The IAPWS Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL)

Matthias Kunick[C,S], Hans-Joachim Kretzschmar,
Ray A. Berry, Richard C. Martineau, and
Uwe Gampe

Dept. of Technical Thermodynamics, Zittau/Görlitz University of Applied Sciences, Zittau, Germany
MKunick@hs-zigr.de

Nuclear Science & Technology, Idaho National Laboratory, Idaho Falls, Idaho, U.S.A.

Institute for Power Engineering, Dresden University of Technology, Dresden, Germany

Numerical simulations of transient processes with heat-cycle calculation software, computational fluid dynamics (CFD), or thermohydraulic codes, are widely used in power engineering. During these simulations, thermodynamic and transport properties of the utilized working fluids need to be calculated extremely often. The calculation of these properties from multiparameter equations is very time-consuming and leads to inacceptable overall computing times. Therefore, property calculations are often simplified through the use of the ideal-gas equation or a cubic equation of state. Depending on the range of state, these simplifications cause inaccuracies in the results of the process simulations.

To provide more suitable property calculation algorithms for computationally intensive process simulations, the Spline-Based Table Look-up Method (SBTL) was developed in a project of the International Association for the Properties of Water and Steam (IAPWS). This method applies spline-interpolation techniques and specialized coordinate transformations to reproduce the results of an underlying formulation, e.g., the industrial formulation for water and steam IAPWS-IF97, with high accuracy and low computing time. The IAPWS Guideline contains a detailed description of the SBTL method as well as SBTL property functions of specific volume and specific internal energy (v,u), as required in CFD, and of pressure and specific enthalpy (p,h), as used in heat-cycle calculations, for water and steam. Fast and numerically consistent inverse functions of (p,v) and (u,s), as well as of (p,T), (p,s), and (h,s) are also provided. The maximum deviations of the SBTL functions from the underlying IAPWS formulations are less than 10-100 ppm. With regard to IAPWS-IF97, computations from the (v,u) spline functions are more than 130 times faster. The applicability of the SBTL method has been verified in various process simulations. The results of these simulations show negligible differences to those obtained with the direct application of IAPWS-IF97, but the overall computing times are reduced significantly.