



# Innovative

## More accurate in soils with high bulk EC

### Benefits and Features

- › More accurate water content measurements in soils with bulk EC  $\leq 3$  dS m<sup>-1</sup> (CS650) or  $\leq 8$  dS m<sup>-1</sup> (CS655) without performing a soil-specific calibration
- › Larger sample volume reduces error
- › Measurement corrected for effects of soil texture and electrical conductivity
- › Estimates soil-water content for a wide range of mineral soils
- › Versatile sensor—measures dielectric permittivity, bulk electrical conductivity (EC), and soil temperature

### Overview

The CS650 and CS655 soil water content reflectometers use innovative techniques to monitor soil volumetric water content, bulk electrical conductivity, and temperature. They consist of two stainless-steel rods connected to a printed circuit board. The

CS650 has 30-cm rods, and the CS655 has 12-cm rods. The probe's circuit board is encapsulated in epoxy and a shielded cable is attached to the circuit board for datalogger connection.

### Ordering Information

#### Water Content Reflectometers

For either reflectometer, must choose a cable termination option and SDI-12 Address option (see below).

- CS650-L** 30-cm Water Content Reflectometer with user-specified cable length. Enter cable length, in feet, after -L. Refer to specifications for maximum cable length.
- CS655-L** 12-cm Water Content Reflectometer with user-specified cable length. Enter cable length, in feet, after -L. Refer to specifications for maximum cable length.

#### Cable Termination Options (choose one)

- PT** Cable terminates in pigtailed for direct connection to datalogger's terminals.
- PW** Cable terminates in a connector for attachment to a prewired enclosure.

#### SDI-12 Address Options (choose one)

- DS** SDI-12 Address is set to 0
- VS** SDI-12 Address is set to the last digit of the probe's serial number (0 to 9).

#### Installation Tools and PC Interface

- CS650G** Rod Insertion Guide Tool with Pilot Rod that helps maintain the proper spacing and parallel orientation of the rods during probe insertion. It also helps the insertion of the probe in high density or rocky soils.
- A200** Sensor to PC Interface (for configuring sensor)

#### DIN-Rail Accessories

The following accessories can facilitate wiring when several reflectometers need to be connected to one terminal.

- 25458** 5-in. Din Rail Mounting Kit. A complete configuration requires terminal strips, end plates, and jumpers (see below).
- 15920** 3-Pin 4-mm Spring Loaded Din Rail Connectors that provide connection points for individual wires. Up to 20 of these terminal strips may be fastened to the 25458.
- 15909** Horizontal Jumper for Din Rail Connector that electrically connects terminals on the 15920 connectors.
- 15907** The 15907 End Plates separate the terminal strips.

## Measurement Method

The CS650 and CS655 measure propagation time, signal attenuation, and temperature. Dielectric permittivity, volumetric water content, and bulk electrical conductivity are then derived from these raw values.

Measured signal attenuation is used to correct for the loss effect on reflection detection and thus propagation time measurement. This loss-effect correction allows accurate water content measurements in soils with bulk EC  $\leq 3$  dS m<sup>-1</sup> (CS650) or  $\leq 8$  dS m<sup>-1</sup> (CS655)

without performing a soil specific calibration. Soil bulk electrical conductivity is also calculated from the attenuation measurement.

A thermistor in thermal contact with a probe rod near the epoxy surface measures temperature. Horizontal installation of the sensor provides accurate soil temperature measurement at the same depth as the water content. Temperature measurement in other orientations will be that of the region near the rod entrance into the epoxy body.

## Specifications

- › Sensing Volume<sup>1</sup>: 7800 cm<sup>3</sup> (CS650), 3600 cm<sup>3</sup> (CS655)
- › Maximum Cable Length: 610 m (2000 ft) combined length for up to 10 sensors connected to the same datalogger control port.
- › Probe Head Dimensions: 85 x 63 x 18 mm (3.3 x 2.5 x 0.7 in.)
- › Rod Diameter: 3.2 mm (0.13 in.)
- › Rod Spacing: 32 mm (1.3 in.)

### Rod Length

- › CS650: 300 mm (11.8 in.)
- › CS655: 120 mm (4.72 in.)

### Weight

- › CS650 w/o cable: 280 g (9.9 oz.)
- › CS655 w/o cable: 240 g (8.5 oz.)
- › Cable: 35 g per m (0.38 oz. per ft)

### Soil Temperature

- › Measurement Range: -10° to + 70°C
- › Accuracy<sup>2</sup>:  $\pm 0.5^\circ\text{C}$  for probe body buried in soil
- › Precision<sup>2</sup>:  $\pm 0.02^\circ\text{C}$

### Relative Dielectric Permittivity Measurements

- › Range: 1 to 81
- › Accuracy<sup>2</sup>

Range	CS650	CS655
1 to 40	$\pm(2\% \text{ of reading} + 0.6)$ for solution EC $\leq 3$ dS m <sup>-1</sup>	$\pm(3\% \text{ of reading} + 0.8)$ for solution EC $\leq 8$ dS m <sup>-1</sup>
40 to 81	$\pm 1.4$ for solution EC $\leq 1$ dS m <sup>-1</sup>	$\pm 2$ for solution EC $\leq 2.8$ dS m <sup>-1</sup>

- › Precision<sup>2</sup>:  $< 0.02$

### Volumetric Water Content Measurements

- › Range: 5% to 50%
- › Precision<sup>3</sup>:  $< 0.05\%$

### Accuracy<sup>2</sup>

- › CS650:  $\pm 3\%$  typical in mineral soils, where solution EC  $\leq 3$  dS m<sup>-1</sup>
- › CS655:  $\pm 3\%$  typical in mineral soils, where solution EC  $\leq 10$  dS m<sup>-1</sup>

### Electrical Conductivity Measurements

- › Range

	CS650	CS655
Solution EC	0 to 3 dS m <sup>-1</sup>	0 to 8 dS m <sup>-1</sup>
Bulk EC	0 to 3 dS m <sup>-1</sup>	0 to 8 dS m <sup>-1</sup>

- › Accuracy<sup>2</sup>:  $\pm(5\% \text{ of reading} + 0.05)$
- › Precision<sup>2</sup>: 0.5% of BEC

### Electrical

- › Sensor Output: SDI-12; serial RS-232.
- › Warmup Time: 3 s
- › Measurement Time: 3 ms to measure; 600 ms to complete SDI-12 command
- › Power Supply Requirements: 6 Vdc to 18 Vdc; must be able to supply 45 mA @ 12 Vdc
- › Electromagnetic: CE compliant (EMC compliant performance criteria available upon request). Meets EN61326 requirements for protection against electrostatic discharge and surge. External RF sources can affect the probe's operation. Therefore, the probe should be located away from significant sources of RF such as ac power lines and motors.
- › Interprobe Interference: Multiple reflectometers can be installed within 4 inches of each other when using the standard datalogger SDI-12 "M" command. The SDI-12 "M" command allows only one reflectometer to be enabled at a time.

### Current Drain (see graph in manual)

- › Active (3 ms): 45 mA typical @ 12 Vdc (80 mA @ 6 Vdc, 35 mA @ 18 Vdc)
- › Quiescent: 135  $\mu\text{A}$  typical @ 12 Vdc
- › Average:  $I = 0.09n + [3.5 + 0.024(n-1)]n/s$   
Where,  
I = average current in milliamps  
n = number of probes  
s = number of seconds between measurement

<sup>1</sup> Approximately 7.5 cm radius around each probe rod and 4.5 cm beyond the end of the rods.

<sup>2</sup> Accuracy specifications are based on laboratory measurements in a series of solutions with dielectric permittivities ranging from 1 to 81 and solution electrical conductivities ranging from 0 to 3 dS/m.

<sup>3</sup> Precision describes the repeatability of a measurement. It is determined for the reflectometer by taking repeated measurements in the same material.