

Welcome

Vaisala Humidity 101 – Calibration of the Humidity Instrument



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Engineer

VAISALA

Humidity 101

\ webinar series

“all humidity sensors drift to some extent”

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Agenda

1. Calibration Fundamentals
 - Definitions
 - Traceability
 - Accreditation
2. Saturated Salts and Other Humidity Reference Equipment
3. Humidity Calibration Processes
4. Humidity Calibration Best Practice

Why do we calibrate?

- Economical Impact
- Health, Safety & Environment
- Scientific Research Results
- Distributed Manufacturing



Premise for Humidity Calibration

A humidity sensor cannot be protected hermetically: its active parts are always exposed to the dirt and chemicals in the ambient air. This may cause the sensor to drift under some circumstances.

The electronics of a measurement instrument may be affected by time, temperature changes and mechanical or electrical shocks.

Definitions

Calibration = comparing the output of a measurement instrument against a reference instrument and reporting the result

Adjustment = changing the output to correspond to the output of a reference instrument

Specification = the performance criteria for an instrument

Normal service procedure (also called “calibration”):

- first calibration + adjustment
- then calibration

Quality Measurement Standards (QMS)

States the minimum requirements and guidance for the maintenance of measurement equipment

ISO/TS 16949:2002

GLP (good laboratory practice)

ISO 10012

ISO/IEC 17025

ANSI/NCSL Z540

Traceability

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Traceability

“a traceable measurement is one which can be related to appropriate measurement standards, generally national or international, through an unbroken chain of comparisons”

further

“humidity parameters may be considered as traceable if they are derived from actual realized measurements at the national level along with recognized numerical conversions”

RH Traceability Chain – Vaisala Boston Lab

SI Units

Metre Convention – May 20, 1875

May 20th

National Metrology Day



International System of Units (SI Units)

Administered by the BIPM in Paris or International Bureau of Weights & Measures



Bureau International des Poids et Mesures

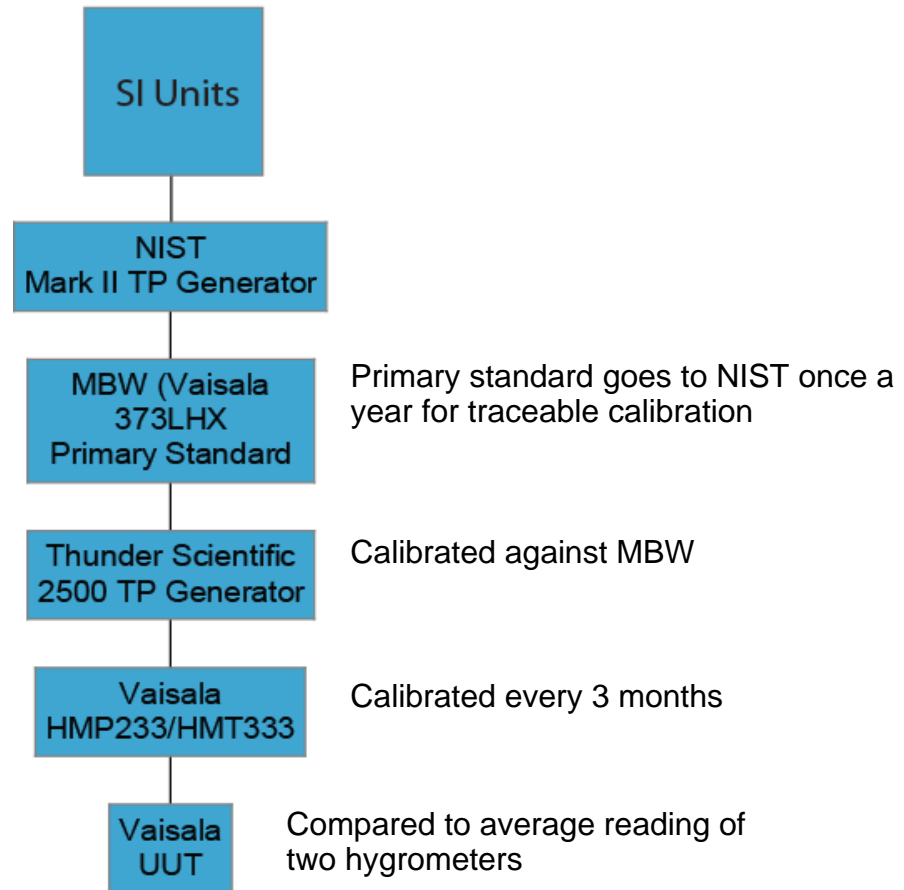
Seven basic units of measure

1. Length (meter)
2. Mass (kilogram)
3. Time (second)
4. Current (ampere)
5. Temperature (kelvin)
6. Amount of a substance (mole)
7. Light intensity (candela)



IPK – International Prototype Kilogram

RH Traceability Chain – Vaisala Boston Lab



Accredited or Non-Accredited

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3rd Party Accrediting Agencies

EA MRA (European co-operation for Accreditation for Calibration and Testing :

- + NATA(Australia)
- + BMWA(Austria)
- + BKO(Belgium)
- + CGCRE/INMETRO(Brazil)
- + CAI(Czech Republic)
- + DANAK(Denmark)
- + FINAS(Finland)
- + COFRAC(France)
- + DKD, DACH, DAP, DATech(Germany)
- + ESYD(Greece)
- + INAB(Ireland)
- + ISRAC(Israel)
- + SINAL, SIT(Italy)
- + A2LA(USA)
- + IANZ(New Zealand)
- + RvA(Netherlands)
- + NA(Norway)
- + PCA(Poland)
- + RENAR(Romania)
- + SNAS(Slovakia)
- + SA(Slovenia)
- + SAC-SINGLAS(Singapore)
- + SANAS(South Africa)
- + ENAC(Spain)
- + SWEDAC(Sweden)
- + SAS(Switzerland)
- + UKAS(UK)



APLAC MRA (Asia Pacific Laboratory Accreditation Co-operation) :

- + NATA(Australia)
- + SCC, CASEAL(Canada)
- + CNAL(China)
- + HKAS(Hong Kong, China)
- + NABL(India)
- + KAN(Indonesia)
- + JAB, IA JAPAN(Japan)
- + KOLAS(Korea)
- + DSM(Malaysia)
- + IANZ(New Zealand)
- + SAC-SINGLAS(Singapore)
- + TAF(Chinese Taipei)
- + DMSc, TLAS/TISI(Tailand)
- + A2LA, IAS, NVLAP(USA)
- + BOA/VILAS(Vietnam)
- + EMA(Mexico)
- + BPSLAS(Philippines)

Other :

- + OAA(Argentina)
- + ONARC(Cuba)
- + NLAB(Egypt)

* Source : ILAC web site(<http://www.ilac.org/>) on January 2006

Accredited Calibrations

- QMS = ISO/IEC 17025 or in some cases ANSI/NCSL Z540
- Competence and compliance are ensured by third party such as NVLAP or A2LA

Agency assures that...

- Measurements carried out to the highest standards of technical competence
- Traceable to recognized national or international standards
- Using accepted and agreed methods
- Realistic statements of uncertainty

Accredited
Humidity Calibration Certificate

Certificate #: 010106-B-B1234567

Procedure #:
Asset #:
Model #:
Serial Number:
Instrument:
Manufacturer:
RMA #:
Calibration Date:

Accredited
Humidity Calibration Certificate

Certificate #: 010106-B-B1234567
Procedure #: 11603108
Asset #: 123456
Model #: HMP231
Serial Number: B1234567
Instrument: Humidity & Temperature
Manufacturer: Vaisala
RMA #: n/a
Calibration Date: January 1, 2006

Customer Infort

Condition of Ins

Date Received:

Requested Due

Signatures
Calibrated By:

Levyn Palao
Calibration Technician

This certificate may no
The measurement res
results of this calibrati
comply with the require

* Any due date given is
prior to the expiration c
measurement error.

The CSL is controlled

Special Limitations
None

Laboratory Environment

Uncertainty

The reported expanded uncertainty of the r
measurement multiplied by the coverage fa
coverage probability of approximately 95%
in accordance with U.S. Guide to the Expre

Description

The humidity calibration was performed in t
commencement of the calibration the instru
conditions for a period of at least 8 hours. 1
outlet air stream of a Thunder Scientific 25
plugged to prevent outside conditions from

Sa

References

Thunder Scientific 2500 Two-Pressure gen
vapor at a given pressure and temperature
traceable to NIST via Thunder Scientific an

Measurement results

The measurement results were obtained by
the setpoint had been reached. The meas
simultaneously. The average of each meas
measurement are valid only for the product

Calibration II	
Station	Model

Accredited
Humidity Calibration Certificate

Certificate #: 010106-B-B1234567

Procedure #: 11603108
Asset #: 123456
Model #: HMP231
Serial Number: B1234567
Instrument: Humidity & Temperature
Manufacturer: Vaisala
RMA #: n/a
Calibration Date: January 1, 2006

AS FOUND

Out of Tolerance as

**Humidity,
Calibration Data**

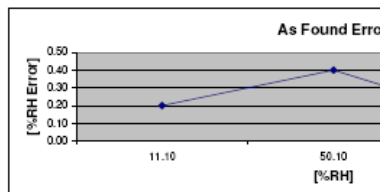
Reference	Unit Under Test	Deviasi
11.10	11.30	0.20
50.10	50.50	0.40
80.10	80.20	0.10

Coverage factor

**Temperatu
Calibration Data**

Reference	As Found Unit Under Test	Deviasi
22.10	22.10	0.00

Out of tolerance conditions are determined by the product spe



Accredited
Humidity Calibration Certificate

Certificate #: 010106-B-B1234567

Procedure #: 11603108
Asset #: 123456
Model #: HMP231
Serial Number: B1234567
Instrument: Humidity & Temperature
Manufacturer: Vaisala
RMA #: n/a
Calibration Date: January 1, 2006



Certificate No: 2093.01

AS LEFT DATA

**Humidity, %RH
Calibration Data "As Left"**

Reference	Unit Under Test	Deviation	± Tolerance	± Measurement Uncertainty
11.10	11.30	0.20	1.00	0.61
50.10	50.50	0.40	1.00	0.68
80.10	80.20	0.10	1.00	0.79

Coverage factor of k = 2

**Temperature, °C
Calibration Data "As Left"**

Reference	As Found Unit Under Test	Deviation	± Tolerance	± Measurement Uncertainty
22.10	22.10	0.00	0.20	0.05

Certificate Sample



Non-Accredited Calibrations

1. Operate according to other QMS guidelines
2. Competence is not certified or audited and should be audited by you before entrusting your calibration to a non-accredited lab

Certificate of Calibration

Report #: 122908--RH RMA #: Calibration Date: Dec-29-2008
 Model #: HMT331 Serial #:

Instrument Type: Humidity Transmitter Ch 1: 4...20 mA, 0...100 %RH Calibration Procedure: 11603100
 Instrument Range: 0 to 100%, RH Ch 2: 4...20 mA, -40...+180 °C, T
 Instrument Range: -40 to +60 °C, T

Customer: Sample
 City, State:

This unit was calibrated by adjusting its reading at 0% against a dry-air line and at 75% against reference humidity and temperature instrument. Vaisala model HMP233. Additional instrument verification checkpoints were made against HMP233 reference at 11%RH and 33%RH. Calibration and instrument verification sequences utilize a dry-air line and a set of controlled aqueous salt solutions Vaisala model HMK13B. Laboratory ambient conditions are humidity and temperature controlled. The calibration uncertainty is presented at 95% confidence level, k=2. The standard uncertainty of the measurement has been determined in accordance with U.S. Guide to the Expression of Uncertainty in Measurement.

Calibration Data (As Found)				
Out of Tolerance: YES				
Temperature Calibration, °C				
Reference	Unit Under Test	Error	± Tolerance, °C	± Uncertainty, °C
22.00		-22.00	0.20	0.07
Humidity Calibration, %RH				
Reference	Unit Under Test	Error	± Tolerance, %	± Uncertainty %
0.03		-0.03	1.00	0.50
11.30		-11.30	1.00	0.92
32.60		-32.60	1.00	1.01
75.50		-75.50	1.00	1.02
Calibration Data (As Left)				
Temperature Calibration, °C				
Reference	Unit Under Test	Error	± Tolerance, °C	± Uncertainty, °C
22.00		-22.00	0.20	0.07
Humidity Calibration, %RH				
Reference	Unit Under Test	Error	± Tolerance, %	± Uncertainty %
0.03		-0.03	1.00	0.50
11.30		-11.30	1.00	0.92
32.60		-32.60	1.00	1.01
75.50		-75.50	1.00	1.02

Problem Noted: None
 Action Taken: The Unit Was Calibrated

The results of this calibration are related only to the items being calibrated at the time of calibration, and, are traceable to the National Institute of Standards and Technology. Vaisala's calibration system has been established to meet the requirements of ANSI/NCSL Z540-1-1994. This certificate can not be reproduced, except in full, without the expressed written consent of Vaisala. The certificate was established to comply with the requirements of ISO/IEC 17025. Vaisala is ISO 9001:2000 certified.

Calibration Equipment Used: Workstation 1A			
Model Number	Serial Number	Calibration Date	Due Date
Power Supply	21609053	Dec. 1, 2008	Dec. 1, 2010
Fluke 45	6666019	Dec. 19, 2007	Jun. 19, 2009
HMK13B	500005	Oct. 1, 2008	Apr. 1, 2009
HMP233	V4210035	Oct. 1, 2008	Jan. 1, 2009
HMT333	B0920009	Oct. 1, 2008	Jan. 1, 2009
HMK41/HMP45	S0720005	Oct. 14, 2008	Apr. 14, 2009

Ambient Conditions	
Temperature:	22.00 °C
Humidity:	50.00 %RH

Approved By _____ Technical Operator
 Collins Nzul

Page 1 of 1

Do you need an accredited calibration?

- Yes, if a regulating agency requires it
- Yes, if your internal operating rules require it
- Yes, if you will have a regular need to defend or demonstrate proper procedures
- No, if your internal guidelines do not specify
- No, if you determine that calibration is not critical for your operation

Saturated Salts & Other Reference Equipment

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Reference Equipment

■ Two-temperature Generator

- Uses the principle that RH changes with temperature

■ Two-pressure Generator

- Uses the principle that RH changes proportionately with pressure



Reference Equipment

Two-temperature, Two-pressure Generator

- Uses a combination of temperature and pressure changes to generate a specific dewpoint



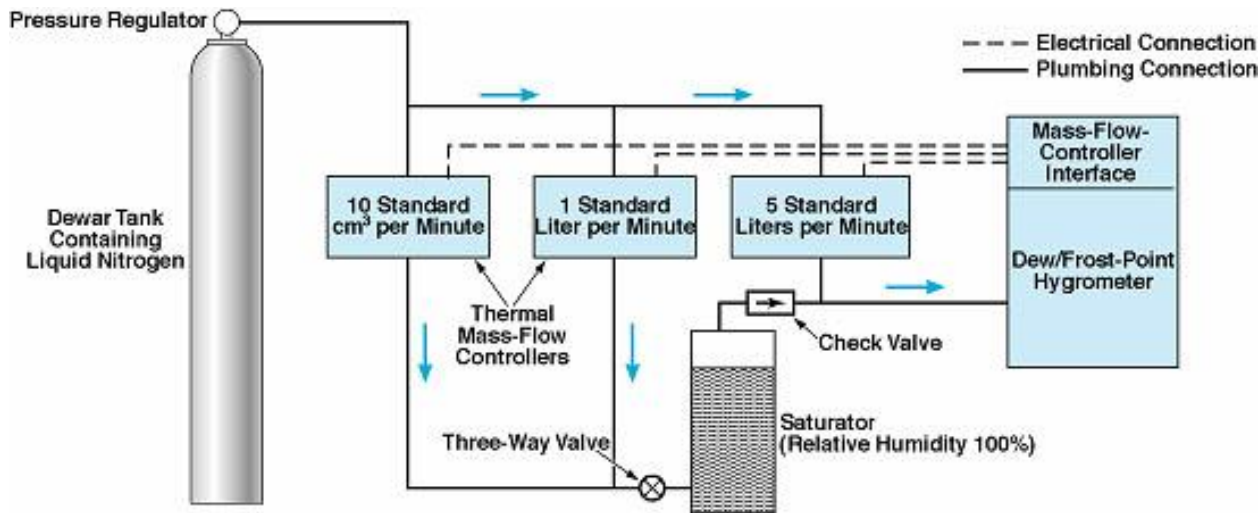
Thunder Scientific 3900

Reference Equipment

Mixed-flow Generator

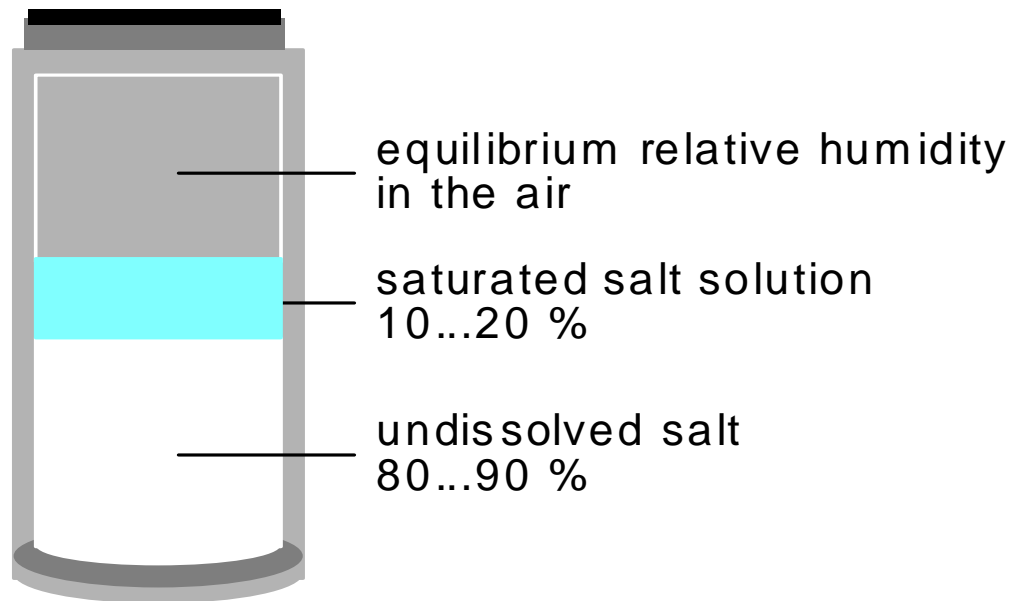
- Mixes specific proportions of dry air and saturated air

$$RH_m = \frac{V_d RH_d + V_s RH_s}{V_d + V_s}$$



Saturated Salt Solutions

An aqueous salt solution generates a certain equilibrium relative humidity in the air above it; different salts generate different relative humidity



Saturated Salt Solutions

Table 9. Equilibrium relative humidities generated over saturated solutions of a selection of salts.

<i>Saturated salt solution</i>	<i>Temperature</i> °C										
	0	5	10	15	20	25	30	35	40	50	60
	<i>Relative humidity (%)</i>										
Potassium sulphate	99	98	98	98	98	97	97	97	96	96	--
Potassium nitrate	96	96	96	95	95	94	92	91	89	85	--
Potassium chloride	89	88	87	86	85	84	84	83	82	81	80
Ammonium sulphate	82	82	82	82	81	81	81	80	80	79	--
Sodium chloride	76	76	76	76	75	75	75	75	75	74	75
Sodium nitrite	--	--	--	--	65	64	63	62	61	--	--
Ammonium nitrate	--	--	75	70	67	64	60	53	--	--	--
Sodium dichromate	61	59	57	57	55	54	53	51	50	49	47
Magnesium nitrate	60	59	57	56	54	53	51	50	48	45	--
Potassium carbonate	43	43	43	43	43	43	43	--	--	--	--
Magnesium chloride	34	34	33	33	33	33	32	32	32	31	29
Potassium acetate	--	--	23	23	23	23	22	--	--	--	--
Lithium chloride	11	11	11	11	11	11	11	11	11	11	11
Potassium hydroxide	--	14	12	11	9	8	7	7	6	6	5

The values listed in the table are taken from papers by Greenspan (1976), O'Brien (1948), Wexler (1954) and Young (1967). Where gaps are shown in the table, no reliable data are available.

Saturated Salt Solutions

Good choices for common salts (at 20°C)

LiCl (lithium chloride)	11.3 %RH
MgCl ₂ (magnesium chloride)	33.1 %RH
NaCl (sodium chloride)	75.5 %RH
K ₂ SO ₄ (potassium sulphate)	97.6 %RH

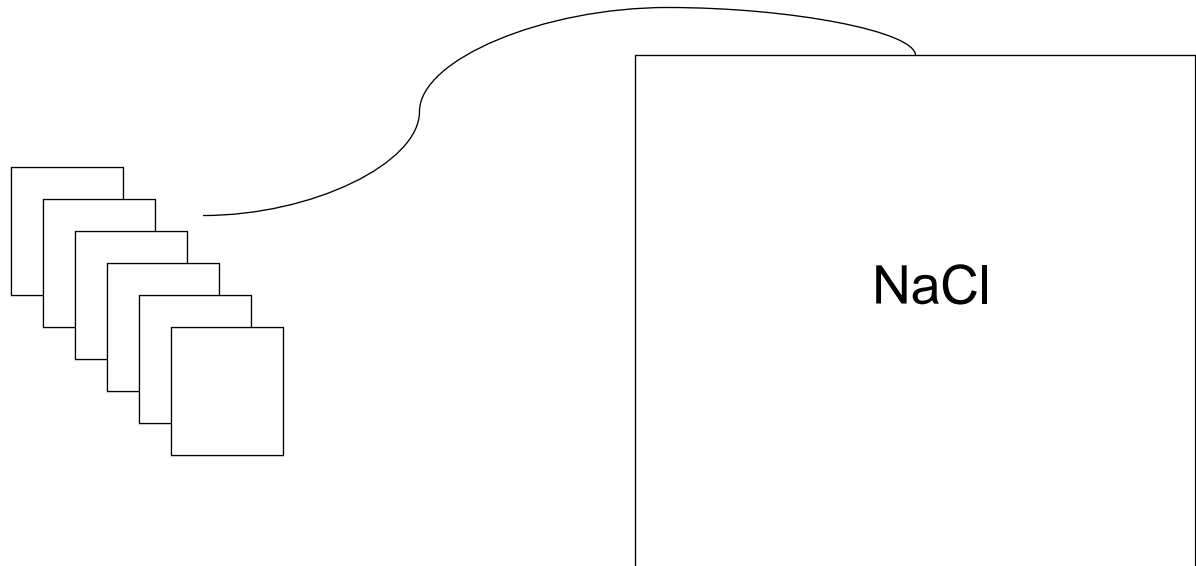


Traceability & Saturated Salts

Standards

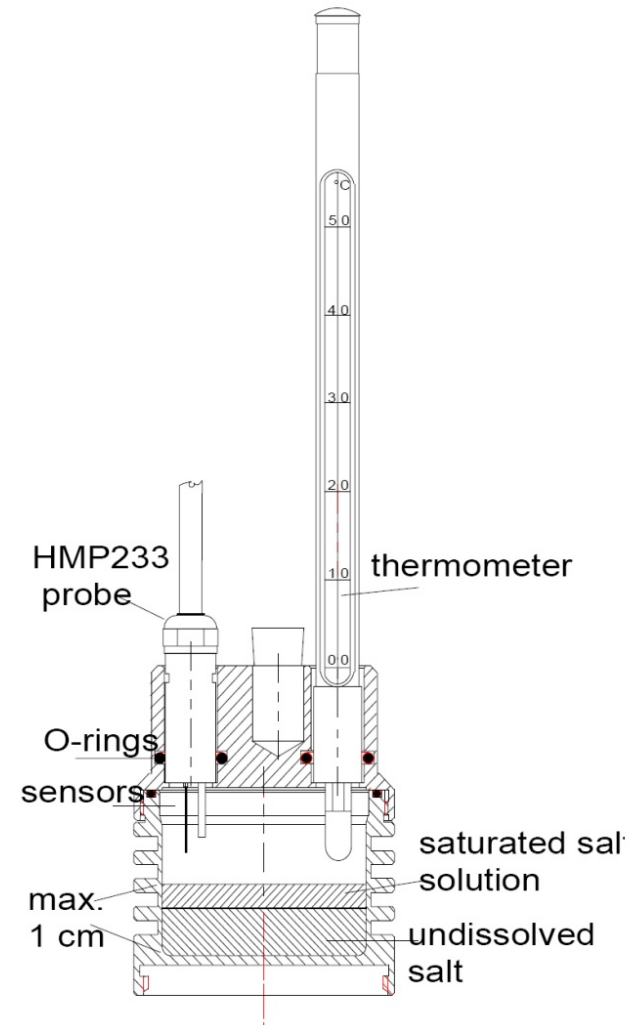
ASTM E104-02 (2007), JIS Z 8806, DIN 50 008

Batch Traceability



Traceability & Saturated Salts

For NIST traceability use a reference hygrometer



The Calibration Process

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Choose your approach...

1. In-house metrology lab

- Manage your own lab, training, standards, traceability, documentation, etc.

2. Contract with outside commercial lab

- Send instruments to an independent lab for calibration, adjustment, repair, etc.

3. Field Calibration

- Calibrate instruments in the process or in-situ with a portable reference or transfer standard
- Use in-house staff or contract for outside service

1. Lab Calibration – example of steps in a lab

1. Instrument equilibrates in the lab for 24 hours
2. Conduct visual inspection
3. Calibrator uses saturated salts and 2 reference hygrometers
4. Place probe in each salt for 30 minutes
 - Record as found data for 0%, 11%, 33%, 75%
5. Make adjustments (2 point)
 - adjustment is made if out of tolerance more than 50% of nominal
6. Record 'as left' data
7. Print certificate and place calibration sticker

2. Field Calibrations – 1 point or multi-point

- Choose 1 point
 - Measurement point does not change more than +/- 20% RH
 - Conditions are not extreme in RH, temperature or other (i.e. gas composition)



Field Calibrations – 1 point or multi- point

- Choose multi-point
 - RH or temperature varies across wide spectrum (i.e. 5 to 95% RH as in outdoor measurement conditions)
 - Extreme conditions (i.e. 90% + RH, 300°F)



Field Calibrations – choose transfer standard

Generator (multi point)



Generator (multi point)

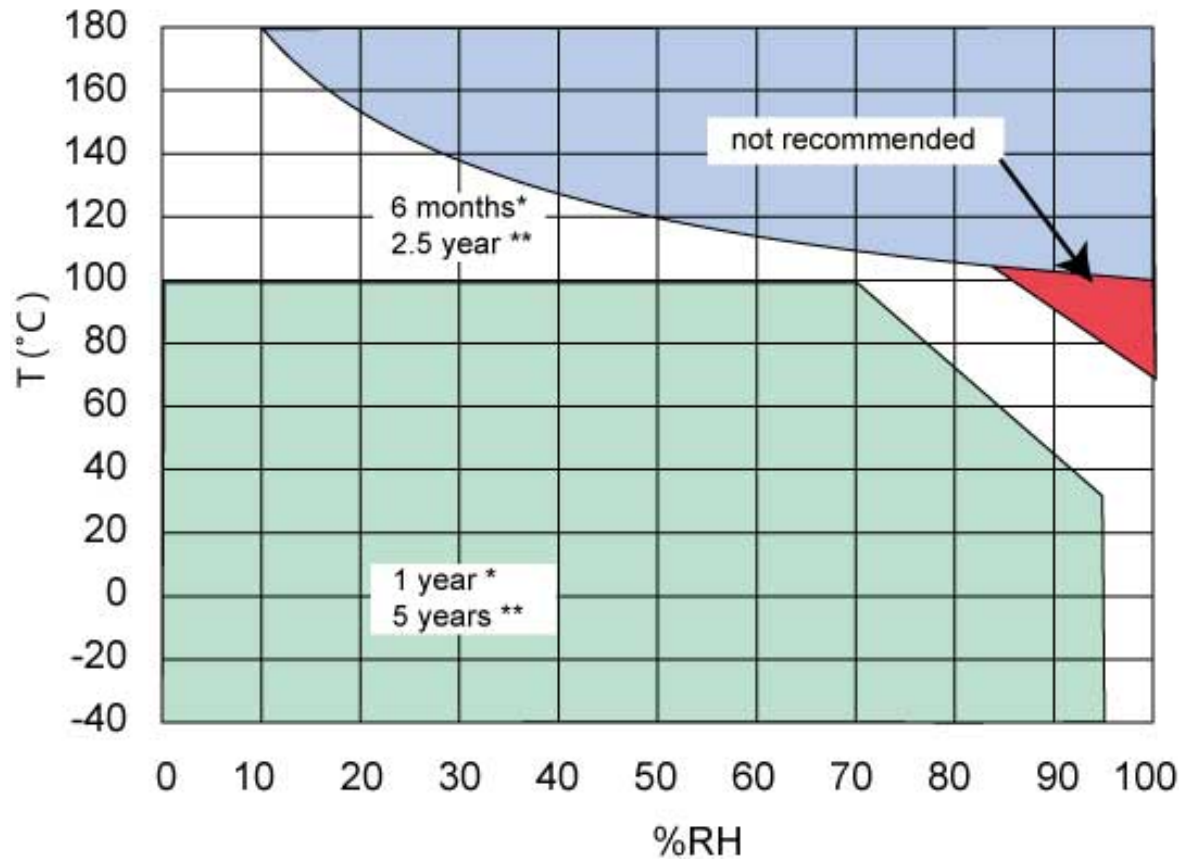


measurement only (one point)

Field Calibration – determine the interval

* to maintain +/- 1% 2%

** to maintain +/- 3.5%



HUMICAP® 180R sensor

Field Calibration – follow your QMS

1. Confirm calibration and check operation of the standard
 - Does the standard meet the specifications of the measurement
 - Standard should be at least 2x better uncertainty of the unit under calibration
2. Be aware of the conditions around the measurement point
 - Breathing on the probe
 - Time for equilibration
 - Non-representative sources of heat or cold
3. Pre-heat and or Purge (if applicable)



Field Calibration – follow your QMS

4. Place probes together and allow equilibrium & take measurement
5. Repeat for multiple points
6. Make adjustments as necessary (one point or two point)
7. Record the results, place stickers, etc.



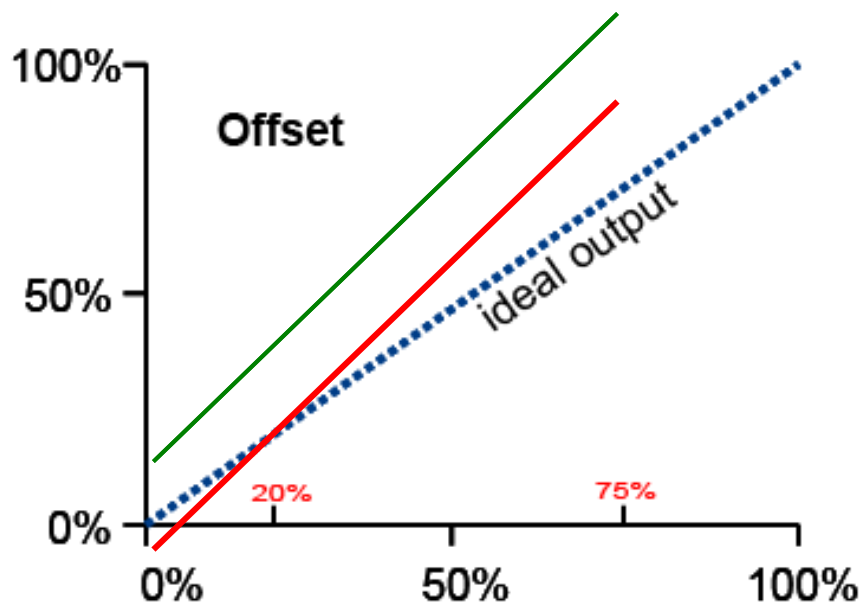
Note about Adjustment

- **One Point** calibration – usually in the ambient environment
 - if an adjustment is necessary:
 - an **OFFSET** adjustment is made when $RH < 65\%$
 - a **GAIN** adjustment is made when $RH > 65\%$
- **Multiple Point** calibration using two or more reference humidities:
 - a salt calibrator or humidity generator is needed
 - if an adjustment is necessary:
 - first an **OFFSET** adjustment is made in the dry point
 - then a **GAIN** adjustment in the wet point

Note about Adjustment

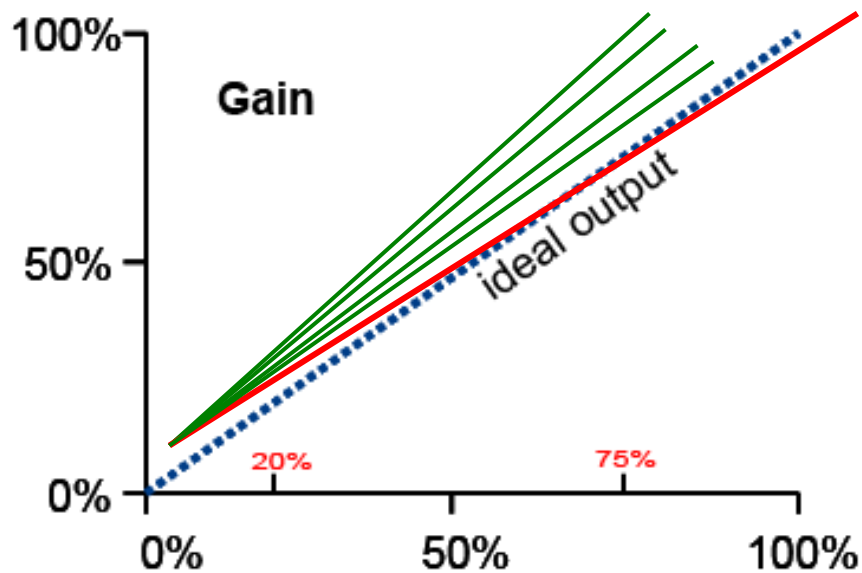
- **OFFSET** adjustment (for $RH < 65\%$):
 - the same correction is made for every point in the measurement range

Example of an **OFFSET** adjustment at 20%RH



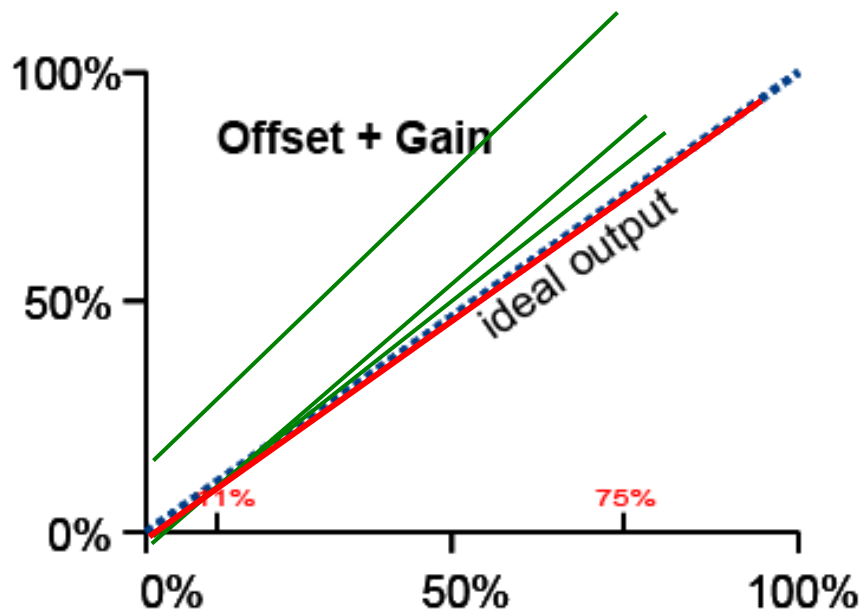
Note about Adjustment

- **GAIN** adjustment (for RH > 65%):
 - the correction is in proportion to the measured value



Note about Adjustment

- **Point 1 = OFFSET**; **Point 2 = GAIN**
 - the correction is in proportion to the measured value
 - the same correction is made for every point in the measurement range
- Example of a **2 point** adjustment at 11% and 75%RH



Best Practice

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Reference: “A Guide to the Measurement of Humidity”, National Physical Laboratory

Best Practice - general

1. Measure as close as possible to the U.U.C probe/sensor
2. Allow enough time for the instruments/probes to stabilize
 - temperature & water vapor
 - anywhere from 5 minutes to 30 minutes depending on the differences
 - use the graphing feature to see it visually
3. Read the measurement results simultaneously

Best Practice - general

4. Choose one point or multi point calibrations and adjustments carefully
5. Follow all manufacturers recommendations and procedures
6. Don't forget to calibrate the analog signal with a calibrated multi-meter
 - if separate from the digital reading

Best Practice – Spot Checking

Use intermediate spot checking

- not the same as field calibration but similar
- use procedures where full calibration is required if spot checking shows out of tolerance by a certain %

Error	Potential action
0 %...1 %	No actions needed
1 %...3 %	Perform one-point field calibration
3 %...5 %	Perform multi-point field or laboratory calibration
>5 %	Unit needs to be serviced

Best Practice & using an outside commercial lab

Be familiar with your calibration lab procedures and equipment

- Is the lab going to adjust if out of tolerance? At what point?
- What is the traceability chain from NIST to your instrument?
- Is the traceability chain documented?
- In accordance with which QMS is the lab operating?
- Does the service include documenting 'as found'?
- Are the lab technicians trained regularly?
- Does the lab offer Accredited Services?
- Is the lab able to calculate the 'uncertainty' or just providing 'accuracy'?

Common Sources of Error

1. **Temperature** fluctuations in the calibration environment
2. **Temperature** difference between reference and unit under calibration
3. **Temperature** leakage into sensor environment
4. Not enough stabilization time
5. Accuracy of reference
6. Calibration methodology

Summary

1. Calibration Fundamentals
2. Saturated Salts and Other Humidity Reference Equipment
3. Humidity Calibration Processes
4. Humidity Calibration Best Practice

Summary of Questions from the Audience

Vaisala Humidity Measurement Resources

- On-line Humidity Calculator www.vaisala.com/humiditycalculator
- Slide Rule Calculator to order – <http://forms.vaisala.com/forms/RequestSlideRule>
- Psychrometric Chart - <http://forms.vaisala.com/forms/RequestPsychChart>
- Humidity Conversion Formulas - http://forms.vaisala.com/forms/humidity_conversion

For expert assistance with your humidity measurement:

North America:

Email: instruments@vaisala.com

Direct telephone: 800-408-9454

Web: www.vaisala.com/instruments

Global – www.vaisala.com/contact

Next Webinar – FDA Regulations & Humidity Measurement

Thursday, November 18th , 10:00AM PDT

Full Webinar Schedule info & registration:

www.vaisala.com/webinars

Everyone who registered for previous webinar will get the invitation for all subsequent webinars.

You will receive a follow up email with all of the resource links & link to recording.

Live Humidity Seminars

Boston – October 27th & 28th

Los Angeles – December 1st

<http://vaisala.com/seminars>

Thank you!

This concludes the webinar.

Follow-up email will arrive shortly with the resource links & further contact information.

Link to the recorded version will follow.