STANDARD OPERATING PROCEDURES FOR VAISALA HUMICAP HUMIDITY and TEMPERATURE PROBE HMP 155

AQSB SOP 507

First Edition

MONITORING AND LABORATORY DIVISION

June 2024

Disclaimer: Mention of any trade name or commercial product in this standard operating procedure does not constitute endorsement or recommendation of this product by the California Air Resources Board. Specific brand names and instrument descriptions listed in the standard operating procedure are for equipment used by the California Air Resources Board's laboratory. Any functionally equivalent instrumentation is acceptable.

CALIFORNIA AIR RESOURCES BOARD

Approval of Standard Operating Procedures

Title:	Vaisala HUMICAP Humidity and Temperature Probe HMP 155
SOP:	AQSB SOP 507, First Edition
Section:	Air Monitoring North Section (AMNS)
Branch:	Air Quality Surveillance Branch (AQSB)
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8/26/2024
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FIGURES

REVISION HISTORY

Edition	Release Date	Changes
First		n/a
Second		
Third		

LIST OF ACRONYMS

AMNS - Air Monitoring North Section
AMSS - Air Monitoring South Section
AQS - Air Quality System
AQSB - Air Quality Surveillance Branch
CARB - California Air Resources Board
CFR - Code of Federal Regulations
DAS - Data Acquisition System.
DMS - Data Management System
DFU - Dry Filter Unit
MLD - Monitoring and Laboratory Division
ODSS - Operations and Data Support Section
NIST - National Institute of Standards and Technology
OT - Outside Temperature
PQAO - Primary Quality Assurance Organization
PST - Pacific Standard Time
QA - Quality Assurance
QAS - Quality Assurance Section
QA/QC - Quality Control/Quality Assurance
QMB - Quality Management Branch
RH - Relative Humidity
RTD - Resistance Temperature Detector
SOP - Standard Operating Procedure
U.S. EPA - United States Environmental Protection Agency
VDC - Voltage Direct Current

1.0 GENERAL INFORMATION

1.1 Introduction:

This Standard Operating Procedures (SOP) describes procedures used by the California Air Resources Board (CARB) Air Quality Surveillance Branch (AQSB) to operate the Vaisala HUMICAP HMP 155 (or Vaisala) for the measurement of outside temperature (OT) and relative humidity (RH). This procedure was designed to supplement the manufacturer's instrument manual by describing any modifications in operating procedures, if any, implemented by the AQSB and is not intended to be a replacement for the instrument manual.

CARB highly recommends a thorough review of the Vaisala HMP 155 Instruction Manual.

1.2 Principle of Operation:

The measurement of temperature for air quality applications is generally thought of as air temperature (T), or a difference between two temperature measurements (delta T). Temperature instruments are made up of three important parts: transducers, signal conditioning, and solar radiation shields.

The effect of solar radiation and wind can severely affect the performance of temperature sensors. For this reason, a radiation shield is essential to any outdoor temperature measurement system.

The Vaisala uses a resistance temperature detector (RTD) to measure outside temperature. RTDs have long been used for industrial temperature measurement and in precise laboratory work.

An RTD sensor consists of a sensing element, usually made of highly pure metal, housed within a protective probe and connected to monitor or control equipment by insulated lead wires. Because the relationship between resistance and temperature is stable and consistent for the metals employed in RTD sensors, measuring the resistance across the sensing element at any given temperature allows that temperature to be calculated with a high degree of accuracy.

RH is a measure of the water vapor content of air. More explicitly, it is the amount of water vapor present in air expressed as a percentage (%RH) of the amount needed to achieve saturation at the same temperature.

RH is strongly proportional to temperature and sensitive to temperature

changes. This means that if temperature is stable in a system, RH will also be stable. As well as temperature, relative humidity also depends on the pressure of the system in question.

The Vaisala uses a capacitive thin-film polymer sensor consisting of a substrate on which a thin film of polymer is deposited between two conductive electrodes. The sensing surface is coated with a porous metal electrode to protect it from contamination and exposure to condensation. The substrate is typically glass or ceramic. The thin-film polymer either absorbs or releases water vapor as the relative humidity of the ambient air rises or falls. The dielectric properties of the polymer film depend on the amount of absorbed water. As the relative humidity around the sensor changes, the dielectric properties of the polymer film change, and so does the capacitance of the sensor. The instrument's electronics measure the capacitance of the sensor and converts it into a humidity reading.

1.3 Safety Precautions:
Installation, operation, maintenance, and calibration of the sensor should only be performed by properly trained personnel. Due to typical rooftop installations, the risks of working outdoors at elevation should also be considered.

Do not modify the unit. Improper modification can damage the product or lead to malfunction.

1.4 Interferences/Limitations:
There are no known interferences of the Vaisala when used in ambient temperature applications.

1.5 Personnel Qualifications:
Staff installing, operating, calibrating, or performing maintenance on the Vaisala should be familiar with its operating manual and this SOP.

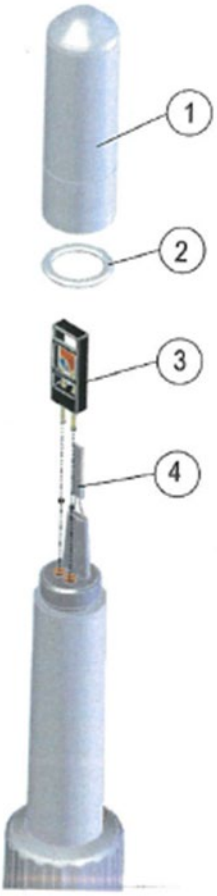
2.0 INSTALLATION PROCEDURE

2.1 General Information:

The Vaisala HMP 155 arrives from the factory calibrated and ready to use. Note: this factory calibration and subsequent certifications are valid for one year. Prior to use, carefully unpack the sensor, inspect for physical damage, and record the sensor's ID information and date of last vendor calibration on the appropriate Monthly Maintenance Check Sheet and Station Logbook. Report any damage to the stockroom or the Operations Data and Support Section (ODSS) Instrument Laboratory personnel.

Figure 1: Vaisala HMP 155

Figure 2: Field Installation of Vaisala in Solar Shield



1 = Filter
2 = O-ring
3 = HUMICAP® sensor
4 Pt100 temperature sensor

Figure 3: Vaisala HMP 155 Components

2.2 Equipment Required for Installation:

- Vaisala HMP 155 Probe
- Vaisala Radiation Shield
- Wiring harness
- Direct Current (DC) Power Supply, 12 to 24 Voltage Direct Current (VDC) fixed output, and 500 mA minimum.
- Hand Tools including but not limited to:

  - Screwdrivers, flat and Phillips, numbers 0, 1, and 2
  - Wrenches, fixed SAE, and adjustable
  - Pliers, long nose
  - Pliers, diagonal cutting
  - Strippers, wire, 24 to 14 gauge
- Operator's Manuals for the Vaisala and the data logger in use.

2.3 Siting and Mounting the Sensor:

Proper operation of any meteorological sensor is directly related to the siting of the sensor. An ideal installation is one where the operator can safely access the sensor, perform a test adjacent to the electronics and recorder, and reinstall the sensor in a timely manner. Station operators should read the United States Environmental Protection Agency (U.S. EPA), Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV; and U.S. EPA Prevention of Significant Deterioration (PSD) guidelines to get a more detailed description of siting requirements.

As a general rule, the Vaisala should be located at least six feet from any building structure, i.e. walls, roof, parapet, etc.

Prior to mounting the sensor to a tower, obtain a serial cable of sufficient length to allow the sensor to connect to the data logger.

- Mount the radiation shield to a meteorological tower or pole using the supplied U-bolt. Insert the Vaisala probe into the radiation shield and tighten the knurled fitting to secure the Vaisala in the radiation shield.

- Attach the cable to the Vaisala probe and cover the end of the probe with the supplied cover.

- Route the cable to the data logger.

2.4 Sensor Configuration and RS-232 Cable:

Prior to installing the Vaisala and connecting the probe to CARBLogger, ensure RS-232 serial cable was assembled to sufficient length. The cable is not a typical RS-232 cable, as it has a RS-485 to RS-232 converter integrated into the cable. These cables are assembled by the ODSS Instrument Lab at the request of field staff. Field staff should request a cable with enough length to reach from CARBLogger to the sensor connector with extra for a drip line.

Vaisala sensors purchased by the AQSB do not include a power supply. Hence, ODSS purchases a third-party adjustable 12 VDC power supply to provide power for the sensors. Power supplies for the Vaisalas are configured by the ODSS Instrument Lab.

Some air monitoring sites in the network require long cable connections (greater than 100 feet). It is possible that the voltage produced by power supplies at these sites may not be adequate to properly power the Vaisala sensor. In these cases, it may require field staff to increase the output voltage of the power supply.

Prior to adjusting the voltage, it is recommended to disconnect any sensors to the power supply to prevent damage to the sensor in the event of a power surge or short circuit.

If the length of the cable is causing an excessive voltage drop, adjust the power supply potentiometer to increase its output voltage. Turn the power supply potentiometer clockwise to increase voltage, or counterclockwise to decrease voltage. It may be necessary to adjust the voltage higher especially if more than one sensor is connected to a single power supply.

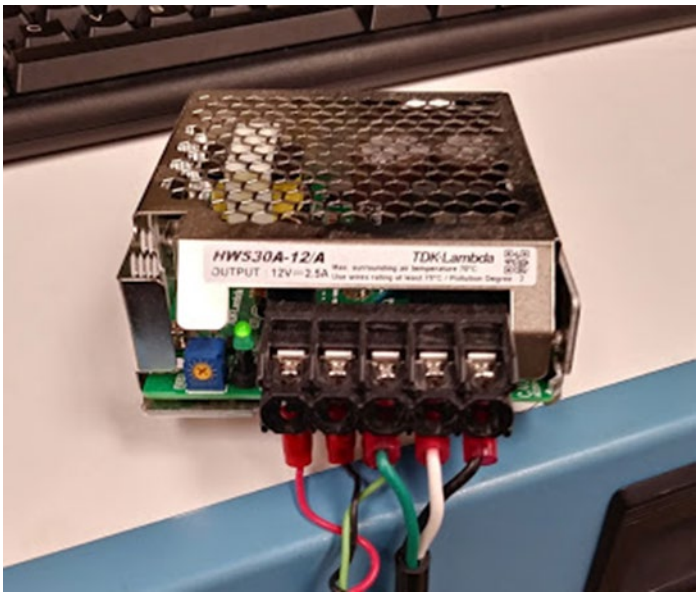


Figure 4: Power Supply

2.5 Data Logger Connection:

The Vaisala can be configured for either digital or analog outputs. AQSB's standard operation for the Vaisala Probe is to configure the instrument for digital output for the CARB's CARBLogger system. Information for connecting the Vaisala to an analog data logger is not supported by CARB but can be found in the Vaisala HMP 155 instrument manual (Figure 9).

Connect the serial connector to a serial port on the CARBLogger and configure the CARBLogger for the Vaisala.

Section 3.0 of this document describes the Vaisala probe configuration and connections to CARBLogger.

3.0 CARBLOGGER CONFIGURATION

Prior to using the Vaisala, the Vaisala driver must be enabled on the CARBLogger. To select or verify that the Vaisala driver is in use, select "Add Driver" from the CARBLogger user interface. The Vaisala driver was developed evaluating various RS-232 serial cable lengths and baud rates. For most if not all AQSB installations, a sensor output interval of two points per minute and 9600 baud rate are optimal. As normally configured, the Vaisala ideally collects one valid data point per second. The Vaisala standard CARB configuration is 9600 baud, 7 data bits, 1 stop bit and even parity; however, other configurations are possible.

Connect the Vaisala cable to the power supply and the serial port of the CARBLogger.

If the Vaisala is replacing an existing probe for which the CARBLogger had been previously configured, no configuration changes to CARBLogger or the Vaisala would be required. The power supply should be unplugged prior to the replacement of the sensor. The Vaisala should then begin reporting data and can be verified by checking the "display data" screen in CARBLogger (option 6 from the main menu),

If the Vaisala is being installed for the first time or replacing another type of OT sensor, the Vaisala will need to be added to the CARBLogger. For instructions on adding instruments to CARBLogger, follow instructions in Section 3.4 "Add Instrument" of CARB SOP 605.

4.0 CERTIFICATION

No field calibration of the Vaisala should be attempted. Any Vaisala requiring calibration or service should be returned to the CARB Standards Lab for a replacement. Out-of-certification sensors should be stored in the Standards Lab and not at field sites or in the office.

Approximately four to six weeks prior to the expiration of the Vaisala's certification, the CARB Standards Lab should be notified, and arrangements made to replace the Vaisala with one that has a current certification. The Standards Lab should have a couple of certified sensors on-hand, but this notification lead time helps with unforeseen circumstances. Additionally, due to the on-demand availability of sensors by the Standards Lab, field staff should note that the certification of a sensor may expire less than one year from deployment.

The following steps outline the process for sensor replacement at CARB air monitoring sites:

a. Site operators must notify their CARB Standards Lab contact 4 – 6 weeks prior to needing a replacement sensor. This request can be made via e-mail, phone, or in person. During data review, the second level data reviewer should review Vaisala HMP155 Monthly Maintenance Check Sheet (Figure 6) and monitor the sensor replacement date. If noted that the sensor replacement date is approaching, confirm with the site operator that a new sensor has been requested.

b. CARB Standards Lab staff will contact the site operator when a replacement sensor will be shipped. If a sensor is available when a replacement is requested, the sensor will be shipped as soon as possible after receiving the request and no fewer than three weeks prior to field unit expiration date. If no sensors are available at the time a request is made, an estimated date of shipment will be given.

c. Site operators must commit to installing replacement sensors within two weeks of receipt. If replacement is not possible, the sensor should be returned to CARB Standards Lab for re-deployment to another location. A new shipment date will be scheduled for the original request.

d. Site operators should return the expired sensor to CARB Standards Lab within one week of installing a replacement sensor. Monitoring

managers should monitor sensor replacement status to ensure sensors are returned in a timely manner.

e. Site operators must note on the weekly status report email that the new sensor has been installed. In addition, site operators should notify the designated CARB Standards Lab contact of sensor installation dates for tracking purposes.

f. Site operators must document the installation and expiration date on the Vaisala HMP 155 and Hampshire Controls Monthly Checksheet. (Figure 6).

5.0 ROUTINE SERVICE CHECKS

5.1 Daily Checks:

Daily Checks (or each time site is serviced): Review data logger results from previous day(s) for consistency/being reasonable.

5.2 Monthly Checks:

Visually check the Vaisala for physical damage to the shield, sensor, or cables.

5.3 Hampshire Controls Indoor Temperature (IT):

Due to the US EPA 2018 Technical Systems Audit (2018 TSA), the Hampshire Control monthly checks have been added to the Vaisala Monthly Check Sheet for simplifying purposes.

The station operator will record the Hampshire property number, the Hampshire IT reading, the temperature standard reading (i.e. Mesa Lab DeltaCal) on the lower portion of the combined Vaisala/Hampshire Check Sheet.

5.4 Verification Procedures:

Replace Vaisala and return "old" sensor to CARB Standards Lab. The "new" Vaisala's expiration date is one year from the date indicated on the Certificate of Certification and Testing for the "new" sensor.

Prior to installation of a newly certified Vaisala, clean the exterior of the solar shield with a cloth or paper towel to remove any debris, dirt, cobwebs, leaves, etc.

5.5 As-Needed Checks:

Clean the sensor tip screen and the radiation shield as needed whenever excess dirt and debris accumulates or prior to returning replaced unit to Standards Lab.

5.6 Octennial Checks:

Recommend retiring sensor from use when it is over approximately eight years of age. Experience has shown that after approximately eight years, sensors start to deviate on the upper end of their range and thus could lead to failed

certification and data loss.

6.0 TROUBLESHOOTING

The Vaisala has no moving parts and when properly configured is typically problem free requiring little if any maintenance. Most problems associated with the sensor manifest themselves as problems with the data (no data reported, data gaps or abnormal data readings). Most data related problems with the Vaisala are the result of improper configurations within CARBLogger and/or Data Management System (DMS).

Common sensor issues field staff may encounter with the Vaisala are shown in the table below. In general, the solution to these issues is to inspect the wires and connections to ensure that they are secure and clean. Also check the power supply to verify power to the sensor is at least 12 VDC. In addition, a review of CARBLogger diagnostic e-mails will indicate whether the sensor is generating enough sub-minute data to properly report OT/RH data. Should field staff not identify the cause of a Vaisala issue, contact ODSS for support.

Issue	Possible Problem
Random missing 1-minute IT or RH data	• Poor power to sensor • Loose connections to CARBLogger • Malfunctioning sensor • RH values more than 101.8 being flagged by CARBLogger
Slow response of OT or RH	• Vaisala probe screen dirty
Abnormal daily increases in OT or RH data	• Malfunctioning sensor

Figure 5: Troubleshooting Table

7.0 DATA HANDLING AND VALIDATION

The data handling process involves collecting ambient temperature and relative humidity data from the Vaisala. The data is collected at the ambient air monitoring station using the CARBLogger data logger and then sent to CARB's Data Management System. Site operators and data reviewers review and edit air quality data on their PC workstations via the DMS terminal server. Refer to AQSB SOP 610, Data Review and Validation for information and procedures on performing data review for the Vaisala.

Data should be reviewed periodically to confirm its validity. Data reviewers should examine the data for missing data points, spikes or extreme changes, daily and seasonal high and low values, and comparisons to nearby sites.

Occasionally, values more than 100 percent relative humidity may be reported from the Vaisala. When this occurs, CARBLogger will flag each minute value over 101.8 percent. If enough data points exceed the 101.8 percent threshold, the hourly average is considered invalid and should be flagged with the Op code 57: Positive Overrange Invalid, and the QC code 47: Instrument Overrange. The "BN" null data code should also be applied to the invalid hour.

8.0 QUALITY CONTROL/QUALITY ASSURANCE

CARB has established a robust QA/QC assurance program. The program ensures that ambient air monitoring data collected by CARB is high quality and complies with procedures and regulations set forth by the U.S. EPA. More guidance regarding meteorological measurements can be found in the U.S. EPA QA Handbook for Pollution Measurement Systems Volume IV (Meteorological Measurements). CARB staff should refer to AQSB SOP 610 Data Review and Validation for more detailed guidance regarding data validation and review. Data review and validation for meteorological parameters should parallel procedures used to validate gaseous and PM continuous parameters.

The procedures outlined in this document ensure that Vaisala is operated in accordance with federal requirements. QC maintenance checks for the Vaisala should be documented on monthly QC sheets and station logbooks.

When instruments are found to be operating outside CARB's Performance Criteria, a corrective action notification (CAN) or Air Quality Data Action (AQDA) request may be issued.

9.0 REFERENCES

Primary Quality Assurance Organization (PQAO) Resources

CARB QAPP for Gaseous Pollutant Air Monitoring Program

AQSB SOP 605 CARBLogger

AQSB SOP 606 Data Management System

AQSB SOP 610 Data Review and Validation

Vaisala HMP 155 User Manual

EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II

EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements

EPA Prevention of Significant Deterioration guidelines

CALIFORNIA AIR RESOURCES BOARD
MONTHLY MAINTENANCE CHECKSHEET
VAISALA HMP 155
AND HAMPSHIRE CONTROLS INDOOR TEMP

Location: _____ Month/Year: _____

Station Number: _____ Operator: _____

Vaisala Property Number: _____ Agency: _____

Hampshire Controls Property Number: _____

OPERATOR INSTRUCTIONS FOR VAISALA:

1) Daily Checks: Review data logger results from previous day(s) for consistency/believability
2) Monthly Checks: Visually check the Vaisala for physical damage to the shield, sensor, or cables.
3) Annual Checks: Replace the Vaisala and return the "old" sensor to the Standards Lab. The "NEW" Vaisala's expiration date is one years from the date indicated on the Certificate of Certification and Testing for the new sensor. Prior to the installation of the new Vaisala, clean the exterior of the solar shield with a cloth or paper towel.
4) As Required Checks: Clean the sensor screen tip as needed to remove dirt and debris.

Vaisala Certification Expiration Date: _____

Vaisala Site Installation Date: _____

Vaisala Site Replacement Date: _____

HAMPSHIRE CONTROLS INDOOR TEMP (IT) MONTHLY CHECK

Temperature Standard Property Number: _____

Temperature Standard Certification Date: _____

Monthly Check Date: _____

Hampshire Controls IT Reading: _____

Temperature Standard Reading: _____

IT and Temperature Standard must agree within +/- two degrees Celsius or you must replace the Hampshire Controls IT sensor.

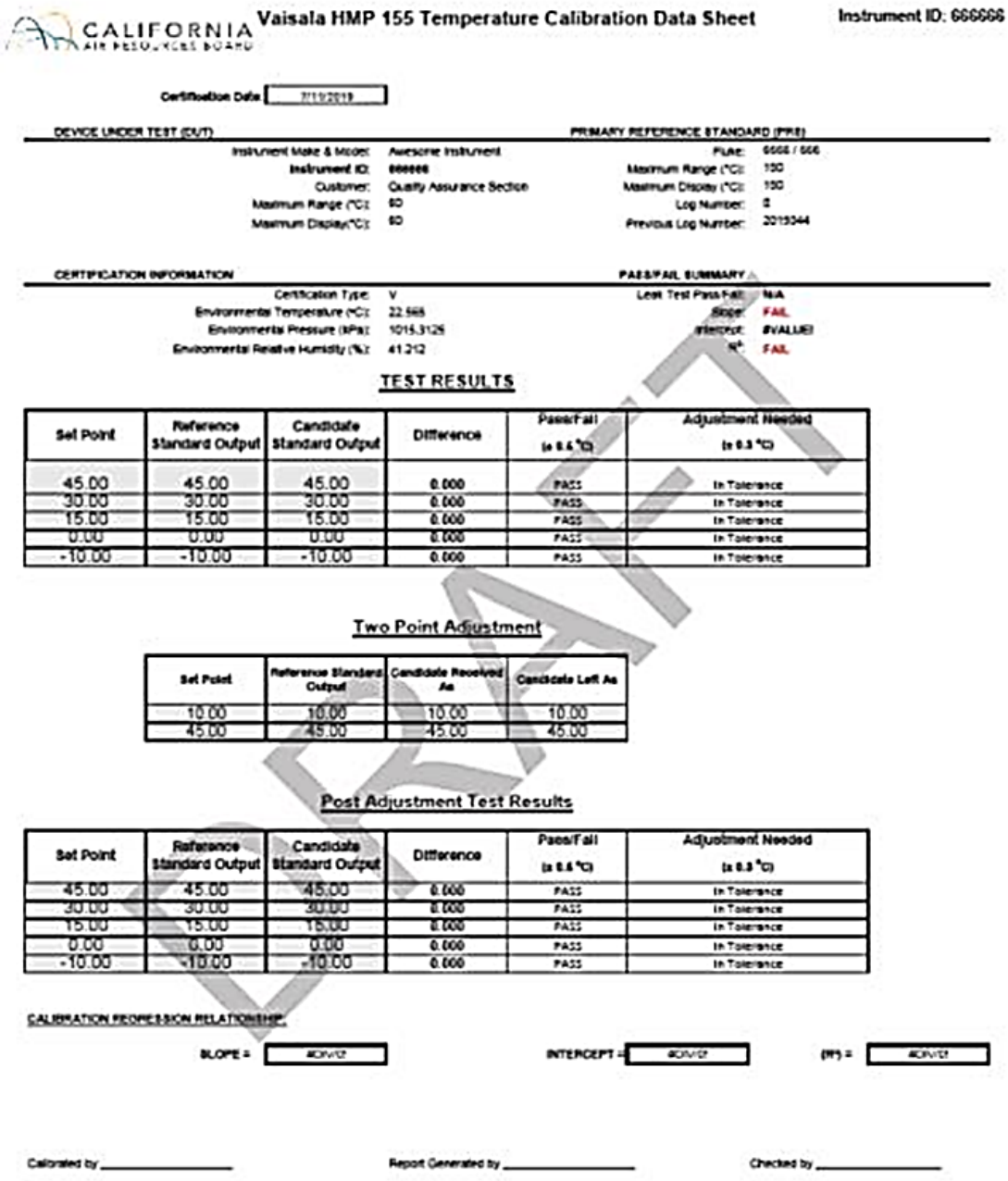
Comments: _____

_____

Reviewed by:_____ Date: _____

AQSB QC Form 507 (VAISALA HMP-155)

Figure 6: Vaisala HMP 155 and Hampshire Controls Monthly Check Sheet



CALIFORNIA AIR RESOURCES BOARD

Vaisala HMP 155 Temperature Calibration Data Sheet

Instrument ID: 666666

Certification Date: 7/19/2019

DEVICE UNDER TEST (DUT)

Instrument Make & Model:	Awesome Instrument
Instrument ID:	666666
Customer:	Quality Assurance Section
Maximum Range (°C):	60
Maximum Display(°C):	60

PRIMARY REFERENCE STANDARD (PRS)

PRS:	6666 / 666
Maximum Range (°C):	150
Maximum Display (°C):	150
Log Number:	0
Previous Log Number:	2015344

CERTIFICATION INFORMATION

Certification Type:	V
Environmental Temperature (°C):	22.565
Environmental Pressure (kPa):	1015.3125
Environmental Relative Humidity (%):	41.212

PASS/FAIL SUMMARY

Last Test Pass/Fail:	N/A
Slope:	FAIL
Intercept:	#VALUE!
R^2:	FAIL

TEST RESULTS

Set Point	Reference Standard Output	Candidate Standard Output	Difference	Pass/Fail (± 0.6 °C)	Adjustment Needed (± 0.3 °C)
45.00	45.00	45.00	0.000	PASS	In Tolerance
30.00	30.00	30.00	0.000	PASS	In Tolerance
15.00	15.00	15.00	0.000	PASS	In Tolerance
0.00	0.00	0.00	0.000	PASS	In Tolerance
-10.00	-10.00	-10.00	0.000	PASS	In Tolerance

Two Point Adjustment

Set Point	Reference Standard Output	Candidate Received As	Candidate Left As
10.00	10.00	10.00	10.00
45.00	45.00	45.00	45.00

Post Adjustment Test Results

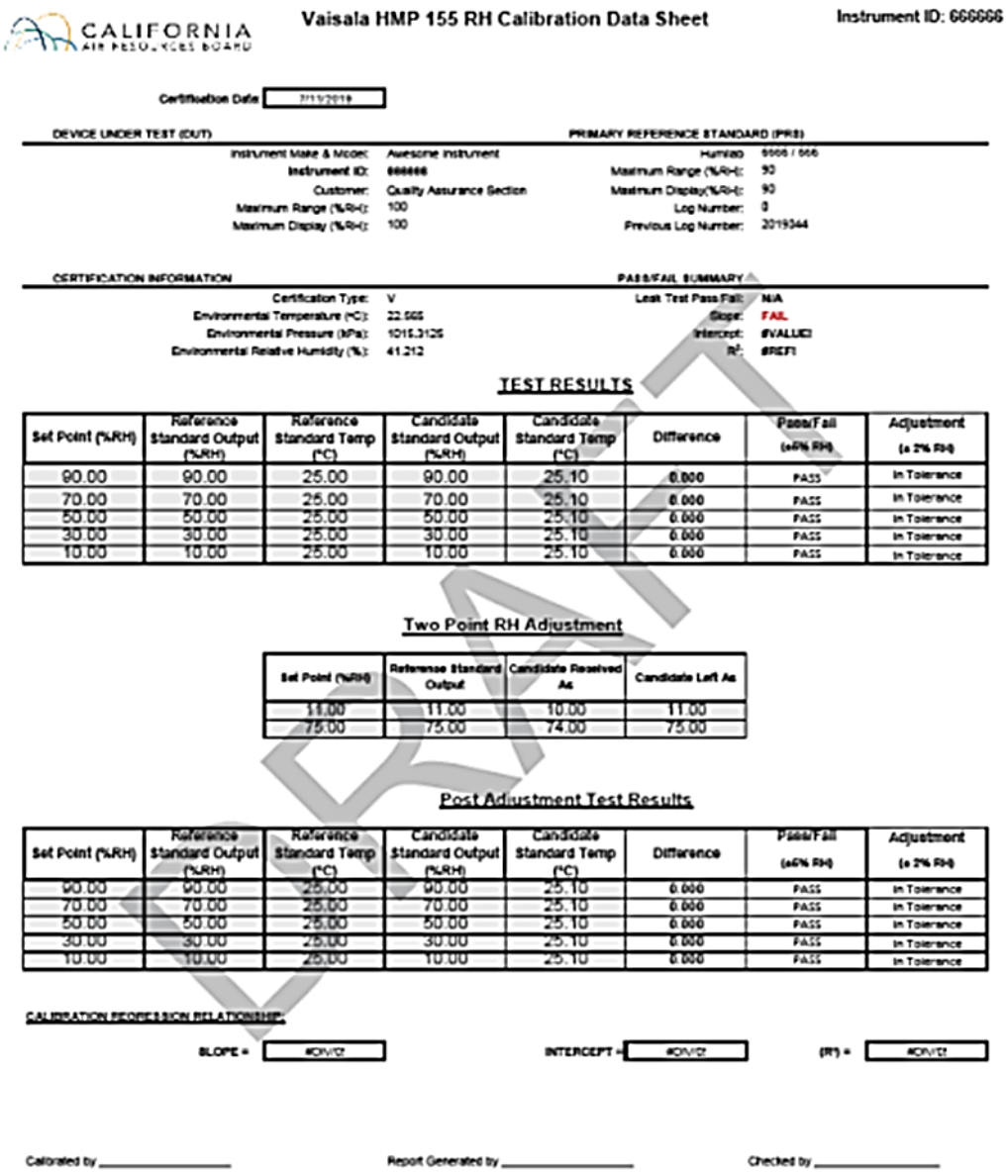
Set Point	Reference Standard Output	Candidate Standard Output	Difference	Pass/Fail (± 0.6 °C)	Adjustment Needed (± 0.3 °C)
45.00	45.00	45.00	0.000	PASS	In Tolerance
30.00	30.00	30.00	0.000	PASS	In Tolerance
15.00	15.00	15.00	0.000	PASS	In Tolerance
0.00	0.00	0.00	0.000	PASS	In Tolerance
-10.00	-10.00	-10.00	0.000	PASS	In Tolerance

CALIBRATION REGRESSION RELATIONSHIP:

SLOPE = #DIV/0! INTERCEPT = #DIV/0! (R^2) = #DIV/0!

Calibrated by _____ Report Generated by _____ Checked by _____

Figure 7: Temperature Sensor Certification Sheet



CALIFORNIA AIR RESOURCES BOARD

Vaisala HMP 155 RH Calibration Data Sheet

Instrument ID: 666666

Certification Date: 7/11/2019

DEVICE UNDER TEST (DUT)

Instrument Make & Model:	Awesome Instrument
Instrument ID:	666666
Customer:	Quality Assurance Section
Maximum Range (%RH):	100
Maximum Display (%RH):	100

PRIMARY REFERENCE STANDARD (PRS)

Humidity:	9966 / 666
Maximum Range (%RH):	90
Maximum Display(%RH):	90
Log Number:	0
Previous Log Number:	2019344

CERTIFICATION INFORMATION

Certification Type:	V
Environmental Temperature (°C):	22.665
Environmental Pressure (kPa):	1015.3125
Environmental Relative Humidity (%):	41.212

PASS/FAIL SUMMARY

Leak Test Pass/Fail:	N/A
Slope:	FAIL
Intercept:	#VALUE!
R^2:	#REF!

TEST RESULTS

Set Point (%RH)	Reference Standard Output (%RH)	Reference Standard Temp (°C)	Candidate Standard Output (%RH)	Candidate Standard Temp (°C)	Difference	Pass/Fail (±6% RH)	Adjustment (± 2% RH)
90.00	90.00	25.00	90.00	25.10	0.000	PASS	In Tolerance
70.00	70.00	25.00	70.00	25.10	0.000	PASS	In Tolerance
50.00	50.00	25.00	50.00	25.10	0.000	PASS	In Tolerance
30.00	30.00	25.00	30.00	25.10	0.000	PASS	In Tolerance
10.00	10.00	25.00	10.00	25.10	0.000	PASS	In Tolerance

Two Point RH Adjustment

Set Point (%RH)	Reference Standard Output	Candidate Received As	Candidate Left As
11.00	11.00	10.00	11.00
75.00	75.00	74.00	75.00

Post Adjustment Test Results

Set Point (%RH)	Reference Standard Output (%RH)	Reference Standard Temp (°C)	Candidate Standard Output (%RH)	Candidate Standard Temp (°C)	Difference	Pass/Fail (±6% RH)	Adjustment (± 2% RH)
90.00	90.00	25.00	90.00	25.10	0.000	PASS	In Tolerance
70.00	70.00	25.00	70.00	25.10	0.000	PASS	In Tolerance
50.00	50.00	25.00	50.00	25.10	0.000	PASS	In Tolerance
30.00	30.00	25.00	30.00	25.10	0.000	PASS	In Tolerance
10.00	10.00	25.00	10.00	25.10	0.000	PASS	In Tolerance

CALIBRATION REGRESSION RELATIONSHIP:

SLOPE = #DIV/0! INTERCEPT = #DIV/0! (R^2) = #DIV/0!

Calibrated by _____ Report Generated by _____ Checked by _____

DRAFT

Figure 8: Relative Humidity Certification Sheet

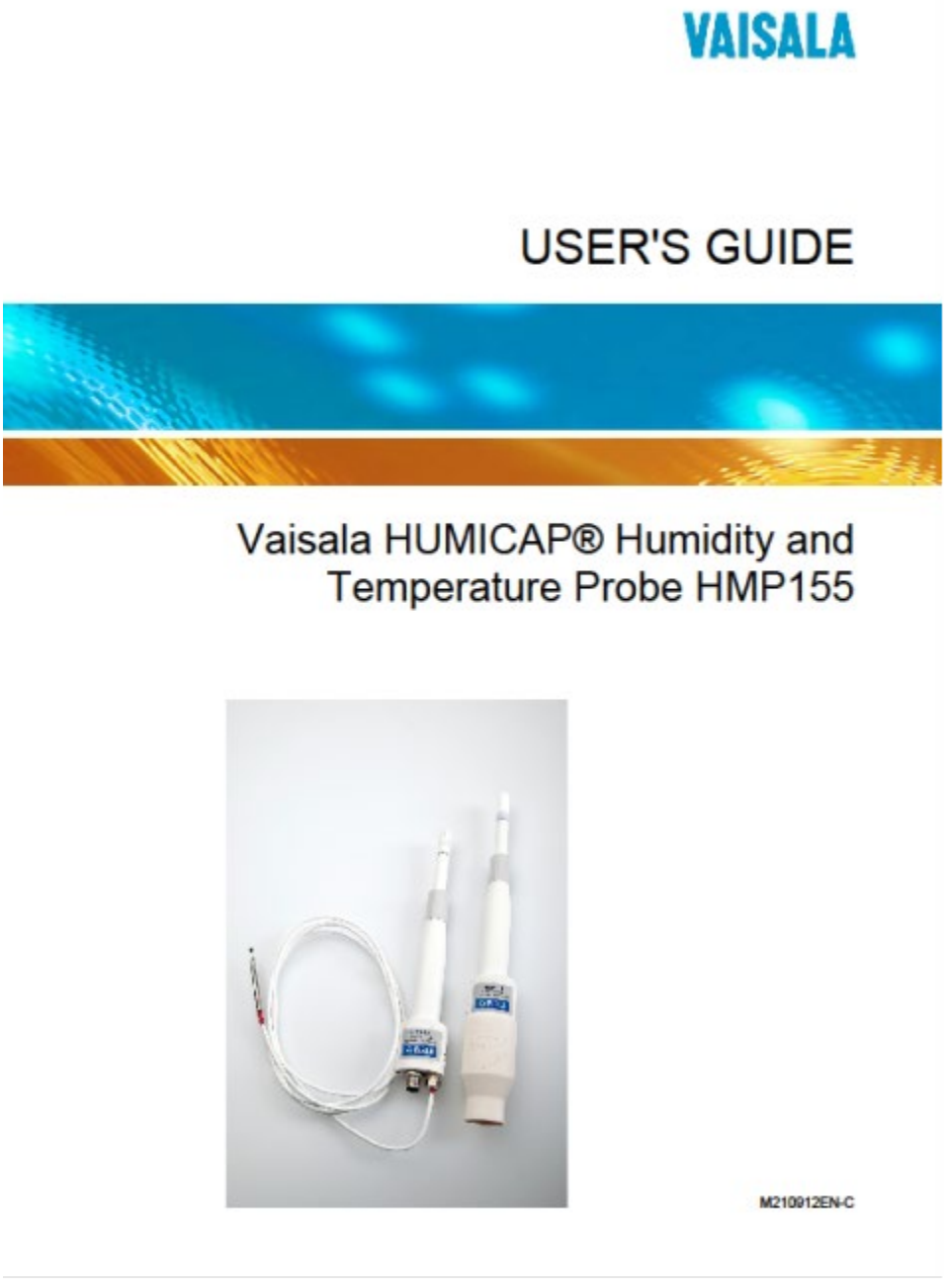


Figure 9: Vaisala HUMICAP HMP 155 Manual Cover