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Supplementary Backward Equations for Pressure as a Function of Enthalpy and Entropy $p(h,s)$ to the Industrial Formulation IAPWS-IF97 for Water and Steam

In modeling steam power cycles, thermodynamic properties as functions of the variables enthalpy and entropy are required in the liquid and the vapor regions. It is difficult to perform these calculations with IAPWS-IF97, because they require two-dimensional iterations calculated from the IAPWS-IF97 fundamental equations. While these calculations are not frequently required, the relatively large computing time required for two-dimensional iteration can be significant in process modeling. Therefore, the International Association for the Properties of Water and Steam (IAPWS) adopted backward equations for pressure as a function of enthalpy and entropy $p(h,s)$ as a supplement to the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (IAPWS-IF97) in 2001. These $p(h,s)$ equations are valid in the liquid region 1 and the vapor region 2. With pressure p, temperature $T(h,s)$ can be calculated from the IAPWS-IF97 backward equations $T(p,h)$. By using the $p(h,s)$ equations, the two dimensional iterations of the IAPWS-IF97 basic equations can be avoided. The numerical consistency of pressure and temperature obtained in this way is sufficient for most heat cycle calculations. This paper summarizes the need and the requirements for the $p(h,s)$ equations and gives complete numerical information about the equations. Moreover, the achieved quality of the equations and their use in the calculation of the backward function $T(h,s)$ is presented. The three aspects, numerical consistency with the IAPWS-IF97 basic equations, consistency along subregion boundaries, and computational speed important for industrial use are discussed. [DOI: 10.1115/1.1915392]

1 Introduction

In 1997 the International Association for the Properties of Water and Steam (IAPWS) adopted the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (IAPWS-IF97) [1,2]. This set of equations contains fundamental equations, saturation equations, and equations for the most often used backward functions $T(p,h)$ and $T(p,s)$ valid in liquid region 1 and vapor region 2; see Fig. 1.

In modeling power cycles and steam turbines, the backward functions $p(h,s)$ and $T(h,s)$ are also required, though not as often as $T(p,h)$ and $T(p,s)$. Table 1 contains the relative frequency of

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