STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME V

AUDIT PROCEDURES
FOR
AIR QUALITY MONITORING

APPENDIX S

PERFORMANCE AUDIT PROCEDURES
FOR
METEOROLOGICAL SENSORS

MONITORING AND LABORATORY DIVISION

AUGUST 2002

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STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME V

AUDIT PROCEDURES
FOR
AIR QUALITY MONITORING

APPENDIX S.1

PERFORMANCE AUDIT PROCEDURES
FOR
RELATIVE HUMIDITY SENSORS

MONITORING AND LABORATORY DIVISION

AUGUST 2002

S.1 RELATIVE HUMIDITY AUDIT PROCEDURES

S.1.0 INTRODUCTION

Humidity is a general term for the water vapor content of air. This term may be expressed as relative humidity or dew point. Relative humidity (RH) is the ratio of the existing amount of water vapor in the air at a given temperature to the maximum amount that could exist at that temperature. This value is usually expressed in percent relative humidity (%RH). Percent relative humidity is a variable parameter which is affected by atmospheric conditions during its measurement. This creates a difficult auditing situation. If the auditing day is cloudy and calm, equilibrium of the percent relative humidity auditing sensor can occur within 10 minutes. However, if the conditions are sunny and windy, there will be quick moving pockets of air showing a high degree of variation in percent relative humidity. This variation can occur in both a horizontal and vertical profile. Thus, it is critical that the instrument auditing relative humidity is positioned as near the ambient measurement sensor as possible. An operator who is familiar with the meteorological equipment should be present during the audit to perform the required manipulations of the tower and sensors.

S.1.1 GENERAL OPERATING PROCEDURES

A certified Fisher Digital Hygrometer (or equivalent) is used to measure relative humidity in percent (%RH). The instrument is powered by a 9 volt alkaline battery. The %RH is displayed continuously on the liquid crystal display (LCD) by pressing the HOLD/SCROLL button on the front of the instrument when the %RH value appears. This instrument provides a direct read out of %RH, thus, eliminating the need for the conversion charts needed in psychrometry. The %RH is measured with a thin film capacitance. The %RH operating range is 5 to 95% (non-condensing) with an accuracy of ±1.5%.

The audit sensor and station sensor are compared by inserting them into the General Eastern C-1 Relative Humidity Generator (%RH Generator), and using the %RH Generator to generate relative humidity at three audit levels (approximately 30%, 60%, and 90%RH). The %RH Generator itself is not calibrated, so the digital display on the box is only approximate and the Fisher Digital Hygrometer is used to determine the actual %RH in the chamber.

S.1.2 AUDIT EQUIPMENT

1. The following equipment is needed to perform an audit on a percent relative humidity sensor:

    a. Fisher Digital Hygrometer relative humidity/temperature sensor.

    b. General Eastern C-1 Relative Humidity Generator.

    c. A container of distilled or deionized water.

    d. Siphon/fill apparatus.

    e. Acrylic humidity chamber covers.

    f. Rubber inserts for acrylic humidity chamber covers.

2. A QA Audit Worksheet Temperature and Relative Humidity (Worksheet) (see Figure S.1.2.1).

    NOTE: During the audit, inspect the condition of the relative humidity sensor, the cables, and the radiation shield. Review the maintenance records for the sensor and radiation shield. Record any pertinent information on the Worksheet.

QA AUDIT WORKSHEET
TEMPERATURE AND RELATIVE HUMIDITY

Site Name: ________________________ Site#: _________ Date: ______________

Address: __________________________ Agency: ___________________________

Site Technician: ________________ Auditors: _________________________________

Data Read From: Chart[ ] DAS[ ] Other[ ] DAS Type: ______________________

Ambient Temperature		
Audit Point	Station Sensor	Audit Sensor
1		
2		
3		
4		
5		

Relative Humidity		
Audit Point	Station Sensor	Audit Sensor
1		
2		
3		
4		
5		

Equipment	Audit Sensor Information	
Specifications	Temperature Sensor	Humidity Sensor
Manufacturer		
Serial Number		

Equipment	Station Instrument Information		
Specifications	Ambient Temperature	Relative Humidity	Radiation Shield
Manufacturer			
Model Number			
Serial Number			
Operating Range			
Sensor Height			
Last Calibrated			
Motor/Naturally Aspirated			
Cal. Equipment Cert. Date			

QA-TRH1 REVISED 02/02

Figure S.1.2.1 QA Audit Worksheet Temperature and Relative Humidity

S.1.3 AUDITING PROCEDURES

S.1.3.1 GENERAL EASTERN C-1 RH GENERATOR

NOTE: If possible, conduct all %RH audits with the General Eastern C-1 RH Generator (C-1) in a temperature controlled environment. If this is not possible and the audit must be conducted outdoors, shield the C-1 from direct sunlight to avoid overheating the electronics.

1. Check the desiccant cartridge to make certain the blue color is present in at least 1/4 of the cartridge. If not, remove the desiccant cartridge by grasping it with both hands an slowly pulling it straight up towards you. Unscrew the metal cap and remove the spring and felt washer. Empty the used desiccant and fill it to the proper level with fresh desiccant. Reinstall the felt washer, spring, and metal cap. Reinsert the desiccant cartridge in the C-1 by pushing it straight down to make certain that it seals properly. Retain the used desiccant for later drying after returning from audits.

2. Plug the C-1 in and turn power on. The red "FILL" light will com on and the humidity LED will display the last %RH entered as "XX.X H".

3. Using the siphon/fill device, carefully fill the reservoir, labeled "FILL", of the C-1 with distilled or deionized water until the red "FILL" light goes out. Avoid splashing water into the RH chamber. The reservoir will hold approximately 0.8 liters (800 mL) of water.

4. Make certain the CAL/OPERATE/AUTO toggle switch is in the "OPERATE" position. If the toggle switch is inadvertently placed in the "CAL" or "AUTO" position, the only way to interrupt the routine is to shut off the power to the C-1 and power it up again. .

5. Attach an acrylic chamber cover to the C-1 for the %RH sensor being audited. There are three acrylic covers. Each cover is drilled for a different size of %RH sensor. If the %RH sensor to be audited does not fit snugly into any of the drilled acrylic covers, it will be necessary to drill a hole the correct size for the sensor.

6. Using the "INC/DEC" toggle switch, either increase or decrease the %RH until the LED indicator reads approximately "30.0 H". Allow the C-1 to run for 15 to 20 minutes. This will clear out any ambient air from the internal plumbing.

7. Insert the audit %RH sensor and the station %RH sensor into the acrylic chamber cover until they are approximately 1/2" from the bottom of the chamber. Plug all unused drilled holes.

8. When the %RH sensors have stabilized (after 15 to 20 minutes) record the audit and station %RH responses on the Worksheet.

9. Using the "INC/DEC" toggle switch, increase the %RH until the LED display reads approximately "60.0 H".

10. When the %RH sensors have stabilized (after 15 to 20 minutes) record the audit and station %RH responses on the Worksheet.

11. Using the "INC/DEC" toggle switch, increase the %RH until the C-1 LED display reads approximately "90.0 H".

12. When the %RH sensors have stabilized (after 15 to 20 minutes) record the audit and station %RH responses on the Worksheet.

13. Using the "INC/DEC" toggle switch, decrease the %RH until the C-1 LED display reads approximately "30.0 H". Allow 5 minutes to stabilize.

14. Remove both sensors from the C-1 and turn the power off..

15. Using the siphon/fill apparatus, remove the distilled/deionized water from the C-1 reservoir. Tilt the C-1 in order to remove as much water as possible from the reservoir. Be careful to avoid spilling water on the C-1 or into the %RH chamber.

16. Enter the data into the van's computer.

S.1.4 PREVENTATIVE MAINTENANCE

S.1.4.1 FISHER DIGITAL HYGROMETER

1. 9-volt battery requires periodic replacement.

2. The Fisher Scientific Hygrometer should always be stored in its case to prevent any damage to the sensor.

S.1.4.2 GENERAL EASTERN C-1 RELATIVE HUMIDITY GENERATOR

1. As much water as possible should be removed from the reservoir after use to prevent spillage into the %RH chamber.

2. Periodic replacement of the desiccant is required.

3. Distilled/deionized water is used to prevent build up of solids in the C-1.

S.1.5 CALIBRATION AND CERTIFICATION PROCEDURES

S.1.5.1 CALIBRATION PROCEDURES

1. Fisher Digital Hygrometer

   The Fisher Digital Hygrometer is sent out annually for National Institute of Standards and Technology traceable certification of the sensors.

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AUDIT PROCEDURES
FOR
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APPENDIX S.2

PERFORMANCE AUDIT PROCEDURES FOR WIND SPEED SENSORS

MONITORING AND LABORATORY DIVISION

AUGUST 2002

S.2 WIND SPEED AUDIT PROCEDURES

S.2.0 INTRODUCTION

Horizontal wind speed sensors commonly utilize a cup or propeller assembly turning on either a vertical or horizontal axis. The aerodynamic shape of the cups convert the wind pressure into torque. This will turn a shaft which is supported in low friction, precision bearings. The shaft rate of rotation is converted to wind speed by the use of a transducer. Ideally, there is a linear relation between rate of rotation and wind speed, above the starting threshold. A performance audit on this sensor provides physical verification that: 1) the sensor's starting threshold has not changed and 2) the transducer is properly converting cup rate of rotation (rpm) to wind speed.

The vertical wind speed sensor employs a helicoid four blade propeller. A miniature tach-generator produces an analog DC voltage proportional to the axial wind component. When propeller rotation reverses, signal polarity reverses. This produces a plus (+) or minus (-) direction of rotation. Performance audits verify starting threshold, rpm to wind speed conversion, and proper signal polarity reversal.

An operator who is familiar with the meteorological equipment should be present during the audit to perform the required manipulations of the tower and sensors.

S.2.1 GENERAL OPERATING PROCEDURES

The cups/propeller are removed from the sensor and the variable speed motor is attached with a coupling to the sensor shaft. The motor will provide a rotation of the wind speed shaft. This will challenge the relationship between rate of rotation and output wind speed. Figure S.2.1.1 provides a diagram of the R.M. Young anemometer drive unit (control unit, motor and clamp and bar assembly). The rotation rate provided by the motor is verified by a large 4 digit Liquid Crystal Display (LCD). The motor rotation and time base for display are referenced to an internal crystal oscillator, which provides 0.1 (rpm) accuracy. A suggested comparison of five points is performed (0, 300, 600, 900, 1200 rpm) which provide a known input in rpm. The rpm applied to the sensor is converted to wind speed by using the transfer function provided by the sensor manufacturer. This transfer function is calculated when the manufacturer has an example of the wind speed sensor calibrated by the National Institute of Standards and Technology (NIST). This calibration provides the relationship between wind speed and rate of rotation, measured by counting pulses, frequencies, or voltage. The transfer function defines what the signal conditioning electronics require to express the measured rotation rate in wind speed units. Following Guidance for PAMS Meteorological Monitoring, the accuracy of the wind speed sensor should be ±0.2 meters per second (m/s) plus 5% of the observed speed from 0.5 to 50 m/s, with a resolution of 0.1 m/s.

The starting threshold of a sensor is a function of torque. The sensor is removed from it's location on the tower and the cups or propeller assembly are removed. The sensor is positioned horizontally to allow free access to the shaft. The R.M. Young torque disc (Range: 0.0-5.4 gram- centimeters) is attached to the shaft. Torque disc 18310 is used on propeller anemometers and torque disc 18312 is used on cup anemometers. These discs are essentially the same, except for the length of the shaft extending from the center hole. Figure S.2.1.2 provides a diagram of a R.M. Young torque disc. The disc has a number of concentric circles etched on its face, with holes drilled at various points along each circle. These holes are used to screw in weights, which at some point will provide sufficient torque to turn the anemometer shaft. The force of gravity provides a gram-centimeters (gm-cm) torque at the center of rotation. This gram-centimeters torque applied equals the weights and distances when the weights are in the same horizontal plane as the shaft. EPA Volume IV Handbook provides for a threshold accuracy of 0.5 m/s for horizontal wind speed sensors and 0.25 m/s for vertical wind speed sensors.

The Waters torque watch gauge can also be used to make torque measurements. It is sensitive equipment which normally remains at the Quality Assurance laboratory. Its use is limited to those cases when verification of the audit results of the torque vane gauge or disc is needed. Figure S.2.1.3 provides a diagram of a Waters torque watch. The torque watch has a chuck which is connected to the wind speed sensor shaft. This chuck should be drilled or adjustable so that it securely fits on the sensor shaft. The torque watch is turned while holding its shaft in line with the sensor shaft. The pointer is watched and the maximum reading is recorded when the sensor shaft turns. The anemometer shaft should be turned at least one full turn to ascertain that the maximum friction of the bearings is recorded.

The indicator provides the torque measurement in gram-centimeters, and has a minimum torque required to move the pointer. The Waters model 366-3M has a range from 0.2 gram-centimeters to 2.0 gram-centimeters. If the torque watch turns the sensor shaft without reaching the lowest scale point, the sensor has a starting threshold below the measurable limit of the torque watch. This indicates that the sensor's starting threshold is well within EPA's Volume IV specifications. Any torque reading providing up to 0.5 m/s starting threshold is acceptable. In some cases, the anemometer shaft may require a torque greater than the force that can be provided by the model 366-3M. This greater torque is provided by using the model 651-3M (Range: 2.5-80 gram-centimeters) to quantify the actual force needed to turn the shaft.

Figure S.2.1.1
R.M. Young Anemometer Drive Unit

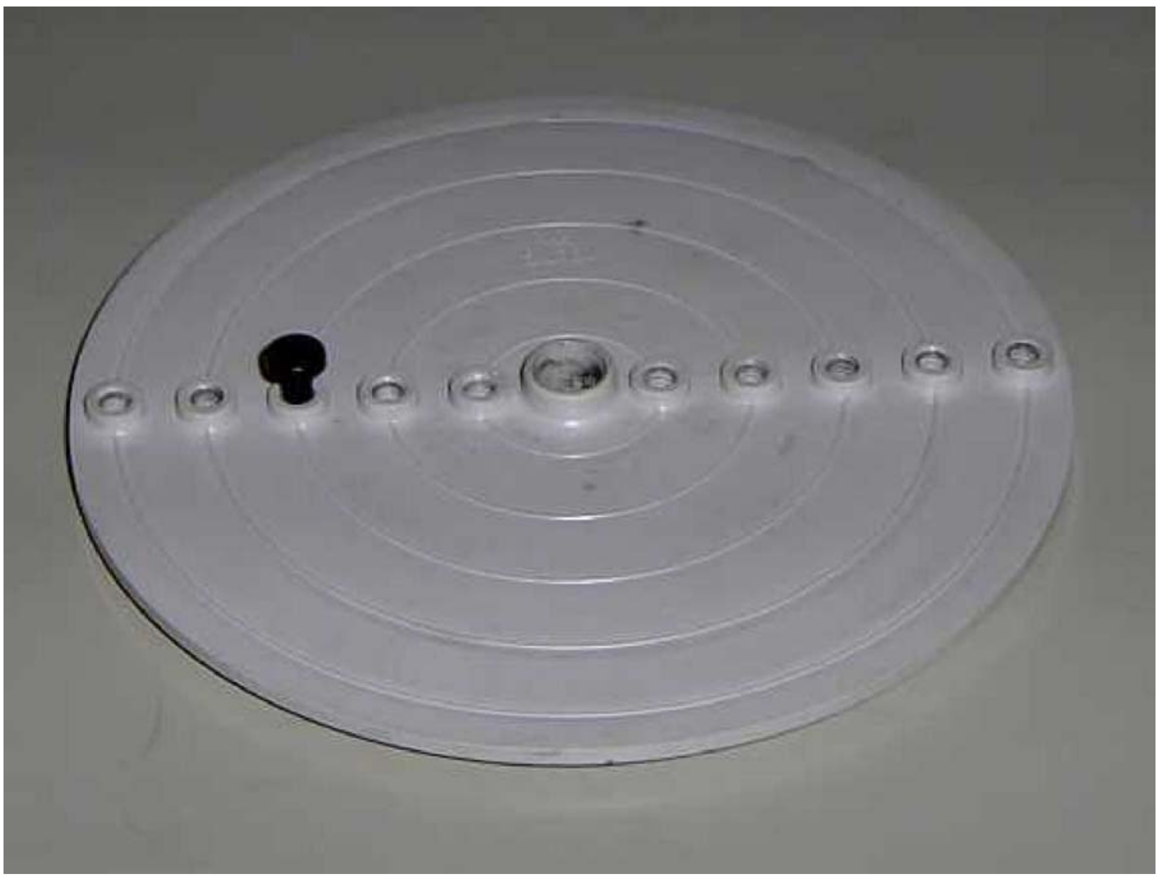

Figure S.2.1.2
R.M. Young Torque Disc

Figure S.2.1.3
Waters Torque Watch

S.2.2 AUDIT EQUIPMENT

1. R.M. Young 18801 variable speed anemometer drive (100-10,000 rpm range motor) with 18831 motor assembly (10-1,000 rpm range with 10:1 gear reduction). Flexible tubing of varying diameters and lengths.

2. R.M. Young 18310/18312 torque disc (Range: 0.0-5.4 gram-centimeters)

3. Waters 366-3M torque watch (Range: 0.2-2.0 gram-centimeters) and Waters 651-1M (Range 2.5-80 gram-centimeters)

4. QA Audit Worksheet Wind Speed and Direction (Worksheet) (Figure S.2.2.1).

NOTE: During the audit, inspect the condition of the wind speed sensor, cups/propeller, and associated cables. Review the maintenance records for the sensor. Record any pertinent information on the Worksheet.

QA AUDIT WORKSHEET
WIND SPEED AND DIRECTION

Site Name: ______________________________ Site #: ____________ Date: ____________________

Address: ______________________________ Agency: ____________________

Technician: ______________________________ Auditors: ____________________

Data Read From: Chart[ ] DAS[ ] Other[ ] DAS Type: ____________________

Wind Speed Audit		
Audit Test Point	Station Sensor Response	Motor Speed (RPM)
1		
2		
3		
4		
5		
6		

Wind Speed Units	
M/S	[ ]
MPH	[ ]
KNOTS	[ ]
FT/S	[ ]
KPH	[ ]
CM/S	[ ]

Wind Direction Audit		
Audit Test Point	Station Sensor Response	Audit Direction Fixture
1		
2		
3		
4		
5		
6		

Audit Parameters	Wind Speed	Wind Direction
Measured Torque (gm/cm)		
Measured Boom Alignment Using Compass (deg)		
Vane Alignment With Boom (deg)		

	Station Instrument Parameters	
Sensor Specifications	Wind Speed	Wind Direction
Manufacturer:		
Model Number:		
Serial Number:		
Operating Range:		
Sensor Height:		
K Factor		
Slope and Intercept		
Site Declination:		
Last Calibrated:		
Calibration Equipment Certification Date:		

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Figure S.2.2.1
QA Audit Worksheet Wind Speed and Direction

S.2.3 AUDIT PROCEDURES

S.2.3.1 R.M. YOUNG ANEMOMETER DRIVE UNIT

This procedure applies to those sensors which have cups/propellers which can be removed from the sensor shaft. If a sensor does not have removable cups/propellers, it may be possible to perform the audit by fabricating an appropriate coupling. If this can not be done, the audit can not be conducted.

1. Horizontal Wind Speed Sensor

   Before conducting the audit, have the site operator provide the wind speed units (m/s, mph, knots, ft/s, kph, or cm/s) as well as the sensor specifications requested on the Worksheet. These data will include the K factor, slope, and intercept for the particular model of wind speed sensor.

   The rate of rotation check is performed with the sensor on the tower and electrical lines intact. Suggested input rotations are 0, 300, 600, 900, and 1200 rpm. Normally at zero rotation there is a positive value on the station's data acquisition system (DAS) which represents the starting threshold value. The rotation speeds can be varied if there is a desire to challenge different points of the sensor's operational range or if the range is exceeded at 1200 rpm. The actual wind speed input is calculated by using the manufacturer's transfer function for the sensor.

   a. Observe the orientation of the cups/propeller to determine the direction of rotation. This rotation can either be clockwise (cw) or counterclockwise (ccw). Remove the cups/propellers from the shaft. Record the reading from the DAS on the Worksheet. This will be the zero rpm value.

   b. Use the 18831-05 coupling disc or rubber tubing to attach the appropriate rpm motor to the shaft. The coupling disc is used for attachment to R.M. Young wind speed sensors. The R.M. Young motors come with a black tubing which fits securely over the motor shaft. If this black tubing does not properly fit over the sensor shaft, rubber tubing (of varying diameters) is used for attachment to wind speed sensors from other manufacturers.

      NOTE: If the sensors can only be accessed by climbing the tower, the operator will be required to attach the variable speed motors to the sensor(s) and change the rotation speeds on the drive unit.

c. The proper coupling (rubber tubing) size must be used to prevent slippage or binding. Also care must be taken to ensure proper alignment of the connection between the motor and the sensor shaft. This will allow the motor free movement to produce the selected speed.

d. If electricity is available, use the AC adapter to provide power to the anemometer drive unit. Otherwise, run the drive unit on battery power.

e. Plug the rpm motor into the control unit and support the motor by hand. If an R.M. Young AQ 05305 is being audited, the clamp and bar assembly can be used to support the motor.

f. Select a rotation rate of 300 rpm by adjusting the rpm switch. The rotation direction switch set to coincide with the normal rotation direction of the sensor cups/propeller (see step b). Turn the power switch to on.

g. The motor will start turning the shaft and the control unit display will show a value. This display should agree with the value selected on the rpm switch. If it does not, check for proper alignment of the connection between the motor and sensor shaft. Correct the alignment if necessary. The display should be monitored to verify the stability of the rotation rate.

h. Leave the motor at the specified speed until a constant reading can be recorded from the control unit display and DAS. Usually, a minute is adequate. Record the input speed and sensor output speed on the audit worksheet (Figure S.2.2.1).

i. Adjust the rpm switch to 600. Be sure to keep the motor supported and the coupling properly aligned as the speed increases. Record readings on the Worksheet after stabilization occurs.

j. Increase the rpm switch to 900. Record readings on the Worksheet after stabilization occurs.

k. If the sensors operational range will accommodate a 1200 rpm rate (see step a.), adjust the rpm switch accordingly or switch motors, if necessary. Record the reading on Worksheet after stabilization occurs.

l. The five point wind speed comparison is now complete. Turn off the power switch and disconnect the motor from the sensor.

Disconnect the motor from the console. Disconnect the AC power adapter, if used. The sensor can now be removed from the tower to perform the threshold check.

m. The measured wind speed above the starting threshold should be within 0.25 meters per second (m/s) at speeds equal to or less than 5.0 m/s and above 5.0 m/s it should be within ±5.0% of the observed speed (not to exceed 2.5 m/s).

n. Enter the data into the van's computer.

2. Vertical Wind Speed Sensor

a. Before conducting the audit, have the site operator provide the wind speed units (m/s, mph, knots, ft/s, kph, or cm/s) as well as the sensor specifications requested on the Worksheet. These data will include the slope and intercept for the particular model of wind speed sensor.

b. Remove the propeller from the shaft. Record the zero readings from the station DAS on the Worksheet. This DAS value represents the sensors starting threshold speed. Inspect the condition of the propeller. Note any evidence of nicks, cracks, etc in the comments section of the Worksheet. If the propeller is damaged, the station operator should be notified that the propeller should be replaced.

c. Use the black rubber tubing to attach the appropriate rpm motor to the shaft.

NOTE: If the sensors can only be accessed by climbing the tower, the operator will be required to attach the variable speed motors to the sensor(s) and change the rotation speeds on the drive unit.

d. The proper coupling (rubber tubing) size must be used to prevent slippage or binding. Also care must be taken to ensure proper alignment, as this will allow the motor free movement to produce the selected speed.

e. If electricity is available, use the AC power adapter to provide power to the anemometer drive unit. Otherwise, run the drive unit on battery power.

f. Plug the appropriate rpm motor into the console and support the motor by hand.

g. Set the rpm switch to 100 rpm. Set the direction of rotation switch on the control unit face to clockwise (cw). Turn the power switch to on.

h. The motor will start turning the shaft and the console display will show a value. This display should agree with the value selected on the rpm switch. If it does not, check for proper tubing alignment. Correct the alignment if necessary. The display should be monitored to verify the stability of the rotation rate.

i. Leave the motor at the specified speed until a constant reading can be recorded from the station DAS. Usually, a minute is adequate. Record the input speed (rpm) and sensor output on the Worksheet.

j. Increase the rpm switch to 200 rpm.. Record all readings on the Worksheet.

k. Flip the rotation switch to counter clockwise (ccw). Record the sensor output and rpm speed at both 200 rpm and 100 rpm.

l. Disconnect the motor from the console. The sensor can now be removed from the tower to perform the threshold check.

m. The measured wind speed above the starting threshold should be within 0.25 meters per second (m/s) at speeds equal to or less than 5.0 m/s and above 5.0 m/s it should be within ±5.0% of the observed speed (not to exceed 2.5 m/s).

n. Enter the data in the van's computer.

S.2.3.2 R.M. YOUNG TORQUE DISK

a. The operator disconnects the horizontal wind speed or vertical wind speed sensors from the electrical connections on the tower and the cups/propellers are removed. The sensor is placed in an area free of wind or excess air movement.

b. Rotate or spin the shaft while listening to the sound of the bearings. Note the location of any sound of abrasion or scraping.

c. The position of the wind speed sensor shaft will vary according to the type of sensor being audited. If a R. M. Young wind monitor is being audited, the sensor can be supported in its normal operating position. The R.M. Young sensor can be positioned in the R.M.

Young wind direction degree wheel (with the tower mount fixture removed) on a bench or table. If the sensor is of the Climatronics F460 or Met One design, it is placed on its side. Make sure that there is good access to the shaft and that it has freedom to turn easily.

d. Determine the desired torque value, starting threshold speed, and K factor from the sensors specifications. Record this information on the Worksheet. Refer to section S.2.4 for the torque to starting threshold speed conversion formula.

e. There are two types of weights provided with the disc. There are the black nylon screws which weigh 0.1 gram (gm). There are also the stainless steel screws which weigh 1.0 gm. The weights can be combined at different radii to provide a total torque.

f. If any rough spots were noted in step b, it is best to start the torque measurement at this point. Attach the torque disc to the shaft. Make sure that the fit is secure without excess slippage. If a R. M. Young 05305 AQ sensor is being audited, then a 18310 propeller torque disc is used. The 18312 torque disc can be used on cup anemometers. In some cases, the center hole of the disc will require machining to properly fit the shaft of various sensors (Met One 020/024, Climatronics F460).

g. Orient the disc such that the holes for the screws are horizontally positioned from the shaft. There are a total of 10 holes on the disc, but only 5 holes on one side of the main center hole are used for a torque test. Screw in weights on the torque disk to equal the calculated torque (step d.). The weight used times the radius determines the gram-centimeters torque. If multiple weights are used, then the gram-centimeters are added for the total torque.

h. Ideally, you are looking for the minimum weight at the minimum distance from the center. When the disc makes the slightest movement (i.e. moves from the 90 degree to 85 degree position), the torque has been measured. This gram- centimeters number is the torque of the wind speed sensor. Record the torque on the Worksheet.

i. If the disc does not turn, move the weight to the second hole on the disc. Continue moving the weight out from the center until the disc starts to turn slightly. The torque can be increased by choosing a heavier weight, placing the weight at a further distance from the center, or combining different weights at different radii.

j. Remove all the weights and repeat step g and h, except screw in the weights in the corresponding holes on the opposite side of the disc. Record the gram-centimeters value on the Worksheet. Calculate the measured starting threshold speed (Section S.2.4) and record on the Worksheet.

k. The horizontal wind speed starting threshold should be less than 0.5 m/s and the vertical wind speed should be less than 0.25 m/s. Exceedances beyond the specified starting threshold indicate bearing corrosion or wear. Replacement or maintenance of bearings and recalibration/reaudit are recommended.

l. Remove the torque disc from the sensor and install the sensor with cups/propellers back onto the tower. Reconnect all electrical lines.

S.2.3.3 WATERS TORQUE WATCH

The Waters Torque Watches (366-3M and 651-1M) are maintained at the Quality Assurance office. Since these are precision instruments, their field use is limited to verification of torques measured with the R.M. Young torque disc. The chuck used on the 366-3M requires drilling to fit the sensor shaft.

a. The operator removes the sensor from the electrical connections on the tower. The sensor is taken to an area free of wind or excess air movement.

b. Rotate or spin the shaft while listening to the sound of the bearings. Note the location of any sound of abrasion or scraping.

c. Engage the chuck of the torque watch into place on the anemometer shaft. Ensure that the chuck properly fits the sensor shaft. Hold the torque watch vertically by the top with one hand and twist the torque watch, while holding the sensor with the other hand.

d. The memory needle can be used as a maximum reading pointer of the starting threshold. Position the needle at the expected range of reading by adjusting the knurled knob located in the center of the crystal.

e. The starting torque is obtained after turning the watch or sensor until a maximum reading is obtained. The memory needle will move to a constant position to indicate the highest torque measured.

f. Record the gram-centimeters reading on the Worksheet.

g. Remove the torque watch from the sensor and install the sensor back onto the tower.

h. The horizontal wind speed starting threshold should be less than 0.5 m/s and the vertical wind speed should be less than 0.25 m/s. Exceedances beyond the specified starting threshold indicate bearing corrosion or wear. Replacement or maintenance of bearings and recalibration / reaudit are required.

S.2.4 AUDIT DATA CALCULATIONS

The van's audit program will calculate the percent difference and starting threshold by using the following equations:

The actual wind speed in meters per second (m/s) is calculated by applying the manufacturer's slope and intercept to the rpms of the audit device:

Actual Speed = Reference RPM * Slope + Intercept

The indicated speed of the sensor in m/s is calculated by multiplying the station's reported speed by a conversion factor:

Indicated Speed (M/S) = Reported Speed*Conversion Factor

The conversion factor converts the station's units (knots/ mph, etc.) into m/s. The percent difference is calculated from these two values.

The starting threshold is calculated using the measured torque (gm-cm) and the manufacturer's K factor:

Starting Threshold = Squareroot (Measured Torque/K Factor)

The horizontal wind speed should have a starting threshold speed less than 0.5 m/s. Vertical wind speed sensors should have a starting threshold speed less than 0.25 m/s.

S.2.5 PREVENTATIVE MAINTENANCE

S.2.5.1 R.M. YOUNG ANEMOMETER DRIVE UNIT

1. Periodic battery replacement is required (AA M alkaline batteries). The decimal points on the console display will blink when the voltage is low on the batteries.

2. Turn the power off when the unit is not in use and perform wind speed sensor audits in an efficient manner.

3. Be careful not to drop the control unit or motors.

S.2.5.2 R.M. YOUNG TORQUE DISC

1. Keep the disc and weights clean. Dirt, lint, etc. may add weight and effect the balance of the wheel.

2. Periodically, inspect the center hole of the disc for excessive wear to ensure that the disc continues to fit properly onto the anemometer shaft. If the center hole is too large or abraded, the disc should not be used for the torque measurement on that sensor.

S.2.5.3 WATERS TORQUE DISC

1. Keep the torque watch in its case when not in use. This protects the watch from dust.

2. Care must be taken not to drop or excessively jar the torque watch as the torque mechanism may become damaged or the calibration may shift. If this occurs, the watch should be returned to the manufacturer for recalibration.

S.2.6 CALIBRATION AND CERTIFICATION PROCEDURES

S.2.6.1 R.M. YOUNG ANEMOMETER DRIVE UNIT

1. The unit can be returned to the manufacturer on an annual basis. A verification of generated rotation rate by comparison to a phototachometer or frequency counter may be performed on a quarterly basis. During each audit, the large four digit LCD provides independent confirmation of the rotation rate, showing actual rpm. This provides a visual method of monitoring the rotation rate being imposed to the wind speed sensor shaft. The output of the integral high resolution optical encoder can be measured from a jack on the side of the console case. This output is connected to an external frequency counter (Fluke 8020A multimeter) to further confirm the motor speed. If there is any discrepancy between the selected rpm rate and the measured rpm rate, the manufacturer will be contacted to initiate a troubleshooting/repair sequence which may entail returning the defective unit to the factory.

2. The motors and drive unit are returned to the manufacturer on an annual basis for certification.

S.2.6.2 R.M. YOUNG TORQUE DISC

1. The weights (0.1 and 1.0 grams) can be verified on a scale on a quarterly basis.

S.2.6.3 WATERS TORQUE WATCH

1. The torque watch is returned to the manufacturer for annual calibration. The need for recalibration depends on frequency of use.

STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME V

AUDIT PROCEDURES
FOR
AIR QUALITY MONITORING

APPENDIX S.3

PERFORMANCE AUDIT PROCEDURES
FOR
WIND DIRECTION SENSORS

MONITORING AND LABORATORY DIVISION

AUGUST 2002

S.3.0 INTRODUCTION

Wind direction sensors indicate the direction from which the wind is blowing. The wind direction is expressed as an azimuth angle on a 360° circle where 0° or 360° indicates North and 180° indicates South. Wind direction sensors use a tail assembly positioned on a vertical shaft to detect wind direction. Wind applies a force to the tail assembly of the sensor forcing the assembly to turn into the wind seeking a position of minimum force. The shaft of the sensor rests on low friction precision grade bearings and is connected to a low torque potentiometer. The potentiometer yields a voltage output proportional to the wind direction. The starting threshold of the sensor is controlled by the relationship of shape, size, distance from the axis of rotation of the tall assembly to the vertical shaft, bearings, and potentiometer torque requirements. The proper orientation of the sensor, efficient operation of the bearing assembly, and correct potentiometer function are factors that affect the quality of wind direction data. Thus, performance audits of wind direction sensors quantify the correct function of these components. Wind direction orientation and accuracy audits are performed with the sensor positioned on the meteorological tower. The starting torque audit is performed with the sensor removed from the tower. A station operator familiar with the meteorological equipment must be present during the entire audit to perform the required manipulations of the tower and sensors.

S.3.1 GENERAL OPERATING PROCEDURES

A Brunton F-3008 pocket transit or a David White TR-300 site path transit is used to check the orientation of the wind direction sensor. Either method is capable of an accuracy of one degree with two to three degrees being the upper limit of error. The pocket transit or site path transit is used to verify the orientation of the boom and wind direction sensor center line or index to true North. The U.S. EPA Volume IV criteria provides for an agreement of less than or equal to 3 degrees relative to the sensor mount or index (less than or equal to 5 degrees absolute error for the installed system). See Figure S.3.1.1 for a diagram of the Brunton pocket transit. See Figure S.3.1.2 for a diagram of the David White site path transit.

The R.M. Young 18331 vane torque gauge, R.M. Young 18310/18312 torque disc, or Water's 651C-1M torque watch are used to quantify the torque of the wind direction sensor. The R.M. Young 18331 vane torque gauge (0-60 gram-centimeter (gm-cm) range) can measure the torque with the tail assembly in normal operating position on the shaft. The vane torque gauge verifies the end load effect of the tail assembly on the bearings and transducer. It measures the starting torque by imposing a known force at a measured radial distance from the axis of rotation. The R.M. Young 18310/18312 torque disc or Water's 651C-1M torque watch can be used to quantify the starting torque of the wind direction sensor with the tail assembly removed. The U.S. EPA Volume IV (Quality Assurance Handbook for Meteorological Measurements), provides for a starting threshold speed less than or equal to 0.5 m/s. See Figure S.3.1.3 for a diagram of the RM. Young torque gauge, Figure S.3.1.4 for a diagram of R.M. Young torque disc, and Figure S.3.1.5 for a diagram of a Water's torque watch.

The accuracy measurement for wind direction sensors can be performed by manually orienting the vane to the cardinal directions (North, South, East, and West). This is done by measuring the orientation of the sensor centerline to true North, then rotating the sensor. The sensor (0-360° range) should be oriented by hand to four points (North: 360 degrees; Low East: 90 degrees; South: 180 degrees; West: 270 degrees). If the sensor's range is 0-540 degrees, a Hi-East (450 degrees) check is added. For improved accuracy, a degree fixture may be attached to the wind direction sensor. The design of the degree fixture will vary depending on the manufacturer. In any case, the degree fixture will provide a physical indication of direction in known increments. After attachment, the vane is positioned at known increments on the degree fixture to measure the linearity of the transducer or potentiometer. See Figure S.3.1.6 for a diagram of the R.M. Young degree fixture, Figure S.3.1.7 for diagrams of the Met One degree fixtures, and Figure S.3.1.8 for a diagram of the Climatronics degree fixture.

Figure S.3.1.1
Brunton Pocket Transit

Figure S.3.1.2
David White TR-300 Site Path Transit

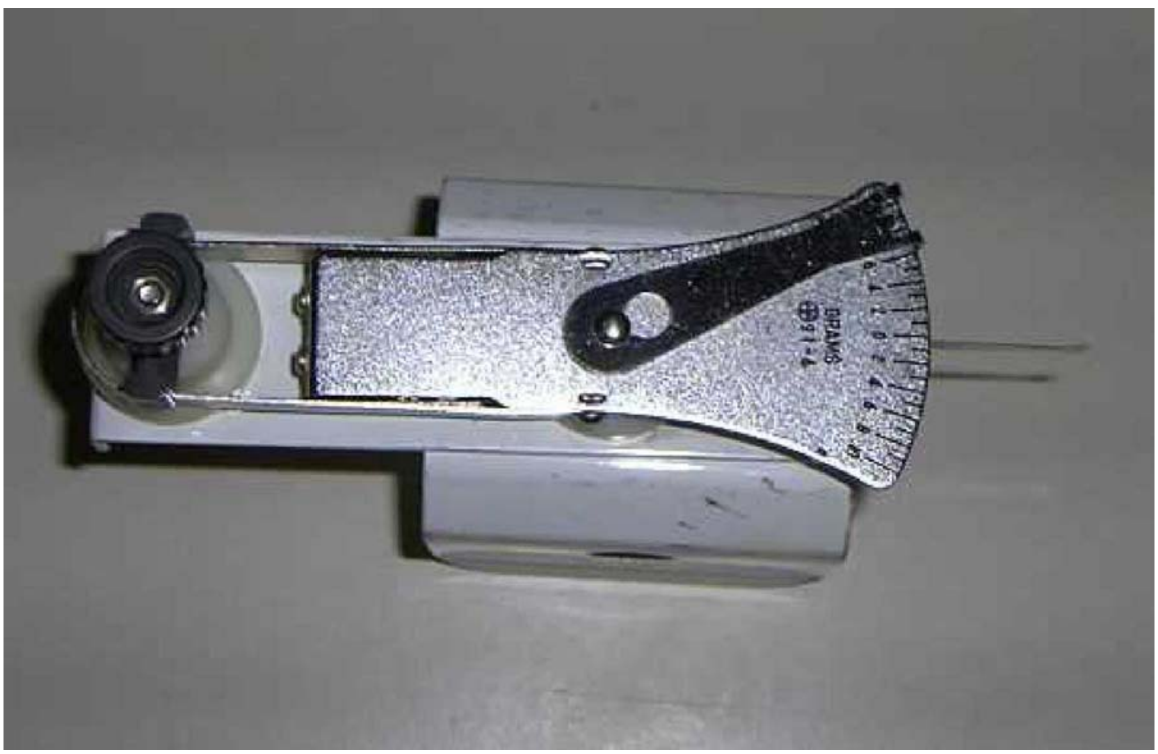


Figure S.3.1.3
R.M. Young Torque Gauge

Figure S.3.1.4
R.M. Young Torque Disc

Figure S.3.1.5
Waters Torque Watch

Figure S.3.1.6
R.M. Young Degree Fixture

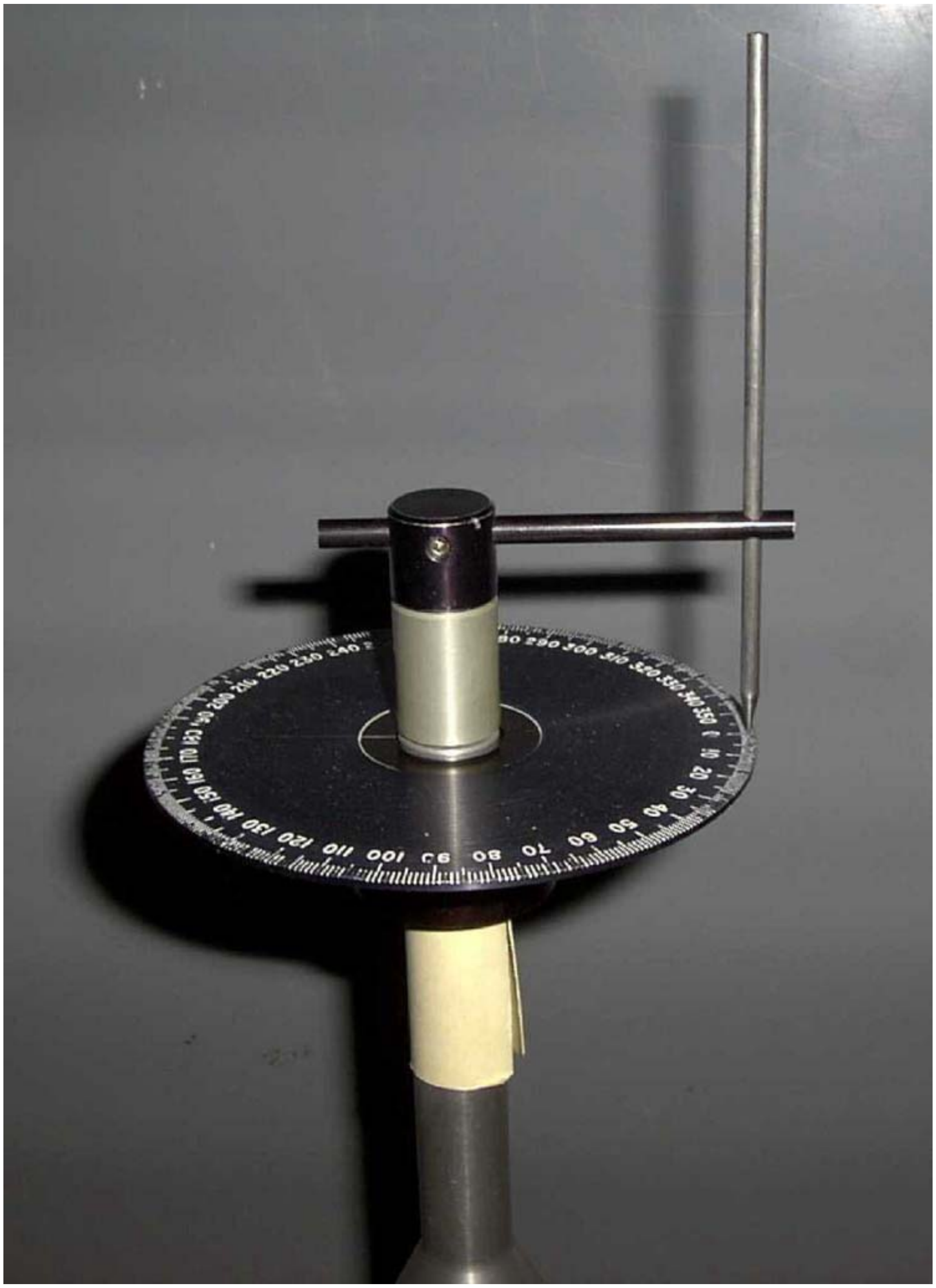


Figure S.3.1.7
Met One Degree Fixture

Figure S.3.1.8
Climatronics Degree Fixture

S.3.2 AUDIT EQUIPMENT

1. Brunton F-3008 pocket transit with tripod and ball/socket joint binoculars.

2. David White TR-300 site path transit with tripod.

3. R.M. Young 18331 vane torque gauge (range: 0-60 gm-cm).

4. R.M. Young 18310/18312 torque disc (range: 0-15.0 gm-cm).

5. Water's 651C-1M torque watch (range: 2.5 - 80.0 gm-cm).

6. Wind direction degree fixture: a) R.M. Young 18212, b) Climatronics, 10175, c) Met One 040, d) Met One 044.

7. A QA Audit Worksheet Wind Speed and Direction (Worksheet) (Figure S.3.2.1).

QA AUDIT WORKSHEET
WIND SPEED AND DIRECTION

Site Name: ______________________ Site #: __________ Date: ______________

Address: ______________________ Agency: ______________________

Technician: ______________________ Auditors: ______________________

Data Read From: Chart[ ] DAS[ ] Other[ ] DAS Type: ______________________

Wind Speed Audit		
Audit Test Point	Station Sensor Response	Motor Speed (RPM)
1		
2		
3		
4		
5		
6		

Wind Speed Units	
M/S	[ ]
MPH	[ ]
KNOTS	[ ]
FT/S	[ ]
KPH	[ ]
CM/S	[ ]

Wind Direction Audit		
Audit Test Point	Station Sensor Response	Audit Direction Fixture
1		
2		
3		
4		
5		
6		

Audit Parameters	Wind Speed	Wind Direction
Measured Torque (gm/cm)		
Measured Boom Alignment Using Compass (deg)		
Vane Alignment With Boom (deg)		

	Station Instrument Parameters	
Sensor Specifications	Wind Speed	Wind Direction
Manufacturer:		
Model Number:		
Serial Number:		
Operating Range:		
Sensor Height:		
K Factor		
Slope and Intercept		
Site Declination:		
Last Calibrated:		
Calibration Equipment Certification Date:		

QA-WSWD1 Revised 02/02

Figure S.3.2.1
QA Audit Worksheet Wind Speed and Direction

S.3.3 AUDITING PROCEDURES

S.3.3.1 WIND DIRECTION ORIENTATION AUDIT

The wind direction sensor orientation is verified before the accuracy or starting torque audit is performed. The sensor orientation is also verified after all portions of the audit are completed and the wind direction sensor is back in operating position on the tower.

1. Direct Transit Reading Method Using the Pocket Transit

   a. Prior to going into the field, the declination of the station can be obtained on line at: http://web.ngdc.noaa.gov/cgi-bin/seg/gmag/fldsnth1.pl by entering the station's latitude and longitude. The declination of the station can also be obtained from the California Declination Chart (Figure S.3.4.1) or from the site operator. The California Declination Chart provides a general declination value; however, the position of the magnetic North Pole can vary slightly from year to year. Once the station declination is known, it is subtracted from 360 to provide the magnetic North value. Record the declination value on the Worksheet.

   b. Set the tripod on a flat stable surface with the legs extended. Attach the transit (Figure S.3.1.1) to the socket head with the clamp screw.

   c. Position the tripod/transit assembly where the previous orientation check of the wind direction sensor was performed. This position can be indicated by a mark on the ground or by the recommendation of the site operator. If it is difficult to sight the wind direction sensor, use a pair of binoculars for positioning the transit.

   d. Place the transit in the horizontal position.

   e. Open the mirrored lid so that the mirror faces away from you. The large sight is set perpendicular to the bottom case.

   f. Tilt the mirror towards you so that you can look into it. The shaft of the wind direction sensor (or orientation cross-arm) should be visible in the mirror. Binoculars can help sight the sensors on the tower. If not, change the angle of the mirror until it is visible.

   g. Confirm the black center-line on the mirror bisects both the reflection of the large site and the sighted wind direction sensor (or orientation cross-arm).

h. Center the bubble in the circular level.

i. Confirm the North seeking end of the needle points to the azimuth or bearing angle on the transit circle.

NOTE: The transit can be affected by magnetic materials or field (watches, belt buckles, railroad tracks, power lines, etc.). To determine if the transit is being affected, slowly move the transit back and forth in a direction that is perpendicular to the compass needle pointing direction. If the compass needle changes direction more than 3 degrees, the transit is being affected by magnetic materials or fields. Move the transit to an unaffected area.

j. Record the azimuth angle of the sensor orientation on the audit worksheet under "Measured Boom Alignment Using Compass (deg)".

k. Commonly, the sensor manufacturer specifies orienting the sensor in respect to true North. Alternately, it may specify orientation to one of the other cardinal directions. In any case, the azimuth angle of the sensor orientation should be less than or equal to 3 degrees relative to the sensor mount (less than or equal to 5 degrees absolute error).

l. Verify the sensor orientation has not changed after all the meteorological audits are completed and the wind direction sensor is back in operating position on the tower.

m. Close the cover on the transit.

n. Place the transit and tripod in their carrying case.

2. Prismatic Compass Method Using the Pocket Transit

This method is used if the sighting location is far from the tower and the audit is performed using the pocket transit.

a. Attach the transit to the tripod.

b. Open the mirrored lid so the mirror is facing you, with the small sight above the mirror raised. The large site is set perpendicular to the bottom case, facing towards the operator.

c. Position the transit at eye level and sight the wind direction sensor (or orientation cross-arm) through the large sight and over the small sight on the mirror, or through the mirror window.

d. Center the round level and recheck that the compass is still directly sighted on the sensor.

e. Confirm the South seeking end of the needle points to the azimuth angle.

NOTE: The transit can be affected by magnetic materials or fields (watches, belt buckles, railroad tracks, power lines, etc.). To determine if the transit is being affected, slowly move the transit back and forth in a direction that is perpendicular to the compass needle pointing direction. If the compass needle changes direction more than 3 degrees, the transit is being affected by magnetic materials or fields. Move the transit to an unaffected area.

f. Record the azimuth angle of the sensor orientation on the audit worksheet under "Measured Boom Alignment Using Compass (deg)".

g. Commonly, the sensor manufacturer specifies orienting the sensor in respect to true North. Alternately, it may specify orientation to one of the other cardinal directions. In any case, the azimuth angle of the sensor orientation should be less than or equal to 3 degrees relative to the sensor mount (less than or equal to 5 degrees absolute error).

h. Verify the sensor orientation has not changed after all the meteorological audits are completed and the wind direction sensor is back in operating position on the tower.

i. Close the cover on the transit.

j. Place the transit and tripod in their carrying case.

3. Direct Transit Reading Method Using the Site Path Transit

This method is used if the sighting location is far from the tower and the audit is performed using the site path transit.

a. Determine the declination of the station (See the Direct Transit Reading Method Using the Pocket Transit, step a). Record the declination value on the Worksheet.

b. Set the tripod on a flat stable surface. Loosen the leg clamp wing nuts and extend the legs until the tripod stands about chest high with the legs spread about three and a half feet apart. Tighten the leg clamp wing nuts finger tight.

NOTE: See Figure S.3.1.2 for a picture of the transit and the location of the parts. The parts mentioned in this procedure are numbered according to their part number on the figure.

c. Loosen the lower clamp screw (20) before setting the transit on the tripod.

d. Attach the transit to the tripod securely, hand tightening the base to the tripod head.

e. Locate the transit/tripod assembly where the previous orientation check of the wind direction sensor was performed. This position can be indicated by a mark on the ground or by the recommendation of the site operator. It may be necessary to move the transit from the indicated area due to magnetic materials or fields (see note below), or poor siting conditions. If this is the case, move along a line which bisects the wind direction sensor and the indicated area.

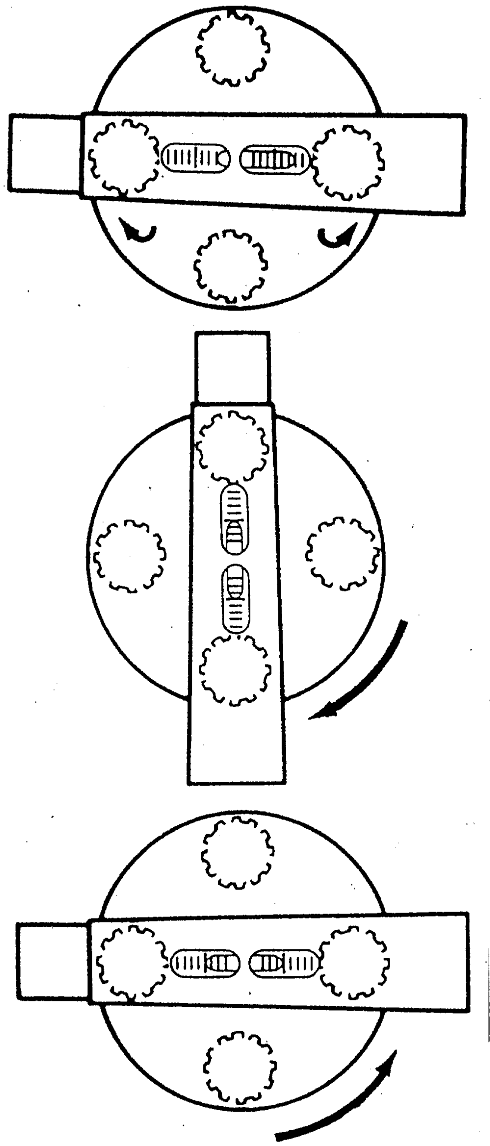
f. Loosen the compass locking screw (9) so the compass needle can rotate freely.

NOTE: The transit can be affected by magnetic materials or fields (watches, belt buckles, railroad tracks, power lines, etc.). To determine if the transit is being affected, slowly move the transit back and forth in a direction that is perpendicular to the compass needle pointing direction. If the compass needle changes direction more than 3 degrees, the transit is being affected by magnetic materials or fields. Move the transit to an unaffected area.

g. Tighten the four leveling screws (18) until resistance is felt. There should be firm contact with the instrument base. If the transit can still shift on its base, tighten the screws more firmly.

NOTE: Do not over tighten the leveling screws.

h. Level the transit (see Figure S.3.3.1 on the next page). Be careful not to touch the tripod during or after leveling.



1. Align up the telescope (1) so it is directly over a pair of leveling screws (18). Grasp these two leveling screws (18) with the thumb and forefinger of each hand. Turn both screws at the same time by moving your thumbs toward or away from each other, until the plate level vial bubble (6) is centered. The direction your left thumb moves is the direction the bubble will move.

2. Rotate the telescope 90 degrees over the second pair of leveling screws (18). Repeat the leveling process.

3. Rotate the telescope (1) back to the original position and check the level. Make minor adjustments as necessary.

Figure S.3.3.1
Leveling the David White TR-300 Site Path Transit

i. Loosen the lower clamp screw (20) and the vertical clamp screw(14). Aim the telescope (1) in the general direction of the winddirection sensor by sighting along the top of the telescope tube. Tighten the lower clamp screw (20) and the vertical clamp screw (14).

CAUTION: Do not look at or near the sun with the telescope (1).

j. Sight through the eyepiece (3), and bring the cross hairs into focus by turning the eyepiece focusing ring (4). Focus the telescope (1) by turning the focusing knob (5) until the wind direction sensor is sharp and clear.

k. Make final adjustments of the telescope (1) by rotating the horizontal upper tangent screw (13) and the vertical tangent screw (15). The cross hairs should bisect the wind direction sensor (or the orientation cross-arm).

NOTE: If the cross hairs do not bisect the wind direction sensor (or the orientation cross-arm), it may be necessary to move the transit/tripod assembly to a position that allows proper viewing.

l. The North seeking end of the compass needle will point to a quadrant angle on the transit circle. The North seeking end of the compass needle does not have copper coils on it.

NOTE: The compass is divided into four quadrants of 90 degrees each. The “W” and “E” are reverse of normal map position because the dial surface is attached to the instrument and revolves with the transit. The needle remains in a fixed position and designates the direction the telescope is facing.

m. Correct the transit reading based on the quadrant it is in and record the azimuth angle of the sensor orientation on the audit worksheet under "Measured Boom Alignment Using Compass (deg)".

n. Verify the sensor orientation has not changed after all the meteorological audits are completed and the wind direction sensor is back in operating position on the tower.

o. Lock the compass needle by tightening the compass locking screw (9).

p. Remove the transit from the tripod and store in its case.

S.3.3.2 WIND DIRECTION SENSOR ACCURACY AUDIT

The various methods for auditing wind direction accuracy are presented below. In all methods, accuracy should be less than or equal to 3 degrees from the sensor mount (less than or equal to 5 degrees absolute error). If the sensors can only be accessed by climbing the tower, the operator will be required to perform the wind direction sensor accuracy check. The manual orientation should be performed when: 1) a free standing tower is being used and the operator is climbing the tower to access the equipment, 2) a wind direction degree fixture is not available for the particular wind direction sensor in use at the site or, 3) there is a need to limit the sensor "down time".

1. Manual Orientation - This procedure can be performed by orienting the sensor tail assembly to the cardinal directions or towards reference points with known compass bearings.

   a. Cardinal Direction Method

      1) Hold the tail assembly steady towards North (360°) and record the Data Acquisition System (DAS) and/or strip chart values on the worksheet.

      2) Move the tail assembly to the low East (90 degree) position and record the DAS and/or strip chart values on the audit worksheet. If the sensor has a range of 0-540 degrees, rotate the tail assembly in the opposite direction to the high East (450 degree) position and record the DAS and/or strip chart values on the Worksheet.

      3) Move the tail assembly to the South (180 degree) position and record the DAS and/or strip chart values on the Worksheet.

      4) Move the tail assembly to the West (270 degree) position and record the DAS and/or strip chart values on the Worksheet.

   b. Compass Reference Point Method

      1) Choose a reference point with a known compass bearing in respect to true North. Record the reference point compass bearing on the Worksheet.

      2) Sight down the sensor's centerline and orient the sensor to or from the known reference points.

3) Hold the vane steadily at each reference position while the DAS and/or strip chart values are recorded on the Worksheet.

2. Wind Direction Degree Fixture Orientation

The physical design and specific use of the wind direction degree fixture or wheel will vary according to the manufacturer. Therefore, general procedures for orientation, with specific instructions pertaining to each degree wheel design are presented here. The station operator will install and remove the degree fixture from the wind direction sensor.

a. R.M. Young 18212 Fixture

1) Slide the fixture or degree wheel (Figure S.3.1.6) over the sensor shaft.

2) Attach the tail assembly to the sensor shaft with the orientation notch coinciding with the orientation notch on the wheel.

3) Screw the tail support into position on the wheel and provide steady support during the orientation of the sensor.

4) Position the sensor to 360 degrees (North) and verify this with the number etched on the wheel face. Record the degree wheel and DAS and/or chart recorder values on the Worksheet.

5) Rotate the sensor to 90 degrees (East). Record the values on the Worksheet.

5) Repeat the sensor rotation and record each value on the Worksheet for 180 (South), and 270 (West).

6) Remove the tail support and degree wheel. Reinstall the wind direction sensor.

b. Met One 040/044 Fixture - The Met One 040 fixture (Figure S.3.1.7) is used on the 020 wind direction sensor and the 044 fixture (Figure S.3.1.7) is used on the 024 wind direction sensor.

1) Disconnect the sensor from its electrical connection on the cross-arm. Slide the appropriate degree fixture over the shaft with the etched side facing up. Reattach the sensor to its electrical connection.

2) Remove the tail shaft and attach the pointer. Slide the degree fixture up near the pointer and rotate until the pointer indicates 180 degrees on the fixture.

3) Rotate the pointer to 270, 360, and 90 degrees. Record the values indicated on the fixture and the station DAS and/or the chart at each point on the Worksheet.

4) Remove the pointer and disconnect the sensor from its electrical connection on the cross-arm. Slide the degree fixture off the shaft. Replace the tail shaft and reconnect the electrical connections.

c. Climatronics 101754 Fixture - The Climatronics 101754 fixture (Figure S.3.1.8) is used on the Climatronics F460 wind direction sensor. The procedure requires a North-South orientation of the cross-arm, with the wind direction sensor at the South end.

1) Verify the North-South orientation of the cross-arm with the wind sensor at the South end.

2) Visually align the centerline of the vane assembly along the cross-arm with the vane tail pointing towards the wind speed sensor. A reading of 180 degrees should be obtained. Record the DAS and/or chart values on the Worksheet.

3) Remove the wind direction sensor from the cross-arm. The allen key provided with the Climatronics 101754 degree fixture is used to loosen the two set screws in the vane hub. The vane assembly is removed from the shaft.

4) Plug the connector at the end of the cable on the fixture into the cross-arm. Plug the sensor into the fixture base by aligning the slot in the wind direction sensor with the pin in the fixture base.

5) Loosen the thumb screw on the back of the pointer column to slide the pointer out of its storage groove. Slide the pointer into the hole located at the top of the pointer column.

6) Place the notched dial over the shaft so that the index end of the pointer is in the 180 degree notch. Rotate the sensor cap until the dial hub fits on the stepped portion of the dial. The sensor should provide an output of 180 degrees.

7) If 180 degrees was not obtained, use the allen wrench to loosen the two set screws in the sensor cap. While the pointer is still in the 180 degree notch, rotate the shaft until a corresponding reading of 180 degrees output on the DAS and/or chart is obtained. Retighten the set screws.

8) Move the pointer out of the 180 degree notch and rotate the dial to next notch. This notch corresponds to 270 degrees. Record the station DAS and strip chart values on the Worksheet.

9) Rotate the pointer to the next notch and record the DAS and/or strip chart values at each notch on the Worksheet. Check the full 360 degree rotation. The dial is calibrated so that 90 degrees = East, 0 degrees = North, and 270 degrees = West. The dial has marks for each degree on its face, but is only notched at the cardinal directions.

10) Remove the notch dial and unplug the connector from the cable. Return the pointer to its storage groove on the back of the pointer column. Unplug the sensor from the fixture base. Reinstall the vane on the shaft and plug the sensor back onto the cross-arm.

S.3.3.3 STARTING TORQUE AUDIT

The starting threshold of the wind direction sensor is influenced by the design of the vane. The K factor along with the measured starting torque of the vane will provide a starting threshold speed. To comply with the U.S. EPA Volume IV, Meteorological Measurements, the wind direction sensor should have a starting threshold less than 0.5 m/s. The station operator will be required to disconnect and reconnect the wind direction sensor from the electrical connections. Also, the operator will be required to remove and reinstall the vane from the sensor shaft, if the torque check procedure requires it.

1. R.M. Young 18331 Vane Torque Gauge

   a. The station operator removes the R.M. Young sensor from the tower and places it on a level surface, inside the station or similar structure. The area should be free of air movement.

   b. Support the sensor in its normal operating position, using the R.M. Young vane angle fixture (Figure S.3.1.6).

   c. Record the K factor and starting threshold speed of the sensor on the Worksheet.

d. Select the torque value from the sensor specifications and preset the stop on the leaf spring to this value.

e. Install the torque gauge (Figure S.3.1.3) on the mounting bracket with the tip of the leaf spring 6 cm forward of the R.M. Young sensor centerline. The leaf spring will be facing the propeller or vane counter weight.

f. Place your finger on the tip of the leaf spring and apply gentle pressure to move it. Remove your finger when the leaf spring touches the stop at the preselected torque value. The sensor should rotate through 360 degrees.

g. If the sensor is operating outside the specifications, the leaf spring will touch the stop, but the sensor will not rotate through 360 degrees. The leaf spring will also move away from the stop when the force required to rotate the sensor exceeds the preset value.

h. There has been sufficient force placed on the torque gauge if the sensor freely rotates 360 degrees. The measured force is multiplied by 6, then recorded on the audit worksheet.

i. Repeat steps f through h, but apply pressure on the leaf spring so that the sensor will rotate in the opposite direction. Record the torque on the audit worksheet.

2. R.M. Young 18310/18312 Torque Discs

The R.M. Young torque disc (Figure S.3.1.4) may be used on wind direction sensors with a torque less than 15 gm-cm. The torque disc (Model 18310/18312) used in the audit will be selected based on the proper fit of the disc on the sensor shaft.

a. The station operator will remove the sensor from the tower and place it inside the station or similar structure. The area should be free of air movement.

b. Remove the tail assembly from the shaft by loosening the small hex screw which holds the tail assembly to the shaft. Place the sensor on its side on a flat surface which provides comfortable access.

c. Attach the torque disc to the shaft. Make sure that the center fits the shaft properly without excess slippage. The center hole will require matching to fit the shaft of some sensors (Met One 020). If the sensor has a small shaft (Climatronics F460), 1/4" tubing is inserted inside the center hole of a cup torque disk. Slide the torque disk over the shaft, with the disk face flush with the sensor shaft.

d. Determine the desired torque value, starting threshold, and K factor from the sensor's specifications. Record this information on the audit worksheet (Figure S.3.2.1). Refer to Section S.3.4 for the torque to wind speed conversion formula.

e. Orient the disc such that the holes are horizontally positioned from the shaft. Screw in a weight at the appropriate distance from the center hole to correspond to the calculated starting threshold torque. The black nylon screws weigh 0.1 gm and the stainless steel screws weigh 1.0 gm.

f. If the disc does not turn, continue moving the weight out from the center, until the disc turns. The torque can be increased by either choosing a heavier weight, placing the weight further from the center, or combining different weights at different radii. Multiply the weights used times the radius to determine gm-cm torque. If multiple weights are used, then the gm-cm are added for the total torque.

g. When the disc makes the slightest movement (i.e., moves from the 90 degree to 85 degree position) the torque has been measured, record the weight and the distance from center on the Worksheet. The gm-cm number is the torque of the wind direction sensor.

h. Remove all the weights and orient the disc such that the holes are horizontal from the center. Select the same weight which turned the disc in step g and place it in the hole at the same distance from the center on the opposite side.

i. Record the gm-cm value from this measurement on the Worksheet.

3. Water's 651C-1M Torque Watch

The Water's torque watch (Figure S.3.1.5) is a precision instrument, so its use is limited to verification of the torques measured with the torque gauge or torque disc.

a. The station operator removes the sensor from the tower and places it inside the station or similar structure. The area should be free of air movement.

b. Remove the tail assembly from the shaft by loosening the small hex screws which hold the tail assembly to the shaft.

c. Hold the wind direction sensor and attached torque watch in a vertical position.

d. Position the memory needle within the expected torque range by adjusting the knurled knob in the center of the crystal.

e. Rotate the sensor shaft to measure the torque. The final location of the memory needle will indicate the highest torque measured.

f. Record this value on the Worksheet.

g. Repeat steps c through f rotating the shaft in the opposite direction.

S.3.3.4 POST AUDIT CHECKS

After the performance audits are completed, the sensor should be checked to determine if it is operating correctly.

1. Check the sensor orientation. The sensor orientation should be determined with the transit used in the wind direction orientation audit. The sensor orientation should not have changed from the audit results unless the station operator has adjusted it. If the sensor orientation has changed, consult with the station operator and take corrective action as necessary.

2. Check the sensor movement. During windy conditions, the sensor should rotate freely and point into the wind. If the sensor does not rotate freely, consult with the station operator and take corrective action as necessary.

3. Check the data. Visually determine the general direction the sensor is indicating and compare it to the DAS and/or strip chart values. They should be reasonably close (±10 degrees). If they are not close, consult with the station operator and take corrective action as necessary.

S.3.4 AUDIT DATA CALCULATIONS

1. Declination Adjustment

Since wind direction sensors are oriented to true North, and the audit transits operate with respect to magnetic North, it is necessary to adjust for the local declination. The declination is the angular difference between magnetic North and true North and is caused by variations in the Earth's magnetic field. The declination can be determined by using the California Declination Chart (Figure S.3.4.1). The chart provides the declination (15°, 16°, 17°, etc.) and the annual rate of declination change (2.0', 2.5', 3.0', etc.). To determine the declination for a specific site using the California Declination Chart, interpolate the declination and annual rate of declination change then algebraically add the annual rate of declination change for each year since the publication of the chart (1990). To determine the magnetic orientation of a wind direction sensor which is properly oriented to true North, subtract the declination from 360°. This is the sensor orientation that would be seen on the audit transits.

Example: Determine the 1996 declination and magnetic orientation for a wind direction sensor located in Sacramento.

a. Interpolate the declination and annual rate of declination change:

Declination = 15.9° E.
Annual rate of declination change = 2.9' W/year.

b. Calculate the declination change since the chart was published: The chart was published in 1990, so 6 years have passed.

2.9' W/year x 6 years = 17.4' W declination change

c. Convert the declination change to degrees (60' = 1°):

$$17.4' \text{ W} \times \frac{1°}{60'} = 0.3° \text{ W}$$

d. Algebraically add the declination and the declination change:

15.9° E + 0.3° W = 15.6° E

The 1996 declination in Sacramento is 15.6° E.

e. The magnetic orientation of a wind direction sensor is found by subtracting the declination from 360°.

Magnetic orientation = 360° - Declination
The 1996 magnetic orientation of a wind direction sensor located in Sacramento would be 344.4° (360° - 15.6°).

2. Sensor Input Conversion

The wind direction sensor transducer or potentiometer converts the angle of wind direction into output voltage. The translator converts this output voltage into degrees. The audit is concerned with the accuracy of the entire wind direction system (wind direction sensor, translator, and data logger), so the read-out in degrees is a sufficient check of the system.

3. Starting Threshold Speed

The van's audit program calculates the starting threshold by using the following equation:

$$T = Ku^2$$

Where: T is the torque
u^2 is the square of the wind speed
K is the constant supplied by the manufacturer

The torque formula is converted to provide the starting threshold speed by the following relationship:

$$u = \sqrt{T / K}$$

Starting Threshold = Squareroot (Measured Torque/K Factor)

The wind direction starting threshold should be less than or equal to 0.5m/s.

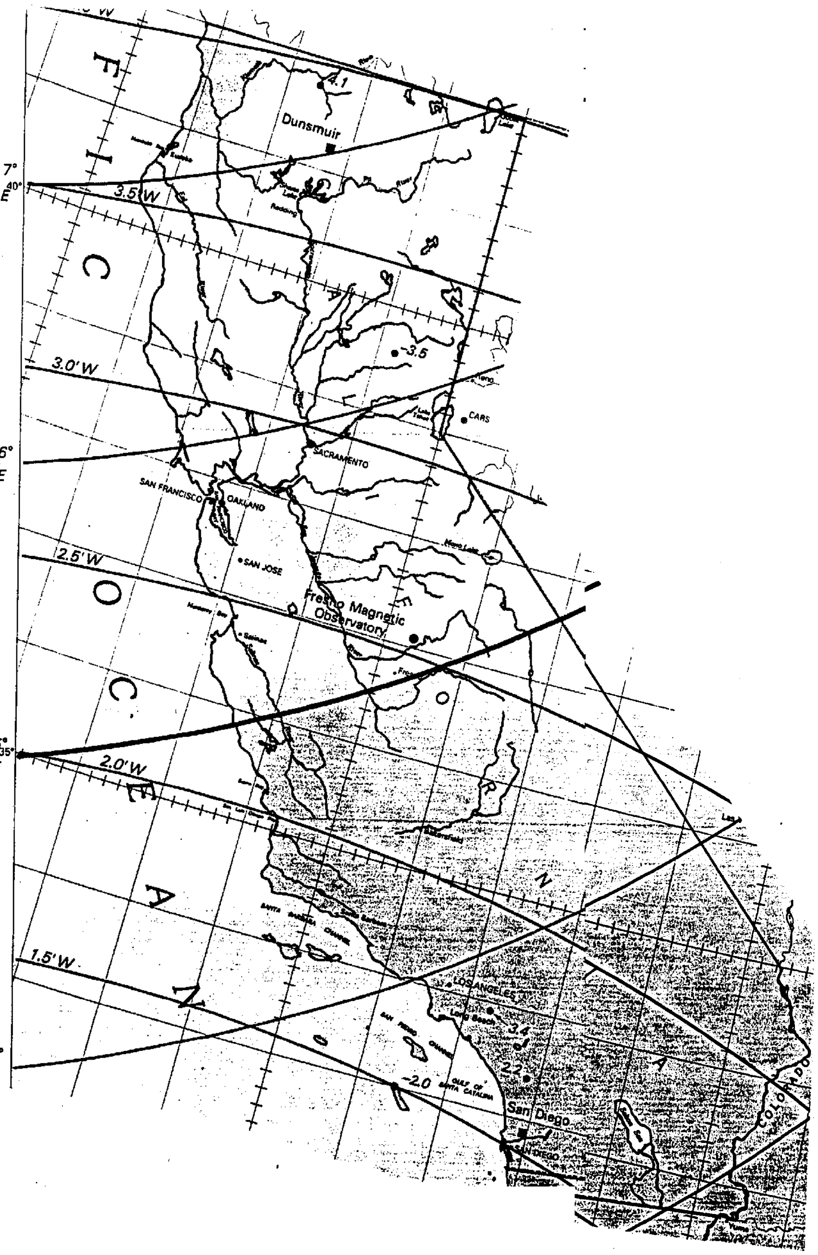


Figure S.3.4.1
California Declination Chart
(US Geological Survey, 1990)

S.3.5 PREVENTATIVE MAINTENANCE

S.3.5.1 BRUNTON F-3008 POCKET TRANSIT

Care must be taken not to drop the transit. Store it in its case when not in use.

S.3.5.2 DAVID WHITE TR-300 SITE PATH TRANSIT

1. Keep the lens cover on the telescope when it is not in use.

2. Handle the transit by its base when removing it from its case or attaching it to the tripod. Always use two hands when carrying the transit.

3. Carry the transit/tripod assembly in an upright position only.

S.3.5.3 R.M. YOUNG 18212 AND MET ONE 040/044 FIXTURES

None required except keep the fixtures clean.

S.3.5.4 CLIMATRONICS 10175 FIXTURE

Keep the connector plugs clean and protect the electrical cable from damage.

S.3.5.5 R.M. YOUNG 18331 TOROUE GAUGE

1. Protect the leaf spring from rough handling.

2. Keep the spring mechanism free of lint or dirt and keep the gauge in a protective case when not in use.

S.3.5.6 R.M. YOUNG 18310/18312 TORQUE DISC

Keep the disc and weights clean and free of dirt, etc.

S.3.5.7 WATER’S 651C-1M TORQUE WATCH

The torque watch should be handled carefully and it should be stored in its case when not in use.

S.3.6 CALIBRATION AND CERTIFICATION

S.3.6.1 BRUNTON F-3008 POCKET TRANSIT

The Brunton F-3008 pocket transit does not require recalibration. It should be replaced if any components are broken.

S.3.6.2 DAVID WHITE TR-300 SITE PATH TRANSIT

The Site Path Transit does not require recalibration. It should be checked and adjusted by a qualified instrument repair station or by the manufacturer at least once a year.

S.3.6.3 R.M. YOUNG 18212 AND MET ONE 040/044 FIXTURES

The accuracy of these degree fixtures is based on correct installation of the fixture on the sensor shaft and interpretation of the direction indicators. Thus, calibration checks are not part of the equipment's accuracy.

S.3.6.4 CLIMATRONICS 10175 FIXTURE

The accuracy of this fixture is based on correct installation on the sensor. In addition, the electrical connections should be checked for proper operation on a quarterly basis.

S.3.6.5 R.M. YOUNG 18331 TORQUE GAUGE

The gauge should be replaced if the spring mechanism appears bent or misaligned. Otherwise, there are not any calibration checks performed.

S.3.6.6 R.M. YOUNG 18310/18312 TORQUE DISCS

The weights (0.1 and 1.0 grams) can be verified on a scale on a quarterly basis.

S.3.6.7 WATER'S 651C-1M TORQUE WATCH

The torque watch is returned to the manufacturer for calibration on an annual basis. It should also be returned to the manufacturer if it has been dropped.

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VOLUME V

AUDIT PROCEDURES
FOR
AIR QUALITY MONITORING

APPENDIX S.4

PERFORMANCE AUDIT PROCEDURES
FOR
AMBIENT TEMPERATURE SENSORS

MONITORING AND LABORATORY DIVISION

AUGUST 2002

S.4.0 INTRODUCTION

For air quality applications, ambient temperature is measured with a temperature probe. The probe can be a thermistor, resistance temperature detector (RTD), or thermocouple. The probe should be located in a radiation shield to protect it from the effects of solar heating and wind variations. The shield can be naturally aspirated. However, a motor aspirated shield is strongly advised since its use will minimize potential radiation errors. The ambient temperature probe audit is performed by removing the probe from the radiation shield, immersing it and the audit thermistor probe in water baths of three temperatures (cold, ambient, and hot). The results of each temperature system are compared to provide the accuracy of the station temperature system. If the station ambient temperature probe cannot be immersed in water, the audit thermistor is positioned as near to the station temperature sensor as possible (within 5”). Three readings of each temperature system are recorded and the results compared. An operator who is familiar with the meteorological equipment must be present during the audit to perform the required manipulations of the tower and sensors.

S.4.1 GENERAL OPERATING PROCEDURES

A T-Type thermocouple is plugged into a Digi-Sense J, K, T thermocouple thermometer to measure temperature. The digital thermometer has a liquid crystal display (LCD) with a resolution of 0.1 degree and an accuracy of ± 0.4°C. Its readout is in values of degrees Fahrenheit (°F) or Centigrade (°C). Figure S.4.1.1 shows a diagram of the digital thermometer and thermistor. The thermistor and station temperature probe are inserted in three water baths of varying temperatures. Each water bath is held in a thermos container. The digital thermometer and the station temperature probe readouts are compared. Following EPA Volume IV (Quality Assurance Handbook for Meteorological Measurements), the agreement should be ±0.5°C between the temperature readout of the audit thermistor and the station temperature probe. If the station temperature sensor cannot be in contact with water, a collocated check can be performed. The collocated check is a triplicate comparison of the temperature readings from the audit thermistor and the station sensor. This triplicate comparison is performed by placing the audit thermistor within 5” of the station sensor, then recording the values from both temperature systems. The comparison is repeated at three different times. The results of all three comparisons are used to provide the accuracy of the station sensor.

S.4.2 AUDIT EQUIPMENT

1. Omega Model 450-ATH thermister thermometer (Figure S.4.2.1).

2. Three thermos containers.

3. Ice water (at or near $0^{o}C$), ambient water (approximately $20^{o}C$), and hot water ($40\text{-}50^{o}C$).

4. The QA Audit Worksheet Temperature and Relative Humidity (Worksheet) (Figure S.4.2.2).

Figure S.4.2.1
Omega Model 450-ATH Thermister Thermometer

QA AUDIT WORKSHEET
TEMPERATURE AND RELATIVE HUMIDITY

Site Name: ________________________ Site#: __________ Date: ________________

Address: ___________________________ Agency: ____________________________

Site Technician: _________________ Auditors: __________________________________

Data Read From: Chart[ ] DAS[ ] Other[ ] DAS Type: ________________________

Ambient Temperature		
Audit Point	Station Sensor	Audit Sensor
1		
2		
3		
4		
5		

Relative Humidity		
Audit Point	Station Sensor	Audit Sensor
1		
2		
3		
4		
5		

Equipment Specifications	Audit Sensor Information	
	Temperature Sensor	Humidity Sensor
Manufacturer		
Serial Number		

Specifications Equipment	Station Instrument Information		
	Ambient Temperature	Relative Humidity	Radiation Shield
Manufacturer			
Model Number			
Serial Number			
Operating Range			
Sensor Height			
Last Calibrated			
Motor/Naturally Aspirated			
. Equipment Cert. Date			

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Figure S.4.2.2
QA Audit Worksheet Temperature and Relative Humidity

S.4.3 AUDITING PROCEDURES

S.4.3.1 WATER BATH METHOD

Prior to using the water bath method, have the operator verify that the station sensor can be immersed in water. If it cannot be immersed, a collocated audit can be performed (see Section S.4.3.2). The collocated audit should be used if there is any concern that water may harm the station sensor.

1. Prepare the water baths 10 to 15 minutes prior to the audit to allow temperature equilibrium to be reached. Pour the ice into one of the plastic thermoses. Fill the thermos about 3/4's full with ice. Pour water over the ice, until it is about 1/2" to 1" from the thermos top, depending on the length of the sensor probe. The bath should be an easily penetrable slurry. Prepare the ambient temperature bath using tepid tap water filled to 1/2" to 1" of the thermos top.

2. Complete the "Equipment Specifications" section on the Worksheet for the temperature sensor.

3. Turn on the digital thermometer by pressing the "ON ^{o}C" key.

4. Have the operator remove the station temperature probe from the radiation shield. The operator should check the probe for any signs of cracking or material degradation prior to immersion in the water baths. If there is visible damage to the probe do not proceed with the audit, until repairs or replacement are made. Also, have the operator verify that the station temperature probe can be immersed in water.

5. Immerse the audit thermister probe and station temperature sensor into the ice bath. Gently agitate the water by moving the probe around. After about 30 seconds, stop the agitation. The audit thermometer reading should be at near 0°C. If it is not, repeat the agitation procedure. Do not immerse either probe in the solution up to the connector caps. The station sensor may have exposed wires leading into the probe (e.g., Climatronics 10093 sensor). In this case, the station probe should only be immersed in the water bath from 1/2 to 3/4 of the probe length. This will prevent water from leaking into the electrical connections. Keep the two probes within 1" of each other in the water and at the same depth (i.e., the probes can be closer than 1" of each other, but not greater than 1" apart). During the audit, a cloth may be placed around the probes to cover the opening of the thermos container. This will help to keep the ice bath temperature constant.

6. When the station temperature readings are stable (1 to 2 minutes) record the audit probe temperature and the station sensor temperature values on the Worksheet.

7. Move the audit thermistor and station probe to the ambient temperature water bath.

8. Repeat steps 5 and 6 for the ambient bath and the hot bath.

9. Have the operator place the station probe back into the radiation shield.

10. Check the electrical connections of the station probe and radiation shield. If the radiation shield is motor aspirated, verify that the aspirator fan is operating. Visually check the radiation shield for an excessive amount of dirt, insects, etc. Note any abnormalities on the Worksheet.

11. Remove the audit thermistor from the water bath, and press the off button.

S.4.3.2 COLLOCATED METHOD

Until alternate methods can be developed, a collocated temperature audit will be performed if the station probe cannot be immersed in water. The accuracy claim should be limited to the sum of the accuracies of the station sensor and the audit sensor (±0.4°C). However, this value should only be used if it is higher than the ±0.5°C audit limit.

1. Turn on the digital thermometer by pressing the “ON ^{o}C” button. Place the thermometer outside to equilibrate to ambient conditions.

2. Position the audit thermister as close as possible to the temperature sensor (do not exceed 5”). Protect the audit thermistor from direct sunlight or excessive air movement as much as possible. If feasible, the thermister may be positioned near the air intake of the radiation shield. The operator may be required to position the audit thermister, if the station sensor cannot be accessed from the ground.

3. When the audit thermometer and station (DAS) temperature readings are stable, record the values on the Worksheet.

4. Repeat steps 2 and 3 two more times.

5. Have the operator place the station probe back into the radiation shield.

6. Check the electrical connections of the station probe and radiation shield. If the radiation shield is motor aspirated, verify that the aspirator fan is operating. Visually check the radiation shield for an excessive amount of dirt, insects, etc. Note any abnormalities on the Worksheet.

7. Enter the data into the van's computer.

S.4.4 POST AUDIT CHECK

After completing the audit and reinstalling the station probe back into its normal operating position, check for correct sensor operation.

1. Determine the ambient air temperature using the audit thermometer by holding the thermocouple in the air for approximately two minutes.

2. Compare the ambient temperature to the temperature on the station data logger and/or chart recorder. The temperatures should be reasonably close, within ±3°C, depending on the current ambient conditions. If the temperatures are not close or the station temperature sensor is malfunctioning, consult with the station operator and take appropriate action as necessary.

S.4.5 AUDIT DATA CALCULATIONS

EPA Volume IV handbook states that the difference between the station temperature probe and the audit temperature readings be less than or equal to 0.5°C. The measured audit thermometer value is corrected by applying the slope and intercept from the annual calibration. The audit computer program will automatically apply the correction factor, so only the raw audit thermometer values are required. If a collocated test is being performed, the limit is determined by adding the accuracy of the audit thermometer (±0.4°C) to the accuracy of the station temperature sensor. This value will be used if it is above the listed audit limit of ±0.5°C.

S.4.6 PREVENTIVE MAINTENANCE

1. The digital thermometer requires replacement of the batteries every quarter.

2. Wipe the console keyboard with a soft, damp cloth, if necessary.

3. The thermister should be checked for any damage to the probe, the probe to cable interface, and connector plug, prior to each audit.

S.4.7 CALIBRATION AND CERTIFICATION

The digital thermometer and thermister are certified annually by a certification laboratory.

STATE OF CALIFORNIA

AIR RESOURCES BOARD

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VOLUME V

APPENDIX S.5

PERFORMANCE AUDIT PROCEDURES
FOR
AIR QUALITY MONITORING

PERFORMANCE AUDIT PROCEDURES
FOR
BAROMETRIC PRESSURE SENSORS

MONITORING AND LABORATORY DIVISION

AUGUST 2002

S.5.0 INTRODUCTION

Barometric pressure measurements can be used in modeling and can be used to correct an ambient measurement to standard conditions (25^{o}C and 760 millimeters of mercury). The altimeter setting from an airport near the station will provide the current barometric pressure. If the station's barometric pressure is measured on site, the station's barometer can be taken to the local National Weather Service (NWS) office and set to agree with the NWS station pressure. Alternately, the station's barometer can remain on site and the sea level barometric pressure is obtained from the NWS office. This sea level barometric pressure must be corrected for the station's altitude. The Environmental Protection Agency Quality Assurance Handbook for Air Pollution Measurements, Volume IV, Meteorological Measurements, EPA-450/4-90-003 (EPA Volume IV) guidelines recommend a measurement accuracy of 10 mb (7.50 mm Hg). This is approximately 1% of standard pressure (760 mm Hg) or 100 meters in elevation.

Pressure is commonly measured in millibars (mb). However, barometric pressure can also be expressed in units of millimeters of mercury (mm Hg), inches of mercury (in. Hg), hectoPascal (hPa),or poundfeet per square inch (lbf/in^2). The hectoPascal (hPa) is the common expression for International System of Units (SI) and is equivalent to millibars. The audit barometric pressure value is provided in mm Hg. The formulas for converting units are provided in Section S.5.4.

S.5.1 GENERAL OPERATING PROCEDURES

Presently the audit barometer is an industrial transducer with a minimum accuracy of 0.1% full scale. The transducer has a hermetically sealed, stainless steel construction to provide high measurement stability. The transducer is plugged into an electrical power source. The voltage from the transducer will vary with the barometric pressure and is displayed on the liquid crystal display (LCD). The calibration slope and intercept is applied to this voltage by the van's audit computer. The resultant value (mm Hg) is compared to the value from the station's barometric pressure sensor. Air Resources Board guidelines require the station's sensor to be within 2.25 mm Hg (3 hPa as defined in PAMS requirements) of true.

S.5.2 AUDIT EQUIPMENT

1. Aneroid barometer.

2. QA Audit Worksheet Barometric Pressure & Solar Radiation (Worksheet) (Figure S.5.2.1.).

QA AUDIT WORKSHEET
BAROMETRIC PRESSURE & SOLAR RADIATION

Site Name: ______________________ Site Number:__________ Date:____________

Address:__________________________ Agency:__________________________

Technician: ______________________ Auditors:__________/______________

Data Read From: Chart[ ] DAS[ ] Other[ ] DAS Type:_______________________

Barometric Pressure		
Audit Test Point	Station Sensor Value	Audit Sensor Value
1		
2		
3		
4		

Solar Radiation		
Audit Test Point	Station Sensor Value	Audit Sensor Value
1		
2		
3		
4		

Station Instruments		
Instrument Information	Barometric Pressure	Solar Radiation
Manufacturer:		
Model Number:		
Serial Number:		
Operating Range:		
Sensor Height:		
Radiation Shield Type:		
Last Calibrated:		
Calibration Equipment Last Certified:		

Conversion Formulas For Instantaneous Data:

Langleys/minute * 697.32 = Watts/meter^2

Calories/centimeter^{2}minute * 697.32 = Watts/meter^2

Joules/centimeter^{2}minute * 166.66 = Watts/meter^2

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Figure S.5.2.1
QA Audit Worksheet Barometric Pressure & Solar Radiation

S.5.3 AUDIT PROCEDURES

1. Turn on the audit barometer. Allow approximately 10-15 minutes for the barometer to stabilize before taking the digital readings.

   NOTE: The audit barometer transducer has an operating temperature range of -17.8°C to 85 °C, with compensated temperature of 15.6°C to 71.1°C.

2. Record the instrument information requested on the audit worksheet (Figure S.5.2.1).

3. Record the value from the van's barometer and the station's barometric pressure on the audit worksheet (Figure S.5.2.1).

4. Repeat step 3 two more times throughout the day.

5. Enter the values in the van's computer.

S.5.4 AUDIT DATA CALCULATIONS

The value from the audit barometer should be input into the audit computer. The van's computer will automatically apply the slope and intercept to the LED value. The sensor error between the audit barometer and the station barometer should be 7.50 mm Hg (10 mb) to meet EPA Volume IV guidelines.

If the station's readout is not in mm Hg, the following formulas may be used to convert units:

Millibars x 0.7500616 = Millimeters of mercury
Millibars x 0.02953 = Inches of mercury
Millibars x 0.014504 = Pounds/Square inch
Inches of Mercury x 33.864 = Millibars
Inches of Mercury x 25.4 = Millimeters of mercury
Inches of Mercury x 0.4912 = Pounds/Square inch

S.5.5 PREVENTATIVE MAINTENANCE

No specific preventative maintenance measures are required.

S.5.6 CALIBRATION AND CERTIFICATION

The audit barometer is calibrated by a standards laboratory on an annual basis. The values from the audit barometer are compared to a National Institute of Standards and Technology (NIST) traceable pressure measurement unit. A slope and intercept is derived from this comparison. The slope and intercept from this calibration are used to convert the LED display of the audit barometer to units of mm Hg. The slope and intercept are in the standards file of the audit computer and will automatically correct the value when the audit results are calculated.

STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME V

AUDIT PROCEDURES
FOR
AIR QUALITY MONITORING

APPENDIX S.6

PERFORMANCE AUDIT PROCDURES
FOR
SOLAR RADIATION SENSORS

MONITORING AND LABORATORY DIVISION

AUGUST 2002

S.6.0 INTRODUCTION

Solar radiation is related to atmospheric stability and is commonly described in units of energy flux: Watts/meter^2 (W/m^2), Langleys/minute, Calories/centimeter^2 minute (Cal/cm^2 min.) or Joules/centimeter^2 minute. The two common instruments for measuring solar radiation are pyranometers and net radiometers.

The pyranometer measures sun and sky radiation on a horizontal surface. Most pyranometers incorporate a thermopile sensor; however, a silicon photovoltaic cell can also be used. The net radiometer measures the difference between downward (solar) and upward (terrestrial) radiation. This sensor is based on the thermopile design.

This audit procedure describes the pyranometer sensor. The audit sensor is an Eppley Precision Spectral Pyranometer (Eppley PSP) with wavelength filtering hemispheres covering the thermopile. The Eplab Model No. 455 Instantaneous Solar Radiation Meter (Eplab 455) is connected to the pyranometer to measure its output in volts. The output voltage is converted to Watts/m^2.which is displayed on the liquid crystal display (LCD).

The solar radiation audit is a collocated audit where the Eppley PSP values are compared to the station pyranometer values. The EPA Prevention of Significant Deterioration (PSD) and On-Site Meteorological Program Guidance for Regulatory Modeling Applications guidelines provide for an accuracy of ±5% or 25 W/m^2 (whichever is greater) agreement between the Eppley PSP and the station pyranometer values.

S.6.1. GENERAL OPERATING PROCEDURES

The Eppley PSP is a multi-junction, wire-bound thermopile. The receiver is coated with Parson's black lacquer. The sensor is supplied with a pair of removable, precision ground, Schott optical glass hemispheres. The clear (WG295 glass) hemisphere has uniform transparency to radiation between 285 and 2800 nanometers. The sensor includes a level, adjustable leveling screws, and a desiccator. The sensor has a cast bronze body with a white enamel guard disc and is protected in a storage case when it is not in use. A calibration certificate to the World Radiation Reference is included with conversion factors for various units.

The Eplab 455 contains a 9V rechargeable battery. To operate it, the power switch must be turned on and the toggle switch placed in the appropriate position: "Internal" when the battery is used and "External" when the power cord is connected to line voltage.

Audits are performed by connecting the electrical cable from the Eppley PSP to the Eplab 455. The Eppley PSP is positioned outside as close to the location of the station pyranometer as possible. The Eplab 455 is turned on and allowed a few minutes to stabilize. Full scale is 2000 W/m^2, with a resolution of 1 W/m^2. The station readout is compared to the value displayed on the Eplab 455. The Eppley PSP and the station sensor values should be within 5% or 25 W/m^2 (whichever is greater) of each other.

S.6.2 AUDIT EQUIPMENT

1. Eppley PSP, connector cable, and Eplab 455 (Figure S.6.2.1).

2. QA Audit Worksheet Barometric Pressure & Solar Radiation (Worksheet) (Figure S.6.2.2).

Figure S.6.2.1
Eppley PSP, Connector Cable, and Eplab 455

QA AUDIT WORKSHEET
BAROMETRIC PRESSURE & SOLAR RADIATION

Site Name: ______________________ Site Number:__________ Date:__________

Address:______________________ Agency:______________________

Technician: ______________________ Auditors:__________/__________

Data Read From: Chart[ ] DAS[ ] Other[ ] DAS Type:______________________

Barometric Pressure		
Audit Test Point	Station Sensor Value	Audit Sensor Value
1		
2		
3		
4		

Solar Radiation		
Audit Test Point	Station Sensor Value	Audit Sensor Value
1		
2		
3		
4		

Station Instruments		
Instrument Information	Barometric Pressure	Solar Radiation
Manufacturer:		
Model Number:		
Serial Number:		
Operating Range:		
Sensor Height:		
Radiation Shield Type:		
Last Calibrated:		
Calibration Equipment Last Certified:		

Conversion Formulas For Instantaneous Data:

Langleys/minute * 697.32 = Watts/meter^2

Calories/centimeter^{2}minute * 697.32 = Watts/meter^2

Joules/centimeter^{2}minute * 166.66 = Watts/meter^2

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Figure S.6.2.2
QA Audit Worksheet Barometric Pressure & Solar Radiation

S.6.3 AUDIT PROCEDURES

Each Eplab 455 is factory matched to a specific Eppley PSP. This is done because of the unique properties of each Eppley PSP. As such, each Eplab 455 should not be used with any other Eppley PSP, unless the reading on the Eplab 455 is multiplied by the ratio of the radiometer sensitivities. Make certain that the Eplab 455 is correctly matched to the Eppley PSP before beginning the audit. Each Eplab 455 is factory calibrated to read directly in W/m^2 so no correction is needed. The only calculation that may be necessary would be to convert the station sensor values into W/m^2. The most common formulas are on the bottom of the Worksheet.

NOTE: If it is raining do not perform the audit. The best time to conduct the audit is at mid-day, with a cloudless sky, and the sun directly overhead.

1. Remove the Eppley PSP and its associated electrical cable from the carrying case. Position the Eppley PSP on a flat surface as close to the station pyranometer as possible and at the same height. Do not locate it in areas where the Eppley PSP face will be shaded or near reflective surfaces. Also, do not block the light to the station pyranometer.

2. Attach the electrical cable to the Eppley PSP and the Eplab 455. Level the Eppley PSP by adjusting the leveling screws and centering the bubble in the level. The plug on the Eppley PSP should be oriented to true North.

5. The Eplab 455 contains a 9V rechargeable battery. To operate it, the power switch must be turned on and the toggle switch placed in the appropriate position: "Internal" when the battery is used and "External" when the power cord is connected to line voltage. Allow the unit to warm up for 10 minutes.

6. Complete the "Instrument Information" requested on the Worksheet.

7. Record the display value of the Eplab 455 on the Worksheet. If the station sensor units are different, then the readings from the station sensor will require conversion to W/m^2 (see Section 5.6.4 or the Worksheet for conversion formulas).

8. Repeat Step 7 twice more at approximately 10 minute intervals.

9. Enter the data into the van's computer.

S.6.4 AUDIT DATA CALCULATIONS

1. The percent difference and direct difference between the Eppley PSP and the station sensor values are calculated to find the total sensor error. This is accomplished once the station sensor values have been converted to W/m^2 (if necessary) and entered into the van's computer.

2. The following formulas are used to convert between units:

   Watts/meter^2 X 0.00529 = BTU/foot^2 min.
   Watts/meter^2 X 0.006 = Joules/centimeter^2 min.
   Watts/meter^2 X 0.00143 = Langleys/min
   Langleys/min.. X 697.32 = Watts/meter^2
   Langleys/min.. X 4.1855 = Joules/centimeter^2 min.
   Langleys/min.. X 3.692 = BTU/foot^2 min.
   Joules/centimeter^2 mm X 0.8821 = BTU/foot^2 min.
   Joules/centimeter^2 mm. X 0.2389 = Langleys/min.
   Joules/centimeter^2 mm X 166.66 = Watts/meter^2

   NOTE: Calories/centimeter^2 min. have the same conversion formulas as Langleys/min. BTU is British Thermal Unit, and min. is minute.

3. If the Eppley PSP is used with another Eplab 455, other than the one that was matched to it, the reading on the LCD must be multiplied by the ratio of the radiometer sensitivities. If this is not done, the response will not be accurate.

S.6.5 PREVENTATIVE MAINTENANCE

S.6.5.1 Eppley PSP

Before each audit, check that the clear outer glass hemisphere is clean. If it is not, wipe it clean with a lint-free soft cloth. Be careful not to scratch the glass, as this will alter the transmission properties of the glass. If the internal surfaces of the outer hemisphere becomes coated with moisture, carefully remove the outer hemisphere on a dry day to expose it to the air for drying. The inside of the hemisphere should not be wiped unless smears are evident. The external surface of the inner hemisphere can be cleaned while the outer hemisphere is removed. The inner hemisphere can also be removed if moisture is evident on the inside surface. Be very careful not to touch or damage the exposed thermopile when the inner hemisphere is removed. The dessicant visible in the side of the white pyranometer case should be checked and changed, if necessary, before each audit (the color should be blue; pink or white indicate that the dessicant should be changed).

S.6.5.2 EPLAB 455

1. Before each audit, make certain that the internal battery is charged. To check this, place the power selector in the "Internal" position and the On/Off switch in the "On" position. If there is no display (it usually displays "-1"), the unit will have to be used with the battery eliminator until the internal battery is charged. To charge the internal battery, place the toggle switch in the "Internal" position, insert the battery eliminator into the "Battery Charger Eliminator Input", and plug the unit into a 110-volt power source for at least two hours.

2. Even though the battery is rechargeable, it still needs periodic replacement. To replace the battery,, remove the four screws that secure the rubber feet to the bottom of the Eplab 455. Remove the other 4 screws near the rubber feet. Slide the top of the unit away from you to remove it. The 9V battery is now accessible and can be replaced. Reassemble the unit in reverse order.

S.6.6 CALIBRATION AND CERTIFICATION

The Eppley PSP sensor, along with the Eplab 455, should be returned to the Eppley Laboratory in Rhode Island for calibration and certification annually. Eppley provides a certification sheet with conversion factors for the Eppley PSP and its associated Eplab 455.