

The International Association for the Properties of Water and Steam

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Advisory Note No. 2

Roles of Various IAPWS Documents Concerning the Thermodynamic Properties of Ordinary Water Substance

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This advisory note is updated annually as necessary to reflect the issuance of new or revised IAPWS documents. Date of this update September 2008.

IAPWS has issued several documents that give information on the thermodynamic properties of ordinary water substance. These documents are listed on the following page. The first document, IAPWS-95, is considered by IAPWS to define the thermodynamic properties of water and steam. This advisory note has been prepared to explain the purpose of some of these documents, which might appear to give contradictory information. The name “ordinary water substance” is used to denote any phase or phases in equilibrium of water with normal naturally occurring isotopic abundances of hydrogen and oxygen. These abundances are those of Vienna Standard Mean Ocean Water as given in document 14. Other documents issued earlier by IAPWS have been superseded and are not considered in this note (obsolete recommendations are discussed in a document linked from the “Releases and Guidelines” section of www.iapws.org).

IAPWS documents containing information on the thermodynamic properties of ordinary water substance:

1. Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. (Subsequently referred to as IAPWS-95). (September 1996).
2. Release on an Equation of State for H₂O Ice Ih. (September 2006).
3. Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam. (IAPWS-IF97). (Revised August 2007).
4. Advisory Note No. 1: Uncertainties in Enthalpy for the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use (IAPWS-95) and the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (IAPWS-IF97). (August 2003).
5. Supplementary Release on Backward Equations for Pressure as a Function of Enthalpy and Entropy $p(h, s)$ to the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam. (September 2001).
6. Revised Supplementary Release on Backward Equations for the Functions $T(p, h)$, $v(p, h)$ and $T(p, s)$, $v(p, s)$ for Region 3 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam. (Revised September 2004).
7. Supplementary Release on Backward Equations $p(h, s)$ for Region 3, Equations as a Function of h and s for the Region Boundaries, and an Equation $T_{\text{sat}}(h, s)$ for Region 4 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam. (September 2004).
8. Supplementary Release on Backward Equations for Specific Volume as a Function of Pressure and Temperature $v(p, T)$ for Region 3 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam. (July 2005).
9. Supplementary Release on Properties of Liquid Water at 0.1 MPa. (September 2008).
10. Guideline on the Tabular Taylor Series Expansion (TTSE) Method for Calculation of Thermodynamic Properties of Water and Steam Applied to IAPWS-95 as an Example. (August 2003).
11. Supplementary Release on Saturation Properties of Ordinary Water Substance. (Revised September 1992).
12. Revised Release on the Pressure along the Melting and Sublimation Curves of Ordinary Water Substance. (Revised September 2008).
13. IAPWS Release: Values of Temperature, Pressure and Density of Ordinary and Heavy Water Substances at their Respective Critical Points. (Revised September 1992).

14. Guideline on the Use of Fundamental Constants and Basic Constants of Water. (Updated September 2008).
15. Release “Surface Tension of Ordinary Water Substance”. (Revised September 1994).
16. Release on the IAPWS Formulation 2008 for the Thermodynamic Properties of Seawater. (September 2008).

Further information about the above documents and others issued by IAPWS can be obtained from the Executive Secretary of IAPWS or the IAPWS Website at <http://www.iapws.org>.

Notes on the listed documents and their application

- a) IAPWS-95 is a fundamental equation of Helmholtz free energy as a function of temperature and density, $f = f(T, \rho)$, which yields other thermodynamic properties by differentiation and algebraic manipulation without the use of any other information. IAPWS-95 defines accurately the thermodynamic properties of the fluid phases of ordinary water substance, with complete thermodynamic consistency between these properties, over a wide range of states. (Pressures up to 1000 MPa and temperatures from the melting and sublimation temperatures to 1273 K). This definition of properties includes those on the liquid–vapor equilibrium line. The equation extrapolates sensibly to higher pressures and temperatures. Thus IAPWS-95 is recommended as the source of the thermodynamic properties of water and steam. However, since the independent variables of IAPWS-95 are temperature and density, computing times for some applications may be excessive and alternatives are available as indicated below.
- b) The IAPWS Release on an Equation of state for ice Ih defines the thermodynamic properties of the solid phase at temperatures below those for which IAPWS-95 describes the stable phase.
- c) IAPWS-IF97 is a set of equations designed to give accurate thermodynamic properties of liquid and gas with short computing times. The equations have been fitted to properties calculated from IAPWS-95 and therefore should not be considered as definitive for the thermodynamic properties. In order to achieve fast computing times, this formulation

covers a smaller range of states than IAPWS-95 and this smaller range is divided into sub-regions. Some of these regions have backward equations with different independent variables from the basic equation for the particular region. These backward equations may give directly a required property from the user's particular independent variables or provide a very close initial value for an iterative solution.

- d) Advisory Note No. 1 provides information on the uncertainties of the enthalpies obtained from IAPWS-95 and IAPWS-IF97 in addition to the information given in the releases on IAPWS-95 and IAPWS-IF97.
- e) The supplementary releases numbered 5, 6, 7 and 8 on page 2 provide additional backward equations for use with IAPWS-IF97 or for use in their own right. They are intended to reduce computing times further when using IAPWS-IF97.
- f) The supplementary release, 9 on page 2, contains simple equations for thermodynamic and other properties of the liquid at or close to atmospheric pressure to save the user the task of writing code for IAPWS-95 or IAPWS-IF97. The equations for thermodynamic properties have been fitted to data obtained from IAPWS-95.
- g) TTSE is a method of providing fast calculations for thermodynamic properties with an accuracy dependent on the grid size selected for the table of look-up properties used in the computation. The TTSE method can be applied to any property, with the values in the look-up table taken from an appropriate source. The guideline, numbered 10 on page 2, uses properties computed from IAPWS-95 for the look-up table.
- h) The equations described in the supplementary release, numbered 11 on page 2, for the saturation properties can be used to calculate saturation pressure, and density, specific enthalpy and specific entropy of the coexisting liquid and vapor phases directly from temperature. The range is from the triple point to the critical point. Although IAPWS-95 defines these properties, the equations from this release can be more quickly applied. The difference in a property obtained from the two sources is generally negligible.
- i) The release for the pressures along the melting and sublimation curves gives, as the title indicates, equations for the pressures as functions of temperature for solid-liquid for ice Ih, ice III, ice V, ice VI and ice VII, and for ice Ih-vapor equilibrium. The equations thus give the lower temperature bounds for the range of equilibrium fluid states to which

IAPWS-95 applies. IAPWS-95 and the release (2) on ice Ih also yield the pressures for at given temperatures together with all the thermodynamic properties for coexisting ice Ih and liquid and ice Ih and gas. The pressures from release 12 are negligibly different from those obtained from IAPWS-95 and release 2.

- j) The release on values at the critical point, numbered 13 on page 2, gives values recommended by IAPWS for the critical temperature, pressure and density. These values are used as parameters in many of the formulations discussed above.
- k) Document number 14 gives the recommendations of IAPWS for the best current values of fundamental physical constants of water (such as its molar mass, isotopic composition, and dipole moment). This document is reviewed (and updated if necessary) annually, so values of these constants in older IAPWS documents may differ slightly from the latest values given in this document.
- l) The release on seawater, document number 16, specifies an equation for the thermodynamic properties with a limited range of temperature, pressure from 0 to 100 MPa and varying salinity. The properties for the saline water are obtained by adding values from the equation to those calculated from IAPWS-95.
- m) Document number 15 providing information on surface tension is included to complete the list.