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Informal Report

BROOKHAVEN NATIONAL LABORATORY METEOROLOGICAL SERVICES

INSTRUMENT CALIBRATION PLAN AND PROCEDURES

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1.0 Purpose

This document describes the Meteorological Services (Met Services) Calibration and Maintenance Schedule and Procedures, The purpose is to establish the frequency and mechanism for the calibration and maintenance of the network of meteorological instrumentation operated by Met Services. The goal is to maintain the network in a manner that will result in accurate, precise and reliable readings from the instrumentation.

2.0 Responsibilities

This plan is administered through BNL Met Services and all members of Met Services are required to follow this plan. In addition to this plan all Met Services members are required to follow the BNL SBMS Subject Area on Calibration. The Head of Met Services as custodian of the Met Network equipment is responsible for maintaining the calibration records, documenting the calibrations, monitoring the calibration status and for keeping the calibration current. The Operations Officer is responsible for recording data, sensor repairs and monthly data assurance checks and reports to the Head of Met Services.

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3.0 Background

Met Services is responsible for the maintenance, calibration, data collection and data archiving for the weather instrumentation network associated with atmospheric dispersion concerns for BNL. This includes measuring wind speed, wind direction, temperature, rainfall, barometric pressure and relative humidity. Wind speed, wind direction and temperature are measured at 85 meters, 50 meters and at 10 meters. Rainfall, relative humidity and barometric pressure are taken at the 2 meter height. This critical data set is used for NEPA calculations, emergency planning and operations (i.e., chemical spill or accidental release), research in renewable energy and other science fields, historic investigation of incidents and is required to maintain a nuclear facility. In addition to the weather instruments, Met Services also maintains a seismic sensor that is located in the basement of the emergency operations center. This is a regulatory requirement for the Waste management facility.

In addition to the regulatory and DOE required meteorological network, Met Services, under separate funding, maintains a network of sensors related to solar power research. This network includes total sky imagers, pyranometers, and air, soil and panel temperature sensors, which are located throughout the Long Island Solar Farm (LISF) and a base station of solar irradiance instruments located on the roof of building 490D.

3.1 Instrument Towers

3.1.1 85-meter Tower

The 85-meter (280-ft.) meteorological tower was placed in operation in May 1981 to replace the former and original "Ace Tower" used in the first 30 operational years at BNL. The tower is located in an open field west of the majority of the Brookhaven building complex at latitude 40°52'14.84"N and longitude 72°53'20.05"W and its base is 24 m (80 ft.) above sea level and is referred to as "Tower Ten" In this document, the primary, tall tower will be called, simply, the "Main Tower" to avoid confusion with the smaller, secondary 10-meter tower also in operation at the Met field. A summary of all Met Services maintained instrument/sensors and locations is given in Appendix A.

The main tower is made of galvanized steel, is triangular in shape with 3 ft. sides and has 3 sets of 8 guy wires to keep it upright. It has an inside ladder for climbing, and two working levels with small platforms. It is difficult to mount booms and equipment or to work on this tower. Special safety belts and harnesses are required when climbing, maintaining or calibrating equipment on this tower. Sensor location names designate the approximate height of the sensors above the ground. At each location there are fully redundant sensor sets. Each set is independent of the other with unique data loggers and sensors. At locations M85 and M50 instrumentation includes; R.M. Young model 5106 Marine grade wind monitors for wind speed and direction and R.M. Young model 41342VC temperature probes. Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

3.1.2 10-meter Tower

A foldable-mast, ten-meter tower is located approximately at the center of the Meteorological field. Again, fully redundant sensor sets are present. Instrumentation includes R.M. Young model 5106 Marine grade wind monitors for wind speed and direction, and R.M. Young 41342VC temperature probes Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

3.1.3 2-meter pole

At two meters (located near the 10-meter tower) sensors include; R.M. Young model 41372VC temperature and relative humidity probes and R.M. Young model 61302V barometric pressure sensors. Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

3.1.4 Building 490D

Met Services maintains a platform on the roof of building 490D. This platform is used for testing of sensors and also houses the LISF research projects base station for solar irradiance measurements. Instrumentation at this location includes a Kipp and Zonen model Solys-2 suntracker equipped with; a shaded Kipp and Zonen model CGR-4 pyrgeometer, two Kipp and Zonen model CMP-22 research grade pyranometers (one shaded and one unshaded) and a Kipp and Zonen model CHP-1 pyrheliometer. There is also a pair of Kipp and Zonen model SP-lite2 pyranometers (one at the 27° angle of inclination for the panels at the LISF and one horizontal) and a YES model TSI-880 Total Sky Imager. In addition, redundant tipping-bucket rain gauges (Novalynx model 260-2501) are mounted on the roof near the platform. Each rain gauge has a wind screen around it. Data collection is via a Campbell CR3000 data loggers serially connected to a computer on the BNL network.

3.2 LISF sensor locations

Solar irradiance and temperature monitoring sensors are located throughout the LISF. There are 25 inverter boxes for the LISF and Met Services maintains sensor groups at each of the inverter box locations. All 25 locations have pairs of SP-lite2 pyranometers (one mounted at the incident angle of 27° and one parallel to the earth's plane), Omega model PRCU-10-2-100-1/4-6-e Fast Response Copper Tip RTDs to measure shaded air temperature and Omega model SA1-TH-44006-120-T thermistors to measure panel temperature on the underside of the PV panels. In addition, seven locations have duplicate SP-lite 2 pyranometers and ten locations have soil temperature (shaded and sunny) and shaded air temperature and relative humidity. The soil temperature probes are Campbell model 109-SS and the air temperature/relative humidity probes are Campbell model HMP45C.

4.0 Maintenance and Calibration Frequency and Documentation

4.1 Daily Instrument/Sensor Inquiry

Daily (Monday-Friday) and weekly checks of all the Met Services sensors will be performed to check that the sensors are reporting reasonable data, where possible whether a given sensor needs maintenance or repair and that peripheral equipment is operational (e.g., fans on powered aspirators are turning, shadowband on TSI is correct, etc.). Appendix G contains the check list for sensors requiring daily checks and those requiring weekly checks. Met Services is working on automating the sensor checks as much as possible. Currently the calibration status is monitored in Excel and email warnings are sent to the Head of Met Services and data stream to the database is monitored and emails are sent out to several Met Service members if the data stream stops for more than one hour. The system also emails once the stream is restored. We are working on having the historian database email warnings if sensors stop reporting, if duplicates do not match (within specifications/error bands) or the values go off scale (unrealistic values).

4.2 Annual Calibrations

At a minimum, each sensor will be calibrated on an annual basis. Where the instrument is sent off-site for calibration a duplicate unit will be available. The duplicate unit will be calibrated (and serviced if needed) approximately one month before the calibration of the in-use unit expires.

The calibration and maintenance frequency is based on the following hierarchy:

1. Manufacturer's recommendation as stated in the instrument's Operation Manual or Owner's Instruction Manual
2. Manufacturer's recommendation as stated in other communications such as a memorandum, email, or documented phone conversation
3. Other engineering or scientific standards specifically referring to a particular type of instrument (e.g., American Nuclear Society, American National Standards Institute)
4. Met Services determination of calibration needs based on experience with the equipment or recommendations from other sources

Calibration certificates will be required from the company performing the calibration(s) and these certificates will be compiled in the Instrument Calibration Notebook. Sensors that are calibrated on-site or in-situ will be calibrated by BNL personnel annually and the data taken will be recorded on instrument specific data sheets and the sheets will be compiled into the Instrument Calibration Notebook. The original notebook will be maintained in the Met Services trailer at the met field. A copy of the notebook will be kept in the Met Services Operations Officer's office. The Head of Met Services will maintain an electronic master list of equipment and the current status of each instruments calibration.

4.3 Quality Assurance of Data

On a monthly basis, the data goes through a QA/QC process to help eliminate faulty records and correct or remove any erroneous values. The post processing of the data involves visually analyzing the data in eight day increments looking for faulty data points. MatLab, data analysis software, is used for this purpose. Using a series of scripts, it is relatively easy to remove single or multiple data points. Once the faulty data is removed the operator can chose to fill in the missing points by interpolation or leave the data as "missing". The data is then saved to a file. This data is then backed up along with the raw unedited data. In addition to this we also do a comparative analysis on the "A" and "B" datasets to ensure precision between the two independent systems. After the editing is complete, daily and hourly averages and sums are calculated and saved to files to be disseminated upon request. A monthly data check and duplicate sensor inter comparison sheet is completed and placed in the Met Services Maintenance Notebook.

An annual data report is prepared that presents the meteorological data collected at BNL for the prior calendar year. The purpose is to publicize the data sets available to emergency personnel, researchers and facility operations. In addition, annual data summaries are included that detail data set completeness, percent data recovery and percent reliable vs. erroneous data.

5.0 Instrument Maintenance and Calibration:

The following details the maintenance and calibration procedures for each sensor type. A complete list of the Met Services sensor inventory can be found in Appendix A.

5.1 R.M. Young Model 5106 Wind Speed and Direction -

Maintenance and repair

The wind speed and direction at all locations should be checked daily to make certain units are reporting data. Note this in the Daily Log Sheet (see Appendix G. Data can be inter-compared (e.g., wind direction) with one another or with outside sources such as the National Weather Service (e.g., wind speed, temperature).

Calibration

These units require a wind tunnel calibration and will be sent out for calibration on an annual basis. Enough spare units are stocked to allow all locations to be changed out at once rather than sending sensors out piece meal. Spare units are sent out for calibration approximately one month prior to the in service units calibration due dates. When returned the newly calibrated units are swapped out with the in service units that will be going out of calibration. Calibration of the sensors will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor that replaces an old sensor (see Section 6.0, Appendix J and Appendix K) as well as scanning the removed sensor, so it is known to be out-of-service and placed in reserve.

Met Services has a master Excel file that has the inventory of sensors and equipment and also tracks the calibration dates. The program emails the Head of Met Services one month before the calibration date is due (this is true for all sensors), then weekly until the calibration is updated or the unit is taken out of service.

Companies performing calibrations shall be required to provide "as-received" and "as-left" test reports. Removal and calibration of the sensors will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each sensor removed and the replacement sensor (see Section 6.0, Appendix J and Appendix K).

5.2 R.M. Young Model 41342VC and Omega model PRCU-10-2-100-1/4-6-e Platinum Resistance Temperature Detectors -

Met Services uses two types of platinum resistance temperature detectors (RTD). The first is the R.M. Young Model 41342VC Temperature probe which is used for all tower and base station temperature measurements. The second is the Omega Class A (IEC-751) Fast Response Copper Tip RTD – model PRCU-10-2-100-1/4-6-E, which is used in the LISF to measure shaded air temperature at 1-2 meters above the ground.

Maintenance

The R.M. Young temperature probes are used on all locations of all the tower locations (10, 50 and 85 meters). All of these locations require aspirated radiation shields to prevent the probes from heating up via direct sunlight radiant heating and have R.M. Young, model 41003, naturally aspirated, multi-plate radiation shields.

The Omega RTDs are not aspirated as they are measuring shaded temperature and are located such that they are never in direct sunlight.

All of the R.M. Young sensors will be checked daily to determine that they are reporting. Data can be inter-compared with one another (e.g., Side A to Side B, 85-meter tower to 50-meter) or with outside sources such as the National Weather Service. The Omega sensors will be checked weekly to determine that they are reporting and will be inter compared to see if any are overtly different from the group.

Calibration

All temperature sensors shall be calibrated annually and will be calibrated ex-situ in the Meteorological Laboratory. Calibration of the sensors will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor that replaces an old sensor (see Section 6.0, Appendix J and Appendix K) as well as scanning the removed sensor, so it is known to be out-of-service and placed in reserve.

Met Services use a characterization calibration using at least three points (temperatures). The characterization calibration consists of;

1. Place a reference probe and the test probe in the temperature source in close proximity to one another.
2. Determine the actual temperature from the reference probe
3. Measure and record the temperature of the test probe
4. Fit the data to determine the calibration coefficients

The calibration coefficients are then entered into the Campbell data logger program.

For Platinum resistance probes and modest accuracy applications the resistance-temperature relationship can be approximated by the Callendar-Van Dusen equation as:

$$R(t) = R(0)[1 + At + Bt^2 + C(t-100)t^3]$$

Where:
t = temperature (°C),
R(t) = resistance at temperature t,
R(0) = resistance at 0°C,
and using ASTM 1137 and IEC 60751 coefficient values for a standard 100 ohm sensor having an alpha value of 0.00385;
$A = 3.9083 \times 10^{-3}$ ($°C^{-1}$),
$B = -5.775 \times 10^{-7}$($°C^{-2}$) and
$C = -4.183 \times 10^{-12}$ ($°C^{-4}$) [for temperatures above 0°C, C = 0]

ANSI/ANS-3.11-2005 lists the air temperature minimum accuracy of 0.5°C and a minimum resolution of 0.1°C (see Appendix H). For stability class determinations using vertical temperature differences the requirements are; a minimum accuracy of 0.1°C and a minimum resolution of 0.01°C Within the temperature range of BNLs minimum observed temperature (-

31°C) and maximum observed temperature (38°C), the B and C coefficients can be ignored and approximated as zero and;

$R(t) = R(0) + R(0) \cdot At$

Met Services uses the comparison method of calibrating temperature sensors. The thermometer is calibrated by comparison with a reference or standard thermometer in a thermally stabilized bath. The procedure (see Appendix B) uses a four point calibration consisting of -10°C, 5°C, 20°C and 35°C as follows;

1. Remove the temperature sensor and place into the temperature bath a long with the reference thermometer.
2. Set the temperature bath to -5°C.
3. Wait until the temperature bath is stabilized and document both the reference reading and test unit reading on the calibration form (see Appendix B).
4. Repeat step 2-3 for 5°C, 20°C and 35°C.
5. If temperature sensor fails to meet the required precision and accuracy (either ±0.1°C for meteorological/stability class applications or ±0.5°C for LISF monitoring) it must be replaced and this procedure repeated. [Note: the tolerances are taken from the table in Appendix H.]
6. Complete the calibration sheet, sign and place into Instrument Calibration Log Book.

The reference thermometer will be sent off-site to an approved calibration service for a NIST traceable calibration. The calibration certificate will include "as Found" and "as Left" data.

5.3 R.M. Young Model 41372VC and Campbell HMP45C Temperature and Relative Humidity probes -

For meteorological data, R.M. Young model 41372VC Temperature/RH probes are deployed at the 2 meter site. These consist of a PRT and a capacitance type humidity sensor and are installed in actively aspirated (powered fan) radiation shields. The powered aspirators have tachometers on the fans and the rpms are reported. This will be checked daily to determine that the fans are working. If the tachometer reading is low or zero, the aspirator will be repaired or changed. The temperature and humidity will be checked daily to determine that they are reporting correctly and that the two sensors are within spec to each other.

The Campbell HMP45C T/Rh probe consists of a 1000 ohm PRT (Platinum resistance thermometer) coupled with a capacitive polymer H chip to measure RH.

Both probe types will be calibrated annually and enough reserve units are on hand to swap out sensors when calibrations are due. Freshly calibrated units will replace the going out of calibration units. Calibration of the sensors will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor that replaces the old sensor (see Section 6.0, Appendix J and Appendix K) as well as scanning the removed sensor, so it is known to be out-of-service and placed in reserve.

The temperature sensor will be calibrated, in the laboratory, using the same comparison (four point) calibration method described in Section 5.2 (also see Appendix B). The data will be recorded on a calibration sheet and compiled into the Instrument Calibration Notebook. The temperature probe calibration sheet is given in Appendix B. If the temperature probe fails to meet the required precision (±0.1°C for the R.M. Young probes or ±0.5°C for the Campbell) it must be replaced.

The relative humidity sensor will be calibrated, in the laboratory, using saturated salt baths (see Appendix C). Ex-situ (in the laboratory rather than in field) calibration of RH probes will be used to avoid errors due to fluctuating temperature instability. The use of saturated salt baths is one of the oldest methods for generating humidity at different levels. The RH value is a function of the chemical properties of the salt when mixed with water, with different saturated salt solutions yielding different Rh values. Although cumbersome, saturated salt solutions are very reliable. The saturated salt solutions are easy to make and result in a fairly constant humidity over a reasonable temperature range. BNL Met Services will use saturated aqueous salt solutions as described in ASTM E104-02 to obtain a three point calibration of the Rh probes. The specific solutions include; Sodium Chloride (NaCl) for 75.5 ±0.2 % Rh @ 20°C, Sodium Bromide (NaBr) for 59.1 ± 0.5 % Rh @ 20° and Magnesium Chloride (MgCl) for 33.1 ±0.2 % Rh @ 20°C. In contrast, the Campbell HMP45C has an accuracy of ±2% Rh (0 to 90% Rh) ±3% Rh (90% to 100% Rh) and the R.M. Young 41372VC has a stated accuracy of ±1% @ 20-25°C. The ANS requirement (see Appendix H) is ±4%.

Temperature instability can be the leading cause of inaccurate humidity calibrations. The salt solutions should be stored in the room the calibration will be performed and this room should have a stable temperature over the course of a measurement. Place the calibration solutions in the most temperature stable part of the room, out of sunlight and away from local heating or cooling sources. The probe and solution containers should be handled as little as possible to avoid heat transfer. Stabilize reference solutions for at least 60 minutes at ambient temperature.

Met Services has specific humidity calibration chamber covers to fit each probe type and separate chambers for each salt solution. The reference solutions are stored in the sealed chambers. The calibration procedure is as follows:

1. Inspect each solution chamber and make certain they are filled to the fill line and not significantly above or below.
2. Add or remove water to achieve the proper solution level.
3. Make certain there are excess salt crystals on the bottom of the container (to assure a saturated solution).
4. Add the proper salt if the crystals are not visible.
5. Stir the solution and re-inspect, adding additional salts if needed. If any water or salts are added/removed stabilize the reference solutions for at least 30 minutes. Connect the probe to the Campbell CR3000 or CR1000 data logger in the calibration laboratory. This data logger is used to monitor the RH and temperature during the calibration and is identical to the data loggers used in the field.
6. Starting with the lowest RH solution (MgCl), remove the storage cap from the container and replace it with the cap for the specific probe. The Campbell HMP45C probes use the cover with a single hole in it. The R.M. Young probes have two holes to accommodate the temperature probe.
7. Insert the probe through the hole and into the reference container until it stops. The probe should stop just above the surface of the solution. **Make certain the probe does not contact the solution.** Make certain the probe fits snuggly and a good seal is obtained. NOTE: A tight seal is important. Allow the probe and solution to stabilize for a minimum

of one hour. [It can take several hours to equilibrate if the container/probe seal is not tight, the solution or probe is handled or moved or if the room temperature is changing]. The sensor output is read from the data logger and displayed on the calibration computer monitor.

8. Take three consecutive readings (one-minute averages) at five minute intervals and record the humidity and temperature on the Relative Humidity Calibration Log sheet (see Appendix C). This data sheet will be compiled in the Instrumentation Calibration Log book.

Repeat the procedure with the next two solutions, proceeding from lower to higher Rh values. Check the recorded Rh values against the equilibrium Rh values found in ASTM E104-02 at the corresponding measured temperature. If the probe fails to meet the ±4% it must be replaced.

5.4 R.M. Young 61302V Barometric Pressure sensor -

The R.M. Young barometric sensors are calibrated to ± 0.015 inches of mercury (in. Hg). The units will be returned annually to the manufacturer for recalibration. A duplicate/spare unit will kept in inventory and sent out for calibration one month before the in service unit needs recalibration. Upon return, the newly calibrated unit will replace the in service unit. The calibration certificate will include as found and as is data and the certificate will be compiled into the Instrument Calibration Notebook. Calibration of the sensors will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor that replaces the old sensor (see Section 6.0, Appendix J and Appendix K) as well as scanning the removed sensor, so it is known to be out-of-service and placed in reserve.

5.5 Novalynx Tipping Bucket Rain gauge Model 260-2501

The Novalynx Rain gauges will be calibrated annually. Calibration of the gauges will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor (see Appendix J and Appendix K). The calibration will be completed in-situ. A calibration sheet will be filled out and compiled into the Instrument Calibration Notebook. The sheet/methodology is given in Appendix D.

Besides calibration, annual and periodic maintenance of the rain gauge is required. Cleaning of the gauge more often may be necessary in areas where there are considerable amounts of airborne debris such as leaves, and dust that is blown into the gauge. The gauges will be checked weekly for dirt or obstructions. Cleaning includes removal of the outer cover, rinsing and drying off of the buckets, cleaning of the drain holes, and removal of debris from all of the screens. The outer and inner funnels should also be rinsed and dried off to remove dirt, dust and insects. Use a baby bottle brush and clean water to clean out the funnel tubes as per the manufacturer's manual.

5.6 Kipp and Zonen Model SP-Lite2 pyranometers

BNL calibrates the field pyranometers at the base station. These are the SP-Lite2 units used at the LISF and the pair at the base station. A calibration platform is installed at the base station and kept level to within 0.1°. The pyranometers are mounted on this platform along with the calibration standards and a comparison calibration is performed (see Appendix M). Three SP-Lite2 units are designated as permanent "Control Standards" and are sent to the NREL BORCAL for calibration annually. All three units participate in each group calibration to serve as process controls and to identify any spectral mis-match conditions that could affect the calibration results.

The field units are calibrated, in groups, against the reference SP-Lite2s. A spare/reserve group consisting of an addition 25% of the number of units in the field is kept on hand. The reserve group will be calibrated around May 1. Once calibrated, they will be installed in the field and the replaced sensors will then be calibrated. This will be repeated until all the field units are replaced/re-calibrated and the last set removed will be placed into the reserve group. The NREL calibration certificates for the reference units will be compiled into the Instrument Calibration Notebook. Calibration of the sensors will be documented via Appendix M and will include the solar irradiance plot (time vs. watts) for the calibration date. Removal and replacement of the SP-Lite2s will follow the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor that replaces the old sensor (see Section 6.0, Appendix J and Appendix K) as well as scanning the removed sensor, so it is known to be out-of-service and placed in reserve.

The SP-lite2s will require periodic cleaning and inspection. The level of each unit should be checked monthly and corrected if needed. Cleaning of the units will depend on research requirements. If a maintenance study is being conducted the units will be cleaned according to the study schedule following the procedure in Appendix L (unless the study directs otherwise). If no maintenance study is being conducted the units will be cleaned as needed and at least monthly for the base station pair, following the procedure in Appendix L.

5.7 Omega Thermistor Panel Temperature sensor

Omega Model SA1-TH-44006-120-T thermistors are used to measure panel temperature of the photovoltaic panels at the LISF. The panel temperature thermistors are glued to the back of an individual panel (Second panel from the bottom of the rack; looking at the back of the panel, three cells in from the right; two cell up from the bottom). This makes removal and ex-situ calibration impossible. An exact in-situ calibration is also not possible as the panel temperatures cannot be varied. To circumvent this limitation the thermistor temperature will be calibrated by comparison to the panel temperature as measured by a calibrated infrared thermometer aimed directly at the thermistor. Each thermistor is covered in black electricians tape to assist in both adhering the thermistor to the panel and providing a better black body for the IR thermometer.

Several measurements are made at the center of the thermistor patch (on top of the thermistor bead itself). Such measurements are made at three different times of the day to obtain a range of temperature readings. This will be performed annually. The thermistor temperature and the IR panel temperatures will be recorded in the Thermistor Calibration Log Sheet (see Appendix F) and if the corrected thermistor reading varies by more than ±1 degree + 1% from the actual readings the thermistor shall be replaced. The Thermistor Calibration Log Sheet will be compiled into the Instrument Calibration Notebook. The IR temperature sensor will be sent off-site for annual calibration. Calibration of the sensors will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor (see Section 6.0, Appendix J and Appendix K).

5.8 Campbell 109SS Soil Temperature probes

Soil temperature probes (Campbell 109SS) are deployed in the LISF. These are used in ecology/conservation study applications. They are located at ten locations in the north array and are buried ~18" below grade. At each location, probes are located in shaded and un-shaded soil. Since these probes are permanently installed, an in-situ performance check will be performed annually.

Thermo-wells are installed within a foot of the probe. These wells allow a reference RTD probe to be inserted and compared to the ground sensor. This will only allow a one point comparison rather than a true calibration. To compensate for this, ten days of data will be taken and will include measurements made in the earlier part of the day and just after solar noon in order to obtain a range of temperatures. The temperature comparison will be recorded on the form found in Appendix N. Data will be plotted (soil probe reading versus RTD/actual reading) in Excel and the slopes of each probe compared to one another. The slopes are expected to be reasonably parallel and the error bands to be with in ±1°C. The Principal Investigator (PI) for ecology and conservation programs will determine if the sensor "accuracy" is acceptable for the project. The plots will be printed out and placed into the Meteorological Services Calibration Notebook.

Calibration/comparison of the sensors will be documented via the BNL Meteorology Instrument Network Inventory only by the Head of Met Services or the Operations Officer. Once the PI for ecology and conservation programs approves the sensor calibration, the calibration data for each probe will be entered into the BNL Meteorology Instrument Network Inventory and the proper entries in the change log sheet will be made.

5.9 Yankee Environmental Systems, Inc., Total Sky Imager model TSI-880

Met Services has three sky imagers. The main unit is located at the base station on the roof of building 490. The TSI-880 (TSI) image processing and shadowband location are based on the internal clock setting. It is vital that this clock be accurate and the TSIs are all auto time synced to the network clock. The time setting is checked weekly as part of the routine Met Services weekly instrument inquiry. TSIs also require routine monthly maintenance. The mirror needs to be kept clean for proper imaging and should also be waxed and polished to reduce corrosion. The weekly met Services instrument inquiry will check the image quality to determine if the mirror needs cleaning. Cleaning will occur at least monthly or as needed based on the image check. The monthly maintenance procedure, including battery check, is given in Appendix I. Maintenance will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each unit (see section 6.0, Appendix J and Appendix K).

5.10 Kinemetrics Etna Accelerograph

The Kinemetrics Model Etna, Strong-Motion Accelerograph is located in the basement of the Emergency Operations Center. DOE O 420.1A (Facility Safety) requires BNL to have the accelerometer. The requirements of rigid mounting to the concrete basement floor mandate an in-situ calibration/annual system check. The unit is a self-contained, three-channel digital recorder and includes an internal triaxial force-balance accelerometer (EpiSensor) and a GPS timing system. The system is housed in a watertight case which contains all of the system electronics, the data storage modules, a battery (12V 12 Ahr) and the EpiSensor deck. The procedure/System Check Sheet for the annual systems check is given in Appendix E. The completed check sheet will be compiled into the Instrument Calibration Notebook and a copy will be forwarded to the Quality Management Office (attn: Steve Stein). This unit is not part of the BNL Meteorological Instrument Network Inventory and the calibration sheet will serve as the only documentation (this unit is not recorded in the Met Services Instrument Calibration Inventory database).

5.11 Base Station Solar irradiance sensors

The 10-meter platform, on the roof of Bldg. 490D, is designated as the solar base station. The base station solar irradiance instrument cluster includes; a Kipp & Zonen model CGR-4 pyrgeometer, a Kipp & Zonen model CHP-1 pyrheliometer, two each Kipp & Zonen model CMP-21 & CMP-22 research grade pyranometers and a Kipp & Zonen SOLYS 2 sun tracker. These instruments are sent to NREL for calibration, at the Solar Radiation Research Laboratory, using the ISO-accredited Broadband Outdoor Radiometer Calibration (BORCAL) method (Reda et al). These calibrations are scheduled annually. Calibration of the sensors will be documented via the BNL Meteorology Instrument Network Inventory by proper scanning of the barcodes for each calibrated sensor (see Sec 6.0, Appendix J and Appendix K).

Monthly maintenance includes cleaning the units (see Appendix L) and checking the desiccant. The desiccant packs have color indicators to tell when they are spent. If the desiccant pack is spent then it will be replaced following the manufacturers procedure. The monthly maintenance will be documented in the BNL Meteorological Instrument Network Inventory via barcode scanning (see Appendix J and Appendix K) along with the Maintenance procedure (Appendix L).

6.0 Sensor removal and equipment tracking

Every sensor within the Met Services calibration plan will be bar-coded and tracked via the Met Services Instrument Calibration Inventory database. Whenever a change is made, such as re-calibration, maintenance, replacement or repair, the old sensor, if applicable, the new sensor and the enclosure box the sensor(s) connect to will be scanned and any/all actions documented via a hand-held scanner. The scan file (data file from the hand-held scanner) will be appended to the Meteorological Instrument Network Inventory (an Excel file). The scan file is appended to the change list using the "Open Data File" button and then the inventory database is updated using the "Update Database" macro button. The instrument inventory and change action documentation procedure for calibration, removal, repair, replacement or maintenance are given in Appendix J. The scanning/recording of actions can be performed by the field technician performing the action (repair, calibration, etc.) The database maintenance/update procedure is detailed in Appendix K. The database update and maintenance can only be carried out by the Head of Meteorological Services or the Meteorological Services Operations Officer. This is to maintain the database integrity. The only "official" copies of the database will reside on the Meteorological Services Control Computer (this is the main file) with copies available on the computer of the Head of Meteorological Services and the computer of the Meteorological Operation Officer. Any changes to the database should be followed by updating of the two copies.

Appendix A Meteorological Services Sensors

Equipment Description	Vendor	MODEL	LOCATION	PROJECT ID
Barometric pressure sensor 0-5VDC output	R.M. Young	61302V	2-meter tower	Met
Barometric pressure sensor 0-5VDC output	R.M. Young	61302V	2-meter tower	Met
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 1	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 2	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 3	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 4	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 5	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 6	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 7	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 8	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 9	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 10	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 11	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 12	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 13	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 14	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 15	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 16	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 17	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 18	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 19	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 20	PV

Equipment Description	Vendor	MODEL	LOCATION	PROJECT ID
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 21	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 22	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 23	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 24	PV
Fast Response Copper Tip RTD - 100 Ohm	Omega	PRCU-10-2-100-1/4-6-e	Inverter box 25	PV
Marine grade wind monitor (speed & direction)	R.M. Young	5106	M85	PV
Marine grade wind monitor (speed & direction)	R.M. Young	5106	M85	PV
Marine grade wind monitor (speed & direction)	R.M. Young	5106	M50	Met
Marine grade wind monitor (speed & direction)	R.M. Young	5106	M50	Met
Marine grade wind monitor (speed & direction)	R.M. Young	5106	M10	Met
Marine grade wind monitor (speed & direction)	R.M. Young	5106	M10	Met
Pyranometer - high performance research grade	KIPP & ZONEN	CMP 22	Solar Base Station (490)	PV
Pyranometer - high performance research grade	KIPP & ZONEN	CMP 22	Solar Base Station (490)	PV
Pyranometer - high performance research grade	KIPP & ZONEN	CMP 21	Replaces CMP 22	PV
Pyranometer - high performance research grade	KIPP & ZONEN	CMP 21	Replaces CMP 22	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 1	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 1	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 1	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 1	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 2	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 2	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 3	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 3	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 4	PV

Equipment Description	Vendor	MODEL	LOCATION	PROJECT ID
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 4	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 5	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 5	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 5	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 5	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 6	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 6	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 7	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 7	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 8	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 8	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 9	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 9	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 10	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 10	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 10	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 10	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 11	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 11	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 12	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 12	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 13	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 13	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 13	PV

Equipment Description	Vendor	MODEL	LOCATION	PROJECT ID
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 13	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 14	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 14	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 15	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 15	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 16	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 16	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 17	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 17	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 18	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 18	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 18	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 18	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 19	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 19	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 20	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 20	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 20	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 20	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 21	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 21	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 22	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 22	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 23	PV

Equipment Description	Vendor	MODEL	LOCATION	PROJECT ID
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 23	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 23	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 23	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 24	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 24	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 25	PV
Pyranometer - solar radiation sensor	KIPP & ZONEN	SP Lite2	inverter box 25	PV
Pyrgeometer	KIPP & ZONEN	CGR 4	Solar Base Station (490)	PV
Pyrheliometer	KIPP & ZONEN	CHP 1	Solar Base Station (490)	PV
Rain guage	Nova Lynx	260-2500E-12	Solar Base Station (490)	Met
Rain guage	Nova Lynx	260-2500E-12	Solar Base Station (490)	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 1	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 2	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 3	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 4	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 5	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 6	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 7	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 8	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 9	PV
Relative humidity and temperature probe	Campbell	HMP45C	inverter box 10	PV
Relative humidity and temperature probe 0-1 VDC output	R.M. Young	41372VC	2-meter tower	Met
Relative humidity and temperature probe 0-1 VDC output	R.M. Young	41372VC	2-meter tower	Met

Equipment Description	Vendor	MODEL	LOCATION	PROJECT ID
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 1	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 2	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 3	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 4	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 5	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 6	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 7	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 8	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 9	PV
Soil temperature probe (thermistor)	Campbell	109SS-L	inverter box 10	PV
Sun tracker	KIPP & ZONEN	Solys-2	Solar Base Station (490)	PV
Temperature probe 0-1 VDC output	R.M. Young	41342VC	M10	Met
Temperature probe 0-1 VDC output	R.M. Young	41342VC	M10	Met
Temperature probe 0-1 VDC output	R.M. Young	41342VC	M50	Met
Temperature probe 0-1 VDC output	R.M. Young	41342VC	M50	Met
Temperature probe 0-1 VDC output	R.M. Young	41342VC	M85	Met
Temperature probe 0-1 VDC output	R.M. Young	41342VC	M85	Met
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 1	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 2	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 3	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 4	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 5	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 6	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 7	PV

Equipment Description	Vendor	MODEL	LOCATION	PROJECT ID
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 8	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 9	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 10	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 11	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 12	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 13	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 14	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 15	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 16	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 17	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 18	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 19	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 20	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 21	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 22	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 23	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 24	PV
Thermistor	Omega	SA1-TH-44006-120-T	inverter box 25	PV
Total Sky imager	Yankee (YES)	TSI-880	inverter box 5	PV
Total Sky imager	Yankee (YES)	TSI-880	Solar Base Station (490)	PV
Total Sky imager	Yankee (YES)	TSI-880	Inverter box 19	PV

Appendix B

Brookhaven National Laboratory
R.M. Young Model 41342VC Temperature Sensor
Omega model PRCU-10-2-100-1/4-6-e
R.M. Young Model 41372VC Temperature/Rh Sensor
Campbell HMP45C Temperature/Rh Sensor
Temperature Calibration Data Sheet

Date:_____________ Technician:_____________________

Equipment:

1. NIST traceable thermometer (±0.1C)
2. Necessary tools to gain access to the temperature sensor
3. Temperature bath capable of maintaining temperatures in the range -10°C to 35°C at ±0.1°C and ±0.01°C stability.
4. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded.

Applicability:

This procedure applies only to RTDs and to models RM. Young 41372VC and R.M. Young 41342VC (capable of ±0.1°C accuracy and 0.01°C resolution; for tower temperatures used in stability class determinations), Omega PRCU-10-2-100-1/4-6-e and Campbell HMP45C (capable of ±0.5°C accuracy and 0.1°C resolution; for standard air temperature).

Procedure:

The thermometer is calibrated by comparison with a reference or standard thermometer in a thermally stabilized bath. The procedure uses a four point calibration consisting of -10°C, 5°C, 20°C and 35°C as follows;

1. Remove the temperature sensor and bring it to the Meteorology Lab (Met lab)
2. In the Met lab, connect the sensor to the appropriate data logger (CR3000 or CR1000 to match the field unit)
3. Scan (see Appendix J) and record the barcode number of the sensor/group B/C=_______________
4. Place the sensor into the temperature bath along with the reference thermometer.
    a. Note: the combination Rh/temperature probes must be placed in a test tube sheath before immersion. This is required to avoid soaking the humidity sensor. This results in a dry well type calibration and greater time should be given to allow equilibration to occur.
5. Set the temperature bath to -10°C.

6. Wait until the temperature bath is stabilized and document both the reference reading and test unit reading on the calibration form below.
    a. Take three measurements one minute apart
7. Repeat step 4-5 for 5°C, 20°C and 35°C.
8. If temperature sensor fails to meet the required precision (for stability class measurements; corrected ±0.1°C or uncorrected ±0.5°C, all others corrected ±0.5°C) it must be taken out of service.
9. Complete the calibration sheet, sign and place the sheet into the Instrument Calibration Log Book.

Temperature Bath Set point (°C)	**Reference Thermometer Reading (°C)**	**Test sensor Reading (°C)**
-10		
-10		
-10		
Average=		
Std. Dev.=		
5		
5		
5		
Average=		
Std. Dev.=		
20		
20		
20		
Average=		
Std. Dev.=		
35		
35		
35		
Average=		
Std. Dev.=		

BNL B/C ______________

Sensor ☐Passed ☐Failed

____

Inspector's signature

Notes/Observations:____

____

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Appendix C

Brookhaven National Laboratory
Relative Humidity Calibration Data

Date:______________ Technician:_______________________

Equipment:

Humidity calibration containers with:

1. Saturated NaCl solution (75.5% Rh @ 20°C)
2. Saturated NaBr solution (59.1% Rh @ 20°C)
3. Saturated MgCl solution (32.8% Rh @ 20°C) [Note: Solutions should be allowed to equilibrate for at least one hour in the calibration laboratory before beginning procedure]
4. Calibration container covers appropriate for the probe being calibrated (one hole for Campbell, two holes for R.M. Young)
5. CR3000 data logger connected to Calibration Laboratory computer
6. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded.

Procedure:

1. Remove the sensor and bring it to the Meteorology Lab (Met lab)
2. In the Met lab, connect the sensor to the appropriate data logger (CR3000 or CR1000 to match the field unit)
3. Scan (see Appendix J) and record the barcode number of the sensor/group B/C=________________
4. Check each of the solutions for proper liquid level, if level is OK go to step 6.
5. Add distilled water or remove solution to obtain the proper liquid level (to the fill line).
6. Check that there are excess salts in each solution. (undissolved salts should be visible at the bottom of the container. If salts are visible go to step 9.
7. Add salts and stir. If salts are still not visible repeat additions until excess salts are visible.
8. Allow solutions to equilibrate for 30 minutes and go to step 4.
9. Remove the storage cover from the container with the MgCl solution.
10. Put on the appropriate calibration cover (one that fits the probe) on the container.
11. Gently insert the Rh probe through the hole until the probes stops. **(Make certain the probe does not contact the liquid).**
12. Allow the system to equilibrate for at least 60 minutes.
13. Once equilibration has been reached take three consecutive readings five minutes apart and record the results in Table 1 below.
14. Repeat Steps 9-13 using the NaBr solution
15. Repeat Steps 9-13 using the NaCl solution
16. Compare the measured Rh values to the equilibrium Rh values (see Equipment section above or table in ASTM E104-02)

17. If the values agree within ±4% the sensor passes. If the values do not meet the ±4% requirement, the sensor fails and must be taken out of service.

Solution	Measured Rh	Temperature
MgCl (Rh=32.8%)		
Average		
Standard Deviation		
NaBr (Rh=59.1%)		
Average		
Standard Deviation		
NaCl (Rh=75.5%)		
Average		
Standard Deviation		

BNL B/C ______________

Sensor ☐Passed ☐Failed

____
Inspector's signature

Notes/Observations: ____

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Appendix D

Brookhaven National Laboratory
Tipping Bucket Rain Gauge Calibration Data
(Model 260-2500E-12)

Date: __________ Technician: _____________________

Equipment:

1. 250 mL graduated cylinder, analytical balance and/or calibrator bottle
2. Squeeze/wash bottle (500 mL capacity) filled with tap water
3. NovaLynx Calibration Assembly (model 260-2595), which includes: a one quart calibrated bottle (has a black fill mark labeled 946mL), a circular water dispenser base plate, plastic fitting with a 1/16" orifice and a 10 cc syringe
4. NovaLynx Users Manual for Tipping Bucket Rain Gauge Model 260-2500E-12
5. 2.7 L plastic container (Dimensions: 11.0" W x 8-1/4" L x 2.0" H)
6. Paper Towels
7. Needle Nose pliers (small and medium size long nose pliers)
8. NovaLynx electronic rain gauge tip counter
9. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded
10. Excel spreadsheet "Excel Template_Tipping bucket Rain Gauge_2011"

Pre-Calibration Procedure:

1. If not already done, disconnect the 115 AC power cord.
2. Scan (see Appendix J) and record the barcode number of the sensor/group B/C=__________
3. (See Users Manual drawing no. 10000341, "Assembly, 8" Electrically Heated Rain Gauge"). Using the pliers, carefully remove the two screens located inside the 12" diameter funnel. The larger screen sits inside the top portion of the funnel (11-1/2" diameter) and the smaller screen (1-5/8" diameter) covers the funnel drain opening located inside the funnel by the drain stem. Clean the screens of debris and wash if necessary.
4. Next, gently lift the funnel out of the rain gauge housing (white cylindrical metal housing) being careful not to pull too aggressively on the wires connected to the thermostat switch.
5. Carefully disconnect the 2-prong plug attached to the thermostat switch, which is secured to the thermostat mounting bracket and lift the funnel out of the rain gauge housing.
6. Using a damp paper towel clean the funnel ensuring that the funnel stem is free of any debris eliminating any potential for clogging. Do not re-connect the thermostat electrical cable at this time, rather take masking tape and fasten

wire/connection to the exterior of funnel wall so that it doesn't interfere with the tipping bucket during operation/calibration of the rain gauge.

7. Remove the white cylindrical housing surrounding the rain gauge base using a 5/16" nut driver (three screws). Use a damp paper towel and clean the exterior of housing.
8. While the housing is removed clean the top surface of the base with a damp paper towel (be careful to avoid contacting electrical components) and then refasten the housing to the base.
9. Next, observe the tipping buckets making sure they are free of debris and gently clean with a Kimwipe.
10. Below each tipping bucket is a drain tube which is covered with 1-5/8" diameter protective metal screen. Remove the screens and clean as necessary. Caution! Prior to removing the metal screens, remove the small inner funnel (approximate dimensions: 1-1/2" Dia. X 1-1/2" H), which is centrally positioned over the tipping buckets, but not secured to the frame of the rain gauge. After cleaning reposition the metal screen in each of the drain tubes.
11. Once all the cleaning around the tipping buckets is completed reposition the inner funnel (after cleaning), place the large funnel back into the rain gauge housing (do not connect 2-pronged plug at this time) and begin the calibration.

Calibration Procedure:

1. Read entire procedure before commencing.
2. Place the 2.7 L plastic container (11" W x 8-1/4" L x 2" H) below the rain gauge frame (specifically below tipping bucket drain tubes to catch the water). The container will slide under the rain gauge frame and the mounting feet. Using the bulls-eye/bubble level, ensure that the rain gauge is level adjusting the leveling feet as necessary.
3. Prior to initiating the calibration one must determine what method will be used to "count the number of bucket tips." There are several options; (a) Count the bucket tips manually by listening for the sound of the bucket hitting the bucket stop (b) use a computer aided interface/software package, e.g., Lab1000 to electronically count the tips or (c) use the pocket-size digital event counter supplied by the manufacturer, which can also be wired to the rain gauge permitting electronic bucket tip counting.
4. Take the plastic calibrator bottle and fill with tap water to the ***black fill mark line*** on the neck of the bottle that is labeled 946 mL (or weigh 938.6 g of tap water). Another option is to use a graduated cylinder and accurately add 946 mL of tap water to the calibration bottle. [946.3 mL should produce 0.51" rain equivalent, each 18.55 mL should yield one bucket tip, which equals 0.01" rain equivalent. This should result in a final tip count of 51 at the end of any given run]
5. Wet the gauge thoroughly allowing water to flow through the gauge prior to starting the test. Wetting the gauge surfaces compensates for the water that adheres to gauge surfaces potentially causing small error in counts.
6. With the calibrator bottle filled with 946 mL of tap water, invert the base assembly (with nozzle length of 5/16" and orifice diameter = 1/16" i.d., Nova

Lynx part # 16000202) carefully thread the bottle to the plate. Do not cross-thread or over tighten the plastic bottle to the base plate. [The orifice supplies water at steady rate equaling one to six inches of precipitation equivalence per hour).

7. Next, the entire assembly will be placed onto the rain gauge funnel with the orifice facing downward so that the water flows out of the orifice and into the funnel.
    a. Take the entire base plate/bottle assembly in hand and place it over the funnel.
    b. ***<u>Quickly and gently invert the entire assembly</u>*** avoiding any splashing (This may require a few practice trials prior to the first calibration attempt). **NOTE: Inversion of the assembly *<u>initiates</u>* the calibration**.
    c. Intiate counting of bucket tips
    d. Record start time in the appropriate row of column G in the spreadsheet.
8. Confirm that the bumper pads on the base plate are resting firmly against the rain gauge funnel surface and that the calibrator bottle is sitting plumb in the funnel.
9. Once water flow ceases, gently lift the calibration bottle/plate assembly vertically inside the funnel (1-3") ensuring all the water has been dispensed into the rain gauge funnel via the orifice. If the water is still streaming or dripping from the orifice place the assembly back onto the funnel until flow has stopped.
10. Some water will remain in the dispenser portion of the calibrator. To remove and collect this water, hold the calibrator assembly over the rain gauge funnel and tip the bottle so that the residual water spills out of the slot in the dispenser and falls into the funnel. This can be accomplished by rotating the calibrator slowly and shaking the assembly moderately to release the water remaining inside the dispenser. Caution! Avoid contacting or bumping the rain gauge inadvertently, thus preventing accidental activation of the tipping bucket.
11. Record the number of bucket tips in the appropriate row of column B in spreadsheet.
12. Record the stop time in the appropriate row of column H in the spreadsheet.
13. Next, *<u>carefully</u>* remove the large funnel (11-1/2" diameter) and check the tipping buckets for potential water collection.
14. If water remains in one of the tipping-buckets fill the 10 cc syringe with tap water and determine how many additional milliliters of water are necessary to produce another tip of the bucket.
    a. Slowly dispense the water via the syringe into the inner-centering funnel (located where the larger funnel stem dispenses the water) located directly over the tipping bucket. Add the water from the syringe at a reasonable rate and slow down the water addition when the bucket approaches being full.
    b. If necessary, fill the 10 cc syringe a second time and slowly dispense the water until the bucket tips.
    c. Record the total volume (mL) in the appropriate row of column C in the spread-sheet.
15. Repeat this procedure from step four until a total of five runs is complete. Remember to <u>empty</u> the 2.7 L plastic container after <u>each</u> calibration run.

16. If the results are within ±3% of the expected volume (946.3 mL ±28.4 mL) the calibration is complete. If the results are outside the 3% accuracy requirement the following procedure must be used to adjust the tipping bucket calibration and bring it within specs.

Adjusting the Tipping Bucket Calibration Screws

1. Take the 10 cc syringe and measure the volume of water required to trigger each bucket to tip (target volume = 18.55 mL). This is a rough estimate for a single tip and is an indicator of how closely the calibration post screw may be to the position needed for the bucket to tip. Record volumes on spreadsheet.
2. Make adjustments to the bucket stop calibration screws by turning the tip bucket post screw. Only turn the screws small amount for each adjustment. Use turns of ⅛ to ¼ of full rotation per adjustment.
    a. Moving the bucket stop upward decreases the amount of water required to tip the bucket and results in a higher number of tips per volume of water. Conversely, moving the bucket stop downward increases the amount of water required to tip the bucket and results in a lower tip count per volume of water.
    b. Note, that the bucket stop screws/calibration adjustment screws are the screws that the tipping buckets rest on top of after it tips and dumps the tap water. Important, ***the screw is on the opposite side of the gauge from the bucket it affects***.
    c. This model gauge has nylon screws where the bucket rests on the end of the nylon screws. Remember to lock the screws into place at the end of each adjustment.
3. Repeat steps One and Two until the desired results are obtained (each bucket at 18.55 mL or 51 tips for 946.3 grams of water)
4. After the rain gauge adjustments, run the calibration test again.

BNL B/C _____________

Attach a printout of the final Excel spreadsheet to complete the report.

Notes/Observations:____

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Exhibit D1 Facsimile of Excel spreadsheet

Tipping Bucket Rain Gauge Calibration Results

Calibration Date: ____________________

Calibration Location: ____________________

Rain Gauge Information

Manufacturer: NovaLynx Corporation

Style: 12" Heated Rain Gauge

Model: 260-2500E-12

S/N:

Calibration Information

Standard rain gauge calibration volume = 0.01" or 18.55 mL

Suggested flow rate 1 mL/sec

Accuracy of the calibration in the LAB ±3% and FIELD ±5% of the volume at 1" to 6" of precipitation per hour

Tipping Bucket Rain Gauge Calibration Using Large Volume of Tap Water (946 mL Total)

1 Quart of tape water = 946.3 mL

0.01" = 18.55 mL = 1 Tip

946.3 mL/18.55 mL/tip = 51.02 Tips or 0.51" (51.02 tips x 0.01"/tip)

Determining the Volume of Water Needed for One Bucket Tip Using a 10cc Syringe

Left Tipping Bucket Volume: ________ mL ***Right Tipping Bucket Volume: ________ mL***

A	B	C	D	E	F	G	H		I
Calibration Run #	Number of Tips	Volume of H_2O Added to Tipping Bucket, (mL)	Water Volume Difference[(1)] (mL)	Volume of Water Needed for Tip Correction[(2)]	% Error[(3)] mL	Calibration Test			Total Time to Dispense H_2O (min)
						Start Time	End	Time	
1									
2									
3									
4									
5									
			Mean						
			% Error						

[(1)]18.55 mL - Column "C" mL)

[(2)]Tip correction compared to expected number of tips - 51 tips (946.3 mL); 946.3 mL ("B" x 18.55 mL + "D")

[(3)]Plus/minus target volume of 946.3 mL; (946.3 mL -"E"/946.3 mL x 100)

Notes/Observations: ____

Appendix E

Brookhaven National Laboratory
ETNA Accelerograph System Check
[IP is 130.199.118.151, baud rate=19200]

Date of Check ________________ **Time** _______________

Inspector ________________ **L/N** _______________

Equipment – Digital multimeter and laptop

Step 1 Functional Test & Sensor Response Test

To perform a **Sensor Response Test**, open the Terminal window:

Enter **AQ OFF - response should be "Serial data streaming stopped"**
Enter **AQ SRT – response should be "Filling buffer…Writing frame"**
Enter **AQ ON – response should be "Starting Aq….Serial data streaming enabled"**

Retrieve the event files generated by these tests, then use **QuickLook** to make sure the records look correct. If they do, you have confirmed that the system can trigger and that the sensors are operational. [Go to date in ALTUS directory; retrieve EVT files]

Files written (Y/N) ________
File looks OK (Y/N) ________

Step 2 Checking Sensor Offsets

Check the sensor offsets by looking at the functional test record, or

Enter **AQ DVM** in the Terminal window

```
* aq dvm    Press 'C' to clear accelerometer offset voltage
            Press 'S' to toggle accelerometer step voltage
            Press 'Z' to zero, or press any other key to quit.

            1: -0.080 0.231 0.854
```

ENTER OFFSETS _______ _______ _______
X **Y** **Z**

If the offset exceeds ± 25mV adjust the EpiSensor accelerometer offsets. The procedure for adjusting the offset is described in Chapter 2 (pg 26) of the users manual.

Step 3 Checking System Restarts

Enter **STA** in the Terminal window to check on the system status.

The system displays a message similar to this:

Status for Recorder S/N 675 Restart Counts: 235 (reset status: 80)
Restart Time: Apr 17, 1997 19:30:52.000
Current Time: Apr 17, 1997 19:51:37.000 (GPS)
GPS: ON
Events: 2 (Errors: 0)
Acquisition: ON (NOT TRIGGERED)
Alarm: NOT TRIGGERED
Battery: 13.0 V
Temperature: 32.2 C
PEM Banks: 1
Drive A: 20 MB FREE B: NOT READY
*

Compare the entry in the Restart Counts field with the count at your last maintenance visit. Each time the reset count is incremented, it means the system went through a reset due to either loss of power or some other event. The cause of the last reset is shown as the reset status.

Be aware of these two codes:

> Code 80H indicates either the power to the recorder was turned off or the recorder lost power. If you didn't turn off the power, this means the recorder probably lost power for a long-enough time to discharge the battery backup. You should investigate why this happened.
>
> Code 20H indicates the recorder reset itself, from either a software watchdog reset or a user-initiated system reset. If the recorder resets itself frequently, it may have a hardware problem and you should contact Kinemetrics Technical Support.

Step 4 Checking System Voltages

From the QuickTalk Terminal window, enter **DG** to start Diagnostics Mode.

When you see the Diagnostic Prompt (DG>), enter **ADC**.

The unit displays a sequence similar to this:

Starting CPU16 ADC... Press any key to abort
13.490V [1] 000H [2] 27.761C [3] 000H [4]
14.118V [5] 000H [6] 000H [7]

Check whether the numbers on your screen fall within the acceptable ranges shown below.

Variable [1] Switched voltage; range 0-20VDC; **Minimum = 10.5; Maximum = 14**
Variable [2] ignore not used
Variable [3] Temperature; range -39 to +89° C; **Minimum = -20°C; Maximum = +70°C**
Variable [4] ignore not used
Variable [5] Charger voltage; range 0- 14.2VDC; **Minimum =13.5VDC; Maximum = 14.2 VDC**
Variable [6] ignore not used
Variable [7] ignore not used

Is Switched voltage within min/max (Y/N) __________ Value __________

Is Temperature within min/max (Y/N) __________ Value __________

Is Charger voltage within min/max (Y/N) __________ Value __________

If the Etna is operating correctly, all the voltages should be within the limits shown above. If the voltages are too high or too low, the unit requires service. If the charger voltage is too low, there might be a failed power supply or insufficient AC power. If the internal or external battery is too low, their might be a charger or an AC power failure. Press any key to return to Diagnostics Mode. Type Q or quit to leave diagnostic mode.

On-site test physical inspection

Check battery with AC adapter unplugged. After several minutes does battery voltage remain above 11.7VDC (Y/N)? _________

Desiccant check – Is 50% humidity indicator blue or pink? _________
If blue desiccant is good, if pink replace.

Final check

Power cord is plugged in (after battery check) □

Cover replaced and fasteners secured □

Quit diagnostic mode □

Acquisition restarted (**AQ ON**) □

System check complete ____
Inspectors signature Date

Appendix F

Brookhaven National Laboratory
Omega model SA1-TH-44006-120-T Thermistor
Temperature Calibration Data Sheet

Date:_____________ Technician:_____________________

Equipment:

1. Calibrated Infrared (IR) temperature sensor
2. Access to the CR3000 data logger to get thermistor readings
3. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded.

Applicability:

This procedure applies only to Omega model SA1-TH-44006-120-T Thermistors as mounted on PV panels at the LISF. This procedure requires two people; one to read and record the thermistor temperature using the IR sensor and the other to simultaneously read and record the panel thermistor temperature from the seconds data table of the CR3000.

Procedure:

1. This procedure shall be performed on sunny or mostly sunny days only. This provides the greatest range in panel temperature.
2. Check that the calibration of the IR temperature sensor is current
3. Scan (see Appendix J) and record the barcode number of the sensor/group B/C=_______________
4. Place the IR sensor such that the cone covers the thermistor and the thermistor itself is centered in the cone.
5. Press the measurement button on the IR sensor
6. Record the temperature reading of the IR sensor in the table below.
7. Record the thermistor reading, taken from the seconds table of the CR3000 data logger, in the table below.
8. Repeat Steps 2-4 until four readings are obtained
9. Repeat steps 2-5 in the am, near the solar zenith and in the pm.
10. If the thermistor temperature reading differs from the IR reading by more than 1 degree + 1% from the corrected thermistor reading the thermistor must be replaced.

Temperature Location	IR Thermometer Reading (°C)	Thermistor Reading (°C)
AM Time = ____________		
Mid-Day Time = ____________		
PM Time = ____________		
Average =		
Standard Deviation =		

BNL B/C ____________

Sensor ☐Passed ☐Failed

____
Inspector's signature

Notes/Observations:____
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Appendix G **Daily Instrument Check Log Sheet**

Technician ____________________________ Date________________________

85-meter tower

M85 reporting	Temp	☐	Wind speed	☐	Wind direction	☐
M50 reporting	Temp	☐	Wind speed	☐	Wind direction	☐

10-meter tower

2 M reporting	Temp	☐	Rh	☐	Aspirator fan	☐	Pressure	☐
10M reporting	Temp	☐	Wind speed	☐	Wind direction	☐		

Solar Base Station (490D)

TSI imaging ☐ TSI Clock Check ☐ shaded CMP-22 ☐ Aspirator fan shaded CMP-22 ☐

unshaded CMP-22 ☐ Aspirator fan unshaded CMP-22 ☐ CGR-4 ☐ Aspirator fan CGR-4 ☐

CHP-1 ☐ MFR-7 ☐ SP-lite-2 horizontal ☐ SP-lite-2 angled ☐

LISF

Box 1 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 2 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 3 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 4 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 5 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 6 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 7 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 8 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 9 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 10 reporting	PRT	☐	Panel	☐	Pyranometers	☐	Soil T1	☐	Soil T2	☐	T/Rh	☐
Box 11 reporting	PRT	☐	Panel	☐	Pyranometers	☐						
Box 12 reporting	PRT	☐	Panel	☐	Pyranometers	☐						

Box 13 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 14 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 15 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 16 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 17 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 18 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 19 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 20 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 21 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 22 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 23 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 24 reporting	PRT	☐	Panel	☐	Pyranometers	☐
Box 25 reporting	PRT	☐	Panel	☐	Pyranometers	☐
TSI #1 imaging	☐	TSI clock check		☐		
TSI #2 imaging	☐	TSI clock check		☐		
TSI #3 imaging	☐	TSI clock check		☐		

Inspected by ____________________________ Date________________________

Notes/Observations:____

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Appendix H Meteorological Measurement requirements

Measurement [a]	**Units** [b]	**Accuracy (±)** [c]	**Resolution** [d]
Wind Speed	Meters per second	0.2 or 5% of observed wind speed	0.1
Standard Deviation of Wind Speed Sigma-ν (horizontal) Sigma-ω (vertical)	 Meters per second Meters per second	 n/a [e] n/a	 0.01 0.01
Wind Direction Horizontal Vertical	 degrees azimuth degrees elevation	 5 5	 1.0 0.1
Standard deviation of horizontal wind direction fluctuations Sigma theta (or sigma-α)	degrees azimuth	n/a	0.1
Standard deviation of vertical wind direction fluctuations Sigma phi (or sigma-e)	degrees elevation	n/a	0.1
Air temperature	Degrees Celsius	0.5	0.1
Vertical Air temperature difference Delta T	Degrees Celsius	0.1	0.01
Dew point temperature	Degrees Celsius	1.5	.1
Wet-bulb temperature	Degrees Celsius	0.5	0.1
Relative humidity	Percent	4	0.1
Barometric pressure	Millibars or hectopascals	3	0.1
Precipitation	Millimeters	10% of volume [f]	0.25
Solar/terrestrial radiation	Watts/meter^2	10 5% of observed	1 1
Soil temperature	Degrees Celsius	1	0.5
Soil Moisture	Percent	10% of actual	1
Time	Minutes	5	1

[a] For measurements that are not listed, accuracy should be based on the manufacturer's guidance.
[b] Other measurement units (e.g., miles per hour, degrees Fahrenheit, inches, hours) may be used to be consistent with monitoring program objectives.
[c] These are both system accuracy and sensor accuracy values. The system accuracy encompasses all components impacting system accuracy (i.e., sensors, data processing equipment, computer, calibrations, etc.). The sensor accuracy applies to the manufacturer's instrument specification. If calculations described in 7.1 indicate that the system accuracy is not adequate, a sensor with an accuracy.

better than that listed below may be required. [d] Recommended resolutions are based on the recommended units. [e] n/a = not applicable [f] Accuracy is for volume equivalent to 2.54-mm precipitation and rate <50 mm/h.

Appendix I

Brookhaven National Laboratory
TSI-880 Total Sky Imager
Monthly Maintenance Procedure

Date:_____________ Technician:_____________________

Equipment:

1. Non-abrasive window cleaner (i.e., Windex)
2. Soft, clean cloth
3. Automotive paste wax
4. Digital multimeter
5. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded.

Applicability:

This procedure applies Total Sky Imagers, model TSI-880 manufactured by Yankee Environmental Systems, Inc.

Procedure:

1. Scan (see Appendix J) and record the barcode number of the sensor/group B/C=_______________
2. Clean the mirror with window cleaner and dry with cloth (make certain all debris is removed from the mirror).
3. Apply wax and (Avoid getting wax on shadowband) polish mirror. (make certain are no visible smears).
4. Check the imager lens and filter and clean if needed.
5. Check and adjust as needed the shadowband to ensure it is blocking the sun.
6. Check the shadowband for pealing or cracking, if either are visible the shadowband must be replaced
7. Check the battery voltage.
    a. Open the enclosure by unclipping the fasteners.
    b. With the TSI on, measure the voltage across the red (positive) and Black (negative) battery terminals.
    c. Voltage should be approximately 13.1 VDC
    d. Unplug the TSI and disconnect the positive lead to the battery
    e. Repeat the voltage measurement across the battery terminals
    f. If the voltage reads approximately 12.4 VDC to 13.1 VDC the battery is OK, if not the battery must be replaced.

Battery ☐Passed ☐Failed

BNL B/C _____________

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Inspector's signature

Notes/Observations:____

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Appendix J

Brookhaven National Laboratory
Meteorological Instrument Inventory Update and Change Action Documentation Procedure

Equipment:

1. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded.
2. Meteorological Instrument Network Inventory Maintenance and Update Procedure

Applicability:

This procedure is required to fully document any actions taken on any sensor or piece of equipment that is included in the BNL Meteorological Instrument Inventory. Any piece that has a Met Services Bar-code number on it is included in the inventory. Actions are any calibration, removal, repair, replacement or maintenance or other procedure that could affect the calibration or operation of a sensor. Non-calibrated equipment is included as it could affect the sensor (e.g., the sun tracker that sensors are mounted on, the data loggers collecting sensor data).

Procedure:

1. Check battery status of scanner, if OK continue otherwise charge scanner.
    a. Press power on button and hold until unit beeps.
    b. Using the up and down arrow keys highlight "3. Utilities" the on screen menu and press either of the blue buttons.
    c. When the next menu appears choose "7. RAM, Power"
    d. Batt voltage Main: should be ~4.36V and Backup: should be 3.2V, if not recharge the unit.
2. Use the ESC key return to the main menu and make sure the date/time displayed are correct.
    a. If the date/time are not correct, select "3. Utilities", followed by "5. Set Date & Time".
    b. Press 2 to enter "set" mode and enter the year, month, day, hour, minute, second.
    c. Press ESC twice to return to the main menu.
3. Select "1. Collect" and choose the appropriate action from the menu.
    a. To add/remove items which are associated with a group barcode, choose Add Group Item or Remove Group Item. A "Scan Group ID" prompt will appear.
        i. Scan the group ID barcode. An "Add Item:" prompt should appear followed by "Group ID:" with the corresponding group number.
        ii. Scan each item to add/remove from the selected group; there is no need to rescan the group code between items.

        iii. When finished scanning, press ESC to return to the data collection menu and again to return to the main menu.
    b. To add/remove individual items, select Add Item or Remove Item. An "Add Item:" or "Remove Item:" prompt will appear.
        i. Scan each item to add/remove.
        ii. When finished scanning, press ESC to return to the main menu.
    c. To replace an item, choose Replace Item.
        i. At the "Current Item:" prompt, scan the item to be removed from service. A prompt for "New Item:" will appear.
        ii. Scan the replacement item (item going in to service). The scanner will return to the data collection menu.
    d. To update the calibration dates for an item, select Update Calibration Date.
        i. Scan each item to update its calibration date to the current date.
        ii. When finished, press ESC to return to the main menu.
    e. To update a maintenance date for an item, select Maintenance.
        i. Scan each item.
        ii. When finished, press ESC to return to the main menu.
4. When finished scanning all items to be modified, the scanner data should uploaded to the Control computer to update the Network Inventory Database. (See Appendix K)

Appendix K

Brookhaven National Laboratory
Meteorological Instrument Network Inventory
Database Maintenance and Update Procedure

Equipment:

1. Master Excel file; “BNL Meteorological Instrument Network Inventory_master”
2. Meteorological Services main control computer [Note: this is the computer used to display current sensor data and used for the daily instrument inquiries].
3. Hand-held Scanner [Cipher Lab model 8000] containing Met Services calibration/repair program and the scan file.
4. Cipher Lab USB communications docking cradle connected to control computer.

Applicability:

This procedure is used to update the master inventory list that tracks all BNL Meteorological Instrument Network sensors/equipment. It can only be performed by the Head of Meteorological Services or the Meteorological Services Operations Officer. There are three official copies of the inventory; one on the Control computer, one on the computer of the Head of Meteorological Services and one on the computer of the Meteorological Services Operations Officer.

Procedure:

1. In Excel, open the file “BNL Meteorological Instrument Network Inventory_master”.
2. Make certain the Cipher Lab USB communications docking cradle is plugged in and connected to the Control Computer.
3. Open the Forge AG 8000 program on the Control Computer (this is the programming, down loading, etc utility program for the scanner.
4. Turn the scanner on by pressing and holding the power key until the scanner beeps.
5. Using the up and down arrow keys, highlight “2. Upload” on the on screen menu and select it by pressing either one of the blue buttons.
6. The screen should read “Connecting….Press ESC to cancel. (If the scanner only beeps no data was collected and the scan file does not exist).
7. Place the scanner into the cradle.
8. On the Control Computer, in Forge AG, choose “Get file via direct-link”.
9. A pop-up window should appear titled Data read Ver 1.23.
10. All of the left hand side check boxes should be checked (Add return character, add line feed, view data, always show this box and show messages in case of error).
11. All right hand side check boxes should be unchecked.
12. Choose a directory and fill in File name; use the default “datafile.TXT”.

13. Save mode should be overwrite.
14. Interface should be RS232/IrDA/USB VCOM. [Note Cradle-IR will also work]
15. COM port should be set to match the COM port of the cradle and baud rate to 115200.
    a. To check the cradle COM port, open Device Manager from the Control Panel and expand the Ports (COM & LPT) item.
    b. Look for Silicon Labs CP210X USB to UART Bridge; this will be followed by COMn, where n is the port number of the cradle.
16. Press OK.
17. A pop-up window should appear that reads, "Done XX records received. View the received data?"
18. Click yes.
19. The text file will be displayed in notepad. Verify the scan file is correct.
20. Close notepad and Forge AG.
21. Go to Excel, and chose the worksheet tab labeled "Update List".
22. Click on the Open Data File button.
23. A pop-up window will appear; go to the proper directory and choose the file "datafile.TXT".
24. A list of the items scanned should appear, along with the corresponding action for each. Verify that this list is accurate.
25. Click Update Database.
26. As changes are incorporated into the main inventory, they will be removed from the update list. If an error occurs and any items are left on the changes list when the process completes, these should be incorporated into the inventory manually.
27. The Change Log sheet will automatically be updated to include the changes made.
28. Verify that the changes have been properly incorporated onto the Inventory sheet.
29. Save the updated inventory file and make certain the remaining two master copies are also updated.

Appendix L

Brookhaven National Laboratory
Pyranometer, Pyrgeometer and Pyrheliometer
Dome Cleaning and Desiccant Maintenance Procedure

Date:_____________ Technician:_____________________

Equipment:

1. Isopropyl alcohol
2. Distilled/deionized water
3. Dish washing detergent (do not use soap) or Kodak Photoflo
4. Two laboratory squirt bottles
5. Lens paper/Lint-free cloth or paper [recommended: C3E wipes and Luminex Microfiber Cleaning Cloth from Electron Micropscopy Sciences]
6. Canned air (oil free compressed air or compressed gas for electronics cleaning) or camel hair lens brush [Ultra Brush from Electron Micropscopy Sciences]
7. Fresh small grain desiccant with color indicator (orange or blue)
8. Plastic wide mouth bottle for spent desiccant
9. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded.

Applicability:

This procedure applies to solar irradiance sensors that have glass/quartz domes covering the detector(s) including the following; Kipp & Zonen pyranometers models SP-Lite2, CMP-21, CMP-22 and CMP-11, Kipp & Zonen pyrgeometer model CGR-4 and Kipp & Zonen pyrheliometer model CHP-1.

Procedure:

1. Scan (see Appendix J) and record the barcode number of the sensor/group B/C=_______________
2. For the CMP-21, CMP-22, CGR-4 and CHP-1 Check the desiccant to see if it has changed color.
    a. The desicant canister is clear and can be visually inspected
    b. The original Kipp & Zonen desiccant pack changes from orange (good) to clear (spent). BNL re-filled canisters will change from blue (good) to red (spent).
3. If the desiccant is good, go to step 5.
4. If the desiccant is spent, replace the desiccant in the canister with fresh.
    a. Unscrew the desiccant chamber cover and remove the desiccant pack.

b. Dump the spent desiccant into the waste desiccant bottle.
c. Fill the canister with fresh desiccant.
d. Reinstall the canister.
    i. The rubber o-ring is coated with a silicon grease to improve the seal. If the rubber o-ring looks dry apply some grease to it (Vaseline will also do);
e. Check that the drying cartridge is tightly threaded into the radiometer body.

5. Prepare cleaning solution as follows:
    a. 1 drop dishwashing detergent (not soap!)(or Kodak Photoflo)
    b. 1/3 cup 99% Isopropyl alcohol
    c. 1 2/3 cup distilled water
6. Gently blow (using canned air) or brush (using Ultra Brush or equivalent) dust off dome
7. Using a squirt bottle and gentle pressure, rinse the dome with cleaning solution.
8. If dirt/spotting persist, wet the lens paper/lint free paper with cleaning solution then gently the rub dome to clean, else go to step 9.
9. Using a squirt bottle, rinse the dome with distilled/deionized water.
10. Rinse the dome with alcohol.
11. If dirt/spotting still persists go to step 8.
12. Rinse the dome with water
13. Using "canned air", blow dry the dome to remove any beads of water

BNL B/C _____________

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Technician's signature

Notes/Observations:____

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Appendix M

Brookhaven National Laboratory
SP2-Lite Pyranometer Calibration Summary Sheet

Date:_____________ Technician:____________________

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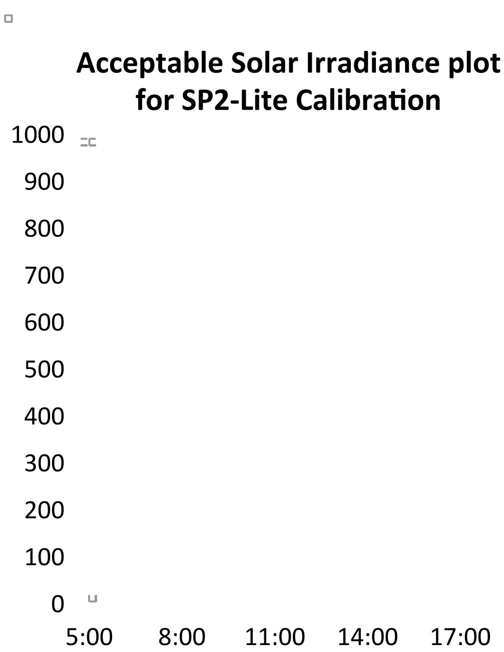
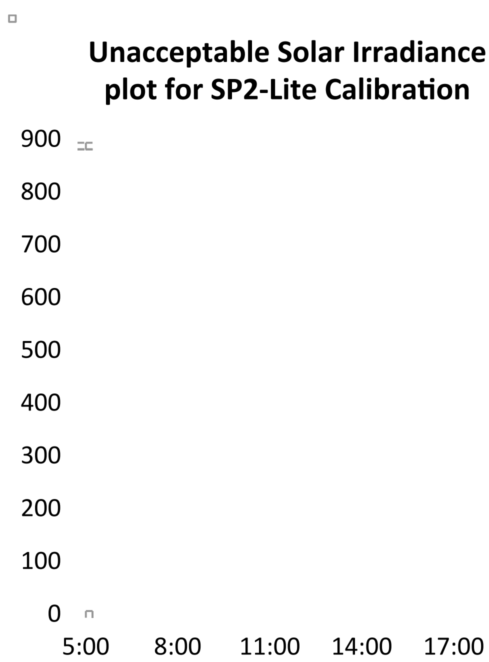
Technician’s signature

This page contains a summary of the calibration of field SP2-Lite pyranometers by comparison to three reference SP2-Lite pyranometers. The calibrations are carried out on the sensor platform on building 490D. the platform contains a rigid, ½” thick aluminum plate leveled to ±0.1°. the field pyranometers are placed side by side with the reference units and all are connected to the same data logger. When using a single CR3000 data logger, up to 25 field units can be calibrated per trial (The test plate can hold 35 units, which would require two CR3000s). The units are left on the calibration plate until at least one fully sunny day occurs. This requires a solar irradiance curve that is nearly cloud free from Zenith angle (Z) 30° < Z < 70°.





Date of data Collection _______________ Solar Noon_______________

Calibration File name (Excel)____

Plate Position	BNL barcode #	Original Sensitivity (uV/W/m^2)	Ratio Reference Reading/Sensor Reading	Corrected Sensitivity (uV/W/m^2)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17	**0069**			
18	**0011**			
19	**0072**			
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				

Attach plot of irradiance vs time for sensors and references.

Notes:____

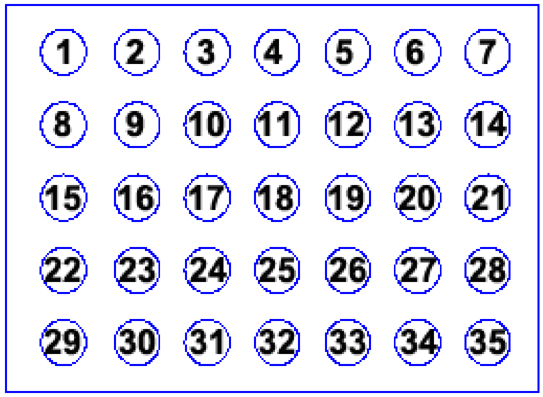


Figure 1 SP2-Lite calibration plate numbering sequence

Appendix N

Brookhaven National Laboratory
Campbell model 109SS-L Soil Temperature probe
Temperature Calibration Data Sheet

Date:______________ Technician:______________________

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Technician's signature

Equipment:

1. Calibrated hand held reference RTD and data logger
2. Access to the CR3000 data logger to get soil probe readings
3. Cipher lab model 8000 hand-held scanner with Met Services inventory program loaded.
4. Two pairs of water pump pliers to remove cap from thermal well should it be stuck.
5. CR 3000 manual (or training on how to read the temperature of the soil probe off the CR 3000 data logger).

Applicability:

This procedure applies only to buried soil probes for the LISF (Campbell model 109SS-L soil temperature probe). The measurements need to be performed on ten different days and it is preferred that some measurements be earlier morning and some late afternoon. A mix of sunny and cloudy days is also preferred. This is to get as large a range of temperatures in the comparisons as possible. Measurement days do not need to be consecutive and can be spread out over a month or more if this will increase the measurement range.

Procedure:

1. Check that the calibrations of the Reference PRT probe and hand-held data logger are current
2. Proceed to a power block and uncap the two thermal wells, one under the array and one in the walkway.
3. Place the RTD probe into the walkway thermal well, making certain it is pushed into the soil at the well bottom until the probe handle just touches the well casing.
4. Wait at least one minute for the temperature readout of the datalogger/RTD to stabilize

5. Record the temperature into the data sheet below and proceed to the Campbell 3000 datalogger.
6. Immediately go to the CR 3000 and record the temperature of the walkway soil probe into the sheet below.
7. Repeat the above for the under array thermal well and probe.
8. Repeat steps 1 to 7 for all ten power blocks.
9. Wait at least 24 hours and repeat this procedure until a minimum of ten days of data have been collected.
10. Plot the soil probe temperature versus RTD probe temperature for all 20 soil probes (all on one plot).
    a. Include regression analysis (with trend line) and r^2 value
11. Present data plots to Head of Met Service, who will then discuss them with the ecology/conservation PI.
12. Upon acceptance the plot and this sheet will be placed into the Met Services Calibration Notebook and the calibration dates updated in BNL Meteorology Instrument Network Inventory and change log.

Notes/Observations:____

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Long Island Solar Farm – Soil Temperature Probe Calibration Data Sheet

Power Block	Date / Time	1st Reading / /	2nd Reading / /	3rd Reading / /	4th Reading / /	5th Reading / /	6th Reading / /	7th Reading / /	8th Reading / /	9th Reading / /	10th Reading / /
	Time										
1 Array	RTD										
	CR3000										
1 Walkway	RTD										
	CR3000										
2 Array	RTD										
	CR3000										
2 Walkway	RTD										
	CR3000										
3 Array	RTD										
	CR3000										
3 Walkway	RTD										
	CR3000										
4 Array	RTD										
	CR3000										
4 Walkway	RTD										
	CR3000										
5 Array	RTD										
	CR3000										
5 Walkway	RTD										
	CR3000										

Long Island Solar Farm – Soil Temperature Probe Calibration Data Sheet

Power Block Date Time		1st Reading / /	2nd Reading / /	3rd Reading / /	4th Reading / /	5th Reading / /	6th Reading / /	7th Reading / /	8th Reading / /	9th Reading / /	10th Reading / /
6 Array	RTD										
	CR3000										
6 Walkway	RTD										
	CR3000										
7 Array	RTD										
	CR3000										
7 Walkway	RTD										
	CR3000										
8 Array	RTD										
	CR3000										
8 Walkway	RTD										
	CR3000										
9 Array	RTD										
	CR3000										
9 Walkway	RTD										
	CR3000										
10 Array	RTD										
	CR3000										
10 Walkway	RTD										
	CR3000										

References

ASTM D6176-97 (reapproved 2008), Standard Practice for Measuring Surface Atmospheric Temperature with Electrical Resistance Temperature Sensors.

ASTM E102-02 (reapproved 2007), Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions.

ASTM G183-05, Standard Practice for Field Use of Pyranometers, Pyrheliometers and UV Radiometers.

ASTM D3631-99 (reapproved 2007), Standard Test Methods for Measuring Surface Atmospheric Pressure.

American National Standard ANSI0ANS-3.11-2005, "Determining Meteorological Information at Nuclear Facilities", American Nuclear Society, 2005.

Novalynx Tipping Bucket Rain gauge, Electrically Heated 115 VAC, Models 260-2500E, 260-2500E-12, Users Manual, Novalynx Corporation, Auburn, CA, ECO: 970502, Revision date August 2000.

Reda, I.; Myers, D.; Stoffel, T. (2008). Uncertainty Estimate for the Outdoor Calibration of Solar Pyranometers: A Metrologist Perspective. Measure. (NCSLI Journal of Measurement Science). Vol. 3(4), December 2008; pp. 58-66; NREL Report No. JA-581-41370.