DEPARTMENT OF
ECOLOGY
State of Washington

Meteorological Monitoring Procedure

Air Quality Program

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State of Washington
Department of Ecology
Air Quality Program

METEOROLOGICAL MONITORING PROCEDURE

Prepared by: Michael Thompson

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____________________________________ Date: ____________
Stu Clark, Air Quality Program Manager

____________________________________ Date: ____________
Mike Ragan, Air Monitoring Coordinator

____________________________________ Date: ____________
Stan Rauh, Quality Assurance Coordinator

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INTRODUCTION

The purpose of this document is to provide information and guidance to meteorological site operators. It should be used as the standard operating procedure for all meteorological stations operated as part of the Washington State monitoring network.

This document describes the guidelines for installing and operating meteorological monitoring sites in accordance with the EPA guidance document, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements Version 2.0. Topics covered include: site selection, site installation, quality control, maintenance, quality assurance, data recording and data quality assessment. In addition, this document provides the minimum requirements for meteorological data collection to support air quality impact analysis performed for programs administered by the Washington State Department of Ecology's Air Quality Program and its partners.

SITE SELECTION

The primary objectives when selecting a meteorological monitoring station location are to avoid the influence of obstructions such as buildings and trees on monitored data and to pick a location that is representative of the atmosphere in the area of interest. A secondary consideration is accessibility and security; however these considerations should not be allowed to compromise the quality of the data.

Wind Measurements

Wind measurements are typically taken over open, level terrain at a height of 10 meters. Open terrain is defined as an area where the horizontal distance between the instrument and any obstruction, man-made or natural is at least 10 times the height of that obstruction. See Figure 1.

In general, the siting of meteorological towers on top of buildings should be avoided. However, if the wind instruments are to be mounted on the roof of a building then the measurements should be taken high enough to be away from any turbulence caused by the building.

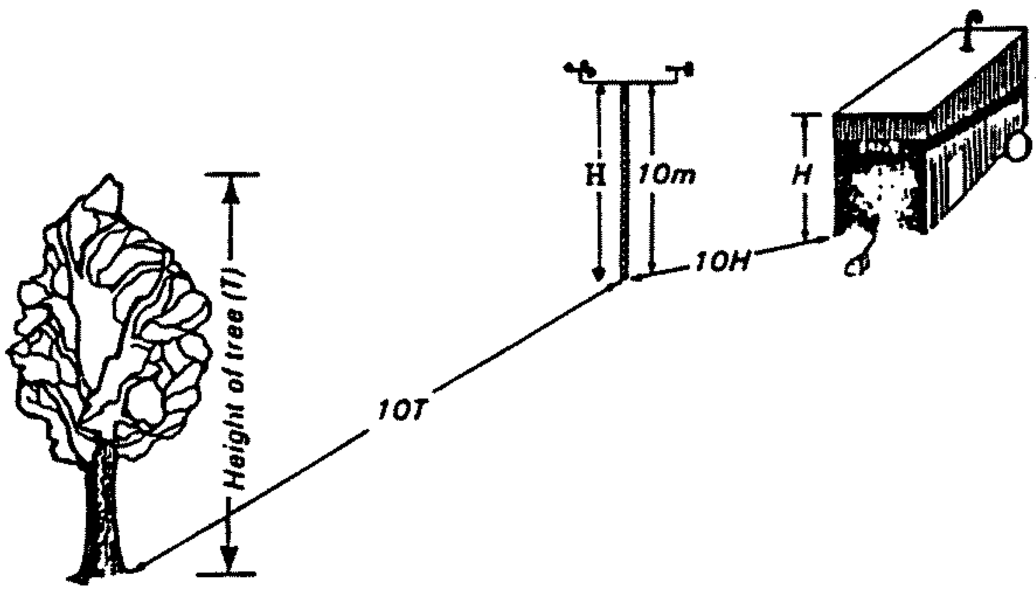

Figure 1: Distance from Obstructions

Temperature Measurements

Temperature measurements should be taken at a height of approximately 2 meters but not more than 10 meters above ground level. The temperature sensors must be protected from thermal radiation by mounting the sensors in naturally ventilated or motor-aspirated radiation shields. All temperature measurements should be taken over a level plot of ground at least 10 meters in diameter. Ground cover should be short grass, preferably non-irrigated, or natural earth.

Temperature sensors should be mounted at least 4 times the height of any obstructions away from that obstruction, and at least 30 meters away from large paved areas. Other siting situations to be avoided include:

- large industrial heat sources
- rooftops
- sheltered hollows
- high vegetation
- shaded areas
- swamps or areas where standing water can accumulate

Measurements should not be made near ridges, steep slopes or valleys unless those areas are of specific interest. Measurements taken close to bodies of water should be avoided due to the large temperature variations.

Atmospheric Pressure Measurements

Atmospheric pressure is the pressure exerted upon a unit area of the earth's surface by the atmosphere above and is generally reported in millibars (mb) or millimeters of mercury (mmHg). Sensors are usually placed 2 meters above ground level.

Relative Humidity Measurements

Relative humidity is the ratio of actual vapor pressure of moist air compared to the saturation vapor pressure at the same temperature, expressed as a percentage. Sensors are usually placed 2 meters above ground level.

Towers

Towers should be located over an open level area. Attention should be taken when choosing a site to ensure that the location is representative of the area under study and is free from obstructions that might affect the measurements.

Towers should be of the open lattice variety to allow wind to flow through freely. Regardless of the type, the tower should be rugged enough to withstand substantial wind and adverse weather conditions. Tilt down, hinged base towers are rugged enough to keep the instrumentation properly oriented and provide easy access to the sensors.

Wind instruments should be mounted above the top of the tower on a boom or mast. If a crossarm is employed in the mounting of the wind instruments, the crossarm should be mounted perpendicular to the prevailing wind flow and at least one tower diameter above the top of the tower structure. This will ensure that wind measurements are not affected by the wind sensor bodies or the tower itself.

Station Siting

When choosing a meteorological monitoring location it is important to have a clear monitoring objective. This facilitates the selection of a site that best meets the objective. In some cases the purpose of the monitoring is to provide PSD quality meteorological data to be used for computer modeling in support of an existing air quality concern and/or as part of a PSD application requirement. Site selection requirements may differ for other objectives such as calling burn bans.

Once a location is selected, it must be documented in Ecology's Site Information Management System (SIMS) before installation can commence. Ecology employees can access the SIMS system using the following URL. http://ecyapps4/sims/index.aspx

INSTALLATION

Upon procurement and receipt of the meteorological instrumentation, but prior to installation, a complete acceptance testing program will be performed by the Repair and Calibration Unit to verify the operational status of the sensors. This acceptance test should include, but is not limited to: physical examination of all sensors, cables, and connectors and verification of equipment calibration.

Install the meteorological monitoring instruments according to the manufacturer's recommendations. The information contained in the manual includes instructions on:

- installation of the equipment
- calibration
- operation
- preventative maintenance
- troubleshooting

Tower

Properly installing a tower requires physical labor and specialized knowledge. Don't attempt to install the tower by yourself unless you are confident that you can properly complete the job. Hauling and mixing a considerable amount of concrete and water is required. You need to know how to properly use a carpenter's level, a transit, a plumb bob and various hand tools. It is recommended that tower installations be done by two people, one of whom should have prior experience.

All of the Washington State network meteorological stations use a 3-section 10-meter aluminum tower that is either 14 or 18 inches wide. A 3-foot square, 4-foot deep concrete footing is needed for ground based installations. Rooftop installations stand atop a 3-foot square, 4-inch deep concrete slab and are securely guyed. Larger towers require larger footings. Check manufacturer's recommendations for different towers.

Tower bases come in 2 varieties; an in-ground type and a rooftop type. Either type can be used for ground level installations but in-ground type tower bases cannot be used on rooftops.

Rooftop

A 3-foot square form should be constructed using 2x4 lumber. Attach 3 J-bolts to the rooftop base with 2 nuts on the upper and 2 on the lower side of the base. This allows for an adjustment nut and a lock nut on each side. Be mindful of the direction that the tower will fold down. Fill the form with concrete and sink the J-bolts into the concrete without sinking the lower nuts. Allow 48 hours for the concrete to cure.

Install the lower section of the tower to the base and use a carpenter's level to adjust the tower perpendicular to the horizon. Add the upper two sections of tower and stand it up. Readjust the base if necessary. Lower the tower and install guy wires.

In-Ground

Dig a 3-foot square hole, 4 foot deep. Attach the lower section of the tower to the base using the proper bolts. Place the in-ground base into the hole. Note the direction that the tower will fold down and make sure no obstructions will hinder completely collapsing the tower. Fill the hole with concrete, leveling as you pour. Do not fill above the hinges used to lower the tower. In-ground bases have no provision to level the tower once the concrete cures so it is important to immediately level the tower. Tamp the concrete and once again make sure that the tower is perpendicular with the horizon. Allow 3 or 4 days for the concrete to cure. Tilt the lower section to the ground and assemble the remainder of the tower according to manufacturer's recommendations.

Orientation

Install the 3-foot mast at the top of the tower. Slip the ring with the vane alignment rod over the mast. Place the anemometer atop the mast and temporarily tighten the clamp. Slide the vane alignment rod up to the base of the anemometer and position the key on the ring into the notch on the anemometer. Draw a circle around the mast, just below the ring of the vane alignment rod and remove the anemometer from the mast. The circle marks the final vertical position for the vane alignment rod.

All Air Quality Program anemometers are referenced to true north. This means that the vane alignment rod must be oriented on the true north/true south axis. There are a variety of methods used to find true north. Experimentation has shown that best results are obtained using the solar method so it will be explained here.

Obtain accurate coordinates of the tower's location using a hand-held Global Positioning System (GPS) unit. Find the time of day for solar noon using these coordinates. Solar noon is the precise time that the sun is at its highest angle above the horizon. There are many web-based computer programs available for determining solar noon. Solar noon is also the midpoint between sunrise and sunset. At this precise time, mark the ground at the shadow cast by the top of the mast. The shadow will move rapidly at this time of day so you must be accurate to within 15 seconds. An imaginary line drawn on the ground from the center of the tower to the mark on the ground is oriented to true north. A roll of twine may be useful to extend the point out farther away from the tower.

Set up a transit on the south side of the tower on this imaginary line, approximately 10 meters from the base of the tower. This must be done as accurately as possible. If fencing or other barriers prevent setting up the transit on the south side of the tower, set up the transit on the north side of the tower instead.

If possible, mark the transit's location with a bright colored spike to make it easier to find during future quality control checks and performance audits. Adjust the angle of the vane alignment rod using the transit so that it is oriented on the true north/true south axis and tighten the clamp. This may require raising and lowering the tower multiple times. Further explanation of this method can be found in EPA's document, "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV – Meteorological Measurements Version 2.0" or by searching for "solar noon" on the internet

Distant Object

Pick a stationary object some distance away that is likely to be visible year round. The farther away this object is from the tower the more precise your measurement will be during quality control checks. Radio towers and water towers make good distant objects. With the transit in line with the vane alignment rod, measure the angle from tower to distant object. Draw a diagram of the distant object and the documented angle. The diagram needs to be detailed enough that someone else can easily understand it. Send a copy to the Quality Assurance unit and keep a copy at the meteorological station, preferably on the wall inside the shelter.

QUALITY CONTROL (QC)

Quality control checks are used as a way of increasing confidence in collected data. Quality control checks must be performed by the operator at least every calendar quarter and any time a repair or replacement is made. The meteorological quality control check form can be found on the last page of this document. It should be used to record QC results and a copy of the completed form must be sent to the Air Quality Program's Quality Assurance Unit. An electronic version of the form is available from the Quality Assurance Unit. For safety, two staff must be present anytime the tower is raised or lowered.

Required Equipment

Specialized tools and measuring devices are required to perform QC checks on meteorological sensors. The table in figure 2 lists the minimum tools and measuring devices that are required to perform a QC check on the equipment at an Ecology Air Quality Program meteorological monitoring station.

Device	Vendor	Part Number
Vane Torque Gauge	R. M. Young	18331
Propeller Torque Disk	R. M. Young	18310
Anemometer Drive	R. M. Young	18802
Vane Angle Bench Stand	R. M. Young	18112
ASTM Thermometers	VWR & Others	Various
Insulated Bottle	Various	Various
Transit and Tripod	Various	Various
Altimeter/Barometer	Thommen	Classic

Figure 2: Necessary QC Equipment

QC Procedures

Data Collection

Disable logging of the data before lowering the tower or performing any QC procedures. Make an entry in the station log of all work performed and enable data logging prior to leaving the monitoring station.

Anemometer Orientation

This procedure is to be done prior to lowering the tower. Set up a transit on the south side of the tower, in line with the vane alignment rod. If fencing or other obstructions prevent setting up the transit on the south side of the tower, set it up on the north side of the tower. Alignment with the vane alignment rod is critical. For best accuracy make sure both ends of the vane alignment rod intersect the transit's reticle. Finding the proper spot to set up the transit will be easiest if a bright colored spike was placed in the ground marking the appropriate location during the initial installation. Measure the angle from the vane alignment rod to the distant object using the transit. Record this angle as distant object "measured" on the QC form. Record the "documented" distant object angle on the QC form. This is the angle that was documented at the time that true north was determined and a distant object was selected. It should have been written down in the station log and/or posted on the wall inside the station. Position the transit back on the vane alignment rod for verification of alignment after the QC check is complete and the tower is re-positioned upright.

Temperature

The temperature sensor must be compared to a National Institute of Standards and Technology (NIST) traceable thermometer. Because of the known toxicity of mercury, do not use mercury thermometers in the field. Very precise, electronic standards are available and should be used in lieu of mercury thermometers. Checks must be performed at two different temperatures to establish a high degree of confidence in the linearity of the system. Whenever practical, the sensor should be tested while connected to the data logger as it is during normal operation in order to mimic operational conditions as closely as possible and avoid electronic signal loss due to wiring resistance differences. If this is not practical the sensor may be disconnected and reconnected within the station's shelter.

Fill an insulated bottle with ice. Add enough water to create an ice bath. Place both the temperature sensor and the NIST traceable thermometer into the ice bath. Immerse them to the depth suggested by the manufacturers and stir vigorously until stable readings can be obtained on the thermometer and the data logger at the same time. It is helpful to have a second person reading the value from the data acquisition system. Record these values on the QC form.

Replace the ice bath with warm water at approximately 50°C and perform the same procedure to obtain a second set of values. Record these values on the QC form.

Delta Temperature

Stations that monitor delta temperature (△T) have one sensor mounted to the tower at 10 meters and another sensor at 2 meters above ground level. The sensors must be precise to within 0.1°C of each other and each must be accurate to within 0.5°C of an NIST traceable thermometer.

This procedure should be done with the temperature sensors connected to the data logger as they are during normal operation in order to mimic operational conditions as closely as possible and avoid electronic signal loss due to wiring resistance differences. The QC check is performed the same as a single temperature sensor check with the exception that both sensors and the traceable thermometer must be immersed in the baths at the same time. It requires some practice to be able to read the NIST traceable thermometer while stirring all three devices and keeping them immersed at the proper depth.

Wind Direction Accuracy

The sensor should be tested while connected to the system as it is during normal operation in order to mimic normal operational conditions as closely as possible. If this is not practical the sensor may be disconnected and reconnected within the station's shelter.

Place the anemometer on the Vane Angle Bench Stand shown in Figure 3 and position the protrusion on the stand into the notch on the anemometer located under the electrical connection box. Secure the anemometer by tightening the clamp with a screwdriver. The Vane Angle Bench Stand is marked with numbers that correspond with compass points. It is graduated in degrees of a circle with zero corresponding to north. Holding the base of the Vane Angle Bench Stand secure, rotate the anemometer through the compass points on the quality control check form and record the values reported by the data logger.

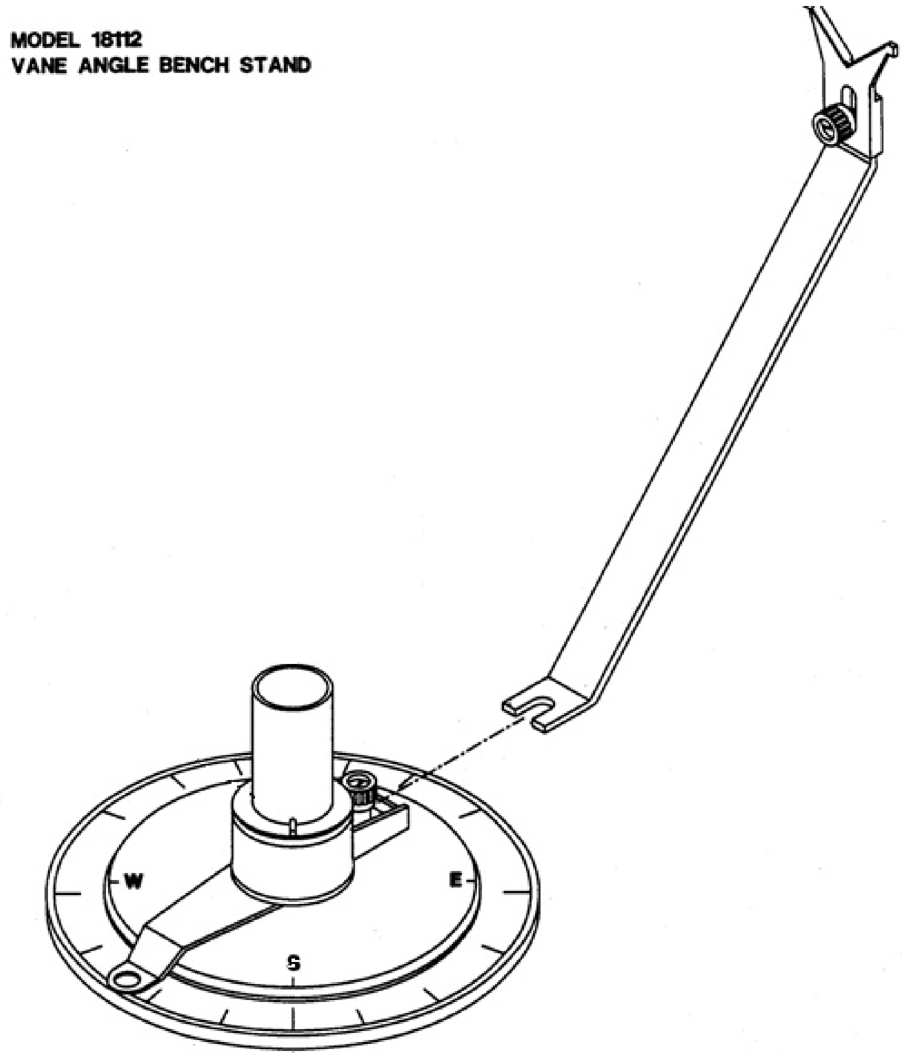

Figure 3: Vane Alignment Bench Stand

Wind Speed Accuracy

Remove the propeller from the anemometer. Connect the anemometer drive, seen in Figure 4, to the anemometer as recommended by the manufacturer. Check each speed listed on the quality control check form and record the speed reported by the data logger.

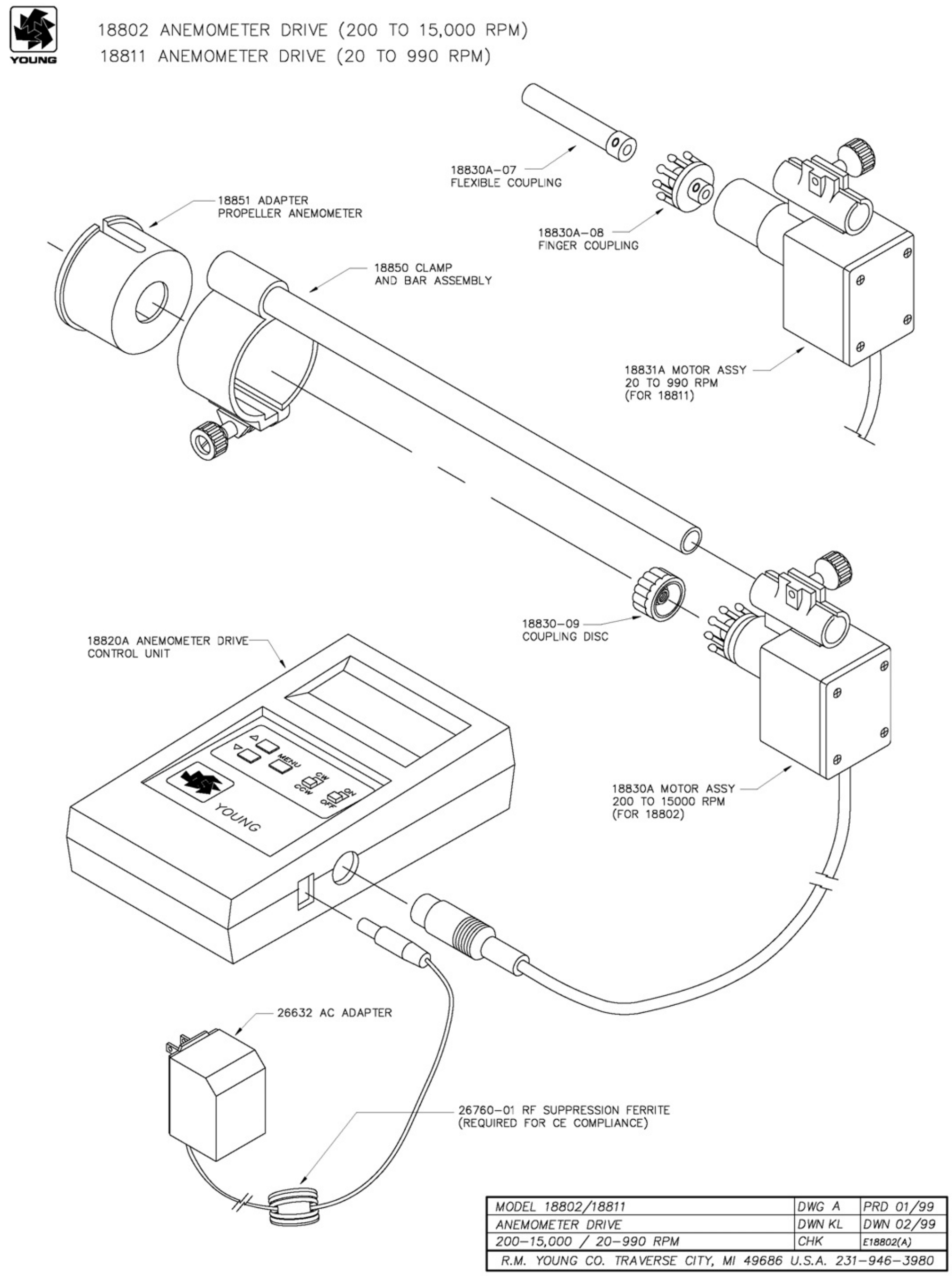

Figure 4: Anemometer Drive

Wind Direction Starting Torque
Secure the anemometer to the Vane Angle Bench Stand and place in a location that is both level and free of any wind turbulence. This usually requires unplugging the power supply and disconnecting the cable from the anemometer and taking it into an enclosed

location. Temporarily turn off any air conditioning or fans that are moving air within the enclosure. Position the Vane Torque Gauge seen in Figure 5 atop the anemometer as shown in Figure 6. Carefully pull on the thread attached to the leaf spring at the end of the Torque Gauge. This tests the torque that is required to move the anemometer from a rested position and should be performed at multiple vane angles. Record the highest value reported by the data logger on the quality control check form.

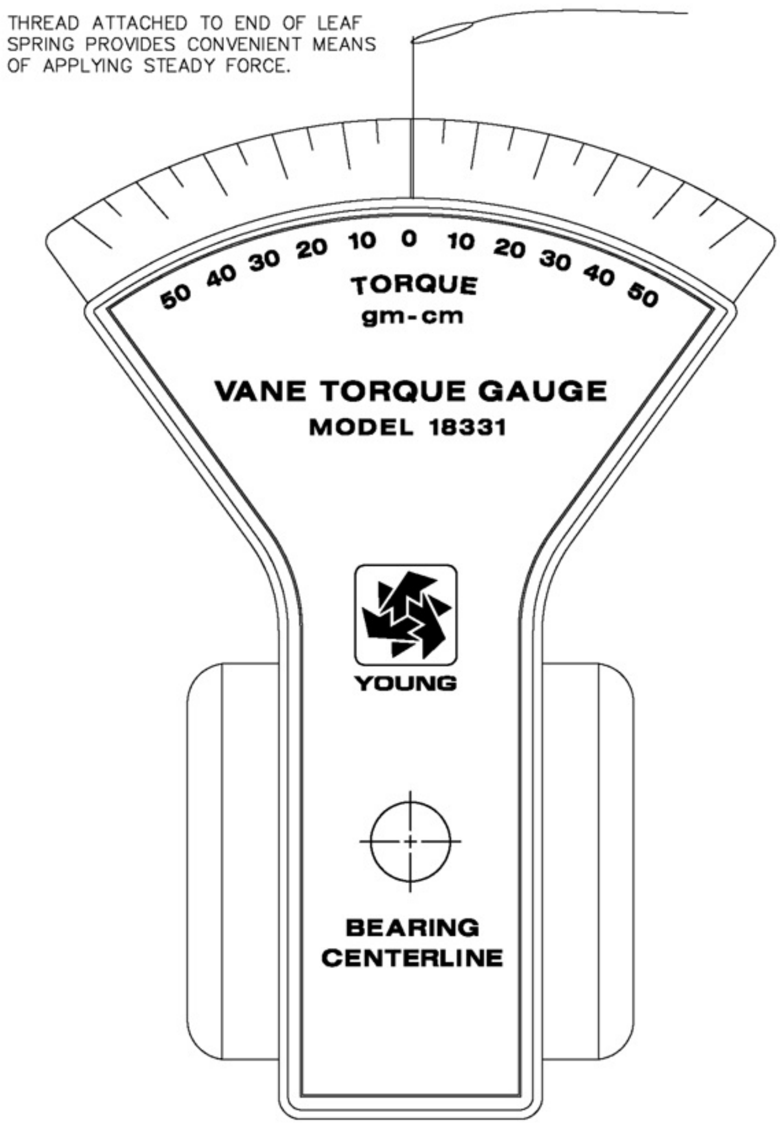

Figure 5: Vane Torque Gauge

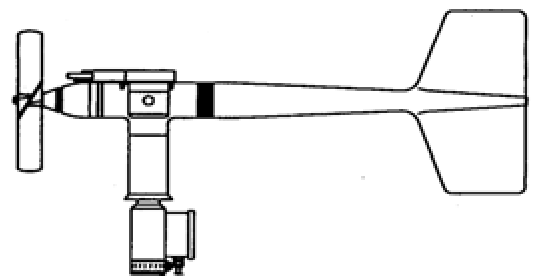

Figure 6: Positioning the Vane Torque Gauge

Wind Speed Starting Torque

Remove the propeller from the anemometer. Install the Anemometer Torque Disk and locking nut shown in Figure 7. Verify that the Disk is in balance with the anemometer assembly by setting the orientation of the screw holes to a variety of positions (at least six) and verify that the Disk does not turn when released.

Install the 0.1 gram black nylon screw on the left side of the Anemometer Torque Disk 1 centimeter from the center as seen looking at the disk from the front. Position the line of screw holes in the horizontal plane as shown in Figure 7. This imposes a 0.1 gram-centimeter torque in the direction the wind would turn the propeller.

If the Disk moves five degrees or more, this is the torque required to start the propeller shaft. If it does not move five degrees, increase the torque by moving the nylon screw outwards to the next hole on the disk and repeat the test. Moving from the center of the Disk outward, each hole adds 0.1 gram-centimeters. If five degrees of movement from horizontal cannot be achieved with the nylon screw in the hole at the outer perimeter of the Disk, replace the nylon screw with the metal screw that came with the Torque Disk and retest starting with the hole nearest the center of the Disk. The metal screw imparts 1.0 gram-centimeter of torque when installed in the hole nearest the center of the Disk. Each consecutive hole moving outward adds 1 gram-centimeter of torque.

It may be necessary to use two nylon screws or both the nylon screw and metal screw to obtain a starting torque value. As an example, with the metal screw in the hole nearest the center of the Disk and the nylon screw in the third hole from the center the torque applied to the propeller shaft is 1.3 gram-centimeters. Another example would be a nylon screw in the hole nearest the center of the Disk and another nylon screw nearest the perimeter of the disk for a torque of 0.6 gram-centimeters.

Record the minimum torque required to move the Disk five degrees from horizontal, on the QC form.

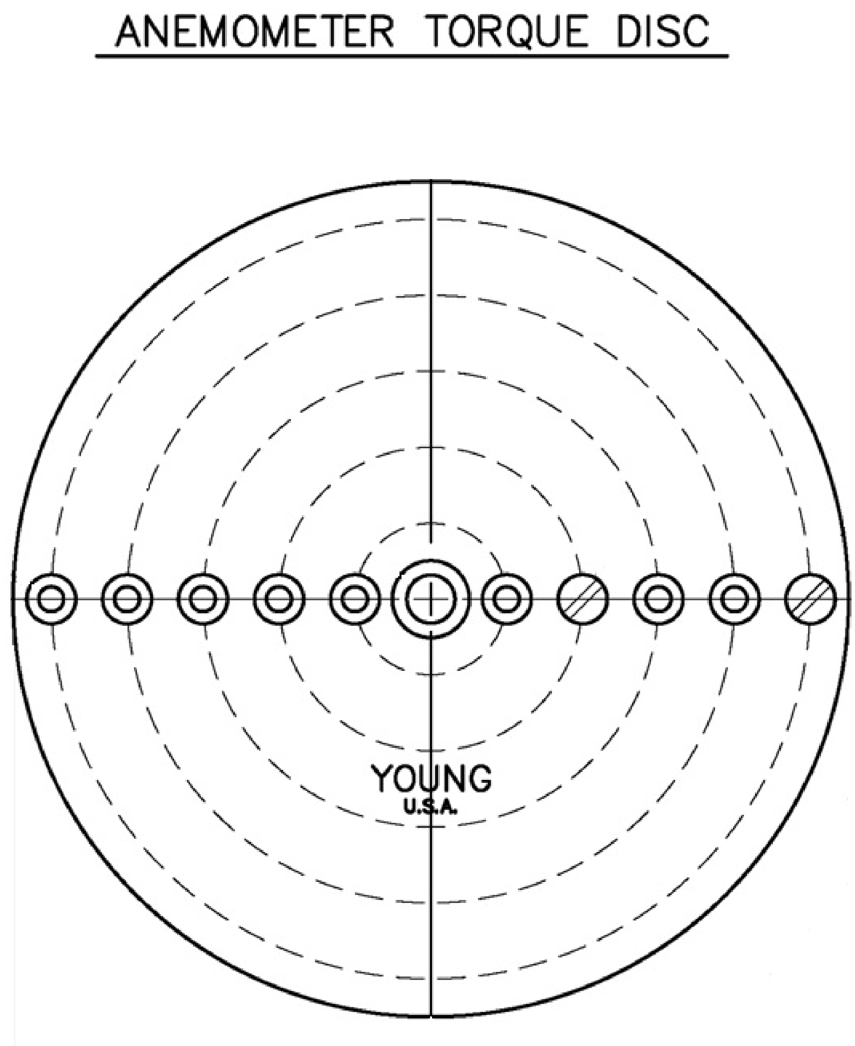

Figure 7: Anemometer Torque Disk

Relative Humidity
The only relative humidity sensor currently approved for use at Ecology's air monitoring stations is the Hygroclip sensor made by Rotronic. Quality control checks are performed using lithium chloride standards that are supplied by the manufacturer. A test chamber that isolates the sensor from the environment is also needed and can be purchased from Rotronic. A minimum of two points are to be checked.

Equilibration times vary depending on the humidity standard used. Values must be corrected to ambient temperature according to the manufacturer's recommendation.

Remove the screw-cap from the calibration chamber. Remove the sensor from the tower and carefully remove the filter from the end of the sensor. If the weather has been dry, removing the filter is not necessary. Insert the end of the sensor into the calibration chamber and tighten the environmental seal. Place one textile pad (supplied with standards) into the screw-cap of the chamber. While wearing gloves, tap the contents to the bottom of the chloride standard ampule and snap the top off. Completely empty the ampule onto the textile pad by tapping it lightly. Orient the chamber so that the opening is downward and replace the screw-cap. This is done so that excess liquid will not drip from the screw-cap onto the sensor. After the required equilibration time has passed, read the value recorded by the data logger and record it on the QC form along with the temperature-corrected standard value.

The calibration chamber must be thoroughly cleaned with water and dried before and after the next standard is used.

Atmospheric Pressure

The Air Quality Program's collection of atmospheric pressure data is limited. The R. M. Young model 61302V sensor is the only sensor currently being used. Station operators should compare the reading from their altimeter/barometer field standard to the station's pressure sensor at every station visit. A multi-point comparison will be done annually during the quality assurance audit.

Quality Control Limits

Quality control limits have been established for each parameter and are summarized in Figure 8. If the QC check results are outside the Failure Point then the QC check has failed and corrective action is required. If results of the QC check are at or above the Corrective Action Level, but below the Failure Point, corrective measures are highly recommended. Failure to take corrective action could lead to a failure during the next QC or QA check, resulting in invalidation of collected data.

Parameter	Corrective Action Level	Failure Point
Distant Object Angle		> 2.0°
Temperature	≥ ± 0.35°C	≥ ± 0.5°C of NIST
Delta Temperature		≥ ± 0.5°C of NIST OR ≥ ± 0.1°C between sensors
WD Accuracy	≥ ± 3.0°	≥ ± 5.0°
WD Torque	≥ ± 7 gm/cm	≥ ± 12 gm/cm
WS Accuracy		> ± 0.25 m/s @ 5 m/s or less > 5% @ speeds > 5 m/s
WS Torque	≥ ± 0.6 gm/cm	≥ ± 1.0 gm/cm
Relative Humidity	≥ ± 7 percentage pts	≥ ± 7 percentage pts
Atmospheric Pressure	≥ ± 3 hPa	≥ ± 3 hPa

Figure 8: QC Limits

QUALITY ASSURANCE (QA)

Quality Assurance (QA) checks/Performance Audits are performed by a quality assurance specialist annually. Two staff must be present anytime the tower is raised or lowered.

QA Procedure

The procedure used to perform quality assurance checks on meteorological equipment in the field is identical to that which is used by the station operator when performing the quality control check. The quality assurance specialist must use standards and measuring devices that are independent of those used by the operator.

EQUIPMENT CALIBRATION

Anemometers, relative humidity sensors and barometric pressure sensors require specialized equipment to calibrate. If one of these sensors requires calibration it must be returned to Air Quality Program’s Repair and Calibration Laboratory at Ecology Headquarters. Temperature sensors can be calibrated in the field.

MAINTENANCE

Maintenance on meteorological sensors requires specialized equipment and an environment that is conducive to performing detailed work. Therefore, a wind speed bearing change is the only maintenance that should be performed on an anemometer in the field. When equipment requires repair or calibration it must be returned to the Air Quality Program's Repair and Calibration Laboratory at the Ecology Headquarters.

DATA VALIDATION

The Air Quality Program's data acquisition system makes real-time data available to the operator. Operators should check data from their stations on a daily basis to ensure that monitors are functioning correctly. Operators should alert Quality Assurance personnel any time they discover an instrument problem or invalid data. The Quality Assurance Unit is responsible for final data validation.

DATA QUALITY ASSESSMENT

For each calendar quarter and year, the Quality Assurance Unit will prepare a quality assessment report.

Data Completeness

Data completeness will be determined for each parameter and will be expressed as a percentage. Percent valid data will be a gauge of the amount of valid data obtained compared to the amount expected under ideal conditions (24 hours per day, 365 days per year).

REFERENCES

1) "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV – Meteorological Measurements Version 2.0." EPA-454/B-08-002 March, 2008.

2) Code of Federal Regulations, Title 40, Part 58 (40 CFR 58).

3) Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD) EPA/450/4-87-07 May 1987

4) http://www.youngusa.com/

5) Wind System Calibration, R. M. Young, PN 18860-90, February 2003

AIRS No.	________	Date	________
Location	________	QC Technician	________
		Site Operator (if different)	________

Quality Control Check Results

Date of Last QC	________	Temp Probe Model #	________
Logbook Current (Y/N)?	________	Temp Probe Serial #	________
Wind Monitor Model #	________	RH Probe Serial #	________
Wind Monitor Serial #	________	Prop Serial #	________

Vane Alignment Test	
Dist. Object (Documented)	
Distant Object (Measured)	
Difference ($\pm 2^0$)	

Ambient Temperature Accuracy Test				
		ACT (C^0)	IND (F^0)	Diff ($\pm .5\ C^0$)
2 meter	Ice Bath			
	Hot Bath			
10 meter	Ice Bath			
	Hot Bath			

WS Torque Test ≤ 1.0 g/cm	
WS Torque CW	
WS Torque CCW	

WD Torque Test ≤ 12 g/cm	
WD Torque CW	
WD Torque CCW	

Ambient Relative Humidity Test			
Std Serial#	ACT	IND	Diff (±7)

Calibration Equipment Used		
Description	Model #	Serial #
Torque Disk	18310	None
Vane Torque Guage	18331	None
Speed Calibrator	18801	None
Transit		
ASTM Thermometer		
ASTM Thermometer		
ASTM Thermometer		

Wind Speed Accuracy Test Wind Speed Volts @ 100mph = 2.2369			
RPM	ACT	IND	Result
0	0.00		
600	6.87		
1200	13.74		
2400	27.48		
4800	54.96		

Wind Direction Accuracy Test Wind Direction Volts @ 540^0 = 5		
ACT	IND	± 5 Deg
5		
30		
60		
90		
120		
150		
180		
210		
240		
270		
300		
330		
350		
358		
270		
180		
90		
5		