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Meteorological Monitoring Procedure

by
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1. Introduction

This standard operating procedure describes the requirements and guidance for operating meteorological monitoring stations within the Washington State Ambient Air Monitoring Network (Washington network). Ecology revised this procedure to replace the mechanical anemometer with the ultrasonic anemometer.


In addition to the requirements described in EPA’s PSD document, this procedure also draws heavily from the requirements and guidance for installing and operating meteorological monitoring sites described in EPA guidance document, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements Version 2.0.

Topics covered include:
- site selection
- site and sensor installation
- quality control processes
- maintenance
- quality assurance
- data recording
- data quality assessment

2. Principles of Operation

Ultrasonic anemometers use ultrasonic sound waves to measure wind velocity. They measure wind speed based on the time of flight of sonic pulses between four transducers. There are no moving parts, which makes them appropriate for long-term use in automated weather stations adversely affected by salty air or dust.

3. Site Selection

The primary objectives when selecting the location of a meteorological monitoring station 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. Secondary considerations are accessibility and security; however, these considerations should not be allowed to compromise the quality of the data.
3.1 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 3.

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

![Figure 3-1. Distance from Obstructions](image)

3.2 Temperature measurements

EPA’s guidance states that the standard height to place temperature sensors for climatological purposes is 1.25 to 2 meters, but different heights may frequently be required in air quality studies. A height of up to 10 meters might also be needed when located on a rooftop, next to a structure such as a shed, or over a concrete surface where the heat effect may be a concern.

Temperature sensors must be protected from thermal radiation by mounting the sensors in ventilated radiation shields. All temperature measurements should be taken over level 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 obstruction away from that obstruction, and at least 30 meters away from any large paved area such as a parking lot. Avoid siting temperature sensors in the following locations:
• large industrial heat sources
• rooftops
• sheltered hollows
• high vegetation
• shaded areas
• swamps or areas where standing water can accumulate

Do not take measurements near ridges, steep slopes, or valleys unless those areas are of specific interest. Do not take measurements near bodies of water because of the large temperature variations.

3.3 Atmospheric pressure measurements

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

3.4 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.

3.5 Towers

The Washington network exclusively uses tilt down towers. Tilt down, hinged base towers are rugged enough to keep the instrumentation properly oriented and provide easy access to the sensors. Other types of towers may be used only with approval from the Quality Assurance Coordinator.

Towers should be located over an open, level area. When choosing a site, ensure that the location is representative of the area under study and is free from obstructions that might affect the measurements. Towers should be the open lattice type to allow wind to flow through freely.

Wind sensors should be mounted above the top of the tower on a boom or mast. If a crossarm is used to mount the wind sensors, 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.

3.6 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 that will be used for computer modeling about 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 start. Contact the Air Quality Program’s IT unit for access to SIMS.

Further information on siting can be found in the Air Quality Program’s Air Monitoring Project Approval, Site Selection, and Installation Procedure.

4. Installation

Once you have the meteorological instrumentation, but before you install it, the Calibration and Repair Laboratory will complete an acceptance test to verify the operational status of the sensors. This acceptance test should include, but is not limited to: physical examination of all sensors, cables, connectors; and verification of equipment calibration.

Install the meteorological monitoring sensors according to the manufacturer’s recommendations. The information contained in the manufacturer’s manual includes instructions about:

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

4.1 Tower

Properly installing a tower requires physical labor and specialized knowledge. Some of the tasks to install the tower include:

- hauling and mixing concrete and water
- properly using a carpenter’s level, a transit, a plumb bob, and various hand tools

Tower installation must be done by two people, one of whom should have prior experience.

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

Tower bases come in 2 types: in-ground and rooftop. Either type can be used for ground level installations, but in-ground type tower bases cannot be used on rooftops.
4.1.1 Rooftop
Instructions to install a rooftop tower:
- Build a 3-foot square form using 2x4 lumber.
- Attach 3 J-bolts to the rooftop base with 2 nuts on the upper side and 2 on the lower side of the base. This allows for an adjustment nut and a lock nut on each side.
- Consider the direction that the tower will fold down. Make sure nothing will prevent the tower from being lowered.
- 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. Use a carpenter’s level to adjust the tower perpendicular to the horizon.
- Add the upper 2 sections of tower and stand it up.
- Readjust the base if necessary.
- Lower the tower and install guy wires.

4.1.2 In-ground
Instructions to install an in-ground tower:
- Dig a hole 3 feet square by 4 feet deep.
- Consider the direction that the tower will fold down. Make sure nothing will prevent the tower from being lowered.
- Attach the lower section of the tower to the base using the proper bolts.
- Place the in-ground base into the hole.
- Fill the hole with concrete, leveling as you pour. Do not fill above the hinges used to lower the tower.
- Immediately level the tower. There is no way to level a tower with an in-ground base after the concrete cures.
- Tamp the concrete. Use a carpenter’s level to confirm the tower perpendicular to the horizon.
- Allow 3 – 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.

4.2 Orientation
Instructions to orient the tower:
- 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.
- Adjust the mast so that the length from the base of the tower to the center of the anemometer’s black sensor spikes is 10 meters.
- 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 Washington network anemometers are aligned to true north. This means that the vane alignment rod must be oriented on the true north/true south axis. You can use a variety of methods to find true north. We will explain the solar method since it has shown the best results.

Solar method for finding true north:
• Use a GPS unit to get accurate coordinates of the tower’s location.
• Using these coordinates, find the time of day for solar noon. Solar noon is the precise time that the sun is at its highest angle above the horizon. Many web-based computer programs can determine 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. True north is the line from the center of the tower to the mark on the ground. You may use a roll of twine to extend the point farther away from the tower.
• Set up a transit on the south side of the tower on this imaginary line, about 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.

4.3 Distant object
• After you have established true north orientation, pick a stationary object at least several hundred meters away that will be visible year round and into the future. 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 are good distant objects due to their high visibility and permanence.
• 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 of the diagram to the Quality Assurance unit and keep a copy at the meteorological station, preferably on the wall inside the shelter.
5. Quality Control (QC)

Quality control checks are used to understand and ensure data quality. The operator must perform quality control (QC) checks at least every 90 days, and any time a repair or replacement is made. An example of the meteorological quality control check form is found at the end of this document. The Excel form is available from the Quality Assurance unit and must be used to record QC results. Send a copy of the completed form to the Quality Assurance Coordinator within 10 days after a QC check.

The due date for annual certification of the ultrasonic anemometer is 365 days from the date the anemometer is installed or reinstalled after certification. A QC anemometer orientation check must be performed before removing the anemometer for certification. The site operator is responsible for tracking when the ultrasonic anemometer is due for certification and sending it to Ecology’s Calibration and Repair Laboratory. Calibration and repair staff will ship the sensor to the test facility (currently R.M. Young) for recertification. If you have questions about the annual ultrasonic recertification process, ask Ecology’s calibration and repair staff.

To ensure proper safety of personnel, the Air Quality Program requires two staff to raise and lower towers.

5.1 Required equipment

Performing QC checks on meteorological sensors requires specialized tools and measuring devices. Table 5-1 provides a list of these tools.

Table 5-1. Necessary QC Equipment

<table>
<thead>
<tr>
<th>Device</th>
<th>Vendor</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM/NIST traceable thermometers</td>
<td>VWR and others</td>
<td>must be compared to a National Institute of Standards and Technology (NIST) traceable thermometer once a year</td>
</tr>
<tr>
<td>insulated bottles</td>
<td>various</td>
<td>2 bottles, one with ice water and one with hot water (about 120°F)</td>
</tr>
<tr>
<td>transit and tripod</td>
<td>various</td>
<td></td>
</tr>
<tr>
<td>altimeter/barometer</td>
<td>Thommen</td>
<td>must be compared to a National Institute of Standards and Technology (NIST) traceable thermometer once a year</td>
</tr>
<tr>
<td>GPS device</td>
<td>various</td>
<td>horizontal accuracy of ±3 meters and resolution of 0.000001 decimal degrees or finer</td>
</tr>
</tbody>
</table>
5.2 QC procedures

5.2.1 Data collection

- Disable data logging before lowering the tower or performing any QC procedures.
- Enter all work performed into the electronic logbook.
- Re-enable data logging before leaving the monitoring station.

5.2.2 Anemometer orientation

Do this procedure before lowering the tower.

- Set up a transit on the south side of the tower. If fencing or other obstructions prevent setting it up on the south side, set it up on the north side.
- Align the transit with the vane alignment rod. For best accuracy, make sure both ends of the vane alignment rod intersect the transit’s reticle.
- Use a bright-colored spike in the ground to mark the appropriate location during initial installation.

Two methods – distant object and GPS – are used to determine that the vane alignment rod is oriented on the true north/true south axis.

5.2.2.1 Distant object method

- Find the documented distant object angle in the station log and/or posted on the wall inside the station. The documented distant object angle is the angle that was written down when true north was determined and a distant object was selected.
- Measure the angle from the vane alignment rod to the distant object using the transit.
- Record both documented and measured distant objects on the QC form.
- After the QC check is complete and the tower is back in the upright position, use the viewfinder on the transit to verify that the vane alignment rod and tower orientation are in the same position as before the QC check.

5.2.2.2 GPS method

- Make sure the GPS is programmed to display coordinates in decimal degree (ddd.ddddddd) format.
- Set the GPS to display latitude and longitude coordinates. Place it on the tower base, directly underneath the tower, and allow it to stabilize.
- Record the coordinates.
- Walking in a straight line, carry the GPS at least 100 feet to the north or south of the tower.
- Align the GPS with the vane alignment rod using the transit as a reference point. The latitude number (N) on the GPS will have changed, but the longitude number (W) should be within 0.000014 of a degree from the longitude recorded underneath the tower.
- Record both longitude readings on the QC form.

This method verifies that the anemometer alignment is the same and validates the true north alignment to within 2 degrees anywhere in Washington.
5.2.3 Temperature

Because of the known toxicity of mercury, do not use mercury thermometers in the field. Precise electronic standards are available and should be used instead of mercury thermometers. Perform checks at two different temperatures to establish accuracy and linearity of the system. Test the sensor while it is connected to the data logger the same way it is during normal operation. This will mimic operational conditions as closely as possible. If this is not practical, disconnect and reconnect the sensor inside the station’s shelter.

To perform a quality control check:

- 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 both the thermometer and data logger have stable readings. 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 120° F.
- Do the same procedure to get a second set of values.
- Record these values on the QC form.

5.2.4 Relative humidity

The only relative humidity (RH) 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. Check at least two points. The RH values most commonly used are 35 percent and 80 percent.

Equilibration times vary depending on the humidity standard used. This information is included in the manufacturer’s materials that accompany the standards. The standard relative humidity values must be corrected to ambient temperature according to the manufacturer’s recommendation.

To perform a quality control check:

- Remove the screw cap from the calibration chamber.
- Remove the sensor from the tower and place one textile pad (supplied with standards) into the screw cap of the chamber.
- Wearing gloves, tap the ampule to ensure liquid contents are not stuck in the cap. Snap the top off the ampule. Completely empty the ampule onto the textile pad by tapping it lightly.
- Insert the end of the sensor into the calibration chamber and tighten the environmental seal.
- Orient the chamber so that the opening is downward and replace the screw cap. This is so that excess liquid will not drip from the screw cap onto the sensor.
- After the required equilibration time has passed, read the indicated 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.
5.2.5 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 during every 90-day QC check. A multi-point comparison will be done annually during the quality assurance audit.

5.3 Quality control action levels and acceptance limits

PSD-quality acceptance limits for meteorological parameters are summarized in Table 5-2. If the QC check results are outside the acceptance limits, the QC check has failed and corrective action is required. If results are at or above the action level, but below the acceptance limits, preventive action is required. Failure to take corrective action may result in invalidation of collected data. Ultrasonic anemometers cannot be calibrated in the field and must be verified by an independent laboratory once every 365 days. Anemometers not meeting the acceptance criteria will be calibrated by the independent laboratory. Therefore, there are no action levels associated with accuracy of wind direction and wind speed.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Action Level</th>
<th>Acceptance Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distant object</td>
<td>N/A</td>
<td>±2.0° (distant object)</td>
</tr>
<tr>
<td>GPS angle</td>
<td>N/A</td>
<td>±0.000014 decimal degrees</td>
</tr>
<tr>
<td>Temperature</td>
<td>±0.65° F</td>
<td>±0.9°F of NIST</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>±7 percentage points</td>
<td>±7 percentage points</td>
</tr>
<tr>
<td>Atmospheric pressure</td>
<td>±3 mb</td>
<td>±3 mb</td>
</tr>
<tr>
<td>Wind speed</td>
<td>N/A</td>
<td>±0.25 m/s below 5 m/s and ± 5% above 5 m/s</td>
</tr>
<tr>
<td>Wind direction</td>
<td>N/A</td>
<td>±5 degrees</td>
</tr>
</tbody>
</table>

6. Quality Assurance (QA)

Quality Assurance (QA) performance evaluations are conducted every year by quality assurance personnel. When the tower is raised or lowered, two staff must be present. Both must wear hardhats.

The procedure used to perform quality assurance performance evaluations on meteorological equipment in the field is similar 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.
7. Equipment Calibration

Anemometers, relative humidity sensors, temperature 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 Calibration and Repair Laboratory at Ecology.

8. Maintenance

Maintenance on meteorological sensors requires specialized equipment and an environment that is conducive to performing detailed work. Therefore, no maintenance 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 Calibration and Repair Laboratory at Ecology.

9. Data Validation

The Air Quality Program’s data acquisition system provides near-real-time data. 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. You can find a description of the parameters checked during data validation in the Air Monitoring Documentation, Data Review, and Validation Procedure SOP.

10. Data Quality Assessment

For each calendar quarter and year, the Quality Assurance Unit will prepare a data quality assessment (DQA) report. The results of the DQA are used to regularly evaluate the effectiveness of meteorological monitoring systems and processes within the Washington network and inform improvements.

10.1 Data completeness

Data completeness is 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). As required by EPA:

- Hours with less than 75 percent* of their minute data valid are not considered valid.
- Days with less than 75 percent* of their hourly data valid are not considered complete.
- Quarters with less than 75 percent* of their days complete are not considered complete.

* NOTE: The Washington network has set a goal of 80 percent data completeness quarterly and annually.
11. References


40 CFR Part 58.

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

12. Appendix

Sample meteorological QC check form

The meteorological QC check form is shown below. All operators of meteorological sites in the Washington network must use this form. Contact the Ecology Quality Assurance unit for a copy of this form as a fillable spreadsheet.

![Sample Meteorological QC Check Form](image.png)

Figure 12-1. Sample Meteorological Quality Control Check Results