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| **World Meteorological Organization****Second Session of the Expert Team on Operational Metrology (ET-OpMet)**Tokyo, Japan, 27-30 November 2017 | **CIMO/ET-OpMet-2/Doc. 6**  |
| Submitted by:Ferdinand Barcenas12 November 2017 |

#

# TITLE

**Guidance on Field Inspection of AWS Sensors**

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| **Summary and purpose of document**This document provides information on the draft of the Guidance on Field Inspection of AWS Sensors. |

**Action proposed**

The Meeting is invited to review the text of the draft of the Guidance on Field Inspection of AWS Sensors and propose the way of finalizing it in accordance with the Workplan.

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**Appendices:** I AWS Maintenance Guide

 II Main field inspections or checks at surface observation sites in JMA

 III Proposed Methodology for the Comparison/Checking of AWS Sensors at the

 Field Stations

**Guidance on Field Inspection of AWS Sensors**

1. Introduction

As a support to the calibration strategy in which the CIMO suggests the need to sensitize WMO Members to the regular instrument calibrations, in addition to preventive maintenance and periodic instrument checks as a tool to ensure traceability and quality of measurement results, this guidance is developed.

Field inspection of AWS sensors, besides laboratory/mobile calibrations for the whole ranges, involves the strategy to identify instruments which are out of limits, or tolerances and the required uncertainties. As it is known, the ways of traceability are whether fully assured, assured, partially assured and lacking traceability. It is a must that WMO Members have the responsibility to achieve the required calibrations and field inspection to choose the best fitted approach for their traceability assurance such that all the measurement within any particular NMHSs has to be traceable to International Standard (SI).

1. Field Inspection

Field inspection can be subdivided into categories:

1. Field inspection using portable device with travelling standard that can calibrate for the whole range of measurable weather elements. This is usually done with mobile calibration test equipment.
2. Field inspection also using portable device, or travelling standard in checking the sensors which is termed as a “one-point calibration” but could be an acceptable means of ensuring the network observations quality.

For field inspection using portable devices with travelling standards that can calibrate for the whole range, a vehicle is usually used equipped with good cross-country performance for field test, carrying several vehicle-mounted calibration devices. Its operation could be the same with laboratory calibration of sensors but preferably of smaller sizes.

Field inspection is usually associated with the preventive maintenance which should also be done during or prior to such inspection. Maintenance guide can be found in WMO-No. 8, Part II, Chapter 1.6. Maintenance should include replacement of the sensors before their lifetime expires if specified by the manufacturer, replacement or repair of sensors and other apparatus if the result of inspection suggests it is needed, and as reported by the users that it is verified defective, and the status of the AWS if it is in accordance with the standard exposure and may not need to be transferred in location or it can be a special station. It may also include cutting grass and vegetation which could affect sensor exposure, checking enclosures for water ingress and replacing desiccants, treating and painting weathered and corroded enclosures, screens and supports; checking cable and connector integrity, cleaning and levelling sensors noting the measurement issues, cleaning of exposed instrument surfaces, like the domes of radiation meters, rain gauge,

solar panel, checking of battery status and many more. All these should be documented by logging the times when these works have been performed.

There should be requirements which a station should be inspected, the metadata records to which the siting and changes that happened to the station, the frequency of inspections, the process of analysing and addressing non-conformance, and the documentation of inspection.

Further guidance on regular inspection can be found from WMO-No. 488 Guide to the GOS, Part III, Section 3.1.3.8. Metadata records should be available as a result of verification of calibration to include the changes in exposure of the sensors like plant growth, newly erected building and other obstacles.

Checking the sensors during inspection may serve to eliminate gross errors and can alert the inspector as soon as possible to a faulty or unreliable sensor. By making the best effort possible, it gives us confidence to those using the data accumulated, who can allow for possible errors and apply corrections where appropriate.

Calibration corrections should only be applied when the sensor has been monitored for some time so that the magnitude and bias of deviations can be logged. If these are random and within the required accuracy, then adjustments are not necessary. However, where a clear tendency or the sensor exhibited stability of measurement, calibration adjustments or corrections should be carried out.

It is also important that instrument hysteresis and lag, or more likely related to the response time and sensitivity can manifest themselves as a difference of reading between two instruments at any point in time. For this reason it is important to carry out calibration checks when readings are reasonably stable and certainly not changing rapidly during field inspection.

It is worth mentioning that most good quality AWS have the facility to adjust the recorded weather elements, either via the equipment hardware, or through software, and in the case of rain gauges often a physical adjustment of the mechanism is possible (see tipping bucket rain gauge calibration procedure at Annex III, Part IV). Once a calibration requirement has been identified the offset should be applied to bring the readings into correct calibration and a note made to be kept with the data of the calibration applied, along with date and time (Overton, 2009). An offset adjustment like interpolation should be applied to the measured parameter especially when the error is not linear throughout the range of the instrument. In applying the correction, you have to know if it is an offset or a scale error. If it is the latter and an offset correction is applied to all data, this will be entirely inappropriate with some values. Non-linear corrections cannot be applied to the instrument if necessary but must be carried out manually or by data manipulation as in interpolation executed in the program or software with a PC. As an example with humidity sensor: if a correction is made at 90% RH you have to interpolate between 90% and 100% for a correction for 90% and zero to 100% in order not to overshoot more that 100%, or under-read at 100% depending on the error. Not of course for a very large correction, that is why we need to set a limit.

An AWS should be checked and serviced at a maximum of 12 months, with 3 to 6 months recommended in aggressive environments. For high quality data, sensor calibration should be checked every two years. WMO-No. 544 Manual on the GOS, Part III, Section 3.1.10 states that, automatic weather stations should be inspected not less than once every six months. Maintenance and calibration of AWS sensors should be in accordance with WMO-No. 8, Part II, Chapters 1.3.2.11, 1.6 and 1.7. Most countries and manufacturers of AWS, usually have the process and procedures for field inspection of AWS sensors. Annexes I & II give us this guidance approach.

As with field inspection test, the use of similar instruments and site configurations can greatly aid the quality assurance (QA) process because it allows for efficient troubleshooting. It is certain that the most straightforward QA test involves the comparison of two or more identical sensors at the same station at the same height (Fiebrich et al, 2010). It means that like-instrument checks detect observations that significantly differ from identical or similar instruments at the same station and time. A procedure is introduced at Annex III, which is somewhat similar to this method for field inspection of AWS sensors.

**References and further reading:**

WMO-No. 8, 2012, Guide to Meteorological Instruments and Method of Observation

WMO-No. 488, 2007, Guide to the Global Observing System

WMO-No. 544, 2003, Manual on the Global Observing System Vol. 1

Overton, Andrew K., 2009, A Guide to the Siting, Exposure and Calibration of Automatic

 Weather Stations for Synoptic and Climatological Observations

Fiebrich, Christopher A., et. al., 2010, Quality Assurance Procedures for Mesoscale Meteorological Data

Anjan, Anjit, et. al., Implementation of Quality control by India Meteorological Department on its

 Automatic weather Station and Automatic Raingauge Station network

South African Weather Service, Standard Operating Instruction: Operation and management of

 verification instrumentation for wind, temp/humidity, rainfall and air pressure at weather offices

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**APPENDIX I**

AWS Maintenance Guide

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Chapter 1

# Quality Management of AWS network

Good quality meteorological data requires quality management system. The quality management system operates continuously at all point of the whole observing system, from network planning and training, through installation and station operations to data transmission and archiving.

WMO CIMO Guide has given the basic instructions which operations shall be covered in the quality management system of AWS network.

 This paper

- gathers some of the WMO general recommendations related to surface weather data quality requirements and AWS network maintenance.

- gives manufacturer’s recommendations for maintenance of equipment.

## WMO Quality Management Framework

The WMO Quality Management Framework gives the basic recommendations that are based on the experiences of National Hydro Meteorological Services. The necessary conditions for successful certifications against ISO 90001 are explained in WMO documents.

Important is that successful quality management depends heavily on the co-operation of senior management. The necessary conditions for successful certifications are summarized and the terms of ISO 9001 standards are explained in ISO 20000.

Senior level management defines a quality policy and the quality objectives and staff have to be trained to understand the basis of quality management process.

Chapter 2

# WMO recommendations FOR Equipment Maintenance

Network management is responsible of corrective actions in response to the network performance revealed by quality–control procedures and performance monitoring.

Equipment maintenance may be a direct function of the network maintenance unit. If not, there should be effective collaboration between the network manager and the officer responsible for the equipment.

## Inspection of stations

All manned synoptic and principal climatological stations should be inspected no less than once every two years. Appropriate inspection interval for automatic stations should be not less than once every six months. Agricultural meteorological and special stations should be inspected at intervals sufficiently short to ensure the maintenance of a high standard of observations and the correct function of instruments.

 The objective of such inspections is to:

* Check that siting and exposure of instruments are known, acceptable and adequately documented
* Instruments are of approved type, in good order, and regularly verified against standards, as necessary
* There is uniformity in the methods of observations and procedures of calculating derived quantities from the observations
* The observers are competent to carry out their duties
* The metadata information is up to date.

##

## Maintenance

Observing sites and instruments should be maintained regularly so that the quality of observations does not deteriorate significantly between station inspections.

### Preventive maintenance

Routine maintenance schedules include regular ‘housekeeping’ at observing sites. For example, grass cutting and cleaning of exposed instrument surfaces. Routine maintenance also includes manufacturer’s recommended checks on automatic instruments. The aim of the preventive maintenance check is to detect equipment faults at the earliest possible stage.

### Calibrations

Instrument calibrations can be part of the site inspections or part of the preventive maintenance.

Instrument requiring calibration must be checked against a suitable standard.

## WMO Maintenance Classification

In 2012 a classification scheme for surface weather measurements was proposed. This scheme can be found from WMO Internet pages, CIMO Commission for instruments and methods of observation, CIMO expert team on standardization, First session, Geneva Switzerland 26-29 November 2012.

 The classification is still under work and not published and accepted.

Chapter 3

# recommendations FOR Equipment Maintenance

It is recommended that frequent instrument inspections as guided in the WMO CIMO guide are necessary. Depending on the sensor set, frequency of the inspections can vary from 6 months to 1 year.

Inspection visit to site shall include:

 - Field-checking of humidity and pressure instruments against reference

 instruments

- Field checking of rain gauge against reference weight/liquid test

- Battery charging check

- Opening of the AWS box and visual check of the components and wiring

- Data collection check: each sensor is sending data to logger

- Data collection check: logger is sending data to data collection center

As most of the weather station sensors shall be calibrated in laboratory conditions, devices must be taken from site to laboratory for checking. To avoid data breaks of the system, calibrated spare sensors should always be in storage to replace the instrument taken to calibration.

Most manufacturers provide Calibration Guide and User Guide for the calibration and maintenance procedures of their instrument’s products.

## Remote connections to sites

When installing AWS sites please ensure that remote connections to sites are working. It is easier to make fault diagnostics and know the perfect timing to go to site, if you can connect to site remotely.

##

## AWS enclosure checking

- Check that all surfaces are clean and undamaged

- Check that all sensors are connected and connectors are tight

- Open the AWS enclosure and check that all components are tightly in their

 places and secured

## Barometric pressure

 These maintenance instructions are related to pressure instruments.

###

###  Calibration maintenance

Frequent calibration of atmospheric pressure devices is essential as field barometers can drift to some degree. However, to ensure the best data quality, barometers can be easily calibrated by the user.

 *Example of Long-term stability*:

± 0.1 hPa /year

± 0.15 hPa /year

It is recommended to have yearly calibration. However, calibration must be done always when there is reason to believe that the device is not within the accuracy specifications.

Pressure calibration shall be carried out in laboratory conditions. However, an easy field check can be done by using transfer standard.

Note: WMO recommends 1 year calibration interval for class A pressure

 instruments.

###  Preventive maintenance

The only preventive maintenance for most pressure instruments is cleaning, if required.

###  Corrective maintenance

Spare devices shall always be in the storage, in case of device damages on site. Remote connections to sites shall always be available.

## Relative humidity and temperature

These maintenance instructions are related to the humidity and temperature instruments.

### Calibration maintenance

Recommended calibration interval is one year. Depending on the application, it may be necessary to make more frequent checks. Calibration must always be done when there is reason to believe that the device is not within the accuracy specifications.

Humidity and temperature calibration are recommended to be carried out in laboratory conditions. However, an easy field check can be done by using transfer standard.

Note: WMO-recommendation for class A instruments is 6 months calibration

 interval for humidity and one year for temperature instruments.

###  Preventive maintenance

Clean filter e.g. with compressed air, replace if necessary. In the course of time the probe filter will be contaminated with matter that you cannot remove by cleaning. When this happens, the sensor response time becomes longer and measurement accuracy decreases.

 Check tightness always after handling probe

* Sensor filter
* Calibration buttons cover
* Cable connector

Radiation shield affects on the humidity sensor performance. Wipe clean if dirty, inspect also radiation shield interior

###  Corrective maintenance

In case of instrument damages on site, spare devices and cables shall always be in the storage.

In case of sensor chip damage, you can change the sensor yourself and the whole probe does not have to be sent in for service for a sensor change.

Most humidity sensor chip is replaceable.

* Calibration is needed after sensor replacement
* Replace only with same sensor type used
* Composite sensors should be replaced by the manufacturer

Dirty humidity sensor can be cleaned with distilled water or isopropyl alcohol

* Detach sensor and rinse with distilled water
* Dry with nitrogen flush if possible. Allow to dry completely before sensor reinstallation

## Temperature

These maintenance instructions are related to temperature instruments.

###

### Calibration maintenance

The recommended calibration interval is 2 years. However, calibration should be carried out always when there is a reason to believe that readings are not correct.

A rough calibration can be done at field by comparing temperature probe reading in air against a calibrated reference sensor. If the deviation from the reference is remarkable, probe shall be taken to the laboratory for further checking.

Note: WMO recommends 1 year calibration interval for class A temperature

 instruments.

### Preventive maintenance

 No preventive maintenance.

### Corrective maintenance

In case of instrument or cable damages on site, spare sensors shall always be in the storage.

## Wind speed and direction

These maintenance instructions are related to the wind instruments.

###

### Calibration maintenance

Periodic calibration of some ultrasonic devices is not required for technical reasons. Test the mechanical integrity of the device and perform one-point calibration. However, some quality management systems may require regular calibration of the measuring instruments. To fulfil these requirements, it is recommended that you recalibrate the wind sensor every 2 years.

Wind equipment is usually calibrated at the wind tunnel, or the devices shall be sent to manufacturer for calibration.

Note: WMO recommends 1 year calibration interval for class A wind

 instruments.

### Preventive maintenance

 Ultrasonic sensor

It is recommended that you carry out a periodic visual inspection of the wind sensor to ensure correct operation and clean the wind sensor if it becomes contaminated. If necessary, you can also test the operation of the device with an optional verifier, which is a small echo-free chamber. If any of the transducers have been bent, twisted or rotated, the measurement results might not be accurate.

Mechanical (propeller type) sensor

Sensor surface must be kept clean and ball bearings must be checked yearly and replace the bearings if needed.

###  Corrective maintenance

In case of instrument damages on site, spare devices and cables shall always be in the storage. For the mechanical wind sensors, there are spare part sets to fix the broken sensors.

## Precipitation

###  Calibration maintenance

Periodic calibration of tipping bucket and weighing type of rain gauges is needed to ensure for data quality. It is recommended to check precipitation devices as follows:

* Tipping bucket, 6 months interval
* Weighing type of gauge, 1 year interval

Note: WMO recommends 6 months calibration interval for class A precipitation

 instruments.

###

###  Preventive maintenance

Precipitation devices shall be kept clean and if there are trees near to the site, visual checking and cleaning shall be done more often especially in the autumn time.

Weighing type of gauge must empty when the collecting bucket is 80% full.

### Corrective maintenance

In case of instrument damages on site, spare devices, components and cables shall always be in the storage.

##

## Solar radiation

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###  Calibration maintenance

Sensor manufacturer often recommends calibration every two years. This can be done at the manufacturer’s factory.

Note: WMO recommends 2 years calibration interval for class A global solar

 radiation instruments.

###  Preventive maintenance

Solar sensors shall be cleaned and checked frequently depending on the environment. Usually cleaning is required several times in a year.

The most important regular maintenance for a solar radiation sensor is to keep the dome or window clean. Dirt, water droplets, frost or any medium that absorbs or scatters solar radiation will affect the accuracy of the measurement.

The second most important thing is to make sure that the sensor remains dry internally by regularly checking the condition of the desiccant and replacing it if necessary. This prevents internal condensation when the temperature of the sensor passes through the prevailing dew-point.

 Spare dome and drying cartridges with desiccant shall be in storage.

### Corrective maintenance

In case of instrument damages on site, spare devices and cables shall always be in the storage.

## Visibility

These maintenance instructions are related to the visibility instruments.

###

### Calibration maintenance

A periodic check every 6 months is recommended. The user checks the visibility calibration using the calibration kit. If the check shows less than ±5 % change, recalibration is not recommended, because the change is within the repeatability of the calibration procedure.

Note: WMO recommends (3) or 6 months calibration interval for class A

 visibility instruments.

###

### Preventive maintenance

 Periodic maintenance of visibility sensor includes the following:

 - Cleaning the transmitter and receiver lenses and hoods.

 - Cleaning the Rain Detector.

 - Checking the visibility calibration and calibrating it, if necessary.

###  Corrective maintenance

In case of instrument damages on site, spare devices, cables and components shall always be in the storage.

 **References:**

 - WMO CIMO Guide, 2012

 - Kipp & Zonen: A guide to solar radiation measurement.

**Submitted by:**

 **Jing Lin**, 2013, VAISALA AWS Maintenance Guide,

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**APPENDIX II**

**Main field inspections or checks at surface observation sites in JMA**

(Submitted by Kouichi Nakashima, 1 Nov. 2017, RIC-Tsukuba, JMA)

Although there are many inspection and check items at surface observation sites in JMA, only those which are directly related to observation data are described.

**Surface observation types and numbers in JMA**

Manned stations: 61 sites

Special AWS: 95 sites

(http://www.jma.go.jp/jma/en/Activities/surf/surf.html)

AWS: approximately 1150 sites

(http://www.jma.go.jp/jma/en/Activities/amedas/amedas.html)

1. **Temperature**
2. Manned station

<Every 3 months>

Check by using an Assmann psychrometer (tolerance range within +/- 0.4 °C)

1. Special AWS

<Every 3 or 6 months \*1>

Check by using an Assmann psychrometer (tolerance range within +/- 0.4 °C)

1. AWS

<Every year>

Check by using an Assmann psychrometer (tolerance range within +/- 1.0 °C)

1. **Pressure**
2. Manned station

<Every year>

Comparison by using a travelling standard of barometer at an atmospheric pressure at a site, and set a new collection value on the barometer at the site.

1. Special AWS

<Every year>

Comparison by using a travelling standard of barometer at an atmospheric pressure at a site, and set a new collection value on the barometer at the site.

1. AWS

No observation.

1. **Humidity**
2. Manned station

<Every 3 months>

Check by using an Assmann psychrometer (tolerance range within +/- 4 %)

1. Special AWS

<Every 3 or 6 months \*1>

Check by using an Assmann psychrometer (tolerance range within +/- 4 %)

1. AWS

No observation.

1. **Wind speed**

Only visual check by a staff at the time of site check and maintenance.

1. **Wind direction**
2. Manned station

<Every 3 months>

Check the all directions are displayed by rotating anemometer by a staff.

1. Special AWS

<Every 3 or 6 months\*1>

Check the all directions are displayed by rotating anemometer by a staff.

1. AWS

<Every year>

Check three directions (SE, SW, N) are correctly displayed by a staff.

1. **Precipitation**
2. Manned station

<Every 3 months>

Check precipitation counter up by pouring water to the gauge.

1. Special AWS

<Every 3 or 6 months\*1>

Check precipitation counter up by pouring water to the gauge.

1. AWS

<Every year>

Check precipitation counter up by pouring water to the gauge.

1. **Sunshine duration**

Only visual check by a staff at the time of site check and maintenance.

1. **Visibility**
2. Manned station

<Every year>

 Calibration by using a visibility meter calibrator at a site.

1. Special AWS

<Every year>

Calibration by using a visibility meter calibrator at a site.

1. AWS

No observation.

**9. Snow depth meter**

(1) Manned station

<Before snowy season (usually in October)>

Check a measuring height by using an object which size is already known on the ground.

1. Special AWS

<Before snowy season (usually in October)>

Check a measuring height by using an object which size is already known on the ground.

1. AWS

 <No snowy season>

0 cm level check and adjust on the no snow ground.

\*1: Interval depends on its class of station in JMA.

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**APPENDIX III**

**Proposed methodology for the comparison/checking**

**of AWS sensors at the field stations**

This methodology provides the necessary steps in establishing the corrections of AWSs at the field stations through comparison/checking of the AWS sensors. Using an AWS preferably using the same brand and model with better accuracy and uncertainty as the calibrator, which is calibrated at the laboratory with traceability, is considered best for the comparison due to similar exposure (side by side) of the sensors especially the radiation shield to be used and the proper synchronization of the time of checking or observations recorded.

These procedures will rely on the maximum and minimum ranges the sensors can provide during the 24 hours recorded observations, or the estimated time the maximum and minimum will occur for all the sensors (less than 24 hours), in order that the corrections and its uncertainties for each of the sensors can be processed.

For the tipping bucket rain gauge, a separate calibrator or test kit, which can simulate rainfall rates, is necessary.

**I. Preparation at the site:**

1. Check the status and record in a checklist any observations at the site and the AWS. Clean, repair or replace any broken parts.
2. Clean the site if necessary.
3. Install the sensors of the calibrator (one set of AWS) side by side (at the tower mast) near the AWS to be calibrated (using mounting support, tools, & observe safety measure).
4. Position the data logger’s housing of the calibrator with the tripod provided, or mount it at the tower mast and connect all the cables to the sensors. (Switch the power on)

**II. Initiate the comparison:** (Note: You should know how to manipulate or program both

 AWS using the manual provided by the manufacturer)

1. Using a PC laptop, retrieve or save the old data of the AWS to be tested for archiving. After saving, clear the records of the data logger if necessary.
2. Synchronize the time of the calibrator’s data logger with the data logger of the AWS to be tested using the PC laptop.
3. Using the same laptop, set the program of both AWSs to the desired time interval that can be set for the comparisons or observations depending on the type or brand of AWS and the logging interval (preferably every minute). This will also ensure to detect erratic sensors.
4. It begins the 24 hours of observations to get the comparisons between the maximum and minimum readings of each of the sensors. (Disconnect the PC laptop from either AWSs during the 24 hours of recordings in the data loggers)

**III. Retrieving the records of the AWS’s sensors for corrections:**

1. Connect the PC laptop to the calibrator’s data logger and save the 24 hours records, and also the AWS under test. After saving, clear the records of the data loggers if necessary.
2. After restarting anew the AWS under test, transfer each of the records (saved data of under test and calibrator) using spreadsheet or excel at the same corresponding time rows tabulation for comparisons and use statistical and mathematical analysis for the corrections and uncertainties between the maximum and minimum records of each of the sensors.
3. Record the computed corrections, uncertainties and status to the space provided in the checklist.
4. Replace erratic or with bigger corrections or uncertainties of sensors (not conforming to tolerance) with new calibrated sensors.
5. Submission of the report to the authorized person after completion of the whole process.

**IV. Calibration of the tipping bucket:**

 During a part of waiting time for the comparisons of the sensors, you can proceed to the calibration of the tipping bucket rain gauge.

***Steps in the calibration of a TB rain gauge***

1. Check the status of the rain gauge.

2. If functional, disconnect the attached cable from the sensor terminal then clean the rain gauge (be careful not to short the terminals in order not to reflect as tipping in the AWS data logger).

3. Check and record the size (diameter) of the tipping bucket rain gauge. This is needed in the computation.

4. Test the initial volume (static value) per tip in the bucket, then record.

5. Adjust the tipping mechanism (usually screw at the bottom of the bucket) to the recommended volume per tip [or through trial & error to meet the required percentage error (+/-5%) by repeating step 5 to 12, & record the volume per tip, or (volume or mass of water) of the filled calibrator and take note of temperature if mass is considered; refer to annex 6.D & 6.E, WMO No. 8, Chapter 6, for other conditions].

6. Connect a data (mini) logger to the rain gauge sensor and the laptop (PC) with the cable provided. Conduct a test if the tipping registers into the data logger software window in the PC monitor.

7. Fill the calibration device with water (note of proper filling of H2O to the device). Close it with the nozzle specified. (Record the mass and temperature of the water if we are considering mass; if using volume, the calibration device must be calibrated with graduated cylinder)

8. Place the calibration device with the nozzle down to a holder provided at the top of the funnel.

9. Clear the screen of the software window or make sure there is no tipping initiated as seen in the monitor.

10. Start the stop watch at the same time w/ the switching ON of the calibration device to make the H2O flows down from the nozzle. Check the tipping if it registers in the screen.

11. Wait until the H2O is emptied from the calibration device to the last drop from the nozzle and at the same time stopping the stop watch.

12. Compute the percentage error and the corresponding rate of simulated rainfall.

13. Repeat steps 6 to 12 for other nozzles to cover the applicable ranges. The nozzle simulates certain rate of rainfall. All percentage errors should be within +/-5%. Make the report (Certificate of Calibration).

Note: Calibration of the tipping bucket is usually accomplished by passing a known amount of water through the tipping mechanism at various rates and by adjusting the mechanism to the known volume. (WMO No. 8, Chapter 6.5.2.3, Calibration and maintenance)

For expected large temperature operational ranges of the location, it is recommended that mass should be used instead of directly by volume, then converting to equivalent amount (depth) of rainfall.

**References for further reading:**

WMO No 8, 2014, Chapter 6. Measurement of precipitation, Annex 6.D.

 Standardized Procedure for Laboratory Calibration of Catchment Type Rainfall

 Intensity Gauges; Annex 6.E. Procedure for Field Calibration of Catchment

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Cristophe Alexandropoulos and Muriel Lacombe (France), TECO 2006, The laboratory

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