SUPPLEMENTARY BACKWARD EQUATIONS $v(p,T)$ FOR THE CRITICAL AND SUPERCRITICAL REGIONS (REGION 3) OF THE INDUSTRIAL FORMULATION IAPWS-IF97 FOR WATER AND STEAM

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As a complement to the "IAPWS Industrial Formulation 1997 for the thermodynamic properties of water and steam" (IAPWS-IF97), supplementary backward equations to calculate the specific volume from given pressure and temperature $v(p,T)$ in the critical and supercritical regions (region 3) will be presented.

The deviation of the specific volume calculated from the new $v(p,T)$ equations to the IAPWS-IF97 basic equation $f(v,T)$ is lower than 0.001 %.

The backward equations together with the IAPWS-IF97 basic equation make it possible to determine all thermodynamic properties from pressure and temperature in region 3 without iteration. The deviations from the IAPWS-IF97 basic equation $f(v,T)$ are less than 0.001 % for enthalpy and entropy, and less than 0.01 % for isobaric heat capacity and speed of sound.

The range of validity of the equations presented is region 3 of IAPWS-IF97 – except for a small region very close to the critical point. To meet the high numerical consistency requirements, the range of validity has been divided into subregions. The deviations between the backward equations of the adjacent subregions are smaller than the numerical consistencies of these equations with the IAPWS-IF97 basic equation.

Since the numerical consistency of the $v(p,T)$ equations with IAPWS-IF97 is sufficient for most applications in heat cycle, boiler and turbine calculations, the otherwise necessary iteration can be avoided. Therefore, calculations of specific volume as a function of pressure and temperature using the equations presented are more than 3 times faster than the iteration from IAPWS-IF97. For users not satisfied with the numerical consistency, the equations are nevertheless still recommended for generating good starting points for an iterative process.

The basis for the development of the backward equations is a special approximation algorithm, which was developed at the Technical University of Dresden and at the Zittau/Goerlitz University of Applied Sciences. The algorithm is based on the structure optimization method of Wagner.