HFT3 SOIL HEAT FLUX PLATE

REVISION: 2/99

WARRANTY AND ASSISTANCE

The **HFT3 SOIL HEAT FLUX PLATE** is warranted by CAMPBELL SCIENTIFIC, INC. to be free from defects in materials and workmanship under normal use and service for twelve (12) months from date of shipment unless specified otherwise. Batteries have no warranty. CAMPBELL SCIENTIFIC, INC.'s obligation under this warranty is limited to repairing or replacing (at CAMPBELL SCIENTIFIC, INC.'s option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CAMPBELL SCIENTIFIC, INC. CAMPBELL SCIENTIFIC, INC. will return such products by surface carrier prepaid. This warranty shall not apply to any CAMPBELL SCIENTIFIC, INC. products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CAMPBELL SCIENTIFIC, INC. is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 753-2342. After an applications engineer determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. CAMPBELL SCIENTIFIC's shipping address is:

CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
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CAMPBELL SCIENTIFIC, INC. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover the repair.

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MODEL HFT3
SOIL HEAT FLUX PLATE

1. GENERAL DESCRIPTION

The HFT3 Soil Heat Flux plate uses a thermopile to measure temperature gradients across the plate. Each plate is individually calibrated to output flux.

In order to measure soil heat flux at the surface, several HFT3s are used to measure the soil heat flux at a depth of eight cm. A TCAV Averaging Soil Thermocouple is used to measure the temporal change in temperature of the soil layer above the HFT3. Finally, a CS615 Water Content Reflectometer is used to measure the soil water content. The temporal change in soil temperature and soil water content are used to compute the soil storage term.

The -L option on the model HFT3 Soil Heat Flux plate (HFT3-L) indicates that the cable length is user specified. This manual refers to the sensor as the HFT3.

2. SPECIFICATIONS

Operating Temperature: -40°C to +55°C

Storage Temperature: -40°C to +55°C

Plate Thickness: 3.91 mm (0.154 in.)

Plate Diameter: 38.2 mm (1.5 in.)

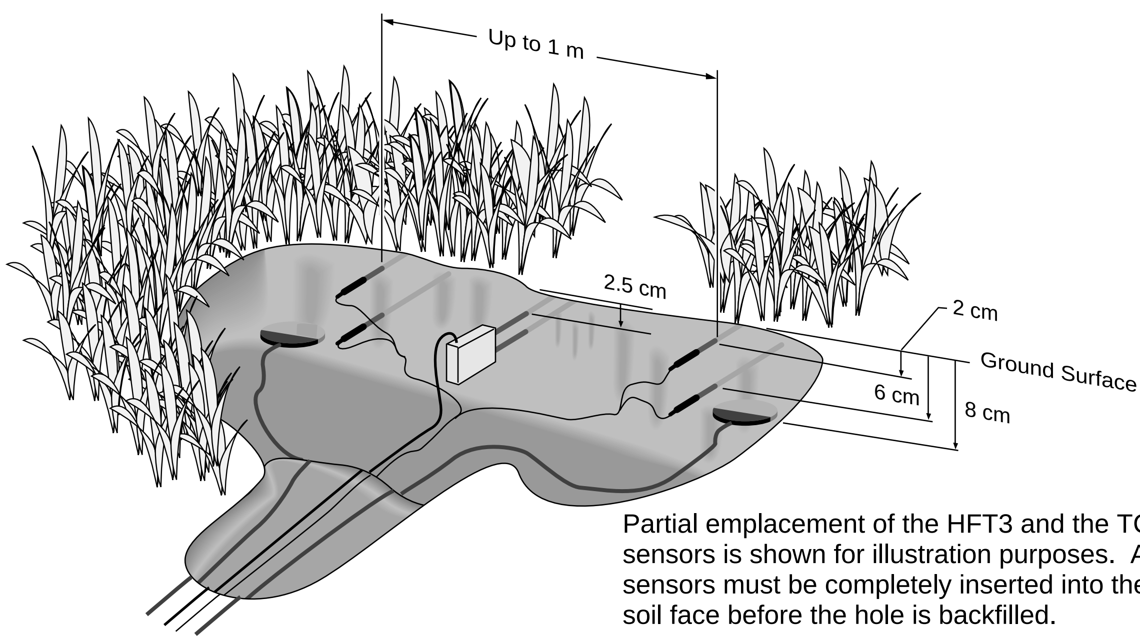
Sensor: thermopile

Measurement Range: ±100 W m^{-2}

Signal Range: ±2.4 mV for the above range

Accuracy: better than ±5% of reading

Thermal Conductivity: 1.22 W m^{-1} K^{-1}



Partial emplacement of the HFT3 and the TCAV sensors is shown for illustration purposes. All sensors must be completely inserted into the soil face before the hole is backfilled.

FIGURE 1. Placement of Heat Flux Plates

3. INSTALLATION

The HFT3 Soil Heat Flux plates, the TCAV Averaging Soil Temperature probes, and the CS615 Water Content Reflectometer are installed as shown in Figure 1.

The location of the heat flux plates and thermocouples should be chosen to be representative of the area under study. If the ground cover is extremely varied, it may be necessary to have additional sensors to provide a valid average of soil heat flux.

Use a small shovel to make a vertical slice in the soil. Excavate the soil to one side of the slice. Keep this soil intact so that is can be replaced with minimal disruption.

The sensors are installed in the undisturbed face of the hole. Measure the sensor depths from the top of the hole. With a small knife, make a horizontal cut eight cm below the surface into the undisturbed face of the hole. Insert the heat flux plate into the horizontal cut.

> **NOTE:** Install the HFT3 in the soil such that the side with the white dot is facing the sky.

> **CAUTION:** In order for the HFT3 to make quality soil heat flux measurements, the plate must be in full contact with the soil.

Never run the sensors leads directly to the surface. Rather, bury the sensor leads a short distance back from the hole to minimized thermal conduction on the lead wire. Replace the excavated soil back into it original position after all the sensors are installed.

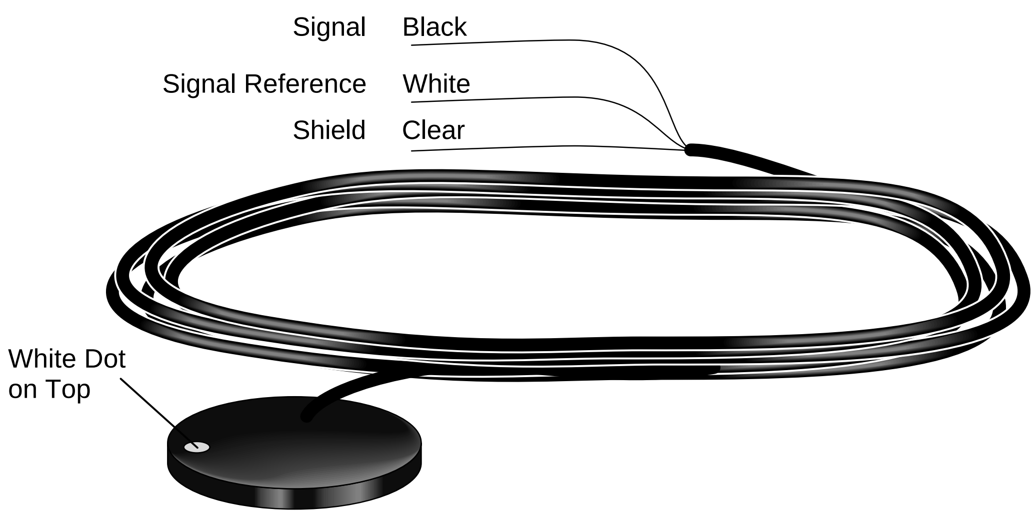


FIGURE 2. HFT3 Plate to Datalogger Connections

TABLE 1. Datalogger Connections for a Single-Ended Measurement

Description	Color	CR10(X), CR510	CR23X, 21X, CR7
Signal	Black	Single-Ended Input	Single-Ended Input
Signal Reference	White	AG	⏚
Shield	Clear	G	⏚

TABLE 2. Datalogger Connections for a Differential Measurement

Description	Color	CR10(X), CR510	CR23X, 21X, CR7
Signal	Black	Differential Input (H)	Differential Input (H)
Signal Reference	White	Differential Input (L)	Differential Input (L)
Shield	Clear	G	⏚

4. WIRING

Connections to Campbell Scientific dataloggers are given in Tables 1 and 2. The output of the HFT3 can be measured using a single-ended analog measurement (Instruction 1) or a differential analog measurement (Instruction 2).

The wiring convention is that the black wire is positive with respect to the other insulated wire, when energy is flowing through the transducer from the side with white dot to the side without the white dot.

5. EXAMPLE PROGRAMS

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

The HFT3 has a nominal calibration of 42 W m^{-2} mV^{-1}. Each sensor is accompanied with a calibration certificate. Each sensor has a unique calibration label on it. The label is located on the pigtail end of the sensor leads.

TABLE 3. Wiring for Example 1

Description	Color	CR10(X)
Signal	Black	SE 5 (3H)
Signal Reference	White	AG
Shield	Clear	G

Example 1 Sample CR10(X) Program using a Single-Ended Measurement Instruction

```
01:     Volt (SE) (P1)
        1:     1      Reps
        2:     2      7.5 mV Slow Range          ;CR510 (7.5 mV);CR23X (10 mV); 21X, CR7 (5 mV)
        3:     5      SE Channel                 ;Black wire (SE 5), White wire (AG)
        4:     1      Loc [ HFT3      ]
        5:     1      Mult                       ;Enter Calibration
        6:     0      Offset
```

TABLE 4. Wiring for Example 2

Description	Color	CR23X
Signal	Black	9H
Signal Reference	White	9L
Shield	Clear	⏚

Example 2 Sample CR23X Program using a Differential Measurement Instruction

```
;Measure the HFT3 Soil Heat Flux plate.
;
01:   Volt (Diff) (P2)
      1:    1      Reps
      2:   21      10 mV, 60 Hz Reject, Slow Range   ;CR510, CR10(X) (7.5 mV); 21X, CR7 (5 mV)
      3:    9      DIFF Channel                      ;Black wire (9H); White wire (9L)
      4:    1      Loc [ HFT3     ]
      5:    1      Mult                              ;Enter Calibration
      6:    0      Offset
```

6. SOIL HEAT FLUX AND STORAGE

The soil heat flux at the surface is calculated by adding the measured flux at a fixed depth, d, to the energy stored in the layer above the heat flux plates. The specific heat of the soil and the change in soil temperature, ΔT_S, over the output interval, t, are required to calculate the stored energy.

The heat capacity of the soil is calculated by adding the specific heat of the dry soil to that of the soil water. The values used for specific heat of dry soil and water are on a mass basis. The heat capacity of the moist is given by:

$$C_s = \rho_b\left(C_d + \theta_m C_w\right) = \rho_b C_d + \theta_v \rho_w C_w \quad (1)$$

$$\theta_m = \frac{\rho_w}{\rho_b}\theta_v \quad (2)$$

where C_S is the heat capacity of moist soil, ρ_b is bulk density, ρ_w is the density of water, C_d is the heat capacity of a dry mineral soil, θ_m is soil water content on a mass basis, θ_v is soil water content on a volume basis, and C_w is the heat capacity of water.

This calculation requires site specific inputs for bulk density, mass basis soil water content or volume basis soil water content, and the specific heat of the dry soil. Bulk density and mass basis soil water content can be found by sampling (Klute, 1986). The volumetric soil water content is measured by the CS615 water content reflectometer. A value of 840 J kg^{-1} K^{-1} for the heat capacity of dry soil is a reasonable value for most mineral soils (Hanks and Ashcroft, 1980).

The storage term is then given by Eq. (3) and the soil heat flux at the surface is given by Eq. (4).

$$S = \frac{\Delta T_S\, C_S\, d}{t} \quad (3)$$

$$G_{sfc} = G_{8cm} + S \quad (4)$$

7. MAINTENANCE

The HFT3 requires minimal maintenance. Check the sensor leads monthly for rodent damage.

Recalibrate the HFT3 every two years of continuous use. Obtain an RMA number before returning the HFT3 to Campbell Scientific for calibration.

8. REFERENCES

Hanks, R. J., and G. L. Ashcroft, 1980: *Applied Soil Physics: Soil Water and Temperature Application.* Springer-Verlag, 159 pp.

Klute, A., 1986: *Method of Soil Analysis.* No. 9, Part 1, Sections 13 and 21, American Society of Agronomy, Inc., Soil Science Society of America, Inc.