Water Content Reflectometer

Model CS616-L

The CS616 Water Content Reflectometer measures the volumetric water content of porous media using time-domain measurement methods that are sensitive to dielectric permittivity. The probe consists of two 30 cm long stainless steel rods connected to a printed circuit board. The circuit board is encapsulated in epoxy, and a shielded four-conductor cable is connected to the circuit board to supply power, enable probe, and monitor the output. The probe rods can be inserted from the surface or the probe can be buried at any orientation to the surface.

Compatible dataloggers include our CR510, CR800, CR10X, CR1000, CR3000, and CR5000. Please note that the CS616 is not compatible with the CR200-series, CR7, or CR9000X dataloggers. However, a similar sensor, the CS625, has been developed specifically for our CR200-series dataloggers.

The CS616 (at left) is compatible with many of our dataloggers including the CR1000 (shown above).

The reflectometer connects directly to one of the datalogger's single-ended analog inputs. A datalogger control port is typically used to enable the CS616 for the amount of time required to make the measurement. Datalogger instructions convert the probe square-wave output to period which is converted to volumetric water content using a calibration.

Reflectometer measurement method

The differentially-driven probe rods form a transmission line with a wave propagation velocity that is dependent on the dielectric permittivity of the medium surrounding the rods. Nanosecond rise-times produce waveform reflections characteristic of an open-ended transmission line. The return of the reflection from the ends of the rods triggers a logic state change which initiates propagation of a new wavefront. Since water has a dielectric permittivity significantly larger than other soil constituents, the resulting oscillation frequency is dependent upon the average water content of the medium surrounding the rods. The megahertz oscillation frequency is scaled down and easily read by a Campbell Scientific datalogger.

Each CS616 requires a single-ended input channel. A control port is used to enable one or more probes. Our AM16/32 multiplexer can be used to increase the number of CS616 probes the datalogger can measure. Our CR510 and CR10X dataloggers use Instruction 138 to measure the probe's output period. A control port parameter within Instruction 138 allows you to enable a single CS616 or automatically increment control ports to monitor multiple CS616s connected to sequential analog inputs. Measurement time using Instruction 138 is about 0.5 ms. The period averaging instruction (Instruction 27) can also be used with the CR510 and CR10X dataloggers. The Portset and PeriodAvg instructions are used to measure the CS616 with a CR800, CR1000, CR3000, or CR5000 datalogger. Use of the CS616 requires LoggerNet software. The operating system of older dataloggers might need to be upgraded. Operating system upgrades are available, at no charge, from: www.campbellsci.com/downloads

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Summary of Measurement Performance

- probe-to-probe variability: ±0.5% VWC in dry soil, ±1.5% VWC in typical saturated soil
- accuracy ±2.5% VWC using standard calibration with bulk electrical conductivity ≤0.5 deciSiemen meter^{-1} (dS m^{-1}) and bulk density ≤1.55 g cm^{-3} in measurement range 0% VWC to 50% VWC
- precision 0.05% VWC
- resolution 0.1% VWC

CS616 Response Characteristics

The signal propagating along the parallel rods of the CS616 is attenuated by free ions in the soil solution and conductive constituents of the soil mineral fraction. In most applications, the attenuation is not enough to affect the CS616 response to changing water content, and the response is well described by the standard calibration. However, in soil with relatively high soil electrical conductivity levels, compacted soils, or soils with high clay content, the calibration should be adjusted for the specific medium. Guidance for making these adjustments is provided in the operating manual.

Figure 1 shows calibration data collected during laboratory measurements in a loam soil with bulk of density 1.4 g cm^{-3} (porosity = 0.47). The bulk electrical conductivity at saturation was 0.4 dS m^{-1} (solution electrical conductivity @ 2 dS m^{-1}). The linear calibration works well in the typical water content range of 10% and 40%. Outside this range, a quadratic calibration may be needed.

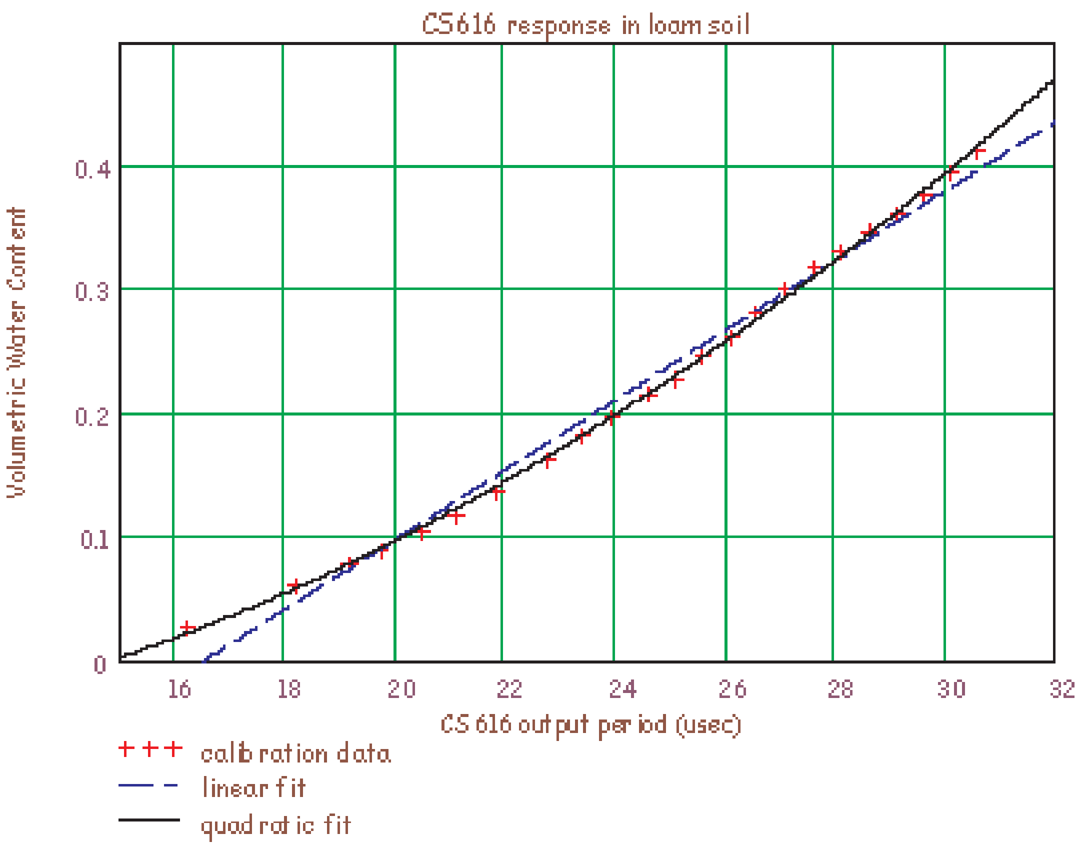

Figure 1. CS616 linear and quadratic calibration derived from loam.

In soil with relatively high soil electrical conductivity levels, compacted soils, or soils with high clay content, the calibration must be adjusted for the specific application to maintain measurement accuracy. Figure 2 compares the CS616 response in a loam soil to a higher density sandy clay loam for two different electrical conductivities. The bulk density for both sandy clay loam soils is 1.6 cm^{-3}. The electrical conductivity at saturation for the sandy clay loam labeled "compacted soil" is 0.4 dS m^{-1}. The "compacted soil, high EC" had an electrical conductivity at saturation of 0.75 dS m^{-1}.

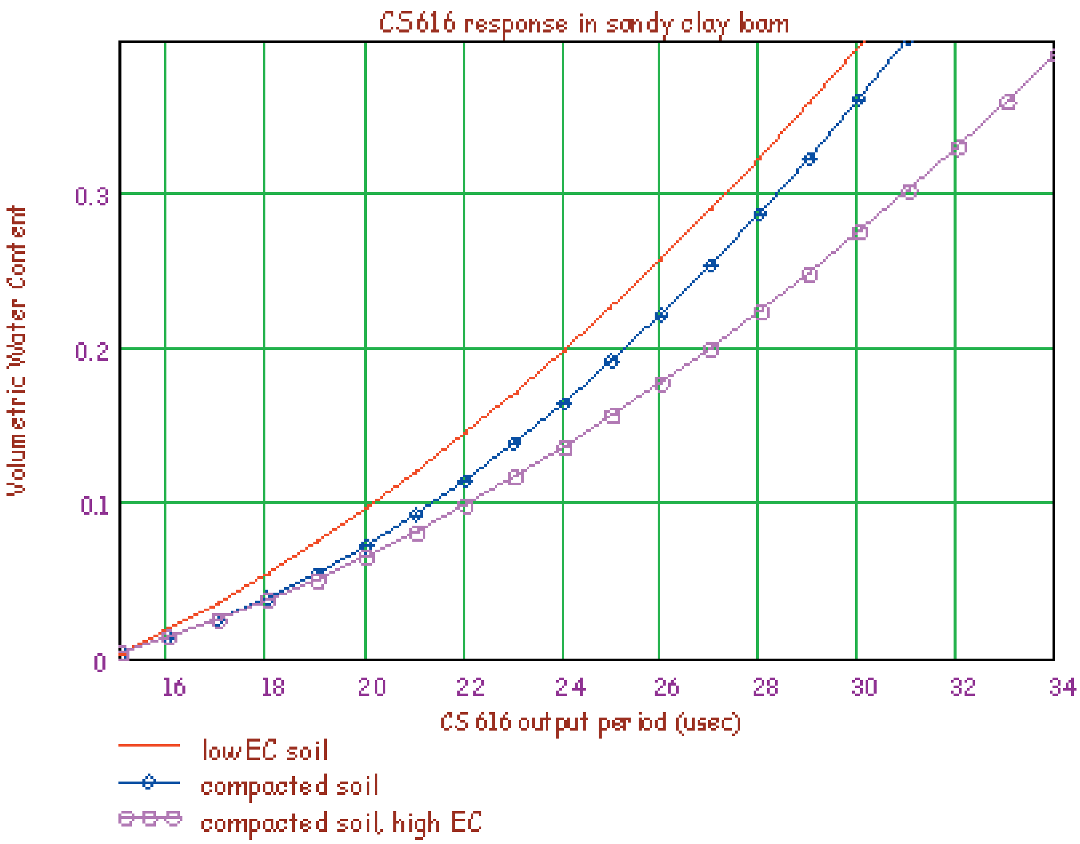

Figure 2. CS616 response in compacted, sandy clay loam soil and low EC loam for comparison.

The low EC soil response curve is shown for reference. The compacted soil response curve shows the effect of compaction. Since fine textured soils seldom have a water content of less than 10%, the adjustment is simply an offset. The compacted soil, high EC response curve shows the expected bulk electrical conductivity increase with increasing water content. Again, the response above 10% volumetric water content is nearly linear, which simplifies the calibration adjustment.

Optional Installation Tools

The 14384 Pilot Tool (at right) helps the insertion of the CS616 in high density or rocky soils. Its rods have similar diameters and the same spacing as the CS616. The tool can be driven into the soil using force levels that might damage the CS616. After removing the 14384, the CS616 is inserted into the established holes. Best results are obtained when the 14384 is used with the 14383.

The 14383 Installation Tool (far right) is used to help maintain the proper spacing and parallel orientation of rods during insertion. Use of the 14383 may reduce measurement errors by minimizing soil disturbance.

Ordering Information

CS616-L	Water Content Reflectometer. Enter lead length, in feet, after -L.
14384	Optional Pilot Tool
14383	Optional Installation Tool

Specifications

Output

±0.7 volt square wave with frequency dependent on water content

Power

65 milliamps @ 12 Vdc when enabled, 45 microamps quiescent typical

Measurement Time

With Instruction 138: 0.50 milliseconds

With Instruction 27: 50 milliseconds

Power Supply Voltage

5 Vdc minimum, 18 Vdc maximum

Enable Voltage

4 Vdc minimum, 18 Vdc maximum

Maximum cable length

1000 feet (305 m)

Electromagnetic Compatibility

The RF emissions are below FCC and EU limits as specified in EN61326 if the CS616 is enabled less than 0.6 milliseconds, and measurements are made no more frequently than once a second. Instruction 138 for the CR510 and CR10X limits the enable time to less than 0.6 milliseconds. External RF sources can also affect the CS616 operation. Consequently, the CS616 should be located away from significant sources of RF such as ac power lines and motors. The CS616 meets EN61326 requirements for protection against electrostatic discharge.

Dimensions

Rods:	300 mm (11.8″) long, 3.2 mm (0.13″) diameter, 32 mm (1.3″) spacing
Probe Head:	85 mm x 63 mm x 18 mm (3.3″ x 2.5″ x 0.7″)

Weight

Probe (without cable):	280 g (9.9 oz)
Cable:	35 g m^{-1} (0.38 oz ft^{-1})
14384:	2 oz. (57 g)
14383:	9.2 oz (260 g)

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