



## **Meteorological Monitoring Procedure**

---

By

James Laing and Sarah Clouse

For the

**Air Quality Program**

Washington State Department of Ecology  
Olympia, Washington

July 2021, Publication 00-02-003

## Publication Information

This document is available on the Department of Ecology's website at:  
<https://fortress.wa.gov/ecy/publications/summarypages/0002003.html>

## Contact Information

### Air Quality Program

P.O. Box 47600  
Olympia, WA 98504-7600  
Phone: 360-407-6800

**Website**<sup>1</sup>: [Washington State Department of Ecology](http://www.ecology.wa.gov)

## ADA Accessibility

The Department of Ecology is committed to providing people with disabilities access to information and services by meeting or exceeding the requirements of the Americans with Disabilities Act (ADA), Section 504 and 508 of the Rehabilitation Act, and Washington State Policy #188.

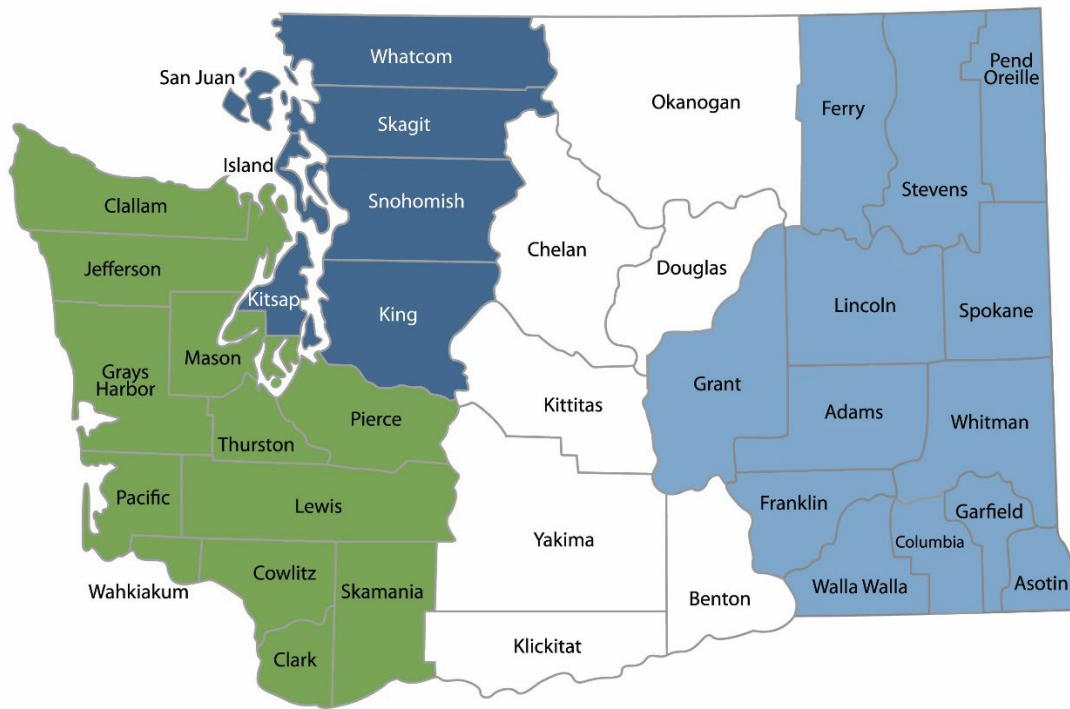
To request an ADA accommodation, contact Ecology by phone at 360-407-6800 or email at [melanie.forster@ecy.wa.gov](mailto:melanie.forster@ecy.wa.gov). For Washington Relay Service or TTY call 711 or 877-833-6341. Visit Ecology's website for more information.

---

<sup>1</sup> [www.ecology.wa.gov/contact](http://www.ecology.wa.gov/contact)

# Department of Ecology's Regional Offices

## Map of Counties Served



<b>Southwest Region</b> 360-407-6300	<b>Northwest Region</b> 206-594-0000	<b>Central Region</b> 509-575-2490	<b>Eastern Region</b> 509-329-3400
---	---	---------------------------------------	---------------------------------------

Region	Counties served	Mailing Address	Phone
<b>Southwest</b>	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
<b>Northwest</b>	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
<b>Central</b>	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
<b>Eastern</b>	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
<b>Headquarters</b>	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

# Meteorological Monitoring Procedure

---

Air Quality Program  
Washington State Department of Ecology  
Olympia, WA

**July 2021 | Publication 00-02-003**



DEPARTMENT OF  
**ECOLOGY**  
State of Washington

**Approved by:**

Signature: \_\_\_\_\_ Date: \_\_\_\_\_  
Arati Kaza, Ecology Quality Assurance Officer

Signature: \_\_\_\_\_ Date: \_\_\_\_\_  
Rob Dengel, Air Quality Deputy Program Manager

Signature: \_\_\_\_\_ Date: \_\_\_\_\_  
Sean Lundblad, Technical Services Section Manager

Signature: \_\_\_\_\_ Date: \_\_\_\_\_  
Jill Schulte, Air Monitoring Coordinator

Signature: \_\_\_\_\_ Date: \_\_\_\_\_  
Scott Dubble, NWRO/SWRO & Air Quality Operations Unit Supervisor

Signature: \_\_\_\_\_ Date: \_\_\_\_\_  
Beth Friedman, Air Quality Program Quality Assurance Coordinator

Signatures are not available on the Internet version

# Table of Contents

<b>List of Figures and Tables .....</b>	<b>8</b>
Figures.....	8
<b>1. Introduction .....</b>	<b>9</b>
<b>2. Principles of Operation .....</b>	<b>9</b>
<b>3. Site Selection .....</b>	<b>9</b>
3.1. Wind measurements .....	9
3.2. Temperature measurements.....	10
3.3. Atmospheric pressure measurements .....	11
3.4. Relative humidity measurements.....	11
3.5. Solar and UV radiation measurements.....	11
3.6. Precipitation measurements .....	11
3.7. Towers .....	11
3.8. Station siting.....	12
<b>4. Installation .....</b>	<b>12</b>
4.1. Tower .....	13
4.1.1. Rooftop .....	13
4.1.2. In-ground .....	13
4.2. Orientation .....	14
4.3. Distant object .....	15
4.4. Data and electrical setup.....	16
4.5. Envidas setup.....	17
<b>5. Quality Control (QC) and Maintenance.....</b>	<b>20</b>
5.1. Required equipment.....	21
5.2. QC procedures .....	21
5.2.1. Data collection .....	21
5.2.2. Anemometer orientation.....	22
5.2.3. Temperature.....	22
5.2.4. Relative humidity.....	23
5.2.5. Atmospheric pressure.....	24
5.2.6. Solar radiation.....	24
5.2.7. UV radiation.....	24
5.2.8. Precipitation.....	24
5.3. Maintenance.....	25
<b>6. Quality Assurance (QA).....</b>	<b>26</b>
<b>7. Equipment Calibration.....</b>	<b>26</b>

<b>8. Data Validation</b> .....	<b>26</b>
<b>9. Data Quality Assessment</b> .....	<b>26</b>
9.1. Data completeness .....	26
<b>10. References</b> .....	<b>27</b>
<b>Appendix</b> .....	<b>28</b>
Sample meteorological QC check form.....	28
Envidas Setup Screenshots .....	29

# List of Figures and Tables

## Figures

Figure 1: Distance from Obstructions.....	10
Figure 2: Looking down at the top of the WMT700 sonic anemometer .....	14
Figure 3: Sample Meteorological Quality Control Check Results .....	28
Figure 4: Screenshot of the port setup for the WMT700 .....	29
Figure 5: Screenshot of the analyzer setup for the WMT700 .....	29

## Tables

Table 1: WMT700 Cable Connections.....	16
Table 2: WMT700 Cable Connections-COM ports.....	16
Table 3: Port Settings .....	17
Table 4: Analyzer Settings.....	17
Table 5: Channel settings for Wind Speed Scalar .....	18
Table 6: Channel settings for Wind Direction Scalar. ....	18
Table 7: Channel settings for Wind Speed Vector. ....	19
Table 8: Channel settings for Wind Direction Vector. ....	20
Table 9: Necessary QC Equipment.....	21
Table 10: PSD-Quality QC Limits and PAMS Acceptance Limits. ....	25



# 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.

Meteorological monitors operated in the Washington network comply with the PSD-quality acceptance criteria described in EPA's Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD).

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 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 1.

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.

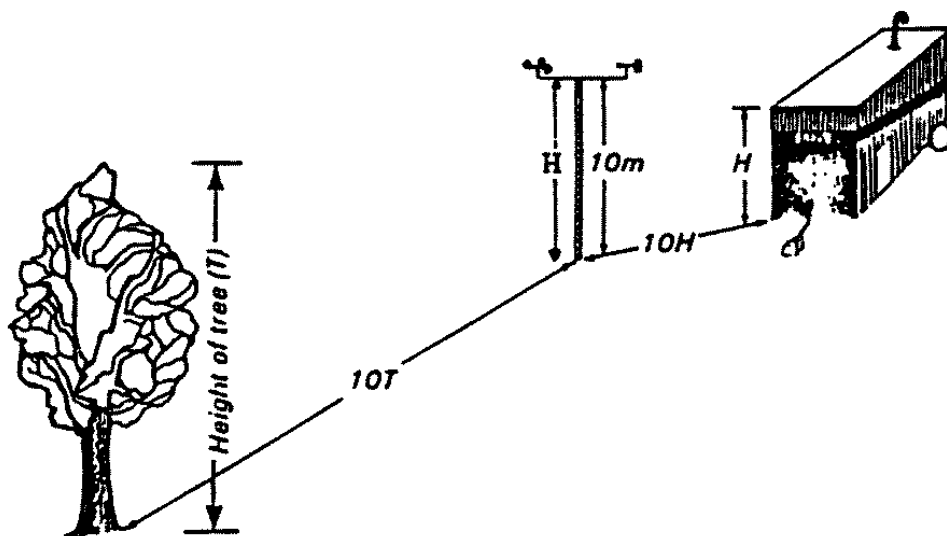


Figure 1: Distance from Obstructions

### 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. Solar and UV radiation measurements**

Solar radiation refers to the electromagnetic energy in the solar spectrum (0.10 to 4.0  $\mu\text{m}$  wavelength). Ultraviolet (UV) radiation can be divided into three sub-ranges: UV-A (0.315 to 0.400  $\mu\text{m}$ ), UV-B (0.280 to 0.315  $\mu\text{m}$ ), and UV-C (0.100 to 0.280  $\mu\text{m}$ ). Due to absorption by stratospheric ozone, the UV radiation reaching the surface of the earth consists primarily of wavelengths longer than 0.28  $\mu\text{m}$  (UV-A and UV-B ranges). These measurements are required as part of the Photochemical Assessment Monitoring Stations (PAMS) Required Monitoring program. They should be located with an unrestricted view of the sky in all directions. Locations should be avoided where there are obstructions that could cast a shadow or reflect light on the sensor. Light colored walls or artificial sources of radiation should also be avoided. Tall platforms or roof tops are typical locations

### **3.6. Precipitation measurements**

Precipitation should be measured with a recording precipitation gauge such as a tipping bucket or weighing bucket. This measurement is required as part of the PAMS Required Monitoring program. The precipitation gauge should be located on level ground in an open area. Obstructions should not be closer than two to four times their height from the instrument. The mouth of the gauge should be level and should be as low as possible while preventing in-splashing from the ground.

### **3.7. Towers**

The Washington network primarily 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.

### 3.8. 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

New installations will use Vaisala WMT700 series wind sensors, though some sites may continue to operate with RM Young ultrasonic wind sensors. Please contact the Calibration and Repair Laboratory for instructions regarding the RM Young sensors. Once you have the meteorological instrumentation, but before you install it, the Calibration and Repair Laboratory will setup your sensor and 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 functionality.

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

- Installation of equipment
- Alignment
- Operation
- Configuration
- Troubleshooting
- Communication

## 4.1. Tower

Properly installing a tower requires physical labor and specialized knowledge. Before installing a new tower check plans with the Calibration and Repair Laboratory. 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
- Soils analysis to determine the footprint and likelihood of settling issues

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

Most 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 at least 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 an in ground 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

The sonic anemometer has an arrow on the top of it to mark the north direction of the sonic. See Figure 2 below. This arrow must point to true north when installed on the tower. There is also a piece of orange tape on one of the transducer arms. This tape indicates the north arm. When looking down at the top of the sonic anemometer, the south transducer arm is 120° counter clockwise from the northern arm. The north arrow on the top of the sonic is parallel to the imaginary line that runs through the center of the north and south arms when looking down from the top. When aligning the sonic with the transit, the northern and southern arms should be centered on the center line in the transit.

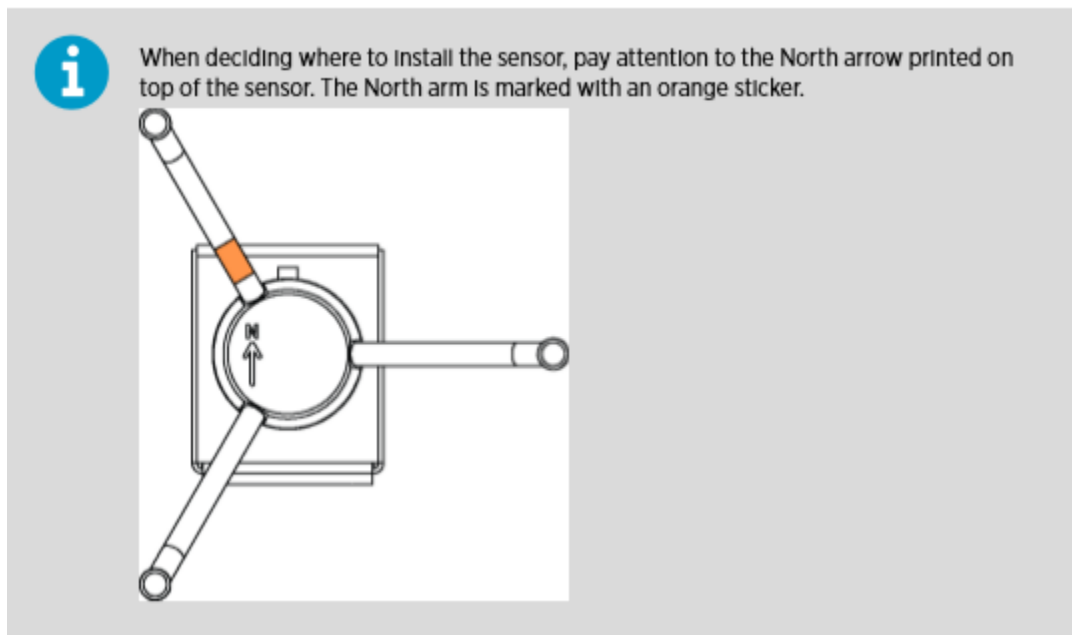


Figure 2: Looking down at the top of the WMT700 sonic anemometer

Instructions to orient the tower (see WMT700 user's manual for detailed instructions):

- Install the 3-foot mast at the top of the tower.
- Slip the U-bolt mounting hardware over the mast.
- Place the anemometer atop the mast and temporarily tighten the nuts on the U-bolt.

- Adjust the mast so that the length from the base of the tower to the center of the anemometer's transducers is 10 meters.

All Washington network anemometers are aligned to true north. This means that the north and south transducers 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 north and south transducer arms, and vane alignment rod, if installed, using the transit, so that they are oriented on the true north/true south axis, and tighten the clamps. 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 north and south arms, 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.

## 4.4. Data and electrical setup

This section describes the electrical connection of the Vaisala WMT700 series ultrasonic wind sensor. This device has two serial ports. Both need to be connected to the data logger. The first port, COM1 is the service port. This port is used to poll diagnostics and to configure the sonic anemometer. The second port, COM2 is the data port and is used to collect data on the logger. The anemometer is powered with a 24 VDC power supply. Both the heater and the operating power can be connected to the same 24 VDC power supply provided it is 60 W or greater. Table 1 below shows the connections for the WMT700 cable. Note that while there is an analog output option for data collection, this is not recommended unless serial communication is not possible. Contact the calibration and repair laboratory if you think that you need to log the analog output.

Table 1: WMT700 Cable Connections

Power Supply/analog output	Wire color	Pin	Connection
Operating power supply	White	1	+24 VDC PS
Operating Power Supply Ground	Gray-Pink	11	PS GND
Heater Power Supply	Gray	5	+24 VDC PS
Heater Power Supply	Pink	6	+24 VDC PS
Heater Power Supply Ground	Blue	7	PS GND
Heater Power Supply Ground	Red	8	PS GND
Enclosure Ground	Shield	Shield	NC
Analog Output AOUT2, Wind Direction	Brown	2	NC
Analog Output AOUT1, Wind Speed	White-Green	13	NC
Reference Input for AOUT2	White-Gray	17	NC
Analog Output Ground	Red-Blue	12	NC

Table 2: WMT700 Cable Connections-COM ports

COM port	RS 232	RS 422	RS 485	SDI 12	Wire color	Pin	Connection
COM2	Rx	Rx-	Rx-	-	Green	3	Pin 3 Serial
	Tx	Tx-	Tx-	Data	Yellow	4	Pin 2 Serial
	-	Tx+	Tx+	-	Brown-Green	14	NC
	-	Rx+	Rx+	-	White-Yellow	15	NC
COM1 and COM2 Communication Port Ground	-	-	-	-	Violet	10	Pin 5 Serial
COM1 RS 485-	-	-	-	-	Black	9	T/R- Dtech
COM1 RS 485+	-	-	-	-	Brown-Yellow	16	T/R+ Dtech



## 4.5. Envidas setup

This section describes the setup of the WMT700 in Envidas. The WMT700 will come configured for serial communications using the NMEA 425 protocol and the corresponding settings must be configured in Envidas. The port settings, analyzer settings, and four channels Wind Speed Scalar (WindSpeedS), Wind Speed Vector (WindSpeedV), Wind Direction Scalar (WindDirectionS), and Wind Direction Vector (WindDirectionV) will need to be configured during setup. Below in Table 3 are the settings for the port. Table 4 shows the analyzer settings and Table 5 through Table 8 show the settings for the four channels. Screenshots for the setup can be found in Appendix A as well. After setting up your channels, contact someone in the calibration and repair laboratory to check your settings. If you have any questions, contact the calibration and repair laboratory.

When setting up temperature, atmospheric pressure, relative humidity, solar radiation, UV radiation, or precipitation measurement in Envidas contact the Calibration and Repair Lab.

Table 3: Port Settings

Name	Value
State	on
Client/Server	Client
Port	Determined by setup
Baud Rate	9600
Parity	none
Data Bit	8
Stop Bit	1
Flow Control	none
Use Rado RTS/CTS	unchecked
Baud Rate	9600
Packet Watt	300

Table 4: Analyzer Settings

Name	Value
State	On
Name	Vaisala_WS425_NMEA
Send Calib Command	Unchecked
Sample Rate	5 sec
Sample Timeout	500 ms
Sample Active	Checked

Table 5: Channel settings for Wind Speed Scalar

<b>Name</b>	<b>WindSpeedS</b>
Ch. Address	set by Envidas
Unit	mph
Serial #	Leave Blank
Low Range	0
High Range	89.48
Threshold %	75
24Hr Thresh. %	75
Pollutant Type	(None)
View Format	##
State	On
Average	Mean
Analyzer	Vaisala_WS425_NMEA
Channel	Wind Speed
EU Conversion	Unchecked
Web Display	Unchecked
Range Deviation	Checked
By Value	Checked
Low	0
High	100
<b>Channels for Average Calculation</b>	-
Role	Channel
Blank	Blank
<b>Extra data for Average</b>	-
Blank	Blank

Table 6: Channel settings for Wind Direction Scalar.

<b>Name</b>	<b>WindDirectionS</b>
Ch. Address	set by Envidas
Unit	degrees
Serial #	Leave Blank
Low Range	0
High Range	360
Threshold %	75
24Hr Thresh. %	75
Pollutant Type	(None)
View Format	##
State	On
Average	Unit Vector Direction
Analyzer	Vaisala_WS425_NMEA
Channel	Wind Direction
EU Conversion	Unchecked

Name	WindDirectionS
Web Display	Unchecked
Range Deviation	Unchecked
By Value	Unchecked
<b>Channels for Average Calculation</b>	-
Role	Channel
Wind Speed	WindSpeedS
<b>Extra Data for Average</b>	-
Minimum Valid WS	0

Table 7: Channel settings for Wind Speed Vector.

Name	WindSpeedV
Ch. Address	set by Envidas
Unit	mph
Serial #	Leave Blank
Low Range	0
High Range	89.48
Threshold %	75
24Hr Thresh. %	75
Pollutant Type	(None)
View Format	##
State	On
Average	VectorSpeed
Analyzer	Vaisala_WS425_NMEA
Channel	Wind Speed
EU Conversion	Unchecked
Web Display	Unchecked
Range Deviation	Checked
By Value	Checked
Low	0
High	100
<b>Channels for Average Calculation</b>	-
Role	Channel
Wind Direction	WindDirectionS
<b>Extra data for Average</b>	-
Minimum Valid WS	0

Table 8: Channel settings for Wind Direction Vector.

Name	WindDirectionV
Ch. Address	set by Envidas
Unit	degrees
Serial #	Leave Blank
Low Range	0
High Range	360
Threshold %	75
24Hr Thresh. %	75
Pollutant Type	(None)
View Format	#. #
State	On
Average	Vector Direction
Analyzer	Vaisala_WS425_NMEA
Channel	Wind Direction
EU Conversion	Unchecked
Web Display	Unchecked
Range Deviation	Unchecked
By Value	Unchecked
<b>Channels for Average Calculation</b>	-
Role	Channel
Wind Speed	WindSpeedS
<b>Extra Data for Average</b>	-
Minimum Valid WS	0

## 5. Quality Control (QC) and Maintenance

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 SOH Wind Laboratories) for recertification. If you have questions about the annual ultrasonic recertification process, ask Ecology's calibration and repair staff.

The due date for annual certification of the radiometer and pyranometer is 183 days from the date of installation at the site. The site operator is responsible for tracking when the radiometer and pyranometer anemometer is due for certification and sending the sensor to the test facility (OTT HydroMet) for recertification. As these measurements are specifically for PAMS, which lasts from June 1 to August 31, the recertifications should be completed in the spring and falls.

To ensure proper safety of personnel, the Air Quality Program requires two staff to raise and lower towers unless the tower is a fold-over type tower. Staff raising and lowering towers must wear hardhats.

## 5.1. Required equipment

Performing QC checks on meteorological sensors requires specialized tools and measuring devices. Table 9 provides a list of these tools.

Table 9: Necessary QC Equipment

Device	Vendor	Comments
ASTM/NIST traceable thermometers	VWR and others	must be compared to a National Institute of Standards and Technology (NIST) traceable thermometer once a year
insulated bottles	Various	2 bottles, one with ice water and one with hot water (about 120°F)
transit and tripod	Various	-
altimeter/barometer	Various	must be compared to a National Institute of Standards and Technology (NIST) traceable barometer once a year
GPS device	Various	horizontal accuracy of $\pm 3$ meters and resolution of 0.000001 decimal degrees or finer
Zero Verifier	Vaisala	Turning off the transducer heaters for the zero check is recommended, but not always necessary
Graduated Cylinder	Various	For measuring water volume for rain gauge tipping bucket verification

## 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 north and south transducers. For best accuracy, make sure both ends of the transducers are centered on 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 north and south transducers, or vane alignment rod, if present, 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 north and south transducers (or 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 north and south transducers (or 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.ddddd) 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 north and south transducers (or 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. Table 10 provides the acceptance criteria for QC checks. If operating this instrument as part of the PAMS Required Monitoring, the criteria are stricter than other sites.

## 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

Table 10 provides the action levels and acceptance criteria for QC checks. If operating this instrument as part of the PAMS Required Monitoring, the criteria are stricter than other sites.

#### **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.

Table 10 provides the action levels and acceptance criteria for QC checks. If operating this instrument as part of the PAMS Required Monitoring, the criteria are stricter than other sites.

### **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. Table 10 provides the action levels and acceptance criteria for QC checks. A multi-point comparison will be done annually during the quality assurance audit.

### **5.2.6. Solar radiation**

The Air Quality Program's collection of solar radiation is very limited and only used at PAMS Required Monitoring sites. The Kipp and Zonen SMP6-V pyranometer (Spectral range: 0.280 to 3.0  $\mu\text{m}$ ) is the only sensor currently being used. The plastic dome on the pyranometer should be checked at least every 90 days. If the dome is dirty, clean with water or alcohol and a lint-free towel. The pyranometer level should be checked and verified 90 days. Table 10 provides the action levels and acceptance criteria for QC checks.

### **5.2.7. UV radiation**

The Air Quality Program's collection of ultraviolet radiation is very limited and only used at PAMS Required Monitoring sites. The Kipp and Zonen SUV5-V radiometer (Spectral range: 0.280 to 0.400  $\mu\text{m}$ ) is the only sensor currently being used. The plastic dome on the radiometer should be checked at least every 90 days. If the dome is dirty, clean with water or alcohol and a lint-free towel. The radiometer level should be checked and verified 90 days. Table 10 provides the action levels and acceptance criteria for QC checks.

### **5.2.8. Precipitation**



The Air Quality Program’s collection of precipitation is very limited and only used at PAMS Required Monitoring sites. The RM Young model 52202 tipping bucket rain gauge is the only sensor currently being used. Station operators should compare a known volume of water added using a graduated cylinder to the output during every 90-day QC check.

To perform a QC/QA check:

- With the rain gauge properly leveled, slowly pour a measured volume of water into the collection funnel. The rate should not exceed 10 ml per minute which is approximately 1 inch per hour. The bucket should tip for each 2 ml, and should be recorded as 0.1 mm per tip. For example, 100 ml should give a count of 50±1, and indicate 5 mm of precipitation.
- If the count shows an error of more than 2%, adjust the calibrating screws to correct the error. Raise the screws if the count is low, lower the screws if the count is high. Always adjust both thumb wheels equally.

Table 10: PSD-Quality QC Limits and PAMS Acceptance Limits.

Parameter	Action Level	Acceptance Limits	PAMS Acceptance Limits
Distant object GPS angle	N/A	±2.0° (distant object) ±0.000014 decimal degrees	±1.0° (distant object)
Temperature	±0.65° F	±0.9°F of NIST	±0.9°F of NIST
Relative humidity	±7 percentage points	±7 percentage points	±5 percentage points
Atmospheric pressure	±3 mb	±3 mb	±3 mb
Wind speed	N/A	±0.25 m/s below 5 m/s and ± 5% above 5 m/s	±0.2 m/s or ± 5%, whichever is greater
Wind direction	N/A	±5 degrees	±5 degrees
Solar Radiation	N/A		≤ ±5% <sup>b</sup>
UV Radiation	N/A		≤ ±5% <sup>b</sup>
Precipitation	N/A		≤ ± 10% of input volume

<sup>b</sup>Comparison should be made during sunny conditions.

### 5.3. 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. The due date for annual certification of the ultrasonic anemometer is 365 days from the date the anemometer is installed at the site. When equipment requires repair or calibration recertification, it must be returned to the Air Quality Program’s Calibration and Repair Laboratory at Ecology.

Radiometer and pyranometer calibrations must be recertified by the manufacturer every 6 months. The due date for annual certification of the radiometer and pyranometer is 183 days from the date of installation at the site. The desiccant in the radiometer and pyranometer must be changed according to the manufactures instructions.

## 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, unless the tower is a cranking fold-over type. Staff raising and lowering towers 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.

Solar radiation must annually be compared to a NIST traceable pyranometer. UV radiation must annually be compared to a NIST traceable radiometer.

## 7. Equipment Calibration

Anemometers, relative humidity sensors, temperature sensors, radiometers, pyranometers, precipitation gauges, 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. 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.

## 9. 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.

### 9.1. 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/ day, 365 days/ 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.

## 10. References

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

40 CFR Part 58.

Technical Assistance Document for Sampling and Analysis of Ozone Precursors for the Photochemical Assessment Monitoring Stations Program – Revision 2. EPA-454/B-19-004. April, 2019. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD) EPA/450/4-87-07 May 1987.

R.M. Young Company website: <http://www.youngusa.com/>

Instructions Ultrasonic Anemometer Model 86000.  
[http://www.youngusa.com/Manuals/86000-90\(E\).pdf](http://www.youngusa.com/Manuals/86000-90(E).pdf)

Instructions Ultrasonic Anemometer Model 85004.  
[http://www.youngusa.com/Manuals/85004-90\(G\).pdf](http://www.youngusa.com/Manuals/85004-90(G).pdf)

Air Monitoring Project Approval, Site Selection, and Installation Procedure. WA Department of Ecology/Publication 16-02-021 November, 2019.

Vaisala Company website: <https://www.vaisala.com/en>

User Guide Vaisala WINDCAP® Ultrasonic Wind Sensor Series WMT700.

<https://www.vaisala.com/sites/default/files/documents/WMT700-User-Guide-in-English-M211095EN-H.pdf>

# 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.

Revised: 4/06/19/2019

AQS ID

Location

Date of Last QC

Date

Operator

### Meteorological Quality Control Check Results

Vane Alignment Test			
	Model #	Serial #	Method
Transit			
Dist. Object (Documented)			
Dist. Object (Measured)			
Difference ( $\pm 2^\circ$ )			

QC Result:

Ultrasonic Anemometer Check	
As Found Serial #	
As Found Due Date	
Any Bent Transducers?	
Anemometer Changed?	
As Left Serial #	
As Left Due Date	
Any Bent Transducers?	
Verifier Ws < 0.3 MPH	

Ambient Temperature Accuracy Test			
	Model #	Serial #	
Temperature Probe			
Temperature Standard			
Probe Height			
	10m	2m	
ACT ( $^\circ$ F)			
	IND ( $^\circ$ F)	Diff ( $\pm 0.9^\circ$ F)	
Ice Bath			
Hot Bath			

Ambient Relative Humidity Test			
Std Serial#	ACT	IND	Diff ( $\pm 7$ )

Barometric Pressure Test		
ACT (mmHg)	IND (mmHg)	Diff (hPa)
Mean Difference ( $\pm 3$ hPa)		

Comments:

Figure 3: Sample Meteorological Quality Control Check Results

# Envidas Setup Screenshots

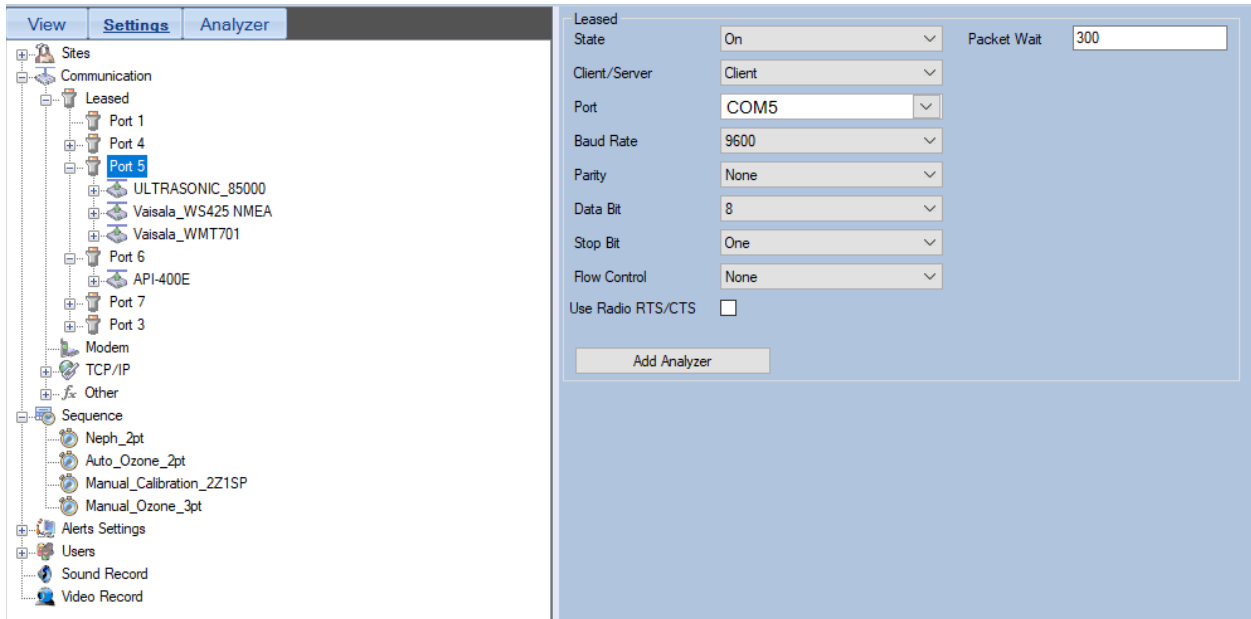


Figure 4: Screenshot of the port setup for the WMT700

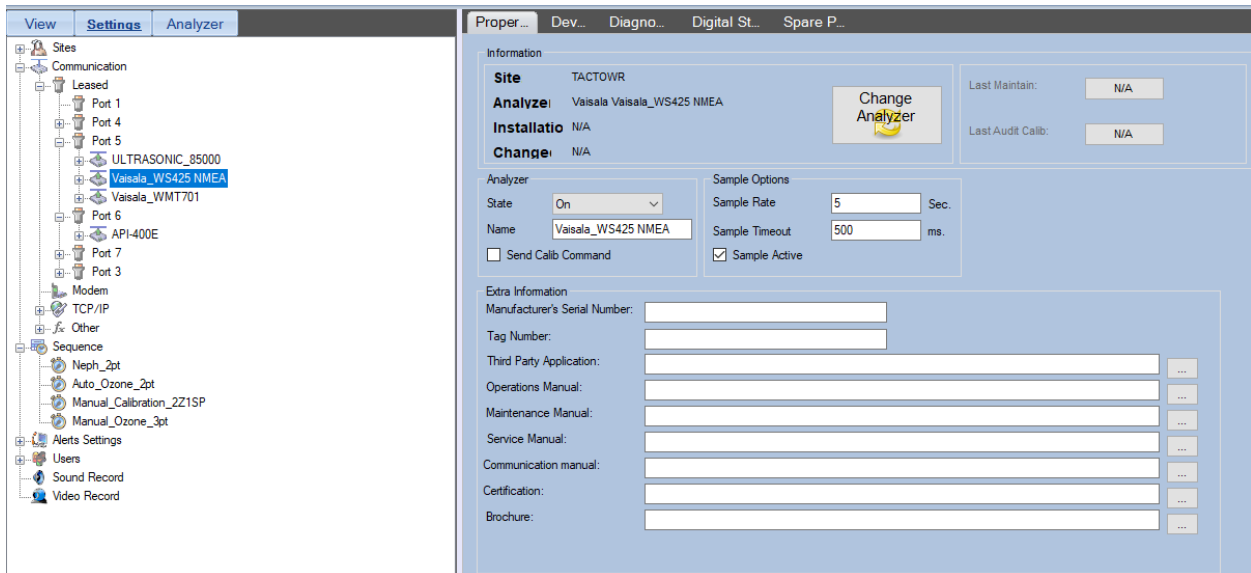


Figure 5: Screenshot of the analyzer setup for the WMT700