Parts

Contact Technical Support about replacement parts. The Soil Moisture Probe Cable Assembly description is CBL ASSY SOIL MOISTURE SNS 5M LONG 5P-MDIN.

For more information about the Soil Moisture Sensor and the latest revision of this Instruction Manual, visit the PASCO Web site at

www.pasco.com/manuals

and enter the product name or number (PS-2163) in the Search text area.

Product End of Life Disposal Instructions:

This electronic product is subject to disposal and recycling regulations that vary by country and region. It is your responsibility to recycle your electronic equipment per your local environmental laws and regulations to ensure that it will be recycled in a manner that protects human health and the environment. To find out where you can drop off your waste equipment for recycling, please contact your local waste recycle/disposal service, or the place where you purchased the product.

The European Union WEEE (Waste Electronic and Electrical Equipment) symbol (to the right) and on the product or its packaging indicates that this product **must not** be disposed of in a standard waste container.