Quality Control & Quality Assurance Manual

for the

Cabras Power Plant

Meteorological Monitoring Program

Guam Power Authority

Planning & Regulatory Department
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ABBREVIATIONS AND DEFINITIONS

cm	Centimeter; a metric unit of length
°C	Degrees Celsius; a metric unit of temperature
gm	Gram; a metric unit of mass and weight
GPA	Guam Power Authority
MPS	Meters per Second: A measurement of wind speed velocity.
PSD	Prevention of Significant Deterioration: A set of USEPA air quality and meteorological monitoring QA and QC guidelines designed to prevent any significant deterioration of clean, healthy air within a given location.
QA	Quality Assurance: An assessment of the effectiveness of a Quality Control Program.
QC	Quality Control: Specific operational activities which are designed to sustain the quality of a product or service.
RPM	Revolutions per Minute: A measurement of rotational frequency.
SOP	Standard Operating Procedure: A detailed description for operating and maintaining an instrument or piece of equipment.
USEPA	United States Environmental Protection Agency
Guam EPA	Guam Environmental Protection Agency

QUALITY CONTROL and QUALITY ASSURANCE MANUAL

FOR THE

CABRAS POWER PLANT METEOROLOGICAL MONITORING PROGRAM

1.0 INTRODUCTION

Quality Control and Quality Assurance are essential elements of a successful meteorological monitoring program. By definition, Quality Control (QC) consists of "those operational procedures that will be routinely followed during the normal operation of the monitoring system to ensure that a measurement process is working properly. These procedures include periodic calibration of the instruments, site inspections, data screening, data validation, and preventive maintenance. Quality Assurance (QA) is defined as those procedures that will be performed on a more occasional basis to provide assurance that the measurement process is producing data that meets the data quality objectives. These QA procedures include routine evaluation of how the QC procedures are implemented (systems audits) and assessments of instrument performance (performance audits)"[3] In other words, QC includes everything that an organization does to produce a quality product (in this case, meteorological data) and QA is the mechanism that checks and quantifies the effectiveness of the QC procedures.

The purpose of this manual is to present the QC and QA procedures employed by Guam Power Authority (GPA) in operating and maintaining the meteorological monitoring station located at the Cabras Power Plant in Piti, Guam. This QA/QC Manual presents a planned and practical approach designed to achieve the desired goal of collecting and reporting acceptable meteorological data. This manual contains a general discussion of the overall requirements for a successful meteorological monitoring program. In addition to the general QA/QC topics presented in the sections to follow, this manual provides detailed Standard Operating Procedures (SOPs) in Appendix A that contain detailed information regarding the specific operational tasks and procedures which, if rigorously followed, will assure that meteorological data of acceptable quality are collected. The information presented in this manual follows USEPA-recommended guidelines for meteorological monitoring programs that are designed to meet the data quality requirements for PSD (Prevention of Significant Deterioration)[1] programs as outlined in US 40 Code of Federal Regulations, Part 58, Appendix B.

Although most of the information presented in this QA/QC Manual is generally applicable to any meteorological monitoring program, its main focus is on the requirements of the Cabras Power Plant meteorological station. The operating permit for the Cabras Power Plant requires GPA to operate a meteorological monitoring station at the plant site for the purpose of determining when fuel switching procedures at the plant are to be initiated. When onshore winds persist for at least 15 minutes, the plant is required to switch to a low-sulfur fuel for generating electrical power. Under offshore wind conditions, the plant is allowed to burn a more economical fuel containing higher amounts of sulfur. The Cabras meteorological monitoring station consists of a 60-meter tower that is instrumented with wind speed and wind direction sensors at the 60 and 10-meter levels. The 10-meter level also has a vertical wind speed sensor. Ambient air temperature is measured at the 2-meter level. Solar radiation and precipitation are measured by sensors mounted at approximately 1 meter above ground level. Only the wind speed and wind direction sensors are used for fuel switching requirements.

This QA/QC Manual provides the foundation for GPA's meteorological monitoring program. The information contained herein is germane to the monitoring program as it existed when this manual was written. Revisions and updates to the original QA/QC Manual should be made on an as needed basis as the meteorological monitoring program evolves over time. The individual sections of this QA/QC Manual present information regarding the following topics:

- QA/QC program objectives
- Hardware descriptions
- Quality control procedures
- Quality assurance procedures, and
- Data processing and reporting

2.0 OBJECTIVES OF THE QA/QC PROGRAM

The primary objective of GPA's QA/QC Program is to assure that the meteorological data collected and reported by GPA are complete, accurate, and representative of the area. To this end, the following subsections define GPA's objectives for completeness, accuracy, and representativeness.

2.1 Completeness

The data completeness objective (often referred to as "data capture") is to collect and report 90 percent, or greater, of valid meteorological data that are possible during any month of operation. For example, during a month containing 30 days there are 720 hourly averages that are possible to collect for any one reported parameter. To achieve a 90 percent data capture rate, at least 648 hours of valid meteorological data must be reported for each parameter (720 x 0.90 = 648). Examples of events that count against the data capture results include inoperable or out-of-tolerance sensors, and data loss due to routine and non-routine QC checks and maintenance tasks. In other words, any event or activity that produces invalid hourly averages for a reported parameter will be subtracted from the total hours possible per month. The final data capture rate will result from the valid hourly averages reported each month, expressed as a percentage of completeness.

2.2 Accuracy

Accuracy is defined as the degree of agreement between an observed measurement value and an accepted known reference value.[2] The accuracy of the individual meteorological instruments, and thus the data they produce, is normally determined during the semiannual instrument performance audits. Accuracy may be expressed in terms of unit values or percentage error. When the accuracy of an instrument is expressed in terms of percentage error, it is calculated by the following equation:

$$\%\,\text{error} = \left(\frac{\text{y - x}}{\text{x}}\right) \text{x}100$$

Where: y = observed measured value
x = known reference value

Table 2-1 lists the accuracy limits for meteorological instruments.

Table 2-1

ACCURACY OBJECTIVES FOR METEOROLOGICAL INSTRUMENTS

Parameter	Acceptance Limits
Wind Speed	≤ (±0.2 mps + 5% of known input) error mps.
WS Torque	≤0.5 mps
Wind Direction	≤ ±5 degree error per direction test point (accuracy), and ≤ ±3 degrees change input error (linearity)
Wind Direction Torque	≤0.5 mps
Vertical Wind Speed	≤ (±0.2 mps + 5% of known input) error mps.
Vertical Wind Speed Torque	≤0.25 mps
Solar Radiation	≤ ±5% error per audit test point
Temperature	±0.5° C error per known test point
Precipitation	±10% error from known test volume
Relative Humidity	±10% relative humidity error from known test point

2.3 Representativeness

For meteorological data to be useful it must be representative of the weather conditions in the area of interest. Although it is difficult to quantify the representativeness of meteorological data, there are USEPA guidelines for the exposure and siting of meteorological instruments that, if meticulously followed, will meet the requirements for representativeness. The reference documents identified in Section 6.0 provide information for siting meteorological instruments. General guidelines for achieving representative meteorological data include, but are not limited to, the following siting requirements:

- Meteorological towers should be located in open, level terrain that is representative of the area of interest.
- In areas where significant topographic features that may influence wind patterns cannot be avoided, the conditions should be well documented.
- Locations with steep slopes, ridges, hollows, large paved areas, and areas of standing water should be avoided.
- Obstacles, either natural or man-made, that could affect wind patterns in the immediate vicinity of the tower should be at least ten times their height away from the tower.
- Towers should be of the open grid type construction to minimize influencing wind patterns. Enclosed towers, smoke stacks, water storage tanks, grain elevators, cooling towers and similar structures should not be used.
- Wind speed and wind direction sensors should be mounted at the top of the tower, or on booms, mounted so that they are positioned away from the tower at a distance equal to twice the maximum diameter of the tower.
- Booms must be rigid enough so that they do not sway or vibrate in strong winds.
- Booms should project into the prevailing winds.
- Temperature and humidity sensors should not be mounted over concrete of asphalt pavement, but over terrain with natural ground cover, such as grass or earth.
- Solar radiation sensors must have full exposure to sunlight during the entire day. Areas where shadows may occur and sources of reflected or man-made light must be avoided.

To establish the representativeness of the data, USEPA recommends conducting a systems audit. A systems audit consists of an independent review of the monitoring station's design, installation, and operating procedures. During the systems audit, the independent auditor documents whether or not the station has been sited and is being operating in accordance to USEPA-recommended guidelines. Any deficiencies that could affect the data reported by the monitoring station are noted, along with possible remedies, in the systems audit report. Additional information regarding the systems audit is found in Section 5.0, Quality Assurance Procedures.

3.0 HARDWARE DESCRIPTIONS

This section provides brief descriptions of the hardware and meteorological instruments in use at the Cabras meteorological monitoring site. The specific meteorological instruments selected for the Cabras site are of professional quality and highly regarded in the industry. The field technicians and operators responsible for maintaining the instruments at the site should be very familiar with each piece of equipment associated with the monitoring program. Instrument manuals, which provide much more detailed information about the individual instruments than what is presented here, should be maintained in a safe and convenient location where they can be referred to as needed. Table 4.1 lists the meteorological instruments currently in use at the Cabras monitoring site.

Table 3-1

INSTRUMENTS AT THE CABRAS METEOROLOGICAL MONITORING SITE

Parameter	Make & Model Number	Comments
Wind Speed	R.M. Young, Model 05305 Wind Monitor-AQ (wind speed & dir.)	2, sensors are present; 1, at the 60-m, and 1, at the 10-m level.
Wind Direction	R.M. Young, Model 05305 Wind Monitor-AQ	"
Vertical Wind Speed	R.M.Young, Model 27106	1, VWS sensor is mounted at the 10-m level.
Temperature	Climatronics RDT, P/N 100093	1, temperature probe is mounted 2 meters above ground.
Solar Radiation	Apogee SP110	1, SR sensor is mounted 1 meter above ground level.
Precipitation	Climatronics, Tipping Bucket, P/N 100097	1, precipitation gauge is mounted 1 meter above ground level.

3.1 R.M. Young 05305 Wind Monitor-AQ (Wind Speed and Wind Direction Sensor)

The R.M. Young 05305 wind speed and wind direction sensor has a low starting threshold, which is essential for air quality-type measurements, and exhibits excellent fidelity. The sensor combines a propeller anemometer with a vane assembly and resembles a "wingless airplane". The wind speed sensor component consists of a helicoid-shaped, four-blade propeller. Rotation of the propeller produces an ac sine wave that has a frequency directly proportional to wind speed. The ac signal is induced in a transducer coil by a six-pole magnet mounted on the propeller shaft . The coil resides on the non-rotating central portion of the main mounting assembly, eliminating the need for slip rings and brushes. The wind direction component consists of a vane/body assembly. The position of the vane is transmitted by a 10K ohm precision conductive plastic potentiometer which requires a regulated excitation voltage. With a constant voltage applied to the potentiometer, the output signal is an analog voltage directly proportional to the azimuth.

3.2 R.M. Young 27106 Propeller Anemometer Vertical Wind Speed Sensor

The R.M. Young 27106 propeller anemometer is a low threshold precision air velocity sensor employing a fast response helicoid propeller. The instrument uses a high quality tach-generator transducer which converts propeller rotation to a DC voltage that is linearly proportional to air velocity. Air flow from any direction may be measured, however, the propeller responds only to the component of the air flow which is parallel to the axis of its rotation. Off-axis response closely approximates a cosign curve with appropriate polarity. In conditions where air flow is perpendicular to the sensor shaft, the propeller does not rotate.

3.3 Climatronics RTD Temperature Sensor

The Climatronics 100093 air temperature sensor consists of a two thermistor composite housed in a stainless steel sheath. When the thermistors are connected in a network, a voltage that varies as the temperature changes is obtained. This voltage is approximately linear with temperature (±0.16° C). The thermistor signal is used by a Climatronics temperature signal conditioner, which includes the non-sensor portion of the network's circuitry. The Climatronics RTD temperature sensor is housed in the R.M. Young 41002 naturally-aspirated radiation shield. The 41002 multi-plate shield is designed to reduce errors that could be caused by solar heating of the temperature probe's exterior surface. Air moves naturally between the shield's plates so that the temperature probe can accurately measure ambient air temperature.

3.4 Apogee Silicon-Cell Solar Radiation Sensor

The solar radiation sensor at the Cabras site is an Apogee SP110 pyranometer. The sensor is a silicon cell-type pyranometer. As sunlight strikes the sensor, a millivolt signal that is proportional to the amount of direct sunlight is sent to the data logger. The data logger converts the millivolt signal to solar energy units expressed in watts per square meter (W/m^2).

3.5 Climatronics 100097 Tipping Bucket Precipitation Gauge

The Climatronics 100097 precipitation gauge is a tipping bucket-type precipitation gauge with an 8-inch opening. The gauge is cylindrical in shape, 18.25 inches (46.3 cm) high and 8 inches (20.3 cm) in diameter. Precipitation that falls into the gauge's opening is funneled to a triangular, double-bucket mechanism that tips once for every 0.01 inch or 0.1 mm of water collected. When the collection bucket under the funnel's opening fills with water its weight causes the bucket to tip, emptying its water volume and bringing the second bucket into the collection position. Each tip of the bucket mechanism activates a sealed reed switch that sends an event message to the data logger. The data logger records each tip event and converts the tips to millimeters (mm) of rainfall.

3.6 Campbell Scientific CR1000 Data Logger

The data collection system at the Cabras site is a Campbell Scientific, Model CR1000. The CR1000 scans each channel once per second, then generates and stores 1-hour averages for each monitored parameter. Data are routinely transferred from the CR1000 by radio modem or by direct connection to a laptop computer through an RS-232 port.

4.0 QUALITY CONTROL PROCEDURES

Quality Control (QC) is generally understood to include all of the specific techniques and standards applied on a regular basis by individuals internal to the monitoring organizations directly responsible for producing the final product (in this case, meteorological data). Monitoring organizations are required to develop and implement QC programs consisting of policies, procedures, specifications, standards, and documentation necessary to: (1) provide data of adequate quality to meet the monitoring objectives, and (2) minimize loss of data due to malfunctions or out-of-tolerance conditions. The practice of QC procedures begins as early as the planning phase of a monitoring program (e.g. site selection, equipment selection and installation) and continues through the monitoring phase (e.g. routine station visits, calibrations, reasonability checks, instrument repairs and maintenance), and finally on to the data reporting tasks (e.g. data collection, data handling, data validation, report generation). Quality Control must be part of the program each step of the way. The QC tasks that most affect the Cabras meteorological monitoring program include:

- Equipment Selection Procedures
- Instrument Checkout Procedures
- Development and Use of Standardized QC Report Forms
- Routine Station Visits
- Calibrations
- Preventive Maintenance
- Data Processing and Reporting

4.1 Equipment Selection Procedures

Selection of the proper equipment is an important step in a successful monitoring program. The selection process is based on the individual monitoring application and the intended purpose or use of the data produced by the instruments. In general, instrumentation selected for meteorological monitoring should match the specifications recommended in USEPA's Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD) and Meteorological Monitoring Guidance for Regulatory Modeling Applications (see reference documents 1 and 3 in Section 6.0). In addition to meeting the performance standards recommended by USEPA, the instruments should be selected for reliability and durability characteristics suitable for the environment in which the sensors will be located.

4.2 Instrument Checkout Procedures

Following the selection of the individual instruments, it is essential that the instruments be checked and performance tested prior to installation in a particular system. Equipment that has been checked prior to installation has a better chance of providing quality data with fewer periods of missing data due to instrument failure. Testing should follow the manufacturer's recommendations, usually listed in the instrument's operation manual. Normally, upon receipt, new instruments should be set up as per the manufacturer's instructions and allowed to operate continuously for 24 to 72 hours prior to their full integration into the monitoring program. If used or previously owned equipment is selected, it should be tested in the same manner as new equipment, with the addition of examining the instrument's maintenance record, if available.

4.3 Development and Use of Standardized QC Report Forms

It is absolutely essential that all QC activities conducted at the monitoring site and during data processing be properly documented. Standardized QC report forms will be developed to properly document all program activities that will, or potentially will, affect the data collected and reported by the Cabras meteorological monitoring site. Examples of QC activities that must be reported include, routine site visits, instrument calibrations and response checks, instrument repairs and replacement, data validation, and data editing and adjustments. The QC report forms must be used religiously and must be as complete and accurate as possible.

4.4 Routine Station Visits

The Cabras meteorological monitoring station is to be visited routinely by a field technician familiar with the program and the instruments at the site. Certain QC tasks should be performed during the routine visits. Listed below is a summary of the frequency of the routine visits and the tasks that are to be completed during the routine visits.

1. Every Visit (At a minimum, this will occur biweekly.)
    - Confirm sensor integrity (i.e. the sensors and all their components are present and appear to be working properly).
    - Confirm integrity of the tower sections and guy wires.
    - Check the solar radiation sensor and wipe away any moisture that is present on the glass dome.
2. Biweekly (Includes all of the “Every Visit” tasks listed above, plus…)
    - Conduct Reasonability Checks (see SOPs in Appendix A).
    - Document results on Biweekly Station Operation Checklist form.
3. Quarterly (Includes the “Every Visit” and the “Biweekly” tasks, plus…)
    - Check the operation of the tipping buckets in the precipitation gauge, and clean away any debris if present.
4. Semiannually (Includes the “Every Visit”, “Biweekly” and the Quarterly tasks, plus…)
    - Conduct Sensor Performance Tests (see SOPs in Appendix A).
    - Document results on calibration report forms.
    - Conduct External QA Audits.
5. Annually (Includes all of the above tasks, plus…)
    - Perform annual preventive maintenance tasks (see PM tasks in Section 4.7).

4.5 Calibrations

Calibrations, which may also be referred to as “Sensor Performance Tests”, should be conducted semiannually. Calibrations should also be performed whenever a sensor is replaced or undergoes repairs to the extent that its performance could be affected. Detailed, step-by-step procedures for conducting the calibrations on the Cabras site’s sensors are presented in the SOPs found in Appendix A. Brief descriptions of the calibration procedures for the meteorological instruments currently in place at the Cabras site are as follows:

4.5.1 Wind Speed Sensor

The wind speed sensor’s anemometer cups are removed to simulate a wind speed of zero mps. The sensor shaft is connected to an electric motor and a known constant RPM equivalent to a known wind speed is input into the system. The output value of the wind speed system is compared to the known input value and noted on the appropriate report form. In a similar manner, at least three additional wind speed test points spread over the sensor’s operational range are input into the system and the results are recorded. Finally, a torque disk device is attached to the wind speed sensor’s shaft to measure the sensor’s starting torque threshold. The torque measurement is taken in gram-centimeters and converted to meters per second according to guidelines provided by the manufacturer.

4.5.2 Wind Direction Sensor

Calibration of the wind direction sensor involves taking measurements in three test categories; (1) accuracy, (2) linearity, and (3) starting torque threshold. To determine accuracy, the sensor's vane is held in at least four known directions relative to true north. The system's observed output to each known direction input is noted and reported on the proper form. Sensor linearity is established by rotating the vane clockwise and counterclockwise in discrete increments of 30 degrees over the sensor's full operating range. As with the accuracy test, the sensor's observed response to the known incremental inputs is noted and reported. The starting torque threshold is measured in a similar fashion described above for the wind speed sensor. The sensor's starting torque value is then calculated and reported on the calibration form.

4.5.3 Air Temperature Sensor

The station's temperature sensor is placed together with a certified thermometer (0.1 °C resolution) in an insulated container and exposed to at least three separate water bath temperatures (ice, cool and hot) over the probes' range. The baths are constantly agitated to assure a uniform temperature within the baths. After stabilization in each water bath, the test thermometer is read to the nearest 0.1° Celsius and compared to the observed response of the station's sensor. The results are noted and reported on the appropriate form.

4.5.4 Vertical Wind Speed Sensor

The sensor's propeller anemometer is removed to permit a zero wind speed reference point. Next, three upscale test points in the ranges of less than 1 mps, 2 to 4 mps, and 5 to 8 mps are generated in clockwise and counter-clockwise directions by an R.M. Young, Model 18810, variable speed anemometer drive unit. Finally, the sensor's starting torque threshold is measured by an R.M. Young 18312 torque disk.

4.5.5 Solar Radiation Sensor

The solar radiation sensor is covered with a lightproof cap to simulate zero solar input. Next, the cover is removed and a solar radiation sensor (pyranometer) that is certified as a transfer standard is collocated at approximately the same level and identical exposure conditions as the station solar radiation sensor and allowed to collect solar data over a period of time. The transfer standard's millivolt output is read by a digital multimeter. The millivolt values are then converted to W/m^2 values and compared against the station's solar radiation values for the same periods. The results are reported on the appropriate QC form

4.5.6 Precipitation Gauge

A known volume of distilled water equivalent to at least 15 mm of rainfall (60 tips) is dripped from a leak device into the gauge's opening at a slow and constant rate to simulate rainfall. The observed station-reported response is compared to the known audit input volume's expected tip response. The results are noted and reported on the appropriate QC form.

4.6 Calibration and Test Equipment

To calibrate the various sensors of the Cabras monitoring program an inventory of calibration instruments must be maintained. Listed below are the calibration equipment items needed to perform the semiannual calibrations on the Cabras site's meteorological sensors.

Table 4-1

CALIBRATION AND TEST EQUIPMENT LIST

Sensor	Calibration Device	Description & Comments
Wind Speed	1. R.M. Young, Model 18801 (high speed motor) 2. R.M. Young 18301 torque disk device	1. Anemometer drive motor and controller unit that attaches to sensor shaft to rotate the shaft at known rpm to simulate known wind speeds. 2. Circular device used to measure starting torque threshold in gm-cm torque. Screw weights (0.1 gm) are inserted in holes in the disk at 1 cm intervals at right angle to the sensor shaft.
Wind Direction	1. precision compass or transit 2. R.M. Young 18301 torque disk device 3. R.M. Young Model 18112, vane angle device	1. Used to determine alignment (accuracy) of vane or crossarm relative to true north. Corrections must be made for local magnetic declination. 2. Circular device used to measure starting torque threshold in gm-cm torque. Screw weights (0.1 gm) are inserted in holes in the disk at 1 cm intervals at right angle to the sensor shaft. 3. A compass wheel device used to advance the sensor shaft in 30º increments (linearity).
Vertical Wind Speed	1. R.M. Young, Model 18810 (low speed motor) 2. R.M. Young 18301 torque disk device	1. Anemometer drive motor and controller unit that attaches to sensor shaft to rotate the shaft at known rpm to simulate known wind speeds. 2. Circular device used to measure starting torque threshold in gm-cm torque. Screw weights (0.1 gm) are inserted in holes in the disk at 1 cm intervals at right angle to the sensor shaft.
Temperature	1. Red-liquid-in-glass thermometer, or precision digital thermometer.	1. Accurate thermometer with resolution of at least 0.10 °C.
Solar Radiation	1. zero solar radiation cap. 2. certified transfer standard	1. Light-proof cover that fits over the solar radiation sensor's glass dome. 2. A solar radiation sensor (pyranometer) with a current calibration certificate documenting its millivolt output per solar energy value input.
Precipitation	1. graduated cylinder. 2. drip device	1. An measuring container accurate to 1 mm 2. Any device that can drip water into the precipitation at a slow and constant rate. This may be as simple as a paper cup with a hole punched in the bottom.

4.7 Preventive Maintenance

Preventive Maintenance (PM) consists primarily of a routine schedule for replacing expendable parts or instruments at the end of their expected useful lives. The purpose of PM is to minimize the unexpected failure of monitoring instruments or systems and thereby decreasing instrument downtime and data loss. All instruments must be kept within the manufacturer's specifications. Out-of-limit conditions will result in the invalidation of data. Meteorological instruments are generally robust and designed to operate unattended in the outdoor environment for long periods of time. A very simple preventive maintenance schedule is all that is required for the Cabras meteorological monitoring program. Listed below are the preventive maintenance tasks that should be performed and their frequency.

Frequency	**Preventive Maintenance Task**
Quarterly	Check the operation of the tipping buckets in the precipitation gauge, and clean away any debris if present.
Annually	Replace the horizontal and vertical wind speed and wind direction sensor bearings.

4.7.1 Spare Parts Inventory

An important part of the PM program is maintaining a spare parts inventory. GPA will keep on hand the spare parts listed below, which are intended for minor repairs and preventive maintenance only. In the instance where major repairs are required the instrument(s) should be returned to the manufacturer.

Table 4-2

R.M.YOUNG 05305 WIND SPEED & DIRECTION SENSORS
SPARE PARTS INVENTORY LIST

Qty	Part Number	Sensor	Description
12	05363	WS	Flange bearing
3	08254	WS	Propeller (20cm X 30cm, gray CFT)
4	05324	WD	Vertical shaft bearing
1	05374	WS & WD	Main housing and tail assembly

Table 4-3

CLIMATRONICS TEMPERATURE SYSTEM
SPARE PARTS INVENTORY LIST

Qty	Part Number	Description
1	100093	Temperature sensor

Table 4-4

R. M. YOUNG VERTICAL WIND SPEED SENSOR
SPARE PARTS INVENTORY LIST

Qty	Part Number	Description
4	27122	Flange bearing
2	27150B	D.C. generator assembly
1	08254	Carbon fiber propeller (20 cm)

4.8 Data Processing and Reporting

The processing and reporting of data collected by the Cabras meteorological monitoring station are the final, but very critical, last steps in the QC process. This section presents brief descriptions of the tasks required to process and report meteorological data.

4.8.1 Data Collection

The data logger (Campbell Scientific, CR1000) at the Cabras meteorological monitoring site is polled daily to collect or "download" the meteorological information measured by the site's sensors. This process is normally accomplished by telephone connection to the data logger from a remote computer terminal. Once the collection process is activated, the remote computer calls the onsite data logger, which then transfers its most recent data file to the remote computer via a modem. Upon receipt of the data file, the data collection software (Campbell Scientific, LoggerNet) appends the new data file to the existing file stored on the remote computer's hard drive. In addition to downloading data files remotely by telephone connection, data files stored in the site's data logger can also be collected by direct connection through an RS-232 link to a laptop computer, or similar storage device. It is worth noting here that regardless of how the files are collected, the raw data file remains stored in the data logger until it eventually is overwritten. The data logger overwrites its oldest memory locations with the newest data, so its memory storage always remains full. This means that data files are not actually removed from the data logger during the download process.

4.8.2 Data Validation and Editing

Once the data have been collected, the validation and editing process can begin. The tasks required to complete the validation and editing process include:

- Review the daily download file and inspect the data for missing periods and suspicious or questionable data values. (Refer to Table 4-5)
- Screen the daily download file values and flag any out-of-range values. This can be performed manually or with the aid of a computer program. (Refer to Table 4-5 for information on out-of-range values.)
- Document any problems, or potential problems, on the Problem Report form.
- If possible, fill in periods of missing data from other sources (Note: Because the Cabras monitoring site does not have a backup data collection system, it may not be possible to recover lost data from another source.)
- Notify program management of any periods of questionable data and determine the disposition of suspicious data in deciding to accept, correct, or delete the data. This will usually require reviewing other QC documents such as calibration reports, audit reports, station logs, and station operation checklist forms.
- Edit the data in question.

Table 4-5 lists the meteorological data screening criteria recommended by USEPA.[3] Values that are outside of the listed limits are not necessarily rejected, but are flagged to be investigated further. If possible, questionable data should be compared against another nearby monitoring site, or, in the case of wind speed and wind direction values, compared against other sensors on the same tower. Questionable data values for any parameter may indicate problems with that parameter's instrument. The GPA field technician should be notified and perform a QC check in the suspected instrument.

Table 4-5

METEOROLOGICAL DATA SCREENING CRITERIA

Parameter	Screening Criteria: Flag data if the value…
Wind Speed	…is less than zero or greater than 25 mps …does not vary by more than 0.1 mps for 3 consecutive hours …does not vary by more than 0.5 mps for 12 consecutive hours
Wind Direction	…is less than zero or greater than 360 degrees …does not vary by more than 1 degree for more than 3 consecutive hours …does not vary by more than 10 degrees for 18 consecutive hours
Vertical Wind Speed	…is greater than 5.0 mps or less than -5.0 mps …does not vary by more than 0.1 mps for 3 consecutive hours …does not vary by more than 0.5 mps for 12 consecutive hours
Temperature	…is greater than the local record monthly high …is less than the local record monthly low …is greater than a 5° C change from the previous hour …does not vary by more than 0.5° C for 12 consecutive hours
Solar Radiation	…is greater than zero a night …is greater than the maximum possible for the date and latitude
Precipitation	…is greater than 25mm in one hour …is greater than 100mm in 24 hours ..is less than 50mm in 3 months

It is important that all deletions or modifications to the original data be documented on the Data Adjustment Report form. All edits should be approved and verified by a second person who has authority to make the changes. In addition, a backup copy of the raw, unedited data file should be permanently maintained.

4.8.3 Data Reporting

GPA will report the data generated by the Cabras Meteorological Monitoring Station on a schedule required by Guam Environmental Protection Agency (Guam EPA), or any other regulatory agency that has involvement with the monitoring program. The project's reporting details and requirements are available at this time, but may be added to this QA/QC manual at a later date.

5.0 QUALITY ASSURANCE PROCEDURES

Quality Assurance (QA) is the review and evaluation of the effectiveness of the monitoring organization's QC measures in use and is usually accomplished during regularly scheduled audit testing. For PSD-type meteorological monitoring programs, USEPA requires instrument performance tests, or "QA Audits" be conducted on a semiannual basis. USEPA requires that QA audits be performed by individuals and equipment that are independent of the routine operations of the monitoring program. In addition to the semiannual instrument performance audits, USEPA also requires conducting systems audits, which serve to qualitatively evaluate the complete monitoring program and provide information useful in assessing the representativeness of the reported data. The sections that follow give an overview of the QA procedures that are in effect for the Cabras meteorological monitoring program.

5.1 Instrument Performance Audits

Instrument performance audits will be conducted semiannually. Summarized below are the procedures for auditing the meteorological sensors at the Cabras site.

5.1.1 Wind Speed Sensor

The sensor's propeller will be removed to permit a zero wind speed reference point. Once the zero is established, an anemometer drive motor (R.M.Young, Model 18802) will be used to spin the sensor shaft at known revolution per minute (rpm) values to simulate equivalent wind speeds. In addition to the zero, three upscale wind speed test points spaced at (1) less than 5.0 meters per second (mps), (2) 40 to 50 percent of full scale, and (3) 80 to 90 percent of full scale are input to the system. Each rpm test point is converted to an equivalent wind speed value as determined by the manufacturer's calibration equation. The station's observed response to the known audit wind speed input values will be recorded and any differences noted. The audit results are then plotted by linear regression to evaluate the complete system. The wind speed sensor's starting torque threshold will be tested by first manually spinning the sensor shaft to evaluate the shaft's ease of spin and confirm that no "dead spots" existed on the sensor bearings. Next, a torque disk device (R.M.Young, Model 18312) will affixed to the sensor shaft to measure the sensor's starting torque threshold in gram-centimeters. The resulting gram-centimeters of torque will be converted to an equivalent wind speed value and compared to USEPA's starting torque threshold maximum standard of 0.50 meters per second.

5.1.2 Wind Direction Sensor

Each wind direction sensor will be audited in three test categories; (1) accuracy, (2) linearity, and (3) starting torque threshold. Accuracy, which is the sensor's ability to correctly report a known wind direction, will be evaluated by using a surveyor's transit to measure the alignment of the system's crossarm assembly relative to true north. Known audit-measured direction values will be input into the system and compared to the station-reported direction values. Linearity will be tested by attaching a compass wheel device to the wind direction sensor and turning the vane in increments of 30 degrees both clockwise and counter-clockwise through 360 degrees. The system's response to the known incremental changes will be used to assess the sensor's linearity over its operating range. An R.M.Young, Model 18312, torque disk device will be used to measure the sensor's starting torque.

5.1.3 Vertical Wind Speed Sensor

First, the sensor's propeller anemometer will be removed to permit a zero wind speed reference point. After the zero wind speed point is obtained, an R.M.Young, Model 18810, anemometer drive unit will be used to generate six upscale test points (three clockwise and three counterclockwise) to test the system's accuracy. Finally, the sensor's starting torque threshold will be measured by the R.M.Young, Model 18312, torque disk device.

5.1.4 Temperature Probe

The station's 2-meter level temperature probe will be placed in an insulated container, along with an NIST-traceable thermometer, and exposed to three separate temperatures (ice, cool and hot) over the probe's range. All three test baths must be thermally stable and will be constantly agitated by a motor-driven propeller to assure uniform temperature. After stabilization, the audit thermometer will be read to the nearest 0.1 degree Celsius and compared against the station's temperature probes. The station's observed response to the three test temperatures will compared to the audit thermometer's known values.

5.1.5 Solar Radiation Sensor

The station's solar radiation sensor will be covered with a lightproof cap to simulate zero solar input. A certified audit pyranometer transfer standard (Kipp & Zonen, Model CM21) will be collocated at the same level and exposure conditions as the station solar radiation sensor and allowed to collect solar data over a period of time. A total of at least eight test points, including the zero, will be taken. Accuracy of the station's pyranometer will be determined by calculating the difference between the audit-reported values and the station-reported values for the same time periods. The results will be plotted by linear regression.

5.1.6 Precipitation Gauge

A known volume of distilled water will be dripped from a leak device into the gauge's opening at a slow and constant rate (<1 inch rainfall per hour) to simulate rainfall. The observed station-reported response will be compared to the known audit input volume. Percent error will be used to express accuracy.

5.1.7 Performance Audit Methods and Acceptance Limits

The instrument performance audit methods and the acceptance limits which determine the pass or fail status of the audited instrument are listed below in Table 5-1.

Table 5-1

METEOROLOGICAL SENSORS
PERFORMANCE AUDIT METHODS AND ACCEPTANCE LIMITS

Parameter	Audit Method	Acceptance Limits	Traceability
Wind Speed	Variable rpm motor	≤ (±0.2 mps + 5% of known input) error mps.	Annual factory recertification
WS Torque	Torque disk	≤0.5 mps	NA
Wind Direction Accuracy	Compass transit, known direction inputs	≤ ±5 degree error per direction audit input point	Biannual test of compass
Wind Direction Linearity	Degree wheel, known interval changes	≤ ±3 degrees change input error	NA
Wind Direction Torque	Spring torque gauge	≤0.5 mps	NA
Vertical Wind Speed	Variable rpm motor (cw and ccw)	≤ (±0.2 mps + 5% of known input) error mps.	Annual factory recertification
VWS Torque	Torque disk	≤0.25 mps	NA
Temperature	Digital thermometer, insulated water baths	≤ ±0.5° C error per audit point	Annual recertification
Temperature Difference	Digital thermometer, insulated water baths	≤ ±0.1° C error per audit point	Annual recertification
Solar Radiation	Collocated transfer standard	≤ ±5% error per audit test point	Annual recert. of transfer standard
Precipitation	Addition of a known water volume	≤ ±10% error	NA

5.2 Systems Audits

To comply with USEPA recommendations and in following good monitoring program practices, GPA will conduct at least one systems audit of the Cabras meteorological monitoring program. The systems audit "provides an overall assessment of the commitment to data validity"[3]. Unlike the performance audit, which quantitatively evaluates the individual monitoring instruments, the systems audit qualitatively evaluates all aspects of the entire monitoring program. For example it documents such items as the work facilities, equipment, program management, personnel training, instrument siting, operational procedures, record-keeping, and data processing and reporting. In short, it evaluates all aspects of the monitoring program and provides important information for assessing the representativeness of the reported data. The systems audit should be conducted by an independent auditor who is not part of the normal monitoring program. The audit is organized in a question-answer format with room for additional comments and descriptions. This format greatly facilitates the reader's ability to understand the audit's results. The questions in the systems audit are designed to ascertain whether or not the complete monitoring program and the procedures that are in place follow USEPA-recommend guidelines for an effective meteorological monitoring program. Normally, the systems audit is conducted within 30 days of the monitoring program's start-up date and repeated whenever major changes occur within the monitoring program. While instrument performance audits are routinely conducted semiannually, the systems audit may be conducted only once during the length of a monitoring program, unless significant changes make it reasonable to repeat the systems audit at a later date.

6.0 REFERENCE DOCUMENTS

Listed below are the USEPA publications upon which this QA/QC program has been based. GPA will maintain copies of the publications for additional information and guidelines in executing a successful meteorological monitoring program at the Cabras site.

1. USEPA, Ambient Monitoring guidelines for Prevention of Significant Deterioration (PSD), EPA-450/4-87-007, Research Triangle Park, North Carolina, May 1987.

2. USEPA, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements, Version 2.0 (Final), EPA-454/B-08-002, Research Triangle Park, North Carolina, March 2008.

3. USEPA, Meteorological Monitoring Guidance for Regulatory Modeling Applications, EPA-454/R-99-005, Research Triangle Park, North Carolina, February 2000.

APPENDIX A

STANDARD OPERATING PROCEDURES

- **Wind Speed Sensor**
- **Wind Direction Sensor**
- **Vertical Wind Speed Sensor**
- **Air Temperature Probe**
- **Solar Radiation Sensor**
- **Precipitation Gauge**

SOP

Standard Operating Procedure

WIND SPEED SENSOR

Operation and Maintenance of the R.M. Young 05305-AQ Wind Speed Sensor

Original Date:	4 September 2011	**Revision Date:**	
Prepared By:	*AMSTech* Boulder, CO	**Approved By:**	

SOP SUMMARY

This SOP provides detailed operation and maintenance (O&M) procedures for the R.M. Young 05305 Wind Monitor-AQ wind speed / wind direction sensors currently installed on the 60-meter meteorological tower at GPA's Cabras Power Plant, Piti, Guam. This SOP addresses the O&M procedures for the wind speed measuring component of the 05305-AQ only. The sensor's wind direction component is covered in a separate SOP. The O&M procedures presented in this SOP are based on the manufacturer's 05305-AQ instrument manual as well as USEPA-recommended quality control guidelines for wind speed sensors.[1,2]

INSTRUMENT DESCRIPTION

The R.M. Young 05305 Wind Monitor-AQ is a combination wind speed / wind direction sensor resembling a wingless airplane. "The wind speed sensor for all the (R.M. Young) Wind Monitors is a helicoid-shaped, four-blade propeller. Rotation of the propeller produces an ac sine wave that has a frequency directly proportional to wind speed. The ac signal is induced in a transducer coil by a six-pole magnet mounted on the propeller shaft . The coil resides on the non-rotating central portion of the main mounting assembly, eliminating the need for slip rings and brushes."[3] The photograph on the next page shows the major components of the R.M. Young 05305 Wind Monitor-AQ wind speed / wind direction sensor.

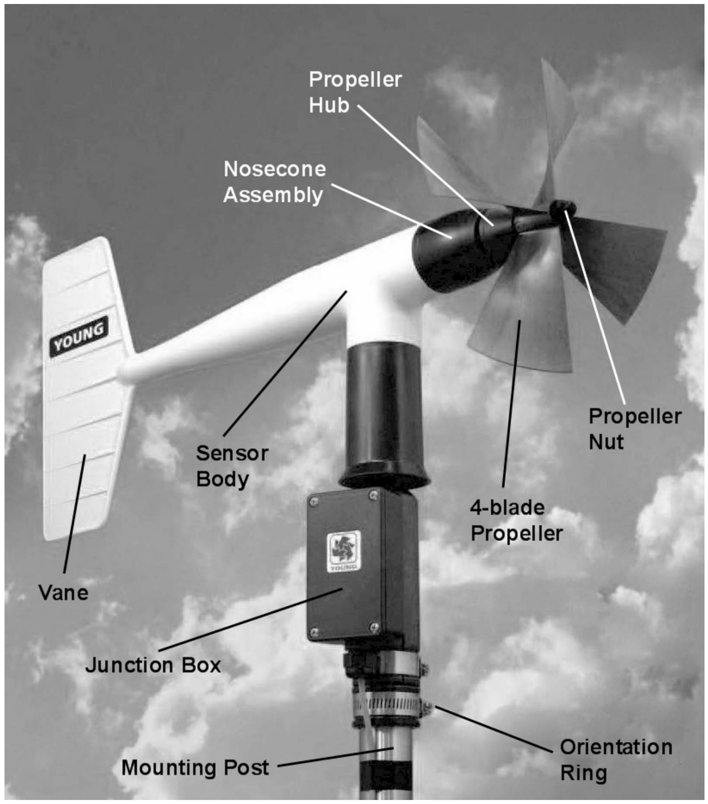
OPERATION OF THE 05305-AQ WIND SPEED SENSOR

Two categories of routine tasks are required to assure that the 05305-AQ wind speed sensor is operating within acceptable limits. These are: (1) reasonability checks, and (2) sensor performance tests.

Reasonability Check: The wind speed sensor Reasonability Check is to be performed biweekly. Its purpose is to confirm that the sensor is at the proper location on the tower, intact, and operational. There are two parts to the Reasonability Check; (A) visual observation of the wind speed sensor, and (B) estimation of the sensor's accuracy. The following steps will guide the technician in completing the biweekly Reasonability Check.

Tools and Test Equipment Required for Reasonability Check

- Biweekly Station Operation Checklist form



Part A: Visual Observation

1. Look up at the tower's 10-meter and 60-meter level 05305-AQ wind speed / wind direction sensors.
2. Visually determine that both 05305-AQ sensors are present.
3. Confirm that the propeller is present on each sensor.
4. Observe whether or not the propeller is rotating. (Note: A very light breeze of only 1 MPH, or less, is all that is needed to cause the propeller to rotate. A non-rotating propeller is an indication of worn bearings and should be investigated further.)
5. Note any problems on the Biweekly Checklist Form.

Part B: Estimation of Accuracy

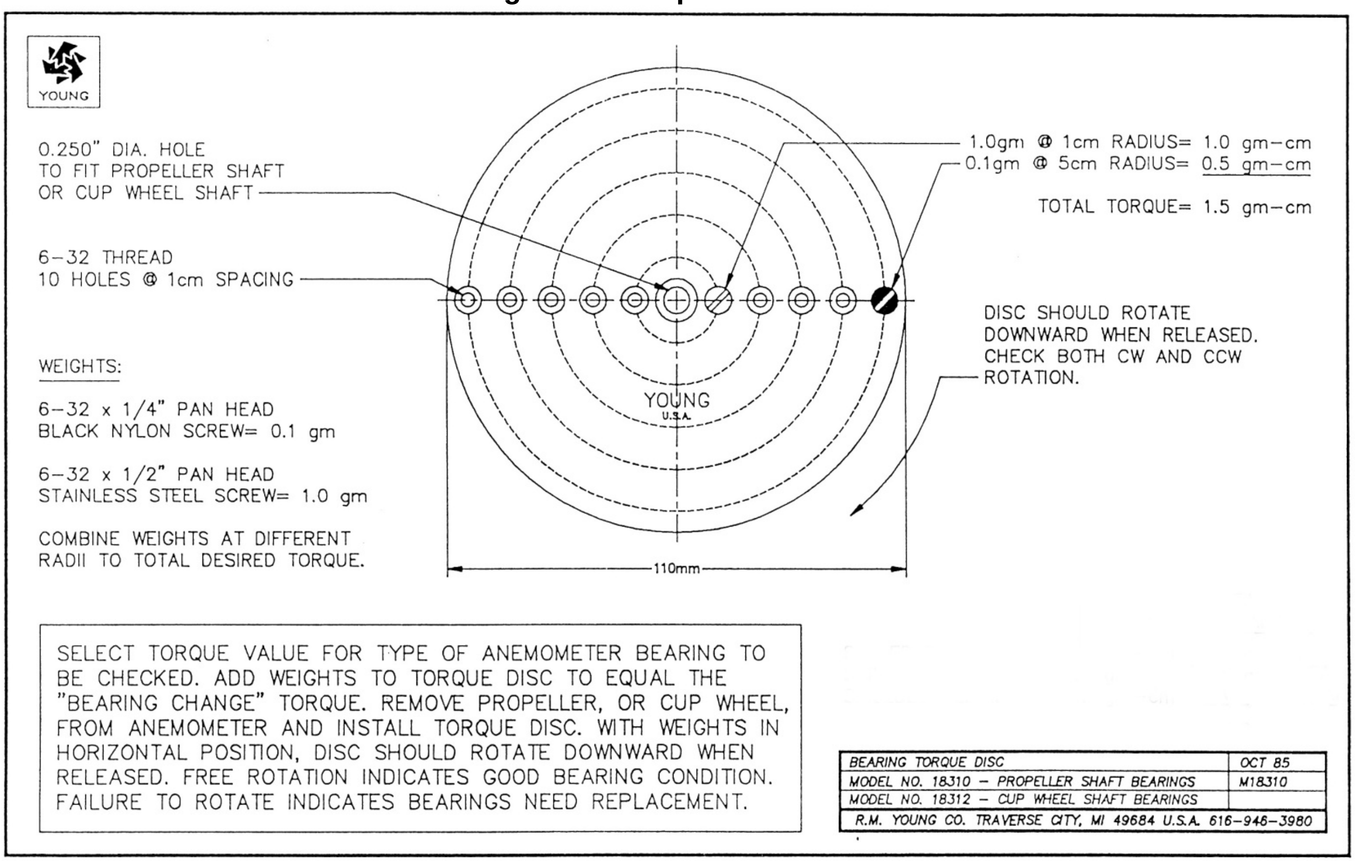
6. Open the door to the data logger enclosure at the base of the tower.
7. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
8. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
9. Press the "Down Arrow" to navigate to the wind speed channel.
10. Estimate the current wind speed at the tower in meters/second (MPS). (Note: The data logger displays wind speed in MPS. If you are more comfortable estimating the current wind speed in miles/hour (MPH), you can convert MPH to MPS by the following equation: **MPS = MPH x 0.447**.)
11. Compare your current wind speed estimate to the data logger-reported wind speed value. Allow an estimation error of ±5 MPS.
12. Record the results of your observation on the Biweekly Checklist Form.

Wind Speed Sensor Performance Test: The Wind Speed Sensor Performance Test is also referred to as a "Calibration Test". Actually, the 05305-AQ wind speed sensor itself does not have user-accessible adjustments normally associated with calibrating an instrument, so the real purpose of the "Calibration Test" is to confirm that the sensor is operating within acceptable performance limits. If the sensor's performance does not meet the required standards, it should be returned to the manufacturer for repair. The Wind Speed Sensor Performance Test is to be conducted semiannually. The test consists of (A) measuring the sensor's starting torque threshold, and (B) documenting the sensor's accuracy in responding to a zero and at least four additional known wind speed input values. Listed below are the necessary test equipment and the step-wise procedures that technician(s) will need to complete the Wind Speed Sensor Performance Test.

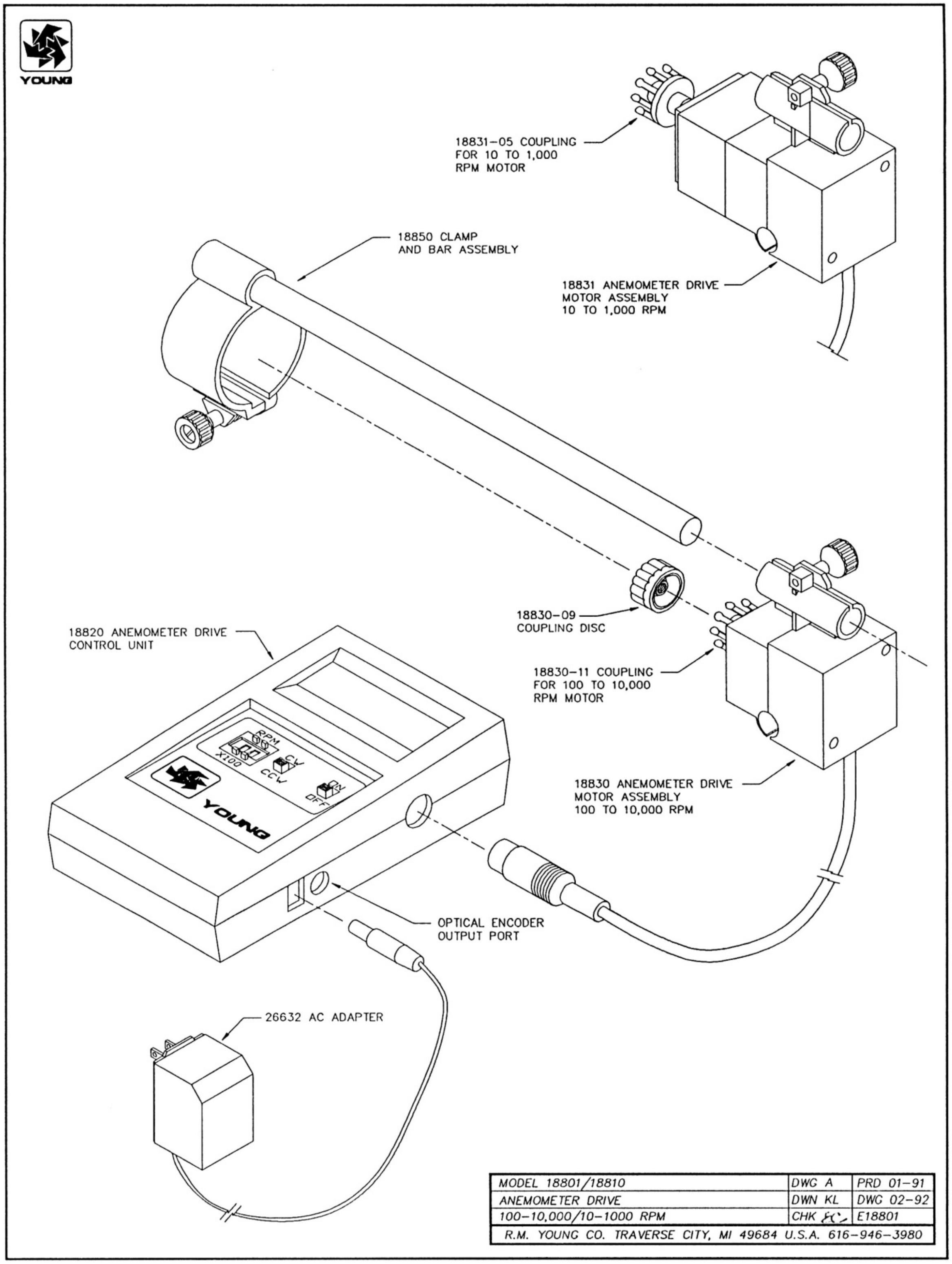
Tools and Test Equipment Required for the Wind Speed Sensor Performance Test

- R.M. Young, 18312, torque disk device
- R.M. Young, 18801, 100 to 10,000 rpm anemometer drive motor
- R.M. Young, 18820, anemometer drive control unit
- R.M. Young, 18850, motor clamp and bar assembly
- Wind Speed Sensor Calibration form

R.M. Young 18312 Torque Disk Device



R.M. Young Anemometer Drive Motors and Controller



Part A: Starting Torque Threshold Test

1. Use the tower winch to lower the carriages and booms holding the 10-meter and 60-meter wind speed sensors. (Note: The 10-m carriage and boom will be removed from the winch cable and placed on the ground. The 60-m carriage and boom will remain on the tower, at the lowest level possible. A tall step ladder will be needed to reach the 60-meter level sensor even after the boom assemblies have been lowered to ground level. Follow normal step ladder safety precautions when removing and replacing the sensors.)
2. Loosen the plastic nut that holds the propeller on the nosecone assembly and remove the propeller.
3. Inspect the propeller for any signs of damage.
4. Place the propeller in a safe location that will protect it from damage during the rest of the performance test.
5. Leave the sensor attached to its mounting post on the boom and carriage assembly.
6. While holding the 05305-AQ in one hand, use your other hand to quickly spin the sensor's propeller shaft and hub assembly in one direction, and do the following:
    a. Observe the sensor shaft and hub and listen to the bearings' noise as the hub's rotation begins to slow down.
    b. Note whether or not the hub's slowing action is smooth and even.
    c. The noise made by the bearings should not be louder than a quiet "hum".
    d. Noisy bearings and uneven or "jerky" movements during the slowing of the propeller shaft and hub indicate potentially worn bearings.
7. Carefully push the plastic R.M. Young torque disk device onto the sensor's propeller shaft and reinstall the propeller nut to hold the torque disk device in place.
8. With the torque disk attached, rotate the sensor shaft hub until the torque disk device's screw weight attachment holes are horizontal (parallel to the ground).
9. Carefully release the hub and confirm that the torque disk's holes remain horizontal. (Note: If the torque disk holes do not remain horizontal, hold the hub steady with the thumb and forefinger of one hand and with the other hand slightly rotate the torque disk on the sensor shaft tip in one direction. Then, once again position the torque disk holes parallel to the table and release the shaft hub to confirm that the holes remain horizontal. Repeat this process until the torque disk device's screw weight holes remain in the horizontal position.)
10. While holding the sensor shaft hub with one hand and maintaining the torque disk holes horizontal, insert a black, 0.1 gram screw weight into one of the two inner most holes located 1 centimeter out from the disk's axis point.
11. Release the propeller shaft hub and observe whether or not the screw weight is sufficient to cause the torque disk to rotate approximately 5 degrees in the direction of the weight's normal direction of fall.
12. Rotate the hub and torque disk 180 degrees and repeat Step 11 for the opposite direction of movement.
13. If no rotational movement of the disk is observed, place the 0.1 gram screw weight into one of the two test holes located 2 centimeters out from the disk's axis point and repeat the actions described in Steps 10, 11, and 12.
14. Continue placing the screw weight in the 1-centimeter-spaced holes sequentially more distant from the axis point until the weight causes the disk to rotate approximately 5 degrees.

15. Determine the torque in gram-centimeters (gm-cm) required to rotate the sensor's hub 5 degrees by multiplying the screw weight times the number of centimeters out from the axis point that caused to disk to rotate. For example, if the hub rotated approximately 5 degrees with the screw weight in hole #2, the final test result would be 0.2 gm-cm torque.
16. Use the following equation to convert the sensor's starting torque in gm-cm to MPS:

$$\mathrm{MPS} = \sqrt{\frac{\mathrm{gm-cm}}{3.8}}$$

17. Record the results on the wind speed calibration report form.
18. If the resulting starting torque threshold is greater than 0.5 MPS, the bearings are worn and need replacing. (Refer to the Maintenance Section of this SOP for instructions on replacing worn bearings.)

<u>Part B: Wind Speed Accuracy Test</u>

19. Leave the 05305-AQ sensor on its mounting post. (Note: Do not replace the propeller at this time.)
20. Open the door to the data logger enclosure at the base of the tower.
21. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
22. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
23. Press the "Down Arrow" to navigate to the wind speed channel.
24. With the propeller removed and wind speed shaft / hub assembly still, read data logger-reported value for <u>zero</u> wind speed.
25. Contact the Control Room by radio or cell phone and request the value reported by the Control Room computer for the <u>zero</u> wind speed test point.
26. Record the Tower and Control Room <u>zero</u> wind speed values on the wind speed sensor calibration report form.
27. Slip the large opening of the R.M. Young 18850 motor clamp and bar assembly onto the 05305-AQ's body and tighten the clamp screw. (Note: Refer to Anemometer Drive diagram above on Page 4.
28. Slide the R.M. Young 18801 anemometer drive motor onto the motor clamp bar.
29. Attach the anemometer drive motor to the propeller shaft.
30. Fix the anemometer drive motor in place on the bar by gently tightening the motor's locking screw. Do not over tighten the locking screw.
31. Connect the anemometer drive motor cable to the R.M. Young 18820 control unit.
32. Turn on the 18820 control unit, and press the increase speed button until the desired target RPM is displayed. (Note: The order in which the wind speed values are input into the wind speed sensor is not critical. However, the lowest wind speed value must be less than 5.0 MPS while the remaining three test values are to be spaced evenly over the sensor's range. Possible RPM test ranges are: (1) 100 to 200 RPM, (2) 300 to 500 RPM, (3) 700 to 1,100 RPM, and (4) 1,700 to 2,000 RPM.)
33. Use the following equation to convert RPM to MPS for the carbon fiber-type propeller: MPS = RPM x 0.00512
34. When the control unit LCD display has stabilized, read the tower's data logger-reported value for the known RPM setting.

35. Contact the Control Room by radio or cell phone and request the wind speed value reported by the Control Room computer.
36. Record the Tower and Control Room wind speed values on the calibration report form.
37. Repeat Steps 38 through 43 for the remaining three wind speed test points.

MAINTENANCE OF THE 05305-AQ WIND SPEED SENSOR

The 05305-AQ wind speed sensor is very robust and will operate for long periods of time with little maintenance. The few maintenance tasks that could effectively be performed by the end-user include: (1) sensor inspection and evaluation (2) bearing replacement, and (3) nosecone assembly "O" ring replacement. Maintenance or service tasks more complex than those mentioned in this SOP should be performed by the manufacturer. The information presented below provides guidance for the routine maintenance tasks. Refer to the manufacturer's instrument manual for additional instruction.

Inspection and Evaluation: The 05305-AQ wind speed sensor body components should be inspected and evaluated semiannually to assure it's intact and in good condition. Normally, the inspection and evaluation is done during the semiannual "Sensor Performance Test", but can be conducted anytime a problem with the wind speed sensor is suspected. The inspection includes a close examination of the sensor body and the nose cone assembly. Inspect the sensor and its components closely looking for cracks, dents, loose connectors or other indicators of potential damage that could affect sensor performance. Spin the sensor's propeller hub with thumb and forefinger. Watch the hub as its spinning slows down. The spinning should decline slowly and evenly. A rapid slow down and "jerky" or "halting" actions of the hub indicates worn bearings. If worn bearings are suspected, follow the procedures described above for conducting the "Starting Torque Threshold Test" to determine if the bearings need replacing.

Replacing the Flange Bearings: Perform this task indoors on a well-lighted work table. The steps listed below are taken from the R.M. Young 05305-AQ Wind Speed Sensor instrument manual.[3] Read all of the procedures before beginning. The sensor should be removed from its mount on the tower, and the propeller should be removed from the nose cone assembly

Required Tools and Test Equipment

- 1/16, Allen wrench
- Replacement flange bearings
- Flange bearing gap gauge

Part A: Remove Old Bearings

1. Remove the nose cone assembly and set it aside in a safe place.
2. With the Allen wrench, loosen the set screw on the magnet collar attached to propeller shaft and remove the magnet.
3. Slide the propeller shaft out of the nose cone assembly.
4. Remove the plastic bearing cap covering the front bearing.
5. Remove the front and rear flange bearings. (Note: It may be necessary to insert a knife edge under the bearing flange to remove the bearing.)

Part B: Install New Bearings

6. Install new front and rear flange bearings onto the propeller shaft.
7. Replace the front bearing cap.
8. Replace the magnet on the propeller shaft, allowing 0.5 mm (0.020 inch) clearance from the rear bearing. Use the flange bearing gap gauge to set the proper gap.
9. Tighten the set screw on the magnet collar.
10. Screw the nose cone assembly onto the sensor body. (Note: Be sure the nose cone assembly O-ring is in place at the back end of the nose cone. Be careful not to cross-thread the nose cone assembly onto the sensor body.)
11. Confirm that the shaft spins freely and that there is no binding or drag on the bearings.
12. Perform a "Starting Torque Threshold" test as described above in Part A of the Wind Speed Sensor Performance Test.

REFERENCE DOCUMENTS

[1] Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements, Version 2.0 (Final) USEPA, March 2008

[2] Meteorological Monitoring Guidance for Regulatory Modeling Applications, USEPA, February 2000.

[3] Model 05305 Wind Monitor-AQ Instrument Manual, Revision C080905, R.M. Young, Traverse City, Michigan.

EXAMPLE OF BIWEEKLY STATION OPERATION CHECKLIST REPORT FORM

CABRAS POWER PLANT METEOROLOGICAL TOWER
BIWEEKLY STATION OPERATION CHECKLIST

Mo. / Day →						
Year →						
Tech. Initials →						

	Checklist Item	Standard	Indicate Checklist Item Results					
	All tower guy wires intact?	YES						
	All WS / WD sensors present?	YES						
	WS propellers present and intact?	YES						
G	WD vanes present and intact?	YES						
E	VWS propeller present and intact?	YES						
N	Temperature probe present?	YES						
E	SR sensor level and clean?	YES						
R	Precip gauge present and intact?	YES						
A	Data Logger on line?	YES						
L	Indicate **L**ocal **S**tandard **T**ime	NA						
	Indicate DAS clock time	±3 min of LST						
	Indicate DAS battery voltage	12 – 16 VDC						
	Is the MODEM connected?	YES						
R	10-m WS estimate, MPS	NA						
E	10-m WS DAS value, MPS	±5.0 MPS						
A	10-m WS check PASS? FAIL?	PASS						
S	10-m WD estimate, degrees	NA						
O	10-m WD DAS value, degrees	±30 deg						
N	10-m WD check PASS? FAIL?	PASS						
A	60-m WS estimate, MPS	NA						
B	60-m WS DAS value, MPS	±5.0 MPS						
I	60-m WS check PASS? FAIL?	PASS						
L	60-m WD estimate, degrees	NA						
I	60-m WD DAS value, degrees	±30 deg						
T	60-m WD check PASS? FAIL?	PASS						
Y	10-m VWS direction check, +/-	NA						
	10-m VWS DAS value, +/-	+ or -						
C	10-m VWS check PASS? FAIL?	PASS						
H	2-m temperature estimate, °C	NA						
E	2-m temperature DAS value, °C	±5° C						
C	2-m temp check PASS? FAIL?	PASS						
K	SR range estimate, Low, Med, High[1]	NA						
S	SR DAS value, Low, Med, High[1]	Low, Med, High						
	SR estimate check PASS? FAIL?	PASS						

[1] Solar Radiation W/m^2 range values are: 0 to 300 = Low, 300 to 700 = Medium, 700 to >1,000 = High

EXAMPLE OF WIND SPEED SENSOR CALIBRATION REPORT FORM

Cabras Meteorological Tower

60-Meter Wind Speed Sensor Calibration Report

Date: ________________ **Start:** ________ **Technician(s):** ________________
End: ________

SENSOR INFORMATION

Make: R.M. YOUNG
Model: 05305-AQ
SN: ________________

Propeller Type: Carbon Fiber
Propeller SN: ________________
Operating Range: 0 to 50 mps

CALIBRATION TEST EQUIPMENT

Item: Variable rpm motor. R.M.Young, 18830 (100 to 10,000 rpm) **SN:** NA
Item: Torque disk device. R.M. Young 18312 **SN:** NA

SENSOR CALIBRATION TEST RESULTS

Sensor Starting Threshold: ________ gm-cm, equal to ________ mps **Pass? / Fail?:** ________ ≤ 0.50 mps

TOWER DATA LOGGER RESPONSE

Known Input rpm	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
0.0	0.00			NA	NA
200	1.02			0.25	
800	4.10			0.41	
3,200	16.38			1.02	
9,000	46.08			2.50	

EMSYS RESPONSE

Known Input rpm	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
0.0	0.00			NA	NA
200	1.02			0.25	
800	4.10			0.41	
3200	16.38			1.02	
9000	46.08			2.50	

* Allowed Error = ±(5% of known input + 0.20 mps)

COMMENTS

	As Found	As Left
Results are:		

To PASS, the sensor response must have... 1) Observed Error = ± Allowed Error per test point
2) Starting Torque = ≤ 0.50 mps

Standard Operating Procedure

WIND DIRECTION SENSOR

Operation and Maintenance of the R.M. Young 05305-AQ Wind Direction Sensor

Original Date:	12 September 2011	**Revision Date:**	
Prepared By:	*AMSTech* Boulder, CO	**Approved By:**	

SOP SUMMARY

This SOP provides detailed operation and maintenance (O&M) procedures for the R.M. Young 05305 Wind Monitor-AQ wind speed / wind direction sensors currently installed on the 60-meter meteorological tower at GPA's Cabras Power Plant, Piti, Guam. This SOP addresses the O&M procedures for the wind direction measuring component of the 05305-AQ only. The sensor's wind speed component is covered in a separate SOP. The O&M procedures presented in this SOP are based on the manufacturer's 05305-AQ instrument manual as well as USEPA-recommended quality control guidelines for wind speed sensors.[1,2]

INSTRUMENT DESCRIPTION

The R.M. Young 05305 Wind Monitor-AQ is a combination wind speed / wind direction sensor resembling a wingless airplane. "Vane position is transmitted by a 10K ohm precision conductive plastic potentiometer which requires a regulated excitation voltage. With a constant voltage applied to the potentiometer, the output signal is an analog voltage directly proportional to the azimuth angle."[3] The photograph on the next page shows the major components of the R.M. Young 05305 Wind Monitor-AQ wind speed / wind direction sensor.

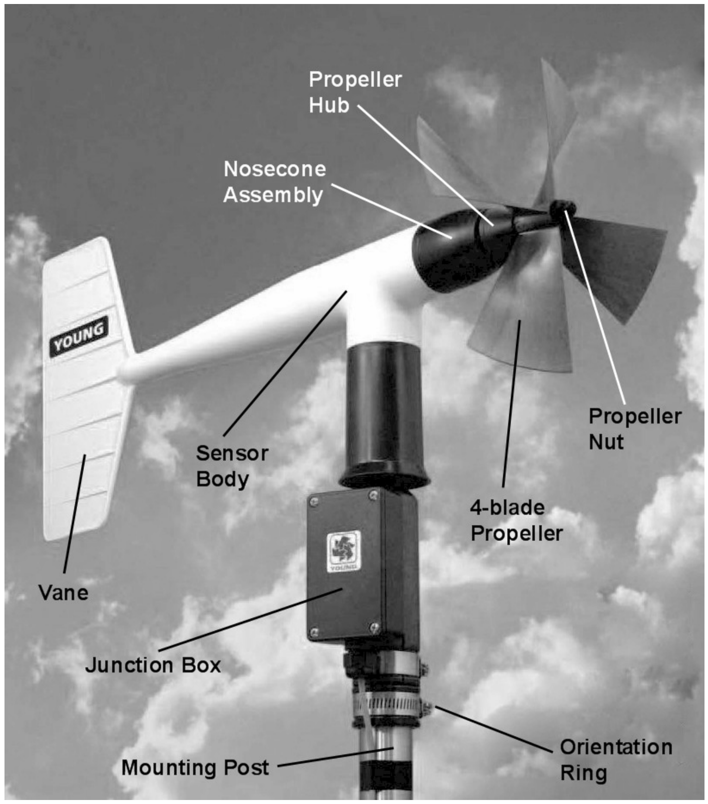
OPERATION OF THE 05305-AQ WIND DIRECTION SENSOR

Two categories of routine tasks are required to assure that the 05305-AQ wind direction sensor is operating within acceptable limits. These are: (1) reasonability checks, and (2) sensor performance tests.

Reasonability Check: The wind direction sensor Reasonability Check is to be performed biweekly. Its purpose is to confirm that the sensor is at the proper location on the tower, intact, and operational. There are two parts to the Reasonability Check; (A) visual observation of the wind direction sensor, and (B) estimation of the sensor's accuracy. The following steps will guide the technician in completing the biweekly Reasonability Check.

Tools and Test Equipment Required for Reasonability Check

- Biweekly Station Operation Checklist form



Part A: Visual Observation

1. Look up at the tower’s 10-meter and 60-meter level 05305-AQ wind speed / wind direction sensors.
2. Visually determine that both 05305-AQ sensors are present.
3. Confirm that the vane assembly is present on each sensor.
4. Observe whether or not the sensor’s body and vane assembly is moving back and forth in the wind. (Note: A very light breeze of only 1 MPH, or less, is all that is needed to cause the vane to move. A non-moving vane can be an indication of worn bearings and should be investigated further.)
5. Note any problems on the Biweekly Checklist Form.

Part B: Estimation of Accuracy

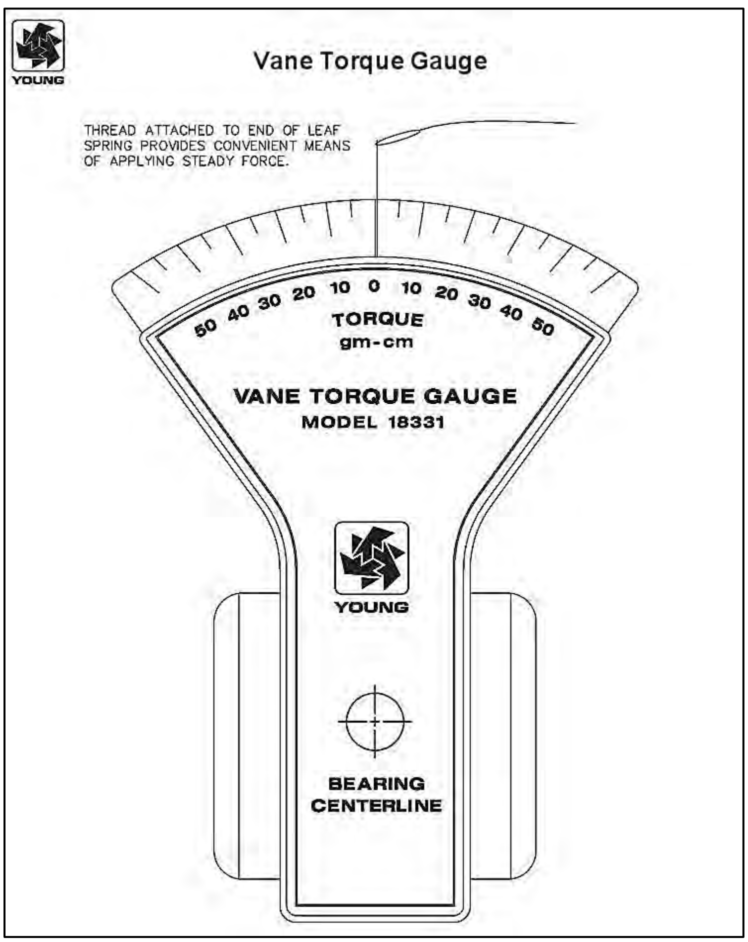
6. Open the door to the data logger enclosure at the base of the tower.
7. Connect the KD1000 keypad to the CR1000 data logger’s CSI data port. The main menu screen will appear.
8. Press the “Enter” key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
9. Press the “Down Arrow” to navigate to the wind direction channel.
10. Estimate the current wind direction at the tower in degrees.
11. Compare your current wind direction estimate to the data logger-reported wind direction value. Allow an estimation error of ±30 degrees.
12. Record the results of your observation on the Biweekly Checklist Form.

Wind Direction Sensor Performance Test: The Wind Direction Sensor Performance Test is also referred to as a "Calibration Test". Actually, the 05305-AQ wind direction sensor itself does not have user-accessible adjustments normally associated with calibrating an instrument, so the real purpose of the "Calibration Test" is to confirm that the sensor is operating within acceptable performance limits. If the sensor's performance does not meet the required standards, it should be returned to the manufacturer for repair. The Wind Direction Sensor Performance Test is to be conducted semiannually. The test consists of (A) measuring the sensor's starting torque threshold, and (B) documenting the sensor's accuracy in responding to known wind direction input values. Listed below are the necessary test equipment and the step-wise procedures that technician(s) will need to complete the Wind Direction Sensor Performance Test.

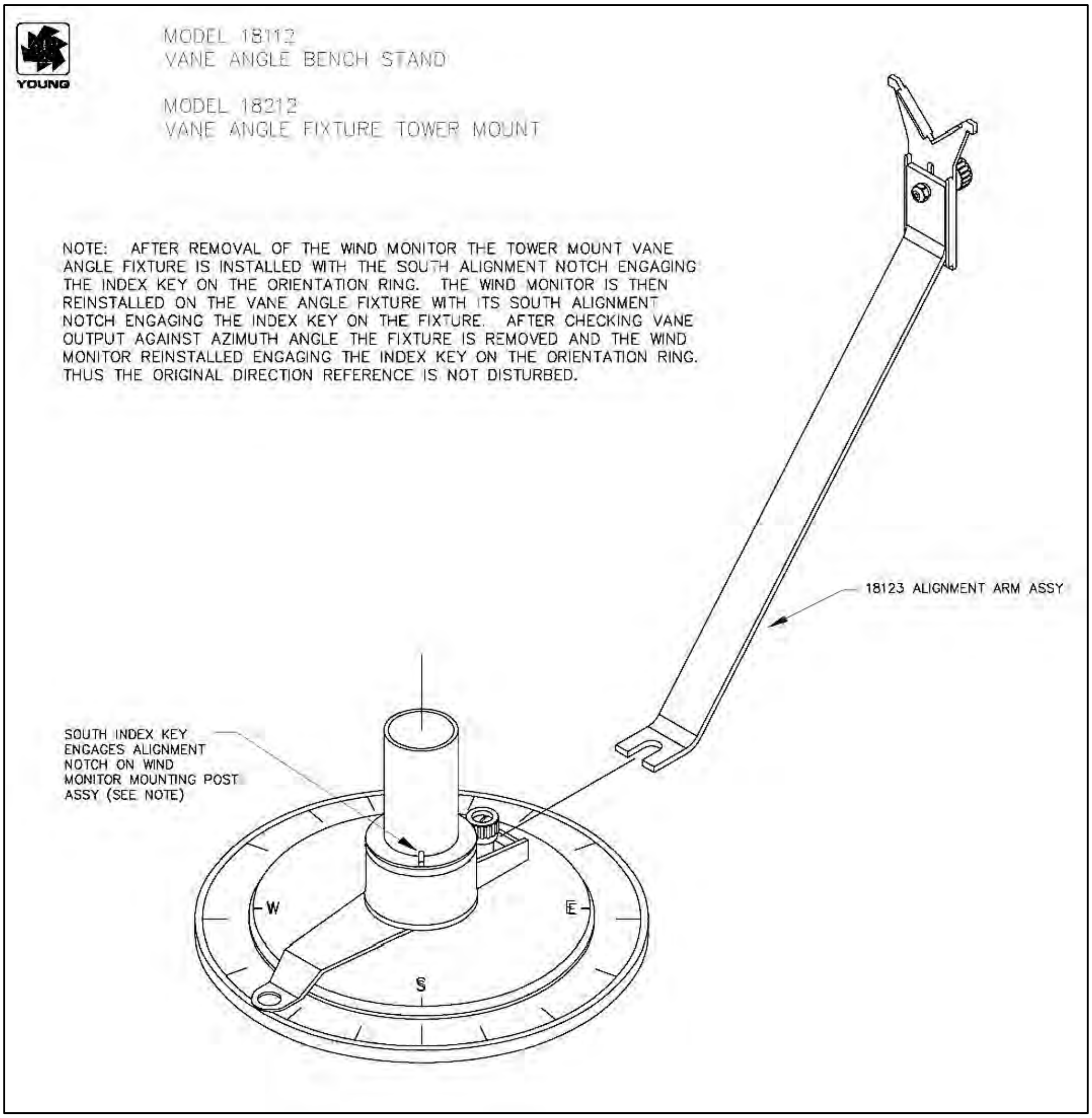
Tools and Test Equipment Required for the Wind Direction Sensor Performance Test

- R.M. Young, 18331, vane torque gauge
- R.M. Young, 18112, vane angle bench stand
- Binoculars or telescope (10x magnification, or greater)
- Direction compass with 1 degree resolution markings
- Wind Direction Sensor Calibration form

R.M. Young 18331 Vane Torque Gauge



R.M. Young 18112 Vane Angle Bench Stand



<u>Part A: Starting Torque Threshold Test</u>

1. Lower the 10-meter and 60-meter wind direction sensors to ground level. (Note: A tall step ladder will be needed to reach the sensors even after the boom assemblies have been lowered to ground level. Follow normal step ladder safety precautions when removing and replacing the sensors.)
2. Carefully remove the 05305 wind speed / wind direction sensor from the mounting post.
3. Inspect the vane assembly for signs of damage.
4. Place the 05305 wind speed / wind direction sensor on the 18112 vane angle bench stand and tighten the base clamp. Do <u>not</u> attach the 18123 alignment arm at this point. (Note: The vane angle bench stand must be completely stable and level to avoid biasing the torque test.)
5. Install the 18331 vane torque gauge centered on top of the vane/ body assembly.

6. Slowly pull the leaf spring thread until the vane/body assembly moves at least 5 degrees. (Note: It is essential that the sensor be completely isolated from any wind movement during this test. The slightest breeze will affect the response of the sensor. One solution is to perform this test inside a closed vehicle.)
7. Read the torque scale in gram-centimeters (gm-cm) required to move the vane at least 5 degrees.
8. Repeat this process in the opposite direction.
9. Use the following equation to convert the sensor's starting torque in gm-cm to MPS:

$$\mathrm{MPS} = \sqrt{\frac{\mathrm{gm-cm}}{37}}$$

10. Record the results on the wind direction calibration report form.
11. If the resulting starting torque threshold is greater than 0.5 MPS, the bearings are worn and need replacing. (Refer to the Maintenance Section of this SOP for instructions on replacing worn bearings.)

Part B: Wind Direction Accuracy Test

12. Place the 05305-AQ sensor on its mounting post on the tower. (Note: Do not replace the propeller at this time.)
13. Open the door to the data logger enclosure at the base of the tower.
14. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
15. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
16. Press the "Down Arrow" to navigate to the desired wind direction channel.
17. Use the compass and telescope, or binoculars, to determine the azimuth (direction), relative to True North, from the 05305 to a recognizable landmark feature, such as a power pole, smoke stack, light post, etc., some distance from the tower.
18. Point the nose of 05305's body/vane assembly directly at the landmark feature by siting along the 05305's body and holding it directly in line with the landmark.
19. Read data logger-reported value for the known wind direction input.
20. Contact the Control Room by radio or cell phone and request the value reported by the Control Room computer for the wind direction test point.
21. Record the Tower and Control Room wind direction values in the Accuracy Test sections of the wind direction sensor calibration report form.
22. Turn the vane/body assembly 180 degrees and point the tail section at the same landmark feature.
23. Repeat Steps 19 and 20 for this back-azimuth direction.
24. Select another landmark feature approximately 90 degrees apart from the first landmark feature.
25. Repeat Steps 17 through 22 and record the results in the Accuracy Test section on the wind direction sensor calibration report form. (Note: Taking the azimuth and back-azimuth to two landmarks will result in four direction input test points needed to evaluate the accuracy of the 05305 sensor.)

Part C: Wind Direction Linearity Test

26. Attach the wind direction sensor to the 18112 vane angle bench stand. Attach the 18123 alignment arm to the bench stand (see diagram).
27. Turn the vane assembly until the pointer on the vane angle bench stand points to the 5 degree position.
28. Allow a few seconds for the signal to stabilize, and read the tower's data logger display for this test point.
29. Contact the Control Room by radio or cell phone and request the value reported by the Control Room computer for this wind direction test point.
30. Record the Tower and Control Room wind direction values in Linearity Test sections of the wind direction sensor calibration report form.
31. Turn the vane assembly until the pointer on the vane angle bench stand points to the 30 degree position.
32. Repeat Steps 28 through 30 for the remaining 30 degree intervals of 60, 90, 120, 150, 180, 210, 240, 270, 300, 330, and 350 degrees. (Note: The 05305 has an "open" spot on its potentiometer at the 355 to 360 degree position resulting in unreliable direction values. Avoid taking readings in that location.)
33. Replace the wind direction sensor into its mounting post on the tower.
34. Tighten the sensor's base clamp.

MAINTENANCE OF THE 05305-AQ WIND DIRECTION SENSOR

The 05305-AQ wind direction sensor is very robust and will operate for long periods of time with little maintenance. The few maintenance tasks that could effectively be performed by the end-user include: (1) sensor inspection and evaluation (2) vertical shaft bearing replacement, and (3) potentiometer replacement. Maintenance or service tasks more complex than those mentioned in this SOP should be performed by the manufacturer. The information presented below provides guidance for the routine maintenance tasks. Refer to the manufacturer's instrument manual for additional instruction.

Inspection and Evaluation: The 05305-AQ wind direction sensor body components should be inspected and evaluated semiannually to assure it's intact and in good condition. Normally, the inspection and evaluation is done during the semiannual "Sensor Performance Test", but can be conducted anytime a problem with the wind direction sensor is suspected. The inspection includes a close examination of the sensor body and the nose cone assembly. Inspect the sensor and its components closely looking for cracks, dents, loose connectors or other indicators of potential damage that could affect sensor performance. Turn the vane/body assembly back and forth to confirm that it moves freely without any resistance. If worn bearings are suspected, follow the procedures described above for conducting the "Starting Torque Threshold Test" to determine if the vertical shaft bearings need replacing.

Replacing the Vertical Shaft Bearings: Perform this task indoors on a well-lighted work table. The steps listed below are taken from the R.M. Young 05305-AQ Wind Direction Sensor instrument manual.[3] Read all of the procedures before beginning. The sensor should be removed from its mount on the tower, and the propeller should be removed from the nose cone assembly

Required Tools and Test Equipment

- Soldering iron
- Replacement vertical shaft bearings

Part A: Remove Old Bearings

1. Remove the nose cone assembly and set it aside in a safe place.
2. Push the main housing latch located inside the opening that holds nose cone assembly and lift upward to remove the sensor body from the vertical shaft rearing rotor.
3. Slide the junction box cover up, exposing the circuit board.
4. Remove the screws holding the circuit board.
5. Unsolder the three potentiometer wires (white, green, black), the two wind speed coil wires (red, black), and the earth ground wire (red) from the board.
6. Remove the entire assembly from the vertical shaft.
7. Slide the vertical shaft bearing rotor upward and off the vertical shaft.
8. Remove the old vertical shaft bearings.

Part B: Install New Bearings

9. Install the new bearings. (Note: Be careful not to apply pressure to the bearing shields.)
10. Replace the vertical shaft bearing rotor.
11. Replace the transducer and reconnect (resolder) the wires in their original positions.
12. Replace the main housing (vane/body assembly)
13. Align the vane. (described below in replacing the potentiometer)
14. Replace the nose cone.
15. Perform a vane torque test to confirm the starting torque threshold is within the required ±0.5 mps limit.

Part C: Remove & Replace the Potentiometer

1. Gain access to the potentiometer by following the procedure described above for replacing the vertical shaft bearings.
2. Loosen the set screw on the potentiometer coupling and remove it from the potentiometer adjust thumbwheel.
3. Loosen the set screw on the potentiometer adjust thumbwheel and remove it from the potentiometer shaft extension.
4. Loosen two set screws at the base of the transducer assembly and remove the assembly from the vertical shaft.
5. Unscrew the potentiometer housing from the potentiometer mounting and coil assembly.
6. Apply firm but gentle pressure on the potentiometer shaft extension and push the potentiometer out of the potentiometer mounting and coil assembly.
7. Loosen the set screw on the potentiometer shaft extension and remove it from the potentiometer shaft.
8. Place the potentiometer shaft extension on the new potentiometer (gap at 0.040 inches) and tighten the set screw. (Note: Do not over tighten the set screw.)
9. Push the new potentiometer into the potentiometer mounting and coil assembly.
10. Feed the potentiometer and coil wires through the hole in the bottom of the potentiometer housing.
11. Screw the potentiometer housing onto the potentiometer mounting and coil assembly. Apply a small amount of silicone sealant on the threads.
12. Gently pull the transducer wires through the bottom of the potentiometer housing to take up any slack. Apply a small amount of silicone sealant around the hole.
13. Install the transducer assembly on the vertical shaft (gap 0.5 mm).
14. Tighten the set screws at the bottom of the transducer assembly.
15. Place the potentiometer adjustment thumbwheel on the potentiometer shaft extension and tighten the set screw.
16. Place the potentiometer coupling on the potentiometer adjust thumbwheel. Do not tighten set screw yet.
17. Use needle-nose pliers to gently pull the transducer wires through the hole in the junction box.
18. Solder the wires to the circuit board according to the wiring diagram.
19. Secure the circuit board in the junction box.

20. Place the sensor's main housing over the vertical shaft bearing rotor just until the potentiometer coupling is near the top of the main housing. (Note: Be sure to align the indexing key and channel for these two assemblies.)
21. Turn the potentiometer adjust thumbwheel until the potentiometer coupling is oriented to engage the ridge in the top of the main housing.
22. Tighten the potentiometer coupling set screw. (Note: The set screw should be facing the main housing's nose cone opening.
23. Slide the main housing the rest of the way onto the vertical shaft rotor assembly until a soft click in heard indicating that the two assemblies are locked together.
24. Connect excitation voltage and signal leads to the terminal strip according to the wiring diagram and connect the sensor to an output device such as a data logger.
25. Orient the vane to a known direction value and turn the potentiometer set thumbwheel until the proper direction is reported by the output device.
26. Replace the nose cone.

REFERENCE DOCUMENTS

[1] Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements, Version 2.0 (Final) USEPA, March 2008

[2] Meteorological Monitoring Guidance for Regulatory Modeling Applications, USEPA, February 2000.

[3] Model 05305 Wind Monitor-AQ Instrument Manual, Revision C080905, R.M. Young, Traverse City, Michigan.

EXAMPLE OF BIWEEKLY STATION OPERATION CHECKLIST REPORT FORM

CABRAS POWER PLANT METEOROLOGICAL TOWER
BIWEEKLY STATION OPERATION CHECKLIST

		Mo. / Day →						
		Year →						
		Tech. Initials →						
	Checklist Item	**Standard**	**Indicate Checklist Item Results**					
	All tower guy wires intact?	YES						
	All WS / WD sensors present?	YES						
	WS propellers present and intact?	YES						
G	WD vanes present and intact?	YES						
E	VWS propeller present and intact?	YES						
N	Temperature probe present?	YES						
E	SR sensor level and clean?	YES						
R	Precip gauge present and intact?	YES						
A	Data Logger on line?	YES						
L	Indicate **L**ocal **S**tandard **T**ime	NA						
	Indicate DAS clock time	±3 min of LST						
	Indicate DAS battery voltage	12 – 16 VDC						
	Is the MODEM connected?	YES						
R	10-m WS estimate, MPS	NA						
E	10-m WS DAS value, MPS	±5.0 MPS						
A	10-m WS check PASS? FAIL?	PASS						
S	10-m WD estimate, degrees	NA						
O	10-m WD DAS value, degrees	±30 deg						
N	10-m WD check PASS? FAIL?	PASS						
A	60-m WS estimate, MPS	NA						
B	60-m WS DAS value, MPS	±5.0 MPS						
I	60-m WS check PASS? FAIL?	PASS						
L	60-m WD estimate, degrees	NA						
I	60-m WD DAS value, degrees	±30 deg						
T	60-m WD check PASS? FAIL?	PASS						
Y	10-m VWS direction check, +/-	NA						
	10-m VWS DAS value, +/-	+ or -						
C	10-m VWS check PASS? FAIL?	PASS						
H	2-m temperature estimate, °C	NA						
E	2-m temperature DAS value, °C	±5° C						
C	2-m temp check PASS? FAIL?	PASS						
K	SR range estimate, Low, Med, High[1]	NA						
S	SR DAS value, Low, Med, High[1]	Low, Med, High						
	SR estimate check PASS? FAIL?	PASS						

[1] Solar Radiation W/m^2 range values are: 0 to 300 = Low, 300 to 700 = Medium, 700 to >1,000 = High

EXAMPLE OF WIND DIRECTION SENSOR CALIBRATION REPORT FORM

Cabras Meteorological Tower

60-Meter Wind Direction Sensor Calibration Report

Date: ________ **Start:** ________ **Technician(s):** ________
End: ________

SENSOR INFORMATION

Make: R.M. YOUNG
Model: 05305-AQ
SN: ________
Operating Range: 0 to 360 degrees

CALIBRATION TEST EQUIPMENT

Item: Compass transit **SN:** NA
Item: Vane angle bench stand. R.M. Young 18112 **SN:** NA
Item: Vane torque gauge. R.M. Young 18331 **SN:** NA

SENSOR CALIBRATION TEST RESULTS

Local Magnetic Declination: 1.3 deg. east (NGDC 8/10)

Vane Starting Threshold: ________ gm-cm equal to ________ mps **Pass? / Fail?:** ________ ≤ 0.50 mps

Test Input Deg.	Accuracy at Met Tower Output Deg.	Error Deg.	Pass? Fail?	Accuracy at EMSYS Output Deg.	Error Deg.	Pass? Fail?
149						
329						
42						
222						

Accuracy Pass / Fail
To PASS, the system error must be: ± 5 deg. per test point.

Test Input Deg.	Linearity at Met Tower Output Deg.	Nrmlzd* Deg.	Pass? Fail?	Linearity at EMSYS Output Deg.	Nrmlzd* Deg.	Pass? Fail?
5		NA	NA		NA	NA
30						
60						
90						
120						
150						
180						
210						
240						
270						
300						
330						
350						

* Normalized error in degrees.

Linearity Pass / Fail
To PASS, the system error must be: ± 3 deg. per test point.

COMMENTS:

	As Found	As Left
Results are:		

SOP

VERTICAL WIND SPEED SENSOR

Standard Operating Procedure

Operation and Maintenance of the R.M. Young 27106 Gill Propeller Anemometer

Original Date:	2 February 2005	**Revision Date:**	26 September 2011
Prepared By:	*AMSTech* Boulder, CO	**Approved By:**	

SOP SUMMARY

This SOP provides detailed operation and maintenance (O&M) procedures for the R.M. Young, 27106 Gill Propeller Anemometer, referred to in this SOP as a "vertical wind speed sensor" or "VWS sensor". The R.M. Young 27106 vertical wind speed sensor is used to measure the speed and upward or downward movement of the wind's vertical component. The VWS sensor is currently installed at the 10-meter level of the 60-meter meteorological tower at GPA's Cabras Power Plant, Piti, Guam. The O&M procedures presented in this SOP are based on information contained in the manufacturer's 27106 Gill Propeller Anemometer Instrument Manual.

INSTRUMENT DESCRIPTION

"The Gill Propeller Anemometer is a low threshold precision air velocity sensor employing a fast response helicoid propeller. The instrument uses a high quality tach-generator transducer which converts propeller rotation to a DC voltage that is linearly proportional to air velocity. Air flow from any direction may be measured, however, the propeller responds only to the component of the air flow which is parallel to the axis of its rotation. Off-axis response closely approximates a cosign curve with appropriate polarity. With perpendicular air flow the propeller does not rotate."[1] The photograph on the next page shows the 27106 vertical wind speed sensor and identifies its major components.

OPERATION OF THE 27106 VERTICAL WIND SPEED SENSOR

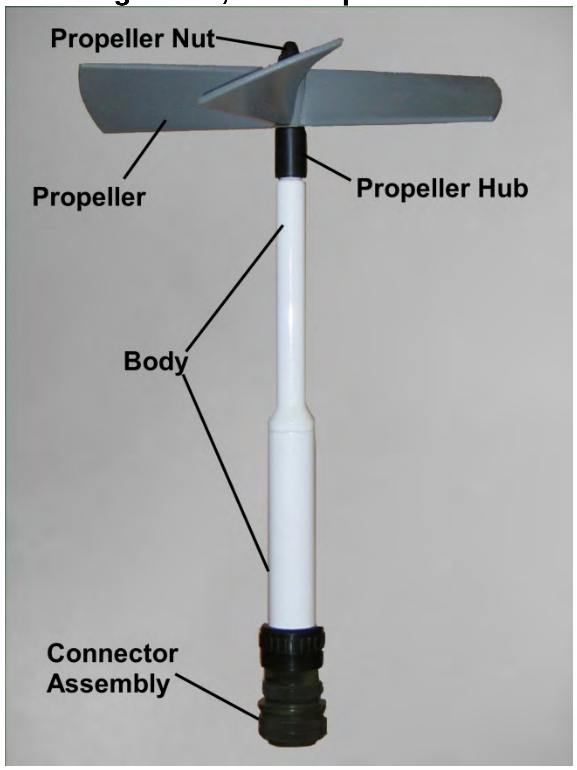
Two categories of routine tasks are required to assure that the VWS sensor is operating within acceptable limits. These are: (1) reasonability checks, and (2) sensor performance tests.

Reasonability Check: The wind speed sensor Reasonability Check is to be performed biweekly. Its purpose is to confirm that the sensor(s) is/are at the proper location on the tower, intact, and operational. There are two parts to the Reasonability Check; (A) visual observation of the wind speed sensor, and (B) evaluation of sensor performance. The following steps will guide the technician in completing the biweekly Reasonability Check.

Tools and Test Equipment Required for Reasonability Check

- Biweekly Station Operation Checklist form

R.M. Young 27106, Gill Propeller Anemometer



Part A: Visual Observation

1. Look up at the VWS sensor located at the tower's 10-meter level.
2. Visually determine that the sensor is present.
3. Confirm that all four blades of the propeller assembly are present.
4. Observe whether or not the propeller is rotating. (Note: A very light breeze is all that is needed to cause the propeller to rotate. Depending on the wind's angle of attack, the propeller will rotate clockwise or counter-clockwise. A non-rotating propeller could mean that the wind is exactly perpendicular to the propeller's axis, but that condition should only be of short duration. Non-rotation for more than 5 minutes could be an indication of worn bearings and should be investigated)
5. Note any problems on the Biweekly Checklist Form.

Part B: Evaluation of Performance

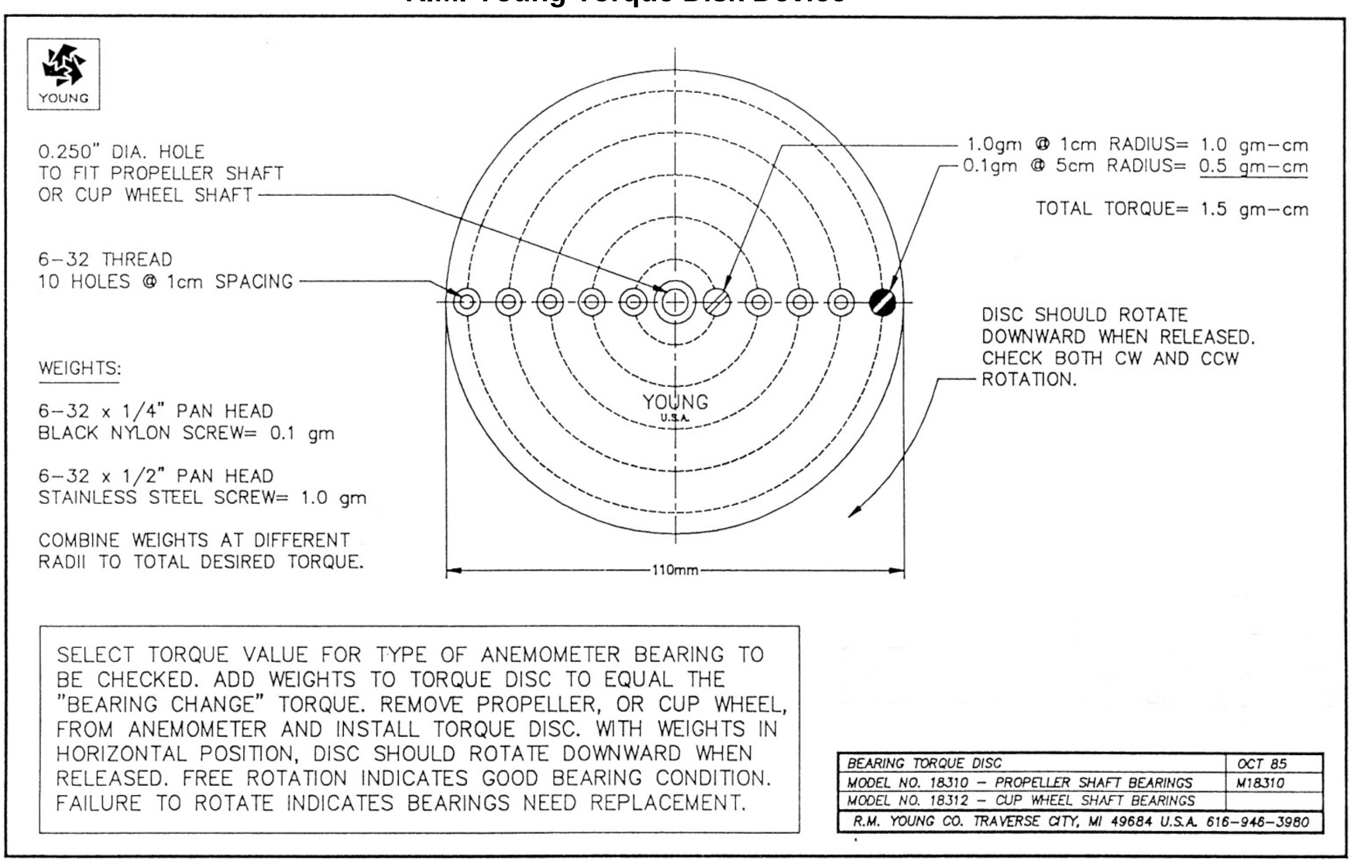
6. Open the door to the data logger enclosure at the base of the tower.
7. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
8. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
9. Press the "Down Arrow" to navigate to the vertical wind speed channel.
10. Determine whether or not the sensor's performance is "normal". A downward wind (towards the ground) causes the propeller to rotate clockwise, as seen from below, and produces a POSITIVE value. An upward wind has the opposite effect.
11. Observe the sensor for approximately 1 minute and compare its CW and CCW rotations to the positive and negative values reported by the data logger.
12. Record the results of your observation on the Biweekly Checklist Form.

VWS Sensor Performance Test: The Wind Speed Sensor Performance Test is also referred to as a "Calibration Test". Actually, the 27106 vertical wind speed sensor itself does not have user-accessible adjustments normally associated with calibrating an instrument, so the real purpose of the "Calibration Test" is to confirm that the sensor is operating within acceptable performance limits. If the sensor's performance does not meet the required standards, it should be returned to the manufacturer for repair. The VWS Sensor Performance Test is to be conducted <u>semiannually</u>. The test consists of (A) measuring the sensor's starting torque threshold, and (B) documenting the sensor's accuracy in responding to a zero and at least six additional known wind speed input values, three CW and three CCW. Listed below are the necessary test equipment and the step-wise procedures that technician(s) will need to complete the VWS Sensor Performance Test.

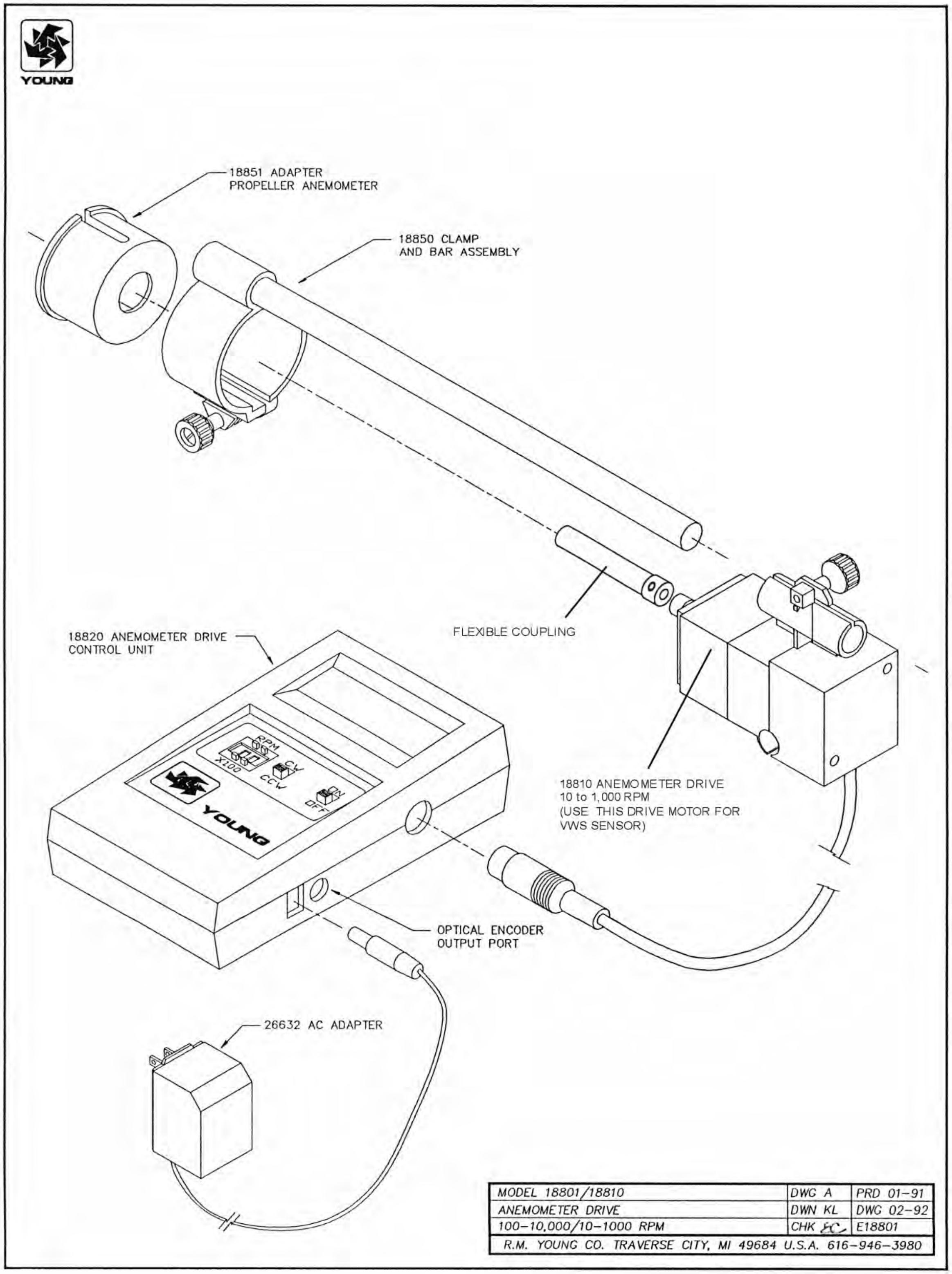
<u>Tools and Test Equipment Required for VWS Sensor Performance Test</u>

- R.M. Young, 18312, torque disk device
- R.M. Young, 18810, low-speed (10 to 1,000 rpm) anemometer drive motor
- R.M. Young, 18820, anemometer drive controller unit
- R.M. Young, 18850, motor clamp and bar assembly
- R.M. Young, 18851, propeller anemometer motor clamp adapter
- Vertical Wind Speed Sensor Calibration Report form

R.M. Young Torque Disk Device



R.M. Young Anemometer Drive Motor and Controller



⇨**IMPORTANT NOTE**! If a Wind Direction Sensor Performance Test is to be conducted in conjunction with the VWS Sensor Performance Test, the orientation of the 10-meter and 60-meter crossarm assemblies, relative to true north, must be determined before lowering the booms to ground level. This measurement must be taken with the sensors at their normal monitoring heights and positions on the tower. A surveyor's transit with compass is the best tool for measuring the crossarm orientation, however, a 10x power telescope or a good pair of binoculars and a high-quality direction compass with at least 1 degree resolution will also work. To be effective, the compass must be mounted on a tripod. Move 100 to 200 feet away from the base of the tower and along the same axis as the crossarm to be measured. Use the binoculars (or telescope) to position yourself directly in line with the crossarm's wind speed and wind direction sensors. Adjust the compass to compensate for the **1.5 degrees east magnetic declination** for the location. Stand directly behind the compass and tripod to take the measurement.

Part A: Starting Torque Threshold Test

1. Lower the VWS sensor to ground level. (Note: A tall step ladder will be needed to reach the sensors even after the boom assemblies have been lowered to ground level. Follow normal step ladder safety precautions when removing and replacing the sensors.)
2. Loosen by hand the knurled nut attached to the connector assembly at the base of the VWS sensor.
3. Carefully remove the VWS sensor from its mounting base.
4. Loosen by hand the propeller nut.
5. Carefully remove the propeller from the hub assembly.
6. Inspect the propeller for signs of damage.
7. Place the propeller in a safe location that will protect it from damage during the rest of the performance test.
8. While holding the VWS sensor in one hand, use your other hand to quickly spin the sensor shaft hub in one direction, and do the following:
   a. Observe the sensor shaft hub and listen to the bearings' noise as the hub's rotation begins to slow down.
   b. Note whether or not the hub's slowing action is smooth and even.
   c. The noise made by the bearings should not be louder than a quiet "hum".
   d. Noisy bearings and uneven or "jerky" movements during the slowing of the sensor shaft hub indicate potentially worn bearings.
9. Lay the wind speed sensor on its side on a flat, stable, horizontal surface such as a table or work bench.
10. Carefully push the plastic R.M. Young 18312 torque disk device onto the VWS sensor shaft hub.
11. With the torque disk attached, rotate the sensor shaft hub until the torque disk device's screw weight attachment holes are horizontal (parallel to the table supporting the sensor).

12. Carefully release the hub and confirm that the torque disk's holes remain horizontal. (Note: If the torque disk holes do not remain horizontal, hold the hub steady with the thumb and forefinger of one hand and with the other hand slightly rotate the torque disk on the sensor shaft tip in one direction. Then, once again position the torque disk holes parallel to the table and release the shaft hub to confirm that the holes remain horizontal. Repeat this process until the torque disk device's screw weight holes remain in the horizontal position.)
13. While holding the sensor shaft hub with one hand and maintaining the torque disk holes horizontal, insert a black, 0.1 gram screw weight into one of the two inner most holes located 1 centimeter out from the disk's axis point.
14. Release the sensor shaft hub and observe whether or not the screw weight is sufficient to cause the torque disk to rotate approximately 5 degrees in the direction of the weight's normal direction of fall.
15. Rotate the hub and torque disk 180 degrees and repeat Step 14 for the opposite direction of movement.
16. If no rotational movement of the disk is observed, place the 0.1 gram screw weight into one of the two test holes located 2 centimeters out from the disk's axis point and repeat the actions described in Steps 13, 14, and 15.
17. Continue placing the screw weight in the 1-centimeter-spaced holes sequentially more distant from the axis point until the weight causes the disk to rotate approximately 5 degrees.
18. Determine the torque in gram-centimeters (gm-cm) required to rotate the sensor's hub 5 degrees by multiplying the screw weight times the number of centimeters out from the axis point that caused to disk to rotate. For example, if the hub rotated approximately 5 degrees with the screw weight in hole #2, the final test result would be 0.2 gm-cm torque.
19. Use the following equation to convert the sensor's starting torque in gm-cm to MPS:

$$\mathrm{MPS} = \sqrt{\frac{\mathrm{gm} - \mathrm{cm}}{3.8}}$$

20. Record the results on the wind speed calibration report form.
21. If the resulting starting torque threshold is greater than 0.5 MPS, the bearings are worn and need replacing. (Refer to the Maintenance Section of this SOP for instructions on replacing worn bearings.)

Part B: VWS Sensor Accuracy Test

22. Open the door to the data logger enclosure at the base of the tower.
23. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
24. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
25. Press the "Down Arrow" to navigate to the wind speed channel.
26. Read the data logger-reported value for zero vertical wind speed, and record it on the VWS Sensor Calibration Report form.

27. Insert the R.M. Young 18851 adapter into the large opening of the R.M. Young 18850 motor clamp and bar assembly and attach the combined bar assembly onto the VWS sensor body by tightening the clamp screw. (Note: Refer to Anemometer Drive diagram on Page 4.
28. Slide the R.M. Young 18810 anemometer drive motor onto the motor clamp bar.
29. Use the flexible coupling to attach the anemometer drive motor to the tip of the VWS sensor shaft hub.
30. Fix the anemometer drive motor in place on the bar by gently tightening the motor's locking screw. Do not over tighten the locking screw.
31. Connect the anemometer drive motor cable to the R.M. Young 18820 control unit.
32. On the 18820 control unit, choose CW (clockwise) or CCW (counter-clockwise) direction and select the desired RPM by pressing the RPM thumbwheel buttons. (Note: The order in which the vertical wind speed values are input into the wind speed sensor is not critical. Remember that the sensor must be tested in CW and CCW directions, and the lowest vertical wind speed value must be less than 1.0 MPS. Possible CW and CCW test points are: (1) 100 RPM, (2) 400 RPM, and (3) 900 RPM.)
33. Use the following equation to convert RPM to MPS for the 20x30 cm carbon fiber propeller: MPS = [RPM x 0.0049 x 1.25]
34. Once the desired RPM value has been entered on the thumbwheel display, switch ON the control unit and allow a few seconds for the motor and LCD display to stabilize.
35. When the control unit LCD display has stabilized, read the tower's data logger-reported value for the known RPM setting. (Remember that CW test points produce POSITIVE vertical wind speed values, and CCW test points are NEGATIVE.)
36. Read the data logger-reported value for the first vertical wind speed test point, and record it on the VWS Sensor Calibration Report form.
37. Switch the direction selector to the opposite position (CW or CCW) and record the second test value for the same RPM on the VWS Sensor Calibration Report form.
38. Repeat Steps 32 through 37 for the remaining four (two CW and two CCW.) vertical wind speed test points

MAINTENANCE OF THE 27106 VERTICAL WIND SPEED SENSOR

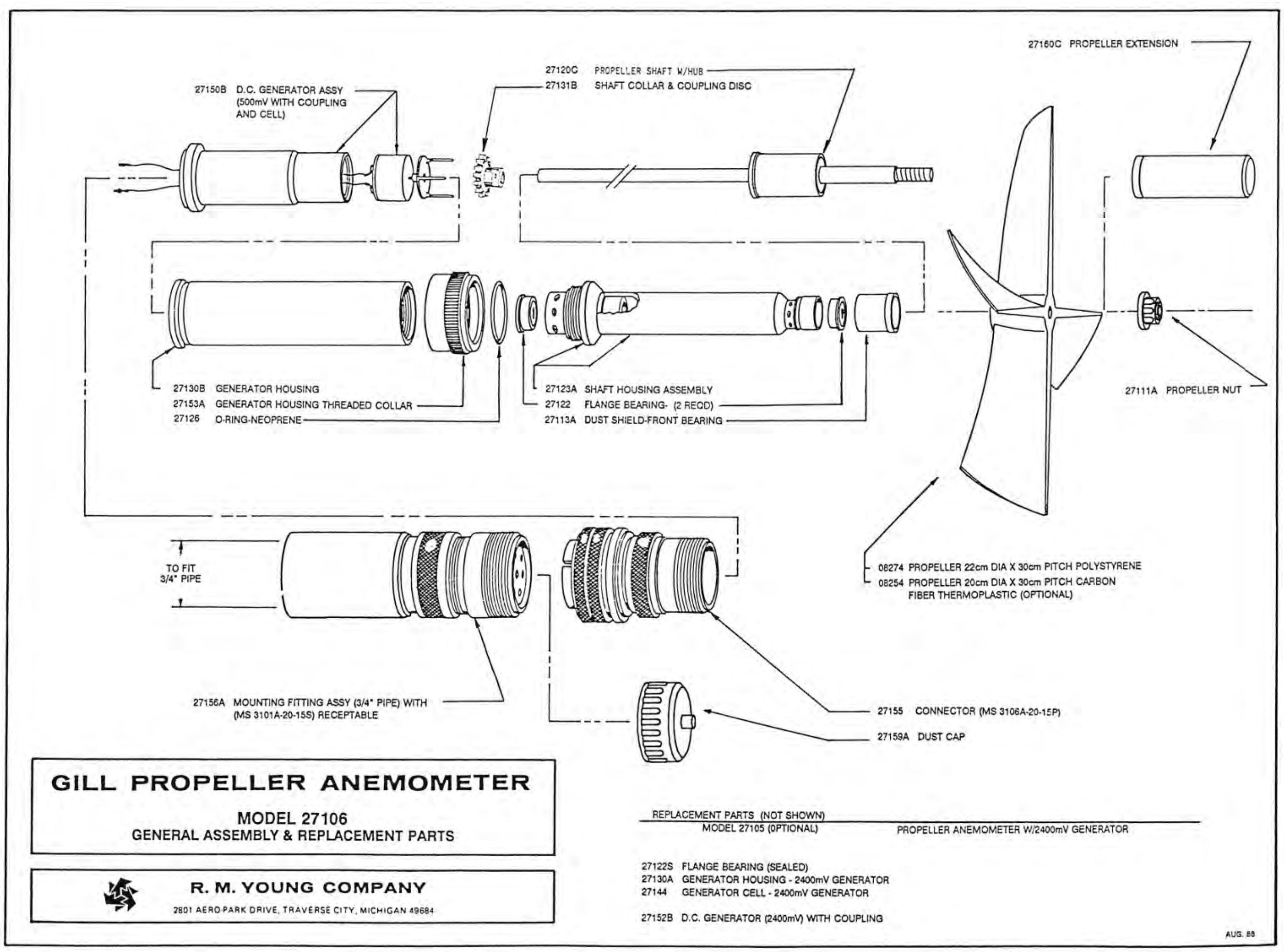
The R.M. Young 27106 vertical wind speed sensor is very robust and will operate for long periods of time with little maintenance. The few maintenance tasks that could effectively be performed by the end-user include: (1) sensor inspection and evaluation (2) bearing replacement, and (3) propeller replacement. Maintenance or service tasks more complex than those mentioned in this SOP should be performed by the manufacturer or the sensor should be replaced. The information presented below provides guidance for the routine maintenance tasks. Refer to the manufacturer's instrument manual for additional instruction.

Inspection and Evaluation: The R.M. Young 27106 VWS sensor, should be inspected and evaluated semiannually to assure it's intact and in good condition. Normally, the inspection and evaluation is done during the semiannual "Sensor Performance Test", but can be conducted anytime a problem with the VWS sensor is suspected. The inspection includes a close examination of the sensor body and propeller assembly. Inspect the sensor and its components closely looking for cracks, dents, loose connectors or other indicators of potential damage that could affect sensor performance. Remove the propeller and spin the sensor's propeller shaft with thumb and forefinger. Watch the shaft as its spinning slows down. The spinning should decline slowly and evenly. A rapid slow down and “jerky” or “halting” actions of the hub indicates worn bearings. If worn bearings are suspected, follow the procedures described above for conducting the “Starting Torque Threshold Test” to determine if the bearings need replacing.

Replacing the Bearings: If the VWS sensor’s bearings become noisy or the sensor’s starting torque threshold increases above the acceptable level, (refer to the “Starting Torque Threshold Test” presented above) the bearings may need replacement. It is recommended that this task be performed indoors on a well-lighted work table. The steps listed below are based on information listed in the R.M. Young, Model 27106 Gill Propeller Anemometer instruction manual listed in this SOP’s Reference Documents section. Read all of the procedures before beginning.

<u>Tools and Test Equipment Required for VWS Sensor Bearings Replacement</u>

- 1/16 inch Allen wrench



NOTE: It is assumed that at this point the sensor has already been removed from its mount on the meteorological tower.

Part A: Remove Old Bearings

1. Loosen by hand the propeller nut and remove the propeller from the sensor shaft.
2. Place the propeller in a safe location.
3. Unthread and separate the shaft housing (upper body) from the generator housing (lower body). Refer to the above assembly diagram of the Model 27106 Gill Propeller Anemometer.
4. Use the 1/16 Allen wrench to loosen the shaft collar and coupling disk found at the bottom of the shaft housing.
5. Remove the shaft collar and push the propeller shaft upward (toward the propeller hub) through both bearings and out of the end of the shaft housing.
6. Pull the front (upper) bearing dust shield off the shaft housing.
7. Remove the front (upper) and rear (lower) bearings from their recessed seats in the shaft housing. (NOTE: The blade of a pocket knife, or similar tool, will make this task easier.)

Part B: Install New Bearings

8. Gently insert the front bearing into its seat in the upper part of the housing.
9. Replace the front bearing dust shield onto the housing.
10. Carefully slide the propeller shaft through the front bearing and into the housing.
11. Slide the rear bearing onto the propeller shaft and gently push it into its seat in the housing.
12. Replace the shaft collar / coupling disk onto the propeller shaft.
13. Allow a 0.010 inch (0.25 mm) end play gap between the shaft collar / coupling disk and the rear bearing.
14. Gently tighten the shaft collar / coupling disk set screw with the 1/16 inch Allen wrench. Do not over tighten the set screw.
15. Rethread the shaft housing onto the generator housing.
16. Determine the VWS sensor's starting torque threshold as described above in Part A of the VWS Performance Test section.

Replacing the Propeller: If, during the "Inspection and Evaluation" maintenance task, the propeller is found to be damaged, replace it by the following procedure:

1. Loosen by hand the propeller nut and remove the propeller from the sensor shaft.
2. Remove the old propeller.
3. Install the new propeller on the shaft (NOTE: The propeller's serial number should be placed next to the propeller nut.)
4. Replace the propeller nut and hand tighten.

REFERENCE DOCUMENTS

[1] Instructions, Model 27106 Gill Propeller Anemometer, R.M. Young Company, Traverse City, Michigan, July 1990

EXAMPLE OF BIWEEKLY STATION OPERATION CHECKLIST REPORT FORM

CABRAS POWER PLANT METEOROLOGICAL TOWER
BIWEEKLY STATION OPERATION CHECKLIST

Mo. / Day →						
Year →						
Tech. Initials →						

	Checklist Item	**Standard**	**Indicate Checklist Item Results**					
	All tower guy wires intact?	YES						
	All WS / WD sensors present?	YES						
	WS propellers present and intact?	YES						
G	WD vanes present and intact?	YES						
E	VWS propeller present and intact?	YES						
N	Temperature probe present?	YES						
E	SR sensor level and clean?	YES						
R	Precip gauge present and intact?	YES						
A	Data Logger on line?	YES						
L	Indicate **L**ocal **S**tandard **T**ime	NA						
	Indicate DAS clock time	±3 min of LST						
	Indicate DAS battery voltage	12 – 16 VDC						
	Is the MODEM connected?	YES						
R	10-m WS estimate, MPS	NA						
E	10-m WS DAS value, MPS	±5.0 MPS						
A	10-m WS check PASS? FAIL?	PASS						
S	10-m WD estimate, degrees	NA						
O	10-m WD DAS value, degrees	±30 deg						
N	10-m WD check PASS? FAIL?	PASS						
A	60-m WS estimate, MPS	NA						
B	60-m WS DAS value, MPS	±5.0 MPS						
I	60-m WS check PASS? FAIL?	PASS						
L	60-m WD estimate, degrees	NA						
I	60-m WD DAS value, degrees	±30 deg						
T	60-m WD check PASS? FAIL?	PASS						
Y	10-m VWS direction check, +/-	NA						
	10-m VWS DAS value, +/-	+ or -						
C	10-m VWS check PASS? FAIL?	PASS						
H	2-m temperature estimate, °C	NA						
E	2-m temperature DAS value, °C	±5° C						
C	2-m temp check PASS? FAIL?	PASS						
K	SR range estimate, Low, Med, High[1]	NA						
S	SR DAS value, Low, Med, High[1]	Low, Med, High						
	SR estimate check PASS? FAIL?	PASS						

[1] Solar Radiation W/m² range values are: 0 to 300 = Low, 300 to 700 = Medium, 700 to >1,000 = High

EXAMPLE OF VERTICAL WIND SPEED SENSOR CALIBRATION REPORT FORM

Cabras Meteorological Tower

Vertical Wind Speed Sensor Calibration Report

Date: ____________ **Start:** ________ **Technician(s):** 0.00
End: ________

SENSOR INFORMATION

Make: R.M. YOUNG
Model: 27106
SN: ____________
Propeller Type: CARBON FIBER
Operating Range: -9.0 to +9.0 mps
Height Above Ground: 10 METERS

CALIBRATION TEST EQUIPMENT

Item: Variable rpm motor; RMY 18810 (10 to 1,000 rpm) **SN:** ____________
Item: Torque disk device; RMY 18312 **SN:** ____________

SENSOR CALIBRATION TEST RESULTS

Sensor Starting Threshold: ________ gm-cm ,equal to ________ mps **Pass? / Fail?:** ________ ≤ 0.25 mps

	Known Input RPM	Known Input mps	Tower DAS Response: Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
	0.0	0.00			NA	NA
CW	100	0.61			0.23	
CCW	100	-0.61			-0.23	
CW	400	2.45			0.32	
CCW	400	-2.45			-0.32	
CW	900	5.51			0.48	
CCW	900	-5.51			-0.48	

* Allowed Error = ±(5% of known input + 0.20 mps)

	Known Input RPM	Known Input mps	EMSYS Response: Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
	0.0	0.00			NA	NA
CW	100	0.61			0.23	
CCW	100	-0.61			-0.23	
CW	400	2.45			0.32	
CCW	400	-2.45			-0.32	
CW	900	5.51			0.48	
CCW	900	-5.51			-0.48	

* Allowed Error = ±(5% of known input + 0.20 mps)

COMMENTS

	Found	Left
Results are:		

To PASS, the sensor response must have... 1) Observed Error = ± Allowed Error per test point
2) Starting Torque = ≤ 0.50 mps

SOP

Standard Operating Procedure

AIR TEMPERATURE PROBE

Operation and Maintenance of the Climatronics 100093 Air Temperature Probe and Associated R.M. Young 41002 Radiation Shield

Original Date:	10 February 2005	**Revision Date:**	11 February 2012
Prepared By:	*AMSTech* Boulder, CO	**Approved By:**	

SOP SUMMARY

This SOP provides detailed operation and maintenance (O&M) procedures for the Climatronics, Model 100093 air temperature probe and its associated housing, the R.M. Young 41002 naturally-aspirated radiation shield. Together, the 100093 temperature probe and the 41002 radiation shield are used to measure ambient air temperature at the meteorological monitoring station located at GPA's Cabras Power Plant, Piti, Guam. The O&M procedures presented in this SOP are based on information contained in the manufacturer's instrument manual as well as USEPA-recommended quality control guidelines for air temperature measurements.[1,2]

INSTRUMENT DESCRIPTION

"The Climatronics 100093 air temperature probe consists of a two thermistor composite housed in a stainless steel sheath. When the thermistors are connected in a network, a voltage that varies as the temperature changes is obtained. This voltage is approximately linear with temperature (±0.16° C). The thermistor signal is used by a Climatronics temperature signal conditioner, which includes the non-probe portion of the network's circuitry."[3] The Model 41002 naturally-aspirated radiation shield prevents solar warming of the probe's exterior surface that would bias the air temperature values reported at the station.

OPERATION OF THE 100093 TEMPERATURE PROBE

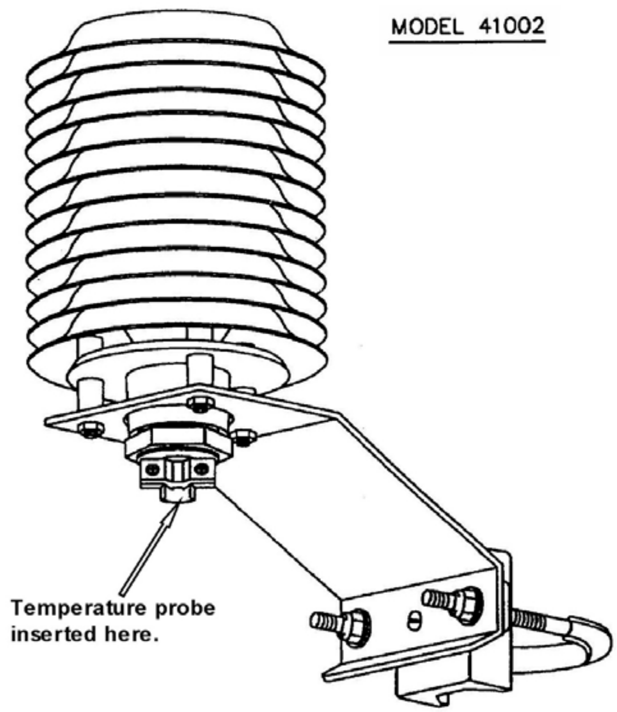
The two types of routine tasks required to assure that the air temperature probe is operating within acceptable limits are: (1) reasonability checks, and (2) probe performance tests.

Reasonability Check: The temperature probe Reasonability Check is to be performed biweekly. Its purpose is to confirm that the probe is present and operational. There are two parts to the Reasonability Check; (A) confirmation that the air temperature probe and solar shield are present, and (B) estimation of the temperature probe's accuracy. The following steps will guide the technician in completing the biweekly Reasonability Check.

Tools and Test Equipment Required for Reasonability Check

- Biweekly Station Operation Checklist form

NOTE: The Climatronics 100093 air temperature probe consists of a sealed stainless steel sheath that is 4.5 inches long and 5/32 inch in diameter. Attached to one end of the sheath is a 3-conductor signal cable approximately 1 meter (3 feet) long. The temperature probe is mounted in the thermally isolated inner portion of the 41002 radiation shield. The probe is inserted at the bottom of the radiation shield. Shown below is a diagram of the 41002 radiation shield indicating the location of the 100093 air temperature probe.



Part A: Visual Observation

1. Visually determine that the 41002 radiation shield is present.
2. Confirm that that the 100093 air temperature probe is firmly attached to the bottom of the radiation shield.
3. Note any problems on the Biweekly Checklist Form.

Part B: Estimation of Accuracy

4. Open the door to the data logger enclosure at the base of the tower.
5. Connect the KD1000 keypad to the CR1000 data logger’s CSI data port. The main menu screen will appear.
6. Press the “Enter” key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
7. Press the “Down Arrow” to navigate to the temperature channel.
8. Estimate the current ambient air temperature in degrees Celsius. (NOTE: The data logger reports air temperature in degrees Celsius. If you are more familiar estimating temperature in degrees Fahrenheit, the following equation will convert degrees Fahrenheit to degrees Celsius: **°C = (°F - 32) x 0.556**.)
9. Record the results of your observation on the Biweekly Checklist Form.

Air Temperature Probe Performance Test: The Air Temperature Probe Performance Test is also referred to as a "Calibration Test". Actually, the 100093 air temperature probe itself does not have user-accessible adjustments normally associated with calibrating an instrument, so the real purpose of the "Calibration Test" is to confirm that the probe is operating within acceptable performance limits. If the probe's performance does not meet the required standards, it should be replaced. The Temperature Probe Performance Test is conducted semiannually. The test consists of documenting the probe's accuracy in responding to at least three known temperature test points over its normal operating range. In conducting the test, the 100093 air temperature probe is placed along with an NIST-traceable thermometer into an insulated container that maintains water baths at stable and uniform temperatures within three temperature categories; ice, cool, and hot. The recommended temperature ranges are as follows: Ice = 0.0 to 2.0° C, Cool = 20 to 27° C, Hot = 40 to 50° C. Listed below are the test equipment and the step-wise procedures that technician(s) will need to complete the Air Temperature Probe Performance Test.

Tools and Test Equipment Required for the Air Temperature Probe Performance Test

- Insulated container such as a Thermos® bottle or Dewar flask with 2 to 4 liters volume
- NIST-traceable glass or digital thermometer with at least 0.10 degree Celsius, or better, resolution
- Approximately two gallons distilled water
- Approximately one pound of crushed or cube ice
- Electric heater suitable for heating water
- Air Temperature Probe Calibration Report form

⇨**IMPORTANT NOTES!**

(1) It is recommended that the water bath used to test the temperature probe be allowed to equilibrate for 30 to 45 minutes prior to beginning the performance test. This is especially important if the ice test point is to be performed first. Each water bath (ice, cool, and hot) should be thermally stable, uniform, and constantly agitated to assure that there are no temperature gradients within the bath. Begin the Air Temperature Probe Performance Test only after the water bath's temperature has stabilized at the desired test point.

(2) To help prevent "thermal shock" from damaging some temperature probes, USEPA recommends that the test baths be kept in sequential order. For example, you may use an ascending temperature order of ice, cool, and hot, or the reverse, but not directly from ice to hot or hot to ice.

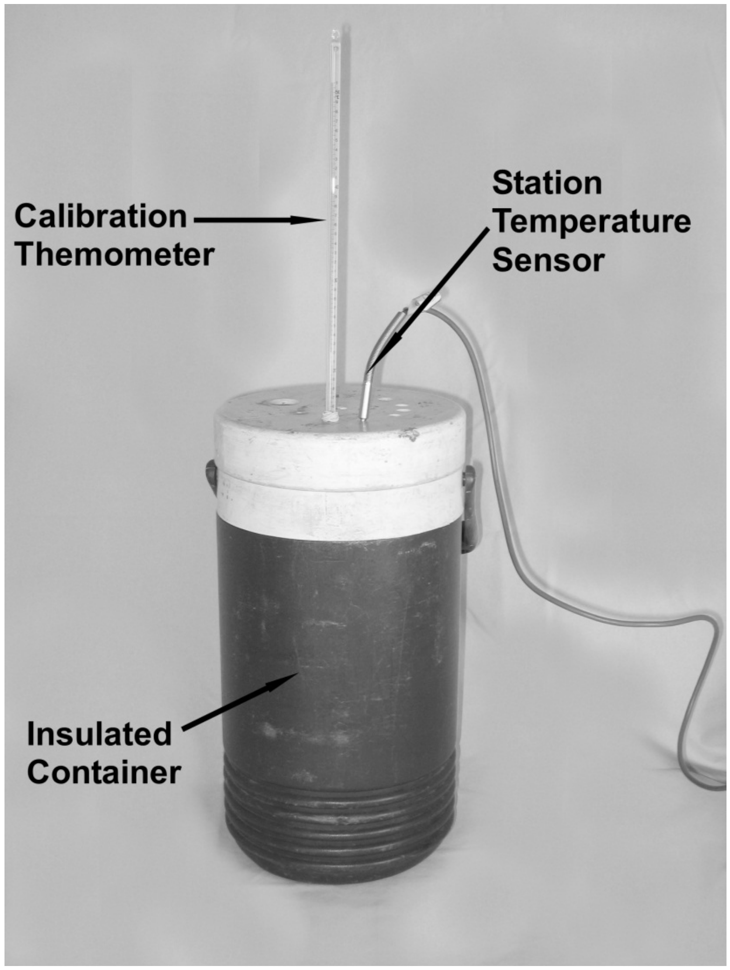
(3) When preparing the ice temperature bath, avoid using large chunks of ice. Crushing the ice into 1/2 inch or smaller sized pieces will shorten the time needed to reach equilibration.

(4) The ice test point does not need to be exactly at 0.0° C (32.0° F), but should be within ±2.0 degrees, or so, of the ice melting point. Once the ice test point temperature has been reached, any remaining crushed ice should be removed from the bath to avoid creating temperature gradients within the bath.

(5) Constant agitation of the bath during the test, either by gently shaking the container or by mechanical mixing, will help assure that temperature gradients do not form.

(6) The calibration thermometer and the station temperature probe should be placed as closely together as possible when inserted into the water bath during the test. It may be helpful to attach one to another by a rubber band.

**Example of Insulated Water Bath Container
Used for Temperature Probe Performance Test**



Air Temperature Probe Performance Test

1. Remove the 100093 temperature probe from the 41002 radiation shield.
2. Position the previously prepared water bath (see the above notes on preparing the test baths) on a stable and level base, such as a table or the ground, and within reach of the temperature probe's signal lead.
3. Place the station's temperature probe, together with the calibration thermometer into the water bath.
4. Gently agitate the bath to prevent temperature gradients from occurring.
5. Allow both the calibration thermometer and the station temperature probe to stabilize. (5 to 7 minutes is usually sufficient)
6. After stabilization, read the values reported by the calibration thermometer and the station temperature probe to the nearest 0.1° Celsius.
7. Record the values in the appropriate areas on the Air Temperature Probe Calibration Report form.
8. Repeat steps 4 through 9 for the remaining test points.

MAINTENANCE OF THE CLIMATRONICS 100093 AIR TEMPERATURE PROBE AND THE 41002 NATURALLY-ASPIRATED HOUSING

The 100093 air temperature probe requires no maintenance other than occasionally wiping any dust or debris from its surface. If the instrument performance test indicates that the temperature probe's performance is outside acceptable limits, the probe should be replaced. The only maintenance item required by the 41002 naturally-aspirated housing is confirming that it is intact and there is no debris blocking air movement between the radiation plates.

Inspection and Evaluation: Semiannually inspect the 41002 radiation and look closely for signs of damage or blockage that could affect its performance. The openings between the solar plates should be clear of any debris that would impede air flow past the 100093 air temperature probe. Confirm that the 100093 probe is firmly attached to the bottom of the radiation shield. Report any problems on the Station Checklist form.

REFERENCE DOCUMENTS

[1] Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements, Version 2.0 (Final), USEPA, March 2008

[2] Meteorological Monitoring Guidance for Regulatory Modeling Applications, USEPA, February 2000.

[3] Climatronics 100093 Air Temperature Probe Instrument Manual, Climatronics Corporation, Bohemia, NY, Rev. A, June 1983

EXAMPLE OF BIWEEKLY STATION OPERATION CHECKLIST REPORT FORM

CABRAS POWER PLANT METEOROLOGICAL TOWER
BIWEEKLY STATION OPERATION CHECKLIST

Mo. / Day →						
Year →						
Tech. Initials →						

	Checklist Item	Standard	Indicate Checklist Item Results					
	All tower guy wires intact?	YES						
	All WS / WD sensors present?	YES						
	WS propellers present and intact?	YES						
G	WD vanes present and intact?	YES						
E	VWS propeller present and intact?	YES						
N	Temperature probe present?	YES						
E	SR sensor level and clean?	YES						
R	Precip gauge present and intact?	YES						
A	Data Logger on line?	YES						
L	Indicate **L**ocal **S**tandard **T**ime	NA						
	Indicate DAS clock time	±3 min of LST						
	Indicate DAS battery voltage	12 – 16 VDC						
	Is the MODEM connected?	YES						
R	10-m WS estimate, MPS	NA						
E	10-m WS DAS value, MPS	±5.0 MPS						
A	10-m WS check PASS? FAIL?	PASS						
S	10-m WD estimate, degrees	NA						
O	10-m WD DAS value, degrees	±30 deg						
N	10-m WD check PASS? FAIL?	PASS						
A	60-m WS estimate, MPS	NA						
B	60-m WS DAS value, MPS	±5.0 MPS						
I	60-m WS check PASS? FAIL?	PASS						
L	60-m WD estimate, degrees	NA						
I	60-m WD DAS value, degrees	±30 deg						
T	60-m WD check PASS? FAIL?	PASS						
Y	10-m VWS direction check, +/-	NA						
	10-m VWS DAS value, +/-	+ or -						
C	10-m VWS check PASS? FAIL?	PASS						
H	2-m temperature estimate, °C	NA						
E	2-m temperature DAS value, °C	±5° C						
C	2-m temp check PASS? FAIL?	PASS						
K	SR range estimate, Low, Med, High[1]	NA						
S	SR DAS value, Low, Med, High[1]	Low, Med, High						
	SR estimate check PASS? FAIL?	PASS						

[1] Solar Radiation W/m^2 range values are: 0 to 300 = Low, 300 to 700 = Medium, 700 to >1,000 = High

EXAMPLE OF AIR TEMPERATURE PROBE CALIBRATION REPORT FORM

Cabras Meteorological Tower

Air Temperature Sensor Calibration Report

Date: ______________ Start: ________ Technician(s): ______________
End: ________

SENSOR INFORMATION

Make: CLIMATRONICS
Model: 100093
SN: ______________
Probe Type: RTD
Operating Range: -30 to +50° C
Height Above Ground: 2 METERS

CALIBRATION TEST EQUIPMENT

Item: Glass thermometer with 0.10° C resolution SN: HB05146
Item: Insulated water bath SN: N/A

SENSOR CALIBRATION TEST RESULTS

Known	Input	Tower DAS Response			
Test Bath	Temp. Deg. C	DAS Deg. C	Error Deg. C	Limit Deg. C	Pass? Fail?
Ice				±0.5 C	
Cool				±0.5 C	
Hot				±0.5 C	

Known	Input	EMSYS Response			
Test Bath	Temp. Deg. C	DAS Deg. C	Error Deg. C	Limit Deg. C	Pass? Fail?
Ice				±0.5 C	
Cool				±0.5 C	
Hot				±0.5 C	

COMMENTS

	As Found	As Left
Results are:		

To PASS, the sensor response must have... 1) Accuracy = ±0.50 °C error per test point.

Standard Operating Procedure

SOLAR RADIATION SENSOR

Operation and Maintenance of the Apogee SP110 Pyranometer

Original Date:	24 February 2005	**Revision Date:**	25 September 2011
Prepared By:	*AMSTech* Boulder, CO	**Approved By:**	

SOP SUMMARY

This SOP provides detailed operation and maintenance (O&M) procedures for the Apogee, Model SP110 pyranometer. The SP110 pyranometer (also referred to as a “solar radiation sensor”) is used to measure solar radiation values at the meteorological monitoring station located at GPA’s Cabras Power Plant, Piti, Guam. The O&M procedures presented in this SOP are based on information available from the manufacturer as well as USEPA-recommended quality control guidelines for solar radiation measurements.[1,2]

INSTRUMENT DESCRIPTION

The Apogee SP110 pyranometer is a silicon cell-type sensor that measures global (direct and diffuse) solar radiation. The SP110 solar radiation sensor operates in the spectral range wavelength of 300 to 1200 nm and is designed to output a millivolt signal that is directly proportional to the incoming solar irradiance. The SP110 pyranometer is connected to the station data logger, which records the millivolt signal and converts it to an output value reported in Watts per meter squared (W/m^2).

OPERATION OF THE SP110 PYRANOMETER

Two categories of routine tasks are required to assure that the SP110 pyranometer is operating within acceptable limits. These are: (1) reasonability checks, and (2) sensor performance tests.

Reasonability Check: The Reasonability Check is to be performed biweekly and consists of two parts: (A) visual inspection of the sensor to confirm that it present, undamaged, and operational, and (B) estimation of the sensor’s accuracy. The following steps will guide the technician in completing the biweekly Reasonability Check.

Tools and Test Equipment Required for Reasonability Check

- Biweekly Station Operation Checklist form

Part A: Visual Inspection

1. Visually inspect the sensor for any signs of damage.
2. Confirm that the glass dome covering the thermopile is clean and clear.
3. Confirm that the sensor is stable and level. (NOTE: An off-level condition can bias the solar radiation data.) of warn bearings and should be investigated further.)
4. Note any problems on the Biweekly Checklist Form.

Part B: Estimation of Accuracy

1. Open the door to the data logger enclosure at the base of the tower.
2. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
3. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
4. Press the "Down Arrow" to navigate to the solar radiation channel.
5. Estimate the current solar radiation condition in one of three categories; low, middle, or high and note it on the Biweekly Checklist form. (NOTE: The SP110 solar radiation sensor's range is 0.0 to 1,400 W/m^2. A rainy or heavy cloud day will produce LOW solar values (0.0 to ~300 W/m^2). A day with haze or light clouds will produce MIDDLE solar values (~300 to ~700 W/m^2). On a bright, clear day expect HIGH solar values (~700 to ~1,000+ W/m^2).
6. Record the current data logger-reported solar radiation value on the Biweekly Checklist form.
7. Compare your low, middle, or high solar radiation value estimates against the data logger-reported values and determine whether or not the solar radiation sensor is "reasonably accurate".

Solar Radiation Sensor Performance Test: The Solar Radiation Sensor Performance Test is also referred to as a "Calibration Test". Because the SP110 solar radiation sensor does not have user-accessible adjustments normally associated with calibrating an instrument, the real purpose of the "Calibration Test" is to confirm that the sensor is operating within acceptable performance limits. If the sensor's performance does not meet the required standards, it should be returned to the manufacturer for repair and/or recertification to known solar radiation standards. The Apogee, Model SP110 pyranometer will receive a calibration test semiannually. The test consists of collocating a second solar radiation adjacent to the station's solar radiation sensor and allowing both sensors to operate under identical conditions for a period of 2 to 4 hours. Throughout the test period, the output values of both sensors are periodically checked, recorded, and compared. The collocated "calibration solar radiation sensor" outputs a millivolt signal which is monitored by a digital multimeter (volt meter). The collocated sensor's millivolt value must then be converted to a W/m^2 value, based on its certified performance, before it can be compared to the station's solar radiation values. A zero value, where the sensors are covered with a lightproof cap to simulate night, and at least 8 upscale solar radiation values are collected and used to document the station's performance. Listed below are the necessary test equipment and the step-wise procedures that technician(s) will need to complete the Solar Radiation Sensor Performance Test.

Tools and Test Equipment Required for the Solar Radiation Sensor Performance Test

- Certified pyranometer with spectral response characteristics similar to the station's pyranometer
- Tripod with base to hold the collocated sensor
- Digital multimeter with 0.01 millivolt, or better, resolution
- Lightproof cap
- Solar Radiation Sensor Calibration Report form

⇨**IMPORTANT NOTES:**

(1) The calibration of the solar radiation sensor consists of a zero check, where all light is blocked from the sensor, and at least eight upscale solar radiation values collected during midday over a 2 to 4 hour period.
(2) Ideally, the test day should be clear, or only partly cloudy, to allow stable solar values to be obtained. If clouds are blocking the sun, the sensor's solar values will be changing rapidly and it will be difficult to compare simultaneous values from the station and collocated sensors.
(3) Prior to beginning the test, confirm that <u>both</u> sensors, the station sensor and the collocated calibration sensor, are perfectly level. An off-level condition for either sensor will bias its performance.
(4) Be sure that neither sensor will be in an object's shadow, such as the tower, during the calibration test period.
(5) The collocated calibration sensor should be in place for at least <u>one hour</u> prior to beginning the test to allow the sensor to be "at temperature" during the test.

Solar Radiation Sensor Performance Test

1. Open the door to the data logger enclosure at the base of the tower.
2. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
3. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
4. Press the "Down Arrow" to navigate to the solar radiation channel.
5. Position the collocated calibration sensor as close as possible to the station's solar sensor. (NOTE: Be sure that no shadow will fall on the collocated sensor during the test period.)
6. Confirm that the glass domes on both solar sensors (station and collocated) are clean and clear.
7. Confirm that both sensors (station and collocated) are level.
8. Connect the signal from the collocated sensor to the digital volt meter.
9. Turn ON the digital volt meter and select a millivolt output on the meter's display.
10. Cover the station's solar radiation sensor with the lightproof cap.
11. Allow a few minutes for the station's sensor to "zero".
12. Record the station's zero value on the Solar Radiation Sensor Calibration form.
13. Repeat Steps 9, 10, and 11 and "zero" the collocated calibration sensor.
14. Remove the lightproof cap and allow a few minutes for both sensors to stabilize.
15. Simultaneously monitor the station's solar radiation value (W/m^2) and the collocated solar radiation sensor's value (millivolt), and note them, along with the time, on the

calibration form. (NOTE: Be sure that the values from both sensors are reasonably stable (3 to 5 seconds) before you record them.)

16. Repeat Step 14 at least seven more times throughout the test period.

17. Inspect the two tipping buckets and clean out any debris, if present.
18. Manually tip the bucket mechanism 10 times and confirm that each tip was recorded. (NOTE: Manually tipping the buckets tests operation of the magnetic reed switch. Wait approximately 10 seconds between tips to allow the data logger ample time to record the events.)
19. Use the collocated solar radiation sensor's current certified solar response factor to convert each millivolt value to its equivalent W/m^2 value.
20. Record the results on the Solar Radiation Sensor Calibration form.

MAINTENANCE OF THE APOGEE SP110 SOLAR RADIATION SENSOR

The SP110 solar radiation sensor requires virtually no routine maintenance. A biweekly inspection, which is described below, is all that is needed. All repairs should be performed by the manufacturer.

Biweekly Inspection: Biweekly, inspect the solar radiation sensor for any signs of damage. Also, confirm the following:

- Is the sensor level?
- Is the sensor's glass dome clean?

Note any problems, or potential problems on the Biweekly Checklist form.

REFERENCE DOCUMENTS

[1] Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements, Version 2.0 (Final), USEPA, March 2008

[2] Meteorological Monitoring Guidance for Regulatory Modeling Applications, USEPA, February 2000.

EXAMPLE OF BIWEEKLY STATION OPERATION CHECKLIST REPORT FORM

CABRAS POWER PLANT METEOROLOGICAL TOWER
BIWEEKLY STATION OPERATION CHECKLIST

	Mo. / Day →						
	Year →						
	Tech. Initials →						

	Checklist Item	Standard	Indicate Checklist Item Results					
	All tower guy wires intact?	YES						
	All WS / WD sensors present?	YES						
	WS propellers present and intact?	YES						
G	WD vanes present and intact?	YES						
E	VWS propeller present and intact?	YES						
N	Temperature probe present?	YES						
E	SR sensor level and clean?	YES						
R	Precip gauge present and intact?	YES						
A	Data Logger on line?	YES						
L	Indicate **L**ocal **S**tandard **T**ime	NA						
	Indicate DAS clock time	±3 min of LST						
	Indicate DAS battery voltage	12 – 16 VDC						
	Is the MODEM connected?	YES						
R	10-m WS estimate, MPS	NA						
E	10-m WS DAS value, MPS	±5.0 MPS						
A	10-m WS check PASS? FAIL?	PASS						
S	10-m WD estimate, degrees	NA						
O	10-m WD DAS value, degrees	±30 deg						
N	10-m WD check PASS? FAIL?	PASS						
A	60-m WS estimate, MPS	NA						
B	60-m WS DAS value, MPS	±5.0 MPS						
I	60-m WS check PASS? FAIL?	PASS						
L	60-m WD estimate, degrees	NA						
I	60-m WD DAS value, degrees	±30 deg						
T	60-m WD check PASS? FAIL?	PASS						
Y	10-m VWS direction check, +/-	NA						
	10-m VWS DAS value, +/-	+ or -						
C	10-m VWS check PASS? FAIL?	PASS						
H	2-m temperature estimate, °C	NA						
E	2-m temperature DAS value, °C	±5° C						
C	2-m temp check PASS? FAIL?	PASS						
K	SR range estimate, Low, Med, High[1]	NA						
S	SR DAS value, Low, Med, High[1]	Low, Med, High						
	SR estimate check PASS? FAIL?	PASS						

[1] Solar Radiation W/m^2 range values are: 0 to 300 = Low, 300 to 700 = Medium, 700 to >1,000 = High

EXAMPLE OF SOLAR RADIATION SENSOR CALIBRATION REPORT FORM

Cabras Meteorological Tower

Solar Radiation Sensor Calibration Report

Date: ____________ Start: ________ Technician(s): ____________
End: ________

SENSOR INFORMATION

Make: APOGEE Sensor Type: SILICA WAFER
Model: SP-110 Operating Range: 0 to 1,400 W/m^2
SN: 15301 Height Above Ground: 2 METERS

CALIBRATION TEST EQUIPMENT

Item: Transfer Standard Pyranometer SN: ________
Item: 4.5 digit multimeter SN: ________

SENSOR CALIBRATION TEST RESULTS

Report Period hhmm	T. Std Value W/m^2	Tower DAS Response				EMSYS Response			
		DAS W/m^2	Error W/m^2	Error %	Pass? Fail? [1]	DAS W/m^2	Error W/m^2	Error %	Pass? Fail? [1]
Covered				NA	NA			NA	NA

COMMENTS

	As Found	As Left
Results are:		

To PASS, the sensor response must have... 1) Percent Error = ±5.0% per test point

SOP

Standard Operating Procedure

PRECIPITATION GAUGE

Operation and Maintenance of the Climatronics 100097 Precipitation Gauge

Original Date:	17 February 2005	**Revision Date:**	23 September 2011
Prepared By:	*AMSTech* Boulder, CO	**Approved By:**	

SOP SUMMARY

This SOP provides detailed operation and maintenance (O&M) procedures for the Climatronics, Model 100097, 8-inch, tipping bucket, precipitation gauge. The 100097 precipitation gauge is used to measure rainfall amounts at the meteorological monitoring station located at GPA's Cabras Power Plant, Piti, Guam. The O&M procedures presented in this SOP are based on information available from the manufacturer as well as USEPA-recommended quality control guidelines for precipitation measurements.[1,2]

INSTRUMENT DESCRIPTION

The Climatronics 100097 precipitation gauge is a tipping bucket-type precipitation gauge with an 8-inch opening. The gauge is cylindrical in shape, 18.25 inches (46.3 cm) high and 8 inches (20.3 cm) in diameter. Precipitation that falls into the gauge's opening is funneled to a triangular, double-bucket mechanism that tips once for every 0.01 inch or 0.1 mm of water collected. When the collection bucket under the funnel's opening fills with water its weight causes the bucket to tip, emptying its water volume and bringing the second bucket into the collection position. Each tip of the bucket mechanism activates a sealed reed switch that sends an event message to the data logger. The data logger records each tip event and converts the tips to millimeters (mm) of rainfall.

OPERATION OF THE 100097 PRECIPITATION GAUGE

The 10097 precipitation gauge is nearly maintenance-free and requires only minimal attention, along with the semiannual performance tests, to assure that it is operating within acceptable limits. The only biweekly check required for the precipitation gauge is to confirm that its opening is clear and free of any objects or debris that could impede water from entering the tipping bucket mechanism.

Biweekly Check: During the biweekly station check, the station operator should confirm the following items that relate to the precipitation gauge:

- Is the precipitation gauge present and in apparent good condition?
- Is the gauge's opening clear of any objects or debris that could impede water flowing into the gauge?

Climatronics 100097 Precipitation Gauge

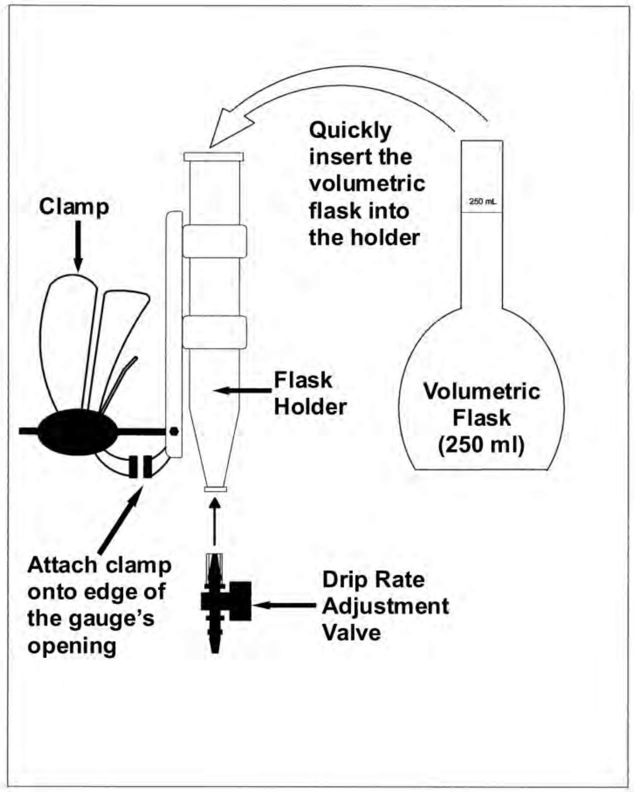
Precipitation Gauge Calibration Test: A calibration test will be conducted semiannually on the 100097 precipitation gauge. The test consists of documenting the sensor's accuracy in responding to a known volume of water dripped into its opening. The volume of water dripped into the gauge should be between 500 and 1,000 ml, measured accurately to within ±2 ml. To avoid biasing the calibration test results, the water should be dripped into the gauge at a slow rate of approximately 1,000 ml per hour. Listed below are the necessary test equipment and the step-wise procedures that technician(s) will need to complete the Precipitation Gauge Calibration Test.

Tools and Test Equipment Required for the Precipitation Gauge Calibration Test

- 1 liter (approximately pints) of water
- Drip device
- Precipitation Gauge Calibration Report form

NOTE: The drip device used to slowly drip water into the precipitation gauge can be as simple as a plastic cup or tin can with a small hole punched in the bottom. A graduated cylinder or similar measuring device can be used to measure an accurate known amount of water into the can or cup. Shown below is an example of an adjustable drip device which has the advantage of controlling the drip rate into the precipitation gauge.

Adjustable Precipitation Gauge Drip Device



NOTES:

(1) The calibration of the 100097 precipitation gauge consists of two parts: a) manually tipping the bucket mechanism 10 times to confirm the correct operation of the magnetic switch, and b) dripping a known volume of water into the sensor to document the bucket mechanism's ability to accurately measure rainfall.

(2) Consider starting the precipitation gauge calibration test just after the beginning of the hour, permitting the test to be completed within one hour.

(3) Confirm that the precipitation gauge is properly anchored and stable.

(4) Periodically check the "cats-eye" bubble level inside the gauge's body to confirm that the gauge is plumb and level across its top.

Part A: Manual Tip Test

1. Open the door to the data logger enclosure at the base of the tower.
2. Connect the KD1000 keypad to the CR1000 data logger's CSI data port. The main menu screen will appear.
3. Press the "Enter" key on the CR1000 keypad to sequence through the following menu choices; Data / Real Time Tables / Public.
4. Press the "Down Arrow" to navigate to the precipitation channel.
5. Remove the funnel portion of the 100097 precipitation by lifting up gently and separating it from the rest of the gauge's body.
6. Inspect the two tipping buckets and clean out any debris, if present.
7. Manually tip the bucket mechanism 10 times and confirm that each tip was recorded. (NOTE: Manually tipping the buckets tests operation of the magnetic reed switch. Wait approximately 10 seconds between tips to allow the data logger ample time to record the events.)
8. Replace the funnel portion onto the gauge's body.
9. Record the manual tip test results on the Precipitation Gauge Calibration form.

Part B: Water Volume Test

10. Assemble the adjustable drip device and attach it to the side of the precipitation gauge (refer to the above diagram and photograph).
11. Fill the 250 ml flask to the mark with distilled water.
12. Without spilling water, quickly invert the flask and insert it completely into the holder.
13. Adjust the drip valve to allow approximately 20 to 30 seconds between bucket tips.
14. After the flask has emptied its water completely into the gauge, repeat Steps 10, 11, and 12 for the next 250 ml volume of water.
15. Repeat this process two more times until 1 liter (1,000 ml) of water has been passed through the precipitation gauge's tipping bucket mechanism.
16. Calculate the expected data logger response in mm of rain for the 1 liter of water dripped into the gauge (NOTE: 1 tip = 0.254 mm rain = 8.24 ml of water for the 8-inch gauge opening. And, expected tips = 1,000 ml ÷ 8.24 ml = 121.36 tips / liter of water. Therefore, mm rain = 121.36 tips x 0.254 = 30.83 mm rain for 1 liter of water.)
17. Record the results on the Precipitation Gauge Calibration form.
18. If the gauge's response is outside acceptable limits, refer to the maintenance section of this SOP for instructions on adjusting the tipping bucket mechanism.

MAINTENANCE OF THE CLIMATRONICS 100097 PRECIPITATION GAUGE

The 100097 precipitation gauge requires very little routine maintenance. The gauge should be opened and inspected periodically (approximately monthly) to make sure the tipping buckets are clean and in good working order. Normally, the tipping mechanism will not need any routine adjustments. If, however, an adjustment is needed, follow the guidelines listed below for performing that task.

Periodic Inspection: Periodically, inspect the precipitation gauge, its overall condition and the stability of its mounting base. Confirm that the gauge has not been damaged in a way that would affect its ability to collect rainfall. Lift out the funnel portion of the gauge and check the tipping buckets for debris or objects that would affect the gauge's proper operation. Report any problems on the Station Checklist form.

Adjusting the Tipping Mechanism: If the precipitation gauge is found to be operating outside of acceptable performance limits, the tipping bucket mechanism should be adjusted. Refer to the manufacture's instruction manual when adjusting the tipping mechanism. Summarized below are the recommended procedures.

Tools and Test Equipment Required for Adjusting the Tipping Mechanism

- Pliers or small crescent wrench
- Screw driver

1. Remove the funnel portion of the precipitation gauge.
2. Use the screw driver to remove the screws from around the bottom of the gauge's body.
3. Use the pliers or small crescent wrench to loosen the locking nut on each adjustment screw located immediately below each bucket. (NOTE: The tipping bucket that is in the empty position rests against the top of its adjustment screw. Adjusting the screws upward reduces the amount of water the buckets will hold before tipping. Adjusting the screws downward increases the buckets' capacity. When adjusting the screws, they both should be turned the same way for the same number of turns.)
4. Repeat the water volume test, as described above, and determine whether or not further adjustment is needed.
5. Once the proper adjustment has been made, retighten the lock nuts on the adjustment screws.
6. Replace the gauge's body and funnel components.
7. Record the adjustment on the Station Activity Log.

REFERENCE DOCUMENTS

[1] Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements, Version 2.0 (Final), USEPA, March 2008

[2] Meteorological Monitoring Guidance for Regulatory Modeling Applications, USEPA, February 2000.

EXAMPLE OF BIWEEKLY STATION OPERATION CHECKLIST REPORT FORM

CABRAS POWER PLANT METEOROLOGICAL TOWER
BIWEEKLY STATION OPERATION CHECKLIST

Mo. / Day →							
Year →							
Tech. Initials →							

	Checklist Item	Standard	Indicate Checklist Item Results					
	All tower guy wires intact?	YES						
	All WS / WD sensors present?	YES						
	WS propellers present and intact?	YES						
G	WD vanes present and intact?	YES						
E	VWS propeller present and intact?	YES						
N	Temperature probe present?	YES						
E	SR sensor level and clean?	YES						
R	Precip gauge present and intact?	YES						
A	Data Logger on line?	YES						
L	Indicate **L**ocal **S**tandard **T**ime	NA						
	Indicate DAS clock time	±3 min of LST						
	Indicate DAS battery voltage	12 – 16 VDC						
	Is the MODEM connected?	YES						
R	10-m WS estimate, MPS	NA						
E	10-m WS DAS value, MPS	±5.0 MPS						
A	10-m WS check PASS? FAIL?	PASS						
S	10-m WD estimate, degrees	NA						
O	10-m WD DAS value, degrees	±30 deg						
N	10-m WD check PASS? FAIL?	PASS						
A	60-m WS estimate, MPS	NA						
B	60-m WS DAS value, MPS	±5.0 MPS						
I	60-m WS check PASS? FAIL?	PASS						
L	60-m WD estimate, degrees	NA						
I	60-m WD DAS value, degrees	±30 deg						
T	60-m WD check PASS? FAIL?	PASS						
Y	10-m VWS direction check, +/-	NA						
	10-m VWS DAS value, +/-	+ or -						
C	10-m VWS check PASS? FAIL?	PASS						
H	2-m temperature estimate, °C	NA						
E	2-m temperature DAS value, °C	±5° C						
C	2-m temp check PASS? FAIL?	PASS						
K	SR range estimate, Low, Med, High[1]	NA						
S	SR DAS value, Low, Med, High[1]	Low, Med, High						
	SR estimate check PASS? FAIL?	PASS						

[1] Solar Radiation W/m^2 range values are: 0 to 300 = Low, 300 to 700 = Medium, 700 to >1,000 = High

EXAMPLE OF PRECIPITATION GAUGE CALIBRATION REPORT FORM

Cabras Meteorological Tower

Precipitation Gauge Calibration Report

Date: ____________ Start: ________ End: ________ Technician(s): ____________

SENSOR INFORMATION

Make: CLIMATRONICS
Model: 100097
SN: UNK
Sensor Type: TIPPING BUCKET
Operating Range: NA
Height Above Ground: 1 METER

CALIBRATION TEST EQUIPMENT

Item: Controlable drip device SN: NA
Item: Graduated measuring flask SN: NA

SENSOR CALIBRATION TEST RESULTS

PART A: Manual Tip Test

Known Input		Tower DAS Response				EMSYS Response			
Manual Tips	DAS Tips	DAS mm	Error mm	Error %	Pass? Fail? [1]	DAS mm	Error mm	Error %	Pass? Fail? [1]
10	2.54								

PART B: Water Volume Test

Known Input		Tower DAS Response				EMSYS Response			
Water ml	DAS mm	DAS mm	Error mm	Error %	Pass? Fail? [1]	DAS mm	Error mm	Error %	Pass? Fail? [1]
1000	30.84								

COMMENTS

	As Found	As Left
Results are:		

To PASS, the sensor response must have... 1) Accuracy = ±10.0% error

APPENDIX B

EXAMPLES OF QC REPORT FORMS

- **60-m Wind Speed Sensor Calibration Report**
- **60-m Wind Direction Sensor Calibration Report**
- **10-m Wind Speed Sensor Calibration Report**
- **10-m Wind Direction Sensor Calibration Report**
- **Vertical Wind Speed Sensor Calibration Report**
- **Air Temperature Probe Calibration Report**
- **Solar Radiation Sensor Calibration Report**
- **Precipitation Gauge Calibration Report**
- **Biweekly Station Operation Checklist**
- **Problem Report**
- **Data Adjustment & Editing Report**
- **Station Activity Log**

60-Meter Wind Speed Sensor Calibration Report

Date: ____________ **Start:** ________ **Technician(s):** ____________

End: ________

SENSOR INFORMATION

Make: R.M. YOUNG

Model: 05305-AQ

SN:

Propeller Type: Carbon Fiber

Propeller SN:

Operating Range: 0 to 50 mps

CALIBRATION TEST EQUIPMENT

Item: Variable rpm motor. R.M.Young, 18830 (100 to 10,000 rpm) **SN:** NA

Item: Torque disk device. R.M. Young 18312 **SN:** NA

SENSOR CALIBRATION TEST RESULTS

Sensor Starting Threshold: ________ gm-cm ,equal to ________ mps **Pass? / Fail?:** ________ ≤ 0.50 mps

TOWER DATA LOGGER RESPONSE

Known Input rpm	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
0.0	0.00			NA	NA
200	1.02			0.25	
800	4.10			0.41	
3,200	16.38			1.02	
9,000	46.08			2.50	

EMSYS RESPONSE

Known Input rpm	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
0.0	0.00			NA	NA
200	1.02			0.25	
800	4.10			0.41	
3200	16.38			1.02	
9000	46.08			2.50	

* Allowed Error = ±(5% of known input + 0.20 mps)

COMMENTS

	As Found	As Left
Results are:		

To PASS, the sensor response must have… 1) Observed Error = ± Allowed Error per test point
2) Starting Torque = ≤ 0.50 mps

60-Meter Wind Direction Sensor Calibration Report

Date: ____________ **Start:** ________ **Technician(s):** ____________

End: ________

SENSOR INFORMATION

Make: R.M. YOUNG

Model: 05305-AQ

SN: ____________

Operating Range: 0 to 360 degrees

CALIBRATION TEST EQUIPMENT

Item: Compass transit **SN:** NA

Item: Vane angle bench stand. R.M. Young 18112 **SN:** NA

Item: Vane torque gauge. R.M. Young 18331 **SN:** NA

SENSOR CALIBRATION TEST RESULTS

Local Magnetic Declination: 1.3 deg. east (NGDC 8/10)

Vane Starting Threshold: ________ gm-cm ,equal to ________ mps **Pass? / Fail?:** ________ ≤ 0.50 mps

Test Input Deg.	Accuracy at Met Tower: Output Deg.	Accuracy at Met Tower: Error Deg.	Accuracy at Met Tower: Pass? Fail?	Accuracy at EMSYS: Output Deg.	Accuracy at EMSYS: Error Deg.	Accuracy at EMSYS: Pass? Fail?
149						
329						
42						
222						

Accuracy Pass / Fail

To PASS, the system error must be: ± 5 deg. per test point.

Test Input Deg.	Linearity at Met Tower: Output Deg.	Linearity at Met Tower: Nrmlzd* Deg.	Linearity at Met Tower: Pass? Fail?	Linearity at EMSYS: Output Deg.	Linearity at EMSYS: Nrmlzd* Deg.	Linearity at EMSYS: Pass? Fail?
5		NA	NA		NA	NA
30						
60						
90						
120						
150						
180						
210						
240						
270						
300						
330						
350						

* Normalized error in degrees.

Linearity Pass / Fail

To PASS, the system error must be: ± 3 deg. per test point.

COMMENTS:

	As Found	As Left
Results are:		

10-Meter Wind Speed Sensor Calibration Report

Date: ____________ **Start:** ________ **Technician(s):** ____________

End: ________

SENSOR INFORMATION

Make: R.M. YOUNG

Model: 05305-AQ

SN: ____________

Propeller Type: Carbon Fiber

Propeller SN: ____________

Operating Range: 0 to 50 mps

CALIBRATION TEST EQUIPMENT

Item: Variable rpm motor. R.M.Young, 18830 (100 to 10,000 rpm) **SN:** NA

Item: Torque disk device. R.M. Young 18312 **SN:** NA

SENSOR CALIBRATION TEST RESULTS

Sensor Starting Threshold: ________ gm-cm ,equal to ________ mps **Pass? / Fail?:** ________ ≤ 0.50 mps

TOWER DATA LOGGER RESPONSE

Known Input rpm	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
0.0	0.00			NA	NA
200	1.02			0.25	
800	4.10			0.41	
3,200	16.38			1.02	
9,000	46.08			2.50	

EMSYS RESPONSE

Known Input rpm	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
0.0	0.00			NA	NA
200	1.02			0.25	
800	4.10			0.41	
3200	16.38			1.02	
9000	46.08			2.50	

* Allowed Error = ±(5% of known input + 0.20 mps)

COMMENTS

	As Found	As Left
Results are:		

To PASS, the sensor response must have… 1) Observed Error = ± Allowed Error per test point
2) Starting Torque = ≤ 0.50 mps

10-Meter Wind Direction Sensor Calibration Report

Date: ____________________ **Start:** __________ **Technician(s):** ____________________

End: __________

SENSOR INFORMATION

Make: R.M. YOUNG

Model: 05305-AQ

SN: ____________________

Operating Range: 0 to 360 degrees

CALIBRATION TEST EQUIPMENT

Item: Compass transit **SN:** NA

Item: Vane angle bench stand. R.M. Young 18112 **SN:** NA

Item: Vane torque gauge. R.M. Young 18331 **SN:** NA

SENSOR CALIBRATION TEST RESULTS

Local Magnetic Declination: 1.3 deg. east (NGDC 8/10)

Vane Starting Threshold: __________ gm-cm ,equal to __________ mps **Pass? / Fail?:** __________ ≤ 0.50 mps

Test Input Deg.	Accuracy at Met Tower			Accuracy at EMSYS		
	Output Deg.	Error Deg.	Pass? Fail?	Output Deg.	Error Deg.	Pass? Fail?
149						
329						
42						
222						

Accuracy Pass / Fail

To PASS, the system error must be: ± 5 deg. per test point.

Test Input Deg.	Linearity at Met Tower			Linearity at EMSYS		
	Output Deg.	Nrmlzd* Deg.	Pass? Fail?	Output Deg.	Nrmlzd* Deg.	Pass? Fail?
0		NA	NA		NA	NA
30						
60						
90						
120						
150						
180						
210						
240						
270						
300						
330						
350						

* Normalized error in degrees.

Linearity Pass / Fail

To PASS, the system error must be: ± 3 deg. per test point.

COMMENTS:

	As Found	As Left
Results are:		

Vertical Wind Speed Sensor Calibration Report

Date: ____________ **Start:** ________ **Technician(s):** 0.00

End: ________

SENSOR INFORMATION

Make: R.M. YOUNG
Propeller Type: CARBON FIBER
Model: 27106
Operating Range: -9.0 to +9.0 mps
SN: ____________
Height Above Ground: 10 METERS

CALIBRATION TEST EQUIPMENT

Item: Variable rpm motor; RMY 18810 (10 to 1,000 rpm) **SN:** ________
Item: Torque disk device; RMY 18312 **SN:** ________

SENSOR CALIBRATION TEST RESULTS

Sensor Starting Threshold: ________ gm-cm ,equal to ________ mps **Pass? / Fail?:** ________ ≤ 0.25 mps

			Tower DAS Response			
	Known Input RPM	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
	0.0	0.00			NA	NA
cw	100	0.61			0.23	
ccw	100	-0.61			-0.23	
cw	400	2.45			0.32	
ccw	400	-2.45			-0.32	
cw	900	5.51			0.48	
ccw	900	-5.51			-0.48	

* Allowed Error = ±(5% of known input + 0.20 mps)

			EMSYS Response			
	Known Input RPM	Known Input mps	Observed Output mps	Observed Error mps	Allowed Error * ±mps	Results Pass? Fail?
	0.0	0.00			NA	NA
cw	100	0.61			0.23	
ccw	100	-0.61			-0.23	
cw	400	2.45			0.32	
ccw	400	-2.45			-0.32	
cw	900	5.51			0.48	
ccw	900	-5.51			-0.48	

* Allowed Error = ±(5% of known input + 0.20 mps)

COMMENTS

	Found	Left
Results are:		

To PASS, the sensor response must have… 1) Observed Error = ± Allowed Error per test point
2) Starting Torque = ≤ 0.50 mps

Air Temperature Sensor Calibration Report

Date: ____________________ **Start:** __________ **Technician(s):** ____________________

End: __________

SENSOR INFORMATION

Make: CLIMATRONICS

Model: 100093

SN: ______________________________

Probe Type: RTD

Operating Range: -30 to +50° C

Height Above Ground: 2 METERS

CALIBRATION TEST EQUIPMENT

Item: Glass thermometer with 0.10° C resolution **SN:** HB05146

Item: Insulated water bath **SN:** N/A

SENSOR CALIBRATION TEST RESULTS

Known	**Input**	**Tower DAS Response**			
Test Bath	Temp. Deg. C	DAS Deg. C	Error Deg. C	Limit Deg. C	Pass? Fail?
Ice				±0.5 C	
Cool				±0.5 C	
Hot				±0.5 C	

Known	**Input**	**EMSYS Response**			
Test Bath	Temp. Deg. C	DAS Deg. C	Error Deg. C	Limit Deg. C	Pass? Fail?
Ice				±0.5 C	
Cool				±0.5 C	
Hot				±0.5 C	

COMMENTS

	As Found	**As Left**
Results are:		

To PASS, the sensor response must have… 1) Accuracy = ±0.50 ºC error per test point.

Solar Radiation Sensor Calibration Report

Date: ____________________ **Start:** __________ **Technician(s):** ____________________

End: __________

SENSOR INFORMATION

Make: APOGEE
Model: SP-110
SN: 15301

Sensor Type: SILICA WAFER
Operating Range: 0 to 1,400 W/m^2
Height Above Ground: 2 METERS

CALIBRATION TEST EQUIPMENT

Item: Transfer Standard Pyranometer **SN:** __________
Item: 4.5 digit multimeter **SN:** __________

SENSOR CALIBRATION TEST RESULTS

Report Period hhmm	**T. Std. Value** W/m^2	**Tower DAS Response**				**EMSYS Response**			
		DAS W/m^2	Error W/m^2	Error %	Pass? Fail? [4]	DAS W/m^2	Error W/m^2	Error %	Pass? Fail? [4]
Covered				NA	NA			NA	NA

COMMENTS

	As Found	**As Left**
Results are:		

To PASS, the sensor response must have… 1) Percent Error = ±5.0% per test point

Precipitation Gauge Calibration Report

Date: ____________ **Start:** ________ **Technician(s):** ____________

End: ________

SENSOR INFORMATION

Make: CLIMATRONICS
Model: 100097
SN: UNK
Sensor Type: TIPPING BUCKET
Operating Range: NA
Height Above Ground: 1 METER

CALIBRATION TEST EQUIPMENT

Item: Controlable drip device **SN:** NA
Item: Graduated measuring flask **SN:** NA

SENSOR CALIBRATION TEST RESULTS

PART A: Manual Tip Test

Known Input		Tower DAS Response				EMSYS Response			
Manual Tips	DAS Tips	DAS mm	Error mm	Error %	Pass? Fail? [1]	DAS mm	Error mm	Error %	Pass? Fail? [1]
10	2.54								

PART B: Water Volume Test

Known Input		Tower DAS Response				EMSYS Response			
Water ml	DAS mm	DAS mm	Error mm	Error %	Pass? Fail? [1]	DAS mm	Error mm	Error %	Pass? Fail? [1]
1000	30.84								

COMMENTS

	As Found	As Left
Results are:		

To PASS, the sensor response must have… 1) Accuracy = ±10.0% error

CABRAS POWER PLANT METEOROLOGICAL TOWER
BIWEEKLY STATION OPERATION CHECKLIST

Mo. / Day →						
Year →						
Tech. Initials →						

Checklist Item		**Standard**	**Indicate Checklist Item Results**					
	All tower guy wires intact?	YES						
	All WS / WD sensors present?	YES						
	WS propellers present and intact?	YES						
G	WD vanes present and intact?	YES						
E	VWS propeller present and intact?	YES						
N	Temperature probe present?	YES						
E	SR sensor level and clean?	YES						
R	Precip gauge present and intact?	YES						
A	Data Logger on line?	YES						
L	Indicate **L**ocal **S**tandard **T**ime	NA						
	Indicate DAS clock time	±3 min of LST						
	Indicate DAS battery voltage	12 – 16 VDC						
	Is the MODEM connected?	YES						
R	10-m WS estimate, MPS	NA						
E	10-m WS DAS value, MPS	±5.0 MPS						
A	10-m WS check PASS? FAIL?	PASS						
S	10-m WD estimate, degrees	NA						
O	10-m WD DAS value, degrees	±30 deg						
N	10-m WD check PASS? FAIL?	PASS						
A	60-m WS estimate, MPS	NA						
B	60-m WS DAS value, MPS	±5.0 MPS						
I	60-m WS check PASS? FAIL?	PASS						
L	60-m WD estimate, degrees	NA						
I	60-m WD DAS value, degrees	±30 deg						
T	60-m WD check PASS? FAIL?	PASS						
Y	10-m VWS direction check, +/-	NA						
	10-m VWS DAS value, +/-	+ or -						
C	10-m VWS check PASS? FAIL?	PASS						
H	2-m temperature estimate, °C	NA						
E	2-m temperature DAS value, °C	±5° C						
C	2-m temp check PASS? FAIL?	PASS						
K	SR range estimate, Low, Med, High[1]	NA						
S	SR DAS value, Low, Med, High[1]	Low, Med, High						
	SR estimate check PASS? FAIL?	PASS						

[1] Solar Radiation W/m^2 range values are: 0 to 300 = Low, 300 to 700 = Medium, 700 to >1,000 = High

PROBLEM REPORT

Part A: To Be Completed by Person Reporting the Problem

Project Name: ________________ **Report Date:** ________________ **Submitted By:** ________________

Distribution List (Initial next to name when received)

Project Mgr: ______________________________

Field Ops Supervisor: ______________________________

Data Mgr: ______________________________

Other: ______________________________

Other: ______________________________

Urgency Level (Check one)

- ☐ Emergency (1-2hrs)
- ☐ Immediate (4-8 hrs)
- ☐ Urgent (24-36 hrs)
- ☐ Routine (1-4 days)
- ☐ Informational Only

Date Problem Discovered: ______________________ **Time Problem Discovered:** ____________

Affected Parameter(s): ______________________ **Is Problem Resolved? (Y / N):** ____________

Description of Problem:

Initial Actions Taken:

Additional Recommended Actions:

Part B: To Be Completed by Project Manager and/or Data Manager

Actions Reviewed and Approved by Project Mgr. ⇨ **Date:** ______________ **Initials:** ________

Actions Reviewed and Approved by Data Mgr. ⇨ **Date:** ______________ **Initials:** ________

Project Mgr. and/or Data Mgr. Comments:

Part C: To Be Completed by Initiator of the Report (Returned after completion of Part B)

Problem Resolved and Report Closed by Initiator ⇨ **Date:** ______________ **Initials:** ________

DATA ADJUSTMENT & EDITING REPORT

Project Name: ______________________ **Month / Year:** _______ / _______ **Data Technician:** ____________________

Affected	Beginning		Ending				Correction Factor[1]	
Parameter	Day	Hour	Day	Hour	Action Taken	Reason for Action	Slope	Inter.

1. The correction factor may also be a single multiplier (no intercept) or the addition or subtraction of a set value. Use available space to explain how the correction was applied.

The data adjustments and edits on this page have been approved by…

Project Manager: ______________________ **Date:** ______________

Data Manager: ______________________ **Date:** ______________

CABRAS POWER PLANT METEOROLOGICAL TOWER STATION ACTIVITY LOG

Date & Time	Description of Activities and/or Work Performed	Indiv. Initials