COLORADO
Department of Public Health & Environment

Air Pollution Control Division

Technical Services Program

APPENDIX GM5

Standard Operating Procedures for Meteorological Monitoring

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1 SCOPE AND APPLICABILITY

1.1 Introduction

Meteorological parameters are crucial for air pollution modeling. They provide information on the current state of an atmosphere into which pollutants (or pollutant precursors) are released. Using these data, predictions can be made for pollution levels and the transport of pollution into different areas.

1.2 Method Overview

There are no specific methods for meteorological monitoring that are cited in Volume 40 of the Code of Federal Regulations (CFR). Meteorological parameters are not regulated criteria pollutants, but are an indication of the atmosphere into which pollutants are released or generated.

1.3 Format and Purpose

Topics covered in this meteorological method follow 2007 Environmental Protection Agency (EPA) guidance on preparing standard operating procedures (SOPs). This method was also written to help field operators understand why (not just how) key procedures are performed (US EPA, 2007).

2 SUMMARY OF METHOD

Meteorological parameters have been measured and used for tracking air movement for several decades. Parameters measured by the Air Pollution Control Division (APCD) may include wind speed (WS), wind direction (WD), ambient temperature (AT), relative humidity (RH), solar radiation, and barometric pressure.

2.1 Meteorological Measurements

Wind speed is measured by two instrument methods at APCD sites. The Met One instrument uses a set of three cups mounted on the top of a shaft and the R.M. Young instrument uses a shaft-mounted propeller on the nose cone. With both devices, as the shaft spins, the number of revolutions per second is measured and converted to a voltage output. These data are typically recorded in miles per hour (mph) or meters-per-second (m/s).

Wind direction is also measured using two instrument methods at APCD sites. The Met One has a vane mounted to the top of a shaft. As the vane rotates in the wind, the shaft rotation and location is measured by a potentiometer. The result is then converted to an analog output. These data are expressed in degrees, from 0 to 360, or 0 to 540. With the R.M. Young instrument method, the same instrument provides both WS and WD. As the body of the device is rotated by the wind, azimuth direction is also measured by a potentiometer, with the result provided directly to the data logger.

The AT is measured using a thermistor sensor with an analog output. The sensor is mounted in a naturally aspirated or fan-aspirated radiation shield to minimize heating from direct solar or terrestrial radiation. Results are expressed in degrees Fahrenheit or Celsius.

RH is measured using a Met One, a Rotronics, or R.M. Young supplied probe, housed in a platter or fan aspirated enclosure. The R.M. Young units have a temperature sensor mounted on the same instrument housing to provide increased accuracy to the RH reading.

Solar radiation in a spectral range of 285 to 2800 nm is measured by a Kipp & Zonen model CMP 11 pyranometer. A subset of total ultraviolet light in a spectral range of 280 to 400 nm is measured by a Kipp & Zonen CUV5 UV Radiometer. Solar Radiation will be recorded at the data logger as watts per square meter (W/m^2.)

3 DEFINITIONS

The CDPHE/APCD/TSP QAPP contains an appendix of acronyms and definitions. Any commonly used shorthand designations for items such as the sponsoring organization, monitoring site, and the geographical area will be defined and included in this SOP or in the QAPP Appendix P2.

4 HEALTH AND SAFETY WARNINGS

To prevent personal injury or equipment damage, the following warnings should be complied with:

<u>Do Not Climb Towers</u>

APCD meteorological towers are formed from lightweight aluminum, and are not designed to be climbed. Abnormal weight loading, from climbing the tower, causes the tower rungs to bend. Bent and weakened rungs, coupled with repeated high winds, causes the tower to bend with possibility of eventual collapse. APCD had a tower collapse at the now defunct Rocky Flats South site, which may have been exasperated by weakened tower rungs.

<u>Electrical Hazards</u>

1. Always use a third ground wire on all instruments.

2. If it is necessary to work inside the translator while it is in operation, use extreme caution to avoid contact with high voltage. The translator has high voltages in certain parts of the circuitry, including a 12-volt direct current (DC) power supply and a 110-volt alternating current (AC) power supply. Refer to the manufacturer's instruction manual and know the precise locations of these components before working on the instrument.

3. Avoid electrical contact with jewelry. Remove rings, watches, bracelets, and necklaces to prevent electrical burns.

4. Always unplug the translator whenever possible when servicing or replacing parts.

5 CAUTIONS

To prevent damage to meteorological equipment, the following precautions should be taken:

1. Disconnect power to the translator before working on electronic boards or sensors unless power is required for troubleshooting or maintenance. High AC voltages exist on some surfaces.

2. Never remove or install translator cards without switching the primary power supply to the off position.

3. Keep the interior of the translator clean to reduce the chance of an electrical short.

6 INTERFERENCES

The validity of measurements from meteorological sensors can be compromised by interferences. These include but are not limited to, buildings, trees, or other obstructions in close proximity to the shelter and higher than the sensors. Asphalt or other constructed surfaces can also cause abnormal temperature heat islands. Sensors can become frozen in place during high moisture / low temperature events, and are subject to environmental damage such as hail and solar deterioration of plastic parts.

7 PERSONNEL QUALIFICATIONS

General personnel qualifications are discussed in the CDPHE/APCD/TSP QAPP.

8 APPARATUS AND MATERIALS

8.1 Meteorological and Supporting Equipment

8.1.1 Meteorological Equipment

For Met One sites, monitoring equipment includes: The Met One model 120 translator, WS indicator model 010, WD model 020, and an AT sensor with a single 060 unit or as a dual 062 set. There may also be a RH sensor made by Rotronics or other vendor.

For sites with the RM Young equipment, hardware would include a 5305V wind sensor. The RM Young AT sensor model is 41342V. If RH is needed, AT and RH are provided by model 41372V, Rain gauge tipping bucket model 52202. Barometric pressure model 61302V.

For sites with solar radiation measurements, a Kipp & Zonen CMP11 and/or CUV5

A 10 meter tall tower, made of aluminum with triangular base, provides the mounting point for all outside meteorological sensors in the APCD network.

8.1.2 Equipment Shelter

A building (shelter) is required to house and protect the computer, translator, and other air monitoring equipment, from weather elements. The shelters provide protection from precipitation and adverse weather conditions, physical security, electrical power, and more stable operational temperatures for the electronic equipment. Following are shelter temperature requirements for the SLAMS and NCore networks (US EPA, 2013) (US EPA, 2005):

SLAMs: 5-40 °C (20-30 °C preferred) at <± 2 °C Standard Deviation over 24 hours.
SLAMs: 41-104 °F (68-86 °F preferred) at <± 3.6 °F Standard Deviation over 24 hours

NCore: 20-30 °C, daily changes in hourly temperature should not exceed ±5 °C over a 24-hour period.
NCore: 68-86 °F, daily changes in hourly temperature should not exceed ±9 °F over a 24-hour period.

Note: The above mentioned shelter temperature criteria are stated for informational purposes only, as the vast majority of meteorological sites operate within these conditions. However, meteorological sensors, translator, and data loggers can effectively operate outside the above mentioned temperate ranges and still collect valid data.

8.1.3 Meteorological Tower

A 10-meter high aluminum tower is attached to the side of the shelter or to a small cement pad outside the shelter. The air measuring instruments are mounted on the tower with cables passing through the wall of the shelter to the translator and data logger inside. At most locations the tower is lowered by a winch/cable system attached to the shelter. At some locations a winch is not practical and two people are required to lower the tower by hand.

Towers are commonly ordered through Universal Towers. Most sites use the light weight 01-model-04-30 10 meter tower, but occasionally conditions call for the slightly heavier duty 02-model-09-30 10 meter tower. Bases are not interchangeable between the two since the 09-30 is wider. Sites may require the larger tower due to high winds or heavy equipment load.

8.1.4 Data Acquisition System

The APCD employs three different models of onsite, data acquisition system equipment (DAS) in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, ESC 8864 data logger and the Agilaire 8872 data logger. The 8816 model is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. The following are descriptions of these data loggers.

ESC 8816 Data Logger

The ESC Model 8816 Data System Controller is a microprocessor-based, data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8816 is designed around an expansion bus that gives the user great flexibility in configuring the unit with a combination of analog and serial input and output (I/O) types.

For more details, refer to APCD's Data Logger SOP or the individual operator manuals (Environmental Systems Corporation, 2001).

ESC 8832/8864 Data Logger

The ESC Model 8832 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8832 is designed around an expansion bus that gives the user great flexibility in configuring the unit with almost any combination of input and output types. It is the successor to the 8816 data logger and is more robust in numerous areas. Of significance is expanded memory, faster processing speeds, faster communication speeds, remote Ethernet communications and polling and Modbus enabled communications with peripheral devices.

For more details, refer to APCD's Data Logger SOP or the individual operator manuals (Environmental Systems Corporation, 2006).

Agilaire 8872 Data Logger

The Model 8872 is a Windows-based data logger, a departure from the earlier 8816 / 8832 embedded systems designs. The 8872 includes a number of hardware and software features to ensure that the device matches the field reliability of the 8832, while offering the convenience of a Windows-based platform and integration with Agilaire's AirVision software.

The core of the 8872 is a fan-less PC, typically 2 GB of RAM. The device can be equipped with a 160 GB standard hard drive or, more commonly, a 64 GB solid state flash drive (SSD). For all digital versions of the 8872, the remainder of the enclosure simply provides convenient universal serial bus (USB), serial, and VGA I/O connections in a standard 3U rack mount enclosure, a form factor similar to the 8816 / 8832 family. However, the 8872 also supports traditional analog/discrete I/O via a variety of internal I/O modules and a protection / connector board to provide familiar detachable terminal block connections to the back. The layout of the connections is designed to make the unit easy to use as a 'drop in' replacement for an 8816 or 8832. (Agilaire, 2013)

For more details, refer to APCD's Data Logger & Central SOP, D1 or the individual operator manuals.

8.1.5 Wiring and Support Equipment

Each meteorological sensor has wiring standards that must be met in order to obtain a clean and accurate signal from the respective sensor. Wiring standards are detailed with the individual instrument model number spec sheet. Wiring must be ordered in lengths sufficient to run the 10 meter distance of the tower length and then the additional distance from the tower base to the support equipment inside. Attaching the wiring all the way to the bottom of the tower ensures enough wiring is available for the instruments to remain attached as the tower is lowered (the pivot point is usually the bottom of the tower). Often this would result in 10 meters of wire for the tower and a return of 2-3 meters up the side of the shelter to the bulkhead, and an additional 2-3 meters of wire to reach the translator or data logger.

8.1.6 Standards

All meteorological standards must be traceable to NIST Standard Reference Material (SRM) and EPA protocol procedures.

8.1.7 Spare Parts and Incidental Supplies

Adequate spare instruments, replacement parts, and supporting equipment and cables should be readily available to support the maintenance needs of the meteorological sites.

8.2 Calibration Equipment

8.2.1 Calibration System

The following meteorological standards are used during the calibration effort. Manufacturers and model number may vary but each model must adhere to NIST standards for meteorological systems. Each instrument must undergo an annual recertification.

- Surveyor's Transit – Used to align cross-arm to true north/south
- Temperature standard – provides measurements in F° or C°
- RH standard – provides measurements from 0 to 100 % RH
- Degree wheel standard – provides measurements from 0 to 360 degrees relative to true north
- WS standard – powers the WS from 100 rpm to 15000 rpm
- Rain Gauge tipping bucket calibration bottle-provides calibrated water flow in mm/hr
- Barometric pressure standard-provides site atmospheric pressure

8.2.2 Accessories and Incidental Supplies

Maintenance of the meteorological network requires test equipment compatible with any of the sites maintained by the Criteria Monitoring Sector. Additionally, the following list contains minimum requirements for equipment needed to maintain the network.

- Meteorological tool box containing spare bearings, meteorological related tools, torque wrenches, adjustable wrenches, Allen wrenches, screw drivers, silicone sealant, electrical tape and other necessary supplies
- 50 foot power cord
- 6 foot stepladder
- Multi-meter (MM) preferably with 4 positions behind the decimal
- Spare WS and WD instruments, speed cups, wind vanes, propeller nuts, and translator cards

- Appropriate meteorological equipment operation manuals and data sheets
- Meteorological calibration form (Figure 12)

9 CALIBRATION

9.1 Introduction and Summary

Calibration of the tower cross-arm azimuth is necessary because the WD instrument is aligned with true north/south. The calibration of meteorological (Met) instruments is comprised of providing known rpm and directional input to wind sensors using a speed calibration motor attached to the wind sensor. Resultant output is then recorded. For AT and RH, certified AT and RH calibration measurements are compared to the output of the respective instrument.

9.2 Site Inspection

A site inspection is conducted every time a calibration specialist goes to a monitoring station to calibrate, audit, or perform any other kind of calibration unit operation.

The inspection routine includes:

- Check visually that the meteorological tower cross-arm is properly aligned with true north/south. Check that meteorological sensors aren't damaged and are moving without binding.
- Check that all operational parameters such as AT, wind speed and direction, and RH are reasonable compared to values shown on the data logger. Refer to instrument manuals for allowable parametric ranges. If any parameter is out of bounds then the monitoring technician should be notified that day. Maintenance should be performed by the calibration specialist if possible, and calibration of the instrument may be necessary.
- If equipped, verify that mechanical powered AT aspirator fans are operational.
- Check the station logs for non-routine actions.
- If you need access to data logger functions through one or more login codes (codes are required) and aren't sure if you're authorized for access, call either the GMM supervisor or the GMM monitoring lead to see if you are. If you know that you are authorized, but have forgotten the login codes, call key contact personnel within the Technical Services Program (TSP) for the codes. Check that the shelter is not damaged.

If anything is found out of the ordinary it should be recorded on the proper log sheet, along with the date and the calibration specialist's initials. The site operator (or work lead or supervisor of the GMM unit if that person is not available) should be notified that day. Maintenance should be performed if appropriate and within the scope of the calibration specialist's resources. Any time faulty instrumentation or supporting equipment is repaired or replaced due to a failure which affects data quality; a Maintenance Report (Figure 14) should be completed and submitted to your supervisor. This allows supervisory staff to delete erroneous or compromised data as appropriate.

9.3 Calibration Procedures

9.3.1 Calibrate Cross-Arm to True North / South

The WD sensor is mounted on the tower cross-arm with north/south alignment along the cross-arm axis, so the cross-arm must be aligned with true north/south.

Check Cross-arm Alignment

1. From a distance of (optimally) 75 to 200 feet, either north or south of the tower, position the transit, (Figure 1) and align it with the cross-arm using the optical sight. Loosen the silver transit swivel lock (Item 1.) to allow transit rotation as needed. Loosen the elevation lock knob (Item 2.) to adjust the sight to proper elevation. With cross-arm in focus, gently tighten the elevation lock (Item 2.) knob and use the elevation fine tune knob (Item 3.) for fine adjustments. Tighten the silver lock (Item 1.) and using the transit swivel fine tune (Item 4.) center the eyepiece cross-hair on the center opening of the cross-arm.

2. Adjust the cross-hair eye piece (Item 5.) to bring the cross-hairs into focus. Adjust the top sight knob (Item 6.) to bring the cross-arm into focus. Once focused, you may need to move the entire transit left or right several feet at a time until aligned with the cross-arm. Alignment is determined when the front and rear ends of the cross-arm are in line with one another.

3. Once aligned, use the transit leveler knobs (Item 7.) and bubble levels (Item 8.) to level the transit. It must be level to allow the compass needle to work properly.

4. Raise one of the two white plastic lids (Item 9) to view the metal 360 degree disk. Loosen the 360 degree disk lock (Item 10) to free and rotate the disk to align the letter “A” with 180 deg (if sighting to the south) or 0 deg (if sighting north), then re-tighten the disk lock.

5. Next, loosen the compass needle float lock (Item 11.) to allow the needle to float freely.

6. Loosen the transit swivel lock (Item 1.) and manually steer the transit sight to true north, if sighting north, or steer to true south, if sighting south; be sure to add the declination value. For example, If shooting true north with a site declination value of 8 deg (western hemisphere), to point directly to true north one would steer until the compass needle stops on 008 degrees (360+8 = 008.) Tighten the swivel lock (Item 1.)

7. Next loosen the 360 deg disk lock (Item 10.) and steer back to alignment with the cross-arm. Tighten the disk lock (Item 10.) and use the 360 degree disk fine tune knob (Item 12.) as needed to align the cross-hairs dead center on the cross-arm. This activity will provide the true bearing of the cross-arm relative to true north or south.

8. Read the 360 degree metal disk at this point and record the reading on the Met Cal form. This is the true north (or true south) reading of the cross arm. If greater than two degrees from true north / true south, once the tower is lowered, adjust the cross-arm to bring it more closely into alignment.

9. Disable data logger channels just before the tower is lowered.

1

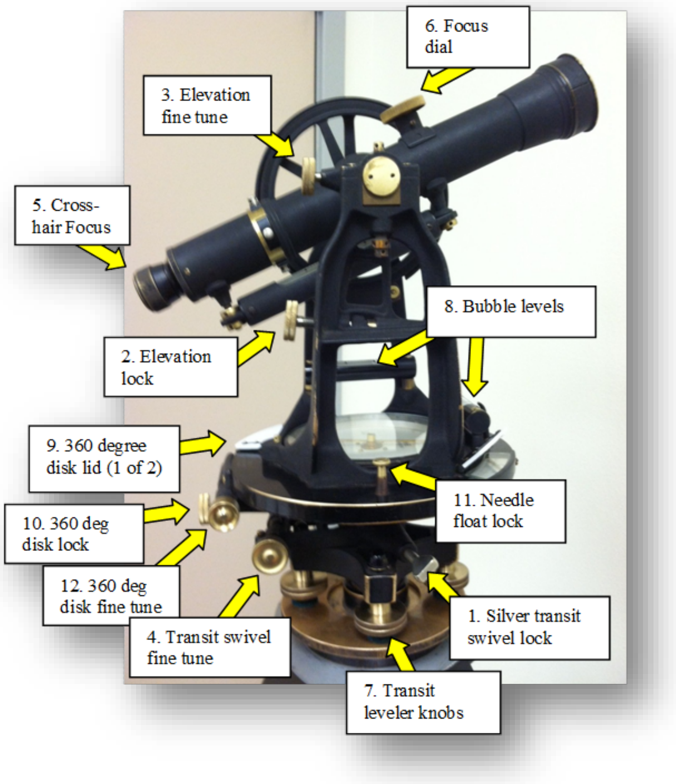

Figure 1. Transit

9.3.2 Lower Meteorological Tower for Calibration

<u>Disable Meteorological Channels</u>

1. Disable the specific meteorological data logger channels dedicated to wind speed (WS and RS), wind direction (WD and RD), SIGMA, external temperature (TEMP) and RH as applicable, using the “CDM” command with the 8816 or 8832/8864 data loggers. With the 8872 data logger, disable these same channels by going to the “Channels” tab and setting each meteorological channel to “True” for disabled.

2. For the 8816 or 8832/8864 data loggers, from the top level menu select menu item “DF” to verify the channels are disabled. A 'D' is displayed, to indicate that the channel is disabled.

3. On the calibration form, record the time when the meteorological channels were disabled, (Figure 12) also on the station's site/meteorological equipment log (Figure 13).

4. See the Appendix D1 of this QAPP or operator’s manuals if specific instructions are needed on how to use data loggers.

<u>Lower the Tower</u>

1. With the winch cable secured, remove the bolts securing the tower to the upper shelter brackets. Now, loosen (do not remove) the lower bolts holding the base of the tower to the shelter. If the tower is secured

to a concrete footing and not the shelter, with the tower secured by the winch cable, loosen (do not remove) the bolts holding the two front legs. Then remove the rear bolt securing the back leg.

2. Lower the tower with the winch. Lower it by hand if there is no winch. Lowering by hand requires two people minimum. Place a table or other platform under the tower to keep the bottom cross-arm instrument from hitting the ground.

9.3.3 Calibrate Met One Wind Speed Sensor

1. On the calibration form, (Figure 12) record the sensor serial number, make, and model.

2. Note the condition of the anemometer cups and replace them after the calibration if they appear sun-damaged. In harsh or distant environments, only use metal cups which are much more resistant to hail damage.

3. Use an Allen wrench to remove the cups. Spin the shaft to determine bearing condition. If bearings are bad or dry sounding, perform the pre-calibration audit to record readings of the instrument. After the pre-calibration audit, replace the instrument or bearings. Perform a second calibration audit, and fill out a separate form.

4. Install the variable wind speed motor on the instrument. If using a flex hose over the shaft, ensure it is not compressed. If compressed, it can cause the calibration motor to slow down or bind, affecting accuracy.

5. Turn on the multi-meter (MM) and plug into the WS card TP1 and TP3 ports (Figure 2). Ensure the meter is in the voltage mode and showing four positions behind the decimal. Follow the form as shown (Figure 12) to get voltage and speed readings for each calibration point.

6. For each row in the form record data logger output in either mph or m/s, the data logger voltage, the resultant speed in mph or m/s, and MM voltage. Enter data by hand into the form or directly into a laptop computer for instant pass/fail results.

7. Turn on the variable speed motor, allow 30 seconds for speed to stabilize. For each of the clockwise settings, record speed, data logger voltage, resultant speed, and MM voltage on the calibration form.

8. Next, switch off the motor and change to the counter-clockwise setting. Turn the motor back on and go through each row of the form to record the results.

9. Remove the WS motor and coupling. Re-install the WS cups.

10. Record appropriate data logger wind speeds and voltages and MM voltage responses on the calibration audit form, using the form as a guide. Replace the defective sensor or translator card (as appropriate) if voltage outputs are not within ± 0.005 VDC or within 0.447 mph.

For Met One WS instruments see Table 3 for conversions from mph to voltage. This table shows incremental points from 0 to 100 mph, along with the voltage values that should appear on the MM for each incremental point.

9.3.4 Calibrate Met One Wind Direction Sensor

When notches on the rotating hub and sensor shaft are aligned, the output will correspond to 180° (0.3333 VDC) or 540° (1.000 VDC) on the expanded scale. Clockwise movement of the wind vane should increment the card reading up-scale, until the full scale 540° is reached. It will then drop to 180°. Further clockwise rotation will bring the output to 540° again, and the action is repeated. Rotation in the opposite direction should provide readings up to 360°.

1. Connect the MM to the WS card TP1 and TP3 ports (Figure 2).

2. Record the WS sensor serial number, make, and model on the cal form.

3. Check the wind vane for physical damage. If damaged, record the damage in the audit form and replace the vane after the calibration audit is finished.

4. Remove the wind vane with an Allen wrench

5. Spin the bearing hub. The hub should spin down fairly quickly without noise or spring-back. Note the results on the audit sheet. If the bearings appear worn continue with the audit but do a second post-calibration audit after replacing the instrument or bearings.

6. Mount the Met One Calibration wheel on the shaft of the sensor so the scribed marks on the movable hub and instrument are aligned and the indicator is pointing to 180 deg.

7. Following the outline of the form, for each set point record directional degrees, data logger voltage, resultant degrees, and MM voltage.

    a. Rotate the pointer counter-clockwise to east (90 deg). Record all form readings.

    b. Rotate the pointer counter-clockwise to north (360 deg). Record readings.

    c. Rotate the pointer counter-clockwise to west (270 deg). Record readings.

    d. Stop. Now rotate the pointer clockwise to south (180 deg). Record readings.

    e. Rotate the pointer clockwise to west (270 deg). Record readings.

    f. Rotate the pointer clockwise to north (360 deg). Record readings.

    g. Rotate the pointer clockwise to (175 deg). Record readings.

    h. Rotate the pointer clockwise to south (180 deg). Record readings.

8. The APCD data quality objective is that WD response should be within 5 degrees of the calibration standard plus cross arm alignment error. However if there is also deviation at the cross-arm, excessive deviation with the WD instrument could cause the combined difference to exceed five degrees. Although repair work can occur in the field, due to time constraints and the probability of losing small parts, it is prudent to replace a unit with a working spare, when it exceeds 2 to 3 degrees in any one directional set point, and follow-up with a post-replacement calibration.

9. Re-install the wind vane.

10. Repair or replace the sensor if the voltage outputs are not within ± 0.005 VDC.

For Met One WD instruments see Table 4 for conversions from degrees to voltage. This table shows incremental points from 0 to 540 degrees, along with the voltage values that should appear on the MM for each incremental point.

9.3.5 Calibrate Met One Temperature Sensor

Calibrate using a calibration standard or precision mercury thermometer ± 0.9° F or ± 0.5° C (US EPA, 3/24/2008). It is not possible to adjust the AT reading at the sensor. Compare the output voltage and data logger response to the AT standard.

1. If equipped, ensure that all electrically powered aspiration fans are operational. Repair if faulty.

2. Connect the MM leads to the AT card TP1 and TP3 ports.

3. Place the probe of the NIST-traceable thermometer near the probe of the AT sensor and allow the thermometer to equilibrate until stable.

4. Follow the Calibration form and record the Electric Zero values for the data logger, data logger voltage and MM voltage readings.

5. Record the Electric Span values for the data logger, data logger voltage and MM voltage readings.

6. Take three readings over the time span of the calibration session. Record the calibration thermometer AT value and the data logger (DCN) AT values for Points 1, 2 and 3.

7. Compare the data logger response to the calibration standard. The APCD data quality objective is that temperature response should be within ± 0.9° F or ± 0.5° C of the audit input.

8. If the site is equipped with dual temperature sensors and a temperature differential measurement is performed, the temperature response for a given set of condition, between the two temperature sensors must be within ± 0.2° F or ± 0.1° C.

9. If the above criteria are not achieved, then exchange the temperature sensors for calibrated spares. Return the defective units to the lab for further testing and/or repair as needed.

To calibrate in the laboratory using an ice bath followed by warm water testing for upscale temperatures, use the following procedure:

1. Prepare an ice bath using a large, wide-mouth Dewar flask, holding a quart or more. A practical reference point of 32° F may be obtained by preparing a mixture of fine shaved or cracked ice and water to cover, but not float the ice. The flask is stopped with a cork or such, with two holes provided for the insertion of both, a temperature probe and NIST traceable digital or glass thermometer.

2. Insert both the probe and thermometer into the Dewar flask so the tips are at least 4 ½ inches below the surface and ½ inch from the sides with minimum of one inch remaining below.

3. Using a precision MM, measure the resistance vs. temperature. A warm water bath conducted with the same procedure will provide a check for greater than AT.

For Met One AT instruments see Table 5 for conversions from degrees F to voltage. This table shows incremental points from -58 to 122 degrees F, along with the voltage values that should appear on the MM for each incremental point.

9.3.6 Calibrate Rotronics Relative Humidity Sensor

1. Place the tip of the Vaisala RH probe in close proximity to the RH sensor located on the tower. For best results, place a tarp or other appropriate shade or cover over both units to minimize the effects of wind and solar radiation. This action will reduce erratic readings due to solar or wind effects.

2. Power up the Vaisala meter with attached probe by holding the power button down for a few seconds.

3. When the screen appears, push one of the arrow buttons, then the "Open" button to view the main menu.

4. Using the down arrow button scroll to "Environment" and enter it by hitting the right arrow button. The prompt should show the absolute pressure that was last used, example "12.0 psia." If not select the "Unit" button until it appears.

5. Next hit the "Set" button and enter in the current absolute pressure for the station most near the calibration location. A station example would be Grand Junction, Colorado.

6. To obtain the absolute psia reading, go to a favorite meteorological Website and obtain the absolute psia reading for that station area. Enter the value in the calibration meter and hit the "OK" button when done, followed by "Exit."

7. The meter is typically set up to show RH and AT with one digit behind the decimal point.

8. Compare the three individual RH readings from the data logger to the corresponding three readings from the calibration transfer standard. The APCD data quality objective is that the RH response should be within ± 5% of the transfer standard value. Enter the readings into the calibration form.

9. If the above criteria are not achieved, then exchange the sensor for a calibrated spare. Return the defective unit to the lab for further testing and/or repair as needed. Although the sensor may be repairable in the field, experience has shown that a defective RH sensor should be returned to the lab for cleaning, repair (if possible), and extensive testing before returning it to the field for use.

9.3.7 Calibrate Met One Translator Components

9.3.7.1 Calibrate Met One Power Supply

A typical translator contains (from left to right) an instrument heater power supply (PS) which is turned on in the fall before the first snow and off in late spring. Next, is usually the AT card, then WD and WS cards, and finally the primary power supply (PS).

For Met One sites the most common power supply module is model 1220.

1. Open the door to the model 120 Translator. Power is on if a bright orange-red dot appears in the center of the power supply on/off switch.

2. Next, check the power supply voltages at the pin connectors. Replace defective power supplies with a working spare if they do not meet criteria. Return the defective power supply to the lab for thorough evaluation and/or repair if possible. Ensure the power switch to the power supply is in the off position before a power supply is removed or installed. Voltages should be:

Pin 2	+12.0 ± 0.5 VDC
Pin 12	Common (ground)
Pin 21	-12.0 ± 0.5 VDC

9.3.7.2 Calibrate Met One Wind Speed Card

For Met One sites, the most common designator for the WS card is 1180. Parametric errors exceeding ± 10% will require instrument repair or replacement. Also fill out a pre-cal and a post-cal form for affected equipment.

1. Zero measurements are made by raising the S1 switch, and span measurements are made by raising the S2 switch. Switches and test points are the same for each card, although the S1 and S2 switches may differ in appearance as shown in the photo below.

2. Plug in the MM black ground or common lead into test position 1 (TP1) and the red lead into TP3. Check zero voltage by lifting switch1 (S1). Voltage should read 0.006 ± 0.005 VDC, which is the zero threshold value. Adjust the zero voltage potentiometer (pot) to improve the reading out of specification (spec.)

3. Check the span voltage, with range switch S3 set to position 1 (100 MPH). You should see 1.000 VDC ± 0.005 VDC by lifting switch S2. Adjust the "V1" pot if out of spec.

4. Calibrate the translator WS 1180 card if the voltage outputs are not within ± 0.005 VDC.

Table 6 is a matrix for the advanced user. This matrix steps the user through multiple voltage checks on the WS card. The table indicates what function is being performed (FUNCTION column), which toggle switch position(S) on the card is/are to be set (APPLY column), which pin point the positive lead of the MM should be plugged into, the potentiometer adjust point for adjusting voltage (ADJ column), what the voltage should be (FOR column), where the positive MM lead should be for the test, and the required voltage accuracy.

9.3.7.3 Calibrate Met One Wind Direction Card

For Met One sites, the most common designator for the WD card is 1190. Any parameter with more than ± 10.0 % relative error will require replacement or repair of affected equipment, along with filling out a pre-cal and a post-cal form for affected equipment.

1. Check the zero voltage for 0.000 VDC by lifting switch S1. Adjust the zero pot if out of spec.

2. Check half scale voltage for 0.500 VDC ± 0.005 VDC by lifting switch S2, adjust the "V1" pot if out of spec.

3. Calibrate the WDI card if the voltage outputs are not within ± 0.002 VDC.

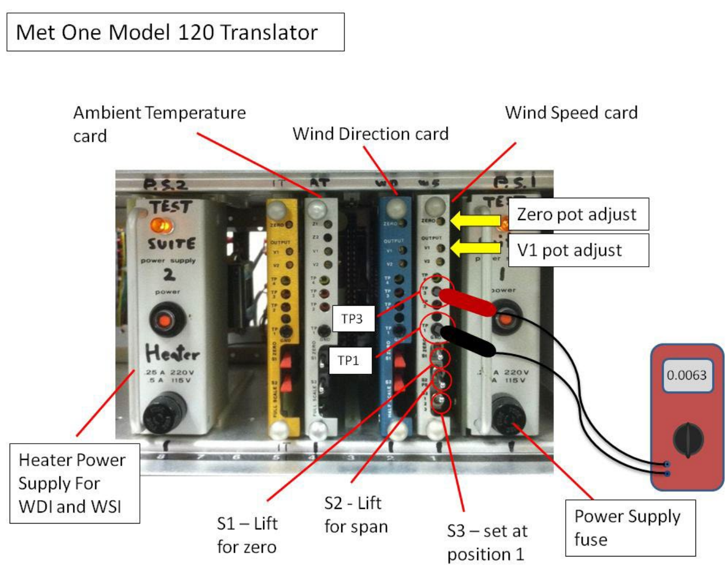

Figure 2. Translator

Table 7 is a matrix for the advanced user. This matrix steps the user through multiple voltage checks on the WD card. The table indicates what function is being performed (FUNCTION column), which toggle switch position(S) on the card is/are to be set (APPLY column), which pin point the positive lead of the MM should be plugged into, the potentiometer adjust point for adjusting voltage (ADJ column), what the voltage should be (FOR column), where the positive MM lead should be for the test, and the required voltage accuracy.

9.3.7.4 Calibrate Met One Ambient Temperature Card

For sites with Met One equipment, the Translator card is usually numbered either as a 1230 or 1760. Any parameter with more than ± 10.0 % relative error will require replacement or repair of affected equipment, along with filling out a pre-cal and a post-cal form for that equipment.

1. Plug the MM into TP1 and TP3
2. Check the zero voltage for 0.000 VDC by lifting switch S1. Adjust the zero pot if out of spec.
3. Check span voltage for 1.000 VDC ± 0.003 VDC by lifting switch S2. Adjust the "V1" pot if out of spec.
4. Calibrate the AT card if the voltage outputs are not within ± 0.1 VDC.
5. These electronic tests need only be done once per calibration cycle unless adjustment is required, in which case a full calibration audit including the affected sensor is performed before the adjustment. Sensor tests should always be performed first as an audit, then as a calibration when a sensor or sensor support equipment is replaced or repaired.

Table 8 and Table 9 provide a matrix of steps for the advanced user. This matrix steps the user through multiple voltage checks on the AT card. The table indicates what function is being performed (FUNCTION column), which toggle switch position(S) on the card is/are to be set (APPLY column), which pin point the positive lead of the MM should be plugged into, the potentiometer adjust point for adjusting voltage (ADJ column), what the voltage should be (FOR column), where the positive MM lead should be for the test, and the required voltage accuracy.

9.3.8 Calibrate RM Young Wind Monitor

The model 5305V Wind Monitor may require calibration after maintenance operations. Accurate WD calibration requires a Model 18112 Vane Angle Bench Stand. Begin by connecting the instrument to the data logger. Orient the base so the junction box faces 180 degrees. Align the vane with the cross markings and observe the indicator output.

Note: although the sensor mechanically rotates through 360°, full scale WD from the signal conditioning, occurs at 355°. Signal conditioning electronics must be adjusted accordingly. For example, in a circuit where 0 to 5 VDC represents 0° to 360°, the output must be adjusted for 4.930 VDC when the instrument is at 355° (355°/360° X 5.000 volts = 4.930 volts).

Wind speed calibration is determined by propeller pitch and the output characteristics of the transducer. The calibration formula relating propeller rpm to WS is shown below. Standard accuracy is ±0.2 m/s (0.4 mph). For greater accuracy, the sensor must be individually calibrated in comparison with a WS standard.

To calibrate wind system electronics, temporarily remove the propeller and connect an anemometer drive (18802 or equivalent) to the propeller shaft. Apply the calibration formula to the calibrating motor rpm and adjust the electronics for the proper value. For example, with the propeller shaft turning at 3600 rpm, adjust an indicator to display 18.4 m/s [3600 rpm x 0.00512 (m/s)/ rpm = 18.4 m/s].

<u>Calibration Formulas</u>

Model 05305V Wind Monitor with 08254 Propeller

WIND SPEED vs. PROPELLER RPM
m/s = 0.00512 x rpm
knots = 0.00995 x rpm
mph = 0.01145 x rpm
km/h = 0.01843 x rpm

WIND SPEED vs. 0-5 VDC OUTPUT
m/s = mV x 0.0200
knots = mV x 0.0389
mph = mV x 0.0447
km/h = mV x 0.0720

WIND DIRECTION vs. 0-5 VDC OUTPUT
DEGREES = mV x 0.072

9.3.9 Calibrate RM Young Air Temperature Sensor

The Model 41372VC/VF Platinum Temperature Probe is an accurate 1000 ohm Platinum RTD temperature sensor and low power voltage interface circuit mounted in a weatherproof junction box. The probe is available in Celsius or Fahrenheit calibration. Output signal is 0-1 VDC full scale. The probe is designed for easy installation in either the multi-plate and fan aspirated radiation shields.

1. If equipped, ensure that all electrically powered aspiration fans are operational. Repair if faulty.

2. Place the probe of the NIST-traceable thermometer near the probe of the AT sensor and allow the thermometer to equilibrate until stable.

3. Follow the calibration form. Take three readings over the time span of the calibration session. Record the calibration thermometer AT value and the data logger (DCN) AT values for Points 1, 2 and 3.

4. Compare the data logger response to the calibration standard. The APCD data quality objective is that temperature response should be within ± 0.9° F or 0.5° C of the audit input (US EPA, 3/24/2008).

5. If the site is equipped with dual temperature sensors and a temperature differential measurement is performed, the temperature response for a given set of condition, between the two temperature sensors must be within ± 0.2° F or ± 0.1° C (US EPA, 3/24/2008).

6. Little can be done if a temperature sensor is out of specification, since there is no adjustment. If the above criteria are not achieved, then exchange the sensor with a calibrated spare/s. Return the defective unit to the lab for further testing and/or any repair that may be possible.

To calibrate in the laboratory using an ice bath followed by warm water testing for upscale temperatures, use the following procedure:

1. Prepare an ice bath using a large, wide-mouth Dewar flask, holding a quart or more. A practical reference point of 32° F may be obtained by preparing a mixture of fine shaved or cracked ice and water to cover, but not float the ice. The flask is stopped with a cork or such, with two holes provided for the insertion of both, a temperature probe and NIST traceable digital or glass thermometer.

2. Insert both the probe and thermometer into the Dewar flask so the tips are at least 4 ½ inches below the surface and ½ inch from the sides with minimum of one inch remaining below.

Using a precision multi-meter, measure the resistance vs. temperature. A warm water bath conducted with the same procedure will provide a check for greater than AT.

9.3.10 Calibrate RM Young Relative Humidity Sensor

The RM Young Model 41382VF RH/AT Probe combines humidity and temperature sensors in a single housing. The output signal is 0-1 V (standard) or 0-5 V (user selected option) for both RH and AT. RH range is 0-100%. AT range is -58 to +122°F.

1. Place the tip of the Vaisala RH probe in close proximity to the RH sensor located on the tower. To reduce erratic readings due to solar or wind effects place a tarp or appropriate cover over both units.

2. Power up the Vaisala transfer standard by holding the power button down for a few seconds. (Other certified standards may also be used.)

3. When the screen appears, push one of the arrow buttons, then the "Open" button to view the main menu.

4. Using the down arrow button scroll to "Environment" and enter it by hitting the right arrow button. The prompt should show the absolute pressure that was last used. If not select the "Unit" button until it appears.

5. Next hit the "Set" button and enter in the current absolute pressure for the station most near the calibration location. A station example would be Grand Junction, Colorado for the Pitkin site.

6. To obtain the absolute psia reading, go to a favorite meteorological Website and obtain the absolute psia reading for that station or area. Enter the value in the calibration meter and hit the "OK" button when done, followed by "Exit." The meter is typically set up to show RH and temperature, with one digit behind the decimal point.

7. Compare the three individual RH readings from the data logger to the corresponding three readings from the calibration transfer standard. The APCD data quality objective is that the RH response should be within ± 5% of the transfer standard value. Enter the readings into the calibration form.

8. If the above criteria are not achieved, then exchange the sensor with a calibrated spare. Return the defective unit to the lab for further testing and/or repair as needed.

9.3.11 Calibrate RM Young Barometric Pressure Sensor

The RM Young Model 61302V Barometric Pressure Sensor maintains 0.2% FS stability per year. A quality control unit is sent back annually to a qualified NIST-traceable recertifying entity. If field barometric pressure sensors are found to be outside of allowable specifications by following this SOP, they are then sent to a qualified recertifying entity.

1. Collocate a portable electronic barometer situated such that it is exposed to the same height and environment as the site 61302V

2. Follow the calibration form. Multiple pressure readings from the station barometer and the collocated barometer should be compared over a period of several days. A barometric pressure sensor that demonstrates a mean difference from the collocated standard exceeding 0.25 hPa should be regarded as unserviceable and returned to a qualified recertifying entity.

9.3.12 Calibrate RM Young Tipping Bucket Rain Gauge

The RM Young Model 52202/52203 Tipping Bucket Rain Gauge measures precipitation through counting each 2 milliliters of wet precipitation (i.e. rain, melted snow or hail). The output signal is a magnetic reed switch, normally open. Catchment area is 200 cm^2.

1. Remove bird wire assembly. Remove outer housing by loosening the 3 screws at the base and carefully lifting housing free of base assembly

2. Level the rain gauge before calibration by using leveling screws to microadjust until the bubble settles in the bull's-eye of level. DO NOT confuse black leveling screws with white-capped calibration screws.

3. Connect rain gauge to an electronic counter, or bucket tips may be counted visually

4. Select the appropriate nozzle for the desired rainfall rate. (Refer to chart below). Attach nozzle to constant-head adapter.

Orfice Number	Approx Flow Rate	200 cm^2	100 cm^2	8" Diamter
50 (0.032 in Dia)	1000 ml/hr	50 mm/hr	25 mm/hr	30.8 mm/hr
75 (0.040 in Dia)	1500 ml/hr	75 mm/hr	37.5 mm/hr	46.2 mm/hr
100 (0.045 in Dia)	2000 ml/hr	100 mm/hr	50 mm/hr	61.7 mm/hr

5. Fill the RM Young Model 52260 Rain Gauge Calibrator water bottle to desired level. Maximum accuracy is obtained by using a laboratory balance to weigh the water (1 ml = 1 g). Reasonable accuracy may be obtained by using the bottle graduations (1000 ml is the top of rough band on the bottle). Attach adapter with nozzle.

6. Position bottle stand in rain gauge funnel. Carefully invert calibration bottle and place into stand such that water streams out against funnel sides, not directly down hole in funnel bottom. Water should flow from nozzle.

7. Allow water in bottle to flow through rain gauge until empty. Record bucket tips or rainfall value. The bucket should tip once for each 2 ml of water. Flow calibrator for 15 minutes. Average the last 10 minute data values.

8. 1 tip = 2 mL = 0.00394 in

9. If the error is outside of specifications, adjust the rain gauge calibrating screws to bring the rain gauge into specification. **Always adjust screws equally.**

9.3.13 Calibrate Kipp & Zonen Solar Sensor

The CMP 11 pyranometer and CUV5 solar radiation meters will degrade slightly with time due to UV exposure of the black detector coating. Both of these devices are also referred to as radiometers. A quality control unit is stored in dark packaging to avoid such exposure to light, and the quality control unit is sent back annually to a qualified NIST-traceable recertifying entity. If field solar radiation meters are found to be outside of allowable specifications by following this SOP, they are then sent to a qualified recertifying entity.

1. Collocate a second CMP 11 or CUV5 using the metal mounting plate and tripod. Situate the radiometer such that it is exposed to the same environment as the site radiometer – avoid placing the collocated radiometer anywhere that it will register shadows, reflections, or heat sources that the site radiometer does not. Level the collocated radiometer using the balancing features on the tripod.

2. Connect the collocated radiometer to the data logger using the pre-installed yellow cable at each site running from the back of the data logger by connecting the male end of the cable to the female fitting on the solar rad unit.

3. Take a "zero" reading of both the collocated and site radiometers by placing the cap over the glass dome of the radiometer for 1 minute each.

4. Follow the calibration form. Compare two 1-hour-long averages at both sides of the local solar noon (for example, for an hour between 11 and 12 am, and again between 1 and 2 pm). Record the solar radiation averages for the zero and the two 1-hour-long averages. The EPA data quality objective is that the site radiometer response should be within ± 5% of the collocated radiometer, with an APCD target of ± 3%. Enter the readings into the calibration form.

Note: There are no user-serviceable parts within the solar radiation meters. They must not be opened without the agreement and instruction of Kipp & Zonen.

9.3.14 Raise the Tower to Finish the Calibration

Before raising the tower, adjust the cross-arm if it was off by more than two degrees.

1. This is done by loosening the heavy bolt(s) which secures the cross-arm swivel point in the tower support collar.

2. Measure from the ground up to the cross-arm and adjust it between 1/4 up to 1 inch. The angle of the cross-arm relative to the ground and the number of degrees the cross-arm was in error will determine the distance to be moved. This activity is more art than science and it can take a few tries to get it right.

3. Raise the tower.

4. Re-sight the cross-arm (Section 9.3.1). If it is less than two degrees, you may not want to adjust further. For further adjustment repeat steps 1 through 4.

5. Re-install and tighten the bolts holding the tower in place. Leave a little slack in the winch cable and remove the winch handle and place it back inside the shelter.

The meteorological calibration is finished at this point.

9.4 Post-Calibration Assessment

Once the calibration is complete and all data recorded, return to the lab and enter all data into the Calibrations database (J:\ZSFILES\Calibrations\Master Calibrations DB). An alternate method is to take a laptop to the field and enter the data directly into the database via the laptop. This method can provide a more clear perspective on whether or not the calibration audit passed.

9.5 Documentation

When performing these tests and procedures, fill out the appropriate forms to provide the necessary documentation for data validation, completeness, and correctness. Electronic versions, as they become routinely used, will be stored in the Technical Services network directory J:\met cal and printed copies will be in the Meteorological Calibration notebook.

10 OPERATION AND MAINTENANCE

10.1 Meteorological Monitoring Instruments

The GMM network contains the Met One Model 120 Translator at Met One sites with 010 WS, 020 WS, 060 or 062 AT Sensors, and the Rotronics RH sensor. For RM Young sites it contains the 5305V wind sensor, and the 41372V combination RH/AT sensor.

10.1.1 Inspections

10.1.1.1 Daily Inspection

1. Record all actions on Station/Met log, (Figure 13)

2. Visually check the WS and direction sensor(s). Check the AT radiation shield for condition and responsiveness to wind, if it is wind directed. For fan-cooled AT sensors, place your ear near the tower frame and listen for the low hum of fan noise. Alternately, lower the tower to see if fan is working.

3. Make sure that meteorological data are being recorded and look reasonable in the data logger.

4. Check the pyranometer and/or solar radiation meter (if present)

    a. Verify that instrument measurements seem reasonable for current weather conditions.

    b. Verify that instrument is secure and free of damage

    c. Clean the dome with a clean lint-free cloth using pure alcohol or distilled water. Ensure smears or deposits are not left on the dome.

    d. Check for levelness – adjust the housing feet to re-level as needed.

10.1.1.2 Monthly Inspection

1. Record all actions on Station/Met log, (Figure 13)

2. Disable the Met DCN channels including all of the following that appear on the data logger screen; WS, RS, WD, RD, SIGMA, RH, TEMP or TEMPU and TEMPL.

3. Perform operational checks on Translator 1220 Power supply module. Use MM to check operating voltages with respect to pin 12 (common) on:

    a. Pin 2 : +12.0 VDC ± 0.5 VDC

    b. Pin 21 : -12.0 VDC ± 0.5 VDC

Check the WS card voltage for the following card type:

1. Translator 1180-1 WS card (model 010 WS sensor). All of the following measurements are made with respect to common TP1.

a. Push Zero switch S1 up and hold it, the output voltage at TP3 should go to the threshold value 0.006 VDC. Release S1.

b. Push Full scale switch S2 up and hold it, the output voltage should go to the full scale value 1.000 VDC ± 0.005 VDC at TP3. Release S2.

Check the WD card voltage for the following card type:

1. 1190-1 WD translator card (with 020 WD sensor)

   a. Momentarily push half scale switch S2, this sets internal logic to operate below 360°.

   b. Push Zero switch S1 up and hold it, the voltage output should be 0.000 VDC. - ± 0.005 VDC. Push HALF SCALE switch S2 up and hold it, the output voltage at TP3 should go to 0.500 VDC ± 0.005 VDC.

Check the AT card voltage for the following card type:

1. Translator 1230-1 AT card (With 060A-2 AT sensor)

   a. Push Zero switch S1 up and hold it, the output voltage should be 0.000 VDC.

   b. Push Full scale switch S2 up and hold it, the output voltage should go to 1.000 VDC ± 0.005 VDC at TP3.

Check the AT card voltage for the following card type:

1. Translator 1760-65 AT card (With 060A-2 AT sensor)

   a. Push Zero switch S1 up and hold it, the output voltage should be 0.000 VDC.

   b. Push Full scale switch S2 up and hold it, the output voltage go to 1.000 VDC ± 0.005 VDC at TP3.

Check the AT card voltage for the following card type:

1. Translator 1230-83 AT card (With 060A-2 AT sensor)

   a. Push Zero switch S1 up and hold it, the output voltage at TP3 or TP4 should be 0.000 VDC.

   b. Push Full scale S2 up and hold it, the output voltage should go to 1.000 VDC ± 0.005 VDC at TP3 or TP4.

Check the total solar and/or uv radiometer (if present):

1. Perform each duty of the Daily Maintenance schedule

2. Check desiccant color and replace if clear. To replace it, unscrew the cartridge from the housing. If tight use a 16 mm or 5/8" open-ended wrench to loosen it. Remove the cap from the end of the cartridge and safely dispose of the used silica-gel.

3. Refill with one pack of fresh desiccant, and refit the end cap to the cartridge. Ensure O-ring seal and housing seat are clean. Grease the seal with Vaseline, if dry.

4. Hand-tighten the drying cartridge to avoid distorting the O-ring seal.
5. Check that the sun shield is firmly in place.
6. Finally, enable the DCN channels.

10.1.1.3 6 to 12 Month Maintenance (Performed During Calibration)

1. Record actions on Station/Met log, (Figure 13).
2. Perform pre-orientation sighting of the tower cross arm, see section 9.1.2.
3. Disable meteorological channels including; WS, RS, WD, RD, SIGMA, RH, and TEMP or TEMPU and TEMPL.
4. Unbolt the tower retention bracket, and loosen the rear bolts for the retention bracket, also loosen the tower base swivel bolts. Lower the meteorological tower.
5. Inspect the tower, the sensor cables and the cable connectors for signs of corrosion, deterioration and cracks.
6. Check the anemometer cups and the wind vane for breaks or cracks.
7. Test and calibrate all translator cards. (See meteorological calibration, Section 9)
8. Remove the sensors from the cross arm assembly.
    a. Inspect the interior of the sensors for signs of corrosion or damage or dust buildup, check all bearings and drive shafts.
    b. Inspect the signal-conditioning module for cracks or corrosion around soldered connections.
    c. Check the internal heater operation – it should feel warm to the touch when the heater power supply is switched on. Clean the sensors as needed.
    d. Test and calibrate the sensors. (See meteorological calibration procedures, Section 9)
9. Slide the instrument case open and apply a small amount of silicon lubricant to the sensor case o-ring seals. This allows a tight fit when the case is closed. Wipe off excess lubricant.
10. Remove the AT radiation shield, clean the shield and the AT probe, inspect for signs of corrosion or cracks, and check the bearings and O-rings.
11. Reinstall all components and ensure the system is working properly.
12. Re-enable disabled meteorological channels. Check the meteorological translator and DCN for normal operation.

10.1.1.4 12 To 24 Month Maintenance. (Performed During Calibration)

1. Replace the WS and WD bearings, and the AT radiation shield bearings.

2. Perform the six to twelve month inspection and maintenance.

3. If a solar radiometer is present also do the following:

    a. Check all electrical connections. Unscrew the cable connector, clean inside with alcohol or electrical contact spray if necessary, then reconnect.

    b. Check cables for any damage.

    c. Check that instrument mountings and/or base supports are secure.

10.1.1.5 24 To 36 Month Maintenance. (Performed During Calibration)

1. Replace the WD sensor potentiometer.

2. Perform the six to twelve month inspection and maintenance.

10.1.2 Data Logger Setup

Data logger settings are dependent upon the type of meteorological equipment fielded at the site. Currently the meteorological vendor choices are between Met One and RM Young for wind sensors and WD instruments. For external or AT, the choices are between Met One and RM Young. For internal shelter temperature, the vendors are Omega, and Analog Devices.

When an instrument is installed at a new site or at a site that previously used a different type of meteorological instrument, the installer or operator must ensure the correct settings are in place. To do so, log into the data logger and from the top level menu:

1. Type, “CDC” to access the instrument/data channel list.

2. A list of all available channels appears which includes the following meteorological instrument specific channels:

    ITEMP [14]
    WS [21]
    RS [22]
    WD [23]
    RD [24]
    SIGMA [25]
    TEMP [26]
    SOLRAD [27]

3. From the data logger display, scroll down and highlight the channel to be edited, and then hit the “Return” or “Enter” key.

Based upon your selection (above), a list will appear. The fields to be concerned with are: Volts full scale, High Input, Low Input, High Output, Low Output, and Units Measure. Use table below to set up each of these fields according to the instrument requirements. For example, for a new or different wind instrument(s), you would be concerned with wind speed (WS) resultant speed (RS), wind direction (WD), resultant direction (RD), and SIGMA. For the internal shelter temperature you would scroll to ITEMP, and for the external AT, TEMP. Total solar radiation is SOLRAD, and total UV solar radiation is UVRAD. Ensure that each channel affected has the values shown in the tablebelow based upon type of instrument and whether the values are to be measured in US Customary Standard or in Metric.

Table 1. Data Logger Setup for Meteorological Instruments

Analyte	Model	Volts Full Scale	High Input	Low Input	High Units	Low Units	Units
Met One							
Wind Speed	010	1	1V	0V	45	0	M/S
Wind Direction	020	1	1V	0V	540	0	DEG
Ambient Temperature	060/062	1	1V	0V	50	-50	DEGC
Kipp & Zonen							
Solar Rad	CMP11		150mV	0mV	150	0	W/m^2
UV Rad	CUV5		150mV	0mV	150	0	W/m^2
RM Young							
Wind Speed	5035V	5	5V	0V	100	0	M/S
Wind Direction	5035V	5	5V	0V	360	0	DEG
Ambient Temperature	41342V	1	1V	0V	50	-50	DEGC
Relative Humidity	41342V	1	1V	0V	100	0	%
Omega							
Internal Temperature	EWS-TX	5	5V	1V	50	-50	DEGC
SparkFun							
Internal Temperature	TMP36	1	1V	0V	50	-50	DEGC

10.1.3 Meteorological Instrument Maintenance (Detailed)

10.1.3.1 Maintenance of Met One Model 010 Wind Speed Sensor

1. With cups mounted, ensure cup assembly rotates freely.

2. Install the sensor in the mount bushing of the cross-arm. Tighten the set screws in the bushing which holds the instrument.

3. Connect the cable assembly to the keyed sensor receptacle and wrap the connector/receptacle with weather resistant tape.

4. Check to see that the instrument is parallel to the tower. Adjust vertical placement as necessary by loosening the two set screws in the mounting clamp. After the tower is raised, verify that the instrument is vertical with reference to the ground.

10.1.3.2 Maintenance of Met One Model 020 Wind Direction Sensor

Install Wind Direction Sensor

1. Balance the unattached wind vane of your finger tip, out of the wind. Ensure vane assembly is balanced and balance counterweight secure. Verify balance and adjust if necessary.

2. With the vane mounted on the instrument, ensure that it rotates freely.

3. Install the sensor in the keyed bushing mount arm. The orientation screw in the stem of the sensor will fit through the hole in the mounting bushing. Tighten the orientation screw.

4. Connect the cable assembly to the keyed sensor receptacle and wrap the connector/receptacle with weather resistant tape.

5. Check to see that the vane is parallel with the cross-arm. The vane (counterweight end) points directly south. Adjust it if necessary by loosening the two setscrews in the mounting clamp. IMPORTANT: Consult senior personnel before making any adjustment.

6. After the tower is raised, check the orientation of the cross-arm (North/South) direction by a compass orientation device or transit (section 9.3.1).

Parts Replacement

1. Any time the bearing, shaft, hub, or potentiometer is removed and replaced, the alignment of the potentiometer must be re-established. Perform the following steps for calibration.

   a. Connect the sensor to a 12-volt power supply: (Pin A to +12V; Pin B to common).

   b. Connect MM positive lead to terminal 3 of potentiometer; adjust R1 on the card itself for a reading of 5.000 VDC.

   c. Connect MM between common and Pin C (signal output).

   d. Slide the 040-degree wheel calibrator onto the column of the WD sensor. Install the 040 pointer assembly onto the rotating hub. Tape the sensor hub and column together to align the index notches.

   e. Slide the degree wheel up to the pointer, allowing clearance space, and rotate the degree wheel until the pointer is at exactly 180° on the wheel. Tighten the degree wheel to the column, checking to ensure that it does not interfere with the rotation of the pointer.

   f. Remove tape and rotate the pointer, then re-check the alignment of the two notches with the 180° mark on the degree wheel. Readjust if necessary.

   g. Loosen the setscrews in the drive coupler.

   h. Place the pointer at 180° and rotate the potentiometer drive coupler so that an output of 2.500 ± 0.005 VDC is measured. Tighten setscrews in the drive coupler and recheck at 180°. Readjust if necessary.

   i. Rotate the pointer to 180°; output should be 2.500 +/- 0.040 VDC.

   j. Perform tests as outlined in c and d above. If necessary a field adjustment can be performed using the data logger readout in place of the voltmeter and independent 12 volt power to reposition the potentiometer.

   k. Remove 040 degree wheel and pointer. This completes the alignment procedure.

10.1.3.3 Maintenance of Met One Ambient Temperature Sensors

Maintenance of AT sensors is primarily comprised of bearing replacement on the 060 style sensors. If the probe fails calibration, check the wiring harness and cabling for damage, water, or corrosion. If the probe still fails, replace it with a spare. If the model 062 fan aspirated unit fails, replace both sensors with a paired set if there are any available. Otherwise replace with a paired RM Young set.

Temperature Sensor Model 060

1. Ensure both radiation shield bearings turn quietly and freely. If either bearing turns roughly or makes a rough sound it should be replaced.

2. Install the sensor in the bushing of the mounting arm. Tighten the two Allen screws that hold the instrument in place.

3. Mount the radiation shield (part number 071) over the shield bearings. Once it clears the second bearing, install security screw. The screw SHOULD NOT touch the bearing, but fit down beside it.

4. Connect the cable assembly to the keyed sensor coupling and wrap the connector/receptacle with weather resistant tape.

Temperature Sensor Model 062

Model 062 comes as a NIST traceable paired set of AT sensors. Each sensor is mounted in a fan aspirated enclosure at 3 and 6 meters above ground level. Met One model 062 dual sensors are no longer being fielded so installation will not be addressed.

10.1.3.4 Maintenance of Met One Wind Sensor Internal Heat

For Met One systems, during the early fall season turn on the sensor heater power supply. This unit is used to provide heat to the individual WSI and WDI sensors to keep them from freezing up during icing conditions. It is located inside the translator box, usually on the left hand side. This unit usually looks similar to the primary power supply except it is typically located at the left side of the translator and has one large blue capacitor instead of two.

1. Check to ensure the heater is working by sliding the cover back on both the WSI and WDI instruments. Touch the housing behind the printed circuit board, it should feel warmer than adjoining parts.

2. If there is no heat, check the wiring, the power supply fuses, then test the power supply for proper voltage. Replace the power supply if it has failed.

10.1.3.5 Maintenance of RM Young Wind Monitor

With the RM Young model 5305V wind monitor (both horizontal WS and direction are measured with a single instrument. Wind speed is determined by revolutions per minute (RPM) from a wind driven propeller. Wind direction is derived from the alignment of the balanced tail vane. The instrument Model 05305V provides calibrated voltage outputs directly to the data logger.

Propeller rotation produces an alternating current (AC) sine wave signal with the frequency proportional to WS. Tail position is sensed by a 10K ohm potentiometer with the signal converted to a linear voltage output.

The instrument mounts directly on standard one inch pipe, with outside diameter 34 mm (1.34"). An orientation ring (with arrow pointing north) is provided so the instrument can be removed for maintenance and re-installed without loss of WD reference. Both the sensor and the orientation ring are secured to the mounting pipe by stainless steel clamps. Electrical connections are made in a junction box at the base of the instrument.

Figure 3. RM Young Wind Sensor

Initial Checkout

After unpacking, remove the plastic nut on the propeller shaft. Install the propeller with propeller serial number facing forward (into the wind). The instrument should be checked both mechanically and electrically before installation. Vane and propeller should rotate 360° without friction. Check tail balance by holding the instrument base so the surface is horizontal. It should have near neutral torque without any particular tendency to rotate. A slight imbalance will not degrade performance.

Proper Grounding

Static electricity can build up and discharge through the transducers which could cause erroneous signals or even transducer failure. To direct static away from the transducers, they are attached to an anti-static, plastic mounting post. The Wind Monitor may be safely mounted on an unpainted, bare metal pipe connected to an earth ground. A second method of grounding provides that inside the junction box, the terminal labeled "EARTH GND" is internally connected to the anti-static mounting post and connected to earth ground. To ensure the best possible earth ground, towers set in a concrete base should be attached to one or more grounding rods.

After initial installation, the instrument can be removed and returned to its mounting without re-alignment since the orientation ring preserves the WD reference. An optional directional metal arrow can also be used to align the instrument to true north. This directional arrow fits into the orientation ring with an alignment nub. The wind sensor also has an alignment nub which allows it to align correctly with the directional arrow and orientation ring. Install the Wind Monitor using the following steps:

Mount Wind Monitor

Place orientation ring on mounting post. Do not tighten band clamp yet. The Orientation ring may be omitted when a portable tripod is used.

Place Wind Monitor on mounting post. Do not tighten band clamp yet.

Connect Sensor Cable

For concise wiring directions, refer to the wiring diagram located at the back of RM Young manual or data sheet which can be downloaded from the RM Young Website.

Align Wind Sensor

1. Align the directional arrow with the meteorological tower cross-arm and tighten.
2. Sighting down the cross-arm, point it to a reference point on horizon. For example, 360 degrees true north. This will provide a rough alignment.
3. Fit the wind instrument alignment slot into the directional arrow alignment tab, and tighten the band clamp. The instrument, arrow, and cross-arm are now in alignment.
4. Tighten the cross-arm mounting.
5. Raise the tower and tighten in place.
6. Follow instructions in the "Calibrate RM Young Wind Monitor" section (9.3.8) of this document to align the cross-arm with reference to true north.

Connect 5305V Wind Sensor to Data Logger

The following diagram provides the wire connectivity from the RM Young 05305V Wind Sensor to the 8816/8832/8864 Data Logger.

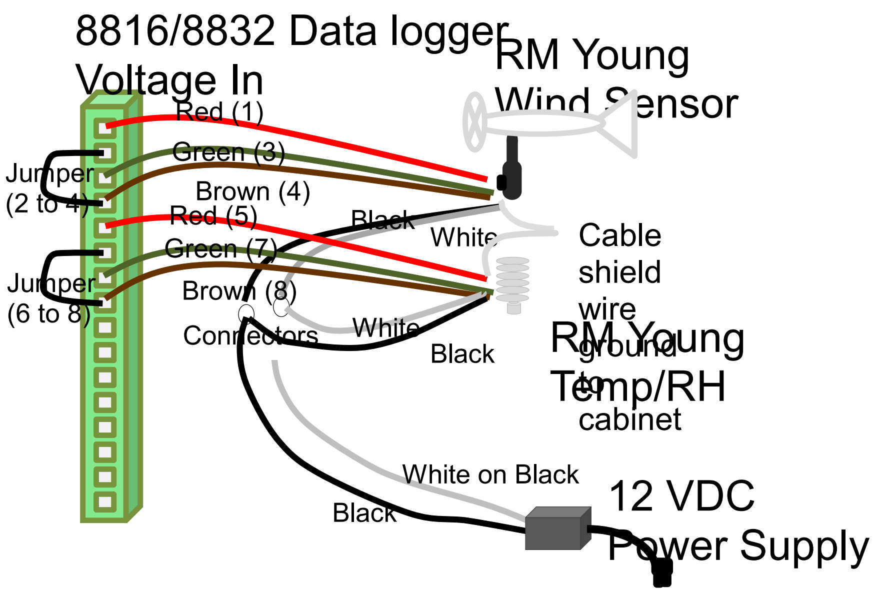

Figure 4. Data Logger to Wind Sensor Wiring Diagram

Components likely to need replacement due to normal wear are the ball bearings and the WD potentiometer. Refer to RM Young instruction sheets to become familiar with part names and locations. Maximum torque on all set screws is 80 ounce-inches.

Potentiometer Replacement

The potentiometer has a life expectancy of fifty million revolutions. As it becomes worn, it may produce noisy signals or become nonlinear. When signal noise or non-linearity becomes unacceptable, replace the potentiometer. Refer to RM Young exploded view drawings and proceed as follows:

1. Remove main housing
    a. Unscrew nose cone from main housing. Set o-ring aside.
    b. Gently push main housing latch.
    c. While pushing latch, lift main housing and remove it from vertical shaft bearing rotor.
2. Unsolder transducer wire
    a. Slide junction box cover up, exposing circuit board.
    b. Remove screws holding circuit board.
    c. Unsolder three potentiometer wires (white, green, black), two WS coil wires (red, black), and earth ground wire (red) from board.
3. Remove potentiometer
    a. Loosen set screw on potentiometer coupling and remove it from adjustment thumbwheel.
    b. Loosen set screw on potentiometer adjustment thumbwheel and remove it from shaft.
    c. Loosen two set screws at base of transducer assembly and remove assembly from vertical shaft.
    d. Unscrew potentiometer housing from potentiometer mounting & coil assembly.
    e. Push potentiometer out of potentiometer mounting & coil assembly by applying firm but gentle pressure on potentiometer shaft.
4. Install new potentiometer
    a. Push new potentiometer into potentiometer mounting & coil assembly.
    b. Feed potentiometer and coil wires through hole in bottom of potentiometer housing.
    c. Screw potentiometer housing onto potentiometer mounting & coil assembly. Apply a small amount of silicone sealant on threads.
    d. Gently pull transducer wires through bottom of potentiometer housing to take up any slack. Apply a small amount of silicone sealant around hole.
    e. Install transducer assembly on vertical shaft allowing 0.5 mm (0.020") clearance from vertical bearing. Tighten set screws at bottom of transducer assembly.
    f. Place potentiometer adjustment thumbwheel on potentiometer shaft and tighten set screw.
    g. Place potentiometer coupling on potentiometer adjustment thumbwheel. Do not tighten set screw yet.

5. Reconnect transducer wires

    a. Using needle-nose pliers or a paper clip bent to form a small hook, gently pull transducer wires through hole in junction box.

    b. Solder wires to circuit board according to wiring diagram. Observe color code.

    c. Secure circuit board in junction box using two screws removed in step 2b. Do not over tighten.

6. Replace main housing

    a. Place main housing over vertical shaft bearing rotor. Be careful to align indexing key and channel in these two assemblies.

    b. Place main housing over vertical shaft bearing rotor until potentiometer coupling is near top of main housing.

    c. Turn potentiometer adjust thumbwheel until potentiometer coupling is oriented to engage ridge in top of main housing. Set screw on potentiometer coupling should be facing the front opening.

    d. With potentiometer coupling properly oriented, continue pushing main housing onto vertical shaft bearing rotor until main housing latch locks into position with a “click”.

7. Align Vane

    a. Connect excitation voltage and signal conditioning electronics to terminal strip according to wiring diagram.

    b. With mounting post held in position so junction box is facing due south, orient vane to a known angular reference. Details appear in CALIBRATION section.

    c. Reach in through front of main housing and turn potentiometer adjust thumbwheel until signal conditioning system indicates proper value.

    d. Tighten set screw on potentiometer coupling.

8. Replace nose cone

    a. Screw nose cone into main housing until o-ring seal is seated. Be certain threads are properly engaged to avoid cross-threading.

Flange Bearing Replacement

If anemometer bearings become noisy or WS threshold increases above an acceptable level, bearings may need replacement. Check anemometer bearing condition using a Model 18310 Propeller Torque Disc. Bearings are replaced as follows.

1. Remove old bearings

    a. Unscrew nose cone. Set o-ring aside for later use.

    b. Loosen set screw on magnet shaft collar and remove magnet.

    c. Slide propeller shaft out of nose cone assembly.

d. Remove front bearing cap which covers front bearing.

e. Remove both front and rear bearings from nose cone assembly. Insert edge of a pocket knife under bearing flange and lift it out.

2. Install new bearings

   a. Insert new front and rear bearings into nose cone.

   b. Replace front bearing cap.

   c. Carefully slide propeller shaft thru bearings.

   d. Place magnet on propeller shaft allowing 0.5 mm (0.020") clearance from rear bearing.

   e. Tighten set screw on magnet shaft collar.

   f. Screw nose cone into main housing until o-ring seal is seated. Be certain threads are properly engaged to avoid cross-threading.

<u>Vertical Shaft Bearing Replacement</u>

Vertical shaft bearings are much larger than the anemometer bearings. Ordinarily, these bearings will require replacement less frequently than anemometer bearings. Check bearing condition using a Model 18331 Vane Torque Gauge. Since this procedure is similar to potentiometer replacement, only the major steps are listed here.

1. Remove main housing

2. Unsolder transducer wires and remove transducer assembly. Loosen set screws at base of transducer assembly and remove entire assembly from vertical shaft.

3. Remove vertical shaft bearing rotor by sliding it upward off vertical shaft.

4. Remove old vertical bearing and install new ones. Be careful not to apply pressure to bearing shields.

5. Replace vertical shaft bearing rotor.

6. Replace transducer & reconnect wires.

7. Replace main housing.

8. Align vane.

9. Replace nose cone.

10.1.3.6 Maintenance of RM Young Ambient Temperature Sensor

For accurate measurements, the model 41372V AT probe should be installed in a protective radiation shield. Use of the probe without a radiation shield may result in large errors due to solar heating. For best performance, the probe and shield should be placed in a location with good air circulation clear of large masses (buildings, pavement, solar panels...etc). Connect the sensor to the data logger using the wiring diagram as shown in figure 5.

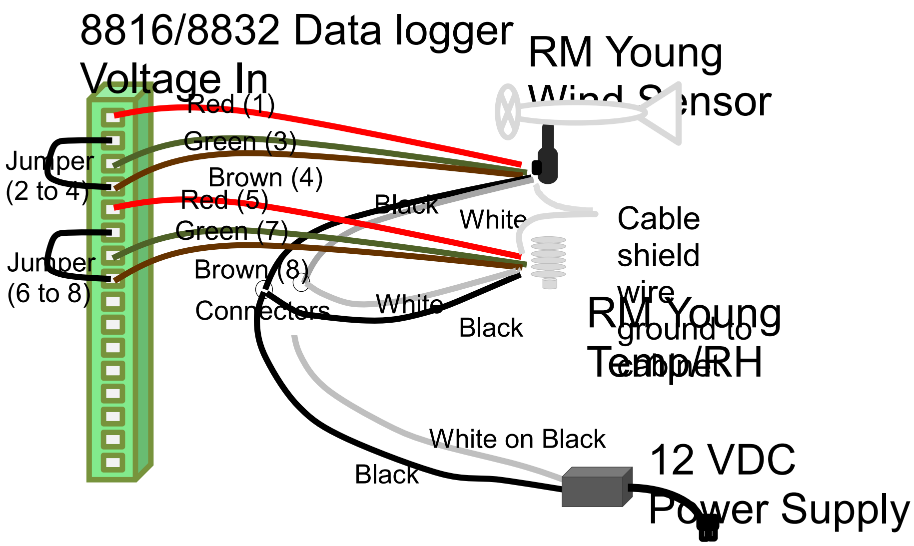

Figure 5. Data Logger to Temperature Wiring Diagram

The AT probe is designed to offer years of service with minimal maintenance. Maintenance activities are comprised of visual inspection of the cable, connectors, connector tape, and instrument itself.

<u>AT Specifications</u>

Measuring Range: -58 to +122F or -50 to +50°C
Accuracy at 73°F: ±0.5°F
Response Time: 10 seconds (Without Filter)
Sensor type: Platinum RTDW
Output signal: 0-1 or 0-5 VDC (jumper option)
Power Required: 8-30 VDC at 7 mA
Recommended Cable: 5 conductor shielded, Young 18446
Recommended Shields: Young Model 43502 Aspirated Radiation Shield
Young Model 41003P Multi-Plate Radiation Shield

10.1.3.7 Maintenance of RM Young Relative Humidity Sensor

For accurate measurements, the model 41382V AT probe should be installed in a protective radiation shield. Use of the probe without a radiation shield may result in large errors due to solar heating. For best performance, the probe and shield should be placed in a location with good air circulation clear of large masses (buildings, pavement, solar panels...etc).. The RH probe is designed to offer years of service with minimal maintenance. When used in areas of high dust or pollution, periodically clean the RH sensor filter by removing the filter from the sensor and rinsing with water. DO NOT USE SOLVENTS. Allow to dry completely before reinstalling on sensor. Other maintenance activities are comprised of visual inspection of the cable, connectors, connector tape, and instrument itself.

<u>RH Specifications</u>

Measuring Range: 0 – 100% RH
Accuracy at 23°C: ±1%
Stability: Better than ±1%RH per year
Response Time: 10 seconds (Without Filter)
Sensor type: Platinum RTD
Output signal: 0-1 or 0-5 VDC (jumper option)
Power Required: 8-30 VDC at 7 mA
Recommended Cable: 5 conductor shielded, Young 18446

Recommended Shields: Young Model 43502 Aspirated Radiation Shield
Young Model 41003P Multi-Plate Radiation Shield

10.1.4 Maintenance of RM Young Pressure Sensor

For accurate outdoor measurements, the model 61302V barometric pressure sensor should be installed using RM Young model 61360 weatherproof enclosure and RM Young model 61002 pressure port to ensure reliable data. The pressure port prevents strong wind gusts from affecting barometric pressure readings, while the weatherproof enclosure protects the instrument from adverse conditions including rain and snow. Connect the sensor to the data logger using the wiring diagram as shown in Figure 7. The barometric pressure sensor is designed to offer years of service with minimal maintenance. Maintenance activities are comprised of visual inspection of the cable, connectors, connector tape, pressure port, and instrument itself.

Pressure Specifications

Measuring Range: 500-1100 hPa
Operating Temperature: -40° to + 60°C
Digital Accuracy at 25°C: ±0.2hPa
Digital Accuracy at -40°C to +60°C: ±0.3hPa
Analog Accuracy: 0.05% of analog pressure range
Analog Temperature Dependence (25°C reference): 0.0017% of analog pressure range/°C
Long Term Stability: 0.2% FS per year
Update Rate: 1.8 (max) to 1 Hz per minute
Output signal: 0-2.5 or 0-5 VDC
Power Required: 7-30 VDC at 2.8 mA with Vout
Recommended Cable: 5 conductor shielded, Young 18446
Recommended Accessories: RM Young Model 61360 weatherproof enclosure
RM Young Model 61002 pressure port

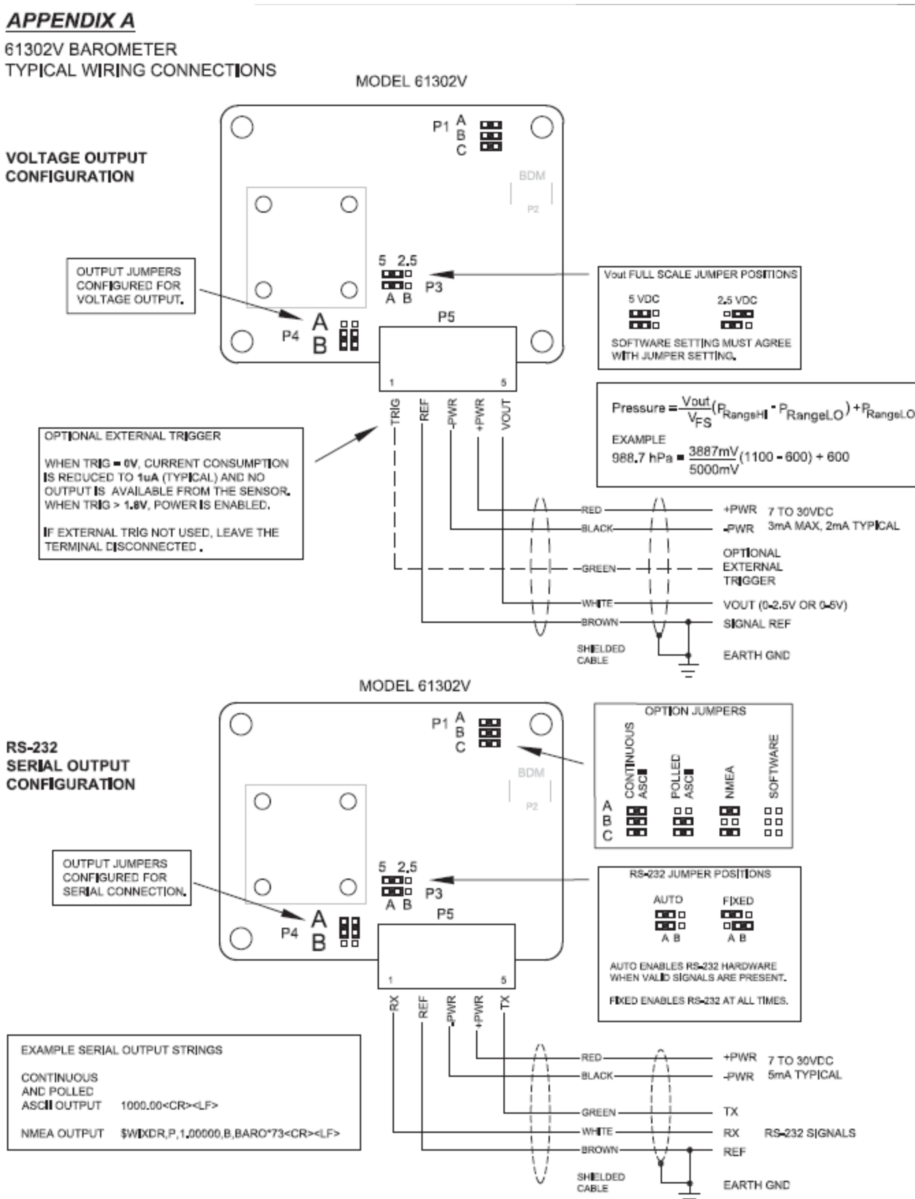

Figure 6. Wiring Diagram for RM Young Barometric Pressure Sensor

10.1.5 Maintenance of RM Young Tipping Bucket Rain Gauge

The RM Young model 52202 is a heated tipping bucket rain gauge. To ensure the most accurate measurements possible, the rain gauge should be located such that it is blocked from gusts and crosswinds as much as possible. According to the National Weather Service, rain gauges should not be located on roofs or wide open areas, as turbulence will affect precipitation collection, nor should rain gauges be installed on paved surfaces to avoid splashing. Ideally, rain gauges should be located such that they are protected on all sides, such as in an orchard or low-density forest. However, a sparsely wooded area would be undesirable due to eddies created by individual trees. If no such location exists at a particular site, a NWS approved windshield, such as a nipher or alter shield should be used.

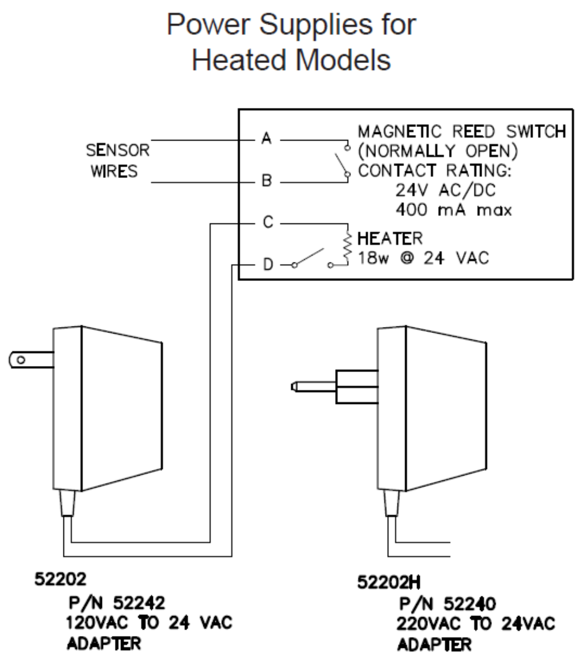

Figure 7. Wiring the Heated Tipping Bucket

10.1.6 Maintenance of Kipp & Zonen Solar Radiation Sensor

A pyranometer is essentially a solar radiation analyzer, and is a type of radiometer. Solar radiation data is used by Colorado air pollution modelers as input to an air quality model named AERMOD. AERMOD is the EPA air quality model used by sources to demonstrate compliance with the National Ambient Air Quality Standards (NAAQS). Compliance with NAAQS is required in order to obtain an air quality permit. AERMOD uses solar radiation data along with other meteorological parameters to determine the amount of plume dispersion.

The APCD uses the Kipp & Zonen CMP 11 pyranometer and the CUV5 UV Radiometer. Connected with the data logger, it provides output as watts per-meter-squared (W/m^2.) The working solar radiation meters produces a low-level voltage output. The output signal can be negative at night, and is automatically set to zero when negative. For more technical specifics please refer to the Kipp & Zonen CMP 11 Instruction Manual.

In the northern hemisphere, the sun is at the highest point in the sky during the summer solstice on June 21st. On that date, the sun will reflect values listed in Table 2. Information in the table was extracted using the NOAA ESRL Solar Position Calculator, and using Denver coordinates (39 43 59N by 104 58 59W):

Table 2. From NOAA ESRL Solar Position Calculator

Date / MST	Solar Elevation Position (degrees up from horizon)	Solar Azimuth Position (degrees clockwise from true north)	Degrees behind True East and Forward of True West
June 21 / 0433:41	0.0 (east horizon)	58.29	- 31.71
June 21 / 1201:44	73.7 (high point in sky)	180.00	0.0
June 21 / 1929:42	0.0 (west horizon)	301.69	+ 31.71

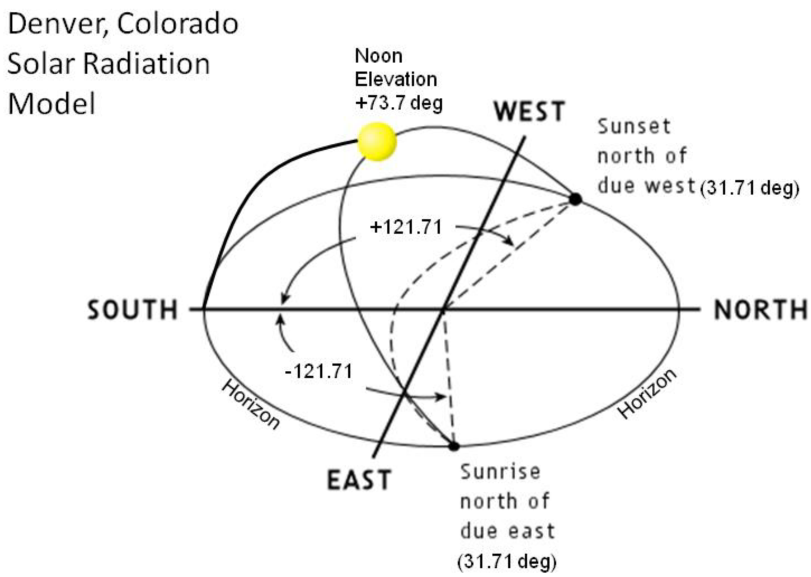

Figure 8. Solar Radiation Model for Denver

A pyranometer mounted to the south side of the shelter, and extended also at 180 degrees azimuth, would need to be clear of shadows on an elliptical path from 31.71 degrees aft of true east (at sunrise), to a point 16.3 degrees forward of zenith at noon, followed by 31.71 degrees forward of true west at sunset as shown in Figure 6. From these points to the horizon, shadow clearance is necessary year-around. Since this is the furthest north path the sun can take (longest day of the year) the sun will always appear within these points to the horizon.

Certification & Traceability

The CMP 11 and CUV 5 complies with ISO 9060 requirements and is fully traceable to the World Radiometric Reference (WRR) in Davos, Switzerland.

Unpack the Radiometer

The radiometer is shielded by two glass domes made of 2 mm, high quality glass – one dome within the other, as shown in Figure 7. This allows 97 to 98 percent of the sun's energy within the given spectral range to be absorbed by a temperature compensated thermopile detector. This design provides for equal transmittal of solar radiation for each position of the sun across the sky. Since solar irradiance can come from any direction, the domes are designed to minimize errors in measurement at all incident angles.

1. Unpack the radiometer and ensure all elements are present.

2. Review the instructions included with the unit.

Check the Drying Cartridge

A drying cartridge in the housing is filled with replaceable silica gel, which is a drying agent (desiccant). This desiccant prevents condensation on the inner sides of the domes. The domes can cool down considerably on clear, windless nights. Temperature and pressure changes can cause water vapor to enter the housing as well. When fresh, the desiccant is orange, but it fades to clear as moisture is absorbed over time. Once it becomes clear, it should be replaced.

1. If the unit will be deployed soon, inspect the silica-gel. It should be orange in color. However, it is still good until it becomes clear in color.

2. If the color of the silica-gel is clear in color, remove the drying cartridge and discard the contents. Open a new pack of silica-gel, fill the cartridge, and screw it back into the housing finger-tight.

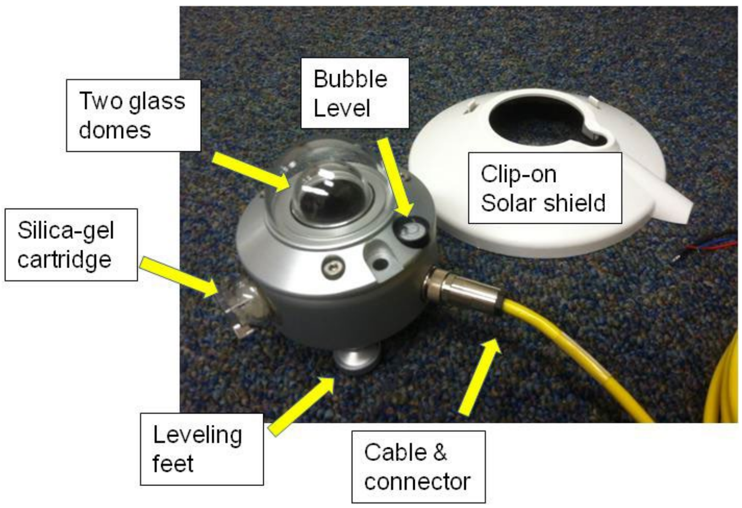

Figure 9. Pyranometer Model CMP 11

Install Radiometer Mount Platform

Once installed, the radiometer must be secure, and must be accessible for cleaning the dome, checking for levelness, and for servicing the desiccant. Since every shelter is unique, the platform construction materials will have to be customized for each application. Figure 11 shows the La Casa Site installation. The mount platform built for La Casa has a leveling turnbuckle on the support cable.

1. Mount the radiometer on the south side of the shelter, with the platform extending to the south.

2. Level the radiometer platform.

La Casa Site

Cable tensioner for leveling platform

Pyranometer extends beyond tower on south side of site structure

Figure 10. La Casa Site - Pyranometer Installation

Mount Radiometer to Pedestal

The mount stand temperature may vary much more than air temperature, so the instrument housing is mounted on legs to segregate temperature offsets.

1. Orientation of the instrument is not specified. However, to minimize heating of the electrical connections, orient the unit so the cable connector is pointed towards the nearest pole. In Colorado, that would be north.

2. Mount the pyranometer to the mount platform using the two 5 mm stainless steel screws, washers, nuts; and two nylon insulation rings that came with the radiometer.

3. Properly ground the pedestal to conduct away lightning induced currents.

Level the Instrument

Accurate measurement of the sun's radiation requires a level instrument.

1. First ensure the instrument platform is reasonably level.

2. Next level the instrument by turning the two adjustable feet to bring the leveling bubble within the marked ring. First, level the foot nearest the bubble, then the second foot.

3. Ensure the radiometer leveling bubble is within the marked ring (the instrument is within the specified accuracy when the bubble is at least half within the ring.)

Connect the Cable

The radiometer does not require any excitation power to operate, so it can connect directly to our data loggers. Solar radiation reaching the sensing element produces a small analog output voltage which is sent directly to the data logger.

1. To connect the radiometer cable, carefully position and gently push the connector into the receptacle. Hand-tighten the lock-ring. Do not over-tighten or you may damage the waterproof seal.

2. Secure the cable to the platform mounting arm. Run the yellow cable from the sensor to the data logger.

3. Connect the positive and negative wires to the correct channel allocated to Solar Rad.

4. Connect the cable ground wire to the computer cabinet.

Note: Once mounted, the cable should be arranged with a curve below the instrument so that moisture drips off, rather than running along the cable up to the connector.

Enter the calibration coefficients into AVTrend

The radiometer comes from the certification entity with a calibration coefficient in watts meter $^{-2}$. The 8872 (currently a radiometer cannot be installed on an 8832 or 8816) is programmed to convert the voltage from the radiometer into watts meter $^{-2}$ by a formula that takes the scaling on the Adam 6066 into account and multiplies that by the calibration coefficient. As such, the calibration coefficient needs to be entered into AVTrend.

Open AVTrend, and click on the Home ribbon, then the Configuration Editors group, and select Logger Channels. Explode the Site in the hierarchy to the left, and double click the logical Logger entity. This will open the Logger properties shown in Figure 11. Select the Math Constants tab. Highlight the appropriate Primary Value by assessing the Description of the math constant. Enter the new calibration coefficient value. Click Save.

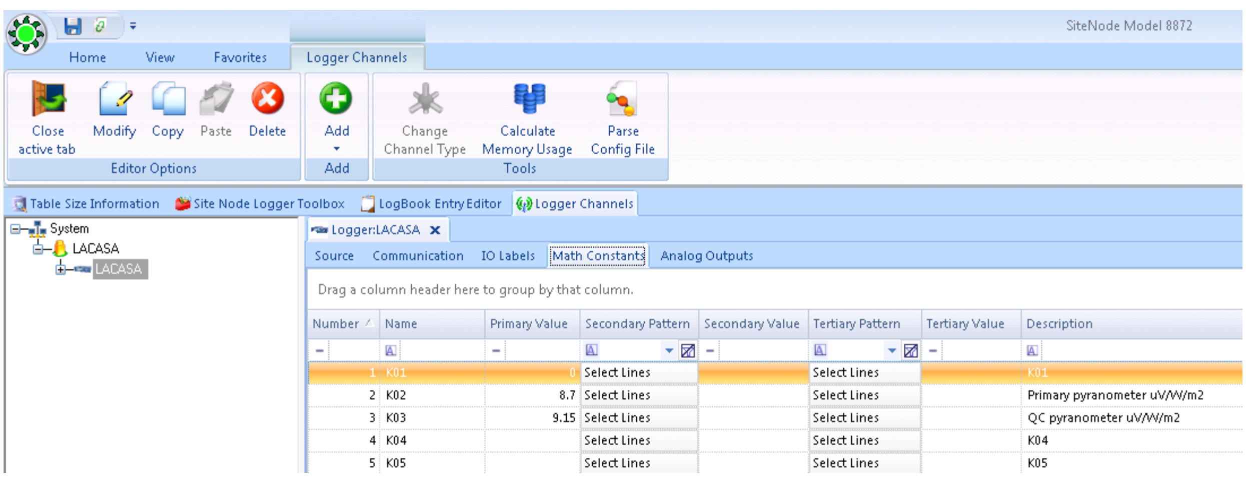

Figure 11. Radiometer Calibration Coefficient Entry in AVTrend

Trouble-Shooting

Output signal not present or incorrect:

1. Check the dome, if water, frost or ice forms on the dome, clean it. Usually, water droplets will evaporate in less than one hour under sunlight. If condensation forms inside, change the desiccant.

2. If too much water is deposited internally the drying cartridge should be removed and the instrument warmed to dry out. Once dry, replace the cartridge with new desiccant. It may take several days to recover full sensitivity. Any malfunction or visible damage should be reported to vendor.

3. Check instrument location. Are there any obstructions that cast a shadow on the instrument by blocking the direct sun during some part of the day?

4. Check the data logger or readout offset by connecting a dummy load (100 Ohm resistor). This should give a 'zero' reading.

5. Check leveling. The bubble should be at least half inside the marked ring of the level.

6. Check that cable is properly connected to the instrument housing and the data logger. Ensure there is no corrosion inside the housing plug.

11 HANDLING AND PRESERVATION

Meteorological parameters are monitored continuously; no discrete samples are collected, handled, or preserved. Therefore this SOP for meteorological monitoring does not need a section on Handling and Preservation.

12 SAMPLE PRESERVATION AND ANALYSIS

Meteorological parameters receive no special preparation prior to analysis. Therefore a SOP for meteorological monitoring does not need a section on Sample Preparation and Analysis.

13 TROUBLESHOOTING

13.1 Environmental Factors

Environmental conditions can play a role in the operational characteristics of monitoring equipment. Some factors may be constant while others are sporadic in nature. Factors to check include:

- Is the shelter temperature stable throughout the day?
- Is vibration from other equipment causing an effect?
- Is the air conditioner or heater blowing directly on the translator?
- Is the instrument heater on during the colder months?

13.2 General Factors

Power to the site is another factor that can contribute to data loss. Incoming power needs to be stable and have a good waveform.

13.3 Instrument Troubleshooting

Troubleshooting of problems with meteorological sensors is specific to each sensor and its design. Common problems with instruments include:

- Erratic or noisy readings (readings may also be too stable, or flat-line at a value)

- No readings or off-scale readings
- No output or intermittent output
- Bearings becoming worn with increased drag
- Sensor completely inoperative
- Translator or Translator card inoperative
- Bent wind vane or broken wind vane tail
- Wind sensor propeller missing
- Broken WS cups
- Water or ice interference

Refer to the troubleshooting sections in specific sensor or translator operation and service manuals, located at each site or in the APCD office. These should be consulted to assist in resolving instrument problems. Equipment used for troubleshooting includes a MM, data sheets, and operations manuals.

14 DATA ACQUISITION, CALCULATIONS, AND DATA REDUCTION

All data are collected, stored and retrieved digitally. While scalar wind speed and direction are direct measurements collected by measuring voltage provided by the sensor, vector wind speed and direction are derived. ESC data loggers provide functionality for such derivation by internally calculation using commonly accepted calculations. See Section 5.17 in the ESC 8816 or 8832 operator manuals (Environmental Systems Corporation, 2001) (Environmental Systems Corporation, 2006) for equations to determine resultant vector wind speed and wind direction.

14.1 Data Acquisition

Currently, the APCD/TSP collects, stores, and retrieves all data from continuous meteorological monitoring equipment using an electronic data acquisition system (DAS). Advantages of DAS include:

1. Accuracy. The DAS collects data at a rate of several times per second and automatically compiles the data into hourly averages.
2. Collection options. Data collected with a DAS can be stored as hourly averages, or short-term averages, or both.
3. Data flags. DAS software/firmware can be programmed to flag data as suspect or invalid based on pre-set or operator-set parameters.
4. Data availability. With a DAS, the data are available remotely as soon as the averaging period is complete.
5. ESC manufactures the 8816 and 8832/8864 DAS, and Agilaire manufactures the 8872 DAS. The DAS is composed of electronic data loggers at the sites and a "Central" polling computer and software at the APCD office. The data loggers are model 8816, 8832,8864, and 8872 units. An AirVision software application is used to communicate with data loggers. A more detailed description of the DAS is given in the CDPHE/APCD/TSP Appnedix D1 of this QAPP, Data Logger & Central SOP.

6. Currently, no backup storage system is used for meteorological monitoring equipment.

14.2 Calculations and Data Reduction

As mentioned above, data collected on a DAS are available as soon as the averaging period is complete. Data are downloaded automatically via modem to the "Central" polling computer. If needed, remote checks can also be performed more frequently.

Data from the meteorological monitoring equipment are generally stored as hourly averages, secondarily as 15-minute averages. At the end of each month, the hourly data for that month are quality assured and corrections or deletions made, as needed. The software on the "Central" polling computer is then used to create a file of the data that is transmitted to the EPA Air Quality System for long-term storage.

A more detailed description of the DAS is given in the CDPHE/APCD/TSP QAPP Data Logger and Central Polling SOP, Appendix D1.

15 COMPUTER HARDWARE AND SOFTWARE

The data acquisition system (DAS) used by the APCD/TSP for collecting data from continuous air monitors is generally described in the CDPHE/APCD/TSP QAPP.

The primary DAS Central polling computer is a Windows based server. The AirVision data system on this server provides for polling the sites using dial-up modems and broadband access for data. A printer is attached to the system for printing out reports. The primary repository for data, and the engine for information assembly, is the Microsoft SQL Server operated and maintained by the Governor's Office of Information Technology. The CDPHE/APCD/TSP maintains a database owner position responsible for logical maintenance of the data system.

The 8872 is a Windows based PC with attached monitor, keyboard, and mouse. The 8832/8864 and 8816 are proprietary hard-circuit solid state systems that may or may not have attached screens and keyboards. Sites usually include other computer hardware and software such as switches, RS232 cables, Ethernet cables, and analog cables.

16 DATA MANAGEMENT AND RECORDS MANAGEMENT

16.1 Data Management

Meteorological monitoring data are generally reported as hourly averages. Approximately 720 hourly averages are collected per month per parameter/instrument. Thus, over the course of months or years, large amounts of data are collected.

Data are sent to the EPA centralized Air Quality System (AQS) database for long-term storage. Additionally, the data are stored and archived by the APCD/TSP in both electronic and hard copy formats. Monthly electronic data files and related printed material packets (maintenance forms, etc.) are produced.

A more detailed description of the data management is given in the Data Validation SOP, Appendix D2 in the CDPHE/APCD/TSP QAPP.

16.2 Records Management

Meteorological monitoring data are archived both in electronic and hard copy formats. Electronic data and calibration files from the primary data acquisition system are stored on a recoverable routinely backed up network drive. Hard copy printouts of the data are kept in the APCD office for a minimum of three years before being sent to an off-site archive/storage facility.

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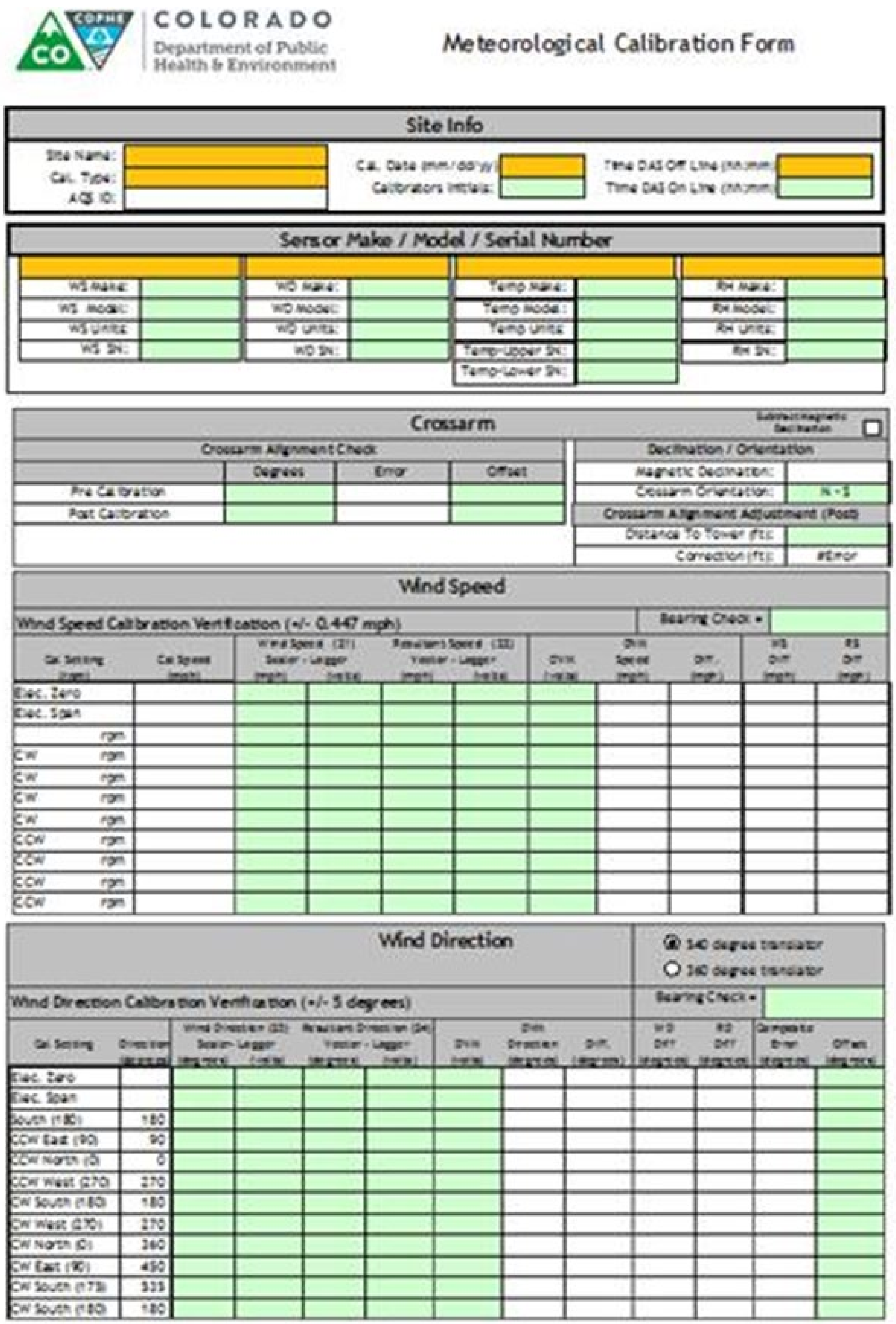

COLORADO
Department of Public Health & Environment

Meteorological Calibration Form

Site Info

Site Name:		Cal. Date (mm/dd/yy):		Time DAS Off Line (hh:mm):	
Cal. Type:		Calibrators Initials:		Time DAS On Line (hh:mm):	
AQS ID:					

Sensor Make / Model / Serial Number

WS Make:		WD Make:		Temp Make:		RH Make:	
WS Model:		WD Model:		Temp Model:		RH Model:	
WS Units:		WD Units:		Temp Units:		RH Units:	
WS SN:		WD SN:		Temp-Upper SN:		RH SN:	
				Temp-Lower SN:			

Crossarm

Subtract Magnetic Declination ☐

Crossarm Alignment Check

	Degrees	Error	Offset
Pre Calibration			
Post Calibration			

Declination / Orientation

Magnetic Declination:	
Crossarm Orientation:	N - S

Crossarm Alignment Adjustment (Post)

Distance To Tower (ft):	
Correction (ft):	#Error

Wind Speed

Wind Speed Calibration Verification (+/- 0.447 mph) Bearing Check =

Cal Setting (rpm)	Cal Speed (mph)	Wind Speed (21) Scalar - Logger (mph)	Wind Speed (21) Scalar - Logger (volts)	Resultant Speed (22) Vector - Logger (mph)	Resultant Speed (22) Vector - Logger (volts)	DVM (volts)	DVM Speed (mph)	DVM Diff. (mph)	WS Diff (mph)	RS Diff (mph)
Elec. Zero										
Elec. Span										
rpm										
CW rpm										
CW rpm										
CW rpm										
CW rpm										
CCW rpm										
CCW rpm										
CCW rpm										
CCW rpm										

Wind Direction

◉ 540 degree translator
○ 360 degree translator

Wind Direction Calibration Verification (+/- 5 degrees) Bearing Check =

Cal Setting	Direction (degrees)	Wind Direction (23) Scalar - Logger (degrees)	Wind Direction (23) Scalar - Logger (volts)	Resultant Direction (24) Vector - Logger (degrees)	Resultant Direction (24) Vector - Logger (volts)	DVM (volts)	DVM Direction (degrees)	DVM Diff. (degrees)	WD Diff (degrees)	RD Diff (degrees)	Composite Error (degrees)	Offset (degrees)
Elec. Zero												
Elec. Span												
South (180)	180											
CCW East (90)	90											
CCW North (0)	0											
CCW West (270)	270											
CW South (180)	180											
CW West (270)	270											
CW North (0)	360											
CW East (90)	450											
CW South (175)	535											
CW South (180)	180											

Figure 12. Meteorological Calibration Form

Table 3. Met One Wind Speed to Voltage Conversion

Voltage Output Range: 0.006 to 1.000 VDC and (minimum threshold value: 0.006 VDC)

0 MPH	0.006 VDC	30 MPH	0.300 VDC	70 MPH	0.700 VDC
5 MPH	0.050 VDC	40 MPH	0.400 VDC	80 MPH	0.800 VDC
10 MPH	0.100 VDC	50 MPH	0.500 VDC	90 MPH	0.900 VDC
20 MPH	0.200 VDC	60 MPH	0.600 VDC	100 MPH	1.000 VDC

Table 4. Met One Wind Direction Degrees to Voltage Conversion

Wind Direction Range: 0 to 540 degrees Voltage Output Range: 0.000 to 1.000 VDC

DEG	Volts	DEG	Volts	DEG	Volts
0	.000				
10	.019	190	.352	370	.685
20	.037	200	.370	380	.704
30	.056	210	.389	390	.722
40	.074	220	.407	400	.741
45	.083	225	.417	405	.750
50	.093	230	.426	410	.759
60	.111	240	.444	420	.778
70	.130	250	.463	430	.796
80	.148	260	.481	440	.815
90	.167	270	.500	450	.833
100	.185	280	.519	460	.852
110	.204	290	.537	470	.870
120	.222	300	.556	480	.889
130	.241	310	.574	490	.907
135	.250	315	.583	495	.917
140	.259	320	.593	500	.926
150	.278	330	.611	510	.944
160	.296	340	.630	520	.963
170	.315	350	.648	530	.981
180	.333	360	.667	540	1.000

Table 5. Met One Ambient Temperature to Voltage Conversion

Temperature Range : -58 F to +122 F (-50 C to +50 C) Voltage Output Range : 0.000 to 1.000 VDC

DEGF	VDC	DEGF	VDC	DEGF	VDC	DEGF	VDC	DEGF	VDC	DEGF	VDC
-58	.000										
-57	.006	-27	.172	3	.339	33	.506	63	.672	93	.839
-56	.011	-26	.178	4	.344	34	.511	64	.678	94	.844
-55	.016	-25	.183	5	.350	35	.517	65	.683	95	.850
-54	.022	-24	.189	6	.356	36	.522	66	.689	96	.856
-53	.028	-23	.194	7	.361	37	.528	67	.694	97	.861

-52	.033	-22	.200	8	.367	38	.533	68	.700	98	.867
-51	.039	-21	.206	9	.372	39	.539	69	.706	99	.872
-50	.044	-20	.211	10	.378	40	.544	70	.711	100	.878
-49	.050	-19	.217	11	.383	41	.550	71	.717	101	.883
-48	.056	-18	.222	12	.389	42	.556	72	.722	102	.889
-47	.061	-17	.228	13	.394	43	.561	73	.728	103	.894
-46	.067	-16	.233	14	.400	44	.567	74	.733	104	.900
-45	.072	-15	.239	15	.406	45	.572	75	.739	105	.906
-44	.078	-14	.244	16	.411	46	.578	76	.744	106	.911
-43	.083	-13	.250	17	.417	47	.583	77	.750	107	.917
-42	.089	-12	.256	18	.422	48	.589	78	.756	108	.922
-41	.094	-11	.261	19	.428	49	.594	79	.761	109	.928
-40	.100	-10	.267	20	.433	50	.600	80	.767	110	.933
-39	.106	- 9	.272	21	.439	51	.606	81	.772	111	.939
-38	.111	-8	.278	22	.444	52	.611	82	.778	112	.944
-37	.117	-7	.283	23	.450	53	.617	83	.783	113	.950
-36	.122	-6	.289	24	.456	54	.622	84	.789	114	.956
-35	.128	-5	.294	25	.461	55	.628	85	.794	115	.961
-34	.133	-4	.300	26	.467	56	.633	86	.800	116	.967
-33	.139	-3	.306	27	.472	57	.639	87	.806	117	.972
-32	.144	-2	.311	28	.478	58	.644	88	.811	118	.978
-31	.150	-1	.317	29	.483	59	.650	89	.817	119	.983
-30	.156	0	.322	30	.489	60	.656	90	.822	120	.989
-29	.161	1	.328	31	.494	61	.661	91	.828	121	.994
-28	.167	2	.333	32	.500	62	.667	92	.833	122	1.000

Table 6. Met One 1180-24 Wind Speed Card

Input: 010 Range: 25/50/100 mph VI: 0 to 1V V2: 0 to 1V

STEP	FUNCTION	APPLY	TO	ADJ	FOR	AT	REMARKS (1)
1	+12V			CHECK	+12 VDC	PIN 2	+/- 1 VDC
2	-12V			CHECK	-12 VDC	PIN 21	+/- 1 VDC
3	+ER			CHECK	+7,000 VDC	U1-13	+/- 0.3 VDC
4	THRESHOLD VOLTAGE	RANGE S3-1 APPLY S1 (Zero)		R36	0.045 VDC	Q1-E	+/- 0.003 DVC
5	Full scale VOLTAGE RANGE 1	RANGE S3-1 1111.09 HZ (2) 900.0 us PERIOD	PIN 5+ PIN 6-	R30	7.500 VDC	Q1-E	+/- 0.010 VDC
6	Full scale VOLTAGE RANGE 2	RANGE S3-2 552-19 HZ (2) 1.811 ms PERIOD	PIN 5+ PIN 6-	R32	7.500 VDC	Q1-E	+/- 0.010 VDC
7	Full scale VOLTAGE RANGE 3	RANGE S3-3 272.74 HZ (2) 3.6666 ms PERIOD	PIN 5+ PIN 6-	R35	7.500 VDC	Q1-E	+/- 0.010 VDC
8	CALIBRATOR	RANGE S3-1 APPLY F.S. S2		CHECK	7.500 VDC	Q1-E	+/- 0.010 VDC
9	Full scale	RANGE S3-1 APPLY F.S. S2		R52	1.000 VDC	TP-3	+/- 0.05 VDC
10	Full scale	RANGE S3-1 APPLY F.S. S2		CHECK	1.000 VDC	PIN 16	+/- 0.005 VDC
11	Full scale	1400 OHMS		R56	1.000 VDC	TP-3	+/- 0.005 VDC
12	Full scale	RANGE S3-1 APPLY F.S. S2		CHECK	1.000 VDC	PIN 16	+/- 0.005 VDC

Table 7. Met One 1190-14 Wind Direction Card

Input: 020 V1: 0 to 1V V2: 0 to 1V

STEP	FUNCTION	APPLY	TO	ADJ	FOR	AT	REMARKS (1)
1	+12V			Check	+12 VDC	Pin 2	+/- 1.000 VDC
2	-12V			Check	-12 VDC	Pin 21	+/- 1.000 VDC
3	+ER			Check	7,000 VDC	U2-14	+/- 0.300 VDC
4	Pot gap locator	4.965 V	Pin 5	R35	Logic 0	U2-2	(2)
5	Threshold Detect	2.500 V	Pin 5+	R42	Logic 0	U2-1	(2)
6	Signal Voltage	4.000 V	Pin 5+	R6	-4.000 VDC	U4-6	+/- 0.005 VDC (3)
7	Adder Voltage		Pins	R8	-5.000 VDC	U4-6	+/- 0.005 VDC
8	Zero	Zero S1		R32	QV	Q1-E	+/- 0.002 VDC
9	Calibration Voltage	1		R3	3.750 VCD	TP-2	+/- 0.003 VDC
10	Half Scale	Half-scale S2		R23	0.500 VDC	TP-3	+/- 0.005 VDC
11	Half Scale	Half-scale S2		Check	0.500 VDC	Pin 16	+/- 0.005 VDC
12	Half Scale	Half-scale S2		R26	0.500 VDC	TP-4	+/- 0.005 VDC
13	Half Scale	Half-scale S2		Check	0.500 VDC	Pin 18	+/- 0.005 VDC

Table 8. Met One 1760-65 Ambient Temperature Card

Input: 060A-2 Range: -50 to +50 C V1: 0 to 1V V2: 0 to 1V

STEP	FUNCTION	APPLY	TO	ADJ	FOR	AT	REMARKS (1)
1	-12V			Check	-10.8 VDC	E30	+/- 1 VDC
2	+VR			R56	+5.000 VDC	E35	+/- 0.003 VDC
3	Zero output	Zero S1		R16	0.000 VDC	Q1-E	+/- 0.005 VDC
4	Full scale output	Full scale S2		R24	5.100 VDC	Q1-E	+/- 0.005 VDC
5	Repeat steps 3 and 4 until no further adjustment is required						
6	Full scale output	Full scale S2		R30	1.000 VDC	TP-3	+/- 0.005 VDC
7	Full scale output	Full scale S2		R33	1.000 VDC	TP-4	+/- 0.005 VDC
8	Zero output	158.181 K	Pin 5 & 6				
9	Zero output			check	0.000 VDC	TP-3	+/- 0.005 VDC
10	Full scale output	10.545 K	Pin 5 & 6				
	Full scale output			check	1.000 VDC	TP-3	+/- 0.005 VDC

Table 9. Met One 1230-1 Ambient Temperature Card

Input: 060A-2 Range: -50 to +50 C V1: 0 to 1V V2: 0 to 1MA/1400 OHM

STEP	FUNCTION	APPLY	TO	ADJ	FOR	AT	REMARKS (1)
1	+ VR			check	7.070 VDC	U3-6	+/- 0.350 VDC
2	Zero	Zero - s1		R10	0.000 VDC	Q1-E	+/- 0.010 VDC
3	Full Scale	Full Scale S2		R18	1.000 VDC	TP-3	+/- 0.003 VDC
4	Full Scale	1400 OHM	Pin 18				
5	Full Scale	Full Scale S2		R21	1.400 VDC	TP-4	+/- 0.003 VDC
6	Full Scale	158,181 OHM	Pin 5	check	0.000 VDC	TP-3	+/- 0.003 VDC
7	Full Scale	10,545 OHM	Pin 5	check	1.000 VDC	TP-3	+/- 0.003 VDC

Colorado Department of Public Health and Environment
Air Pollution Control Division - Technical Services Program

STATION: ____________________

STATION/MET

/
Month Year

	Supplier	Bottle #	Expiration	Conc
CO Span				
CO Prec				
NO				
NOy				
SO2				
O3	TAPI	SN:		

	Date						
Max Temp	<90F						
Min Temp	>50F						
Inlet check	Clean, in place						
CO Span Press	>200psi						
CO Prec Press	>200psi						
NO Press	>200psi						
NOy Press	>200psi						
SO2 Press	>200psi						
Wind Speed	<100mph						
Wind Direction	>0<540						
Radiometer	Clean						
Radiometer	Dessicant						
Rain Gauge	free						
Temp Shield	free						
	Operator						

Temp fans running (monthly): ____________

Day	Time	Action	Initials	Time

Use ✓ for yes and in-range and ✗ for no and out-of-range, Δ for changed figure 13. Station/Met Log

MAINTENANCE REPORT

DATE____________________

STATION____________________

ASSIGNED TO____________________

ORIGINATED BY____________________

ANALYZER or EQUIPMENT____________________ S/N__________

MALFUNCTION DESCRIPTION OR COMPLAINT

ACTION TAKEN

DATA TO BE DELETED (IF ANY)
ENTER EXACT DATES AND DATA HOURS

COMPLETED BY____________________

COMPLETION DATE____________________

J:\zsfiles\forms\forms.xls:MaintRpt

Figure 14. Maintenance Report