

**Research Activities on the Thermodynamic Properties of Water and Steam**  
**Report "Research in Progress 2016"**

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Projects

1. Development of fast property algorithms based on spline interpolation
  - The draft “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 completed and adopted by IAPWS
  - Spline property algorithms were developed for functions of the variables specific volume and specific internal energy ( $v,u$ ) and related inverse functions for water and steam based on the scientific formulation IAPWS-IF95.
  - The range of validity of the spline-property functions based on IAPWS-IF97 has been expanded to metastable subcooled steam and metastable superheated liquid water.
  - Spline property algorithms have been developed for functions of the variables specific volume and specific enthalpy ( $v,h$ ) as well as for the related inverse functions for water and steam based on the industrial formulation IAPWS-IF97.
2. Application of the developed spline algorithms for calculating thermodynamic properties  
The developed spline property algorithms have been implemented into the following process simulation codes:
  - Non-stationary thermo-hydraulic cycle program RELAP-7 of the Idaho National Institute INL
  - Heat cycle simulation program EBSILON of STEAG Energy Services
  - Heat cycle simulation program KRAWAL of Siemens Energy Solutions
  - Non-stationary heat cycle program DYNAPLANT of Siemens Energy Solutions.
3. Updating the algorithms for calculating transport properties of moist air and working on the ASHRAE Research Project 1767

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.  
Int. J. Thermophys. (2016), 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".  
Int. J. Thermophys. (2016), in preparation.
- 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.; 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 (2016), in preparation.

- 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), pp. R1–R11.
- Vogel, E., Span, R., Herrmann, S.: Reference Correlation for the Viscosity of Ethane. *J. Phys. Chem. Ref. Data* 44 (2015), 0431011.
- Herrmann, S.; Vogel, E.: Viscosity and Density of Normal Butane Simultaneously Measured at Temperatures from (298 to 448) K and at Pressures up to 30 MPa Incorporating the Near-Critical Region. *J. Chem. Eng. Data* 60 (2015), 3703–3720.
- Herrmann, S.; Hassel, E.; Vogel, E.: Viscosity and Density of Isobutane Measured in Wide Ranges of Temperature and Pressure Including the Near-Critical Region. *AIChE J.* 61 (2015), 3116-3137.
- Kunick, M.; Kretzschmar, H.-J.; di Mare, F.; Gampe, U.: CFD Analysis of Steam Turbines with the IAPWS Standard on the Spline-Based Table Look-Up Method (SBTL) for the Fast Calculation of Real Fluid Properties. In: *Proceedings of ASME Turbo Expo 2015: Turbine Technical Conference and Exposition. GT2015, Montreal, Canada (2015). ISBN: 978-0-7918-5679-6*
- Herrmann, S.; Hassel, E.; Vogel, E.: Simultaneous Viscosity-Density Measurements of Gases over a Wide Range of Temperature and Pressure Using a Vibrating-Wire Viscometer and a Single-Sinker Densimeter. In: *Young Scientist 2015 9th International Conference of Young Scientists of the Academic Coordination Centre in the Euroregion Neisse, Adamczuk, F.; Adamczuk, J. (Hrsg.), Publishing House Wydawnictwo 'AD REM': Jelenia Gora (2015), 31-40, ISBN: 978-83-65295-16-3.*
- Kretzschmar, H.-J.; Feistel, R.; Wagner, W.; Miyagawa, K.; Harvey, A. H.; Cooper, J. R.; Hiegemann, M.; Blangetti, F. L.; Orlov, K. A.; Weber, I.; Singh, A.; Herrmann, S.: The IAPWS Industrial Formulation for the Thermodynamic Properties of Seawater. *Desalination and Water Treatment* 55 (2015), pp. 1177-1199, doi: 10.1080/19443994.2014.925838.
- Kretzschmar, H.-J.; Herrmann, S.; Feistel, R.; Wagner, W.: The International IAPWS Formulation for the Thermodynamic Properties of Seawater for Desalination Processes. *The International Desalination Association World Congress on Desalination and Water Reuse, San Diego, CA, USA (2015), doi: 10.13140/RG.2.1.4734.7444.*