MODEL HMP45CF
TEMPERATURE AND RELATIVE HUMIDITY PROBE

INSTRUCTION MANUAL

PRELIMINARY DRAFT: 5/99

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MODEL HMP45CF
TEMPERATURE AND RELATIVE HUMIDITY PROBE

1. GENERAL DESCRIPTION

The HMP45CF Temperature and Relative Humidity probe contains a YSI 44002A thermistor and a Vaisala HUMICAP® 180 capacitive relative humidity sensor.

The -L option on the model HMP45CF Temperature and Relative Humidity probe (HMP45CF-L) indicates that the cable length is user specified. This manual refers to the sensor as the HMP45CF.

2. SPECIFICATIONS

Operating Temperature: -55°C to +50°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

Supply Voltage (via CSI switching circuit):
7 to 35 VDC

Settling Time: 0.15 seconds

2.1 TEMPERATURE SENSOR

Sensor: YSI 44002 Thermistor

Temperature Measurement Range:
-55°C to +50°C

Temperature Interchangeability Error:
Typically <±0.2°C

Polynomial Linearization Error:
<±0.2°C over –53°C to +48°C
<±0.4°C over –55°C to +50°C

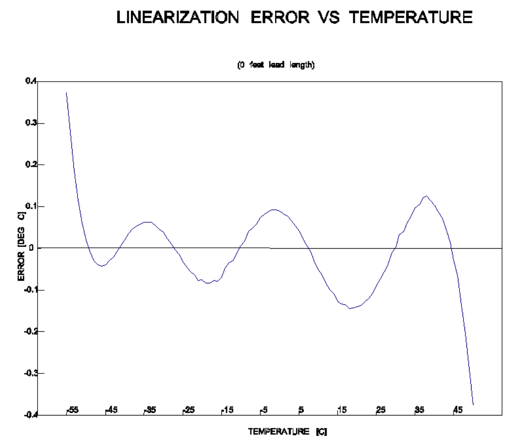

FIGURE 1. Temperature Probe Polynomial Error Curve (0 ft lead)

Linearization Range from -55 to 50°C

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

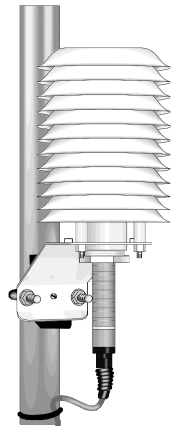

FIGURE 2. HMP45CF and 41002 Radiation Shield on a CM6/CM10 Tripod Mast or UT10 Tower Leg

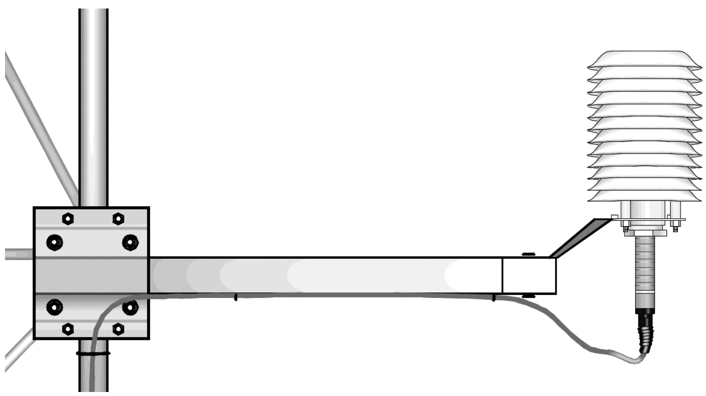

FIGURE 3. HMP45CF with UT018 Mounting Bracket and Crossarm and UT12VA Radiation Shield Mounted on a UT30 Tower

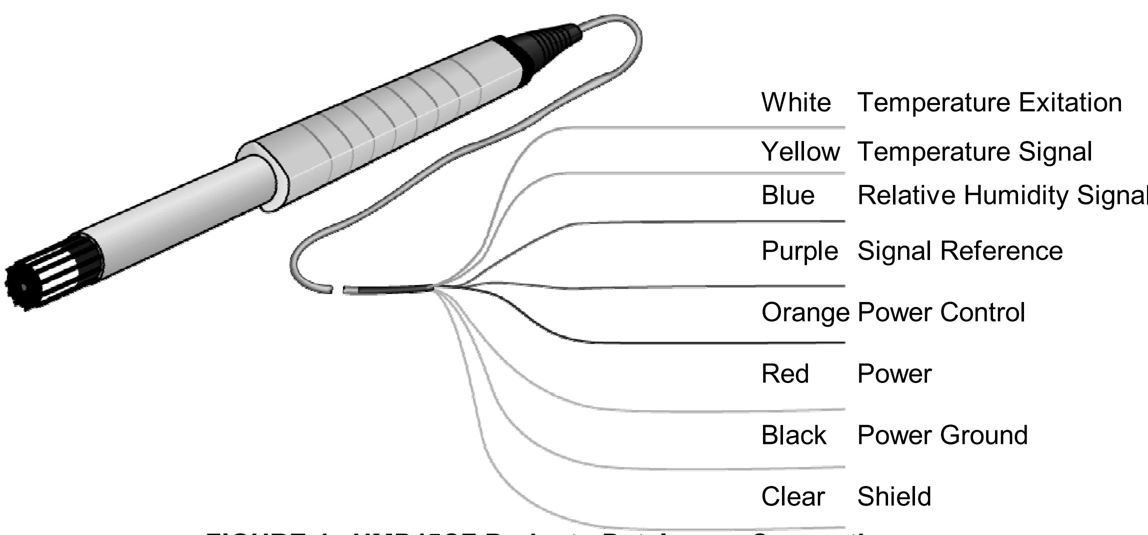

FIGURE 4. HMP45CF Probe to Datalogger Connections

TABLE 1. Datalogger Connections

Description	Color	CR10(X), CR500	CR23X	21X, CR7
Temperature	Yellow	Single-Ended Input	Single-Ended Input	Single-Ended Input
Temperature Excitation	White	Excitation	Excitation	Excitation
Relative Humidity	Blue	Single-Ended Input	Single-Ended Input	Single-Ended Input
Signal Reference	Purple	AG	⏚	⏚
Power Control	Orange	Control Port	Control Port	Control Port
Power	Red	12 V	12 V	12 V
Power Ground	Black	AG	⏚	⏚
Shield	Clear	G	⏚	⏚

3. INSTALLATION

The HMP45CF must be housed inside a radiation shield when used in the field. The 41002 Radiation Shield (Figure 1) mounts to a CM6/CM10 tripod or UT10 tower. The UT018 mounting arm and UT12VA Radiation Shield mount to a UT30 tower (Figure 2).

A lead length of 6 feet allows the HMP45CF to be mounted at a 2 meter height on a CM6/CM10 tripod. Use a lead length of 9 feet for the UT10 tower or a UT30 tower respectively.

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.

4. WIRING

Connections to Campbell Scientific dataloggers are given in Table 1. The probe can be measured by two single-ended analog input channels.

CAUTION: When measuring the HMP45CF with a single-ended measurement, do not connect the Purple and the Black leads to AG and G on the CR10(X) and CR500 or to ⏚ and G on the CR23X. Doing so connects the two ground plains to each other and in some cases may cause offsets on low level analog measurements.

5. EXAMPLE PROGRAMS

The temperature signal from the HMP45CF can be measured using Instruction 4 (EX-DEL-SE). The relative humidity signal from the HMP45CF can be measured using a single-ended analog measurement (Instruction 1).

The HMP45CF output scale is 0 to 1000 millivolts for the relative humidity range of 0 to 100%. Tables 2 and 4 provide calibration information for temperature and relative humidity.

TABLE 2: COEFFICIENTS FOR USE WITH 22 AWG CABLE

LEAD LENGTH (feet)	CABLE RESISTANCE (ohms)	COEFFICIENTS C0	C1	C2	C3	C4	C5
10	0.30	-74.146	645.35	-3837.9	16039	-34037	29809
25	0.75	-74.154	645.68	-3842.1	16065	-34108	29885
30	0.90	-74.157	645.78	-3843.4	16073	-34130	29909
35	1.05	-74.159	645.87	-3844.6	16081	-34152	29933
50	1.50	-74.168	646.22	-3848.9	16107	-34225	30009
75	2.25	-74.181	646.76	-3855.7	16149	-34341	30134
100	3.00	-74.194	647.28	-3862.4	16191	-34458	30258
125	3.75	-74.208	647.83	-3869.3	16233	-34574	30383
150	4.50	-74.221	648.34	-3875.8	16274	-34691	30508
175	5.25	-74.235	648.88	-3882.7	16317	-34810	30636
200	6.00	-74.248	649.41	-3889.5	16359	-34927	30762
225	6.75	-74.261	649.94	-3896.3	16401	-35045	30889
250	7.50	-74.276	650.51	-3903.4	16446	-35168	31020
275	8.25	-74.289	651.04	-3910.2	16488	-35287	31148
300	9.00	-74.301	651.55	-3916.8	16529	-35403	31274
325	9.75	-74.316	652.10	-3923.8	16573	-35525	31405
350	10.50	-74.329	652.64	-3930.7	16616	-35646	31535
375	11.25	-74.343	653.20	-3937.8	16660	-35768	31666
400	12.00	-74.356	653.73	-3944.6	16703	-35888	31796
425	12.75	-74.369	654.26	-3951.4	16745	-36009	31926
450	13.50	-74.384	654.83	-3958.8	16791	-36135	32061
475	14.25	-74.397	655.35	-3965.4	16833	-36254	32191
500	15.00	-74.410	655.89	-3972.3	16876	-36376	32323

TABLE 3: Temperature VS Thermistor Resistance for YSI44002

°C	OHMS						
		-32.0	3400.0	-4.0	919.0	24.0	310.8
		-30.0	3069.0	-2.0	844.8	26.0	289.7
-56.0	13170.0	-28.0	2775.0	0.0	777.5	28.0	270.3
-54.0	11650.0	-26.0	2512.0	2.0	716.3	30.0	252.4
-52.0	10330.0	-24.0	2278.0	4.0	660.6	32.0	235.9
-50.0	9171.0	-22.0	2068.0	6.0	609.9	34.0	220.6
-48.0	8158.0	-20.0	1880.0	8.0	563.6	36.0	206.5
-46.0	7270.0	-18.0	1712.0	10.0	521.5	38.0	193.4
-44.0	6489.0	-16.0	1561.0	12.0	482.9	40.0	181.4
-42.0	5803.0	-14.0	1424.0	14.0	447.6	42.0	170.2
-40.0	5198.0	-12.0	1302.0	16.0	415.4	44.0	159.8
-38.0	4663.0	-10.0	1191.0	18.0	385.8	46.0	150.1
-36.0	4191.0	-8.0	1091.0	20.0	358.6	48.0	141.2
-34.0	3772.0	-6.0	1001.0	22.0	333.7	50.0	132.9

TABLE 4. Calibration for Relative Humidity

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

TABLE 5. Wiring for Example 1

Description	Color	CR10(X)
Temperature	Yellow	SE 3 (2H)
Temperature Excitation	White	E1
Relative Humidity	Blue	SE 4 (2L)
Signal Reference	Purple	AG
Power Control	Orange	C1
Power	Red	12 V
Power Ground	Black	AG
Shield	Clear	G

Example 1. Sample CR10(X) Program using Single-Ended Measurement Instructions

```
;Turn the HMP45CF on.
;
01:  Do (P86)
     1:  41      Set Port 1 High          ;Orange wire (C1)

;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 HMP45CF temperature.
;
03:  EX-DEL-SE (P4)
     1:   1      Reps
     2:   4      250 mV Slow Range        ;CR500 (250 mV); 21X, CR7 (500 mV)
     3:   3      SE Channel               ;Yellow wire (SE 3), Purple wire (AG)
     4:   1      EX Channel               ;White wire (E1)
     5:   0      Delay 0.01 s
     6: 250      mV Excitation            ;CR500 (250 mV); 21X, CR7 (500 mV)
     7:   1      Loc [ T_C      ]
     8:    .002 Mult                      ;CR500 (.002); 21X, CR7 (.001)
     9:   0      Offset
```

```
04:  Polynomial (P55)
     1:    1      Reps
     2:    1      X Loc[T_C   ]
     3:    1      F(X) Loc[T_C   ]
     4: ???       C0                     ;See Table 2 for coefficient values.
     5: ???       C1
     6: ???       C2
     7: ???       C3
     8: ???       C4
     9: ???       C5

;Measure the HMP45CF relative humidity.
;
05:  Volt (SE) (P1)
     1:    1      Reps
     2:    5      2500 mV Slow Range     ;CR500 (2500 mV); 21X, CR7 (5000 mV)
     3:    4      SE Channel             ;Blue wire (SE 4) ), Purple wire (AG)
     4:    2      Loc [ RH_pct    ]
     5:     .1    Mult                   ;See Table 4 for alternative multipliers
     6:    0      Offset

;Turn the HMP45CF off.
;
06:  Do (P86)
     1:  51       Set Port 1 Low         ;Orange wire (C1)
```

6. ABSOLUTE HUMIDTY

The HMP45CF 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 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.

TABLE 6. Wiring for Example 2

Description	Color	CR10(X)
Temperature	Yellow	SE 3 (2H)
Temperature Excitation	White	E1
Relative Humidity	Blue	SE 4 (2L)
Signal Reference	Purple	AG
Power Control	Orange	C1
Power	Red	12 V
Power Ground	Black	AG
Shield	Clear	G

Example 2. Sample CR10(X) Program that Computes Vapor Pressure and Saturation Vapor Pressure

```
;Turn the HMP45CF on.
;
01:  Do (P86)
     1:  41      Set Port 1 High          ;Orange wire (C1)

;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 HMP45CF temperature.
;
03:  EX-DEL-SE (P4)
     1:   1      Reps
     2:   4      250 mV Slow Range        ;CR500 (250 mV); 21X, CR7 (500 mV)
     3:   3      SE Channel               ;Yellow wire (SE 3), Purple wire (AG)
     4:   1      EX Channel               ;White wire (E1)
     5:   0      Delay 0.01 s
     6: 250      mV Excitation            ;CR500 (250 mV); 21X, CR7 (500 mV)
     7:   1      Loc [ T_C      ]
     8:    .002  Mult                     ;Cr500 (.002); 21X, CR7 (.001)
     9:   0      Offset

04:  Polynomial (P55)
     1:   1      Reps
     2:   1      X Loc[T_C   ]
     3:   1      F(X) Loc[T_C   ]
     4: ???      C0                       ;See Table 2 for coefficient values.
     5: ???      C1
     6: ???      C2
     7: ???      C3
     8: ???      C4
     9: ???      C5
```

```
;Measure the HMP45CF relative humidity.
;
05:  Volt (SE) (P1)
     1:   1      Reps
     2:   5      2500 mV Slow Range   ;CR500 (2500 mV); 21X, CR7 (5000 mV)
     3:   4      SE Channel           ;Blue wire (SE 4) ), Purple wire (AG)
     4:   2      Loc [ RH_frac   ]
     5:    .001  Mult                 ;See Table 4 for alternative mulipliers
     6:   0      Offset

;Turn the HMP45CF off.
;
06:  Do (P86)
     1:  51      Set Port 1 Low       ;Orange wire (C1)

;Compute the saturation vapor pressure.
;The temperature must be in degrees Celsius.
;
07:  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.
;
08:  Z=X*Y (P36)
     1:   3      X Loc [ e_sat     ]
     2:   2      Y Loc [ RH_frac   ]
     3:   4      Z Loc [ e         ]
```

7. MAINTENANCE

The HMP45CF Probe requires minimal maintenance. Check monthly to make sure the radiation shield is free from debris. The black screen on the sensor's end should also be checked.

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 7 lists the maximum ambient concentrations, of some chemicals, that the HUMICAP® can be exposed to. Detailed information on allowed concentrations can be requested from Vaisala representatives.

TABLE 7. Chemical Tolerances of HMP45CF

Chemical	Concentration (PPM)
Organic solvents	1000 to 10,000
Aggressive chemicals (e.g. SO_2, H_2SO_4, H_2S, HCL, CL_2, ect.)	1 to 10
Weak Acids	100 to 1000
Bases	10,000 to 100,000

Recalibrate the HMP45CF annually. Obtain an RMA number before returning the HMP45CF to Campbell Scientific for recalibration.

8. 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.