INSTRUCTION MANUAL

Black Globe

Temperature Sensor for Heat Stress

March 2012

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CAMPBELL SCIENTIFIC®
11564 149 Street | Edmonton AB T5M 1W7 | Canada
780.454.2505 | fax 780.454.2655 | campbellsci.ca

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Black Globe Temperature Sensor for Heat Stress

1. General

The Black Globe Temperature Sensor for Heat Stress (Black Globe) uses a thermistor inside a 6” 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 wet bulb globe thermometer (WBGT) index, which is sometimes referred to as the Humidex. This manual describes how to use this sensor with Campbell Scientific table and array based dataloggers.

The sensor comes standard with 10 feet of cable and may be ordered with up to 1000 feet of cable.

To calculate the wet bulb globe thermometer index (WBGT), the measurement of the black globe (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 4. Calculations.

1.1 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 @ 95°C.

Polynomial Linearization Error: <±0.5°C over -7°C to +90°C.

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.

2. Accuracy

The overall probe accuracy is a combination of the thermistor's interchangeability specification, the precision of the bridge resistors, and the polynomial error. 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 -7°C to 95°C. The major error component is the interchangeability specification of the thermistor, tabulated in Table 2-1. 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 2-2 and plotted in Figure 2-1.

TABLE 2-1. Thermistor Interchangeability Specification

Temperature (°C)	Temperature Tolerance (±°C)
–10	0.25
0 to +50	0.20
+70	0.20
+90	0.31

TABLE 2-2. Polynomial Error

-10 to +95	<±1.0°C
-7 to +95	<±0.5°C
-3 to +90	<±0.1°C

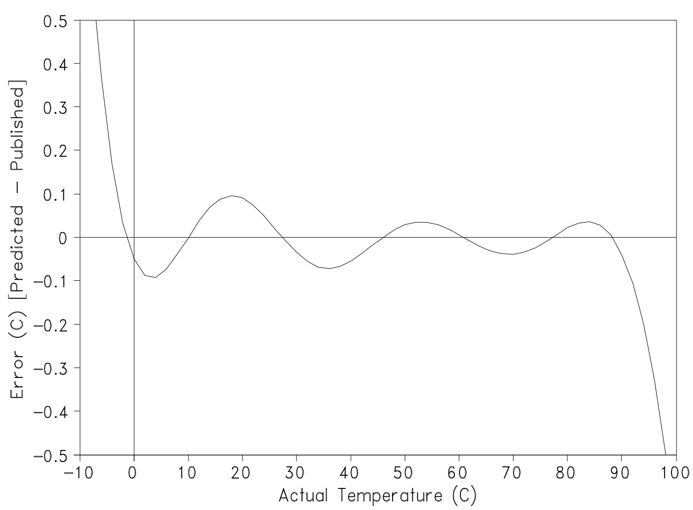
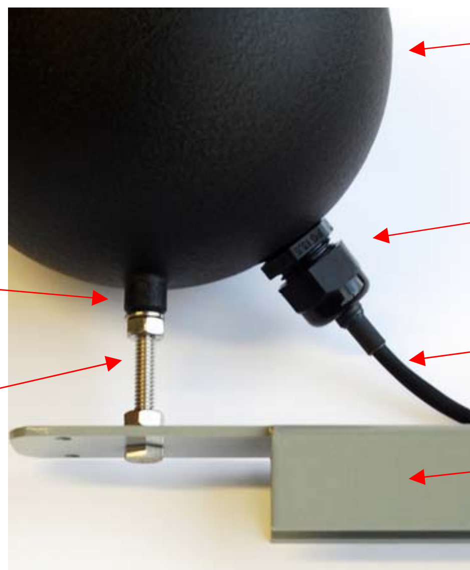


FIGURE 2-1. Thermistor Probe Polynomial Error Curve

3. Installation and Wiring

The Black Globe and C2490 mount kit requires assembly before installation. Place the bolt included in the mounting kit through the hole at the end of the mount. Secure the bolt to the mount with a lock washer and nut. Then thread on a nut and lock washer onto the bolt. Now thread the Black Globe fitting onto the bolt. Be sure that the nut and washer are far enough down so that you can thread the Black Globe all the way on. The gland seal and cable should be able to line up with the C2490 mounting arm. Complete the assembly with tightening the nut and lock washer to the Black Globe fitting.



The Black Globe must be mounted on a horizontal crossarm using the C2490 mount kit. The Black Globe must mounted in a location that will not be shadowed by the surrounding environment. Position the sensor so that the sensor entry port at the bottom of sphere is facing down. Use the mounting hardware supplied with the C2490 (i.e. band clamps or v-bolts) to hold the sensor on the horizontal crossarm.

Connections to the datalogger for the Black Globe are shown in Table 3-1. The probe is measured using a single-ended analog input channel. The red lead is connected to a single ended analog input. The black lead connects to an excitation channel. The purple leads connect to Analog Ground (AG) on the CR500 and CR10(X), and Ground on the 21X, CR23X, and CR7. The clear lead is the shield that connects to Ground (G) on the datalogger.

TABLE 3-1. Connections to Campbell Scientific Dataloggers				
Color	**Description**	**CR800 series CR1000 CR3000 CR5000**	**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	⏚

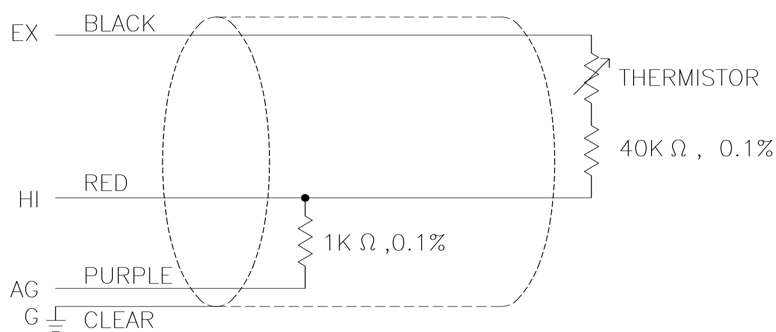


FIGURE 3-1. Thermistor Probe Schematic

4. Calculations

To calculate the wet bulb globe thermometer index (WBGT), a measurement of the Black Globe (radiant heat), wet bulb (evaporative heat), and ambient air (dry bulb) temperatures are required. In the approach discussed here, Air Temperature and Relative Humidity measurements are used to calculate the actual vapour pressure, and a Dew Point Temperature which is then 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 5 we are using the HMP45C.

Ultimately,

WBGT = (0.2 x Black Globe Temp) + (0.7 x Wet Bulb Temp) + (0.1 x Dry Bulb Temp)

Dew Point and Wet-Bulb temperature units include: °C, °F, °K

The equation used to calculate dew point is:

Td=(241.88*ln(P/0.61078))/(17.558-ln(P/0.61078))

where

Td = dew point (°C)
P = vapour pressure (kPa)

The equation is an inverse of a version of Teten's equation (Tetens, O. 1930. Z. Geophys., 6:297), optimized for dew points in the range -35 to 50 °C, and is accurate to within plus or minus 0.1 °C within that range.

Vapour pressure is calculated by the datalogger with the following equation:

P=RH*Psw/100

where

RH = relative humidity (%)
Psw = saturation vapour pressure (kPa) over water

Saturation vapour pressure over water is calculated by the datalogger with the following approximating polynomial (see Lowe, P.R. 1977. J. Appl. Meteor., 16:100-103):

Psw=6.107799961+T*(4.436518521*10^-1+T*(1.428945805*10^-2+T*(2.650648471*10^-4+T*(3.031240396*10^-6+T*(2.034080948*10^-8+6.136820929*10^-11*T)))))

where

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

Wet-bulb is derived using an iterative process. The wet-bulb temperature lies somewhere between the dry-bulb temperature (air temperature) and the dew point temperature. The datalogger uses the following algorithm to calculate vapour pressure using the dry-bulb temperature and a wet-bulb temperature guess:

P=Pw-(0.000660*(1+0.00115*Tw)*(T-Tw)*SP)

where

Pw = saturation vapour pressure (kPa) at the wet-bulb temperature (°C)
Tw = wet-bulb temperature (°C)
T = air temperature (dry-bulb temperature) (°C)
SP = standard air pressure (kPa) at the user entered elevation

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

Campbell Scientific has a 'Calculating Dew Point from RH and Air Temperature' Application Note at

ftp://ftp.campbellsci.com/pub/csl/outgoing/uk/technotes/16_oct05.pdf

5. Programming

EXAMPLE 1. Sample CR1000 Instructions

The example includes measurements of the black globe temperature, and the calculation of wet-bulb temperature and wet-bulb globe temperature. Measurements of air temperature and relative humidity are supplied by an HMP45C in this example. Calculations for dew point, wetbulb, and wetbulb globe temperature are also included

```
'Declare Variable and Units
Dim AirTC_7
Dim SPkPa_8
Dim Twg_9
Dim Twpg_10
Dim Vpg_11
Dim Vp_12
Dim SVp_13
Dim Twch_14
Dim VpgVpd_15
Dim Top_16
Dim Bottom_17
Dim SVpW_18
Dim N_19
Public BattV
Public Air_TempC
Public Air_RH
Public TdC'= Dewpoint Temperature
Public TwC'= Wetbulb Temperature
Public BGT '= Black Globe Temperature
Public WBGT '= Wet-Bulb Globe Temperature

Units BattV=Volts
Units Air_TempC=Deg C
Units Air_RH=%
Units TdC=Deg C
Units TwC=Deg C

'Define Data Tables
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
```

```
  Average(1,Air_TempC,FP2,False)
  Sample(1,Air_RH,FP2)
  Average(1,TdC,FP2,False)
  Average(1,TwC,FP2,False)
EndTable

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

'Main Program
BeginProg
  Scan(5,Sec,1,0)

    'Measure Black Globe Temperature
    BrHalf(BGT, 1, mV25, 1, VX1, 1, 1000, True, 0, 250, 200, 0)
    BGT=(-26.97+69.635*BGT)+(-40.66*BGT^2+16.573*BGT^3)+(-
    3.455*BGT^4+0.301*BGT^5)

    'HMP45C  (6-wire, panel switched power) Temperature & Relative Humidity Sensor
measurements Air_TempC and Air_RH
    PortSet(9,1)
    Delay(0,150,mSec)
    VoltSe(Air_TempC,1,mV2500,1,0,0,_60Hz,0.1,-40)
    VoltSe(Air_RH,1,mV2500,2,0,0,_60Hz,0.1,0)
    PortSet(9,0)
    If Air_RH>100 AND Air_RH<108 Then Air_RH=100

    'Dew Point and Wet-Bulb calculation prep
    AirTC_7=Air_TempC
    SPkPa_8=101.325
    SatVP(SVp_13,AirTC_7)
    Vp_12=Air_RH*SVp_13/100

    'Dew Point calculation TdC
    DewPoint(TdC,AirTC_7,Air_RH)
    If TdC>AirTC_7 OR TdC=NAN Then TdC=AirTC_7

    'Find Wet-Bulb TwC
    Top_16=AirTC_7
    Bottom_17=TdC
    For N_19 = 1 To 25
      Twpg_10=Twg_9
      Twg_9=((Top_16-Bottom_17)/2)+Bottom_17
      WetDryBulb(Vpg_11,AirTC_7,Twg_9,SPkPa_8)
      VpgVpd_15=Vpg_11-Vp_12
      Twch_14=ABS(Twpg_10-Twg_9)
      If VpgVpd_15>0 Then
        Top_16=Twg_9
      Else
        Bottom_17=Twg_9
      EndIf
      If Twch_14<0.01 OR N_19=25 Then ExitFor
    Next
```

```
    TwC=Twg_9

    'Calculate Wetbulb Globe Temperature (WBGT - Humidex) (deg C)
    WBGT = (0.1*Air_TempC)+(0.2*BGT)+(0.7*TwC)

    'Call Data Tables and Store Data
    CallTable(Table1)
    CallTable(Table2)

  NextScan
EndProg
```

EXAMPLE 2. Sample CR10X Instructions

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 example includes instructions for measuring an HMP45C to supply air temperature & relative humidity values. Calculations for dew point, wetbulb, and wetbulb globe temperature are also included.

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

2:  Polynomial (P55)
 1: 1        Reps
 2: 1        X Loc [ BlkGlb_T  ]
 3: 1        F(X) Loc [ BlkGlb_T  ]
 4: -26.97   C0
 5: 69.635   C1
 6: -40.66   C2
 7: 16.573   C3
 8: -3.455   C4
 9: 0.301    C5
;* Proper entries will vary with program and datalogger channel and input location
assignments.
;** On the 21X and CR7 use the 50 mV input range and 2000 mV excitation.

;Measure HMP45C Air Temperature & Relative Humidity Sensor
3:  Do (P86)
 1: 41       Set Port 1 High

4:  Excitation with Delay (P22)
 1: 2        Ex Channel
 2: 0        Delay W/Ex (0.01 sec units)
 3: 15       Delay After Ex (0.01 sec units)
```

```
 4: 0        mV Excitation

5:  Volt (SE) (P1)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range
 3: 1        SE Channel
 4: 3        Loc [ Air_TempC ]
 5: 0.1      Multiplier
 6: -40.0    Offset

6:  Volt (SE) (P1)
 1: 1        Reps
 2: 25       2500 mV 60 Hz Rejection Range
 3: 2        SE Channel
 4: 4        Loc [ Air_RH    ]
 5: 0.1      Multiplier
 6: 0        Offset

7:  Do (P86)
 1: 51       Set Port 1 Low

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

    9:  If (X<=>F) (P89)
     1: 4        X Loc [ Air_RH    ]
     2: 4        <
     3: 108      F
     4: 30       Then Do

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

    11:  End (P95)

12:  End (P95)

;Calculate Dew Point (TdC)
13:  Z=X (P31)
 1: 3        X Loc [ Air_TempC ]
 2: 5        Z Loc [ AirTC_7   ]

14:  Z=F x 10^n (P30)
 1: 95.4606  F
 2: 0        n, Exponent of 10
 3: 6        Z Loc [ SPkPa_8   ]

15:  Saturation Vapor Pressure (P56)
 1: 5        Temperature Loc [ AirTC_7   ]
 2: 7        Loc [ SVp_13    ]
```

```
16:  Z=X*Y (P36)
 1: 7        X Loc [ SVp_13    ]
 2: 4        Y Loc [ Air_RH    ]
 3: 8        Z Loc [ Res2_19   ]

17:  Z=X*F (P37)
 1: 8        X Loc [ Res2_19   ]
 2: .01      F
 3: 9        Z Loc [ Vp_12     ]

18:  Z=X*F (P37)
 1: 9        X Loc [ Vp_12     ]
 2: 1.6373   F
 3: 10       Z Loc [ Res1_18   ]

19:  Z=LN(X) (P40)
 1: 10       X Loc [ Res1_18   ]
 2: 10       Z Loc [ Res1_18   ]

20:  Z=X*F (P37)
 1: 10       X Loc [ Res1_18   ]
 2: 241.88   F
 3: 8        Z Loc [ Res2_19   ]

21:  Z=F x 10^n (P30)
 1: 17.558   F
 2: 0        n, Exponent of 10
 3: 11       Z Loc [ Res3_20   ]

22:  Z=X-Y (P35)
 1: 11       X Loc [ Res3_20   ]
 2: 10       Y Loc [ Res1_18   ]
 3: 11       Z Loc [ Res3_20   ]

23:  Z=X/Y (P38)
 1: 8        X Loc [ Res2_19   ]
 2: 11       Y Loc [ Res3_20   ]
 3: 12       Z Loc [ TdC       ]

;Find Wetbulb Temperature (TwC)
24:  Z=X (P31)
 1: 5        X Loc [ AirTC_7   ]
 2: 13       Z Loc [ Top_16    ]

25:  Z=X (P31)
 1: 12       X Loc [ TdC       ]
 2: 14       Z Loc [ Bottom_17 ]

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

    27:  Z=X (P31)
     1: 15       X Loc [ Twg_9     ]
```

```
 2: 16       Z Loc [ Twpg_10   ]

28:  Z=X-Y (P35)
 1: 13       X Loc [ Top_16    ]
 2: 14       Y Loc [ Bottom_17 ]
 3: 15       Z Loc [ Twg_9     ]

29:  Z=X*F (P37)
 1: 15       X Loc [ Twg_9     ]
 2: .5       F
 3: 15       Z Loc [ Twg_9     ]

30:  Z=X+Y (P33)
 1: 15       X Loc [ Twg_9     ]
 2: 14       Y Loc [ Bottom_17 ]
 3: 15       Z Loc [ Twg_9     ]

31:  Wet/Dry Bulb Temp to VP (P57)
 1: 6        Pressure Loc [ SPkPa_8   ]
 2: 5        Dry Bulb Loc [ AirTC_7   ]
 3: 15       Wet Bulb Loc [ Twg_9     ]
 4: 17       Loc [ Vpg_11    ]

32:  Z=X-Y (P35)
 1: 17       X Loc [ Vpg_11    ]
 2: 9        Y Loc [ Vp_12     ]
 3: 18       Z Loc [ VpgVpd_15 ]

33:  Z=X-Y (P35)
 1: 16       X Loc [ Twpg_10   ]
 2: 15       Y Loc [ Twg_9     ]
 3: 19       Z Loc [ Twch_14   ]

34:  Z=ABS(X) (P43)
 1: 19       X Loc [ Twch_14   ]
 2: 19       Z Loc [ Twch_14   ]

35:  If (X<=>F) (P89)
 1: 19       X Loc [ Twch_14   ]
 2: 4        <
 3: 0.01     F
 4: 31       Exit Loop if True

36:  If (X<=>F) (P89)
 1: 18       X Loc [ VpgVpd_15 ]
 2: 3        >=
 3: 0        F
 4: 30       Then Do

     37:  Z=X (P31)
      1: 15       X Loc [ Twg_9     ]
      2: 13       Z Loc [ Top_16    ]

38:  Else (P94)
```

```
        39:  Z=X (P31)
         1: 15       X Loc [ Twg_9     ]
         2: 14       Z Loc [ Bottom_17 ]

    40:  End (P95)

41:  End (P95)

42:  Z=X (P31)
 1: 15       X Loc [ Twg_9     ]
 2: 20       Z Loc [ TwC       ]

;Calculate Wetbulb Globe Temperature (Humidex) (Deg C)
43:  Z=X*F (P37)
 1: 3        X Loc [ Air_TempC ]
 2: 0.1      F
 3: 22       Z Loc [ DB_Temp   ]

44:  Z=X*F (P37)
 1: 1        X Loc [ BlkGlb_T  ]
 2: 0.2      F
 3: 23       Z Loc [ BG_Temp   ]

45:  Z=X*F (P37)
 1: 20       X Loc [ TwC       ]
 2: 0.7      F
 3: 24       Z Loc [ WB_Temp   ]

46:  Z=X+Y (P33)
 1: 22       X Loc [ DB_Temp   ]
 2: 23       Y Loc [ BG_Temp   ]
 3: 21       Z Loc [ WBGT      ]

47:  Z=X+Y (P33)
 1: 21       X Loc [ WBGT      ]
 2: 24       Y Loc [ WB_Temp   ]
 3: 21       Z Loc [ WBGT      ]

;Hourly Output
48:  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)

49:  Set Active Storage Area (P80)^15230
 1: 1        Final Storage Area 1
 2: 101      Array ID

50:  Real Time (P77)^28286
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

51:  Average (P71)^12736
 1: 1        Reps
 2: 3        Loc [ Air_TempC ]
```

```
52:  Sample (P70)^30407
 1: 1        Reps
 2: 4        Loc [ Air_RH    ]

53:  Average (P71)^2079
 1: 1        Reps
 2: 12       Loc [ TdC       ]

54:  Average (P71)^19067
 1: 1        Reps
 2: 20       Loc [ TwC       ]

55:  Average (P71)^17420
 1: 1        Reps
 2: 21       Loc [ WBGT      ]
```

TABLE 5-1. 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 5-2. Actual vs. Computed Temperatures

Actual Temperature (°C)	Sensor Resistance (Ω)	Calculated 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
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

Actual Temperature (°C)	Sensor Resistance (Ω)	Calculated Output (°C)
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
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

6. Maintenance

The Black Globe 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.

7. Long Lead Lengths

If the Black Globe has a lead length of greater than 300 feet, up to a maximum of 1000 feet, use the DC Half Bridge instruction (Instruction 4) with a 2 millisecond delay to measure temperature. The delay provides a longer settling time before the measurement is made. Do not use the Black Globe with long lead lengths in an electrically noisy environment.

Example 3. Sample Program CR10(X) Using DC Half Bridge with Delay

```
01:  Excite, Delay,Volt(SE) (P4)
  1:  1            Rep
  2:  3**          ±25 mV slow range
  3:  1*           IN Chan
  4:  1*           Excite all reps w/EXchan 3
  5:  2            Delay (units .01sec)
  6:  1000**       mV Excitation
  7:  1*           Loc [BG_Temp ]
  8:  .2***        Mult
  9:  0            Offset

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

*   Proper entries will vary with program and datalogger channel and input location assignments.
**   On the 21X and CR7 use the 50 mV input range and 2000 mV excitation.
***   Use a multiplier of 0.1 with a 21X and CR7.

Appendix A. The Theory of Black Globe 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 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. 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 litres/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 litres/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 litres/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 litres/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 litres/hr. The work/rest cycle for an acclimatized person (non-strenuous activity) should be 20/40 min/hr.