Model CS505 Fuel Moisture Sensor

User Guide

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CSL 472

Guarantee

This equipment is guaranteed against defects in materials and workmanship. This guarantee applies for twelve months from date of delivery. We will repair or replace products which prove to be defective during the guarantee period provided they are returned to us prepaid. The guarantee will not apply to:

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CS505 Fuel Moisture Sensor

1. General Description

The CS505 Fuel Moisture Sensor provides an automated measurement of the moisture content of a standard 10-hour fuel moisture dowel. The moisture content of the 10-hour fuel sensor represents the moisture content of small-diameter (10-hour time lag) forest fuels.

Traditionally, the standard fuel moisture stick consists of a rack of four 1/2 inch diameter ponderosa pine dowels. The resulting rack is about 20 inches long with an oven-dry weight of 100 grams. The characteristic time constant of the rack is 10 hours. The rack is mounted 12 inches or about 30 centimetres above the forest floor. The rack is left outside continually exposed to the same conditions as forest fuels. The rack absorbs and desorbs moisture from its surroundings. As the rack transfers moisture, its weight changes. Periodic weighing of the rack determines changes in moisture content and provides an indication of moisture changes in forest fuels.

The CS505 sensor incorporates the same carefully selected USFS standard ponderosa dowels as the traditional weighing fuel moisture racks. No artificial materials (e.g., epoxy sealant) are added to the dowel that would adversely influence the natural behaviour characteristics of the dowel. Because the complete dowel surface is accessible for moisture exchange, the response of the CS505 is similar to that of the traditional weighing racks. To optimize probe-to-probe repeatability and to allow probe interchangeability without individual calibration, two additional sorts are performed on the dowels before they are selected to be used as a sensor. First, the dowels are sorted dry by density to improve accuracy in the dry range of 0 to 15%. Second, the dowels are sorted after a 50-minute soak by weight to reduce probe-to-probe time response variation and minimize variability in the wet range of 20 to 50%.

Even after careful selection and sorting is performed to choose the most representative dowels, the majority of measurement error is due to the variability of wood. Wood's ability to transfer moisture is dependent on many variables, primarily cell structure and wood resin content. These variables change over time and after repeated wetting and drying cycles. Only a small amount of overall measurement error is due to the electronic circuitry.

2. Specifications

The fuel moisture sensor consists of two stainless steel strips pressed into grooves in a standard 1/2 inch ponderosa pine dowel and secured with nylon tie wraps. The probe connects to the electronics with two Phillips head screws. A shielded four-conductor cable is connected to the circuit board to supply power, enable the electronics, and monitor the signal output. The printed circuit board is encapsulated in a waterproof epoxy housing.

High speed electronic components on the circuit board are configured to oscillate when power is applied. The output of the circuit is connected to the fuel moisture probe which acts as a wave guide. The oscillation frequency and therefore output signal of the circuit is dependent on the dielectric constant of the media surrounding the stainless steel strips. The dielectric constant is predominantly dependent on the water content of the wood. Digital circuitry scales the oscillation frequency to an appropriate range for measurement with a datalogger. The CS505 output is essentially a square wave with an amplitude of ±2.5 VDC. The frequency of the square wave output ranges from approximately 600 to 1500 Hz.

***Fuel moisture accuracy:**
(with a new stick)

range	90% of all measurements	rms error
0 to 10%	±2%	±1.0%
10 to 20%	±3%	±1.5%
20 to 30%	±5%	±2.2%
30 to 50%	±6%	±2.4%

Range: 0-50%

Power Supply: 9 VDC minimum to
18 VDC maximum

Enable voltage: off at 0 V (<1 VDC)
on at 5 V (>1.5 VDC maximum 12 VDC)

Current usage: 70 mA active/ 10 uA quiescent

Output signal: ±2.5 V square wave with an output frequency of approximately 600 to 1500 Hz.

Dimensions:
sensor: 1/2 inch dowel, 20 inch long
electronics: 4 x 2.5 x 0.75 inches

*The above accuracy is a static accuracy derived at slow changing conditions with experimental data.

3. Installation

As shown in Figure 3-1 and Figure 3-2, both the CS505 and CS205 install on the 10974 mounting stake. The probes install horizontally and should point south in the northern hemisphere and north in the southern. The rack is mounted above a representative forest-floor duff layer. The stake is carefully hammered into the ground so that it is vertical. Don't hammer on the spot-welded clips that hold the CS505 electronics. Once the stake is installed, insert the CS505 electronics into the two spring clips. The fuel moisture sensor installs on the CS505 electronics with the supplied Phillips-head screws. The CS205 fuel temperature stick is inserted into the mounting stake's compression fitting. The 107 temperature probe is then inserted into the CS205 stick. Tighten the compression fitting so that it compresses the split wood and snugly holds the 107 probe.

The mounting stake ships with a package of 12 ultraviolet light resistant cable ties. The mounting stake has five holes punched along the edge of the shaft. There are two pairs of holes higher and one single hole lower on the shaft. When the stake is inserted into the ground to a depth level with the lower hole, the probes are at 12 inches or about 30 centimetres above the ground surface. The two upper pairs of holes are used to attach two tie wraps per cable—one pair for both the CS505 and CS205/107.

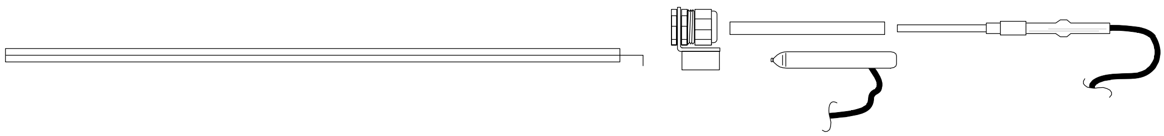

Figure 3-1. Exploded View of CS505 and CS205 Mounting

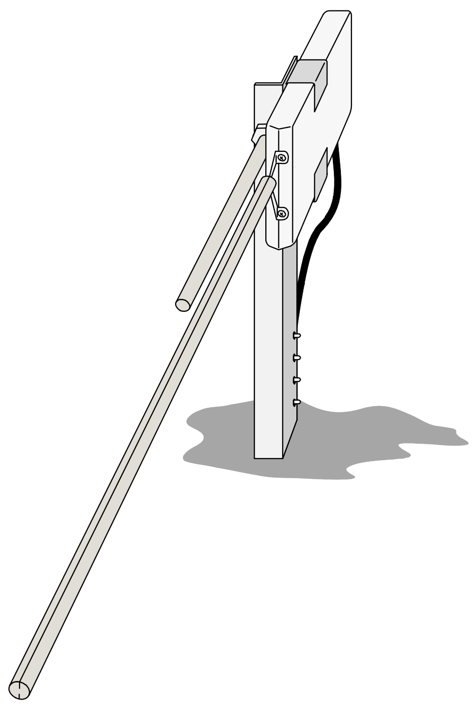

Figure 3-2. CS505 Installation Over Forest Floor, 30cm Over Duff Layer

4. Wiring

Connections to Campbell Scientific dataloggers are given in Table 4-1. When Short Cut for Windows software is used to create the datalogger program, the sensor should be wired to the channels shown on the wiring diagram created by Short Cut.z

Table 4-1. Wiring for CS505

Colour	**Description**	**CR800/CR1000/ CR3000**	**CR10(X)/CR500/ CR510**	**CR23X**	**21X/CR7**
red	power	12 V	12 V	12 V	12 V
black	ground	G	G	G	⏚
green	signal	Analogue Channel	Analogue Channel	Analogue Channel	Pulse Channel
orange	enable	Control Port	Control Port	Control Port	Control Port
clear	ground	⏚	G	⏚	⏚

5. Datalogger Programming

This section is for users who write their own datalogger programs. A datalogger program to measure this sensor can be created using Campbell Scientific's Short Cut Program Builder software. You do not need to read this section to use Short Cut.

The CS505 has a built in enable circuit. When voltage on the enable lead is less than 1.3 VDC, the sensor is off. When a voltage greater than 1.3 VDC, commonly 5 VDC, is applied to the enable lead, the sensor is on. The output signal is a ±2.5 volt square wave. Instruction P27 Period Average in the CR500, CR510, CR10(X), and CR23X dataloggers measures the frequency of the square wave with an analogue channel.

Since fuel moisture doesn't change very rapidly, the sensor is typically measured only once an hour.

Instruction P27 measures the period of the output signal in microseconds. To prepare for the polynomial, the output is scaled by 0.001. A second-order polynomial is used to convert signal period to percent moisture content with the following constants:

C0 = -220.14
C1 = 365.89
C2 = -114.96

or, expressed as a second order polynomial
$y=-220.14+365.89x-114.96x^2$

5.1 CR1000 Programming

```
'CR1000

'CR1000 Program for CS505

'Declare Variables and Units
Public FuelM
Public PA_uS

Units FuelM=%
Units PA_uS=uSec

'Define Data Tables
DataTable(Table1,True,-1)
    DataInterval(0,60,Min,10)
    Sample(1,FuelM,FP2)
    Sample(1,PA_uS,FP2)
EndTable

'Main Program
BeginProg
    Scan(10,Sec,1,0)
        'CS505 Fuel Moisture Sensor measurement FuelM and PA_uS:
        If IfTime(0,1,Hr) Then
            PortSet(1,1)
            PeriodAvg(PA_uS,1,mv2500,1,0,0,10,50,1,0)
            FuelM=PA_uS*0.001
            FuelM=-220.14+(365.89*FuelM)+(-114.96*FuelM^2)
            PortSet(1,0)
        EndIf
        'Call Data Tables and Store Data
        CallTable(Table1)
    NextScan
EndProg
```

5.2 CR10X Programming

A program to measure a CS505 fuel moisture sensor using the Period Averaging instruction P27. P27 is the preferred measurement technique with a Campbell Scientific, Inc. datalogger. P27 is not an option in the 21X or CR7 datalogger.

```
;{CR10X}

;CR10X Program for CS505

*Table 1 Program
  01:  10.0000       Execution Interval (seconds)

1:  If time is (P92)
  1:    0            Minutes (Seconds --) into a
  2:    60           Interval (same units as above)
  3:    30           Then Do

2:  Do (P86)
  1:    41           Set Port 1 High

3:  Period Average (SE) (P27)
  1:    1            Reps
  2:    4            200 kHz Max Freq @ 2 V Peak to Peak, Period Output
  3:    1            SE Channel
  4:    10           No. of Cycles
  5:    5            Timeout (0.01 sec units)
  6:    4            Loc [ PA_uS     ]
  7:    1            Multiplier
  8:    0            Offset

4:  Z=X*F (P37)
  1:    4            X Loc [ PA_uS     ]
  2:    0.001        F
  3:    3            Z Loc [ FuelM     ]

5:  Polynomial (P55)
  1:    1            Reps
  2:    3            X Loc [ FuelM     ]
  3:    3            F(X) Loc [ FuelM     ]
  4:    -220.14      C0
  5:    365.89       C1
  6:    -114.96      C2
  7:    0            C3
  8:    0            C4
  9:    0            C5

6:  Do (P86)
  1:    51            Set Port 1 Low

7:  End (P95)
```

5.3 21X Programming

A program to measure a CS505 fuel moisture sensor using the Pulse Count Instruction P3. The fuel moisture sensor is measured when flag 1 is set high. The measurement is made then flag 1 is set low.

```
;{21X}

;21X Program for CS505

*Table 1 Program
  01:  10.0000   Execution Interval (seconds)

1:  If time is (P92)
  1:   0          Minutes into a
  2:   60         Minute Interval
  3:   30         Then Do

2:  Do (P86)
  1:   41         Set Port 1 High

3:  Beginning of Loop (P87)
  1:   10         Delay
  2:   2          Loop Count

4:  End (P95)

5:  Pulse (P3)
  1:   1          Reps
  2:   1          Pulse Input Channel
  3:   21         Low Level AC, Output Hz
  4:   5          Loc [ FkHz_5    ]
  5:   0.001      Multiplier
  6:   0          Offset

6:  Z=1/X (P42)
  1:   5          X Loc [ FkHz_5    ]
  2:   4          Z Loc [ PA_uS     ]

7:  Z=X*F (P37)
  1:   4          X Loc [ PA_uS     ]
  2:   0.001      F
  3:   4          Z Loc [ PA_uS     ]

8:  Z=X*F (P37)
  1:   4          X Loc [ PA_uS     ]
  2:   0.001      F
  3:   3          Z Loc [ FuelM     ]
```

```
9:  Polynomial (P55)
   1:    1              Reps
   2:    3              X Loc [ FuelM     ]
   3:    3              F(X) Loc [ FuelM     ]
   4:    -220.14        C0
   5:    365.89         C1
   6:    -114.96        C2
   7:    0              C3
   8:    0              C4
   9:    0              C5

10:  Do (P86)
   1:    51             Set Port 1 Low

11:  End (P95)
```

6. Maintenance

The sensor element should be changed at least once a year with a new element in the spring. Since the characteristics of wood change so rapidly, more frequent replacements may be desirable.

To change the sensor element, loosen the Phillips head screws and replace with the new element. Tighten the screws after replacing the element.

Appendix A. Explanation of Experimental Data

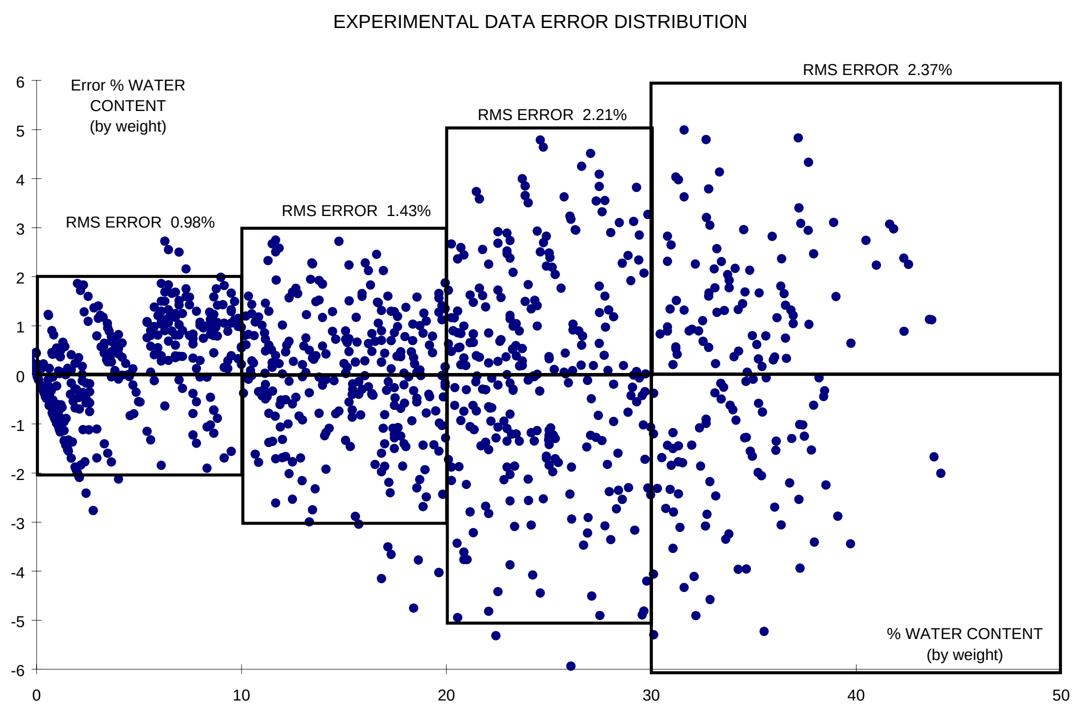

Figure A-1. Experimental Data Error-Distribution

Experiments were conducted to characterize measurement error and to determine the calibration polynomial coefficients used to convert the output signal to percent moisture content.

Populated circuit boards (before epoxy) oscillate with a period in the range of 0.6761 and 0.6780 milliseconds. In these experiments, three worst-case units were chosen. Only fuel moisture sticks that pass the standard rigorous selection criteria and then additional sorting for both oven-dry density and sorption qualities are chosen for production. For this experiment, 36 fuel moisture sticks were randomly selected from 300 production units. Electronic measurements were compared to actual stick weights. The sticks were soaked for 45 minutes, then after a five-minute dry, measured electrically and weighed every 10 to 60 minutes until they reached 15%. Then the sticks were placed in a 103°C oven for further drying; more measurements were taken. At each weigh point the sticks where rotated and measured by each of the three electronic units. Over one thousand data points were measured for this calibration experiment.

The full scale range is broken into four sub ranges: 0-10, 10-20, 20-30, and 30-50 percent. The computed rms errors are shown in Table 1. For each range band an error band was determined in which more than 90 percent of all measurements fall (also shown in Table A-1 and Figure A-1).

Table A-1. Accuracies at Measurement Ranges		
Range	**90% of All Measurements**	**rms Error**
0 to 10%	±2%	±1%
10 to 20%	±3%	±1.5%
20 to 30%	±5%	±2.2%
30 to 50%	±6%	±3%
*At least ninety percent of all experimental data fall within these error bands at the noted range divisions.		

The above accuracy is a static accuracy derived at slow changing conditions with experimental data. In rapidly changing conditions (e.g., in the beginning of a rain event) the rate of response for each wood dowel differs. After sufficient time to equilibrate, the dowels will come to the same water content. This difference in rate of response is inherent in the traditional weighing fuel stick racks. The effects are lessened by the additional sorting of the dowels performed at the factory. Readings above 50% are caused by surface water on the probe or other external factors. Readings are mathematically limited to 70%.

The sensor error is the sum of three influences:

1. Error due to the variability and non-reproducibility of the response characteristics of the wood: density, sorption characteristics, resin content, etc.

2. Error due to the aging of the wood (cracking, discoloration, mass loss as resin evaporates). This effect is not a factor for new sticks.

3. Offset error due to the electronic circuitry interchangeability, this error is negligible over 10% fuel moisture.

Appendix B. CS505 Advisory Note: Electromagnetic Interference — Avoiding Problems

The principle of operation of the CS505 is that it forms a high frequency oscillator, where the sensing elements are part of the oscillator circuit. A consequence of this is that it can act like a small radio frequency transmitter, where the rods form the transmitting antenna.

This note lists the potential problems with respect to electromagnetic interference, and ways to minimise the effects of this interference.

B.1 Introduction

Depending on the exact type of installation and the method of operation of the CS505, the radio emissions from the sensor can exceed the EU limits for the generation of interference as defined in the Standard BS EN55022.

The emissions are at a very low level – at the worst case less than 1/300th of the output of a cellular phone – but have the potential to cause interference to other measurement equipment, and also nearby radio and television reception equipment.

The sensors should be operated following the general guidelines below to minimise the risk of interference to both your own, and other, measurement systems.

B.2 Minimising General Interference

To avoid generalised interference, you should take the following steps:

a) Only power the sensor when actually taking measurements – never power up the sensor continuously.

b) If possible, use the Period Averaging Instruction (P27) with the CS505, as this allows you to take a measurement in only a few tens of milliseconds.

c) Do not take measurements from the probe more frequently than required. For example, in most experiments, a measurement every few minutes, or even every hour or so, is adequate, due to the slow rate of change of moisture content.

d) Avoid operating the probe near to other equipment, and preferably at least 200 metres away from domestic residences.

e) Avoid installing the probe with the rods close to other metal objects; e.g. grounding rods, earth wires, etc. A separation of at least 300mm is recommended.

B.3 Minimising Problems within a Measurement System

To avoid problems in a specific measurement system:

a) Do not install the probes very close to other types of sensor, especially if you will be powering up the CS505 at the same time as you will be taking readings from the other sensor.

b) If several CS505 probes are installed close together, they should either be enabled and measured individually, or they should be physically separated by at least 300mm. This separation is required as adjacent probes have sometimes been found to lock on to each other and resonate at a common, erroneous, frequency.

c) The CS505 itself can also be affected by the effects of strong radio interference. Usually this will result in an increase in the frequency output giving unrealistically low, or even negative, water content readings. To avoid these problems, do not install or operate the probe near to strong sources of radio frequency emissions, for example cellphones or RF transceivers.

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