INSTRUCTION MANUAL

HC-S3 & HC-S3-XT

Temperature & Relative Humidity Probe

September 2007

WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") 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 are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC 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. CSC is not liable for special, indirect, incidental, or consequential damages.

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HC-S3 & HC-S3-XT Temperature and Relative Humidity Probe

Warning: HygroClip probes plug in straight - do not twist the connector when inserting. Twisting the connectors will destroy the probe and mating connector and will void the warranty. Refer to Section 9 for maintenance instructions.

1. General

The HC-S3 and HC-S3-XT measure air temperature with a Pt100 RTD and relative humidity based on the HygroClip technology. The distinction between the two models is their measurement range.

NOTE: HC-S3 will be used to refer to both models throughout the manual unless otherwise specified.

Each HygroClip probe is 100% interchangeable and can be swapped in seconds without any loss of accuracy, eliminating the downtime typically required for the recalibration process.

2. Specifications

Operating Temperature: -40°C to +60°C (model HC-S3)

-50°C to +50°C (model HC-S3-XT)

Probe Length: 168 mm (6.6 in.)

Probe Body Diameter: 15.25 mm (0.6 in.)

Housing Material: Polycarbonate

Power Consumption: <4 mA

Supply Voltage: 3.5 to 50 VDC (typically 5 VDC)

Settling Time after power is switched on: 3 seconds

2.1 Temperature Sensor

Sensor: Pt100 RTD, 1/3 DIN, IEC 751

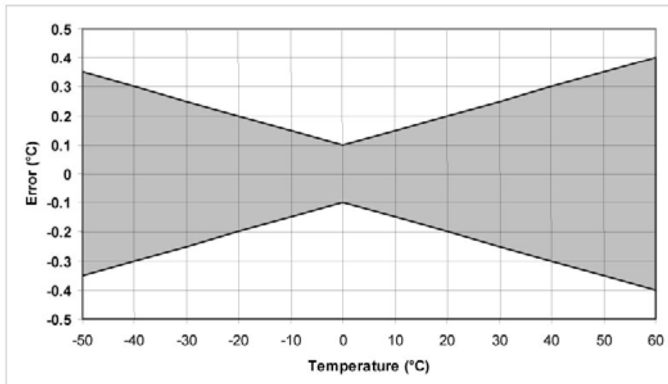
Temperature Measurement Range: -40°C to +60°C (model HC-S3)

-50°C to +50°C (model HC-S3-XT)

Temperature Output Signal Range: 0 to 1.0 VDC

Temperature Resolution: 0.1°C or better

Temperature Accuracy:



2.2 Relative Humidity Sensor

Sensor: HygroClip S3

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

RH Output Signal Range: 0 to 1.0 VDC

Relative Humidity Resolution: 0.1% or better

Accuracy at 23°C: ±1.5% RH

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

Response Time: 12 to 15 seconds

3. Installation

The HC-S3 must be housed inside a solar radiation shield when used in the field. The 41003-X 10-Plate Radiation Shield (Figure 1) mounts to either of the CM6/CM10 tripods, the CM110/115/120 aluminium tripods, or the UT30 tower. The HC-S3 is held within the 41003-X Radiation Shield by securing the sensor in the R41049 adaptor and screwing the adaptor into the base of the Radiation Shield (Figure 1). The sensor must be placed as far in the Radiation Shield without making contact with the inside surface of the Shield.

Figure 1 – HC-S3, 41003-X Radiation Shield, and R41049 adaptor

4. Wiring

Connections to Campbell Scientific dataloggers are given in Table 1. The probe is measured by two single-ended analog input channels, one for temperature and one for relative humidity. This configuration is meant to be used with probes of standard cable length (10 feet). Please refer to Sections 6 and 7 for wiring and programming of probes with cable lengths greater than 10 feet.

CAUTION Always connect the Blue and Grey leads to the datalogger first, followed by the Brown, White, and Clear leads. Connect the Green (Power) lead last.

TABLE 1. Single-Ended Datalogger Connections

Description	Colour	CR23X/CR1000	CR10(X), CR510	CR200/205
Temperature	Brown	Single-Ended Input	Single-Ended Input	Single-Ended Input
Relative Humidity	White	Single-Ended Input	Single-Ended Input	Single-Ended Input
Signal Reference	Blue	⏚	AG	⏚
Power Reference	Grey	G	G	G
Power	Green	5 V	5 V	12 V
Shield	Clear	⏚	AG	⏚

5. Single-Ended Wiring 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.

The temperature and relative humidity signals from the HC-S3 are measured using two single-ended analog measurements.

The probe 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 2 and 3 provide calibration information for temperature and relative humidity.

Table 2. Calibration for Temperature

Units	Multiplier (degrees mV-1)	Offset (degrees)	Offset (XT)
Celsius	0.1	-40	-50
Fahrenheit	0.18	-40	-50

TABLE 3. Calibration for Relative Humidity

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

5.1 Example for CR1000

```
'CR1000


'Declare Variables and Units
Public Batt_Volt
Public Air_Temp
Public RH

Units Batt_Volt=Volts
Units Air_Temp=mV
Units RH=mV

'Define Data Tables
DataTable(Table1,True,-1)
	DataInterval(0,60,Min,0)
	Average(1,Air_Temp,FP2,False)
	Sample(1,RH,FP2)
EndTable

DataTable(Table2,True,-1)
	DataInterval(0,1440,Min,10)
	Minimum(1,Batt_Volt,FP2,False,False)
```

```
EndTable

'Main Program
BeginProg
    Scan(5,Sec,1,0)
        'Default Datalogger Battery Voltage measurement Batt_Volt:
        Battery (Batt_Volt)
        'Generic Single-Ended Voltage measurements Air_Temp:
        VoltSE(Air_Temp,1,mV2500,1,True,0,_60Hz,0.1,-40.0) **-50 for XT model
        'Generic Single-Ended Voltage measurements RH:
        VoltSE(RH,1,mV2500,2,True,0,_60Hz,0.1,0)
        'Call Data Tables and Store Data
        CallTable(Table1)
        CallTable(Table2)
    NextScan
EndProg
```

5.2 Example for CR10X

```
;Measure the HC-S3 temperature.
;
1:  Volt (SE) (P1)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range; CR510 (2500mV), CR23X (1000mV)
 3: 3        SE Channel; Brown Wire (SE3), Blue Wire (G)
 4: 1        Loc [ Air_Temp  ]
 5: 0.1      Multiplier; See Table 3 for alternate multiplier
 6: -40      Offset; **-50 for XT model

;Measure the HC-S3 relative humidity.

2:  Volt (SE) (P1)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range ; CR510 (2500mV), CR23X (1000mV)
 3: 4        SE Channel; White Wire (SE4)
 4: 2        Loc [ RH_pct   ]
 5: 0.1      Multiplier; See Table 3 for alternate multiplier
 6: 0        Offset

;Limit the maximum relative humidity to 100% (Optional).

3:  If (X<=>F) (P89)
 1: 2        X Loc [ RH_pct    ]
 2: 3        >=
 3: 100      F
 4: 30       Then Do

    4:  Z=F x 10^n (P30)
     1: 100      F
     2: 0        n, Exponent of 10
     3: 2        Z Loc [ RH_pct    ]
```

```
5:  End (P95)

;Sample of Typical Hourly Data Output for HC-S3

6:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 60       Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

;Label Output Array

7:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 60       Array ID

8:  Real Time (P77)
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

9:  Average (P71)
 1: 1        Reps
 2: 1        Loc [ Air_Temp  ]

10:  Sample (P70)
 1: 1        Reps
 2: 2        Loc [ RH_pct    ]
```

6. Long Lead Lengths

This section describes the error associated with measuring the HC-S3 with a single-ended measurement if the probe has a cable length greater than 10 feet. To avoid this problem, Campbell Scientific Canada recommends measuring the HC-S3 using a differential analog measurement when custom lead lengths are required.

Generic datalogger connections for measuring the HC-S3 using a differential measurement are given in Table 4. The wiring for these custom lead lengths has been configured to allow differential measurements, and therefore varies from the single-ended wiring of Section 4.

Understanding the details in this section are not required for the general operation of the HC-S3 with Campbell Scientific's dataloggers.

The signal references (Blue & Black) and the power ground (Grey) are in common inside the HC-S3. When the HC-S3 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 either 5 V or 12 V. There will be a voltage drop along those leads because the wire itself has resistance. The HC-S3 draws approximately 4 mA when it is powered. The wire used in the HC-S3 (P/N L9721) has 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 (Vd), along the signal reference/power ground, is given by Eq. (1).

$$\begin{aligned} V_d &= I * R \\ &= 4mA * 13.9\,\Omega / 1000ft \\ &= 55.6mV / 1000ft \end{aligned} \tag{1}$$

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 Vd. The approximate error in temperature and relative humidity is 0.56°C and 0.56% per 100 feet of cable length, respectively.

CAUTION Always connect the Blue, Black, and Grey leads to the datalogger first, followed by the Brown, White, and Clear leads. Connect the Green (Power) lead last.

TABLE 4. Differential Datalogger Connections

Description	Colour	CR23X/CR1000	CR10(X), CR510	CR200/205
Air Temperature (AT)	Brown	Differential Input (H)	Differential Input (H)	Differential Input (H)
Signal Reference	Blue	Differential Input (L)	Differential Input (L)	Differential Input (L)
Relative Humidity (RH)	White	Differential Input (H)	Differential Input (H)	Differential Input (H)
Signal Reference	Jumper to Blue	Differential Input (L)	Differential Input (L)	Differential Input (L)
Power Reference	Grey	G	G	G
Power	Green	5 V	5 V	12 V
Shield	Clear	⏚	AG	⏚

7. Differential Wiring 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.

The temperature and relative humidity signals from the HC-S3 are measured using two differential analog measurements.

The probe 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 2 and 3 provide calibration information for temperature and relative humidity.

7.1 Example for CR1000

```
'Differential Example measurement of HC-S3 AT / RH
'Declare Variables and Units
Public Batt_Volt
Public Air_Temp
Public RH

Units Batt_Volt=Volts
Units Air_Temp=mV
Units RH=mV

'Define Data Tables
DataTable(Table1,True,-1)
    DataInterval(0,60,Min,0)
    Average(1,Air_Temp,FP2,False)
    Sample(1,RH,FP2)
EndTable

DataTable(Table2,True,-1)
    DataInterval(0,1440,Min,10)
    Minimum(1,Batt_Volt,FP2,False,False)
EndTable

'Main Program
BeginProg
    Scan(5,Sec,1,0)
        'Default Datalogger Battery Voltage measurement Batt_Volt:
        Battery (Batt_Volt)
        'Generic Differential Voltage measurements Air_Temp:
            VoltDiff (Air_Temp,1,mV2500,1,True ,0,_60Hz,0.1,-40)**-50 for XT model
        'Generic Differential Voltage measurements RH:
            VoltDiff (RH,1,mV2500,2,True ,0,_60Hz,0.1,0)
        'Call Data Tables and Store Data
        CallTable(Table1)
        CallTable(Table2)
    NextScan
EndProg
```

7.2 Example for CR10X

```
;Measure the HC-S3 temperature

1:  Volt (Diff) (P2)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range ; CR510 (2500mV), CR23X (1000mV)
 3: 1        DIFF Channel ; Brown Wire (Diff 1H), Blue Wire (Diff 1L)
 4: 1        Loc [ Air_Temp  ]
 5: 0.1      Multiplier
 6: -40      Offset **-50 for XT model

;Measure the HC-S3 RH
```

```
2:  Volt (Diff) (P2)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range ; CR510 (2500mV), CR23X (1000mV)
 3: 2        DIFF Channel ; White Wire (Diff 2H), Black Wire (Diff 2L)
 4: 2        Loc [ RH_pct    ]
 5: 0.1      Multiplier
 6: 0        Offset

;Limit the maximum relative humidity to 100% (Optional).

3:  If (X<=>F) (P89)
 1: 2        X Loc [ RH_pct    ]
 2: 3        >=
 3: 100      F
 4: 30       Then Do

    4:  Z=F x 10^n (P30)
     1: 100      F
     2: 0        n, Exponent of 10
     3: 2        Z Loc [ RH_pct    ]

5:  End (P95)

;Sample of Typical Hourly Data Output for HC-S3

6:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 60       Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

;Label Output Array

7:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 60       Array ID

8:  Real Time (P77)
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

9:  Average (P71)
 1: 1        Reps
 2: 1        Loc [ Air_Temp  ]

10:  Sample (P70)
 1: 1        Reps
 2: 2        Loc [ RH_pct    ]
```

8. Absolute Humidity & Dew Point

The HC-S3 measures the relative humidity. Relative humidity is defined by Equation (2) below:

$$RH = \frac{e}{e_s} * 100 \tag{2}$$

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

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

For example, for an air temperature of 20°C and a vapour pressure of 1.17 kPa, the saturation vapour 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 vapour 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 vapour. However, the actual amount of water vapour in the air has not changed. Thus, the amount of water vapour 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 vapour pressure. The mean vapour pressure can be computed on-line by the datalogger.

The example program also shows how Dew Point can be calculated from the Air Temperature and Relative Humidity values. Please note that if you are using an HC-S3 with a custom lead length you will need to refer to Section 7 for the necessary measurement instructions. These will need to be used in place of the voltage measurement instructions used in the following to Examples.

Please refer to Campbell Scientific Technical Note 16 (22.12.00). Example 1 is for use with the CR10(X) datalogger. Example 2 is for use with the CR1000 datalogger.

Example 1. Sample CR10(X) Program that Computes Vapor Pressure (e) and Dew Point.

```
;Measure the HC-S3 temperature.
;
1:  Volt (SE) (P1)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range; CR510 (2500mV), CR23X (1000mV)
 3: 3        SE Channel; Brown Wire (SE3), Blue Wire (G)
 4: 1        Loc [ Air_Temp  ]
 5: 0.1      Multiplier; See Table 3 for alternate multiplier
 6: -40      Offset; **-50 for XT model

;Measure the HC-S3 relative humidity.

2:  Volt (SE) (P1)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range ; CR510 (2500mV), CR23X (1000mV)
 3: 4        SE Channel; White Wire (SE4)
 4: 2        Loc [ RH_frac   ]
 5: 0.001    Multiplier
 6: 0        Offset

;Limit the maximum value of relative humidity
;to 1 (expressed as a fraction).
;
3:  If (X⇔F) (P89)
 1: 2        X Loc [ RH_frac   ]
 2: 3        >=
 3: 1        F
 4: 30       Then Do

    4:  Z=F x 10^n (P30)
     1: 1        F
     2: 0        n, Exponent of 10
     3: 2        Z Loc [ RH_frac   ]

5:  End (P95)

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

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

```
; Estimate Dew Point using the equation:
; Dew_Pt = 241.88 * In(e/0.61078) / (17.558 – In(e/0.61078))

; Mulitply e by 1/0.61078 (= 1.6373)

8:  Z=X*F (P37)
 1: 4        X Loc [ e        ]
 2: 1.6373   F
 3: 5        Z Loc [ Work_R    ]

9:  Z=LN(X) (P40)
 1: 5        X Loc [ Work_R    ]
 2: 5        Z Loc [ Work_R    ]

10:  Z=X*F (P37)
 1: 5        X Loc [ Work_R    ]
 2: 241.88   F
 3: 6        Z Loc [ Work_1    ]

11:  Z=F x 10^n (P30)
 1: 17.558   F
 2: 0        n, Exponent of 10
 3: 7        Z Loc [ Work_2    ]

12:  Z=X-Y (P35)
 1: 7        X Loc [ Work_2    ]
 2: 5        Y Loc [ Work_R    ]
 3: 7        Z Loc [ Work_2    ]

13:  Z=X/Y (P38)
 1: 6        X Loc [ Work_1    ]
 2: 7        Y Loc [ Work_2    ]
 3: 8        Z Loc [ Dew_Pt    ]

;Convert Relative Humidity Fraction to Percentage

14:  Z=X*F (P37)
 1: 2        X Loc [ RH_frac   ]
 2: 100      F
 3: 9        Z Loc [ RH_pct    ]

;Example of typical hourly output for Dew Point

14:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 60       Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

;Label Output Array

15:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 60       Array ID
```

```
16:  Real Time (P77)
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

17:  Average (P71)
 1: 1        Reps
 2: 1        Loc [ Air_Temp  ]

19:  Sample (P70)
 1: 1        Reps
 2: 9        Loc [ RH_pct    ]

20:  Average (P71)
 1: 1        Reps
 2: 4        Loc [ e         ]

20:  Average (P71)
 1: 1        Reps
 2: 8        Loc [ Dew_Pt    ]
```

Example 2. Sample CR1000 Program that Computes Dew Point.

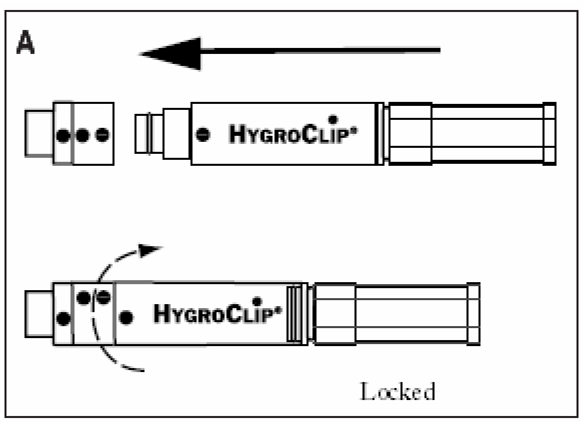
```
'CR1000
'Created by Short Cut (2.5)

'Declare Variables and Units
Public Batt_Volt
Public Air_Temp
Public RH
Public AirTC_5
Public SVp_6
Public Vp_7
Public Dew_Pt

Units Batt_Volt=Volts
Units Air_Temp=mV
Units RH=mV
Units SVp_6=kPa
Units Vp_7=kPa
Units Dew_Pt=Deg C

'Define Data Tables
DataTable(Table1,True,-1)
      DataInterval(0,60,Min,10)
      Average(1,Air_Temp,FP2,False)
      Sample(1,RH,FP2)
      Average (1,Vp_7,FP2,False)
      Average(1,Dew_Pt,FP2,False)
EndTable
```

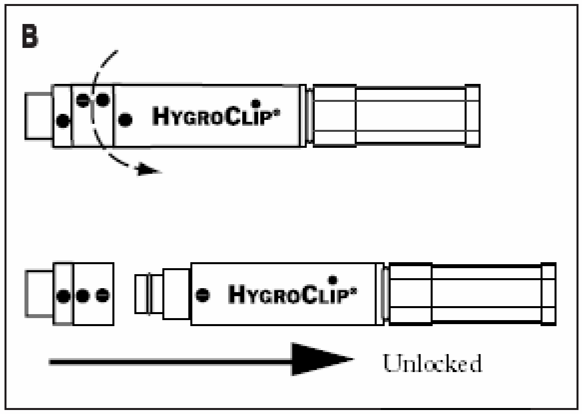
```
'Main Program
BeginProg
    Scan(5,Sec,1,0)
        'Default Datalogger Battery Voltage measurement Batt_Volt:
        Battery(Batt_Volt)
        'Generic Single-Ended Voltage measurements Air_Temp:
        VoltSE(Air_Temp,1,mV2500,1,True,0,_60Hz,0.1,-40) **-50 for XT model
        'Generic Single-Ended Voltage measurements RH:
        VoltSE(RH,1,mV2500,2,True,0,_60Hz,0.1,0.0)
        'Saturation Vapour Pressure calculation Vp
        SatVP (SVp_6,Air_Temp)
        Vp_7=(RH/100)*SVp_6
        'Dew Point calculation Dew_Pt:
        AirTC_5=Air_Temp
        DewPoint(Dew_Pt,AirTC_5,RH)
        If Dew_Pt>AirTC_5 Or Dew_Pt=NAN Then Dew_Pt=AirTC_5
        'Call Data Tables and Store Data
        CallTable(Table1)
    NextScan
EndProg
```

9. Maintenance

Both the HygroClip S3 and the base of the probe connector are marked with a black dot. The grey locking ring has two of the dots. The HygroClip S3 can be inserted or removed from the connector when all four dots are aligned. Be sure to turn the grey locking ring as in Image A to secure the HygroClip S3 in place.

WARNING: Under no circumstance rotate or twist the HygroClip S3 while insertion or removal, as this will severally damage the probe.





The HC-S3 Probe requires minimal maintenance. Check monthly to make sure the radiation shield is free from debris. The metallic screen at the tip of the probe should also be checked for contaminants and dust.

When installed in close proximity to the ocean or other bodies of salt water, 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 can delay or destroy the response to atmospheric humidity.

The filter can be rinsed gently in distilled water and wiped, after being unscrewed from the probe. If any stains are not removed, the filter may need replacement.

Please contact Campbell Scientific (Canada) Corp. with any concerns regarding filter replacement, RH chip replacement, or probe recalibration.

9.1 Replacement Parts for Maintenance Concerns

Please note that Part Numbers listed are from Campbell Scientific (Canada) Corp. and are follows:

1. C2084 – Replacement HygroClip probe Relative Humidity (0 to 100%) and Air Temperature

   (-40°C to +60°C). For use with probe model HC-S3.

2. C2085 – Replacement HygroClip probe Relative Humidity (0 to 100%) and Air Temperature

   (-50°C to +50°C). For use with probe model HC-S3-XT.

3. C2086 – HC-S3 Probe Adaptor with Cable to Bare Leads (6 foot Lead)

4. C2091 – Replacement Filter Cap

Please contact Campbell Scientific (Canada) Corp. regarding pricing and availability.

10. 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.