

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

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Numerical process simulations, such as power-plant design with heat-cycle calculation software, flow analysis with computational fluid dynamics (CFD), and real-time process optimizations, are widely used in power engineering. These simulations are computationally intensive, especially when transient processes are considered. The calculation of thermodynamic properties from fundamental equations is very time-consuming and leads to unacceptable computing times in complex process simulations. 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 simulation. In order to provide property calculation algorithms for computationally intensive 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). The SBTL method applies polynomial 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. Furthermore, so called inverse spline functions enable the calculation of backward functions from their corresponding forward spline functions with complete numerical consistency. The new "IAPWS Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL)" contains detailed information on the SBTL method. Furthermore, it contains SBTL property functions for calculations from specific volume and specific internal energy (v,u), as required in CFD. By means of inverse spline functions, numerically consistent property functions of (p,v) and (u,s) are calculated. Moreover, SBTL property functions of pressure and specific enthalpy (p,h) , as used in heat-cycle simulations, and the corresponding backward functions of (p,T) , (p,s) , and (h,s) are provided. The maximum deviations of the SBTL functions from the underlying IAPWS formulations are less than 10-100ppm. With regard to IAPWS-IF97, computations from the (v,u) spline functions are more than 150 times faster. The applicability of the SBTL method has been tested in the CFD software TRACE, developed at DLR, and in heat-cycle calculations. The results of these tests show negligible differences to those obtained from simulations with IAPWS-IF97, but the overall computing times are reduced significantly.