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DAQ-07-004.2 Standard Operating Procedure (SOP)
DAQ-07-004.3 SOP
MetOne 370D Tipping Bucket Rain Gauge Operator and Coordinator
Responsibilities

Revision 0.0
Effective Date: June 1st, 2021

1.0 Approval Sign Off-Sheet

I certify that I have read and approve of the contents of the MetOne AIO2 All-in-One Met Sensor Standard Operating Procedure with an effective date of June 1st, 2021.

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Disclaimer: This document, and any revision hereto, is intended solely as a reference guide to assist individuals in the operation of the instrument, related to the North Carolina Division of Air Quality's Ambient Monitoring Program.

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2.0 SCOPE AND PURPOSE

The SOP for the Met One 370D Tipping Bucket Rain Gauge is for supporting the collection of meteorological data required by the United States Environmental Protection Agency's (EPA) Photochemical Assessment Monitoring Station (PAMS) monitoring program (updated in 40 Code of Federal Register, Part 58, Appendix D, Section 5.0). The purpose of this document is to provide guidance to the operators and coordinators responsible for the 370D Tipping Bucket Rain Gauge operation and Level-1/Level-2 data review.

Only the Precipitation parameter applies to this SOP. Other meteorological parameters, such as: Wind Speed, Wind Direction, Temperature, Relative Humidity, Barometric Pressure, Solar Radiation, Ultra-Violet Radiation, and Mixing Height are dealt with in separate SOPs. Any records generated by the Operator will be reviewed and verified by the Regional Ambient Monitoring Coordinator (RAMC). The Raleigh Central Office (RCO) Chemist validates routine and associated Quality Control data monthly. The block of data generated by an individual monitor in one month is defined as the data set. Monthly review has proven to be the most efficient period for these verification and validation activities.

3.0 EQUIPMENT CHECKS

The model 370D Tipping Bucket Rain Gauge is an accurate, sensitive, and low maintenance sensor designed to measure rainfall on a continuous basis. Water is not retained by the sensor. It is drained each time an internal bucket fills with 0.01 inches of rainfall. As the bucket tips over and pours the water out the base of the sensor, a switch closure pulse is sent to a connected transistor module for counting.

Instrument Specifications:

Measurement Principle: Tipping bucket

Orifice: Eight inches

Switch Type: Magnet & Reed

Switch Specification: 500 milliamp, 200 Volts Direct Current maximum*

Operating Temperature: 0 Degrees Celsius to +70 Degrees Celsius Ambient Temperature

Calibration (standard) 0.01 inches per switch closure

Calibration (options) 0.2 millimeter (mm), 0.25 mm per switch closure

Calibration (372D) 0.5 mm per switch closure

Accuracy: +/-1% at 1 inch per hour at 70 degrees Fahrenheit

Deployed Dimensions: 18- $\frac{1}{4}$ inches high, 8 inches diameter not including mounting pads

Mounting: 3 Pads for $\frac{1}{4}$ -inch bolts on 9- $\frac{21}{32}$ inch (9.66 inches) circle diameter

Weight: 6.7 pounds/ 3 kilograms without cabling

Shipping Weight: Approximately 10 pounds with cabling

4.0 SITE CHECKS

The site operator shall, when visiting the site for regular gaseous monitor operations, verify that the 370D Rain Gauge is or has communicated values to the Envidas site computer during the most recent rain event. On a daily basis, both the site operator and the RAMC shall check that the 370D Rain Gauge has reported hourly values along with the other meteorological parameters.

4.1 Operational Spot Checks

While not required, it is encouraged that the site operator or RAMC use rain events as opportunities to perform an operational spot check. Should a rain event occur, the site operator or RAMC reviewers should check the data collected by the instrument for elevated readings the next day. Should the instrument fail to show elevated readings, the site operator reviewer should contact the Electronics and Calibration Branch (ECB).

Alternatively, the site operators or RAMC can use days with no rain events to check to see if the rain bucket shows near zero readings. Should the instrument fail to show near zero readings, the site operator should travel to the site and check to see if the drain on the instrument is clogged. If so, the site operator should clean the 370D Tipping Bucket Rain gauge as per section 5.1. If the instrument is not clogged, the site operator should contact the ECB

5.0 DETAILED PROCEDURES

Rain measurements have a unique challenge in that there is no way to verify the accuracy of their measurements daily with a precision check like the criteria pollutants. Instead, the site operator and RAMC use a weight of evidence approach to check the completeness and validity of the data generated by the 370D Tipping Bucket Rain Gauge (see section 6.0). To verify that the tipping mechanism is functioning, the operator shall on a monthly basis pour an amount of water between 8 and 16 milliliters to activate the tipping mechanism and register non-zero readings.

The precision and bias of the instrumentation, relative to nearby sensors, shall be reviewed by the RAMC on a monthly basis. Hourly data is available through the State Climate Office (SCO) CRONOS system for the "KRDU" meteorological station located at Raleigh Durham International airport. The data can be requested as Validated or Raw. For the purpose of verifying the operation of the DAQ meteorological data, the Raw version of data should be downloaded from the SCO system. Until the SCO CRONUS system is updated (projected April-2021) the maximum amount of historical data that may be directly downloaded is seven (7) days. The regional coordinator will have to schedule weekly SCO downloads for use during monthly data validations at the end of the month (<https://climate.ncsu.edu/cronos>).

The instrument is formally audited every 6 months by ECB personnel. Should the site operator or RAMC believe that the 370D Tipping Bucket Rain Gauge is not functioning properly, he or she should contact the ECB and request an unscheduled audit.

5.1 Cleaning Procedure

Once every 30 days, the site operator should go to the site and clean the 370D Rain Gauge to prevent the instrument from getting clogged. This procedure may occur more often based on need.

To clean the instrument:

1. Remove and clean the upper and lower debris screens.
2. Remove the sensor housing assembly (loosen three screws at base, twist and lift off carefully) and thoroughly clean the collection funnel.
3. Carefully clean both sides of the tipping bucket assembly.
4. Clean the lower drain screen in the base of the sensor.
5. Do **NOT** lubricate the pivot shafts, as any lubricant may attract dust and dirt.
6. Verify the bucket moves freely and that the translator card or datalogger registers 0.25 mm (or as calibrated) for each bucket tip.
7. Using a calibrated graduated cylinder perform a calibration check (See Section 5.2). All results should be noted in the appropriate Elog.

8. Check around the instrument for vegetation growth. If the vegetation is easily removable, the site operator should do so. If not, contact the appropriate person to have the vegetation removed.

5.2 Calibration Check

Once every 30 days, the site operator should go to the site and check the calibration of the 370D Rain Gauge. This procedure may occur more often as the site operator and RAMC see fit.

To perform a calibration check:

1. Remove the outer housing assembly. This will expose the tipping mechanism, terminal block, and built-in level on the base of the gauge.
2. Verify the sensor is level using the built-in level in the base of the sensor.
3. Wet the mechanism and tipping bucket assembly by pouring water (in a controlled manner) through the inner funnel and into the tipping bucket until it tips. Repeat this for the other half of the bucket. Tip the bucket one more time by hand to allow any excess water to drain. ***Do not wipe out or dry off any residual water droplets!***
4. Using a calibrated graduated cylinder, slowly pour 81 milliliters (mL) of water through the inner funnel to the tipping bucket, counting the number of “tips”. The buckets make an audible metallic ‘click’ when they actuate. The buckets are 8.11 mL each; 81 mL of water should equal ten “tips”. How carefully water is poured can affect the number of tips by ± 1 tip. Then check Envista for how much rainfall it collected. If the number of tips do not equal 10 ± 1 or Envista is not within 10% of the Elog’s calculated rainfall volume, contact the ECB.
5. Document calibration check results in the Elog.

Table 1: Tip Calibration vs Water Quantity

Tip Calibration	Water Quantity
0.01 inches (standard)	8.24 milliliters
0.20 mm	6.49 milliliters
0.25 mm	8.11 milliliters
0.50 mm (372D)	16.2 milliliters

6.0 Logbook Submittal and Data Retrieval

6.1 Logbook Submittal

The Elog, or Electronic Logbook, serves as the Transfer Record and Document for evaluating the Success/Failure of the operation of the 370D Tipping Bucket Rain Gauge monitoring site and is the essential record for determining the quality of the rain measurement data reported from each site.

1. The **Site Operator** must complete the Elog to document the purpose of Every site visit, the observations and findings during the site visit, and the evaluation of the performance of the rain measurement monitoring system for each site visit. This includes any and all startups and shutdowns (including severe weather events, temperature extremes, and etc.). The Site Operator must initial and date the last time the Elog was altered.
2. The Site Operator must submit the Elog to the RAMC or Designee for review and comment as soon as reasonably possible after the site visit and at a minimum by the end of each month. Additionally, a Site logbook page should be annotated with any site visit; i.e. shutting down for approaching weather, start-ups and shut downs, and etc. Each site visit should provide an Elog and an entry in the Site logbook stating, at a minimum, a purpose for the visit.
3. The **RAMC** or Designee must review site operator monthly submitted Elogs for each site in their region and evaluate each Elog for completeness and operator adherence to operating procedures. Following that review the RAMC must Initial and submit each logbook to the RCO Chemist for review.
4. The **RCO Chemist** must review the logbooks submitted for completeness and adherence to operating procedures. The RCO Chemist must also review the logbook submitted from each site and from all regions to determine if there is a systemic problem or pattern of operation that may be negatively impacting the overall operation of the metrological monitoring network and the quality of the metrological data reported.

6.2 Data Retrieval and End Processing

Every business day, the RCO statistician initiates a data review for the previous day by providing a raw data report (in a spreadsheet format) to each regional office (RO) (Reference DAQ-15-006.5 Data Validation SOP for Continuous Gaseous and Meteorological Monitors for details on data review). The RCO may request the RO to send additional data that are needed beyond what the RCO requires for verifying any missing data supplied by the RO. These data can be retrieved from the site computer.

7.0 FILE MANAGEMENT

Site operators must have a personal computer (PC) (or laptop) to generate the Elog files from a Microsoft Excel template file. These Elogs are provided by the RCO and updated periodically. The file naming protocol is provided below. A formalized file naming convention has been established and should be used by all operators.

The 370D Rain Gauge data will be polled and managed by the DAQ Envista database administrator, under the same, established protocols, used for gaseous monitors. The RAMC will submit a monthly log to the RCO P:drive using the same protocols as used for gaseous and particulate monitors (P:\Ambient \Incoming \RegOffices.NC \Raleigh \LogbookReports \YYYY \MET) comparing the SCO hourly data with the 370D Rain Gauge hourly data.

7.1 File Naming Convention

The Elog template file used at the site should be stored on the PC used for field operations by the field technician. Elogs can also be found in DAQ's Internet Based Enterprise Application Management system (IBEAM). To access this file, open the Elog template file using Excel. Every time a new e-log is filled out using the template, it must be renamed and saved as a separate and complete workbook (all sheets, i.e., tabs, saved) to preserve the record. Do NOT copy over a previously completed Elog.

NOTE: Refer to the Logbook file naming convention "Policy Memorandum" dated January 1, 2011 located in the DAQ IBEAM module (summarized below).

Renaming and Saving the Elog

1. Open the Elog workbook template file using Excel.
2. Left click the "file" toolbar icon. Scroll down to "save as" and left click.
3. Under file name change workbook file name using the following format:
Site ID Met Date Activity. For example, MQ Met 20120730 SV.xlsx is a Site Visit at Millbrook on July 30, 2012
4. Change save location to operator's choice of folders (example: previously created folder named Met).
5. Left click "save".
6. Find the tab needed for the task involved. The first tab selected should be the Logbook. Fill in information as indicated.
7. Open other tabs as needed and fill in information as indicated.
8. Save the workbook when finished entering data.

8.0 Quality Assurance & Data Handling

All site files, Elogs or other supporting documents generated in the field will be stored on dedicated server space in the RO in a folder named for the official site operation files. These files should be transferred to the Official File on a frequent and regular schedule as established by the Region. This is necessary to prevent the potential loss of such files from the field computer and to maintain a “paper trail” for providing defensible data. This also makes the data easily and readily available for review by the Regional Ambient Monitoring Coordinator and transfer to the P: drive for review by the RCO. The files on the site/operator PC can be copied and transferred to the common hard drive via email or flash drive for storage in the official file folder.

The site files should be transferred every three business days and backed up monthly. This serves as a backup system in the event the official PC fails or is removed or the site files are damaged. These files will be retained for a minimum of five years. When the need arises to review a file for data validation or site operations, the official folder is used or a hardcopy is created from this file. For details on data validation procedures, please reference DAQ-15-006.5 Data Validation SOP for Continuous Gaseous and Meteorological Monitors. The following verification checks shall be completed every month:

1. Providing proper null codes indicating calibrations, audits etc.
2. Providing missing valid data.
3. Documenting any invalid data as to reason with proper null code.
4. Identifying any data that may be associated with exceptional events.

All data within the DAQ data set must meet the following conventions:

- All data must be reported in Eastern Standard Time year-around.
- Hourly data are reported at the start of the hour (1:00-1:59 is time stamped as 01:00)
- All missing or invalid data must be accounted for by the use of proper null codes. The null codes must be accompanied by the identifying reasons for the missing or invalid data on the monthly data verification and validation pages.
- All data, including any supporting documentation, must be kept for a minimum of three calendar years after the calendar year in which it was collected. Exceptions to this are discussed elsewhere in this SOP.
- Completeness - Data are considered complete if 75 percent or more of the total possible number of observations are present. Continuous measurement criteria for completeness are listed below:
 - 75 percent of the minutes in the hour must be valid; and
 - 75 percent of the hours in a quarter must be valid.

8.1 Monthly Verification and Validation

Preliminary verification is completed by the RO Operator. The operator must account for and identify the reasons for missing or invalid data within Envista using proper flags and null codes while performing maintenance or shortly thereafter. The operator must review the previous month of data and add any flags or void codes to the Status column as necessary. For each changed status, a comment must be entered with a description of why the status was changed.

The RAMC will perform the second level review of the month of data, adding any additional void codes and comments, and requesting additional information from the operator as necessary. If required, the RAMC can send data back to the RO Operator for additional comments or to correct any codes. When possible the data will be validated within 15 workdays from the end of the collection month.

The RCO Chemist performs the final validation of the one-month period of data. Void codes and comments should all be added, and the RCO Chemist can send the data back to the previous reviewer. Final validation of the data should be completed within 30 days of the end of the collection month. Once the data has been approved and has had the "final validation" label applied by the RCO Chemist, it is automatically entered into a queue within Envista ARM. The Database Manager will send all approved data to AQS automatically on a regularly scheduled basis.

In some cases, "valid" data that are judged to be out of the ordinary are retained and an outlier ("5") or validated data ("V") flag is added in AQS by the RCO. An example would be high or low values resulting from an event that is not observed by another nearby site.

A list of Null Codes that are routinely used during data validation on the AQS monthly summary report are listed in the following table.

Table 2: Commonly Used EPA-AQS Null Value Codes (partial list)

AN	Machine or Equipment Malfunction
AS	Poor Quality Assurance Results
AT	Calibration
AV	Power Failure
AZ	QC (ECB) Audit
BA	Maintenance and Routine Repairs
BJ	Operator Error
BK	Site Computer/Data Logger Down

8.2 Common Rain Measurement Trends

The Site Operator, RAMC, and RCO Chemist should use other metrological instrumentation at the site (such as the AIO2) and look for the following trends:

- **Rain measurements vs. Humidity:** As rain measurements are observed, relative humidity should increase.
- **Rain measurements vs. Barometric Pressure:** When barometric pressure is low or decreasing, there is more likely a chance of rain measurements to be observed. When barometric pressure is high or increasing, there is less likely a chance for rain measurements to be observed.
- **Rain measurements vs. Solar Radiation:** Rain events are more likely to occur when solar radiation reads lower.

In general, if the data does not follow these trends, a reviewer should look at nearby weather sites to confirm if a rain event occurred or not and put a QX (does not meet QC criteria) qualifier flag on any data that cannot be confirmed by one of these metrological trends or from the other weather station.

9.0 TROUBLESHOOTING AND CORRECTIVE ACTIONS

In general, troubleshooting and corrective actions should be taken by the ECB. Should there be an immediate need to arise for corrective action, contact the ECB.

10.0 REVISION HISTORY

The following revisions were made:

1. This is a new SOP

11.0 REFERENCES

1. See "370D/372D 8" Rain Gauge Manual, Document No. 370D-9800 Rev. A"