IAPWS Certified Research Need – ICRN

Thermodynamic Properties of Metastable Steam

Closing Statement

In 2002, the IAPWS Working Groups "Thermophysical Properties of Water and Steam" and “Industrial Requirements and Solutions” examined the published work and common industrial practice in the area of the thermodynamic properties of supercooled vapor which is of interest to the electric power industry. IAPWS recognized that there was a requirement for work to be pursued in this field, in particular with respect to design of low-pressure steam turbines, and prepared ICRN15 to assist potential investigators to obtain sponsorship.

Although the ICRN stimulated interest of researchers, it did not lead to significant outputs. The following reasons were identified:

1. No experimental methods were available for the determination of the density, the speed of sound, or other thermodynamic properties of metastable steam. With respect to the fact that the development of specialized methods is expensive and their success is uncertain, apparently no laboratory undertook a serious attempt to generate the required data.

2. The properties of metastable steam are, in particular, needed in computational fluid dynamics (CFD). However, CFD simulations faced other serious problems, in particular due to turbulence, the complex 3D geometry of flow passages, and non-equilibrium condensation. With respect to the current status of the computing hardware and software, a large part of the simulation work assumed ideal gas behavior to simplify the mathematical model. Consequently, the correct representation of the properties of metastable steam did not receive an adequate attention.

At present, the IAPWS-recommended practice of computing the thermodynamic properties of metastable steam is to use the metastable-steam equation of the IAPWS Industrial Formulation 1997 (Eq. (18), Ref. [1]). Alternatively, for low pressures it is possible to use a virial equation of state truncated after the second virial coefficient, which was correlated by Harvey and Lemmon [2], in conjunction with the ideal-gas thermodynamic properties given in the Industrial Formulation [1]. These approaches provide plausible extrapolations of the measured data from the stable region into the metastable-steam region.

At the time of writing this closing statement, the need of reliable data on the properties of metastable steam is continuing. However, IAPWS recognizes that the changed circumstances require a new formulation of the needs. In particular, it appears that molecular simulation might provide a feasible way to the determination of the properties of metastable steam. A new ICRN will be formulated to reflect the changed needs.

References:

[1] International Association for the Properties of Water and Steam, Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, IAPWS Secretariat (2007), available from http://www.iapws.org.

[2] A.H. Harvey and E.W. Lemmon: Correlation for the Second Virial Coefficient of Water. J. Phys. Chem. Ref. Data 33 (2004) 369–376.

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