

German National Committee to IAPWS

Research Activities on the Thermodynamic Properties of Water and Steam Report "Research in Progress 2012"

Baltic Sea Research Institute, Warnemuende
Dr. Rainer Feistel

Book Publication

Feistel, R., Ebeling, W. (2011): Physics of Self-Organization and Evolution. Wiley-VCH, Weinheim, 517 pp.

Articles

Pawlowicz, R., McDougall, T., Feistel, R., Tailleux, R. (2012):
Preface: An historical perspective on the development of the Thermodynamic Equation of Seawater – 2010.

Ocean Science 8, 161–174, <http://www.ocean-sci.net/8/161/2012/>

Safarov, J., Berndt, S., Millero, F., Feistel, R., Heintz, A., Hassel, E. (2012):
(p,rho,T) properties of seawater: Extensions to high salinities.
Deep-Sea Research I 65, 146-156

McDougall, T.J., Feistel, R., Pawlowicz, R. (2012):
Thermodynamics of Seawater.

In: Gerold Siedler, John Church, John Gould, Stephen Griffies (eds.) Ocean Circulation and Climate, second edition, Academic Press (Elsevier), in press

Feistel, R., Wagner, W. (proposers):

Guideline on a Low-Temperature Extension of the IAPWS-95 Formulation for Water Vapor.

The International Association for the Properties of Water and Steam, Boulder, Colorado, USA, September/October 2012, to be adopted

Pawlowicz, R., Feistel, R. (2012):

Limnological applications of the Thermodynamic Equation of Seawater 2010 (TEOS-10).
Limnology & Oceanography - Methods, submitted

Feistel, R. (2012):

Thermodynamic Properties of Seawater in Oceanography, [Eds. UNESCO-EOLSS Joint Committee],

in Encyclopedia of Life Support Systems(EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK, [<http://www.eolss.net>]

<http://www.eolss.net/Sample-Chapters/C01/E2-03-07.pdf>

Feistel, R. (2012):

TEOS-10: A New International Oceanographic Standard for Seawater, Ice, Fluid Water and Humid Air.

International Journal of Thermophysics, DOI: 10.1007/s10765-010-0901-y,
<http://www.springerlink.com/content/p4834412420n5j6/>

Marion, G.M., Millero, F.J., Camoes, F., Spitzer, P., Feistel, R., Chen, C.-T.A. (2011):
 pH of Seawater.

Marine Chemistry 126, 89–96

Wagner, W., Riethmann, T., Feistel, R., Harvey, A.H. (2011):

New Equations for the Sublimation Pressure and Melting Pressure of H₂O Ice Ih.

Journal of Physical and Chemical Reference Data, 40, 043103; doi:10.1063/1.3657937 (11 pages)

Leibniz Institute for Tropospheric Research, Leipzig

Dr. Olaf Hellmuth

Recent Publications

Hellmuth, O.:

Weather forecast.

In: C. Bernhofer, J. Schanze and J. Seegert: A Textbook on Integrated Flood Risk Management, Springer-Verlag, Berlin (submitted and accepted in 2011).

Hellmuth, O., Khvorostyanov, V. I., Curry, J. A., Shchekin, A.K., Schmelzer, J. W. P., Baidakov V. G. (2011):

Review on the Phenomenology and Mechanism of Atmospheric Ice Formation: Selected Questions of Interest. In: J. W. P. Schmelzer, G. Röpke, and V. B. Priezzhev (eds.):

Nucleation Theory and Applications,

JINR Dubna, 483 pp., ISBN 978-5-9539-0301-8, <http://theor.jinr.ru/meetings/2012/nta/>

Hellmuth, O., Khvorostyanov, V. I., Curry, J. A., Shchekin, A.K., Schmelzer, J. W. P., Feistel, R., Djikaev, Y., Baidakov V. G. (2012):

Theoretical Aspects of Atmospheric Ice Formation. In: J. W. P. Schmelzer (eds.):

Nucleation Theory and Applications. Special Issues.

Review Series on Selected Topics of Atmospheric Sol Formation, Volume 5, JINR Dubna (textbook, in press).

Zittau/Goerlitz University of Applied Sciences, Faculty of Mechanical Engineering, Department of Technical Thermodynamics

Prof. Dr. Hans-Joachim Kretzschmar

Projects

1. Development of Fast Property Algorithms Based on Spline Interpolation

- The algorithms for fast spline-interpolation methods was developed and applied to the calculation of thermodynamic properties of water and steam in CFD and non-stationary calculations.

- An algorithm for generating spline-interpolation data grids with optimized data density for the user requirements 'range of state' and 'accuracy' was developed.
2. Stoffwerte für Wasser und Wasserdampf (Steam Tables for Water and Steam), VDI Wärme Atlas 2012
- Section D2.1 "Stoffwerte für Wasser und Wasserdampf" (Properties of Water and Steam) of the VDI-Wärme Atlas 2012 (VDI-Heat Atlas), 11th German Edition, is being worked on. The reference for this publication will read: *Wagner, W. and Kretzschmar, H.-J., Stoffwerte von Wasser und Wasserdampf, VDI-Wärmeatlas, 11. Auflage, Abschnitt D2.1, pp. 1-15, Springer-Verlag, Berlin. Status: The proofs are being checked.*
3. Property Libraries for Calculating Heat Cycles
- The property library LibIF97 for steam and water has been extended to ice properties including sublimation and melting pressures.
 - The property libraries for steam, water, ice, seawater, humid combustion gases, humid air, ammonia/water mixtures and water/lithium bromide mixtures have been connected to LabVIEW.
 - An Online Property Calculator for calculating thermodynamic and transport properties for steam, water and other working fluids in power engineering was installed on the website www.thermodynamics-zittau.com.
 - A steam tables App for iPhone, iPad, and iPod touch has been developed.
 - A student version of the steam tables program FluidLAB for MATLAB was prepared and its link installed on the IAPWS Website www.iapws.org under "Education".

Recent Publications

Kretzschmar, H.-J., Kraft, I.:

Kleine Formelsammlung Technische Thermodynamik, 4. Auflage.
Carl Hanser Verlag, München (2011)

Kretzschmar, H.-J.:

Bereitstellung von thermodynamischen Stoffdaten für Arbeitsfluide der Energietechnik.
In: Aktuelle Beiträge zur Technischen Thermodynamik, Energietechnik und Fernwärmeversorgung,
Verlag AGFW, Frankfurt am Main (2011)

Herrmann, S.; Kretzschmar, H.-J.; Gattley, D. P.:

Berechnung der thermodynamischen Eigenschaften von feuchter Luft.
KI - Kälte Luft Klimatechnik, 48 (2012) S. 22-28

Kunick, M; Kretzschmar, H.-J.; Gampe, U.:

Schnelle und flexible Berechnung thermodynamischer Stoffwerte mit Spline-Interpolation für die Modellierung instationärer Energieumwandlungsprozesse.
In: W. Honekamp, P. Schindler, Tagungsband der 13. Nachwuchswissenschaftlerkonferenz mitteldeutscher Fachhochschulen Görlitz, S.209-214, Re Di Roma-Verlag, Remscheid (2012), ISBN 978-3-86870-436-5

Kretzschmar, H.-J., Stöcker, I.:

Mollier h,s-Diagramm von Wasserdampf (Mollier h-s Diagram for Steam).
Siemens Energy, Erlangen (2012)

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

Projects

The group chaired by Prof. Span has actively been involved in a number of research projects related to CO₂-rich mixtures as they are typical for power generation with carbon capture and storage (CCS). On its 2011 meeting IAPWS has encouraged this kind of work under ICRN 27, *Thermodynamic Properties of Humid Gases and CO₂-Rich Mixtures*. The work of Prof. Span primarily addresses the

- improvement of the experimental data base available for CCS-relevant mixtures. As part of this activity co-operations with colleagues at the University of Valladolid and at SINTEF in Trondheim were established.
- improvement of accurate models available for CCS-relevant mixtures. Main foci of this work have been the development of improved mixing models and a consistent description of complex phase equilibria, including the formation of hydrates and other solid phases. This work is linked to close co-operations with the group of Dr. J. Hruby at the Czech Academy of Sciences (Hruby and Vins, see separate report presented by Dr. Vins) and with Dr. E. W. Lemmon at NIST in Boulder.
- application of accurate property models in process simulation. The relevance of the accuracy of property models could be shown both for the processes of the LNG product-chain and for CCS-applications.

Many aspects of the work on CCS-relevant mixtures are closely related to work on properties of natural gases, particularly in conjunction with LNG processing. However, this work is not considered within the scope of IAPWS.

Journal Articles and Proceedings

F. Dauber, J. Gernert, R. Span and P. Schley:

On the Use of Highly Accurate Thermodynamic Property Models in Process Simulation. Proceedings International Gas Union Research Conference - IGRC, Seoul (2011).

R. Span:

Kraftwerkstechnik mit CO₂-Rückhaltung – Anforderungen an Stoffdatenmodelle.

In: Nordrhein-Westfälische Akademie der Wissenschaften und Künste, Ferdinand Schöningh Verlag, Paderborn, ISBN 978-3-506-77367-8 (2011).

M. E Mondéjar, M. C. Martín, R. Span and C. R. Chamorro:

New (p, ρ, T) data for carbon dioxide - nitrogen mixtures from 250 K to 400 K at pressures up to 20 MPa.

J. Chem. Thermodynamics 43, 1950–1953 (2011).

M. E Mondéjar, M. C. Martín, R. Span and C. R. Chamorro:

(p, ρ, T) behavior of two mixtures of carbon monoxide with nitrogen in the temperature range from 250 K to 400 K and pressures up to 20 MPa.

J. Chem. Eng. Data 56, 3933–3939 (2011).

V. Vins, A. Jäger, J. Hrubý and R. Span:

Phase equilibria of carbon dioxide and methane gas-hydrates predicted with the modified analytical S-L-V equation of state.

Proc. Experimental Fluid Mechanics, Czech Republic (2011).

M. E. Mondéjar, R. M. Villamañán, R. Span, and C. R. Chamorro:

Accurate (p,ρ,T) data for two new (carbon dioxide+nitrogen) mixtures from (250 to 400)K at pressures up to 20MPa.

J. Chem. Thermodyn. 48, 254–259 (2012)

A. Jäger and R. Span:

Equation of state for solid carbon dioxide based on the Gibbs free enthalpy.

J. Chem. Eng. Data 57, 590-597 (2012)

**Ruhr University Bochum, Faculty of Mechanical Engineering,
Department of Thermodynamics
Prof. em. Dr. Wolfgang Wagner**

Projects

1. Stoffwerte für Wasser und Wasserdampf (Steam Tables for Water and Steam), VDI Wärme Atlas 2012
Section D2.1 “Stoffwerte für Wasser und Wasserdampf” (Properties of Water and Steam) of the VDI-Wärme Atlas 2012 (VDI-Heat Atlas), 11th German Edition, is being worked on. The corresponding steam tables are calculated based on the Industrial Formulation IAPWS-IF97 and the current equations for the transport properties and other properties based on the corresponding IAPWS Releases. The reference for this publication will read: *Wagner, W. and Kretzschmar, H.-J.*, Stoffwerte von Wasser und Wasserdampf, VDI-Wärmeatlas, 11. Auflage, Abschnitt D2.1, pp. 1-15, Springer-Verlag, Berlin. Status: The proofs are being checked.
2. The behavior of the IAPWS-95 Formulation in the liquid region of water near the melting line at high pressures was investigated. A corresponding report on this matter will be presented on the IAPWS Meeting in Boulder 2012 in the Session of the IAPWS Working Group „Thermophysical Properties of Water and Steam“ (TPWS).

Recent Publications

- Wagner, W., Riethmann, T., Feistel, R., Harvey, A. H.:
New equations for the melting pressure and sublimation pressure of H₂O ice Ih.
J. Phys. Chem. Ref. Data 40 (2011), 043103-1 - 043103-11 (online publication 05.12.2011).