

MPS-1



Dielectric Water Potential Sensor Operator's Manual

Version 2.0



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Contents

1. Introduction	1
Contact Information	1
Warranty Information.....	1
Seller's Liability	1
2. About the MPS-1.....	3
Specifications.....	3
3. Theory	5
4. Installing the Sensors	8
5. Collecting Data	9
Datalogger Requirements.....	9
6. Calibration	13
Units Conversions.....	13
7. Handling and Care	14
MPS-1 in Frozen Soils	14
8. Sample Programs	17
Appendix A	21
Declaration of Conformity.....	21

1. Introduction

Thank you for choosing the Dielectric Water Potential Sensor, model MPS-1 for measuring soil water potential. This manual is designed to help you understand the sensor's features, and how to use this device successfully.

In the engineering community, the term soil suction is commonly used instead of soil water potential. Soil water potential is simply the negative of soil suction and will be used throughout the remainder of this manual.

Contact Information

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Telephone:

1-800-755-2751 (USA and Canada Only)

1-509-332-2756 International

Our Customer Support and Sales Representatives are available Monday thru Friday, 8am-5pm Pacific Time.

NOTE: With any correspondence please include your name, contact information, instrument serial number(s), and a description of your problem or question.

Water Potential Probe

1. Introduction

Warranty Information

The Dielectric Water Potential Sensor has a 30-day satisfaction guarantee and a one-year warranty.

Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not to be considered a defect); but Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts F.O.B. the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

2. About the MPS-1

The MPS-1 measures the water potential of soil and other porous materials. The MPS-1 has a low power requirement which makes it an ideal sensor for permanent burial in the soil and continuous reading with a datalogger or periodic reading with a handheld reader.

Specifications

Range: -10 to -500 kPa (pF 2 to pF 3.71)

Accuracy: ± 5 kPa from -10 to -50 kPa
 $\pm 20\%$ of reading from -50 to -500 kPa

Resolution: 1 kPa from -10 to -100 kPa
4 kPa from -100 to -500 kPa

Measurement Time: 10 ms (milliseconds)

Power requirements: 2 to 5 V DC @ 25 mA

Output: 500 to 1000 mV DC independent of excitation voltage

Operating Temperature: 0 °C to +50 °C

Survival Temperature: -40 °C to 50 °C

Sensor Dimensions: 75 mm x 32 mm x 15mm

Water Potential Probe

2. About the MPS-1

Connector types: 3.5 mm “stereo”
plug or stripped and tinned lead wires (3)

Cable length: Standard cable length is 5 m. Extension cables and custom cable lengths available upon request, up to a maximum length of 15 m.

Datalogger Compatibility: (not exclusive)

Decagon: Em50, Em50R (firmware version 1.14)

Campbell Scientific: CR10X, 21X, 23X, CR1000, CR3000,
Etc.

Other: Any data acquisition system capable of switched 2 to 5 V excitation and single ended voltage measurement at 12 bit or better resolution

Software Compatibility:

ECH2O Utility 1.09 or later

ECH2O Utility Mobile 1.17 or later

ECH2O Data Trac 2.77 or later

3. Theory

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 water in the soil. Although water content is useful when trying to describe the water balance of a soil, i.e. how much water is moving in, out, or being stored, 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 addition, water potential can be used to determine plant availability of water, determine soil stress, and simply schedule irrigation, among other things.

All soil water potential measurement techniques measure the potential energy of water in equilibrium with water in the soil. The Second Law of Thermodynamics states that connected systems with differing energy levels will move toward an equilibrium energy level. Thus, if an object comes into hydraulic contact with the soil, the water potential of the object will come into equilibrium with the soil water potential. Examples of instruments that make use of this principal are tensiometers, which measure the potential energy of a liquid water reservoir in equilibrium with the soil water (liquid equilibration), and psychrometers/dewpoint hygrometers, which measure the potential energy of water vapor in equilibrium with the soil water (vapor equilibration).

Another category of water potential sensors use a solid matrix equilibration technique to measure the water poten-

Water Potential Probe

3. Theory

tial of the soil. This technique introduces a known material with a static matrix of pores into the soil and allows it to come into hydraulic equilibrium according to the Second Law of Thermodynamics noted above. Because the two are in equilibrium, measuring the water potential of the material will give the water potential of the soil. Historically, instruments have measured the thermal conductivity or electrical conductivity of the solid matrix to determine its water potential with varying degrees of success.

The MPS-1 uses the same principle, but instead measures the dielectric permittivity of a solid matrix - porous ceramic disks - to determine its water potential. The dielectric permittivity of air, the solid ceramic, and water are 1, 5, and 80 respectively. So, the dielectric permittivity of the porous ceramic disks is highly dependent on the amount of water that is present in the pore spaces of the ceramic. Thus, by measuring the dielectric permittivity of the ceramic disks, a wide range of water contents can be resolved.

Water content and water potential are related by a relationship unique to a given material. The ceramic used with the MPS-1 has a wide pore size distribution and is consistent between disks. So, if the water content of the ceramic is measured accurately, along with a measurement of actual water potential, then a calibration curve is generated that will give a standard calibration for the MPS-1 in terms of water potential. This calibration is not dependent on the type of soil into which the MPS-1 is installed.

The total soil water potential (Ψ_t) is made up of four water potential components:

$$\Psi_t = \Psi_p + \Psi_g + \Psi_o + \Psi_m$$

where the subscripts p, g, o, and m are pressure, gravitational, osmotic, and matric respectively. Of these four components, only Ψ_o and Ψ_m are important and often measured in soil. Ψ_o arises from dissolved salts in the soil, and only becomes important if a semi permeable barrier is present that prevents ionic movement (e.g. plant roots, cell membranes). Ψ_m arises from the attraction of water to the soil particles, and is the most important component of water potential in all but the most salt affected soils. The MPS-1 only measures the matric potential of the soil (Ψ_m). In highly salt affected soils, it may be necessary to quantify Ψ_o independently if measures of soil water potential relating to biological activity are being conducted.

Water Potential Probe

4. Installing the Sensors

4. Installing the Sensors

Because it measures water potential, the MPS-1 is not as sensitive to air gaps or soil disturbance as water content sensors. It does, however, need good hydraulic contact with the surrounding soil. The preferred method for installing the sensor is to take some native soil, wet it, and pack it in a ball around the entire MPS-1, making sure that the moist soil is in contact with all surfaces of the ceramic. The sensor and moist soil are then packed into the soil at the desired depth.

In sandy soils, the soil may not adhere to the sensor even when wet. In this case the sensor can be packed into soil at the bottom of a hole dug to the desired installation depth. Again, care should be taken to pack the sandy soil around the sensor with good contact to all ceramic surfaces.

After installing the sensor and moist soil, the hole that was excavated to bury the sensor at depth should be back-filled with care taken to re-pack the soil back to its native bulk density. It is best to leave at least six inches of sensor cable beneath the soil before bringing the cable to the surface. The cable should never be bent in a tight radius as it leaves the sensor body. At least four inches of cable should exit the sensor body in a straight line before bending the cable.

5. Collecting Data

Datalogger Requirements

The MPS-1 is designed to work most efficiently with Decagon's Em50 or Em50R dataloggers or our ProCheck hand-held readout. They can, however, be adapted for use with other dataloggers, such as those from Campbell Scientific, Inc., for example. The MPS-1 requires an excitation voltage in the range of 2 to 5 volts. It produces an output voltage that is related to the water potential of the soil in which it is buried, and ranges between approximately 0.5 to 1 V DC. The output of the MPS-1 is independent of the excitation voltage between 2 and 5V. Any datalogger which can produce a 2 to 5V excitation with approximately 10 millisecond duration and read a volt-level signal with 12-bit or better resolution should be compatible with the MPS-1. The current requirement for the MPS-1 is 25mA.

Note: MPS-1 is intended only for use with dataloggers and readout devices which can provide short excitation pulses, leaving the sensor turned off most of the time. Continuous excitation not only wastes battery power, but may, under certain circumstances, cause the sensor to exceed government specified limits on electromagnetic emissions.

Using the MPS-1 with Em50/Em50R dataloggers

The MPS-1 is designed for very easy integration into the Em50 based datalogging system. Simply plug the stereo plug into one of the five ports on the Em50/Em50R, use ECH₂O Utility or DataTrac software to configure that

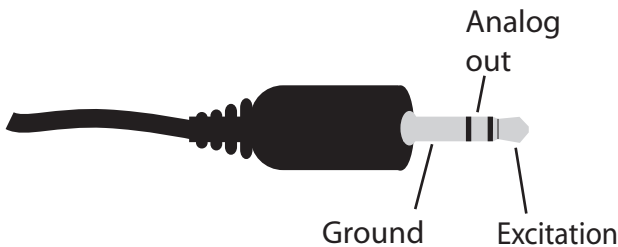
Water Potential Probe

5. Collecting Data

port for an MPS-1 and set a measurement interval for the logger. For more detailed instructions on configuring the Em50/Em50R, consult your Em50/Em50R user manual.

3.5mm Stereo Plug Wiring

MPS-1 sensors used with Decagon loggers come with a 3.5mm “stereo plug” connector. The stereo plug allows for rapid connection directly to Decagon’s Em50 and Em50R logger (Firmware R1.14 or greater) and to the hand-held ProCheck. Below is a diagram showing the wiring configuration for this connector.



Extending sensor cables

Decagon offers 10-foot (3m) extension cables for use with the stereo plug type MPS-1 sensors. You can safely connect up to four of the 10-foot cables without significant signal attenuation. For field applications, it is **critical** to seal the connections from the elements to maintain a good connection and to prevent corrosion. It is imperative that these connections are checked before the sensor is buried. On the Decagon website you can access a step by step photo tutorial of how to seal the connection. To access this file go to www.decagon.com/litature/app_notes

Water Potential Probe

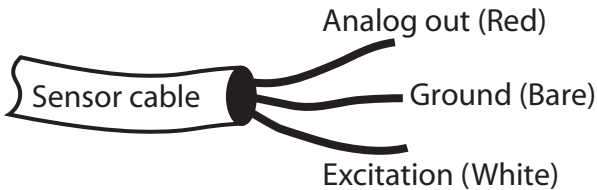
5. Collecting Data

and click on the Wire Splicing and Sealing Technique for Soil Moisture Sensors.

MPS-1 sensors with stereo plug ends can be made with custom cable lengths, up to 50 ft (15m) on a per foot fee basis. This option gets around the need for waterproofing connections.

Connecting to a non-Decagon Datalogger

MPS-1 sensors for use with non-Decagon dataloggers come pre-configured with stripped and tinned lead wires at the customer's request. Below is a diagram showing the wiring configuration for this connection

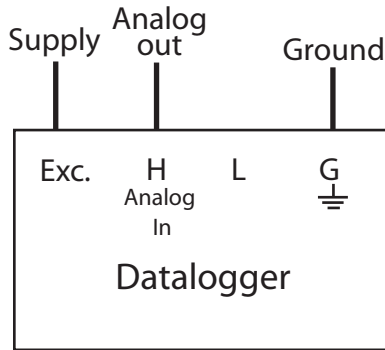


MPS-1 sensors with stripped and tinned cable option can be made with custom cable lengths up to 50ft (15m) on a per foot fee basis. This option gets around the need for splicing cables.

Connect the wires to the datalogger as shown, with the supply wire (white) connected to the excitation, the analog out wire (red) to an analog input, and the bare ground wire to ground as seen below.

Water Potential Probe

6. Calibration



If your MPS-1 is equipped with the standard 3.5mm plug, and you wish to connect it to a non-Decagon datalogger, you have two options. First, you can clip off the plug on the sensor cable, strip and tin the wires, and wire it directly into the datalogger. This has the advantage of creating a direct connection with no chance of the sensor becoming un-plugged; however, it then cannot be used in the future with a Decagon Em50 or Em50R logger.

The other option is to obtain an adapter cable from Decagon. The 3-wire sensor adapter cable has a connector for the sensor jack on one end, and three wires on the other end for connection to a datalogger (this type of wire is often referred to as a “pigtail” adapter). Both the stripped and tinned adapter cable wires have the same termination as seen above; the white wire is excitation, red is output, and the bare wire is ground.

6. Calibration

The MPS-1 does not require any calibration by the user. Each MPS-1 sensor is calibrated at Decagon to equate the relationship between sensor output and soil water potential. With Decagon's Em50, Em50R, and ProCheck readers, this relationship is:

$$\text{water potential (kPa)} = -e^{(6.43 \times 10^{-6} * \text{raw counts}^2 - 3.10 \times 10^{-2} * \text{raw counts} + 39.45)}$$

With other data acquisition equipment, if the sensor is excited with a voltage level between 2 and 5V, the relationship is:

$$\text{water potential (kPa)} = -e^{(4.80 \times 10^{-5} * \text{mV}^2 - 8.46 \times 10^{-2} * \text{mV} + 39.45)}$$

Note that this calibration is only valid from -10 to -500 kPa. The MPS-1 has sensitivity below this range, but the calibration equations provided above may not result in accurate measurements of water potential below -500 kPa.

Units Conversions

Other commonly used measures of water potential are MPa (megapascals), bars and pF.

$$1 \text{ MPa} = 1000 \text{ kPa}$$

$$1 \text{ Bar} = 100 \text{ kPa}$$

$$1 \text{ pF} = \log_{10}(-10.2 * \text{kPa})$$

7. Handling and Care

The MPS-1 sensor measures the water potential of two engineered ceramic disks sandwiched between stainless steel screens and the MPS-1 circuit board. The ceramic disks are somewhat brittle, and can chip or crack if abused. The metal screens afford the disks some amount of protection, but sharp trauma on the disk edges or massive impact (such as dropping the sensor onto a hard surface) can cause the ceramic to break. One or two small chips on the edge of the disk will not affect the sensor accuracy significantly. However, a cracked ceramic will create a loss of accuracy.

For the MPS-1 to accurately measure water potential, the ceramic disks must readily take up water. If the ceramic is exposed to oils or other hydrophobic substances, then the ability of the disks to take up water from the soil can be compromised leading to slow equilibration times and/or loss of accuracy. It is recommended that exposure of the ceramic material to skin oils be minimized as much as is conveniently possible, and it is highly recommended that the disks not be handled with greasy hands, or otherwise exposed to synthetic oils or other hydrophobic compounds.

MPS-1 in Frozen Soils

The MPS-1 measures the dielectric permittivity of two ceramic disks to measure their water content and then derive their water potential. The dielectric permittivity of water in

Water Potential Probe

7. Handling and Care

the ceramic disks is 80 compared to a dielectric permittivity of ~ 5 for the ceramic material, and 1 for air. When water freezes to ice, the dielectric permittivity drops to 5 at the frequency of the MPS-1 measurement meaning that the MPS-1 can no longer accurately measure the water in the ceramic. Under frozen soil conditions, the MPS-1 will not accurately measure the water potential of soil. However, under frozen soil conditions, the water potential of the soil can be measured simply by measuring the soil temperature accurately (Koopmans and Miller, 1966). For each 1°C decrease in temperature below 0°C , the water potential in the soil decreases by $\sim 1200\text{ kPa}$. Spaans and Baker (1996) showed that this relationship is valid in field soils for water potentials below about -50 kPa .

Rigorous testing indicates that the MPS-1 ceramic disks are unaffected by repeated freeze-thaw cycles. Several sensors were equilibrated in saturated soil, and then subjected to numerous freeze-thaw cycles in a temperature control chamber. The freezing rate of the soil containers was at least an order of magnitude faster than could be achieved in field soil under natural conditions. At several points during the test, and at the end of the test, the ceramic disks were evaluated for damage due to repeated rapid freezing with pore spaces full of water. None of the ceramic disks showed any signs of physical damage, and none of the sensors showed any significant change in output due to the freezing tests.

Water Potential Probe

7. Handling and Care

References:

Koopmans, R. W. R., and R. D. Miller 1966. Soil freezing and soil water characteristic curves, *Soil Sci. Soc. Am. Proc.*, 30, 680– 685, 1966.

Spaans, E. J. A., and J. M. Baker 1996. The soil freezing characteristic: Its measurement and similarity to the soil moisture characteristic, *Soil Sci. Soc. Am. J.*, 60, 13– 19, 1996.

8. Sample Programs

The following programs are examples that can be used with dataloggers from Campbell Scientific. The first program is for a CR10X datalogger, but can be easily adapted to other “Edlog” type loggers. The second program is for a CR1000 datalogger, but can be easily adapted for other “CRBasic” type loggers. Note that the MPS-1 will draw up to 25 mA of current while excited. On most Campbell Scientific dataloggers, each excitation port will only source 25 mA of current, meaning that only one MPS-1 can be excited by any one excitation port without the use of a multiplexer.

Edlog Type program

```

;{CR10X}
;Sample program for reading MPS-1 with CR10X
;
;Wiring:
;White - Excitaiton - E1
;Red - Analog out - SE CH1
;Bare - ground - AG
;
;output is water potential in units of kPa
```

*Table 1 Program

01: 10 Execution Interval (seconds)

Water Potential Probe

8. Sample Programs

1: Excite-Delay (SE) (P4)

- 1: 1 Reps
- 2: 5 2500 mV Slow Range
- 3: 1 SE Channel
- 4: 1 Excite all reps w/Exchan 1
- 5: 1 Delay (0.01 sec units)
- 6: 2500 mV Excitation
- 7: 1 Loc [MPS1_mV]
- 8: 1.0 Multiplier
- 9: 0.0 Offset

2: Z=X*Y (P36)

- 1: 1 X Loc [MPS1_mV]
- 2: 1 Y Loc [MPS1_mV]
- 3: 2 Z Loc [mV_sq]

3: Z=F x 10^n (P30)

- 1: 4.8 F
- 2: -5 n, Exponent of 10
- 3: 3 Z Loc [C2]

4: Z=X*Y (P36)

- 1: 3 X Loc [C2]
- 2: 2 Y Loc [mV_sq]
- 3: 4 Z Loc [term1]

5: Z=X*F (P37)

- 1: 1 X Loc [MPS1_mV]
- 2: -0.0846 F
- 3: 5 Z Loc [term2]

6: Z=X+Y (P33)

Water Potential Probe

8. Sample Programs

1: 4 X Loc [term1]
2: 5 Y Loc [term2]
3: 6 Z Loc [power]

7: Z=X+F (P34)

1: 6 X Loc [power]
2: 39.45 F
3: 6 Z Loc [power]

8: Z=EXP(X) (P41)

1: 6 X Loc [power]
2: 7 Z Loc [MPS1_kPa]

9: Z=X*F (P37)

1: 7 X Loc [MPS1_kPa]
2: -1 F
3: 7 Z Loc [MPS1_kPa]

10: If time is (P92)

1: 0000 Minutes (Seconds --) into a
2: 60 Interval (same units as above)
3: 10 Set Output Flag High (Flag 0)

11: Real Time (P77)^7092

1: 1110 Year,Day,Hour/Minute (midnight = 0000)

12: Average (P71)^2789

1: 1 Reps
2: 7 Loc [MPS1_kPa]

*Table 2 Program

02: 0.0000 Execution Interval (seconds)

Water Potential Probe

8. Sample Programs

*Table 3 Subroutines

End Program

CRBasic type program

'CR1000 Series Datalogger

'Sample program to read MPS-1 sensor with CR1000

'wiring:

'white - excitation - EX1

'red - analog out - SE CH1

'bare - ground - ground

Public MPS1_mV, MPS1_kPa

DataTable (table1,1,-1)

 DataInterval (0,60,Min,10)

 Average (1,MPS1_kPa,FP2,False)

EndTable

BeginProg

 Scan (10,Sec,0,0)

 BrHalf (MPS1_mV,1,mV2500,1,Vx1,1,2500, False
10000,_60Hz,2500,0)

 MPS1_kPa = -EXP(0.000048 * MPS1_mV^2 -
0.0846 * MPS1_mV + 39.45)

 CallTable table1

 NextScan

EndProg

Appendix A

Declaration of Conformity

Application of Council Directive: 89/336/EE6

Standards to which conformity is declared:

EN61326 :1998 EN51022 : 1998

Manufacturer's Name:

Decagon Devices, Inc.
2365 NE Hopkins Court
Pullman, WA 99163 USA

Type of Equipment:

Dielectric Water Potential Sensor

Model Number: MPS-1

Year of First Manufacture: 2007

This is to certify that the dielectric water potential sensor, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

Index

A

About the MPS-1 4

Adapter cable 13

C

Cable length 5

Calibration 14

Campbell Scientific 5

Care 15

Ceramic disks 15

Compatibility 5

Conformity 22

Contact Information 2

Conversions 14

Corrosion 11

CR10X datalogger 18

Custom cable lengths 12

D

Datalogger Requirements 10

Dielectric permittivity 7

E

Em50R 10

E-mail 2

Energy of water 6

Extending sensor cables 11

F

Fax 2

Frozen Soils 15

H

Handling 15

Hydraulic contact 9

Hydrophobic substances 15

I

Installing the Sensors 9

L

Liability 2

M

Manufacturer 22

Model Number 22

N

Non-Decagon Datalogger 12

P

Power 4

ProCheck 10

Programs 18

R

References 16

S

Water Potential Probe

Index

Sandy soils 9
Soil water content 6
Soil water potential 6
Specifications 4

T

Telephone 2
Temperature 4
Tensiometers 6

W

Warranty 2
Water potential components 7
Waterproofing 11
Wiring configuration 11