INSTRUCTION MANUAL

BlackGlobe Temperature Sensor for Heat Stress

Revision: 7/14

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.

Products may not be returned without prior authorization. To obtain a Return Merchandise Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., at (780) 454-2505. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

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

CAMPBELL SCIENTIFIC

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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm
	1 ft (foot) = 304.8 mm
	1 yard = 0.914 m
	1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g
	1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

About sensor wiring

Please note that certain sensor configurations may require a user supplied jumper wire. It is recommended to review the sensor configuration requirements for your application and supply the jumper wire is necessary.

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BlackGlobe Temperature Sensor for Heat Stress

1. Introduction

The BlackGlobe Temperature Sensor for Heat Stress (BlackGlobe) measure radiant temperature. This measurement, along with the measurement of ambient air and wet-bulb temperatures, is used to calculate the wet-bulb globe temperature (WBGT). The WBGT index combines the effects of temperature, humidity, radiant heat, and wind into one single index employed to express environmental heat stress. The measurement of heat stress is important because loss of physical and mental efficiency occurs under definable degrees of heat stress. Severe heat stress can lead to fatigue, exhaustion and possibly even disability or death.

Before installing the BlackGlobe, please study

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*

2. Cautionary Statements

- The BlackGlobe is a precision instrument. Please handle it with care.
- 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.
- Do not use the BlackGlobe with long lead lengths in an electrically noisy environment.

3. Initial Inspection

- Upon receipt of the BlackGlobe, inspect the packaging and contents for damage. File damage claims with the shipping company. Immediately check package contents against the shipping documentation (see Section 3.1, *Ships With List*). Contact Campbell Scientific about any discrepancies.
- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the expected product and cable length are received.

3.1 Ships With List

- ResourceDVD

4. Overview

The BlackGlobe uses a thermistor inside a 15.24 cm (6 in) hollow copper sphere, painted black to measure radiant temperature. This measurement along with the measurement of ambient air and wet-bulb temperatures may be used to calculate the WBGT index.

Sensor cable length is specified at the time of order. Do not exceed 1000 feet of cable.

To calculate the wet-bulb globe thermometer index (WBGT), the measurement of the BlackGlobe (radiant heat), wet-bulb (evaporative heat), and ambient air (dry-bulb) temperatures are required. The wet-bulb temperature can be calculated using air temperature and relative humidity if a wet-bulb thermometer is not available. See Section 7.2, *Calculations*.

5. Specifications

Temperature Measurement Range:	–5° to +95°C
Temperature Survival Range:	–50° to +100°C
Thermistor Interchangeability Error:	Typically < ±0.2°C over 0°C to 70°C and ±0.3 at 95°C
Polynomial Linearization Error:	< ±0.5°C over –7°C to +90°C
Near Normal Emittance:	0.957
Maximum Cable Length:	305 m (1000 ft)

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 V.L. 94 H.B. and will pass FMVSS302. Local fire codes may preclude its use inside buildings.

5.1 Accuracy

The overall probe accuracy is a combination of the thermistor's interchangeability specification, the precision of the bridge resistors, and the Steinhart-Hart equation error (CRBasic dataloggers) or the polynomial error (Edlog dataloggers). In a worst case, all errors add to an accuracy of ±0.3°C over the range of –3° to 90°C and ±0.7°C over the range of –5° to 95°C. The major error component is the interchangeability specification of the thermistor, tabulated in TABLE 5-1 and plotted in FIGURE 5-2. For the range of 0° to 50°C, the interchangeability error is predominantly offset and can be determined with a single point calibration. Compensation can then be done with an offset entered in the measurement instruction. The bridge resistors are 0.1% tolerance with a 10 ppm temperature coefficient. Polynomial errors are tabulated in TABLE 5-2 and plotted in FIGURE 5-1.

TABLE 5-1. Thermistor Interchangeability Specification	
Temperature (°C)	**Temperature Tolerance (±°C)**
–5	0.14
0 to +70	0.10
+85	0.25
+95	0.35

TABLE 5-2. Polynomial Error	
–5° to +95°	< ±0.5°C
–3° to +90°	< ±0.1°C

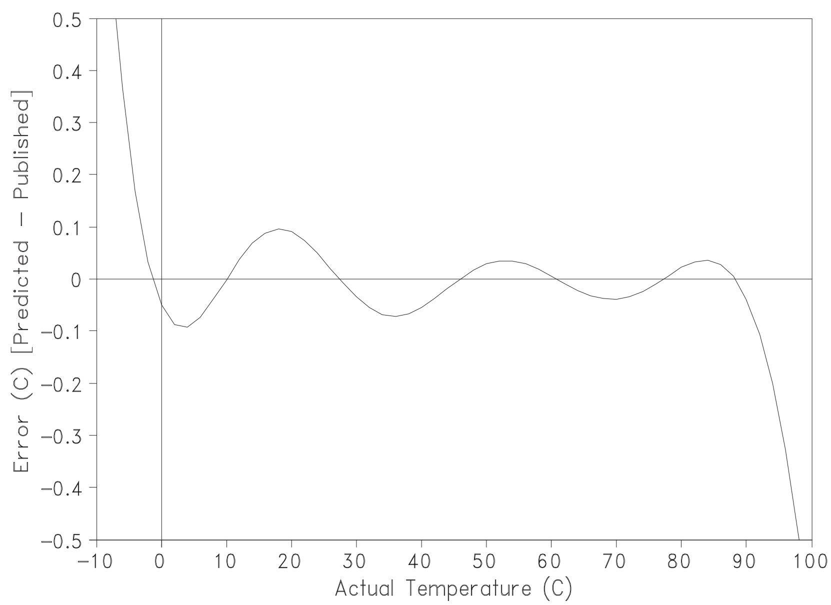

FIGURE 5-1. Polynomial error curve (Edlog dataloggers only)

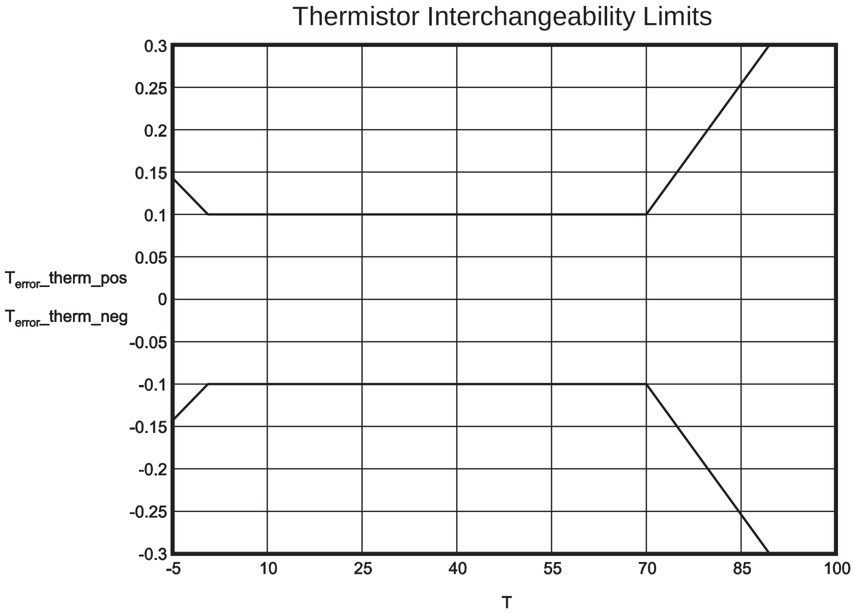

FIGURE 5-2. Thermistor interchangeability limits

6. Installation

6.1 Siting

The BlackGlobe must be mounted in a location that will not be shadowed and is representative of the environmental conditions to be measured.

6.2 Assembly and Mounting

Tools required for installing on a tripod or tower:

- Adjustable end wrench or 7/16 in. and 1/2 in. open end wrench
- Small screwdriver provided with the datalogger
- Small pair of diagonal-cutting pliers
- UV resistant cable ties not provided with the BlackGlobe

6.2.1 Mounting the BlackGlobe on the Mounting Arm

The BlackGlobe and mounting kit requires some assembly before installation. The mounting kit comes with (see Figure 6.1):

- Mounting arm
- Mounting bolt
- Two lock washers
- Two nuts
- Two pipe clamps (not used when mounted to a horizontal pipe cross arm)
- U-bolt with associated nuts and washers

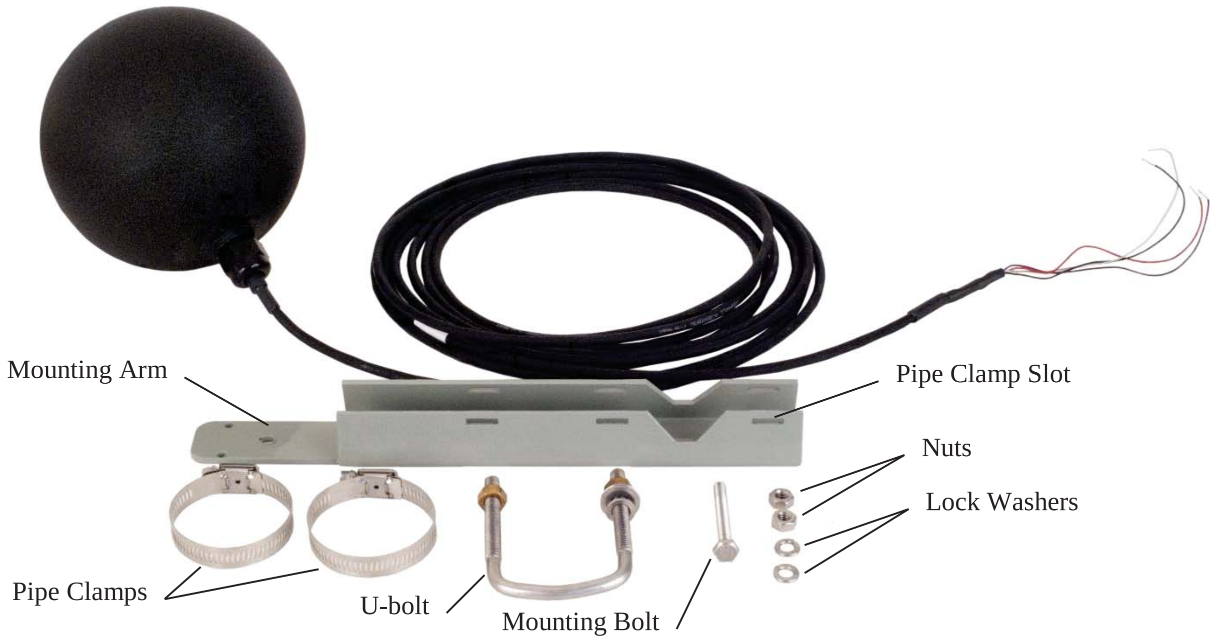

FIGURE 6-1. Mounting kit components

1. Place the mounting bolt through the hole in the mounting arm as shown in FIGURE 6-2.

2. Slide one of the lock washers against the mounting arm.

3. Thread both nuts about half way down the bolt and then slide on the last lock washer. The hardware should be arranged as shown in FIGURE 6-2.

FIGURE 6-2. Nuts and lock washers on mounting bolt

4. Tighten down the nut closest to the mounting arm so the bolt is held firmly in place.

5. Thread the BlackGlobe fitting onto the bolt. Thread it as far down as it will go, but you may have to back it off a bit. The cable gland and cable should align with the mounting arm as shown in FIGURE 6-3.

6. Tighten down the nut closest to the BlackGlobe fitting. The BlackGlobe and mounting bolt should not move when the all the hardware is tightened down.

FIGURE 6-3. BlackGlobe fitting and cable alignment

6.2.2 Mounting the BlackGlobe Assembly on a Horizontal Crossarm

The BlackGlobe assembly must be mounted on a horizontal crossarm.

1. Position the sensor so that the cable gland is facing down (FIGURE 6-3).

2. Use the mounting hardware supplied to hold the sensor on the horizontal crossarm. FIGURE 6-4 and FIGURE 6-5 show a BlackGlobe mounted on a crossarm by using the U-bolts.

3. Use the wire ties provided with the unit to secure the cabling to the crossarm.

4. Leave a small loop of cable at the cable entry into the sensor to act as a drip line for any condensed moisture or rain (FIGURE 6-4).

FIGURE 6-4. BlackGlobe mounted to a crossarm (front view)

FIGURE 6-5. BlackGlobe mounted to a crossarm (back view)

7. Operation

7.1 Wiring

The wiring diagram for the BlackGlobe to a Campbell Scientific datalogger is given in TABLE 7-1. Temperature is measured with one single-ended input channel and a voltage excitation channel. Multiple probes can be connected to the same excitation channel (the number of probes per excitation channel is physically limited by the number lead wires that can be inserted into a single voltage excitation terminal, approximately six).

TABLE 7-1. Wiring Diagram for Campbell Scientific Dataloggers

Color	Description	CR800 CR850 CR5000 CR3000 CR1000 CR9000(X)	CR510 CR500 CR10(X)	21X CR7 CR23X
Black	Voltage Excitation	Switched Voltage Excitation	Switched Excitation	Switched Excitation
Red	Temperature Signal	Single-Ended Input	Single-Ended Input	Single-Ended Input
Purple	Signal Ground	⏚	AG	⏚
Clear	Shield	⏚	G	⏚

7.2 Calculations

7.2.1 Wet-Bulb Globe Thermometer Index (WBGT)

To calculate the WBGT index, a measurement of the BlackGlobe (radiant heat), wet-bulb (evaporative heat), and ambient air (dry-bulb) temperatures are required (Equation 1). In the approach discussed here, air temperature and relative humidity measurements are used to calculate the actual vapor pressure, and a dewpoint temperature is used to calculate the wet-bulb temperature.

Air temperature and relative humidity (%) measurements required for this calculation can be made by a variety of sensors. In the examples shown in Section 7.3, *Programming*, the HC2S3 is used.

Ultimately,

WBGT = (0.2 * BlackGlobe Temp) + (0.7 * Wet-bulb Temp) + (0.1 * Dry-Bulb Temp) (1)

Dewpoint and Wet-bulb temperature units include: °C, °F, °K

7.2.2 Dewpoint

Equation 2 is used to calculate dewpoint.

$$T_d = (241.88 * \ln(P / 0.61078)) / (17.558 - \ln(P / 0.61078)) \quad (2)$$

where

T_d = dewpoint (°C)

P = vapor pressure (kPa)

The equation is an inverse of a version of Teten's equation (Tetens, 1930), optimized for dewpoints in the range –35° to 50°C, and is accurate to within plus or minus 0.1°C within that range.

7.2.3 Vapor Pressure

Vapor pressure is calculated by the datalogger using Equation 3.

$$P = RH * P_{sw} / 100 \quad (3)$$

where

RH = relative humidity (%)

P_{sw} = saturation vapor pressure (kPa) over water

7.2.4 Saturated Vapor Pressure

Saturation vapor pressure over water is calculated by the datalogger using Equation 4.

$$P_{sw} = (A_0 + A_1*T + A_2*T^2 + A_3*T^3 + A_4*T^4 + A_5*T^5 + A_6*T^6) * 0.1 \quad (4)$$

where

T = air temperature (dry-bulb temperature) (°C)

$A_0 = 6.107799961$

$A_1 = 4.436518521*10^{-1}$

$A_2 = 1.428945805*10^{-2}$

$A_3 = 2.650648471*10^{-4}$

$A_4 = 3.031240396*10^{-6}$

$A_5 = 2.034080948*10^{-8}$

$A_6 = 6.136820929*10^{-11}$

7.2.5 Wet-Bulb

Wet-bulb is derived using an iterative process. The wet-bulb temperature lies somewhere between the dry-bulb temperature (air temperature) and the dewpoint temperature. The datalogger uses Equation 5 to calculate vapor pressure using the dry-bulb temperature and a wet-bulb temperature estimate:

$$P = P_w - (0.000660 * (1 + 0.00115 * T_w) * (T - T_w) * SP) \qquad (5)$$

where

P_w = saturation vapor pressure (kPa) at the wet-bulb temperature (°C)

T_w = wet-bulb temperature (°C)

T = air temperature (dry-bulb temperature) (°C)

SP = standard air pressure (kPa) at the user entered elevation

The resulting vapor pressure is compared to the true vapor pressure (see above) and the difference determines the next wet-bulb temperature estimate. The process repeats until the difference between the current wet-bulb temperature estimate and the previous wet-bulb temperature estimate is only plus or minus 0.01°C. The datalogger thus derives the wet-bulb temperature.

7.2.6 Mean Site Barometric Pressure Calculation (SP_kPa)

The wet-bulb instruction needs mean barometric pressure which is closely related to elevation of the site. U.S. Standard Atmosphere and dry air were assumed when Equation 6 was derived (Wallace & Hobbes, 1977).

$$SP_{kPa} = 101.325 - 101.325\left\{1 - \left(1 - \frac{E}{44307.69231}\right)^{5.25328}\right\} \qquad (6)$$

The value of SP_{kPa} is in kilopascals and the site elevation, E, is in meters.

Use Equation 7 to convert feet to meters.

$$E(m) = \frac{E(ft)}{3.281\, ft/m} \qquad (7)$$

The value for SP_{kPa} must be put into the datalogger program.

7.3 Programming

7.3.1 Example CR1000 Program

The example includes measurements of the BlackGlobe temperature, and the calculation of wet-bulb temperature and wet-bulb globe temperature. Measurements of air temperature and relative humidity are supplied by an HC2S3 in this example. Calculations for dewpoint, wet-bulb, and wet-bulb globe temperature are also included.

```
'CR1000 Series Datalogger
'Program: BlackGlobe.CR1

'Declare constants
'Mean site barometric pressure at 1357.58 meters.
'CHANGE THIS VALUE TO MATCH YOUR ELEVATION.
Const SP_kPa = 86.04377

'Declare Public Variables
'Datalogger variables.
Public PnlTempC  'Datalogger panel temperature
Units PnlTempC=Deg C
Public Batt_Volt  'Datalogger battery voltage
Units Batt_Volt=VDC

'BlackGlobe variables.
Public BGTemp_C  'BlackGlobe temperature
Units BGTemp_C=Deg C

'Rotronic HC2S3 variables.
Public AirTempC  'Air temperature
Units AirTempC=Deg C
Public AirRH  'Humidity
Units AirRH=%

'Calculated variables.
Public DewPnt_C  'Dewpoint temperature
Public WetBlb_C  'Wet-bulb temperature
Public WBGT_C  'Wet-bulb globe temperature
Dim SVP_kPa
Dim VP_kPa
Dim UpperTmp
Dim LowerTmp
Dim old_wbT, new_wbT
Dim WB_VP_kPa, Diff_VP_kPa
Dim Diff_wbT

'Define Data Tables
'Hourly data table.
DataTable (Hourly,1,-1)
  DataInterval (0,1,Hr,10)
  Average (1,AirTempC,FP2,False)
  Sample (1,AirRH,FP2)
  Average (1,DewPnt_C,FP2,False)
  Average (1,WetBlb_C,FP2,False)
  Average (1,WBGT_C,FP2,False)
EndTable

'Daily datalogger status table.
DataTable (Daily,True,-1)
  DataInterval (0,1,Day,10)
  Maximum (1,Batt_Volt,FP2,False,False)
  Minimum (1,Batt_Volt,FP2,False,False)
  Maximum (1,PnlTempC,FP2,False,False)
  Minimum (1,PnlTempC,FP2,False,False)
EndTable

'Main Program
BeginProg
  Scan (5,Sec,3,0)
    PanelTemp (PnlTempC,250)
```

```
    Battery (Batt_Volt)
    'Rotronic HC2S3 powered up all the time.
    VoltSe (AirTempC,1,mV2500,1,0,0,_60Hz,0.1,-40)
    VoltSe (AirRH,1,mV2500,2,0,0,_60Hz,0.1,0)
    If (AirRH >= 100) AND (AirRH <= 108) Then AirRH = 100
    SatVP (SVP_kPa,AirTempC)
    VP_kPa = SVP_kPa * AirRH/100
    DewPoint (DewPnt_C,AirTempC,AirRH)
    If (DewPnt_C > AirTempC) Or (DewPnt_C = NAN) Then DewPnt_C = AirTempC
    UpperTmp = AirTempC
    LowerTmp = DewPnt_C
    'BlackGlobe wired to SE channel 3 and excitation channel VX1.
    Therm108 (BGTemp_C,1,3,Vx1,0,_60Hz,1.0,0)
    'Loop to find wet-bulb temperature.
    Do
      old_wbT = new_wbT
      new_wbT = ((UpperTmp - LowerTmp)/2) + LowerTmp
      WetDryBulb (WB_VP_kPa,AirTempC,new_wbT,SP_kPa)
      Diff_VP_kPa = WB_VP_kPa - VP_kPa
      Diff_wbT = ABS (old_wbT - new_wbT)
      If Diff_VP_kPa > 0 Then
        UpperTmp = new_wbT
      Else
        LowerTmp = new_wbT
      EndIf
      If Diff_wbT < 0.01 Then ExitDo
    Loop
    'Wet-bulb temperature.
    WetBlb_C = new_wbT
    'Calculate Wet-Bulb Globe temperature.
    WBGT_C = (0.1 * AirTempC) + (0.2 * BGTemp_C) + (0.7 * WetBlb_C)
    'Call data storage tables.
    CallTable Hourly
    CallTable Daily
  NextScan
EndProg
```

7.4 Long Lead Lengths

If the BlackGlobe has lead lengths greater than 300 feet, a longer settling time before the measurement is made is required. For CRBasic loggers, the 60 and 50 Hz integration options include a 3 ms settling time; longer settling times also can be entered into the Settling Time parameter. In Edlog, use the **DC Half Bridge Instruction (Instruction 4)** with a 2 ms delay to measure the temperature.

CAUTION Do not use the BlackGlobe with long lead lengths in an electrically noisy environment.

8. Maintenance

The BlackGlobe requires minimal maintenance. Check monthly to ensure the sphere is free from dirt and debris. Clean with water and soft cloth if necessary. Do not use solvents as they may dissolve the paint.

9. References

Lowe, P.R. 1977. J. Appl. Meteor., 16:100-103

Tetens, O. 1930. Z. Geophys., 6:297

Wallace, J.M. and P.V. Hobbes, 1977: Atmospheric Science: *An Introductory Survey, Academic Press*, pp. 59 – 61

Appendix A. The Theory of BlackGlobe Temperature and Heat Stress

The Wet-Bulb Globe Temperature Index (WBGT) combines the effects of temperature, humidity, radiant heat, and wind into one single index employed to express environmental heat stress. Loss of physical and mental efficiency occurs under definable degrees of heat stress. Severe heat stress can lead to fatigue, exhaustion and possibly even disability or death. Personnel can increase their resistance to heat stress by acclimatizing gradually to hot environments and by maintaining a good water and salt balance.

Heat stress can be reduced by decreasing the lengths of exposure and decreasing the workload of individuals under heat stress. Situational factors such as the type of clothing worn, the type of work performed, the psychological effects of stress, and the availability of fluids can also affect the assessment of heat stress. These factors are not easily quantified, and so the individual in a given situation must estimate their significance. Environmental factors such as temperature, humidity, and wind are more easily measured to assess heat stress. TABLE A-1 provides some guidelines for using the WBGT index.

It is important to understand how WBGT differs from Humidex. The two indices are not directly comparable, as they are not based on the same parameters. Humidex, which takes into account temperature and humidity, is used to describe how hot the weather feels to the average person. Humidex values are higher than WBGT values when indicating the same danger level (e.g. Humidex > 45°C is 'dangerous', while WBGT > 32.2°C is 'dangerous'). Humidex does have shortcomings, in that it does not include the effects of radiant heat and wind. For this reason, WBGT remains the primary index for human safety applications.

TABLE A-1. Sample use of WBGT Index

Readings	**Guidelines**
WBGT Index Reading 26 – 27.5	Precautions should be taken. Water intake should be a minimum of 0.5 liters/hr. The work/rest cycle for an acclimatized person should be 50/10 min/hr.
WBGT Index Reading 27.5 – 29	Increased water intake should be emphasized. Water intake should be 0.5 to 1 liters/hr. The work/rest cycle for an acclimatized person should be 50/10 min/hr.
WBGT Index Reading 29 – 31	Increased supervision of personnel performing physical activity is required. Water intake should be 1 to 1.5 liters /hr. The work/rest cycle for an acclimatized person should be 45/15 min/hr.
WBGT Index Reading 31 – 32	Physical activity should be limited to a maximum of 6 hours per day for fully acclimatized personnel. Water intake should be 1.5 to 2 liters/hr. The work/rest cycle for an acclimatized person should be 30/30 min/hr.
WBGT Index Reading >32	All strenuous activity should be suspended. Water intake should be a minimum of 2 liters/hr. The work/rest cycle for an acclimatized person (non-strenuous activity) should be 20/40 min/hr.

For more detailed exposure limits, please see the link below from the Canadian Center for Occupational Health and Safety:

http://www.ccohs.ca/oshanswers/phys_agents/heat_control.html

Appendix B. Edlog Programming Examples

B.1 Example CR10X Program

Instruction 5 (AC Half Bridge) is used to measure the thermistor probe inside the sphere. **Instruction 55 (Polynomial)** is used to calculate the temperature in degrees Celsius. The polynomial coefficients are shown in TABLE B-1. Thermistor resistance and computed temperature over a –10 to +84°C range is shown in TABLE B-2. The example includes instructions for measuring an HC2S3 to supply air temperature and relative humidity values. Calculations for dewpoint, wet-bulb, and wet-bulb globe temperature are also included.

```
;{CR10X}
;Program: BLACKGLOBE.CSI
;Date: June 2013

*Table 1 Program
  01:  5.0000     Execution Interval (seconds)

1:  Batt Voltage (P10)
  1:   1          Loc [ BattVolt  ]

2:  Internal Temperature (P17)
  1:   2          Loc [ CR10XTmpC ]

;Rotronic HC2S3 temperature and relative humidity.
;Sensor powered on all the time.

3:  Volt (SE) (P1)
  1:   1          Reps
  2:   5          2500 mV Slow Range
  3:   1          SE Channel
  4:   4          Loc [ AirTempC  ]
  5:   0.1        Multiplier
  6:   -40        Offset

4:  Volt (SE) (P1)
  1:   1          Reps
  2:   5          2500 mV Slow Range
  3:   2          SE Channel
  4:   5          Loc [ AirRH     ]
  5:   0.1        Multiplier
  6:   0          Offset

5:  If (X<=>F) (P89)
  1:   5          X Loc [ AirRH     ]
  2:   3          >=
  3:   100        F
  4:   30         Then Do
```

```
    6:  If (X<=>F) (P89)
       1: 5           X Loc [ AirRH     ]
       2: 4           <
       3: 108          F
       4: 30          Then Do

       7:  Z=F x 10^n (P30)
        1:100          F
        2:0   n, Exponent of 10
        3:5   Z Loc [ AirRH     ]

    8:  End (P95)

9:  End (P95)

;BlackGlobe temperature - °C

10:  AC Half Bridge (P5)
  1:   1          Reps
  2:   23         25 mV 60 Hz Rejection Range
  3:   3          SE Channel
  4:   1          Excite all reps w/Exchan 1
  5:   1000       mV Excitation
  6:   3          Loc [ BGTemp_C  ]
  7:   200        Multiplier
  8:   0          Offset

11:  Polynomial (P55)
  1:   1          Reps
  2:   3          X Loc [ BGTemp_C  ]
  3:   3          F(X) Loc [ BGTemp_C  ]
  4:   -26.97     C0
  5:   69.635     C1
  6:   -40.66     C2
  7:   16.573     C3
  8:   -3.455     C4
  9:   0.301      C5

;Calculate saturated vapor pressure.

12:  Saturation Vapor Pressure (P56)
  1:   4           Temperature Loc [ AirTempC  ]
  2:   9          Loc [ SVP_kPa   ]

;Calculate vapor pressure.

13:  Z=X*Y (P36)
  1:   9          X Loc [ SVP_kPa   ]
  2:   5          Y Loc [ AirRH     ]
  3:   10         Z Loc [ VP_kPa    ]

14:  Z=X*F (P37)
  1:   10         X Loc [ VP_kPa    ]
  2:   0.01       F
  3:   10         Z Loc [ VP_kPa    ]

;Dewpoint calculation.

15:  Z=X*F (P37)
  1:   10         X Loc [ VP_kPa    ]
  2:   1.63725    F
  3:   20         Z Loc [ scratch1  ]

16:  Z=LN(X) (P40)
  1:   20         X Loc [ scratch1  ]
  2:   20         Z Loc [ scratch1  ]

17:  Z=X*F (P37)
```

```
  1:   20          X Loc [ scratch1  ]
  2:   241.88      F
  3:   21           Z Loc [ scratch2  ]

18:  Z=F x 10^n (P30)
  1:   17.558      F
  2:   0           n, Exponent of 10
  3:   22          Z Loc [ scratch3  ]

19:  Z=X-Y (P35)
  1:   22          X Loc [ scratch3  ]
  2:   20          Y Loc [ scratch1  ]
  3:   22          Z Loc [ scratch3  ]

20:  Z=X/Y (P38)
  1:   21          X Loc [ scratch2  ]
  2:   22          Y Loc [ scratch3  ]
  3:   7           Z Loc [ DewPnt_C  ]

21:  If (X<=>Y) (P88)
  1:   7           X Loc [ DewPnt_C  ]
  2:   3           >=
  3:   4           Y Loc [ AirTempC  ]
  4:   30          Then Do

    22:  Z=X (P31)
       1: 4           X Loc [ AirTempC  ]
       2: 7           Z Loc [ DewPnt_C  ]

23:  End (P95)

;Mean site pressure at elevation of 1357.58 meters.

24:  Z=F x 10^n (P30)
  1:   86.0437     F
  2:   00          n, Exponent of 10
  3:   17          Z Loc [ SP_kPa    ]

;Wet-bulb calculation

25:  Z=X (P31)
  1:   4           X Loc [ AirTempC  ]
  2:   14          Z Loc [ UpperTmp  ]

26:  Z=X (P31)
  1:   7           X Loc [ DewPnt_C  ]
  2:   15          Z Loc [ LowerTmp  ]

;Iterative loop to figure out wet-bulb temperature.

27:  Beginning of Loop (P87)
  1:   0           Delay
  2:   25          Loop Count

    28:  Z=X (P31)
       1: 12          X Loc [ new_wbT   ]
       2: 11          Z Loc [ old_wbT   ]

    29:  Z=X-Y (P35)
       1: 14          X Loc [ UpperTmp  ]
       2: 15          Y Loc [ LowerTmp  ]
       3: 12          Z Loc [ new_wbT   ]

    30:  Z=X*F (P37)
       1: 12          X Loc [ new_wbT   ]
       2: 0.5         F
       3: 12          Z Loc [ new_wbT   ]
```

```
31:  Z=X+Y (P33)
   1: 12          X Loc [ new_wbT   ]
   2: 15          Y Loc [ LowerTmp  ]
   3: 12          Z Loc [ new_wbT   ]

32:  Wet/Dry-Bulb Temp to VP (P57)
   1: 9           Pressure Loc [ SVP_kPa   ]
   2: 4           Dry-bulb Loc [ AirTempC  ]
   3: 12          Wet-bulb Loc [ new_wbT   ]
   4: 18          Loc [ WB_VP_kPa ]

33:  Z=X-Y (P35)
   1: 11          X Loc [ old_wbT   ]
   2: 12          Y Loc [ new_wbT   ]
   3: 16          Z Loc [ Diff_wbT  ]

34:  Z=ABS(X) (P43)
   1: 16          X Loc [ Diff_wbT  ]
   2: 16          Z Loc [ Diff_wbT  ]

35:  Z=X-Y (P35)
   1: 18          X Loc [ WB_VP_kPa ]
   2: 10          Y Loc [ VP_kPa    ]
   3: 13          Z Loc [ DiffVPkPa ]

36:  If (X<=>F) (P89)
   1: 13          X Loc [ DiffVPkPa ]
   2: 3           >=
   3: 0           F
   4: 30          Then Do
```

```
      37:  Z=X (P31)
       1:12  X Loc [ new_wbT   ]
       2:14  Z Loc [ UpperTmp  ]

   38:  Else (P94)

      39:  Z=X (P31)
       1:12  X Loc [ new_wbT   ]
       2:15  Z Loc [ LowerTmp  ]

   40:  End (P95)

   41:  If (X<=>F) (P89)
      1: 16          X Loc [ Diff_wbT  ]
      2: 4           <
      3: 0.01        F
      4: 31          Exit Loop if True

42:  End (P95)

;Wet-bulb temperature.

43:  Z=X (P31)
  1:   12         X Loc [ new_wbT   ]
  2:   8          Z Loc [ WetBlb_C  ]

;Calculate Wet-Bulb Globe temperature.

44:  Z=X*F (P37)
  1:   4          X Loc [ AirTempC  ]
  2:   0.1        F
  3:   20         Z Loc [ scratch1  ]

45:  Z=X*F (P37)
  1:   3          X Loc [ BGTemp_C  ]
  2:   0.2        F
  3:   21         Z Loc [ scratch2  ]

46:  Z=X*F (P37)
  1:   7          X Loc [ DewPnt_C  ]
  2:   0.7        F
  3:   6          Z Loc [ WBGT_C    ]

47:  Z=X+Y (P33)
  1:   20         X Loc [ scratch1  ]
  2:   6          Y Loc [ WBGT_C    ]
  3:   6          Z Loc [ WBGT_C    ]

48:  Z=X+Y (P33)
  1:   21         X Loc [ scratch2  ]
  2:   6          Y Loc [ WBGT_C    ]
  3:   6          Z Loc [ WBGT_C    ]

;Store hourly data.
```

```
49:  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)

50:  Set Active Storage Area (P80)
  1:   1          Final Storage Area 1
  2:   101        Array ID

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

52:  Average (P71)
  1:   1          Reps
  2:   4          Loc [ AirTempC  ]

53:  Average (P71)
  1:   1          Reps
  2:   7          Loc [ DewPnt_C  ]

54:  Average (P71)
  1:   1          Reps
  2:   8          Loc [ WetBlb_C  ]

55:  Average (P71)
  1:   1          Reps
  2:   6          Loc [ WBGT_C    ]

56:  Sample (P70)
  1:   17         Reps
  2:   3          Loc [ BGTemp_C  ]

;Daily station status data.

57:  If time is (P92)
  1:   0          Minutes (Seconds --) into a
  2:   1440       Interval (same units as above)
  3:   10         Set Output Flag High (Flag 0)

58:  Set Active Storage Area (P80)
  1:   1          Final Storage Area 1
  2:   102        Array ID

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

60:  Maximum (P73)
  1:   1          Reps
  2:   0          Value Only
  3:   1          Loc [ BattVolt  ]

61:  Minimum (P74)
  1:   1          Reps
  2:   0          Value Only
  3:   1          Loc [ BattVolt  ]

62:  Maximum (P73)
  1:   1          Reps
  2:   0          Value Only
  3:   2          Loc [ CR10XTmpC ]

63:  Minimum (P74)
  1:   1          Reps
  2:   0          Value Only
  3:   2          Loc [ CR10XTmpC ]

*Table 2 Program
  01:  0          Execution Interval (seconds)
```

```
*Table 3 Subroutines

End Program
```

TABLE B-1. Polynomial Coefficients

Coefficient	Value
C_0	–26.97
C_1	69.635
C_2	–40.66
C_3	16.573
C_4	–3.455
C_5	0.301

TABLE B-2. Actual Temperature, Sensor Resistance, and Computed Temperature

Temperature °C	Resistance OHMS	Output °C
–10.00	612366	–9.02
–8.00	546376	–7.36
–6.00	488178	–5.63
–4.00	436773	–3.83
–2.00	391294	–1.97
0.00	351017	–0.05
2.00	315288	1.91
4.00	283558	3.91
6.00	255337	5.93
8.00	230210	7.96
10.00	207807	10.00
12.00	187803	12.04
14.00	169924	14.07
16.00	153923	16.09
18.00	139588	18.10
20.00	126729	20.09
22.00	115179	22.07

TABLE B-2. Actual Temperature, Sensor Resistance, and Computed Temperature

Temperature °C	Resistance OHMS	Output °C
24.00	104796	24.05
26.00	95449	26.02
28.00	87026	27.99
30.00	79428	29.97
32.00	72567	31.94
34.00	66365	33.93
36.00	60752	35.93
38.00	55668	37.93
40.00	51058	39.94
42.00	46873	41.96
44.00	43071	43.98
46.00	39613	46.00
48.00	36465	48.02
50.00	33598	50.03
52.00	30983	52.03
54.00	28595	54.03
56.00	26413	56.03
58.00	24419	58.02
60.00	22593	60.01
62.00	20921	61.99
64.00	19388	63.98
66.00	17981	65.97
68.00	16689	67.96
70.00	15502	69.96
72.00	14410	71.97
74.00	13405	73.98
76.00	12479	75.99
78.00	11625	78.01
80.00	10837	80.02
82.00	10110	82.03
84.00	9438.1	84.04
86.00	8816.9	86.03

TABLE B-2. Actual Temperature, Sensor Resistance, and Computed Temperature		
Temperature °C	**Resistance OHMS**	**Output °C**
88.00	8241.9	88.00
90.00	7709.7	89.96
92.00	7216.3	91.89
94.00	6758.9	93.80
96.00	6334.5	95.67
98.00	5940.5	97.51
100.00	5574.3	99.31

B.2 Edlog Programming for Long Lead Lengths

The following is a portion of an example CR10X program that uses the **Excite-Delay (SE) (P4)** instead of the **AC Half Bridge (P5)**.

```
01: Excite, Delay,Volt(SE) (P4)
  1:   1          Rep
  2:   3          ±25 mV slow range          ;On the 21X and CR7 use the 50 mV input range.
  3:   1          IN Chan                    ;Entry depends on the datalogger SE channel
used
  4:   1          Excite all reps w/EXchan 3 ;Entry depends on the excitation channel used
  5:   2          Delay (units .01sec)
  6:   1000       mV Excitatio               ;On the 21X and CR7 use the 2000 mV excitation
  7    1          Loc [BGTemp_C ]
  8:   .2         Mult                       ;Use a multiplier of 0.1 with a 21X or CR7
  9:   0          Offset
```

```
02: Polynomial (P55)
  1:   1          Reps
  2:   1          X Loc [BGTemp_C ]      ;
  3:   1          F(X) Loc [BGTemp_C ]
  4:   -26.97     C0
  5:   69.635     C1
  6:   -40.66     C2
  7:   16.573     C3
  8:   -3.455     C4
  9:   .301       C5
```