

**MODEL 257-LC (WATERMARK 200)
SOIL MOISTURE SENSOR
FOR
METDATA1**

4/97

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MODEL 257-LC (WATERMARK 200) SOIL MOISTURE SENSOR FOR METDATA1

1. GENERAL

The Watermark 200 (CSI sensor Model 257-LC) provides a convenient method of estimating water potential between 0 and 2 bars (wetter soils) with the MetData1 system.

The Watermark block estimates water potential. For applications requiring high accuracy, call a Campbell Scientific applications engineer for information on precision soil moisture measurement systems.

The Watermark consists of two concentric electrodes embedded in a reference matrix material. The matrix material is surrounded by a synthetic membrane for protection against deterioration. An internal gypsum tablet buffers against the salinity levels found in irrigated soils.

If cultivation practices allow, the sensor can be left in the soil all year, eliminating the need to remove the sensor during the winter months.

NOTE: The black outer jacket of the cable is Santoprene® rubber. This compound was chosen for its resistance to temperature extremes, moisture, and UV degradation. However, this jacket will support combustion in air. It is rated as slow burning when tested according to U.L. 94 H.B. and will pass FMVSS302. Local fire codes may preclude its use inside buildings.

2. INSTALLATION AND REMOVAL

Placement of the Watermark is important. To acquire representative measurements, avoid high spots, slope changes, or depressions where water puddles. Typically, the sensor must be located in the root system of the crop.

1. Soak the sensors overnight in irrigation water. Always install a wet sensor. If time permits, allow the sensor to dry for 1 to 2 days after soaking, and repeat the soak/dry cycle twice to improve sensor response.

2. Make a sensor access hole to the depth required with a 7/8" rod. Fill the hole with water and push the sensor to the bottom of the hole. Very coarse or gravelly soils may require an oversized hole (1 to 1-1/4") to prevent abrasion damage to the sensor membrane. In this case, you will need to "grout in" the sensor with a slurry made from the sample soil to get a snug fit in the soil.

Snug fit in the soil is most important. Lack of a snug fit is the premier problem in sensor effectiveness. In gravelly soils, and with deeper sensors, sometimes it is hard to get the sensor in without damaging the membrane. The ideal method of making the access hole is to have a "stepped" tool that makes an oversized hole for the upper portion and an exact size hole for the lower portion. In either case, the hole needs to be carefully backfilled and tamped down to prevent air pockets which could allow water to channel down to the sensor.

A length of 1/2" class 315 PVC pipe fits snugly over the sensor collar and can be used to push in the sensor.

You can leave the PVC in place with the wires threaded through the pipe and the open end taped shut (duct tape is adequate). This practice also makes it easy to remove sensors used in annual crops. When doing this, solvent weld the PVC pipe to the sensor collar. Use PVC/ABS cement on the stainless steel sensors with the green top. Use clear PVC cement only on the PVC sensors with the gray top.

3. When removing sensors prior to harvest in annual crops, do so just after the last irrigation when the soil is moist. Do not pull the sensor out by the wires. Careful removal prevents sensor and membrane damage.
4. When sensors are removed for winter storage, clean, dry, and place them in a plastic bag.

3. CONNECTION

The 257-LC cable is attached to the MetData1 connector #6.

4. MEASUREMENT

NOTE: Information in this section is not necessary when programming the MetData1 with the Short Cut Program Builder software.

Instruction 5, AC Half Bridge, is used to excite and measure the model 257-LC.

4.1 CALCULATE SENSOR RESISTANCE - INSTRUCTION 59

Instruction 59, Bridge Transform, is used to output sensor resistance (R_s). The instruction takes the AC Half Bridge output (V_s/V_x) and computes the sensor resistance as follows.

$$R_s = R1(X/(1-X))$$

where, $X = V_s/V_x$ (Output from Instruction 5)

A multiplier of 1 should be used to output sensor resistance (R_s) in terms of $k\Omega$.

4.2 CALCULATE SOIL WATER POTENTIAL

The datalogger can calculate soil water potential (bars) from the sensor resistance (R_s) and soil temperature (T_s). See Table 2.

The need for a precise soil temperature measurement should not be over emphasized. Soil temperatures vary widely where placement is shallow and solar radiation impinges on the soil surface. A soil temperature measurement may be needed in such situations, particularly in research applications. Many applications, however, require deep placement (5 to 10 inches) in soils shaded by a crop canopy. A common practice is to assume the air temperature at sunrise will be close to what the soil temperature will be for the day.

4.2.1 Linear Relationship

For applications in the range of 0 to 2 bars, the water potential and temperature responses of the Watermark can be assumed to be linear (measurements beyond 1.25 bars have not been verified, but work in practice).

The following equation normalizes the resistance measurement to 21°C.

$$R_{21} = \frac{R_s}{1 - (0.018 * dT)} \quad [1]$$

where

R_{21} = resistance at 21°C

R_s = the measured resistance

$dT = (T_s - 21)$

T_s = soil temperature

Water potential is then calculated from R_{21} with the relationship.

$$SWP = 0.07407 * R_{21} - 0.03704 \quad [2]$$

SWP = Soil Water Potential (bars)

5. PROGRAMMING (MEASURING BLOCK RESISTANCE)

NOTE: Information in this section is not necessary when programming the MetData1 with the Short Cut Program Builder software.

The following examples demonstrate the programming used to measure the resistance (kohms) of one soil moisture block with the MetData1 CR10(X) datalogger.

5.1 CR10(X)

XX:	P5	AC Half Bridge (Measure AC Conductivity)
01:	1	Rep
02:	14	250 mV Fast Range
03:	4	In Channel
04:	3	Excite All Reps w/ Excitation Channel 2
05:	250	mV Excitation
06:	1	Location (Indexed Location to Store) [:kOhms#1]
07:	1	Multiplier
08:	0	Offset

XX:	P59	BR Transform $R_f[X/(1-X)]$ (Compute Resistances)
01:	1	Reps
02:	1	Location [:kOhms#1]
03:	1	Multiplier ($R_f/1000$)

6. PROGRAMMING (CALCULATING SOIL WATER POTENTIAL)

NOTE: Information in this section is not necessary when programming the MetData1 with the Short Cut Program Builder software.

6.1 LINEAR RESISTANCE AND TEMPERATURE RELATIONSHIP (0 TO 2 BARS)

Calculate Temperature Correction Factor. See Equation [1] in Section 4.2.1...

...Calculate $dT = T - 21$

```
XX:   P34      Z=X+F
01:   34      X Loc TmpDegC
02:  -21      F
03:   36      Z Loc [:CorrFctr]
```

...Calculate $(0.018 * dT)$

```
XX:   P37      Z=X*F
01:   36      X Loc CorrFctr
02:   .018    F
03:   36      Z Loc [:CorrFctr]
```

...Calculate $(1 - (0.018 * dT))$

```
XX:   P34      Z=X+F
01:   36      X Loc CorrFctr
02:   -1      F
03:   36      Z Loc [:CorrFctr]
```

```
XX:   P37      Z=X*F
01:   36      X Loc CorrFctr
02:   -1      F
03:   36      Z Loc [:CorrFctr]
```

Apply Temperature Correction and Sensor Calibration to Ohm Measurements. See Equation [2] in Section 4.2.1...

...Temperature Correct Ohms:

```
XX:   P38      Z=X/Y
01:   1       X Loc kOhms#1
02:   36      Y Loc CorrFctr
03:   41      Z Loc [:Bars#1 ]
```

...Apply Calibration Slope and Offset

```
XX:   P37      Z=X*F
01:   41      X Loc Bars#1
02:   .07407  F
```

```
03:   41      Z Loc [:Bars#1 ]
XX:   P34      Z=X+F
01:   41      X Loc Bars#1
02:   -.03704  F
03:   41      Z Loc [:Bars#1 ]
```

7. PROGRAMMING (COMPREHENSIVE)

NOTE: Information in this section is not necessary when programming the MetData1 with the Short Cut Program Builder software.

Follow these steps to create a complete program:

Step 1. Set the execution interval according to need:

```
*           1      Table 1 Programs
01:  3600      Sec. Execution Interval
```

Step 2. Make a temperature measurement to correct for temperature effects. Select from options 1 or 2.

Option 1. If you have a 107-LC probe for measuring soil temperature:

```
XX:   P11      Temp 107 Probe
01:   1       Rep
02:   8 or 9*  IN Chan
03:   3       Excite all reps w/EXchan 3
04:   34      Loc [:TempDegC ]
05:   1       Mult
06:   0       Offset
```

* Specify input channel #8 for connector #4.
Specify input channel #9 for connector #7.

Option 2. If you only have an air temperature measurement, measure air temperature in the early morning (6:00 A.M.) and assume that will be the soil temperature for the day:

```
XX:   P92      If time is
01:   360      minutes (seconds--) into a
02:  1440      minute or second interval
03:   30      Then Do
```

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```
XX:  P11      Temp 107 Probe
01:   1       Rep
02:   8 or 9  IN Chan
03:   3       Excite all reps w/EXchan 3
04:  34      Loc [:TempDegC ]
05:   1       Mult
06:   0       Offset
```

```
XX:  P95      End
```

Step 3. Make the resistance measurements. It may be appropriate to make measurements only once or twice a day. This example makes measurements twice a day at 6:00 AM and 6:00 PM:

```
XX:  P92      If time is
01:  360      minutes (seconds--) into a
02:  720      minute or second interval
03:   30      Then Do
```

Insert example from Section 5 here.

Step 4. Calculate soil water potential using resistance and temperature:

Insert example from Section 6 here.

Step 5. Output data to final storage after each measurement and calculation:

```
XX:  P86      Do
01:   10      Set high Flag 0 (output)

XX:  P77      Real Time
01:  0220     Day,Hour-Minute

XX:  P70      Sample kOhm Resistances
01:   1       Reps
02:   1       Loc

XX:  P70      Sample Deg C Temperature
01:   1       Reps
02:   34      Loc

XX:  P70      Sample Bar Potential
01:   1       Reps
02:   41      Loc

XX:  P95      End 6 am and 6 pm loop
```

8. INTERPRETING RESULTS

As a general guide, Watermark 200 measurements indicate soil moisture as follows:

0 to 10 centibars = Saturated soil.

10 to 20 centibars = Soil is adequately wet (except coarse sands, which are beginning to lose water).

30 to 60 centibars = Usual range for irrigation (except heavy clay).

60 to 100 centibars = Usual range for irrigation for heavy clay soils.

100 to 200 centibars = Soil is becoming dangerously dry for maximum production.

9. TROUBLESHOOTING

To test the sensor, submerge it in water. Measurements should be from -.03 to .03 bars. Let the sensor dry for 30 to 48 hours. You should see the reading increase from 0 to 150+. Put the sensor back in the water. The reading should run right back down to zero in 1 to 2 minutes. If the sensor passes these tests, consider the following.

1. Sensor may not have a snug fit in the soil. This usually happens when an oversized access hole has been used and the backfilling of the area around the sensor is not complete.
2. Sensor is not in an active portion of the root system, or the irrigation is not reaching the sensor area. This can happen if the sensor is sitting on top of a rock or below a hard pan which may impede water movement. Re-installing the sensor usually solves this problem.
3. When the soil dries out to the point where you are seeing readings higher than 80 centibars, the contact between soil and sensor can be lost because the soil may start to shrink away from the sensor. An irrigation which only results in a partial rewetting of the soil will not fully rewet the sensor, which can result in continued high

readings from the Watermark. Full rewetting of the soil and sensor usually restores soil/sensor contact. This is most often seen in the heavier soils and during peak crop water demand when irrigation may not be fully adequate. The plotting of readings on a chart is most useful in getting a good picture of this sort of behavior.

Reference

Thompson, S.J. and C.F. Armstrong, Calibration of the Watermark Model 200 Soil Moisture Sensor, Applied Engineering in Agriculture, Vol. 3, No. 2, pp. 186-189, 1987.

Parts of this manual were contributed by Irrrometer Company, Inc., manufacturer of the Watermark 200.

