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BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

TECHNICAL SERVICES DIVISION

QUALITY ASSURANCE PROJECT PLAN

MET SOP 503

TEMPERATURE

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STANDARD OPERATING PROCEDURE
BAAQMD TECHNICAL SERVICES DIVISION

TEMPERATURE AUDIT PROCEDURES

AUGUST 19, 2009

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INTRODUCTION

For air quality applications, ambient temperature is measured with a temperature probe. The probe used by BAAQMD is a Hycal RTS-32 PRT (Platinum Resistance Temperature) sensor. A Hycal RTS-32 is used as an audit test standard in the field and is also placed at each field site where we do not require percent relative humidity. At field stations, the probes are placed in a radiation shield to protect it from the effects of solar heating and wind variations. Most of the shields are motor aspirated to minimize potential radiation errors. At cool sites with adequate wind ventilation, a naturally aspirated shield is used. The temperature audit is performed by removing the probe from the radiation shield and immersing it and the test standard probe in water baths of three temperatures (cold, ambient, and hot). The results of each temperature system are compared to provide the accuracy of the station temperature system.

GENERAL OPERATING PROCEDURES

The station temperature probe is wired to a Campbell Scientific CR10 datalogger. A Campbell Scientific CR10KD keypad display is connected to the CR10 to monitor sensor output. The audit temperature probe is wired to a Campbell Scientific 21X datalogger with a built-in LCD display. The manufacturer's tolerance of the Hycal RTS-32 is ±0.3ºC at 0ºC and approximately ±0.4ºC at 40ºC. However, the audit probe is calibrated in the lab to within 0.1ºC prior to each season of calibration. The audit and station

temperature probes are inserted in three water baths of varying temperatures. Each water bath is in an insulated thermos container. Three readings of each temperature system are averaged and the results compared. Following *EPA Volume IV* (*Quality Assurance Handbook for Meteorological Measurements*), the agreement should be ±0.5°C between the temperature readout of the audit and the station probe.

A 2-point calibration can be performed on-site by adjusting a *hot* (~40ºC) and *cold* (0ºC) multiplier in the CR10 internal program via the CR10KD keypad. Because each multiplier will slightly affect the temperature reading at the opposite range, temperature readings throughout the entire range must be verified again by performing the three water bath tests after the final multiplier change. Although station sensors should be re-calibrated if readings deviate from the audit sensor temperature by ±0.5ºC or more, BAAQMD performs a re-calibration if readings deviate by ±0.3ºC or more as a preventive measure.

Data should be flagged during an audit to identify invalid data in memory. EPA *Meteorological Monitoring Guidance for Regulatory Modeling Application* states that at least two 15-minute averaged periods of valid data are required to represent an hourly period. The Campbell Scientific CR10 datalogger is programmed to average all data recorded to memory within a given hour with as little as one data point (one data point is recorded per second). If there is not enough valid data for two 15-minute averaged periods, the data for the averaged hourly period must be deleted from the data bank.

Figure 1: Hycal RTS-32 and Campbell Scientific 21X Datalogger

AUDIT EQUIPMENT

1. Hycal RTS-32 PRT Sensor (Audit Probe).
2. Campbell Scientific 21X Datalogger.
3. Three thermos containers.
4. Ice water (at or near 0ºC), ambient water (approximately 20ºC), and hot water (approximately 40ºC).
5. LoggerNet .CSI of the audit site (paper or electronic)
6. Temperature Audit Worksheet

AUDIT PROCEDURES

1. Connect the test probe to the 21X datalogger via the Cinch Jones connector

2. Turn on the 21X via a small toggle switch located on the side of the datalogger. "HELLO" will appear on the display. Wait until the display no longer shows this, and then attach the 9-pin cable to the datalogger on one end and to the SC32A Optically Isolated Interface device on the other. **The datalogger will "lock up" if the cable is attached to it while "HELLO" is displayed**. Attach the 9-to-25 pin adaptor cable to the computer's serial port on one end (9-pin side) and to the SC32A on the other (25-pin side). **Do not attempt to connect the datalogger to the computer directly via a 9-pin-to-9-pin cable as damage may occur to either unit.**

3. Upload the calibration program from the computer to the 21X datalogger. Turn on the computer and run LoggerNet. At the main screen, click "Connect." Select "21X" under the Station List and click "Connect." Once connected, click "Set Station Clock" to synchronize the day and year (the day and year must be correctly set in the computer). Now click "Send", and then select the program "21XCal.dld." Depending on which directory was accessed last, you may have to look for the file in "C:\Campbellsci\LoggerNet\DLD." Select, and then download the file to the datalogger. If the download is successful, a confirmation box will appear. Click "Ok", then "Disconnect." **Failure to click "Disconnect" will cause the 21X to "lock up."** Now, unplug the 9-pin cable.

4. Set flag 2 high on the 21X datalogger to enable the Hycal test probe.

5. Plug the CR10KD Keypad Display into the 9-pin socket on the CR10 wiring panel (a CR10X may also be used).

6. On the CR10KD, press *C1955A to disable the program security.

7. View the program timer by pressing *6, and then A repeatedly to input location 15. If the program timer is not zero, clear it by pressing C0A.

8. Press *6AD to access the software flags. The first digit from the left represents the state of flag 1; the second from the left represents the state of flag 2, etc.

9. Set flag 1 high to indicate data as invalid in memory. – 0 is *low*, 1 is *high*. If flag 1 is *low*, then press 1 to toggle it to *high*.

NOTE: Flag 1 – a software flag – is set *high* during audits to indicate data as invalid in memory. To prevent all data to be identified as invalid when a tower operator forgets to reset the flag, the program automatically does so after 3 hours. A program timer in input location 15 keeps track of the time by decrementing once per second starting from 10800 (the number of seconds in 3 hours). When the timer reaches 0, flag 1 is set *low*. Tower operators should always (1) check that the timer is 10800 when the flag is set and (2) clear the timer when the flag is reset. Failure to do so may cause the timer to reach 0 before the full 3 hours and, as a result, data would not be indicated as invalid in memory.

10. Display temperature on the CR10KD and 21X. Press *6 and A repeatedly to scroll to the temperature input location for each unit. The temperature input location for the 21X datalogger is 02. The temperature input location for the CR10 is 03.

11. Check the operation of the radiation shield fan. If it is not spinning or spinning slowly, note this in the audit sheet and replace the fan.

12. Remove the station probe from the aspirator shield and place it near the test equipment. Check the probe for any signs of cracking or material degradation prior to immersion in the water baths. If there is visible damage to the probe do not proceed with the audit until repairs or replacements are made.

13. Pour the ice into one of the plastic thermoses. Fill the thermos about 3/4's full with ice. Pour melted water over the ice until it is at ice level. The bath should be an easily penetrable slurry.

14. Secure the audit and station temperature probes together with a rubber band and insert into the ice bath. Do not immerse either probe in the solution up to where the wiring interfaces with the probe to prevent water from leaking into the electrical connections. Gently agitate the water by moving the probe around. After about 30 seconds, stop the agitation. The audit thermometer reading at the 21X display should be at near 0°C. If it is not, repeat the agitation procedure. During the audit, a cloth may be placed around the probes to cover the opening of the thermos container. This will help to keep the ice bath temperature constant.

15. When the station temperature readings are stable (1 to 2 minutes) record three audit and three station sensor temperature readings on the Worksheet.

16. Repeat steps 12 and 13 for the ambient bath and hot bath. Because the hot bath water temperature will drop rapidly, start at approximately 40ºC, and then record both temperatures at each moment the audit temperature reading drops by 0.1ºC.

17. If station and audit temperature differences are ≥ ±0.3ºC, adjust the *hot* and/or *cold* multiplier(s):

    a. Identify the two instructions that measure temperature for the station probe in the LoggerNet .CSI file. An example of these instructions is shown below. The *instruction header* on the first line of each instruction consists of the *instruction number* (left), *instruction description* (center), and *instruction code* (right). The *cold* multiplier is parameter 8 of the first instruction (instruction code P9) and the *hot* multiplier is parameter 4 of the next instruction (instruction code P16). **Note: The instruction numbers vary by program, but the instruction codes and location of multipliers do <u>not</u>.**

    12: Full Bridge w/mv Excit (P9)
    1: 1 Reps
    2: 23 25 mV 60 Hz Rejection Ex Range
    3: 23 25 mV 60 Hz Rejection Br Range
    4: 1 DIFF Channel
    5: 2 Excite all reps w/Exchan 2
    6: 2100 mV Excitation
    7: 14 Loc [Resistor]
    8: **1.0018 Mult**
    9: 0.0 Offset

    13: Temperature RTD (P16)
    1: 1 Reps
    2: 14 R/R0 Loc [Resistor]
    3: 3 Loc [Temp_C]
    4: **1.0010 Mult**
    5: 0.0 Offset

    b. Once the instructions are found in the .CSI file, note the *instruction numbers* of both instructions.

    c. At the CR10KD keypad, key in *C1955A to disable security, then *1 to enter program area. Now, key in the P9 (cold) or P16 (hot) *instruction number*, and press A. The value of the first parameter should be displayed. Press A repeatedly to advance to the multiplier parameter. Record the multiplier on the audit sheet.

    d. For either the hot or cold water bath, if the station temperature is reading lower than the audit temperature, raise the corresponding multiplier. If the

station temperature is reading higher, lower the multiplier. To change the multiplier, key in the new desired value (press *D* for decimal), press A to enter, then *0 to re-compile the program.

NOTE (1): When the program is re-compiled, all flags are reset to "low" and probe temperature values will not be identified as invalid in memory immediately after the program is re-compiled. Flag the erroneous data in the data bank at a later time.

e. Return to the temperature display (input location 03) on the CR10KD (press *6AAA) and repeat the appropriate water bath test (steps 12 and 13).

f. Repeat steps (d) – (e) as necessary with different multiplier values until the desired tolerance is met. While the EPA allowed tolerance is ±0.5ºC, BAAQMD often calibrates to within 0.1ºC.

g. If the *cold* multiplier was changed, verify high-temperature accuracy by repeating the hot water bath test. If the *hot* multiplier was changed, verify cold temperature accuracy by repeating the cold water bath test. Repeat steps (d) – (f) until the desired tolerances for both *hot* and *cold* temperatures are met.

h. Record the final multiplier values(s) on the audit worksheet.

i. Verify the ambient temperature accuracy with the ambient water bath test. With *hot* and *cold* temperature tolerances within 0.1ºC, if the ambient temperature difference is greater than 0.3ºC, replace and re-calibrate the station probe as a precautionary measure.

18. The temperature audit is now complete. Place the station probe back into the radiation shield and wait until the probe temperature reaches equilibrium.

19. Set flag 1 *low* if data recording no longer needs to be flagged (e.g. if the audit is complete). Disable security (step 6), display flags in the CR10KD (step 7), then press 1 to toggle flag 1 *low* to resume normal data recording.

20. Clear the program timer (step 7). You may have to first disable the program security (step 6) depending on how much time has elapsed since it was last disabled.

PREVENTIVE MAINTENANCE

<u>HYCAL RTS-32 PRT AUDIT SENSOR</u>

1. The Hycal RTS-32 audit sensor should always be stored in its case to prevent damage to the sensor.
2. Prior to each audit, the probe should be inspected for cracks and other damage; the leads should be re-stripped and re-tinned when necessary.

CAMPBELL 21X DATALOGGER

1. Charge the 21X overnight after about 12 hours of use.
2. The 21X should always be stored in the calibration case when not charging or in use.
3. Test the internal nickel-cadmium rechargeable battery once per year (see Battery Testing SOP)
4. Replace the battery when it no longer can hold an adequate charge.

CALIBRATION PROCEDURES

HYCAL RTS-32 PRT AUDIT SENSOR

The Hycal RTS-32 audit sensor should undergo a 3-point calibration against a NIST mercury thermometer in the lab prior to each season of audits.

CAMPBELL 21X DATALOGGER

The Campbell 21X Datalogger is sent to the factory for calibration every 5 years.

AUTHORS, REVISIONS, AND APPROVALS

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APPENDIX A

BAAQMD AUDIT RECORD

TEMPERATURE AUDIT WORKSHEET

BAAQMD AUDIT RECORD

Site Name _____

Auditor _____

Date __/__/__ Start Time _____(pst) Finish Time _____(pst)

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TEMPERATURE SENSOR

Temp Sensor Mfg **HYCAL**
Model No **RTS-32**
Sensor Ht _____

Last Calibration Date _____
Is the Fan Operating: Yes ☐ No ☐ N/A ☐

ICE BATH TEST Old Multiplier: _____ Results: Pass/Fail

New Multiplier: _____

Ice Bath Temperature	Logger Temperature	Difference

Tolerance: 0.5^{o} C for ice bath comparisons.

AMBIENT BATH TEST Results: Pass/Fail

Ambient Bath Temperature	Logger Temperature	Difference

Tolerance: 0.5^{o} C for water bath comparisons.

WARM BATH TEST Old Multiplier: _____ Results: Pass/Fail

New Multiplier: _____

Warm Bath Temperature	Logger Temperature	Difference

Tolerance: 0.5^{o} C for water bath comparisons.

Comments: