23 September 2013

The International Association for the Properties of Water and Steam

Greenwich, United Kingdom
September 2013

BIPM[1], CCT[2]-WG6/CCQM[3] & JCS[4] Joint Workshop on

Metrological Aspects of Humidity
Protocol

held during the ICPWS 2013
Tuesday, 3 September 2013
(Queen Anne Building)

Content

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[1] Bureau International des Poids et Mesures
[2] Consultative Committee for Thermometry
[3] Consultative Committee for Amount of Substance – Metrology in Chemistry
[4] Joint Committee on Seawater, established by SCOR and IAPWS

1 Aim of the Workshop

Aim of the workshop was

(a) to discuss specific aspects of 'humidity metrology', especially the current status of a SI-based definition of 'relative humidity', the deficiencies of current definitions, different possibilities to define the 'saturation state', open questions regarding the response behaviour of humidity sensors,

(b) to clarify the notional basis of humidity metrology among the workshop participants, and

(c) to depict a 'roadmap' toward a universal definition of relative humidity.

The realisation of the workshop is part of joint activities between BIPM, CCT-WG6/CCQM & JCS on 'humidity metrology', as agreed at an initial IAPWS-BIPM meeting, held on 7 February 2012 at the International Bureau of Weights and Measures, Paris-Sèvres with participation of Dan Friend, Karol Daucik, Jeff Cooper, Alain Picard, Petra Spitzer, Rainer Feistel, Michael Kuehne, Andy Henson, and Robert Wielgosz.

2 Agenda of the Workshop

(1) Introduction

- Olaf Hellmuth (TROPOS Leibniz Institute of Tropospheric Research, Germany) and Jeremy Lovell-Smith (Measurement Standards Laboratory , New Zealand) (chairs of the workshop; protocol by Jana Kalova)
  - What we are aiming at?
  - Reference to conference day 1: Robert Wielgosz (BIPM), "Linking essential climate variables to SI traceable measurements"
  - Reference to conference day 1: Rainer Feistel (Institute for Baltic Sea Research, Germany, IAPWS) "Water, Steam and Climate" (How we can support planned cooperation between IAPWS, BIPM, SCOR, IAPSO and WMO, and JCS?)

(2) Presentations

(a) Jana Kalova (University of South Bohemia, Czech Republic):
"Thermophysical Properties of Water for Atmospheric Applications"

(b) Stephanie Bell (National Physical Laboratory, United KingdomK):
"Calibration of Hygrometers in Non-Air Gases and at a Range of Pressures"

(c) Jeremy Lovell-Smith:
"Toward a Universal Definition of Relative Humidity"

(d) Olaf Hellmuth:
„Meteorologist's View on Relative Humidity in Bread & Butter Business" and progress report on ‚Workshop Report'

(3) Open Discussion

Subjects of the general discussion were:

- problems and deficiencies of current definitions
- definition of physical basis (axiomatic approach), pro's and con's regarding a new definition of relative humidity

- possible way's toward a universally acceptable and accepted definition
- long-term perspective, physical rigorousness vs. realisation aspects
- chances of adoption
- proposal of a roadmap on humidity definition
- BIPM/CCT points of view
- information about other activitites (‚natural allies')

Several propositions of workshop participants were basis for the discussion, formulated in preparation of the workshop and presented (in parts) to the audience by Jeremy Lovell-Smith. In Appendix A some propositions suggested in the prefield of the meeting and brought forward during the discussion have been summarised.

3 Outcome of the Workshop: Decisions, Responsibility, and Deadlines

(a) General Agreement

Observational data of relative humidity need to be globally comparable within requisite uncertainties over time spans of centuries. This increasingly urgent and long-pending goal can only be achieved by proper metrological traceability to the International System of Units (SI). Consistent with such SI-based definitions, state-of-the-art correlation equations for thermophysical properties of water, seawater, ice and humid air should be developed and adopted as joint international standards for all branches of climate research, in oceanography, meteorology and glaciology for data analysis and numerical models. The IAPWS-SCOR Joint Committee on Seawater JCS is targeting at these aims in cooperation with BIPM, WMO and other international bodies.

There is consensus among the workshop participants regarding

(i) the need for SI-traceable measurement results of relative humidity, based on a world-wide uniform and long-term stable international standard,

(ii) an increasing demand for standardised, consistent and uniform correlation equations to be used for the calculation of humid air properties in the climate system, and

(iii) resulting requirements in estimating robust and comprehensive uncertainty estimates related to such properties.

(b) Establishment of a Joint Task Group on Relative Humidity

To continue with the activities toward a universal relative humidity (RH) definition a Joint BIPM/CCT-WG6/JCS Task Group on Relative Humidity (here 'JTG-RH') has been established. Members are: Stephanie Bell (BIPM), Rainer Feistel, Martii Heinonen (BIPM), Olaf Hellmuth, Jana Kalova, Jeremy Lovell-Smith (BIPM). The group decided that Olaf Hellmuth should chair the task group to take care of organisational obligations, meetings and exchange of information among participants, liaison with other communities, and being speaker of the working group.

(c) Setup of a Distribution List

The workshop participants agreed to setup an e-mail distribution list to inform all participants (who desired entry in this list) about progress of discussion.

Task, deadline, responsibility:
- Olaf Hellmuth, immediately

(d) Elaboration of a Technical Report

Based on a common IAPWS, BIPM, CCT-WG6 position paper to be published in Metrologia by Feistel et al. (2013), there is need for a 'Technical Report' outlining basic notions, current humidity definitions, open (physical) questions regarding the saturation state, and containing an outlook to overcome the current situation (axiomatic approach to define RH). This report should serve as 'lingua franca' among the workshop participants on basic metrological notions of humidity, and to support further discussion between BIPM, CCT/WG-6 and JCS. According to the ongoing discussion and specific BIPM requirements, the report should be updated correspondingly.

Task, deadline, responsibility:
- Submission of draft version to JWG-RH members: **until 15 September 2013** (Olaf Hellmuth, Jeremy Lovell-Smith);
- Comments by JWG-RH members: **until 30 September 2013**
- Submission of **updated** draft to workshop participants: **until 15 October 2013 (**Olaf Hellmuth, Jeremy Lovell-Smith)
- Final comments: **until 15 November 2013**
- Submission of updated report to workshop participants and JCS chair: **until 30 November 2013** (Olaf Hellmuth, Jeremy Lovell-Smith)
- Placement of report in JCS website: by Rich Pawlowicz

(e) Cooperation

JCS representatives will take part in the BIPM/CCT meeting in June 2014 at Sevres, France, and in the 'Metrology for Meteorology and Climate Workshop 2014 (MMC2014)', planned for September 16-18, 2014 at Portoroz, Slovenia, and report back to JCS.

Task, deadline, responsibility:
- Rainer Feistel, Rich Pawlowicz, Olaf Hellmuth. Details who will participate and what will be presented will be specified according to deadlines for these workshops.

(f) Feasibility study for conversion between different RH definitions

For conversion between any user-specific RH definition and a fugacity-based definition a set of correlation equations will be developed and demonstrated by means of examples.

Task, deadline, responsibility:
- Olaf Hellmuth (in close cooperation/discussion with JWG-RH members)
- Presentation at IAPWS Meeting in Moscow, 23-27 June 2014.

4 Information about Other Activities

(1) ACP Special Issue, http://www.atmos-chem-phys.net/special_issue243.html
Water Vapour in the Climate System (WAVACS) COST Action: Observations, Processes and Modelling
Editor(s): G. Vaughan, W. Lahoz, F. Fierli, and S. Buehler
Collection of research papers from the WAVACS final workshop

Main topics:
- Water vapour time series and trends;
- Cirrus inhomogeneities and relationship to the environmental water vapor field and radiative transfer
- Accuracy of atmospheric water vapor observations and harmonization;
- Results from specific field campaign;
- Processes related to water vapour isotopes;
- Regional/Global modelling and data assimilation.

Abbreviations:
COST - European Cooperation in Science and Technology (http://www.cost.eu/)
WAVACS – Atmospheric Water Vapour in the Climate System

(2) There was an initiative at NDACC (Network for the Detection of Atmospheric Composition Change), residing at ISSI (International Space Science Institute (www.issibern.ch), to review the state-of-the-art on atmospheric water vapour monitoring. The result can be found in:

Nikolaus Kämpfer (Ed.), Institute of Applied Physics, University of Bern, Switzerland
Monitoring Atmospheric Water Vapour
Ground-Based Remote Sensing and In-site Methods
ISSI Scientifc Report 10. Springer New York, 2013,
ISBN978-1-4614-3908-0, DOI 10.1007/978-1-4614-3909-7

(3) MMC 2014 - Metrology for Meteorology and Climate Workshop, Portoroz, Slovenia, September 16-18 (below some preliminary information), organised by CCT-WG2
Metrology for space based observations: pre-launch and in-fligh calibrations
Euramet projects: status and future
Roadmaps for establishing permanent cooperation
Upper air network: aiming at the complete traceability and uncertainty evaluation
Upper air measurements, ocean research, ground based systems:
Measured quantities
Measurements traceability: state of the art and needs
Uncertainty definitions
Instruments and measurements capabilities
Calibration
Best practice and regulations
Water : Water vapour, liquid water, ice, hygrometry, soil moisture, permafrost

Appendix A: Parts of the Discussion

Below, some arguments have been put together which were part of the discussion per e-mail in preparation of the workshop, and which were also discussed during the workshop. A selection, editing, and condensation was necessary, performed by O. Hellmuth, who has tried to keep the message and intention of the disputants as close as possible to their statements. In so doing, perhaps a certain degree of subjectivism could, unfortunately, not be avoided. Cases of disagreement/misinterpretation are asked to be announced in order to correct for the text.

Don Gatley (14 June 2012 – 7 May 2013):

Stimulated by Donald P. Gatley (DG), ASHRAE Fellow and author of the book "Understanding Psychrometrics, 2nd ed., ASHRAE, Atlanta (2005)", there was an intensive discussion, mainly between DG, Jeremy Lovell-Smith, Rainer Feistel, and Olaf Hellmuth on different aspects of the humidity part of the Metrologia paper, about which in the meantime agreement could be achieved (climatological relevance, history, definitions etc.). Some points have been left open for further discussion.

- DG informed us about an in-progress document showing how a definition of RH, which is based on dew-point temperatures, can (a) be directly converted to mole fractions to satisfy researchers and numerical modelers, and can (b) be converted to $RH_{ideal} = p_v/p_{vs}(T,p)$ to satisfy the broadcast meteorologists, first time students and most users. This document will be forwarded in the future.
- DG recommended the consideration of the definitions of relative humidity issued by 'The International Joint Committee on Psychrometric Data (IJCPD)' at its May 5, 1950 meeting in Philadelphia. He estimated that at least 85% or all relative humidity readings or uses annually are made by the industries represented by the WMO, ASHRAE, Drying Societies and Instrument Societies. These societies and the industries represented have used the IJCPD definitions or their equivalents for the last sixty years.
  (a) In regard to a mixture of air and water vapour under given conditions of barometric pressure and temperature at which saturation of air is possible, relative humidity is the ratio of the mole fraction of water vapour in the mixture to the mole fraction of water vapour in a mass of air saturated with water vapour at the given barometric pressure and temperature.
  (b) In regard to a mixture of air and water vapour or a sample of pure water vapour 'unadmixed' with any other substance under given conditions of barometric pressure and temperature at which saturation is *impossible*, relative humidity is the ratio of the partial pressure of water vapour in the mixture or sample to the saturation pressure of pure water at the given temperature. **The Committee adopted (b) subject to verification.**

  The mole fraction of water vapour in any mixture is the number of moles, or molecules, of water vapour in the mixture divided by the total number of moles, or molecules, of all constituents in the mixture. (The term 'unadmixed' means 'not mixed', which might be illustrated by pulling a very deep vacuum on a container and then introducing some liquid H_2O into the deep vacuum. A portion of the liquid will evaporate and then the space above the liquid will be only water vapour 'unadmixed', i.e., the only gas (vapour) present is H_2O water vapour.)
- According to DG, any effort to promulgate a revised or a new definition of relative humidity needs to be in the 'language of the majority of users and presented without bias'. He does not think that 'BIPM, IAPWS, or IUPAC wants to promulgate a new definition ignored by a majority of users'. The current definition used by a majority of users is the one adopted by WMO in 1953 and used by ASHRAE since 1945. Apart

from this definition, we will remain being faced with the problem of 'proliferation of amateur definitions, a majority of loose, abbreviated and ambiguous definitions appearing in introductory pre-college science texts and books by TV weather persons'. Using the terms 'mole fraction' and 'partial pressure' will only result in the 'glazed over eyes of the audience'.

- There should be a short list of objections to the current WMO and ASHRAE definitions.
- In DG's view relative humidity in psychrometrics appears mainly as an input parameter and also has 'limited use as an output parameter' used to determine the equilibrium moisture content of hundreds of hygroscopic materials. It appears only as an input and an output in numerical psychrometric models. It is not used in intermediate calculations.
- In view of the large number of people with widely varying background using the term relative humidity it should not be surprising that there are both 'well defined definitions and a good many simplified or over-simplified definitions'. The National Laboratories, WMO and ASHRAE represent greater than 100000 professionals, which (all but a few) use the mole fraction definition or one that is exactly equivalent. **We need an agreement on a RH definition 'as it applies to *real* moist air'.** DG emphasised that meteorologists and air conditioning engineers often use psychrometric equations based on the assumption that at the pressures and temperatures they deal with that dry air, water vapour and their mixture behave as ideal gases. This assumption results in negligible difference for air conditioning design and meteorological calculations. There would be less confusion if they used a relative humidity symbol such as RH_{ideal}.
- The mass of water vapour and the mass of dry air of samples of unsaturated and saturated moist air at T and p can be accurately measured using the gravimetric hygrometer. These measurements are directly convertible to mole fractions. Thus the IJCPD, the WMO definition and the ASHRAE 'real moist air' definition for RH have a physical basis.
- The interactions between air and water may be ignored with insignificant deviations for meteorological and 99% of all air conditioning calculations. **Deviations are 'not insignificant' at high pressures and some very deep temperatures.**
- A definition of relative humidity when the moist-air saturated vapour pressure at the dry-bulb temperature exceeds the system (atmospheric) pressure (not a meteorological condition, but occurring in lumber kilns and some vacuum processes), is close to or exactly the same as the IJCPD 1950 definition.
- It would be very helpful to have an overview of percentage of use for the different RH definitions ('*users', 'estimated number of users' and 'notes').* An example of users would be national humidity calibration facilities and instrument manufacturers etc. The categories of definition should be limited to those scientific definitions applicable to or used by researchers, national humidity calibration facilities, meteorologists and similar. The pure H_2O definition (essentially the ideal gas definition) should be eliminated because it is no longer in use by the above entities and the departure from ideal gas behaviour is known with reasonable accuracy. Furthermore, the mass based definition should be eliminated. While it may appear in textbooks, no industry is known that uses a mass based definition. Also the mole fraction definition of IJCPD, WMO and ASHRAE can be easily converted to mass units.
- The formulations of Goff/Gratch (1945), Hyland/Wexler (1983) and the Herrmann et. al. (2009) significant update of Hyland/Wexler formulation are **all based on a definition of saturation as equal chemical potential of phases at the same temperature and pressure**. Goff and Gratch utilized proven thermodynamic theory and statistical mechanics combined with experimental data in their basic formulation of psychrometric properties at saturation and in their equation for the enhancement factor. The differences between TEOS-10 and Herrmann 2009, disclosed from psychrometric comparisons, are insignificant in their output of saturated moist air (density, enthalpy, dewpoint temperature). One underlying reason is that both are

based on equal chemical potential of the relevant phases, the IAPWS formulations for vapour, liquid and solid H_2O, the Lemmon et al formulation for dry air, the C_{aaw} and C_{aww} formulations from Hyland and Wexler and the B_{aw} formulation from Harvey and Huang.

Jeremy Lovell-Smith (16 September 2012):

- The standard definition does not meet the range of conditions under which relative humidity hygrometers respond. In this sense, the WMO definition is 'non-physical'. The WMO definition meets meteorological needs but does not meet all needs.
- JLS raised the question, on which physical property 'humidity' sensors intrinsically respond. Do they respond to vapour mole fraction, to specific humidity, to partial vapour pressure or to fugacity? The use of a mole fraction-based RH definition would become questionable, if not the number of molecules is crucial, i.e., if the partial vapour pressure $p_v = xp$ is not an appropriate measure of the processes taking place when a sensor (or a material of interest) comes to equilibrium with non-saturated humid air, but just the ability of vapour molecules to interact with the sensor material. Alternatively, one could suggest a RH definition based on the pure vapour pressure, allowing the saturation state to be independent of the actual pressure. How one can interpret the ability of an unsaturated vapour or a moist gas to interact with a material at a temperature above the boiling point? In view of the unclear determinants of sensor response one could raise the question whether 'relative humidity' measurement has a well-defined physical basis. Does the physical basis of the WMO and ASHRAE equations correspond to what drives the response of sensors, and other materials?

Jeremy Lovell-Smith (28 August 2013)

- **Fugacity:** propabably great difficulty in attempting to make relative fugacity the new definition of RH in the sense of replacing the WMO/ASHRAE definition for example. It would be at some cost necessitating rewriting of procedures, software, accredited scope and CMCs.
- **Physical rigorousity:** It may be that relative fugacity represents a fundamental definition of relative humidity and does relate to a physical realisation better than the "standard" definition.

Stephanie Bell (28 August, 2013)

- **Physical rigorousity:** possibility to have a "physics" definition of a quantity while still needing a different (albeit consistent) one for metrology - because metrology definitions also cover other details, such as definitive realisations of quantifies;
- **Realisation aspect:** incline towards definitions of relative humidity in terms of vapour pressure (or vapour-pressure-like quantity) against a definition in terms of amount fraction;
- **Adoption by WMO and others:** doubtful, because payoff for them would not be worth the disruption; keeping WMO busy on more practical basic metrology culture change
- **Best hope** if we change our definition (like redefinition of the kelvin etc.): having coherence at the SI level while doing no harm at the practical level;
- **Sensor response:** Any small difference between approaches of relative fugacity and relative humidity would be immaterial to the response of sensors. Response of RH sensors is only approximately aligned with RH, and they all have linearising electronics

to adjust them to the desired characteristic (and then calibration errors/corrections in addition).

Martti Heinonen (28 August 2013):

- **Long-term perspective:** unrealistic to expect that the standards and practices in various fields would change in a short time period (or at all in some fields) due to our actions; change taking time;
- **Change of metrology culture:** Whatever we decide to do (except if we decide to do nothing) the new definition will be more or less different from the one used/referred by most of the users.
- **Need for conversion relations:** high importance of clear definition of the relationships between the quantity according to the new definition and the quantities defined in the existing standards etc.; more realistic to introduce a new well-defined quantity and its symbol and unit (similar to the definition of t90, temperature according to the ITS-90) and to recommend its use than trying to rename the quantities based on existing standards or preventing use them;
- **Physical rigorousity:** Especially now when we are developing SI towards better universality through anchoring the base quantities to universal constants, I find it important that we'll have a definition with true physical meaning.
- **Openness of future:** impossibility to predict technological progress over 50 or 100 years possibly enabling realisations of RH based on a totally different approach than present generator methods; no sense to restart discussion then again;
- **Separating "realisation" from "definition":** far more practical to separate the realisation from the definition and to take care that realisations can be based on the definition;
- **Insignificant differences between definitions:** Because none of us actually measures vapour pressures but only calculates them using empirical and/or semi-empirical formulae, MH can't find a significant difference between fugacity based definition and vapour pressure based definition.

Rainer Feistel (28 August 2013)

- **JCS contribution:** derivation and endorsement of "standard" conversion formulas between the different RH definitions, derived from TEOS-10, regardless of which of those will finally be selected as "the SI definition", if at all; achievable with the equations we have, it may be formally endorsed within IAPWS, and it may assist WG-6 in its task of "harmonising" the current multitude.
- **Needs for specification:** It is to be specified what *T-p* range needs to be covered and what tolerance is acceptable.
- **Proposition of a "Seven-milestones atmospheric humidity roadmap":**
  Step 1: Define RH according to the "standard" definition (or an alternative)
  Step 2: Calculate this ratio for a chemical reference model
  Step 3: By experimental and theoretical data, relate #2 to SI-traceable measurands of sufficient accuracy (e.g. TEOS-10 equation)
  Step 4: Officially endorse #3 as a standard equation
  Step 5: Produce reference materials of certified RH from #4
  Step 6: Calibrate routine instruments (whatever they actually measure) with #5

Step 7: to support #6, add auxiliary standard equations, such as one between RH and dewpoint temperature, fugacity, etc.

- The single steps needs to be discussed and specified, especially concerning chemical model specification.

Jeremy Lovell-Smith after conference with Rainer Feistel (29 August 2013)

- **Humidity traceability:** humidity reference functions representing a weak (but not broken) link in humidity traceability.
- **Evaluation needs:** need to address the range of possible functions and approximations, and the reliance on uncertainty analyses. This is not because the equations are necessarily horribly wrong. They are not. It is just that the validity and error associated with various equations has rarely been formally evaluated and fugacity *f*(T,p) is especially weak
- **Role of IAPWS:** non-profite, open-source international organisation with widespread linkages; incredibly valuable and productive; acting as the guardian and maintainer of the reference equations (although not for the enhancement factor yet); providing a central place to which users can be directed for these equations and guidelines
- **Hopeful view:** possibility to achieve uniformity and consistency looks and to fix the weak link in traceability.
- **Links between WG6 and IAPWS:** very important to humidity metrology;
- **Proposal how to ensure SI tracability of RH:**

  At first, RH has to be calculated as function of as a function of *x, T and p*:

  $$\psi_x^{\mathrm{WMO}}(x,T,p)=\frac{x}{x^{\mathrm{sat}}}=\frac{p_{\mathrm{V}}}{p_{\mathrm{V,sat}}}=\frac{x\,p}{e^{\mathrm{sat}}(T)\,f(T,p)},\quad f(T,p)=\frac{p_{\mathrm{V,sat}}(T)}{e^{\mathrm{sat}}(T)}$$

  Here, $e^{\mathrm{sat}}(T)$ and the water-vapour pressure enhancement factor $f(T,p)$ are reference equations. If SI traceability for $e^{\mathrm{sat}}(T)$ and $f(T,p)$ as well as for x, T and p is ensured, then also traceability for $\psi_x^{\mathrm{WMO}}(x,T,p)$ is ensured.

  Secondly, the functions $e^{\mathrm{sat}}(T)$ and $f(T,p)$ need to be declared standard equations as do the equations $x^{\mathrm{sat}}(T)=e^{\mathrm{sat}}(T)\,f\left(T,p^{\mathrm{sat}}\right)\big/p^{\mathrm{sat}}$ and $\Psi_x^{\mathrm{WMO}}=x/x^{\mathrm{sat}}$.

  Currently these ideas and equations are understood but they have not always been formally endorsed or validated. It is supposed that WMO and ASHRAE have endorsed them or parts of them, or different versions of $e^{\mathrm{sat}}(T)$ and $f(T,p)$. Similarly bodies like the British and German Standards organisations have produced versions. It is suggested that IAPWS would act to formally endorse and publish these and other such equations necessary to traceability to the SI.

Jeremy Lovell-Smith, Vito Fernicola, Stephanie Bell and Andrew Dickson (3 September 2013):

The discussion on the determination of a ‘reference fugacity’ (see also corresponding parts in Metrologia paper and Technical Report on the RH Workshop) is still open and deserves deepening. It should be clarified how ‘reference mole fraction’ and, alternatively, a ‘reference fugacity’ can be determined in a SI traceable manner. This subject touches a core of ‘humidity metrology’ is discussed here and is of primary importance for definition of a universal relative humidity standard. In this context there is also further need for discussion, what ‘SI traceability’ means with respect to a RH definition.

<u>**Olaf Hellmuth (3 September 2013)**</u>

- **Metrological vs. meteorological requirements:** Need for a synthesis of ‘metrological rigorousness’ and ‘meteorological continuousness’ with respect to RH definition and application in meteo practice;
- **Practical problem:** Changing the definition of RH in order to increase the consistency and accuracy of various water vapour measurements would likely wreak havoc on a wide range of modeling and other research that uses, e.g., radiosonde data as input (Miloshevich et al., 2006).
- **Support for a fugacity-based RH definition**, provided the metrological problem of determination of ‘reference fugacity’ can be solved.
- **Guarantee of continuousness:** Making available a set of easy-to-use correlation functions for mutual conversion from one definition into another; Parallel to the ongoing discussion on the determination of a ‘reference humidity measure’, we should demonstrate (as a practical step for user’s benefit) the mutual conversion between **fugacity-based** and **mole fraction-based (WMO) definition** for different formulations of saturation vapour pressures over water and ice.

<u>**Rainer Feistel (19 September 2013)**</u>

- Not sure what the above mentioned putative ‘reference fugacity’ problem is referring to. Relative fugacity does not need a reference state or reference conditions to be specified, not even a saturation state to be formally defined.
- CCT WG6 is kindly asked to discuss in the Working Group what role TEOS-10 as an already endorsed international standard may take for the intended SI definition of relative humidity. A decision on this matter may significantly influence the kind and direction of cooperation required or intended between CCT and JCS with respect to the humidity problem.

Appendix B: List of Participants (see also ICPWS2013 Delegate Liste)

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