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Prandtl number of water and steam

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Physical Data, Chemical Engineering Sub-series

Physical Data, Mechanical Engineering Sub-series

Engineering Sciences Data Items provide evaluated data and authoritative information for use in engineering design. The results of much valuable work, both theoretical and practical, are frequently not applied because they are not readily available or because the form in which they are available is not suitable for use directly in design. Accordingly, the Engineering Sciences Data Unit has for many years issued Data Sheets and Memoranda in numerous Sub-series. This work is sponsored by the following Institutions: the Royal Aeronautical Society, the Institution of Mechanical Engineers, the Institution of Chemical Engineers and the Institution of Structural Engineers. Crucial support for this work is provided voluntarily by industrial companies, government research laboratories, universities and others through the attendance at Technical Committees (see below) of their leading experts.

The work of the permanent professional staff of the Engineering Sciences Data Unit on this particular Item, which supersedes Item No. 68011, was monitored and guided by the Physical Data and Reaction Kinetics Committee which has the following constitution:

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The Physical Data and Reaction Kinetics Committee, which first met in May 1966, has the co-operation of many engineers and scientists in industry, research establishments and universities from whom much assistance and information is being received. For this particular Item the initial assessment of the available information, the correlations and the tables calculated from them were prepared by the National Engineering Laboratory. The work was undertaken by Mr J.T.R. Watson of the Properties of Fluids Division and sponsored by ESDU.

In order to assist the preparation of new work, and particularly to assist the periodic review and revision of work already issued, users are encouraged to make known their experience in using the information and procedures and to notify the Unit of any additional information which they can provide or to which reference can be made. Prepaid reply service cards are available for this purpose. Whenever an Item is revised, users who are Associates of ESDU (i.e. have a standing order for one or more Sub-series) automatically receive any material required to up-date Items in the Sub-series held. While it is always advisable to check by use of the current edition of the Engineering Sciences Data Index that Items held are the latest issue and incorporate the latest amendments, those who are not Associates are particularly advised to take this action at reasonable intervals since the Unit cannot undertake to supply them with an appropriate up-dating service. Any missing amendments can be supplied on request.

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* Corresponding Member

PRANDTL NUMBER OF WATER AND STEAM

1. INTRODUCTION

This Item presents values in SI units for the Prandtl number of water and steam for temperatures between 0 and 800 °C and for pressures between 0 and 1000 bar. The data are presented in the form of Tables generated by computer.

Table I gives the variation of the Prandtl number of water and steam with temperature, and with pressure, along the saturation line from the triple point to the critical point and Table II gives the variation of the Prandtl number with temperature and pressure in the single-phase region.

The tabulated values of Prandtl number have been calculated at specific values of temperature and pressure from values of:

(a) the specific isobaric heat capacity as given by the 1968-IFC Formulation for Scientific and General Use (Derivation 1),

(b) the dynamic viscosity as given by the single representative equation for the viscosity of water substance (Derivation 4 and Reference 9), and

(c) the thermal conductivity as given by the single representative equation recommended by the International Association for the Properties of Steam (Derivations 3 and 5 and Reference 8).

Values of the thermodynamic properties and derivatives used in conjunction with the representative equations for viscosity and thermal conductivity have been calculated from the IFC-68 Formulation (Derivation 1). The equation for the viscosity used in this work represents the International Skeleton Table values for viscosity (Derivation 2) to well within their tolerances and is in good agreement with sets of new viscosity values not previously considered.

2. NOTATION AND UNITS

c_p	specific isobaric heat capacity	kJ/kg K
p	absolute pressure	bar
p_s	saturation pressure	bar
Pr	Prandtl number, $c_p\ \eta/\lambda$	
Pr_f	Prandtl number of saturated liquid	
Pr_g	Prandtl number of saturated vapour	
t	Celsius temperature *	°C
t_s	saturation temperature	°C
η	dynamic viscosity	N s/m²
λ	thermal conductivity	W/m K

* Within the uncertainties given in Section 4.2, the choice of temperature scale for use with the data in this Item is not significant, see Reference 10.

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3. GENERAL INFORMATION

The critical and triple point values for water given here are those of the 1968-IFC Formulation for Scientific and General Use (Derivation 1).

Critical temperature:	374.12 °C 705.4 °F
Critical pressure:	221.15 bar 3207. lbf/in^2
Critical volume:	3.147 x 10^{-3} m^3/kg 5.041 x 10^{-2} ft^3/lb
Normal boiling point:	100 °C 212 °F
Normal freezing point:	0 °C 32 °F
Triple point temperature:	0.01 °C 32.02 °F
Triple point pressure:	6.112 x 10^{-3} bar 8.864 x 10^{-2} lbf/in^2

4. PRANDTL NUMBER OF WATER AND STEAM

4.1 Data Presented in the Tables

Values of the Prandtl number of water and steam along the saturation line are presented in Table I as a function of temperature, and as a function of pressure. In Table II the values of the Prandtl number of water and steam in the single-phase region are given as functions of temperature and pressure for the p-t domain 1 to 1000 bar and 0 to 800 °C. The data in Tables I and II have been calculated from the values of isobaric heat capacity derived from the 1968-IFC Formulation for Scientific and General Use (Derivation 1), and from the values of thermal conductivity and dynamic viscosity derived from the representative equations given in Item Nos 78039 and 78040, respectively. For the convenience of the user the tabular entries in Table II are presented on the same pressure-temperature grid as used in the latter Items.

In general the last figure, and on occasions the penultimate figure, in the Tables is not significant but is included to reduce errors in interpolation. Linear interpolation between adjacent tabulated values will usually be sufficient. However for the liquid region below 50 °C in Tables I and II and for the critical and supercritical regions, that is for temperatures above 340 °C in Table I and for temperatures between 340 and 420 °C and pressures between 150 and 350 bar in Table II, graphical interpolation is required.

Data given are for pure water but may be taken to hold for town's water except near the critical point when impurities have a large effect. For data for the Prandtl number of sea water and heavy water see References 6 and 7, respectively.

4.2 Accuracy of the Tables

The user should allow for an uncertainty in the Prandtl number equal to the percentages shown in Sketch (4.1). The uncertainty has been obtained as the square root of the sum of the squares of the uncertainties for c_p, η