

**Research Activities on the Thermodynamic Properties of Water and Steam
of the German National Committee in the Period 2016/2017**

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Chair: Ingo Weber, Siemens Power and Gas, Erlangen

Vice Chair: Prof. Dr. Hans-Joachim Kretzschmar, Zittau/Goerlitz University of Applied
Sciences, Zittau

Annual Meeting of the German National Committee

The 2017 Annual Meeting of the German National Committee took place at the Helmut Schmidt University in Hamburg on 17th March 2017. 25 Colleagues attended this meeting. Six papers were presented in the scientific session.

In the following, activities of certain members of the German National committee are summarized.

Baltic Sea Research Institute, Warnemuende

Dr. Rainer Feistel

Projects

1. Development of a draft Advisory Note No. 6: "Relationship between Various IAPWS Documents and the International Thermodynamic Equation of Seawater – 2010 (TEOS-10)".
2. Preparation of a paper about Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air to be submitted to an international journal.
3. Preparation of a paper about unleashing empirical equations using nonlinear fitting & GUM tree calculator (published in Int. J. Thermophys.).
4. Preparation of a paper toward a fundamental definition on relative humidity (published in Metrologia).

Recent Publications

- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.: Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air. N.N. (2017), in preparation.
- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.: Digital Supplement to "Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air". N.N. (2017), in preparation.
- Lovell-Smith, J. W.; Saunders, P.; Feistel, R.: Unleashing Empirical Equations with "Nonlinear Fitting" and "GUM Tree Calculator". Int. J. Thermophys. 38 (2017), 148. DOI 10.1007/s10765-017-2282-y
- Feistel, R.; Lovell-Smith, J. W.: Defining relative humidity in terms of water activity. Part 1: definition. Metrologia 54 (2017) 566-576. <https://doi.org/10.1088/1681-7575/aa7083>

- Feistel, R.:
Salzgehalt des Meeres und relative Feuchte der Luft: Rolle im Klima-system und Probleme ihrer Definition. Vortrag in der Klasse für Naturwissenschaften und Technikwissenschaften am 10. 11. 2016.
Zeitschrift der Leibniz-Sozietät e. V. Leibniz Online 25 (2017).
<https://leibnizsozietat.de/wp-content/uploads/2017/01/Feistel.pdf>
- Feistel, R.; Lovell-Smith, J. W.:
Uncertainty propagation using dispersion matrices accounting for systematic error in least-squares regression.
Metrologia 54 (2017), submitted.
- IAPWS:
Relationship between Various IAPWS Documents and the International Thermodynamic Equation of Seawater – 2010 (TEOS-10).
The International Association for the Properties of Water and Steam (2016).
Available at <http://www.iapws.org>.

Highlight 2016 in the journal "Metrologia":

- Feistel, R.; Wielgosz, R.; Bell, S. A.; Camões, M. F.; Cooper, J. R.; Dexter, P.; Dickson, A. G.; Fiscaro, P.; Harvey, A. H.; Heinonen, M.; Hellmuth, O.; Kretzschmar, H.-J.; Lovell-Smith, J. W.; McDougall, T. J.; Pawlowicz, R.; Ridout, P.; Seitz, S.; Spitzer, P.; Stoica, D.; Wolf, H.:
Metrological challenges for measurements of key climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview.
Metrologia 53 (2016), R1-R11, doi: 10.1088/0026-1394/53/1/R1.
- Lovell-Smith, J. W.; Feistel, R.; Harvey, A. H.; Hellmuth, O.; Bell, S. A.; Heinonen, M.; Cooper, J. R.:
Metrological challenges for measurements of key climatological observables. Part 4: Atmospheric relative humidity.
Metrologia 53 (2016), R40-R59, doi: 10.1088/0026-1394/53/1/R40.

German Aerospace Center (DLR), Cologne

Institute of Propulsion Technology

Prof. Dr. Francesca di Mare

Project

1. Implementation of the Fast Steam Property Algorithms Based on Spline Interpolation into the CFD Code TRACE.
 - The “IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)” has been implemented into the CFD code TRACE.
 - On this basis the implementation has been further improved, especially regarding the software architecture, solution algorithm and boundary treatment.
 - The capability of the SBTL-method has been tested on Laval-nozzle and Cascade test cases. The calculation of a real steam engine configuration is targeted next.

Recent Publications

- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Wagner, W.; Friend, D. G.; Harvey, A. H.:
Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL),
J. Eng. Gas Turbines Power, in preparation.

Helmholtz Centre for Environmental Research – UFZ, Magdeburg

PD Dr. Bertram Boehrer

Project

1. Properties of limnic waters and effect on circulation of lakes.

Recent Publications

- Moreira, S., Schultze, M., Rahn, K., Boehrer, B.:
A practical approach to lake water density from electrical conductivity and temperature.
Hydrol. Earth Syst. Sci. 20 (2016), 2975-2986.
doi: 10.5194/hess-20-2975-2016

Leibniz Institute for Tropospheric Research, Leipzig

Dr. Olaf Hellmuth

Projects

1. Investigation on Virial Approximation for Humid Air
2. Preparation of a Paper about Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air
3. Preparation of Three Further Volumes on New Particle Formation in the Earth Atmosphere

Recent Publications

- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.:
Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air.
N.N. (2017), in preparation.
- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.:
Digital Supplement to "Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air".
N.N. (2017), in preparation.

Physikalisch-Technische Bundesanstalt Braunschweig und Berlin, Braunschweig

Dr. Henning Wolf

Highlight 2016 in the journal "Metrologia":

- Feistel, R.; Wielgosz, R.; Bell, S. A.; Camões, M. F.; Cooper, J. R.; Dexter, P.; Dickson, A. G.; Fisticaro, P.; Harvey, A. H.; Heinonen, M.; Hellmuth, O.; Kretzschmar, H.-J.; Lovell-Smith, J. W.; McDougall, T. J.; Pawlowicz, R.; Ridout, P.; Seitz, S.; Spitzer, P.; Stoica, D.; Wolf, H.:
Metrological challenges for measurements of key climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview.
Metrologia 53 (2016), R1-R11, doi: 10.1088/0026-1394/53/1/R1.R

Ruhr University Bochum
Faculty of Mechanical Engineering, Department of Thermodynamics
Prof. Dr. Roland Span

Projects:

1. Improvement of accurate models available for CCS-relevant mixtures. Within this project humid mixtures are of particular interest, since existing models from the GERG-2008 package for natural gases are not designed for higher concentrations of water. A first version of this new-mixture model was published in Journal of Chemical Thermodynamics (Gernert and Span, 2016). Software enabling the application of the latest version of our property models has been made available and is by now used by more than 80 groups worldwide (both in academia and in industry). Current work addresses an improved description of less well measured minor mixtures. In conjunction with the Norsk Research Center on CCS (NCCS) a project has been granted, which will provide funding for continued work on this subject.
2. The work on models describing hydrate formation has been continued in cooperation with Dr. V. Vinš and Dr. J. Hruby. S. Hielscher continues the work at RUB as Ph.D. candidate. Andreas Jäger has changed to TU Dresden, where he involves the institute of Technical Thermodynamics headed by Prof. Cornelia Breittkopf into the work on hydrates. Three journal articles describing the latest status of the hydrate model in detail were published (Vinš *et al.*, 2016, 2017; Jäger *et al.*, 2016).
3. Development of a new reference equation of state for heavy water. This work is linked to an IAPWS grant awarded in 2012 and to a close cooperation with Dr. A. H. Harvey and Dr. E. W. Lemmon at NIST in Boulder, CO. The work on the new equation of state has largely been finished. A draft release will be submitted to the evaluation task group and will be presented at the 2017 IAPWS meeting in Kyoto.

Recent Publications

- Gernert, J.; Span, R.:
EOS-CG: A Helmholtz energy mixture model for humid gases and CCS mixtures.
J. Chem. Thermodyn. 93 (2016), 274-293.
- Vinš, V.; Jäger, A.; Span, R.; Hrubý, J.:
Model for gas hydrates applied to CCS systems part I. Parameter study of the van der Waals and Platteeuw model.
Fluid Phase Equilib. 427 (2016), 268-281.
- Vinš, V.; Jäger, A.; Hrubý, J.; Span, R.:
Model for gas hydrates applied to CCS systems part II. Fitting of parameters for models of hydrates of pure gases.
Fluid Phase Equilib. 435 (2017), 104-117.
- Jäger, A.; Vinš, V.; Span, R.; Hrubý, J.:
Model for gas hydrates applied to CCS systems part III. Results and implementation in TREND 2.0.
Fluid Phase Equilib. 429 (2016), 55-66.

Ruhr University Bochum
Faculty of Mechanical Engineering, Chair of Thermodynamics
Prof. em. Dr. Dr. e. h. Wolfgang Wagner

Project

1. Preparation of the 3rd edition of the book "International Steam Tables".

Recent Publications

- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Wagner, W.; Friend, D. G.; Harvey, A. H.:
Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL),
J. Eng. Gas Turbines Power, in preparation.

Siemens Energy Solutions, Erlangen

Michael Rziha

Projects

1. Development of new Technical Guidance Documents:
 - Application of Film Forming Amines in Fossil, Combined Cycle, and Biomass Power Plants – Released 2016 in Dresden
 - HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemical Clean – Released 2016 in Dresden
2. Developing of drafts for a new technical guidance documents
 - Monitoring Corrosion Products in Flexible (cycling and two-shifting) Plants. White paper is developed for presentation at the 2017 Meeting. TGD will be further developed based on this input.
 - Ensuring the Integrity and Reliability of Demineralized Makeup Water Supply to the Unit Cycle. Skeleton and list of contents is finalized. Further progress will be discussed during 2017 meeting.
 - Air In-Leakage in Steam Water Cycles. White paper in preparation.
 - Film Forming Products. Following the release of the IAPWS TGD on FFP for Fossil and Combined Cycle Plants and the IAPWS International Conference on FFP in Lucerne, IAPWS will be developing two new TGD on FFP:
 - a) Application of Film Forming Products in Nuclear Plants. The Task Group will have a working session during the Kyoto week.
 - b) Application of Film Forming Products in Industrial Plants.
 - Aspects of Geothermal Steam Chemistry. A White Paper for the 2017 Meeting is in preparation. This will be used to determine if a TGD can be developed.

Siemens Energy Solutions, Erlangen

Ingo Weber, Stefan Bennoit, Julien Bonifay

Projects

1. Implementation of the fast steam property spline-interpolation algorithms into the heat cycle simulation code KRAWAL
 - The “IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)” has been implemented into the heat cycle code KRAWAL which is used worldwide by Siemens.
 - The computing time consumption of KRAWAL has been significantly reduced.

2. Implementation of the fast steam property spline-interpolation algorithms into the non-stationary power-plant simulation code DYNAPLANT
 - The “IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)” has been implemented into the non-stationary power-plant simulation code DYNAPLANT.
 - The computing time consumption of DYNAPLANT has been significantly reduced.

Recent Publications

- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Wagner, W.; Friend, D. G.; Harvey, A. H.:
Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL),
J. Eng. Gas Turbines Power, in preparation.

STEAG Energy Services, Zwingenberg Dr. Reiner Pawellek, Dr. Tobias Löw

Project

1. Implementation of the fast steam property spline-interpolation algorithms into the heat cycle simulation code EBSILON
 - The “IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)” has been implemented into the heat cycle code EBSILON which is used worldwide by the power industry.
 - The computing time consumption of EBSILON has been significantly reduced.

Recent Publications

- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Wagner, W.; Friend, D. G.; Harvey, A. H.:
Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL),
J. Eng. Gas Turbines Power, in preparation.

Zittau/Görlitz University of Applied Sciences

Department of Technical Thermodynamics

Prof. Dr. Hans-Joachim Kretzschmar, Dr. Sebastian Herrmann, Matthias Kunick

Projects

1. Development of fast property calculation algorithms based on spline interpolation
 - The Spline-Based Table Look-Up Method (SBTL) is being applied to the mixture humid air.
2. Application of the developed SBTL method for calculating thermodynamic properties
The developed spline-based property libraries have been implemented into the following process simulation codes:
 - Non-stationary thermo-hydraulic codes SubChanFlow and TwoPorFlow of the Karlsruhe Institute of Technology KIT
 - Non-stationary thermo-hydraulic code RELAP-7 of the Idaho National Laboratory INL
 - Heat-cycle simulation program EBSILON of STEAG Energy Services
 - Heat-cycle simulation program KRAWAL of Siemens Energy Solutions
 - Non-stationary heat-cycle simulation program DYNAPLANT of Siemens Energy Solutions.

3. Development of algorithms for the transport properties of moist air, ASHRAE Research Project 1767.
4. Preparation of a new ASHRAE standard for calculating moist air properties, ASHRAE Project SPC 213P.
5. Reworking on the 3rd edition of the book "International Steam Tables".

Recent Publications

- Kunick, M.; Berry, R. A.; Martineau, R. C.; Kretzschmar, H.-J.; Gampe, U.:
Application of the new IAPWS Guideline on the fast and accurate calculation of steam and water properties with the Spline-Based Table Look-Up Method (SBTL) in RELAP-7. *Kerntechnik* 82/3 (2017), 264-279.
- Herrmann, S.; Kretzschmar, H.-J.; Gatley, D. P.:
In: 2017 ASHRAE HANDBOOK FUNDAMENTALS, SI and I-P Editions, Chapter 1 PSYCHROMETRICS, Table 2 Thermodynamic Properties of Moist Air at Standard Atmospheric Pressure. Table 3 Thermodynamic Properties of Water at Saturation. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA (2017), ISBN 978-1-939200-58-0.
www.ashrae.org
- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Wagner, W.; Friend, D. G.; Harvey, A. H.:
Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL).
J. Eng. Gas Turbines Power, in preparation.
- Kunick, M.:
Fast Calculation of Thermophysical Properties in Extensive Process Simulations with the Spline-Based Table Look-Up Method (SBTL).
Fortschritt-Berichte VDI, in preparation.
- Vogel, E., Herrmann, S.:
New Formulation for the Viscosity of Propane.
J. Phys. Chem. Ref. Data 45 (2016), 043103.
- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.:
Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air.
N.N. (2017), in preparation.
- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.:
Digital Supplement to "Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air".
N.N. (2017), in preparation.