This SOP is subject to
review and revision in 2015.

BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

TECHNICAL SERVICES DIVISION

QUALITY ASSURANCE PROJECT PLAN

MET SOP 502

WIND DIRECTION

REVISION 502.1.00 8/29/2007

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STANDARD OPERATING PROCEDURE
BAAQMD TECHNICAL SERVICES DIVISION

WIND DIRECTION AUDIT PROCEDURES

AUGUST 29, 2007

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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° indicates north and 180° indicates south. Wind direction sensors use a vane 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, and 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.

GENERAL OPERATING PROCEDURES

Twice yearly, a Tamaya transit (Figure 1) and Brunton pocket transit (Figure 2) are used to verify the crossarm orientation relative to true North. The Tamaya is used to check the magnetic orientation of the crossarm and the Brunton pocket transit is used to determine the magnetic declination. Together, a measurement accuracy of within 0.5º relative to true north can be achieved. A GPS (Figure 3) is used to verify the crossarm orientation at other times of the year. The tolerance of the GPS is ±1º. The wind vane orientation is then checked against the crossarm by setting the vane parallel to the crossarm and reading the output. The R.M. Young 18312 torque disc (Figure 4) is used to quantify the starting torque of the wind direction sensor with the vane removed.

The accuracy measurement for Climatronics F460 wind direction sensors are performed with a Climatronics 101984 degree fixture and degree wheel (Figure 5). After attaching the sensor to the degree fixture, the degree wheel is rotated at 30º increments clockwise, then counterclockwise on the degree fixture to measure the linearity of the potentiometer. See Figure 4 for a diagram of the Climatronics degree fixture and degree wheel

The U.S. EPA Volume IV criteria provides for an agreement of less than or equal to 3º relative to the sensor mount or index (sensor error) and less than or equal to 5º absolute error for the installed system (system error). 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.

Data recording should be disabled during an audit to prevent audit data from being recorded into memory. EPA *Meteorological Monitoring Guidance for Regulatory Modeling Application* states that at least two 15-minute averaged periods of valid data are required to represent an hourly period. The Campbell Scientific CR10 datalogger is programmed to average all data recorded to memory within a given hour with as little as one data point (one data point is recorded per second). If there is not enough valid data for two 15-minute averaged periods, the data for the averaged hourly period must be deleted from the data bank.

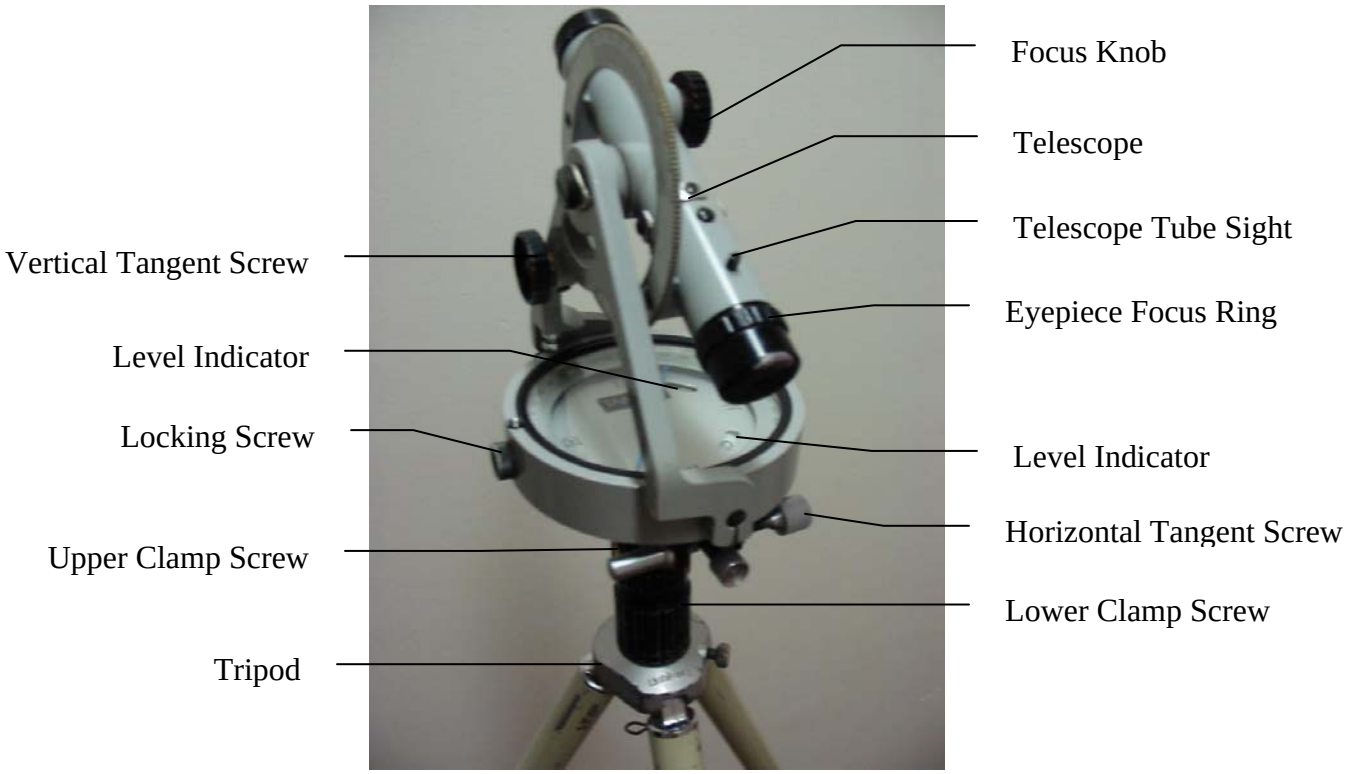

Figure 1: Tamaya Transit

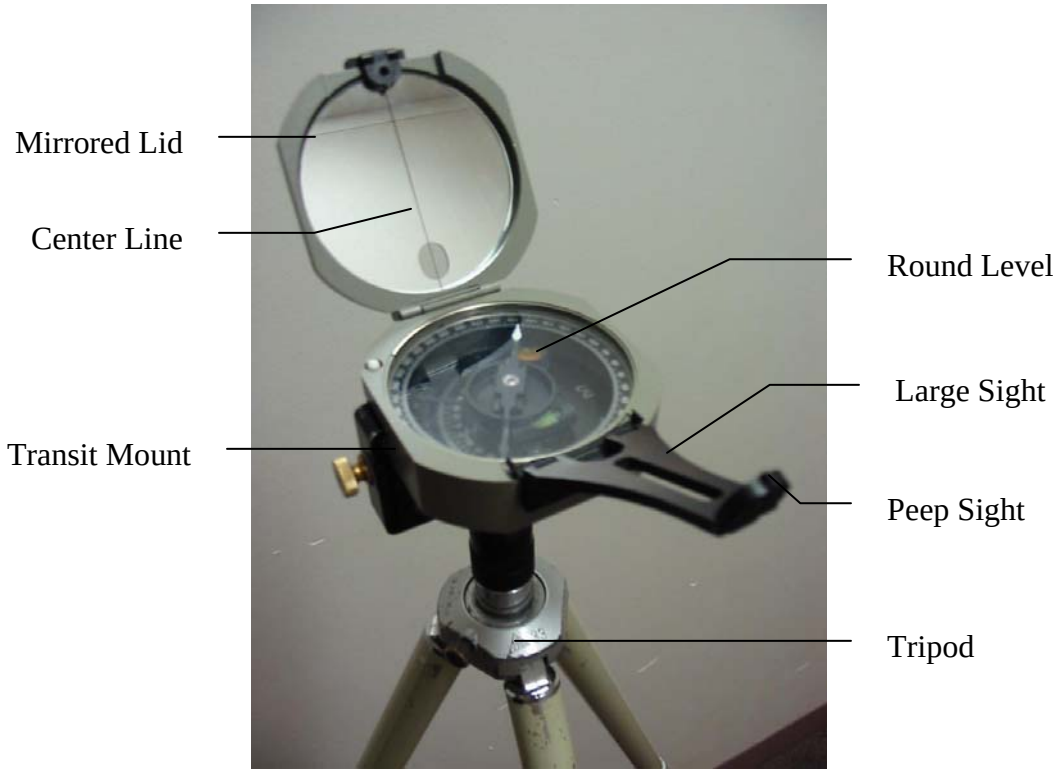

Figure 2: Brunton Pocket Transit

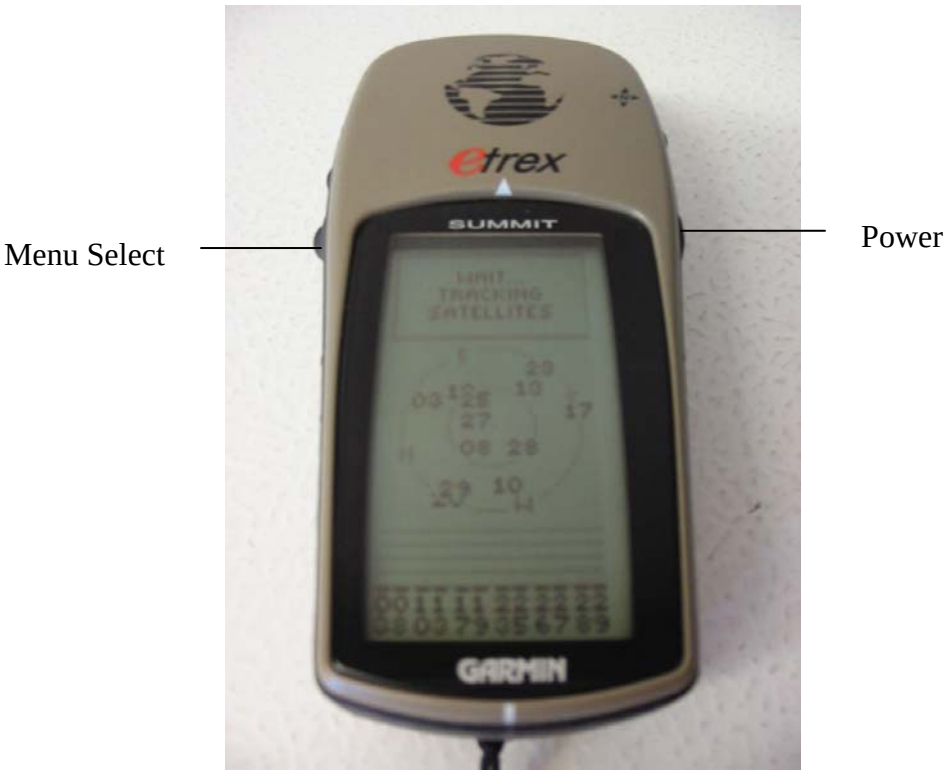

Figure 3: Garmin eTrex GPS

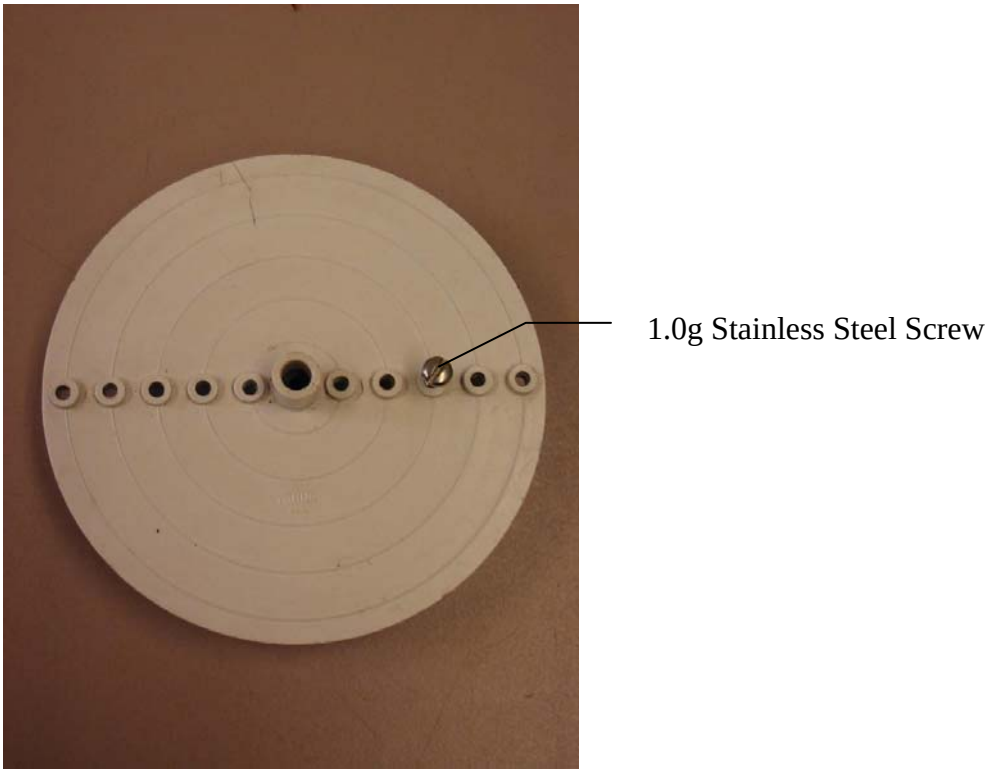

Figure 4: R.M. Young 18312 Torque Disk

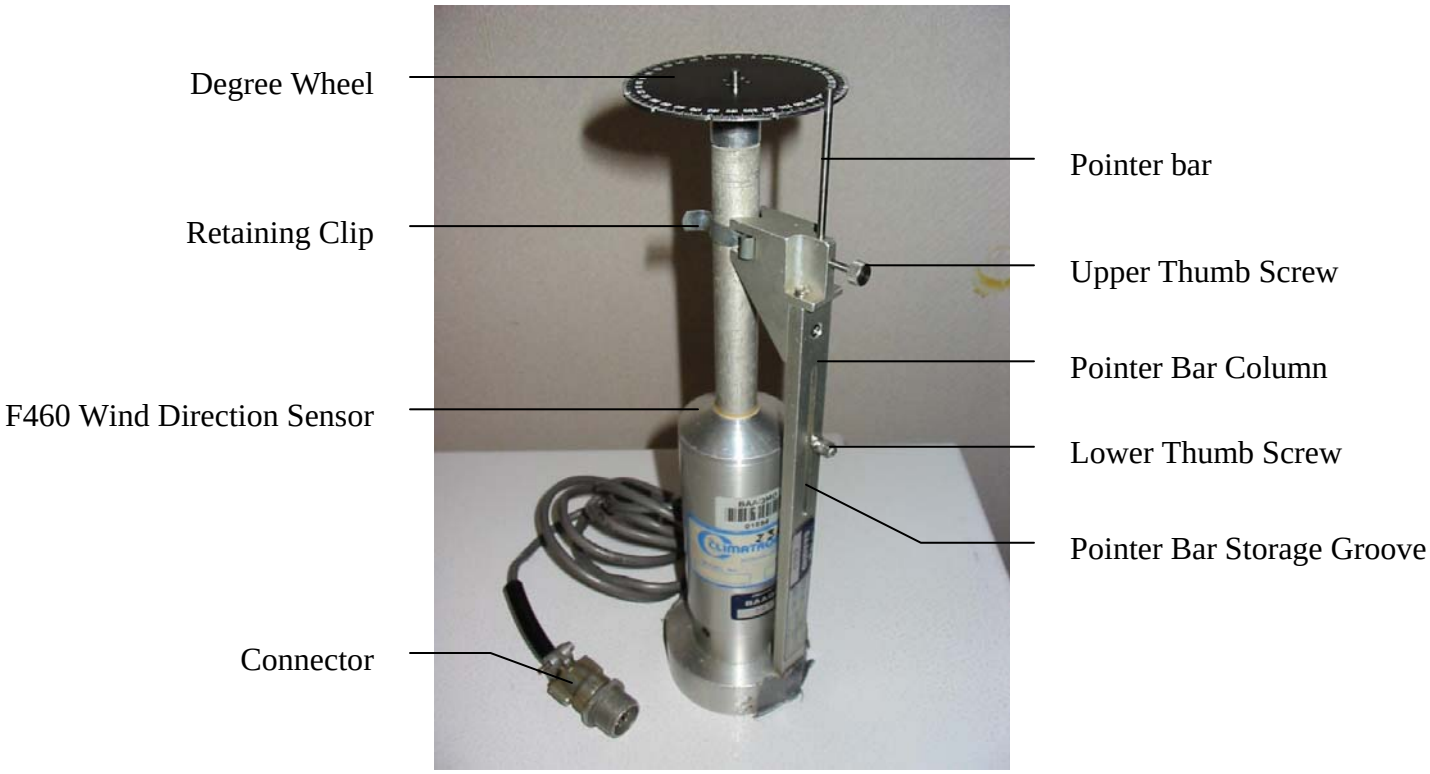

Figure 5
Climatronics 101984 Degree Fixture with
Degree Wheel and F460 Wind Direction Sensor

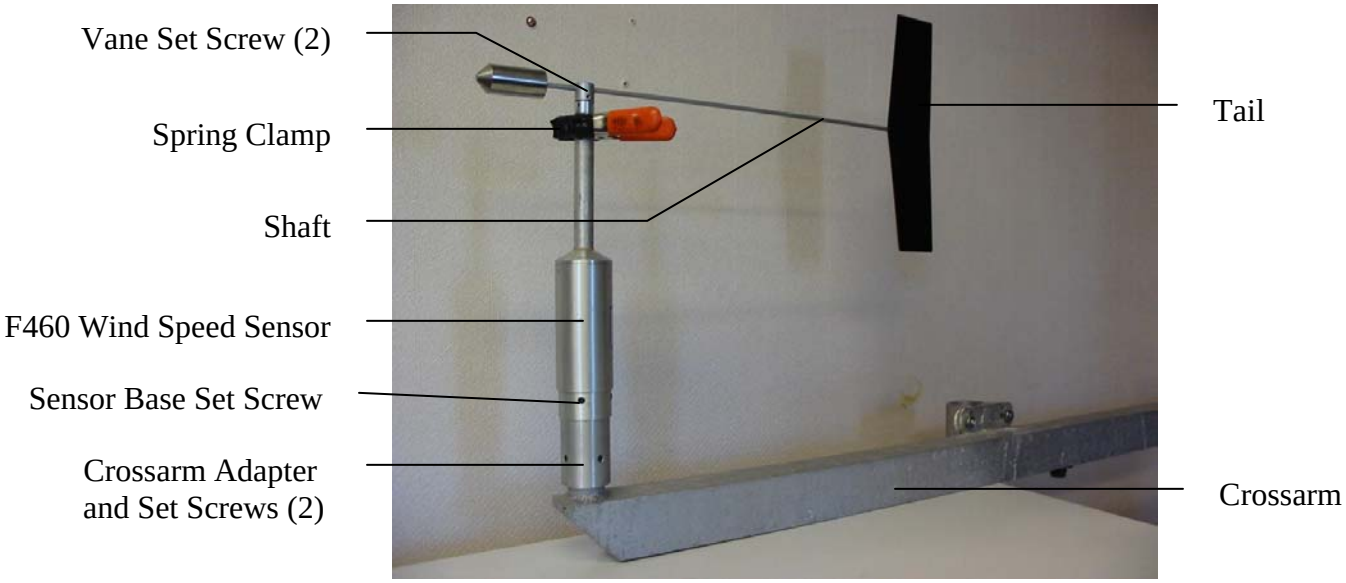

Figure 6:
Climatronics Crossarm, Wind Direction Sensor,
Wind Vane, and Spring Clamp.

AUDIT EQUIPMENT

1. Tamaya Transit
1. Brunton Pocket Transit with transit mount.
2. Tripod.
3. Garmin eTrex GPS.
4. R.M. Young 18312 Torque Disc with 1.0g and 0.1g screws.
5. Climatronics 101984 Degree Fixture.
6. Climatronics 101137 Degree Wheel.
7. Campbell CR10KD Keypad Display.
8. 1/16” and 1/8” hex keys.
9. Spring Clamp.
10. Laptop with Solsite and WDDiff programs.
11. Field Binder with UTM site coordinate sheet.
12. Wind Direction (Magnetic and GPS) and Linearity Worksheet (Appendix A, B, and C).

AUDIT PROCEDURES

CROSSARM ORIENTATION (MAGNETIC SITING)

The crossarm orientation is verified before the wind direction sensor orientation, 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. During winter and summer audits, a magnetic sighting on the crossarm is accurately performed to verify its orientation. In fall and spring, a GPS is used to check the orientation.

Tamaya Transit (Figure 1)

1. From the tower, go out ~50 feet along a line parallel to the length of the crossarm. The side of the crossarm with the wind speed cups is the “along” side. The side of the crossarm with the wind direction vane is the “opposite” side. To avoid confusion, it is recommended that you start on the “along” side.

2. Set the tripod on a flat stable surface. Loosen and extend the legs until the tripod stands about chest high with the legs spread about three and a half feet apart. Tighten the legs.

3. Attach the Tamaya transit to the tripod securely, hand tightening the *lower clamp screw* to the tripod head.

4. Loosen the *locking screw* so the compass needle can rotate freely.

5. The Tamaya can be affected by magnetic materials generated by magnetic materials on your body (mobile phones, watches, belt buckles, etc.). If the compass needle moves as you slowly approach it to take a reading, it is being affected. Remove any materials that may be causing this. Other materials in the environment (underground metal objects, railroad tracks, power lines, automobiles, etc.) may also affect the readings. As long as these objects are stationary, the effects will be compensated for in the magnetic declination using the Brunton pocket transit. If the interfering object is moving (i.e. an automobile), move the tripod and Tamaya to a different location or wait until the offending objects are far enough away before taking readings.

6. Aim the telescope in the general direction of the crossarm by sighting along the top of the telescope tube. Tighten the *upper clamp screw* sufficiently but not too tight so that the base can be leveled by hand with some resistance. If further required, aim the telescope by rotating the unit at the base. **CAUTION: Do not look at or near the sun with the telescope.**

7. Level the transit using the two *level indicators*. Be careful not to touch the tripod during or after leveling.

8. Sight through the eyepiece. Bring the cross hairs into focus by turning the *eyepiece focusing ring*. Focus the telescope by turning the *focus knob* until the crossarm and sensors are sharp and clear. Make final adjustments of the telescope by rotating the *horizontal tangent screw* and the *vertical tangent screw*. The cross hairs should be parallel to the side of the crossarm on either side. It will most likely be necessary to move the scope/tripod assembly to a difference position (to the left or right) until the cross hairs are perfectly aligned with the side of the crossarm. Finally, check again that the base is level via the level indicators. If not, level the unit and site again.

9. The needle on the compass has a copper coil on one end. Take the azimuth angle reading with the side of the needle with the coil facing you, using a magnifying glass if necessary. Record the value in the space labeled *Mag* in the audit sheet (Appendix A).

10. Lock the compass needle by tightening the compass locking screw.

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

<u>Brunton Pocket Transit</u> (Figure 2)

12. Power on the GPS, go to the *time* screen, and set aside while the time is automatically updated (~ 2 min).

13. Attach the transit mount to the transit, then the mount to the tripod.

14. Open the mirrored lid and face the mirror towards the sun. Fold the *large sight* out, set it perpendicular to the bottom case, and flip the *peep sight* up all the way.

15. When the mirror is faced directly at the sun, the vertical *center line* running down the center of the mirror casts a shadow onto the *peep sight*. Adjust the angle of the mirror and rotate the unit until the reflected line is visible and just to the right side of the *peep sight* center mark.

16. Center the *round level* and recheck that the reflected line is just to the right side of the *peep sight* center mark. If not, repeat steps 4 and 5.

17. As the sun moves, the line will approach the center mark. Using the time from the GPS, record the exact time when the reflected line reaches the center mark in the space (*along* or *opposite*) labeled *Time* in the audit sheet.

18. Record the azimuth angle in the space labeled *Az* in the audit sheet.

19. Close the cover on the transit. Remove the transit mount from the transit. Place the transit in its carrying case.

<u>Orientation Calculations</u>

20. Run the program *Solsite* on the laptop computer. When prompted, enter the UTM coordinates of the site (a list of UTM coordinates of all sites can be found in the field binder), the time, and azimuth angle recorded with the Brunton. The program will output the magnetic declination. Record this in the space labeled *Dec* in the audit sheet.

21. The true orientation is the sum of the magnetic angle (*Mag*) and declination (*Dec*). Write down the true orientation in the space labeled *True* in the audit sheet.

22. Go to the *opposite* side of the tower and repeat the process of finding true crossarm orientation by repeating steps 1-21.

23. Either add or subtract 180º to/from the *opposite* true orientation while keeping this new value between 0º and 359.9º. Average this new value with the *along* true orientation and place the result in the spaces labeled *Old Along* and *New Along*.

24. The *Old Opposite* and *New Opposite* values are calculated by adding or subtracting 180º to/from the *Old Along* value (keep this value between 0º and 359.9º).

CROSSARM ORIENTATION (GPS)

1. Power on the GPS (Figure 3). Go to the *compass* screen and wait for the position to update (~2 min). When ready to use, it should indicate an accuracy of less than or equal to 20 feet.

2. From the tower, go out ~50 feet along a line parallel to the length of the crossarm (either side). The side of the crossarm with the wind speed cups is the *along* side. The side of the crossarm with the wind direction vane is the *opposite* side. Note which side you are on.

3. Face the crossarm and align yourself along the parallel line. Have an assistant stand directly behind, also on the line.

4. As straight and smooth as possible, walk along the line towards the crossarm. As you walk, the compass reading will be displayed on the GPS but may vary by as much as ±4º. Record the average reading in the appropriate space (along or opposite) in the GPS audit sheet (Appendix B).

5. Turn around and walk towards the assistant while observing the reading displayed on the GPS. Record the average reading in the appropriate space in the GPS audit sheet.

6. Repeat steps 4 and 5 for a total of 3 *along* and 3 *opposite* readings in the audit sheet.

7. Either add or subtract 180º to/from all three *opposite* readings while keeping the results between 0º and 359.9º. The *Old Along* and *New Along* values are found by averaging these three new values and the three *along* readings.

8. The *Old Opposite* and *New Opposite* values are calculated by either adding or subtracting 180º to/from the *Old Along* value while keeping this value between 0º and 359.9º.

INITIAL SENSOR VERIFICATION

U.S. EPA Volume IV, Meteorological Measurements states that wind direction accuracy should be less than or equal to 3 degrees from the sensor mount, and less than or equal to 5 degrees total error. Both of these parameters will be verified when measured values are keyed into the linearity worksheet on a computer. As a precautionary measure in the field, a sensor with greater than 4º of non-linearity (see step 15) and 2º of hysteresis (see step 16) should be replaced.

NOTE: Flag 1 – a software flag – is set *high* during audits to disable audit data from recording to memory. To prevent data loss when a tower operator forgets to re-enable data recording, the program automatically does so after 3 hours. A program timer in

input location 10 keeps track of the time by incrementing once per second. When the timer reaches 10800 (the number of seconds in 3 hours), flag 1 is set *low*. Tower operators should always (1) check that the timer is zeroed before disabling data recording and (2) clear the timer after enabling data recording. Failure to do so may cause the timer to reach 10800 before the full 3 hours and, as a result, enable audit data to be recorded to memory.

1. Plug the CR10KD Keypad Display (keypad) into the 9-pin socket on the CR10 wiring panel (a CR10X may also be used).

2. On the CR10KD, press *C1955A to disable security.

3. View the program timer by pressing *6, and then A repeatedly to input location 10. If the program timer is not zero, clear it by pressing C0A.

4. Press *6AD to access the software flags. The first digit from the left represents the state of flag 1, the second from the left – the state of flag 2, etc.

5. Set flag 1 high to disable data recording to memory. – 0 is *low*, 1 is *high*. If flag 1 is *low*, then press 1 to toggle it *high*.

6. Display wind direction in *input location 2* by keying in *6AA.

7. Turn the wind vane on the wind direction sensor so that the tail is facing *in* towards the center of the crossarm (Figure 6). Hold the vane in place with the spring clamp so that the sensor cap is "locked" with the sensor body. With the help of an assistant, adjust the vane until its shaft is parallel with the edge of the crossarm. *NOTE: During windy conditions (greater than ~5 m/s), the vane may not stay in position. If this is the case, replace the vane with a tail-less vane before aligning it with the crossarm.*

8. In the row labeled *Old Along* in the audit sheet, record the keypad readout in the space under the row labeled *Along*. Remove the clamp.

9. Turn the wind vane so that the tail is facing *out* away from the crossarm. Place the spring clamp on the sensor and adjust the vane so that the shaft is parallel to the crossarm.

10. In the row labeled *Old Opposite*, record the keypad readout in the space under the row labeled *Measured*. Remove the clamp.

11. Remove the wind vane and wind direction sensor from the crossarm.

12. Inspect the wind vane for damage. If there is damage, replace the vane. If the shaft is bent, you may carefully straighten it by hand.

13. Plug the connector at the end of the cable on the Climatronics degree fixture into the crossarm. Plug the sensor into the fixture base by aligning the slot in the wind direction sensor with the pin in the fixture base.

14. Loosen the *lower thumb screw* (refer to Figure 5) on the back of the *pointer column* to slide the *pointer bar* out of its *storage groove*. Tighten the upper thumb screw. Loosen the *upper thumb screw* and slide the pointer bar into the hole located at the top of the pointer bar column. Tighten the upper thumb screw against the pointer bar.

15. Place the *degree wheel* over the shaft and rotate the sensor cap until the dial hub fits on the stepped portion on the bottom of the wheel. Rotate the wheel clockwise so that the index end of the pointer bar is in the 0º notch. The sensor should provide an output of close to 0º at the keypad. Have the assistant record the keypad readout on the linearity audit worksheet (Appendix C).

16. Rotate the degree wheel clockwise in 30º increments until 330º is reached. After each rotation, the assistant should record the wind direction readout at the keypad.

17. The same procedure must now be done in the counterclockwise direction. Rotate the degree wheel clockwise past 0º to 330º. Then rotate it counterclockwise to 0º. Have the assistant record the keypad readout on the linearity audit sheet.

18. Rotate the degree wheel counterclockwise from 330º in 30º increments until 30º is reached. After each rotation, the assistant should record the wind direction readout at the keypad.

19. Check for excessive sensor non-linearity. Identify the highest and lowest error (*WD Bearing* minus *Ref Angle*) on the linearity sheet. If the difference between the highest and lowest error exceeds 4º, replace the sensor and re-test in the lab.

20. Check for excessive hysteresis. Take the difference between the clockwise and counterclockwise measured value of each reference angle. If the absolute value of this difference exceeds 2º, replace the sensor and re-test in the lab.

21. Remove the degree wheel, remove the pointer bar out of the pointer column and place it into the storage groove. Tighten the upper thumb screw. Unplug the connector from the crossarm and remove the sensor from the degree fixture.

STARTING TORQUE TEST

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 (see *Audit Calculations*). 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 starting threshold is calculated using the measured torque (gm-cm) and the manufacturer's K factor:

$$\textit{Starting Threshold} = (\textit{Measured Torque/K Factor})^{1/2}$$

The K-factor for the Climatronics F460 wind direction sensor and heavy duty wind vane is 29.8. The transfer function for starting threshold *st* given measured torque *tq* is:

$$st = \left(\frac{tq}{29.8}\right)^{1/2} \qquad [1]$$

The maximum starting threshold is 0.5 m/s. This is equivalent to a maximum starting torque of 7.5 g-cm.

1. Go to an area free of wind or excess air movement (usually inside the vehicle). Rotate or spin the shaft while listening to the sound of the bearings. Note any sounds of abrasion or scraping.

2. The maximum wind direction threshold is 0.5 m/s. Using the transfer function provided (see worksheet), this equates to a maximum threshold torque of 9 g-cm.

3. Attach the torque disc (Figure 4) to the sensor by sliding the disc all the way into the shaft so that the mating surface at the center of the disc is flush with the surface of the sensor cap.

4. Rotate the disc against the sensor cap so that the holes are on the line created by the notch on the sensor cap. Place the sensor on its side on a flat surface which provides comfortable access and orient the disc such that the holes are horizontally positioned from the shaft.

5. There are a total of 10 holes on the disc – 5 on each side. Attach the 1.0g stainless steel screw onto the side that would cause the disc to rotate clockwise. The weight of the screw times the distance from center determines the gram-centimeters (g-cm) torque. 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 5 degrees downwards from horizontal), the torque has been measured at that position.

6. Measure the maximum starting torque over the entire 360 degree clockwise rotation. Slowly and carefully rotate the sensor in the direction that moves the weight higher than at equilibrium. If the weight goes above the height of the shaft at any position, the torque indicated by the position of the weight has been exceeded and the weight will have to be moved closer towards the outer edge of the torque disc. Above 5 g-cm, you may attach more screws to increase the torque. For example, the torque can be set to 7.5 g-cm – the maximum passing torque – by placing the 0.1g weight at 5 cm and the two 1.0g weights at 3 cm and

4 cm. Repeat this process until the minimum torque threshold is found throughout the entire 360 degree range.

7. Remove the screw and attach it on the other side of the disc. Repeat step 4–6 in the counterclockwise direction to find the minimum torque threshold.

8. Record the larger of the two threshold values (clockwise and counterclockwise) in the audit sheet. Calculate and record the starting threshold according to the given transfer function (equation 1).

9. The maximum allowed threshold torque is 7.5 g-cm. As a preventive measure, replace the sensor if the starting torque value exceeds 5 gm-cm.

10. Remove the torque disc from the sensor (*NOTE: Be sure to lift the disc off the sensor shaft by pulling from close to the center of the disc or else the disc may bend and/or crack*).

FINAL SENSOR VERIFICATION

1. Reinstall the sensor and wind vane onto the crossarm.

2. Align the wind vane with the crossarm in the *along* position. If the reading differs by more than 0.5º from the reference direction, adjust the *crossarm adapter* (Figure 6) on the crossarm. Loosen the *crossarm adapter set screws*. With the help of the assistant, rotate the mount with the sensor until the wind vane shaft is parallel to the crossarm. Tighten the set screws.

3. To prevent rust from forming on the vane, sensor base, and sensor mount set screws, apply silicone grease in the set screw holes to keep out moisture.

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

5. Check the data. Visually determine the general direction the wind vane is facing and compare it to the reading on the keypad display. If they are not close, take corrective action as necessary.

6. Set flag 1 *low* if data recording no longer needs to be disabled (e.g. the wind speed and temperature audit is complete). Display flags in the CR10KD (*Initial Sensor Verification* step 2), then press 1 to toggle flag 1 *low* to resume data recording.

7. Clear the program timer (*Initial Sensor Verification* step 3). You may have to first disable the program security (*Initial Sensor Verification* step 2) depending on how much time has elapsed since it was last disabled.

WIND DIRECTION ERROR CALCULATION

In the audit worksheet, *Difference* is the error due to sensor orientation at the measured angle. It is calculated by the following:

Difference = Reference Value – Measured Value [2]

Corrected Difference is calculated with the *WDDiff* program in the laptop or lab computer. It is the orientation error after correcting for the linearity error at the measured angle.

In the field or lab, the measured values (*WD bearing*) of the linearity test and *Corrected Difference* (top left) are to be entered into the Excel Linearity spreadsheet (see Appendix C). The spreadsheet will calculate the mean error and *normalize* all measurements referenced from the mean error. The *Average Error* is the average of the clockwise and counterclockwise *normalized* errors at each reference angle. Finally, *Total Error* is the sum of the *Corrected Difference* (orientation error) and *Highest Linearity* (sensor error). *U.S. EPA Volume IV, Meteorological Measurements* specifies that *Total Error* at each reference angle should be less than or equal to 5º.

1. Calculate and record the *Difference* onto the audit worksheet (equation 2) in the rows labeled *Old Along*, *Old Opposite*, *New Along*, and *New Opposite*.

2. Run *WDDiff* on the laptop or lab computer. When prompted, enter the *Reference Angle* and *Measured Angle* from the *Old Along* column in the audit worksheet and the *Average Linearity Error* at the specified angles from the linearity worksheet.

3. Record the output (*Corrected Difference)* onto the audit worksheet.

4. Enter all the linearity test measurements and *Corrected Difference* onto the Excel Linearity spreadsheet.

5. In the spreadsheet, identify the *Average Error* value that results in the largest *Total Error* value. Record this *Average Error* value in the audit worksheet in the space labeled *Highest Linearity*. Record this *Total Error* value from the spreadsheet onto the audit worksheet in the space labeled *WD Total Error*.

6. As a final check in the audit worksheet, the sum of *Corrected Difference* and *Highest Linearity* should equal *WD Total Error* as shown on the linearity worksheet.

PREVENTATIVE MAINTENANCE

TAMAYA TRANSIT

1. 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.
2. Lock the compass needle by tightening the compass locking screw and store it in its case when not in use.

BRUNTON POCKET TRANSIT

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

GARMIN ETREX GPS

When the unit reports low battery voltage, replace the 2 AA batteries.

R.M. YOUNG TORQUE DISC

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

CLIMATRONICS 101984 DEGREE FIXTURE

1. Always keep the pointer bar in the storage groove and both thumb screws tightened when not in use.
2. Keep the connector plugs clean and protect the electrical cable from damage.

CALIBRATION AND CERTIFICATION

TAMAYA TRANSIT

The Tamaya transit does not need to be calibrated. It should be repaired if any components are broken.

BRUNTON POCKET TRANSIT

The Brunton pocket transit does not need to be calibrated. It should be repaired or replaced if any components are broken.

GARMIN ETREX GPS

The Garmin GPS will display a message when it needs to be calibrated. To do so, follow the instructions give on the screen.

R.M. YOUNG TORQUE DISC

The 1.0g stainless steel and 0.1g black screws should be weighed quarterly with a precision scale. The tolerances are ±0.1g and ±0.01g, respectively.

CLIMATRONICS 101984 DEGREE FIXTURE

The accuracy of this fixture is based on condition of its parts. On a quarterly basis, ensure that the retaining clip and degree wheel is in good condition, and that the pointer bar is straight.

AUTHORS, REVISIONS, AND APPROVALS

August, 2007 (Original Version)
Author: Jiawei Toh, Air Quality Instrument Specialist I
Approved: Dick Duker, Meteorology and Quality Assurance Manager

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APPENDIX A

BAAQMD CALIBRATION RECORD

WIND WORKSHEET (MAGNETIC)

BAAQMD CALIBRATION RECORD

Site Name _____ Start Time _____(pst) Finish Time _____(pst)

Auditor _____ Logger Clock Diff: _____ Logger Model No **CR10**

Date __ /__ /__ Logger Serial No _____ Last Audit Date _____

WIND SPEED & DIRECTION SENSOR:

Sensor Mfg	**Climatronics**	Old WD SN	
Model No	**F460**	Old WS SN	
Sensor Ht		New WD SN	
		New WS SN	

EPA PASSING CRITERIA[1]:

WS Max Difference:	**0.22 m/s**
WS Starting Threshold:	**0.5 m/s**
WD Total Error:	**5 deg**
WD Starting Threshold:	**0.5 m/s**

[1] *EPA-454/R-99-005 Meteorological Guidance for Regulatory Modeling Applications Table 5-1*

WIND SPEED TEST:

No.	rpm's	Reference	Measured	Difference
1	0	0.0	_____	_____
2	30	0.93	_____	_____
3	100	2.57	_____	_____
4	200	4.92	_____	_____
5	300	7.27	_____	_____
6	600	14.32	_____	_____
7	1200	28.42	_____	_____

Transfer Function (rpm to m/s): (rpm)/42.55+0.2235

WS Max Difference: _____

Results: Pass/Fail

Torque Test: Rotation ☐ Disk☐ _____ g-cm

WS Starting Threshold: $(T/1.4)^{½}$ _____ m/s

Results: Pass/Fail

WIND DIRECTION TEST:

2. Calculate from Wddiff.exe program total error.

3. Average Error column value that results in highest total error.

Object	Reference	Measured (Adjust if diff. > 1 deg.)	Difference	Corrected Difference[2]	Highest Linearity[3]	WD Total Error
Old Along	_____	_____	_____	_____°	_____°	_____°
Old Opposite	_____	_____	_____			
New Along	_____	_____	_____			
New Opposite	_____	_____	_____			

Results: Pass/Fail

WD Torque Disk Test: _____ g-cm

WD Starting Threshold: $(T/29.8)^{½}$ _____ m/s

Results: Pass/Fail

CROSSARM REFERENCE CALCULATION: (re-shoot if >15 deg diff. front/back)

Along: Mag.=	_____	Dec.=	_____	True=	_____	Az.=	_____	Time=	_____
Opposite: Mag.=	_____	Dec.=	_____	True=	_____	Az.=	_____	Time=	_____

COMMENTS:

Auditor: _____

APPENDIX B

BAAQMD CALIBRATION RECORD

WIND WORKSHEET (GPS)

BAAQMD CALIBRATION RECORD

Site Name _____ Start Time _____(pst) Finish Time _____(pst)

Auditor _____ Logger Clock Diff: _____ Logger Model No **CR10**

Date __ /__ /__ Logger Serial No _____ Last Audit Date _____

WIND SPEED & DIRECTION SENSOR:

Sensor Mfg	**Climatronics**	Old WD SN	
Model No	**F460**	Old WS SN	
Sensor Ht		New WD SN	
		New WS SN	

EPA PASSING CRITERIA[1]:

WS Max Difference:	**0.22 m/s**
WS Starting Threshold:	**0.5 m/s**
WD Total Error:	**5 deg**
WD Starting Threshold:	**0.5 m/s**

[1] *EPA-454/R-99-005 Meteorological Guidance for Regulatory Modeling Applications Table 5-1*

WIND SPEED TEST:

No.	RPM's	Reference	Measured	Difference
1	0	0.0	_____	_____
2	30	0.93	_____	_____
3	100	2.57	_____	_____
4	200	4.92	_____	_____
5	300	7.27	_____	_____
6	600	14.32	_____	_____
7	1200	28.42	_____	_____

Transfer Function (rpm to m/s): (rpm)/42.55+0.2235

WS Max Difference: _____

Results: Pass/Fail

Torque Test: Rotation ☐ Disk☐ _____ g-cm

WS Starting Threshold: $(T/1.4)^{½}$ _____ m/s

Results: Pass/Fail

WIND DIRECTION TEST:

2. Calculate from Wddiff.exe program total error.

3. Average Error column value that results in highest total error.

Object	Reference	Measured	Difference	Corrected Difference[2]	Highest Linearity[3]	WD Total Error
Old Along	_____	_____	_____	_____°	_____°	_____°
Old Opposite	_____	_____	_____			
New Along	_____	_____	_____			
New Opposite	_____	_____	_____			

Results: Pass/Fail

WD Torque Disk Test: _____ g-cm

WD Starting Threshold: $(T/29.8)^{½}$ _____ m/s

Results: Pass/Fail

CROSSARM REFERENCE CALCULATION GPS: (GPS accuracy must be < 20 ft.)

Along: 1)_____ 2) _____ 3)_____

Opposite: 1)_____ 2) _____ 3)_____

COMMENTS:

Auditor: _____

APPENDIX C

BAAQMD CALIBRATION RECORD

SENSOR LINEARITY WORKSHEET

Site:
WD Sensor:
Date:
Corrected Diff:

Ref Angle	Rotation	WD Bearing	WD Error	Hysteresis	Normalized	Average Error	Total Error
0	cw		0.00		165.00		
30	cw		-30.00		135.00		
60	cw		-60.00		105.00		
90	cw		-90.00		75.00		
120	cw		-120.00		45.00		
150	cw		-150.00		15.00		
180	cw		-180.00		-15.00		
210	cw		-210.00		-45.00		
240	cw		-240.00		-75.00		
270	cw		-270.00		-105.00		
300	cw		-300.00		-135.00		
330	cw		-330.00		-165.00		
0	ccw		0.00	0.00	165.00	165.00	165.00
330	ccw		-330.00	0.00	-165.00	-165.00	-165.00
300	ccw		-300.00	0.00	-135.00	-135.00	-135.00
270	ccw		-270.00	0.00	-105.00	-105.00	-105.00
240	ccw		-240.00	0.00	-75.00	-75.00	-75.00
210	ccw		-210.00	0.00	-45.00	-45.00	-45.00
180	ccw		-180.00	0.00	-15.00	-15.00	-15.00
150	ccw		-150.00	0.00	15.00	15.00	15.00
120	ccw		-120.00	0.00	45.00	45.00	45.00
90	ccw		-90.00	0.00	75.00	75.00	75.00
60	ccw		-60.00	0.00	105.00	105.00	105.00
30	ccw		-30.00	0.00	135.00	135.00	135.00

Average error:	-165.00			
Average hysteresis Error		0.00		
Max hysteresis error:		0.00		
Max linearity error:			165.00	**FAIL**
Max linearity audit tolerance			±3	
Total Error of wind direction				165.00

Definitions:

WD Error: The difference between the Reference Angle and the Measured Angle.
Hysteresis: The difference between the two measured angles.
Normalized: The difference between the mean of the WD errors and the individual errors.
Average Error: The mean of the two normalized errors for each direction.
Total Error: The sum of the Corrected Difference and the Average Error.