INSTRUCTION MANUAL

HMP45C Temperature and Relative Humidity Probe

November 2007

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Model HMP45C Temperature and Relative Humidity Probe

1. General Description

The HMP45C Temperature and Relative Humidity probe contains a Platinum Resistance Temperature detector (PRT) and a Vaisala HUMICAP® 180 capacitive relative humidity sensor.

The -L option on the model HMP45C Temperature and Relative Humidity probe (HMP45C-L) indicates that the cable length is user specified. This manual refers to both models as the HMP45C.

The HMP45C can be powered continuously or the power may be cycled to conserve battery life. The HMP45C consumes less than 4 milliamperes current at 12 volts. Approximately 0.15 seconds is required for the sensor to warm up after power is switched on. At measurement rates slower than once per second, the overall power consumption (datalogger and sensors) may be reduced by switching power to the HMP45C.

2. Specifications

Operating Temperature: -40°C to +60°C

Storage Temperature: -40°C to +80°C

Probe Length: 25.4 cm (10 in.)

Probe Body Diameter: 2.5 cm (1 in.)

Filter: 0.2 µm Teflon membrane

Filter Diameter: 1.9 cm (0.75 in.)

Power Consumption: <4 mA @ 12 V

Supply Voltage (via CSCC Switching Circuit): 7 to 35 VDC

Settling Time: 0.15 seconds

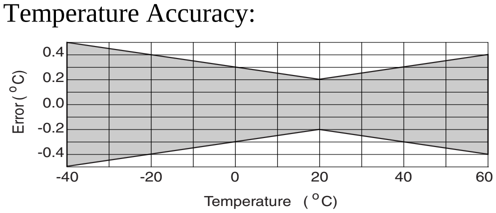
2.1 Temperature Sensor

Sensor: 1000 Ω PRT, IEC 751 1/3 Class B

Temperature Measurement Range: -40°C to +60°C

Temperature Output Signal range: 0.008 to 1.0 V

Temperature Accuracy:



2.2 Relative Humidity Sensor

Sensor: HUMICAP® 180

Relative Humidity Measurement Range: 0 to 100% non-condensing

RH Output Signal Range: 0.008 to 1 VDC

Accuracy at 20°C
±2% RH (0 to 90% Relative Humidity)
±3% RH (90 to 100% Relative Humidity)

Temperature Dependence of Relative Humidity Measurement: ±0.05% RH/°C

Typical Long Term Stability: Better than 1% RH per year

Response Time (at 20°C, 90% response): 15 seconds with membrane filter

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.

3. Installation

3.1 Siting

Sensors should be located over an open level area at least 6 m x 6 m in diameter (AES – ordinary climatological station guideline). The surface should be covered by short grass, or where grass does not grow, the natural earth surface. Sensors should be located at a distance of at least four times the height of any nearby obstruction. Sensors should be protected from thermal radiation, and adequately ventilated.

Standard measurement heights:

1.25 – 2,0 m (AES)
1.5 m +/- 1.0 m (AASC)
1.25 – 2.0 m (WMO)
2.0 m (US EPA)
2.0 m and 10.0 m temperature difference (US EPA)

See Section 10 for a list of references that discuss temperature and relative humidity sensors.

3.2 Assembly and Mounting

Hardware Required:

41003-X Ten plate radiation shield or equivalent

R41046DS-24A split nut

Tools Required:

- 1/2" open end wrench
- Small flathead screw driver provided with datalogger
- UV resistant cable ties
- small pair of diagonal-cutting pliers

The HMP45C must be housed inside a radiation shield when used in the field. The 41003-X Radiation Shield (Figure 3-1 and 3-2) mounts to vertical or horizontal pipes up to 2 inches in diameter.

The radiation shield ships with the U-bolt configured for attaching the shield to a vertical pipe. Move the U-bolt to the other set of holes to attach the shield to a crossarm.

Insert the HMP45C into the split nut. Remove the yellow protective cap on the HMP45C, and insert the sensor into the shield. Tighten the split-nut to secure the sensor in the shield. Route the sensor cable to the instrument enclosure. Secure the cable to the tripod/tower using cable ties.

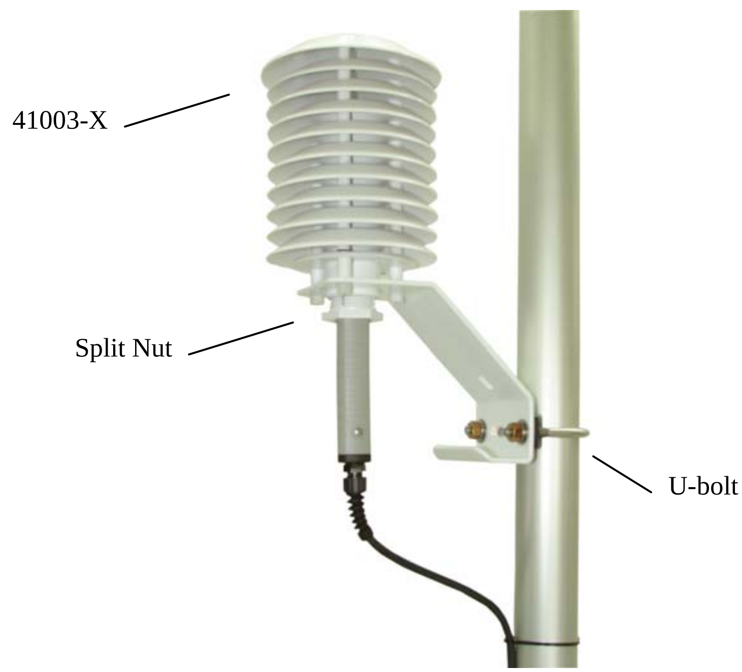


FIGURE 3-1. HMP45C and 41003-X Radiation Shield on a Tripod Mast

FIGURE 3-2. HMP45C and 41003-X Radiation Shield on a CM200 Series Crossarm

4. Wiring

Connections to Campbell Scientific dataloggers are given in Tables 4-1 and 4-2. The probe can be measured by two single-ended or differential analog input channels.

CAUTION When measuring the HMP45C with single-ended measurements, the purple or white and black leads must both be connected to AG on the CR10(X) and CR500/CR510 or to ⏚ on the CR1000, CR5000, and CR23X. Doing otherwise will connect the datalogger's analog and power ground planes to each other, which in some cases can cause offsets on low-level analog measurements. To avoid 4 mA flowing into analog ground, switch the sensor on/off for its own measurement.

TABLE 4-1. Connections for Single-Ended Measurements

Color	Description	CR10X	CR1000, CR3000, CR800, CR5000, CR23X	CR10, CR510, CR500	21X, CR7
Yellow	Temperature Signal	Single-Ended Input	Single-Ended Input	Single-Ended Input	Single-Ended Input
Blue	Relative Humidity Signal	Single-Ended Input	Single-Ended Input	Single-Ended Input	Single-Ended Input
Purple	Signal Reference	AG	⏚	AG	⏚
Orange	Power Control	Control Port	Control Port	Control Port	Control Port
Red	Power Continuous/Switched	12V	12V	12V	12V
Black	Power Ground	AG	⏚	AG	⏚
Shield	Shield	G	⏚	G	⏚

TABLE 4-2. Connections for Differential Measurements

Color	Description	CR10X	CR1000, CR3000, CR800, CR5000, CR23X	CR10, CR510, CR500	21X, CR7
Yellow	Temperature Signal	Differential Input – H	Differential Input – H	Differential Input – H	Differential Input – H
Jumper to Purple	Temperature Signal Reference	Differential Input – L	Differential Input – L	Differential Input – L	Differential Input – L
Blue	Relative Humidity Signal	Differential Input – H	Differential Input – H	Differential Input – H	Differential Input – H
Purple	Signal Reference	Differential Input – L	Differential Input – L	Differential Input – L	Differential Input – L
Orange	Power Control	Control Port	Control Port	Control Port	Control Port
Black	Power Ground	G	G	G	⏚
Shield	Shield	G	⏚	G	⏚
Red	Power Continuous/Switched	12V	12V	12V	12V

5. Example Programs

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 temperature and relative humidity signals from the HMP45C can be measured using a single-ended analog measurement or a differential analog measurement.

The HMP45C output scale is 0 to 1000 millivolts for the temperature range of -40°C to +60°C and for the relative humidity range of 0 to 100%. Tables 5-1 and 5-2 provide calibration information for temperature and relative humidity.

TABLE 5-1. Calibration for Temperature

Units	Multiplier (degrees mV^{-1})	Offset (degrees)
Celsius	0.1	-40
Fahrenheit	0.18	-40

TABLE 5-2. Calibration for Relative Humidity

Units	Multiplier (% mV^{-1})	Offset (%)
Percent	0.1	0
Fraction	0.001	0

5.1 Short Lead Lengths

Use a single-ended analog measurement when the HMP45C signal lead length is less than 6.1 m (20 ft.) or if the probe will be turned on and off under datalogger control between measurements. For lead lengths greater than 6.1 m (20 ft.) or when the probe will be continuously powered, use a differential analog measurement. For a discussion on errors caused by long lead lengths see Section 5.2. Generic datalogger connections for measuring the HMP45C using single-ended measurement are given in Table 4-1.

CR1000 Program using Single-Ended Measurement Instructions

```
'CR1000 program to measure HMP45C with single-ended measurements

'Declare Public Variables
Public AirTC
Public RH
```

```
'Declare Data Tables
DataTable(Temp_RH,True,-1)
DataInterval(0,60,Min,0)
Average(1,AirTC,FP2,0)
Sample(1,RH,FP2)
EndTable

'Main Program
BeginProg
Scan(5,Sec,1,0)
'HMP45C Temperature & Relative Humidity Sensor
'measurements AirTC in Celcius and RH in percentage:

'Turn on HMP45C and delay measurement 150mSec
PortSet (1,1)
Delay (0,150,mSec)

'Measure HMP45C
VoltSE(AirTC,1,mV2500,1,True,0,_60Hz,0.1,-40.0)
VoltSE(RH,1,mV2500,2,True,0,_60Hz,0.1,0)

Turn off HMP45C

PortSet (1,0)

'Correct RH if reading is over 100

If RH>100 And RH<108 Then RH=100
'Call Data Table
CallTable(Temp_RH)
NextScan
EndProg
```

CR10(X) Program using Single-Ended Measurement Instructions Using SW12V on Datalogger

```
;Turn the HMP45C on.
;
01:  Do (P86)
   1:   41              Set Port 1 High

;Pause 150 mSec before making measurements so the
;probe can stabilize on true readings.
;
02:  Excitation with Delay (P22)
   1:   1               Ex Channel
   2:   0               Delay W/Ex (units = 0.01 sec)
   3:   15              Delay After Ex (units = 0.01 sec)
   4:   0               mV Excitation
;Measure the HMP45C temperature.
;
03:  Volt (SE) (P1)
   1:   1               Reps
```

```
  2:  5          2500 mV Slow Range     ;CR510, CR500 (2500mv); CR23X (1000 mV);
                                        21X, CR7 (5000 mV)
  3:  3          SE Channel             ;Yellow wire (SE 3), white or purple wire (AG)
  4:  1          Loc [ T_C      ]
  5:  .1         Mult                   ;See Table 5-1 for alternative multipliers
  6:  -40        Offset                 ;See Table 5-1 for alternative offsets

;Measure the HMP45C relative humidity.
;
04:  Volt (SE) (P1)
  1:  1          Reps
  2:  5          2500 mV Slow Range     ;CR510, CR500 (2500 mV); CR23X (1000 mV);
                                        21X, CR7 (5000 mV)
  3:  4          SE Channel             ;Blue wire (SE 4), white or purple wire (AG)
  4:  2          Loc [ RH_pct    ]
  5:  .1         Mult                   ;See Table 5-2 for alternative multipliers
  6:  0          Offset

;Turn the HMP45C off.

 05:  Do (P86)
  1:  51         ;Set Port 1 Low        ;Turn the HMP45C off.
```

5.2 Long Lead Lengths

This section describes the error associated with measuring the HMP45C with a single-ended measurement if the probe has a long cable. To avoid these problems, Campbell Scientific recommends measuring the HMP45C using a differential analog measurement (Instruction 2) when long lead lengths are required. Generic datalogger connections for measuring the HMP45C using a differential measurement are given in Table 4-2.

Understanding the details in this section are not required for the general operation of the HMP45C with Campbell Scientific's dataloggers.

The signal reference (purple) and the power ground (black) are in common inside the HMP45C. When the HMP45C temperature and relative humidity are measured using a single-ended analog measurement, both the signal reference and power ground are connected to ground at the datalogger. The signal reference and power ground both serve as the return path for 12 V. There will be a voltage drop along those leads because the wire itself has resistance. The HMP45C draws approximately 4 mA when it is powered. The wire used in the HMP45C (P/N 9721) has a resistance of 27.7 Ω/1000 feet. Since the signal reference and the power ground are both connected to ground at the datalogger, the effective resistance of those wires together is half of 27.7 Ω/1000 feet, or 13.9 Ω/1000 feet. Using Ohm's law, the voltage drop (V_d), along the signal reference/power ground, is given by Eq. (1).

$$\begin{aligned} V_d &= I * R \\ &= 4\ \text{mA} * 13.9\ \Omega / 1000\ \text{ft} \\ &= 55.6\ \text{mV} / 1000\ \text{ft} \end{aligned} \qquad (1)$$

This voltage drop will raise the apparent temperature and relative humidity because the difference between the signal and signal reference lead, at the datalogger, has increased by V_d. The approximate error in temperature and relative humidity is 0.56°C and 0.56% per 100 feet of cable length, respectively.

CR1000 Program using Differential Measurement Instructions

```
'CR1000 program to measure HMP45C with Differential measurements

'Declare Public Variables
Public AirTC
Public RH

'Declare Data Tables
DataTable(Temp_RH,True,-1)
 DataInterval(0,60,Min,0)
 Average(1,AirTC,FP2,0)
 Sample(1,RH,FP2)
EndTable

'Main Program
BeginProg
 Scan(5,Sec,1,0)
		'HMP45C Temperature & Relative Humidity Sensor
		'measurements AirTC  in Celcius and RH in  percent:

		'Turn on HMP45C and delay measurement 150mSec
		PortSet (1,1)
		Delay (0,150,mSec)

		'Measure HMP45C
		VoltDiff (AirTC,1,mV2500,1,True,0,_60Hz,0.1,-40.0)
		VoltDiff (RH,1,mV2500,2,True ,0,_60Hz,0.1,0)

		Turn Off HMP45C

		'Correct RH if reading is over 100

		If RH>100 And RH<108 Then RH=100

		'Call Data Table
		CallTable(Temp_RH)
 NextScan
EndProg
```

CR10(X) Program using Differential Measurement Instructions

```
;Turn the HMP45C on.
;
01:  Do (P86)
  1:    41              Set Port 1 High                 ;Turn the HMP45C on
```

```
;Pause 150 mSec before making measurements so the
;probe can stabilize on true readings.
;
02:  Excitation with Delay (P22)
   1:   1            Ex Channel
   2:   0            Delay W/Ex (units = 0.01 sec)
   3:   15           Delay After Ex (units = 0.01 sec)
   4:   0            mV Excitation

;Measure the HMP45C temperature.
;
03:  Volt (Diff) (P2)
   1:   1            Reps
   2:   5            2500 mV Slow Range     ;CR510, CR500 (2500mv); CR23X (1000 mV);
                                            21X, CR7 (5000 mV)
   3:   3            DIFF Channel           ;Yellow wire (3H), jumper (3L to 4L)
   4:   1            Loc [ T_C      ]
   5:   .1           Mult                   ;See Table 5-1 for alternative multipliers
   6:   -40          Offset                 ;See Table 5-1 for alternative offsets

;Measure the HMP45C relative humidity.
;
04:  Volt (Diff) (P2)
   1:   1            Reps
   2:   5            2500 mV Slow Range     ;CR510, CR500 (2500mv); CR23X (1000 mV);
                                            21X, CR7 (5000 mV)
   3:   4            DIFF Channel           ;Blue wire (4H), white or purple wire (4L)
   4:   2            Loc [ RH_pct    ]
   5:   .1           Mult                   ;See Table 5-2 for alternative multipliers
   6:   0            Offset

;Turn the HMP45C off.
;
05:  Do (P86)
   1:   51           Set Port 1 Low         ;Turn the HMP45C off.
```

6. Absolute Humidity

The HMP45C measures the relative humidity. Relative humidity is defined by the equation below:

$$RH = \frac{e}{e_s} * 100 \qquad (2)$$

where RH is the relative humidity, e is the vapor pressure in kPa , and e_s is the saturation vapor pressure in kPa. The vapor pressure, e, is an absolute measure of the amount of water vapor in the air and is related to the dew point temperature. The saturation vapor pressure is the maximum amount of water vapor that air can hold at a given air temperature. The relationship between dew point and vapor pressure, and air temperature and saturation vapor pressure are given by Goff and Gratch (1946), Lowe (1977), and Weiss (1977).

When the air temperature increases, so does the saturation vapor pressure. Conversely, a decrease in air temperature causes a corresponding decrease in saturation vapor pressure. It follows then from Eq. (2) that a change in air temperature will change the relative humidity, without causing a change to absolute humidity.

For example, for an air temperature of 20°C and a vapor pressure of 1.17 kPa, the saturation vapor pressure is 2.34 kPa and the relative humidity is 50%. If the air temperature is increased by 5°C and no moisture is added or removed from the air, the saturation vapor pressure increases to 3.17 kPa and the relative humidity decreases to 36.9%. After the increase in air temperature, the air can hold more water vapor. However, the actual amount of water vapor in the air has not changed. Thus, the amount of water vapor in the air, relative to saturation, has decreased.

Because of the inverse relationship between relative humidity and air temperature, finding the mean relative humidity is meaningless. A more useful quantity is the mean vapor pressure. The mean vapor pressure can be computed on-line by the datalogger as shown in the following examples.

CR1000 Program that Computes Vapor Pressure and Saturation Vapor Pressure

```
'CR1000 program to measure HMP45C with single-ended measurements

'Declare Public Variables
Public AirTC
Public RH
Public RH_Frac
Public e_Sat
Public e_kPa

'Define Data Tables
DataTable(Temp_RH, 1,-1)
        DataInterval(0,60,Min,0)
        Average(1,AirTC,FP2,False)
        Sample(1,RH,FP2)
        Sample (1,e_kPa,FP2)
EndTable

'Main Program
BeginProg
        Scan(5,Sec,1,0)
                'HMP45C Temperature & Relative Humidity Sensor
                'measurements AirTC (degrees Celcius) and RH (as
                percentage):

                'Turn on HMP45C and delay measurement 150mSec
                PortSet (1,1)
                Delay (0,150,mSec)

                'Measure HMP45C
                VoltSE(AirTC,1,mV2500,1,1,0,_60Hz,0.1,-40.0)
```

```
                    VoltSE(RH,1,mV2500,2,1,0,_60Hz,0.1,0)

                    'Turn HMP45C off:
                    PortSet (1,0)

                    'Correct RH if reading is over 100%
                    If RH>100 And RH<108 Then RH=100

                    'Calculate Vapor Pressure
                    'Convert RH percent to RH Fraction
                    RH_Frac = RH*0.01
                    'Calculate Saturation Vapor Pressure
                    SatVP (e_Sat,AirTC)
                    'Compute Vapor Pressure
                    e_kPa=e_Sat*RH_Frac
                    'Call Output Tables
                    CallTable Temp_RH
        NextScan
    EndProg
```

CR10(X) Program that Computes Vapor Pressure and Saturation Vapor Pressure

```
;Turn the HMP45C on.
;
01:  Do (P86)
   1:   41          Set Port 1 High              ;Turn the HMP45C on.


;Pause 150 mSec before making measurements so the
;probe can stabilize on true readings.
;
02:  Excitation with Delay (P22)
   1:   1           Ex Channel
   2:   0           Delay W/Ex (units = 0.01 sec)
   3:   15          Delay After Ex (units = 0.01 sec)
   4:   0           mV Excitation

;Measure the HMP45C temperature.
;
03:  Volt (SE) (P1)
   1:   1           Reps
   2:   5           2500 mV Slow Range           ;CR510, CR500 (2500mv); CR23X (1000 mV);
                                                 21X, CR7 (5000 mV)
   3:   3           SE Channel                   ;Yellow wire (SE 3), white or purple wire (AG)
   4:   1           Loc [ T_C      ]
   5:   .1          Mult
   6:   -40         Offset

;Measure the HMP45C relative humidity.
;
04:  Volt (SE) (P1)
   1:   1           Reps
   2:   5           2500 mV Slow Range           ;CR510, CR500 (2500mv); CR23X (1000 mV);
                                                 21X, CR7 (5000 mV)
   3:   4           SE Channel                   ;Blue wire (SE 4), white or purple wire (AG)
```

```
  4:   2              Loc [ RH_frac   ]
  5:   .001           Mult
  6:   0              Offset
;
05:  Do (P86)
  1:   51             Set Port 1 Low               ;Turn the HMP45C off.

;Compute the saturation vapor pressure.
;The temperature must be in degrees Celsius.
;
06:  Saturation Vapor Pressure (P56)
  1:   1              Temperature Loc [ T_C       ]
  2:   3              Loc [ e_sat     ]

;Compute the vapor pressure.
;Relative humidity must be a fraction.
;
07:  Z=X*Y (P36)
       1:          3  X Loc [ e_sat     ]
       2:          2  Y Loc [ RH_frac   ]
       3:          4  Z Loc [ e         ]
```

7. Sensor Maintenance

The HMP45C Probe requires minimal maintenance. Check monthly to make sure the radiation shield is free from debris. The black screen at the end of the sensor should also be checked for contaminates.

When installed in close proximity to the ocean or other bodies of salt water (e.g., Great Salt Lake), a coating of salt (mostly NaCl) may build up on the radiation shield, sensor, filter and even the chip. NaCl has an affinity for water. The humidity over a saturated NaCl solution is 75%. A buildup of salt on the filter or chip will delay or destroy the response to atmospheric humidity.

The filter can be rinsed gently in distilled water. If necessary, the chip can be removed and rinsed as well. Do not scratch the chip while cleaning.

Long term exposure of the HUMICAP® relative humidity sensor to certain chemicals and gases may affect the characteristics of the sensor and shorten its life. Table 8-1 lists the maximum ambient concentrations, of some chemicals, that the HUMICAP® can be exposed to.

TABLE 8-1. Chemical Tolerances of HMP45C

Chemical	**Concentration (PPM)**
Organic solvents	1000 to 10,000
Aggressive chemicals (e.g. SO_2, H_2SO_4, H_2S, HCl, Cl_2, etc.)	1 to 10

Weak Acids	100 to 1000
Bases	10,000 to 100,000

Recalibrate the HMP45C annually. Obtain an RMA number before returning the HMP45C to Campbell Scientific for recalibration.

8. Troubleshooting

Symptom: -9999, NAN, -40 deg C, or 0 % relative humidity

1. Check that the sensor is wired to the correct excitation and analog input channels as specified by the measurement instructions.

2. Verify the Range code is correct for the datalogger type.

3. Verify the red power wire is correctly wired to the 12V, Switched 12V, or SW12V module. The terminal the wire is connected to will depend on the datalogger program.

   Connect the red wire to a 12V terminal to constantly power the sensor for troubleshooting purposes. With the red wire connected to12V, a voltmeter can be used to check the output voltage for temperature and relative humidity on the yellow and blue wires respectively (temperature °C = mV * 0.1 – 40.0; relative humidity % = mV * 0.1).

Symptom: Incorrect temperature or relative humidity

1. Verify the multiplier and offset parameters are correct for the desired units (Table 5-1).

9. References

Goff, J. A. and S. Gratch, 1946: Low-pressure properties of water from -160° to 212°F, *Trans. Amer. Soc. Heat. Vent. Eng.*, **51**, 125-164.

Lowe, P. R., 1977: An approximating polynomial for the computation of saturation vapor pressure, *J. Appl. Meteor.*, **16**, 100-103.

Weiss, A., 1977: Algorithms for the calculation of moist air properties on a hand calculator, *Amer. Soc. Ag. Eng.*, **20**, 1133-1136.