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D2.1 Properties of Water and Steam

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1 Introduction

The International Association for the Properties of Water and Steam (IAPWS) adopted two international standards for the thermodynamic properties of water substance.

The scientific equation of state was adopted in 1995 and is called "The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use" [1] or just IAPWS-95 for short. The formulation is valid in the entire stable fluid region of H_2O from the melting curve to 1,000°C at pressures up to 10,000 bar; the lowest temperature on the melting curve is $t = -21.985$°C (at 2099 bar). In this entire region, IAPWS-95 represents the most accurate experimental data within their uncertainties. This formulation can be reasonably extrapolated far beyond its range of validity. A comprehensive article [2] describes all details about this formulation.

The industrial standard for the thermodynamic properties of water and steam was adopted in 1997 and is called "IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam" [3] or "IAPWS-IF97" for short. IAPWS-IF97 consists of a set of equations for different regions that covers the following range of validity:

$$0°C \le t \le 800°C \qquad p \le 1000 \text{ bar}$$
$$800°C < t \le 2000°C \qquad p \le 500 \text{ bar}$$

This industrial standard has been coupled to the scientific standard IAPWS-95 by fitting the basic equations of IAPWS-IF97 to values of several thermodynamic properties calculated from IAPWS-95. The Industrial Formulation IAPWS-IF97 is comprehensively described in the book "International Steam Tables" [4].

2 Tables of Thermophysical Properties

The values of the thermophysical properties listed in the following tables were calculated from the Industrial Formulation IAPWS-IF97 [3, 4], except for the temperature range $t < 0$°C of Table 1. The tabulated values of the transport properties were calculated from the current IAPWS equations for the thermal conductivity [5] and the dynamic viscosity [6], each in the version for industrial use. These equations are also given in the latest International Steam Tables [4]. Apart from the basic equations of IAPWS-IF97, this book contains all backward equations that have been developed in the past years. These backward equations allow quick calculations of properties for input values other than (p,T), for example, (p,h), (p,s), and (h,s) without iterations. The book also contains the representation of 25 properties in pressure-temperature diagrams. The property values in Tables 1–14 were calculated with the CD providing the interactive program "IAPWS-IF97 Electronic Steam Tables" that accompanies the International Steam Tables [4]. This software allows the calculation of "personal" steam tables for arbitrary values of pressure and temperature.

Tables 1–14 cover the following properties:

t – Celsius temperature	α_v – Isobaric cubic expansion coefficient, $\alpha_v = (1/v)(\partial v/\partial T)_p$
T – Thermodynamic temperature	
p – Pressure	λ – Thermal conductivity
ρ – Density	η – Dynamic viscosity
v – Specific volume	ν – Kinematic viscosity, $\nu = \eta/\rho$
Z – Compression factor, $Z = p/(\rho RT)$	a – Thermal diffusivity, $a = \lambda/(c_p\,\rho)$
h – Specific enthalpy	Pr – Prandtl number, $\text{Pr} = \eta\, c_p/\lambda$
s – Specific entropy	σ – Surface tension
c_p – Specific isobaric heat capacity	b – Laplace coefficient, $b = \{\sigma/[g(\rho' - \rho'')]\}^{0.5}$, where g is the acceleration of gravity, $g = 9.80655$ m s^{-2}

Further properties are tabulated in the International Steam Tables [4].

The characteristic properties of water are:

Molar mass $\tilde{M} = 18.015\,275$ g mol^{-1}	Triple point: $T_t = 273.16$ K or $t_t = 0.01$°C $p_t = 6.116\,57$ mbar
Specific gas constant $R = 0.461\,526$ kJ kg^{-1} K^{-1}	
Critical point: $T_c = 647.096$ K or $t_c = 373.946$°C $p_c = 220.64$ bar $\rho_c = 322$ kg m^{-3}	Normal boiling point ($p = 1.013\,25$ bar): $T_b = 373.124$ K or $t_b = 99.974$°C

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