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University of California
Lawrence Livermore National Laboratory

YUCCA MOUNTAIN PROJECT **Technical Implementing Procedure**	QA:QA x QA:N/A No. TIP-CM-72 Revision: 0 Change Notice: 0 Page: 1 of 14 W/ 1, 2, 3, 4 Attachments
Subject: Calibration of RH Meters Using the Bi-Thermal RH Calibration System	Author: Kirk Staggs

Training Required: Yes ☐ No ☒
Comments:

REVISION HISTORY

Rev. No.	CN No.	Effective Date	Description of Revision/CN
0		12/16/05	Initial Issue.
		12/16/05	Corrective action per CR 5430.

Approved by: _[signature]_ 12 15 05
Technical Area Lead Date

Concurrence: _[signature]_ 12 15 05
BSC Quality Assurance Representative Date

Verification: _[signature]_ 12/16/05
LLNL YMP Document Server Verification Date

1.0 PURPOSE

1.1. This technical implementing procedure (TIP) describes the process to calibrate relative humidity (RH) probes used in high temperature applications using a Bi-Thermal System.

2.0 SCOPE

2.1 This procedure is applicable to LLNL personnel assigned to the Yucca Mountain Project. It addresses the calibration of Vaisala Temperature/Relative Humidity probes used in scientific experiments at temperatures from 115 to 160 degrees Celsius.

3.0 RESPONSIBILITIES

3.1 The Principal Investigator (PI) or designee is responsible for the implementation of the methods described in this procedure and maintaining scientific notebooks and/or electronic recording media records.

3.2 The Technical Area Leader (TAL) is responsible for verifying that this procedure meets the objectives of the planning documents and that work proceeds according to this TIP.

3.3 The YMP Engineering Assurance Manager is responsible for monitoring the implementation of this TIP and to ensure its continuing effectiveness and applicable controls.

4.0 CONCEPT OF THE BI-THERMAL RH CALIBRATION SYSTEM

4.1 The bi-thermal apparatus (see attachment 1; figure 1) for relative humidity calibration at temperatures between 115 and 180°C is a modification of a bi-thermal system developed by Stokes and Robinson (1947) to measure water activity (or relative humidity) in electrolyte solutions. We use the bi-thermal apparatus to calibrate the relative humidity probes by equilibrating water vapor between two vessels at two different temperatures. The lower temperature reservoir contains boiling pure liquid water at 100°C; the higher temperature reservoir contains only a vapor phase (no liquid water is present). The water vapor pressure will be the same in the two reservoirs after it is allowed to diffuse for a sufficient period of time. However, the water vapor pressure in the higher temperature reservoir $p_w(T_2)$ will be below saturation at that temperature. At equilibrium,

$$p_w(T_2) = p_w^\circ(T_1) \qquad (1)$$

The relative humidity in the lower temperature reservoir will always be 100 % at the liquid water/water vapor interface. In the higher temperature reservoir the relative humidity is given by

$$\% \ RH_{T2} = 100(p_w(T_2) / p_w^o(T_2)) \tag{2}$$

Substitution of equation (1) into (2) yields an expression for the relative humidity of the higher temperature reservoir as a unique ratio of the saturation vapor pressures of pure water at the two temperatures T_2 and T_1:

$$\% \ RH_{T2} = 100\{ p_w^o(T_1) / p_w^o(T_2) \} \tag{3}$$

We use the temperature dependence of vapor pressure of water from the steam tables in the Handbook of Chemistry and Physics (R. C. Weast (Editor-in-Chief) *CRC Handbook of Chemistry and Physics* (CRC Press, Boca Raton, Florida, 1987-1988), pages B-119, B-130, B-131, D-189, D-190) as our standard, because no NIST standard is available for the calibration of relative humidity probes to temperatures above 60 C. Use of the steam tables as a standard has been qualified as product output in the *Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier* AMR (BSC 2004a, DTN: LL040601512251.103). Additionally the steam tables are built into NUFT 3.0 code used to calculate the thermal budget of the repository[1]. Determination of percent relative humidity from the steam tables still requires that the temperature probes are calibrated against a NIST traceable standard. The bi-thermal apparatus allows calibration from 100°C and 100%RH to 180°C and 10%RH. An M&TE Justification has been prepared and appended to this TIP to provide authorization for calibration in this manner (See Attachment 4).

5.0 EQUIPMENT

5.1 Bi-Thermal RH Calibration System is shown in attachment 1 figures 1-4 and consist of the following items:

5.1.1 A computer based data acquisition system with the follow setup:

5.1.1.1 Dell Optiplex GS260 running Window 2000 Professional version 5.00.2195 Service Pack 4

5.1.1.2 Data acquisition software; DasyLab version 7.00.05 (DASYTec USA). DasyLabs software is used for temperature control and display and is exempt from qualification in accordance with LP-SI.11Q-BSC, Section 2.1.2.

5.1.1.3 IOtech DaqBook 2000A

5.1.1.4 DBK84 Thermocouple Module

5.1.1.5 DBK42 5B Signal Conditioning Chassis

5.1.1.6 5B RTD modules model SCM5B34-03

5.1.1.7 DBK5 4 channel current output card

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[1] BSC (Bechtel SAIC Company) 2004b. Multiscale Thermohydrologic Model. ANL-EBS-MD-000049 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041014.0008

5.1.1.7 DBK5 4 channel current output card

5.1.2 Two convection ovens, VWR Model 1330FZZ, are used for uniformed heating of the saturator and non-condensing test vessel.

5.1.3 Two 1000 ml multi-port flasks are used for the saturator and non-condensing test vessel.

5.1.4 Two temperature controllers are used to control the temperature of the interconnecting tube.

5.1.5 Various heaters and temperature sensors (not requiring qualified calibrations) are used throughout the system for heating, controlling, and monitoring of select areas or components.

5.1.6 High temperature (≥200°C) heat transfer fluid (silicone oil)

5.1.7 High precision thermometer and probe(s) are used to measure the temperature in non-condensing test vessel to calibrate the RH meter against the steam tables. It is also used for conventional temperature calibration of RH meter temperature probes.

5.1.7.1 The high precision thermometer and temperature probe(s) require a combined (reader and probe) accuracy better than 0.07°C. For qualified measurements of temperatures the probe shall be equal to or less than ¼" in diameter to insure rapid temperature response, at least 6" long, and designed for wet or very humid environments at elevated temperatures between 100 and 180°C.

5.1.7.2 The high precision thermometer and probes are calibrated by a supplier listed on the OCRWM QSL and are traceable to NIST.

5.2 Changes in equipment, setup, and software can be made as long as it meets specification identified in this TIP, does not degrade the performance of the system, and does not reduce the accuracy of the measured data. Changes should be recorded and identified in the notebook and may require changes to this TIP in accordance with 033-YMP-QP 5.0.

5.3 Equipment referenced in this TIP that requires an operator to perform an operation according to manufactures instructions or guidelines must have the operating manual for this equipment submitted to document control. See Section 15.3 for listing of controlled documents.

6.0 OVERVIEW OF CALIBRATION PROCESS

6.1 Relative humidity measurements require that both water vapor and temperature be measured. To ensure accurate RH measurements the RH meter vapor or moisture sensor and the temperature sensor must be operating properly. Since the measured RH is calibrated against RH calculated from the steam tables and the measured temperature, it is essential that the temperature probe be evaluated for accuracy against a NIST traceable temperature probe. Once the RH meter temperature probe is calibrated against a NIST traceable source it can be used to calculate the RH of the atmosphere surrounding the RH sensor.

The following sections define the processes for checking the calibration of the RH meter temperature probe at temperature between 100-180°C (this range can be extended from ambient temperatures to 180°C) and the RH calibration process. Various heat sources can be used to check the calibration of the RH meter temperature probes. as described in section 7.0 of this TIP. to accommodate the different probe configurations.

Although this TIP describes calibration of RH probes from 115 to 180°C. probes will require periodic adjustments due to drift over time. For this reason, all RH units must be properly adjusted and calibrated at lower temperatures by an approved YMP laboratory. At the time of writing this TIP, Thunder Scientific is the only calibration laboratory. on the qualified suppliers list for the YMP that can meet the requirements to calibrate and adjust this unit at low temperatures.

7.0 SETUP OF RH METER TEMPERATURE PROBE

7.1 The precision of RH measured is tied to the precision of the thermometer because water saturation is dependent on temperature. Highest degree of precision is achieved by validating temperature probes in an oil bath. This method can only be used for RH units with separate temperature probes.

7.1.1 The RH meter temperature probes can be validated in an oil bath against a NIST traceable thermometer and probe as required in section 5.1.7 of this TIP. An oil bath with a stirrer or recirculation pump, temperature stability equal to or better than ±0.10°C/min, a reservoir that is ≥ three inches across and will hold ≥ four inches of oil can be used for this process.

7.1.2 High Temperature silicone oil or similar heat transfer medium rated for heating to 200°C shall be used in the bath.

7.1.3 The high precision temperature probe and RH meter temperature probe(s) under test shall be supported near the center of the oil bath with at least ¼" separation (to allow the oil to flow between them). The probes under test shall be immersed down into the oil at least ¾ of their length. The NIST traceable thermometer probe shall be in the center of the probes (if only one probe is being tested the high precision temperature probe will be placed approximately ¼" away from this probe in any direction) with the tip of the probe at the same level as the tip(s) of the probes under test.

7.1.4 If the bath is to be heated unattended for prolonged periods (>4hrs) then a secondary temperature control or high limit temperature cutoff shall be used to prevent the oil from exceeding the maximum operating temperature of the probes or system components.

7.2 Several of the RH units contain RH and temperature probe combinations in a single unit. For these units it is not possible to validate the temperature probe in an oil bath, so it is necessary to use dry heated air.

7.2.1 The RH meter temperature probes can be validated in dry heated air against a NIST traceable thermometer and probe as describe in section 5.1.7. The dry heated air chamber constructed from common laboratory equipment or a manufactured unit with stability equal to or better than ±0.10°C per minute and a chamber that can support the RH Meter temperature probe so that they do not contact the walls of the chamber. See Attachment 1 for a description of laboratory equipment used.

7.2.2 If the dry air chamber is to operate unattended for prolonged periods (>4hrs) then a secondary temperature control or high limit temperature cutoff shall be used to prevent it from exceeding the maximum operating temperature of the probes or system components.

7.3 As an alternate to an oil bath or heated air, a dry block heater or fluidized sand bath that has a uniformed temperature and thermal stability better than ±0.10°C/min (measured against the NIST traceable thermometer and probe required in section 5.1.7) can be used to validate the RH meter temperature probes.

7.3.1 The dry block heater or fluidized sand bath must accommodate the temperature and thermal stability requirements identified above and contain the physical openings needed to accommodate the RH/temp probes.

8.0 RH METER TEMPERATURE PROBE CALIBRATION PROCESS

The following temperature calibration process shall be conducted regardless of the type of unit used as a stable heat source.

8.1 The probe(s) shall be calibrated at a minimum of four temperature points ≤180°C and separated by a minimum of 25°C or 25% of the range of calibration.

8.2 The following information will be recorded on the Temperature Probe Calibration sheet in attachment 2:

8.2.1 The date of this calibration and operators name.

8.2.2 RH probe model, serial number.

8.2.3 Approved YMP calibration RH probe ID# (NIST standards laboratory calibration and adjustment), date of calibration, and calibration due date.

8.2.4 NIST traceable precision thermometer and probe(s) approved YMP calibration ID#, date of calibration, and calibration due date.

8.3 Calibration and accuracy of RH meter temperature probes will be made and recorded in the Temperature Probe Calibration Sheet (Attachment 2) as follows:

8.3.1 At least three temperature readings shall be recorded from the NIST traceable precision thermometer probe(s) and the RH meter temperature probe(s) under test at selected intervals ≥10 seconds apart on the Temperature Probe Calibration Sheet (attachment 2).

8.3.2 Average these readings for each temperature point and compared them against the high precision temperature thermometer to determine the RH meter temperature probe error.

8.3.2.1 The RH meter temperature probe error will be calculated by subtracting the RH probe meter temperature reading from the NIST traceable thermometer and recorded as the absolute value or with a plus or minus (±) prefix for this result.

8.3.3 The average of the readings, the calculated error for each probe, and if this error is acceptable (the criterion for acceptance is ±0.2°C unless otherwise specified by the principle investigator) shall be recorded on the Temperature Probe Calibration Sheet. Use of different acceptance criteria will be justified and documented in the scientific notebook.

8.3.4 The completed sheet shall be signed and placed in the notebook supplement for the Bi-Thermal RH Calibration System.

9.0 SETUP OF THE BI-THERMAL RH CALIBRATION SYSTEM

9.1 Insert the probes from the RH meters into the non-condensing test vessel at room temperature and support them at mid height in the vessel by silicone stoppers. Insert a RH meter that has separate RH and temperature probes through the same port, positioning the probes away from the sidewall of the vessel (straight down or slightly inboard from the axis of the port through which they are inserted).

9.2 Fill the saturator vessel to the top mark (see attachment 1; figure 3) with distilled or deionized water by injecting it into the saturator with the attached syringe and tubing.
ATTENTION: For the following steps DO NOT pull out the syringe plunger with the syringe connected to the tube. This will cause ambient air to be pulled into the non-condensing vessel. The syringe should be removed from the tube, filled with deionized or distilled water, reconnected to the tube, and plunger depressed. There are two marks half way up on the vessel indicating the minimum and maximum water level required during the calibration process.

9.3 Ensure that all ports on the saturator and non-condensing test flasks are closed and that the silicone stoppers are firmly pressed into the port and sealed around wires, probes, or tubes.

9.4 Power up the RH probes as described in the Vaisala manufacturer's operations manuals and ensure that they are working. All temperature and RH reading should be similar if conditions inside the non-condensing vessel are at ambient temperature and RH.

10.0 OPERATION OF BI-THERMAL RH CALIBRATION SYSTEM

10.1 Turn on the Iotech data acquisition modular units and the computer.

10.1.1 Start DasyLab7 and open the "Bi-Thermal RH Cal System Program" worksheet. The program should appear as shown in attachment 1 figure 5 of this TIP.

10.2 After opening the worksheet file and with the program stopped (square indicator in the upper left hand corner of the window should be gray) select the Experimental Settup under Experiment in the tool bar and ensure that the following program parameters are set:

10.2.1 Global settings:

10.2.1.1 Sample Rate/channel to 50.0 hertz

10.2.1.2 Block size to 1

10.2.1.3 PC Clock selected

10.2.2 Driver Settings

10.2.2.1 Buffer set to 4096 Kbytes

10.2.2.2 Isolated Series selected

10.2.2.3 Block per series set to 1

10.2.2.4 Delay in seconds set to 0.1 seconds

10.3 Set the Data store to off by selecting the OFF button in the "Switch00" window in the lower left hand corner of the program window.

10.4 Set the temperature setting switch to zero by selecting the "0" button in the "Coded Switch 0" window.

10.5 With the probe loaded in to the non-condensing test vessel and the saturator filled in accordance with section 9.0, perform the following steps:

10.5.1 Close the non-condensing oven door and ensure that it is latched

10.5.2 Set the external control by-pass switch to the OFF position.

10.5.3 Set the oven temperature control to approximately 7.2 on the dial.

10.5.4 Set the over temperature control to approximately 7.8 on the dial.

10.5.5 Set the power switch to the ON position.

10.6 Start the Bi-Thermal RH Cal System Program" in DasyLabs by selecting the play arrow in the upper left hand side of the program window. Ensure that program is running by reviewing the temperature displays and chart windows.

10.6.1 Select the highest temperature required for calibration of the probe by clicking on the proper button in the "Coded Switch 0" window.
NOTE: The interconnecting tube heaters can be started at this point (see section 10.7 for instructions on starting the interconnecting tube heaters).

10.6.2 There may be a difference as much as ±7°C between the measured temperature and selected temperature when the system starts to stabilize. The non-condensing vessel must stabilize at this offset temperature for at least 4 hours. *This temperature is displayed in the "Test Vessel Air" in the "Q Temps" window in the upper left hand side of the program window. The vessel air temperature will not exactly match the selected temperature, but if operating properly should be within 7°C. The stabilization period of 4 hours is only required for the initial heating up of the probes to ensure that all areas of the vessel are well above the condensate point of water.*
Check that the temperature is stable by the round indictor in the Status Lamp "Comparator Switch 0" window on the left hand side of the program window, or by observing that the temperature is not fluctuating more than a 0.01°C per minute. Monitor the system during warm up to ensure that it does not exceed 180°C or the maximum operating temperature of the probe(s) under test whichever is less.

10.6.2.1 The top graph ("Q Temps") in the program window can be used to verify that the temperature has stabilized. The scale can be adjusted with the program running by clicking on the "y" axis and entering into the pop window the proper parameters (see the DasyLab 7 operation manual for details on this process).

10.7 Start the interconnecting tube temperature controller and set the temperature to 160°C according the controller manual. Ensure that the upper temperature or alarm limits are set to ≤200°C and that the loop break is set to ≤ 60 minutes.

10.7.1 Allow the interconnect tube to stabilize for 2 hours at the 160°C ±5°C. NOTE: the interconnecting tube heat controllers can be started while the non-condensing vessel is heating up, but must not be left on unattended for more than 4 hours.

10.8 Start the saturator oven as follows:

10.8.1 Close the door.

10.8.2 Set the oven temperature control to 5.4 on the dial.

10.8.3 Set the over temperature control to 7.6 on the dial.

10.8.4 Set the power switch to the ON position and allow the oven to heat up for approximately 30 minutes.

10.8.5 Make sure that the saturator water is boiling by noting the temperature in the "Sat Vessel Water" display in the "Q Temp" window and by briefly opening the saturator oven door and observing that it is boiling.

10.9 Allow the RH to stabilize by observing the RH probe display(s) before recording readings.
NOTE: The readout for each probe should be stable to ±0.2%RH unit over a period of 1 minute.

10.10 Check saturator water level every 30 minutes and between non-condensing vessel temperature changes to ensure that the water level is at the proper level as required in section 9.2.

10.11 Record calibration data as follows:

10.11.1 Fill out the heading information on the RH calibration sheet (see attachment 3)

10.11.1.1 The date of this calibration and the operator name.

10.11.1.2 RH probe model, serial number.

10.11.1.3 Approved YMP calibration RH probe ID#, date of calibration, and calibration due date.

10.11.1.4 NIST traceable precision thermometer and probe(s) approved YMP calibration ID#, date of calibration, and calibration due date.

10.11.2 To determine the RH target, type the temperature reading from the High Precision Thermometer into the "In from DP251 A" text entry box in the "Slider00" window on the left hand side of the program window and note the expected RH is shown in the "Calc RH from DP251" display window on the left hand side of the program.
NOTE: This is for reference only and is not the official RH.

10.11.3 At the selected temperature setting record the reading for the High Precision thermometer, selected program readings and the RH probes under test as indicted on the RH Probe Calibration Sheet.

10.11.4 Three readings shall be recorded for each meter under test, and at least 1 minute apart for each temperature setting.
NOTE: At each temperature setting all readings should be taken within 30 minute to ensure that the saturator's water level does not drop below the minimum level.

10.11.5 RH calibration will be done for at least four temperature settings between 115 and 180°C at least 15°C apart from each other when possible.

10.11.6 Select the next temperature setting as indicted in section 10.6.2 and allow the system to stabilize for at least one hour.

10.11.7 Check and add water as indicted in section 9.2.

10.11.8 Repeat sections 10.8.5 to 10.11.4 of this TIP for each temperature setting.

10.11.9 RH probe acceptance criteria will be ± 2.5% of the calculated RH + 1.5% RH.

10.12 Perform the following steps to remove the probes and to prevent condensation from forming:

10.12.1 Turn off the saturator oven and open the door. Add water to the saturator if the level is below the upper line. This will help cool the saturator.

10.12.2 After the saturator water temperature has cooled below 60°C, remove the glass stopper from one of the ports.

10.12.3 Turn off the interconnecting tube temperature controllers.

10.12.4 Turn off the Non-condensing vessel oven

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10.12.5 After the non-condensing vessel has cooled to below 60°C remove the RH probe(s) and inspect them for any condensations. If any moisture is present allow it to air dry before storing the probe.
NOTE: Cooling down to below 60°C is a safety requirement. If working procedure permits the probe can be removed hot with appropriate personal protection equipment (PPE), such as gloves, face shield and aprons when handling hot vessels and fluids.

10.12.6 Disconnect the probes from the power source and place them in storage.

11.0 REDUCTION OF PROBE CALIBRATION DATA (optional: primarily used to determine error over a range of use)

The response of the measured RH compared to the standard RH calculated from steam stables and Q temperature measurements are linear with small drift between the pre and post experiment calibrations. Percent RH is calibrated against a linear regression of the combined pre- and post-calibration runs. Uncertainty in RH is calculated as the standard deviation of RH calculated for the pre- and post-calibration runs separately and is typically less than 1.5% RH units.

11.1 Determine the RH at each temperature point using the recorded temperatures (from the NIST traceable thermometer or the validated RH meter temperature probe) using the following equation:
$\%RH = -1.3125 \times 10^{-8} t^5 + 1.1448 \times 10^{-5} t^4 - 0.0040281 t^3 + 0.71886 t^2 - 65.66 t + 2491.8$
t=Centigrade Temperature
This equation was derived from the steam tables (see tables 1 and 2, and figure 6 in attachment 1) in the Handbook of Chemistry and Physics (R. C. Weast (Editor-in-Chief) *CRC Handbook of Chemistry and Physics* (CRC Press, Boca Raton, Florida, 1987–1988), pages B-119, B-130, B-131, D-189, D-190)

11.2 Perform a linear fit of the calculated RH data plotted against the recorded RH from the RH meter using Microsoft Excel. Excel is a commercial off-the-shelf software program that is exempt from qualification in accordance with LP-SI.11Q-BSC, Section 2.1.6.

This information can be used to determine RH probe corrections and probe errors. This optional step can be included with the calibration information or in the notebook for the experiment where the RH probe will be used.

12.0 FREQUENCY OF CALIBRATION

12.1 Before RH probes are used in a new or modified experiment.

12.2 After the experiment or selected set of experiments are complete.

13.0 OUT OF CALIBRATION

13.1 Out of calibration equipment will be handled as specified by LP-12.1Q-BSC "Control of Measuring and Test Equipment".

13.1.1 If linear regression correlation coefficient is less than 0.90, repeat temperature and RH calibration procedure. If it is not possible to obtain R2>0.90, then the RH unit is considered out of calibration and an OCR shall be initiated.

14.0 RECORDING DATA

14.1 The scientific notebook or supplement will be used to store the calibration documentation including standards measurements, the YMP approved supplier standards certifications, and measurements as described in sections 8.0 and 10.0. Scientific notebooks and supplements will be maintained and reviewed in accordance with LP-SIII.11Q-BSC, Scientific Notebooks.

14.2 Documentation of instrument calibration shall be performed each time instrument calibration is conducted. Calibration documentation shall be signed and dated by the person conducting the calibration and shall consist of the following:

14.2.1 The unique identification of the M&TE calibrated

14.2.2 Date calibrated

14.2.3 Calibration data

14.2.4 Procedure (including revision level) used to calibrate the M&TE

14.2.5 Recalibration due date or calibration interval/frequency

14.2.6 Specified range and tolerance and whether M&TE met those tolerances

14.2.7 Identification of and traceability to the calibration standards used for the calibration

14.2.8 Results of the calibration and statement of acceptability

14.2.9 As-found condition of the M&TE, as appropriate

14.2.10 Personnel performing calibrations

14.2.11 Reference to M&TE OCR if generated as a result of calibration

14.3 Calibration Stickers

14.3.1 A calibration sticker from Thunder Scientific will be attached to the Temp/RH Probe that contains the following information:

- The name or initials of the person performing the calibration
- The date (month, day, year) of calibration
- The due date (month, day, year) for the next calibration
- The unique identification number of the probe

14.3.2 Upon satisfactory completion of the Temp/RH Probe calibration in accordance with this TIP, attach an M&TE Limited Calibration Sticker to the probe in a location that does not impair the function or accuracy of the probe. The M&TE Limited Calibration Sticker shall contain the following information:

- The name or initials of the person performing the calibration
- The date (month, day, year) of calibration
- Calibrate prior to use
- The unique identification number of the probe
- The range of calibration (the lower end of the range will be based on the Thunder Scientific calibration [range is typically 20°C to 60°C] and the upper end of the range will be based on the TIP CM-72 calibration [range is typically 115°C to 180°C]). [2]

14.3.3 The M&TE Limited Calibration Sticker shall comply with the following requirements:

- The sticker shall be partially or entirely red, orange or yellow.
- The sticker shall be labeled with a header indicating "Limited Calibration"

15.0 QUALITY ASSURANCE RECORDS

15.1 Lifetime

15.1.1 RH meter humidity and calibration data

15.1.2 The calibration certificates with NIST traceable standards

15.1.3 Out of Calibration Reports (OCR)

15.2 Non-Permanent

15.2.1 None

15.3 Controlled Documents

15.3.1 This Technical Implementing Procedure

15.3.2 Vaisala Operating Manuals (HMP 140, 230 & 240 Series)

15.3.3 DasyLab7 Programming Manual

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[2] Acceptable calibration by Thunder Scientific from 20°C – 60°C, coupled with acceptable calibration in accordance with this TIP from 115°C to 180°C is considered adequate justification for calibration range of 20°C to 180°C, as appropriate

15.4 Records Processing Center Documents

15.4.1 Records generated as a result of this TIP are entries in scientific notebooks or attachments to such notebooks, and/or excel spreadsheets of data package files and are processed to the RPC with the notebook in accordance with AP-17.1Q "Records Management." OCRs are processed and submitted to the RPC in accordance with LP-12.1Q-BSC.

16.0 TERMS AND DEFINITIONS

16.1 Calibration- The calibration or verification of calibration and/or tolerance conducted by the user prior to using the instrument to take measurements.

17.0 ATTACHMENTS

17.1 Attachment 1 - Figures 1- 6 and Tables 1 & 2

17.2 Attachment 2 - RH Meter Temperature Probe Calibration Sheet

17.3 Attachment 3 - RH Meter Humidity Calibration Sheet

17.4 Attachment 4 - M&TE Justification Form

18.0 TRAINING

18.1 No formal training is required for this TIP. However, on the job instruction will be provided to personnel implementing the TIP until such time that the Principal Investigator is satisfied with their proficiency.

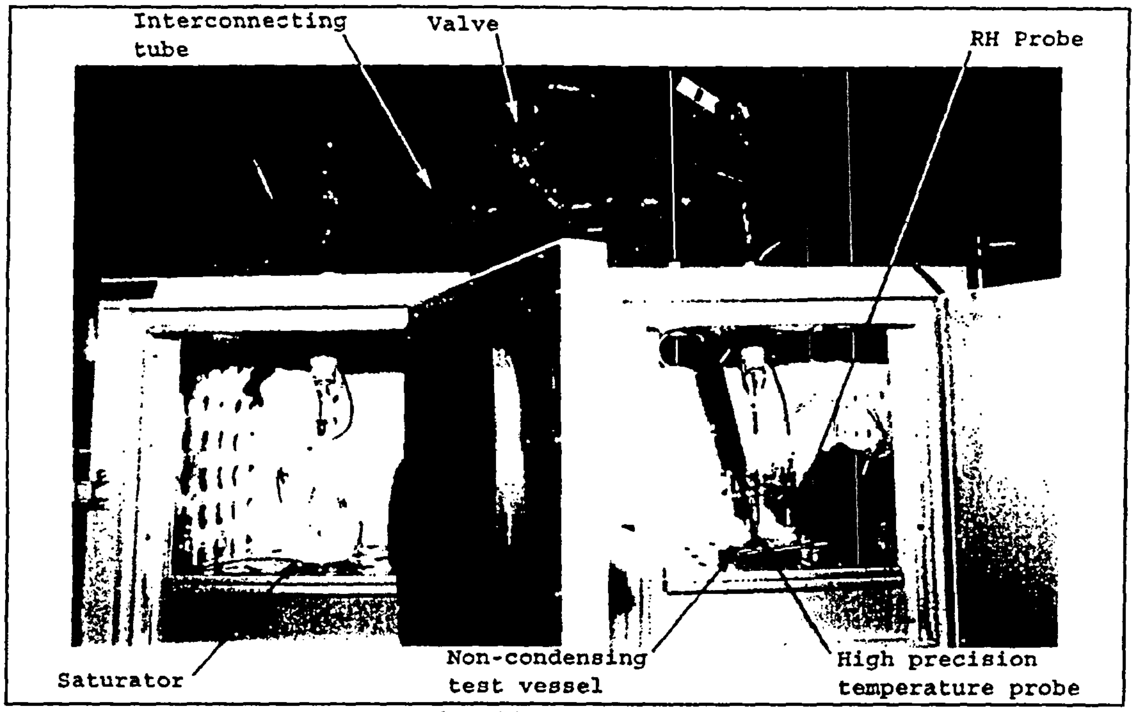

Figure 1 - Photo of the high temperature humidity system

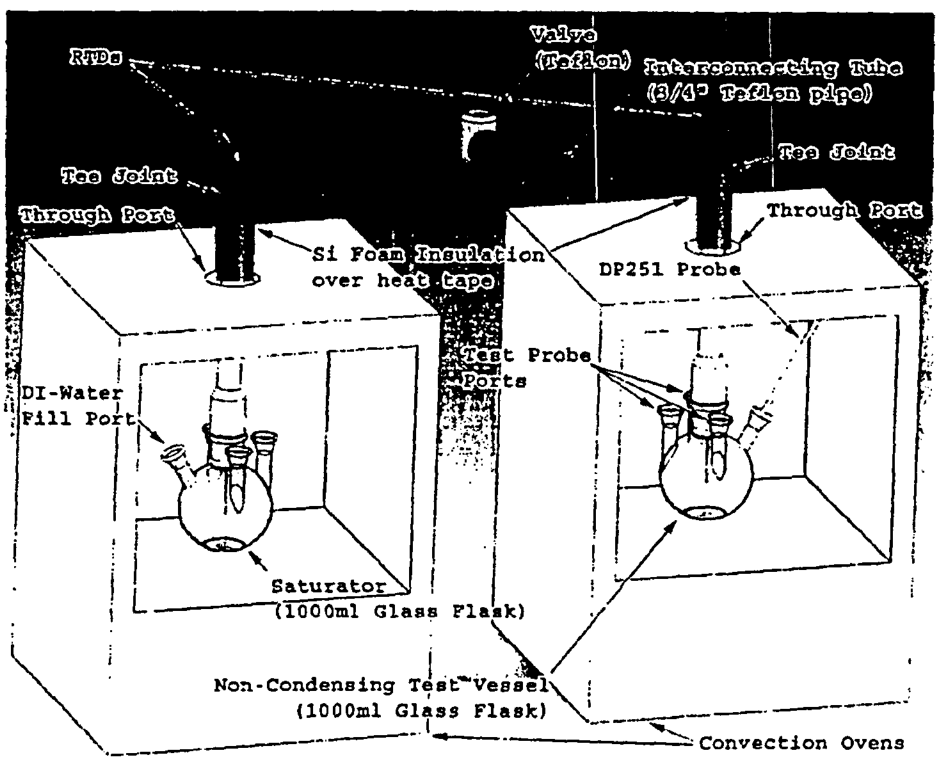

Figure 2 - Schematic of the humidity generating system

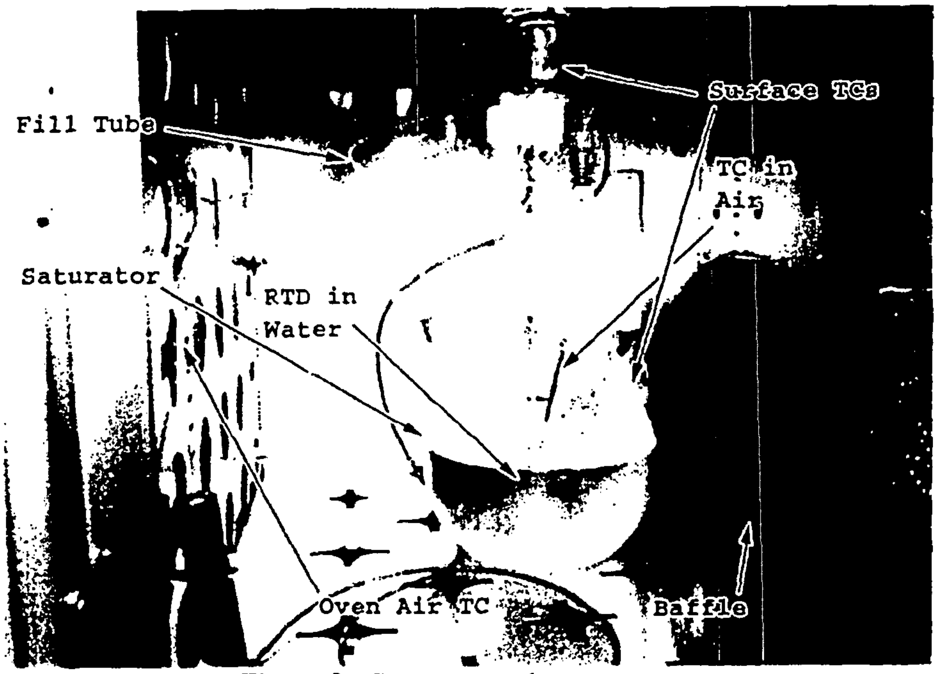

Figure 3 - Saturator and components

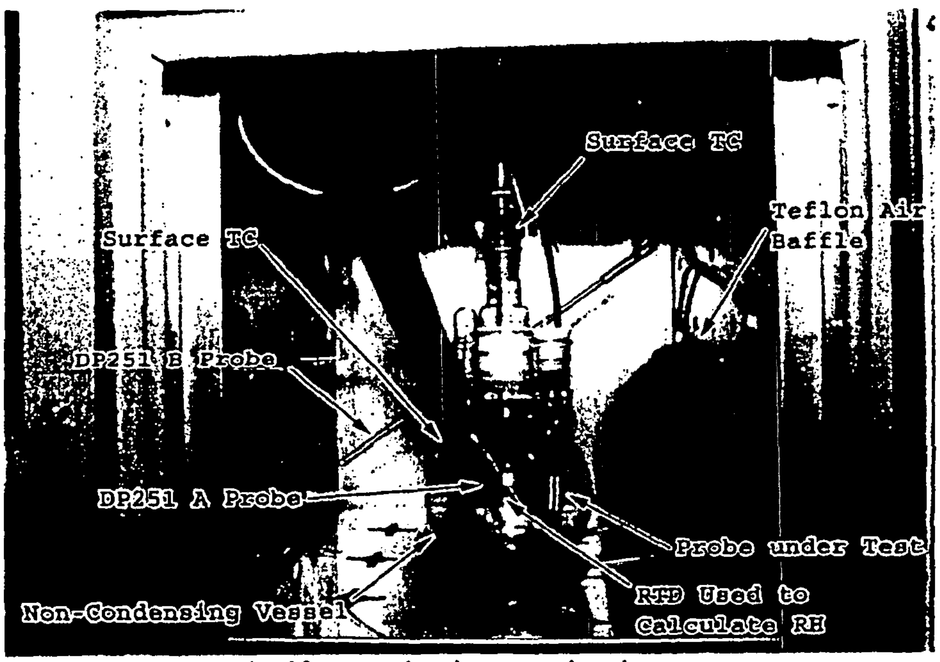

Figure 4 – Non-condensing vessel and components

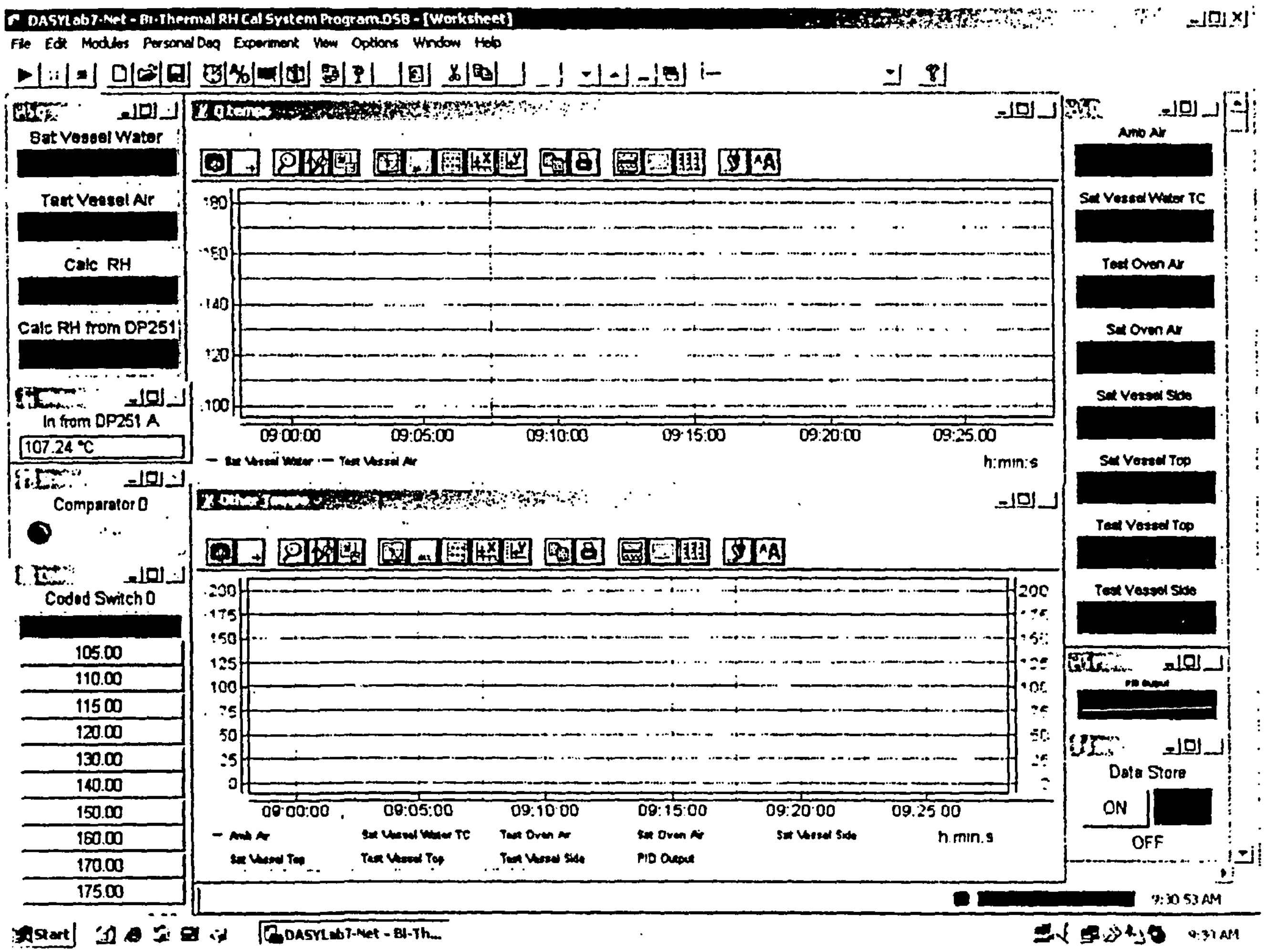

Figure 5 – DasyLab7 program window

$Y = M0 + M1*x + ... M8*x^8 + M9*x^9$	
M0	2491.8
M1	-65.66
M2	0.71886
M3	-0.0040281
M4	1.1448e-05
M5	-1.3125e-08
R	1

Table 1 – 5th order polynomial for Temperature to RH conversion

Temperature °C	Vapor Pressure mm Hg	% Relative Humidity
100	760.00	100.00
105	906.07	83.88
110	1074.56	70.72
115	1267.98	59.94
120	1489.14	51.04
125	1740.93	43.65
130	2026.16	37.51
135	2347.26	32.38
140	2710.92	28.03
145	3116.76	24.38
150	3570.48	21.29
155	4075.88	18.65
160	4636.00	16.39
165	5256.16	14.46
170	5940.92	12.79
175	6694.08	11.35
180	7520.20	10.11
185	8423.84	9.02
190	9413.36	8.07
195	10488.76	7.25
200	11659.16	6.52
205	12922.81	5.88

Table 2 – Selected temperatures for the Handbook of Chemistry and Physics steam tables (R. C. Weast (Editor-in-Chief) *CRC Handbook of Chemistry and Physics* (CRC Press, Boca Raton, Florida, 1987–1988), pages B-119, B-130, B-131, D-189, D-190)

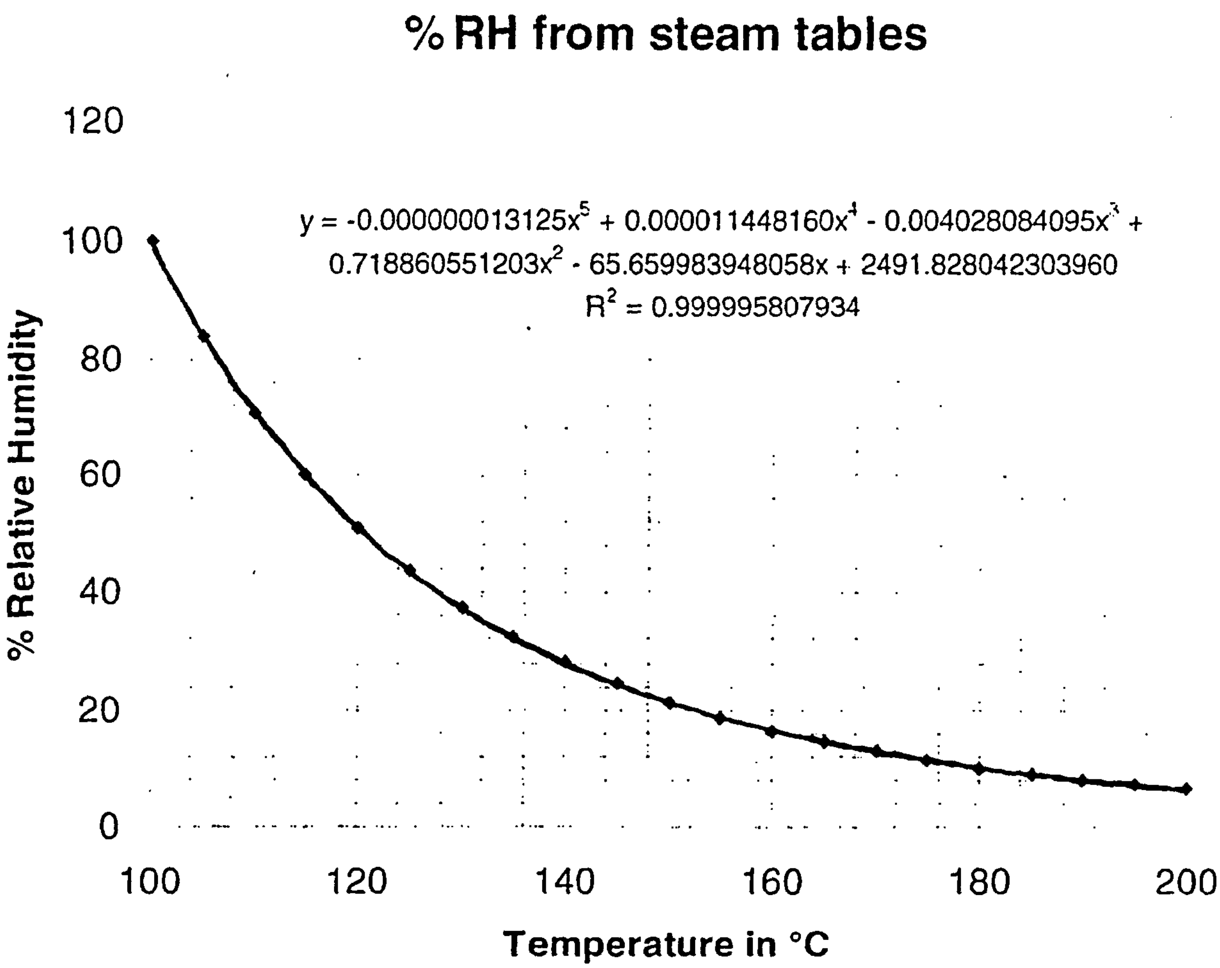

Figure 6 – Calculation of standard RH from steam tables (table 2, in this TIP)

ATTACHMENT 2
TIP CM-72, Rev. 0, CN 0

Bi-Thermal RH Calibration System Temperature Probe Calibration Form

Form ID   Humidity Probe ID Date (Date Format: YYYYMMDD)   Date

Humidity Probe SN   Operator's Name

YMP Calibration ID   Cal Date   Cal Due

NIST Traceable High Precision Thermometer ID

YMP Calibration ID   Cal Date   Cal Due

Note Wait for the NIST Traceable High Precision Thermometer and RH meter temperature readings to stabilize before recording readings

Date	Time	Target* Temperature		RH Meter Temperature Reading	Average of 3 Readings		Is Error# Acceptable

* Actual temperature shall be within [illegible] value. ** NIST Traceable High Precision Thermometer and probe.

Default tolerance is 0.2 [illegible]

TIP-CM-72 (6-6)   Signature: Date:

DRAFT

ATTACHMENT 3
TIP CM-72, Rev. 0, CN 0

Bi-Thermal RH Calibration System RH Probe Calibration Form

Form ID Humidity Probe SN Date (Date Format: YYYYMMDD) Date

Humidity Probe SN. Operator's Name

YMP Calibration ID: Cal Date: Cal Due

NIST Traceable High Precision Thermometer ID

YMP Calibration ID Cal Date Cal Due

Note: Wait for the computer and the High Precision Thermometer temperature readings to stabilize before recording readings. Ensure that all ports and feed throughs are sealed and that the saturator water level is between the marks on the side of the vessel. Check the saturator to make sure the water is boiling.

Date	Time	Target Temp*			RH Meter Temp Probe	Avg of 3 Readings	RH Meter RH Reading	Avg of 3 Readings		Tol.# Error in (%RH units) Accept

* Actual temperature shall be within ± 7.0 C of this value. ** NIST Traceable High Precision Thermometer and probe
\# Tolerance ±(2.5% of the calculated RH + 1.5%RH) Temperature readings in C Relative Humidity in %RH

Signature: Date:

BSC	**Measuring and Test Equipment Justification** *Complete only applicable items.*	QA: QA Page 1 of 1

1. M&TE ID No. See Section 6 below for M&TE ID Numbers		2. M&TE Type Vaisala Temperature/Relative Humidity Probes
3. Initiator Name K. Staggs	4. Date 11/18/2005	5. Responsible Manager or Principal Investigator S. Carroll

6. Justification:

The following Temp/RH probes are calibrated by Thunder Scientific, a calibration supplier listed on the OCRWM Qualified Suppliers List.
Model HMP 243 (SN T4610028 - 030, V0810002 & -3; X3250114 - 116; U5110014; Y4710001, Y4750012, Y1110101, Z1420005 & 06
Model HMP 235 (SN Z1440126 & 127)
Model HMP 233 (SN Y1110102, Y1110101)
Model HMP 141/46 (SN T1750263/T4150003)

Thunder Scientific is unable to calibrate the probes greater than 60 degrees C due to the unavailability of a NIST traceable standard. CR 5430 identified that the Vaisala Temp/RH probes are used to measure temperature and relative humidity above 60 degrees C. To accommodate the performance of scientific experiments above this temperature, LLNL has designed a test setup and developed a calibration methodology to calibrate the Temp/RH probes from 100 to 180 degrees C.

The equipment and calibration methodology is described in YMP TIP CM-72, Calibration of RH Meters Using the Bi-Thermal Calibration System. Specifically, Section 4.0, Concept of the Bi-Thermal RH Calibration System, and Section 6.0, Overview of the Calibration Process, provide the scientific and technical basis for the calibration methodology.

The calibration methodology described in the TIP is considered acceptable to calibrate the probes from 100 to 180 degree C and will not invalidate the calibration performed by Thunder Scientific from 20-60 degrees C.

7. Approved By

Responsible Manager or Principal Investigator: Susan A. Carroll (Printed Name) Date: 11/18/05

Susan A. Carroll (Signature)

DRAFT

Appendix 12: Letter from Jane Long, LLNL, Associate Director, to Donald Beckman, Licensing and Nuclear Safety, BSC

DRAFT

University of California
Lawrence Livermore National Laboratory

Energy and Environment Directorate

January 20, 2006
E&E06-045

Donald Beckman
Licensing and Nuclear Safety
Bechtel SAIC Co., LLC
1180 Town Center Drive
Las Vegas, NV 89144

Subject: Relative Humidity Probes

Dear Mr. Beckman:

This letter is to inform you that the Lawrence Livermore National Laboratory Yucca Mountain Program will not utilize Vaisala Relative Humidity probes in any Yucca Mountain related experiments until calibration issues raised by the NRC (OAR-05-05) are responded to and resolved.

Some calibration activities may be conducted associated with completed experiments. However probes are not used in any of our current ongoing experiments, nor will they be used in any future experiments until we have a resolution of this issue. The probes will be controlled in accordance with the requirements of LP-12.1Q-BSC, Control of Measuring and Test Equipment.

Sincerely,

Jane C. S. Long, Ph.D.
Laboratory Associate Director
for
Energy and Environment Directorate
Telephone: (925) 422-0315

JCSL:clc

Copy to:
Dave McCallen LLNL

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