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NORTH CAROLINA
Environmental Quality

DAQ-07-003.1 Standard Operating Procedure (SOP)

MetOne AIO2 All-in-One Weather Sensor

for the North Carolina Division of Air Quality (DAQ)

ECB Responsibilities

Revision 1

Effective Date: November 01, 2021

NORTH CAROLINA
Department of Environmental Quality

Disclaimer:

This document, and any revision hereto, is intended solely as a reference guide to assist operators in the setup, calibration, operation, and the collection of data related to the North Carolina Division of Air Quality's Meteorological (Met) Program. This document is intended as a supplement to, and not a substitute for, the education, training and experience required for the efficient operation of ambient air quality monitoring equipment and the collection of scientifically valid data. If an event affecting Met monitoring is outside the purview of this Standard Operating Procedure, contact the Electronics and Calibration Branch and the Raleigh Central Office for guidance.

1.0 Approval Sign-Off Sheet

I certify that I have read and approve of the contents of the Standard Operating Procedure for the MetOne All-in-One Weather Sensor, ECB Responsibilities written here with an effective date of Nov 01, 2021.

Director, Air Quality Division

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SOP Acronym Glossary

ADQ - Audit of data quality

AIO2 - MetOne All In One 2

AQS - Air Quality System (EPA's Air database)

CFR – Code of Federal Regulations

Chief – Ambient Monitoring Section chief

CTS – Collocated Transfer Station

DAQ - North Carolina Division of Air Quality

DAS – Data acquisition system

°C – degrees Celsius

°F – degrees Fahrenheit

DEQ – North Carolina Department of Environmental Quality

Director – Division of Air Quality Director

ECB – Electronics and Calibration Branch

e-log – electronic logbook

EPA – United States Environmental Protection Agency

FEM – Federal equivalent method

FRM – Federal reference method

hPa – hecto Pascals

mA - milliamps

MDL – Method detection limit

mm - millimeters

mph – miles per hour

m/s – meters per second

NIST – National Institute of Standards and Technology

O.D. – outer diameter

PM – Particulate matter

PPB – Projects and Procedures Branch

QA – Quality assurance

QA/QC - Quality assurance/quality control

QAPP - Quality assurance project plan

QC – Quality control

RCO – Raleigh central office

SDI – Serial Digital Interface

SOP - Standard operating procedure

TSA - Technical systems audit

VDC – Volts of direct current

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2.0 SCOPE AND PURPOSE

While outside entities such as the National Weather Service can provide atmospheric data across the state, there are many instances where knowing the exact conditions of the environment around a site is beneficial to interpreting pollutants. Meteorological data can influence the behavior of pollutants in the atmosphere. It can also be invaluable to determining the impact of commercial activity in the area that can help DAQ determine if regulatory action is required.

This SOP describes the process of procuring equipment, initial testing for functionality, site installation, auditing, and ongoing maintenance of the MetOne All In One 2 (AIO2) weather sensor.

3.0 EQUIPMENT SELECTION AND PROCUREMENT

The Electronics and Calibration Branch (ECB) shall procure air monitoring equipment and supplies for DAQ. Although there are no minimum requirements for meteorological data in the codex of federal regulations, equipment selected by ECB is expected to be accurate, precise, and able to reflect actual conditions present at a site. When selecting new equipment, ECB uses a combination of the EPA's "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements ", the EPA's QAPP "PAMS Required Site Network for Speciated Volatile Organic Compounds, Carbonyls, and Meteorological Parameters Including Mixing Layer Height", and any specifications or recommendations of a manufacturer.

The current meteorological instrument used by DAQ is the METONE AIO2 sensor. The AIO2 provides measurements of windspeed, wind direction, ambient air temperature, relative humidity, and barometric pressure in a single, compact, rugged unit. It integrates a folded-path, low-power sonic anemometer with a precision thermistor temperature sensor, fast-response capacitive relative humidity sensor, and a barometric pressure sensor. It also includes an internal flux-gate compass that allows for automatic alignment of wind direction to magnetic north, regardless of the sensor's orientation. The small footprint and power efficiency of the AIO2 make it ideal for many applications and site conditions.

The AIO2 operates on the principal that the speed of the wind affects the time it takes for sound to travel from one point to a second point. If the sound is traveling in the direction of the wind, then the transit time is decreased. If the sound is traveling in a direction opposite of the wind, then the transit time is increased.

4.0 AIO2 DESCRIPTION

The AIO2 manual provides a more detailed description of the AIO2 sensor including the operating limits and calibrated limits of the individual parameters monitored by the AIO2 (windspeed, wind direction, ambient temperature, relative humidity, barometric pressure, and alignment compass).

A copy of the AIO2's manual can be found here:

https://metone.com/wp-content/uploads/2020/02/AIO-2-9800-Manual-Rev-F.pdf

The AIO2 specifications are:

The AIO2 specifications are:

Parameter	Specification
Windspeed Operating Range	0 to 75 meters per second (m/s) [0 to 168 miles per hour (mph)]
Windspeed Calibrated Range	0 to 60 m/s (0 to 134 mph)
Windspeed Accuracy	±0.5m/s or 5% of reading (whichever is greater)
Windspeed Resolution	0.1 m/s
Wind Direction Range	0 to 360 degrees
Wind Direction Accuracy	±5° (including Compass)
Wind Direction Resolution	1.0°
Alignment Compass Accuracy	±2°
Alignment Compass Resolution	1°
Temperature Range	-40 to +60 degrees Celsius (°C) [-40to +140 degrees Fahrenheit (°F)]
Temperature Accuracy	±0.2°C from 0 to 60°C, ±0.5°C from -40 to 0°C
Temperature Resolution	0.1°C
Relative Humidity Range	0 to 100%
Relative Humidity Accuracy	±3% at 25°C
Relative Humidity Resolution	1.0%
Barometric Pressure Range	600 to 1100 hecto Pascals (hPa)
Barometric Pressure Accuracy	±0.5 hPa 25°C
Barometric Pressure Resolution	0.1 hPa
External Rain Gauge Input	Resolution 0.25 millimeters (mm) or 0.01 inches, user selectable
External Solar Radiation Sensor Input	Measured in Watts per meter squared
Measurement Rate Output	1 Hertz
Signal Output Type	RS-232, RS-485, and SDI-12
Operating Temperature	-40 to +60°C (-40 to +140°F)
Operating Relative Humidity	0 to 100%
Dimensions	4.5 inches diameter, 11 inches height
Shipping Weight	6 pounds (including packaging)

5.0 DESCRIPTION OF EQIUPMENT CHECKS

If the AIO2 sensor has been sent to the manufacturer for repair, calibration, recertification, or if receiving a new sensor out of the box, the ECB must verify the accuracy, precision, and functionality of the sensor before deployment in the field.

5.1 Functionality Check

Upon arrival at the ECB, the instrument should be visually inspected for any damage. An ECB Technician should then power up the AIO2 sensor to ensure that the instrument can be operated before carrying it to the field. When powered on, the ECB Technician should check that each channel of the AIO2 can produce some sort of data.

5.2 Collocated Transfer Station Method

The AIO2 sensor does not contain any moving parts that measures windspeed and wind direction which can be tested with a certified transfer standard, instead the accuracy, precision and functionality checks are completed by the collocated transfer station (CTS) method.

A CTS check should be performed:

- At least once a calendar year and once every 365 days
- When a new or repaired AIO2 is received from the manufacturer
- When the AIO2 produces data that appears suspect by DAQ staff

The CTS method involves mounting a specially maintained AIO2 (Audit AIO) in the vicinity of the subject AIO2 being audited. The CTS should have National Institute of Standards and Technology (NIST)-traceable certificates.

The AIO2 should be sited as followed:

- The AIO2 should be within 10 horizontal meters of the Audit AIO.
- The AIO2 should be at least 1 horizontal meter away from the Audit AIO.
- The AIO2 should be within 1 vertical meter of the Audit AIO.
- The AIO2 should be placed away from any tower or structure that could interfere with the free flow of air and sound by a minimum of twice the diameter of that that tower or structure

The AIO2 should be left with the Audit AIO for a minimum of one week. Before the AIO2 is removed from CTS environment, the ECB should check that the AIO2 has provided for at least 48 hours of windspeed values over 1 meter per second and under 10 meters per second. If there are not at least 48 values, the AIO2 should be left until a time that there is. Hours that contain windspeeds less than 1 meter per second or more than 10 meters per second are invalid for purposes of CTS checks for windspeed and wind direction. Days that have rain events will be omitted from CTS checks unless that site has a rain gauge operated by DAQ.

AIO2 devices will be audited by an Audit AIO that will remain at the ECB (See Section 9.1). This Audit AIO2 device should be sent to the manufacturer to be calibrated once a calendar year and every 365 days.

Should a CTS check fail for windspeed or wind direction at a site, the site's AIO2 should be removed, and a CTS check should be run against it and the Audit AIO at the Millbrook site. If the CTS check passes at Millbrook, the ECB Technician should work with regional staff and green square staff to identify and rectify any site issues. In this case the data at the AIO2's site will still be valid but should be qualified back to the last CTS check at that site with a 3 Flag. If the CTS check fails at Millbrook, the data at the AIO2's site should be flagged back to the last CTS check at the site with a QX qualifier.

See Table 1 for Control Limits for windspeed and wind direction.

5.2.1 Compass Stability

While running a CTS check, the ECB Technician should monitor the stability of the compass of both AIO2 devices. If the compass is unstable, windspeed and wind direction readings should be invalidated during that period. A compass is considered stable if its standard deviation does not exceed ±2.0 degrees for a day over a 24-hour period.

Should a compass become unstable during the CTS check, the ECB Technician should consider going to the site and securing the AIO2 better. If this occurs, the CTS should be restarted from that point. If the site's AIO2 is what is resecured, the data should be qualified back to the last day that the compass was stable. If resecuring the AIO2 does do stabilize the compass, it should be sent to the manufacturer for repair.

5.3 Zero Check

Once a calendar year and every 365 days, an ECB Technician should run a zero check on the AIO2. Typically, this would be done at the same time as a CTS check. Any Audit AIO device should also have a zero-check performed on it when used as part of a CTS check at a site. If any zero check fails, windspeed and wind direction data should be invalidated back to the last good zero check.

To perform a zero check, an ECB Technician should place a specially made box with foam covered walls over the AIO2. The ECB Technician should then use foam under the box to insulate the AIO2 device. The ECB Technician should then wait ten minutes and average the last five minutes of reading values. If the readings for windspeed are greater than ±0.2 m/s, attempt to reinsulate the AIO2, attempt the Zero Check again, and send the AIO2 to the manufacturer if it fails the second attempt.

5.4 Barometric Pressure

At least once a calendar year and every 365 days, Barometric Pressure should be checked with a Druck DPI 705 handheld digital pressure indicator. The Druck DPI 705 pressure indicator uses a micro-machined silicon transducer to produce a pressure reading in units of pressure measurement.

To check the barometric pressure with the DPI 705, place the handheld unit close to the AIO2 and wait for it to stabilize. Ideally, the DPI 705 should be within 10 horizontal meters and 1 vertical meter. However, due to siting, this may not be possible. ECB technicians should use their best judgement to determine where to place the DPI 705 when these conditions can't be met. Make sure the DPI 705 is set to the same unit scale as the AIO2. Compare the readings on the DPI 705 to the minute readings of the AIO2. Record the date and time of the first minute value used. Calculate the precision and bias using the control limits in Table 1.

If the AIO2 fails this check, remove the AIO2 and send it to the manufacturer for recalibration. Then contact the RCO chemist to flag the barometric pressure data with a QX flag back to the last time the barometric pressure was checked.

Per manufacturer's instructions, the Druck DPI 705 should be calibrated once a year. Should the DPI 705 fail a calibration or need repair, it should be sent to the manufacturer.

Should a Druck DPI 705 digital pressure indicator be unavailable, an Audit AIO2 can be used to perform a CTS for the barometric pressure parameter. While performing a CTS in this way, hours with windspeeds and rain events that would not be used for windspeed and wind direction should be used for barometric pressure. The CTS should be operated as it is for windspeed and wind direction in every other way.

5.5 Ambient Temperature

At least once a calendar year and every 365 days, Ambient Temperature should be checked with the Robotronic HygroPalm HP23-A. The HP23-A is a handheld rugged device that is very stable with little required maintenance.

To check the ambient temperature with the HP23-A, place the handheld unit close to the AIO2 and wait for it to stabilize. This should take 20 to 30 minutes. Ideally, the HP23-A should be within 10 horizontal meters and 1 vertical meter. However, due to siting, this may not be possible. ECB technicians should use their best judgement to determine where to place the HP23-A when these conditions can't be met. Make sure the HP23-A is set to the same unit scale as the AIO2. Compare the readings on the HP23-A to the minute readings of the AIO2. Record the date and time of the first minute value used. Calculate the precision and bias using the control limits in Table 1.

Every 12 months, the battery of the HP23-A should be replaced. The Pt 100 RTD temperature sensor used in the HP23-A's probe and associated electronics are very stable and should not require any calibration after the initial factory adjustment. Calibration of the probe should be verified every 12 months. Applications where the probe is exposed to significant pollution may require more frequent verifications. The ECB technician may have to clean or replace the probe filter as needed.

Should a Robotronic HygroPalm HP23-A be unavailable, an Audit AIO2 can be used to perform a CTS for the ambient temperature parameter. While performing a CTS in this way, hours with windspeeds and rain events that would not be used for windspeed and wind direction should be used for ambient temperature. The CTS should be operated as it is for windspeed and wind direction in every other way.

5.6 Relative Humidity

At least once a calendar year and every 365 days, Relative Humidity should be checked with the Robotronic HygroPalm HP23-A. The HP23-A is a handheld rugged device that is very stable with little required maintenance.

To check the relative humidity with the HP23-A, place the handheld unit close to the AIO2 and wait for it to stabilize. This should take 20 to 30 minutes. Ideally, the HP23-A should be within 10 horizontal meters and 1 vertical meter. However, due to siting, this may not be possible. ECB technicians should use their best judge to determine where to place the HP23-A when these conditions can't be met. Make sure the HP23-A is set to the same unit scale as the AIO2. Compare the readings on the HP23-A to the minute readings of the AIO2. Record the date and time of the first minute value used. Calculate the precision and bias using the control limits in Table 1.

Every 12 months, the battery of the HP23-A should be replaced. Long term stability of the HP23-A humidity sensor is typically better than 1 %Relative Humidity per year. Calibration of the probe should be verified every 12 months. Applications where the probe is exposed to significant pollution may require more frequent verifications. The ECB technician may have to clean or replace the probe filter as needed.

Should a Robotronic HygroPalm HP23-A be unavailable, an Audit AIO2 can be used to perform a CTS for the relative humidity parameter. While performing a CTS in this way, hours with windspeeds and rain events that would not be used for windspeed and wind direction should be used for relative humidity. The CTS should be operated as it is for windspeed and wind direction in every other way.

Table 1: Control limits

	Windspeed	Wind Direction	Ambient Temperature	Barometric Pressure	Relative Humidity
Average (Bias)	±1.0 m/s	±10.0˚	±0.5˚C	±2.0 hPa	±5.0%
Standard Deviation (Precision)	±0.5 m/s	±10.0˚	±0.25˚C	±1.0 hPa	±2.5%

6.0 INITIAL STARTUP

When receiving an AIO2 from the manufacturer, an ECB Technician should document the serial number, date of calibration or recertification, and identify which site the AIO2 will be intended for in a dedicated spreadsheet. If the AIO2 is intended to be an Audit device, the ECB Technician should enter 'Audit' for the AIO2's location. If the AIO2 has not had a location determined for it, the ECB Technician should enter 'ECB' for the AIO2's location. The certification certificate should be stored securely at the ECB.

6.1 Mounting the AIO2

Proper siting of the AIO2 is directly related to the quality of data generated by the sensor. An ideal installation of the AIO2 is one in which an ECB Technician can safely access the sensor, can easily install an audit device near the sensor to perform a CTS Check, and replace the sensor within an hour. The ECB Technician should review the EPA's Quality Assurance Handbook for Air Pollution Systems Volume IV: Meteorological Measurement for more detailed information on siting requirements. The ECB Technician should work with regional staff and RCO staff to identify optimal siting locations.

At a minimum, the AIO2 should be sited:

- 10 meters above ground
- Located at least twice the diameter of the tower away from the tower the sensor is mounted on
- 1 horizontal meter away from any location that may be used to place an audit device
- 10 times the height of any obstruction in horizontal meters (for example, place the site AIO2 30 meters from a shelter that is 3 meters high)

Mounting an AIO2 to the roof of a structure should be discouraged but can be used if no other optimal siting location is applicable or available. The ECB Technician should contact regional staff and RCO staff before mounting a sensor in this way.

Prior to mounting the sensor to the tower, procure a signal cable of enough length to allow the sensor to connect to the datalogger. Secure a ¾-inch O.D. alignment tube to the meteorological tower or sled assembly. Mount the AIO2 to a piece of vertical ¾-inch O.D. rigid tube and secure it to the crossarm. The AIO2 when securely mounted should not twist, rotate, or sway.

Route the signal cable connector through the mount adapter. Plug the cable connector into the base of the AIO2 and turn the connector sleeve clockwise until tight. Then slide the AIO2 onto the top of the mount adaptor and tighten the two slotted base set screws.

Position the cable in the slot on the side of the mount and then slide the assembly onto the alignment tube. Tighten the 2 set screws on the mount to affix it to the alignment tube.

The AIO2 does not need to be oriented to True North as it has an internal compass that will allow the sensor to orient itself. Before leaving the site, the ECB Technician should wait 20 minutes and check to see that the compass readings do not deviate more than ±2.0 degrees.

Run the signal cable to the datalogger.

6.2 Connecting to the datalogger

The ECB Technician should consult the AIO2 user's manual for connecting the AIO2 to the datalogger.

Table 2: Cable Wire Color Designations:

Red	POWER POSITIVE (8-36VDC, 30mA nominal @ 12VDC)
Black	POWER COMMON
Blue	SDI-12
Green	SIGNAL COMMON
White	RS-232 TX
Brown	RS-232 RX
Yellow	RS-485+A
Gray	RS-485-B
Orange	EXTERNAL RAIN GAUGE OPTION INPUT
Violet	EXTERNAL SOLAR RADIATION SENSOR OPTION INPUT
White/Brown	SHIELD (must be grounded for transient protection to function)

Warning: Do not short any of the signal or power wires to ground or to each other.

7.0 ONSITE INSTALLATION

Due to the nature of the AIO2, the initial setup procedure and onsite installation procedure are the same. ECB Technicians should refer to section 6.0 for guidance on Onsite Installation. When an AIO2 is installed on the site, the ECB Technician should document the event in the site logbook. A CTS check at the Millbrook site should be completed before taking a new AIO2 to a site for installation.

7.1 User Interface

The output of the AIO2 is a fixed length, comma delimited, serial data stream. The serial output is factory set for 9600 baud, no parity, 8 data bits, 1 stop bit, and no flow control. The output interval default is once per second. The ECB Technician should change the output interval to once per ten seconds. This may be changed using the OI command. The data is easily viewed and can be displayed and captured using Met One Instruments' Comet Software or other terminal communication program.

7.2 Manufacturer Calibration and Recertification Schedule

The AIO2 has no way to perform a manual calibration by ECB Technician. Due to this, the AIO2 should be sent to the manufacturer for calibration and recertification even if the AIO2 appears to be functioning accurately. Every 2 calendar years and 730 days, the ECB Technician should send the AIO2 to the manufacturer for calibration and recertification. Before a AIO2 is removed from the site, a CTS check should be performed. Audit AIO devices should be sent to calibration and recertification every calendar year and 365 days.

8.0 ROUTINE MAINTENANCE BY ECB

The AIO2 has no moving parts and therefore has no need for routine maintenance. Should an AIO2 appear to be giving suspect data, a CTS check should be performed.

8.1 Rain and Snow

Anything that blocks the acoustic signal path will degrade the measurement. If the path is blocked sufficiently, measurements cannot be made. Rain and snow are common natural events that can block the path. Before traveling to a site, the ECB Technician should check the weather to see if erratic Met data can be explained by one of those events.

9.0 ACCURACY AUDITS

The AIO2 sensor does not contain any moving parts that measures windspeed and wind direction which can be tested with a certified transfer standard, instead the accuracy, precision and functionality checks are completed by the collocated transfer station method (Section 5.2). It is encouraged that sites should undergo a CTS check as often as possible. However, it is only required once a calendar year and every 365 days.

The Ambient Temperature, Barometric Pressure, and Relative Humidity can be audited using the same process as described in section 5.4, 5.5, and 5.6.

Note: The Millbrook site should undergo a CTS audit twice a calendar year and every 182 days at a minimum.

Regional Staff or Raleigh Central Office Staff may request an audit be performed based on data observed from the instrument.

9.1 Audit AIO

To maintain the validity of an AIO2's accuracy, precision and functionality used for audits, the unit must be checked more often. Once a calendar year and every 365 days, the Audit AIO should be sent to the manufacturer for recalibration and recertification. An Audit AIO should only be left in the field only as long as it takes to complete a CTS Check and cannot be used to replace an AIO2 that fails the CTS.

It is encouraged that the ECB maintains multiple Audit AIOs. A newly received Audit AIO should have an CTS performed at the Millbrook Site before using it for any other CTS. Should that check fail, another CTS check should be performed against a second Audit AIO to determine which device is reading incorrectly.

10.0 REVISION HISTORY

The following revisions were made:

Date	Person Revising Document	Revision	Page No.	Approved by/Date
5/20/2021	Jeremy Pope	Fixed mistake with compass stability. Standard deviation should be used.	**Error! Bookmark not defined.**	Joette Steger/ 20 May 2021
10/21/2021	Jeremy Pope	Adjusted audit/CTS limits to achievable limits.	13	Joette Steger / 23 October 2021
		Added a section for checking ambient temperature, barometric pressure, and relative humidity.	12-13	
		Changed qualifying windspeeds from 1m/s and greater to 1-10m/s.	10	
		Added a sentence that says to disregard days with rain events during a CTS unless there is a rain gauge. If there is a rain gauge, just disregard the hours with rain.	10	
		Changed Zero limit for windspeed from 0.1m/s to 0.2m/s.	10	

11.0 REFERENCES

1. See “MODEL AIO 2 ALL IN ONE WEATHER SENSOR OPERATION MANUAL Document No. AIO2-9800 Rev. F”
2. U.S. EPA, (2008) Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements (Version 2.0). Prepared by Office of Air Quality Planning and Standards