This SOP is subject to
review and revision in 2015.

BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

TECHNICAL SERVICES DIVISION

QUALITY ASSURANCE PROJECT PLAN

MET SOP 510

BATTERY MAINTENANCE

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STANDARD OPERATING PROCEDURE
BAAQMD TECHNICAL SERVICES DIVISION

BATTERY MAINTENANCE AND TESTING PROCEDURES

FEBRUARY 28, 2008

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INTRODUCTION

All BAAQMD meteorological sites include a 12V battery as part of the meteorological system. At sites where AC power is available (powered sites), the battery provides backup power to the logger and instruments when power is lost. At sites where a solar panel provides the only source of power (solar sites), the battery is charged during sunny days and provide power through the night and on overcast days. BAAQMD uses a 7.5 amp-hour sealed rechargeable battery at powered sites and a larger 22-26 amp-hour battery at solar sites. After a few years, battery charging capacity decreases to a level where it no longer can hold an adequate charge. Batteries at meteorological sites are tested annually to determine when replacement is needed.

GENERAL OPERATING PROCEDURES

Once per year, the battery from each meteorological site is brought to the meteorological instrument lab for testing. When removing the battery in the field, a transition battery is plugged into the power regulator to keep the instruments running while the field battery is removed. After the replacement battery is installed, the transition battery is removed.

In the instrument lab, large batteries taken from solar sites must be charged to full capacity prior to testing. Small batteries at powered sites should already be fully charged, so no additional charging is needed. During a test, batteries are discharged through a 2A light bulb. The light bulb is cycled on and off in 5-minute intervals to prevent damage to the battery. A custom-made control circuit (switch box) using a latching relay turns the

light bulb on and off. The relay is activated by a pulse from C1 on the CR10, and deactivated by a pulse from C2. A Campbell Scientific CR10 datalogger controls the switching, logs the battery voltage, stops the test when battery voltage drops to 10.5V, and calculates the battery capacity. CR10 analog inputs measure battery voltage. Because the inputs can only accept up to 2.5 volts, a 10:1 voltage divider cable scales down the battery voltage by a factor of 10. The CR10 then converts the scaled-down measurement to the true voltage with a program multiplier (See *Voltage Divider Cable and Multiplier* under *Notes*). Batteries should be replaced if the tested capacity drops below 50% of rated capacity for small batteries or 75% of rated capacity for large batteries.

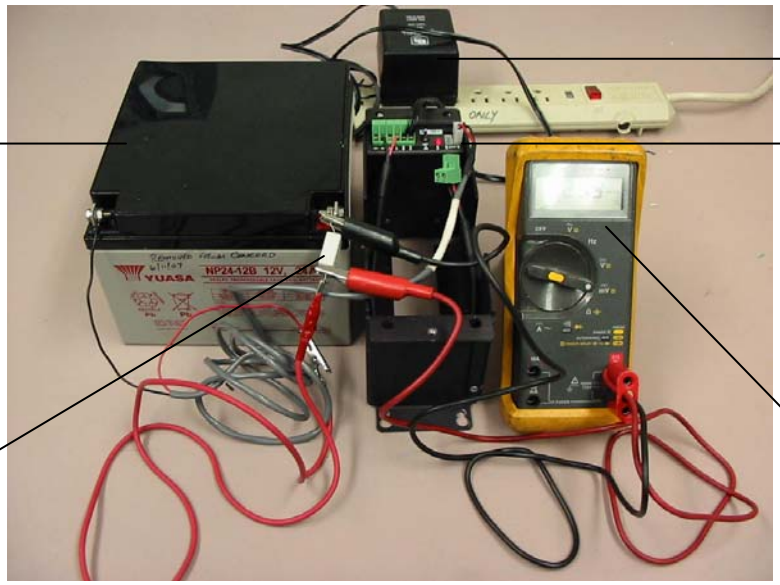

Figure 1: Charging Setup

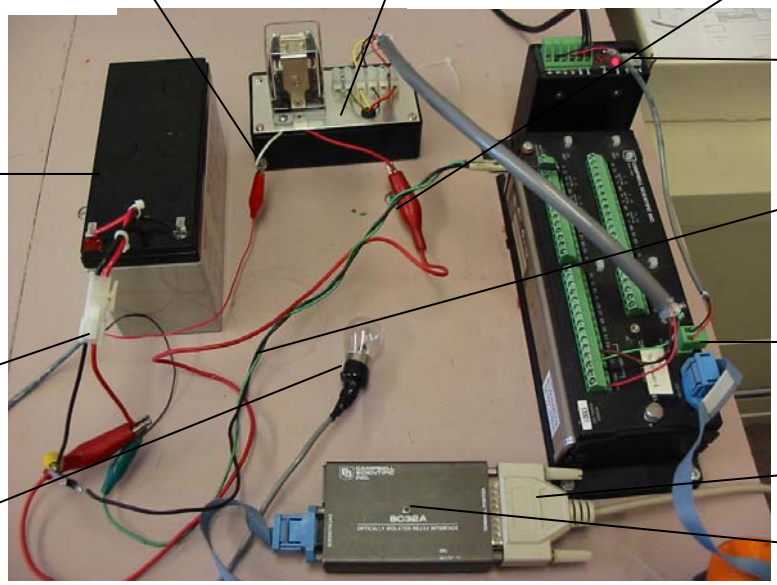

Figure 2: Test Setup

EQUIPMENT

1. Field Equipment
    a. Replacement field battery (with connector)
    b. Transition battery (with at least 1 ft. of cable and connector)
2. Charging Equipment
    a. Campbell power regulator with transformer
    b. Voltmeter
    c. 1/4W (or greater) 0.1 ohm resister
3. Test Equipment
    a. Campbell power regulator with transformer
    b. Campbell CR10 datalogger
    c. Switch box
    d. 10:1 voltage divider cable

PROCEDURE

Field

1. Locate the PS12 power regulator and plug the transition battery into an empty battery terminal. Do not disconnect the solar panel or AC power cables from the input screw terminals. Unplug the existing battery and plug in the replacement battery. Now unplug the transition battery.

2. With a permanent marker, document the removal on the existing battery and the installation on the replacement battery. Include the site name and date.

Lab

3. If the battery was taken from a solar site, fully charge the battery (Figure 1). You may assume that the battery is fully charged if the charge current is 2 mA or less. To determine the charge current, connect the battery to the charger and attach a 0.1 ohm resistor (1/4W or greater) in-line at one of the battery terminals. The charge current can be found by measuring the voltage across the resistor and dividing by the resistor value (I = V/R). With a 0.1 ohm resistor, the charge current will be ten times the measured voltage.

4. Power down the CR10 by pulling the power connector from its socket.

5. Connect the CR10 datalogger to the switch box. On both units, connect the red wire to 12V, black wire to ground, and yellow wire to 5V. Connect the green wire from C1 on the CR10 to *pulse on* at the switch box, and connect the brown wire from C2 on the CR10 to *pulse off* on the switch box.

6. Connect the battery, light bulb, and switch box. Clip a wire from the positive power wire at the switch box (red) to the positive power battery terminal. Clip the positive (red) end of the light bulb to the negative (white) switch box power wire.

Clip the negative (black) end of the light bulb to the negative battery terminal. NOTE: If the battery terminals consist of screw terminals (i.e. large batteries), clip the wires directly to them. If the battery has a molex-type connector, attach a matching female connector, then clip the wires to the wire leads.

7. Connect the voltage divider cable from the battery to the CR10. Connect the orange/green wire to 1H on the CR10 and clip the other end to the positive battery terminal. Connect the black wire to 1L on the CR10 and clip the other end to the negative battery terminal.

8. Attach the 9/25-pin data cable to the computer's COM port and the SC32 Interface. Attach the 9-pin ribbon cable from the interface to the CS I/O port on the CR10. Attach the power connector to power up the CR10.

9. Run LoggerNet on the computer and click *Connect* at the main menu. Choose the *LabCR10* at the Connect Screen (or *LabCR10X* if connecting to a CR10X) to the left and click *Connect*. Once connected, click *Send*. Look for the program file *BatteryTest.DLD* and click *Open*. Click *Yes* at the warning to begin uploading the program to the CR10. After the program has uploaded, click *OK* at the confirmation, then *Disconnect*. The test has begun and the light bulb should illuminate.

10. The CR10 stops the test when battery voltage drops to 10.5V. To determine if the test has stopped, view the input parameter *Cycle* at Input Location 2 (see *Input Locations* under *Notes*). The test has stopped when *Cycle* is no longer incrementing. To download the test data, connect to the CR10 with LoggerNet (step 8) and click *Collect Now*. The location of the file is specified in the file-path located in the setup portion of the program. Rename the file with the battery serial number and a ".dat" extension. You may open the file with any text editor (i.e. Notepad) or with the sub-program *View* in LoggerNet.

11. The total energy drain (test capacity in amp-hours) is printed on the last column (4th) on the last row (see *Notes* below for details on output file parameters; see Table-1 for an output file example). Recycle the battery if the test capacity is less than 50% of rated capacity for small batteries or 75% for large batteries.

NOTES

1. **Voltage Divider Cable and Multiplier:** The CR10 datalogger maximum input analog voltage is 2.5V. Therefore, the battery voltage must be scaled down for voltage monitoring. The voltage divider cable scales down the voltage by a 10:1 ratio (a 12V input results in a 1.2V output). The program scales the sampled voltage back to its true value with a multiplier. The multiplier is located in *Table 1, Instruction 1, Parameter 5* of the program (Appendix A). Due to resistor variances, the voltage ratio is approximate. The program multiplier compensates

for this variance and so it is unique to each divider circuit. To determine the multiplier, connect the divider cable and measure the voltage V_{in} at the battery, then measure the output voltage V_{out}. The multiplier is:

$$\text{Multiplier} = \frac{V_{in}}{V_{out}} x\, 10^{-3}.$$

The cable is built with a 10k ohm and 20k ohm resistor. If another cable needs to be made, use 10k ohm or greater resistors to minimize current leakage.

2. **Light Bulb Current Draw:** The light bulb is assumed to draw 2 amps of current regardless of battery voltage. Over a minute, the energy draw is .033 amp-minutes. This value, located in *Table 3, Instruction 13, Parameter 2* of the program (Appendix A), is incremented onto Input Location *AmpHours* each minute until the end of the program. Its final value is the total energy drawn in amp-hours. If a different device is used in place of this light bulb, this amp-minute value will need to be changed depending on its current draw. The amp-minute value is defined as follows:

$$Amp\text{-}Minutes = \frac{Current\ Draw}{60}$$

3. **Input Locations:** Input locations contain test parameters and can be viewed in real time either in LoggerNet on a computer or by using a Campbell Scientific CR10KD Keypad Display. Once connected to the CR10, input locations can be accessed through LoggerNet in the *Connect Screen* by clicking the number *1* in the row labeled *Numeric*. If viewing with the CR10KD, attach it to the CR10 CS/IO port with the 9-pin cable, enter **6* and *A/B* to scroll through the input locations. Input location definitions are as follows:

01	Minutes	Elapsed minutes from start of the test
02	Cycle	Elapsed time in seconds from beginning of on/off cycle Each cycle is 10 minutes (600 sec)
03	Volts	Battery voltage (refreshes every second)
04	AmpHours	Total energy drawn from battery

4. **Output File:** A battery voltage sample is taken and a row is written to the output file at the end of each minute until the end of the test. The output definition for each row is:

[Code][Minutes][Voltage][AmpHours]

Code	10: Relay deactivated (light bulb off) 11: Relay activated (light bulb on)
Minutes	Elapsed time in minutes since the start of the test
Voltage	Measured Battery Voltage
AmpHours	Total energy drawn from battery

Table-1: Example of a 7.5 Amp-Hour Battery Test Output File

```
11,170,11.88,2.833
11,171,10.86,2.866
11,172,10.78,2.9
11,173,10.71,2.933
11,174,10.64,2.966
10,175,10.56
10,176,11.74
10,177,11.78
10,178,11.8
10,179,11.81
11,180,11.82,3
11,181,10.72,3.033
11,182,10.6,3.066
```

An example of an output file for a 7.5 amp-hour battery tested is shown in Table 1. The data indicates that the test had been running for 170 minutes, the bulb was turned on for 5 minutes, off for 5 minutes, and then on for about 3 minutes before the battery voltage dropped to 10.5 volts and the test was ended. The total energy drawn was 3.1 amp-hours, which was less than 50% of the battery's rated capacity. This battery should be recycled.

MAINTENANCE

1. Keep 2 small and 2 large batteries in the lab. At the 1st of each month, charge the batteries for 72 hours or until fully charged (see step 3 in Test Procedure).

2. Batteries in the field should be tested yearly. Test roughly 1/3 of all batteries each winter, spring, and summer. Replace each field battery with one from the lab, charge it to full capacity, and then test them using the above procedure. If the tested capacity exceeds 50% for small batteries or 75% for large batteries, re-charge the battery and use it to replace the next battery that needs to be tested.

AUTHORS, REVISIONS, AND APPROVALS

February, 2008 (Original Version)
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Approved: Dick Duker, Meteorology and Quality Assurance Manager

APPENDIX A

LOGGERNET BATTERY TEST PROGRAM
(CAMPBELL SCIENTIFIC CR10 DATALOGGER)

```
;{CR10}

;Program:       BatteryTest.CSI
;Date:          9/19/07

;Description:   Tests and calculates battery capacity.  CR10 ports C1/C2 activates/deactivates a
;               latching relay at the switch box, turning on/off a light bulb.  Battery is drained by
;               a 2A light bulb at 50% duty cycle - 5 min on, 5 min off until 10.5 volts is ;
                reached.

;Flag Usage:    Flag1: Low when test in progress.
;               High by user or program to stop test

;Port Usage:    Port1: Pulse to activate relay (turn on light bulb)
;               Port2: Pulse to deactivate relay (turn off light bulb)

;Multiplier:    Table 1 Instruction 1 Parameter 5 (P2) determined by Voltage Divider Cable
;               V_in  = Open voltage at battery
;               V_out = Voltage at voltage divider cable output
;               Multiplier = V_in/V_out x 10^-3

;Amp-Minutes:   Table 3 Instruction 13 Parameter 2 (P34) determined by bulb current
;               Incremented to Input Location 4 AmpHour to get final energy draw in amp-hours
;               Amp-Minutes = bulb current/60

;Input         1. Minutes    : Minutes elapsed from beginning of test
;Channel       2. Cycle      : Seconds elapsed from beginning of on/off cycle (10 min)
;Usage:        3. Volts      : Battery voltage (updated every second)
;               4. AmpHour : Accumulated AmpHours drawn from battery
;               5.
;               6.
;               7.
;               8.
;               9.
;               10. Timer     : Seconds elapsed from beginning of test
;               11. Sample    : Seconds elapsed from beginning of sample period (1 min)

;Wiring        CR10            SWITCH BOX
;               C1      Green   Pulse_On  (P/On)
;               C2      Brown           Pulse_Off (P/Off)
;               5V      Yellow          5V
;               12V     Red     12V
;               Gnd     Black   Gnd

;Switch Box    Clip Cable from Power+ (red) to Battery+ (red)

;Light Bulb    Red     Switch Box Power+ (white)
;               Black   Battery- (black)
```

```
;VOLTAGE DIVIDER CABLE
;                    Grn/Or  CR10 1H to Battery+
;                    Black   CR10 1L to Battery-

;Output Array Definitions - 1 minute records
;    01:  Array ID    : 10 = Relay Deactivated (light bulb off)
;                     : 11 = Relay Activated (light bulb on)
;    02:  Minute      : Time Stamp in Minutes
;    03:  Volts       : Sampled Voltage
;    04:  AmpHour     : Accumulated AmpHours Drawn


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

1:  Volt (Diff) (P2)
 1: 1       Reps
 2: 25       2500 mV 60 Hz Rejection Range
 3: 1       DIFF Channel
 4: 3       Loc [ Volts     ]
 5: .01155   Mult
 6: 0.0      Offset

2:  If Flag/Port (P91)
 1: 21       Do if Flag 1 is Low
 2: 30       Then Do

3:  Set Port(s) (P20)
 1: 9999     C8..C5 = nc/nc/nc/nc
 2: 9900     C4..C1 = nc/nc/low/low

; F = Bulb Cycle Period (Seconds)
4:  Z=X MOD F (P46)
 1: 10       X Loc [ Timer     ]
 2: 600      F
 3: 2        Z Loc [ Cycle     ]

; F = Sample Period (Seconds)
5:  Z=X MOD F (P46)
 1: 10       X Loc [ Timer     ]
 2: 60       F
 3: 11       Z Loc [ Sample    ]

; Turn on bulb at the beginning of each cycle
6:  If (X<=>F) (P89)
 1: 2        X Loc [ Cycle     ]
 2: 1        =
 3: 0        F
 4: 30       Then Do

    7:  Do (P86)
     1: 71       Pulse Port 1
```

```
    8:  Do (P86)
     1: 12       Set Flag 2 High

9:  End (P95)

; Turn off bulb midway through the cycle
10:  If (X<=>F) (P89)
 1: 2        X Loc [ Cycle     ]
 2: 1        =
 3: 300      F
 4: 30       Then Do

    11:  Do (P86)
     1: 72       Pulse Port 2

    12:  Do (P86)
     1: 22       Set Flag 2 Low

13:  End (P95)

; Record Battery Voltage and Output at the beginning of each minute
14:  If (X<=>F) (P89)
 1: 11       X Loc [ Sample    ]
 2: 1        =
 3: 0        F
 4: 1        Call Subroutine 1

; Stop test if voltage drops below 10.5V
15:  If (X<=>F) (P89)
 1: 3        X Loc [ Volts     ]
 2: 4        <
 3: 10.5     F
 4: 11       Set Flag 1 High

; Increment Timer
16:  Z=Z+1 (P32)
 1: 10       Z Loc [ Timer     ]

; Threshold reached or Flag 1 manually set high
17:  Else (P94)

    18:  Do (P86)
     1: 72       Pulse Port 2

19:  End (P95)

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

1:  Beginning of Subroutine (P85)
 1: 1        Subroutine 1
```

```
2:  Do (P86)
 1: 10       Set Output Flag High

; If bulb is on, ArrayID=11
3:  If Flag/Port (P91)
 1: 12       Do if Flag 2 is High
 2: 30       Then Do

    4:  Set Active Storage Area (P80)^1116
     1: 1        Final Storage Area 1
     2: 11       Array ID

; If bulb is off, ArrayID=10
5:  Else (P94)

    6:  Set Active Storage Area (P80)^2538
     1: 1        Final Storage Area 1
     2: 10       Array ID

7:  End (P95)

; Output Time Stamp
8:  Sample (P70)^22257
 1: 1        Reps
 2: 1        Loc [ Minutes   ]

; Increment Minutes
9:  Z=Z+1 (P32)
 1: 1        Z Loc [ Minutes   ]

; Output Battery Voltage
10:  Sample (P70)^30329
 1: 1        Reps
 2: 3        Loc [ Volts     ]

; If bulb is on, output Total AmpHours extracted
11:  If Flag/Port (P91)
 1: 12       Do if Flag 2 is High
 2: 30       Then Do

    12:  Sample (P70)^32614
     1: 1        Reps
     2: 4        Loc [ AmpHours  ]

    13:  Z=X+F (P34)
     1: 4        X Loc [ AmpHours  ]
     2: .03333   F
     3: 4        Z Loc [ AmpHours  ]

14:  End (P95)

15:  End (P95)

End Program
```