

Hans-Joachim Kretzschmar
Wolfgang Wagner

International Steam Tables

Properties of Water and Steam based on
the Industrial Formulation IAPWS-IF97
Tables · Algorithms · Diagrams

Third Edition

EBOOK INSIDE

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Properties of Water and Steam based on
the Industrial Formulation IAPWS-IF97

3rd Edition

Tables, Algorithms, and Diagrams

All of the equations of IAPWS-IF97 including a complete set of
supplementary backward equations for fast calculations of heat
cycles, boilers, and steam turbines

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Preface to the Third Edition

The international research regarding the thermophysical properties of water and steam has been coordinated by the International Association for the Properties of Water and Steam (IAPWS). IAPWS is responsible for the international standards for thermophysical properties. These standards and recommendations are given in the form of releases, guidelines, and advisory notes. In 1997, IAPWS adopted the Release “IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam” called IAPWS-IF97 for short.

The first edition of this book, published in 1998, described IAPWS-IF97 as it was adopted by IAPWS in 1997. In 2008, the second edition was published. Apart from incorporating all the “supplementary” backward equations developed after the adoption of IAPWS-IF97, it was a significant extension of the first edition; for details see the preface to the second edition.

In the third edition, apart from some printing errors, the following changes have been made. In *Part A*, all revisions of the Releases and Supplementary Releases adopted after 2008 were taken into account. In connection with the basic equations, equations for calculating the relative pressure coefficient and the isothermal stress coefficient and thus the corresponding partial derivatives have been included. The most important change is the incorporation of the current equation of the thermal conductivity of water and steam adopted by IAPWS in 2011. In *Part B*, the tables of the thermal conductivity and the Prandtl number that contains the thermal conductivity have been recalculated. Further changes are the (partly significant) reduction of the sizes of the tables combined with adding seven new tables of properties that were not yet considered in the second edition. In *Part C*, the diagram for the thermal conductivity is recalculated due to the new equation for this property. Because of the thermal conductivity, the diagrams for the quantities Prandtl number and thermal diffusivity, had also to be recalculated.

The Parts D (IAPWS-IF97 Electronic Steam Tables on CD-ROM) and E (Wall Charts of the Properties of Water and Steam) of the second edition were omitted. However, information how to calculate property values for water and steam online and how to obtain copies of coloured wall charts of the Mollier $h-s$ diagram, the $T-s$ diagram, and the $\log(p)-h$ diagram are given at <http://www.international-steam-tables.com>. In addition, there is also information on property-calculation software for Windows and Linux applications and for IOS and Android smart phones, tablets, and pocket calculators.

We are grateful to the members of the IAPWS Working Groups “Thermophysical Properties of Water and Steam” and “Industrial Requirements and Solutions” for fruitful discussions. Our warmest thanks are dedicated to Dr. M. Kunick and Dr. S. Herrmann for formatting the text of Part A and the tables as Microsoft Excel sheets for Part B, and for their help in revising the pressure-temperature diagrams in Part C of the book. We thank Mr. M. Sünder for reprogramming all of the equations and tables in Parts A and B of the book. We would also like to thank Mrs. R. Gölzenleuchter very much for producing all of the figures.

Preface to the Second Edition

The international research regarding the thermophysical properties of water and steam has been coordinated by the International Association for the Properties of Water and Steam (IAPWS). IAPWS is responsible for the international standards for thermophysical properties. These standards and recommendations are given in the form of releases, guidelines, and advisory notes. One of the most important standards in this sense is the formulation for the thermodynamic properties of water and steam for industrial use.

In 1997, IAPWS adopted the “IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam” for industrial use, called IAPWS-IF97 for short. The formulation IAPWS-IF97 replaced the previous industrial formulation IFC-67 published in 1967.

After the adoption of IAPWS-IF97 in 1997, further so-called backward equations were developed. These studies were coordinated by the IAPWS Task Group on Supplementary Backward Equations for IAPWS-IF97 chaired by one of the authors of this book (H.-J. K.). The final form of these equations is based on contributions by

J. R. Cooper	K. Knobloch	I. Stöcker
A. Dittmann	H.-J. Kretzschmar	R. Span
D. G. Friend	R. Mareš	W. Wagner
J. S. Gallagher	K. Miyagawa	I. Weber
A. H. Harvey	N. Okita	

In addition to these scientists, many other IAPWS colleagues, particularly the members of the working group “Industrial Calculations” (chairman up to 2001: B. Rukes, chairman from 2001 to 2003: K. Miyagawa, and chairman from 2004 onwards: Bill Parry) from 2002 onwards renamed in “Industrial Requirements and Solutions”, and the working group “Thermophysical Properties of Water and Steam” (chairman up to 2000: J. R. Cooper, chairman from 2000 to 2005: D. G. Friend, and chairman from 2005 onwards: H.-J. Kretzschmar), have contributed to the entire success of this IAPWS project; we appreciate their contribution very much. We are particularly grateful to the chairman of the evaluation task group, K. Miyagawa, for his exceptional efforts in testing these backward equations to ensure that they fulfill all requirements and checking the drafts of the several supplementary releases.

In 1998, Springer-Verlag published the book “Properties of Water and Steam” authored by W. Wagner and A. Kruse. This book described the industrial formulation IAPWS-IF97 as it was adopted by IAPWS in 1997. This new book is considered to be the second edition of the book published in 1998, although it has a different title and authorship and is only in English and no longer bilingual English/German. This second edition describes the industrial formulation in its current form, thus including all of the new so-called backward equations adopted by IAPWS between 2001 and 2005.

In addition to IAPWS-IF97, the industrial standard for the *thermodynamic* properties of water and steam, the most recent equations for the *transport* properties dynamic viscosity and thermal conductivity are also presented. Moreover, equations for the surface tension, dielectric constant,

and refractive index are given.

In contrast to the first edition, this second edition contains a number of extensions and new parts, namely:

- Incorporation of all “supplementary” backward equations.
- Inclusion of the uncertainty of the specific enthalpy into the uncertainty values of IAPWS-IF97 for the most important properties.
- Formulas to calculate all partial derivates of the eight most important thermodynamic properties.
- Additional properties in the steam tables.
- Incorporation of the new basic equation for the high-temperature region (1073.15 K to 2273.15 K) with pressures up to 50 MPa (previously up to 10 MPa).
- Pressure-temperature diagrams with isolines of all properties contained in the steam tables and further properties.
- A compact disc (CD) providing the interactive program “IAPWS-IF97 Electronic Steam Tables” for the calculation of all properties (contained in the book) dependent on freely selectable pressures and temperatures in the single-phase region and on pressure or temperature along the saturated-vapour and saturated-liquid lines. Those properties for which it is reasonable can also be calculated within the two-phase region for given values of pressure or temperature and vapour fraction.

We are very grateful to Dr. K. Knobloch who developed the supplementary backward equations in her dissertation. We would like to thank Mr. M. Kunick for calculating and formatting the tables as Microsoft Excel sheets for Part B. We are very grateful to Dr. I. Stöcker, Dr. K. Knobloch, Ms. M. Weidner, and Mr. S. Buchholz for their help in producing all of the pressure-temperature diagrams in Part C of the book. Our warmest thanks are dedicated to Dr. U. Overhoff for his assistance in preparing the “IAPWS-IF97 Electronic Steam Tables” on the CD in Part D and for several checkups, and to Dr. I. Stöcker for her help in producing the large size Mollier $h-s$ and $T-s$ diagrams, which are included as attachments to the book. We thank Mr. R. Preusche, Mr. M. Markward, and Mr. B. Salomo for reprogramming all of the equations presented in the book. We would also like to thank Mrs. B. Esch for typing the text of the manuscript and Mrs. R. Gölzenleuchter for producing all of the figures. Our thanks go to Dr. O. Kunz for his help in creating the electronic printing version of Part A of the manuscript. Finally, we are grateful to Dr. E. W. Lemmon and Mrs. R. Smith for carefully reading the manuscript and for a number of suggestions on improving the English style.

One of us (H.-J. Kretzschmar) is particularly grateful to the Saxon State Ministry for Science and Art for the financial support of the development of the supplementary backward equations at the Zittau/Görlitz University of Applied Sciences from 2001 to 2003.

Bochum and Zittau, November 2007

W. Wagner
H.-J. Kretzschmar

Preface to the First Edition

In 1997, the International Association for the Properties of Water and Steam (IAPWS) adopted a new formulation for the thermodynamic properties of water and steam for industrial use. This formulation is called “IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam” and “IAPWS Industrial Formulation 1997” or “IAPWS-IF97” for short. The new formulation IAPWS-IF97 replaces the previous industrial formulation, IFC-67, that has formed the basis for power-plant calculations and other industrial applications since the late 1960’s. IAPWS-IF97 improves significantly both the accuracy and the speed of the calculation of thermodynamic properties. The differences from IFC-67 will require many users, particularly boiler and turbine manufacturers but also power-station companies and corresponding engineering offices, to modify design and application codes. In addition to these applications, IAPWS-IF97 is also of importance for energy-engineering applications in chemical industry and in other branches of industry. Therefore, this book presents the individual equations of IAPWS-IF97 for calculating the thermodynamic properties of water and steam for industrial use.

The IAPWS Industrial Formulation 1997 was developed in an international research project. This development was coordinated by the IAPWS Task Group “New Industrial Formulation” chaired by one of the authors of this book (W. W.). The final form of IAPWS-IF97 is based on contributions and equations by

J. R. Cooper	R. Mareš	Y. Takaishi
A. Dittmann	K. Oguchi	I. Tanishita
J. Kijima	H. Sato	J. Trübenbach
H.-J. Kretzschmar	I. Stöcker	W. Wagner
A. Kruse	O. Šifner	Th. Willkommen.

Besides these “developers” many other IAPWS colleagues, particularly the members of the two working groups “Industrial Calculations” and “Thermophysical Properties of Water and Steam”, contributed to the entire success of this comprehensive project; we appreciate their contribution very much. We are especially grateful to the chairmen of these two working groups, B. Rukes and J. R. Cooper. In addition, we would like to thank the members of the IAPWS Task Group “New Industrial Formulation - Evaluation” for testing IAPWS-IF97 regarding the fulfilment of requirements and checking the influence on real power-cycle calculations; concerning these important pieces of work we are particularly grateful to the chairman of this task group, K. Miyagawa, and his colleagues R. Spencer, R. B. McClintock, and H. W. Bradly for their exceptional efforts.

In addition to IAPWS-IF97, the industrial standard for the thermodynamic properties of water and steam, the most recent equations for the transport properties dynamic viscosity and thermal conductivity are also presented. Moreover, equations for the surface tension, static dielectric constant, and refractive index are given.

The text of this book is bilingual. Part A contains the description of the above mentioned equations for the thermophysical properties in English and Part B the corresponding description

in German. Comprehensive tables of the most important thermophysical properties of water and steam are given in Part C in both languages.

The values in the tables of Part C were exclusively calculated from the corresponding equations summarized in Part A and Part B, respectively. These tables, which are mainly based on the new industrial formulation IAPWS-IF97, replace the tables "Properties of Water and Steam in SI-Units" prepared by E. Schmidt and edited by U. Grigull (Springer-Verlag Berlin Heidelberg New York, R. Oldenbourg München, Fourth, Enlarged Printing, 1989) which are based on the previous industrial formulation IFC-67.

We wish to express our warmest thanks to Mr. C. Bonsen for his help in handling the computer programs for calculating the transport properties and for producing all the tables. We would also like to thank Mrs. A.-M. Sieg for typing the text of the manuscript. We are particularly grateful to the Deutsche Forschungsgemeinschaft for their financial support of that part of the development of IAPWS-IF97 which was carried out at the Ruhr-University Bochum.

Bochum, February 1998

W. Wagner
A. Kruse

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Nomenclature

Quantities

A	Function
a	Thermal diffusivity, $a = \lambda/(\rho c_p)$
a	Coefficient
B	Function
c_p	Specific isobaric heat capacity
$c_{p,m}^0$	Mean specific isobaric heat capacity in the ideal-gas state
c_v	Specific isochoric heat capacity
CTR	Computing-Time Ratio
f	Specific Helmholtz free energy, $f = u - Ts$
f^*	Fugacity
g	Specific Gibbs free energy, $g = h - Ts$
\bar{g}	\bar{g} -factor of Harris and Alder
h	Specific enthalpy
Δh_v	Specific enthalpy of vaporization, $\Delta h_v = h'' - h'$
I	Exponent
i	Serial number; Exponent
J	Exponent
j	Serial number; Exponent
k	Boltzmann's constant
M	Molar mass
N_A	Avogadro's number
n	Refractive index
n	Coefficient
Pr	Prandtl number, $Pr = \eta c_p \lambda^{-1}$
p	Pressure
R	Specific gas constant
R_m	Molar gas constant
s	Specific entropy
Δs_v	Specific entropy of vaporization, $\Delta s_v = s'' - s'$
T	Thermodynamic temperature ¹
t	Celsius temperature, $t/^\circ\text{C} = T/\text{K} - 273.15$
u	Specific internal energy
v	Specific volume
w	Speed of sound

¹ All temperature values given in this book are temperatures according to the International Temperature Scale of 1990 (ITS-90)

x	Vapour fraction
x	Arbitrary state variable
y	Arbitrary state variable
z	Compression factor, $z = pv/(RT)$
z	Arbitrary state variable
α	Mean molecular polarizability of the isolated water molecule
α_p	Relative pressure coefficient, $\alpha_p = p^{-1}(\partial p/\partial T)_v$
α_v	Isobaric cubic expansion coefficient, $\alpha_v = v^{-1}(\partial v/\partial T)_p$
β	Transformed pressure, Eq. (2.12a)
β_p	Isothermal stress coefficient, $\beta_p = -p^{-1}(\partial p/\partial v)_T$
γ	Dimensionless Gibbs free energy, $\gamma = g/(RT)$
Δ	Difference in any quantity
δ	Reduced density, $\delta = \rho/\rho^*$
δ_T	Isothermal throttling coefficient, $\delta_T = (\partial h/\partial p)_T$
ε	Dielectric constant (relative static dielectric constant or relative static permittivity)
ε_0	Permittivity of vacuum (electric constant)
η	Dynamic viscosity
η	Reduced enthalpy, $\eta = h/h^*$
θ	Reduced temperature, $\theta = T/T^*$
ϑ	Transformed temperature, Eq. (2.12b)
κ	Isentropic exponent, $\kappa = -vp^{-1}(\partial p/\partial v)_s$
κ_T	Isothermal compressibility, $\kappa_T = -v^{-1}(\partial v/\partial p)_T$
λ	Thermal conductivity
Λ	Reduced thermal conductivity, $\Lambda = \lambda/\lambda^*$
$\bar{\lambda}$	Wavelength of light
$\bar{\Lambda}$	Reduced wavelength of light, $\bar{\Lambda} = \bar{\lambda}/\bar{\lambda}^*$
μ	Joule-Thomson coefficient, $\mu = (\partial T/\partial p)_h$
μ	Dipole moment of the isolated water molecule
ν	Kinematic viscosity, $\nu = \eta\rho^{-1}$
π	Reduced pressure, $\pi = p/p^*$
ρ	Mass density
σ	Surface tension
σ	Reduced entropy, $\sigma = s/s^*$
τ	Inverse reduced temperature, $\tau = T^*/T$
ϕ	Dimensionless Helmholtz free energy, $\phi = f/(RT)$
Ψ	Reduced dynamic viscosity, $\Psi = \eta/\eta^*$
ω	Reduced volume, $\omega = v/v^*$

Superscripts

o	Ideal-gas part; ideal gas
r	Residual part
$^{\max}$	Maximum value of a quantity
$^{\min}$	Minimum value of a quantity

- * Reducing quantity
- ' Saturated-liquid state
- " Saturated-vapour state

Subscripts

- ad Adiabat
- b Normal boiling point
- c Critical point
- h At constant specific enthalpy
- ind Industrial equation for λ
- m State on the melting line
- m Mean value
- max Maximum value of a quantity
- p At constant pressure
- perm Permissible
- RMS Root-mean-square value of a quantity, see below
- ρ At constant density
- s Saturation state
- s At constant specific entropy
- sub State on the sublimation line
- t Triple point
- T At constant temperature
- v At constant specific volume

Root-mean-square value:

$$(\Delta x)_{\text{RMS}} = \sqrt{\frac{1}{N} \sum_{n=1}^N (\Delta x_n)^2},$$

where Δx_n can be either absolute or percentage differences of the corresponding property x ; N is the number of Δx_n values (depending on the property, between 10 million and 100 million points are uniformly distributed over the respective range of validity)



Introduction

This book consists of three parts, Part A to Part C.

Part A presents the current internationally agreed equations for industrial calculations of the most relevant thermophysical properties of water and steam.

The current industrial standard for the *thermodynamic* properties, which replaced the former industrial standard IFC-67 [1], was adopted by the International Association for the Properties of Water and Steam (IAPWS) in 1997 under the name “IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam” or simply IAPWS-IF97 for short. All relevant numerical details of the entire set of equations of IAPWS-IF97 are given in Chap. 2.

For the so-called basic and backward equations of IAPWS-IF97, all revisions of the Releases and Supplementary Releases adopted after 2008 have been taken into account. In addition to the uncertainty values given in IAPWS-IF97 for the properties specific volume, specific isobaric heat capacity, speed of sound, and saturation pressure, this book contains uncertainty values for the specific enthalpy and differences in specific enthalpy. Moreover, formulas are presented to calculate all partial derivatives from the equations of IAPWS-IF97 formed by any three combinations of the properties pressure, temperature, and the specific properties volume, enthalpy, internal energy, entropy, Gibbs free energy, and Helmholtz free energy. Examples for such calculations are given when using the needed property values given in the tables of Part B or when these values are determined with corresponding software tools.

In addition to the equations for the thermodynamic properties of water and steam, Chap. 3 of Part A summarizes current equations for industrial use for the *transport* properties dynamic viscosity and thermal conductivity and also equations for the surface tension, dielectric constant, and refractive index. In comparison to the second edition, this chapter has been fundamentally revised. The equation for the thermal conductivity was replaced by the current IAPWS equation for this property.

Part B contains the tables of all the properties of water and steam considered in this book. These tables were calculated from the corresponding equations of Chaps. 2 and 3 in Part A. In comparison to the second edition, the size of the tables has been reduced, sometimes significantly. The tables of the thermal conductivity and the Prandtl number that contains the thermal conductivity have been recalculated. This third edition presents eight additional tables for further properties, for example, thermal diffusivity, Joule-Thomsen coefficient, and fugacity.

Part C of this book presents pressure-temperature diagrams with isolines of all the properties tabulated in Part B and of further properties such as the specific Gibbs free energy and a number of partial derivatives. The diagram for the thermal conductivity is recalculated due to the new equation for this property. Since the thermal conductivity is also included in the quantities Prandtl number and thermal diffusivity, these diagrams had also to be recalculated.

Part A

Equations for the Calculation of the Thermophysical Properties of Water and Steam



1 Reference Constants

This chapter summarizes all reference constants needed for evaluating the equations given in Chaps. 2 and 3.

The specific gas constant of ordinary water,

$$R = 0.461\ 526\ \text{kJ kg}^{-1}\ \text{K}^{-1}, \quad (1.1)$$

results from the value of the molar gas constant [2],

$$R_m = 8.314\ 51\ \text{kJ kmol}^{-1}\ \text{K}^{-1}, \quad (1.2)$$

and from the molar mass of ordinary water,

$$M = 18.015\ 257\ \text{kg kmol}^{-1}. \quad (1.3)$$

The value of the molar mass of ordinary water results from the molar masses of hydrogen, M_H , and oxygen, M_O , based on the molar masses of H and O [3] and the concentration of the corresponding isotopes [4]. The values of R_m and M are not the current values for these quantities² and thus not for the specific gas constant R as given in Eq. (1.1). However, this value of R must be used in all equations in Chap. 2, which contain the specific gas constant, because the equations were developed based on the value of R according to Eq. (1.1).

The values of the critical parameters

$$T_c = 647.096\ \text{K}, \quad (1.4)$$

$$p_c = 22.064\ \text{MPa}, \quad (1.5)$$

$$\rho_c = 322\ \text{kg m}^{-3} \quad (1.6)$$

are from the corresponding IAPWS release [5]. The triple-point temperature is

$$T_t = 273.16\ \text{K} \quad (1.7)$$

according to the International Temperature Scale of 1990 (ITS-90) [6] and the triple-point pressure

$$p_t = 611.657\ \text{Pa} \quad (1.8)$$

was determined by Guildner et al. [7]. According to the scientific standard for the thermodynamic properties of ordinary water, the IAPWS-95 formulation [8, 9], the temperature of the normal boiling point (at a pressure of 0.101 325 MPa (1 atm)) amounts to

$$T_b = 373.1243\ \text{K}. \quad (1.9)$$

²The current value of the molar gas constant is $R_m = 8.314\ 459\ 8\ \text{kJ kmol}^{-1}\ \text{K}^{-1}$ [10]. The current value of the molar mass of ordinary water is that of VSMOW (Vienna Standard Mean Ocean Water) [11]. Its value is $M = 18.015\ 268\ \text{kg kmol}^{-1}$ [12]. This value is based on combining the isotopic composition of VSMOW with the accepted atomic mass of each isotope. According to these values for R_m and M the current value for the specific gas constant of ordinary water is $R = 0.461\ 523\ 1\ \text{kJ kg}^{-1}\ \text{K}^{-1}$.



2 IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam

At the IAPWS meeting in Erlangen, Germany in 1997, the “IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam” was adopted as the new international industrial standard for the thermodynamic properties of water and steam. This new industrial standard is also called “IAPWS Industrial Formulation 1997” or “IAPWS-IF97” for short. The IAPWS-IF97 formulation replaced the previous industrial standard IFC-67 [1]. In comparison with IFC-67, IAPWS-IF97 significantly improves both the accuracy and the calculation speed of thermodynamic properties.

This chapter presents all of the information about the individual equations of IAPWS-IF97 necessary for calculating the thermodynamic properties of water and steam. It also includes the supplementary backward equations developed after 1997 and adopted by IAPWS between 2001 and 2005, and also a new basic equation for the high-temperature region 1073.15 K to 2273.15 K for pressures up to 50 MPa (previously 10 MPa). The backward equations are not presented region by region, but all backward equations dependent on the same input variables are summarized in the same section. Section 2.4 presents formulas to calculate all of the partial derivatives $(\partial z / \partial x)_y$ from the equations of IAPWS-IF97, where the variables x , y , and z can represent any of the thermodynamic properties: pressure p , temperature T , and the specific properties volume v , enthalpy h , internal energy u , entropy s , Gibbs free energy g , or Helmholtz free energy f . In addition to the uncertainties of the equations of IAPWS-IF97 in the properties specific volume, specific isobaric heat capacity, speed of sound, and saturation pressure, Sec. 2.5 also contains uncertainty statements on the specific enthalpy and differences in specific enthalpy. Moreover, illustrations show the achieved consistency between the basic equations along the region boundaries.

Information about the development of the IAPWS-IF97 equations and details about their quality and calculation speed in comparison with the previous industrial standard IFC-67 are given in the international publications on IAPWS-IF97 [13, 14]. The entire numerical description of IAPWS-IF97 is given in the IAPWS Release on this formulation [15]. Details about the development of the supplementary backward equations that are not included in the Release on IAPWS-IF97 are given in the articles [16-19]. These equations were adopted by IAPWS as Supplementary Releases [23-26] to supplement IAPWS-IF97.

2.1 Characteristic Features of IAPWS-IF97

This section gives general information about the structure of the industrial formulation IAPWS-IF97, including the entire range of validity, and makes some general statements about the quality of IAPWS-IF97 concerning accuracy and consistency along the region boundaries. In addition, statements on the calculation speed are made not only when the basic equations are used for calculations of properties that are not dependent on pressure and temperature, but also when the supplementary backward equations are used.

2.1.1 Structure of IAPWS-IF97

The IAPWS Industrial Formulation 1997 [15] consists of a set of equations for different regions which cover the following range of validity:

$$\begin{aligned} 273.15 \text{ K}^3 \leq T \leq 1073.15 \text{ K} & \quad 0 < p \leq 100 \text{ MPa} \\ 1073.15 \text{ K} < T \leq 2273.15 \text{ K} & \quad 0 < p \leq 50 \text{ MPa} \end{aligned}$$

Figure 2.1 shows the five regions, which divide the entire range of validity of IAPWS-IF97; for the exact definition of the five regions see Sec. 2.2. Regions 1 and 2 are each covered by a fundamental equation for the specific Gibbs free energy $g(p, T)$, region 3 by a fundamental equation for

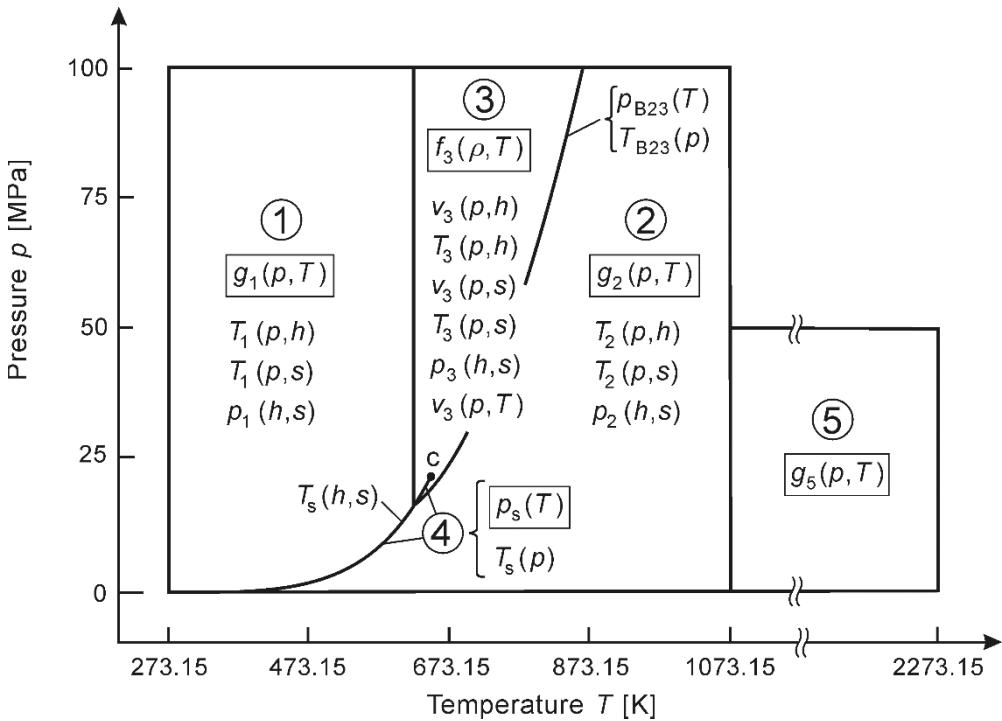


Fig. 2.1 Regions and equations of the industrial formulation IAPWS-IF97.

the specific Helmholtz free energy $f(\rho, T)$, and region 4, the two-phase region (corresponding to the saturation curve in the p - T diagram), by a saturation-pressure equation $p_s(T)$. The high-temperature region 5 is also covered by a $g(p, T)$ equation. These five equations, shown in rectangular boxes in Fig. 2.1, form the so-called *basic equations*.

The industrial standard IAPWS-IF97 has been coupled to the scientific standard, the “IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use” [8, 9], hereafter abbreviated to IAPWS-95. This coupling was achieved by fitting the basic equations of regions 1 to 3 and 5 to values of the specific volume v , specific enthalpy h ,

³In order to remain consistent with the previous industrial formulation IFC-67 [1], the range of validity of IAPWS-IF97 in temperature starts at 273.15 K (0°C) rather than at the triple-point temperature $T_t = 273.16 \text{ K}$ (0.01°C). Thus, when being thermodynamically exact, states in the temperature range $273.15 \text{ K} \leq T \leq 273.16 \text{ K}$ and at pressures $p_{\text{sub}}(T) \leq p < p_m(T)$ are in the metastable region, where p_{sub} and p_m are the pressures along the sublimation and melting line [20], respectively.

specific isobaric heat capacity c_p , and speed of sound w calculated from IAPWS-95 [8, 9]. Accordingly, the basic equation for region 4, the saturation-pressure equation, was fitted to the values of the saturation pressure p_s calculated from IAPWS-95.

In addition to these basic equations, so-called *backward equations* are provided for all regions except for region 5, where the backward equations are only valid for pressures $p \geq p_s(273.15 \text{ K}) \approx 0.000\,611 \text{ MPa}$. These backward equations were developed in the following combinations of variables: For regions 1 and 2 as equations of the form $T(p, h)$, $T(p, s)$, and $p(h, s)$, for region 3 as equations of the form $v(p, h)$, $T(p, h)$, $v(p, s)$, $T(p, s)$, $p(h, s)$, and $v(p, T)$, for the entire region 4 as a saturation-temperature equation $T_s(p)$, and for the technically most important part of region 4 ($s \geq s''(623.15 \text{ K})$) as a saturation-temperature equation of the form $T_s(h, s)$. In Fig. 2.1, in addition to the (framed) basic equations, all of these types of backward equations are assigned to the corresponding region of IAPWS-IF97. The subscripts relate to the region for which the equation is valid.

These backward equations were developed in such a way that they are numerically consistent with the corresponding basic equation. Thus, properties as functions of (p, h) , (p, s) , and (h, s) for regions 1 to 3, of (p) for the entire region 4, and of (h, s) for the technically most important part of region 4 can be calculated without any iteration. Due to the backward equation $v(p, T)$ for region 3, the specific volume can be calculated for this region without the necessity of its iteration from the basic equation $f_3(\rho, T)$. Consequently, properties such as $s(p, h)$ and $h(p, s)$ can be calculated directly from the corresponding backward equation or in combination with the corresponding basic equation, for example, $h(p, s)$ via the relation $h(p, T(p, s))$. As a result of this special concept of the industrial standard IAPWS-IF97, all important combinations of properties can be calculated extremely quickly; more details are given in the next section and in Sec. 2.3.7.

2.1.2 Quality of IAPWS-IF97

The achieved overall quality of the industrial formulation IAPWS-IF97 is characterized by the following general results in the light of the three criteria accuracy, consistency between basic equations along region boundaries and between backward equations along subregion boundaries, and calculation speed.

The accuracy of IAPWS-IF97 is illustrated by the fact that for its entire range of validity only 0.2% of the calculated v values, 6% of the c_p values, 2% of the w values, and none of the p_s values are outside the uncertainty of the corresponding IAPWS-95 values [8, 9]. The corresponding comparison [13] with the previous industrial standard IFC-67 [1] showed that IAPWS-IF97 is more than one order of magnitude more accurate than IFC-67. The estimated uncertainties of IAPWS-IF97 in the properties v , c_p , w , p_s , h , and Δh over the entire range of validity are given in Sec. 2.5. In addition to the representation of the properties for the stable homogeneous regions and at saturation, the corresponding IAPWS-IF97 equations also yield reasonable values for both the metastable superheated-liquid region and the metastable subcooled-vapour region close to the saturated-liquid line and the saturated-vapour line, respectively.

An additional important jump in quality was achieved by the fact that IAPWS-IF97 clearly meets the requirements regarding the consistencies along the region boundaries, see Fig. 2.1. IAPWS-IF97 is clearly within the permitted inconsistencies according to the so-called Prague values [21]. This is also true for the “difficult” boundary between regions 2 and 3, along which the consistency requirements for the specific isobaric heat capacity are also met by the basic equations of regions 2 and 3.

For IAPWS-IF97, the maximum inconsistency in c_p at this boundary amounts to 0.35% whereas the corresponding IFC-67 inconsistency was more than 15 times greater. Details of the achieved consistencies along the boundaries between regions 1 and 3, regions 2 and 3, and regions 2 and 5 are given in Sec. 2.5.3.

The third and probably the greatest advantage is the very large improvement in the calculation speed compared with IFC-67. Even when using only the backward equations that existed in 1997 when IAPWS-IF97 was adopted (the equations $T(p,h)$ and $T(p,s)$ for regions 1 and 2) for the most important regions 1, 2, and 4, where the computing time is particularly relevant, it was found that IAPWS-IF97 is more than 5 times faster than IFC-67 as long as the individual equations are properly programmed. This result was obtained by taking into account the frequencies of use of the most relevant property functions in these regions based on a survey of the international power-cycle companies and related industries. These investigations are described in detail in [22].

A comparison of the calculation speed within IAPWS-IF97 with and without using the backward equations shows that these equations bring an enormous increase in the calculation speed. When using the backward equations $T(p,s)$ and $T(p,h)$ for regions 1 and 2 (these backward equations were developed along with the basic equations of IAPWS-IF97), the calculation of properties in these regions as functions of (p,s) and (p,h) is between 11 and 38 times faster than calculating these properties by iteration from the respective basic equation.

A further essential step towards even shorter computing times was made by the supplementary backward equations developed after 1997. When using these equations, the calculation of properties dependent on (h,s) in regions 1 and 2 is more than 35 times faster than iterating the basic equations. For region 3, the calculation speed is increased by a factor of more than 10 for calculating properties as functions of (p,h) , (p,s) , and (h,s) with the help of the respective backward equations. The calculation of properties as a function of (p,T) using the backward equations $v(p,T)$ in combination with the basic equation $f_3(\rho,T)$ is 17 times faster than determining these properties only by iteration from the basic equation. In the part of the two-phase region 4, which is important for designing steam turbines, the calculation of the saturation properties p_s , T_s , and the vapour fraction x as a function of (h,s) from backward equations is 14 times faster than the determination of these properties by iteration with the corresponding basic equations. Thus, the backward equations, developed after IAPWS-IF97 was adopted, allow a significant increase in the calculation speed.

Details about the accuracy, consistency along region boundaries, and calculation speed are given in the comprehensive article on IAPWS-IF97 [13].

2.2 Basic Equations of IAPWS-IF97

This section contains all of the details relevant for using the basic equations of IAPWS-IF97. Figure 2.2 shows the assignment of the five basic equations to the corresponding regions. The boundaries of the regions can be taken directly from Fig. 2.2 except for the boundary between regions 2 and 3; this boundary is defined by the so-called B23-equation given in Sec. 2.2.1.

The boundary $T = 623.15$ K belongs to regions 1 and 3, the boundary corresponding to the p_{B23} -line (the T_{B23} -line is exactly the same line, see Eqs. (2.1) and (2.2)) belongs to regions 2 and 3, and the boundary $T = 1073.15$ K belongs to regions 2 and 5. Thus, the properties along these boundaries could be calculated from equations $g_1(p, T)$ or $f_3(\rho, T)$ on the boundary $T = 623.15$ K, from equations $g_2(p, T)$ or $f_3(\rho, T)$ on the boundary $p_{B23}(T)$, and from equations $g_2(p, T)$ or $g_5(p, T)$ on the boundary $T = 1073.15$ K. In this way, on these boundaries one gets (slightly) different values from the g_1 and f_3 equations, from the g_2 and f_3 equations, and from the g_2 and g_5 equations. In order to avoid such ambiguities, the boundary $T = 623.15$ K is considered to belong to region 1, and the boundaries $p_{B23}(T)$ and $T = 1073.15$ K are considered to belong to region 2. Thus, the properties along these boundaries can be calculated unambiguously from the g_1 and g_2 equations, respectively.

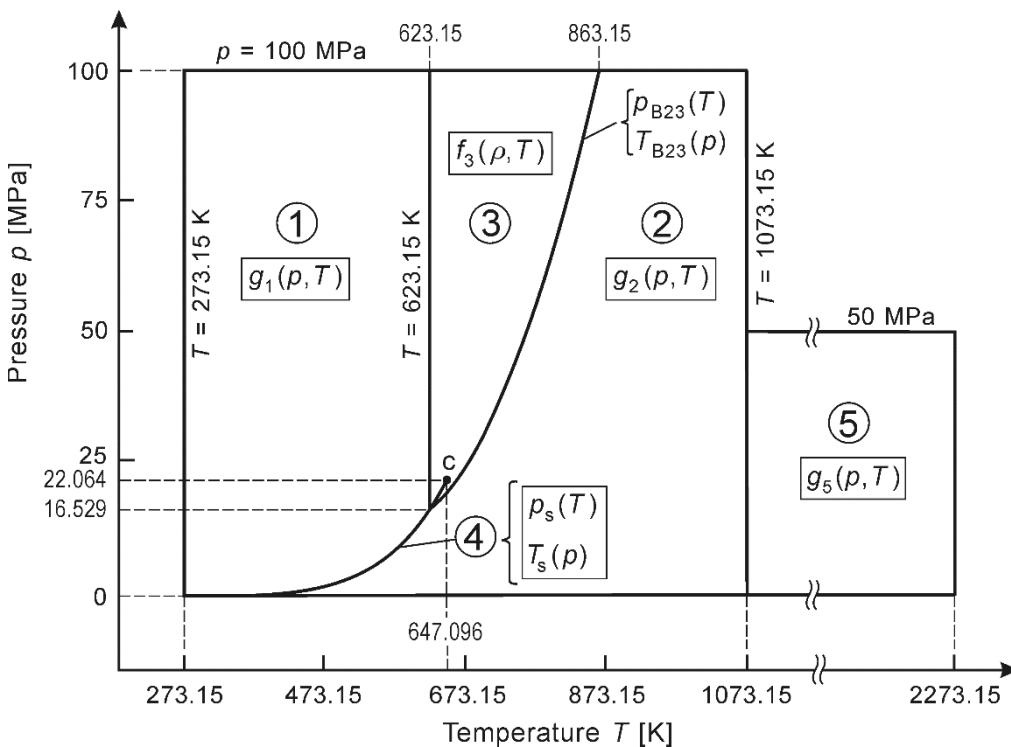


Fig. 2.2 The assignment of the basic equations to the five regions of IAPWS-IF97.

Although the saturation-temperature equation $T_s(p)$ is formally a backward equation, see Sec. 2.1.1 and [13, 15], it is nevertheless included in this section because it was derived from the same implicit quadratic equation for the saturation line, Eq. (2.12), as the saturation-pressure equation $p_s(T)$, and is, in contrast to the “normal” backward equations given in Sec. 2.3, completely consistent with the

$p_s(T)$ equation. Thus, from here onwards the saturation-temperature equation $T_s(p)$ is dealt with like a basic equation.

When using only *the* basic equations for the calculation of any thermodynamic property as a function of any of the most important combinations of input variables other than (p, T) , e.g. (p, h) , (p, s) , and (h, s) , due to necessary iterations, the calculation is clearly slower than the calculation via the backward equations, but (within the iteration accuracy) consistent with all properties at the point fixed by the two input variables selected.

Uncertainty estimates of the most relevant properties, calculated from the IAPWS-IF97 basic equations, are summarized in Secs. 2.5.1 and 2.5.2. The inconsistencies between the corresponding basic equations along the boundaries between regions 1 and 3, regions 2 and 3, and regions 2 and 5 are given in Sec. 2.5.3.

Note. The user should be aware of these inconsistencies, in particular when calculating across and very near the region boundaries, see Sec. 2.3.1.2.

2.2.1 Auxiliary Equation for the Boundary between Regions 2 and 3

The boundary between regions 2 and 3, see Fig. 2.2, is defined by the following simple quadratic pressure-temperature relation (the B23-equation):

$$\frac{p_{B23}(T)}{p^*} = \pi(\theta) = n_1 + n_2\theta + n_3\theta^2, \quad (2.1)$$

where $\pi = p/p^*$ and $\theta = T/T^*$ with $p^* = 1 \text{ MPa}$ and $T^* = 1 \text{ K}$. The coefficients n_1 to n_3 of Eq. (2.1) are listed in Table 2.1. Equation (2.1) roughly describes an isentropic line; the entropy values along this boundary line are between $s = 5.047 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and $s = 5.261 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

Alternatively, Eq. (2.1) can be expressed explicitly in temperature as

$$\frac{T_{B23}(p)}{T^*} = \theta(\pi) = n_4 + [(\pi - n_5)/n_3]^{0.5} \quad (2.2)$$

with θ and π as defined for Eq. (2.1) and the coefficients n_3 to n_5 listed in Table 2.1. Equations (2.1) and (2.2) cover the range from 623.15 K at 16.5292 MPa up to 863.15 K at 100 MPa.

Table 2.1 Coefficients of the equations $p_{B23}(T)$ and $T_{B23}(p)$, Eqs. (2.1) and (2.2)

i	n_i	i	n_i
1	$0.348\ 051\ 856\ 289\ 69 \times 10^3$	4	$0.572\ 544\ 598\ 627\ 46 \times 10^3$
2	$-0.116\ 718\ 598\ 799\ 75 \times 10^1$	5	$0.139\ 188\ 397\ 788\ 70 \times 10^2$
3	$0.101\ 929\ 700\ 393\ 26 \times 10^{-2}$		

Computer-Program Verification. Eqs. (2.1) and (2.2) must meet the following T - p point: $T = 0.623\ 150\ 000 \times 10^3 \text{ K}$, $p = 0.165\ 291\ 642\ 5 \times 10^2 \text{ MPa}$.

2.2.2 Basic Equation for Region 1

This section contains all details relevant for using the basic equation for region 1 of IAPWS-IF97, see Fig. 2.2. Uncertainty estimates of the most relevant properties calculated from IAPWS-IF97 can be found in Sec. 2.5.

The basic equation for this region is a fundamental equation for the specific Gibbs free energy g . This equation is expressed in dimensionless form, $\gamma = g/(RT)$, and reads

$$\frac{g_1(p, T)}{RT} = \gamma(\pi, \tau) = \sum_{i=1}^{34} n_i (7.1 - \pi)^{I_i} (\tau - 1.222)^{J_i}, \quad (2.3)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $p^* = 16.53 \text{ MPa}$ and $T^* = 1386 \text{ K}$; $R = 0.461\,526 \text{ kJ kg}^{-1} \text{ K}^{-1}$ according to Eq. (1.1). The coefficients n_i and exponents I_i and J_i of Eq. (2.3) are listed in Table 2.2.

All thermodynamic properties can be derived from Eq. (2.3) by using the appropriate combinations of the dimensionless Gibbs free energy γ and its derivatives. The relations of the relevant thermodynamic properties to γ and its derivatives are summarized in Table 2.3. Moreover, with the information given in Sec. 2.4, particularly with the formulas of Sec. 2.4.1, all partial derivatives formed by the properties p , T , v , u , h , s , g , and f can be easily calculated. All required derivatives of the equation for the dimensionless Gibbs free energy γ , Eq. (2.3), are explicitly given in Table 2.4.

Since the 5th International Conference on the Properties of Steam in London in 1956, the specific internal energy and the specific entropy of the saturated liquid at the triple point have been set equal to zero:

$$u'_t = 0, \quad s'_t = 0. \quad (2.4)$$

In order to meet this condition at the temperature and pressure of the triple point, see Eqs. (1.7) and (1.8), the coefficients n_3 and n_4 in Eq. (2.3) have been adjusted accordingly, which results in a specific enthalpy of the saturated liquid at the triple point given by

$$h'_t = 0.000\,611\,78 \text{ kJ kg}^{-1}. \quad (2.5)$$

Table 2.2 Coefficients and exponents of the basic equation $g_1(p, T)$ in its dimensionless form, Eq. (2.3)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	-2	0.146 329 712 131 67	18	2	3	$-0.441\,418\,453\,308\,46 \times 10^{-5}$
2	0	-1	-0.845 481 871 691 14	19	2	17	$-0.726\,949\,962\,975\,94 \times 10^{-15}$
3	0	0	$-0.375\,636\,036\,720\,40 \times 10^1$	20	3	-4	$-0.316\,796\,448\,450\,54 \times 10^{-4}$
4	0	1	$0.338\,551\,691\,683\,85 \times 10^1$	21	3	0	$-0.282\,707\,979\,853\,12 \times 10^{-5}$
5	0	2	-0.957 919 633 878 72	22	3	6	$-0.852\,051\,281\,201\,03 \times 10^{-9}$
6	0	3	0.157 720 385 132 28	23	4	-5	$-0.224\,252\,819\,080\,00 \times 10^{-5}$
7	0	4	$-0.166\,164\,171\,995\,01 \times 10^{-1}$	24	4	-2	$-0.651\,712\,228\,956\,01 \times 10^{-6}$
8	0	5	$0.812\,146\,299\,835\,68 \times 10^{-3}$	25	4	10	$-0.143\,417\,299\,379\,24 \times 10^{-12}$
9	1	-9	$0.283\,190\,801\,238\,04 \times 10^{-3}$	26	5	-8	$-0.405\,169\,968\,601\,17 \times 10^{-6}$
10	1	-7	$-0.607\,063\,015\,658\,74 \times 10^{-3}$	27	8	-11	$-0.127\,343\,017\,416\,41 \times 10^{-8}$
11	1	-1	$-0.189\,900\,682\,184\,19 \times 10^{-1}$	28	8	-6	$-0.174\,248\,712\,306\,34 \times 10^{-9}$
12	1	0	$-0.325\,297\,487\,705\,05 \times 10^{-1}$	29	21	-29	$-0.687\,621\,312\,955\,31 \times 10^{-18}$

Continued on next page.

Table 2.2 – Continued

i	I_i	J_i	n_i	i	I_i	J_i	n_i
13	1	1	$-0.218\ 417\ 171\ 754\ 14 \times 10^{-1}$	30	23	-31	$0.144\ 783\ 078\ 285\ 21 \times 10^{-19}$
14	1	3	$-0.528\ 383\ 579\ 699\ 30 \times 10^{-4}$	31	29	-38	$0.263\ 357\ 816\ 627\ 95 \times 10^{-22}$
15	2	-3	$-0.471\ 843\ 210\ 732\ 67 \times 10^{-3}$	32	30	-39	$-0.119\ 476\ 226\ 400\ 71 \times 10^{-22}$
16	2	0	$-0.300\ 017\ 807\ 930\ 26 \times 10^{-3}$	33	31	-40	$0.182\ 280\ 945\ 814\ 04 \times 10^{-23}$
17	2	1	$0.476\ 613\ 939\ 069\ 87 \times 10^{-4}$	34	32	-41	$-0.935\ 370\ 872\ 924\ 58 \times 10^{-25}$

Table 2.3 Relations of thermodynamic properties^a to the dimensionless Gibbs free energy γ and its derivatives when using Eq. (2.3)

Property	Relation
Specific volume $v = (\partial g / \partial p)_T$	$v(\pi, \tau) \frac{p}{RT} = \pi \gamma_\pi$
Specific enthalpy $h = g - T(\partial g / \partial T)_p$	$\frac{h(\pi, \tau)}{RT} = \tau \gamma_\tau$
Specific internal energy $u = g - T(\partial g / \partial T)_p - p(\partial g / \partial p)_T$	$\frac{u(\pi, \tau)}{RT} = \tau \gamma_\tau - \pi \gamma_\pi$
Specific entropy $s = -(\partial g / \partial T)_p$	$\frac{s(\pi, \tau)}{R} = \tau \gamma_\tau - \gamma$
Specific isobaric heat capacity $c_p = (\partial h / \partial T)_p$	$\frac{c_p(\pi, \tau)}{R} = -\tau^2 \gamma_{\tau\tau}$
Specific isochoric heat capacity $c_v = (\partial u / \partial T)_v$	$\frac{c_v(\pi, \tau)}{R} = -\tau^2 \gamma_{\tau\tau} + \frac{(\gamma_\pi - \tau \gamma_{\pi\tau})^2}{\gamma_{\pi\pi}}$
Speed of sound $w = v \left(-(\partial p / \partial v)_s \right)^{0.5}$	$\frac{w^2(\pi, \tau)}{RT} = \frac{\gamma_\pi^2}{\frac{(\gamma_\pi - \tau \gamma_{\pi\tau})^2}{\tau^2 \gamma_{\tau\tau}} - \gamma_{\pi\pi}}$
Isentropic exponent $\kappa = -v p^{-1} (\partial p / \partial v)_s$	$\kappa(\pi, \tau) = \frac{\gamma_\pi}{\frac{\pi(\gamma_\pi - \tau \gamma_{\pi\tau})^2}{\tau^2 \gamma_{\tau\tau}} - \pi \gamma_{\pi\pi}}$
Isobaric cubic expansion coefficient $\alpha_v = v^{-1} (\partial v / \partial T)_p$	$\alpha_v(\pi, \tau) T = 1 - \frac{\tau \gamma_{\pi\tau}}{\gamma_\pi}$
Isothermal compressibility $\kappa_T = -v^{-1} (\partial v / \partial p)_T$	$\kappa_T(\pi, \tau) p = -\frac{\pi \gamma_{\pi\pi}}{\gamma_\pi}$
$\gamma_\pi = \left(\frac{\partial \gamma}{\partial \pi} \right)_\tau, \quad \gamma_{\pi\pi} = \left(\frac{\partial^2 \gamma}{\partial \pi^2} \right)_\tau, \quad \gamma_\tau = \left(\frac{\partial \gamma}{\partial \tau} \right)_\pi, \quad \gamma_{\tau\tau} = \left(\frac{\partial^2 \gamma}{\partial \tau^2} \right)_\pi, \quad \gamma_{\pi\tau} = \left(\frac{\partial^2 \gamma}{\partial \pi \partial \tau} \right)$	

^aThe relative pressure coefficient α_p and the isothermal stress coefficient β_p can be calculated as follows: $\alpha_p = \alpha_v (p \kappa_T)^{-1}$, $\beta_p = (p v \kappa_T)^{-1}$.

Table 2.4 The dimensionless Gibbs free energy γ , Eq. (2.3), and its derivatives

$\gamma = \sum_{i=1}^{34} n_i (7.1 - \pi)^{I_i} (\tau - 1.222)^{J_i}$	$\gamma_\tau = \sum_{i=1}^{34} n_i (7.1 - \pi)^{I_i} J_i (\tau - 1.222)^{J_i - 1}$
$\gamma_\pi = \sum_{i=1}^{34} -n_i I_i (7.1 - \pi)^{I_i - 1} (\tau - 1.222)^{J_i}$	$\gamma_{\pi\tau} = \sum_{i=1}^{34} n_i (7.1 - \pi)^{I_i} J_i (J_i - 1) (\tau - 1.222)^{J_i - 2}$
$\gamma_{\pi\pi} = \sum_{i=1}^{34} n_i I_i (I_i - 1) (7.1 - \pi)^{I_i - 2} (\tau - 1.222)^{J_i}$	$\gamma_{\pi\tau} = \sum_{i=1}^{34} -n_i I_i (7.1 - \pi)^{I_i - 1} J_i (\tau - 1.222)^{J_i - 1}$
$\gamma_\pi = \left(\frac{\partial \gamma}{\partial \pi} \right)_\tau, \quad \gamma_{\pi\pi} = \left(\frac{\partial^2 \gamma}{\partial \pi^2} \right)_\tau, \quad \gamma_\tau = \left(\frac{\partial \gamma}{\partial \tau} \right)_\pi, \quad \gamma_{\pi\tau} = \left(\frac{\partial^2 \gamma}{\partial \tau^2} \right)_\pi, \quad \gamma_{\pi\pi} = \left(\frac{\partial^2 \gamma}{\partial \pi \partial \tau} \right)$	

Range of Validity. Equation (2.3) covers region 1 of IAPWS-IF97 defined by the following range of temperature and pressure, see Fig. 2.2:

$$273.15 \text{ K} \leq T \leq 623.15 \text{ K} \quad p_s(T) \leq p \leq 100 \text{ MPa}.$$

In addition to the properties in the stable single-phase liquid region, Eq. (2.3) also yields reasonable values in the metastable superheated-liquid region close to the saturated-liquid line.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.3), Table 2.5 contains test values of the most relevant properties.

Table 2.5 Thermodynamic property values calculated from the basic equation $g_1(p, T)$, Eq. (2.3), for selected temperatures and pressures^a

Property	$T = 300 \text{ K}$ $p = 3 \text{ MPa}$	$T = 300 \text{ K}$ $p = 80 \text{ MPa}$	$T = 500 \text{ K}$ $p = 3 \text{ MPa}$
$v [\text{m}^3 \text{ kg}^{-1}]$	$0.100\ 215\ 168 \times 10^{-2}$	$0.971\ 180\ 894 \times 10^{-3}$	$0.120\ 241\ 800 \times 10^{-2}$
$h [\text{kJ kg}^{-1}]$	$0.115\ 331\ 273 \times 10^3$	$0.184\ 142\ 828 \times 10^3$	$0.975\ 542\ 239 \times 10^3$
$u [\text{kJ kg}^{-1}]$	$0.112\ 324\ 818 \times 10^3$	$0.106\ 448\ 356 \times 10^3$	$0.971\ 934\ 985 \times 10^3$
$s [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.392\ 294\ 792$	$0.368\ 563\ 852$	$0.258\ 041\ 912 \times 10^1$
$c_p [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.417\ 301\ 218 \times 10^1$	$0.401\ 008\ 987 \times 10^1$	$0.465\ 580\ 682 \times 10^1$
$c_v [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.412\ 120\ 160 \times 10^1$	$0.391\ 736\ 606 \times 10^1$	$0.322\ 139\ 223 \times 10^1$
$w [\text{m s}^{-1}]$	$0.150\ 773\ 921 \times 10^4$	$0.163\ 469\ 054 \times 10^4$	$0.124\ 071\ 337 \times 10^4$
$\kappa [-]$	$0.756\ 132\ 220 \times 10^3$	$0.343\ 938\ 651 \times 10^2$	$0.426\ 742\ 799 \times 10^3$
$\alpha_v [\text{K}^{-1}]$	$0.277\ 354\ 533 \times 10^{-3}$	$0.344\ 095\ 843 \times 10^{-3}$	$0.164\ 118\ 128 \times 10^{-2}$
$\kappa_T [\text{MPa}^{-1}]$	$0.446\ 382\ 123 \times 10^{-3}$	$0.372\ 039\ 437 \times 10^{-3}$	$0.112\ 892\ 188 \times 10^{-2}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.2.3 Basic Equation and Supplementary Equation for Region 2

This section contains all details relevant for using the basic equation of region 2 of IAPWS-IF97, see Fig. 2.2. The B23-equation for defining the boundary between regions 2 and 3 is given in Sec. 2.2.1. Uncertainty estimates of the most relevant properties calculated from IAPWS-IF97 can be found in Sec. 2.5.

2.2.3.1 Basic Equation

The basic equation for this region is a fundamental equation for the specific Gibbs free energy g . This equation is expressed in dimensionless form, $\gamma = g/(RT)$, and is separated into two parts, an ideal-gas part γ^0 and a residual part γ^r , so that it reads

$$\frac{g_2(p, T)}{RT} = \gamma(\pi, \tau) = \gamma^0(\pi, \tau) + \gamma^r(\pi, \tau), \quad (2.6)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $R = 0.461\ 526\ \text{kJ kg}^{-1}\ \text{K}^{-1}$ given by Eq. (1.1), and γ^0 and γ^r according to Eqs. (2.7) and (2.8).

The equation for the dimensionless ideal-gas part γ^0 of the basic equation $g_2(p, T)$ reads

$$\gamma^0(\pi, \tau) = \ln \pi + \sum_{i=1}^9 n_i \tau^{J_i}, \quad (2.7)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $p^* = 1\ \text{MPa}$ and $T^* = 540\ \text{K}$. The coefficients n_1 and n_2 were adjusted in such a way that the values for the specific internal energy and specific entropy, calculated from Eq. (2.6), correspond to Eq. (2.4). Table 2.6 contains the coefficients n_i and exponents J_i of Eq. (2.7).

Table 2.6 Coefficients and exponents of the ideal-gas part γ^0 , Eq. (2.7)

i	J_i	n_i	i	J_i	n_i
1	0	$-0.969\ 276\ 865\ 002\ 17 \times 10^1$ ^a	6	-2	$0.142\ 408\ 191\ 714\ 44 \times 10^1$
2	1	$0.100\ 866\ 559\ 680\ 18 \times 10^2$ ^a	7	-1	$-0.438\ 395\ 113\ 194\ 50 \times 10^1$
3	-5	$-0.560\ 879\ 112\ 830\ 20 \times 10^{-2}$	8	2	$-0.284\ 086\ 324\ 607\ 72$
4	-4	$0.714\ 527\ 380\ 814\ 55 \times 10^{-1}$	9	3	$0.212\ 684\ 637\ 533\ 07 \times 10^{-1}$
5	-3	$-0.407\ 104\ 982\ 239\ 28$			

^aIf Eq. (2.7) is incorporated into Eq. (2.9), instead of the values for n_1 and n_2 given above, the following values for these two coefficients must be used: $n_1 = -0.969\ 372\ 683\ 930\ 49 \times 10^1$, $n_2 = 0.100\ 872\ 759\ 700\ 06 \times 10^2$.

The form of the dimensionless residual part γ^r of the basic equation $g_2(p, T)$ is as follows:

$$\gamma^r(\pi, \tau) = \sum_{i=1}^{43} n_i \pi^{I_i} (\tau - 0.5)^{J_i}, \quad (2.8)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $p^* = 1\ \text{MPa}$ and $T^* = 540\ \text{K}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.8) are listed in Table 2.7.

All thermodynamic properties can be derived from Eq. (2.6) by using the appropriate combinations of the ideal-gas part γ^0 , Eq. (2.7), and the residual part γ^r , Eq. (2.8), of the dimensionless Gibbs free energy and their derivatives. The relations of the relevant thermodynamic properties to γ^0 and γ^r and their derivatives are summarized in Table 2.8. Moreover, with the information given in Sec. 2.4, particularly with the formulas of Sec. 2.4.1, all partial derivatives formed by the properties p, T, v, u, h, s, g , and f can be easily calculated. All required derivatives of the equations for γ^0 and γ^r are explicitly given in Table 2.9 and Table 2.10, respectively.

Table 2.7 Coefficients and exponents of the residual part γ^r , Eq. (2.8)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	1	0	$-0.177\ 317\ 424\ 732\ 13 \times 10^{-2}$	23	7	0	$-0.590\ 595\ 643\ 242\ 70 \times 10^{-17}$
2	1	1	$-0.178\ 348\ 622\ 923\ 58 \times 10^{-1}$	24	7	11	$-0.126\ 218\ 088\ 991\ 01 \times 10^{-5}$
3	1	2	$-0.459\ 960\ 136\ 963\ 65 \times 10^{-1}$	25	7	25	$-0.389\ 468\ 424\ 357\ 39 \times 10^{-1}$
4	1	3	$-0.575\ 812\ 590\ 834\ 32 \times 10^{-1}$	26	8	8	$0.112\ 562\ 113\ 604\ 59 \times 10^{-10}$
5	1	6	$-0.503\ 252\ 787\ 279\ 30 \times 10^{-1}$	27	8	36	$-0.823\ 113\ 408\ 979\ 98 \times 10^1$
6	2	1	$-0.330\ 326\ 416\ 702\ 03 \times 10^{-4}$	28	9	13	$0.198\ 097\ 128\ 020\ 88 \times 10^{-7}$
7	2	2	$-0.189\ 489\ 875\ 163\ 15 \times 10^{-3}$	29	10	4	$0.104\ 069\ 652\ 101\ 74 \times 10^{-18}$
8	2	4	$-0.393\ 927\ 772\ 433\ 55 \times 10^{-2}$	30	10	10	$-0.102\ 347\ 470\ 959\ 29 \times 10^{-12}$
9	2	7	$-0.437\ 972\ 956\ 505\ 73 \times 10^{-1}$	31	10	14	$-0.100\ 181\ 793\ 795\ 11 \times 10^{-8}$
10	2	36	$-0.266\ 745\ 479\ 140\ 87 \times 10^{-4}$	32	16	29	$-0.808\ 829\ 086\ 469\ 85 \times 10^{-10}$
11	3	0	$0.204\ 817\ 376\ 923\ 09 \times 10^{-7}$	33	16	50	$0.106\ 930\ 318\ 794\ 09$
12	3	1	$0.438\ 706\ 672\ 844\ 35 \times 10^{-6}$	34	18	57	$-0.336\ 622\ 505\ 741\ 71$
13	3	3	$-0.322\ 776\ 772\ 385\ 70 \times 10^{-4}$	35	20	20	$0.891\ 858\ 453\ 554\ 21 \times 10^{-24}$
14	3	6	$-0.150\ 339\ 245\ 421\ 48 \times 10^{-2}$	36	20	35	$0.306\ 293\ 168\ 762\ 32 \times 10^{-12}$
15	3	35	$-0.406\ 682\ 535\ 626\ 49 \times 10^{-1}$	37	20	48	$-0.420\ 024\ 676\ 982\ 08 \times 10^{-5}$
16	4	1	$-0.788\ 473\ 095\ 593\ 67 \times 10^{-9}$	38	21	21	$-0.590\ 560\ 296\ 856\ 39 \times 10^{-25}$
17	4	2	$0.127\ 907\ 178\ 522\ 85 \times 10^{-7}$	39	22	53	$0.378\ 269\ 476\ 134\ 57 \times 10^{-5}$
18	4	3	$0.482\ 253\ 727\ 185\ 07 \times 10^{-6}$	40	23	39	$-0.127\ 686\ 089\ 346\ 81 \times 10^{-14}$
19	5	7	$0.229\ 220\ 763\ 376\ 61 \times 10^{-5}$	41	24	26	$0.730\ 876\ 105\ 950\ 61 \times 10^{-28}$
20	6	3	$-0.167\ 147\ 664\ 510\ 61 \times 10^{-10}$	42	24	40	$0.554\ 147\ 153\ 507\ 78 \times 10^{-16}$
21	6	16	$-0.211\ 714\ 723\ 213\ 55 \times 10^{-2}$	43	24	58	$-0.943\ 697\ 072\ 412\ 10 \times 10^{-6}$
22	6	35	$-0.238\ 957\ 419\ 341\ 04 \times 10^2$				

Range of Validity. Equation (2.6) covers region 2 of IAPWS-IF97 defined by the following range of temperature and pressure, see Fig. 2.2:

$$\begin{aligned}
 273.15 \text{ K} \leq T \leq & 623.15 \text{ K} & 0 < p \leq p_s(T) \\
 623.15 \text{ K} < T \leq & 863.15 \text{ K} & 0 < p \leq p_{B23}(T) \\
 863.15 \text{ K} < T \leq & 1073.15 \text{ K} & 0 < p \leq 100 \text{ MPa},
 \end{aligned}$$

where $p_s(T)$ is calculated from Eq. (2.13) and $p_{B23}(T)$ from Eq. (2.1). In addition to the properties in the stable single-phase vapour region, Eq. (2.6) also yields reasonable values in the metastable-vapour region *for pressures above 10 MPa*. Equation (2.6) is not valid in the metastable-vapour region at pressures $p \leq 10$ MPa; for this part of the metastable-vapour region see Sec. 2.2.3.2.

Table 2.8 Relations of thermodynamic properties^a to the ideal-gas part γ^0 and the residual part γ^r of the dimensionless Gibbs free energy and their derivatives when using Eq.(2.6) or Eq.(2.9)

Property	Relation
Specific volume $v = (\partial g / \partial p)_T$	$v(\pi, \tau) \frac{p}{RT} = \pi \left(\gamma_\pi^0 + \gamma_\pi^r \right)$
Specific enthalpy $h = g - T (\partial g / \partial T)_p$	$\frac{h(\pi, \tau)}{RT} = \tau \left(\gamma_\tau^0 + \gamma_\tau^r \right)$
Specific internal energy $u = g - T (\partial g / \partial T)_p - p (\partial g / \partial p)_T$	$\frac{u(\pi, \tau)}{RT} = \tau \left(\gamma_\tau^0 + \gamma_\tau^r \right) - \pi \left(\gamma_\pi^0 + \gamma_\pi^r \right)$
Specific entropy $s = -(\partial g / \partial T)_p$	$\frac{s(\pi, \tau)}{R} = \tau \left(\gamma_\tau^0 + \gamma_\tau^r \right) - \left(\gamma^0 + \gamma^r \right)$
Specific isobaric heat capacity $c_p = (\partial h / \partial T)_p$	$\frac{c_p(\pi, \tau)}{R} = -\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right)$
Specific isochoric heat capacity $c_v = (\partial u / \partial T)_v$	$\frac{c_v(\pi, \tau)}{R} = -\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right) - \frac{\left(1 + \pi \gamma_\pi^r - \tau \pi \gamma_{\pi\pi}^r \right)^2}{1 - \pi^2 \gamma_{\pi\pi}^r}$
Speed of sound $w = v \left(-(\partial p / \partial v)_s \right)^{0.5}$	$\frac{w^2(\pi, \tau)}{RT} = \frac{1 + 2\pi \gamma_\pi^r + \pi^2 \gamma_\pi^{r^2}}{\left(1 - \pi^2 \gamma_{\pi\pi}^r \right) + \frac{\left(1 + \pi \gamma_\pi^r - \tau \pi \gamma_{\pi\tau}^r \right)^2}{\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right)}}$
Isentropic exponent $\kappa = -vp^{-1}(\partial p / \partial v)_s$	$\kappa(\pi, \tau) = \frac{1 + 2\pi \gamma_\pi^r + \pi^2 \gamma_\pi^{r^2}}{\pi \left(\gamma_\pi^0 + \gamma_\pi^r \right) \left[\left(1 - \pi^2 \gamma_{\pi\pi}^r \right) + \frac{\left(1 + \pi \gamma_\pi^r - \tau \pi \gamma_{\pi\tau}^r \right)^2}{\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right)} \right]}$
Isobaric cubic expansion coefficient $\alpha_v = v^{-1}(\partial v / \partial T)_p$	$\alpha_v(\pi, \tau) T = \frac{1 + \pi \gamma_\pi^r - \tau \pi \gamma_{\pi\tau}^r}{1 + \pi \gamma_\pi^r}$
Isothermal compressibility $\kappa_T = -v^{-1}(\partial v / \partial p)_T$	$\kappa_T(\pi, \tau) p = \frac{1 - \pi^2 \gamma_{\pi\pi}^r}{1 + \pi \gamma_\pi^r}$
$\gamma_\pi^r = \left(\frac{\partial \gamma^r}{\partial \pi} \right)_\tau, \gamma_{\pi\pi}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi^2} \right)_\tau, \gamma_\tau^r = \left(\frac{\partial \gamma^r}{\partial \tau} \right)_\pi, \gamma_{\tau\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \tau^2} \right)_\pi, \gamma_{\pi\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi \partial \tau} \right), \gamma_\pi^0 = \left(\frac{\partial \gamma^0}{\partial \pi} \right)_\tau, \gamma_{\tau\tau}^0 = \left(\frac{\partial^2 \gamma^0}{\partial \tau^2} \right)_\pi, \gamma_\pi^0 = \left(\frac{\partial \gamma^0}{\partial \pi} \right)_\tau$	

^aThe relative pressure coefficient α_p and the isothermal stress coefficient β_p can be calculated as follows: $\alpha_p = \alpha_v (p \kappa_T)^{-1}$, $\beta_p = (p v \kappa_T)^{-1}$.

Table 2.9 The ideal-gas part γ^0 of the dimensionless Gibbs free energy, Eq. (2.7), and its derivatives

$\gamma^0 = \ln \pi + \sum_{i=1}^9 n_i \tau^{J_i}$	$\gamma_\tau^0 = \sum_{i=1}^9 n_i J_i \tau^{J_i-1}$
$\gamma_\pi^0 = \pi^{-1}$	$\gamma_{\tau\tau}^0 = \sum_{i=1}^9 n_i J_i (J_i-1) \tau^{J_i-2}$
$\gamma_{\pi\pi}^0 = -\pi^{-2}$	$\gamma_{\pi\tau}^0 = 0$
$\gamma_\pi^0 = \left(\frac{\partial \gamma^0}{\partial \pi} \right)_\tau, \quad \gamma_{\pi\pi}^0 = \left(\frac{\partial^2 \gamma^0}{\partial \pi^2} \right)_\tau, \quad \gamma_\tau^0 = \left(\frac{\partial \gamma^0}{\partial \tau} \right)_\pi, \quad \gamma_{\tau\tau}^0 = \left(\frac{\partial^2 \gamma^0}{\partial \tau^2} \right)_\pi, \quad \gamma_{\pi\tau}^0 = \left(\frac{\partial^2 \gamma^0}{\partial \pi \partial \tau} \right)$	

Table 2.10 The residual part γ^r of the dimensionless Gibbs free energy, Eq. (2.8), and its derivatives

$\gamma^r = \sum_{i=1}^{43} n_i \pi^{I_i} (\tau - 0.5)^{J_i}$	$\gamma_\tau^r = \sum_{i=1}^{43} n_i \pi^{I_i} J_i (\tau - 0.5)^{J_i-1}$
$\gamma_\pi^r = \sum_{i=1}^{43} n_i I_i \pi^{I_i-1} (\tau - 0.5)^{J_i}$	$\gamma_{\tau\tau}^r = \sum_{i=1}^{43} n_i \pi^{I_i} J_i (J_i - 1) (\tau - 0.5)^{J_i-2}$
$\gamma_{\pi\pi}^r = \sum_{i=1}^{43} n_i I_i (I_i - 1) \pi^{I_i-2} (\tau - 0.5)^{J_i}$	$\gamma_{\pi\tau}^r = \sum_{i=1}^{43} n_i I_i \pi^{I_i-1} J_i (\tau - 0.5)^{J_i-1}$
$\gamma_\pi^r = \left(\frac{\partial \gamma^r}{\partial \pi} \right)_\tau, \quad \gamma_{\pi\pi}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi^2} \right)_\tau, \quad \gamma_\tau^r = \left(\frac{\partial \gamma^r}{\partial \tau} \right)_\pi, \quad \gamma_{\tau\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \tau^2} \right)_\pi, \quad \gamma_{\pi\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi \partial \tau} \right)$	

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.6), Table 2.11 contains test values of the most relevant properties.

Table 2.11 Thermodynamic property values calculated from the basic equation $g_2(p, T)$, Eq. (2.6), for selected temperatures and pressures^a

Property	$T = 300 \text{ K}$ $p = 0.0035 \text{ MPa}$	$T = 700 \text{ K}$ $p = 0.0035 \text{ MPa}$	$T = 700 \text{ K}$ $p = 30 \text{ MPa}$
$v [\text{m}^3 \text{ kg}^{-1}]$	$0.394\ 913\ 866 \times 10^2$	$0.923\ 015\ 898 \times 10^2$	$0.542\ 946\ 619 \times 10^{-2}$
$h [\text{kJ kg}^{-1}]$	$0.254\ 991\ 145 \times 10^4$	$0.333\ 568\ 375 \times 10^4$	$0.263\ 149\ 474 \times 10^4$
$u [\text{kJ kg}^{-1}]$	$0.241\ 169\ 160 \times 10^4$	$0.301\ 262\ 819 \times 10^4$	$0.246\ 861\ 076 \times 10^4$
$s [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.852\ 238\ 967 \times 10^1$	$0.101\ 749\ 996 \times 10^2$	$0.517\ 540\ 298 \times 10^1$
$c_p [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.191\ 300\ 162 \times 10^1$	$0.208\ 141\ 274 \times 10^1$	$0.103\ 505\ 092 \times 10^2$
$c_v [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.144\ 132\ 662 \times 10^1$	$0.161\ 978\ 333 \times 10^1$	$0.297\ 553\ 837 \times 10^1$
$w [\text{m s}^{-1}]$	$0.427\ 920\ 172 \times 10^3$	$0.644\ 289\ 068 \times 10^3$	$0.480\ 386\ 523 \times 10^3$
$\kappa [-]$	$0.132\ 481\ 456 \times 10^1$	$0.128\ 494\ 429 \times 10^1$	$0.141\ 678\ 269 \times 10^1$
$\alpha_v [\text{K}^{-1}]$	$0.337\ 578\ 289 \times 10^{-2}$	$0.142\ 878\ 736 \times 10^{-2}$	$0.126\ 019\ 688 \times 10^{-1}$
$\kappa_T [\text{MPa}^{-1}]$	$0.286\ 239\ 651 \times 10^3$	$0.285\ 725\ 461 \times 10^3$	$0.818\ 411\ 389 \times 10^{-1}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.2.3.2 Supplementary Equation for the Metastable-Vapour Region

Such as the basic equation $g_2(p, T)$, Eq. (2.6), the supplementary equation for a part of the metastable-vapour region is given in the dimensionless form of the specific Gibbs free energy, $\gamma^0 = g/(RT)$, consisting of an ideal-gas part γ^0 and a residual part γ^r , so that

$$\frac{g_{2,\text{meta}}(p, T)}{RT} = \gamma(\pi, \tau) = \gamma^0(\pi, \tau) + \gamma^r(\pi, \tau), \quad (2.9)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $R = 0.461\ 526\ \text{kJ kg}^{-1}\ \text{K}^{-1}$ given by Eq. (1.1), and γ^0 and γ^r according to Eqs. (2.7) and (2.10).

The equation for the ideal-gas part γ^0 is identical with Eq. (2.7) except for the values of the two coefficients n_1 and n_2 , see Table 2.6. To use Eq. (2.7) as a part of Eq. (2.9), the coefficients n_1 and n_2 were slightly readjusted to meet the high consistency requirement between Eqs. (2.9) and (2.6) for the properties h and s along the saturated-vapour line, see below.

The equation for the residual part γ^r of Eq. (2.9) reads

$$\gamma^r(\pi, \tau) = \sum_{i=1}^{13} n_i \pi^{I_i} (\tau - 0.5)^{J_i}, \quad (2.10)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $p^* = 1\ \text{MPa}$ and $T^* = 540\ \text{K}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.10) are listed in Table 2.12. There are not any experimental data to which an equation can be fitted in the metastable-vapour region. Thus, Eq. (2.9) is only based on input values extrapolated from the stable single-phase region 2. These extrapolations were not performed with IAPWS-95 but with a special low-density gas equation [9].

Table 2.12 Coefficients and exponents of the residual part γ^r , Eq. (2.10)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	1	0	$-0.733\ 622\ 601\ 865\ 06 \times 10^{-2}$	8	3	4	$-0.634\ 980\ 376\ 573\ 13 \times 10^{-2}$
2	1	2	$-0.882\ 238\ 319\ 431\ 46 \times 10^{-1}$	9	3	16	$-0.860\ 430\ 930\ 285\ 88 \times 10^{-1}$
3	1	5	$-0.723\ 345\ 552\ 132\ 45 \times 10^{-1}$	10	4	7	$0.753\ 215\ 815\ 227\ 70 \times 10^{-2}$
4	1	11	$-0.408\ 131\ 785\ 344\ 55 \times 10^{-2}$	11	4	10	$-0.792\ 383\ 754\ 461\ 39 \times 10^{-2}$
5	2	1	$0.200\ 978\ 033\ 802\ 07 \times 10^{-2}$	12	5	9	$-0.228\ 881\ 607\ 784\ 47 \times 10^{-3}$
6	2	7	$-0.530\ 459\ 218\ 986\ 42 \times 10^{-1}$	13	5	10	$-0.264\ 565\ 014\ 828\ 10 \times 10^{-2}$
7	2	16	$-0.761\ 904\ 090\ 869\ 70 \times 10^{-2}$				

All thermodynamic properties can be derived from Eq. (2.9) by using the appropriate combinations of the ideal-gas part γ^0 , Eq. (2.7), and the residual part γ^r , Eq. (2.10), of the dimensionless Gibbs free energy and their derivatives. The relations of the relevant thermodynamic properties to γ^0 and γ^r and their derivatives are summarized in Table 2.8. Moreover, with the information given in Sec. 2.4, particularly with the formulas given in Sec. 2.4.1, all of the partial derivatives of the properties p , T , v , u , h , s , g , and f can be calculated easily. All of the required derivatives for the equations for γ^0 and γ^r are explicitly given in Table 2.9 and Table 2.13, respectively.

Range of Validity. Equation (2.9) is valid in the metastable-vapour region from the saturated-vapour line to the 5% equilibrium moisture line (corresponding to the vapour fraction $x = 0.95$, determined from the equilibrium h' and h'' values calculated at the given pressure) at pressures from

the triple-point pressure, see Eq. (1.8), up to 10 MPa. This range of validity is shown in a *h-s* diagram in Fig. 13 of Ref. [13]. The consistency of Eq. (2.9) with the basic equation $g_2(p, T)$, Eq. (2.6), along the saturated-vapour line is characterized by the following maximum inconsistencies in the properties v, h, c_p, s, g , and w :

$$\begin{aligned} |\Delta v|_{\max} &= 0.014\% & |\Delta s|_{\max} &= 0.082 \text{ J kg}^{-1} \text{ K}^{-1} \\ |\Delta h|_{\max} &= 0.043 \text{ kJ kg}^{-1} & |\Delta g|_{\max} &= 0.023 \text{ kJ kg}^{-1} \\ |\Delta c_p|_{\max} &= 0.78\% & |\Delta w|_{\max} &= 0.051\% \end{aligned}$$

These maximum inconsistencies are clearly smaller than the consistency requirements along the region boundaries corresponding to the so-called Prague values [21]. Along the 10 MPa isobar in the metastable-vapour region, the transition between Eq. (2.9) and Eq. (2.6) is not smooth, but for practical calculations the inconsistency is sufficiently small.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.9), Table 2.14 contains test values of the most relevant properties.

Table 2.13 The residual part γ^r of the dimensionless Gibbs free energy, Eq. (2.10), and its derivatives

$$\begin{aligned} \gamma^r &= \sum_{i=1}^{13} n_i \pi^{I_i} (\tau - 0.5)^{J_i} & \gamma_{\tau}^r &= \sum_{i=1}^{13} n_i \pi^{I_i} J_i (\tau - 0.5)^{J_i - 1} \\ \gamma_{\pi}^r &= \sum_{i=1}^{13} n_i I_i \pi^{I_i - 1} (\tau - 0.5)^{J_i} & \gamma_{\pi\tau}^r &= \sum_{i=1}^{13} n_i \pi^{I_i} J_i (J_i - 1) (\tau - 0.5)^{J_i - 2} \\ \gamma_{\pi\pi}^r &= \sum_{i=1}^{13} n_i I_i (I_i - 1) \pi^{I_i - 2} (\tau - 0.5)^{J_i} & \gamma_{\pi\tau}^r &= \sum_{i=1}^{13} n_i I_i \pi^{I_i - 1} J_i (\tau - 0.5)^{J_i - 1} \\ \gamma_{\pi}^r &= \left(\frac{\partial \gamma^r}{\partial \pi} \right)_{\tau}, \quad \gamma_{\pi\pi}^r &= \left(\frac{\partial^2 \gamma^r}{\partial \pi^2} \right)_{\tau}, \quad \gamma_{\tau}^r &= \left(\frac{\partial \gamma^r}{\partial \tau} \right)_{\pi}, \quad \gamma_{\pi\tau}^r &= \left(\frac{\partial^2 \gamma^r}{\partial \tau^2} \right)_{\pi}, \quad \gamma_{\pi\pi}^r &= \left(\frac{\partial^2 \gamma^r}{\partial \pi \partial \tau} \right) \end{aligned}$$

Table 2.14 Thermodynamic property values calculated from the $g_{2,\text{meta}}(p, T)$ equation, Eq. (2.9), for selected values of temperature and pressure^a

Property	$T = 450 \text{ K}$	$T = 440 \text{ K}$	$T = 450 \text{ K}$
	$p = 1 \text{ MPa}$	$p = 1 \text{ MPa}$	$p = 1.5 \text{ MPa}$
$v [\text{m}^3 \text{ kg}^{-1}]$	0.192 516 540	0.186 212 297	0.121 685 206
$h [\text{kJ kg}^{-1}]$	$0.276\ 881\ 115 \times 10^4$	$0.274\ 015\ 123 \times 10^4$	$0.272\ 134\ 539 \times 10^4$
$u [\text{kJ kg}^{-1}]$	$0.257\ 629\ 461 \times 10^4$	$0.255\ 393\ 894 \times 10^4$	$0.253\ 881\ 758 \times 10^4$
$s [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.656\ 660\ 377 \times 10^1$	$0.650\ 218\ 759 \times 10^1$	$0.629\ 170\ 440 \times 10^1$
$c_p [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.276\ 349\ 265 \times 10^1$	$0.298\ 166\ 443 \times 10^1$	$0.362\ 795\ 578 \times 10^1$
$c_v [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.195\ 830\ 730 \times 10^1$	$0.208\ 622\ 142 \times 10^1$	$0.241\ 213\ 708 \times 10^1$
$w [\text{m s}^{-1}]$	$0.498\ 408\ 101 \times 10^3$	$0.489\ 363\ 295 \times 10^3$	$0.481\ 941\ 819 \times 10^3$
$\kappa [-]$	$0.129\ 033\ 399 \times 10^1$	$0.128\ 603\ 985 \times 10^1$	$0.127\ 250\ 702 \times 10^1$
$\alpha_v [\text{K}^{-1}]$	$0.318\ 819\ 824 \times 10^{-2}$	$0.348\ 506\ 136 \times 10^{-2}$	$0.418\ 276\ 571 \times 10^{-2}$
$\kappa_T [\text{MPa}^{-1}]$	$0.109\ 364\ 239 \times 10^1$	$0.111\ 133\ 230 \times 10^1$	$0.787\ 967\ 952$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.2.4 Basic Equation for Region 3

This section contains all details relevant for using the basic equation for region 3 of IAPWS-IF97, see Fig. 2.2. The B23-equation for defining the boundary between regions 2 and 3 is given in Sec. 2.2.1. Uncertainty estimates of the most relevant properties calculated from IAPWS-IF97 can be found in Sec. 2.5.

The basic equation for this region is a fundamental equation for the specific Helmholtz free energy f . This equation is expressed in dimensionless form, $\phi = f/(RT)$, and reads

$$\frac{f_3(\rho, T)}{RT} = \phi(\delta, \tau) = n_1 \ln \delta + \sum_{i=2}^{40} n_i \delta^{I_i} \tau^{J_i} \quad (2.11)$$

where $\delta = \rho/\rho_c$ and $\tau = T_c/T$ with $\rho_c = 322 \text{ kg m}^{-3}$, $T_c = 647.096 \text{ K}$ and $R = 0.461\,526 \text{ kJ kg}^{-1} \text{ K}^{-1}$ according to Eqs. (1.6), (1.4), and (1.1). The coefficients n_i and exponents I_i and J_i of Eq. (2.11) are listed in Table 2.15.

Table 2.15 Coefficients and exponents of the basic equation $f_3(\rho, T)$ in its dimensionless form, Eq. (2.11)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	–	–	$0.106\,580\,700\,285\,13 \times 10^1$	21	3	4	$-0.201\,899\,150\,235\,70 \times 10^1$
2	0	0	$-0.157\,328\,452\,902\,39 \times 10^2$	22	3	16	$-0.821\,476\,371\,739\,63 \times 10^{-2}$
3	0	1	$0.209\,443\,969\,743\,07 \times 10^2$	23	3	26	$-0.475\,960\,357\,349\,23$
4	0	2	$-0.768\,677\,078\,787\,16 \times 10^1$	24	4	0	$0.439\,840\,744\,735\,00 \times 10^{-1}$
5	0	7	$0.261\,859\,477\,879\,54 \times 10^1$	25	4	2	$-0.444\,764\,354\,287\,39$
6	0	10	$-0.280\,807\,811\,486\,20 \times 10^1$	26	4	4	$0.905\,720\,707\,197\,33$
7	0	12	$0.120\,533\,696\,965\,17 \times 10^1$	27	4	26	$0.705\,224\,500\,879\,67$
8	0	23	$-0.845\,668\,128\,125\,02 \times 10^{-2}$	28	5	1	$0.107\,705\,126\,263\,32$
9	1	2	$-0.126\,543\,154\,777\,14 \times 10^1$	29	5	3	$-0.329\,136\,232\,589\,54$
10	1	6	$-0.115\,244\,078\,066\,81 \times 10^1$	30	5	26	$-0.508\,710\,620\,411\,58$
11	1	15	$0.885\,210\,439\,843\,18$	31	6	0	$-0.221\,754\,008\,730\,96 \times 10^{-1}$
12	1	17	$-0.642\,077\,651\,816\,07$	32	6	2	$0.942\,607\,516\,650\,92 \times 10^{-1}$
13	2	0	$0.384\,934\,601\,866\,71$	33	6	26	$0.164\,362\,784\,479\,61$
14	2	2	$-0.852\,147\,088\,242\,06$	34	7	2	$-0.135\,033\,722\,413\,48 \times 10^{-1}$
15	2	6	$0.489\,722\,815\,418\,77 \times 10^1$	35	8	26	$-0.148\,343\,453\,524\,72 \times 10^{-1}$
16	2	7	$-0.305\,026\,172\,569\,65 \times 10^1$	36	9	2	$0.579\,229\,536\,280\,84 \times 10^{-3}$
17	2	22	$0.394\,205\,368\,791\,54 \times 10^{-1}$	37	9	26	$0.323\,089\,047\,037\,11 \times 10^{-2}$
18	2	26	$0.125\,584\,084\,243\,08$	38	10	0	$0.809\,648\,029\,962\,15 \times 10^{-4}$
19	3	0	$-0.279\,993\,296\,987\,10$	39	10	1	$-0.165\,576\,797\,950\,37 \times 10^{-3}$
20	3	2	$0.138\,997\,995\,694\,60 \times 10^1$	40	11	26	$-0.449\,238\,990\,618\,15 \times 10^{-4}$

In addition to representing the thermodynamic properties in the single-phase region along the saturation line for temperatures from 623.15 K to $T_c = 647.096 \text{ K}$, Eq. (2.11) meets the phase-equilibrium condition for the coexisting vapour and liquid phases (equality of specific Gibbs free energy for both phases taken into account by the Maxwell criterion, see Table 2.16). Moreover, Eq. (2.11) reproduces exactly the critical parameters according to Eqs. (1.4) to (1.6) and yields zero for the first two pressure derivatives with respect to density at the critical point.

All thermodynamic properties can be derived from Eq. (2.11) by using the appropriate combinations of the dimensionless Helmholtz free energy ϕ and its derivatives. The relations of the relevant thermodynamic properties to ϕ and its derivatives are summarized in Table 2.16. Moreover, with the information given in Sec. 2.4, particularly with the formulas of Sec. 2.4.2, all partial derivatives

formed by the properties p, T, v, u, h, s, g , and f can be easily calculated. All required derivatives of the equation for the dimensionless Helmholtz free energy ϕ are explicitly given in Table 2.17.

Table 2.16 Relations of thermodynamic properties to the dimensionless Helmholtz free energy ϕ and its derivatives when using Eq. (2.11)

Property	Relation
Pressure $p = \rho^2 (\partial f / \partial \rho)_T$	$\frac{p(\delta, \tau)}{\rho R T} = \delta \phi_\delta$
Specific enthalpy $h = f - T (\partial f / \partial T)_\rho + \rho (\partial f / \partial \rho)_T$	$\frac{h(\delta, \tau)}{R T} = \tau \phi_\tau + \delta \phi_\delta$
Specific internal energy $u = f - T (\partial f / \partial T)_\rho$	$\frac{u(\delta, \tau)}{R T} = \tau \phi_\tau$
Specific entropy $s = -(\partial f / \partial T)_\rho$	$\frac{s(\delta, \tau)}{R} = \tau \phi_\tau - \phi$
Specific isobaric heat capacity $c_p = (\partial h / \partial T)_p$	$\frac{c_p(\delta, \tau)}{R} = -\tau^2 \phi_{\tau\tau} + \frac{(\delta \phi_\delta - \delta \tau \phi_{\delta\tau})^2}{2 \delta \phi_\delta + \delta^2 \phi_{\delta\delta}}$
Specific isochoric heat capacity $c_v = (\partial u / \partial T)_v$	$\frac{c_v(\delta, \tau)}{R} = -\tau^2 \phi_{\tau\tau}$
Speed of sound $w = v \left(-(\partial p / \partial v)_s \right)^{0.5}$	$\frac{w^2(\delta, \tau)}{R T} = 2 \delta \phi_\delta + \delta^2 \phi_{\delta\delta} - \frac{(\delta \phi_\delta - \delta \tau \phi_{\delta\tau})^2}{\tau^2 \phi_{\tau\tau}}$
Isentropic exponent $\kappa = -v p^{-1} (\partial p / \partial v)_s$	$\kappa(\delta, \tau) = 2 + \delta \frac{\phi_{\delta\delta}}{\phi_\delta} - \frac{(\delta \phi_\delta - \delta \tau \phi_{\delta\tau})^2}{\delta \tau^2 \phi_\delta \phi_{\tau\tau}}$
Isobaric cubic expansion coefficient $\alpha_v = v^{-1} (\partial v / \partial T)_p$	$\alpha_v(\delta, \tau) T = \frac{\phi_\delta - \tau \phi_{\delta\tau}}{2 \phi_\delta + \delta \phi_{\delta\delta}}$
Isothermal compressibility $\kappa_T = -v^{-1} (\partial v / \partial p)_T$	$\kappa_T(\delta, \tau) \rho R T = \frac{1}{2 \delta \phi_\delta + \delta^2 \phi_{\delta\delta}}$
Relative pressure coefficient $\alpha_p = p^{-1} (\partial p / \partial T)_v$	$\alpha_p(\delta, \tau) T = 1 - \frac{\tau \phi_{\delta\tau}}{\phi_\delta}$
Isothermal stress coefficient $\beta_p = -p^{-1} (\partial p / \partial v)_T$	$\beta_p(\delta, \tau) = 2 + \frac{\delta \phi_{\delta\delta}}{\phi_\delta}$
Phase-equilibrium condition (Maxwell criterion)	$\frac{p_S}{R T \rho'} = \delta' \phi_\delta(\delta', \tau) ; \frac{p_S}{R T \rho''} = \delta'' \phi_\delta(\delta'', \tau)$ $\frac{p_S}{R T} \left(\frac{1}{\rho''} - \frac{1}{\rho'} \right) = \phi(\delta', \tau) - \phi(\delta'', \tau)$
$\phi_\delta = \left(\frac{\partial \phi}{\partial \delta} \right)_\tau, \phi_{\delta\delta} = \left(\frac{\partial^2 \phi}{\partial \delta^2} \right)_\tau, \phi_\tau = \left(\frac{\partial \phi}{\partial \tau} \right)_\delta, \phi_{\tau\tau} = \left(\frac{\partial^2 \phi}{\partial \tau^2} \right)_\delta, \phi_{\delta\tau} = \left(\frac{\partial^2 \phi}{\partial \delta \partial \tau} \right)$	

Table 2.17 The dimensionless Helmholtz free energy ϕ , Eq. (2.11), and its derivatives

$\phi = n_1 \ln \delta + \sum_{i=2}^{40} n_i \delta^{I_i} \tau^{J_i}$	$\phi_\tau = \sum_{i=2}^{40} n_i \delta^{I_i} J_i \tau^{J_i-1}$
$\phi_\delta = n_1 \delta^{-1} + \sum_{i=2}^{40} n_i I_i \delta^{I_i-1} \tau^{J_i}$	$\phi_{\tau\tau} = \sum_{i=2}^{40} n_i \delta^{I_i} J_i (J_i-1) \tau^{J_i-2}$
$\phi_{\delta\delta} = -n_1 \delta^{-2} + \sum_{i=2}^{40} n_i I_i (I_i-1) \delta^{I_i-2} \tau^{J_i}$	$\phi_{\delta\tau} = \sum_{i=2}^{40} n_i I_i \delta^{I_i-1} J_i \tau^{J_i-1}$
$\phi_\delta = \left(\frac{\partial \phi}{\partial \delta} \right)_\tau, \phi_{\delta\delta} = \left(\frac{\partial^2 \phi}{\partial \delta^2} \right)_\tau, \phi_\tau = \left(\frac{\partial \phi}{\partial \tau} \right)_\delta, \phi_{\tau\tau} = \left(\frac{\partial^2 \phi}{\partial \tau^2} \right)_\delta, \phi_{\delta\tau} = \left(\frac{\partial^2 \phi}{\partial \delta \partial \tau} \right)$	

Range of Validity. Equation (2.11) covers region 3 of IAPWS-IF97 defined by the following range of temperature and pressure, see Fig. 2.2:

$$623.15 \text{ K} \leq T \leq 863.15 \text{ K} \quad p_{B23}(T) \leq p \leq 100 \text{ MPa},$$

where $p_{B23}(T)$ is calculated from Eq. (2.1). In addition to the properties in the stable single-phase region defined above, Eq. (2.11) also yields reasonable values in the metastable regions (superheated liquid and subcooled steam) close to the saturated-liquid and saturated-vapour lines.

As stated at the beginning of Sec. 2.2, the boundary between regions 1 and 2 is considered to belong to region 1 and the boundary between regions 2 and 3 is considered to belong to region 2. Thus, the properties along these boundaries are not determined from the basic equation of region 3, $f_3(\rho, T)$, Eq. (2.11), but the properties along the boundary between regions 1 and 3 are calculated from the basic equation $g_1(p, T)$, Eq. (2.3), and the properties along the boundary between regions 2 and 3 are determined from the basic equation $g_2(p, T)$, Eq. (2.6).

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.11), Table 2.18 contains test values of the most relevant properties.

Table 2.18 Thermodynamic property values calculated from the basic equation $f_3(\rho, T)$, Eq. (2.11), for selected temperatures and densities^a

Property	$T = 650 \text{ K}$ $\rho = 500 \text{ kg m}^{-3}$	$T = 650 \text{ K}$ $\rho = 200 \text{ kg m}^{-3}$	$T = 750 \text{ K}$ $\rho = 500 \text{ kg m}^{-3}$
$p \text{ [MPa]}$	$0.255\ 837\ 018 \times 10^2$	$0.222\ 930\ 643 \times 10^2$	$0.783\ 095\ 639 \times 10^2$
$h \text{ [kJ kg}^{-1}\text{]}$	$0.186\ 343\ 019 \times 10^4$	$0.237\ 512\ 401 \times 10^4$	$0.225\ 868\ 845 \times 10^4$
$u \text{ [kJ kg}^{-1}\text{]}$	$0.181\ 226\ 279 \times 10^4$	$0.226\ 365\ 868 \times 10^4$	$0.210\ 206\ 932 \times 10^4$
$s \text{ [kJ kg}^{-1} \text{ K}^{-1}\text{]}$	$0.405\ 427\ 273 \times 10^1$	$0.485\ 438\ 792 \times 10^1$	$0.446\ 971\ 906 \times 10^1$
$c_p \text{ [kJ kg}^{-1} \text{ K}^{-1}\text{]}$	$0.138\ 935\ 717 \times 10^2$	$0.446\ 579\ 342 \times 10^2$	$0.634\ 165\ 359 \times 10^1$
$c_v \text{ [kJ kg}^{-1} \text{ K}^{-1}\text{]}$	$0.319\ 131\ 787 \times 10^1$	$0.404\ 118\ 076 \times 10^1$	$0.271\ 701\ 677 \times 10^1$
$w \text{ [m s}^{-1}\text{]}$	$0.502\ 005\ 554 \times 10^3$	$0.383\ 444\ 594 \times 10^3$	$0.760\ 696\ 041 \times 10^3$
$\kappa [-]$	$0.492\ 519\ 765 \times 10^1$	$0.131\ 906\ 278 \times 10^1$	$0.369\ 468\ 579 \times 10^1$
$\alpha_v \text{ [K}^{-1}\text{]}$	$0.168\ 653\ 107 \times 10^{-1}$	$0.685\ 312\ 229 \times 10^{-1}$	$0.441\ 515\ 098 \times 10^{-2}$
$\kappa_T \text{ [MPa}^{-1}\text{]}$	$0.345\ 506\ 956 \times 10^{-1}$	$0.375\ 798\ 565$	$0.806\ 710\ 817 \times 10^{-2}$
$\alpha_p \text{ [K}^{-1}\text{]}$	$0.190\ 798\ 153 \times 10^{-1}$	$0.818\ 019\ 386 \times 10^{-2}$	$0.698\ 896\ 514 \times 10^{-2}$
$\beta_p \text{ [kg m}^{-3}\text{]}$	$0.565\ 652\ 647 \times 10^3$	$0.238\ 728\ 962 \times 10^2$	$0.791\ 475\ 213 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.2.5 Basic Equations for Region 4

This section contains all details relevant for using the equations for the two-phase region 4 of IAPWS-IF97 (corresponding to the saturation line in the p - T diagram), see Fig. 2.2. Uncertainty estimates of the saturation pressures calculated from IAPWS-IF97 can be found in Sec. 2.5.

The equation for describing the saturation line is an implicit quadratic equation, which can be solved directly with regard to both saturation pressure p_s and saturation temperature T_s . This equation reads

$$\beta^2 \vartheta^2 + n_1 \beta^2 \vartheta + n_2 \beta^2 + n_3 \beta \vartheta^2 + n_4 \beta \vartheta + n_5 \beta + n_6 \vartheta^2 + n_7 \vartheta + n_8 = 0, \quad (2.12)$$

where

$$\beta = \left(p_s / p^* \right)^{0.25} \quad (2.12a)$$

and

$$\vartheta = \frac{T_s}{T^*} + \frac{n_9}{\left(T_s / T^* \right) - n_{10}} \quad (2.12b)$$

with $p^* = 1$ MPa and $T^* = 1$ K; for the coefficients n_1 to n_{10} see Table 2.19.

2.2.5.1 Saturation-Pressure Equation

The solution of Eq. (2.12) with regard to the saturation pressure p_s is as follows:

$$\frac{p_s}{p^*} = \left[\frac{2C}{-B + \left(B^2 - 4AC \right)^{0.5}} \right]^4, \quad (2.13)$$

where $p^* = 1$ MPa and

$$A = \vartheta^2 + n_1 \vartheta + n_2$$

$$B = n_3 \vartheta^2 + n_4 \vartheta + n_5$$

$$C = n_6 \vartheta^2 + n_7 \vartheta + n_8$$

with ϑ according to Eq. (2.12b). The coefficients n_i of Eq. (2.13) are listed in Table 2.19.

Table 2.19 Coefficients of the basic equations for region 4, Eqs. (2.12) to (2.14)

i	n_i	i	n_i
1	$0.116\ 705\ 214\ 527\ 67 \times 10^4$	6	$0.149\ 151\ 086\ 135\ 30 \times 10^2$
2	$-0.724\ 213\ 167\ 032\ 06 \times 10^6$	7	$-0.482\ 326\ 573\ 615\ 91 \times 10^4$
3	$-0.170\ 738\ 469\ 400\ 92 \times 10^2$	8	$0.405\ 113\ 405\ 420\ 57 \times 10^6$
4	$0.120\ 208\ 247\ 024\ 70 \times 10^5$	9	$-0.238\ 555\ 575\ 678\ 49$
5	$-0.323\ 255\ 503\ 223\ 33 \times 10^7$	10	$0.650\ 175\ 348\ 447\ 98 \times 10^3$

Equations (2.12) to (2.14) reproduce exactly the p - T values at the triple point according to Eqs. (1.7) and (1.8), at the normal boiling point according to Eq. (1.9), and at the critical point according to Eqs. (1.4) and (1.5).

Range of Validity. Equation (2.13) is valid along the entire vapour-liquid saturation line from 273.15 K to the critical temperature T_c so that it covers the temperature range

$$273.15 \text{ K} \leq T \leq 647.096 \text{ K}.$$

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.13), Table 2.20 contains corresponding test values.

Table 2.20 Saturation-pressure values calculated from Eq. (2.13) for selected temperatures^a

T [K]	p_s [MPa]
300	$0.353\ 658\ 941 \times 10^{-2}$
500	$0.263\ 889\ 776 \times 10^1$
600	$0.123\ 443\ 146 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.2.5.2 Saturation-Temperature Equation

The solution of Eq. (2.12) with regard to the saturation temperature T_s reads

$$\frac{T_s}{T^*} = \frac{n_{10} + D - \left[(n_{10} + D)^2 - 4(n_9 + n_{10}D) \right]^{0.5}}{2}, \quad (2.14)$$

where $T^* = 1$ K and

$$D = \frac{2G}{-F - (F^2 - 4EG)^{0.5}}$$

with

$$\begin{aligned} E &= \beta^2 + n_3\beta + n_6 \\ F &= n_1\beta^2 + n_4\beta + n_7 \\ G &= n_2\beta^2 + n_5\beta + n_8 \end{aligned}$$

and β according to Eq. (2.12a). The coefficients n_i of Eq. (2.14) are listed in Table 2.19.

Range of Validity. Equation (2.14) has the same range of validity as Eq. (2.13), which means that it covers the vapour-liquid saturation line according to the pressure range

$$611.212\ 677 \text{ Pa} \leq p \leq 22.064 \text{ MPa}.$$

The value of 611.212 677 Pa corresponds to the saturation pressure at 273.15 K. Since the saturation-pressure equation, Eq. (2.13), and the saturation-temperature equation, Eq. (2.14), were derived from the same implicit equation, Eq. (2.12), for describing the saturation line, both Eq. (2.13) and Eq. (2.14) are numerically identical.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.14), Table 2.21 contains corresponding test values.

Table 2.21 Saturation-temperature values calculated from Eq. (2.14) for selected pressures^a

p [MPa]	T_s [K]
0.1	$0.372\ 755\ 919 \times 10^3$
1	$0.453\ 035\ 632 \times 10^3$
10	$0.584\ 149\ 488 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.2.6 Basic Equation for Region 5

Region 5 of IAPWS-IF97 is the high-temperature region that covers temperatures from 1073.15 K to 2273.15 K at pressures up to 50 MPa, see Fig. 2.2. In order to enable users to calculate values of thermodynamic properties for designing future high-temperature power cycles and other processes in this region, there is the basic equation $g_5(p, T)$ [14]. This equation is a further development of the previous equation for this temperature region, which was valid for pressures up to 10 MPa [13]. This present high-temperature equation has been part of IAPWS-IF97 since 2007 [15].

The basic equation for this high-temperature region is a fundamental equation for the specific Gibbs free energy g . This equation is expressed in dimensionless form, $\gamma = g/(RT)$, and is separated into two parts, an ideal-gas part γ^0 and a residual part γ^r , so that

$$\frac{g_5(p, T)}{RT} = \gamma(\pi, \tau) = \gamma^0(\pi, \tau) + \gamma^r(\pi, \tau), \quad (2.15)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $R = 0.461\ 526\ \text{kJ kg}^{-1}\ \text{K}^{-1}$ given by Eq. (1.1), and γ^0 and γ^r according to Eqs. (2.16) and (2.17).

The equation for the ideal-gas part γ^0 of the dimensionless Gibbs free energy reads

$$\gamma^0(\pi, \tau) = \ln \pi + \sum_{i=1}^6 n_i \tau^{J_i}, \quad (2.16)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $p^* = 1\ \text{MPa}$ and $T^* = 1000\ \text{K}$. The coefficients n_1 and n_2 were adjusted in such a way that the values for the specific internal energy and specific entropy, calculated from Eq. (2.15), relate to Eq. (2.4). Table 2.22 contains the coefficients n_i and exponents J_i of Eq. (2.16).

Table 2.22 Coefficients and exponents of the ideal-gas part γ^0 , Eq. (2.16)

i	J_i	n_i	i	J_i	n_i
1	0	$-0.131\ 799\ 836\ 742\ 01 \times 10^2$	4	-2	$0.369\ 015\ 349\ 803\ 33$
2	1	$0.685\ 408\ 416\ 344\ 34 \times 10^1$	5	-1	$-0.311\ 613\ 182\ 139\ 25 \times 10^1$
3	-3	$-0.248\ 051\ 489\ 334\ 66 \times 10^{-1}$	6	2	$-0.329\ 616\ 265\ 389\ 17$

The form of the residual part γ^r of the dimensionless Gibbs free energy is as follows:

$$\gamma^r(\pi, \tau) = \sum_{i=1}^6 n_i \pi^{I_i} \tau^{J_i}, \quad (2.17)$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $p^* = 1\ \text{MPa}$ and $T^* = 1000\ \text{K}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.17) are listed in Table 2.23.

All thermodynamic properties can be derived from Eq. (2.15) by using the appropriate combinations of the ideal-gas part γ^0 , Eq. (2.16), and the residual part γ^r , Eq. (2.17), of the dimensionless Gibbs free energy and their derivatives. The relations of the relevant thermodynamic properties to γ^0 and γ^r and their derivatives are summarized in Table 2.24. Moreover, with the information given in Sec. 2.4, particularly with the formulas of Sec. 2.4.1, all of the partial deriva-

tives of the properties p, T, v, u, h, s, g , and f can be calculated easily. All required derivatives of the equations for γ^0 and γ^r are explicitly given in Table 2.25 and Table 2.26, respectively.

Table 2.23 Coefficients and exponents of the residual part γ^r , Eq. (2.17)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	1	1	$0.157\ 364\ 048\ 552\ 59 \times 10^{-2}$	4	2	3	$0.224\ 400\ 374\ 094\ 85 \times 10^{-5}$
2	1	2	$0.901\ 537\ 616\ 739\ 44 \times 10^{-3}$	5	2	9	$-0.411\ 632\ 754\ 534\ 71 \times 10^{-5}$
3	1	3	$-0.502\ 700\ 776\ 776\ 48 \times 10^{-2}$	6	3	7	$0.379\ 194\ 548\ 229\ 55 \times 10^{-7}$

Table 2.24 Relations of thermodynamic properties^a to the ideal-gas part γ^0 and the residual part γ^r of the dimensionless Gibbs free energy and their derivatives when using Eq. (2.15)

Property	Relation
Specific volume $v = (\partial g / \partial p)_T$	$v(\pi, \tau) \frac{P}{RT} = \pi \left(\gamma_\pi^0 + \gamma_\pi^r \right)$
Specific enthalpy $h = g - T(\partial g / \partial T)_p$	$\frac{h(\pi, \tau)}{RT} = \tau \left(\gamma_\tau^0 + \gamma_\tau^r \right)$
Specific internal energy $u = g - T(\partial g / \partial T)_p - p(\partial g / \partial p)_T$	$\frac{u(\pi, \tau)}{RT} = \tau \left(\gamma_\tau^0 + \gamma_\tau^r \right) - \pi \left(\gamma_\pi^0 + \gamma_\pi^r \right)$
Specific entropy $s = -(\partial g / \partial T)_p$	$\frac{s(\pi, \tau)}{R} = \tau \left(\gamma_\tau^0 + \gamma_\tau^r \right) - \left(\gamma^0 + \gamma^r \right)$
Specific isobaric heat capacity $c_p = (\partial h / \partial T)_p$	$\frac{c_p(\delta, \tau)}{R} = -\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right)$
Specific isochoric heat capacity $c_v = (\partial u / \partial T)_v$	$\frac{c_v(\pi, \tau)}{R} = -\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right) - \frac{\left(1 + \pi \gamma_\pi^r - \tau \pi \gamma_{\pi\tau}^r \right)^2}{1 - \pi^2 \gamma_{\pi\pi}^r}$
Speed of sound $w = v \left(-(\partial p / \partial v)_s \right)^{0.5}$	$\frac{w^2(\pi, \tau)}{RT} = \frac{1 + 2\pi\gamma_\pi^r + \pi^2\gamma_\pi^{r^2}}{\left(1 - \pi^2 \gamma_{\pi\pi}^r \right) + \frac{\left(1 + \pi\gamma_\pi^r - \tau\pi\gamma_{\pi\tau}^r \right)^2}{\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right)}}$
Isentropic exponent $\kappa = -vp^{-1}(\partial p / \partial v)_s$	$\kappa(\pi, \tau) = \frac{1 + 2\pi\gamma_\pi^r + \pi^2\gamma_\pi^{r^2}}{\pi \left(\gamma_\pi^0 + \gamma_\pi^r \right) \left[\left(1 - \pi^2 \gamma_{\pi\pi}^r \right) + \frac{\left(1 + \pi\gamma_\pi^r - \tau\pi\gamma_{\pi\tau}^r \right)^2}{\tau^2 \left(\gamma_{\tau\tau}^0 + \gamma_{\tau\tau}^r \right)} \right]}$

Continued on next page.

Table 2.24 – Continued

Property	Relation
Isobaric cubic expansion coefficient $\alpha_v = v^{-1} (\partial v / \partial T)_p$	$\alpha_v(\delta, \tau) T = \frac{1 + \pi \gamma_\pi^r - \tau \pi \gamma_{\pi\tau}^r}{1 + \pi \gamma_\pi^r}$
Isothermal compressibility $\kappa_T = -v^{-1} (\partial v / \partial p)_T$	$\kappa_T(\pi, \tau) p = \frac{1 - \pi^2 \gamma_{\pi\pi}^r}{1 + \pi \gamma_\pi^r}$
$\gamma_\pi^r = \left(\frac{\partial \gamma^r}{\partial \pi} \right)_\tau, \gamma_{\pi\pi}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi^2} \right)_\tau, \gamma_\tau^r = \left(\frac{\partial \gamma^r}{\partial \tau} \right)_\pi, \gamma_{\tau\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \tau^2} \right)_\pi, \gamma_{\pi\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi \partial \tau} \right), \gamma_\pi^o = \left(\frac{\partial \gamma^o}{\partial \pi} \right)_\tau, \gamma_{\pi\pi}^o = \left(\frac{\partial^2 \gamma^o}{\partial \pi^2} \right)_\tau, \gamma_\tau^o = \left(\frac{\partial \gamma^o}{\partial \tau} \right)_\pi, \gamma_{\tau\tau}^o = \left(\frac{\partial^2 \gamma^o}{\partial \tau^2} \right)_\pi, \gamma_{\pi\tau}^o = \left(\frac{\partial^2 \gamma^o}{\partial \pi \partial \tau} \right)_\tau$	

^aThe relative pressure coefficient α_p and the isothermal stress coefficient β_p can be calculated as follows: $\alpha_p = \alpha_v (p \kappa_T)^{-1}$, $\beta_p = (p v \kappa_T)^{-1}$.

Table 2.25 The ideal-gas part γ^o of the dimensionless Gibbs free energy, Eq. (2.16), and its derivatives

$\gamma^o = \ln \pi + \sum_{i=1}^6 n_i \tau^{J_i}$	$\gamma_\tau^o = \sum_{i=1}^6 n_i J_i \tau^{J_i-1}$
$\gamma_\pi^o = \pi^{-1}$	$\gamma_{\tau\tau}^o = \sum_{i=1}^6 n_i J_i (J_i - 1) \tau^{J_i-2}$
$\gamma_{\pi\pi}^o = -\pi^{-2}$	$\gamma_{\pi\tau}^o = 0$
$\gamma_\pi^o = \left(\frac{\partial \gamma^o}{\partial \pi} \right)_\tau, \gamma_{\pi\pi}^o = \left(\frac{\partial^2 \gamma^o}{\partial \pi^2} \right)_\tau, \gamma_\tau^o = \left(\frac{\partial \gamma^o}{\partial \tau} \right)_\pi, \gamma_{\tau\tau}^o = \left(\frac{\partial^2 \gamma^o}{\partial \tau^2} \right)_\pi, \gamma_{\pi\tau}^o = \left(\frac{\partial^2 \gamma^o}{\partial \pi \partial \tau} \right)$	

Table 2.26 The residual part γ^r of the dimensionless Gibbs free energy, Eq. (2.17), and its derivatives

$\gamma^r = \sum_{i=1}^6 n_i \pi^{I_i} \tau^{J_i}$	$\gamma_\tau^r = \sum_{i=1}^6 n_i \pi^{I_i} J_i \tau^{J_i-1}$
$\gamma_\pi^r = \sum_{i=1}^6 n_i I_i \pi^{I_i-1} \tau^{J_i}$	$\gamma_{\tau\tau}^r = \sum_{i=1}^6 n_i \pi^{I_i} J_i (J_i - 1) \tau^{J_i-2}$
$\gamma_{\pi\pi}^r = \sum_{i=1}^6 n_i I_i (I_i - 1) \pi^{I_i-2} \tau^{J_i}$	$\gamma_{\pi\tau}^r = \sum_{i=1}^6 n_i I_i \pi^{I_i-1} J_i \tau^{J_i-1}$
$\gamma_\pi^r = \left(\frac{\partial \gamma^r}{\partial \pi} \right)_\tau, \gamma_{\pi\pi}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi^2} \right)_\tau, \gamma_\tau^r = \left(\frac{\partial \gamma^r}{\partial \tau} \right)_\pi, \gamma_{\tau\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \tau^2} \right)_\pi, \gamma_{\pi\tau}^r = \left(\frac{\partial^2 \gamma^r}{\partial \pi \partial \tau} \right)$	

Range of Validity. Equation (2.15) covers region 5 of IAPWS-IF97 defined by the following temperature and pressure range, see Fig. 2.2:

$$1073.15 \text{ K} \leq T \leq 2273.15 \text{ K} \quad 0 < p \leq 50 \text{ MPa}.$$

In this range, Eq. (2.15) is only valid for pure undissociated water, any dissociation will have to be taken into account separately.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.15), Table 2.27 contains test values of the most relevant properties.

Table 2.27 Thermodynamic property values calculated from the basic equation $g_5(p, T)$, Eq.(2.15), for selected temperatures and pressures^a

Property	$T = 1500 \text{ K}$	$T = 1500 \text{ K}$	$T = 2000 \text{ K}$
	$p = 0.5 \text{ MPa}$	$p = 30 \text{ MPa}$	$p = 30 \text{ MPa}$
$v [\text{m}^3 \text{ kg}^{-1}]$	$0.138\ 455\ 090 \times 10^1$	$0.230\ 761\ 299 \times 10^{-1}$	$0.311\ 385\ 219 \times 10^{-1}$
$h [\text{kJ kg}^{-1}]$	$0.521\ 976\ 855 \times 10^4$	$0.516\ 723\ 514 \times 10^4$	$0.657\ 122\ 604 \times 10^4$
$u [\text{kJ kg}^{-1}]$	$0.452\ 749\ 310 \times 10^4$	$0.447\ 495\ 124 \times 10^4$	$0.563\ 707\ 038 \times 10^4$
$s [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.965\ 408\ 875 \times 10^1$	$0.772\ 970\ 133 \times 10^1$	$0.853\ 640\ 523 \times 10^1$
$c_p [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.261\ 609\ 445 \times 10^1$	$0.272\ 724\ 317 \times 10^1$	$0.288\ 569\ 882 \times 10^1$
$c_v [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.215\ 337\ 784 \times 10^1$	$0.219\ 274\ 829 \times 10^1$	$0.239\ 589\ 436 \times 10^1$
$w [\text{m s}^{-1}]$	$0.917\ 068\ 690 \times 10^3$	$0.928\ 548\ 002 \times 10^3$	$0.106\ 736\ 948 \times 10^4$
$\kappa [-]$	$0.121\ 485\ 600 \times 10^1$	$0.124\ 544\ 481 \times 10^1$	$0.121\ 958\ 005 \times 10^1$
$\alpha_v [\text{K}^{-1}]$	$0.667\ 539\ 000 \times 10^{-3}$	$0.716\ 950\ 754 \times 10^{-3}$	$0.508\ 830\ 641 \times 10^{-3}$
$\kappa_T [\text{MPa}^{-1}]$	$0.200\ 003\ 859 \times 10^1$	$0.332\ 881\ 253 \times 10^{-1}$	$0.329\ 193\ 892 \times 10^{-1}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.3 Backward Equations of IAPWS-IF97

This section contains details relevant for using all of the backward equations. However, these backward equations are not presented region by region, i.e. not all types of backward equations that are valid in the same region are described in one section, rather, all backward equations dependent on the same input variables are summarized in the same section. This is more practical for application of the different types of backward equations to the corresponding basic equations.

2.3.1 Survey and Important Annotations

A survey of all types of backward equations of the industrial formulation IAPWS-IF97 together with some general statements are given in this section. Important annotations on the use of the backward equations are summarized in Sec. 2.3.1.2.

2.3.1.1 Survey on All Types of Backward Equations

For industrial applications in the single-phase region of water and steam, property functions dependent on the input variables (p, T) are most important. For regions 1 and 2 more than 30% of all property calls relate to these input variables. However, for modelling steam power cycles and other applications, property functions of (p, h) and (p, s) are also necessary. From the basic equa-

tions $g(p, T)$ and $f(\rho, T)$, such property functions can only be calculated by iterations, which require intensive computing time. For very fast yet sufficiently accurate calculations of properties as functions of (p, h) and (p, s) for regions 1 and 2, backward equations in the form $T(p, h)$ and $T(p, s)$ were developed simultaneously with the basic equations of IAPWS-IF97 [13, 15].

In order to make possible fast calculations also as a function of (h, s) , after the adoption of IAPWS-IF97 in 1997, IAPWS decided that backward equations in the form of $p(h, s)$ for regions 1 and 2 should supplement the other backward equations for these regions. The reason is that the determination of such property functions from the basic equations requires two-dimensional iterations, which are very time consuming. Therefore, backward equations in the form of $p(h, s)$ were developed [16, 23]. The combination of these equations with the other backward equations of regions 1 and 2 allows for the calculation of all properties as a function of (h, s) without iterations. Later, IAPWS also decided that it should be possible to calculate properties for region 3 as functions of (p, h) , (p, s) , (h, s) , and even of (p, T) without iterations from the basic equation $f_3(\rho, T)$, Eq. (2.11). Therefore, backward equations of the form $T(p, h)$, $v(p, h)$, $T(p, s)$, $v(p, s)$ [17, 24], $p(h, s)$ [18, 25], and $v(p, T)$ [19, 26] were developed. Moreover, a saturation-temperature equation in the form $T_s(h, s)$ is also provided [18, 25] for the part of the two-phase region 4 that is important for steam-turbine calculations. Figure 2.3 shows the assignment of the existing backward equations to the various regions; all of these equations are described in this section. For region 5 there are no backward equations.

Before properties can be calculated for a given state point, the region in which the point is located must be determined. To minimize the computing time, one should also be able to perform the region determination without iterations. However, for the input variables (h, s) , the region boundaries can only be calculated by iterating the corresponding basic equation. The same is true for the input variables (p, h) and (p, s) with regard to the boundary between the single-phase region 3 and the two-phase region 4. In order to avoid these iterative calculations, special equations for the region boundaries were developed and included in the IAPWS supplementary releases for the respective backward equations. These equations are called region-boundary equations in the following text.

The use of the backward equations and region-boundary equations enormously accelerates the calculation of properties dependent on the different combinations of input variables. The following sections, particularly Sec. 2.3.7, describe how much faster the calculations with the backward equations and region-boundary equations are in comparison with calculations from the basic equations through iteration.

All backward equations presented in this section⁴ meet the requirements for very high consistency to the corresponding basic equation. The exact requirements for these numerical consistency values, set by IAPWS, are summarized in Sec. 2.3.2.

⁴The saturation-temperature equation $T_s(p)$ is not considered to be a backward equation and is therefore described in Sec. 2.2.5.2, see also the beginning of Sec. 2.2.

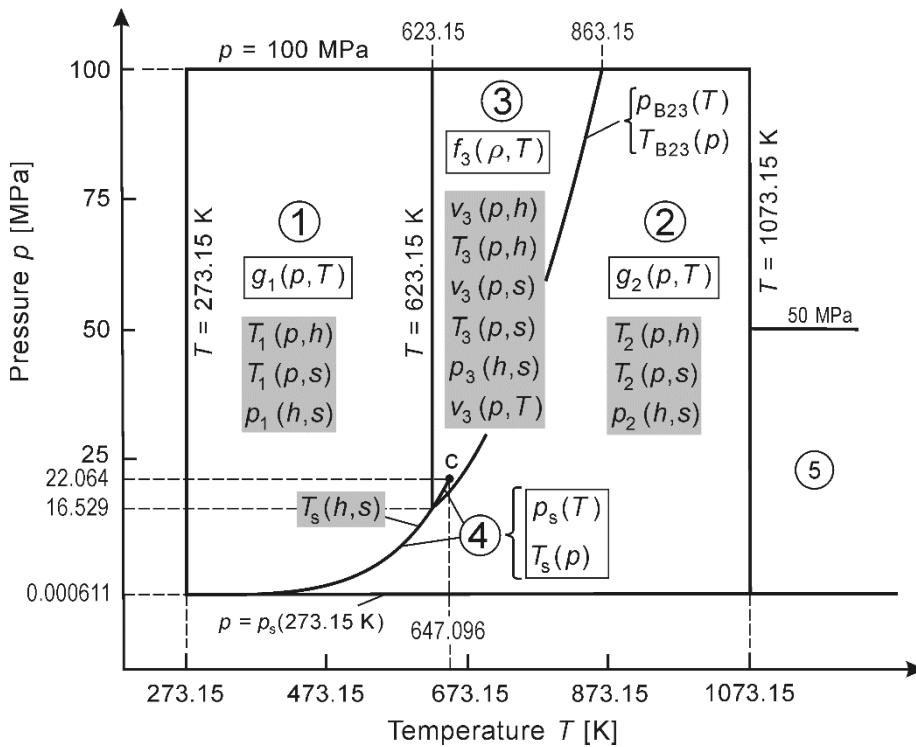


Fig. 2.3 All forms of backward equations (marked in grey) as assigned to the corresponding regions of IAPWS-IF97. The basic equations are shown in rectangular boxes.

2.3.1.2 Important Annotations on the Use of the Backward Equations

Although the backward equations clearly meet the very high numerical consistency requirements given in Sec. 2.3.2, the inconsistencies with respect to the basic equations are, of course, not zero. This fact has several consequences of which the user should be aware, for example:

- When calculating a property as a function of (p, h) , (p, s) , or (h, s) , slightly different results are obtained depending on whether the backward equations are used or if the properties are directly calculated from the basic equations $g(p, T)$ and $f(\rho, T)$ by iteration. These differences are described in detail in the sections for the respective backward equations.
- When calculating properties with the help of backward equations for a given state point extremely close to a region boundary, attention should be paid to the existence of (very small) inconsistencies between backward equations and basic equations, and between region-boundary equations and basic equations. Due to these inconsistencies, the calculations could indicate that the state point is in the adjacent region, but (of course) extremely close to the region boundary. The user should be aware of these effects in order to avoid possible numerical problems by taking suitable measures in the program code. For this purpose, values for the numerical inconsistencies of the backward and region-boundary equations will be given in the respective sections.

- The backward equations and region-boundary equations should never be used to calculate derivatives of a property.
- When properties are to be determined by iteration of the basic equations (because the input variables are not the independent variables of the equation), then these iterations may only be carried out with the basic equations alone, not in combination with any backward or region boundary equation.

These inconsistencies are unavoidable when using backward equations and are therefore an agreed-upon feature of IAPWS-IF97. However, these inconsistencies are insignificant enough to have nearly no practical relevance for any technical application. Thus, because of their great advantage due to shorter computing times, the backward equations should be used whenever possible. For such applications, however, where these minor inconsistencies are indeed not acceptable, the calculations should be performed with the basic equations through the use of iteration. Even in this case the inconsistency is not zero, but depends on the selected convergence criterion of the iteration. For example, the convergence criterion has to be less than 10^{-5} in $\Delta T/T$ to achieve a smaller inconsistency than that with the backward equations. However, even for such direct iterations with the basic equations, the backward equations are still very useful because they provide very good starting values for the iterations.

2.3.2 Requirements for the Numerical Consistencies between Backward Equations, Backward Functions, and Basic Equations

The use of the backward equations of the forms $T(p,h)$, $v(p,h)$, $T(p,s)$, $v(p,s)$, $p(h,s)$, $v(p,T)$ and the backward functions⁵ $T(h,s)$ and $v(h,s)$ in combination with the corresponding basic equations $g(p,T)$ and $f(\rho,T)$ enormously accelerates the calculation of the thermodynamic properties dependent on the given input variables. Figure 2.3 shows the assignment of these input variables to the relevant regions, namely (p,h) , (p,s) , and (h,s) for regions 1 to 3, (p,T) for region 3, and (h,s) for a part of region 4. Such “fast” calculations are particularly important for heat cycle, turbine and boiler calculations. However, the main precondition for the effective use of such backward equations and backward functions in combination with the corresponding basic equations is that these equations must be numerically very consistent with each other. The final requirements for these numerical consistencies were defined by IAPWS based on comprehensive test calculations that were carried out by the international power-cycle industry for several characteristic power cycles. These numerical consistency requirements for the backward equations and backward functions in temperature, pressure and specific volume, assigned to the corresponding region of IAPWS-IF97, are summarized in Fig. 2.4 and described in the following text.

⁵For the explanation of the term “backward function” see the beginning of Sec. 2.3.5.

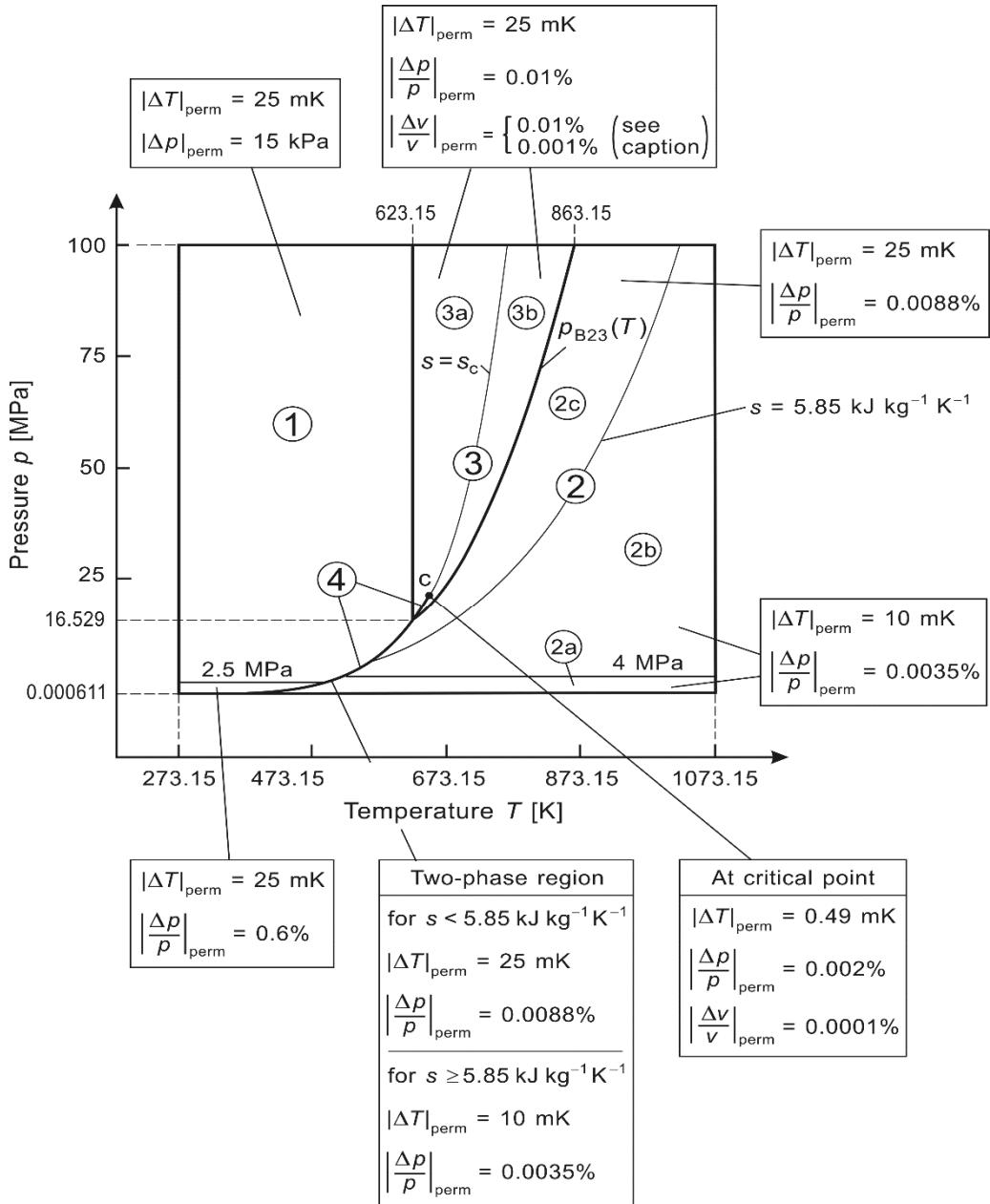


Fig. 2.4 Permissible values for numerical inconsistencies $|\Delta T|_{\text{perm}}$ in calculated temperatures, $|\Delta p/p|_{\text{perm}}$ or $|\Delta p|_{\text{perm}}$ in calculated pressures, and $|\Delta v/v|_{\text{perm}}$ in calculated specific volumes between the backward equations/functions and the corresponding basic equation assigned to the corresponding regions of IAPWS-IF97. For region 3: The value $|\Delta v/v|_{\text{perm}} = 0.01\%$ relates to the backward equations/functions with the input variables (p, h) , (p, s) , and (h, s) . The value $|\Delta v/v|_{\text{perm}} = 0.001\%$ relates to the backward equations $v(p, T)$, for which region 3 is divided into many subregions not shown in this figure; details are given in Sec. 2.3.6.3.

Numerical Consistency Requirements in Temperature. The permissible inconsistency between the temperature calculated from the backward equations and the temperature calculated by iteration from the corresponding basic equations/functions was set to ± 25 mK for the range of specific entropies less than $5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and to ± 10 mK for the range of specific entropies greater than or equal to this value. This means that the value $|\Delta T|_{\text{perm}} = 25$ mK is valid in regions 1, 3, and in the part of region 2 with $s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$. This part of region 2 corresponds to subregion 2c, which will be explained in the following sections, e.g. Sec. 2.3.3.3a. The value $|\Delta T|_{\text{perm}} = 10$ mK is valid in the part of region 2 with $s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$ corresponding to subregions 2a and 2b.

In order to avoid numerical problems at the critical point, the value 647.096 K for the critical temperature should be represented by the backward equations/functions for all six figures. Therefore, the permissible inconsistency value was set to $|\Delta T|_{\text{perm}} = 0.49$ mK. This value has to be met by the backward equations/functions of the adjacent subregions 3a and 3b.

In the part of the two-phase region 4 with $s \geq s''(623.15 \text{ K})$, which is important for steam turbine calculations, see Fig. 2.21, the permissible numerical inconsistency in temperature was set to $|\Delta T|_{\text{perm}} = 10$ mK for $s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and $|\Delta T|_{\text{perm}} = 25$ mK for $s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

Numerical Consistency Requirements in Pressure. In region 1, the permissible inconsistency between the pressure calculated from the backward equations/functions and the pressure calculated by iteration from the corresponding basic equation was set to $\pm 0.6\%$ for pressures less than or equal to 2.5 MPa and to $\pm 15 \text{ kPa}$ for pressures greater than this value. For region 2 with $s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$, corresponding to subregion 2c, the permissible numerical inconsistency in the calculated pressure amounts to $|\Delta p/p|_{\text{perm}} = 0.0088\%$. For region 2 with $s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$, corresponding to subregions 2a and 2b, the permissible inconsistency in pressure is $|\Delta p/p|_{\text{perm}} = 0.0035\%$. For region 3 consisting of subregions 3a and 3b, it is $|\Delta p/p|_{\text{perm}} = 0.01\%$.

At the critical point, the value 22.064 MPa for the critical pressure should be represented by the backward equations for all five figures. Therefore, the permissible inconsistency value was set to $|\Delta p/p|_{\text{perm}} = 0.002\%$. The backward equations in the adjacent subregions 3a and 3b have to fulfil this requirement.

In the part of the two-phase region 4 with $s \geq s''(623.15 \text{ K})$, which is important for steam turbine calculations, see Fig. 2.21, the permissible numerical inconsistency in pressure amounts to $|\Delta p/p|_{\text{perm}} = 0.0035\%$ for $s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and $|\Delta p/p|_{\text{perm}} = 0.0088\%$ for $s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

Numerical Consistency Requirements in Specific Volume. Backward equations/functions for specific volume are required in region 3 because the corresponding basic equation is defined as a function of the input variables density (the reciprocal value of specific volume) and temperature. The permissible difference between the specific volume calculated from the backward equations/functions and the specific volume calculated by iteration from the basic equation was determined to $\pm 0.01\%$ for the input variables (p, h) , (p, s) , and (h, s) .

The functional dependence of the specific volume on pressure and temperature in region 3, see Fig. 2.3, represents a special case for which $|\Delta v/v|_{\text{perm}} = 0.001\%$. The permissible numerical inconsistencies for other properties will be given in Sec. 2.3.6.1. At the critical point, the value $v_c = 0.003\ 105\ 59 \text{ m}^3 \text{ kg}^{-1}$ should be represented by the backward equations/functions for all six significant figures. Therefore, the permissible inconsistency value was set to $|\Delta v/v|_{\text{perm}} = 0.0001\%$. The backward equations/functions in the adjacent subregions 3a and 3b have to meet this requirement.

Summary of the Permissible Inconsistencies. The permissible inconsistencies in temperature, pressure and specific volume between the backward equations/functions and the corresponding basic equation, presented in detail above, are summarized in Table 2.28.

Table 2.28 Permissible numerical inconsistencies $|\Delta T|_{\text{perm}}$ in calculated temperatures, $|\Delta p/p|_{\text{perm}}$ or $|\Delta p|_{\text{perm}}$ in calculated pressures, and $|\Delta v/v|_{\text{perm}}$ in calculated specific volumes between the backward equations/functions and the corresponding basic equation

Region	Subregion	$ \Delta T _{\text{perm}}$	$ \Delta p/p _{\text{perm}}$ or $ \Delta p _{\text{perm}}$	$ \Delta v/v _{\text{perm}}$
1		25 mK	$p \leq 2.5 \text{ MPa}$	0.6%
			$p > 2.5 \text{ MPa}$	15 kPa
2	$s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	2c	25 mK	0.0088%
	$s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	2a, 2b	10 mK	0.0035%
3		25 mK	0.001%	$0.01\%^{\text{a}}$
				$0.001\%^{\text{b}}$
4	$s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	25 mK	0.0088%	
	$s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	10 mK	0.0035%	
Critical point	3a, 3b	0.49 mK	0.002%	0.0001%

^aThis value relates to the input variables (p, h) , (p, s) , and (h, s) .

^bThis value relates to the input variables (p, T) .

For example, the permissible inconsistency $|\Delta T|_{\text{perm}} = 25 \text{ mK}$ in region 1 means that the temperature value determined from the backward equations $T_1(p, h)$, $T_1(p, s)$ and the backward function $T_1(h, s)$ must agree within $\pm 25 \text{ mK}$ with the temperature value determined by iteration from the basic equation $g_1(p, T)$ for the same input values. The permissible value $|\Delta p/p|_{\text{perm}} = 0.6\%$ means that the difference between the pressure calculated from the backward equation $p_1(h, s)$ and the pressure determined by iteration from the basic equation $g_1(p, T)$ must be not greater than 0.6%.

2.3.3 Backward Equations as a Function of the Input Variables (p, h)

In this section, all of the backward equations as a function of (p, h) are summarized. These are the backward equations $T(p, h)$ for regions 1 to 3 and the backward equations $v(p, h)$ for region 3. When these equations are combined with the basic equations for regions 1 to 4, all other properties that are dependent on (p, h) can be calculated without iteration in the four regions.

The backward equations for regions 1 and 2 were developed and adopted together with the basic equations of IAPWS-IF97 [13, 15], whereas the backward equations for region 3 were adopted by IAPWS in 2004, and slightly revised in 2014 [24]. The development of these equations is described in Ref. [17].

2.3.3.1 Regions and Region Boundaries in the Variables (p, h)

Figure 2.5 shows the regions and region boundaries in a pressure-enthalpy diagram along with the assignment of the backward equations $T(p, h)$ and $v(p, h)$ to regions 1 to 3. In order to avoid any iteration in practical calculations with IAPWS-IF97, the region boundaries must also be determinable without iterations. Therefore, a saturation-pressure equation as a function of enthalpy, $p_{s,3}(h)$, for the saturated-liquid and saturated-vapour lines between region 3 and region 4 was developed [17, 24] and is given as Eq. (2.18).

When property calculations with IAPWS-IF97 are carried out with the variables (p, h) as input variables, all tests to determine whether the given (p, h) point is within the range of regions 1 to 4 of IAPWS-IF97 and, if so, in which region, must be performed with respect to these input variables. To make such tests easier, the following subsections describe which equations are used to calculate the h values for given p values (or vice versa) along the respective region boundaries. These explanations are based on Fig. 2.5. Thus, Fig. 2.5 along with the description of the region boundaries given in Secs. 2.3.3.1a to 2.3.3.1c can be regarded as definitions of regions 1 to 4 of IAPWS-IF97 for the variables p and h .

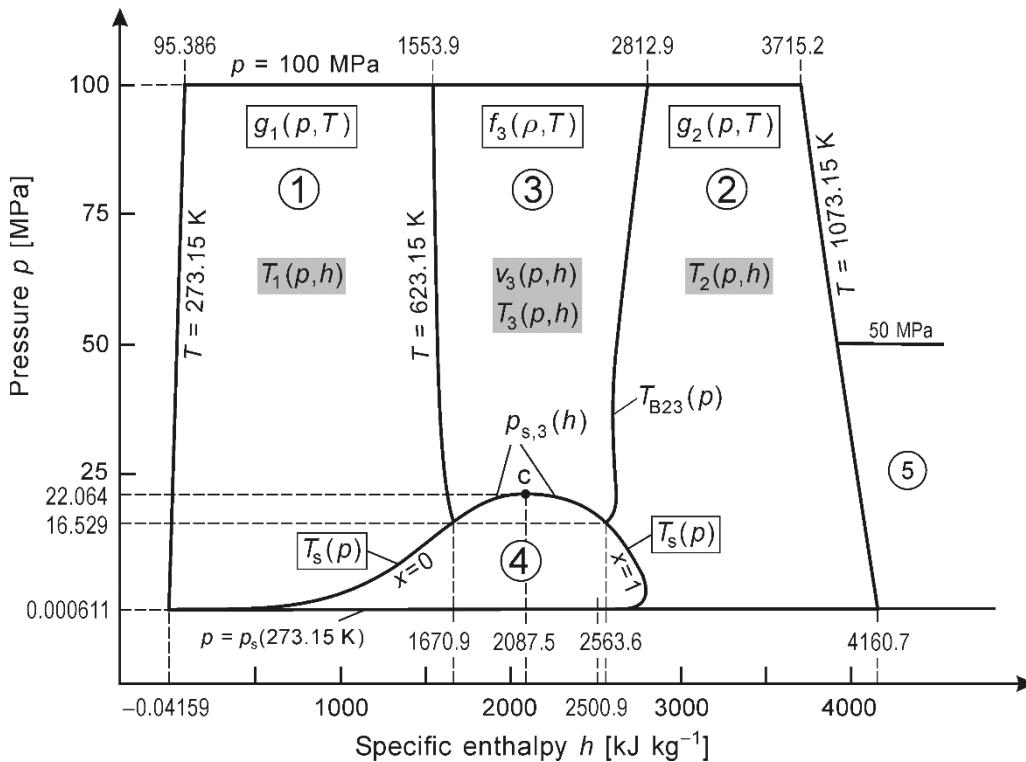


Fig. 2.5 Regions and region boundaries of IAPWS-IF97 for the variables (p, h) . Assignment of the backward equations $T(p, h)$ and $v(p, h)$ to these regions (without showing how regions 2 and 3 will be divided into subregions). The p and h values given at the corner points of the region boundaries are rounded values.

a) Outer Boundaries of Regions 1 to 4

The description of the boundaries starts at the left-hand side of Fig. 2.5 with the isotherm $T = 273.15$ K and proceeds clockwise.

The Isotherm $T = 273.15$ K. This isotherm corresponds to the lowest temperature limit of IAPWS-IF97 and covers the pressure range given by

$$p_s(273.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

where p_s is calculated from the saturation-pressure equation $p_s(T)$, Eq. (2.13). Along this isotherm, the h value for the given p value is calculated from the basic equation of region 1, $g_1(p, T)$, Eq. (2.3), with $T = 273.15$ K. If the specific enthalpy h of a given (p, h) point is less than $h_1(p, 273.15 \text{ K})$, then the (p, h) point is outside the range of validity of IAPWS-IF97, see Fig. 2.5.

The Isobar $p = 100$ MPa. This isobar is the upper pressure limit of the range of validity of IAPWS-IF97 (except for region 5). If the given pressure p is greater than 100 MPa, then the (p, h) point is outside the range of validity of IAPWS-IF97.

The Isotherm $T = 1073.15$ K. This isotherm corresponds to the upper temperature limit of IAPWS-IF97 (except for region 5) and covers the range of pressure

$$p_s(273.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

where p_s is calculated from the equation $p_s(T)$, Eq. (2.13). On this isotherm, the h value for the given p value is obtained from the basic equation of region 2, $g_2(p, T)$, Eq. (2.6), with $T = 1073.15$ K. If the specific enthalpy h of the given (p, h) point is greater than $h_2(p, 1073.15 \text{ K})$ for the given pressure p , then the (p, h) point is outside the range of validity of IAPWS-IF97 for which the backward equations exist, see Fig. 2.5.

The Isobar $p = p_s(273.15 \text{ K}) = 0.000\ 611\ 212\ 677$ MPa. This saturation pressure p_s is calculated from the equation $p_s(T)$, Eq. (2.13), and is the lower pressure limit of the range of validity of the IAPWS-IF97 backward equations. If the given pressure p is lower than $p = 0.000\ 611\ 212\ 677$ MPa, then the (p, h) point is outside the range of validity of the backward equations, see Fig. 2.5.

b) Boundary between the Single-Phase Regions 1 to 3 and the Two-Phase Region 4

According to Fig. 2.5, the boundary between the single-phase regions 1 to 3 and the two-phase region 4 is given by the saturated-liquid line ($x = 0$) and the saturated-vapour line ($x = 1$).

Boundary between Regions 1 and 4. The part of the saturated-liquid line ($x = 0$) that forms the boundary between regions 1 and 4 covers a range of pressures given by

$$p_s(273.15 \text{ K}) \leq p \leq p_s(623.15 \text{ K}),$$

see Fig. 2.5; the p_s values are calculated from the equation $p_s(T)$, Eq. (2.13). Along this boundary, the h value for the given p value is determined from the basic equation $g_1(p, T)$, Eq. (2.3), where $T = T_s$ is obtained from the saturation-temperature equation $T_s(p)$, Eq. (2.14). The given enthalpy value can then be compared with the calculated value for h .

Boundary between Regions 3 and 4. The part of the saturated-liquid line and the saturated-vapour line that forms the boundary between regions 3 and 4 is given by the enthalpy range

$$h'(623.15 \text{ K}) \leq h \leq h''(623.15 \text{ K})$$

with $h'(623.15 \text{ K}) = h_1(p_s(623.15 \text{ K}), 623.15 \text{ K})$
 and $h''(623.15 \text{ K}) = h_2(p_s(623.15 \text{ K}), 623.15 \text{ K})$,

where p_s is calculated from Eq. (2.13). In this relation, h_1 is calculated from the basic equation $g_1(p, T)$, Eq. (2.3), with $p = p_s(T)$ and $T = 623.15$ K. The enthalpy h_2 is obtained from the basic

equation $g_2(p, T)$, Eq. (2.6), for $p = p_s(T)$ and $T = 623.15$ K. The reason for calculating the enthalpies h_1 and h_2 at these corner points from the basic equations for regions 1 and 2, $g_1(p, T)$ and $g_2(p, T)$, Eqs. (2.3) and (2.6), and not from the basic equation for region 3, $f_3(\rho, T)$, Eq. (2.11), is given at the beginning of Sec. 2.3.3.1c. Along this boundary, the p value for the given h value is calculated from the saturation-pressure equation as a function of enthalpy, $p_{s,3}(h)$, which is given in Sec. 2.3.3.1d as Eq. (2.18). The given pressure value can then be compared with the calculated value for p .

Boundary between Regions 2 and 4. The part of the saturated-vapour line ($x = 1$) that forms the boundary with region 2 covers the pressure range

$$p_s(273.15 \text{ K}) \leq p \leq p_s(623.15 \text{ K}),$$

see Fig. 2.5; the p_s values are calculated from the equation $p_s(T)$, Eq. (2.13). Along this boundary, the h value for the given p value is determined from the basic equation $g_2(p, T)$, Eq. (2.6), where $T = T_s$ is obtained from the saturation-temperature equation $T_s(p)$, Eq. (2.14). The given enthalpy value can then be compared with the calculated value for h .

c) Boundaries between the Single-Phase Regions

The boundaries between regions 1 and 3 ($T = 623.15$ K) and between regions 2 and 3 (T_{B23} -line) belong to both adjacent regions, see Figs. 2.2 and 2.5. However, in order to avoid to having two different values along these boundaries, the boundary between regions 1 and 3 is considered to belong to region 1 and the boundary between regions 2 and 3 is considered to belong to region 2. Thus, the properties along the boundary between regions 1 and 3 are calculated from the basic equation for region 1 and the properties along the boundary between regions 2 and 3 are determined from the basic equation for region 2. The calculations can be performed directly in this way; neither iteration nor additional use of any backward equation is required.

Boundary between Regions 1 and 3. The boundary that corresponds to the isotherm $T = 623.15$ K covers the pressure range

$$p_s(623.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

see Fig. 2.5; p_s is calculated from Eq. (2.13). Along this boundary, the h value for the given p value is determined from the basic equation $g_1(p, T)$, Eq. (2.3), with $T = 623.15$ K. The given enthalpy value can then be compared with the calculated value for h .

Boundary between Regions 2 and 3. This boundary, namely the T_{B23} -line, covers the pressure range

$$p_s(623.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

see Fig. 2.5; p_s is obtained from Eq. (2.13). Along this boundary, the h value for the given p value is calculated from the basic equation $g_2(p, T)$, Eq. (2.6), with $T = T_{B23}$ determined from the equation $T_{B23}(p)$, Eq. (2.2). The given enthalpy value can then be compared with the calculated value for h .

d) The Boundary Equation $p_{s,3}(h)$

The boundary equation $p_{s,3}(h)$ has the following dimensionless form:

$$\frac{p_{s,3}(h)}{p^*} = \pi(\eta) = \sum_{i=1}^{14} n_i (\eta - 1.02)^{I_i} (\eta - 0.608)^{J_i}, \quad (2.18)$$

where $\pi = p/p^*$ and $\eta = h/h^*$ with $p^* = 22 \text{ MPa}$ and $h^* = 2600 \text{ kJ kg}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.18) are listed in Table 2.29.

Table 2.29 Coefficients and exponents of the boundary equation $p_{s,3}(h)$ in its dimensionless form, Eq. (2.18)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	0.600 073 641 753 024	8	8	24	$0.252\ 304\ 969\ 384\ 128 \times 10^{18}$
2	1	1	$-0.936\ 203\ 654\ 849\ 857 \times 10^1$	9	14	16	$-0.389\ 718\ 771\ 997\ 719 \times 10^{19}$
3	1	3	$0.246\ 590\ 798\ 594\ 147 \times 10^2$	10	20	16	$-0.333\ 775\ 713\ 645\ 296 \times 10^{23}$
4	1	4	$-0.107\ 014\ 222\ 858\ 224 \times 10^3$	11	22	3	$0.356\ 499\ 469\ 636\ 328 \times 10^{11}$
5	1	36	$-0.915\ 821\ 315\ 805\ 768 \times 10^{14}$	12	24	18	$-0.148\ 547\ 544\ 720\ 641 \times 10^{27}$
6	5	3	$-0.862\ 332\ 011\ 700\ 662 \times 10^4$	13	28	8	$0.330\ 611\ 514\ 838\ 798 \times 10^{19}$
7	7	0	$-0.235\ 837\ 344\ 740\ 032 \times 10^2$	14	36	24	$0.813\ 641\ 294\ 467\ 829 \times 10^{38}$

The equation $p_{s,3}(h)$, Eq. (2.18), describes the saturated-liquid line and the saturated-vapour line including the critical point in the following enthalpy range, see Fig. 2.5:

$$h'(623.15 \text{ K}) \leq h \leq h''(623.15 \text{ K}),$$

where $h'(623.15 \text{ K}) = h_1(p_s(623.15 \text{ K}), 623.15 \text{ K}) = 1.670\ 858\ 218 \times 10^3 \text{ kJ kg}^{-1}$

and $h''(623.15 \text{ K}) = h_2(p_s(623.15 \text{ K}), 623.15 \text{ K}) = 2.563\ 592\ 004 \times 10^3 \text{ kJ kg}^{-1}$.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.18), Table 2.30 contains test values for calculated pressures.

Table 2.30 Pressure values calculated from the boundary equation $p_{s,3}(h)$, Eq. (2.18), for selected specific enthalpies^a

Equation	$h [\text{kJ kg}^{-1}]$	$p [\text{MPa}]$
$p_{s,3}(h)$, Eq. (2.18)	1700	$1.724\ 175\ 718 \times 10^1$
	2000	$2.193\ 442\ 957 \times 10^1$
	2400	$2.018\ 090\ 839 \times 10^1$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Note. For points extremely close to the boundary between the single-phase region 3 and the two-phase region 4, the following procedure is recommended. When calculating the pressure with the $p_{s,3}(h)$ equation, Eq. (2.18), its numerical inconsistency of 0.00043% in pressure with respect to the basic equation $p_s(T)$, Eq. (2.13), has to be considered. Due to this minor inconsistency the result of the calculated pressure should be corrected to $p_{s,3} = p_{s,3}(h) (1 - \Delta p/p)$, where $\Delta p/p = 4.3 \times 10^{-6}$. This procedure ensures that (p, h) points extremely close to the two-phase region are correctly assigned to the single-phase region and not falsely to the two-phase region.

2.3.3.2 Backward Equation $T(p,h)$ for Region 1

Figure 2.6 shows the assignment of the backward equation $T_1(p,h)$ to region 1 in a p - h diagram. The boundaries of region 1 in p - h coordinates are described in Secs. 2.3.3.1a to 2.3.3.1c.

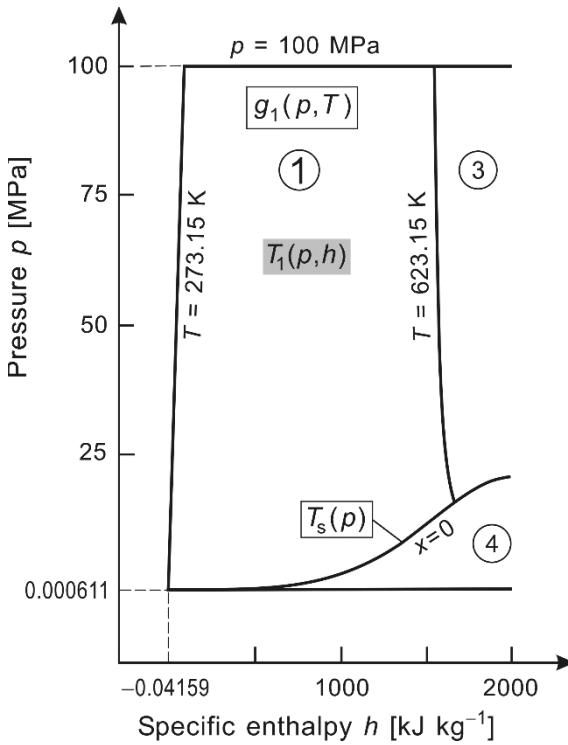


Fig. 2.6 Assignment of the backward equation $T_1(p,h)$ to region 1 in a p - h diagram. The p and h values at the corner points of region 1 are given in Fig. 2.5.

The backward equation $T_1(p,h)$ for region 1 has the following dimensionless form:

$$\frac{T_1(p,h)}{T^*} = \theta(\pi, \eta) = \sum_{i=1}^{20} n_i \pi^{I_i} (\eta + 1)^{J_i}, \quad (2.19)$$

where $\theta = T/T^*$, $\pi = p/p^*$, $\eta = h/h^*$ with $T^* = 1\text{ K}$, $p^* = 1\text{ MPa}$, and $h^* = 2500\text{ kJ kg}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.19) are listed in Table 2.31.

Table 2.31 Coefficients and exponents of the backward equation $T_1(p,h)$ in its dimensionless form, Eq. (2.19)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$-0.238\ 724\ 899\ 245\ 21 \times 10^3$	11	1	4	$-0.659\ 647\ 494\ 236\ 38 \times 10^1$
2	0	1	$0.404\ 211\ 886\ 379\ 45 \times 10^3$	12	1	10	$0.939\ 654\ 008\ 783\ 63 \times 10^{-2}$
3	0	2	$0.113\ 497\ 468\ 817\ 18 \times 10^3$	13	1	32	$0.115\ 736\ 475\ 053\ 40 \times 10^{-6}$
4	0	6	$-0.584\ 576\ 160\ 480\ 39 \times 10^1$	14	2	10	$-0.258\ 586\ 412\ 820\ 73 \times 10^{-4}$
5	0	22	$-0.152\ 854\ 824\ 131\ 40 \times 10^{-3}$	15	2	32	$-0.406\ 443\ 630\ 847\ 99 \times 10^{-8}$
6	0	32	$-0.108\ 667\ 076\ 953\ 77 \times 10^{-5}$	16	3	10	$0.664\ 561\ 861\ 916\ 35 \times 10^{-7}$
7	1	0	$-0.133\ 917\ 448\ 726\ 02 \times 10^2$	17	3	32	$0.806\ 707\ 341\ 030\ 27 \times 10^{-10}$
8	1	1	$0.432\ 110\ 391\ 835\ 59 \times 10^2$	18	4	32	$-0.934\ 777\ 712\ 139\ 47 \times 10^{-12}$
9	1	2	$-0.540\ 100\ 671\ 705\ 06 \times 10^2$	19	5	32	$0.582\ 654\ 420\ 206\ 01 \times 10^{-14}$
10	1	3	$0.305\ 358\ 922\ 039\ 16 \times 10^2$	20	6	32	$-0.150\ 201\ 859\ 535\ 03 \times 10^{-16}$

Range of Validity. The range of validity of the backward equation $T_1(p,h)$, Eq. (2.19), can be derived from the graphical representation of region 1 in Fig. 2.5. The determination of the h values for given p values along the region boundaries is described in Secs. 2.3.3.1a to 2.3.3.1c.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.19), Table 2.32 contains corresponding test values.

Numerical Consistency. The numerical inconsistency between the backward equation $T_1(p,h)$, Eq. (2.19), and the basic equation $g_1(p,T)$, Eq. (2.3), in comparison with the permissible inconsistency, given in Sec. 2.3.2, is listed in Table 2.33.

Note. When calculating properties in the range $p \leq p_s(623.15 \text{ K})$ and extremely close to the saturated-liquid line, Eq. (2.19) might yield temperatures $T_1(p,h) > T_s(p)$ due to the minor inconsistencies. In this case, the result of Eq. (2.19) must be corrected to $T_1 = T_s(p)$, where the saturation temperature $T_s(p)$ is calculated for the given pressure from Eq. (2.14).

Table 2.32 Temperature values calculated from the backward equation $T_1(p,h)$, Eq. (2.19), for selected pressures and specific enthalpies^a

p [MPa]	h [kJ kg ⁻¹]	T [K]
3	500	$0.391\ 798\ 509 \times 10^3$
80	500	$0.378\ 108\ 626 \times 10^3$
80	1500	$0.611\ 041\ 229 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Table 2.33 Maximum and root-mean-square inconsistency in temperature between the backward equation $T_1(p,h)$, Eq. (2.19), and the basic equation $g_1(p,T)$, Eq. (2.3), in comparison with the permissible inconsistency

Inconsistencies in temperature [mK]		
$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
25	23.6	13.4

Computing Time. The calculation of temperature as a function of (p,h) with the backward equation $T_1(p,h)$, Eq. (2.19), is about 25 times faster than when using only the basic equation $g_1(p,T)$, Eq. (2.3), [22]. In this comparison, the basic equation was applied in combination with a one-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirement that were set for the backward equation.

2.3.3.3 Backward Equations $T(p,h)$ for Region 2

The boundaries of region 2 in p - h coordinates are described in Secs. 2.3.3.1a to 2.3.3.1c. Due to the demand for very high numerical consistency between the basic equation $g_2(p,T)$, Eq. (2.6), and a backward equation $T(p,h)$ for region 2, given in Sec. 2.3.2, region 2 is divided into three subregions.

a) Division of Region 2 into Subregions 2a, 2b, and 2c

Figure 2.7 shows how region 2 is divided into three subregions for the backward equations $T(p,h)$. The boundary between subregions 2a and 2b is the isobar $p = 4 \text{ MPa}$, and the boundary between subregions 2b and 2c is described by the equation $h_{2bc}(p)$, Eq. (2.21).

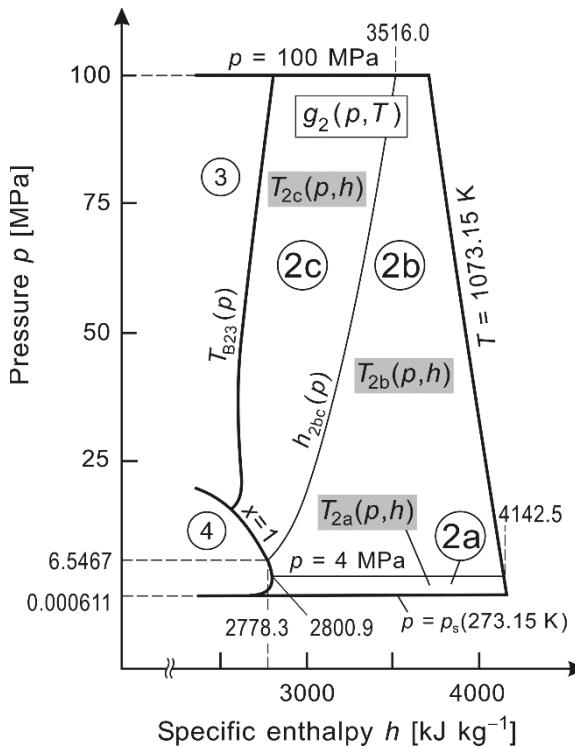


Fig. 2.7 Division of region 2 into subregions 2a, 2b, and 2c and the assignment of the backward equations $T(p, h)$ to these subregions. The p and h values at the corner points of region 2 are given in Fig. 2.5.

The equation for the boundary between subregions 2b and 2c is a simple quadratic pressure-enthalpy relation, which reads

$$\frac{p_{2bc}(h)}{p^*} = \pi(\eta) = n_1 + n_2 \eta + n_3 \eta^2, \quad (2.20)$$

where $\pi = p/p^*$ and $\eta = h/h^*$ with $p^* = 1 \text{ MPa}$ and $h^* = 1 \text{ kJ kg}^{-1}$. The coefficients n_1 to n_3 of Eq. (2.20) are listed in Table 2.34. Equation (2.20) approximately describes the isentropic line $s = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$; the entropy values corresponding to this p - h relation are between $s = 5.81 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and $s = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$. If the subregion determination is not carried out via the function $p(h)$ but via $h(p)$, Eq. (2.21) can be used, which is the enthalpy-explicit form of Eq. (2.20), namely

$$\frac{h_{2bc}(p)}{h^*} = \eta(\pi) = n_4 + \left[(\pi - n_5)/n_3 \right]^{0.5} \quad (2.21)$$

with η and π according to Eq. (2.20) and the coefficients n_3 to n_5 listed in Table 2.34. Equations (2.20) and (2.21) define the boundary line between subregions 2b and 2c from the saturation state at $p_s = 6.546\,699\,678 \text{ MPa}$ and $h'' = 2778.265\,753 \text{ kJ kg}^{-1}$ to $p = 100 \text{ MPa}$ and $h = 3516.004\,323 \text{ kJ kg}^{-1}$. Thus, the h value for the given p value along the boundary between subregions 2b and 2c can be directly calculated from the equation $h_{2bc}(p)$, Eq. (2.21). The given enthalpy value can then be compared with the calculated value for h .

Note. To be in accordance with the statements given in [16, 23], the boundary between subregions 2a and 2b is considered to belong to subregion 2a and the boundary between subregions 2b and 2c is considered to belong to subregion 2b.

Table 2.34 Coefficients of the subregion-boundary equations $p_{2bc}(h)$ and $h_{2bc}(p)$ in their dimensionless forms, Eqs. (2.20) and (2.21)

i	n_i	i	n_i
1	$0.905\ 842\ 785\ 147\ 23 \times 10^3$	4	$0.265\ 265\ 719\ 084\ 28 \times 10^4$
2	$-0.679\ 557\ 863\ 992\ 41$	5	$0.452\ 575\ 789\ 059\ 48 \times 10^1$
3	$0.128\ 090\ 027\ 301\ 36 \times 10^{-3}$		

Computer-Program Verification. For computer-program verification, Eqs. (2.20) and (2.21) must meet the following p - h point: $p = 0.100\ 000\ 000 \times 10^3$ MPa, $h = 0.351\ 600\ 432\ 3 \times 10^4$ kJ kg $^{-1}$.

b) The Backward Equations $T(p,h)$ for Subregions 2a, 2b, and 2c

The backward equation $T_{2a}(p,h)$ for **subregion 2a** in its dimensionless form reads

$$\frac{T_{2a}(p,h)}{T^*} = \theta(\pi, \eta) = \sum_{i=1}^{34} n_i \pi^{I_i} (\eta - 2.1)^{J_i}, \quad (2.22)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\eta = h/h^*$ with $T^* = 1$ K, $p^* = 1$ MPa, and $h^* = 2000$ kJ kg $^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.22) are listed in Table 2.35.

The backward equation $T_{2b}(p,h)$ for **subregion 2b** in its dimensionless form reads

$$\frac{T_{2b}(p,h)}{T^*} = \theta(\pi, \eta) = \sum_{i=1}^{38} n_i (\pi - 2)^{I_i} (\eta - 2.6)^{J_i}, \quad (2.23)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\eta = h/h^*$ with $T^* = 1$ K, $p^* = 1$ MPa, and $h^* = 2000$ kJ kg $^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.23) are listed in Table 2.36.

The backward equation $T_{2c}(p,h)$ for **subregion 2c** in its dimensionless form reads

$$\frac{T_{2c}(p,h)}{T^*} = \theta(\pi, \eta) = \sum_{i=1}^{23} n_i (\pi + 25)^{I_i} (\eta - 1.8)^{J_i}, \quad (2.24)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\eta = h/h^*$ with $T^* = 1$ K, $p^* = 1$ MPa, and $h^* = 2000$ kJ kg $^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.24) are listed in Table 2.37.

Table 2.35 Coefficients and exponents of the backward equation $T_{2a}(p,h)$ for subregion 2a in its dimensionless form, Eq. (2.22)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.108\ 989\ 523\ 182\ 88 \times 10^4$	18	2	7	$0.116\ 708\ 730\ 771\ 07 \times 10^2$
2	0	1	$0.849\ 516\ 544\ 955\ 35 \times 10^3$	19	2	36	$0.128\ 127\ 984\ 040\ 46 \times 10^9$
3	0	2	$-0.107\ 817\ 480\ 918\ 26 \times 10^3$	20	2	38	$-0.985\ 549\ 096\ 232\ 76 \times 10^9$
4	0	3	$0.331\ 536\ 548\ 012\ 63 \times 10^2$	21	2	40	$0.282\ 245\ 469\ 730\ 02 \times 10^{10}$
5	0	7	$-0.742\ 320\ 167\ 902\ 48 \times 10^1$	22	2	42	$-0.359\ 489\ 714\ 107\ 03 \times 10^{10}$
6	0	20	$0.117\ 650\ 487\ 243\ 56 \times 10^2$	23	2	44	$0.172\ 273\ 499\ 131\ 97 \times 10^{10}$
7	1	0	$0.184\ 457\ 493\ 557\ 90 \times 10^1$	24	3	24	$-0.135\ 513\ 342\ 407\ 75 \times 10^5$
8	1	1	$-0.417\ 927\ 005\ 496\ 24 \times 10^1$	25	3	44	$0.128\ 487\ 346\ 646\ 50 \times 10^8$
9	1	2	$0.624\ 781\ 969\ 358\ 12 \times 10^1$	26	4	12	$0.138\ 657\ 242\ 832\ 26 \times 10^1$

Continued on next page.

Table 2.35 – Continued

i	I_i	J_i	n_i	i	I_i	J_i	n_i
10	1	3	$-0.173\ 445\ 631\ 081\ 14 \times 10^2$	27	4	32	$0.235\ 988\ 325\ 565\ 14 \times 10^6$
11	1	7	$-0.200\ 581\ 768\ 620\ 96 \times 10^3$	28	4	44	$-0.131\ 052\ 365\ 450\ 54 \times 10^8$
12	1	9	$0.271\ 960\ 654\ 737\ 96 \times 10^3$	29	5	32	$0.739\ 998\ 354\ 747\ 66 \times 10^4$
13	1	11	$-0.455\ 113\ 182\ 858\ 18 \times 10^3$	30	5	36	$-0.551\ 966\ 970\ 300\ 60 \times 10^6$
14	1	18	$0.309\ 196\ 886\ 047\ 55 \times 10^4$	31	5	42	$0.371\ 540\ 859\ 962\ 33 \times 10^7$
15	1	44	$0.252\ 266\ 403\ 578\ 72 \times 10^6$	32	6	34	$0.191\ 277\ 292\ 396\ 60 \times 10^5$
16	2	0	$-0.617\ 074\ 228\ 683\ 39 \times 10^{-2}$	33	6	44	$-0.415\ 351\ 648\ 356\ 34 \times 10^6$
17	2	2	$-0.310\ 780\ 466\ 295\ 83$	34	7	28	$-0.624\ 598\ 551\ 925\ 07 \times 10^2$

Table 2.36 Coefficients and exponents of the backward equation $T_{2b}(p, h)$ for subregion 2b in its dimensionless form, Eq. (2.23)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.148\ 950\ 410\ 795\ 16 \times 10^4$	20	2	40	$0.712\ 803\ 519\ 595\ 51 \times 10^{-4}$
2	0	1	$0.743\ 077\ 983\ 140\ 34 \times 10^3$	21	3	1	$0.110\ 328\ 317\ 899\ 99 \times 10^{-3}$
3	0	2	$-0.977\ 083\ 187\ 978\ 37 \times 10^2$	22	3	2	$0.189\ 552\ 483\ 879\ 02 \times 10^{-3}$
4	0	12	$0.247\ 424\ 647\ 056\ 74 \times 10^1$	23	3	12	$0.308\ 915\ 411\ 605\ 37 \times 10^{-2}$
5	0	18	$-0.632\ 813\ 200\ 160\ 26$	24	3	24	$0.135\ 555\ 045\ 549\ 49 \times 10^{-2}$
6	0	24	$0.113\ 859\ 521\ 296\ 58 \times 10^1$	25	4	2	$0.286\ 402\ 374\ 774\ 56 \times 10^{-6}$
7	0	28	$-0.478\ 118\ 636\ 486\ 25$	26	4	12	$-0.107\ 798\ 573\ 575\ 12 \times 10^{-4}$
8	0	40	$0.852\ 081\ 234\ 315\ 44 \times 10^{-2}$	27	4	18	$-0.764\ 627\ 124\ 548\ 14 \times 10^{-4}$
9	1	0	$0.937\ 471\ 473\ 779\ 32$	28	4	24	$0.140\ 523\ 928\ 183\ 16 \times 10^{-4}$
10	1	2	$0.335\ 931\ 186\ 049\ 16 \times 10^1$	29	4	28	$-0.310\ 838\ 143\ 314\ 34 \times 10^{-4}$
11	1	6	$0.338\ 093\ 556\ 014\ 54 \times 10^1$	30	4	40	$-0.103\ 027\ 382\ 121\ 03 \times 10^{-5}$
12	1	12	$0.168\ 445\ 396\ 719\ 04$	31	5	18	$0.282\ 172\ 816\ 350\ 40 \times 10^{-6}$
13	1	18	$0.738\ 757\ 452\ 366\ 95$	32	5	24	$0.127\ 049\ 022\ 719\ 45 \times 10^{-5}$
14	1	24	$-0.471\ 287\ 374\ 361\ 86$	33	5	40	$0.738\ 033\ 534\ 682\ 92 \times 10^{-7}$
15	1	28	$0.150\ 202\ 731\ 397\ 07$	34	6	28	$-0.110\ 301\ 392\ 389\ 09 \times 10^{-7}$
16	1	40	$-0.217\ 641\ 142\ 197\ 50 \times 10^{-2}$	35	7	2	$-0.814\ 563\ 652\ 078\ 33 \times 10^{-13}$
17	2	2	$-0.218\ 107\ 553\ 247\ 61 \times 10^{-1}$	36	7	28	$-0.251\ 805\ 456\ 829\ 62 \times 10^{-10}$
18	2	8	$-0.108\ 297\ 844\ 036\ 77$	37	9	1	$-0.175\ 652\ 339\ 694\ 07 \times 10^{-17}$
19	2	18	$-0.463\ 333\ 246\ 358\ 12 \times 10^{-1}$	38	9	40	$0.869\ 341\ 563\ 441\ 63 \times 10^{-14}$

Table 2.37 Coefficients and exponents of the backward equation $T_{2c}(p, h)$ for subregion 2c in its dimensionless form, Eq. (2.24)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-7	0	$-0.323\ 683\ 985\ 552\ 42 \times 10^{13}$	13	1	4	$0.379\ 660\ 012\ 724\ 86 \times 10^1$
2	-7	4	$0.732\ 633\ 509\ 021\ 81 \times 10^{13}$	14	1	8	$-0.108\ 429\ 848\ 800\ 77 \times 10^2$
3	-6	0	$0.358\ 250\ 899\ 454\ 47 \times 10^{12}$	15	2	4	$-0.453\ 641\ 726\ 766\ 60 \times 10^{-1}$
4	-6	2	$-0.583\ 401\ 318\ 515\ 90 \times 10^{12}$	16	6	0	$0.145\ 591\ 156\ 586\ 98 \times 10^{-12}$
5	-5	0	$-0.107\ 830\ 682\ 174\ 70 \times 10^{11}$	17	6	1	$0.112\ 615\ 974\ 072\ 30 \times 10^{-11}$
6	-5	2	$0.208\ 255\ 445\ 631\ 71 \times 10^{11}$	18	6	4	$-0.178\ 049\ 822\ 406\ 86 \times 10^{-10}$
7	-2	0	$0.610\ 747\ 835\ 645\ 16 \times 10^6$	19	6	10	$0.123\ 245\ 796\ 908\ 32 \times 10^{-6}$
8	-2	1	$0.859\ 777\ 225\ 355\ 80 \times 10^6$	20	6	12	$-0.116\ 069\ 211\ 309\ 84 \times 10^{-5}$
9	-1	0	$-0.257\ 457\ 236\ 041\ 70 \times 10^5$	21	6	16	$0.278\ 463\ 670\ 885\ 54 \times 10^{-4}$
10	-1	2	$0.310\ 810\ 884\ 227\ 14 \times 10^5$	22	6	20	$-0.592\ 700\ 384\ 741\ 76 \times 10^{-3}$
11	0	0	$0.120\ 823\ 158\ 659\ 36 \times 10^4$	23	6	22	$0.129\ 185\ 829\ 918\ 78 \times 10^{-2}$
12	0	1	$0.482\ 197\ 551\ 092\ 55 \times 10^3$				

Ranges of Validity. The ranges of validity of the backward equations $T_{2a}(p, h)$, $T_{2b}(p, h)$ and $T_{2c}(p, h)$, Eqs. (2.22) to (2.24), can be derived from the graphical representation of region 2 in Fig. 2.5 and of subregions 2a, 2b, and 2c in Fig. 2.7. The determination of the h values for given p values along the region boundaries is described in Secs. 2.3.3.1a to 2.3.3.1c and along the subregion boundaries in Sec. 2.3.3.3a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.22) to (2.24), Table 2.38 contains corresponding test values.

Numerical Consistencies. The numerical inconsistencies between the backward equations $T_{2a}(p, h)$, $T_{2b}(p, h)$, and $T_{2c}(p, h)$, Eqs. (2.22) to (2.24), and the basic equation $g_2(p, T)$, Eq. (2.6), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.39.

Note. When calculating properties in the range $p \leq p_s(623.15 \text{ K})$ and extremely close to the saturated-vapour line, Eqs. (2.22) to (2.24) might yield temperatures $T_{2a}(p, h) < T_s(p)$, $T_{2b}(p, h) < T_s(p)$, and $T_{2c}(p, h) < T_s(p)$, respectively, due to the minor inconsistencies. In these cases, the results of Eqs. (2.22) to (2.24) must be corrected to $T_{2a} = T_s(p)$, $T_{2b} = T_s(p)$, and $T_{2c} = T_s(p)$, respectively, where the saturation temperature $T_s(p)$ is calculated for the given pressure from Eq. (2.14).

Table 2.38 Temperature values calculated from the backward equations $T_{2a}(p, h)$, $T_{2b}(p, h)$, and $T_{2c}(p, h)$, Eqs. (2.22) to (2.24), for selected pressures and specific enthalpies^a

Equation	p [MPa]	h [kJ kg ⁻¹]	T [K]
$T_{2a}(p, h)$, Eq. (2.22)	0.001	3000	$0.534\ 433\ 241 \times 10^3$
	3	3000	$0.575\ 373\ 370 \times 10^3$
	3	4000	$0.101\ 077\ 577 \times 10^4$
$T_{2b}(p, h)$, Eq. (2.23)	5	3500	$0.801\ 299\ 102 \times 10^3$
	5	4000	$0.101\ 531\ 583 \times 10^4$
	25	3500	$0.875\ 279\ 054 \times 10^3$
$T_{2c}(p, h)$, Eq. (2.24)	40	2700	$0.743\ 056\ 411 \times 10^3$
	60	2700	$0.791\ 137\ 067 \times 10^3$
	60	3200	$0.882\ 756\ 860 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Table 2.39 Maximum and root-mean-square inconsistencies in temperature between the backward equations $T_{2a}(p, h)$, $T_{2b}(p, h)$, and $T_{2c}(p, h)$, Eqs. (2.22) to (2.24), and the basic equation $g_2(p, T)$, Eq. (2.6), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in temperature [mK]		
		$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
2a	$T_{2a}(p, h)$, Eq. (2.22)	10	9.3	2.9
2b	$T_{2b}(p, h)$, Eq. (2.23)	10	9.6	3.9
2c	$T_{2c}(p, h)$, Eq. (2.24)	25	23.7	10.4

c) Computing Time when Using the Backward Equations $T(p,h)$ in Comparison with the Basic Equation

The calculation of temperature as a function of (p,h) with the backward equations $T_{2a}(p,h)$, $T_{2b}(p,h)$, or $T_{2c}(p,h)$, Eqs. (2.22) to (2.24), is about 11 times faster than when using only the basic equation $g_2(p,T)$, Eq. (2.6), [22]. In this comparison, the basic equation was applied in combination with a one-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were set for the backward equations.

2.3.3.4 Backward Equations $v(p,h)$ and $T(p,h)$ for Region 3

The boundaries of region 3 in p - h coordinates are described in Secs. 2.3.3.1a to 2.3.3.1c.

a) Division of Region 3 into Subregions 3a and 3b

Due to the demand for very high numerical consistency between the backward equations for this region and the basic equation $f_3(\rho,T)$, Eq. (2.11), as given in Sec. 2.3.2, region 3 is divided into two subregions as illustrated in Fig. 2.8.

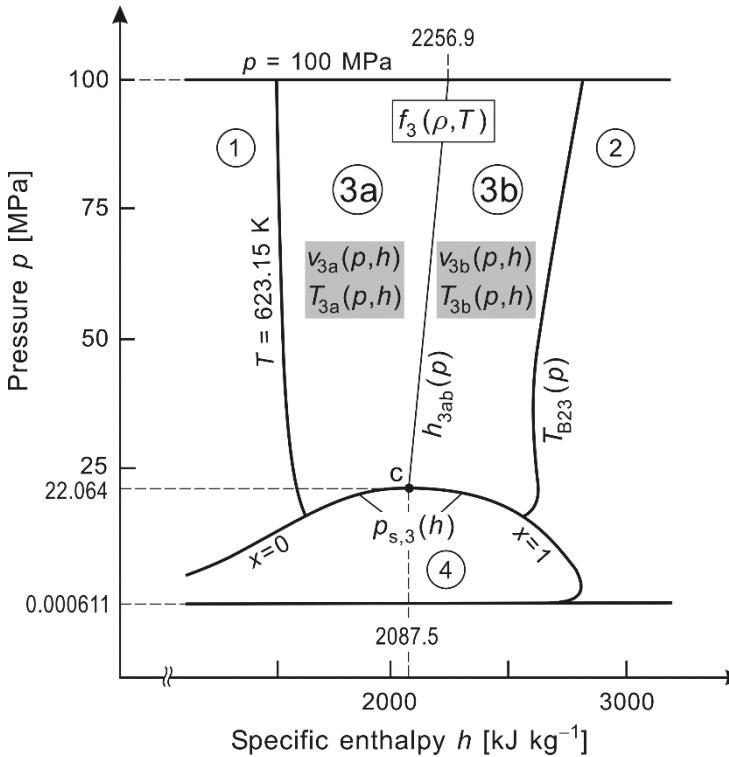


Fig. 2.8 Division of region 3 into subregions 3a and 3b, and the assignment of the backward equations $v(p,h)$ and $T(p,h)$ to these subregions. The p and h values at the corner points of region 3 are given in Fig. 2.5.

The boundary between subregions 3a and 3b is defined by the equation $h_{3ab}(p)$, which reads in its dimensionless form

$$\frac{h_{3ab}(p)}{h^*} = \eta(\pi) = n_1 + n_2 \pi + n_3 \pi^2 + n_4 \pi^3, \quad (2.25)$$

where $\eta = h/h^*$ and $\pi = p/p^*$ with $h^* = 1 \text{ kJ kg}^{-1}$ and $p^* = 1 \text{ MPa}$. The coefficients n_1 to n_4 of Eq. (2.25) are listed in Table 2.40. The equation $h_{3ab}(p)$ describes this subregion boundary

from the critical point ($p_c = 22.064 \text{ MPa}$, $h_c = 2087.546\ 845 \text{ kJ kg}^{-1}$) to 100 MPa at $h = 2256.927\ 860 \text{ kJ kg}^{-1}$. Equation (2.25) approximates the critical isentropic line $s = s_c$, Eq. (2.35), where the maximum deviation from this line amounts to $0.000\ 66 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The given enthalpy value can then be compared with the calculated value for h .

Table 2.40 Coefficients of the subregion-boundary equation $h_{3ab}(p)$ in its dimensionless form, Eq. (2.25), for defining the boundary between subregions 3a and 3b

i	n_i	i	n_i
1	$0.201\ 464\ 004\ 206\ 875 \times 10^4$	3	$-0.219\ 921\ 901\ 054\ 187 \times 10^{-1}$
2	$0.374\ 696\ 550\ 136\ 983 \times 10^1$	4	$0.875\ 131\ 686\ 009\ 950 \times 10^{-4}$

Note. The boundary between subregions 3a and 3b is considered to belong to subregion 3a [17, 24].

Computer-Program Verification. For computer-program verification, Eq. (2.25) yields the following p - h point: $p = 25 \text{ MPa}$, $h_{3ab}(p) = 2.095\ 936\ 454 \times 10^3 \text{ kJ kg}^{-1}$.

b) Backward Equations $v(p,h)$ for Subregions 3a and 3b

The backward equation $v_{3a}(p,h)$ for **subregion 3a** has the following dimensionless form:

$$\frac{v_{3a}(p,h)}{v^*} = \omega(\pi, \eta) = \sum_{i=1}^{32} n_i (\pi + 0.128)^{I_i} (\eta - 0.727)^{J_i}, \quad (2.26)$$

where $\omega = v/v^*$, $\pi = p/p^*$, and $\eta = h/h^*$ with $v^* = 0.0028 \text{ m}^3 \text{ kg}^{-1}$, $p^* = 100 \text{ MPa}$, and $h^* = 2100 \text{ kJ kg}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.26) are listed in Table 2.41.

The backward equation $v_{3b}(p,h)$ for **subregion 3b** has the following dimensionless form:

$$\frac{v_{3b}(p,h)}{v^*} = \omega(\pi, \eta) = \sum_{i=1}^{30} n_i (\pi + 0.0661)^{I_i} (\eta - 0.720)^{J_i}, \quad (2.27)$$

where $\omega = v/v^*$, $\pi = p/p^*$, and $\eta = h/h^*$ with $v^* = 0.0088 \text{ m}^3 \text{ kg}^{-1}$, $p^* = 100 \text{ MPa}$, and $h^* = 2800 \text{ kJ kg}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.27) are listed in Table 2.42.

Table 2.41 Coefficients and exponents of the backward equation $v_{3a}(p,h)$ for subregion 3a in its dimensionless form, Eq. (2.26)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	6	$0.529\ 944\ 062\ 966\ 028 \times 10^{-2}$	17	-2	16	$0.568\ 366\ 875\ 815\ 960 \times 10^4$
2	-12	8	-0.170 099 690 234 461	18	-1	0	$0.808\ 169\ 540\ 124\ 668 \times 10^{-2}$
3	-12	12	$0.111\ 323\ 814\ 312\ 927 \times 10^2$	19	-1	1	0.172 416 341 519 307
4	-12	18	$-0.217\ 898\ 123\ 145\ 125 \times 10^4$	20	-1	2	$0.104\ 270\ 175\ 292\ 927 \times 10^1$
5	-10	4	$-0.506\ 061\ 827\ 980\ 875 \times 10^{-3}$	21	-1	3	-0.297 691 372 792 847
6	-10	7	0.556 495 239 685 324	22	0	0	0.560 394 465 163 593
7	-10	10	$-0.943\ 672\ 726\ 094\ 016 \times 10^1$	23	0	1	0.275 234 661 176 914
8	-8	5	-0.297 856 807 561 527	24	1	0	-0.148 347 894 866 012
9	-8	12	$0.939\ 353\ 943\ 717\ 186 \times 10^2$	25	1	1	$-0.651\ 142\ 513\ 478\ 515 \times 10^{-1}$

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Table 2.41 – Continued

i	I_i	J_i	n_i	i	I_i	J_i	n_i
10	-6	3	$0.192\ 944\ 939\ 465\ 981 \times 10^{-1}$	26	1	2	$-0.292\ 468\ 715\ 386\ 302 \times 10^1$
11	-6	4	0.421 740 664 704 763	27	2	0	$0.664\ 876\ 096\ 952\ 665 \times 10^{-1}$
12	-6	22	$-0.368\ 914\ 126\ 282\ 330 \times 10^7$	28	2	2	$0.352\ 335\ 014\ 263\ 844 \times 10^1$
13	-4	2	$-0.737\ 566\ 847\ 600\ 639 \times 10^{-2}$	29	3	0	$-0.146\ 340\ 792\ 313\ 332 \times 10^{-1}$
14	-4	3	-0.354 753 242 424 366	30	4	2	$-0.224\ 503\ 486\ 668\ 184 \times 10^1$
15	-3	7	$-0.199\ 768\ 169\ 338\ 727 \times 10^1$	31	5	2	$0.110\ 533\ 464\ 706\ 142 \times 10^1$
16	-2	3	$0.115\ 456\ 297\ 059\ 049 \times 10^1$	32	8	2	$-0.408\ 757\ 344\ 495\ 612 \times 10^{-1}$

Table 2.42 Coefficients and exponents of the backward equation $v_{3b}(p, h)$ for subregion 3b in its dimensionless form, Eq. (2.27)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	0	$-0.225\ 196\ 934\ 336\ 318 \times 10^{-8}$	16	-4	6	$-0.321\ 087\ 965\ 668\ 917 \times 10^1$
2	-12	1	0.140 674 363 313 486 $\times 10^{-7}$	17	-4	10	$0.607\ 567\ 815\ 637\ 771 \times 10^3$
3	-8	0	$0.233\ 784\ 085\ 280\ 560 \times 10^{-5}$	18	-3	0	$0.557\ 686\ 450\ 685\ 932 \times 10^{-3}$
4	-8	1	$-0.331\ 833\ 715\ 229\ 001 \times 10^{-4}$	19	-3	2	0.187 499 040 029 550
5	-8	3	0.107 956 778 514 318 $\times 10^{-2}$	20	-2	1	$0.905\ 368\ 030\ 448\ 107 \times 10^{-2}$
6	-8	6	-0.271 382 067 378 863	21	-2	2	0.285 417 173 048 685
7	-8	7	$0.107\ 202\ 262\ 490\ 333 \times 10^1$	22	-1	0	$0.329\ 924\ 030\ 996\ 098 \times 10^{-1}$
8	-8	8	-0.853 821 329 075 382	23	-1	1	0.239 897 419 685 483
9	-6	0	$-0.215\ 214\ 194\ 340\ 526 \times 10^{-4}$	24	-1	4	$0.482\ 754\ 995\ 951\ 394 \times 10^1$
10	-6	1	0.769 656 088 222 730 $\times 10^{-3}$	25	-1	5	$-0.118\ 035\ 753\ 702\ 231 \times 10^2$
11	-6	2	$-0.431\ 136\ 580\ 433\ 864 \times 10^{-2}$	26	0	0	0.169 490 044 091 791
12	-6	5	0.453 342 167 309 331	27	1	0	$-0.179\ 967\ 222\ 507\ 787 \times 10^{-1}$
13	-6	6	-0.507 749 535 873 652	28	1	1	$0.371\ 810\ 116\ 332\ 674 \times 10^{-1}$
14	-6	10	$-0.100\ 475\ 154\ 528\ 389 \times 10^3$	29	2	2	$-0.536\ 288\ 335\ 065\ 096 \times 10^{-1}$
15	-4	3	-0.219 201 924 648 793	30	2	6	$0.160\ 697\ 101\ 092\ 520 \times 10^1$

Ranges of Validity. The ranges of validity of the backward equations $v_{3a}(p, h)$ and $v_{3b}(p, h)$, Eqs. (2.26) and (2.27), can be derived from the graphical representation of region 3 in Fig. 2.5 and of subregions 3a and 3b in Fig. 2.8. The determination of the h values for given p values along the region boundaries is described in Secs. 2.3.3.1a to 2.3.3.1c and along the subregion boundary in Sec. 2.3.3.4a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.26) and (2.27), Table 2.43 contains test values for calculated specific volumes.

Table 2.43 Values of the specific volume calculated from the backward equations $v_{3a}(p, h)$ and $v_{3b}(p, h)$ in their dimensionless form, Eqs. (2.26) and (2.27), for selected pressures and specific enthalpies^a

Equation	p [MPa]	h [kJ kg $^{-1}$]	v [m 3 kg $^{-1}$]
$v_{3a}(p, h)$, Eq. (2.26)	20	1700	$1.749\ 903\ 962 \times 10^{-3}$
	50	2000	$1.908\ 139\ 035 \times 10^{-3}$
	100	2100	$1.676\ 229\ 776 \times 10^{-3}$
$v_{3b}(p, h)$, Eq. (2.27)	20	2500	$6.670\ 547\ 043 \times 10^{-3}$
	50	2400	$2.801\ 244\ 590 \times 10^{-3}$
	100	2700	$2.404\ 234\ 998 \times 10^{-3}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Numerical Consistencies. The numerical inconsistencies between the backward equations $v_{3a}(p, h)$ and $v_{3b}(p, h)$, Eqs. (2.26) and (2.27), and the basic equation $f_3(\rho, T)$, Eq. (2.11), are listed in Table 2.44 in comparison with the permissible inconsistencies given in Sec. 2.3.2. These inconsistencies are less than the permissible values. This is also true when the backward equations are used in combination with the boundary equation $p_{s,3}(h)$, Eq. (2.18). The critical volume $v_c = 1/\rho_c = (1/322) \text{ m}^3 \text{ kg}^{-1} = 0.003\ 105\ 59 \text{ m}^3 \text{ kg}^{-1}$ is calculated by the two $v(p, h)$ equations for the given six significant figures. The maximum inconsistency in specific volume between the two backward equations, Eq. (2.26) and Eq. (2.27), along the subregion boundary $h_{3ab}(p)$, Eq. (2.25), amounts to 0.000 15%, which is within the permissible inconsistency given in Sec. 2.3.2.

Table 2.44 Maximum and root-mean-square inconsistencies in specific volume between the backward equations $v_{3a}(p, h)$ and $v_{3b}(p, h)$, Eqs. (2.26) and (2.27), and the basic equation $f_3(\rho, T)$, Eq. (2.11), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in specific volume [%]		
		$ \Delta v/v _{\text{perm}}$	$ \Delta v/v _{\text{max}}$	$(\Delta v/v)_{\text{RMS}}$
3a	$v_{3a}(p, h)$, Eq. (2.26)	0.01	0.0080	0.0032
3b	$v_{3b}(p, h)$, Eq. (2.27)	0.01	0.0095	0.0042

Computing Time. A statement about the computing time is given in Sec. 2.3.3.4d.

c) Backward Equations $T(p, h)$ for Subregions 3a and 3b

The backward equation $T_{3a}(p, h)$ for **subregion 3a** has the following dimensionless form:

$$\frac{T_{3a}(p, h)}{T^*} = \theta(\pi, \eta) = \sum_{i=1}^{31} n_i (\pi + 0.240)^{I_i} (\eta - 0.615)^{J_i}, \quad (2.28)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\eta = h/h^*$ with $T^* = 760 \text{ K}$, $p^* = 100 \text{ MPa}$, and $h^* = 2300 \text{ kJ kg}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.28) are listed in Table 2.45.

The backward equation $T_{3b}(p, h)$ for **subregion 3b** has the following dimensionless form:

$$\frac{T_{3b}(p, h)}{T^*} = \theta(\pi, \eta) = \sum_{i=1}^{33} n_i (\pi + 0.298)^{I_i} (\eta - 0.720)^{J_i}, \quad (2.29)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\eta = h/h^*$ with $T^* = 860 \text{ K}$, $p^* = 100 \text{ MPa}$, and $h^* = 2800 \text{ kJ kg}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.29) are listed in Table 2.46.

Table 2.45 Coefficients and exponents of the backward equation $T_{3a}(p, h)$ for subregion 3a in its dimensionless form, Eq. (2.28)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	0	$-0.133\ 645\ 667\ 811\ 215 \times 10^{-6}$	17	-3	0	$-0.384\ 460\ 997\ 596\ 657 \times 10^{-5}$
2	-12	1	$0.455\ 912\ 656\ 802\ 978 \times 10^{-5}$	18	-2	1	$0.337\ 423\ 807\ 911\ 655 \times 10^{-2}$
3	-12	2	$-0.146\ 294\ 640\ 700\ 979 \times 10^{-4}$	19	-2	3	$-0.551\ 624\ 873\ 066\ 791$
4	-12	6	$0.639\ 341\ 312\ 970\ 080 \times 10^{-2}$	20	-2	4	$0.729\ 202\ 277\ 107\ 470$
5	-12	14	$0.372\ 783\ 927\ 268\ 847 \times 10^3$	21	-1	0	$-0.992\ 522\ 757\ 376\ 041 \times 10^{-2}$
6	-12	16	$-0.718\ 654\ 377\ 460\ 447 \times 10^4$	22	-1	2	$-0.119\ 308\ 831\ 407\ 288$
7	-12	20	$0.573\ 494\ 752\ 103\ 400 \times 10^6$	23	0	0	$0.793\ 929\ 190\ 615\ 421$
8	-12	22	$-0.267\ 569\ 329\ 111\ 439 \times 10^7$	24	0	1	$0.454\ 270\ 731\ 799\ 386$
9	-10	1	$-0.334\ 066\ 283\ 302\ 614 \times 10^{-4}$	25	1	1	$0.209\ 998\ 591\ 259\ 910$
10	-10	5	$-0.245\ 479\ 214\ 069\ 597 \times 10^{-1}$	26	3	0	$-0.642\ 109\ 823\ 904\ 738 \times 10^{-2}$
11	-10	12	$0.478\ 087\ 847\ 764\ 996 \times 10^2$	27	3	1	$-0.235\ 155\ 868\ 604\ 540 \times 10^{-1}$
12	-8	0	$0.764\ 664\ 131\ 818\ 904 \times 10^{-5}$	28	4	0	$0.252\ 233\ 108\ 341\ 612 \times 10^{-2}$
13	-8	2	$0.128\ 350\ 627\ 676\ 972 \times 10^{-2}$	29	4	3	$-0.764\ 885\ 133\ 368\ 119 \times 10^{-2}$
14	-8	4	$0.171\ 219\ 081\ 377\ 331 \times 10^{-1}$	30	10	4	$0.136\ 176\ 427\ 574\ 291 \times 10^{-1}$
15	-8	10	$-0.851\ 007\ 304\ 583\ 213 \times 10^1$	31	12	5	$-0.133\ 027\ 883\ 575\ 669 \times 10^{-1}$
16	-5	2	$-0.136\ 513\ 461\ 629\ 781 \times 10^{-1}$				

Table 2.46 Coefficients and exponents of the backward equation $T_{3b}(p, h)$ for subregion 3b in its dimensionless form, Eq. (2.29)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	0	$0.323\ 254\ 573\ 644\ 920 \times 10^{-4}$	18	-3	5	$-0.307\ 622\ 221\ 350\ 501 \times 10^1$
2	-12	1	$-0.127\ 575\ 556\ 587\ 181 \times 10^{-3}$	19	-2	0	$-0.574\ 011\ 959\ 864\ 879 \times 10^{-1}$
3	-10	0	$-0.475\ 851\ 877\ 356\ 068 \times 10^{-3}$	20	-2	4	$0.503\ 471\ 360\ 939\ 849 \times 10^1$
4	-10	1	$0.156\ 183\ 014\ 181\ 602 \times 10^{-2}$	21	-1	2	$-0.925\ 081\ 888\ 584\ 834$
5	-10	5	$0.105\ 724\ 860\ 113\ 781$	22	-1	4	$0.391\ 733\ 882\ 917\ 546 \times 10^1$
6	-10	10	$-0.858\ 514\ 221\ 132\ 534 \times 10^2$	23	-1	6	$-0.773\ 146\ 007\ 130\ 190 \times 10^2$
7	-10	12	$0.724\ 140\ 095\ 480\ 911 \times 10^3$	24	-1	10	$0.949\ 308\ 762\ 098\ 587 \times 10^4$
8	-8	0	$0.296\ 475\ 810\ 273\ 257 \times 10^{-2}$	25	-1	14	$-0.141\ 043\ 719\ 679\ 409 \times 10^7$
9	-8	1	$-0.592\ 721\ 983\ 365\ 988 \times 10^{-2}$	26	-1	16	$0.849\ 166\ 230\ 819\ 026 \times 10^7$
10	-8	2	$-0.126\ 305\ 422\ 818\ 666 \times 10^{-1}$	27	0	0	$0.861\ 095\ 729\ 446\ 704$
11	-8	4	$-0.115\ 716\ 196\ 364\ 853$	28	0	2	$0.323\ 346\ 442\ 811\ 720$
12	-8	10	$0.849\ 000\ 969\ 739\ 595 \times 10^2$	29	1	1	$0.873\ 281\ 936\ 020\ 439$
13	-6	0	$-0.108\ 602\ 260\ 086\ 615 \times 10^{-1}$	30	3	1	$-0.436\ 653\ 048\ 526\ 683$
14	-6	1	$0.154\ 304\ 475\ 328\ 851 \times 10^{-1}$	31	5	1	$0.286\ 596\ 714\ 529\ 479$
15	-6	2	$0.750\ 455\ 441\ 524\ 466 \times 10^{-1}$	32	6	1	$-0.131\ 778\ 331\ 276\ 228$
16	-4	0	$0.252\ 520\ 973\ 612\ 982 \times 10^{-1}$	33	8	1	$0.676\ 682\ 064\ 330\ 275 \times 10^{-2}$
17	-4	1	$-0.602\ 507\ 901\ 232\ 996 \times 10^{-1}$				

Ranges of Validity. The ranges of validity of the backward equations $T_{3a}(p, h)$ and $T_{3b}(p, h)$, Eqs. (2.28) and (2.29), can be derived from the graphical representation of region 3 in Fig. 2.5 and of subregions 3a and 3b in Fig. 2.8. The determination of the h values for given p values along the region boundaries and the subregion boundary is described in Secs. 2.3.3.1a to 2.3.3.1c and in Sec. 2.3.3.4a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.28) and (2.29), Table 2.47 contains test values for calculated temperatures.

Table 2.47 Temperature values calculated from the backward equations $T_{3a}(p, h)$ and $T_{3b}(p, h)$, Eqs. (2.28) and (2.29), for selected pressures and specific enthalpies^a

Equation	p [MPa]	h [kJ kg ⁻¹]	T [K]
$T_{3a}(p, h)$, Eq. (2.28)	20	1700	$6.293\ 083\ 892 \times 10^2$
	50	2000	$6.905\ 718\ 338 \times 10^2$
	100	2100	$7.336\ 163\ 014 \times 10^2$
$T_{3b}(p, h)$, Eq. (2.29)	20	2500	$6.418\ 418\ 053 \times 10^2$
	50	2400	$7.351\ 848\ 618 \times 10^2$
	100	2700	$8.420\ 460\ 876 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Numerical Consistencies. The numerical inconsistencies between the backward equations $T_{3a}(p, h)$ and $T_{3b}(p, h)$, Eqs. (2.28) and (2.29), and the basic equation $f_3(\rho, T)$, Eq. (2.11), are listed in Table 2.48 in comparison with the permissible inconsistencies given in Sec. 2.3.2. These inconsistencies are less than the permissible values. This is also true when the backward equations are used in combination with the boundary equation $p_{s,3}(h)$, Eq. (2.18). The critical temperature $T_c = 647.096$ K is calculated using the two $T(p, h)$ equations for all six figures. The maximum temperature difference between the two backward equations, Eq. (2.28) and Eq. (2.29), along the subregion boundary $h_{3ab}(p)$, Eq. (2.25), amounts to 0.37 mK. All of these inconsistency values are within the permissible values given in Sec. 2.3.2.

Note. When calculating properties in the range $p \leq p_c$ and extremely close to the saturation lines, Eq. (2.28) might yield temperatures $T_{3a}(p, h) > T_s(p)$ and Eq. (2.29) might yield temperatures $T_{3b}(p, h) < T_s(p)$ due to the minor inconsistencies. In these cases, the results of Eqs. (2.28) and (2.29) must be corrected to $T_{3a} = T_s(p)$ and $T_{3b} = T_s(p)$, respectively, where the saturation temperature $T_s(p)$ is calculated from Eq. (2.14) for the given pressure.

Table 2.48 Maximum and root-mean-square inconsistencies in temperature between the backward equations $T_{3a}(p, h)$ and $T_{3b}(p, h)$, Eqs. (2.28) and (2.29), and the basic equation $f_3(\rho, T)$, Eq. (2.11), in comparison with the permissible values

Subregion	Equation	Inconsistencies in temperature [mK]		
		$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
3a	$T_{3a}(p, h)$, Eq. (2.28)	25	23.6	10.5
3b	$T_{3b}(p, h)$, Eq. (2.29)	25	19.6	9.6

d) Computing Time when Using the Backward Equations $T(p, h)$ and $v(p, h)$ in Comparison with the Basic Equation

The calculation of specific volume and temperature as a function of (p, h) with the backward equations $v_{3a}(p, h)$ and $T_{3a}(p, h)$, Eqs. (2.26) and (2.28), or $v_{3b}(p, h)$ and $T_{3b}(p, h)$, Eqs. (2.27) and (2.29), is about 14 times faster than when using only the basic equation $f_3(\rho, T)$, Eq. (2.11), [22]. In this comparison, the basic equation was applied in combination with a two-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were set for the backward equations.

2.3.4 Backward Equations as a Function of the Input Variables (p, s)

In this section, all of the backward equations as a function of (p, s) are summarized. These are the backward equations $T(p, s)$ for regions 1 to 3 and the backward equations $v(p, s)$ for region 3. When these equations are combined with the basic equations for regions 1 to 4, all properties that are dependent on (p, s) can be calculated without iteration in the four regions.

The backward equations for regions 1 and 2 were developed and adopted together with the basic equations of IAPWS-IF97 [13, 15], whereas the backward equations for region 3 were developed later [17], adopted by IAPWS in 2004, and slightly revised in 2014 [24].

2.3.4.1 Regions and Region Boundaries in the Variables (p, s)

Figure 2.9 shows the regions and region boundaries in a pressure-entropy diagram along with the assignment of the backward equations $T(p, s)$ and $v(p, s)$ to regions 1 to 3. In order to avoid any iteration in practical calculations with IAPWS-IF97, the region boundaries must also be determinable without iteration. Therefore, a saturation-pressure equation as a function of entropy, $p_{s,3}(s)$, for the saturated-liquid and saturated-vapour lines between regions 3 and 4, was developed [17, 24], and is given as Eq. (2.30).

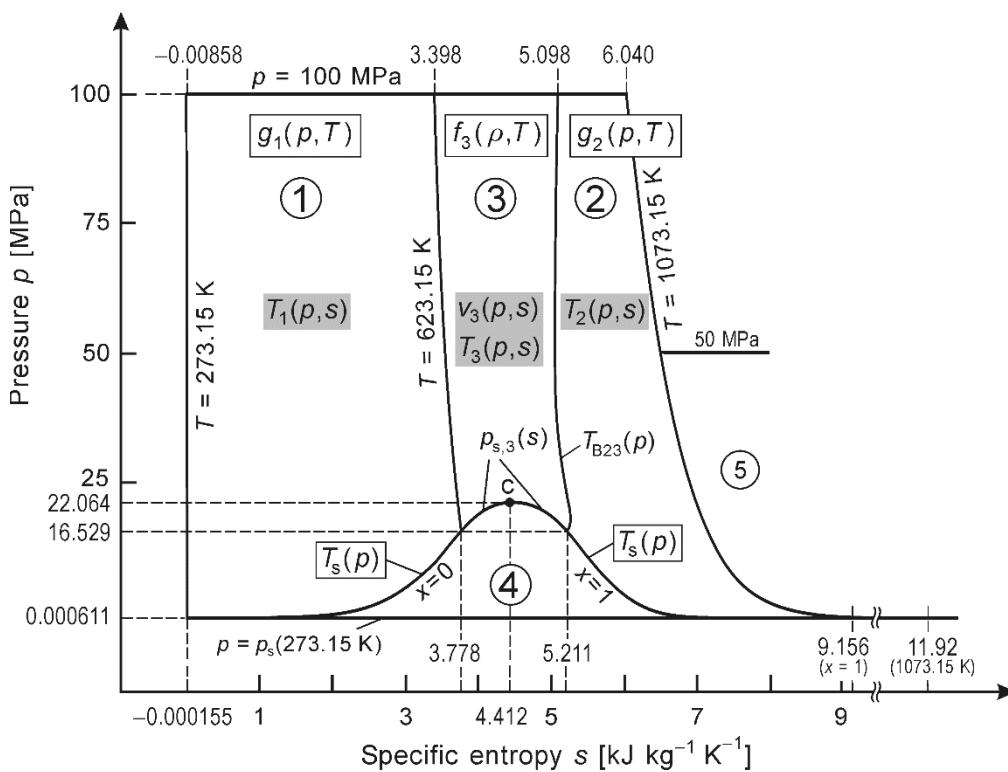


Fig. 2.9 Regions and region boundaries of IAPWS-IF97 for the variables (p, s) . Assignment of the backward equations $T(p, s)$ and $v(p, s)$ to these regions, (without showing how regions 2 and 3 will be divided into subregions). The p and s values at the corner points of the region boundaries are rounded values.

When property calculations with IAPWS-IF97 are carried out with the variables (p, s) as input variables, all tests to determine whether the given (p, s) point is within the range of regions 1 to 4 of IAPWS-IF97 and, if so, in which region, must be performed with respect to these input variables. To make such tests easier, the following subsections show which equations are used to calculate the s values for given p values (or vice versa) along the respective region boundaries. These explanations are based on Fig. 2.9. Thus, Fig. 2.9 along with the description of the region boundaries given in Secs. 2.3.4.1a to 2.3.4.1c can be regarded as definitions of regions 1 to 4 of IAPWS-IF97 in the variables p and s .

a) Outer Boundaries of Regions 1 to 4

The description of the boundaries starts at the left-hand side of Fig. 2.9 with the isotherm $T = 273.15$ K and proceeds clockwise.

The Isotherm $T = 273.15$ K. This isotherm corresponds to the lowest temperature limit of IAPWS-IF97 and covers the pressure range given by

$$p_s(273.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

where p_s is calculated from the saturation-pressure equation $p_s(T)$, Eq. (2.13). Along this isotherm, the s value for the given p value is calculated from the basic equation of region 1, $g_1(p, T)$, Eq. (2.3), with $T = 273.15$ K. If the specific entropy s of a given (p, s) point is less than $s_1(p, 273.15 \text{ K})$, then the (p, s) point is outside the range of validity of IAPWS-IF97, see Fig. 2.9.

The Isobar $p = 100$ MPa. This isobar is the upper pressure limit of the range of validity of IAPWS-IF97 (except for region 5). If the given pressure p is greater than 100 MPa, then the (p, s) point is outside the range of validity of IAPWS-IF97.

The Isotherm $T = 1073.15$ K. This isotherm corresponds to the upper temperature limit of IAPWS-IF97 (except for region 5) and covers the range of pressure

$$p_s(273.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

where p_s is calculated from the equation $p_s(T)$, Eq. (2.13). On this isotherm, the s value for the given p value is calculated from the basic equation of region 2, $g_2(p, T)$, Eq. (2.6), with $T = 1073.15$ K. If the specific entropy s of the given (p, s) point is greater than $s_2(p, 1073.15 \text{ K})$ for the given pressure p , then the (p, s) point is outside the range of IAPWS-IF97 for which the backward equations exist, see Fig. 2.9.

The Isobar $p = p_s(273.15 \text{ K}) = 0.000\ 611\ 212\ 677$ MPa. This saturation pressure p_s is calculated from the equation $p_s(T)$, Eq. (2.13), and is the lower pressure limit of the range of validity of the IAPWS-IF97 backward equations. If the given pressure p is lower than $p = 0.000\ 611\ 212\ 677$ MPa, then the (p, s) point is outside the range of validity of the backward equations, see Fig. 2.9.

b) Boundary between the Single-Phase Regions 1 to 3 and the Two-Phase Region 4

According to Fig. 2.9, the boundary between the single-phase regions 1 to 3 and the two-phase region 4 is given by the saturated-liquid line ($x = 0$) and the saturated-vapour line ($x = 1$).

Boundary between Regions 1 and 4. The part of the saturated-liquid line ($x = 0$) that forms the boundary between regions 1 and 4 covers a range of pressures given by

$$p_s(273.15 \text{ K}) \leq p \leq p_s(623.15 \text{ K}),$$

see Fig. 2.9; the p_s values are calculated from the equation $p_s(T)$, Eq. (2.13). Along this boundary, the s value for the given p value is calculated from the basic equation $g_1(p, T)$, Eq. (2.3), where

$T = T_s$ results from the saturation-temperature equation $T_s(p)$, Eq. (2.14). The given entropy value can then be compared with the calculated value for s .

Boundary between Regions 3 and 4. The part of the saturated-liquid line and the saturated-vapour line that forms the boundary between regions 3 and 4 is given by the entropy range

$$s'(623.15 \text{ K}) \leq s \leq s''(623.15 \text{ K})$$

with $s'(623.15 \text{ K}) = s_1(p_s(623.15 \text{ K}), 623.15 \text{ K})$
and $s''(623.15 \text{ K}) = s_2(p_s(623.15 \text{ K}), 623.15 \text{ K})$,

where p_s is calculated from Eq. (2.13). In this relation, s_1 is calculated from the basic equation $g_1(p, T)$, Eq. (2.3), with $p = p_s(T)$ and $T = 623.15 \text{ K}$. The entropy s_2 results from the basic equation $g_2(p, T)$, Eq. (2.6), for $p = p_s(T)$ and $T = 623.15 \text{ K}$. The reason for calculating the entropies s_1 and s_2 at these corner points from the basic equations of regions 1 and 2, $g_1(p, T)$ and $g_2(p, T)$, Eqs. (2.3) and (2.6), and not from the basic equation for region 3, $f_3(\rho, T)$, Eq. (2.11), is given at the beginning of Sec. 2.3.4.1c. Along this boundary, the p value for the given s value is calculated from the special saturation-pressure equation as a function of entropy, $p_{s,3}(s)$, which is given in Sec. 2.3.4.1d as Eq. (2.30). The given pressure value can then be compared with the calculated value for p .

Boundary between Regions 2 and 4. The part of the saturated-vapour line ($x = 1$) that forms the boundary between regions 2 and 4 covers the pressure range

$$p_s(273.15 \text{ K}) \leq p \leq p_s(623.15 \text{ K}),$$

see Fig. 2.9; the p_s values are calculated from the equation $p_s(T)$, Eq. (2.13). Along this boundary, the s value for the given p value is determined from the basic equation $g_2(p, T)$, Eq. (2.6), where $T = T_s$ is obtained from the saturation-temperature equation $T_s(p)$, Eq. (2.14). The given entropy value can then be compared with the calculated value for s .

c) Boundaries between the Single-Phase Regions

The boundaries between regions 1 and 3 ($T = 623.15 \text{ K}$) and between regions 2 and 3 (T_{B23} -line) belong to both adjacent regions, see Figs. 2.2 and 2.9. However, in order to avoid having different values along these boundaries, the boundary between regions 1 and 2 is considered to belong to region 1 and the boundary between regions 2 and 3 is considered to belong to region 2. Thus, the properties along the boundary between regions 1 and 3 are calculated from the basic equation for region 1 and the properties along the boundary between regions 2 and 3 are determined from the basic equation for region 2. In this way, the calculations can be performed directly, neither iteration nor additional use of any backward equation is required.

Boundary between Regions 1 and 3. The boundary that corresponds to the isotherm $T = 623.15 \text{ K}$ covers the pressure range

$$p_s(623.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

see Fig. 2.9; p_s is calculated from Eq. (2.13). Along this boundary, the s value for the given p value results from the basic equation $g_1(p, T)$, Eq. (2.3), with $T = 623.15 \text{ K}$. The given entropy value can then be compared with the calculated value for s .

Boundary between Regions 2 and 3. This boundary, namely the T_{B23} -line, covers the pressure range

$$p_s(623.15 \text{ K}) \leq p \leq 100 \text{ MPa},$$

see Fig. 2.9; p_s is determined from Eq. (2.13). Along this boundary, the s value for the given p value is calculated from the basic equation $g_2(p, T)$, Eq. (2.6), with $T = T_{B23}$ determined from the equation $T_{B23}(p)$, Eq. (2.2). The given entropy value can then be compared with the calculated value for s .

d) The Boundary Equation $p_{s,3}(s)$

The boundary equation $p_{s,3}(s)$ has the following dimensionless form:

$$\frac{p_{s,3}(s)}{p^*} = \pi(\sigma) = \sum_{i=1}^{10} n_i (\sigma - 1.03)^{I_i} (\sigma - 0.699)^{J_i}, \quad (2.30)$$

where $\pi = p/p^*$ and $\sigma = s/s^*$ with $p^* = 22 \text{ MPa}$ and $s^* = 5.2 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.30) are listed in Table 2.49.

Table 2.49 Coefficients and exponents of the boundary equation $p_{s,3}(s)$ in its dimensionless form, Eq. (2.30)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	0.639 767 553 612 785	6	12	14	$-0.378\ 829\ 107\ 169\ 011 \times 10^{18}$
2	1	1	$-0.129\ 727\ 445\ 396\ 014 \times 10^2$	7	16	36	$-0.955\ 586\ 736\ 431\ 328 \times 10^{35}$
3	1	32	$-0.224\ 595\ 125\ 848\ 403 \times 10^{16}$	8	24	10	$0.187\ 269\ 814\ 676\ 188 \times 10^{24}$
4	4	7	$0.177\ 466\ 741\ 801\ 846 \times 10^7$	9	28	0	$0.119\ 254\ 746\ 466\ 473 \times 10^{12}$
5	12	4	$0.717\ 079\ 349\ 571\ 538 \times 10^{10}$	10	32	18	$0.110\ 649\ 277\ 244\ 882 \times 10^{37}$

The equation $p_{s,3}(s)$, Eq. (2.30), describes the saturated-liquid line and the saturated-vapour line including the critical point in the following entropy range (see Fig. 2.9):

$$s'(623.15 \text{ K}) \leq s \leq s''(623.15 \text{ K}),$$

where $s'(623.15 \text{ K}) = s_1(p_s(623.15 \text{ K}), 623.15 \text{ K}) = 3.778\ 281\ 340 \text{ kJ kg}^{-1} \text{ K}^{-1}$

and $s''(623.15 \text{ K}) = s_2(p_s(623.15 \text{ K}), 623.15 \text{ K}) = 5.210\ 887\ 825 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.30), Table 2.50 contains test values for calculated pressures.

Table 2.50 Pressure values calculated from the boundary equation $p_{s,3}(s)$, Eq. (2.30), for selected specific entropies^a

Equation	$s [\text{kJ kg}^{-1} \text{K}^{-1}]$	$p [\text{MPa}]$
$p_{s,3}(s)$, Eq. (2.30)	3.8	$1.687\ 755\ 057 \times 10^1$
	4.2	$2.164\ 451\ 789 \times 10^1$
	5.2	$1.668\ 968\ 482 \times 10^1$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Note. For points extremely close to the boundary between the single-phase region 3 and the two-phase region 4, the following procedure is recommended. When calculating the pressure with the $p_{s,3}(s)$ equation, Eq. (2.30), its numerical inconsistency of 0.000 33% in pressure with respect to the basic equation $p_s(T)$, Eq. (2.13), has to be considered. Due to this minor inconsistency the result of the calculated pressure should be corrected to $p_{s,3} = p_{s,3}(s) (1 - \Delta p/p)$, where $\Delta p/p = 3.3 \times 10^{-6}$. This procedure ensures that (p, s) points extremely close to the two-phase region are correctly assigned to the single-phase region and not falsely to the two-phase region.

2.3.4.2 Backward Equation $T_l(p, s)$ for Region 1

Figure 2.10 shows the assignment of the backward equation $T_l(p, s)$ to region 1 in a p - s diagram. The boundaries of region 1 in p - s coordinates are described in Secs. 2.3.4.1a to 2.3.4.1c. A statement about the computing speed with this backward equation can be found at the end of this section.

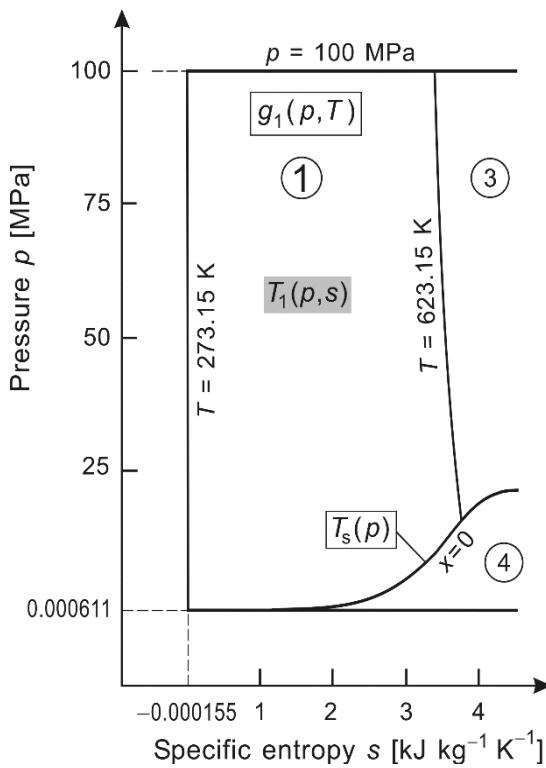


Fig. 2.10 Assignment of the backward equation $T_l(p, s)$ to region 1 in a p - s diagram. The p and s values at the corner points of region 1 are given in Fig. 2.9.

The backward equation $T_l(p, s)$ for region 1 has the following dimensionless form:

$$\frac{T_l(p, s)}{T^*} = \theta(\pi, \sigma) = \sum_{i=1}^{20} n_i \pi^{I_i} (\sigma + 2)^{J_i}, \quad (2.31)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $T^* = 1 \text{ K}$, $p^* = 1 \text{ MPa}$, and $s^* = 1 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.31) are listed in Table 2.51.

Table 2.51 Coefficients and exponents of the backward equation $T_1(p, s)$ in its dimensionless form, Eq. (2.31)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.174\ 782\ 680\ 583\ 07 \times 10^3$	11	1	12	$0.356\ 721\ 106\ 073\ 66 \times 10^{-9}$
2	0	1	$0.348\ 069\ 308\ 928\ 73 \times 10^2$	12	1	31	$0.173\ 324\ 969\ 948\ 95 \times 10^{-23}$
3	0	2	$0.652\ 925\ 849\ 784\ 55 \times 10^1$	13	2	0	$0.566\ 089\ 006\ 548\ 37 \times 10^{-3}$
4	0	3	0.330 399 817 754 89	14	2	1	$-0.326\ 354\ 831\ 397\ 17 \times 10^{-3}$
5	0	11	$-0.192\ 813\ 829\ 231\ 96 \times 10^{-6}$	15	2	2	$0.447\ 782\ 866\ 906\ 32 \times 10^{-4}$
6	0	31	$-0.249\ 091\ 972\ 445\ 73 \times 10^{-22}$	16	2	9	$-0.513\ 221\ 569\ 085\ 07 \times 10^{-9}$
7	1	0	-0.261 076 364 893 32	17	2	31	$-0.425\ 226\ 570\ 422\ 07 \times 10^{-25}$
8	1	1	0.225 929 659 815 86	18	3	10	$0.264\ 004\ 413\ 606\ 89 \times 10^{-12}$
9	1	2	$-0.642\ 564\ 633\ 952\ 26 \times 10^{-1}$	19	3	32	$0.781\ 246\ 004\ 597\ 23 \times 10^{-28}$
10	1	3	$0.788\ 762\ 892\ 705\ 26 \times 10^{-2}$	20	4	32	$-0.307\ 321\ 999\ 036\ 68 \times 10^{-30}$

Range of Validity. The range of validity of the backward equation $T_1(p, s)$, Eq. (2.31), can be derived from the graphical representation of region 1 in Fig. 2.9. The determination of the (p, s) values along the region boundaries is described in Secs. 2.3.4.1a to 2.3.4.1c.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.31), Table 2.52 contains corresponding test values.

Numerical Consistency. The numerical inconsistency between the backward equation $T_1(p, s)$, Eq. (2.31), and the basic equation $g_1(p, T)$, Eq. (2.3), in comparison with the permissible inconsistency, given in Sec. 2.3.2, is listed in Table 2.53.

Note. When calculating properties in the range $p \leq p_s(623.15\text{ K})$ and extremely close to the saturated-liquid line, Eq. (2.31) might yield temperatures $T_1(p, s) > T_s(p)$ due to the minor inconsistencies. In this case, the result of Eq. (2.31) must be corrected to $T_1 = T_s(p)$, where the saturation temperature $T_s(p)$ is calculated for the given pressure from Eq. (2.14).

Table 2.52 Temperature values calculated from the backward equation $T_1(p, s)$, Eq. (2.31), for selected pressures and specific entropies^a

p [MPa]	s [$\text{kJ kg}^{-1}\text{K}^{-1}$]	T [K]
3	0.5	$0.307\ 842\ 258 \times 10^3$
80	0.5	$0.309\ 979\ 785 \times 10^3$
80	3	$0.565\ 899\ 909 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Table 2.53 Maximum and root-mean-square inconsistency in temperature between the backward equation $T_1(p, s)$, Eq. (2.31), and the basic equation $g_1(p, T)$, Eq. (2.3), in comparison with the permissible inconsistency

Inconsistencies in temperature [mK]		
$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
25	21.8	5.8

Computing Time. The calculation of temperature as a function of (p, s) with the backward equation $T_1(p, s)$, Eq. (2.31), is about 38 times faster than when using only the basic equation $g_1(p, T)$, Eq. (2.3), [22]. In this comparison, the basic equation was applied in combination with a one-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirement that were set for the backward equation.

2.3.4.3 Backward Equations $T(p,s)$ for Region 2

The boundaries of region 2 in p - s coordinates are described in Secs. 2.3.4.1a to 2.3.4.1c. Due to the demand for very high numerical consistency between the basic equation $g_2(p,T)$, Eq. (2.6), and a backward equation $T(p,s)$ for region 2, see Sec. 2.3.2, region 2 is divided into three subregions.

a) Division of Region 2 into Subregions 2a, 2b, and 2c

Figure 2.11 shows how region 2 is divided into three subregions for the backward equations $T(p,s)$. The boundary between subregions 2a and 2b is the isobar $p = 4$ MPa, and the boundary between subregions 2b and 2c is given by the isentropic line $s = s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

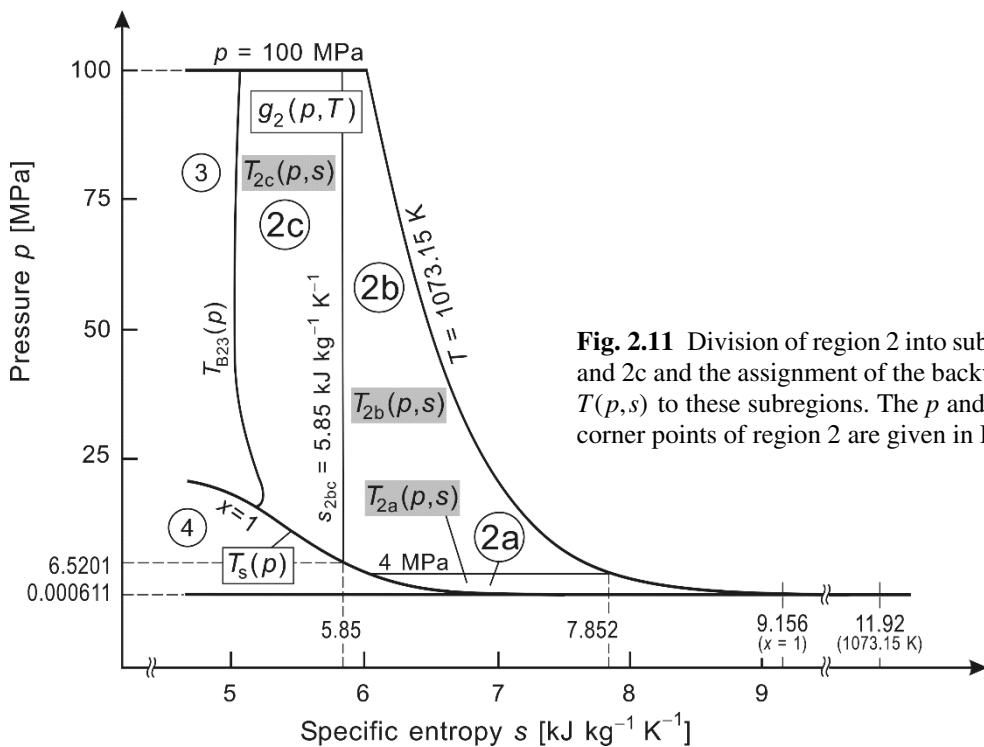


Fig. 2.11 Division of region 2 into subregions 2a, 2b, and 2c and the assignment of the backward equations $T(p,s)$ to these subregions. The p and s values at the corner points of region 2 are given in Fig. 2.9.

Note. To be in accordance with the statements given in [16, 23], the boundary between subregions 2a and 2b is considered to belong to subregion 2a and the boundary between subregions 2b and 2c is considered to belong to subregion 2b.

b) The Backward Equations $T(p,s)$ for Subregions 2a, 2b, and 2c

The backward equation $T_{2a}(p,s)$ for subregion 2a in its dimensionless form reads

$$\frac{T_{2a}(p,s)}{T^*} = \theta(\pi, \sigma) = \sum_{i=1}^{46} n_i \pi^{I_i} (\sigma - 2)^{J_i}, \quad (2.32)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $T^* = 1 \text{ K}$, $p^* = 1 \text{ MPa}$, and $s^* = 2 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.32) are listed in Table 2.54.

The backward equation $T_{2b}(p, s)$ for **subregion 2b** in its dimensionless form reads

$$\frac{T_{2b}(p, s)}{T^*} = \theta(\pi, \sigma) = \sum_{i=1}^{44} n_i \pi^{I_i} (10 - \sigma)^{J_i}, \quad (2.33)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $T^* = 1 \text{ K}$, $p^* = 1 \text{ MPa}$, and $s^* = 0.7853 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.33) are listed in Table 2.55.

The backward equation $T_{2c}(p, s)$ for **subregion 2c** in its dimensionless form reads

$$\frac{T_{2c}(p, s)}{T^*} = \theta(\pi, \sigma) = \sum_{i=1}^{30} n_i \pi^{I_i} (2 - \sigma)^{J_i}, \quad (2.34)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $T^* = 1 \text{ K}$, $p^* = 1 \text{ MPa}$, and $s^* = 2.9251 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.34) are listed in Table 2.56.

Table 2.54 Coefficients and exponents of the backward equation $T_{2a}(p, s)$ for subregion 2a in its dimensionless form, Eq. (2.32)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-1.5	-24	$-0.392\ 359\ 838\ 619\ 84 \times 10^6$	24	-0.25	-11	$-0.597\ 806\ 388\ 727\ 18 \times 10^4$
2	-1.5	-23	$0.515\ 265\ 738\ 272\ 70 \times 10^6$	25	-0.25	-6	$-0.704\ 014\ 639\ 268\ 62 \times 10^3$
3	-1.5	-19	$0.404\ 824\ 431\ 610\ 48 \times 10^5$	26	0.25	1	$0.338\ 367\ 841\ 075\ 53 \times 10^3$
4	-1.5	-13	$-0.321\ 937\ 909\ 239\ 02 \times 10^3$	27	0.25	4	$0.208\ 627\ 866\ 351\ 87 \times 10^2$
5	-1.5	-11	$0.969\ 614\ 242\ 186\ 94 \times 10^2$	28	0.25	8	$0.338\ 341\ 726\ 561\ 96 \times 10^{-1}$
6	-1.5	-10	$-0.228\ 678\ 463\ 717\ 73 \times 10^2$	29	0.25	11	$-0.431\ 244\ 284\ 148\ 93 \times 10^{-4}$
7	-1.25	-19	$-0.449\ 429\ 141\ 243\ 57 \times 10^6$	30	0.5	0	$0.166\ 537\ 913\ 564\ 12 \times 10^3$
8	-1.25	-15	$-0.501\ 183\ 360\ 201\ 66 \times 10^4$	31	0.5	1	$-0.139\ 862\ 920\ 558\ 98 \times 10^3$
9	-1.25	-6	$0.356\ 844\ 635\ 600\ 15$	32	0.5	5	$-0.788\ 495\ 479\ 998\ 72$
10	-1.0	-26	$0.442\ 353\ 358\ 481\ 90 \times 10^5$	33	0.5	6	$0.721\ 324\ 117\ 538\ 72 \times 10^{-1}$
11	-1.0	-21	$-0.136\ 733\ 888\ 117\ 08 \times 10^5$	34	0.5	10	$-0.597\ 548\ 393\ 982\ 83 \times 10^{-2}$
12	-1.0	-17	$0.421\ 632\ 602\ 078\ 64 \times 10^6$	35	0.5	14	$-0.121\ 413\ 589\ 539\ 04 \times 10^{-4}$
13	-1.0	-16	$0.225\ 169\ 258\ 374\ 75 \times 10^5$	36	0.5	16	$0.232\ 270\ 967\ 338\ 71 \times 10^{-6}$
14	-1.0	-9	$0.474\ 421\ 448\ 656\ 46 \times 10^3$	37	0.75	0	$-0.105\ 384\ 635\ 661\ 94 \times 10^2$
15	-1.0	-8	$-0.149\ 311\ 307\ 976\ 47 \times 10^3$	38	0.75	4	$0.207\ 189\ 254\ 965\ 02 \times 10^1$
16	-0.75	-15	$-0.197\ 811\ 263\ 204\ 52 \times 10^6$	39	0.75	9	$-0.721\ 931\ 552\ 604\ 27 \times 10^{-1}$
17	-0.75	-14	$-0.235\ 543\ 994\ 707\ 60 \times 10^5$	40	0.75	17	$0.207\ 498\ 870\ 811\ 20 \times 10^{-6}$
18	-0.5	-26	$-0.190\ 706\ 163\ 020\ 76 \times 10^5$	41	1.0	7	$-0.183\ 406\ 579\ 113\ 79 \times 10^{-1}$
19	-0.5	-13	$0.553\ 756\ 698\ 831\ 64 \times 10^5$	42	1.0	18	$0.290\ 362\ 723\ 486\ 96 \times 10^{-6}$
20	-0.5	-9	$0.382\ 936\ 914\ 373\ 63 \times 10^4$	43	1.25	3	$0.210\ 375\ 278\ 936\ 19$
21	-0.5	-7	$-0.603\ 918\ 605\ 805\ 67 \times 10^3$	44	1.25	15	$0.256\ 812\ 397\ 299\ 99 \times 10^{-3}$
22	-0.25	-27	$0.193\ 631\ 026\ 203\ 31 \times 10^4$	45	1.5	5	$-0.127\ 990\ 029\ 337\ 81 \times 10^{-1}$
23	-0.25	-25	$0.426\ 606\ 436\ 986\ 10 \times 10^4$	46	1.5	18	$-0.821\ 981\ 026\ 520\ 18 \times 10^{-5}$

Table 2.55 Coefficients and exponents of the backward equation $T_{2b}(p, s)$ for subregion 2b in its dimensionless form, Eq. (2.33)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-6	0	$0.316\ 876\ 650\ 834\ 97 \times 10^6$	23	0	2	$0.417\ 273\ 471\ 596\ 10 \times 10^2$
2	-6	11	$0.208\ 641\ 758\ 818\ 58 \times 10^2$	24	0	4	$0.219\ 325\ 494\ 345\ 32 \times 10^1$
3	-5	0	$-0.398\ 593\ 998\ 035\ 99 \times 10^6$	25	0	5	$-0.103\ 200\ 500\ 090\ 77 \times 10^1$
4	-5	11	$-0.218\ 160\ 585\ 188\ 77 \times 10^2$	26	0	6	$0.358\ 829\ 435\ 167\ 03$
5	-4	0	$0.223\ 697\ 851\ 942\ 42 \times 10^6$	27	0	9	$0.525\ 114\ 537\ 260\ 66 \times 10^{-2}$
6	-4	1	$-0.278\ 417\ 034\ 458\ 17 \times 10^4$	28	1	0	$0.128\ 389\ 164\ 507\ 05 \times 10^2$
7	-4	11	$0.992\ 074\ 360\ 714\ 80 \times 10^1$	29	1	1	$-0.286\ 424\ 372\ 193\ 81 \times 10^1$
8	-3	0	$-0.751\ 975\ 122\ 991\ 57 \times 10^5$	30	1	2	$0.569\ 126\ 836\ 648\ 55$
9	-3	1	$0.297\ 086\ 059\ 511\ 58 \times 10^4$	31	1	3	$-0.999\ 629\ 545\ 849\ 31 \times 10^{-1}$
10	-3	11	$-0.344\ 068\ 785\ 485\ 26 \times 10^1$	32	1	7	$-0.326\ 320\ 377\ 784\ 59 \times 10^{-2}$
11	-3	12	$0.388\ 155\ 642\ 491\ 15$	33	1	8	$0.233\ 209\ 225\ 767\ 23 \times 10^{-3}$
12	-2	0	$0.175\ 112\ 950\ 857\ 50 \times 10^5$	34	2	0	$-0.153\ 348\ 098\ 574\ 50$
13	-2	1	$-0.142\ 371\ 128\ 544\ 49 \times 10^4$	35	2	1	$0.290\ 722\ 882\ 399\ 02 \times 10^{-1}$
14	-2	6	$0.109\ 438\ 033\ 641\ 67 \times 10^1$	36	2	5	$0.375\ 347\ 027\ 411\ 67 \times 10^{-3}$
15	-2	10	$0.899\ 716\ 193\ 084\ 95$	37	3	0	$0.172\ 966\ 917\ 024\ 11 \times 10^{-2}$
16	-1	0	$-0.337\ 597\ 400\ 989\ 58 \times 10^4$	38	3	1	$-0.385\ 560\ 508\ 445\ 04 \times 10^{-3}$
17	-1	1	$0.471\ 628\ 858\ 183\ 55 \times 10^3$	39	3	3	$-0.350\ 177\ 122\ 926\ 08 \times 10^{-4}$
18	-1	5	$-0.191\ 882\ 419\ 936\ 79 \times 10^1$	40	4	0	$-0.145\ 663\ 936\ 314\ 92 \times 10^{-4}$
19	-1	8	$0.410\ 785\ 804\ 921\ 96$	41	4	1	$0.564\ 208\ 572\ 672\ 69 \times 10^{-5}$
20	-1	9	$-0.334\ 653\ 781\ 720\ 97$	42	5	0	$0.412\ 861\ 500\ 746\ 05 \times 10^{-7}$
21	0	0	$0.138\ 700\ 347\ 775\ 05 \times 10^4$	43	5	1	$-0.206\ 846\ 711\ 188\ 24 \times 10^{-7}$
22	0	1	$-0.406\ 633\ 261\ 958\ 38 \times 10^3$	44	5	2	$0.164\ 093\ 936\ 747\ 25 \times 10^{-8}$

Table 2.56 Coefficients and exponents of the backward equation $T_{2c}(p, s)$ for subregion 2c in its dimensionless form, Eq. (2.34)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-2	0	$0.909\ 685\ 010\ 053\ 65 \times 10^3$	16	3	1	$-0.145\ 970\ 082\ 847\ 53 \times 10^{-1}$
2	-2	1	$0.240\ 456\ 670\ 884\ 20 \times 10^4$	17	3	5	$0.566\ 311\ 756\ 310\ 27 \times 10^{-2}$
3	-1	0	$-0.591\ 623\ 263\ 871\ 30 \times 10^3$	18	4	0	$-0.761\ 558\ 645\ 845\ 77 \times 10^{-4}$
4	0	0	$0.541\ 454\ 041\ 280\ 74 \times 10^3$	19	4	1	$0.224\ 403\ 429\ 193\ 32 \times 10^{-3}$
5	0	1	$-0.270\ 983\ 084\ 111\ 92 \times 10^3$	20	4	4	$-0.125\ 610\ 950\ 134\ 13 \times 10^{-4}$
6	0	2	$0.979\ 765\ 250\ 979\ 26 \times 10^3$	21	5	0	$0.633\ 231\ 326\ 609\ 34 \times 10^{-6}$
7	0	3	$-0.469\ 667\ 729\ 594\ 35 \times 10^3$	22	5	1	$-0.205\ 419\ 896\ 753\ 75 \times 10^{-5}$
8	1	0	$0.143\ 992\ 746\ 047\ 23 \times 10^2$	23	5	2	$0.364\ 053\ 703\ 900\ 82 \times 10^{-7}$
9	1	1	$-0.191\ 042\ 042\ 304\ 29 \times 10^2$	24	6	0	$-0.297\ 598\ 977\ 892\ 15 \times 10^{-8}$
10	1	3	$0.532\ 991\ 671\ 119\ 71 \times 10^1$	25	6	1	$0.101\ 366\ 185\ 297\ 63 \times 10^{-7}$
11	1	4	$-0.212\ 529\ 753\ 759\ 34 \times 10^2$	26	7	0	$0.599\ 257\ 196\ 923\ 51 \times 10^{-11}$
12	2	0	$-0.311\ 473\ 344\ 137\ 60$	27	7	1	$-0.206\ 778\ 701\ 051\ 64 \times 10^{-10}$
13	2	1	$0.603\ 348\ 408\ 946\ 23$	28	7	3	$-0.208\ 742\ 781\ 818\ 86 \times 10^{-10}$
14	2	2	$-0.427\ 648\ 397\ 025\ 09 \times 10^{-1}$	29	7	4	$0.101\ 621\ 668\ 250\ 89 \times 10^{-9}$
15	3	0	$0.581\ 855\ 972\ 552\ 59 \times 10^{-2}$	30	7	5	$-0.164\ 298\ 282\ 813\ 47 \times 10^{-9}$

Ranges of Validity. The ranges of validity of the backward equations $T_{2a}(p, s)$, $T_{2b}(p, s)$, and $T_{2c}(p, s)$, Eqs. (2.32) to (2.34), can be derived from the graphical representation of region 2 in Fig. 2.9 and of subregions 2a, 2b, and 2c in Fig. 2.11. The determination of the (p, s) values along the region boundaries is described in Secs. 2.3.4.1a to 2.3.4.1c and along the subregion boundaries in Sec. 2.3.4.3a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.32) to (2.34), Table 2.57 contains corresponding test values.

Numerical Consistencies. The numerical inconsistencies between the backward equations $T_{2a}(p, s)$, $T_{2b}(p, s)$, and $T_{2c}(p, s)$, Eqs. (2.32) to (2.34), and the basic equation $g_2(p, T)$, Eq. (2.6), in comparison with the permissible inconsistencies given in Sec. 2.3.2, are listed in Table 2.58.

Note. When calculating properties in the range $p \leq p_s(623.15 \text{ K})$ and extremely close to the saturated-vapour line, Eqs. (2.32) to (2.34) might yield temperatures $T_{2a}(p, s) < T_s(p)$, $T_{2b}(p, s) < T_s(p)$, and $T_{2c}(p, s) < T_s(p)$, respectively, due to the minor inconsistencies. In this case, the results of Eqs. (2.32) to (2.34) must be corrected to $T_{2a} = T_s(p)$, $T_{2b} = T_s(p)$, and $T_{2c} = T_s(p)$, respectively, where the saturation temperature $T_s(p)$ is calculated for the given pressure from Eq. (2.14).

Table 2.57 Temperature values calculated from the backward equations $T_{2a}(p, s)$, $T_{2b}(p, s)$, and $T_{2c}(p, s)$, Eqs. (2.32) to (2.34), for selected pressures and specific entropies^a

Equation	p [MPa]	s [$\text{kJ kg}^{-1}\text{K}^{-1}$]	T [K]
$T_{2a}(p, s)$, Eq. (2.32)	0.1	7.5	$0.399\ 517\ 097 \times 10^3$
	0.1	8	$0.514\ 127\ 081 \times 10^3$
	2.5	8	$0.103\ 984\ 917 \times 10^4$
$T_{2b}(p, s)$, Eq. (2.33)	8	6	$0.600\ 484\ 040 \times 10^3$
	8	7.5	$0.106\ 495\ 556 \times 10^4$
	90	6	$0.103\ 801\ 126 \times 10^4$
$T_{2c}(p, s)$, Eq. (2.34)	20	5.75	$0.697\ 992\ 849 \times 10^3$
	80	5.25	$0.854\ 011\ 484 \times 10^3$
	80	5.75	$0.949\ 017\ 998 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Table 2.58 Maximum and root-mean-square inconsistencies in temperature between the backward equations $T_{2a}(p, s)$, $T_{2b}(p, s)$, and $T_{2c}(p, s)$, Eqs. (2.32) to (2.34), and the basic equation $g_2(p, T)$, Eq. (2.6), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in temperature [mK]		
		$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
2a	$T_{2a}(p, s)$, Eq. (2.32)	10	8.8	1.2
2b	$T_{2b}(p, s)$, Eq. (2.33)	10	6.5	2.8
2c	$T_{2c}(p, s)$, Eq. (2.34)	25	19.0	8.3

c) Computing Time when Using the Backward Equations $T(p, s)$ in Comparison with the Basic Equation

The calculation of temperature as a function of (p, s) with the backward equations $T_{2a}(p, s)$, $T_{2b}(p, s)$, or $T_{2c}(p, s)$, Eqs. (2.32) to (2.34), is about 14 times faster than when using only the basic equation $g_2(p, T)$, Eq. (2.6), [22]. In this comparison, the basic equation was applied in combination with a one-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were set for the backward equations.

2.3.4.4 Backward Equations $v(p,s)$ and $T(p,s)$ for Region 3

The boundaries of region 3 in p - s coordinates are described in Secs. 2.3.4.1a to 2.3.4.1c.

a) Division of Region 3 into Subregions 3a and 3b

Due to the demand for very high numerical consistency between the backward equations and the basic equation $f_3(\rho, T)$, Eq. (2.11), as given in Sec. 2.3.2, region 3 is divided into two subregions as illustrated in Fig. 2.12.

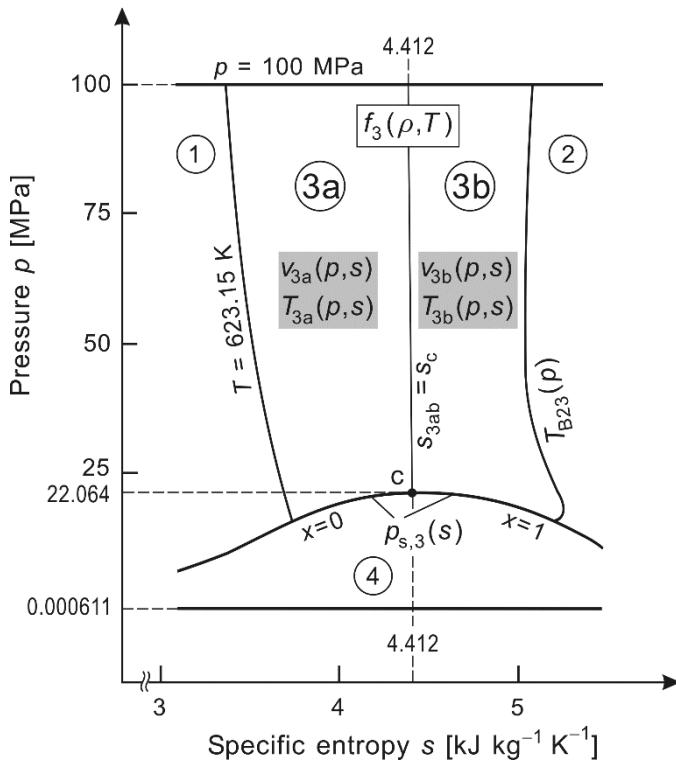


Fig. 2.12 Division of region 3 into subregions 3a and 3b, and the assignment of backward equations $v(p,s)$ and $T(p,s)$ to these subregions. The p and s values at the corner points of region 3 are given in Fig. 2.9.

The boundary between subregions 3a and 3b is defined by the critical isentropic line

$$s_{3ab} = s_c = 4.412\ 021\ 482\ 234\ 76\ \text{kJ kg}^{-1}\ \text{K}^{-1}, \quad (2.35)$$

where this value was calculated from the basic equation of region 3, $f_3(\rho, T)$, Eq. (2.11), for $\rho = \rho_c$ and $T = T_c$ according to Eqs. (1.6) and (1.4).

Note. The boundary between subregions 3a and 3b is considered to belong to subregion 3a [17, 24].

b) Backward Equations $v(p,s)$ for Subregions 3a and 3b

The backward equation $v_{3a}(p,s)$ for subregion 3a reads in its dimensionless form

$$\frac{v_{3a}(p,s)}{v^*} = \omega(\pi, \sigma) = \sum_{i=1}^{28} n_i (\pi + 0.187)^{I_i} (\sigma - 0.755)^{J_i}, \quad (2.36)$$

where $\omega = v/v^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $v^* = 0.0028\ \text{m}^3\ \text{kg}^{-1}$, $p^* = 100\ \text{MPa}$, and $s^* = 4.4\ \text{kJ kg}^{-1}\ \text{K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.36) are listed in Table 2.59.

The backward equation $v_{3b}(p, s)$ for **subregion 3b** reads in its dimensionless form

$$\frac{v_{3b}(p, s)}{v^*} = \omega(\pi, \sigma) = \sum_{i=1}^{31} n_i (\pi + 0.298)^{I_i} (\sigma - 0.816)^{J_i}, \quad (2.37)$$

where $\omega = v/v^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $v^* = 0.0088 \text{ m}^3 \text{ kg}^{-1}$, $p^* = 100 \text{ MPa}$, and $s^* = 5.3 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.37) are listed in Table 2.60.

Table 2.59 Coefficients and exponents of the backward equation $v_{3a}(p, s)$ for subregion 3a in its dimensionless form, Eq. (2.36)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	10	$0.795\ 544\ 074\ 093\ 975 \times 10^2$	15	-3	2	$-0.118\ 008\ 384\ 666\ 987$
2	-12	12	$-0.238\ 261\ 242\ 984\ 590 \times 10^4$	16	-3	4	$0.253\ 798\ 642\ 355\ 900 \times 10^1$
3	-12	14	$0.176\ 813\ 100\ 617\ 787 \times 10^5$	17	-2	3	$0.965\ 127\ 704\ 669\ 424$
4	-10	4	$-0.110\ 524\ 727\ 080\ 379 \times 10^{-2}$	18	-2	8	$-0.282\ 172\ 420\ 532\ 826 \times 10^2$
5	-10	8	$-0.153\ 213\ 833\ 655\ 326 \times 10^2$	19	-1	1	$0.203\ 224\ 612\ 353\ 823$
6	-10	10	$0.297\ 544\ 599\ 376\ 982 \times 10^3$	20	-1	2	$0.110\ 648\ 186\ 063\ 513 \times 10^1$
7	-10	20	$-0.350\ 315\ 206\ 871\ 242 \times 10^8$	21	0	0	$0.526\ 127\ 948\ 451\ 280$
8	-8	5	$0.277\ 513\ 761\ 062\ 119$	22	0	1	$0.277\ 000\ 018\ 736\ 321$
9	-8	6	$-0.523\ 964\ 271\ 036\ 888$	23	0	3	$0.108\ 153\ 340\ 501\ 132 \times 10^1$
10	-8	14	$-0.148\ 011\ 182\ 995\ 403 \times 10^6$	24	1	0	$-0.744\ 127\ 885\ 357\ 893 \times 10^{-1}$
11	-8	16	$0.160\ 014\ 899\ 374\ 266 \times 10^7$	25	2	0	$0.164\ 094\ 443\ 541\ 384 \times 10^{-1}$
12	-6	28	$0.170\ 802\ 322\ 663\ 427 \times 10^{13}$	26	4	2	$-0.680\ 468\ 275\ 301\ 065 \times 10^{-1}$
13	-5	1	$0.246\ 866\ 996\ 006\ 494 \times 10^{-3}$	27	5	2	$0.257\ 988\ 576\ 101\ 640 \times 10^{-1}$
14	-4	5	$0.165\ 326\ 084\ 797\ 980 \times 10^1$	28	6	0	$-0.145\ 749\ 861\ 944\ 416 \times 10^{-3}$

Table 2.60 Coefficients and exponents of the backward equation $v_{3b}(p, s)$ for subregion 3b in its dimensionless form, Eq. (2.37)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	0	$0.591\ 599\ 780\ 322\ 238 \times 10^{-4}$	17	-4	2	$-0.121\ 613\ 320\ 606\ 788 \times 10^2$
2	-12	1	$-0.185\ 465\ 997\ 137\ 856 \times 10^{-2}$	18	-4	3	$0.167\ 637\ 540\ 957\ 944 \times 10^1$
3	-12	2	$0.104\ 190\ 510\ 480\ 013 \times 10^{-1}$	19	-3	1	$-0.744\ 135\ 838\ 773\ 463 \times 10^1$
4	-12	3	$0.598\ 647\ 302\ 038\ 590 \times 10^{-2}$	20	-2	0	$0.378\ 168\ 091\ 437\ 659 \times 10^{-1}$
5	-12	5	$-0.771\ 391\ 189\ 901\ 699$	21	-2	1	$0.401\ 432\ 203\ 027\ 688 \times 10^1$
6	-12	6	$0.172\ 549\ 765\ 557\ 036 \times 10^1$	22	-2	2	$0.160\ 279\ 837\ 479\ 185 \times 10^2$
7	-10	0	$-0.467\ 076\ 079\ 846\ 526 \times 10^{-3}$	23	-2	3	$0.317\ 848\ 779\ 347\ 728 \times 10^1$
8	-10	1	$0.134\ 533\ 823\ 384\ 439 \times 10^{-1}$	24	-2	4	$-0.358\ 362\ 310\ 304\ 853 \times 10^1$
9	-10	2	$-0.808\ 094\ 336\ 805\ 495 \times 10^{-1}$	25	-2	12	$-0.115\ 995\ 260\ 446\ 827 \times 10^7$
10	-10	4	$0.508\ 139\ 374\ 365\ 767$	26	0	0	$0.199\ 256\ 573\ 577\ 909$
11	-8	0	$0.128\ 584\ 643\ 361\ 683 \times 10^{-2}$	27	0	1	$-0.122\ 270\ 624\ 794\ 624$
12	-5	1	$-0.163\ 899\ 353\ 915\ 435 \times 10^1$	28	0	2	$-0.191\ 449\ 143\ 716\ 586 \times 10^2$
13	-5	2	$0.586\ 938\ 199\ 318\ 063 \times 10^1$	29	1	0	$-0.150\ 448\ 002\ 905\ 284 \times 10^{-1}$
14	-5	3	$-0.292\ 466\ 667\ 918\ 613 \times 10^1$	30	1	2	$0.146\ 407\ 900\ 162\ 154 \times 10^2$
15	-4	0	$-0.614\ 076\ 301\ 499\ 537 \times 10^{-2}$	31	2	2	$-0.327\ 477\ 787\ 188\ 230 \times 10^1$
16	-4	1	$0.576\ 199\ 014\ 049\ 172 \times 10^1$				

Ranges of Validity. The ranges of validity of the backward equations $v_{3a}(p, s)$ and $v_{3b}(p, s)$, Eqs. (2.36) and (2.37), can be derived from the graphical representation of region 3 in Fig. 2.9 and of subregions 3a and 3b in Fig. 2.12. The determination of the (p, s) values along the region boundaries is described in Secs. 2.3.4.1a to 2.3.4.1c and along the subregion boundary in Sec. 2.3.4.4a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.36) and (2.37), Table 2.61 contains test values for calculated specific volumes.

Table 2.61 Values of the specific volume calculated from the backward equations $v_{3a}(p, s)$ and $v_{3b}(p, s)$, Eqs. (2.36) and (2.37), for selected pressures and specific entropies^a

Equation	p [MPa]	s [kJ kg ⁻¹ K ⁻¹]	v [m ³ kg ⁻¹]
$v_{3a}(p, s)$, Eq. (2.36)	20	3.8	$1.733\ 791\ 463 \times 10^{-3}$
	50	3.6	$1.469\ 680\ 170 \times 10^{-3}$
	100	4.0	$1.555\ 893\ 131 \times 10^{-3}$
$v_{3b}(p, s)$, Eq. (2.37)	20	5.0	$6.262\ 101\ 987 \times 10^{-3}$
	50	4.5	$2.332\ 634\ 294 \times 10^{-3}$
	100	5.0	$2.449\ 610\ 757 \times 10^{-3}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Numerical Consistencies. The numerical inconsistencies between the backward equations $v_{3a}(p, s)$ and $v_{3b}(p, s)$, Eqs. (2.36) and (2.37), and the basic equation $f_3(\rho, T)$, Eq. (2.11), are listed in Table 2.62 in comparison with the permissible inconsistencies, given in Sec. 2.3.2. These inconsistencies are less than the permissible values. This is also true when the backward equations are used in combination with the boundary equation $p_{s,3}(s)$, Eq. (2.30). The critical volume $v_c = 1/\rho_c = (1/322) \text{ m}^3 \text{ kg}^{-1} = 0.003\ 105\ 59 \text{ m}^3 \text{ kg}^{-1}$ is met by the two $v(p, s)$ equations for the given six significant figures. The maximum inconsistency in specific volume between the two backward equations, Eq. (2.36) and Eq. (2.37), along the subregion boundary $s_{3ab} = s_c$, Eq. (2.35), amounts to 0.000 46%.

Table 2.62 Maximum and root-mean-square inconsistencies in specific volume between the backward equations $v_{3a}(p, s)$ and $v_{3b}(p, s)$, Eqs. (2.36) and (2.37), and the basic equation $f_3(\rho, T)$, Eq. (2.11), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in specific volume [%]		
		$ \Delta v/v _{\text{perm}}$	$ \Delta v/v _{\text{max}}$	$(\Delta v/v)_{\text{RMS}}$
3a	$v_{3a}(p, s)$, Eq. (2.36)	0.01	0.0096	0.0052
3b	$v_{3b}(p, s)$, Eq. (2.37)	0.01	0.0077	0.0037

Computing Time. A statement about the computing time is given in Sec. 2.3.4.4d.

c) Backward Equations $T(p,s)$ for Subregions 3a and 3b

The backward equation $T_{3a}(p,s)$ for **subregion 3a** reads in its dimensionless form

$$\frac{T_{3a}(p,s)}{T^*} = \theta(\pi, \sigma) = \sum_{i=1}^{33} n_i (\pi + 0.240)^{I_i} (\sigma - 0.703)^{J_i}, \quad (2.38)$$

where, $\theta = T/T^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $T^* = 760 \text{ K}$, $p^* = 100 \text{ MPa}$, and $s^* = 4.4 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

The coefficients n_i and exponents I_i and J_i of Eq. (2.38) are listed in Table 2.63.

The backward equation $T_{3b}(p,s)$ for **subregion 3b** reads in its dimensionless form

$$\frac{T_{3b}(p,s)}{T^*} = \theta(\pi, \sigma) = \sum_{i=1}^{28} n_i (\pi + 0.760)^{I_i} (\sigma - 0.818)^{J_i}, \quad (2.39)$$

where $\theta = T/T^*$, $\pi = p/p^*$, and $\sigma = s/s^*$ with $T^* = 860 \text{ K}$, $p^* = 100 \text{ MPa}$, and $s^* = 5.3 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

The coefficients n_i and exponents I_i and J_i of Eq. (2.39) are listed in Table 2.64.

Table 2.63 Coefficients and exponents of the backward equation $T_{3a}(p,s)$ for subregion 3a in its dimensionless form, Eq. (2.38)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	28	$0.150\ 042\ 008\ 263\ 875 \times 10^{10}$	18	-4	10	$-0.368\ 275\ 545\ 889\ 071 \times 10^3$
2	-12	32	$-0.159\ 397\ 258\ 480\ 424 \times 10^{12}$	19	-4	36	$0.664\ 768\ 904\ 779\ 177 \times 10^{16}$
3	-10	4	$0.502\ 181\ 140\ 217\ 975 \times 10^{-3}$	20	-2	1	$0.449\ 359\ 251\ 958\ 880 \times 10^{-1}$
4	-10	10	$-0.672\ 057\ 767\ 855\ 466 \times 10^2$	21	-2	4	$-0.422\ 897\ 836\ 099\ 655 \times 10^1$
5	-10	12	$0.145\ 058\ 545\ 404\ 456 \times 10^4$	22	-1	1	$-0.240\ 614\ 376\ 434\ 179$
6	-10	14	$-0.823\ 889\ 534\ 888\ 890 \times 10^4$	23	-1	6	$-0.474\ 341\ 365\ 254\ 924 \times 10^1$
7	-8	5	$-0.154\ 852\ 214\ 233\ 853$	24	0	0	$0.724\ 093\ 999\ 126\ 110$
8	-8	7	$0.112\ 305\ 046\ 746\ 695 \times 10^2$	25	0	1	$0.923\ 874\ 349\ 695\ 897$
9	-8	8	$-0.297\ 000\ 213\ 482\ 822 \times 10^2$	26	0	4	$0.399\ 043\ 655\ 281\ 015 \times 10^1$
10	-8	28	$0.438\ 565\ 132\ 635\ 495 \times 10^{11}$	27	1	0	$0.384\ 066\ 651\ 868\ 009 \times 10^{-1}$
11	-6	2	$0.137\ 837\ 838\ 635\ 464 \times 10^{-2}$	28	2	0	$-0.359\ 344\ 365\ 571\ 848 \times 10^{-2}$
12	-6	6	$-0.297\ 478\ 527\ 157\ 462 \times 10^1$	29	2	3	$-0.735\ 196\ 448\ 821\ 653$
13	-6	32	$0.971\ 777\ 947\ 349\ 413 \times 10^{13}$	30	3	2	$0.188\ 367\ 048\ 396\ 131$
14	-5	0	$-0.571\ 527\ 767\ 052\ 398 \times 10^{-4}$	31	8	0	$0.141\ 064\ 266\ 818\ 704 \times 10^{-3}$
15	-5	14	$0.288\ 307\ 949\ 778\ 420 \times 10^5$	32	8	1	$-0.257\ 418\ 501\ 496\ 337 \times 10^{-2}$
16	-5	32	$-0.744\ 428\ 289\ 262\ 703 \times 10^{14}$	33	10	2	$0.123\ 220\ 024\ 851\ 555 \times 10^{-2}$
17	-4	6	$0.128\ 017\ 324\ 848\ 921 \times 10^2$				

Table 2.64 Coefficients and exponents of the backward equation $T_{3b}(p,s)$ for subregion 3b in its dimensionless form, Eq. (2.39)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	1	0.527 111 701 601 660	15	-5	6	$0.880\ 531\ 517\ 490\ 555 \times 10^3$
2	-12	3	$-0.401\ 317\ 830\ 052\ 742 \times 10^2$	16	-4	12	$0.265\ 015\ 592\ 794\ 626 \times 10^7$
3	-12	4	$0.153\ 020\ 073\ 134\ 484 \times 10^3$	17	-3	1	$-0.359\ 287\ 150\ 025\ 783$
4	-12	7	$-0.224\ 799\ 398\ 218\ 827 \times 10^4$	18	-3	6	$-0.656\ 991\ 567\ 673\ 753 \times 10^3$
5	-8	0	$-0.193\ 993\ 484\ 669\ 048$	19	-2	2	$0.241\ 768\ 149\ 185\ 367 \times 10^1$
6	-8	1	$-0.140\ 467\ 557\ 893\ 768 \times 10^1$	20	0	0	$0.856\ 873\ 461\ 222\ 588$
7	-8	3	$0.426\ 799\ 878\ 114\ 024 \times 10^2$	21	2	1	$0.655\ 143\ 675\ 313\ 458$
8	-6	0	$0.752\ 810\ 643\ 416\ 743$	22	3	1	$-0.213\ 535\ 213\ 206\ 406$
9	-6	2	$0.226\ 657\ 238\ 616\ 417 \times 10^2$	23	4	0	$0.562\ 974\ 957\ 606\ 348 \times 10^{-2}$
10	-6	4	$-0.622\ 873\ 556\ 909\ 932 \times 10^3$	24	5	24	$-0.316\ 955\ 725\ 450\ 471 \times 10^{15}$
11	-5	0	$-0.660\ 823\ 667\ 935\ 396$	25	6	0	$-0.699\ 997\ 000\ 152\ 457 \times 10^{-3}$
12	-5	1	$0.841\ 267\ 087\ 271\ 658$	26	8	3	$0.119\ 845\ 803\ 210\ 767 \times 10^{-1}$
13	-5	2	$-0.253\ 717\ 501\ 764\ 397 \times 10^2$	27	12	1	$0.193\ 848\ 122\ 022\ 095 \times 10^{-4}$
14	-5	4	$0.485\ 708\ 963\ 532\ 948 \times 10^3$	28	14	2	$-0.215\ 095\ 749\ 182\ 309 \times 10^{-4}$

Ranges of Validity. The ranges of validity of the backward equations $T_{3a}(p,s)$ and $T_{3b}(p,s)$, Eqs. (2.38) and (2.39), can be derived from the graphical representation of region 3 in Fig. 2.9 and of subregions 3a and 3b in Fig. 2.12. The determination of the (p,s) values along the region boundaries is described in Secs. 2.3.4.1a to 2.3.4.1c and along the subregion boundary in Sec. 2.3.4.4a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.38) and (2.39), Table 2.65 contains test values for calculated temperatures.

Table 2.65 Temperature values calculated from the backward equations $T_{3a}(p,s)$ and $T_{3b}(p,s)$, Eqs. (2.38) and (2.39), for selected pressures and specific entropies^a

Equation	p [MPa]	s [kJ kg ⁻¹ K ⁻¹]	T [K]
$T_{3a}(p,s)$, Eq. (2.38)	20	3.8	$6.282\ 959\ 869 \times 10^2$
	50	3.6	$6.297\ 158\ 726 \times 10^2$
	100	4.0	$7.056\ 880\ 237 \times 10^2$
$T_{3b}(p,s)$, Eq. (2.39)	20	5.0	$6.401\ 176\ 443 \times 10^2$
	50	4.5	$7.163\ 687\ 517 \times 10^2$
	100	5.0	$8.474\ 332\ 825 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Numerical Consistencies. The numerical inconsistencies between Eqs. (2.38) and (2.39) and the basic equation $f_3(\rho, T)$, Eq. (2.11), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.66. These inconsistencies are less than the permissible values. This is also true when the backward equations are used in combination with the boundary equation $p_{s,3}(s)$, Eq. (2.30). The critical temperature $T_c = 647.096$ K is calculated by the two $T(p,s)$ equations for all six figures. The maximum inconsistency in temperature between the two backward equations, Eq. (2.38) and Eq. (2.39), along the boundary $s_{3ab} = s_c$, Eq. (2.35), amounts to 0.093 mK, which is within the permissible inconsistency given in Sec. 2.3.2.

Table 2.66 Maximum and root-mean-square inconsistencies in temperature between the backward equations $T_{3a}(p,s)$ and $T_{3b}(p,s)$, Eqs. (2.38) and (2.39), and the basic equation $f_3(\rho,T)$, Eq. (2.11), in comparison with the permissible values

Subregion	Equation	Inconsistencies in temperature [mK]		
		$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
3a	$T_{3a}(p,s)$, Eq. (2.38)	25	24.8	11.2
3b	$T_{3b}(p,s)$, Eq. (2.39)	25	22.1	10.1

Note. When calculating properties in the range $p \leq p_c$ and extremely close to the saturation lines, Eq. (2.38) might yield temperatures $T_{3a}(p,s) > T_s(p)$ and Eq. (2.39) might yield temperatures $T_{3b}(p,s) < T_s(p)$ due to the minor inconsistencies. In these cases, the results of Eqs. (2.38) and (2.39) must be corrected to $T_{3a} = T_s(p)$ and $T_{3b} = T_s(p)$, respectively, where the saturation temperature $T_s(p)$ is calculated from Eq. (2.14) for the given pressure.

d) Computing Time when Using the Backward Equations $T(p,s)$ and $v(p,h)$ in Comparison with the Basic Equation

The calculation of specific volume and temperature as a function of (p,s) with the backward equations $v_{3a}(p,s)$ and $T_{3a}(p,s)$, Eqs. (2.36) and (2.38), or $v_{3b}(p,s)$ and $T_{3b}(p,s)$, Eqs. (2.37) and (2.39), is about 14 times faster than when using only the basic equation $f_3(\rho,T)$, Eq. (2.11), [22]. In this comparison, the basic equation has to be applied in combination with a two-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were set for the backward equations.

2.3.5 Backward Equations and Backward Functions Dependent on the Input Variables (h,s)

In this section, all backward equations as a function of the variables (h,s) are summarized. These are the backward equations $p(h,s)$ for regions 1 to 3 and the backward equation $T_s(h,s)$ for the technically important part of region 4, the two-phase region. For the calculation of thermodynamic properties as a function of the input variables (p,h) and (p,s) without iteration from the basic equations $g(p,T)$ of regions 1 and 2, only one variable, namely the temperature, had to be provided by a backward equation. This was achieved by the backward equations $T(p,h)$ and $T(p,s)$ as given in Secs. 2.3.3 and 2.3.4. However, when thermodynamic properties as a function of the input variables (h,s) need to be calculated from the basic equations $g(p,T)$ without iteration, the backward equations $p(h,s)$ yield only one of the two input variables of the g equation, namely the pressure; the second one, the temperature, is still missing. Although direct backward equations of the form $T(h,s)$ for the single-phase regions 1 to 3 have not been developed, the temperature belonging to the input variables (h,s) can be determined by combining the respective backward equation $p(h,s)$ with the corresponding backward equation $T(p,h)$.⁶ Such a combination of two backward equations, e.g. in the form $T(h,s) = T(p(h,s),h)$, is called a *backward function* in the following text. For given values of (h,s) , property calculations in region 3 from the basic equation $f_3(\rho,T)$, Eq. (2.11), require, in addition to temperature (see above), the determination of the density $\rho = 1/v$. The value of the specific volume v can be obtained without iteration from the backward

⁶The alternative use of the backward equation $T(p,s)$ leads to worse numerical consistency.

function $v(p(h,s),s)$, which is a combination of the two backward equations $p(h,s)$ and $v(p,s)$.⁷ Another example is the calculation of the saturation pressure p_s as a function of (h,s) in the part of the two-phase region 4 that is important for steam-turbine calculations. In this region, $p_s(h,s)$ can be calculated without iteration from the backward function $p_s(T_s(h,s))$ formed by the combination of the backward equation $T_s(h,s)$, Eq. (2.61), with the saturation-pressure equation $p_s(T)$, Eq. (2.13).

The first backward equations that were developed after the adoption of IAPWS-IF97 were the equations $p_s(h,s)$ for regions 1 and 2 [16]; these equations were adopted by IAPWS in 2001 and slightly revised in 2014 [23]. Later, the corresponding backward equations for region 3 including all region-boundary equations were developed [18], adopted by IAPWS in 2004, and slightly revised in 2014 [25].

Figure 2.13 shows in an h - s diagram the assignment of the backward equations $p(h,s)$ to the single-phase regions 1 to 3 and $T_s(h,s)$ to region 4 for $s \geq s''(623.15 \text{ K})$. In Sec. 2.3.5.1, the calculation of h values along the region boundaries for given values of s is described and the region-boundary equations themselves are in Sec. 2.3.5.2.

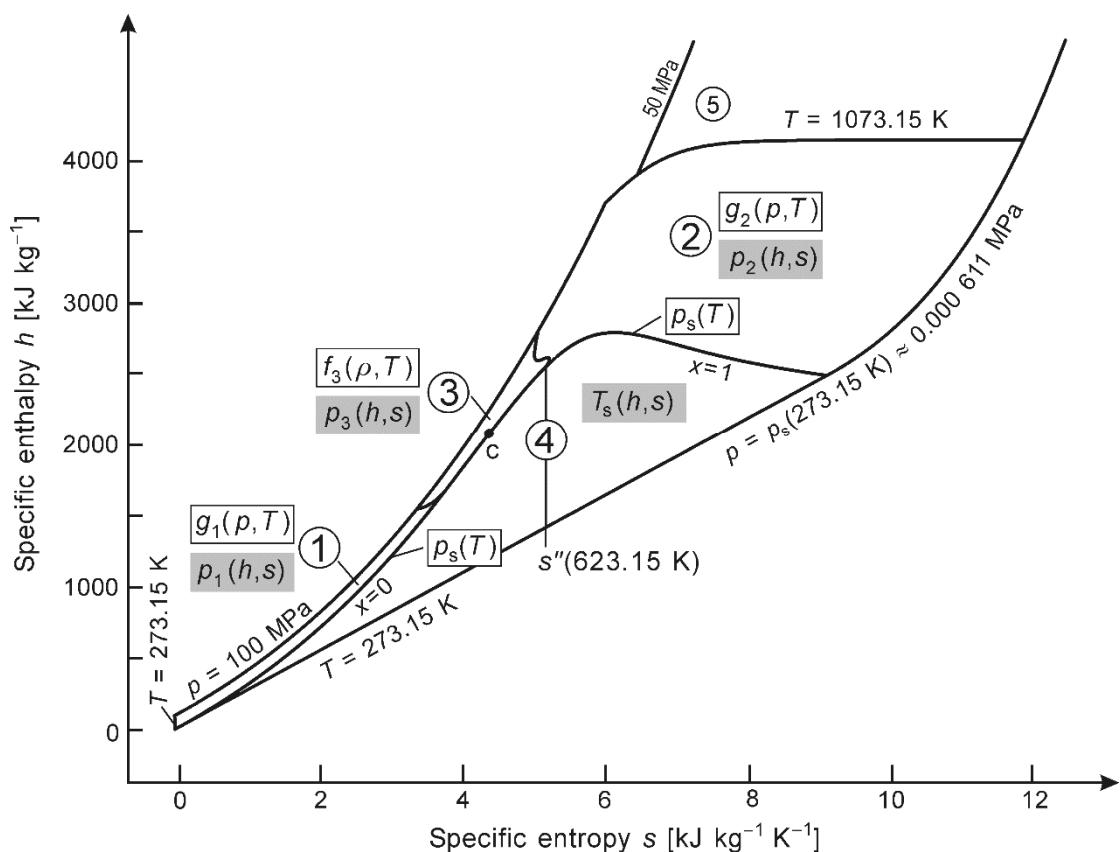


Fig. 2.13 Assignment of the backward equations $p(h,s)$ to the single-phase regions 1 to 3 and $T_s(h,s)$ to that part of the two-phase region 4 with $s \geq s''(623.15 \text{ K})$. For this overview, it is not shown how regions 2 and 3 will be divided into subregions.

⁷The alternative use of the backward equation $v(p,h)$ leads to worse numerical consistency.

2.3.5.1 Regions and Region Boundaries in the Variables (h, s)

When property calculations with IAPWS-IF97 for regions 1 to 4 are carried out with the variables (h, s) as input variables, the regions are defined by describing how to calculate the h values for given s values along the outer region boundaries and the boundaries between the regions of IAPWS-IF97. Thus, all tests to determine whether a given (h, s) point is within the range of regions 1 to 4 of IAPWS-IF97 and, if so, in which region, must be performed with respect to these input variables. To be able to carry out such tests without any iteration, the h values along the region boundaries for given values of s must be calculable without iteration. Therefore, for all boundaries *between* the various regions, special region-boundary equations of the form $h(s)$ and $T(h, s)$, were developed [18], adopted by IAPWS in 2004, and slightly revised in 2014 [25], see Fig. 2.14. All of these region-boundary equations are given in Sec. 2.3.5.2. There are no special region-boundary equations for the outer region boundaries formed by the two isobars $p = 100$ MPa and $p = p_s$ (273.15 K) $\approx 0.000\,611$ MPa and by the two isotherms $T = 273.15$ K and $T = 1073.15$ K, see Fig. 2.14.

Based on Fig. 2.14, the following subsections summarize which equations should be used to calculate h values along the various region boundaries for given values of s . For the two isotherms $T = 273.15$ K and $T = 1073.15$ K, for which the enthalpy calculations cannot be carried out without iterations, a special procedure is presented to perform the necessary tests without calculating the enthalpies along these boundaries.

Note. When calculating properties with the help of backward equations for a given state point extremely close to a region boundary, attention should be paid to the existence of (very small) inconsistencies between backward equations and basic equations, and between region-boundary equations and basic equations. Due to these inconsistencies, the calculations could indicate that the state point is in the adjacent region, but (of course) extremely close to the region boundary. The user should be aware of these effects in order to avoid possible numerical problems by taking suitable measures in the program code. For this purpose, corresponding notes on how to proceed in such cases are given in the respective sections.

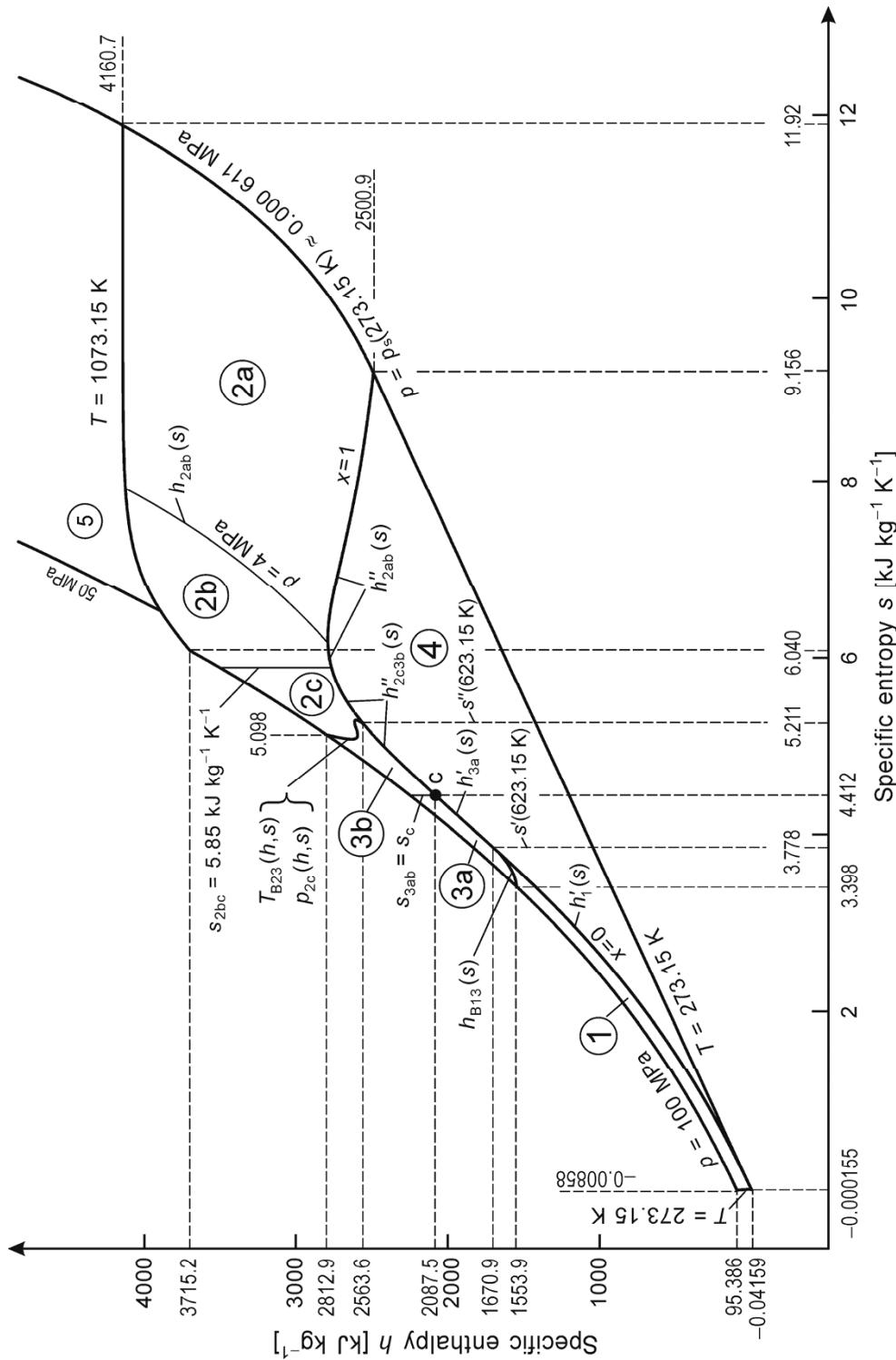


Fig. 2.14 Assignment of the region-boundary equations $h_{B13}(s)$, the combination of $T_{B23}(h, s)$ and $P_{2c}(h, s)$, $h_{23}(s)$, $h_{23a}(s)$, $h_{23b}(s)$, and $h_{2ab}^2(s)$ to the corresponding region boundaries. The h and s values at the corner points of the region boundaries are rounded values.

a) Outer Boundaries of Regions 1 to 4

The description of the boundaries starts at the left-hand side of Fig. 2.14 with the isotherm $T = 273.15$ K and proceeds clockwise.

The Isotherm $T = 273.15$ K. This isotherm is the lowest temperature limit of region 1 and of IAPWS-IF97 as a whole. Figure 2.15 shows the h - s region around the isotherm $T = 273.15$ K in greater detail. In the range between the saturated-liquid line ($x = 0$) and the isobar $p = 100$ MPa, this isotherm covers the ranges of specific enthalpy and specific entropy given by

$$h_1(p_s(273.15 \text{ K}), 273.15 \text{ K}) \leq h \leq h_1(100 \text{ MPa}, 273.15 \text{ K}),$$

$$s_1(100 \text{ MPa}, 273.15 \text{ K}) \leq s \leq s_{\max}(T = 273.15 \text{ K})$$

with $s_{\max}(T = 273.15 \text{ K}) = 4.751\,610\,056\,7 \times 10^{-4} \text{ kJ kg}^{-1} \text{ K}^{-1}$.

The value of p_s is calculated from the $p_s(T)$ equation, Eq. (2.13); s_{\max} was determined from the basic equation of region 1, $g_1(p, T)$, Eq. (2.3), by iteration.

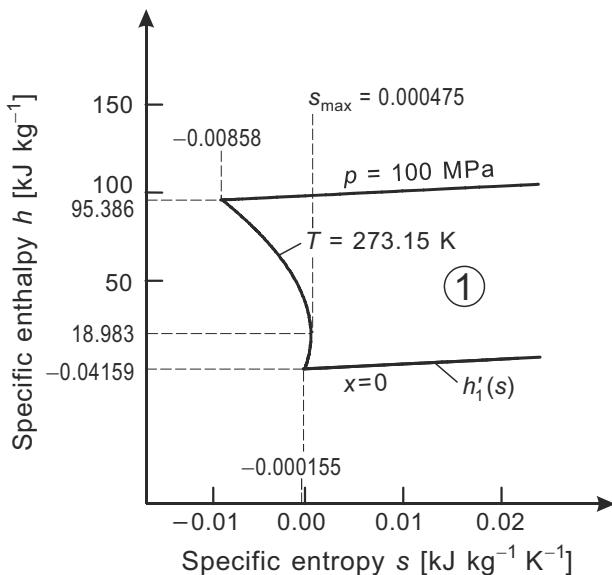


Fig. 2.15 Enlarged section of the h - s diagram of Fig. 2.14 very near the isotherm $T = 273.15$.

Along the isotherm $T = 273.15$ K, the h values for given s values can only be determined by iteration with the basic equation $g_1(p, T)$, Eq. (2.3), because there is no backward equation $p(T, s)$ that could provide the missing pressure. Thus, if values of h are needed along the isotherm $T = 273.15$ K, iterations with Eq. (2.3) cannot be avoided. It can be determined, however, without iteration, whether any given (h, s) point has a temperature $T \geq 273.15$ K, using the following method. For given values of h and s , the corresponding temperature is calculated from the backward function $T = T_1(p_1(h, s), h)$ ⁸ and compared with the boundary temperature $T = 273.15$ K. The value p_1 is determined from the backward equation $p_1(h, s)$, Eq. (2.46), and T_1 is calculated from the backward equation $T_1(p, h)$, Eq. (2.19). The extrapolation capability of the two backward equations into the entropy range down to $s = s_1(100 \text{ MPa}, 273.15 \text{ K})$ was successfully tested.

⁸ The alternative use of the backward equation $T_1(p, s)$ leads to worse numerical consistency.

Note. For (h, s) points extremely close to the boundary $T = 273.15$ K, the following procedure is recommended. When calculating the temperature $T = T_1(p_1(h, s), h)$ as described above, the numerical inconsistency of the combined backward equations $p_1(h, s)$ and $T_1(p, h)$ with respect to the basic equation $g_1(p, T)$ has to be considered. Due to this minor inconsistency the result of the calculated temperature should be corrected to $T = T_1(p_1(h, s), h) + \Delta T$, where $\Delta T = 24$ mK according to the maximum inconsistency given in Table 2.80. This procedure ensures that (h, s) points extremely close to $T = 273.15$ K are correctly assigned to the range of validity of IAPWS-IF97.

The Isobar $p = 100$ MPa. Figure 2.14 shows that the 100 MPa isobar is the upper pressure limit for regions 1 to 4 of IAPWS-IF97 and covers the entropy range

$$s_1(100 \text{ MPa}, 273.15 \text{ K}) \leq s \leq s_2(100 \text{ MPa}, 1073.15 \text{ K}),$$

where s_1 is obtained from the basic equation of region 1, $g_1(p, T)$, Eq. (2.3), and s_2 from the basic equation of region 2, $g_2(p, T)$, Eq. (2.6).

Figure 2.9 shows that, in the range of region 1, the 100 MPa isobar covers the entropy range

$$s_1(100 \text{ MPa}, 273.15 \text{ K}) \leq s \leq s_1(100 \text{ MPa}, 623.15 \text{ K}),$$

where s_1 is calculated as given above. For this entropy range, the h value for the given s value is determined from the basic equation $g_1(p, T)$, Eq. (2.3), with $p = 100$ MPa and $T = T_1$ calculated from the backward equation $T_1(p, s)$, Eq. (2.31), with $p = 100$ MPa. The given enthalpy value can then be compared with the calculated value for h .

According to Secs. 2.3.3.4a and 2.3.4.4a and Figs. 2.8, 2.12, and 2.14, region 3 is divided into subregions 3a and 3b. Along this isobar, subregion 3a covers the entropy range

$$s_1(100 \text{ MPa}, 623.15 \text{ K}) \leq s \leq s_c \\ \text{with } s_c = 4.412\ 021\ 482\ 234\ 76 \text{ kJ kg}^{-1} \text{ K}^{-1}$$

according to Eq. (2.35) and where s_1 is determined from the basic equation $g_1(p, T)$, Eq. (2.3). For this entropy range, the h value for the given s value is calculated from the basic equation of region 3, $f_3(\rho, T)$, Eq. (2.11), with $\rho = 1/v_{3a}$ and $T = T_{3a}$, where v_{3a} and T_{3a} are calculated from the backward equations $v_{3a}(p, s)$ and $T_{3a}(p, s)$, Eqs. (2.36) and (2.38), with $p = 100$ MPa. The given enthalpy value can then be compared with the calculated value for h .

The entropy range of subregion 3b along the isobar $p = 100$ MPa is given by the relation

$$s_c \leq s \leq s_2(100 \text{ MPa}, 863.15 \text{ K})$$

with s_c as given in Eq. (2.35) and s_2 determined from the basic equation of region 2, $g_2(p, T)$, Eq. (2.6), for $p = 100$ MPa and $T = 863.15$ K, the highest temperature on the B23-line that is described by the equation $T_{B23}(p)$, Eq. (2.2). For this entropy range, the h value for the given s value is obtained from the basic equation $f_3(\rho, T)$, Eq. (2.11), with $\rho = 1/v_{3b}$ and $T = T_{3b}$, where v_{3b} and T_{3b} are determined from the backward equations $v_{3b}(p, s)$ and $T_{3b}(p, s)$, Eqs. (2.37) and (2.39), for $p = 100$ MPa. The given enthalpy value can then be compared with the calculated value for h .

As described in Secs. 2.3.3.3a and 2.3.4.3a and illustrated in Figs. 2.7, 2.11, and 2.14, region 2 is divided into subregions 2a, 2b, and 2c. Along the isobar $p = 100$ MPa, region 2c covers the entropy range

$$s_2(100 \text{ MPa}, 863.15 \text{ K}) < s \leq s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1},$$

where $T = 863.15$ K in accordance with the $T_{B23}(p)$ equation, Eq. (2.2), for $p = 100$ MPa. The calculation of s_2 is the same as described above for subregion 3b. For this entropy range, the h value

for the given s value is obtained from the basic equation $g_2(p, T)$, Eq. (2.6), with $p = 100$ MPa and $T = T_{2c}$ determined from the backward equation $T_{2c}(p, s)$, Eq. (2.34), with $p = 100$ MPa. The given enthalpy value can then be compared with the calculated value for h .

According to Fig. 2.14, the uppermost part of the isobar $p = 100$ MPa is given by the entropy range

$$s_{2bc} \leq s \leq s_2(100 \text{ MPa}, 1073.15 \text{ K})$$

with $s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and s_2 calculated from the basic equation $g_2(p, T)$, Eq. (2.6). The h value for the given s value is obtained from the equation $g_2(p, T)$ with $p = 100$ MPa and $T = T_{2b}$ determined from the backward equation $T_{2b}(p, s)$, Eq. (2.33), for $p = 100$ MPa. The given enthalpy value can then be compared with the calculated value for h .

Note. For such (h, s) points extremely close to the boundary $p = 100$ MPa, the following procedure is recommended. When calculating the enthalpy at the boundary $p = 100$ MPa as described above, the numerical inconsistencies of the backward equations $T_1(p, s)$, $v_{3a}(p, s)$ and $T_{3a}(p, s)$, $v_{3b}(p, s)$ and $T_{3b}(p, s)$, $T_{2c}(p, s)$, and $T_{2b}(p, s)$ with respect to the basic equations $g_1(p, T)$, $f_3(\rho, T)$, and $g_2(p, T)$ have to be considered. Due to these minor inconsistencies the results for the calculated temperatures and specific volumes should be corrected according to the maximum inconsistencies given in Tables 2.53, 2.62, 2.66, and 2.58 as follows:

$$\begin{aligned} T &= T_1(p, s) - \Delta T, \text{ where } \Delta T = 21.8 \text{ mK}, \\ v &= v_{3a}(p, s) (1 + \Delta v/v), \text{ where } \Delta v/v = 9.6 \times 10^{-5}, \\ T &= T_{3a}(p, s) - \Delta T, \text{ where } \Delta T = 24.8 \text{ mK}, \\ v &= v_{3b}(p, s) (1 + \Delta v/v), \text{ where } \Delta v/v = 7.7 \times 10^{-5}, \\ T &= T_{3b}(p, s) - \Delta T, \text{ where } \Delta T = 22.1 \text{ mK}, \\ T &= T_{2c}(p, s) - \Delta T, \text{ where } \Delta T = 19.0 \text{ mK}, \text{ and} \\ T &= T_{2b}(p, s) - \Delta T, \text{ where } \Delta T = 6.5 \text{ mK}. \end{aligned}$$

This procedure ensures that (h, s) points given extremely close to the boundary $p = 100$ MPa are correctly assigned to the range of validity of IAPWS-IF97.

The Isotherm $T = 1073.15 \text{ K}$. Figure 2.14 shows that the 1073.15 K isotherm corresponds to the upper temperature limit of region 2 and thus for all of regions 1 to 4 of IAPWS-IF97 and covers the entropy range

$$s_2(100 \text{ MPa}, 1073.15 \text{ K}) \leq s \leq s_2(p_s(273.15 \text{ K}), 1073.15 \text{ K}),$$

where the values of specific entropy s_2 can be calculated simply from the basic equation $g_2(p, T)$, Eq. (2.6). Along this isotherm the h values for given s values can only be calculated by iteration with the basic equation $g_2(p, T)$, Eq. (2.6), because there is no backward equation $p(T, s)$ that can provide the missing pressure. Thus, if h values are needed along this isotherm, iterations with Eq. (2.6) cannot be avoided. It can be determined, however, without iteration, whether any given (h, s) point has a temperature $T \geq 273.15 \text{ K}$, using the following method.

The (h, s) point is first checked to find out whether it meets the condition $h \leq h_{\max}$, where $h_{\max} = h_2(p_s(273.15 \text{ K}))$, 1073.15 K is the highest specific enthalpy value for all of regions 1 to 4 of IAPWS-IF97 and occurs at $p = p_s(273.15 \text{ K})$ and $T = 1073.15 \text{ K}$, see Fig. 2.14. If this enthalpy condition is not met, the (h, s) point is outside regions 1 to 4 of IAPWS-IF97 and no further test is necessary. If $h \leq h_{\max}$ is fulfilled, the backward equations $p_{2a}(h, s)$, $p_{2b}(h, s)$, $T_{2a}(p, h)$, and $T_{2b}(p, h)$ may be used to calculate the temperature for the given (h, s) point. Then, this temperature can be compared with the boundary temperature $T = 1073.15 \text{ K}$ as follows.

In the entropy range

$$s_2(100 \text{ MPa}, 1073.15 \text{ K}) \leq s < s_2(4 \text{ MPa}, 1073.15 \text{ K}),$$

for given values of h and s , the corresponding temperature can be calculated from the backward function $T = T_{2b}(p_{2b}(h, s), h)$ ⁹ and compared with the boundary temperature $T = 1073.15 \text{ K}$. The value p_{2b} is determined from the backward equation $p_{2b}(h, s)$, Eq. (2.50), and T_{2b} is calculated from the backward equation $T_{2b}(p, h)$, Eq. (2.23).

In the entropy range

$$s_2(4 \text{ MPa}, 1073.15 \text{ K}) \leq s \leq s_2(p_s(273.15 \text{ K}), 1073.15 \text{ K}),$$

for given values of h and s , the corresponding temperature can be calculated from the backward function $T = T_{2a}(p_{2a}(h, s), h)$ ¹⁰ and compared with the boundary temperature $T = 1073.15 \text{ K}$. The value p_{2a} is determined from the backward equation $p_{2a}(h, s)$, Eq. (2.49), and T_{2a} is calculated from the backward equation $T_{2a}(p, h)$, Eq. (2.22).

The extrapolation capability of the backward equations into the enthalpy range up to h_{\max} was successfully tested.

Note. For (h, s) points extremely close to the boundary $T = 1073.15 \text{ K}$, the following procedure is recommended. When calculating the temperature $T = T_{2a}(p_{2a}(h, s), h)$ or $T = T_{2b}(p_{2b}(h, s), h)$ as described above, the numerical inconsistencies of the combined backward equations $p_{2a}(h, s)$ and $T_{2a}(p, h)$ and of $p_{2b}(h, s)$ and $T_{2b}(p, h)$ with the basic equation $g_2(p, T)$ have to be considered. Due to these minor inconsistencies the results of the calculated temperatures should be corrected to $T = T_{2a}(p_{2a}(h, s), h) - \Delta T$, where $\Delta T = 9.7 \text{ mK}$, or $T = T_{2b}(p_{2b}(h, s), h) - \Delta T$, where $\Delta T = 9.8 \text{ mK}$ according to the maximum inconsistencies given in Table 2.87. This procedure ensures that (h, s) points extremely close to $T = 1073.15 \text{ K}$ are correctly assigned to region 2 of IAPWS-IF97.

The Isobar $p = p_s(273.15 \text{ K}) = 0.000\ 611\ 212\ 677 \text{ MPa}$. Figure 2.14 shows that this isobar is the lower pressure limit of the IAPWS-IF97 backward equations. Within regions 1 to 4 of IAPWS-IF97, this isobar covers the entropy range entirely:

$$s_1(p_s(273.15 \text{ K}), 273.15 \text{ K}) \leq s \leq s_2(p_s(273.15 \text{ K}), 1073.15 \text{ K}),$$

where s_1 is determined from the basic equation $g_1(p, T)$, Eq. (2.3), and s_2 is obtained from the basic equation $g_2(p, T)$, Eq. (2.6).

As can be seen in Fig. 2.14, the entropy range in which this isobar limits region 2a is defined by

$$s''(273.15 \text{ K}) \leq s \leq s_2(p_s(273.15 \text{ K}), 1073.15 \text{ K}) \\ \text{with } s''(273.15 \text{ K}) = s_2(p_s(273.15 \text{ K}), 273.15 \text{ K}),$$

where the specific entropies s_2 are calculated from the basic equation $g_2(p, T)$, Eq. (2.6), and $p = p_s(T)$ according to Eq. (2.13) with $T = 273.15 \text{ K}$. For this entropy range, the h value for the given s value is determined from the basic equation $g_2(p, T)$ with $T = T_{2a}$ calculated from the backward equation $T_{2a}(p, s)$, Eq. (2.32), with $p = p_s(273.15 \text{ K})$. The given enthalpy value can then be compared with the calculated h value.

The isobar $p = p_s(273.15 \text{ K})$ also forms the lower pressure limit of the two-phase region 4 over the entropy range

⁹ The alternative use of the backward equation $T_{2b}(p, s)$ leads to worse numerical consistency.

¹⁰ The alternative use of the backward equation $T_{2a}(p, s)$ leads to worse numerical consistency.

$$s'(273.15 \text{ K}) \leq s \leq s''(273.15 \text{ K})$$

with $s'(273.15 \text{ K}) = s_1(p_s(273.15 \text{ K}), 273.15 \text{ K})$
 and $s''(273.15 \text{ K}) = s_2(p_s(273.15 \text{ K}), 273.15 \text{ K}),$

where s_1 is calculated from the basic equation $g_1(p, T)$, Eq. (2.3), s_2 from the basic equation $g_2(p, T)$, Eq. (2.6), and p_s is obtained from Eq. (2.13). For this entropy range, the h value for the given s value is calculated by the relation

$$h = h' + \frac{s - s'}{s'' - s'} (h'' - h').$$

In this relation, $h' = h_1(p_s(273.15 \text{ K}), 273.15 \text{ K})$ and $s' = s_1(p_s(273.15 \text{ K}), 273.15 \text{ K})$ are calculated from the basic equation $g_1(p, T)$, Eq. (2.3), and $h'' = h_2(p_s(273.15 \text{ K}), 273.15 \text{ K})$ and $s'' = s_2(p_s(273.15 \text{ K}), 273.15 \text{ K})$ are determined from the basic equation $g_2(p, T)$, Eq. (2.6), where $p = p_s(T)$ is obtained from Eq. (2.13). The given enthalpy value can then be compared with the calculated value for h .

Note. For (h, s) points in the range $s''(273.15 \text{ K}) \leq s \leq s_2(p_s(273.15 \text{ K}), 1073.15 \text{ K})$ extremely close to the boundary $p = 0.000\ 611\ 212\ 677 \text{ MPa}$, the following procedure is recommended. When calculating the enthalpy at the boundary $p = 0.000\ 611\ 212\ 677 \text{ MPa}$ as described above, the numerical inconsistency between the backward equation $T_{2a}(p, s)$ and the basic equation $g_2(p, T)$ has to be considered. Due to this minor inconsistency the result of the calculated temperature should be corrected to $T = T_{2a}(p, s) + \Delta T$, where $\Delta T = 8.8 \text{ mK}$ according to the maximum inconsistency given in Table 2.58. This procedure ensures that (h, s) points extremely close to $p = 0.000\ 611\ 212\ 677 \text{ MPa}$ are correctly assigned to the range of validity of IAPWS-IF97 backward equations.

b) The Boundary between the Single-Phase Regions 1 to 3 and the Two-Phase Region 4

According to Fig. 2.14, this boundary, corresponding to the saturated-liquid and saturated-vapour lines, is described by the equations $h'_1(s)$, $h'_{3a}(s)$, $h''_{2c3b}(s)$, and $h''_{2ab}(s)$ given in Secs. 2.3.5.2a and 2.3.5.2b.

The part of the saturated-liquid line ($x = 0$) that adjoins region 1 covers the entropy range

$$s'(273.15 \text{ K}) \leq s \leq s'(623.15 \text{ K})$$

with $s'(273.15 \text{ K}) = s_1(p_s(273.15 \text{ K}), 273.15 \text{ K})$
 and $s'(623.15 \text{ K}) = s_1(p_s(623.15 \text{ K}), 623.15 \text{ K}),$

where the two values s_1 are calculated from the basic equation $g_1(p, T)$, Eq. (2.3), and $p = p_s(T)$ is determined from Eq. (2.13). Along this part of the boundary, the h value for the given s value is calculated from the equation $h'_1(s)$, Eq. (2.40). The given enthalpy value can then be compared with the calculated value for h .

The part of the saturated-liquid line ($x = 0$) that adjoins subregion 3a is given by the entropy range

$$s'(623.15 \text{ K}) \leq s \leq s_c,$$

with $s'(623.15 \text{ K}) = s_1(p_s(623.15 \text{ K}), 623.15 \text{ K})$

and the value of s_c is given in Eq. (2.35); p_s is determined from Eq. (2.13). Along this part of the boundary, the h value for the given s value is calculated from the equation $h'_{3a}(s)$, Eq. (2.41). The given enthalpy value can then be compared with the calculated value for h .

The part of the saturated-vapour line ($x = 1$) extending from the critical point to the subregion boundary s_{2bc} covers the entropy range

$$s_c \leq s < s_{2bc}$$

with s_c according to Eq. (2.35) and $s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$. Along this part of the boundary, the h value for the given s value is calculated from the equation $h''_{2c3b}(s)$, Eq. (2.43). The given enthalpy value can then be compared with the calculated value for h .

The rest of the saturated-vapour line ($x = 1$) is within the entropy range

$$s_{2bc} \leq s \leq s''(273.15 \text{ K}),$$

with $s''(273.15 \text{ K}) = s_2(p_s(273.15 \text{ K}), 273.15 \text{ K})$,

where $s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and s_2 is obtained from the basic equation $g_2(p, T)$, Eq. (2.6), with $p = p_s(T)$ according to Eq. (2.13). Along this part of the boundary, the h value for the given s value is determined from the equation $h''_{2ab}(s)$, Eq. (2.42). The given enthalpy value can then be compared with the calculated value for h .

Note. The entire boundary between the single-phase regions 1 to 3 and the two-phase region 4 is considered to belong to both single-phase regions and the two-phase region.

c) Boundaries between the Single-Phase Regions

As shown in Fig. 2.14, the boundaries between the single-phase regions are the boundaries between regions 1 and 3, and between regions 2 and 3. According to the statement made at the beginning of Sec. 2.2, see also Figs. 2.2 and 2.5, the boundary between regions 1 and 3 ($T = 623.15 \text{ K}$) is considered to belong to region 1 and the boundary between regions 2 and 3 (T_{B23} -line) is considered to belong to region 2. Thus, the properties along the boundary between regions 1 and 3 are calculated from the basic equation for region 1 and the properties along the boundary between regions 2 and 3 are determined from the basic equation for region 2.

Boundary between Regions 1 and 3. This boundary covers the entropy range

$$s_1(100 \text{ MPa}, 623.15 \text{ K}) \leq s \leq s'(623.15 \text{ K})$$

with $s'(623.15 \text{ K}) = s_1(p_s(623.15 \text{ K}), 623.15 \text{ K})$,

where s_1 is determined from the basic equation $g_1(p, T)$, Eq. (2.3), and $p_s(T)$ from Eq. (2.13). Along this boundary, the h value for the given s value is calculated from the equation $h_{B13}(s)$, Eq. (2.44). The given enthalpy value can then be compared with the calculated value for h .

Boundary between Regions 2 and 3. This boundary is defined by a *combination* of the region-boundary equation $T_{B23}(h, s)$ and the backward equation $p_{2c}(h, s)$ that are given as Eqs. (2.45) and (2.51). The reason why two equations are used for the description of the boundary between regions 2 and 3 is explained below.

In the variables (p, T) , (p, h) , and (p, s) , the region boundary B23 is defined simply by the B23-equation in the forms of $p_{B23}(T)$ and $T_{B23}(p)$, Eqs. (2.1) and (2.2), which is also shown in Figs. 2.2, 2.5, and 2.9. However, the definition of this boundary in the variables (h, s) is more complex. Since the equation $p_{B23}(T)$ has an S-shape in the h - s plane as illustrated in Fig. 2.16, it is not possible to develop equations of the form $h_{B23}(s)$ or $s_{B23}(h)$ for this boundary; such functions would not be single-valued. Therefore, the special region-boundary equation $T_{B23}(h, s)$, Eq. (2.45), for a small region around the B23-boundary was developed [18].

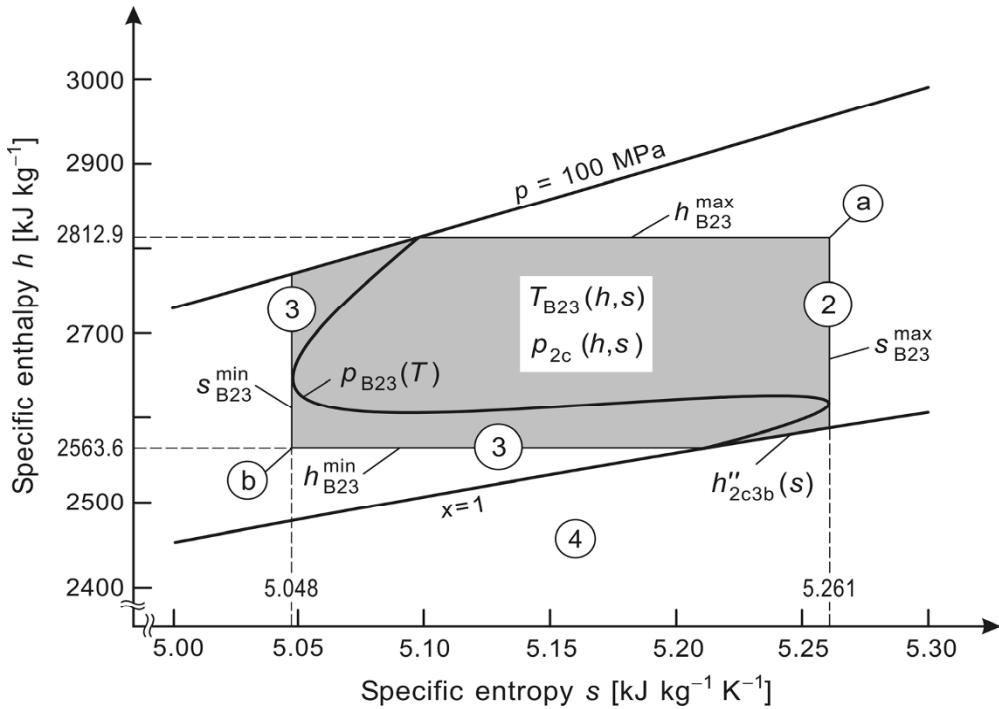


Fig. 2.16 Plot of the equation $p_{B23}(T)$, Eq. (2.1), and the range of validity (grey area) of the equation $T_{B23}(h,s)$, Eq. (2.45), in an h - s diagram. To be exact, region 2 means subregion 2c and region 3 means subregion 3b. The corner points a and b are needed to show their place in Fig. 2.17.

The range of validity of the equation $T_{B23}(h,s)$, which corresponds to the grey area in Fig. 2.16, extends from the saturated-vapour line ($x = 1$) up to 100 MPa over the entropy range

$$s_{B23}^{\min} \leq s \leq s_{B23}^{\max},$$

where $s_{B23}^{\min} = 5.048\ 096\ 828\ \text{kJ kg}^{-1}\ \text{K}^{-1}$
 and $s_{B23}^{\max} = 5.260\ 578\ 707\ \text{kJ kg}^{-1}\ \text{K}^{-1}$,

and in the enthalpy range

$$h_{B23}^{\min} \leq h \leq h_{B23}^{\max},$$

where $h_{B23}^{\min} = h''(623.15\ \text{K}) = h_2(p_s(623.15\ \text{K}), 623.15\ \text{K}) = 2.563\ 592\ 004 \times 10^3\ \text{kJ kg}^{-1}$
 and $h_{B23}^{\max} = h_2(100\ \text{MPa}, 863.15\ \text{K}) = 2.812\ 942\ 061 \times 10^3\ \text{kJ kg}^{-1}$.

The entropy values of s_{B23}^{\min} and s_{B23}^{\max} were calculated from the basic equation $g_2(p,T)$, Eq. (2.6), in combination with the equation $p_{B23}(T)$, Eq. (2.1), via iteration. The two h_2 values were obtained directly from the equation $g_2(p,T)$ with $p = p_s$ that was determined from the equation $p = p_s(T)$, Eq. (2.13), for $T = 623.15\ \text{K}$.

Against this background, the test for whether a given (h,s) point is located in region 2 or region 3 is carried out as follows:

If the two conditions

$$s_{B23}^{\min} \leq s \leq s_{B23}^{\max} \quad \text{and} \quad h_{B23}^{\min} \leq h \leq h_{B23}^{\max}$$

are met, then the (h, s) point is in the grey area of Fig. 2.16. In this case, the region-boundary equation $T_{B23}(h, s)$ along with the backward equation $p_{2c}(h, s)$, Eq. (2.51), determine in which region the given (h, s) point is located.

If the (h, s) point fulfils the condition

$$p_{2c}(h, s) \leq p_{B23}(T_{B23}(h, s)),$$

then the (h, s) point is in region 2, otherwise it is in region 3.

In these tests, the values of s_{B23}^{\min} , s_{B23}^{\max} , h_{B23}^{\min} , and h_{B23}^{\max} are given above, $p_{2c}(h, s)$ is obtained from Eq. (2.51), $T_{B23}(h, s)$ from Eq. (2.45), and $p_{B23}(T)$ from Eq. (2.1) with $T = T_{B23}$. Checks were made to ensure that the backward equation $p_{2c}(h, s)$ can be reasonably extrapolated into region 3 for $s \geq s_{B23}^{\min}$ and $h \geq h_{B23}^{\min}$. For further information, Fig. 2.17 shows the range of validity of the region-boundary equation $T_{B23}(h, s)$, Eq. (2.45), in a p - T diagram.

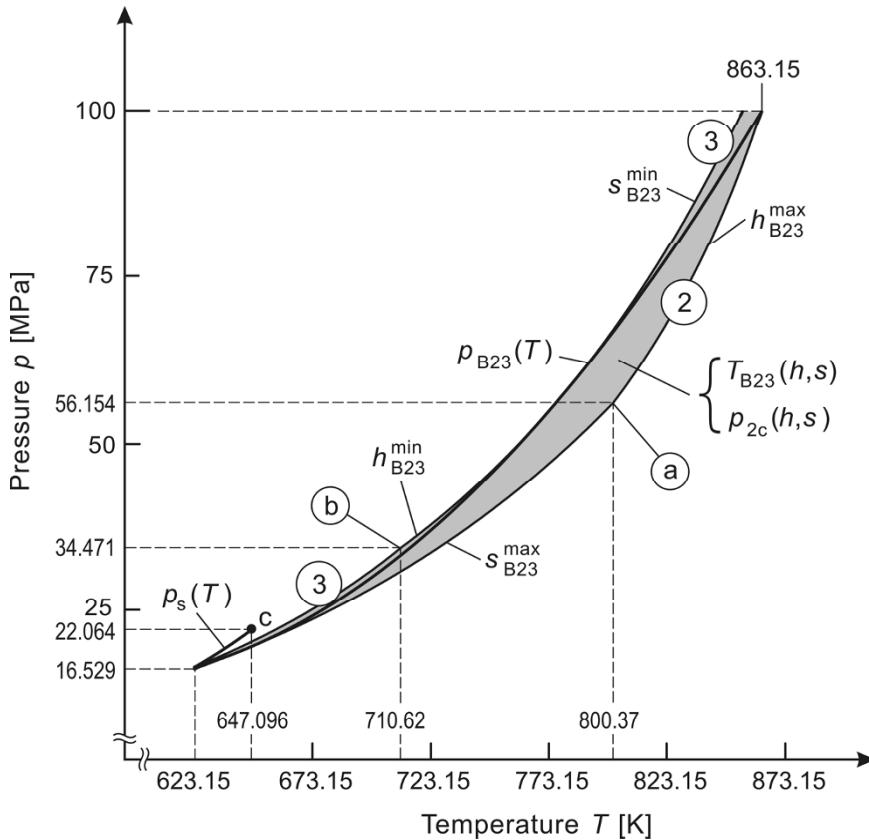


Fig. 2.17 Illustration of the B23-equation $p_{B23}(T)$, Eq. (2.1), and the range of validity of the boundary equation $T_{B23}(h, s)$, Eq. (2.45), in a p - T diagram. To be exact, region 2 means subregion 2c and region 3 means subregion 3b.

Note. For (h, s) points extremely close to the boundary between regions 2 and 3, the following procedure is recommended. When calculating pressures with the equations $p_{B23}(T_{B23}(h, s))$ and $p_{2c}(h, s)$, the numerical inconsistency of 0.0045% in pressure of the used equations $T_{B23}(h, s)$, Eq. (2.45), and $p_{2c}(h, s)$, Eq. (2.51), with the B23-equation $p_{B23}(T)$, Eq. (2.1), have to be considered. Due to this minor inconsistency the result of the calculated pressure p_{B23} should be corrected to $p_{B23} = p_{B23}(T_{B23}(h, s))(1 + \Delta p/p)$, where $\Delta p/p = 4.5 \times 10^{-5}$. This procedure ensures that (p, h) points extremely close to the region boundary $p_{B23}(T)$ are correctly assigned to region 2 and not falsely to region 3.

2.3.5.2 Equations for Region Boundaries in the Variables (h, s)

In this section, all of the equations that describe the region boundaries in the variables (h, s) are summarized. The equations for the saturated-liquid line, for the saturated-vapour line, and for the two boundaries between the single-phase regions are given in separate subsections.

When the backward equations and backward functions depending on (h, s) are used in combination with such boundary equations, their inconsistencies with the respective basic equation are less than the permissible values, as given in Sec. 2.3.2. Therefore, the use of these special region-boundary equations determines the region in which a given (h, s) point is located without computing-time consuming iterations with the basic equations of regions 1 to 4.

a) Boundary Equations $h'(s)$ for the Saturated-Liquid Line

In order to meet the requirements for numerical consistency given in Sec. 2.3.2, the saturated-liquid line ($x = 0$) is covered by two equations of the form $h'_1(s)$.

The equation $h'_1(s)$ describes the saturated-liquid line over the entire range adjoining the single-phase region 1. As shown in Fig. 2.14, the equation $h'_1(s)$ covers the temperature range from 273.15 K to 623.15 K with the entropy range given by:

$$s'(273.15 \text{ K}) \leq s \leq s'(623.15 \text{ K})$$

with $s'(273.15 \text{ K}) = s_1(p_s(273.15 \text{ K}), 273.15 \text{ K}) = -1.545\ 495\ 919 \times 10^{-4} \text{ kJ kg}^{-1} \text{ K}^{-1}$
 and $s'(623.15 \text{ K}) = s_1(p_s(623.15 \text{ K}), 623.15 \text{ K}) = 3.778\ 281\ 340 \text{ kJ kg}^{-1} \text{ K}^{-1}$,

where the two values for s_1 were calculated from the basic equation $g_1(p, T)$, Eq. (2.3), with $p = p_s(T)$ from Eq. (2.13).

The boundary equation $h'_1(s)$ has the following dimensionless form:

$$\frac{h'_1(s)}{h^*} = \eta'(\sigma) = \sum_{i=1}^{27} n_i (\sigma - 1.09)^{I_i} \left(\sigma + 0.366 \times 10^{-4} \right)^{J_i}, \quad (2.40)$$

where $\eta = h/h^*$ and $\sigma = s/s^*$ with $h^* = 1700 \text{ kJ kg}^{-1}$ and $s^* = 3.8 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.40) are listed in Table 2.67.

The equation $h'_{3a}(s)$, Eq. (2.41), describes the saturated-liquid line in the range adjoining the single-phase region 3a. Figure 2.14 shows that this equation covers the entropy range

$$s'(623.15 \text{ K}) \leq s \leq s_c$$

with $s'(623.15 \text{ K}) = 3.778\ 281\ 340 \text{ kJ kg}^{-1} \text{ K}^{-1}$
 and $s_c = 4.412\ 021\ 482\ 234\ 76 \text{ kJ kg}^{-1} \text{ K}^{-1}$

according to Eq. (2.35); the procedure of calculating the value for $s'(623.15 \text{ K})$ is given above.

The boundary equation $h'_{3a}(s)$ has the following dimensionless form:

$$\frac{h'_{3a}(s)}{h^*} = \eta'(\sigma) = \sum_{i=1}^{19} n_i (\sigma - 1.09)^{I_i} (\sigma + 0.366 \times 10^{-4})^{J_i}, \quad (2.41)$$

where $\eta = h/h^*$ and $\sigma = s/s^*$ with $h^* = 1700 \text{ kJ kg}^{-1}$ and $s^* = 3.8 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.41) are listed in Table 2.68.

The equation $h'_1(s)$, Eq. (2.40), meets exactly the enthalpy value $h'(273.15 \text{ K}) = h_1(p_s(273.15 \text{ K}), 273.15 \text{ K}) = -4.158 782 623 \times 10^{-2} \text{ kJ kg}^{-1}$ that was determined from the basic equation $g_1(p, T)$, Eq. (2.3), where $p_s(273.15 \text{ K})$ is obtained from Eq. (2.13). The equation $h'_{3a}(s)$, Eq. (2.41), yields exactly the enthalpy value at the critical point $h_c = 2.087 546 845 \times 10^3 \text{ kJ kg}^{-1}$ calculated from the basic equation $f_3(\rho, T)$, Eq. (2.11), for $\rho = \rho_c$ and $T = T_c$ according to Eqs. (1.6) and (1.4).

Table 2.67 Coefficients and exponents of the boundary equation $h'_1(s)$ in its dimensionless form, Eq. (2.40)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	14	0.332 171 191 705 237	15	8	4	$0.194 486 637 751 291 \times 10^2$
2	0	36	$0.611 217 706 323 496 \times 10^{-3}$	16	12	2	$-0.357 915 139 457 043 \times 10^1$
3	1	3	$-0.882 092 478 906 822 \times 10^1$	17	12	4	$-0.335 369 414 148 819 \times 10^1$
4	1	16	-0.455 628 192 543 250	18	14	1	-0.664 426 796 332 460
5	2	0	$-0.263 483 840 850 452 \times 10^{-4}$	19	14	22	$0.323 321 885 383 934 \times 10^5$
6	2	5	$-0.223 949 661 148 062 \times 10^2$	20	16	10	$0.331 766 744 667 084 \times 10^4$
7	3	4	$-0.428 398 660 164 013 \times 10^1$	21	20	12	$-0.223 501 257 931 087 \times 10^5$
8	3	36	-0.616 679 338 856 916	22	20	28	$0.573 953 875 852 936 \times 10^7$
9	4	4	$-0.146 823 031 104 040 \times 10^2$	23	22	8	$0.173 226 193 407 919 \times 10^3$
10	4	16	$0.284 523 138 727 299 \times 10^3$	24	24	3	$-0.363 968 822 121 321 \times 10^{-1}$
11	4	24	$-0.113 398 503 195 444 \times 10^3$	25	28	0	$0.834 596 332 878 346 \times 10^{-6}$
12	5	18	$0.115 671 380 760 859 \times 10^4$	26	32	6	$0.503 611 916 682 674 \times 10^1$
13	5	24	$0.395 551 267 359 325 \times 10^3$	27	32	8	$0.655 444 787 064 505 \times 10^2$
14	7	1	$-0.154 891 257 229 285 \times 10^1$				

Table 2.68 Coefficients and exponents of the boundary equation $h'_{3a}(s)$ in its dimensionless form, Eq. (2.41)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	1	0.822 673 364 673 336	11	6	4	0.191 413 958 471 069
2	0	4	0.181 977 213 534 479	12	7	2	$0.581 062 241 093 136 \times 10^{-1}$
3	0	10	$-0.112 000 260 313 624 \times 10^{-1}$	13	7	28	$-0.165 505 498 701 029 \times 10^4$
4	0	16	$-0.746 778 287 048 033 \times 10^{-3}$	14	7	32	$0.158 870 443 421 201 \times 10^4$
5	2	1	-0.179 046 263 257 381	15	10	14	$-0.850 623 535 172 818 \times 10^2$
6	3	36	$0.424 220 110 836 657 \times 10^{-1}$	16	10	32	$-0.317 714 386 511 207 \times 10^5$
7	4	3	-0.341 355 823 438 768	17	10	36	$-0.945 890 406 632 871 \times 10^5$
8	4	16	$-0.209 881 740 853 565 \times 10^1$	18	32	0	$-0.139 273 847 088 690 \times 10^{-5}$
9	5	20	$-0.822 477 343 323 596 \times 10^1$	19	32	6	0.631 052 532 240 980
10	5	36	$-0.499 684 082 076 008 \times 10^1$				

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.40) and (2.41), Table 2.69 contains test values for calculated enthalpies.

Table 2.69 Values of the specific enthalpy calculated from Eqs. (2.40) and (2.41) for selected specific entropies^a

Equation	$s \text{ [kJ kg}^{-1} \text{ K}^{-1}\text{]}$	$h \text{ [kJ kg}^{-1}\text{]}$
$h'_1(s)$, Eq. (2.40)	1.0	$3.085\ 509\ 647 \times 10^2$
	2.0	$7.006\ 304\ 472 \times 10^2$
	3.0	$1.198\ 359\ 754 \times 10^3$
$h'_{3a}(s)$, Eq. (2.41)	3.8	$1.685\ 025\ 565 \times 10^3$
	4.0	$1.816\ 891\ 476 \times 10^3$
	4.2	$1.949\ 352\ 563 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Note. For (h, s) points extremely close to the saturated-liquid line, the following procedure is recommended. When calculating specific enthalpies with equations $h'_1(s)$, Eq. (2.40), and $h'_{3a}(s)$, Eq. (2.41), their numerical inconsistencies of $0.0034 \text{ kJ kg}^{-1}$ and $0.0045 \text{ kJ kg}^{-1}$ in specific enthalpy with respect to the basic equations $g_1(p, T)$, Eq. (2.3), and $f_3(\rho, T)$, Eq. (2.11), have to be considered. Due to these minor inconsistencies, the results of the calculated enthalpies should be corrected to $h'_1 = h'_1(s) - \Delta h$, where $\Delta h = 0.0034 \text{ kJ kg}^{-1}$ and $h'_{3a} = h'_{3a}(s) - \Delta h$, where $\Delta h = 0.0045 \text{ kJ kg}^{-1}$. This procedure ensures that (h, s) points extremely close to the saturated-liquid line will be correctly assigned to the single-phase region and not falsely to the two-phase region.

b) Boundary Equations $h''(s)$ for the Saturated-Vapour Line

The equation $h''_{2ab}(s)$ describes the saturated-vapour line in the range adjoining the single-phase subregions 2a and 2b. Figure 2.14 shows that this equation covers the entropy range

$$s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1} \leq s \leq s''(273.15 \text{ K})$$

with $s''(273.15 \text{ K}) = s_2(p_s(273.15 \text{ K}), 273.15 \text{ K}) = 9.155\ 759\ 395 \text{ kJ kg}^{-1} \text{ K}^{-1}$,

where s_2 was calculated from the basic equation $g_2(p, T)$, Eq. (2.6), with $p = p_s(T)$ from Eq. (2.13).

The boundary equation $h''_{2ab}(s)$ has the following dimensionless form:

$$\frac{h''_{2ab}(s)}{h^*} = \eta''(\sigma) = \exp \left[\sum_{i=1}^{30} n_i (\sigma_1^{-1} - 0.513)^{I_i} (\sigma_2 - 0.524)^{J_i} \right], \quad (2.42)$$

where $\eta = h/h^*$, $\sigma_1 = s/s_1^*$, and $\sigma_2 = s/s_2^*$ with $h^* = 2800 \text{ kJ kg}^{-1}$, $s_1^* = 5.21 \text{ kJ kg}^{-1} \text{ K}^{-1}$, and $s_2^* = 9.2 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.42) are listed in Table 2.70.

The equation $h''_{2c3b}(s)$ describes the saturated-vapour line in the range adjoining the single-phase subregions 2c and 3b. Figure 2.14 shows that this equation covers the entropy range

$$s_c \leq s \leq s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1},$$

where $s_c = 4.412\ 021\ 482\ 234\ 76 \text{ kJ kg}^{-1} \text{ K}^{-1}$

according to Eq. (2.35).

The boundary equation $h''_{2c3b}(s)$ has the following dimensionless form:

$$\frac{h''_{2c3b}(s)}{h^*} = \eta''(\sigma) = \left[\sum_{i=1}^{16} n_i (\sigma - 1.02)^{I_i} (\sigma - 0.726)^{J_i} \right]^4, \quad (2.43)$$

where $\eta = h/h^*$ and $\sigma = s/s^*$ with $h^* = 2800 \text{ kJ kg}^{-1}$ and $s^* = 5.9 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.43) are listed in Table 2.71.

The equation $h''_{2ab}(s)$, Eq. (2.42), exactly meets the enthalpy value $h''(273.15 \text{ K}) = h_2(p_s(273.15 \text{ K}), 273.15 \text{ K}) = 2.500\,892\,618 \times 10^3 \text{ kJ kg}^{-1}$ that was calculated from the basic equation $g_2(p, T)$, Eq. (2.6), where $p = p_s(T)$ is obtained from Eq. (2.13). The equation $h''_{2c3b}(s)$, Eq. (2.43), yields exactly the enthalpy value at the critical point $h_c = 2.087\,546\,845 \times 10^3 \text{ kJ kg}^{-1}$ that was calculated from the basic equation $f_3(\rho, T)$, Eq. (2.11), for $\rho = \rho_c = 322 \text{ kg m}^{-3}$ and $T = T_c = 647.096 \text{ K}$ according to Eqs. (1.6) and (1.4).

Table 2.70 Coefficients and exponents of the boundary equation $h''_{2ab}(s)$ in its dimensionless form, Eq. (2.42)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	1	8	$-0.524\,581\,170\,928\,788 \times 10^3$	16	28	8	$0.660\,788\,766\,938\,091 \times 10^{16}$
2	1	24	$-0.926\,947\,218\,142\,218 \times 10^7$	17	28	12	$0.166\,320\,055\,886\,021 \times 10^{23}$
3	2	4	$-0.237\,385\,107\,491\,666 \times 10^3$	18	28	20	$-0.218\,003\,784\,381\,501 \times 10^{30}$
4	2	32	$0.210\,770\,155\,812\,776 \times 10^{11}$	19	28	22	$-0.787\,276\,140\,295\,618 \times 10^{30}$
5	4	1	$-0.239\,494\,562\,010\,986 \times 10^2$	20	28	24	$0.151\,062\,329\,700\,346 \times 10^{32}$
6	4	2	$0.221\,802\,480\,294\,197 \times 10^3$	21	32	2	$0.795\,732\,170\,300\,541 \times 10^7$
7	7	7	$-0.510\,472\,533\,393\,438 \times 10^7$	22	32	7	$0.131\,957\,647\,355\,347 \times 10^{16}$
8	8	5	$0.124\,981\,396\,109\,147 \times 10^7$	23	32	12	$-0.325\,097\,068\,299\,140 \times 10^{24}$
9	8	12	$0.200\,008\,436\,996\,201 \times 10^{10}$	24	32	14	$-0.418\,600\,611\,419\,248 \times 10^{26}$
10	10	1	$-0.815\,158\,509\,791\,035 \times 10^3$	25	32	24	$0.297\,478\,906\,557\,467 \times 10^{35}$
11	12	0	$-0.157\,612\,685\,637\,523 \times 10^3$	26	36	10	$-0.953\,588\,761\,745\,473 \times 10^{20}$
12	12	7	$-0.114\,200\,422\,332\,791 \times 10^{11}$	27	36	12	$0.166\,957\,699\,620\,939 \times 10^{25}$
13	18	10	$0.662\,364\,680\,776\,872 \times 10^{16}$	28	36	20	$-0.175\,407\,764\,869\,978 \times 10^{33}$
14	20	12	$-0.227\,622\,818\,296\,144 \times 10^{19}$	29	36	22	$0.347\,581\,490\,626\,396 \times 10^{35}$
15	24	32	$-0.171\,048\,081\,348\,406 \times 10^{32}$	30	36	28	$-0.710\,971\,318\,427\,851 \times 10^{39}$

Table 2.71 Coefficients and exponents of the boundary equation $h''_{2c3b}(s)$ in its dimensionless form, Eq. (2.43)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.104\,351\,280\,732\,769 \times 10^1$	9	8	2	$0.743\,957\,464\,645\,363 \times 10^4$
2	0	3	$-0.227\,807\,912\,708\,513 \times 10^1$	10	8	20	$-0.356\,896\,445\,355\,761 \times 10^{20}$
3	0	4	$0.180\,535\,256\,723\,202 \times 10^1$	11	12	32	$0.167\,590\,585\,186\,801 \times 10^{32}$
4	1	0	$0.420\,440\,834\,792\,042$	12	16	36	$-0.355\,028\,625\,419\,105 \times 10^{38}$
5	1	12	$-0.105\,721\,244\,834\,660 \times 10^6$	13	22	2	$0.396\,611\,982\,166\,538 \times 10^{12}$
6	5	36	$0.436\,911\,607\,493\,884 \times 10^{25}$	14	22	32	$-0.414\,716\,268\,484\,468 \times 10^{41}$
7	6	12	$-0.328\,032\,702\,839\,753 \times 10^{12}$	15	24	7	$0.359\,080\,103\,867\,382 \times 10^{19}$
8	7	16	$-0.678\,686\,760\,804\,270 \times 10^{16}$	16	36	20	$-0.116\,994\,334\,851\,995 \times 10^{41}$

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.42) and (2.43), Table 2.72 contains test values for calculated enthalpies.

Table 2.72 Values of the specific enthalpy calculated from Eqs. (2.42) and (2.43) for selected specific entropies^a

Equation	s [kJ kg ⁻¹ K ⁻¹]	h [kJ kg ⁻¹]
$h''_{2ab}(s)$, Eq. (2.42)	7.0	$2.723\ 729\ 985 \times 10^3$
	8.0	$2.599\ 047\ 210 \times 10^3$
	9.0	$2.511\ 861\ 477 \times 10^3$
$h''_{2c3b}(s)$, Eq. (2.43)	5.5	$2.687\ 693\ 850 \times 10^3$
	5.0	$2.451\ 623\ 609 \times 10^3$
	4.5	$2.144\ 360\ 448 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Note. For (h, s) points extremely close to the saturated-vapour line, the following procedure is recommended. When calculating specific enthalpies with equations $h''_{2ab}(s)$, Eq. (2.42), and $h''_{2c3b}(s)$, Eq. (2.43), their minor numerical inconsistencies Δh with respect to the basic equations $g_2(p, T)$, Eq. (2.6), and $f_3(\rho, T)$, Eq. (2.11), have to be considered. Thus, the results of Eq. (2.42) should be corrected to $h''_{2ab} = h''_{2ab}(s) - \Delta h$, where $\Delta h = 0.0012$ kJ kg⁻¹ and the results of Eq. (2.43) should be corrected to $h''_{2c3b} = h''_{2c3b}(s) - \Delta h$, where $\Delta h = 0.0058$ kJ kg⁻¹ for $s''(623.15\text{ K}) \leq s < s_{2bc} = 5.85$ kJ kg⁻¹ K⁻¹ and $\Delta h = 0.0073$ kJ kg⁻¹ for $s_c \leq s < s''(623.15\text{ K})$. This procedure ensures that (h, s) points extremely close to the saturated-vapour line will be correctly assigned to the single-phase region and not falsely to the two-phase region.

c) Equation $h_{B13}(s)$ for the Boundary between Regions 1 and 3

The equation $h_{B13}(s)$ describes the enthalpy as a function of entropy for the isotherm $T = 623.15\text{ K}$ from the saturated-liquid line up to 100 MPa. Figure 2.14 shows that this equation covers the entropy range

$$s_1(100\text{ MPa}, 623.15\text{ K}) \leq s \leq s'(623.15\text{ K})$$

with $s_1(100\text{ MPa}, 623.15\text{ K}) = 3.397\ 782\ 955$ kJ kg⁻¹ K⁻¹
and $s'(623.15\text{ K}) = s_1(p_s(623.15\text{ K}), 623.15\text{ K}) = 3.778\ 281\ 340$ kJ kg⁻¹ K⁻¹,

where the two values for s_1 were calculated from the basic equation $g_1(p, T)$, Eq. (2.3)¹¹, and p_s from Eq. (2.13).

The boundary equation $h_{B13}(s)$ has the following dimensionless form:

$$\frac{h_{B13}(s)}{h^*} = \eta(\sigma) = \sum_{i=1}^6 n_i (\sigma - 0.884)^{I_i} (\sigma - 0.864)^{J_i}, \quad (2.44)$$

where $\eta = h/h^*$ and $\sigma = s/s^*$ with $h^* = 1700$ kJ kg⁻¹ and $s^* = 3.8$ kJ kg⁻¹ K⁻¹. The coefficients n_i and exponents I_i and J_i of Eq. (2.44) are listed in Table 2.73. Equation (2.44) describes the isotherm $T = 623.15\text{ K}$ with maximum deviations in temperature of 3.2 mK.

¹¹See the statement at the beginning of Sec. 2.3.5.1c.

Table 2.73 Coefficients and exponents of the boundary equation $h_{B13}(s)$ in its dimensionless form, Eq. (2.44)

i	I_i	J_i	n_i
1	0	0	0.913 965 547 600 543
2	1	-2	$-0.430 944 856 041 991 \times 10^{-4}$
3	1	2	$0.603 235 694 765 419 \times 10^2$
4	3	-12	$0.117 518 273 082 168 \times 10^{-17}$
5	5	-4	0.220 000 904 781 292
6	6	-3	$-0.690 815 545 851 641 \times 10^2$

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.44), Table 2.74 contains test values for calculated enthalpies.

Table 2.74 Values of the specific enthalpy calculated from Eq. (2.44) for selected specific entropies^a

Equation	$s \text{ [kJ kg}^{-1} \text{ K}^{-1}]$	$h \text{ [kJ kg}^{-1}]$
$h_{B13}(s)$, Eq. (2.44)	3.7	$1.632 525 047 \times 10^3$
	3.6	$1.593 027 214 \times 10^3$
	3.5	$1.566 104 611 \times 10^3$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Note. For (h, s) points extremely close to the boundary between regions 1 and 3, the following procedure is recommended. When calculating specific enthalpies with the equation $h_{B13}(s)$, Eq. (2.44), its numerical inconsistency of 0.018 kJ kg^{-1} in specific enthalpy with respect to the basic equation $g_1(p, T)$, Eq. (2.3), has to be considered. Due to this minor inconsistency the result of Eq. (2.44) should be corrected to $h_{B13} = h_{B13}(s) + \Delta h$, where $\Delta h = 0.018 \text{ kJ kg}^{-1}$. This procedure ensures that (h, s) points extremely close to the region boundary are correctly assigned to region 1 and not falsely to region 3.

d) Equation $T_{B23}(h, s)$ for the Boundary between Regions 2 and 3

The equation $T_{B23}(h, s)$ has the following dimensionless form:

$$\frac{T_{B23}(h, s)}{T^*} = \theta(\eta, \sigma) = \sum_{i=1}^{25} n_i (\eta - 0.727)^{I_i} (\sigma - 0.864)^{J_i}, \quad (2.45)$$

where $\theta = T/T^*$, $\eta = h/h^*$ and $\sigma = s/s^*$ with $T^* = 900 \text{ K}$, $h^* = 3000 \text{ kJ kg}^{-1}$, and $s^* = 5.3 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.45) are listed in Table 2.75. The range of validity of Eq. (2.45) and the procedure for its application are described in Sec. 2.3.5.1c, subpoint “Boundary Between Regions 2 and 3.”

Table 2.75 Coefficients and exponents of the boundary equation $T_{B23}(h, s)$ in its dimensionless form, Eq. (2.45)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	10	$0.629\ 096\ 260\ 829\ 810 \times 10^{-3}$	14	3	-2	$0.149\ 276\ 502\ 463\ 272$
2	-10	8	$-0.823\ 453\ 502\ 583\ 165 \times 10^{-3}$	15	3	-1	$0.698\ 733\ 471\ 798\ 484$
3	-8	3	$0.515\ 446\ 951\ 519\ 474 \times 10^{-7}$	16	5	-5	$-0.252\ 207\ 040\ 114\ 321 \times 10^{-1}$
4	-4	4	$-0.117\ 565\ 945\ 784\ 945 \times 10^1$	17	6	-6	$0.147\ 151\ 930\ 985\ 213 \times 10^{-1}$
5	-3	3	$0.348\ 519\ 684\ 726\ 192 \times 10^1$	18	6	-3	$-0.108\ 618\ 917\ 681\ 849 \times 10^1$
6	-2	-6	$-0.507\ 837\ 382\ 408\ 313 \times 10^{-11}$	19	8	-8	$-0.936\ 875\ 039\ 816\ 322 \times 10^{-3}$
7	-2	2	$-0.284\ 637\ 670\ 005\ 479 \times 10^1$	20	8	-2	$0.819\ 877\ 897\ 570\ 217 \times 10^2$
8	-2	3	$-0.236\ 092\ 263\ 939\ 673 \times 10^1$	21	8	-1	$-0.182\ 041\ 861\ 521\ 835 \times 10^3$
9	-2	4	$0.601\ 492\ 324\ 973\ 779 \times 10^1$	22	12	-12	$0.261\ 907\ 376\ 402\ 688 \times 10^{-5}$
10	0	0	$0.148\ 039\ 650\ 824\ 546 \times 10^1$	23	12	-1	$-0.291\ 626\ 417\ 025\ 961 \times 10^5$
11	1	-3	$0.360\ 075\ 182\ 221\ 907 \times 10^{-3}$	24	14	-12	$0.140\ 660\ 774\ 926\ 165 \times 10^{-4}$
12	1	-2	$-0.126\ 700\ 045\ 009\ 952 \times 10^{-1}$	25	14	1	$0.783\ 237\ 062\ 349\ 385 \times 10^7$
13	1	10	$-0.122\ 184\ 332\ 521\ 413 \times 10^7$				

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.45), Table 2.76 contains test values for calculated temperatures.

Table 2.76 Temperature values calculated from Eq. (2.45) for selected specific enthalpies and specific entropies^a

Equation	h [kJ kg $^{-1}$]	s [kJ kg $^{-1}$ K $^{-1}$]	T [K]
$T_{B23}(h, s)$, Eq. (2.45)	2600	5.1	$7.135\ 259\ 364 \times 10^2$
	2700	5.15	$7.685\ 345\ 532 \times 10^2$
	2800	5.2	$8.176\ 202\ 120 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Use of the Equation $T_{B23}(h, s)$, Eq. (2.45). Equation $T_{B23}(h, s)$ should only be used to determine the region for a given (h, s) point within the range of validity of Eq. (2.45) given above and by the grey area in Fig. 2.16. The procedure for such a determination by combining the equation $T_{B23}(h, s)$ with the backward equation of region 2c, $p_{2c}(h, s)$, Eq. (2.51), is described in Sec. 2.3.5.1c.

Numerical consistency. The differences between the backward equation $p_{2c}(h, s)$, Eq. (2.51), and the equation $T_{B23}(h, s)$, Eq. (2.45), combined with the equation $p_{B23}(T)$, Eq. (2.1), are small enough that the region of a given (h, s) point can be determined with sufficient accuracy. The maximum percentage inconsistency between the pressures calculated from equations $p_{B23}(T_{B23}(h, s))$ and $p_{2c}(h, s)$ at the B23-boundary amounts to 0.0045%. For a given (h, s) point extremely close to this boundary, the note at the end of Sec. 2.3.5.1c describes how to proceed.

2.3.5.3 Backward Equation $p(h,s)$ and Backward Function $T(h,s)$ for Region 1

When properties as a function of (h,s) are required from the basic equation of region 1, $g_1(p,T)$, Eq. (2.3), without iteration, both variables p and T must be calculable as a function of (h,s) . As mentioned at the beginning of Sec. 2.3.5, the relation $p(h,s)$ is provided as a direct backward equation and the relation $T(h,s)$ is given as a backward function. This backward function $T(h,s)$ is a combination of the two backward equations $p(h,s)$ and $T(p,h)$ ¹² in the form $T(p(h,s),h)$. A statement about the computing time with the backward equation and backward function can be found at the end of this section.

a) Backward Equation $p(h,s)$ for Region 1

Figure 2.18 shows the assignment of the backward equation $p_1(h,s)$ to region 1 in an h - s diagram. The boundaries of region 1 in h - s coordinates are described in Secs. 2.3.5.1a to 2.3.5.1c.

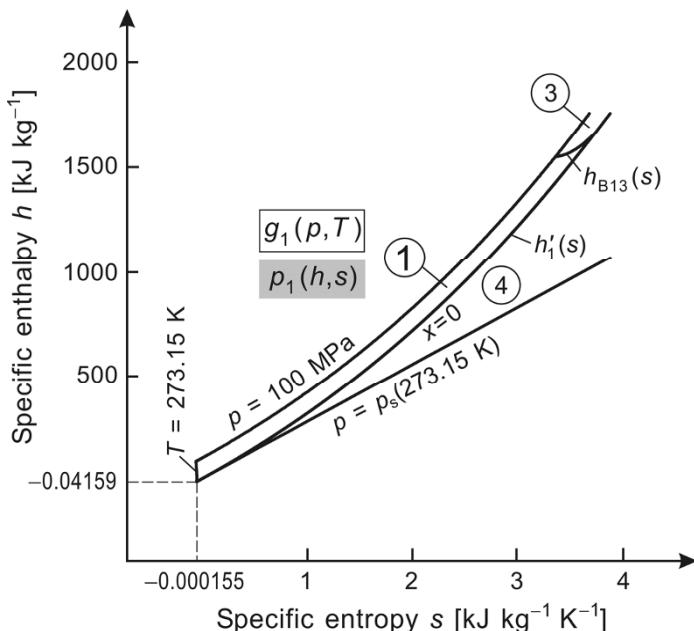


Fig. 2.18 Assignment of the backward equation $p_1(h,s)$ to region 1 in an h - s diagram. The h and s values at the corner points of region 1 are given in Fig. 2.14.

The backward equation $p_1(h,s)$ for region 1 in its dimensionless form reads:

$$\frac{p_1(h,s)}{p^*} = \pi(\eta, \sigma) = \sum_{i=1}^{19} n_i (\eta + 0.05)^{I_i} (\sigma + 0.05)^{J_i}, \quad (2.46)$$

where $\pi = p/p^*$, $\eta = h/h^*$, and $\sigma = s/s^*$ with $p^* = 100 \text{ MPa}$, $h^* = 3400 \text{ kJ kg}^{-1}$, and $s^* = 7.6 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.46) are listed in Table 2.77.

¹²The alternative use of the backward equation $T(p,s)$ leads to worse numerical consistency.

Table 2.77 Coefficients and exponents of the backward equation $p_1(h,s)$ in its dimensionless form, Eq. (2.46)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	-0.691 997 014 660 582	11	1	4	-0.319 947 848 334 300 $\times 10^3$
2	0	1	-0.183 612 548 787 560 $\times 10^2$	12	1	6	-0.928 354 307 043 320 $\times 10^3$
3	0	2	-0.928 332 409 297 335 $\times 10$	13	2	0	0.303 634 537 455 249 $\times 10^2$
4	0	4	0.659 639 569 909 906 $\times 10^2$	14	2	1	-0.650 540 422 444 146 $\times 10^2$
5	0	5	-0.162 060 388 912 024 $\times 10^2$	15	2	10	-0.430 991 316 516 130 $\times 10^4$
6	0	6	0.450 620 017 338 667 $\times 10^3$	16	3	4	-0.747 512 324 096 068 $\times 10^3$
7	0	8	0.854 680 678 224 170 $\times 10^3$	17	4	1	0.730 000 345 529 245 $\times 10^3$
8	0	14	0.607 523 214 001 162 $\times 10^4$	18	4	4	0.114 284 032 569 021 $\times 10^4$
9	1	0	0.326 487 682 621 856 $\times 10^2$	19	5	0	-0.436 407 041 874 559 $\times 10^3$
10	1	1	-0.269 408 844 582 931 $\times 10^2$				

Range of Validity. The range of validity of the backward equation $p_1(h,s)$, Eq. (2.46), can be derived from the graphical representation of region 1 in Fig. 2.14. The determination of h values for given s values along the region boundaries is described in Secs. 2.3.5.1a to 2.3.5.1c.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.46), Table 2.78 contains the corresponding test values.

Numerical Consistency. The numerical inconsistencies between the backward equation $p_1(h,s)$, Eq. (2.46), and the basic equation $g_1(p,T)$, Eq. (2.3), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.79. These inconsistencies are less than the permissible values. This is also true when the backward equation is used in combination with the corresponding boundary equations given in Sec. 2.3.5.2.

Table 2.78 Pressure values calculated from the backward equation $p_1(h,s)$, Eq. (2.46), for selected specific enthalpies and specific entropies^a

h [kJ kg $^{-1}$]	s [kJ kg $^{-1}$ K $^{-1}$]	p [MPa]
0.001	0	9.800 980 612 $\times 10^{-4}$
90	0	9.192 954 727 $\times 10^1$
1500	3.4	5.868 294 423 $\times 10^1$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Table 2.79 Maximum and root-mean-square inconsistencies in pressure between the backward equation $p_1(h,s)$, Eq. (2.46), and the basic equation $g_1(p,T)$, Eq. (2.3), in comparison with the permissible inconsistencies

Inconsistencies in pressure			
	$ \Delta p _{\text{perm}}$	$ \Delta p _{\text{max}}$	$(\Delta p)_{\text{RMS}}$
$p \leq 2.5$ MPa	0.60%	0.55%	0.11%
$p > 2.5$ MPa	15 kPa	14 kPa	6 kPa

Computing Time. A statement about the computing time is given in Sec. 2.3.5.3c.

b) Backward Function $T_1(h,s)$ for Region 1

The backward equation $p_1(h,s)$, Eq. (2.46), in combination with the backward equation $T_1(p,h)$ ¹³, Eq. (2.19), forms the backward function

$$T_1(h,s) = T_1(p_1(h,s),h), \quad (2.47)$$

where p_1 is calculated from Eq. (2.46) and $T_1(p_1,h)$ is determined from Eq. (2.19).

Range of Validity: The backward function $T_1(h,s)$, Eq. (2.47), has the same range of validity as the backward equation $p_1(h,s)$, Eq. (2.46).

Numerical Consistency. The numerical inconsistency between the backward function $T_1(h,s)$, Eq. (2.47), and the basic equation $g_1(p,T)$, Eq. (2.3), in comparison with the permissible inconsistency, given in Sec. 2.3.2, is listed in Table 2.80. This inconsistency is less than the permissible values. This is also true when the backward function in combination with the corresponding boundary equations given in Sec. 2.3.5.2 is used.

Note: When calculating properties extremely close to the saturated-liquid line, the backward function, Eq. (2.47), might yield temperatures $T_1(h,s) > T_s(p_1(h,s))$ due to minor inconsistencies; $p_1(h,s)$ is calculated from Eq. (2.46) and $T_s(p_1)$ from Eq. (2.14). In this case, the result of Eq. (2.47) should be corrected to $T_1 = T_s(p_1)$.

An analogous procedure is recommended for (h,s) points extremely close to the boundary $T = 623.15$ K between regions 1 and 3. Due to minor inconsistencies, the backward function, Eq. (2.47), might yield temperatures $T_1(h,s) > 623.15$ K. In this case, the result of Eq. (2.47) should be corrected to $T_1 = 623.15$ K.

Table 2.80 Maximum and root-mean-square inconsistency in temperature between the backward function $T_1(h,s)$, Eq. (2.47), and the basic equation $g_1(p,T)$, Eq. (2.3), in comparison with the permissible inconsistency

Inconsistencies in temperature [mK]		
$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
25	24.0	13.4

c) Computing Time when Using the Backward Equation $p_1(h,s)$ together with the Backward Function $T_1(h,s)$ in Comparison with the Basic Equation

The calculation of pressure and temperature as a function of (h,s) by using the backward equation $p_1(h,s)$, Eq. (2.46), together with the backward function $T_1(h,s)$, Eq. (2.47), is about 35 times faster than when using only the basic equation $g_1(p,T)$, Eq. (2.3), [22]. In this comparison, the basic equation was applied in combination with a two-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were set for the backward equation.

¹³The alternative use of the backward equation $T_1(p,s)$ leads to worse numerical consistency.

2.3.5.4 Backward Equations $p(h,s)$ and Backward Functions $T(h,s)$ for Region 2

When properties as a function of (h,s) need to be calculated from the basic equation of region 2, $g_2(p,T)$, Eq. (2.6), without iteration, both variables p and T must be calculable as a function of (h,s) . As mentioned at the beginning of Sec. 2.3.5, the relations $p(h,s)$ are provided as direct backward equations and the relations $T(h,s)$ are given as backward functions. These backward functions $T(h,s)$ are a combination of the two backward equations $p(h,s)$ and $T(p,h)$ ¹⁴ in the form $T(p(h,s),h)$.

a) Division of Region 2 into Subregions 2a, 2b, and 2c

Figure 2.19 shows how region 2 is divided into the three subregions 2a, 2b, and 2c for a backward equation $p(h,s)$ as was done in Secs. 2.3.3.3a and 2.3.4.3a for the backward equations $T(p,h)$ and $T(p,s)$ for region 2.

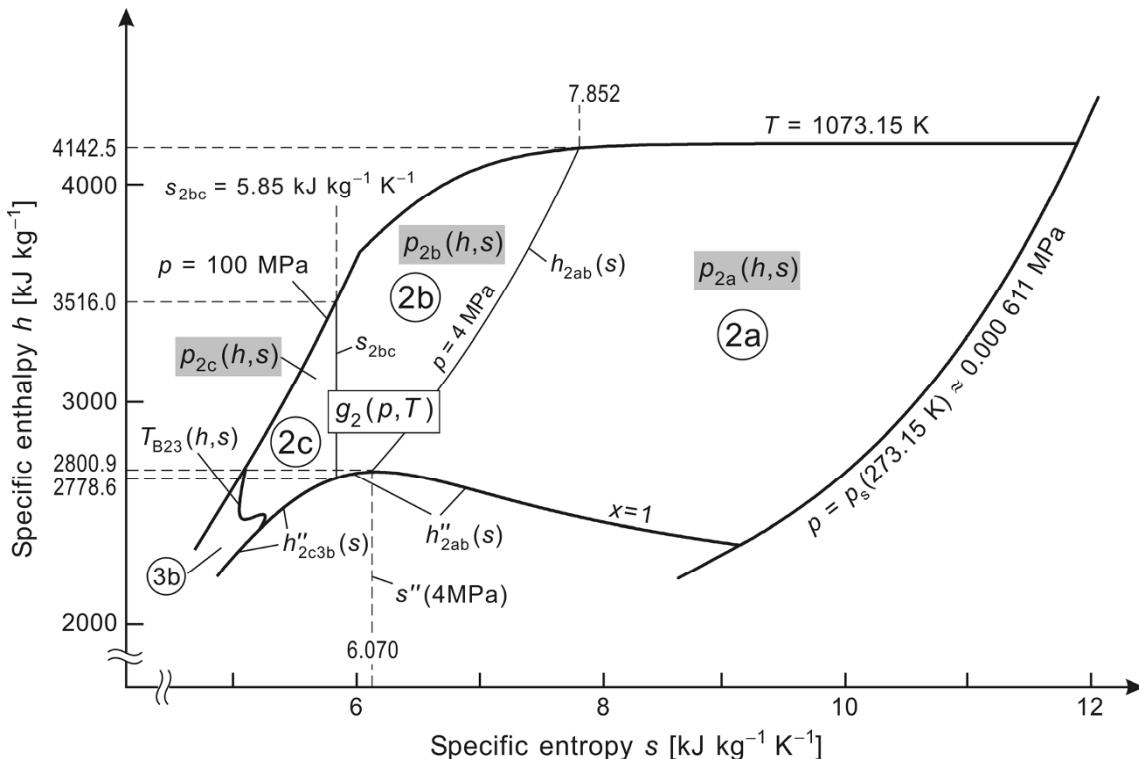


Fig. 2.19 Division of region 2 into subregions 2a, 2b, and 2c and the assignment of the backward equations $p(h,s)$ to these subregions. The h and s values at the corner points of region 2 are given in Fig. 2.14.

Boundary between Subregions 2a and 2b. This boundary corresponds to the isobar $p = 4 \text{ MPa}$. In order to determine without iteration in which of the two subregions a given (h,s) point is located,

¹⁴The alternative use of the backward equation $T(p,s)$ leads to worse numerical consistency.

the boundary equation $h_{2ab}(s)$ was developed [16, 23]. This equation that describes the isobar $p = 4 \text{ MPa}$ for the variables (h, s) reads:

$$\frac{h_{2ab}(s)}{h^*} = \eta(\sigma) = n_1 + n_2 \sigma + n_3 \sigma^2 + n_4 \sigma^3, \quad (2.48)$$

where $\eta = h/h^*$ and $\sigma = s/s^*$ with $h^* = 1 \text{ kJ kg}^{-1}$ and $s^* = 1 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_1 to n_4 of Eq. (2.48) are listed in Table 2.81.

Figure 2.19 shows that Eq. (2.48) covers the entropy range

$$s''(4 \text{ MPa}) = s_2(4 \text{ MPa}, T_s(4 \text{ MPa})) \leq s \leq s_2(4 \text{ MPa}, 1073.15 \text{ K}),$$

where the two values for s_2 are calculated from the basic equation $g_2(p, T)$, Eq. (2.6), with T_s obtained from the equation $T_s(p)$, Eq. (2.14). Thus, the h values for given s values along the boundary between subregions 2a and 2b can be directly calculated from the equation $h_{2ab}(s)$, Eq. (2.48). This equation describes the isobar $p = 4 \text{ MPa}$ with maximum differences in pressure of 22 kPa. The given enthalpy value can then be compared with the calculated value for h .

Note. To be in accordance with the statements given in [16, 23], the boundary between subregions 2a and 2b is counted as belonging to subregion 2a.

Table 2.81 Coefficients of the equation $h_{2ab}(s)$ in its dimensionless form, Eq. (2.48), for defining the boundary between subregions 2a and 2b

i	n_i	i	n_i
1	$-0.349\ 898\ 083\ 432\ 139 \times 10^4$	3	$-0.421\ 073\ 558\ 227\ 969 \times 10^3$
2	$0.257\ 560\ 716\ 905\ 876 \times 10^4$	4	$0.276\ 349\ 063\ 799\ 944 \times 10^2$

Computer-Program Verification. For $s = 7 \text{ kJ kg}^{-1} \text{ K}^{-1}$, Eq. (2.48) yields $h_{2ab} = 3376.437\ 884 \text{ kJ kg}^{-1}$.

Boundary between Subregions 2b and 2c. This boundary corresponds to the isentropic line $s = s_{2bc} = 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$. Therefore, a given (h, s) point can be directly assigned to subregion 2b or subregion 2c.

Note. To be in accordance with the statements given in [16, 23], the boundary between subregions 2b and 2c is considered to belong to subregion 2b.

b) The Backward Equations $p(h, s)$ for Subregions 2a, 2b, and 2c

The backward equation $p_{2a}(h, s)$ for **subregion 2a** in its dimensionless form reads:

$$\frac{p_{2a}(h, s)}{p^*} = \pi(\eta, \sigma) = \left[\sum_{i=1}^{29} n_i (\eta - 0.5)^{I_i} (\sigma - 1.2)^{J_i} \right]^4, \quad (2.49)$$

where $\pi = p/p^*$, $\eta = h/h^*$, and $\sigma = s/s^*$ with $p^* = 4 \text{ MPa}$, $h^* = 4200 \text{ kJ kg}^{-1}$, and $s^* = 12 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.49) are listed in Table 2.82.

The backward equation $p_{2b}(h, s)$ for **subregion 2b** in its dimensionless form reads:

$$\frac{p_{2b}(h, s)}{p^*} = \pi(\eta, \sigma) = \left[\sum_{i=1}^{33} n_i (\eta - 0.6)^{I_i} (\sigma - 1.01)^{J_i} \right]^4, \quad (2.50)$$

where $\pi = p/p^*$, $\eta = h/h^*$, and $\sigma = s/s^*$ with $p^* = 100 \text{ MPa}$, $h^* = 4100 \text{ kJ kg}^{-1}$, and $s^* = 7.9 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.50) are listed in Table 2.83.

The backward equation $p_{2c}(h, s)$ for **subregion 2c** in its dimensionless form reads:

$$\frac{p_{2c}(h, s)}{p^*} = \pi(\eta, \sigma) = \left[\sum_{i=1}^{31} n_i (\eta - 0.7)^{I_i} (\sigma - 1.1)^{J_i} \right]^4, \quad (2.51)$$

where $\pi = p/p^*$, $\eta = h/h^*$, and $\sigma = s/s^*$ with $p^* = 100 \text{ MPa}$, $h^* = 3500 \text{ kJ kg}^{-1}$, and $s^* = 5.9 \text{ kJ kg}^{-1} \text{ K}^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.51) are listed in Table 2.84.

Table 2.82 Coefficients and exponents of the backward equation $p_{2a}(h, s)$ for subregion 2a in its dimensionless form, Eq. (2.49)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	1	$-0.182\ 575\ 361\ 923\ 032 \times 10^{-1}$	16	1	22	$0.431\ 757\ 846\ 408\ 006 \times 10^4$
2	0	3	$-0.125\ 229\ 548\ 799\ 536$	17	2	3	$0.112\ 894\ 040\ 802\ 650 \times 10^1$
3	0	6	$0.592\ 290\ 437\ 320\ 145$	18	2	16	$0.197\ 409\ 186\ 206\ 319 \times 10^4$
4	0	16	$0.604\ 769\ 706\ 185\ 122 \times 10^1$	19	2	20	$0.151\ 612\ 444\ 706\ 087 \times 10^4$
5	0	20	$0.238\ 624\ 965\ 444\ 474 \times 10^3$	20	3	0	$0.141\ 324\ 451\ 421\ 235 \times 10^{-1}$
6	0	22	$-0.298\ 639\ 090\ 222\ 922 \times 10^3$	21	3	2	$0.585\ 501\ 282\ 219\ 601$
7	1	0	$0.512\ 250\ 813\ 040\ 750 \times 10^{-1}$	22	3	3	$-0.297\ 258\ 075\ 863\ 012 \times 10^1$
8	1	1	$-0.437\ 266\ 515\ 606\ 486$	23	3	6	$0.594\ 567\ 314\ 847\ 319 \times 10^1$
9	1	2	$0.413\ 336\ 902\ 999\ 504$	24	3	16	$-0.623\ 656\ 565\ 798\ 905 \times 10^4$
10	1	3	$-0.516\ 468\ 254\ 574\ 773 \times 10^1$	25	4	16	$0.965\ 986\ 235\ 133\ 332 \times 10^4$
11	1	5	$-0.557\ 014\ 838\ 445\ 711 \times 10^1$	26	5	3	$0.681\ 500\ 934\ 948\ 134 \times 10^1$
12	1	6	$0.128\ 555\ 037\ 824\ 478 \times 10^2$	27	5	16	$-0.633\ 207\ 286\ 824\ 489 \times 10^4$
13	1	10	$0.114\ 144\ 108\ 953\ 290 \times 10^2$	28	6	3	$-0.558\ 919\ 224\ 465\ 760 \times 10^1$
14	1	16	$-0.119\ 504\ 225\ 652\ 714 \times 10^3$	29	7	1	$0.400\ 645\ 798\ 472\ 063 \times 10^{-1}$
15	1	20	$-0.284\ 777\ 985\ 961\ 560 \times 10^4$				

Table 2.83 Coefficients and exponents of the backward equation $p_{2b}(h, s)$ for subregion 2b in its dimensionless form, Eq. (2.50)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.801\ 496\ 989\ 929\ 495 \times 10^{-1}$	18	3	12	$0.336\ 972\ 380\ 095\ 287 \times 10^8$
2	0	1	$-0.543\ 862\ 807\ 146\ 111$	19	4	1	$-0.586\ 634\ 196\ 762\ 720 \times 10^3$
3	0	2	$0.337\ 455\ 597\ 421\ 283$	20	4	16	$-0.221\ 403\ 224\ 769\ 889 \times 10^{11}$
4	0	4	$0.890\ 555\ 451\ 157\ 450 \times 10^1$	21	5	1	$0.171\ 606\ 668\ 708\ 389 \times 10^4$
5	0	8	$0.313\ 840\ 736\ 431\ 485 \times 10^3$	22	5	12	$-0.570\ 817\ 595\ 806\ 302 \times 10^9$
6	1	0	$0.797\ 367\ 065\ 977\ 789$	23	6	1	$-0.312\ 109\ 693\ 178\ 482 \times 10^4$
7	1	1	$-0.121\ 616\ 973\ 556\ 240 \times 10^1$	24	6	8	$-0.207\ 841\ 384\ 633\ 010 \times 10^7$

Continued on next page.

Table 2.83 – Continued

i	I_i	J_i	n_i	i	I_i	J_i	n_i
8	1	2	$0.872\ 803\ 386\ 937\ 477 \times 10^1$	25	6	18	$0.305\ 605\ 946\ 157\ 786 \times 10^{13}$
9	1	3	$-0.169\ 769\ 781\ 757\ 602 \times 10^2$	26	7	1	$0.322\ 157\ 004\ 314\ 333 \times 10^4$
10	1	5	$-0.186\ 552\ 827\ 328\ 416 \times 10^3$	27	7	16	$0.326\ 810\ 259\ 797\ 295 \times 10^{12}$
11	1	12	$0.951\ 159\ 274\ 344\ 237 \times 10^5$	28	8	1	$-0.144\ 104\ 158\ 934\ 487 \times 10^4$
12	2	1	$-0.189\ 168\ 510\ 120\ 494 \times 10^2$	29	8	3	$0.410\ 694\ 867\ 802\ 691 \times 10^3$
13	2	6	$-0.433\ 407\ 037\ 194\ 840 \times 10^4$	30	8	14	$0.109\ 077\ 066\ 873\ 024 \times 10^{12}$
14	2	18	$0.543\ 212\ 633\ 012\ 715 \times 10^9$	31	8	18	$-0.247\ 964\ 654\ 258\ 893 \times 10^{14}$
15	3	0	$0.144\ 793\ 408\ 386\ 013$	32	12	10	$0.188\ 801\ 906\ 865\ 134 \times 10^{10}$
16	3	1	$0.128\ 024\ 559\ 637\ 516 \times 10^3$	33	14	16	$-0.123\ 651\ 009\ 018\ 773 \times 10^{15}$
17	3	7	$-0.672\ 309\ 534\ 071\ 268 \times 10^5$				

Table 2.84 Coefficients and exponents of the backward equation $p_{2c}(h, s)$ for subregion 2c in its dimensionless form, Eq. (2.51)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.112\ 225\ 607\ 199\ 012$	17	3	0	$0.772\ 465\ 073\ 604\ 171$
2	0	1	$-0.339\ 005\ 953\ 606\ 712 \times 10^1$	18	3	5	$0.463\ 929\ 973\ 837\ 746 \times 10^5$
3	0	2	$-0.320\ 503\ 911\ 730\ 094 \times 10^2$	19	3	8	$-0.137\ 317\ 885\ 134\ 128 \times 10^8$
4	0	3	$-0.197\ 597\ 305\ 104\ 900 \times 10^3$	20	3	16	$0.170\ 470\ 392\ 630\ 512 \times 10^{13}$
5	0	4	$-0.407\ 693\ 861\ 553\ 446 \times 10^3$	21	3	18	$-0.251\ 104\ 628\ 187\ 308 \times 10^{14}$
6	0	8	$0.132\ 943\ 775\ 222\ 331 \times 10^5$	22	4	18	$0.317\ 748\ 830\ 835\ 520 \times 10^{14}$
7	1	0	$0.170\ 846\ 839\ 774\ 007 \times 10^1$	23	5	1	$0.538\ 685\ 623\ 675\ 312 \times 10^2$
8	1	2	$0.373\ 694\ 198\ 142\ 245 \times 10^2$	24	5	4	$-0.553\ 089\ 094\ 625\ 169 \times 10^5$
9	1	5	$0.358\ 144\ 365\ 815\ 434 \times 10^4$	25	5	6	$-0.102\ 861\ 522\ 421\ 405 \times 10^7$
10	1	8	$0.423\ 014\ 446\ 424\ 664 \times 10^6$	26	5	14	$0.204\ 249\ 418\ 756\ 234 \times 10^{13}$
11	1	14	$-0.751\ 071\ 025\ 760\ 063 \times 10^9$	27	6	8	$0.273\ 918\ 446\ 626\ 977 \times 10^9$
12	2	2	$0.523\ 446\ 127\ 607\ 898 \times 10^2$	28	6	18	$-0.263\ 963\ 146\ 312\ 685 \times 10^{16}$
13	2	3	$-0.228\ 351\ 290\ 812\ 417 \times 10^3$	29	10	7	$-0.107\ 890\ 854\ 108\ 088 \times 10^{10}$
14	2	7	$-0.960\ 652\ 417\ 056\ 937 \times 10^6$	30	12	7	$-0.296\ 492\ 620\ 980\ 124 \times 10^{11}$
15	2	10	$-0.807\ 059\ 292\ 526\ 074 \times 10^8$	31	16	10	$-0.111\ 754\ 907\ 323\ 424 \times 10^{16}$
16	2	18	$0.162\ 698\ 017\ 225\ 669 \times 10^{13}$				

Ranges of Validity. The ranges of validity of the backward equations $p_{2a}(h, s)$, $p_{2b}(h, s)$, and $p_{2c}(h, s)$, Eqs. (2.49) to (2.51), can be derived from the graphical representation of region 2 in Fig. 2.14 and of subregions 2a, 2b, and 2c in Fig. 2.19. The determination of h values for given s values along the region boundaries is described in Secs. 2.3.5.1a to 2.3.5.1c and along the subregion boundaries in Sec. 2.3.5.4a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.49) to (2.51), Table 2.85 contains the corresponding test values.

Numerical Consistencies. The numerical inconsistencies between the backward equations $p_{2a}(h, s)$, $p_{2b}(h, s)$, and $p_{2c}(h, s)$, Eqs. (2.49) to (2.51), and the basic equation $g_2(p, T)$, Eq. (2.6), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.86. These inconsistencies are less than the permissible values. This is also true when the backward equations are used in combination with the corresponding boundary equations given in Sec. 2.3.5.2.

Table 2.85 Pressure values calculated from the backward equations $p_{2a}(h,s)$, $p_{2b}(h,s)$, and $p_{2c}(h,s)$, Eqs. (2.49) to (2.51), for selected specific enthalpies and specific entropies^a

Equation	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	p [MPa]
$p_{2a}(h,s)$, Eq. (2.49)	2800	6.5	1.371 012 767
	2800	9.5	$1.879\ 743\ 844 \times 10^{-3}$
	4100	9.5	$1.024\ 788\ 997 \times 10^{-1}$
$p_{2b}(h,s)$, Eq. (2.50)	2800	6	4.793 911 442
	3600	6	$8.395\ 519\ 209 \times 10^1$
	3600	7	7.527 161 441
$p_{2c}(h,s)$, Eq. (2.51)	2800	5.1	$9.439\ 202\ 060 \times 10^1$
	2800	5.8	8.414 574 124
	3400	5.8	$8.376\ 903\ 879 \times 10^1$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Table 2.86 Maximum and root-mean-square inconsistencies in pressure between the backward equations $p_{2a}(h,s)$, $p_{2b}(h,s)$, and $p_{2c}(h,s)$, Eqs. (2.49) to (2.51), and the basic equation $g_2(p,T)$, Eq. (2.6), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in pressure [%]		
		$ \Delta p/p _{\text{perm}}$	$ \Delta p/p _{\text{max}}$	$(\Delta p/p)_{\text{RMS}}$
2a	$p_{2a}(h,s)$, Eq. (2.49)	0.0035	0.0029	0.0013
2b	$p_{2b}(h,s)$, Eq. (2.50)	0.0035	0.0034	0.0005
2c	$p_{2c}(h,s)$, Eq. (2.51)	0.0088	0.0063	0.0010

Computing Time. A statement about the computing time is given in Sec. 2.3.5.4d.

c) Backward Functions $T(h,s)$ for Subregions 2a, 2b, and 2c

The backward function $T_{2a}(h,s)$ for **subregion 2a** is formed by combining the backward equation $p_{2a}(h,s)$ with the backward equation $T_{2a}(p,h)$ ¹⁵ in the form

$$T_{2a}(h,s) = T_{2a}(p_{2a}(h,s),h), \quad (2.52)$$

where p_{2a} is calculated from Eq. (2.49) and then $T_{2a}(p_{2a},h)$ is obtained from Eq. (2.22).

The backward function $T_{2b}(h,s)$ for **subregion 2b** is formed by combining the backward equation $p_{2b}(h,s)$ with the backward equation $T_{2b}(p,h)$ ¹⁵ in the form

$$T_{2b}(h,s) = T_{2b}(p_{2b}(h,s),h), \quad (2.53)$$

where p_{2b} is calculated from Eq. (2.50) and then $T_{2b}(p_{2b},h)$ is determined from Eq. (2.23).

The backward function $T_{2c}(h,s)$ for **subregion 2c** is formed by combining the backward equation $p_{2c}(h,s)$ with the backward equation $T_{2c}(p,h)$ ¹⁵ in the form

$$T_{2c}(h,s) = T_{2c}(p_{2c}(h,s),h), \quad (2.54)$$

where p_{2c} is calculated from Eq. (2.51) and then $T_{2c}(p_{2c},h)$ is obtained from Eq. (2.24).

¹⁵The alternative use of the backward equations $T_{2a}(p,s)$, $T_{2b}(p,s)$, and $T_{2c}(p,s)$ leads to worse numerical consistency.

Ranges of Validity. The backward functions $T_{2a}(h,s)$, $T_{2b}(h,s)$, and $T_{2c}(h,s)$, Eqs. (2.52) to (2.54), have the same ranges of validity as the corresponding backward equations $p_{2a}(h,s)$, $p_{2b}(h,s)$, and $p_{2c}(h,s)$, Eqs. (2.49) to (2.51).

Numerical Consistencies. The numerical inconsistencies between the backward functions $T_{2a}(h,s)$, $T_{2b}(h,s)$, and $T_{2c}(h,s)$, Eqs. (2.52) to (2.54), and the basic equation $g_2(p,T)$, Eq. (2.6), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.87. These inconsistencies are less than the permissible values. This is also true when the backward functions are used in combination with the corresponding boundary equations given in Sec. 2.3.5.2.

Note: When calculating properties extremely close to the saturated-vapour line, due to minor inconsistencies, the backward functions, Eqs. (2.52) to (2.54), might yield temperatures $T_{2a}(h,s) < T_s(p_{2a}(h,s))$, $T_{2b}(h,s) < T_s(p_{2b}(h,s))$, and $T_{2c}(h,s) < T_s(p_{2c}(h,s))$, where $p_{2a}(h,s)$, $p_{2b}(h,s)$, and $p_{2c}(h,s)$ are calculated from Eqs. (2.49) to (2.51), and $T_s(p_{2a})$, $T_s(p_{2b})$, and $T_s(p_{2c})$ from Eq. (2.14). In this case, the results of Eqs. (2.52) to (2.54) should be corrected to $T_{2a} = T_s(p_{2a})$, $T_{2b} = T_s(p_{2b})$, and $T_{2c} = T_s(p_{2c})$.

An analogous procedure is recommended for (h,s) points extremely close to the B23-boundary. Due to the minor inconsistencies, the backward function, Eq. (2.54), might yield temperatures $T_{2c}(h,s) < T_{B23}(p_{2c}(h,s))$, where $T_{B23}(p)$ is calculated from Eq. (2.2). In this case the result of Eq. (2.54) should be corrected to $T_{2c} = T_{B23}(p_{2c}(h,s))$.

Table 2.87 Maximum and root-mean-square inconsistencies in temperature between the backward functions $T_{2a}(h,s)$, $T_{2b}(h,s)$, and $T_{2c}(h,s)$, Eqs. (2.52) to (2.54), and the basic equation $g_2(p,T)$, Eq. (2.6), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in temperature [mK]		
		$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
2a	$T_{2a}(h,s)$, Eq. (2.52)	10	9.7	3.0
2b	$T_{2b}(h,s)$, Eq. (2.53)	10	9.8	4.0
2c	$T_{2c}(h,s)$, Eq. (2.54)	25	24.9	10.3

d) Computing Time when Using the Backward Functions $T_2(h,s)$ together with the Backward Equations $p_2(h,s)$ in Comparison with the Basic Equation

The calculation of pressure and temperature as a function of (h,s) using the backward equations $p_{2a}(h,s)$, $p_{2b}(h,s)$, or $p_{2c}(h,s)$, Eqs. (2.49) to (2.51), in combination with the corresponding backward function $T_{2a}(h,s)$, $T_{2b}(h,s)$, and $T_{2c}(h,s)$, Eqs. (2.52) to (2.54), is about 46 times faster than when using only the basic equation $g_2(p,T)$, Eq. (2.6), [22]. In this comparison, the basic equation was applied in combination with a two-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were set for the backward equations.

2.3.5.5 Backward Equations $p(h,s)$ and Backward Functions $v(h,s)$ and $T(h,s)$ for Region 3

When properties as a function of (h,s) are required from the basic equation of region 3, $f_3(\rho,T)$, Eq. (2.11), without iteration, both variables $\rho = 1/v$ and T must be calculable as a function of (h,s) . As mentioned at the beginning of Sec. 2.3.5, first the relations $p(h,s)$ are provided as direct backward equations, then the relations $v(h,s)$ and $T(h,s)$ are given as backward functions. The

backward functions $v(h,s)$ are a combination of the two backward equations $p(h,s)$ and $v(h,s)$ ¹⁶ in the form $v(p(h,s),s)$. The backward functions $T(h,s)$ are a combination of the two backward equations $p(h,s)$ and $T(p,h)$ ¹⁷ in the form $T(p(h,s),h)$.

a) Division of Region 3 into Subregions 3a and 3b

Due to the very high demands for numerical consistency between the backward equations of this region and the basic equation $f_3(\rho, T)$, Eq. (2.11), given in Sec. 2.3.2, region 3 is divided into two subregions as was done in Secs. 2.3.3.4 and 2.3.4.4 for the backward equations $T(p,h)$ and $T(p,s)$. This division is illustrated in Fig. 2.20.

The boundary between subregions 3a and 3b is defined by the critical isentropic line $s_{3ab} = s_c = 4.412\ 021\ 482\ 234\ 76\ \text{kJ kg}^{-1}\ \text{K}^{-1}$ according to Eq. (2.35).

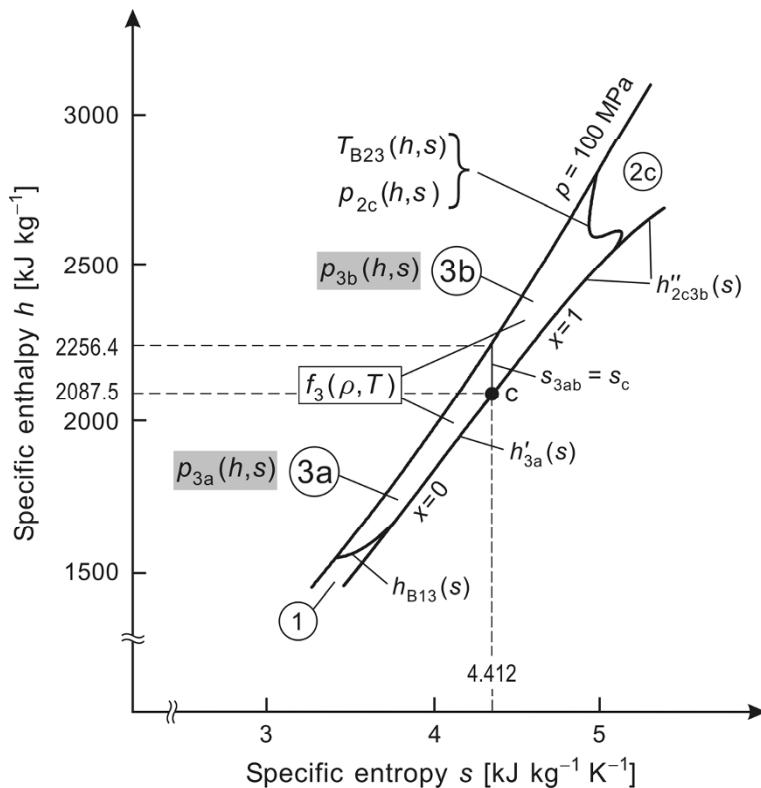


Fig. 2.20 Division of region 3 into subregions 3a and 3b, and the assignment of backward equations $p_{3a}(h,s)$ and $p_{3b}(h,s)$ to these subregions. The h and s values at the corner points of region 3 are given in Fig. 2.14.

Note. The boundary between subregions 3a and 3b is considered to belong to subregion 3a [18, 25].

¹⁶The alternative use of the backward equation $v(p,h)$ leads to worse numerical consistency.

¹⁷The alternative use of the backward equation $T(p,s)$ leads to worse numerical consistency.

b) Backward Equations $p(h,s)$ for Subregions 3a and 3b

The backward equation $p_{3a}(h,s)$ for **subregion 3a** has the following dimensionless form:

$$\frac{p_{3a}(h,s)}{p^*} = \pi(\eta, \sigma) = \sum_{i=1}^{33} n_i (\eta - 1.01)^{I_i} (\sigma - 0.75)^{J_i}, \quad (2.55)$$

where $\pi = p/p^*$, $\eta = h/h^*$, and $\sigma = s/s^*$ with $p^* = 99$ MPa, $h^* = 2300$ kJ kg $^{-1}$, and $s^* = 4.4$ kJ kg $^{-1}$ K $^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.55) are listed in Table 2.88.

The backward equation $p_{3b}(h,s)$ for **subregion 3b** has the following dimensionless form:

$$\frac{p_{3b}(h,s)}{p^*} = \pi(\eta, \sigma) = \left[\sum_{i=1}^{35} n_i (\eta - 0.681)^{I_i} (\sigma - 0.792)^{J_i} \right]^{-1}, \quad (2.56)$$

where $\pi = p/p^*$, $\eta = h/h^*$, and $\sigma = s/s^*$ with $p^* = 16.6$ MPa, $h^* = 2800$ kJ kg $^{-1}$, and $s^* = 5.3$ kJ kg $^{-1}$ K $^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.56) are listed in Table 2.89.

Table 2.88 Coefficients and exponents of the backward equation $p_{3a}(h,s)$ for subregion 3a in its dimensionless form, Eq. (2.55)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.770\ 889\ 828\ 326\ 934 \times 10^1$	18	5	28	$0.538\ 069\ 315\ 091\ 534 \times 10^{20}$
2	0	1	$-0.260\ 835\ 009\ 128\ 688 \times 10^2$	19	6	28	$0.143\ 619\ 827\ 291\ 346 \times 10^{22}$
3	0	5	$0.267\ 416\ 218\ 930\ 389 \times 10^3$	20	7	24	$0.364\ 985\ 866\ 165\ 994 \times 10^{20}$
4	1	0	$0.172\ 221\ 089\ 496\ 844 \times 10^2$	21	8	1	$-0.254\ 741\ 561\ 156\ 775 \times 10^4$
5	1	3	$-0.293\ 542\ 332\ 145\ 970 \times 10^3$	22	10	32	$0.240\ 120\ 197\ 096\ 563 \times 10^{28}$
6	1	4	$0.614\ 135\ 601\ 882\ 478 \times 10^3$	23	10	36	$-0.393\ 847\ 464\ 679\ 496 \times 10^{30}$
7	1	8	$-0.610\ 562\ 757\ 725\ 674 \times 10^5$	24	14	22	$0.147\ 073\ 407\ 024\ 852 \times 10^{25}$
8	1	14	$-0.651\ 272\ 251\ 118\ 219 \times 10^8$	25	18	28	$-0.426\ 391\ 250\ 432\ 059 \times 10^{32}$
9	2	6	$0.735\ 919\ 313\ 521\ 937 \times 10^5$	26	20	36	$0.194\ 509\ 340\ 621\ 077 \times 10^{39}$
10	2	16	$-0.116\ 646\ 505\ 914\ 191 \times 10^{11}$	27	22	16	$0.666\ 212\ 132\ 114\ 896 \times 10^{24}$
11	3	0	$0.355\ 267\ 086\ 434\ 461 \times 10^2$	28	22	28	$0.706\ 777\ 016\ 552\ 858 \times 10^{34}$
12	3	2	$-0.596\ 144\ 543\ 825\ 955 \times 10^3$	29	24	36	$0.175\ 563\ 621\ 975\ 576 \times 10^{42}$
13	3	3	$-0.475\ 842\ 430\ 145\ 708 \times 10^3$	30	28	16	$0.108\ 408\ 607\ 429\ 124 \times 10^{29}$
14	4	0	$0.696\ 781\ 965\ 359\ 503 \times 10^2$	31	28	36	$0.730\ 872\ 705\ 175\ 151 \times 10^{44}$
15	4	1	$0.335\ 674\ 250\ 377\ 312 \times 10^3$	32	32	10	$0.159\ 145\ 847\ 398\ 870 \times 10^{25}$
16	4	4	$0.250\ 526\ 809\ 130\ 882 \times 10^5$	33	32	28	$0.377\ 121\ 605\ 943\ 324 \times 10^{41}$
17	4	5	$0.146\ 997\ 380\ 630\ 766 \times 10^6$				

Table 2.89 Coefficients and exponents of the backward equation $p_{3b}(h,s)$ for subregion 3b in its dimensionless form, Eq. (2.56)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	2	$0.125\ 244\ 360\ 717\ 979 \times 10^{-12}$	19	-4	8	$0.355\ 073\ 647\ 696\ 481 \times 10^4$
2	-12	10	$-0.126\ 599\ 322\ 553\ 713 \times 10^{-1}$	20	-3	1	$-0.115\ 303\ 107\ 290\ 162 \times 10^{-3}$
3	-12	12	$0.506\ 878\ 030\ 140\ 626 \times 10^1$	21	-3	3	$-0.175\ 092\ 403\ 171\ 802 \times 10^1$
4	-12	14	$0.317\ 847\ 171\ 154\ 202 \times 10^2$	22	-3	5	$0.257\ 981\ 687\ 748\ 160 \times 10^3$
5	-12	20	$-0.391\ 041\ 161\ 399\ 932 \times 10^6$	23	-3	6	$-0.727\ 048\ 374\ 179\ 467 \times 10^3$

Continued on next page.

Table 2.89 – Continued

i	I_i	J_i	n_i	i	I_i	J_i	n_i
6	-10	2	$-0.975\ 733\ 406\ 392\ 044 \times 10^{-10}$	24	-2	0	$0.121\ 644\ 822\ 609\ 198 \times 10^{-3}$
7	-10	10	$-0.186\ 312\ 419\ 488\ 279 \times 10^2$	25	-2	1	$0.393\ 137\ 871\ 762\ 692 \times 10^{-1}$
8	-10	14	$0.510\ 973\ 543\ 414\ 101 \times 10^3$	26	-1	0	$0.704\ 181\ 005\ 909\ 296 \times 10^{-2}$
9	-10	18	$0.373\ 847\ 005\ 822\ 362 \times 10^6$	27	0	3	$-0.829\ 108\ 200\ 698\ 110 \times 10^2$
10	-8	2	$0.299\ 804\ 024\ 666\ 572 \times 10^{-7}$	28	2	0	$-0.265\ 178\ 818\ 131\ 250$
11	-8	8	$0.200\ 544\ 393\ 820\ 342 \times 10^2$	29	2	1	$0.137\ 531\ 682\ 453\ 991 \times 10^2$
12	-6	2	$-0.498\ 030\ 487\ 662\ 829 \times 10^{-5}$	30	5	0	$-0.522\ 394\ 090\ 753\ 046 \times 10^2$
13	-6	6	$-0.102\ 301\ 806\ 360\ 030 \times 10^2$	31	6	1	$0.240\ 556\ 298\ 941\ 048 \times 10^4$
14	-6	7	$0.552\ 819\ 126\ 990\ 325 \times 10^2$	32	8	1	$-0.227\ 361\ 631\ 268\ 929 \times 10^5$
15	-6	8	$-0.206\ 211\ 367\ 510\ 878 \times 10^3$	33	10	1	$0.890\ 746\ 343\ 932\ 567 \times 10^5$
16	-5	10	$-0.794\ 012\ 232\ 324\ 823 \times 10^4$	34	14	3	$-0.239\ 234\ 565\ 822\ 486 \times 10^8$
17	-4	4	$0.782\ 248\ 472\ 028\ 153 \times 10^1$	35	14	7	$0.568\ 795\ 808\ 129\ 714 \times 10^{10}$
18	-4	5	$-0.586\ 544\ 326\ 902\ 468 \times 10^2$				

Ranges of Validity. The ranges of validity of the backward equations $p_{3a}(h,s)$ and $p_{3b}(h,s)$, Eqs. (2.55) and (2.56), can be derived from the graphical representation of region 3 in Fig. 2.14 and of subregions 3a and 3b in Fig. 2.20. The determination of h values for given s values along the region boundaries is described in Secs. 2.3.5.1a to 2.3.5.1c and along the subregion boundary in Sec. 2.3.5.5a.

Computer-Program Verification. To assist the user in computer-program verification of Eqs. (2.55) and (2.56), Table 2.90 contains test values for calculated pressures.

Table 2.90 Pressure values calculated from the backward equations $p_{3a}(h,s)$ and $p_{3b}(h,s)$, Eqs. (2.55) and (2.56), for selected specific enthalpies and specific entropies^a

Equation	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	p [MPa]
$p_{3a}(h,s)$, Eq. (2.55)	1700	3.8	$2.555\ 703\ 246 \times 10^1$
	2000	4.2	$4.540\ 873\ 468 \times 10^1$
	2100	4.3	$6.078\ 123\ 340 \times 10^1$
$p_{3b}(h,s)$, Eq. (2.56)	2400	4.7	$6.363\ 924\ 887 \times 10^1$
	2600	5.1	$3.434\ 999\ 263 \times 10^1$
	2700	5.0	$8.839\ 043\ 281 \times 10^1$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Numerical Consistencies. The numerical inconsistencies between the backward equations $p_{3a}(h,s)$ and $p_{3b}(h,s)$, Eqs. (2.55) and (2.56), and the basic equation $f_3(\rho, T)$, Eq. (2.11), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.91. These inconsistencies are less than the permissible values. This is also true when the backward equations in combination with the corresponding boundary equations given in Sec. 2.3.5.2 are used. The critical pressure $p_c = 22.064$ MPa is met by the two $p(h,s)$ equations for all five figures. The maximum inconsistency in pressure between the two backward equations, Eq. (2.55) and Eq. (2.56), along the boundary $s_{3ab} = s_c$, Eq. (2.35), amounts to 0.00074%, which is smaller than the permissible inconsistency.

Table 2.91 Maximum and root-mean-square inconsistencies in pressure between the backward equations $p_{3a}(h,s)$ and $p_{3b}(h,s)$, Eqs. (2.55) and (2.56), and the basic equation $f_3(\rho,T)$, Eq. (2.11), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in pressure [%]		
		$ \Delta p/p _{\text{perm}}$	$ \Delta p/p _{\text{max}}$	$(\Delta p/p)_{\text{RMS}}$
3a	$p_{3a}(h,s)$, Eq. (2.55)	0.01	0.0070	0.0030
3b	$p_{3b}(h,s)$, Eq. (2.56)	0.01	0.0084	0.0036

Computing Time. A statement about the computing time is given in Sec. 2.3.5.5e.

c) Backward Functions $v(h,s)$ for Subregions 3a and 3b

The backward function $v_{3a}(h,s)$ for **subregion 3a** is formed by combining the backward equation $p_{3a}(h,s)$ with the backward equation $v_{3a}(p,s)$ ¹⁸ in the form

$$v_{3a}(h,s) = v_{3a}(p_{3a}(h,s),s), \quad (2.57)$$

where p_{3a} is calculated from Eq. (2.55) and then $v_{3a}(p_{3a},s)$ is obtained from Eq. (2.36).

The backward function $v_{3b}(h,s)$ for **subregion 3b** is formed by combining the backward equation $p_{3b}(h,s)$ with the backward equation $v_{3b}(p,s)$ ¹⁸ in the form

$$v_{3b}(h,s) = v_{3b}(p_{3b}(h,s),s), \quad (2.58)$$

where p_{3b} is calculated from Eq. (2.56) and then $v_{3b}(p_{3b},s)$ is determined from Eq. (2.37).

Ranges of Validity. The backward functions $v_{3a}(h,s)$ and $v_{3b}(h,s)$, Eqs. (2.57) and (2.58), have the same ranges of validity as the corresponding backward equations $p_{3a}(h,s)$ and $p_{3b}(h,s)$, Eqs. (2.55) and (2.56).

Numerical Consistencies. The numerical inconsistencies between the backward functions $v_{3a}(h,s)$ and $v_{3b}(h,s)$, Eqs. (2.57) and (2.58), and the basic equation $f_3(\rho,T)$, Eq. (2.11), are listed in Table 2.92 in comparison with the permissible inconsistencies, given in Sec. 2.3.2. These inconsistencies are less than the permissible values. This is also true when the backward functions are used in combination with the corresponding boundary equations given in Sec. 2.3.5.2. The critical temperature $T_c = 647.096$ K is calculated by the two $T(h,s)$ functions for all six figures. The maximum inconsistency in specific volume between the two backward functions, Eqs. (2.57) and (2.58), along the subregion boundary $s_{3ab} = s_c$, Eq. (2.35), amounts to 0.000 28%.

Table 2.92 Maximum and root-mean-square inconsistencies in specific volume between the backward functions $v_{3a}(h,s)$ and $v_{3b}(h,s)$, Eqs. (2.57) and (2.58), and the basic equation $f_3(\rho,T)$, Eq. (2.11), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in specific volume [%]		
		$ \Delta v/v _{\text{perm}}$	$ \Delta v/v _{\text{max}}$	$(\Delta v/v)_{\text{RMS}}$
3a	$v_{3a}(h,s)$, Eq. (2.57)	0.01	0.0097	0.0053
3b	$v_{3b}(h,s)$, Eq. (2.58)	0.01	0.0095	0.0043

Computing Time. A statement about the computing time is given in Sec. 2.3.5.5e.

¹⁸The alternative use of the backward equations $v_{3a}(p,h)$ and $v_{3b}(p,h)$ leads to worse numerical consistency.

d) Backward Functions $T(h,s)$ for Subregions 3a and 3b

The backward function $T_{3a}(h,s)$ for **subregion 3a** is formed by combining the backward equation $p_{3a}(h,s)$ with the backward equation $T_{3a}(p,h)$ ¹⁹ in the form

$$T_{3a}(h,s) = T_{3a}(p_{3a}(h,s),h), \quad (2.59)$$

where p_{3a} is calculated from Eq. (2.55) and then $T_{3a}(p_{3a},h)$ is obtained from Eq. (2.28).

The backward function $T_{3b}(h,s)$ for **subregion 3b** is formed by combining the backward equation $p_{3b}(h,s)$ with the backward equation $T_{3b}(p,h)$ ²⁰ in the form

$$T_{3b}(h,s) = T_{3b}(p_{3b}(h,s),h), \quad (2.60)$$

where p_{3b} is calculated from Eq. (2.56) and then $T_{3b}(p_{3b},h)$ is determined from Eq. (2.29).

Ranges of Validity. The backward functions $T_{3a}(h,s)$ and $T_{3b}(h,s)$, Eqs. (2.59) and (2.60), have the same ranges of validity as the corresponding backward equations $p_{3a}(h,s)$ and $p_{3b}(h,s)$, Eqs. (2.55) and (2.56).

Numerical Consistencies. The numerical inconsistencies between the backward functions $T_{3a}(h,s)$ and $T_{3b}(h,s)$, Eqs. (2.59) and (2.60), and the basic equation $f_3(\rho,T)$, Eq. (2.11), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.93. These inconsistencies are less than the permissible values. This is also true when the backward functions are used in combination with the corresponding boundary equations given in Sec. 2.3.5.2. The critical volume $v_c = 1/\rho_c = (1/322) \text{ m}^3 \text{ kg}^{-1} = 0.003\ 105\ 59 \text{ m}^3 \text{ kg}^{-1}$ is calculated by the two $v(h,s)$ functions for the given six significant figures. The maximum inconsistency in temperature between the two backward functions, Eq. (2.59) and (2.60), along the subregion boundary $s = s_c$ amounts to 0.68 mK, for details see [25].

Note. When calculating properties in the range $s \leq s_c$ and extremely close to the saturated-liquid line, due to minor inconsistencies, Eq. (2.59) might yield temperatures $T_{3a}(h,s) > T_s(p_{3a}(h,s))$, where $p_{3a}(h,s)$ is calculated from Eq. (2.55) and $T_s(p_{3a})$ from Eq. (2.14). In this case, the result of Eq. (2.59) must be corrected to $T_{3a} = T_s(p_{3a})$. If the given specific entropy s is greater than s_c and the properties to be calculated are located extremely close to the saturated-vapour line, due to minor inconsistencies, Eq. (2.60) might yield temperatures $T_{3b}(h,s) < T_s(p_{3b}(h,s))$, where $p_{3b}(h,s)$ is calculated from Eq. (2.56) and $T_s(p_{3b})$ from Eq. (2.14). In this case, the result of Eq. (2.60) must be corrected to $T_{3b} = T_s(p_{3b})$.

Table 2.93 Maximum and root-mean-square inconsistencies in temperature between the backward functions $T_{3a}(h,s)$, and $T_{3b}(h,s)$, Eqs. (2.59) and (2.60), and the basic equation $f_3(\rho,T)$, Eq. (2.11), in comparison with the permissible inconsistencies

Subregion	Equation	Inconsistencies in temperature [mK]		
		$ \Delta T _{\text{perm}}$	$ \Delta T _{\text{max}}$	$(\Delta T)_{\text{RMS}}$
3a	$T_{3a}(h,s)$, Eq. (2.59)	25	23.7	10.5
3b	$T_{3b}(h,s)$, Eq. (2.60)	25	22.4	9.9

¹⁹The alternative use of the backward equation $T_{3a}(p,s)$ leads to worse numerical consistency.

²⁰The alternative use of the backward equation $T_{3b}(p,s)$ leads to worse numerical consistency.

e) Computing Time when Using the Backward Functions $v_3(h,s)$ and $T_3(h,s)$ together with the Backward Equations $p_3(h,s)$ in Comparison with the Basic Equation

The calculation of specific volume and temperature as a function of (h,s) with the backward functions $v_{3a}(h,s)$ and $T_{3a}(h,s)$, Eqs. (2.57) and (2.59), or $v_{3b}(h,s)$ and $T_{3b}(h,s)$, Eqs. (2.58) and (2.60), in combination with the corresponding backward equations $p_{3a}(h,s)$ or $p_{3b}(h,s)$, Eqs. (2.55) and (2.56), is about 10 times faster than that using only the basic equation $f_3(\rho,T)$, Eq. (2.11), [22]. In this comparison, the basic equation was applied in combination with a two-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were set for the backward equations.

2.3.5.6 Backward Equation $T_s(h,s)$ and Backward Functions $p_s(h,s)$ and $x(h,s)$ for the Technically Important Part of the Two-Phase Region 4

When modelling power cycles and, in particular, steam turbines, thermodynamic properties as a function of the variables (h,s) are also required in the two-phase (wet-steam) region. The important region for steam turbine calculations is the range $s \geq s''(623.15 \text{ K})$, where the saturation temperature is less than or equal to 623.15 K; this region is marked in Fig. 2.21. In the $p-T$ diagram, this part of the two-phase region is located between regions 1 and 2, see Fig. 2.3. In this region, the calculation of saturation properties from given values of h and s requires iterations with the basic equations $g_1(p,T)$, Eq. (2.3), and $g_2(p,T)$, Eq. (2.6), and the saturation-pressure equation $p_s(T)$, Eq. (2.13). In order to avoid such iterations, this subsection provides the backward equation $T_s(h,s)$ and the backward functions $p_s(h,s)$ and $x(h,s)$ for this technically important part of the two-phase region.

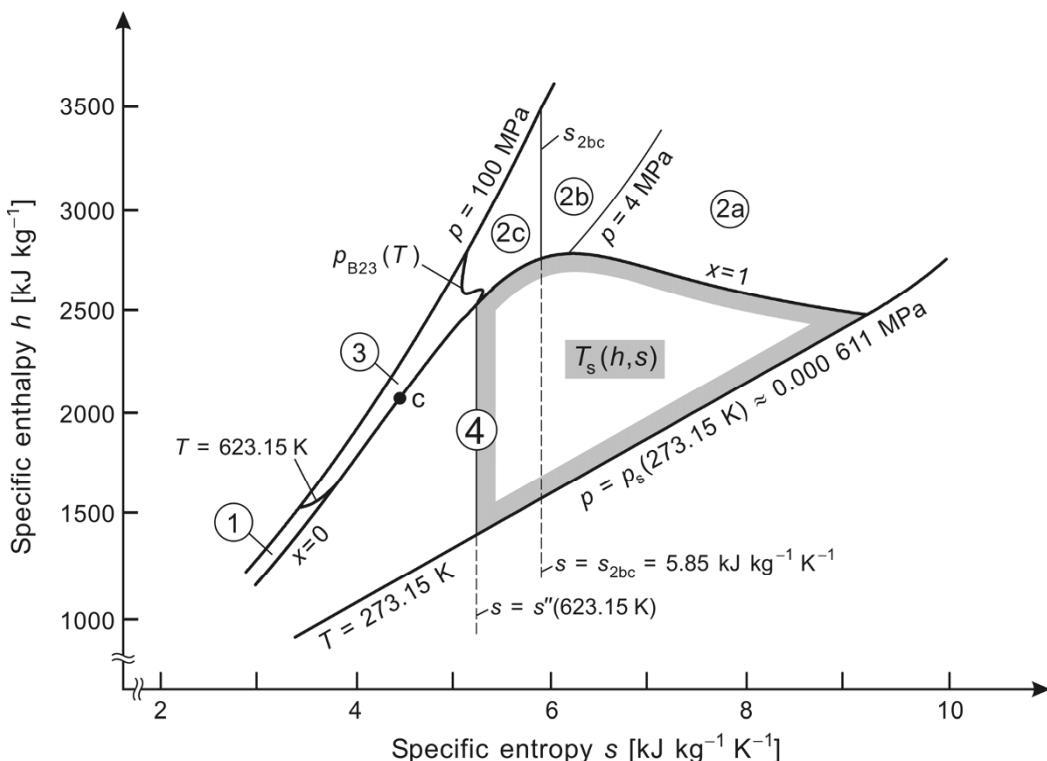


Fig. 2.21 Range of validity of the backward equation $T_s(h,s)$ and assignment of this range to the other regions and subregions of IAPWS-IF97.

a) Backward Equation $T_s(h,s)$

The backward equation $T_s(h,s)$ for the technically important part of the two-phase region 4 has the following dimensionless form:

$$\frac{T_s(h,s)}{T^*} = \theta_s(\eta, \sigma) = \sum_{i=1}^{36} n_i (\eta - 0.119)^{I_i} (\sigma - 1.07)^{J_i}, \quad (2.61)$$

where $\theta_s = T_s/T^*$, $\eta = h/h^*$, and $\sigma = s/s^*$ with $T^* = 550$ K, $h^* = 2800$ kJ kg $^{-1}$, and $s^* = 9.2$ kJ kg $^{-1}$ K $^{-1}$. The coefficients n_i and exponents I_i and J_i of Eq. (2.61) are listed in Table 2.94.

Table 2.94 Coefficients and exponents of the equation $T_s(h,s)$ in its dimensionless form, Eq. (2.61)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	0.179 882 673 606 601	19	5	4	$0.125\ 028\ 363\ 714\ 877 \times 10^1$
2	0	3	-0.267 507 455 199 603	20	5	16	$0.101\ 316\ 840\ 309\ 509 \times 10^4$
3	0	12	$0.116\ 276\ 722\ 612\ 600 \times 10^1$	21	6	6	$-0.151\ 791\ 558\ 000\ 712 \times 10^1$
4	1	0	0.147 545 428 713 616	22	6	8	$0.524\ 277\ 865\ 990\ 866 \times 10^2$
5	1	1	-0.512 871 635 973 248	23	6	22	$0.230\ 495\ 545\ 563\ 912 \times 10^5$
6	1	2	0.421 333 567 697 984	24	8	1	$0.249\ 459\ 806\ 365\ 456 \times 10^{-1}$
7	1	5	0.563 749 522 189 870	25	10	20	$0.210\ 796\ 467\ 412\ 137 \times 10^7$
8	2	0	0.429 274 443 819 153	26	10	36	$0.366\ 836\ 848\ 613\ 065 \times 10^9$
9	2	5	-0.335 704 552 142 140 $\times 10^1$	27	12	24	$-0.144\ 814\ 105\ 365\ 163 \times 10^9$
10	2	8	0.108 890 916 499 278 $\times 10^2$	28	14	1	$-0.179\ 276\ 373\ 003\ 590 \times 10^{-2}$
11	3	0	-0.248 483 390 456 012	29	14	28	$0.489\ 955\ 602\ 100\ 459 \times 10^{10}$
12	3	2	0.304 153 221 906 390	30	16	12	$0.471\ 262\ 212\ 070\ 518 \times 10^3$
13	3	3	-0.494 819 763 939 905	31	16	32	$-0.829\ 294\ 390\ 198\ 652 \times 10^{11}$
14	3	4	0.107 551 674 933 261 $\times 10^1$	32	18	14	$-0.171\ 545\ 662\ 263\ 191 \times 10^4$
15	4	0	0.733 888 415 457 688 $\times 10^{-1}$	33	18	22	$0.355\ 777\ 682\ 973\ 575 \times 10^7$
16	4	1	0.140 170 545 411 085 $\times 10^{-1}$	34	18	36	$0.586\ 062\ 760\ 258\ 436 \times 10^{12}$
17	5	1	-0.106 110 975 998 808	35	20	24	$-0.129\ 887\ 635\ 078\ 195 \times 10^8$
18	5	2	0.168 324 361 811 875 $\times 10^{-1}$	36	28	36	$0.317\ 247\ 449\ 371\ 057 \times 10^{11}$

Range of Validity. The range of validity of the backward equation $T_s(h,s)$ is the part of the two-phase region with $s \geq s''(623.15 \text{ K}) = 5.210\ 887\ 825 \text{ kJ kg}^{-1} \text{ K}^{-1}$ as shown in Fig. 2.21. The corresponding temperature range is $273.15 \text{ K} \leq T \leq 623.15 \text{ K}$.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (2.61), Table 2.95 contains test values for calculated temperatures.

Table 2.95 Temperature values calculated from the backward equation $T_s(h,s)$, Eq. (2.61), for selected specific enthalpies and specific entropies^a

Equation	$h [\text{kJ kg}^{-1}]$	$s [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$T [\text{K}]$
$T_s(h,s)$, Eq. (2.61)	1800	5.3	$3.468\ 475\ 498 \times 10^2$
	2400	6.0	$4.251\ 373\ 305 \times 10^2$
	2500	5.5	$5.225\ 579\ 013 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Numerical Consistency. The numerical inconsistency between the backward equation $T_s(h,s)$, Eq. (2.61), and the basic equations $g_1(p,T)$, $g_2(p,T)$, and $p_s(T)$, Eqs. (2.3), (2.6), and (2.13), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.96. These consistency investigations were carried out as follows: First, values of the saturation temperature T_s and the vapour fraction x were given. For these T_s values, the saturation pressure p_s was calculated from Eq. (2.13). Then, from the basic equation $g_1(p_s,T_s)$, Eq. (2.3), h' and s' were determined, and the basic equation $g_2(p_s,T_s)$, Eq. (2.6), yielded h'' and s'' . With these values and the given values of x , the properties h and s in the two-phase region were calculated. For these values of h and s , the saturation temperature T_s was determined from the backward equation $T_s(h,s)$, Eq. (2.61). The difference between this T_s value and the starting value corresponds to the inconsistency in saturation temperature.

Table 2.96 shows that the inconsistencies are significantly less than the permissible values. This is also true when the backward equation in combination with the corresponding boundary equations given in Sec. 2.3.5.2 is used.

Table 2.96 Maximum and root-mean-square inconsistencies in saturation temperature between the backward equation $T_s(h,s)$, Eq. (2.61), and the basic equations $g_1(p,T)$, $g_2(p,T)$, and $p_s(T)$, Eqs. (2.3), (2.6), and (2.13), in comparison with the permissible inconsistencies

Entropy range	Inconsistencies in temperature [mK]		
	$ \Delta T_s _{\text{perm}}$	$ \Delta T_s _{\text{max}}$	$(\Delta T_s)_{\text{RMS}}$
$s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	10	0.67	0.33
$s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	25	0.86	0.45

Computing Time. A statement about the computing time is given in Sec. 2.3.5.6d.

b) Backward Function $p_s(h,s)$

The backward function $p_s(h,s)$ for the technically important part of the two-phase region 4 is formed by combining the backward equation $T_s(h,s)$ with the saturation-pressure equation $p_s(T)$ in the form

$$p_s(h,s) = p_s(T_s(h,s)), \quad (2.62)$$

where T_s is calculated from Eq. (2.61) and then $p_s(T_s)$ is determined from Eq. (2.13).

Range of Validity. The backward function $p_s(h,s)$, Eq. (2.62), is valid in the same range as the backward equation $T_s(h,s)$, Eq. (2.61).

Numerical Consistency. The numerical inconsistency between the backward function $p_s(h,s)$, Eq. (2.62), and the basic equations $g_1(p,T)$, $g_2(p,T)$, and $p_s(T)$, Eqs. (2.3), (2.6), and (2.13), in comparison with the permissible inconsistencies, given in Sec. 2.3.2, are listed in Table 2.97. These consistency investigations were performed analogously as described above for the backward equation $T_s(h,s)$, Eq. (2.61). Here, however, values for the saturation pressure p_s were compared instead of the values for the saturation temperature T_s .

Table 2.97 shows that the inconsistencies are less than the permissible values. This is also true when the backward function is used in combination with the corresponding boundary equations given in Sec. 2.3.5.2.

Table 2.97 Maximum and root-mean-square inconsistencies in saturation pressure between the backward function $p_s(h, s)$, Eq. (2.62), and the basic equations $g_1(p, T)$, $g_2(p, T)$, and $p_s(T)$, Eqs. (2.3), (2.6), and (2.13), in comparison with the permissible inconsistencies

Entropy range	Inconsistencies in pressure [%]		
	$ \Delta p_s/p_s _{\text{perm}}$	$ \Delta p_s/p_s _{\text{max}}$	$(\Delta p_s/p_s)_{\text{RMS}}$
$s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	0.0035	0.0029	0.0012
$s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	0.0088	0.0034	0.0013

Computing Time. A statement about the computing time is given in Sec. 2.3.5.6d.

c) Backward Function $x(h, s)$

For the formulation of the vapour fraction as a function of (h, s) , $x = x(h, s)$, one can start with the relation²¹

$$x = \frac{h - h'}{h'' - h'} \quad (2.63)$$

When calculating h' and h'' from the basic equations $g_1(p, T)$ and $g_2(p, T)$ with $T = T_s(h, s)$ and $p = p_s(T_s)$, the backward function for the vapour fraction dependent on (h, s) is obtained in the form

$$x(h, s) = \frac{(h - h' \left(p_s(T_s(h, s)), T_s(h, s) \right))}{h'' \left(p_s(T_s(h, s)), T_s(h, s) \right) - h' \left(p_s(T_s(h, s)), T_s(h, s) \right)} \quad (2.64)$$

For the given values of h and s the saturation temperature T_s is calculated from the backward equation $T_s(h, s)$, Eq. (2.61). Then, for this temperature T_s , the saturation pressure p_s is determined from the equation $p_s(T)$, Eq. (2.13). Finally, with these p_s and T_s values, h' is calculated from the basic equation $g_1(p, T)$, Eq. (2.3), and h'' is obtained from the basic equation $g_2(p, T)$, Eq. (2.6), for $p = p_s$ and $T = T_s$.

Range of Validity. The backward function $x(h, s)$, Eq. (2.64), is valid within the same range as the backward equation $T_s(h, s)$, Eq. (2.61).

Numerical Consistency. The numerical inconsistencies between the vapour fraction x calculated from Eq. (2.64) via the backward equation $T_s(h, s)$ and the vapour fraction x calculated by iteration from the basic equations $g_1(p, T)$, Eq. (2.3), $g_2(p, T)$, Eq. (2.6), and $p_s(T)$, Eq. (2.13), are listed in Table 2.98. The inconsistencies in x calculated in these two ways are less than 10^{-5} , i.e. the value of the vapour fraction x calculated from the backward function, Eq. (2.64), agrees within five decimal figures with the x value determined from the basic equation by iterations.

When the backward function is used in combination with the corresponding boundary equations, given in Sec. 2.3.5.2, the inconsistency remains within 10^{-5} .

²¹The use of the relation $x = (s - s')/(s'' - s')$ as a starting point for the derivation of the backward function $x(h, s)$ leads to worse numerical consistency.

Table 2.98 Maximum and root-mean-square inconsistencies in vapour fraction x between calculations with the backward function $x(h,s)$, Eq. (2.64), and by iterations with the basic equations $g_1(p,T)$, Eq. (2.3), $g_2(p,T)$, Eq. (2.6), and $p_s(T)$, Eq. (2.13)

Entropy range	Inconsistencies in vapour fraction	
	$ \Delta x _{\max}$	$(\Delta x)_{\text{RMS}}$
$s \geq 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	0.64×10^{-6}	0.25×10^{-6}
$s < 5.85 \text{ kJ kg}^{-1} \text{ K}^{-1}$	4.40×10^{-6}	0.57×10^{-6}

Note. When calculating properties extremely close to the saturated-vapour line, due to minor inconsistencies, the backward function, Eq. (2.64), might yield vapour fractions $x(h,s) > 1$. In this case, the result of Eq. (2.64) should be corrected to $x = 1$.

d) Computing Time when Using the Backward Equation $T_s(h,s)$ together with the Backward Functions $p_s(h,s)$ and $x(h,s)$

The calculation of temperature, pressure, and vapour fraction in the technically important part of the two-phase region 4 with the backward equation $T_s(h,s)$, Eq. (2.61), together with the corresponding backward functions $p_s(h,s)$, Eq. (2.62), and $x(h,s)$, Eq. (2.64) in combination with the basic equations $g_1(p,T)$, Eq. (2.3), $g_2(p,T)$, Eq. (2.6), and $p_s(T)$, Eq. (2.13), is about 14 times faster than when using only the basic equations [22]. In this comparison, the basic equations were applied in combination with a two-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements that were given for the backward equations in Sec. 2.3.2.

2.3.6 Backward Equations Dependent on the Input Variables (p,T) for Region 3

The basic equation $f_3(\rho,T)$, Eq. (2.11), is used in region 3. This basic equation along with the backward equations $v(p,h)$, $T(p,h)$, $v(p,s)$, $T(p,s)$, and $p(h,s)$, given in Secs. 2.3.3 to 2.3.5, can be used to calculate all thermodynamic properties as a function of (p,h) , (p,s) and (h,s) without any iteration. However, in modelling modern steam power cycles, in particular in boiler calculations, properties as a function of the variables (p,T) are required for region 3. Such calculations from the basic equation $f_3(\rho,T)$, Eq. (2.11), are cumbersome because they require iterations of v for given values of p and T using the relation $p(v,T)$ with $v = 1/\rho$ derived from Eq. (2.11) as given in the first line of Table 2.16.

In order to avoid such iterations, this section provides backward equations $v_3(p,T)$ for region 3 as given in Fig. 2.22. With the specific volume v calculated from the backward equations $v_3(p,T)$, all other properties in region 3 can be calculated without iteration from the basic equation $f_3(\rho,T)$, Eq. (2.11), with $\rho = 1/v_3$.

For process calculations, the numerical consistency requirements for the backward equations $v_3(p,T)$ are very strict. Since the specific volume on the $v-p-T$ surface has a complex shape,²² region 3 had to be divided into 26 subregions. The first 20 subregions and their associated backward equations, described in Sec. 2.3.6.4, cover nearly the entire region 3 and fully meet the consistency requirements given in Sec. 2.3.6.1. For a small area very near the critical point, it was not possible

²²In the critical region, there are very strong changes in the derivative $(\partial v/\partial p)_T$ culminating in the value ∞ at the critical point.

to meet the consistency requirements completely. This near-critical region is covered with reasonable consistency by six subregions with auxiliary equations that are described in Sec. 2.3.6.5.

This set of recently-developed backward and auxiliary equations [19] was adopted by IAPWS in 2005 and revised in 2014 [26].

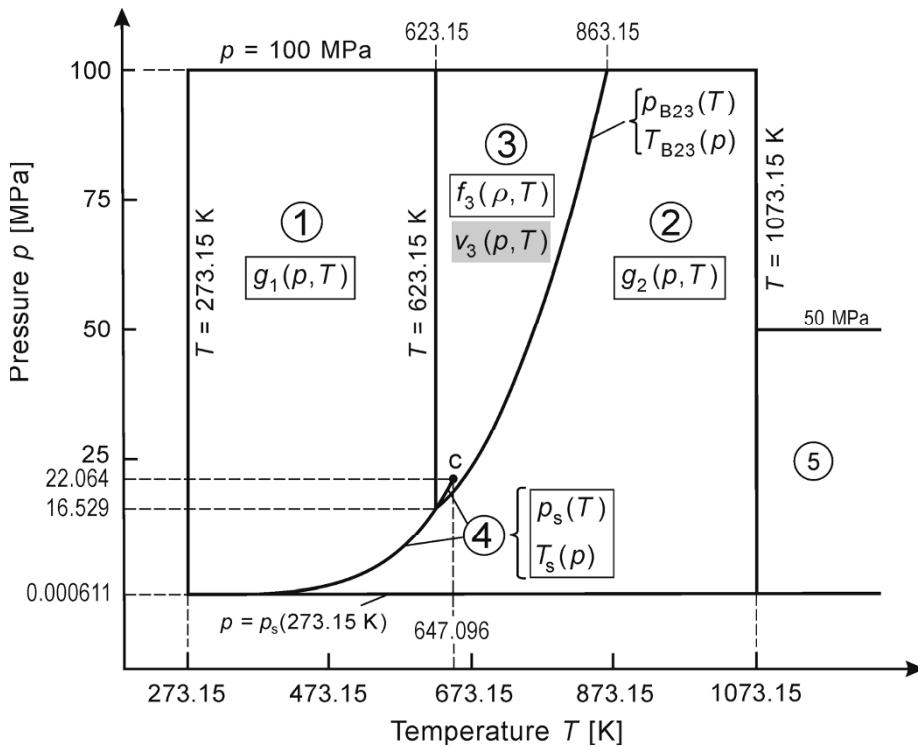


Fig. 2.22 Assignment of backward equations $v_3(p, T)$ to region 3 in a p - T diagram. For this overview, it is not shown how region 3 will be divided into subregions.

2.3.6.1 Numerical Consistency Requirements

In region 3, any property calculation from the basic equation $f_3(\rho, T)$, Eq. (2.11), for given values of p and T requires the determination of the density ρ ($\rho = 1/v$) by iteration. Based on experience with process calculations in this region, the numerical uncertainty in the calculation of the specific volume by iteration should be not greater than 0.001%. Likewise, the uncertainty in the subsequent determination of the specific enthalpy and specific entropy should be less than 0.001%, and for the specific isobaric heat capacity and speed of sound it should not be greater than 0.01%. These requirements must also be fulfilled when v is calculated directly from the backward equations $v_3(p, T)$, rather than calculated by iterating the basic equation $f_3(\rho, T)$, Eq. (2.11). The consistency requirements for all of these properties are summarized in Table 2.99. In order to achieve these very minor inconsistencies simultaneously for all of the properties, the inconsistencies in v between the backward equations $v_3(p, T)$ and the basic equation $f_3(\rho, T)$ had to be at least 0.001%, and for some parts of region 3 even smaller.

In the near-critical region, there are no defined numerical consistency requirements for the auxiliary equations (see the next subsection), but the inconsistencies should be as small as possible.

Table 2.99 Permissible numerical inconsistencies in the properties v, h, s, c_p , and w when v is calculated one time via iteration with the basic equation $f_3(\rho, T)$, Eq. (2.11), for given inputs of p and T , and the other time directly from the respective backward equation $v_3(p, T)$. Based on these two (slightly different) v values, the properties h, s, c_p , and w are obtained from the basic equation $f_3(\rho, T)$ with $\rho = 1/v^a$

Permissible inconsistencies [%]				
$ \Delta v/v _{\text{perm}}$	$ \Delta h/h _{\text{perm}}$	$ \Delta s/s _{\text{perm}}$	$ \Delta c_p/c_p _{\text{perm}}$	$ \Delta w/w _{\text{perm}}$
0.001	0.001	0.001	0.01	0.01

^aThe values for v are calculated from the backward equations $v_3(p, T)$.

2.3.6.2 Range of Validity of the Backward and Auxiliary Equations

The range of validity of the entire set of the backward equations $v_3(p, T)$ corresponds to region 3 of IAPWS-IF97, which is defined by the following range of temperature and pressure:

$$623.15 \text{ K} \leq T \leq 863.15 \text{ K} \quad p_{\text{B23}}(T) \leq p \leq 100 \text{ MPa}$$

with $p_{\text{B23}}(T)$ according to the B23-equation, Eq. (2.1), as shown in Fig. 2.23.

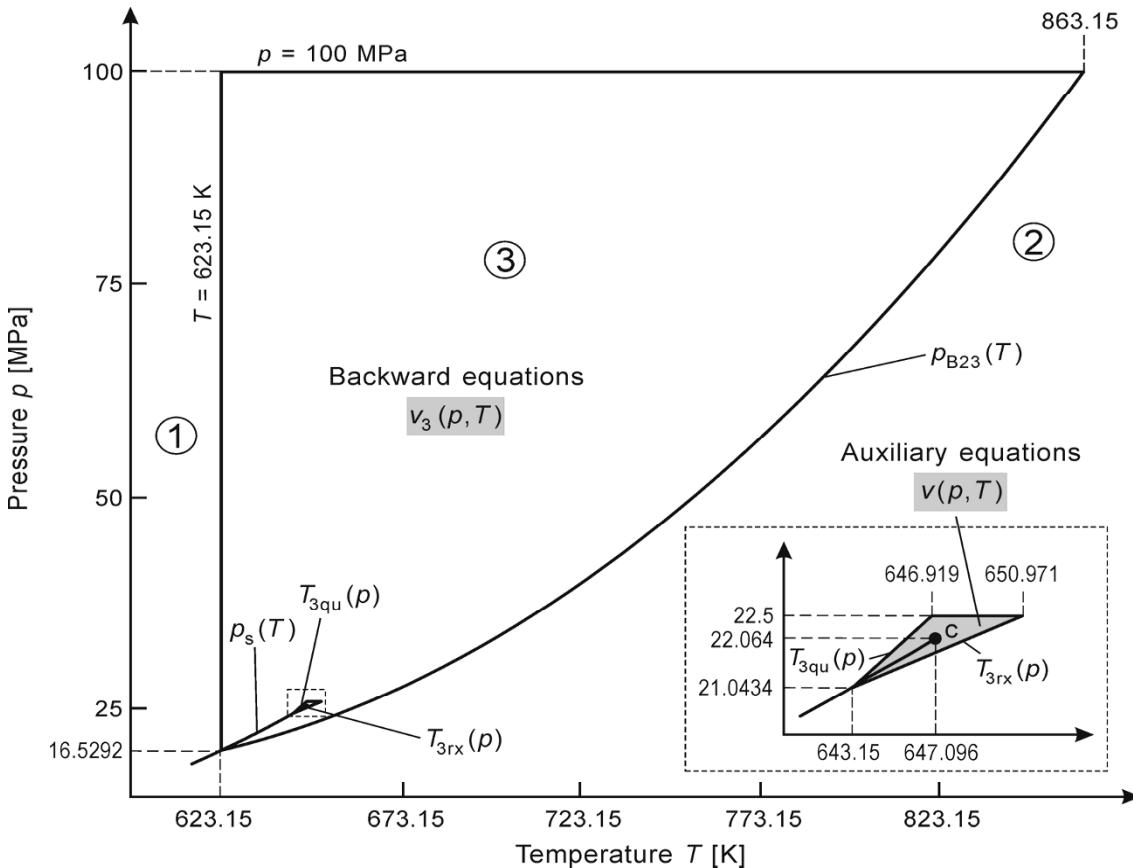


Fig. 2.23 Range of validity of the backward equations $v_3(p, T)$ covering all of region 3 except for the near-critical region. The near-critical region is enlarged and marked in grey in the lower right part of the figure, where this region is covered by the auxiliary equations $v(p, T)$. This near-critical region includes a temperature range from 643.15 K to 650.971 K at pressures from 21.0434 MPa to 22.5 MPa. Figure 2.26 shows this small region in more detail.

Achieving the numerical consistency requirement of 0.001% for $v_3(p, T)$ proved to be infeasible using simple functional forms in the region

$$p_s(643.15 \text{ K}) \leq p \leq 22.5 \text{ MPa} \quad T_{3\text{qu}}(p) \leq T \leq T_{3\text{rx}}(p),$$

$$\text{where } p_s(643.15 \text{ K}) = 21.034\ 367\ 32 \text{ MPa.}$$

This region is marked in grey in Fig. 2.23, which also shows the temperature and pressure range of the boundary equations $T_{3\text{qu}}(p)$ and $T_{3\text{rx}}(p)$; the boundary equations themselves are given in Sec. 2.3.6.3 and $p_s(643.15 \text{ K})$ is calculated from Eq. (2.13). The reason for excluding the near-critical region (grey area in Fig. 2.23) from the range of validity of the backward equations $v_3(p, T)$ is based on the complex structure of the v - p - T surface in this region; see the footnote 22 on page 105. In order to not exclude the near-critical region completely from the equations $v(p, T)$, Sec. 2.3.6.5 contains equations for this small region very close to the critical point. These equations exhibit significant larger inconsistencies with the basic equation $f_3(\rho, T)$ and are called auxiliary equations in the following.

2.3.6.3 Division of Region 3 into Subregions 3a to 3t and the Subregion-Boundary Equations

Preliminary investigations showed that it was not possible to meet the numerical consistency requirements with only a few subregions [19, 26]. Therefore, the main part of region 3 was divided into 20 subregions, 3a to 3t, as illustrated in Figs. 2.24 and 2.25.

The following subscripts mark the subregion boundaries that separate the adjacent subregions:

3ab:	Boundary between subregions 3a/3b and 3d/3e
3cd:	Boundary between subregions 3c/3d, 3c/3g, and 3c/3l
3ef:	Boundary between subregions 3e/3f, 3h/3i, and 3n/o
3gh:	Boundary between subregions 3g/3h and 3l/3m
3ij:	Boundary between subregions 3i/3j and 3p/3j
3jk:	Boundary between subregions 3j/3k and 3r/3k
3mn:	Boundary between subregions 3m/3n
3op:	Boundary between subregions 3o/3p
3qu:	Boundary between subregions 3q/3u
3rx:	Boundary between subregions 3r/3x
3uv:	Boundary between subregions 3u/3v
3wx:	Boundary between subregions 3w/3x
B23:	Boundary between regions 2/3

These subregion boundaries are also shown in Figs. 2.24 and 2.25.

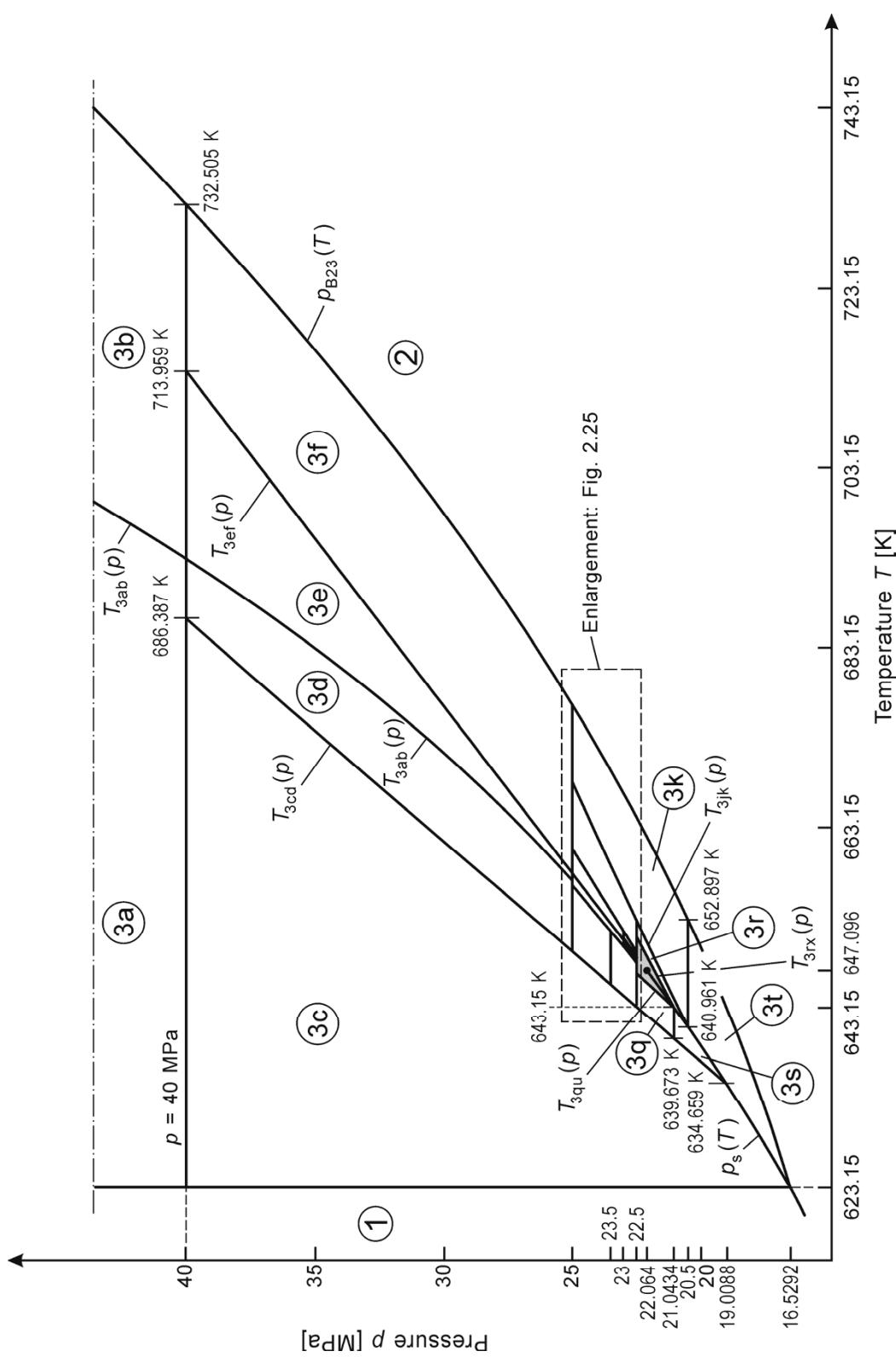


Fig. 2.24 Division of region 3 into subregions for the backward equations $v_3(p, T)$. The subregions 3a and 3b extend up to 100 MPa.

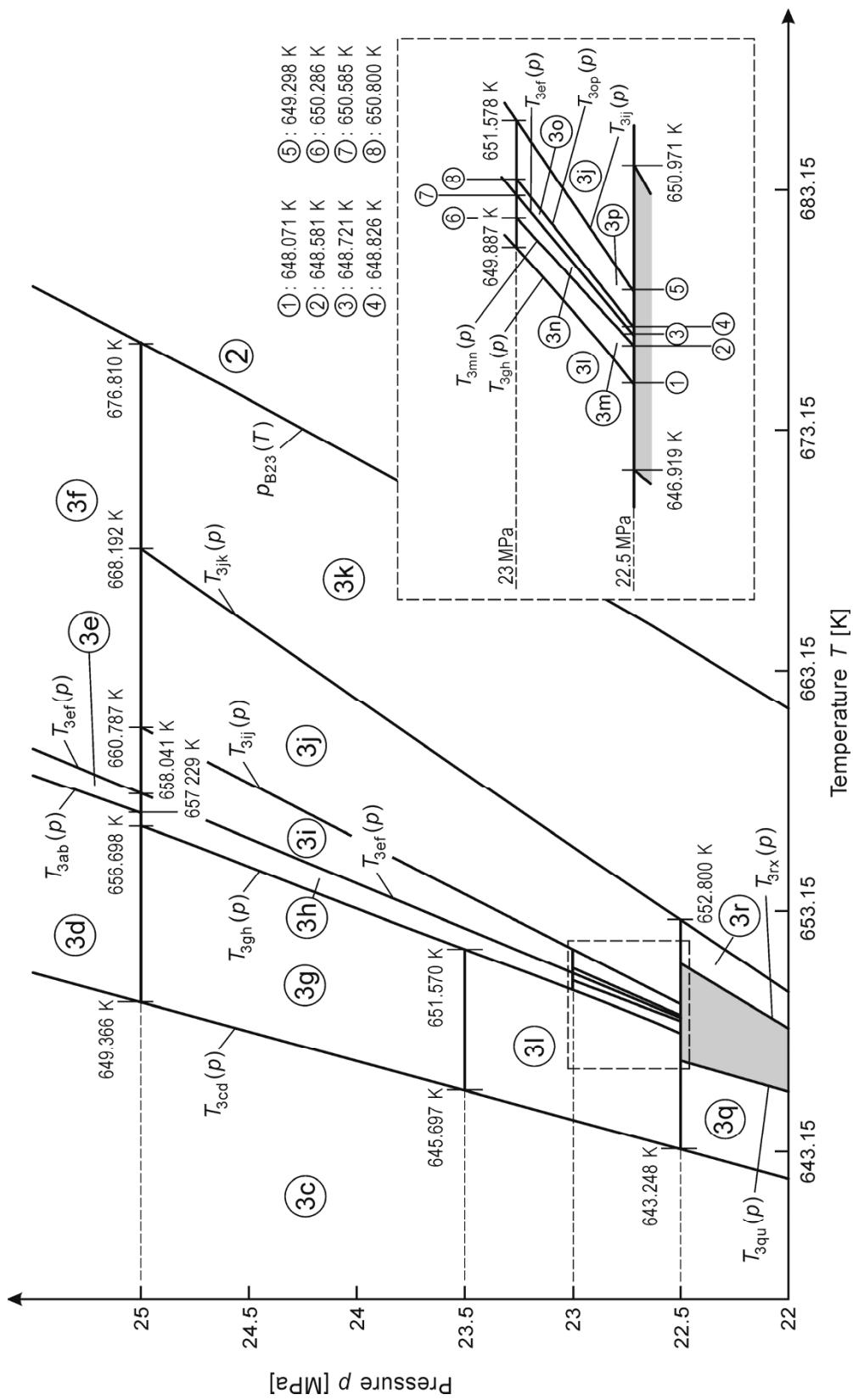


Fig. 2.25 Enlargement of Fig. 2.24 for subregions 3c to 3r for the corresponding backward equations $v_3(p, T)$.

The subregion-boundary equations, except for the equations $T_{3ab}(p)$, $T_{3ef}(p)$, and $T_{3op}(p)$, have the following dimensionless form:

$$\frac{T(p)}{T^*} = \theta(\pi) = \sum_{i=1}^N n_i \pi^{I_i}, \quad (2.65)$$

where $\theta = T/T^*$, $\pi = p/p^*$, with $T^* = 1\text{ K}$, $p^* = 1\text{ MPa}$, and N is the largest value of i given in Table 2.100 for the corresponding equation.

The equations $T_{3ab}(p)$ and $T_{3op}(p)$ have the form:

$$\frac{T(p)}{T^*} = \theta(\pi) = \sum_{i=1}^N n_i (\ln \pi)^{I_i}, \quad (2.66)$$

and the equation $T_{3ef}(p)$ is:

$$\frac{T_{3ef}(p)}{T^*} = \theta(\pi) = \left. \frac{d\theta}{d\pi} \right|_c (\pi - 22.064) + 647.096, \quad (2.67)$$

where the derivative of the saturation-temperature equation, Eq. (2.14), at the critical point is $d\theta/d\pi|_c = 3.727\,888\,004$.

The coefficients n_i and exponents I_i of these subregion-boundary equations are listed in Table 2.100.

Table 2.100 Coefficients n_i and exponents I_i of the subregion-boundary equations, except for the equation $T_{3ef}(p)$.

Equation	i	I_i	n_i	i	I_i	n_i
$T_{3ab}(p)$	1	0	$0.154\,793\,642\,129\,415 \times 10^4$	4	-1	$-0.191\,887\,498\,864\,292 \times 10^4$
	2	1	$-0.187\,661\,219\,490\,113 \times 10^3$	5	-2	$0.918\,419\,702\,359\,447 \times 10^3$
	3	2	$0.213\,144\,632\,222\,113 \times 10^2$			
$T_{3cd}(p)$	1	0	$0.585\,276\,966\,696\,349 \times 10^3$	3	2	$-0.127\,283\,549\,295\,878 \times 10^{-1}$
	2	1	$0.278\,233\,532\,206\,915 \times 10^1$	4	3	$0.159\,090\,746\,562\,729 \times 10^{-3}$
$T_{3gh}(p)$	1	0	$-0.249\,284\,240\,900\,418 \times 10^5$	4	3	$0.751\,608\,051\,114\,157 \times 10^1$
	2	1	$0.428\,143\,584\,791\,546 \times 10^4$	5	4	$-0.787\,105\,249\,910\,383 \times 10^{-1}$
	3	2	$-0.269\,029\,173\,140\,130 \times 10^3$			
$T_{3ij}(p)$	1	0	$0.584\,814\,781\,649\,163 \times 10^3$	4	3	$-0.587\,071\,076\,864\,459 \times 10^{-2}$
	2	1	$-0.616\,179\,320\,924\,617$	5	4	$0.515\,308\,185\,433\,082 \times 10^{-4}$
	3	2	$0.260\,763\,050\,899\,562$			
$T_{3jk}(p)$	1	0	$0.617\,229\,772\,068\,439 \times 10^3$	4	3	$-0.157\,391\,839\,848\,015 \times 10^{-1}$
	2	1	$-0.770\,600\,270\,141\,675 \times 10^1$	5	4	$0.137\,897\,492\,684\,194 \times 10^{-3}$
	3	2	$0.697\,072\,596\,851\,896$			
$T_{3mn}(p)$	1	0	$0.535\,339\,483\,742\,384 \times 10^3$	3	2	$-0.158\,365\,725\,441\,648$
	2	1	$0.761\,978\,122\,720\,128 \times 10^1$	4	3	$0.192\,871\,054\,508\,108 \times 10^{-2}$
$T_{3op}(p)$	1	0	$0.969\,461\,372\,400\,213 \times 10^3$	4	-1	$0.773\,845\,935\,768\,222 \times 10^3$
	2	1	$-0.332\,500\,170\,441\,278 \times 10^3$	5	-2	$-0.152\,313\,732\,937\,084 \times 10^4$
	3	2	$0.642\,859\,598\,466\,067 \times 10^2$			
$T_{3qu}(p)$	1	0	$0.565\,603\,648\,239\,126 \times 10^3$	3	2	$-0.102\,020\,639\,611\,016$
	2	1	$0.529\,062\,258\,221\,222 \times 10^1$	4	3	$0.122\,240\,301\,070\,145 \times 10^{-2}$
$T_{3rx}(p)$	1	0	$0.584\,561\,202\,520\,006 \times 10^3$	3	2	$0.243\,293\,362\,700\,452$
	2	1	$-0.102\,961\,025\,163\,669 \times 10^1$	4	3	$-0.294\,905\,044\,740\,799 \times 10^{-2}$

With the help of the ranges of pressure and temperature given in Table 2.101, any (p, T) point can be assigned to the corresponding subregions 3a to 3t as given in Figs. (2.24) and (2.25); the subregion-boundary equations $T_{3ab}(p)$ to $T_{3rx}(p)$ are defined in Eqs. (2.65) to (2.67) in combination with Table 2.100.

Table 2.101 Pressure ranges and corresponding subregion-boundary equations for determining the correct subregion, 3a to 3t, for the backward equations $v_3(p, T)$

Pressure range	Sub-region	Temperature range	Sub-region	Temperature range
$40 \text{ MPa} < p \leq 100 \text{ MPa}$	3a	$T \leq T_{3ab}(p)$	3b	$T > T_{3ab}(p)$
$25 \text{ MPa} < p \leq 40 \text{ MPa}$	3c	$T \leq T_{3cd}(p)$	3e	$T_{3ab}(p) < T \leq T_{3ef}(p)$
	3d	$T_{3cd}(p) < T \leq T_{3ab}(p)$	3f	$T > T_{3ef}(p)$
	3c	$T \leq T_{3cd}(p)$	3i	$T_{3ef}(p) < T \leq T_{3ij}(p)$
$23.5 \text{ MPa} < p \leq 25 \text{ MPa}$	3g	$T_{3cd}(p) < T \leq T_{3gh}(p)$	3j	$T_{3ij}(p) < T \leq T_{3jk}(p)$
	3h	$T_{3gh}(p) < T \leq T_{3ef}(p)$	3k	$T > T_{3jk}(p)$
	3c	$T \leq T_{3cd}(p)$	3i	$T_{3ef}(p) < T \leq T_{3ij}(p)$
$23 \text{ MPa} < p \leq 23.5 \text{ MPa}$	3l	$T_{3cd}(p) < T \leq T_{3gh}(p)$	3j	$T_{3ij}(p) < T \leq T_{3jk}(p)$
	3h	$T_{3gh}(p) < T \leq T_{3ef}(p)$	3k	$T > T_{3jk}(p)$
	3c	$T \leq T_{3cd}(p)$	3o	$T_{3ef}(p) < T \leq T_{3op}(p)$
$22.5 \text{ MPa} < p \leq 23 \text{ MPa}$	3l	$T_{3cd}(p) < T \leq T_{3gh}(p)$	3p	$T_{3op}(p) < T \leq T_{3ij}(p)$
	3m	$T_{3gh}(p) < T \leq T_{3mn}(p)$	3j	$T_{3ij}(p) < T \leq T_{3jk}(p)$
	3n	$T_{3mn}(p) < T \leq T_{3ef}(p)$	3k	$T > T_{3jk}(p)$
$p_s(643.15 \text{ K})^a < p \leq 22.5 \text{ MPa}$	3c	$T \leq T_{3cd}(p)$	3r	$T_{3rx}(p) < T \leq T_{3jk}(p)$
	3q	$T_{3cd}(p) < T \leq T_{3qu}(p)$	3k	$T > T_{3jk}(p)$
$20.5 \text{ MPa} < p \leq p_s(643.15 \text{ K})^a$	3c	$T \leq T_{3cd}(p)$	3r	$T_s(p) \leq T \leq T_{3jk}(p)$
	3s	$T_{3cd}(p) < T \leq T_s(p)$	3k	$T > T_{3jk}(p)$
$p_{3cd}^b < p \leq 20.5 \text{ MPa}$	3c	$T \leq T_{3cd}(p)$	3t	$T \geq T_s(p)$
	3s	$T_{3cd}(p) < T \leq T_s(p)$		
$p_s(623.15 \text{ K})^c < p \leq p_{3cd}^b$	3c	$T \leq T_s(p)$	3t	$T \geq T_s(p)$

^a $p_s(643.15 \text{ K}) = 21.043\ 367\ 32 \text{ MPa}$.

^b $p_{3cd} = 19.008\ 811\ 89 \text{ MPa}$.

^c $p_s(623.15 \text{ K}) = 16.529\ 164\ 25 \text{ MPa}$.

The **equation $T_{3ab}(p)$** approximates the critical isentrope from 25 MPa to 100 MPa and divides subregions 3a from 3b and 3d from 3e.

The **equation $T_{3cd}(p)$** ranges from $p_{3cd} = 19.008\ 811\ 89 \text{ MPa}$ to 40 MPa. The pressure p_{3cd} corresponds to the pressure p for which $T_s(p) = T_{3cd}(p)$, where $T_s(p)$ is the saturation-temperature equation, Eq. (2.14). The equation $T_{3cd}(p)$ divides subregion 3c from subregions 3d, 3g, 3l, 3q, and 3s.

The subregion-boundary **equation $T_{3ef}(p)$** is a straight line from 22.064 MPa to 40 MPa with the slope of the saturation-temperature line, Eq. (2.14), at the critical point. This equation divides subregion 3e from 3f, 3h from 3i, and 3n from 3o.

The **equation $T_{3gh}(p)$** ranges from 22.5 MPa to 25 MPa and divides subregion 3g from subregion 3h and 3l from 3h and from 3m.

The **equation $T_{3ij}(p)$** approximates the isochore $v = 0.0041 \text{ m}^3 \text{ kg}^{-1}$ from 22.5 MPa to 25 MPa and divides subregion 3j from subregions 3i and 3p.

The **equation $T_{3jk}(p)$** approximates the isochore $v = v''(20.5 \text{ MPa})$ from 20.5 MPa to 25 MPa. This equation divides subregion 3k from subregions 3j and from 3r.

The **equation $T_{3mn}(p)$** approximates the isochore $v = 0.0028 \text{ m}^3 \text{ kg}^{-1}$ from 22.5 MPa to 23 MPa and describes the boundary between subregion 3m and 3n.

The **equation $T_{3op}(p)$** approximates the isochore $v = 0.0034 \text{ m}^3 \text{ kg}^{-1}$ from 22.5 MPa to 23 MPa. It divides subregion 3o from 3p.

The **equation $T_{3qu}(p)$** approximates the isochore $v = v'(643.15 \text{ K})$ from $p = p_s(643.15 \text{ K}) = 21.043\ 367\ 32 \text{ MPa}$ to 22.5 MPa. This equation describes the boundary between subregion 3q and subregion 3u in the range covered by the auxiliary equation as shown in Fig. 2.26.

The **equation $T_{3rx}(p)$** approximates the isochore $v = v''(643.15 \text{ K})$ from $p = p_s(643.15 \text{ K}) = 21.043\ 367\ 32 \text{ MPa}$ to 22.5 MPa. The equation $T_{3rx}(p)$ describes the boundary between subregion 3r and 3x for the auxiliary equations as illustrated in Fig. 2.26.

Computer-Program Verification. To assist the user in computer-program verification of the equations for the subregion boundaries, Table 2.102 contains test values for calculated temperatures.

Table 2.102 Temperature values calculated from the subregion-boundary equations for selected pressures^a

Equation	p [MPa]	T [K]	Equation	p [MPa]	T [K]
$T_{3ab}(p)$	40	$6.930\ 341\ 408 \times 10^2$	$T_{3jk}(p)$	23	$6.558\ 338\ 344 \times 10^2$
$T_{3cd}(p)$	25	$6.493\ 659\ 208 \times 10^2$	$T_{3mn}(p)$	22.8	$6.496\ 054\ 133 \times 10^2$
$T_{3ef}(p)$	40	$7.139\ 593\ 992 \times 10^2$	$T_{3op}(p)$	22.8	$6.500\ 106\ 943 \times 10^2$
$T_{3gh}(p)$	23	$6.498\ 873\ 759 \times 10^2$	$T_{3qu}(p)$	22	$6.456\ 355\ 027 \times 10^2$
$T_{3ij}(p)$	23	$6.515\ 778\ 091 \times 10^2$	$T_{3rx}(p)$	22	$6.482\ 622\ 754 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

2.3.6.4 Backward Equations $v(p, T)$ for Subregions 3a to 3t

This section presents the backward equations $v(p, T)$ for subregions 3a to 3t, explains how to use these equations, and makes statements on the numerical consistencies.

a) Backward Equations $v(p, T)$

The backward equations $v(p, T)$ for subregions 3a to 3t, except for 3n, have the following dimensionless form:

$$\frac{v(p, T)}{v^*} = \omega(\pi, \theta) = \left[\sum_{i=1}^N n_i \left[(\pi - a)^c \right]^{I_i} \left[(\theta - b)^d \right]^{J_i} \right]^e. \quad (2.68)$$

The equation for subregion 3n has the form:

$$\frac{v_{3n}(p, T)}{v^*} = \omega(\pi, \theta) = \exp \left[\sum_{i=1}^N n_i (\pi - a)^{I_i} (\theta - b)^{J_i} \right], \quad (2.69)$$

where $\omega = v/v^*$, $\pi = p/p^*$, and $\theta = T/T^*$. The reducing quantities v^* , p^* , and T^* , the number of coefficients N , the non-linear parameters a and b , and the exponents c , d , and e are listed in Table 2.103. The coefficients n_i and exponents I_i and J_i of these equations are given in Tables 2.106 to 2.125, which are summarized in Sec. 2.3.6.4e.

Table 2.103 Reducing quantities v^* , p^* , and T^* , the number of coefficients N , the non-linear parameters a and b , and the exponents c , d , and e of the backward equations $v(p, T)$, Eqs. 2.68 and 2.69, of subregions 3a to 3t

Subregion	$v^*[\text{m}^3 \text{ kg}^{-1}]$	$p^*[\text{MPa}]$	$T^*[\text{K}]$	N	a	b	c	d	e
3a	0.0024	100	760	30	0.085	0.817	1	1	1
3b	0.0041	100	860	32	0.280	0.779	1	1	1
3c	0.0022	40	690	35	0.259	0.903	1	1	1
3d	0.0029	40	690	38	0.559	0.939	1	1	4
3e	0.0032	40	710	29	0.587	0.918	1	1	1
3f	0.0064	40	730	42	0.587	0.891	0.5	1	4
3g	0.0027	25	660	38	0.872	0.971	1	1	4
3h	0.0032	25	660	29	0.898	0.983	1	1	4
3i	0.0041	25	660	42	0.910	0.984	0.5	1	4
3j	0.0054	25	670	29	0.875	0.964	0.5	1	4
3k	0.0077	25	680	34	0.802	0.935	1	1	1
3l	0.0026	24	650	43	0.908	0.989	1	1	4
3m	0.0028	23	650	40	1.000	0.997	1	0.25	1
3n	0.0031	23	650	39	0.976	0.997	—	—	—
3o	0.0034	23	650	24	0.974	0.996	0.5	1	1
3p	0.0041	23	650	27	0.972	0.997	0.5	1	1
3q	0.0022	23	650	24	0.848	0.983	1	1	4
3r	0.0054	23	650	27	0.874	0.982	1	1	1
3s	0.0022	21	640	29	0.886	0.990	1	1	4
3t	0.0088	20	650	33	0.803	1.020	1	1	1

Computer-Program Verification. To assist the user in computer-program verification of the backward equations $v(p, T)$, Eqs. (2.68) and (2.69), for subregions 3a to 3t, Table 2.104 contains test values for calculated specific volumes.

Table 2.104 Values of the specific volume calculated from the backward equations $v(p, T)$, Eqs. 2.68 and 2.69, of subregions 3a to 3t for selected values of pressure and temperature^a

Equation	p [MPa]	T [K]	v [$\text{m}^3 \text{ kg}^{-1}$]	Equation	p [MPa]	T [K]	v [$\text{m}^3 \text{ kg}^{-1}$]
$v_{3a}(p, T)$	50	630	$1.470\ 853\ 100 \times 10^{-3}$	$v_{3k}(p, T)$	23	660	$6.109\ 525\ 997 \times 10^{-3}$
	80	670	$1.503\ 831\ 359 \times 10^{-3}$		24	670	$6.427\ 325\ 645 \times 10^{-3}$
$v_{3b}(p, T)$	50	710	$2.204\ 728\ 587 \times 10^{-3}$	$v_{3l}(p, T)$	22.6	646	$2.117\ 860\ 851 \times 10^{-3}$
	80	750	$1.973\ 692\ 940 \times 10^{-3}$		23	646	$2.062\ 374\ 674 \times 10^{-3}$
$v_{3c}(p, T)$	20	630	$1.761\ 696\ 406 \times 10^{-3}$	$v_{3m}(p, T)$	22.6	648.6	$2.533\ 063\ 780 \times 10^{-3}$
	30	650	$1.819\ 560\ 617 \times 10^{-3}$		22.8	649.3	$2.572\ 971\ 781 \times 10^{-3}$
$v_{3d}(p, T)$	26	656	$2.245\ 587\ 720 \times 10^{-3}$	$v_{3n}(p, T)$	22.6	649.0	$2.923\ 432\ 711 \times 10^{-3}$
	30	670	$2.506\ 897\ 702 \times 10^{-3}$		22.8	649.7	$2.913\ 311\ 494 \times 10^{-3}$

Continued on next page.

Table 2.104 – Continued

Equation	p [MPa]	T [K]	v [$\text{m}^3 \text{ kg}^{-1}$]	Equation	p [MPa]	T [K]	v [$\text{m}^3 \text{ kg}^{-1}$]
$v_{3e}(p, T)$	26	661	$2.970\ 225\ 962 \times 10^{-3}$	$v_{3o}(p, T)$	22.6	649.1	$3.131\ 208\ 996 \times 10^{-3}$
	30	675	$3.004\ 627\ 086 \times 10^{-3}$		22.8	649.9	$3.221\ 160\ 278 \times 10^{-3}$
$v_{3f}(p, T)$	26	671	$5.019\ 029\ 401 \times 10^{-3}$	$v_{3p}(p, T)$	22.6	649.4	$3.715\ 596\ 186 \times 10^{-3}$
	30	690	$4.656\ 470\ 142 \times 10^{-3}$		22.8	650.2	$3.664\ 754\ 790 \times 10^{-3}$
$v_{3g}(p, T)$	23.6	649	$2.163\ 198\ 378 \times 10^{-3}$	$v_{3q}(p, T)$	21.1	640	$1.970\ 999\ 272 \times 10^{-3}$
	24	650	$2.166\ 044\ 161 \times 10^{-3}$		21.8	643	$2.043\ 919\ 161 \times 10^{-3}$
$v_{3h}(p, T)$	23.6	652	$2.651\ 081\ 407 \times 10^{-3}$	$v_{3r}(p, T)$	21.1	644	$5.251\ 009\ 921 \times 10^{-3}$
	24	654	$2.967\ 802\ 335 \times 10^{-3}$		21.8	648	$5.256\ 844\ 741 \times 10^{-3}$
$v_{3i}(p, T)$	23.6	653	$3.273\ 916\ 816 \times 10^{-3}$	$v_{3s}(p, T)$	19.1	635	$1.932\ 829\ 079 \times 10^{-3}$
	24	655	$3.550\ 329\ 864 \times 10^{-3}$		20	638	$1.985\ 387\ 227 \times 10^{-3}$
$v_{3j}(p, T)$	23.5	655	$4.545\ 001\ 142 \times 10^{-3}$	$v_{3t}(p, T)$	17	626	$8.483\ 262\ 001 \times 10^{-3}$
	24	660	$5.100\ 267\ 704 \times 10^{-3}$		20	640	$6.227\ 528\ 101 \times 10^{-3}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

b) Calculation of Properties with the Help of the Backward Equations $v(p, T)$

The backward equations $v_{3a}(p, T)$ to $v_{3t}(p, T)$, described in Sec. 2.3.6.4a along with the basic equation $f_3(\rho, T)$, Eq. (2.11), make it possible to determine all thermodynamic properties, e.g. specific enthalpy, specific entropy, specific isobaric heat capacity, and speed of sound, for given values of pressure p and temperature T in region 3 without iteration.

The following steps should be taken:

- Identify the subregion (3a to 3t) for the given values of the pressure p and temperature T following the instructions in Sec. 2.3.6.3 in conjunction with Table 2.101 and Figs. 2.24 and 2.25. Then calculate the specific volume v for the subregion using the corresponding backward equation $v(p, T)$, Eq. (2.68) or Eq. (2.69).
- Calculate the desired thermodynamic property for the previously calculated specific volume v and the given temperature T using the relation of this property to the basic equation $f_3(\rho, T)$, Eq. (2.11), where $\rho = 1/v$ is determined from the corresponding backward equation, Eq. (2.68) or Eq. (2.69).

c) Numerical Consistencies

The numerical inconsistencies between the backward equations $v(p, T)$, Eqs. (2.68) and (2.69), and the basic equation $f_3(\rho, T)$, Eq. (2.11), are listed in Table 2.105 in comparison with the permissible inconsistencies given in Table 2.99 in Sec. 2.3.6.1. In addition to the inconsistencies in specific volume v itself, the effect of these inconsistencies with regard to the inconsistencies in specific enthalpy, specific entropy, specific isobaric heat capacity, and speed of sound are also given; the calculation of these properties based on the calculation of v from the backward equations $v(p, T)$, Eqs. (2.68) and (2.69), is described in paragraph b) above.

Table 2.105 Maximum and root-mean-square inconsistencies in v , h , s , c_p , and w when these properties are calculated from the basic equation $f_3(\rho, T)$, Eq. (2.11), after ρ was determined by iteration and when $\rho=1/v$ was calculated directly from the backward equations $v(p, T)$ of regions 3a to 3t

Sub-region	Inconsistencies in v , h , s , c_p , and w [%]									
	$\Delta v/v$		$\Delta h/h$		$\Delta s/s$		$\Delta c_p/c_p$		$\Delta w/w$	
	max	RMS	max	RMS	max	RMS	max	RMS	max	RMS
3a	0.00061	0.00031	0.00018	0.00008	0.00026	0.00011	0.0016	0.0006	0.0015	0.0006
3b	0.00064	0.00035	0.00017	0.00008	0.00016	0.00008	0.0012	0.0003	0.0008	0.0003
3c	0.00080	0.00038	0.00026	0.00012	0.00025	0.00011	0.0059	0.0016	0.0023	0.0010
3d	0.00059	0.00025	0.00018	0.00008	0.00014	0.00006	0.0035	0.0010	0.0012	0.0004
3e	0.00072	0.00033	0.00018	0.00009	0.00014	0.00007	0.0017	0.0005	0.0006	0.0002
3f	0.00068	0.00020	0.00018	0.00005	0.00013	0.00004	0.0015	0.0003	0.0002	0.0001
3g	0.00047	0.00016	0.00014	0.00005	0.00011	0.00004	0.0032	0.0011	0.0010	0.0003
3h	0.00085	0.00044	0.00022	0.00012	0.00017	0.00009	0.0066	0.0018	0.0006	0.0002
3i	0.00067	0.00028	0.00018	0.00008	0.00013	0.00006	0.0019	0.0006	0.0002	0.0001
3j	0.00034	0.00019	0.00009	0.00005	0.00007	0.00004	0.0020	0.0006	0.0002	0.0001
3k	0.00034	0.00012	0.00008	0.00003	0.00007	0.00002	0.0018	0.0003	0.0002	0.0001
3l	0.00033	0.00019	0.00010	0.00006	0.00008	0.00005	0.0035	0.0015	0.0008	0.0004
3m	0.00057	0.00031	0.00015	0.00009	0.00011	0.00006	0.0062	0.0030	0.0006	0.0002
3n	0.00064	0.00029	0.00017	0.00008	0.00012	0.00006	0.0050	0.0013	0.0002	0.0001
3o	0.00031	0.00015	0.00008	0.00004	0.00006	0.00003	0.0007	0.0002	0.0001	0.0001
3p	0.00044	0.00022	0.00012	0.00006	0.00009	0.00005	0.0026	0.0010	0.0002	0.0001
3q	0.00036	0.00018	0.00012	0.00006	0.00009	0.00005	0.0040	0.0016	0.0010	0.0005
3r	0.00037	0.00007	0.00010	0.00002	0.00008	0.00002	0.0030	0.0004	0.0002	0.0001
3s	0.00030	0.00016	0.00010	0.00005	0.00007	0.00004	0.0033	0.0015	0.0009	0.0005
3t	0.00095	0.00045	0.00022	0.00010	0.00018	0.00008	0.0046	0.0015	0.0004	0.0002
Permissible values	0.001		0.001		0.001		0.01		0.01	

Table 2.105 shows that the numerical inconsistencies in specific volume v , specific enthalpy h , and specific entropy s are less than 0.001% when v is calculated one time from the backward equations $v(p, T)$ given in Sec. 2.3.6.4a and the other time from the basic equation $f_3(\rho, T)$, Eq. (2.11). The corresponding inconsistencies in the specific isobaric heat capacity c_p and in the speed of sound w are less than 0.01%. Thus, all inconsistencies are less than the permissible values. This means that the calculation with the backward equations agrees within five significant figures for v , h , and s and within four significant figures for c_p and w with the calculation using the basic equation only.

Comprehensive tests have shown that the maximum inconsistencies between the backward equations $v(p, T)$ of adjacent subregions are less than 0.001%. Moreover, the inconsistencies in h , s , c_p , and w along subregion boundaries, when these properties are calculated one time with the help of the backward equations $v(p, T)$ and the other time with the basic equation $f_3(\rho, T)$ alone, are also less than the permissible values given in Table 2.99; this is valid for subregion boundaries, isobars and lines defined by the subregion-boundary equations according to Eqs. (2.65) to (2.67).

d) Computing Time when Using the Backward Equations $v(p, T)$ in Comparison with the Basic Equation

A very important motivation for the development of the backward equations $v_3(p, T)$ was reducing the computing time for the calculation of thermodynamic properties for the given variables (p, T) in region 3. When only the basic equation $f_3(\rho, T)$, Eq. (2.11), is used, time consuming iterations are required, whereas when the basic equation is used in combination with the backward equations $v_3(p, T)$, all iterations are avoided. Then, the calculation speed is about 17 times faster than that using only the basic equation [22]. In this comparison, the basic equation has to be applied in combination with a one-dimensional Newton iteration with convergence tolerances corresponding to the consistency requirements for the backward equations given in Sec. 2.3.6.1.

e) Coefficients and Exponents of the Backward Equations $v(p, T)$ for Subregion 3a to 3t

This section contains Tables 2.106 to 2.125 with the coefficients n_i and exponents I_i and J_i of the backward equations $v_{3a}(p, T)$ to $v_{3t}(p, T)$ for subregions 3a to 3t according to Eqs. (2.68) and (2.69).

Table 2.106 Coefficients and exponents of the backward equation $v_{3a}(p, T)$ for subregion 3a in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	5	$0.110\ 879\ 558\ 823\ 853 \times 10^{-2}$	16	-3	1	$-0.122\ 494\ 831\ 387\ 441 \times 10^{-1}$
2	-12	10	$0.572\ 616\ 740\ 810\ 616 \times 10^3$	17	-3	3	$0.179\ 357\ 604\ 019\ 989 \times 10^1$
3	-12	12	$-0.767\ 051\ 948\ 380\ 852 \times 10^5$	18	-3	6	$0.442\ 729\ 521\ 058\ 314 \times 10^2$
4	-10	5	$-0.253\ 321\ 069\ 529\ 674 \times 10^{-1}$	19	-2	0	$-0.593\ 223\ 489\ 018\ 342 \times 10^{-2}$
5	-10	10	$0.628\ 008\ 049\ 345\ 689 \times 10^4$	20	-2	2	$0.453\ 186\ 261\ 685\ 774$
6	-10	12	$0.234\ 105\ 654\ 131\ 876 \times 10^6$	21	-2	3	$0.135\ 825\ 703\ 129\ 140 \times 10^1$
7	-8	5	$0.216\ 867\ 826\ 045\ 856$	22	-1	0	$0.408\ 748\ 415\ 856\ 745 \times 10^{-1}$
8	-8	8	$-0.156\ 237\ 904\ 341\ 963 \times 10^3$	23	-1	1	$0.474\ 686\ 397\ 863\ 312$
9	-8	10	$-0.269\ 893\ 956\ 176\ 613 \times 10^5$	24	-1	2	$0.118\ 646\ 814\ 997\ 915 \times 10^1$
10	-6	1	$-0.180\ 407\ 100\ 085\ 505 \times 10^{-3}$	25	0	0	$0.546\ 987\ 265\ 727\ 549$
11	-5	1	$0.116\ 732\ 227\ 668\ 261 \times 10^{-2}$	26	0	1	$0.195\ 266\ 770\ 452\ 643$
12	-5	5	$0.266\ 987\ 040\ 856\ 040 \times 10^2$	27	1	0	$-0.502\ 268\ 790\ 869\ 663 \times 10^{-1}$
13	-5	10	$0.282\ 776\ 617\ 243\ 286 \times 10^5$	28	1	2	$-0.369\ 645\ 308\ 193\ 377$
14	-4	8	$-0.242\ 431\ 520\ 029\ 523 \times 10^4$	29	2	0	$0.633\ 828\ 037\ 528\ 420 \times 10^{-2}$
15	-3	0	$0.435\ 217\ 323\ 022\ 733 \times 10^{-3}$	30	2	2	$0.797\ 441\ 793\ 901\ 017 \times 10^{-1}$

Table 2.107 Coefficients and exponents of the backward equation $v_{3b}(p, T)$ for subregion 3b in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	10	$-0.827\ 670\ 470\ 003\ 621 \times 10^{-1}$	17	-3	2	$-0.416\ 375\ 290\ 166\ 236 \times 10^{-1}$
2	-12	12	$0.416\ 887\ 126\ 010\ 565 \times 10^2$	18	-3	3	$-0.413\ 754\ 957\ 011\ 042 \times 10^2$
3	-10	8	$0.483\ 651\ 982\ 197\ 059 \times 10^{-1}$	19	-3	5	$-0.506\ 673\ 295\ 721\ 637 \times 10^2$
4	-10	14	$-0.291\ 032\ 084\ 950\ 276 \times 10^5$	20	-2	0	$-0.572\ 212\ 965\ 569\ 023 \times 10^{-3}$
5	-8	8	$-0.111\ 422\ 582\ 236\ 948 \times 10^3$	21	-2	2	$0.608\ 817\ 368\ 401\ 785 \times 10^1$
6	-6	5	$-0.202\ 300\ 083\ 904\ 014 \times 10^{-1}$	22	-2	5	$0.239\ 600\ 660\ 256\ 161 \times 10^2$
7	-6	6	$0.294\ 002\ 509\ 338\ 515 \times 10^3$	23	-1	0	$0.122\ 261\ 479\ 925\ 384 \times 10^{-1}$
8	-6	8	$0.140\ 244\ 997\ 609\ 658 \times 10^3$	24	-1	2	$0.216\ 356\ 057\ 692\ 938 \times 10^1$
9	-5	5	$-0.344\ 384\ 158\ 811\ 459 \times 10^3$	25	0	0	$0.398\ 198\ 903\ 368\ 642$
10	-5	8	$0.361\ 182\ 452\ 612\ 149 \times 10^3$	26	0	1	$-0.116\ 892\ 827\ 834\ 085$
11	-5	10	$-0.140\ 699\ 677\ 420\ 738 \times 10^4$	27	1	0	$-0.102\ 845\ 919\ 373\ 532$
12	-4	2	$-0.202\ 023\ 902\ 676\ 481 \times 10^{-2}$	28	1	2	$-0.492\ 676\ 637\ 589\ 284$
13	-4	4	$0.171\ 346\ 792\ 457\ 471 \times 10^3$	29	2	0	$0.655\ 540\ 456\ 406\ 790 \times 10^{-1}$
14	-4	5	$-0.425\ 597\ 804\ 058\ 632 \times 10^1$	30	3	2	$-0.240\ 462\ 535\ 078\ 530$
15	-3	0	$0.691\ 346\ 085\ 000\ 334 \times 10^{-5}$	31	4	0	$-0.269\ 798\ 180\ 310\ 075 \times 10^{-1}$
16	-3	1	$0.151\ 140\ 509\ 678\ 925 \times 10^{-2}$	32	4	1	$0.128\ 369\ 435\ 967\ 012$

Table 2.108 Coefficients and exponents of the backward equation $v_{3c}(p, T)$ for subregion 3c in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	6	$0.311\ 967\ 788\ 763\ 030 \times 10^1$	19	-2	4	$0.234\ 604\ 891\ 591\ 616 \times 10^3$
2	-12	8	$0.276\ 713\ 458\ 847\ 564 \times 10^5$	20	-2	5	$0.377\ 515\ 668\ 966\ 951 \times 10^4$
3	-12	10	$0.322\ 583\ 103\ 403\ 269 \times 10^8$	21	-1	0	$0.158\ 646\ 812\ 591\ 361 \times 10^{-1}$
4	-10	6	$-0.342\ 416\ 065\ 095\ 363 \times 10^3$	22	-1	1	$0.707\ 906\ 336\ 241\ 843$
5	-10	8	$-0.899\ 732\ 529\ 907\ 377 \times 10^6$	23	-1	2	$0.126\ 016\ 225\ 146\ 570 \times 10^2$
6	-10	10	$-0.793\ 892\ 049\ 821\ 251 \times 10^8$	24	0	0	$0.736\ 143\ 655\ 772\ 152$
7	-8	5	$0.953\ 193\ 003\ 217\ 388 \times 10^2$	25	0	1	$0.676\ 544\ 268\ 999\ 101$
8	-8	6	$0.229\ 784\ 742\ 345\ 072 \times 10^4$	26	0	2	$-0.178\ 100\ 588\ 189\ 137 \times 10^2$
9	-8	7	$0.175\ 336\ 675\ 322\ 499 \times 10^6$	27	1	0	$-0.156\ 531\ 975\ 531\ 713$
10	-6	8	$0.791\ 214\ 365\ 222\ 792 \times 10^7$	28	1	2	$0.117\ 707\ 430\ 048\ 158 \times 10^2$
11	-5	1	$0.319\ 933\ 345\ 844\ 209 \times 10^{-4}$	29	2	0	$0.840\ 143\ 653\ 860\ 447 \times 10^{-1}$
12	-5	4	$-0.659\ 508\ 863\ 555\ 767 \times 10^2$	30	2	1	$-0.186\ 442\ 467\ 471\ 949$
13	-5	7	$-0.833\ 426\ 563\ 212\ 851 \times 10^6$	31	2	3	$-0.440\ 170\ 203\ 949\ 645 \times 10^2$
14	-4	2	$0.645\ 734\ 680\ 583\ 292 \times 10^{-1}$	32	2	7	$0.123\ 290\ 423\ 502\ 494 \times 10^7$
15	-4	8	$-0.382\ 031\ 020\ 570\ 813 \times 10^7$	33	3	0	$-0.240\ 650\ 039\ 730\ 845 \times 10^{-1}$
16	-3	0	$0.406\ 398\ 848\ 470\ 079 \times 10^{-4}$	34	3	7	$-0.107\ 077\ 716\ 660\ 869 \times 10^7$
17	-3	3	$0.310\ 327\ 498\ 492\ 008 \times 10^2$	35	8	1	$0.438\ 319\ 858\ 566\ 475 \times 10^{-1}$
18	-2	0	$-0.892\ 996\ 718\ 483\ 724 \times 10^{-3}$				

Table 2.109 Coefficients and exponents of the backward equation $v_{3d}(p, T)$ for subregion 3d in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	4	$-0.452\ 484\ 847\ 171\ 645 \times 10^{-9}$	20	-5	1	$-0.436\ 701\ 347\ 922\ 356 \times 10^{-5}$
2	-12	6	$0.315\ 210\ 389\ 538\ 801 \times 10^{-4}$	21	-5	2	$-0.404\ 213\ 852\ 833\ 996 \times 10^{-3}$
3	-12	7	$-0.214\ 991\ 352\ 047\ 545 \times 10^{-2}$	22	-5	5	$-0.348\ 153\ 203\ 414\ 663 \times 10^3$
4	-12	10	$0.508\ 058\ 874\ 808\ 345 \times 10^3$	23	-5	7	$-0.385\ 294\ 213\ 555\ 289 \times 10^6$
5	-12	12	$-0.127\ 123\ 036\ 845\ 932 \times 10^8$	24	-4	0	$0.135\ 203\ 700\ 099\ 403 \times 10^{-6}$
6	-12	16	$0.115\ 371\ 133\ 120\ 497 \times 10^{13}$	25	-4	1	$0.134\ 648\ 383\ 271\ 089 \times 10^{-3}$
7	-10	0	$-0.197\ 805\ 728\ 776\ 273 \times 10^{-15}$	26	-4	7	$0.125\ 031\ 835\ 351\ 736 \times 10^6$
8	-10	2	$0.241\ 554\ 806\ 033\ 972 \times 10^{-10}$	27	-3	2	$0.968\ 123\ 678\ 455\ 841 \times 10^{-1}$
9	-10	4	$-0.156\ 481\ 703\ 640\ 525 \times 10^{-5}$	28	-3	4	$0.225\ 660\ 517\ 512\ 438 \times 10^3$
10	-10	6	$0.277\ 211\ 346\ 836\ 625 \times 10^{-2}$	29	-2	0	$-0.190\ 102\ 435\ 341\ 872 \times 10^{-3}$
11	-10	8	$-0.203\ 578\ 994\ 462\ 286 \times 10^2$	30	-2	1	$-0.299\ 628\ 410\ 819\ 229 \times 10^{-1}$
12	-10	10	$0.144\ 369\ 489\ 909\ 053 \times 10^7$	31	-1	0	$0.500\ 833\ 915\ 372\ 121 \times 10^{-2}$
13	-10	14	$-0.411\ 254\ 217\ 946\ 539 \times 10^{11}$	32	-1	1	$0.387\ 842\ 482\ 998\ 411$
14	-8	3	$0.623\ 449\ 786\ 243\ 773 \times 10^{-5}$	33	-1	5	$-0.138\ 535\ 367\ 777\ 182 \times 10^4$
15	-8	7	$-0.221\ 774\ 281\ 146\ 038 \times 10^2$	34	0	0	$0.870\ 745\ 245\ 971\ 773$
16	-8	8	$-0.689\ 315\ 087\ 933\ 158 \times 10^5$	35	0	2	$0.171\ 946\ 252\ 068\ 742 \times 10^1$
17	-8	10	$-0.195\ 419\ 525\ 060\ 713 \times 10^8$	36	1	0	$-0.326\ 650\ 121\ 426\ 383 \times 10^{-1}$
18	-6	6	$0.316\ 373\ 510\ 564\ 015 \times 10^4$	37	1	6	$0.498\ 044\ 171\ 727\ 877 \times 10^4$
19	-6	8	$0.224\ 040\ 754\ 426\ 988 \times 10^7$	38	3	0	$0.551\ 478\ 022\ 765\ 087 \times 10^{-2}$

Table 2.110 Coefficients and exponents of the backward equation $v_{3e}(p, T)$ for subregion 3e in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	14	$0.715\ 815\ 808\ 404\ 721 \times 10^9$	16	-3	6	$0.475\ 992\ 667\ 717\ 124 \times 10^5$
2	-12	16	$-0.114\ 328\ 360\ 753\ 449 \times 10^{12}$	17	-3	7	$-0.266\ 627\ 750\ 390\ 341 \times 10^6$
3	-10	3	$0.376\ 531\ 002\ 015\ 720 \times 10^{-11}$	18	-2	0	$-0.153\ 314\ 954\ 386\ 524 \times 10^{-3}$
4	-10	6	$-0.903\ 983\ 668\ 691\ 157 \times 10^{-4}$	19	-2	1	$0.305\ 638\ 404\ 828\ 265$
5	-10	10	$0.665\ 695\ 908\ 836\ 252 \times 10^6$	20	-2	3	$0.123\ 654\ 999\ 499\ 486 \times 10^3$
6	-10	14	$0.535\ 364\ 174\ 960\ 127 \times 10^{10}$	21	-2	4	$-0.104\ 390\ 794\ 213\ 011 \times 10^4$
7	-10	16	$0.794\ 977\ 402\ 335\ 603 \times 10^{11}$	22	-1	0	$-0.157\ 496\ 516\ 174\ 308 \times 10^{-1}$
8	-8	7	$0.922\ 230\ 563\ 421\ 437 \times 10^2$	23	0	0	$0.685\ 331\ 118\ 940\ 253$
9	-8	8	$-0.142\ 586\ 073\ 991\ 215 \times 10^6$	24	0	1	$0.178\ 373\ 462\ 873\ 903 \times 10^1$
10	-8	10	$-0.111\ 796\ 381\ 424\ 162 \times 10^7$	25	1	0	$-0.544\ 674\ 124\ 878\ 910$
11	-6	6	$0.896\ 121\ 629\ 640\ 760 \times 10^4$	26	1	4	$0.204\ 529\ 931\ 318\ 843 \times 10^4$
12	-5	6	$-0.669\ 989\ 239\ 070\ 491 \times 10^4$	27	1	6	$-0.228\ 342\ 359\ 328\ 752 \times 10^5$
13	-4	2	$0.451\ 242\ 538\ 486\ 834 \times 10^{-2}$	28	2	0	$0.413\ 197\ 481\ 515\ 899$
14	-4	4	$-0.339\ 731\ 325\ 977\ 713 \times 10^2$	29	2	2	$-0.341\ 931\ 835\ 910\ 405 \times 10^2$
15	-3	2	$-0.120\ 523\ 111\ 552\ 278 \times 10^1$				

Table 2.111 Coefficients and exponents of the backward equation $v_{3f}(p, T)$ for subregion 3f in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	-3	$-0.251\ 756\ 547\ 792\ 325 \times 10^{-7}$	22	10	-6	$0.470\ 942\ 606\ 221\ 652 \times 10^{-5}$
2	0	-2	$0.601\ 307\ 193\ 668\ 763 \times 10^{-5}$	23	12	-10	$0.195\ 049\ 710\ 391\ 712 \times 10^{-12}$
3	0	-1	$-0.100\ 615\ 977\ 450\ 049 \times 10^{-2}$	24	12	-8	$-0.911\ 627\ 886\ 266\ 077 \times 10^{-8}$
4	0	0	0.999 969 140 252 192	25	12	-4	$0.604\ 374\ 640\ 201\ 265 \times 10^{-3}$
5	0	1	$0.214\ 107\ 759\ 236\ 486 \times 10^1$	26	14	-12	$-0.225\ 132\ 933\ 900\ 136 \times 10^{-15}$
6	0	2	$-0.165\ 175\ 571\ 959\ 086 \times 10^2$	27	14	-10	$0.610\ 916\ 973\ 582\ 981 \times 10^{-11}$
7	1	-1	$-0.141\ 987\ 303\ 638\ 727 \times 10^{-2}$	28	14	-8	$-0.303\ 063\ 908\ 043\ 404 \times 10^{-6}$
8	1	1	$0.269\ 251\ 915\ 156\ 554 \times 10^1$	29	14	-6	$-0.137\ 796\ 070\ 798\ 409 \times 10^{-4}$
9	1	2	$0.349\ 741\ 815\ 858\ 722 \times 10^2$	30	14	-4	$-0.919\ 296\ 736\ 666\ 106 \times 10^{-3}$
10	1	3	$-0.300\ 208\ 695\ 771\ 783 \times 10^2$	31	16	-10	$0.639\ 288\ 223\ 132\ 545 \times 10^{-9}$
11	2	0	$-0.131\ 546\ 288\ 252\ 539 \times 10^1$	32	16	-8	$0.753\ 259\ 479\ 898\ 699 \times 10^{-6}$
12	2	1	$-0.839\ 091\ 277\ 286\ 169 \times 10^1$	33	18	-12	$-0.400\ 321\ 478\ 682\ 929 \times 10^{-12}$
13	3	-5	$0.181\ 545\ 608\ 337\ 015 \times 10^{-9}$	34	18	-10	$0.756\ 140\ 294\ 351\ 614 \times 10^{-8}$
14	3	-2	$-0.591\ 099\ 206\ 478\ 909 \times 10^{-3}$	35	20	-12	$-0.912\ 082\ 054\ 034\ 891 \times 10^{-11}$
15	3	0	$0.152\ 115\ 067\ 087\ 106 \times 10^1$	36	20	-10	$-0.237\ 612\ 381\ 140\ 539 \times 10^{-7}$
16	4	-3	$0.252\ 956\ 470\ 663\ 225 \times 10^{-4}$	37	20	-6	$0.269\ 586\ 010\ 591\ 874 \times 10^{-4}$
17	5	-8	$0.100\ 726\ 265\ 203\ 786 \times 10^{-14}$	38	22	-12	$-0.732\ 828\ 135\ 157\ 839 \times 10^{-10}$
18	5	1	$-0.149\ 774\ 533\ 860\ 650 \times 10^1$	39	24	-12	$0.241\ 995\ 578\ 306\ 660 \times 10^{-9}$
19	6	-6	$-0.793\ 940\ 970\ 562\ 969 \times 10^{-9}$	40	24	-4	$-0.405\ 735\ 532\ 730\ 322 \times 10^{-3}$
20	7	-4	$-0.150\ 290\ 891\ 264\ 717 \times 10^{-3}$	41	28	-12	$0.189\ 424\ 143\ 498\ 011 \times 10^{-9}$
21	7	1	$0.151\ 205\ 531\ 275\ 133 \times 10^1$	42	32	-12	$-0.486\ 632\ 965\ 074\ 563 \times 10^{-9}$

Table 2.112 Coefficients and exponents of the backward equation $v_{3g}(p, T)$ for subregion 3g in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	7	$0.412\ 209\ 020\ 652\ 996 \times 10^{-4}$	20	-2	3	$-0.910\ 782\ 540\ 134\ 681 \times 10^2$
2	-12	12	$-0.114\ 987\ 238\ 280\ 587 \times 10^7$	21	-2	5	$0.135\ 033\ 227\ 281\ 565 \times 10^6$
3	-12	14	$0.948\ 180\ 885\ 032\ 080 \times 10^{10}$	22	-2	14	$-0.712\ 949\ 383\ 408\ 211 \times 10^{19}$
4	-12	18	$-0.195\ 788\ 865\ 718\ 971 \times 10^{18}$	23	-2	24	$-0.104\ 578\ 785\ 289\ 542 \times 10^{37}$
5	-12	22	$0.496\ 250\ 704\ 871\ 300 \times 10^{25}$	24	-1	2	$0.304\ 331\ 584\ 444\ 093 \times 10^2$
6	-12	24	$-0.105\ 549\ 884\ 548\ 496 \times 10^{29}$	25	-1	8	$0.593\ 250\ 797\ 959\ 445 \times 10^{10}$
7	-10	14	$-0.758\ 642\ 165\ 988\ 278 \times 10^{12}$	26	-1	18	$-0.364\ 174\ 062\ 110\ 798 \times 10^{28}$
8	-10	20	$-0.922\ 172\ 769\ 596\ 101 \times 10^{23}$	27	0	0	$0.921\ 791\ 403\ 532\ 461$
9	-10	24	$0.725\ 379\ 072\ 059\ 348 \times 10^{30}$	28	0	1	$-0.337\ 693\ 609\ 657\ 471$
10	-8	7	$-0.617\ 718\ 249\ 205\ 859 \times 10^2$	29	0	2	$-0.724\ 644\ 143\ 758\ 508 \times 10^2$
11	-8	8	$0.107\ 555\ 033\ 344\ 858 \times 10^5$	30	1	0	$-0.110\ 480\ 239\ 272\ 601$
12	-8	10	$-0.379\ 545\ 802\ 336\ 487 \times 10^8$	31	1	1	$0.536\ 516\ 031\ 875\ 059 \times 10^1$
13	-8	12	$0.228\ 646\ 846\ 221\ 831 \times 10^{12}$	32	1	3	$-0.291\ 441\ 872\ 156\ 205 \times 10^4$
14	-6	8	$-0.499\ 741\ 093\ 010\ 619 \times 10^7$	33	3	24	$0.616\ 338\ 176\ 535\ 305 \times 10^{40}$
15	-6	22	$-0.280\ 214\ 310\ 054\ 101 \times 10^{31}$	34	5	22	$-0.120\ 889\ 175\ 861\ 180 \times 10^{39}$
16	-5	7	$0.104\ 915\ 406\ 769\ 586 \times 10^7$	35	6	12	$0.818\ 396\ 024\ 524\ 612 \times 10^{23}$
17	-5	20	$0.613\ 754\ 229\ 168\ 619 \times 10^{28}$	36	8	3	$0.940\ 781\ 944\ 835\ 829 \times 10^9$
18	-4	22	$0.802\ 056\ 715\ 528\ 378 \times 10^{32}$	37	10	0	$-0.367\ 279\ 669\ 545\ 448 \times 10^5$
19	-3	7	$-0.298\ 617\ 819\ 828\ 065 \times 10^8$	38	10	6	$-0.837\ 513\ 931\ 798\ 655 \times 10^{16}$

Table 2.113 Coefficients and exponents of the backward equation $v_{3h}(p, T)$ for subregion 3h in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	8	$0.561\ 379\ 678\ 887\ 577 \times 10^{-1}$	16	-6	8	$-0.656\ 174\ 421\ 999\ 594 \times 10^7$
2	-12	12	$0.774\ 135\ 421\ 587\ 083 \times 10^{10}$	17	-5	2	$0.156\ 362\ 212\ 977\ 396 \times 10^{-4}$
3	-10	4	$0.111\ 482\ 975\ 877\ 938 \times 10^{-8}$	18	-5	3	$-0.212\ 946\ 257\ 021\ 400 \times 10^1$
4	-10	6	$-0.143\ 987\ 128\ 208\ 183 \times 10^{-2}$	19	-5	4	$0.135\ 249\ 306\ 374\ 858 \times 10^2$
5	-10	8	$0.193\ 696\ 558\ 764\ 920 \times 10^4$	20	-4	2	$0.177\ 189\ 164\ 145\ 813$
6	-10	10	$-0.605\ 971\ 823\ 585\ 005 \times 10^9$	21	-4	4	$0.139\ 499\ 167\ 345\ 464 \times 10^4$
7	-10	14	$0.171\ 951\ 568\ 124\ 337 \times 10^{14}$	22	-3	1	$-0.703\ 670\ 932\ 036\ 388 \times 10^{-2}$
8	-10	16	$-0.185\ 461\ 154\ 985\ 145 \times 10^{17}$	23	-3	2	$-0.152\ 011\ 044\ 389\ 648$
9	-8	0	$0.387\ 851\ 168\ 078\ 010 \times 10^{-16}$	24	-2	0	$0.981\ 916\ 922\ 991\ 113 \times 10^{-4}$
10	-8	1	$-0.395\ 464\ 327\ 846\ 105 \times 10^{-13}$	25	-1	0	$0.147\ 199\ 658\ 618\ 076 \times 10^{-2}$
11	-8	6	$-0.170\ 875\ 935\ 679\ 023 \times 10^3$	26	-1	2	$0.202\ 618\ 487\ 025\ 578 \times 10^2$
12	-8	7	$-0.212\ 010\ 620\ 701\ 220 \times 10^4$	27	0	0	$0.899\ 345\ 518\ 944\ 240$
13	-8	8	$0.177\ 683\ 337\ 348\ 191 \times 10^8$	28	1	0	$-0.211\ 346\ 402\ 240\ 858$
14	-6	4	$0.110\ 177\ 443\ 629\ 575 \times 10^2$	29	1	2	$0.249\ 971\ 752\ 957\ 491 \times 10^2$
15	-6	6	$-0.234\ 396\ 091\ 693\ 313 \times 10^6$				

Table 2.114 Coefficients and exponents of the backward equation $v_{3i}(p, T)$ for subregion 3i in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.106\ 905\ 684\ 359\ 136 \times 10^1$	22	12	-12	$0.164\ 395\ 334\ 345\ 040 \times 10^{-23}$
2	0	1	$-0.148\ 620\ 857\ 922\ 333 \times 10^1$	23	12	-6	$-0.339\ 823\ 323\ 754\ 373 \times 10^{-5}$
3	0	10	$0.259\ 862\ 256\ 980\ 408 \times 10^{15}$	24	12	-4	$-0.135\ 268\ 639\ 905\ 021 \times 10^{-1}$
4	1	-4	$-0.446\ 352\ 055\ 678\ 749 \times 10^{-11}$	25	14	-10	$-0.723\ 252\ 514\ 211\ 625 \times 10^{-14}$
5	1	-2	$-0.566\ 620\ 757\ 170\ 032 \times 10^{-6}$	26	14	-8	$0.184\ 386\ 437\ 538\ 366 \times 10^{-8}$
6	1	-1	$-0.235\ 302\ 885\ 736\ 849 \times 10^{-2}$	27	14	-4	$-0.463\ 959\ 533\ 752\ 385 \times 10^{-1}$
7	1	0	$-0.269\ 226\ 321\ 968\ 839$	28	14	5	$-0.992\ 263\ 100\ 376\ 750 \times 10^{14}$
8	2	0	$0.922\ 024\ 992\ 944\ 392 \times 10^1$	29	18	-12	$0.688\ 169\ 154\ 439\ 335 \times 10^{-16}$
9	3	-5	$0.357\ 633\ 505\ 503\ 772 \times 10^{-11}$	30	18	-10	$-0.222\ 620\ 998\ 452\ 197 \times 10^{-10}$
10	3	0	$-0.173\ 942\ 565\ 562\ 222 \times 10^2$	31	18	-8	$-0.540\ 843\ 018\ 624\ 083 \times 10^{-7}$
11	4	-3	$0.700\ 681\ 785\ 556\ 229 \times 10^{-5}$	32	18	-6	$0.345\ 570\ 606\ 200\ 257 \times 10^{-2}$
12	4	-2	$-0.267\ 050\ 351\ 075\ 768 \times 10^{-3}$	33	18	2	$0.422\ 275\ 800\ 304\ 086 \times 10^{11}$
13	4	-1	$-0.231\ 779\ 669\ 675\ 624 \times 10^1$	34	20	-12	$-0.126\ 974\ 478\ 770\ 487 \times 10^{-14}$
14	5	-6	$-0.753\ 533\ 046\ 979\ 752 \times 10^{-12}$	35	20	-10	$0.927\ 237\ 985\ 153\ 679 \times 10^{-9}$
15	5	-1	$0.481\ 337\ 131\ 452\ 891 \times 10^1$	36	22	-12	$0.612\ 670\ 812\ 016\ 489 \times 10^{-13}$
16	5	12	$-0.223\ 286\ 270\ 422\ 356 \times 10^{22}$	37	24	-12	$-0.722\ 693\ 924\ 063\ 497 \times 10^{-11}$
17	7	-4	$-0.118\ 746\ 004\ 987\ 383 \times 10^{-4}$	38	24	-8	$-0.383\ 669\ 502\ 636\ 822 \times 10^{-3}$
18	7	-3	$0.646\ 412\ 934\ 136\ 496 \times 10^{-2}$	39	32	-10	$0.374\ 684\ 572\ 410\ 204 \times 10^{-3}$
19	8	-6	$-0.410\ 588\ 536\ 330\ 937 \times 10^{-9}$	40	32	-5	$-0.931\ 976\ 897\ 511\ 086 \times 10^5$
20	8	10	$0.422\ 739\ 537\ 057\ 241 \times 10^{20}$	41	36	-10	$-0.247\ 690\ 616\ 026\ 922 \times 10^{-1}$
21	10	-8	$0.313\ 698\ 180\ 473\ 812 \times 10^{-12}$	42	36	-8	$0.658\ 110\ 546\ 759\ 474 \times 10^2$

Table 2.115 Coefficients and exponents of the backward equation $v_{3j}(p, T)$ for subregion 3j in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	-1	$-0.111\ 371\ 317\ 395\ 540 \times 10^{-3}$	16	10	-6	$-0.960\ 754\ 116\ 701\ 669 \times 10^{-8}$
2	0	0	$0.100\ 342\ 892\ 423\ 685 \times 10^1$	17	12	-8	$-0.510\ 572\ 269\ 720\ 488 \times 10^{-10}$
3	0	1	$0.530\ 615\ 581\ 928\ 979 \times 10^1$	18	12	-3	$0.767\ 373\ 781\ 404\ 211 \times 10^{-2}$
4	1	-2	$0.179\ 058\ 760\ 078\ 792 \times 10^{-5}$	19	14	-10	$0.663\ 855\ 469\ 485\ 254 \times 10^{-14}$
5	1	-1	$-0.728\ 541\ 958\ 464\ 774 \times 10^{-3}$	20	14	-8	$-0.717\ 590\ 735\ 526\ 745 \times 10^{-9}$
6	1	1	$-0.187\ 576\ 133\ 371\ 704 \times 10^2$	21	14	-5	$0.146\ 564\ 542\ 926\ 508 \times 10^{-4}$
7	2	-1	$0.199\ 060\ 874\ 071\ 849 \times 10^{-2}$	22	16	-10	$0.309\ 029\ 474\ 277\ 013 \times 10^{-11}$
8	2	1	$0.243\ 574\ 755\ 377\ 290 \times 10^2$	23	18	-12	$-0.464\ 216\ 300\ 971\ 708 \times 10^{-15}$
9	3	-2	$-0.177\ 040\ 785\ 499\ 444 \times 10^{-3}$	24	20	-12	$-0.390\ 499\ 637\ 961\ 161 \times 10^{-13}$
10	4	-2	$-0.259\ 680\ 385\ 227\ 130 \times 10^{-2}$	25	20	-10	$-0.236\ 716\ 126\ 781\ 431 \times 10^{-9}$
11	4	2	$-0.198\ 704\ 578\ 406\ 823 \times 10^3$	26	24	-12	$0.454\ 652\ 854\ 268\ 717 \times 10^{-11}$
12	5	-3	$0.738\ 627\ 790\ 224\ 287 \times 10^{-4}$	27	24	-6	$-0.422\ 271\ 787\ 482\ 497 \times 10^{-2}$
13	5	-2	$-0.236\ 264\ 692\ 844\ 138 \times 10^{-2}$	28	28	-12	$0.283\ 911\ 742\ 354\ 706 \times 10^{-10}$
14	5	0	$-0.161\ 023\ 121\ 314\ 333 \times 10^1$	29	28	-5	$0.270\ 929\ 002\ 720\ 228 \times 10^1$
15	6	3	$0.622\ 322\ 971\ 786\ 473 \times 10^4$				

Table 2.116 Coefficients and exponents of the backward equation $v_{3k}(p, T)$ for subregion 3k in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-2	10	$-0.401\ 215\ 699\ 576\ 099 \times 10^9$	18	1	2	$-0.194\ 646\ 110\ 037\ 079 \times 10^3$
2	-2	12	$0.484\ 501\ 478\ 318\ 406 \times 10^{11}$	19	2	-8	$0.808\ 354\ 639\ 772\ 825 \times 10^{-15}$
3	-1	-5	$0.394\ 721\ 471\ 363\ 678 \times 10^{-14}$	20	2	-6	$-0.180\ 845\ 209\ 145\ 470 \times 10^{-10}$
4	-1	6	$0.372\ 629\ 967\ 374\ 147 \times 10^5$	21	2	-3	$-0.696\ 664\ 158\ 132\ 412 \times 10^{-5}$
5	0	-12	$-0.369\ 794\ 374\ 168\ 666 \times 10^{-29}$	22	2	-2	$-0.181\ 057\ 560\ 300\ 994 \times 10^{-2}$
6	0	-6	$-0.380\ 436\ 407\ 012\ 452 \times 10^{-14}$	23	2	0	$0.255\ 830\ 298\ 579\ 027 \times 10^1$
7	0	-2	$0.475\ 361\ 629\ 970\ 233 \times 10^{-6}$	24	2	4	$0.328\ 913\ 873\ 658\ 481 \times 10^4$
8	0	-1	$-0.879\ 148\ 916\ 140\ 706 \times 10^{-3}$	25	5	-12	$-0.173\ 270\ 241\ 249\ 904 \times 10^{-18}$
9	0	0	0.844 317 863 844 331	26	5	-6	$-0.661\ 876\ 792\ 558\ 034 \times 10^{-6}$
10	0	1	$0.122\ 433\ 162\ 656\ 600 \times 10^2$	27	5	-3	$-0.395\ 688\ 923\ 421\ 250 \times 10^{-2}$
11	0	2	$-0.104\ 529\ 634\ 830\ 279 \times 10^3$	28	6	-12	$0.604\ 203\ 299\ 819\ 132 \times 10^{-17}$
12	0	3	$0.589\ 702\ 771\ 277\ 429 \times 10^3$	29	6	-10	$-0.400\ 879\ 935\ 920\ 517 \times 10^{-13}$
13	0	14	$-0.291\ 026\ 851\ 164\ 444 \times 10^{14}$	30	6	-8	$0.160\ 751\ 107\ 464\ 958 \times 10^{-8}$
14	1	-3	$0.170\ 343\ 072\ 841\ 850 \times 10^{-5}$	31	6	-5	$0.383\ 719\ 409\ 025\ 556 \times 10^{-4}$
15	1	-2	$-0.277\ 617\ 606\ 975\ 748 \times 10^{-3}$	32	8	-12	$-0.649\ 565\ 446\ 702\ 457 \times 10^{-14}$
16	1	0	$-0.344\ 709\ 605\ 486\ 686 \times 10^1$	33	10	-12	$-0.149\ 095\ 328\ 506\ 000 \times 10^{-11}$
17	1	1	$0.221\ 333\ 862\ 447\ 095 \times 10^2$	34	12	-10	$0.541\ 449\ 377\ 329\ 581 \times 10^{-8}$

Table 2.117 Coefficients and exponents of the backward equation $v_{31}(p, T)$ for subregion 31 in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	14	$0.260\ 702\ 058\ 647\ 537 \times 10^{10}$	23	-3	20	$-0.695\ 953\ 622\ 348\ 829 \times 10^{33}$
2	-12	16	$-0.188\ 277\ 213\ 604\ 704 \times 10^{15}$	24	-2	2	$0.110\ 609\ 027\ 472\ 280$
3	-12	18	$0.554\ 923\ 870\ 289\ 667 \times 10^{19}$	25	-2	3	$0.721\ 559\ 163\ 361\ 354 \times 10^2$
4	-12	20	$-0.758\ 966\ 946\ 387\ 758 \times 10^{23}$	26	-2	10	$-0.306\ 367\ 307\ 532\ 219 \times 10^{15}$
5	-12	22	$0.413\ 865\ 186\ 848\ 908 \times 10^{27}$	27	-1	0	$0.265\ 839\ 618\ 885\ 530 \times 10^{-4}$
6	-10	14	$-0.815\ 038\ 000\ 738\ 060 \times 10^{12}$	28	-1	1	$0.253\ 392\ 392\ 889\ 754 \times 10^{-1}$
7	-10	24	$-0.381\ 458\ 260\ 489\ 955 \times 10^{33}$	29	-1	3	$-0.214\ 443\ 041\ 836\ 579 \times 10^3$
8	-8	6	$-0.123\ 239\ 564\ 600\ 519 \times 10^{-1}$	30	0	0	$0.937\ 846\ 601\ 489\ 667$
9	-8	10	$0.226\ 095\ 631\ 437\ 174 \times 10^8$	31	0	1	$0.223\ 184\ 043\ 101\ 700 \times 10^1$
10	-8	12	$-0.495\ 017\ 809\ 506\ 720 \times 10^{12}$	32	0	2	$0.338\ 401\ 222\ 509\ 191 \times 10^2$
11	-8	14	$0.529\ 482\ 996\ 422\ 863 \times 10^{16}$	33	0	12	$0.494\ 237\ 237\ 179\ 718 \times 10^{21}$
12	-8	18	$-0.444\ 359\ 478\ 746\ 295 \times 10^{23}$	34	1	0	$-0.198\ 068\ 404\ 154\ 428$
13	-8	24	$0.521\ 635\ 864\ 527\ 315 \times 10^{35}$	35	1	16	$-0.141\ 415\ 349\ 881\ 140 \times 10^{31}$
14	-8	36	$-0.487\ 095\ 672\ 740\ 742 \times 10^{55}$	36	2	1	$-0.993\ 862\ 421\ 613\ 651 \times 10^2$
15	-6	8	$-0.714\ 430\ 209\ 937\ 547 \times 10^6$	37	4	0	$0.125\ 070\ 534\ 142\ 731 \times 10^3$
16	-5	4	$0.127\ 868\ 634\ 615\ 495$	38	5	0	$-0.996\ 473\ 529\ 004\ 439 \times 10^3$
17	-5	5	$-0.100\ 752\ 127\ 917\ 598 \times 10^2$	39	5	1	$0.473\ 137\ 909\ 872\ 765 \times 10^5$
18	-4	7	$0.777\ 451\ 437\ 960\ 990 \times 10^7$	40	6	14	$0.116\ 662\ 121\ 219\ 322 \times 10^{33}$
19	-4	16	$-0.108\ 105\ 480\ 796\ 471 \times 10^{25}$	41	10	4	$-0.315\ 874\ 976\ 271\ 533 \times 10^{16}$
20	-3	1	$-0.357\ 578\ 581\ 169\ 659 \times 10^{-5}$	42	10	12	$-0.445\ 703\ 369\ 196\ 945 \times 10^{33}$
21	-3	3	$-0.212\ 857\ 169\ 423\ 484 \times 10^1$	43	14	10	$0.642\ 794\ 932\ 373\ 694 \times 10^{33}$
22	-3	18	$0.270\ 706\ 111\ 085\ 238 \times 10^{30}$				

Table 2.118 Coefficients and exponents of the backward equation $v_{3m}(p, T)$ for subregion 3m in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.811\ 384\ 363\ 481\ 847$	21	28	20	$0.368\ 193\ 926\ 183\ 570 \times 10^{60}$
2	3	0	$-0.568\ 199\ 310\ 990\ 094 \times 10^4$	22	2	22	$0.170\ 215\ 539\ 458\ 936 \times 10^{18}$
3	8	0	$-0.178\ 657\ 198\ 172\ 556 \times 10^{11}$	23	16	22	$0.639\ 234\ 909\ 918\ 741 \times 10^{42}$
4	20	2	$0.795\ 537\ 657\ 613\ 427 \times 10^{32}$	24	0	24	$-0.821\ 698\ 160\ 721\ 956 \times 10^{15}$
5	1	5	$-0.814\ 568\ 209\ 346\ 872 \times 10^5$	25	5	24	$-0.795\ 260\ 241\ 872\ 306 \times 10^{24}$
6	3	5	$-0.659\ 774\ 567\ 602\ 874 \times 10^8$	26	0	28	$0.233\ 415\ 869\ 478\ 510 \times 10^{18}$
7	4	5	$-0.152\ 861\ 148\ 659\ 302 \times 10^{11}$	27	3	28	$-0.600\ 079\ 934\ 586\ 803 \times 10^{23}$
8	5	5	$-0.560\ 165\ 667\ 510\ 446 \times 10^{12}$	28	4	28	$0.594\ 584\ 382\ 273\ 384 \times 10^{25}$
9	1	6	$0.458\ 384\ 828\ 593\ 949 \times 10^6$	29	12	28	$0.189\ 461\ 279\ 349\ 492 \times 10^{40}$
10	6	6	$-0.385\ 754\ 000\ 383\ 848 \times 10^{14}$	30	16	28	$-0.810\ 093\ 428\ 842\ 645 \times 10^{46}$
11	2	7	$0.453\ 735\ 800\ 004\ 273 \times 10^8$	31	1	32	$0.188\ 813\ 911\ 076\ 809 \times 10^{22}$
12	4	8	$0.939\ 454\ 935\ 735\ 563 \times 10^{12}$	32	8	32	$0.111\ 052\ 244\ 098\ 768 \times 10^{36}$
13	14	8	$0.266\ 572\ 856\ 432\ 938 \times 10^{28}$	33	14	32	$0.291\ 133\ 958\ 602\ 503 \times 10^{46}$
14	2	10	$-0.547\ 578\ 313\ 899\ 097 \times 10^{10}$	34	0	36	$-0.329\ 421\ 923\ 951\ 460 \times 10^{22}$
15	5	10	$0.200\ 725\ 701\ 112\ 386 \times 10^{15}$	35	2	36	$-0.137\ 570\ 282\ 536\ 696 \times 10^{26}$
16	3	12	$0.185\ 007\ 245\ 563\ 239 \times 10^{13}$	36	3	36	$0.181\ 508\ 996\ 303\ 902 \times 10^{28}$
17	0	14	$0.185\ 135\ 446\ 828\ 337 \times 10^9$	37	4	36	$-0.346\ 865\ 122\ 768\ 353 \times 10^{30}$
18	1	14	$-0.170\ 451\ 090\ 076\ 385 \times 10^{12}$	38	8	36	$-0.211\ 961\ 148\ 774\ 260 \times 10^{38}$
19	1	18	$0.157\ 890\ 366\ 037\ 614 \times 10^{15}$	39	14	36	$-0.128\ 617\ 899\ 887\ 675 \times 10^{49}$
20	1	20	$-0.202\ 530\ 509\ 748\ 774 \times 10^{16}$	40	24	36	$0.479\ 817\ 895\ 699\ 239 \times 10^{65}$

Table 2.119 Coefficients and exponents of the backward equation $v_{3n}(p, T)$ for subregion 3n in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	-12	$0.280\ 967\ 799\ 943\ 151 \times 10^{-38}$	21	3	-6	$0.705\ 412\ 100\ 773\ 699 \times 10^{-11}$
2	3	-12	$0.614\ 869\ 006\ 573\ 609 \times 10^{-30}$	22	4	-6	$0.258\ 585\ 887\ 897\ 486 \times 10^{-8}$
3	4	-12	$0.582\ 238\ 667\ 048\ 942 \times 10^{-27}$	23	2	-5	$-0.493\ 111\ 362\ 030\ 162 \times 10^{-10}$
4	6	-12	$0.390\ 628\ 369\ 238\ 462 \times 10^{-22}$	24	4	-5	$-0.158\ 649\ 699\ 894\ 543 \times 10^{-5}$
5	7	-12	$0.821\ 445\ 758\ 255\ 119 \times 10^{-20}$	25	7	-5	$-0.525\ 037\ 427\ 886\ 100$
6	10	-12	$0.402\ 137\ 961\ 842\ 776 \times 10^{-14}$	26	4	-4	$0.220\ 019\ 901\ 729\ 615 \times 10^{-2}$
7	12	-12	$0.651\ 718\ 171\ 878\ 301 \times 10^{-12}$	27	3	-3	$-0.643\ 064\ 132\ 636\ 925 \times 10^{-2}$
8	14	-12	$-0.211\ 773\ 355\ 803\ 058 \times 10^{-7}$	28	5	-3	$0.629\ 154\ 149\ 015\ 048 \times 10^2$
9	18	-12	$0.264\ 953\ 354\ 380\ 072 \times 10^{-2}$	29	6	-3	$0.135\ 147\ 318\ 617\ 061 \times 10^3$
10	0	-10	$-0.135\ 031\ 446\ 451\ 331 \times 10^{-31}$	30	0	-2	$0.240\ 560\ 808\ 321\ 713 \times 10^{-6}$
11	3	-10	$-0.607\ 246\ 643\ 970\ 893 \times 10^{-23}$	31	0	-1	$-0.890\ 763\ 306\ 701\ 305 \times 10^{-3}$
12	5	-10	$-0.402\ 352\ 115\ 234\ 494 \times 10^{-18}$	32	3	-1	$-0.440\ 209\ 599\ 407\ 714 \times 10^4$
13	6	-10	$-0.744\ 938\ 506\ 925\ 544 \times 10^{-16}$	33	1	0	$-0.302\ 807\ 107\ 747\ 776 \times 10^3$
14	8	-10	$0.189\ 917\ 206\ 526\ 237 \times 10^{-12}$	34	0	1	$0.159\ 158\ 748\ 314\ 599 \times 10^4$
15	12	-10	$0.364\ 975\ 183\ 508\ 473 \times 10^{-5}$	35	1	1	$0.232\ 534\ 272\ 709\ 876 \times 10^6$
16	0	-8	$0.177\ 274\ 872\ 361\ 946 \times 10^{-25}$	36	0	2	$-0.792\ 681\ 207\ 132\ 600 \times 10^6$
17	3	-8	$-0.334\ 952\ 758\ 812\ 999 \times 10^{-18}$	37	1	4	$-0.869\ 871\ 364\ 662\ 769 \times 10^{11}$
18	7	-8	$-0.421\ 537\ 726\ 098\ 389 \times 10^{-8}$	38	0	5	$0.354\ 542\ 769\ 185\ 671 \times 10^{12}$
19	12	-8	$-0.391\ 048\ 167\ 929\ 649 \times 10^{-1}$	39	1	6	$0.400\ 849\ 240\ 129\ 329 \times 10^{15}$
20	2	-6	$0.541\ 276\ 911\ 564\ 176 \times 10^{-13}$				

Table 2.120 Coefficients and exponents of the backward equation $v_{3o}(p, T)$ for subregion 3o in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	-12	$0.128\ 746\ 023\ 979\ 718 \times 10^{-34}$	13	6	-8	$0.814\ 897\ 605\ 805\ 513 \times 10^{-14}$
2	0	-4	$-0.735\ 234\ 770\ 382\ 342 \times 10^{-11}$	14	7	-12	$0.425\ 596\ 631\ 351\ 839 \times 10^{-25}$
3	0	-1	$0.289\ 078\ 692\ 149\ 150 \times 10^{-2}$	15	8	-10	$-0.387\ 449\ 113\ 787\ 755 \times 10^{-17}$
4	2	-1	$0.244\ 482\ 731\ 907\ 223$	16	8	-8	$0.139\ 814\ 747\ 930\ 240 \times 10^{-12}$
5	3	-10	$0.141\ 733\ 492\ 030\ 985 \times 10^{-23}$	17	8	-4	$-0.171\ 849\ 638\ 951\ 521 \times 10^{-2}$
6	4	-12	$-0.354\ 533\ 853\ 059\ 476 \times 10^{-28}$	18	10	-12	$0.641\ 890\ 529\ 513\ 296 \times 10^{-21}$
7	4	-8	$-0.594\ 539\ 202\ 901\ 431 \times 10^{-17}$	19	10	-8	$0.118\ 960\ 578\ 072\ 018 \times 10^{-10}$
8	4	-5	$-0.585\ 188\ 401\ 782\ 779 \times 10^{-8}$	20	14	-12	$-0.155\ 282\ 762\ 571\ 611 \times 10^{-17}$
9	4	-4	$0.201\ 377\ 325\ 411\ 803 \times 10^{-5}$	21	14	-8	$0.233\ 907\ 907\ 347\ 507 \times 10^{-7}$
10	4	-1	$0.138\ 647\ 388\ 209\ 306 \times 10^1$	22	20	-12	$-0.174\ 093\ 247\ 766\ 213 \times 10^{-12}$
11	5	-4	$-0.173\ 959\ 365\ 084\ 772 \times 10^{-4}$	23	20	-10	$0.377\ 682\ 649\ 089\ 149 \times 10^{-8}$
12	5	-3	$0.137\ 680\ 878\ 349\ 369 \times 10^{-2}$	24	24	-12	$-0.516\ 720\ 236\ 575\ 302 \times 10^{-10}$

Table 2.121 Coefficients and exponents of the backward equation $v_{3p}(p, T)$ for subregion 3p in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	-1	$-0.982\ 825\ 342\ 010\ 366 \times 10^{-4}$	15	12	-12	$0.343\ 480\ 022\ 104\ 968 \times 10^{-25}$
2	0	0	$0.105\ 145\ 700\ 850\ 612 \times 10^1$	16	12	-6	$0.816\ 256\ 095\ 947\ 021 \times 10^{-5}$
3	0	1	$0.116\ 033\ 094\ 095\ 084 \times 10^3$	17	12	-5	$0.294\ 985\ 697\ 916\ 798 \times 10^{-2}$
4	0	2	$0.324\ 664\ 750\ 281\ 543 \times 10^4$	18	14	-10	$0.711\ 730\ 466\ 276\ 584 \times 10^{-16}$
5	1	1	$-0.123\ 592\ 348\ 610\ 137 \times 10^4$	19	14	-8	$0.400\ 954\ 763\ 806\ 941 \times 10^{-9}$
6	2	-1	$-0.561\ 403\ 450\ 013\ 495 \times 10^{-1}$	20	14	-3	$0.107\ 766\ 027\ 032\ 853 \times 10^2$
7	3	-3	$0.856\ 677\ 401\ 640\ 869 \times 10^{-7}$	21	16	-8	$-0.409\ 449\ 599\ 138\ 182 \times 10^{-6}$
8	3	0	$0.236\ 313\ 425\ 393\ 924 \times 10^3$	22	18	-8	$-0.729\ 121\ 307\ 758\ 902 \times 10^{-5}$
9	4	-2	$0.972\ 503\ 292\ 350\ 109 \times 10^{-2}$	23	20	-10	$0.677\ 107\ 970\ 938\ 909 \times 10^{-8}$
10	6	-2	$-0.103\ 001\ 994\ 531\ 927 \times 10^1$	24	22	-10	$0.602\ 745\ 973\ 022\ 975 \times 10^{-7}$
11	7	-5	$-0.149\ 653\ 706\ 199\ 162 \times 10^{-8}$	25	24	-12	$-0.382\ 323\ 011\ 855\ 257 \times 10^{-10}$
12	7	-4	$-0.215\ 743\ 778\ 861\ 592 \times 10^{-4}$	26	24	-8	$0.179\ 946\ 628\ 317\ 437 \times 10^{-2}$
13	8	-2	$-0.834\ 452\ 198\ 291\ 445 \times 10^1$	27	36	-12	$-0.345\ 042\ 834\ 640\ 005 \times 10^{-3}$
14	10	-3	$0.586\ 602\ 660\ 564\ 988$				

Table 2.122 Coefficients and exponents of the backward equation $v_{3q}(p, T)$ for subregion 3q in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	10	$-0.820\ 433\ 843\ 259\ 950 \times 10^5$	13	-3	3	$0.232\ 808\ 472\ 983\ 776 \times 10^3$
2	-12	12	$0.473\ 271\ 518\ 461\ 586 \times 10^{11}$	14	-2	0	$-0.142\ 808\ 220\ 416\ 837 \times 10^{-4}$
3	-10	6	$-0.805\ 950\ 021\ 005\ 413 \times 10^{-1}$	15	-2	1	$-0.643\ 596\ 060\ 678\ 456 \times 10^{-2}$
4	-10	7	$0.328\ 600\ 025\ 435\ 980 \times 10^2$	16	-2	2	$-0.428\ 577\ 227\ 475\ 614 \times 10^1$
5	-10	8	$-0.356\ 617\ 029\ 982\ 490 \times 10^4$	17	-2	4	$0.225\ 689\ 939\ 161\ 918 \times 10^4$
6	-10	10	$-0.172\ 985\ 781\ 433\ 335 \times 10^{10}$	18	-1	0	$0.100\ 355\ 651\ 721\ 510 \times 10^{-2}$
7	-8	8	$0.351\ 769\ 232\ 729\ 192 \times 10^8$	19	-1	1	$0.333\ 491\ 455\ 143\ 516$
8	-6	6	$-0.775\ 489\ 259\ 985\ 144 \times 10^6$	20	-1	2	$0.109\ 697\ 576\ 888\ 873 \times 10^1$
9	-5	2	$0.710\ 346\ 691\ 966\ 018 \times 10^{-4}$	21	0	0	$0.961\ 917\ 379\ 376\ 452$
10	-5	5	$0.993\ 499\ 883\ 820\ 274 \times 10^5$	22	1	0	$-0.838\ 165\ 632\ 204\ 598 \times 10^{-1}$
11	-4	3	$-0.642\ 094\ 171\ 904\ 570$	23	1	1	$0.247\ 795\ 908\ 411\ 492 \times 10^1$
12	-4	4	$-0.612\ 842\ 816\ 820\ 083 \times 10^4$	24	1	3	$-0.319\ 114\ 969\ 006\ 533 \times 10^4$

Table 2.123 Coefficients and exponents of the backward equation $v_{3r}(p, T)$ for subregion 3r in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-8	6	$0.144\ 165\ 955\ 660\ 863 \times 10^{-2}$	15	8	-10	$0.399\ 988\ 795\ 693\ 162 \times 10^{-12}$
2	-8	14	$-0.701\ 438\ 599\ 628\ 258 \times 10^{13}$	16	8	-8	$-0.536\ 479\ 560\ 201\ 811 \times 10^{-6}$
3	-3	-3	$-0.830\ 946\ 716\ 459\ 219 \times 10^{-16}$	17	8	-5	$0.159\ 536\ 722\ 411\ 202 \times 10^{-1}$
4	-3	3	$0.261\ 975\ 135\ 368\ 109$	18	10	-12	$0.270\ 303\ 248\ 860\ 217 \times 10^{-14}$
5	-3	4	$0.393\ 097\ 214\ 706\ 245 \times 10^3$	19	10	-10	$0.244\ 247\ 453\ 858\ 506 \times 10^{-7}$
6	-3	5	$-0.104\ 334\ 030\ 654\ 021 \times 10^5$	20	10	-8	$-0.983\ 430\ 636\ 716\ 454 \times 10^{-5}$
7	-3	8	$0.490\ 112\ 654\ 154\ 211 \times 10^9$	21	10	-6	$0.663\ 513\ 144\ 224\ 454 \times 10^{-1}$
8	0	-1	$-0.147\ 104\ 222\ 772\ 069 \times 10^{-3}$	22	10	-5	$-0.993\ 456\ 957\ 845\ 006 \times 10^1$
9	0	0	$0.103\ 602\ 748\ 043\ 408 \times 10^1$	23	10	-4	$0.546\ 491\ 323\ 528\ 491 \times 10^3$
10	0	1	$0.305\ 308\ 890\ 065\ 089 \times 10^1$	24	10	-3	$-0.143\ 365\ 406\ 393\ 758 \times 10^5$
11	0	5	$-0.399\ 745\ 276\ 971\ 264 \times 10^7$	25	10	-2	$0.150\ 764\ 974\ 125\ 511 \times 10^6$
12	3	-6	$0.569\ 233\ 719\ 593\ 750 \times 10^{-11}$	26	12	-12	$-0.337\ 209\ 709\ 340\ 105 \times 10^{-9}$
13	3	-2	$-0.464\ 923\ 504\ 407\ 778 \times 10^{-1}$	27	14	-12	$0.377\ 501\ 980\ 025\ 469 \times 10^{-8}$
14	8	-12	$-0.535\ 400\ 396\ 512\ 906 \times 10^{-17}$				

Table 2.124 Coefficients and exponents of the backward equation $v_{3s}(p, T)$ for subregion 3s in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	20	$-0.532\ 466\ 612\ 140\ 254 \times 10^{23}$	16	0	0	0.965 961 650 599 775
2	-12	24	$0.100\ 415\ 480\ 000\ 824 \times 10^{32}$	17	0	1	$0.294\ 885\ 696\ 802\ 488 \times 10^1$
3	-10	22	$-0.191\ 540\ 001\ 821\ 367 \times 10^{30}$	18	0	4	$-0.653\ 915\ 627\ 346\ 115 \times 10^5$
4	-8	14	$0.105\ 618\ 377\ 808\ 847 \times 10^{17}$	19	0	28	$0.604\ 012\ 200\ 163\ 444 \times 10^{50}$
5	-6	36	$0.202\ 281\ 884\ 477\ 061 \times 10^{59}$	20	1	0	$-0.198\ 339\ 358\ 557\ 937$
6	-5	8	$0.884\ 585\ 472\ 596\ 134 \times 10^8$	21	1	32	$-0.175\ 984\ 090\ 163\ 501 \times 10^{58}$
7	-5	16	$0.166\ 540\ 181\ 638\ 363 \times 10^{23}$	22	3	0	$0.356\ 314\ 881\ 403\ 987 \times 10^1$
8	-4	6	$-0.313\ 563\ 197\ 669\ 111 \times 10^6$	23	3	1	$-0.575\ 991\ 255\ 144\ 384 \times 10^3$
9	-4	32	$-0.185\ 662\ 327\ 545\ 324 \times 10^{54}$	24	3	2	$0.456\ 213\ 415\ 338\ 071 \times 10^5$
10	-3	3	$-0.624\ 942\ 093\ 918\ 942 \times 10^{-1}$	25	4	3	$-0.109\ 174\ 044\ 987\ 829 \times 10^8$
11	-3	8	$-0.504\ 160\ 724\ 132\ 590 \times 10^{10}$	26	4	18	$0.437\ 796\ 099\ 975\ 134 \times 10^{34}$
12	-2	4	$0.187\ 514\ 491\ 833\ 092 \times 10^5$	27	4	24	$-0.616\ 552\ 611\ 135\ 792 \times 10^{46}$
13	-1	1	$0.121\ 399\ 979\ 993\ 217 \times 10^{-2}$	28	5	4	$0.193\ 568\ 768\ 917\ 797 \times 10^{10}$
14	-1	2	$0.188\ 317\ 043\ 049\ 455 \times 10^1$	29	14	24	$0.950\ 898\ 170\ 425\ 042 \times 10^{54}$
15	-1	3	$-0.167\ 073\ 503\ 962\ 060 \times 10^4$				

Table 2.125 Coefficients and exponents of the backward equation $v_{3t}(p, T)$ for subregion 3t in its dimensionless form

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	$0.155\ 287\ 249\ 586\ 268 \times 10^1$	18	7	36	$-0.341\ 552\ 040\ 860\ 644 \times 10^{51}$
2	0	1	$0.664\ 235\ 115\ 009\ 031 \times 10^1$	19	10	10	$-0.527\ 251\ 339\ 709\ 047 \times 10^{21}$
3	0	4	$-0.289\ 366\ 236\ 727\ 210 \times 10^4$	20	10	12	$0.245\ 375\ 640\ 937\ 055 \times 10^{24}$
4	0	12	$-0.385\ 923\ 202\ 309\ 848 \times 10^{13}$	21	10	14	$-0.168\ 776\ 617\ 209\ 269 \times 10^{27}$
5	1	0	$-0.291\ 002\ 915\ 783\ 761 \times 10^1$	22	10	16	$0.358\ 958\ 955\ 867\ 578 \times 10^{29}$
6	1	10	$-0.829\ 088\ 246\ 858\ 083 \times 10^{12}$	23	10	22	$-0.656\ 475\ 280\ 339\ 411 \times 10^{36}$
7	2	0	$0.176\ 814\ 899\ 675\ 218 \times 10^1$	24	18	18	$0.355\ 286\ 045\ 512\ 301 \times 10^{39}$
8	2	6	$-0.534\ 686\ 695\ 713\ 469 \times 10^9$	25	20	32	$0.569\ 021\ 454\ 413\ 270 \times 10^{58}$
9	2	14	$0.160\ 464\ 608\ 687\ 834 \times 10^{18}$	26	22	22	$-0.700\ 584\ 546\ 433\ 113 \times 10^{48}$
10	3	3	$0.196\ 435\ 366\ 560\ 186 \times 10^6$	27	22	36	$-0.705\ 772\ 623\ 326\ 374 \times 10^{65}$
11	3	8	$0.156\ 637\ 427\ 541\ 729 \times 10^{13}$	28	24	24	$0.166\ 861\ 176\ 200\ 148 \times 10^{53}$
12	4	0	$-0.178\ 154\ 560\ 260\ 006 \times 10^1$	29	28	28	$-0.300\ 475\ 129\ 680\ 486 \times 10^{61}$
13	4	10	$-0.229\ 746\ 237\ 623\ 692 \times 10^{16}$	30	32	22	$-0.668\ 481\ 295\ 196\ 808 \times 10^{51}$
14	7	3	$0.385\ 659\ 001\ 648\ 006 \times 10^8$	31	32	32	$0.428\ 432\ 338\ 620\ 678 \times 10^{69}$
15	7	4	$0.110\ 554\ 446\ 790\ 543 \times 10^{10}$	32	32	36	$-0.444\ 227\ 367\ 758\ 304 \times 10^{72}$
16	7	7	$-0.677\ 073\ 830\ 687\ 349 \times 10^{14}$	33	36	36	$-0.281\ 396\ 013\ 562\ 745 \times 10^{77}$
17	7	20	$-0.327\ 910\ 592\ 086\ 523 \times 10^{31}$				

2.3.6.5 Auxiliary Equations $v(p, T)$ for the Near-Critical Region

This section contains the entire numerical information about the auxiliary equations $v(p, T)$ for the near-critical region.

a) Range of Validity of the Auxiliary Equations, Division of the Near-Critical Region into Subregions, and Subregion-Boundary Equations

The auxiliary equations $v(p, T)$ for subregions 3u to 3z are valid in the temperature and pressure range given by

$$T_{3\text{qu}}(p) \leq T \leq T_{3\text{rx}}(p) \quad \text{and} \quad p_s(643.15 \text{ K}) \leq p \leq 22.5 \text{ MPa},$$

where $p_s(643.15 \text{ K}) = 21.043\ 367\ 32 \text{ MPa}$

as given in Fig. 2.26.

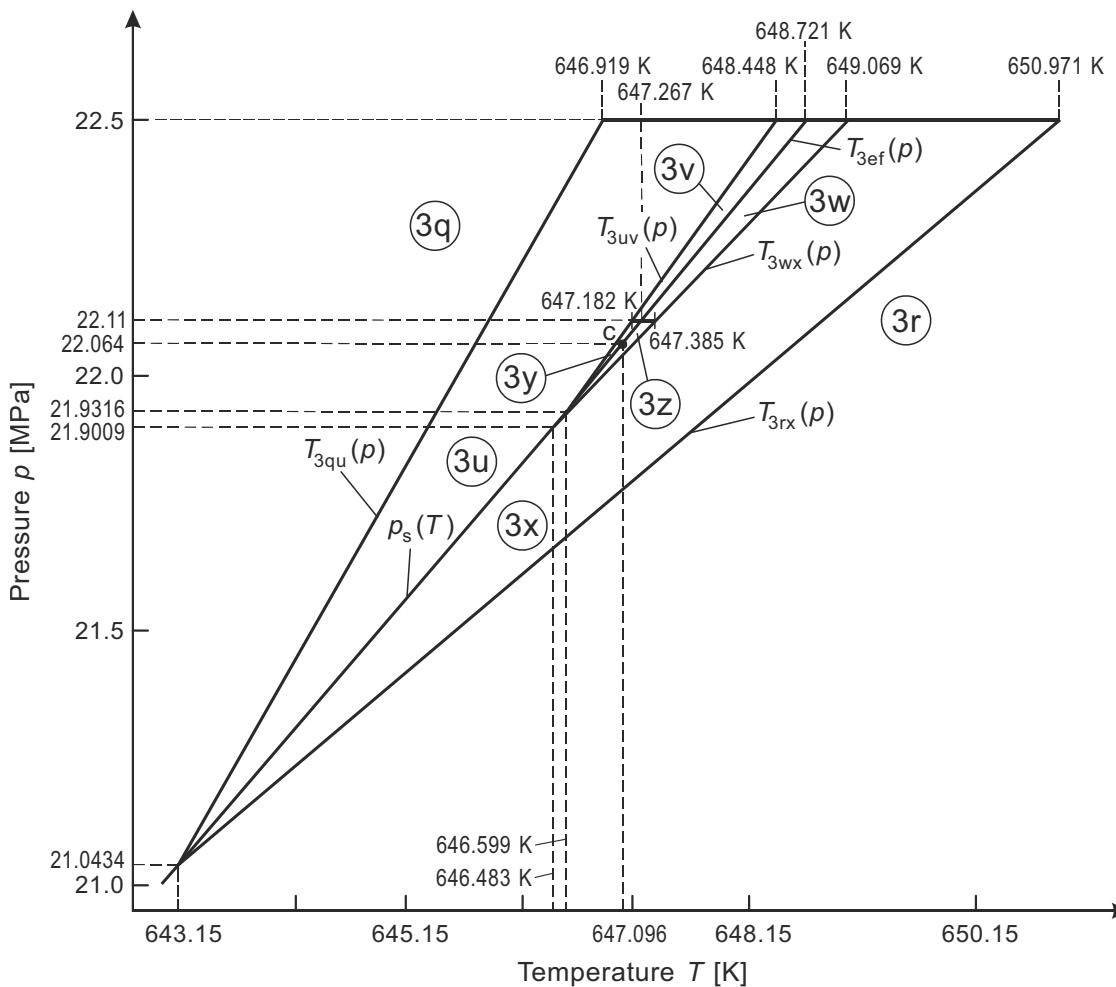


Fig. 2.26 Division of the near-critical region into subregions 3u to 3z for the auxiliary equations $v(p, T)$.

The subregion-boundary equation $T_{3uv}(p)$ has the form of Eq. (2.65) and the equation $T_{3wx}(p)$ has the form of Eq. (2.66). The coefficients n_i and the exponents I_i of these two subregion-boundary equations are listed in Table 2.126. The numerical information on the subregion-boundary equation $T_{3ef}(p)$ is given in Sec. 2.3.6.3.

Table 2.126 Coefficients and exponents of the subregion-boundary equations $T_{3uv}(p)$ and $T_{3wx}(p)$

Equation	i	I_i	n_i	i	I_i	n_i
$T_{3uv}(p)$	1	0	$0.528\ 199\ 646\ 263\ 062 \times 10^3$	3	2	$-0.222\ 814\ 134\ 903\ 755$
	2	1	$0.890\ 579\ 602\ 135\ 307 \times 10^1$	4	3	$0.286\ 791\ 682\ 263\ 697 \times 10^{-2}$
$T_{3wx}(p)$	1	0	$0.728\ 052\ 609\ 145\ 380 \times 10^1$	4	-1	$0.329\ 196\ 213\ 998\ 375 \times 10^3$
	2	1	$0.973\ 505\ 869\ 861\ 952 \times 10^2$	5	-2	$0.873\ 371\ 668\ 682\ 417 \times 10^3$
	3	2	$0.147\ 370\ 491\ 183\ 191 \times 10^2$			

The description of the use of the subregion-boundary equations is summarized in Table 2.127, where the subregion boundaries are shown in Fig. 2.26.

Table 2.127 Pressure ranges and corresponding subregion-boundary equations for determining the correct subregion, 3u to 3z, for the auxiliary equations $v(p, T)$

Subcritical pressure region ($p \leq p_c$)				
Temperature range	Pressure range	Sub-region	Temperature range	
$T \leq T_s(p)$ (liquid)	$p_s(0.00264 \text{ m}^3 \text{ kg}^{-1})^a < p \leq 22.064 \text{ MPa}$	3u	$T_{3\text{qu}}(p) < T \leq T_{3\text{uv}}(p)$	
	$p_s(643.15 \text{ K}) < p \leq p_s(0.00264 \text{ m}^3 \text{ kg}^{-1})^a$	3y	$T_{3\text{uv}}(p) < T$	
$T \geq T_s(p)$ (vapour)	$p_s(0.00385 \text{ m}^3 \text{ kg}^{-1})^b < p \leq 22.064 \text{ MPa}$	3z	$T \leq T_{3\text{wx}}(p)$	
	$p_s(643.15 \text{ K}) < p \leq p_s(0.00385 \text{ m}^3 \text{ kg}^{-1})^b$	3x	$T_{3\text{wx}}(p) < T \leq T_{3\text{rx}}(p)$	
Supercritical pressure region ($p > p_c$)				
Pressure range	Sub-region	Temperature range	Sub-region	
$22.064 \text{ MPa} < p \leq 22.11 \text{ MPa}$	3u	$T_{3\text{qu}}(p) < T \leq T_{3\text{uv}}(p)$	3y	$T_{3\text{uv}}(p) < T \leq T_{3\text{ef}}(p)$
	3z	$T_{3\text{ef}}(p) < T \leq T_{3\text{wx}}(p)$	3x	$T_{3\text{wx}}(p) < T \leq T_{3\text{rx}}(p)$
$22.11 \text{ MPa} < p \leq 22.5 \text{ MPa}$	3u	$T_{3\text{qu}}(p) < T \leq T_{3\text{uv}}(p)$	3v	$T_{3\text{uv}}(p) < T \leq T_{3\text{ef}}(p)$
	3w	$T_{3\text{ef}}(p) < T \leq T_{3\text{wx}}(p)$	3x	$T_{3\text{wx}}(p) < T \leq T_{3\text{rx}}(p)$

^a $p_s(0.00264 \text{ m}^3 \text{ kg}^{-1}) = 21.931 615 51 \text{ MPa}$.^b $p_s(0.00385 \text{ m}^3 \text{ kg}^{-1}) = 21.900 962 65 \text{ MPa}$.

The **equation $T_{3\text{uv}}(p)$** approximates the isochore $v = 0.00264 \text{ m}^3 \text{ kg}^{-1}$ from $p = p_s(0.00264 \text{ m}^3 \text{ kg}^{-1}) = 21.931 615 51 \text{ MPa}$ to $p = 22.5 \text{ MPa}$. This equation divides subregion 3u from subregions 3v and 3y.

The **equation $T_{3\text{wx}}(p)$** approximates the isochore $v = 0.00385 \text{ m}^3 \text{ kg}^{-1}$ from $p = p_s(0.00385 \text{ m}^3 \text{ kg}^{-1}) = 21.900 962 65 \text{ MPa}$ to $p = 22.5 \text{ MPa}$ and divides subregion 3x from subregions 3w and 3z.

The **equations $T_{3\text{qu}}(p)$, $T_{3\text{ef}}(p)$, and $T_{3\text{rx}}(p)$** are described in Sec. 2.3.6.3.

Computer-Program Verification. To assist the user in computer-program verification of the equations $T_{3\text{uv}}(p)$ and $T_{3\text{wx}}(p)$ for the subregion boundaries, Table 2.128 contains test values for calculated temperatures.

Table 2.128 Temperature values calculated from the subregion-boundary equations $T_{3\text{uv}}(p)$ and $T_{3\text{wx}}(p)$ for selected pressures^a

Equation	p [MPa]	T [K]
$T_{3\text{uv}}(p)$	22.3	$6.477 996 121 \times 10^2$
$T_{3\text{wx}}(p)$	22.3	$6.482 049 480 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

b) Auxiliary Equations $v(p, T)$ for Subregions 3u to 3z

The auxiliary equations $v(p, T)$ for subregions 3u to 3z have the dimensionless form of Eq. (2.68). The reducing quantities v^* , p^* , and T^* , the number of coefficients N , the non-linear parameters a and b , and the exponents c , d , and e are listed in Table 2.129. The coefficients n_i and exponents I_i and J_i are given in Tables 2.132 to 2.137 that are given in Sec. 2.3.6.5c.

Table 2.129 Reducing quantities v^* , p^* , and T^* , number of coefficients N , non-linear parameters a and b , and exponents c , d , and e of the auxiliary equations $v(p, T)$, Eqs. 2.68, of subregions 3u to 3z

Subregion	$v^*[\text{m}^3 \text{ kg}^{-1}]$	$p^*[\text{MPa}]$	$T^*[\text{K}]$	N	a	b	c	d	e
3u	0.0026	23	650	38	0.902	0.988	1	1	1
3v	0.0031	23	650	39	0.960	0.995	1	1	1
3w	0.0039	23	650	35	0.959	0.995	1	1	4
3x	0.0049	23	650	36	0.910	0.988	1	1	1
3y	0.0031	22	650	20	0.996	0.994	1	1	4
3z	0.0038	22	650	23	0.993	0.994	1	1	4

Computer-Program Verification. To assist the user in computer-program verification of the auxiliary equations $v(p, T)$, Eq. (2.68), for subregions 3u to 3z, Table 2.130 contains test values for calculated specific volumes.

Table 2.130 Values of the specific volume calculated from the auxiliary equations $v(p, T)$, Eq. (2.68), for subregions 3u to 3z for selected values of pressure and temperature^a

Equation	$p[\text{MPa}]$	$T[\text{K}]$	$v[\text{m}^3 \text{ kg}^{-1}]$	Equation	$p[\text{MPa}]$	$T[\text{K}]$	$v[\text{m}^3 \text{ kg}^{-1}]$
$v_{3u}(p, T)$	21.5	644.6	$2.268\ 366\ 647 \times 10^{-3}$	$v_{3x}(p, T)$	22.11	648.0	$4.528\ 072\ 649 \times 10^{-3}$
	22.0	646.1	$2.296\ 350\ 553 \times 10^{-3}$		22.3	649.0	$4.556\ 905\ 799 \times 10^{-3}$
$v_{3v}(p, T)$	22.5	648.6	$2.832\ 373\ 260 \times 10^{-3}$	$v_{3y}(p, T)$	22.0	646.84	$2.698\ 354\ 719 \times 10^{-3}$
	22.3	647.9	$2.811\ 424\ 405 \times 10^{-3}$		22.064	647.05	$2.717\ 655\ 648 \times 10^{-3}$
$v_{3w}(p, T)$	22.15	647.5	$3.694\ 032\ 281 \times 10^{-3}$	$v_{3z}(p, T)$	22.0	646.89	$3.798\ 732\ 962 \times 10^{-3}$
	22.3	648.1	$3.622\ 226\ 305 \times 10^{-3}$		22.064	647.15	$3.701\ 940\ 010 \times 10^{-3}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Numerical Consistencies. The numerical inconsistencies between the auxiliary equations $v(p, T)$, Eq. (2.68), for subregions 3u to 3z and the basic equation $f_3(\rho, T)$, Eq. (2.11), are listed in Table 2.131. This table shows that the maximum inconsistencies in specific volume between these equations are less than 0.1%. The maximum inconsistencies up to about 2% between the auxiliary equations and the basic equation $f_3(\rho, T)$ occur only in a small region at pressures between 21.9 MPa and 22.11 MPa, see Fig. 2.26.

Table 2.131 Maximum and root-mean-square inconsistencies in specific volume between the auxiliary equations $v(p, T)$ for subregions 3u to 3z and the basic equation $f_3(\rho, T)$, Eq. (2.11)

Subregion	$ \Delta v/v $ [%]		Subregion	$ \Delta v/v $ [%]	
	max	RMS		max	RMS
3u	0.097	0.058	3x	0.090	0.050
3v	0.082	0.040	3y	1.77	1.04
3w	0.065	0.023	3z	1.80	0.921

The maximum inconsistencies in specific volume between the auxiliary equations $v(p, T)$ of adjacent subregions along subregion boundaries are as follows: Along subregion boundaries that are isobars, the inconsistencies are less than 0.1% for all subregions except for the subregion boundaries between subregions 3v/3y and 3w/3z, where the inconsistencies amount to 1.7%. Along subregion boundaries defined by the subregion-boundary equations given in Sec. 2.3.6.5a, the inconsistencies are also less than 0.1% except for the boundaries between subregions 3u/3v and 3u/3y (equation $T_{3uv}(p)$), 3y/3z (equation $T_{3ef}(p)$), and 3z/3x (equation $T_{3wx}(p)$), where the inconsistencies amount to 0.14%, 1.8%, 3.5%, and 1.8%, respectively. Further details are given in Tables 15 and 16 of the IAPWS supplementary release [26].

Calculation of Properties with the Help of the Auxiliary Equations $v(p, T)$. The calculation of thermodynamic properties in the range very close to the critical point with the help of the auxiliary equations $v(p, T)$ for regions 3u to 3t can be performed analogously as described in Sec. 2.3.6.4b for the backward equations $v(p, T)$.

Application of the Auxiliary Equations $v(p, T)$. In comparison with the backward equations $v(p, T)$, the corresponding numerical consistency of the auxiliary equations $v(p, T)$ for the range very close to the critical point is clearly worse. Nevertheless, for many applications, this consistency is satisfactory.

c) Coefficients and Exponents of the Auxiliary Equations $v(p, T)$ for Subregions 3u to 3z

This section contains Tables 2.132 to 2.137 with the coefficients n_i and exponents I_i and J_i of the auxiliary equations $v(p, T)$ for subregions 3u to 3z given in Sec. 2.3.6.5b.

Table 2.132 Coefficients and exponents of the auxiliary equation $v_{3u}(p, T)$ for subregion 3u

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	14	$0.122\ 088\ 349\ 258\ 355 \times 10^{18}$	20	1	-2	$0.105\ 581\ 745\ 346\ 187 \times 10^{-2}$
2	-10	10	$0.104\ 216\ 468\ 608\ 488 \times 10^{10}$	21	2	5	$-0.651\ 903\ 203\ 602\ 581 \times 10^{15}$
3	-10	12	$-0.882\ 666\ 931\ 564\ 652 \times 10^{16}$	22	2	10	$-0.160\ 116\ 813\ 274\ 676 \times 10^{25}$
4	-10	14	$0.259\ 929\ 510\ 849\ 499 \times 10^{20}$	23	3	-5	$-0.510\ 254\ 294\ 237\ 837 \times 10^{-8}$
5	-8	10	$0.222\ 612\ 779\ 142\ 211 \times 10^{15}$	24	5	-4	$-0.152\ 355\ 388\ 953\ 402$
6	-8	12	$-0.878\ 473\ 585\ 050\ 085 \times 10^{18}$	25	5	2	$0.677\ 143\ 292\ 290\ 144 \times 10^{12}$
7	-8	14	$-0.314\ 432\ 577\ 551\ 552 \times 10^{22}$	26	5	3	$0.276\ 378\ 438\ 378\ 930 \times 10^{15}$
8	-6	8	$-0.216\ 934\ 916\ 996\ 285 \times 10^{13}$	27	6	-5	$0.116\ 862\ 983\ 141\ 686 \times 10^{-1}$
9	-6	12	$0.159\ 079\ 648\ 196\ 849 \times 10^{21}$	28	6	2	$-0.301\ 426\ 947\ 980\ 171 \times 10^{14}$
10	-5	4	$-0.339\ 567\ 617\ 303\ 423 \times 10^3$	29	8	-8	$0.169\ 719\ 813\ 884\ 840 \times 10^{-7}$
11	-5	8	$0.884\ 387\ 651\ 337\ 836 \times 10^{13}$	30	8	8	$0.104\ 674\ 840\ 020\ 929 \times 10^{27}$
12	-5	12	$-0.843\ 405\ 926\ 846\ 418 \times 10^{21}$	31	10	-4	$-0.108\ 016\ 904\ 560\ 140 \times 10^5$
13	-3	2	$0.114\ 178\ 193\ 518\ 022 \times 10^2$	32	12	-12	$-0.990\ 623\ 601\ 934\ 295 \times 10^{-12}$
14	-1	-1	$-0.122\ 708\ 229\ 235\ 641 \times 10^{-3}$	33	12	-4	$0.536\ 116\ 483\ 602\ 738 \times 10^7$

Continued on next page.

Table 2.132 – Continued

i	I_i	J_i	n_i	i	I_i	J_i	n_i
15	-1	1	$-0.106\ 201\ 671\ 767\ 107 \times 10^3$	34	12	4	$0.226\ 145\ 963\ 747\ 881 \times 10^{22}$
16	-1	12	$0.903\ 443\ 213\ 959\ 313 \times 10^{25}$	35	14	-12	$-0.488\ 731\ 565\ 776\ 210 \times 10^{-9}$
17	-1	14	$-0.693\ 996\ 270\ 370\ 852 \times 10^{28}$	36	14	-10	$0.151\ 001\ 548\ 880\ 670 \times 10^{-4}$
18	0	-3	$0.648\ 916\ 718\ 965\ 575 \times 10^{-8}$	37	14	-6	$-0.227\ 700\ 464\ 643\ 920 \times 10^5$
19	0	1	$0.718\ 957\ 567\ 127\ 851 \times 10^4$	38	14	6	$-0.781\ 754\ 507\ 698\ 846 \times 10^{28}$

Table 2.133 Coefficients and exponents of the auxiliary equation $v_{3v}(p, T)$ for subregion 3v

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-10	-8	$-0.415\ 652\ 812\ 061\ 591 \times 10^{-54}$	21	-3	12	$0.742\ 705\ 723\ 302\ 738 \times 10^{27}$
2	-8	-12	$0.177\ 441\ 742\ 924\ 043 \times 10^{-60}$	22	-2	2	$-0.517\ 429\ 682\ 450\ 605 \times 10^2$
3	-6	-12	$-0.357\ 078\ 668\ 203\ 377 \times 10^{-54}$	23	-2	4	$0.820\ 612\ 048\ 645\ 469 \times 10^7$
4	-6	-3	$0.359\ 252\ 213\ 604\ 114 \times 10^{-25}$	24	-1	-2	$-0.188\ 214\ 882\ 341\ 448 \times 10^{-8}$
5	-6	5	$-0.259\ 123\ 736\ 380\ 269 \times 10^2$	25	-1	0	$0.184\ 587\ 261\ 114\ 837 \times 10^{-1}$
6	-6	6	$0.594\ 619\ 766\ 193\ 460 \times 10^5$	26	0	-2	$-0.135\ 830\ 407\ 782\ 663 \times 10^{-5}$
7	-6	8	$-0.624\ 184\ 007\ 103\ 158 \times 10^{11}$	27	0	6	$-0.723\ 681\ 885\ 626\ 348 \times 10^{17}$
8	-6	10	$0.313\ 080\ 299\ 915\ 944 \times 10^{17}$	28	0	10	$-0.223\ 449\ 194\ 054\ 124 \times 10^{27}$
9	-5	1	$0.105\ 006\ 446\ 192\ 036 \times 10^{-8}$	29	1	-12	$-0.111\ 526\ 741\ 826\ 431 \times 10^{-34}$
10	-5	2	$-0.192\ 824\ 336\ 984\ 852 \times 10^{-5}$	30	1	-10	$0.276\ 032\ 601\ 145\ 151 \times 10^{-28}$
11	-5	6	$0.654\ 144\ 373\ 749\ 937 \times 10^6$	31	3	3	$0.134\ 856\ 491\ 567\ 853 \times 10^{15}$
12	-5	8	$0.513\ 117\ 462\ 865\ 044 \times 10^{13}$	32	4	-6	$0.652\ 440\ 293\ 345\ 860 \times 10^{-9}$
13	-5	10	$-0.697\ 595\ 750\ 347\ 391 \times 10^{19}$	33	4	3	$0.510\ 655\ 119\ 774\ 360 \times 10^{17}$
14	-5	14	$-0.103\ 977\ 184\ 454\ 767 \times 10^{29}$	34	4	10	$-0.468\ 138\ 358\ 908\ 732 \times 10^{32}$
15	-4	-12	$0.119\ 563\ 135\ 540\ 666 \times 10^{-47}$	35	5	2	$-0.760\ 667\ 491\ 183\ 279 \times 10^{16}$
16	-4	-10	$-0.436\ 677\ 034\ 051\ 655 \times 10^{-41}$	36	8	-12	$-0.417\ 247\ 986\ 986\ 821 \times 10^{-18}$
17	-4	-6	$0.926\ 990\ 036\ 530\ 639 \times 10^{-29}$	37	10	-2	$0.312\ 545\ 677\ 756\ 104 \times 10^{14}$
18	-4	10	$0.587\ 793\ 105\ 620\ 748 \times 10^{21}$	38	12	-3	$-0.100\ 375\ 333\ 864\ 186 \times 10^{15}$
19	-3	-3	$0.280\ 375\ 725\ 094\ 731 \times 10^{-17}$	39	14	1	$0.247\ 761\ 392\ 329\ 058 \times 10^{27}$
20	-3	10	$-0.192\ 359\ 972\ 440\ 634 \times 10^{23}$				

Table 2.134 Coefficients and exponents of the auxiliary equation $v_{3w}(p, T)$ for subregion 3w

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-12	8	$-0.586\ 219\ 133\ 817\ 016 \times 10^{-7}$	19	-1	-8	$0.237\ 416\ 732\ 616\ 644 \times 10^{-26}$
2	-12	14	$-0.894\ 460\ 355\ 005\ 526 \times 10^{11}$	20	-1	-4	$0.271\ 700\ 235\ 739\ 893 \times 10^{-14}$
3	-10	-1	$0.531\ 168\ 037\ 519\ 774 \times 10^{-30}$	21	-1	1	$-0.907\ 886\ 213\ 483\ 600 \times 10^2$
4	-10	8	$0.109\ 892\ 402\ 329\ 239$	22	0	-12	$-0.171\ 242\ 509\ 570\ 207 \times 10^{-36}$
5	-8	6	$-0.575\ 368\ 389\ 425\ 212 \times 10^{-1}$	23	0	1	$0.156\ 792\ 067\ 854\ 621 \times 10^3$
6	-8	8	$0.228\ 276\ 853\ 990\ 249 \times 10^5$	24	1	-1	$0.923\ 261\ 357\ 901\ 470$
7	-8	14	$-0.158\ 548\ 609\ 655\ 002 \times 10^{19}$	25	2	-1	$-0.597\ 865\ 988\ 422\ 577 \times 10^1$
8	-6	-4	$0.329\ 865\ 748\ 576\ 503 \times 10^{-27}$	26	2	2	$0.321\ 988\ 767\ 636\ 389 \times 10^7$
9	-6	-3	$-0.634\ 987\ 981\ 190\ 669 \times 10^{-24}$	27	3	-12	$-0.399\ 441\ 390\ 042\ 203 \times 10^{-29}$
10	-6	2	$0.615\ 762\ 068\ 640\ 611 \times 10^{-8}$	28	3	-5	$0.493\ 429\ 086\ 046\ 981 \times 10^{-7}$
11	-6	8	$-0.961\ 109\ 240\ 985\ 747 \times 10^8$	29	5	-10	$0.812\ 036\ 983\ 370\ 565 \times 10^{-19}$
12	-5	-10	$-0.406\ 274\ 286\ 652\ 625 \times 10^{-44}$	30	5	-8	$-0.207\ 610\ 284\ 654\ 137 \times 10^{-11}$
13	-4	-1	$-0.471\ 103\ 725\ 498\ 077 \times 10^{-12}$	31	5	-6	$-0.340\ 821\ 291\ 419\ 719 \times 10^{-6}$
14	-4	3	$0.725\ 937\ 724\ 828\ 145$	32	8	-12	$0.542\ 000\ 573\ 372\ 233 \times 10^{-17}$
15	-3	-10	$0.187\ 768\ 525\ 763\ 682 \times 10^{-38}$	33	8	-10	$-0.856\ 711\ 586\ 510\ 214 \times 10^{-12}$
16	-3	3	$-0.103\ 308\ 436\ 323\ 771 \times 10^4$	34	10	-12	$0.266\ 170\ 454\ 405\ 981 \times 10^{-13}$
17	-2	1	$-0.662\ 552\ 816\ 342\ 168 \times 10^{-1}$	35	10	-8	$0.858\ 133\ 791\ 857\ 099 \times 10^{-5}$
18	-2	2	$0.579\ 514\ 041\ 765\ 710 \times 10^3$				

Table 2.135 Coefficients and exponents of the auxiliary equation $v_{3x}(p, T)$ for subregion 3x

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-8	14	$0.377\ 373\ 741\ 298\ 151 \times 10^{19}$	19	4	3	$0.397\ 949\ 001\ 553\ 184 \times 10^{14}$
2	-6	10	$-0.507\ 100\ 883\ 722\ 913 \times 10^{13}$	20	5	-6	$0.100\ 824\ 008\ 584\ 757 \times 10^{-6}$
3	-5	10	$-0.103\ 363\ 225\ 598\ 860 \times 10^{16}$	21	5	-2	$0.162\ 234\ 569\ 738\ 433 \times 10^5$
4	-4	1	$0.184\ 790\ 814\ 320\ 773 \times 10^{-5}$	22	5	1	$-0.432\ 355\ 225\ 319\ 745 \times 10^{11}$
5	-4	2	$-0.924\ 729\ 378\ 390\ 945 \times 10^{-3}$	23	6	1	$-0.592\ 874\ 245\ 598\ 610 \times 10^{12}$
6	-4	14	$-0.425\ 999\ 562\ 292\ 738 \times 10^{24}$	24	8	-6	$0.133\ 061\ 647\ 281\ 106 \times 10^1$
7	-3	-2	$-0.462\ 307\ 771\ 873\ 973 \times 10^{-12}$	25	8	-3	$0.157\ 338\ 197\ 797\ 544 \times 10^7$
8	-3	12	$0.107\ 319\ 065\ 855\ 767 \times 10^{22}$	26	8	1	$0.258\ 189\ 614\ 270\ 853 \times 10^{14}$
9	-1	5	$0.648\ 662\ 492\ 280\ 682 \times 10^{11}$	27	8	8	$0.262\ 413\ 209\ 706\ 358 \times 10^{25}$
10	0	0	$0.244\ 200\ 600\ 688\ 281 \times 10^1$	28	10	-8	$-0.920\ 011\ 937\ 431\ 142 \times 10^{-1}$
11	0	4	$-0.851\ 535\ 733\ 484\ 258 \times 10^{10}$	29	12	-10	$0.220\ 213\ 765\ 905\ 426 \times 10^{-2}$
12	0	10	$0.169\ 894\ 481\ 433\ 592 \times 10^{22}$	30	12	-8	$-0.110\ 433\ 759\ 109\ 547 \times 10^2$
13	1	-10	$0.215\ 780\ 222\ 509\ 020 \times 10^{-26}$	31	12	-5	$0.847\ 004\ 870\ 612\ 087 \times 10^7$
14	1	-1	$-0.320\ 850\ 551\ 367\ 334$	32	12	-4	$-0.592\ 910\ 695\ 762\ 536 \times 10^9$
15	2	6	$-0.382\ 642\ 448\ 458\ 610 \times 10^{17}$	33	14	-12	$-0.183\ 027\ 173\ 269\ 660 \times 10^{-4}$
16	3	-12	$-0.275\ 386\ 077\ 674\ 421 \times 10^{-28}$	34	14	-10	$0.181\ 339\ 603\ 516\ 302$
17	3	0	$-0.563\ 199\ 253\ 391\ 666 \times 10^6$	35	14	-8	$-0.119\ 228\ 759\ 669\ 889 \times 10^4$
18	3	8	$-0.326\ 068\ 646\ 279\ 314 \times 10^{21}$	36	14	-6	$0.430\ 867\ 658\ 061\ 468 \times 10^7$

Table 2.136 Coefficients and exponents of the auxiliary equation $v_{3y}(p, T)$ for subregion 3y

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	-3	$-0.525\ 597\ 995\ 024\ 633 \times 10^{-9}$	11	3	4	$0.705\ 106\ 224\ 399\ 834 \times 10^{21}$
2	0	1	$0.583\ 441\ 305\ 228\ 407 \times 10^4$	12	3	8	$-0.266\ 713\ 136\ 106\ 469 \times 10^{31}$
3	0	5	$-0.134\ 778\ 968\ 457\ 925 \times 10^{17}$	13	4	-6	$-0.145\ 370\ 512\ 554\ 562 \times 10^{-7}$
4	0	8	$0.118\ 973\ 500\ 934\ 212 \times 10^{26}$	14	4	6	$0.149\ 333\ 917\ 053\ 130 \times 10^{28}$
5	1	8	$-0.159\ 096\ 490\ 904\ 708 \times 10^{27}$	15	5	-2	$-0.149\ 795\ 620\ 287\ 641 \times 10^8$
6	2	-4	$-0.315\ 839\ 902\ 302\ 021 \times 10^{-6}$	16	5	1	$-0.381\ 881\ 906\ 271\ 100 \times 10^{16}$
7	2	-1	$0.496\ 212\ 197\ 158\ 239 \times 10^3$	17	8	-8	$0.724\ 660\ 165\ 585\ 797 \times 10^{-4}$
8	2	4	$0.327\ 777\ 227\ 273\ 171 \times 10^{19}$	18	8	-2	$-0.937\ 808\ 169\ 550\ 193 \times 10^{14}$
9	2	5	$-0.527\ 114\ 657\ 850\ 696 \times 10^{22}$	19	10	-5	$0.514\ 411\ 468\ 376\ 383 \times 10^{10}$
10	3	-8	$0.210\ 017\ 506\ 281\ 863 \times 10^{-16}$	20	12	-8	$-0.828\ 198\ 594\ 040\ 141 \times 10^5$

Table 2.137 Coefficients and exponents of the auxiliary equation $v_{3z}(p, T)$ for subregion 3z

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	-8	3	$0.244\ 007\ 892\ 290\ 650 \times 10^{-10}$	13	0	3	$0.328\ 380\ 587\ 890\ 663 \times 10^{12}$
2	-6	6	$-0.463\ 057\ 430\ 331\ 242 \times 10^7$	14	1	1	$-0.625\ 004\ 791\ 171\ 543 \times 10^8$
3	-5	6	$0.728\ 803\ 274\ 777\ 712 \times 10^{10}$	15	2	6	$0.803\ 197\ 957\ 462\ 023 \times 10^{21}$
4	-5	8	$0.327\ 776\ 302\ 858\ 856 \times 10^{16}$	16	3	-6	$-0.204\ 397\ 011\ 338\ 353 \times 10^{-10}$
5	-4	5	$-0.110\ 598\ 170\ 118\ 409 \times 10^{10}$	17	3	-2	$-0.378\ 391\ 047\ 055\ 938 \times 10^4$
6	-4	6	$-0.323\ 899\ 915\ 729\ 957 \times 10^{13}$	18	6	-6	$0.972\ 876\ 545\ 938\ 620 \times 10^{-2}$
7	-4	8	$0.923\ 814\ 007\ 023\ 245 \times 10^{16}$	19	6	-5	$0.154\ 355\ 721\ 681\ 459 \times 10^2$
8	-3	-2	$0.842\ 250\ 080\ 413\ 712 \times 10^{-12}$	20	6	-4	$-0.373\ 962\ 862\ 928\ 643 \times 10^4$
9	-3	5	$0.663\ 221\ 436\ 245\ 506 \times 10^{12}$	21	6	-1	$-0.682\ 859\ 011\ 374\ 572 \times 10^{11}$
10	-3	6	$-0.167\ 170\ 186\ 672\ 139 \times 10^{15}$	22	8	-8	$-0.248\ 488\ 015\ 614\ 543 \times 10^{-3}$
11	-2	2	$0.253\ 749\ 358\ 701\ 391 \times 10^4$	23	8	-4	$0.394\ 536\ 049\ 497\ 068 \times 10^7$
12	-1	-6	$-0.819\ 731\ 559\ 610\ 523 \times 10^{-20}$				

2.3.7 Summarizing Statements on the Calculation Speed when Using Backward and Region-Boundary Equations

The decisive argument for the development of backward equations and region-boundary equations was the reduction of computing time needed to calculate thermodynamic properties in process modelling. When using only the basic equations described in Sec. 2.2, time-consuming iterations such as one- or two-dimensional Newton methods are required for calculating properties as a function of the input variables that are not the independent variables of the basic equations. This section summarizes statements on the computing speed when using backward equations and region-boundary equations in comparison with iterative calculations using only the basic equations.

The test calculations were carried out for IAPWS by Miyagawa [22] with a Pentium 4/3.0 GHz PC using the Microsoft Windows XP operating system. The algorithms were programmed in Fortran 77 and compiled using Microsoft PowerStation 4.0 with default options.

The computing time was measured by means of a test program similar to the benchmark program NIFBENCH [15] developed by IAPWS for the determination of the calculation speed of IAPWS-IF97 in comparison with the previous industrial formulation IFC-67 [1]. The basic equations, backward equations, and region-boundary equations were programmed using series of additions and multiplications as given in the Horner algorithm in order to perform the computation as quickly as possible.

The Newton method was used for performing the iterations. The derivatives of the basic equations needed for the Newton method were formed analytically. As starting points for these iterations, single fixed values were used. These values are located in the centres of the respective region, subregion, or region boundary. Starting values defined in this way are called single fixed values in the following.

2.3.7.1 Computing-Time Ratios for Calculations with Basic Equations via Iterations in Comparison with the Use of Backward and Region-Boundary Equations

In order to express how many times the calculations with the backward equations are faster than the iterative calculations with the basic equations, the quantity Computing-Time Ratio (*CTR*) was defined by the following relation:

$$CTR = \frac{\text{Computing time of the iterative calculation with the basic equations}}{\text{Computing time of the calculation with the backward or region-boundary equations}} \quad (2.70)$$

These *CTR* values were determined as ratios when the missing value(s) for the independent variable(s) of the IAPWS-IF97 basic equations are calculated one time from the respective basic equation via iteration and the other time directly from the corresponding backward equation(s) and (if necessary) backward function(s). Single fixed values, see above, were selected as starting values for the iterations, and the permissible values for the numerical consistency given in Sec. 2.3.2 were used as iteration accuracies in the iterations with the basic equations.

Table 2.135 summarizes the *CTR* values obtained for the given input variables (p, h) , (p, s) , (h, s) , and (p, T) . The calculations with the backward equations are between 10 and 46 times faster than the iterative calculations with the basic equations alone.

Table 2.135 Computing-time ratios (*CTR*) obtained from calculating the missing independent variable(s) of the IAPWS-JF97 basic equations for the given input variables (p,h) , (p,s) , (h,s) , and (p,T) , one time from iteration with the basic equations and the other time directly from the backward equations and backward functions; the definition of the *CTR* value is given in Eq. (2.70)

Input variables	Region	Used backward equations and backward functions	<i>CTR</i>
(p,h)	1	$T_1(p,h)$	25
	2	$T_2(p,h)$	11
	3	$T_3(p,h)$ and $v_3(p,h)$	14
(p,s)	1	$T_1(p,s)$	38
	2	$T_2(p,s)$	14
	3	$T_3(p,s)$ and $v_3(p,s)$	14
(h,s)	1	$p_1(h,s)$ and $T_1(h,s)^a$	35
	2	$p_2(h,s)$ and $T_2(h,s)^a$	46
	3	$p_3(h,s)$ and $T_3(h,s)^a$ and $v_3(h,s)^a$	10
	4	$T_S(h,s)$ and $p_S(h,s)^a$ and $x(h,s)^a$	14 ^b
(p,T)	3	$v_3(p,T)$	17

^aBackward function.

^bThis *CTR* value differs from that given in [22], because it also includes the computing time for the calculation of $x(h,s)$.

When using only the basic equations in connection with the input variables (p,h) , (p,s) , or (h,s) , the region boundaries can only be calculated by iterating the corresponding basic equation. These boundaries are listed in Table 2.136. In order to avoid such time-consuming iterations, there are corresponding region-boundary equations that are also listed in Table 2.136 and numerically described in Secs. 2.3.3.1d, 2.3.4.1d, and 2.3.5.2. Table 2.136 summarizes the *CTR* values for the calculations with the basic equations (via iteration) and directly with the region-boundary equations. The calculations using the respective region-boundary equation are between 7 and 128 times faster than the iterations.

In conclusion, the comparisons show that calculations with backward equations, backward functions, and region-boundary equations are between 12 and 50 times faster than calculations with the basic equations via iterations. These factors result from the *CTR* values for the backward equations and backward functions of Table 2.135 and contain the fast determination of the respective region with the region-boundary equations shown in Table 2.136.

Table 2.136 Computing-time ratios when calculating the region boundaries one time from the basic equations via iteration and the other time directly from the region-boundary equations; the definition of the *CTR* value is given in Eq. (2.70)

Input variables	Boundary	Boundary between regions	Region-boundary equation	<i>CTR</i>
(<i>p</i> , <i>h</i>)	$x = 0$ $x = 1$	3 and 4	$p_{s,3}(h)$	31
(<i>p</i> , <i>s</i>)	$x = 0$ $x = 1$	3 and 4	$p_{s,3}(s)$	50
<i>(h, s)</i>	$x = 0$	1 and 4	$h'_1(s)$	39
		3 and 4	$h'_{3a}(s)$	128 ^a
	$x = 1$	2 and 4	$h''_{2ab}(s), h''_{2c3b}(s)$	22
		3 and 4	$h''_{2c3b}(s)$	118 ^a
623.15 K		1 and 3	$h_{B13}(s)$	19
$p_{B23}(T)$	2 and 3		$T_{B23}(h, s)$ and $p_{2c}(h, s)$	7

^aThese *CTR* values differ from that given in [22], because the iterative calculation of $h'(s)$ and $h''(s)$ for region 3 was performed in a different manner.

Taking into account the frequency of use for the various combination of variables in process modelling, the calculations of heat-cycles, boilers, and particularly of steam turbines can be expected to be 2 to 3 times faster when using the backward equations and region-boundary equations.

2.3.7.2 Computing-Time Ratios for Iterations with Basic Equations Using Single Fixed Values or Values from Backward Equations as Starting Points

For applications where the demands on numerical consistency are extremely high, iterations with the basic equations might be necessary. These iterations can be carried out with two different starting values, namely single fixed values (as described at the beginning of Sec. 2.3.7) and values calculated from the backward equations. In order to compare the computing times of the two ways of calculating the starting values for the iterations, computing-time ratios are determined by the following relation:

$$CTR = \frac{\text{Computing time for the iteration with the single fixed values as starting values}}{\text{Computing time for the iteration with starting values from the backward equations}} \quad (2.71)$$

Table 2.137 shows how much faster the iterations with the basic equations are when values from backward equations are used to provide starting values for the iterations instead of using single fixed values. In this comparison, the relative iteration accuracy was set to 10^{-6} as it is usually used for such iterations. The achieved *CTR* factors between 1.5 and 4.4 show that the time to reach convergence of the iteration is clearly reduced when backward equations are used for the calculation of starting values. On average, the iterative calculations will be two times faster when using values from backward equations as starting points in comparison when using single fixed values in the centre of the respective region or of the subregion boundary.

Table 2.137 Computing-time ratios for calculations with the basic equations using single fixed values as starting values for the iterations in comparison with starting values from backward equations; the definition of the *CTR* values is given in Eq. (2.71)

Input variables	Region	Used backward equations and backward functions	<i>CTR</i> ^b
(p, h)	1	$T_1(p, h)$	2.0
	2	$T_2(p, h)$	2.0
	3	$T_3(p, h)$ and $v_3(p, h)$	1.8
(p, s)	1	$T_1(p, s)$	2.1
	2	$T_2(p, s)$	2.0
	3	$T_3(p, s)$ and $v_3(p, s)$	1.7
(h, s)	1	$p_1(h, s)$ and $T_1(h, s)$ ^a	2.1
	2	$p_2(h, s)$ and $T_2(h, s)$ ^a	4.4
	3	$p_3(h, s)$ and $T_3(h, s)$ ^a and $v_3(h, s)$ ^a	1.5
	4	$T_s(h, s)$ and $p_s(h, s)$ ^a and $x(h, s)$ ^a	1.9
(p, T)	3	$v_3(p, T)$	3.1

^aBackward function.

^bThese *CTR* values were determined by K. Miyagawa for IAPWS (personal communication, 2006).

2.4 Partial Derivatives of Thermodynamic Properties Using IAPWS-IF97

Partial derivatives of thermodynamic properties of water and steam are required for solving equation systems in heat cycle, boiler, and turbine calculations and particularly for modelling non-stationary processes. When using the basic equations of IAPWS-IF97, all of the first and second partial derivatives of various properties can be calculated with high accuracy. The formulas for the determination of the general partial derivatives

$$\left(\frac{\partial z}{\partial x}\right)_y (p, T) \text{ based on the basic equations for regions 1, 2, and 5, and}$$

$$\left(\frac{\partial z}{\partial x}\right)_y (v, T) \text{ based on the basic equation for region 3}$$

are given in Sec. 2.4.1 and Sec. 2.4.2, respectively. The variables x , y , and z can represent any thermodynamic property. In this section, formulas are given for the properties pressure p , temperature T , and the specific properties volume v , internal energy u , enthalpy h , entropy s , Gibbs free energy g , and Helmholtz free energy f .

The algorithms are also given in the IAPWS Advisory Note No. 3 “Calculation of Thermodynamic Derivatives for Water and Steam from the IAPWS Formulations” [27].

The application of the method will be described in Sec. 2.4.3 by means of two examples, one for regions 1, 2, and 5 and the other one for region 3. The calculation of any derivative by using the tables in Part B will be described in Sec. 2.4.4.

2.4.1 Partial Derivatives Based on the Basic Equations for Regions 1, 2, and 5

The general expression for the determination of any partial derivative $(\partial z / \partial x)_y$ from an equation of state as a function of pressure p and temperature T has the form

$$\left(\frac{\partial z}{\partial x} \right)_y = \frac{\left(\frac{\partial z}{\partial p} \right)_T \left(\frac{\partial y}{\partial T} \right)_p - \left(\frac{\partial z}{\partial T} \right)_p \left(\frac{\partial y}{\partial p} \right)_T}{\left(\frac{\partial x}{\partial p} \right)_T \left(\frac{\partial y}{\partial T} \right)_p - \left(\frac{\partial x}{\partial T} \right)_p \left(\frac{\partial y}{\partial p} \right)_T}. \quad (2.72)$$

The variables x , y , and z can represent any thermodynamic property. Table 2.138 summarizes the formulas for calculating the partial derivatives of the properties p , T , v , u , h , s , g , and f with respect to p and T that are needed in Eq. (2.72). For example, for the variable $z = v$, the expression $(\partial z / \partial p)_T$ means $(\partial v / \partial p)_T$ which is equal to $-v\kappa_T$ according to Table 2.138. In addition to the values of the parameters p and T , values of the five quantities specific volume v , specific entropy s , specific isobaric heat capacity c_p , isobaric cubic expansion coefficient α_v , and isothermal compressibility κ_T are required. These quantities contain the first and second derivatives of the Gibbs free energy g with respect to p at constant T and vice versa. Depending on the region in which the given values of p and T are located, these five quantities can be calculated from the IAPWS-IF97 basic equations for regions 1, 2, 2 (metastable), or 5, namely $g_1(p, T)$, $g_2(p, T)$, $g_{2,\text{meta}}(p, T)$, or $g_5(p, T)$ corresponding to Eqs. (2.3), (2.6), (2.9), or (2.15).

Table 2.138 Derivatives of x , y , and z with respect to p at constant T and vice versa, where x , y , and z can be any of the quantities p , T , v , u , h , s , g , or f

x, y, z	$\left(\frac{\partial x}{\partial T} \right)_p, \left(\frac{\partial y}{\partial T} \right)_p, \left(\frac{\partial z}{\partial T} \right)_p$	$\left(\frac{\partial x}{\partial p} \right)_T, \left(\frac{\partial y}{\partial p} \right)_T, \left(\frac{\partial z}{\partial p} \right)_T$
p	0	1
T	1	0
v	$v\alpha_v$	$-v\kappa_T$
u	$c_p - p v \alpha_v$	$v(p\kappa_T - T\alpha_v)$
h	c_p	$v(1 - T\alpha_v)$
s	c_p/T	$-v\alpha_v$
g	$-s$	v
f	$-p v \alpha_v - s$	$p v \kappa_T$

2.4.2 Partial Derivatives Based on the Basic Equation for Region 3

The general expression for the determination of any partial derivative $(\partial z / \partial x)_y$ from an equation of state as a function of the specific volume v and temperature T reads:

$$\left(\frac{\partial z}{\partial x} \right)_y = \frac{\left(\frac{\partial z}{\partial v} \right)_T \left(\frac{\partial y}{\partial T} \right)_v - \left(\frac{\partial z}{\partial T} \right)_v \left(\frac{\partial y}{\partial v} \right)_T}{\left(\frac{\partial x}{\partial v} \right)_T \left(\frac{\partial y}{\partial T} \right)_v - \left(\frac{\partial x}{\partial T} \right)_v \left(\frac{\partial y}{\partial v} \right)_T} \quad (2.73)$$

The variables x , y , and z can represent any thermodynamic property. Table 2.139 contains formulas to calculate the partial derivatives of the properties p , T , v , u , h , s , g , and f with respect to v and T that are needed in Eq. (2.73). In addition to the values of the variables v and T , the values of the five quantities pressure p , specific entropy s , specific isochoric heat capacity c_v , relative pressure coefficient α_p , and isothermal stress coefficient β_p are required. These quantities contain the first and second derivatives of the Helmholtz free energy f with respect to v at constant T and vice versa. For the values given for v and T , the five quantities p , s , c_v , α_p , and β_p are calculated from the IAPWS-IF97 basic equation for region 3, $f_3(\rho, T)$, Eq. (2.11), with $\rho = 1/v$.

Table 2.139 Derivatives of x , y , and z with respect to v at constant T and vice versa, where x , y , and z can be any of the quantities p , T , v , u , h , s , g , or f

x, y, z	$\left(\frac{\partial x}{\partial v} \right)_T, \left(\frac{\partial y}{\partial v} \right)_T, \left(\frac{\partial z}{\partial v} \right)_T$	$\left(\frac{\partial x}{\partial T} \right)_v, \left(\frac{\partial y}{\partial T} \right)_v, \left(\frac{\partial z}{\partial T} \right)_v$
p	$-p\beta_p$	$p\alpha_p$
T	0	1
v	1	0
u	$p(T\alpha_p - 1)$	c_v
h	$p(T\alpha_p - v\beta_p)$	$c_v + p v \alpha_p$
s	$p\alpha_p$	c_v / T
g	$-p v \beta_p$	$p v \alpha_p - s$
f	$-p$	$-s$

2.4.3 Examples for Deriving Any Partial Derivative from the Basic Equations

As examples, the partial derivative $(\partial u / \partial p)_v$ is to be derived from a basic equation $g(p, T)$ for regions 1, 2, 2 (metastable), and 5 and from the basic equation $f_3(\rho, T)$ of region 3.

2.4.3.1 Example for Deriving the Partial Derivative $(\partial u / \partial p)_v$ for Regions 1, 2, and 5

Since the basic equations for regions 1, 2, 2 (metastable), and 5 are fundamental equations of the Gibbs free energy $g(p, T)$, Eq. (2.72) and Table 2.138 have to be used for forming the corresponding partial derivative. The comparison of the required partial derivative $(\partial u / \partial p)_v$ with the general expression for the partial derivative according to Eq. (2.72) results in $z = u$, $x = p$, and $y = v$. With these assignments, Eq. (2.72) reads formally:

$$\left(\frac{\partial u}{\partial p}\right)_v = \frac{\left(\frac{\partial u}{\partial p}\right)_T \left(\frac{\partial v}{\partial T}\right)_p - \left(\frac{\partial u}{\partial T}\right)_p \left(\frac{\partial v}{\partial p}\right)_T}{\left(\frac{\partial p}{\partial p}\right)_T \left(\frac{\partial v}{\partial T}\right)_p - \left(\frac{\partial p}{\partial T}\right)_p \left(\frac{\partial v}{\partial p}\right)_T} \quad (2.74)$$

According to Table 2.138, the partial derivatives are:

$$\begin{aligned} \left(\frac{\partial u}{\partial p}\right)_T &= v(p\kappa_T - T\alpha_v) & \left(\frac{\partial v}{\partial T}\right)_p &= v\alpha_v \\ \left(\frac{\partial u}{\partial T}\right)_p &= c_p - p v \alpha_v & \left(\frac{\partial v}{\partial p}\right)_T &= -v\kappa_T \\ \left(\frac{\partial p}{\partial p}\right)_T &= 1 & \left(\frac{\partial p}{\partial T}\right)_p &= 0 \end{aligned} \quad (2.75)$$

The insertion of these results into Eq. (2.74) yields

$$\left(\frac{\partial u}{\partial p}\right)_v = -vT\alpha_v + \frac{c_p \kappa_T}{\alpha_v}. \quad (2.76)$$

Depending on the given values for p and T , the properties v , c_p , α_v , and κ_T can be calculated from one of the basic equations $g(p, T)$ for regions 1, 2, 2 (metastable), or 5 corresponding to Eqs. (2.3), (2.6), (2.9), or (2.15), respectively. Other partial derivatives can be determined in an analogous way.

2.4.3.2 Example for the Derivation of the Partial Derivative $(\partial u / \partial p)_v$, for Region 3

Since the basic equation for region 3 is a fundamental equation of the Helmholtz free energy, $f_3(\rho, T)$, Eq. (2.73) and Table 2.139 have to be used for forming the corresponding partial derivative. The comparison of the needed partial derivative $(\partial u / \partial p)_v$ with the general expression for the partial derivative according to Eq. (2.73) results in $z = u$, $x = p$, and $y = v$. With these assignments, Eq. (2.73) reads formally:

$$\left(\frac{\partial u}{\partial p}\right)_v = \frac{\left(\frac{\partial u}{\partial v}\right)_T \left(\frac{\partial v}{\partial T}\right)_v - \left(\frac{\partial u}{\partial T}\right)_v \left(\frac{\partial v}{\partial v}\right)_T}{\left(\frac{\partial p}{\partial v}\right)_T \left(\frac{\partial v}{\partial T}\right)_v - \left(\frac{\partial p}{\partial T}\right)_v \left(\frac{\partial v}{\partial v}\right)_T} \quad (2.77)$$

According to Table 2.139, the partial derivatives are:

$$\begin{aligned} \left(\frac{\partial u}{\partial v} \right)_T &= p(\alpha_p - 1) & \left(\frac{\partial v}{\partial T} \right)_v &= 0 \\ \left(\frac{\partial u}{\partial T} \right)_v &= c_v & \left(\frac{\partial v}{\partial v} \right)_T &= 1 \\ \left(\frac{\partial p}{\partial v} \right)_T &= -p\beta_p & \left(\frac{\partial p}{\partial T} \right)_v &= p\alpha_p \end{aligned} \quad (2.78)$$

The insertion of these results into Eq. (2.77) yields

$$\left(\frac{\partial u}{\partial p} \right)_v = \frac{c_v}{p\alpha_p} . \quad (2.79)$$

For the given values for v and T , the properties p , c_v , and α_p are calculated from the basic equation $f_3(\rho, T)$, Eq. (2.11), for region 3. Other partial derivatives can be determined in an analogous way.

2.4.4 The Calculation of Any Partial Derivative Using the Tables in Part B, the “Steam Properties Calculator”, or the App “International Steam Tables”

The tables in Part B of this book contain values for the thermodynamic properties specific volume v , specific entropy s , specific isobaric heat capacity c_p , isobaric cubic expansion coefficient α_v , and isothermal compressibility κ_T in pressure-temperature grids over the range of validity of IAPWS-IF97 except for the high-temperature region. These properties can also be calculated over the entire range of validity of IAPWS-IF97 including the high temperature region using the “Steam Properties Calculator” [28]. In addition, the App “International Steam Tables” at IOS or Android smart phones or tablets [29] can be used.

Since the properties v , s , c_p , α_v , and κ_T are tabulated and calculable, the following equation can be used for determining any partial derivative:

$$\left(\frac{\partial z}{\partial x} \right)_y = \frac{\left(\frac{\partial z}{\partial p} \right)_T \left(\frac{\partial y}{\partial T} \right)_p - \left(\frac{\partial z}{\partial T} \right)_p \left(\frac{\partial y}{\partial p} \right)_T}{\left(\frac{\partial x}{\partial p} \right)_T \left(\frac{\partial y}{\partial T} \right)_p - \left(\frac{\partial x}{\partial T} \right)_p \left(\frac{\partial y}{\partial p} \right)_T} . \quad (2.80)$$

In all of the partial derivatives, the variables x , y , z can represent any thermodynamic property. Table 2.140 comprises the formulas to calculate the partial derivatives of the properties pressure p , temperature T , specific volume v , specific internal energy u , specific enthalpy h , specific entropy s , specific Gibbs free energy g , and specific Helmholtz free energy f with respect to pressure p and temperature T that are needed in Eq. (2.80). For example, for the variable $z = v$, the expression $(\partial z / \partial p)_T$ means $(\partial v / \partial p)_T$, which is equal to $-v\kappa_T$ according to Table 2.140.

Table 2.140 Derivatives of x , y , and z with respect to p at constant T and vice versa, where x , y , and z can be any of the quantities p , T , v , u , h , s , g , or f

x, y, z	$\left(\frac{\partial x}{\partial T}\right)_p, \left(\frac{\partial y}{\partial T}\right)_p, \left(\frac{\partial z}{\partial T}\right)_p$	$\left(\frac{\partial x}{\partial p}\right)_T, \left(\frac{\partial y}{\partial p}\right)_T, \left(\frac{\partial z}{\partial p}\right)_T$
p	0	1
T	1	0
v	$v\alpha_v$	$-v\kappa_T$
u	$c_p - p v \alpha_v$	$v(p\kappa_T - T\alpha_v)$
h	c_p	$v(1 - T\alpha_v)$
s	c_p/T	$-v\alpha_v$
g	$-s$	v
f	$-p v \alpha_v - s$	$p v \kappa_T$

2.4.4.1 The Calculation of Any Partial Derivative Using the Tables in Part B

As described at the beginning of Sec. 2.4.4, Eq. (2.80) and Table 2.140 should be used for calculating any partial derivative from tabulated properties. For the single-phase region, values for v , s , and c_p needed in Table 2.140 are given in Table 3 in Part B, while values for α_v and κ_T can be taken from Tables 9 and 10 in Part B. For the saturated liquid or saturated vapour, Table 1 in Part B contains values for v , s , and c_p , while values for α_v and κ_T are given in Table 6 in Part B.

Example

The partial derivative $(\partial h / \partial s)_v$ is calculated for $p = 300$ bar and $t = 400$ °C.

The comparison of the needed derivative $(\partial h / \partial s)_v$ with Eq. (2.80) leads to the assignments $z = h$, $x = s$, and $y = v$. Based on these assignments, Eq. (2.80) results in

$$\left(\frac{\partial h}{\partial s}\right)_v = \frac{\left(\frac{\partial h}{\partial p}\right)_T \left(\frac{\partial v}{\partial T}\right)_p - \left(\frac{\partial h}{\partial T}\right)_p \left(\frac{\partial v}{\partial p}\right)_T}{\left(\frac{\partial s}{\partial p}\right)_T \left(\frac{\partial v}{\partial T}\right)_p - \left(\frac{\partial s}{\partial T}\right)_p \left(\frac{\partial v}{\partial p}\right)_T}. \quad (2.81)$$

The expressions for the partial derivatives in Eq. (2.81) are formed with the help of Table 2.140 and one obtains:

$$\begin{aligned} \left(\frac{\partial h}{\partial p}\right)_T &= v(1 - T\alpha_v) & \left(\frac{\partial v}{\partial T}\right)_p &= v\alpha_v \\ \left(\frac{\partial h}{\partial T}\right)_p &= c_p & \left(\frac{\partial v}{\partial p}\right)_T &= -v\kappa_T \\ \left(\frac{\partial s}{\partial p}\right)_T &= -v\alpha_v & \left(\frac{\partial s}{\partial T}\right)_p &= T^{-1} c_p \end{aligned} \quad (2.82)$$

Inserting these results into Eq. (2.81) yields the final equation for the calculation of the needed partial derivative

$$\left(\frac{\partial h}{\partial s} \right)_v = \frac{c_p \kappa_T + v \alpha_v (1 - T \alpha_v)}{T^{-1} c_p \kappa_T - v \alpha_v^2}. \quad (2.83)$$

Now, the values for the quantities v , c_p , α_v , and κ_T for the given values for p and T (300 bar, 400 °C) are taken from Tables 3, 9, and 10 in Part B, namely:

Table 3: $v = 0.002\ 796\ 41\ \text{m}^3\ \text{kg}^{-1}$, $c_p = 25.797\ \text{kJ}\ \text{kg}^{-1}\ \text{K}^{-1}$

Table 9: $\alpha_v = 37\ 835 \times 10^{-6}\ \text{K}^{-1}$

Table 10: $\kappa_T = 120.34 \times 10^{-6}\ \text{kPa}^{-1}$

Thus, the result for the partial derivative at the given pressure and temperature amounts to

$$\left(\frac{\partial h}{\partial s} \right)_v = 846.95\ \text{K}.$$

Any other partial derivative can be determined using the printed tables in Part B in an analogous way.

2.4.4.2 The Calculation of Any Partial Derivative Using the “Steam Properties Calculator” or the App “International Steam Tables”

All quantities that are required for the calculation of any partial derivative can be precisely determined with the “Steam Properties Calculator” [28] or the App “International Steam Tables” at IOS or Android smart phones or tablets [29]. As described at the beginning of Sec. 2.4.4, Eq. (2.80) and Table 2.140 can be used to determine any partial derivative. For the single-phase region, the mentioned software allows the calculation of the needed properties v , s , c_p , α_v , and κ_T as a function of p and T over the entire range of IAPWS-IF97 (including the high-temperature region 5). For the saturated liquid, saturated vapour and wet steam, these properties can be calculated as functions of p and x or T and x .

Example

The partial derivative $(\partial h / \partial s)_v$ is calculated for $p = 200$ bar and $t = 600$ °C.

The comparison of the required derivative $(\partial h / \partial s)_v$ with Eq. (2.80) leads to the assignments $z = h$, $x = s$, and $y = v$. With these assignments, Eq. (2.80) results in Eq. (2.81). The partial derivatives in Eq. (2.81) can be obtained with the help of Table 2.140. Equation (2.82) yields the results for these partial derivatives. The insertion of these results into Eq. (2.81) leads to the final equation, Eq. (2.83), for the needed partial derivative, namely

$$\left(\frac{\partial h}{\partial s} \right)_v = \frac{c_p \kappa_T + v \alpha_v (1 - T \alpha_v)}{T^{-1} c_p \kappa_T - v \alpha_v^2}. \quad (2.84)$$

Now, the values for the quantities v , c_p , α_v , and κ_T for the given values of p and T can be calculated with the Steam Properties Calculator [28] or with the App International Steam Tables [29]:

$$\begin{aligned} v &= 0.018\,184\,4 \text{ m}^3 \text{ kg}^{-1} \\ c_p &= 2.781\,22 \text{ kJ kg}^{-1} \text{ K}^{-1} \\ \alpha_v &= 1.709\,98 \times 10^{-3} \text{ K}^{-1} \\ \kappa_T &= 55.595\,4 \times 10^{-6} \text{ kPa}^{-1} \end{aligned}$$

Thus, the value for the partial derivative is

$$\left(\frac{\partial h}{\partial s} \right)_v = 1124.09 \text{ K.}$$

Other thermodynamic derivatives can be determined in an analogous way.

2.5 Uncertainties of IAPWS-IF97

This section summarizes the uncertainties of the basic equations of the industrial formulation IAPWS-IF97 given in Sec. 2.2.

The uncertainties in specific volume, specific isobaric heat capacity, speed of sound, and saturation pressure are given in Sec. 2.5.1, while the uncertainties in specific enthalpy and in enthalpy differences are summarized in Sec. 2.5.2. Section 2.5.3 illustrates the high numerical consistency of the basic equations of IAPWS-IF97 along the region boundaries between regions 1 and 3, regions 2 and 3, and regions 2 and 5. The estimated uncertainties in these properties result from two contributions:

- Uncertainties of the scientific standard for the thermodynamic properties of water and steam, the IAPWS-95 formulation [8, 9] that computed the input values for the development of the basic equations of the industrial formulation IAPWS-IF97. The uncertainties of IAPWS-95 are mainly based on the estimated uncertainties of the selected experimental data for each of the properties [8, 9] that were used for the development of IAPWS-95.
- Deviations of IAPWS-IF97 from IAPWS-95 regarding the properties taken into consideration.

The uncertainties of IAPWS-IF97 for the various properties are given as tolerance values. As used here, “tolerance” means the range of possible values as judged by IAPWS, and no statistical significance can be attached to it.

2.5.1 Uncertainties in the Properties Specific Volume, Specific Isobaric Heat Capacity, Speed of Sound, and Saturation Pressure

In this section the uncertainties of IAPWS-IF97 in specific volume v , specific isobaric heat capacity c_p , speed of sound w , and saturation pressure p_s are presented. Based on our assessment, the uncertainty values given for these properties can be considered as estimates of a combined expanded uncertainty with a coverage factor of two corresponding to a confidence level of 95%.

The uncertainties in v , c_p , and w calculated from IAPWS-IF97 in the single-phase region are indicated in Figs. 2.27, 2.28, and 2.29. The uncertainty values for c_p and w , given in Figs. 2.28 and 2.29, increase drastically when approaching the critical point. The statement “no definitive uncertainty estimates possible” for temperatures above 1273 K is based on the fact that this range is beyond the range of validity of IAPWS-95 and the corresponding input values for IAPWS-IF97 were obtained by extrapolating IAPWS-95. Various tests of IAPWS-95 [8, 9] showed that these extrapolations yielded reasonable values.

The estimated uncertainties in the saturation pressure p_s calculated from the IAPWS-IF97 are given in Fig. 2.30.

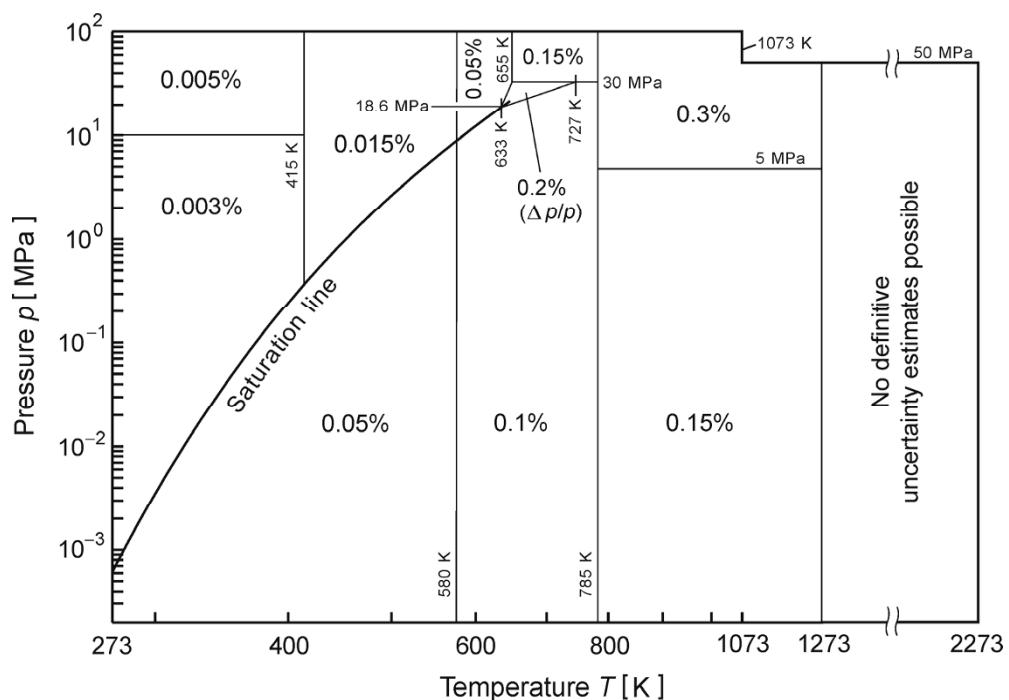


Fig. 2.27 Percentage uncertainties in specific volume estimated for the basic equations for regions 1 to 3 of IAPWS-IF97. In the enlarged critical region (triangle), the uncertainty is given as a percentage uncertainty in pressure, $\Delta p/p$. This region is bordered by the two isochores $0.0019 \text{ m}^3 \text{ kg}^{-1}$ and $0.0069 \text{ m}^3 \text{ kg}^{-1}$ and the given values of pressure and temperature. The positions of the lines separating the uncertainty regions are approximate.

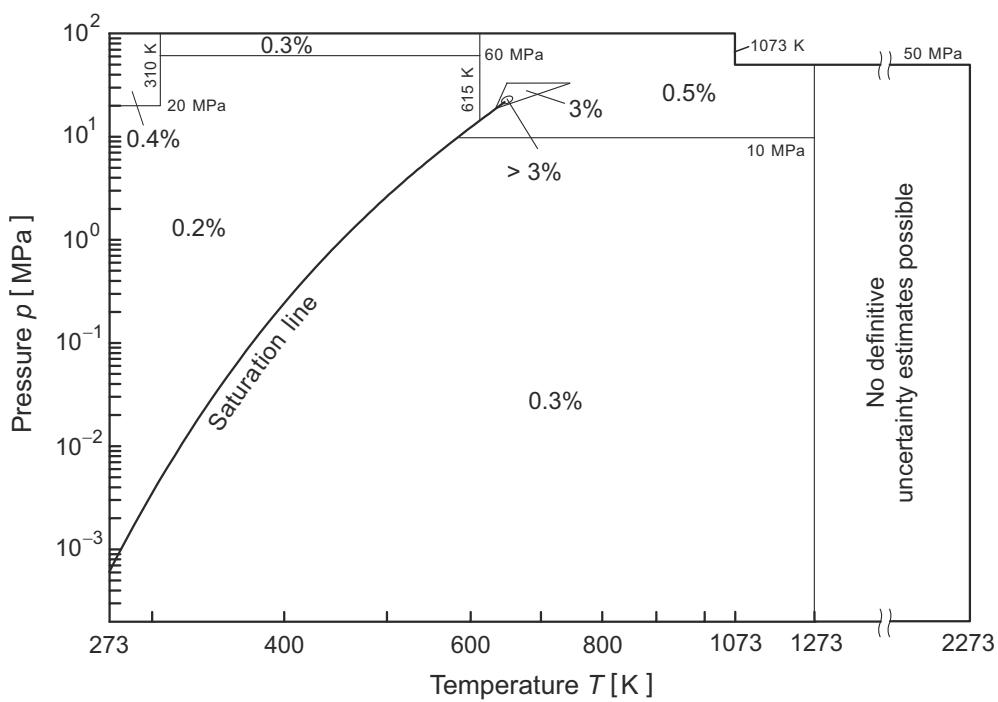


Fig. 2.28 Percentage uncertainties in specific isobaric heat capacity estimated for the basic equations for regions 1 to 3 of IAPWS-IF97. The definition of the triangle showing the enlarged critical region is given in Fig. 2.27. The positions of the lines separating the uncertainty regions are approximate.

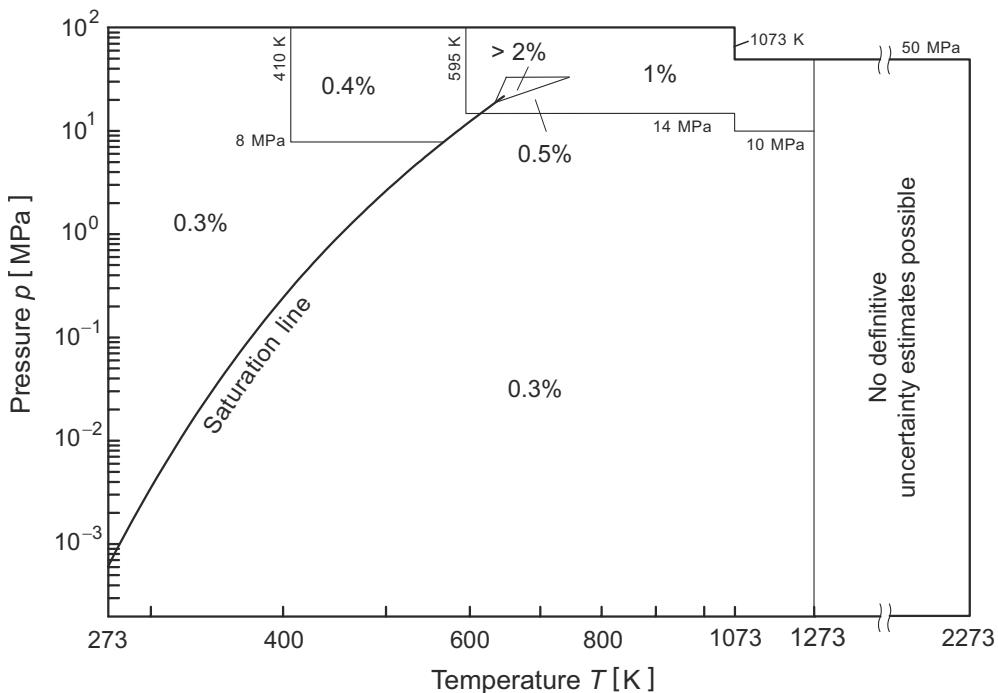


Fig. 2.29 Percentage uncertainties in speed of sound estimated for the basic equations for regions 1 to 3 of IAPWS-IF97. The definition of the triangle showing the enlarged critical region is given in Fig. 2.27. The positions of the lines separating the uncertainty regions are approximate.

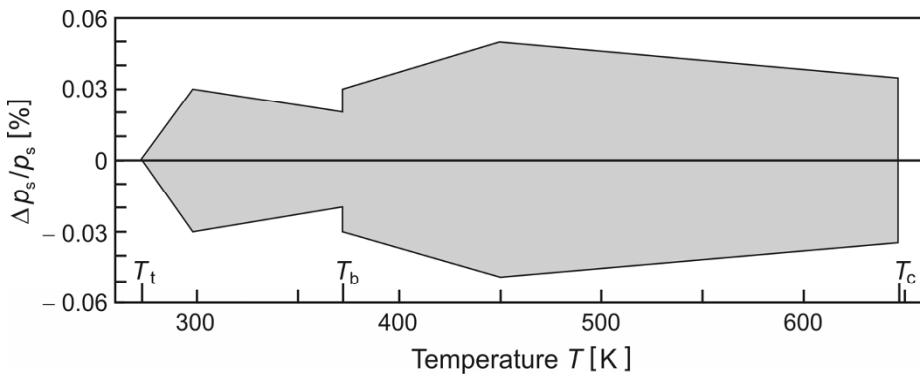


Fig. 2.30 Percentage uncertainties in saturation pressure (region 4 of IAPWS-IF97) estimated for the saturation-pressure equation, Eq. (2.13).

2.5.2 Uncertainties in the Properties Specific Enthalpy, Enthalpy Differences, and Enthalpy of Vaporization

When IAPWS-IF97 was adopted in 1997, estimates for the uncertainty in specific enthalpy calculated from IAPWS-IF97 were not given [13, 15]. However, modern procedures of acceptance tests on energy-conversion and power plants (e.g. VDI Guideline 2048 [30]) require values for the uncertainty in specific enthalpy of H_2O . Thus, corresponding uncertainty values were derived [31] and adopted by IAPWS as Advisory Note No. 1 [32]. This note presents the assumptions and further details for determining these uncertainty values.

Figure 2.31 shows the uncertainties in specific enthalpy calculated from the basic equations of the industrial formulation IAPWS-IF97. The procedure of estimating these uncertainties is described in [32]. The enthalpy values calculated from IAPWS-IF97 and from IAPWS-95 relate to the same enthalpy reference point given in Eq. (2.5).

For numerous technical applications, the uncertainty in enthalpy *differences* is needed. However, when calculating such uncertainties from the uncertainties of the enthalpies given in Fig. 2.31 (i.e. related to the enthalpy reference point of IAPWS-IF97), one obtains unrealistically large percentage uncertainties, particularly for relatively small enthalpy differences. Therefore, uncertainties in enthalpy differences were determined as described in [32]. Different sizes of enthalpy differences were calculated in different directions, namely along isobars, Δh_p , and differences in initial and final states corresponding to adiabatic reversible (isentropic) and adiabatic irreversible paths, Δh_{ad} , representing state paths in steam turbines, boiler feed pumps, and hydroturbines. Enthalpy differences between 10 kJ kg^{-1} and 1000 kJ kg^{-1} have been taken in consideration for the gas region, and between 1 kJ kg^{-1} and 10 kJ kg^{-1} for the liquid region. Apart from the uncertainties of isobaric enthalpy differences $\Delta(\Delta h_p)/\Delta h_p$ in the gas region for pressures up to 1 MPa, all of the other uncertainty values given do not significantly depend on the size of the enthalpy differences considered. As a result of all these comparisons, the estimated percentage uncertainties of enthalpy differences calculated from the basic equations of the industrial formulation IAPWS-IF97 are summarized in Figs. 2.32 and 2.33.

The uncertainty in the enthalpy of vaporization, Δh_v , given as the difference between the enthalpies of the saturated vapour and saturated liquid, $h'' - h'$, was also estimated as described in [32]. The results of estimating the uncertainties in enthalpy of vaporization in this way are shown in Fig. 2.34.

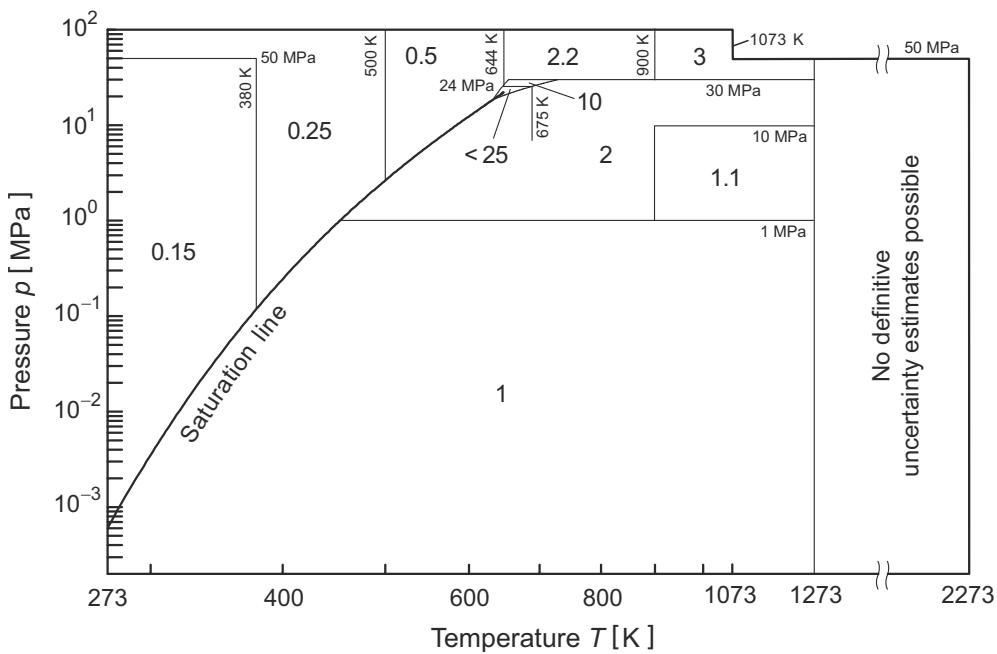


Fig. 2.31 Absolute uncertainties Δh in kJ kg^{-1} in specific enthalpy h estimated for the basic equations for regions 1 to 3 of IAPWS-IF97. The definition of the triangle showing the enlarged critical region is given in Fig. 2.27. The positions of the lines separating the uncertainty regions are approximate.

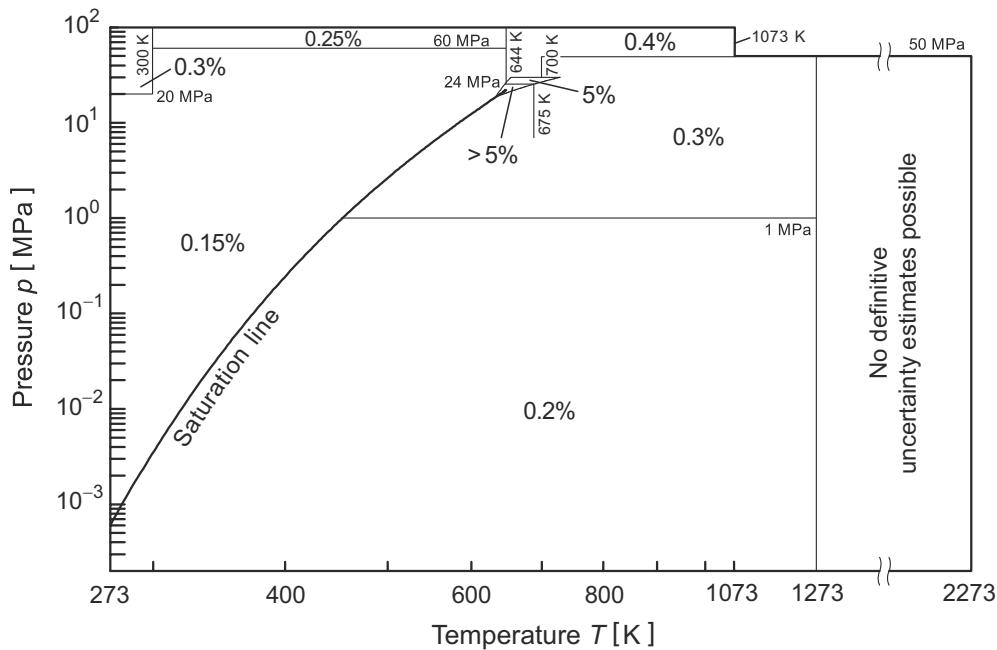


Fig. 2.32 Percentage uncertainties $\Delta(\Delta h_p)/\Delta h_p$ in isobaric enthalpy differences Δh_p estimated for the basic equations for regions 1 to 3 of IAPWS-IF97. In the gas region, the uncertainty values correspond to enthalpy differences of $10 \leq \Delta h_p/(\text{kJ kg}^{-1}) \leq 1000$. For isobaric enthalpy differences $\Delta h_p \geq 100 \text{ kJ kg}^{-1}$ and $p \leq 1 \text{ MPa}$, the uncertainties are smaller than the values given in the diagram, e.g. 0.15% for $\Delta h_p = 500 \text{ kJ kg}^{-1}$ and 0.1% for $\Delta h_p = 1000 \text{ kJ kg}^{-1}$. In the liquid region, the uncertainty values correspond to enthalpy differences of $1 \leq \Delta h_p/(\text{kJ kg}^{-1}) \leq 10$. The definition of the triangle showing the enlarged critical region is given in Fig. 2.27. The positions of the lines separating the uncertainty regions are approximate.

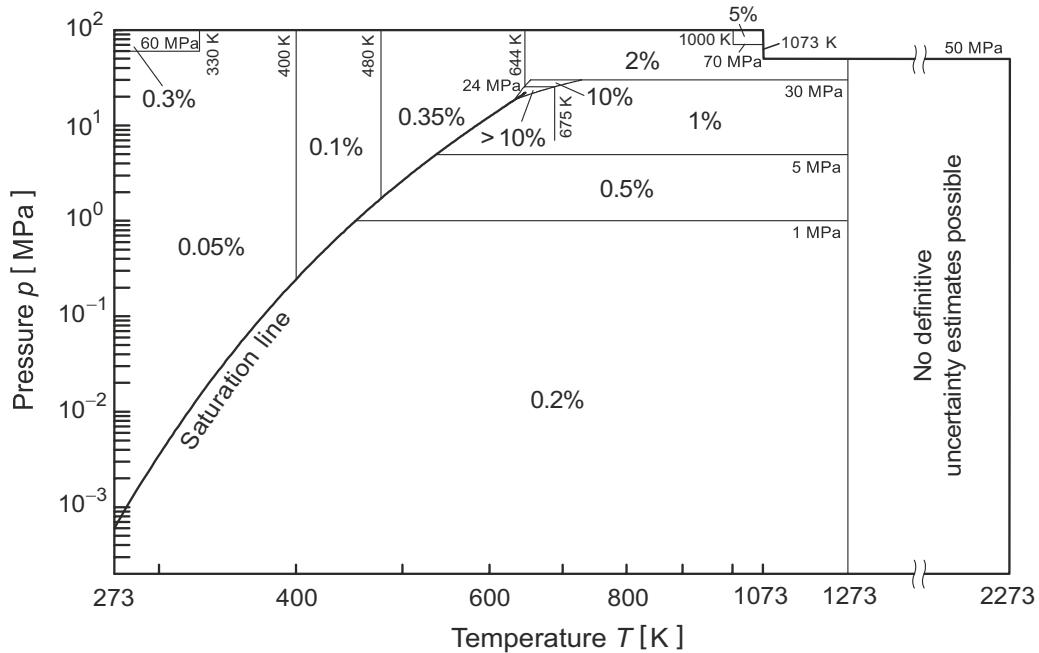


Fig. 2.33 Percentage uncertainties $\Delta(\Delta h_{ad})/\Delta h_{ad}$ in *adiabatic* enthalpy differences Δh_{ad} estimated for the basic equation for regions 1 to 3 of IAPWS-IF97. The uncertainty values given relate to enthalpy differences along adiabatic reversible (isentropic) and adiabatic irreversible paths (state paths in steam turbines, boiler feed pumps, and hydro turbines). In the gas region, the uncertainty values correspond to enthalpy differences of $10 \leq \Delta h_{ad}/(\text{kJ kg}^{-1}) \leq 1000$, whereas in the liquid region, the uncertainty values correspond to enthalpy differences of $1 \leq \Delta h_{ad}/(\text{kJ kg}^{-1}) \leq 10$. The definition of the triangle showing the enlarged critical region is given in Fig. 2.27. The positions of the lines separating the uncertainty regions are approximate.

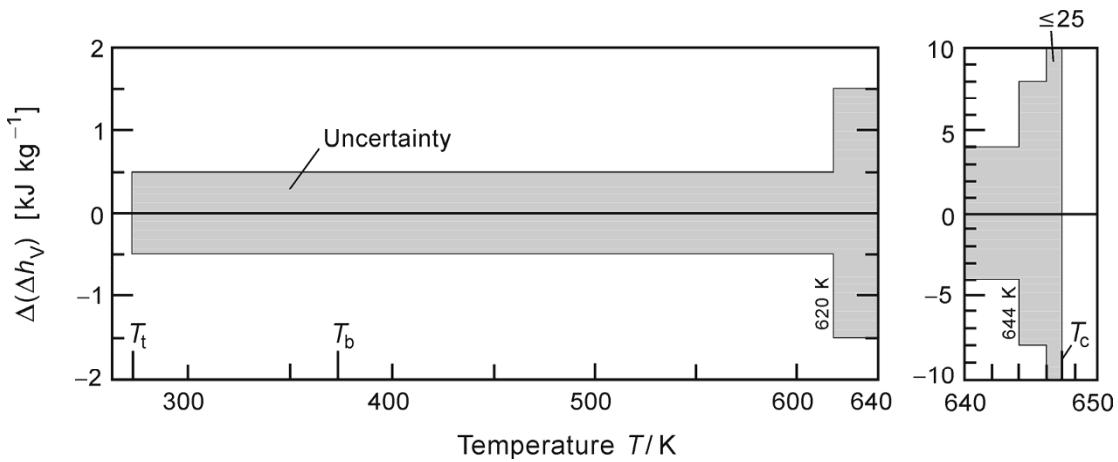


Fig. 2.34 Absolute uncertainties $\Delta(\Delta h_v)$ in enthalpy of vaporization Δh_v estimated for region 4 of IAPWS-IF97. These uncertainty values only correspond to temperatures $273.15 \text{ K} \leq T \leq 647 \text{ K}$ ($T_c = 647.096 \text{ K}$ according to Eq. (1.4)).

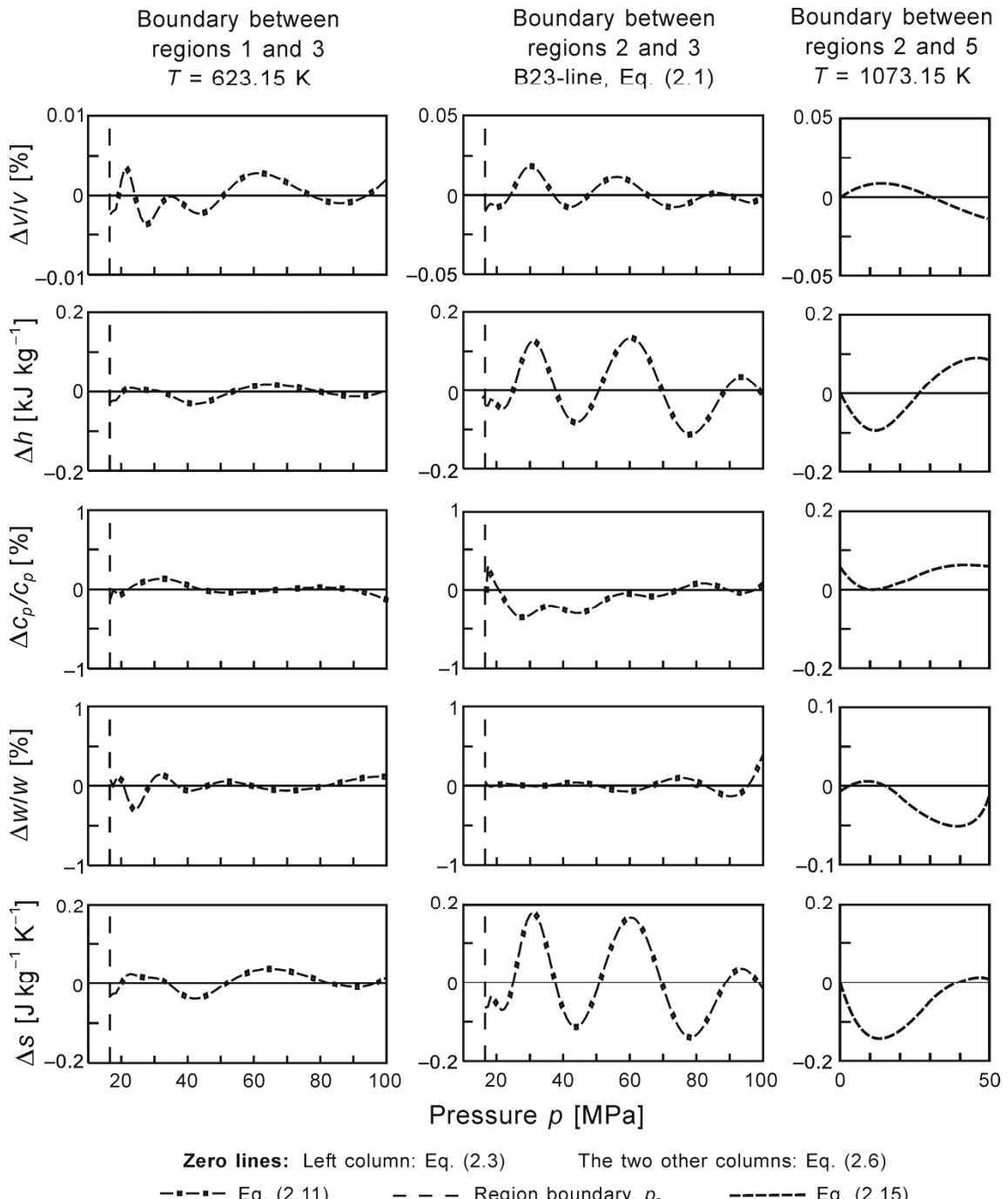


Fig. 2.35 Inconsistencies of IAPWS-IF97 in specific volume $\Delta v/v$, in specific enthalpy Δh , in specific entropy Δs , in specific isobaric heat capacity $\Delta c_p/c_p$, and in speed of sound $\Delta w/w$, along the boundary between regions 1 and 3 (left column), the boundary between regions 2 and 3 (middle column), and the boundary between regions 2 and 5 (right column).

2.5.3 Consistencies at Boundaries between Single-Phase Regions

Consistency investigations along the boundaries between the single-phase regions of IAPWS-IF97 were performed for the following basic equations and region boundaries as given in Fig. 2.2:

- Equations (2.3) and (2.11) along the 623.15 K isotherm for pressures of 16.53 MPa (corresponding to the saturation pressure $p_s(623.15 \text{ K})$) to 100 MPa. This part of the isotherm forms the boundary between regions 1 and 3.
- Equations (2.6) and (2.11) along the boundary between regions 2 and 3 defined by the equation $p_{B23}(T)$, Eq. (2.1), for temperatures between 623.15 K and 863.15 K.
- Equations (2.6) and (2.15) along the 1073.15 K isotherm for $p \leq 50 \text{ MPa}$ corresponding to the boundary between regions 2 and 5.

Figure 2.35, see the previous page, presents the results of these consistency investigations as percentage deviation diagrams for the properties v , c_p , and w and as absolute deviation diagrams for the properties h and s . The inconsistencies between the basic equations along the corresponding region boundaries are small enough to suffice for common technical applications.



3 Equations for Transport Properties and Other Properties

Aside from the development of international standard equations for the thermodynamic properties of water and steam, IAPWS has also initiated and coordinated the development of equations for transport properties and for other properties. The current IAPWS equations for the dynamic viscosity and thermal conductivity for industrial use are presented in Secs. 3.1 and 3.2. The current IAPWS equations for the surface tension, dielectric constant, and refractive index are described in Secs. 3.3 to 3.5. The correlation equations for these properties (except for surface tension) contain density as one of the input variables. In order to calculate these properties for given values of pressure and temperature, the density must first be determined. For these density calculations, the equations for the dielectric constant and refractive index are based on the scientific formulation IAPWS-95 [8, 9] rather than the industrial formulation IAPWS-IF97. However, except for the near-critical region, differences in density calculations from IAPWS-95 and IAPWS-IF97 are negligibly small. Thus, for industrial applications, the input density for these equations for given values of pressure and temperature can be calculated from the corresponding basic equations of the industrial formulation IAPWS-IF97 described in Sec. 2.2. This procedure was applied to calculate the values for the transport properties and other properties listed in the tables in Part B of this book.

3.1 Equation for the Viscosity for Industrial Use

The “Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substances”, which the presented correlation equation for the dynamic viscosity is based on, was adopted at the IAPWS Meeting in 2008 [33]. A discussion of the background, development, and validation of this viscosity equation is presented in the background paper [34].

According to the IAPWS Release [33], the correlation equation for viscosity consists of three functions, which are multiplicatively connected. For industrial use, the third function (called $\bar{\mu}_2$ in the release) may be set to unity. This function, the so-called critical enhancement, is only significant over a very small range around the critical point (for details see later in this section). Since the industrial use is the main focus of this book, only the first two functions are considered here.

The correlation equation for the dynamic viscosity η for industrial use is given in dimensionless form, $\Psi = \eta/\eta^*$, and consists of the two functions Ψ_0 and Ψ_1 that are multiplied with each other. The equation reads

$$\frac{\eta(\rho, T)}{\eta^*} = \Psi(\delta, \theta) = \Psi_0(\theta) \Psi_1(\delta, \theta), \quad (3.1)$$

where $\delta = \rho/\rho_c$ and $\theta = T/T_c$, with $\eta^* = 1 \times 10^{-6}$ Pa s, and Ψ_0 and Ψ_1 according to Eqs. (3.2) and (3.3). The first function of Eq. (3.1), $\Psi_0(\theta)$, represents the viscosity in the dilute-gas limit and has the form

$$\Psi_0(\theta) = \theta^{0.5} \left[\sum_{i=1}^4 n_i \theta^{1-i} \right]^{-1}, \quad (3.2)$$

where $\theta = T/T_c$ with $T_c = 647.096$ K according to Eq. (1.4). The coefficients n_i are listed in Table 3.1. The equation for the second function of Eq. (3.1), $\Psi_1(\delta, \theta)$, reads

$$\Psi_1(\delta, \theta) = \exp \left[\delta \sum_{i=1}^{21} n_i (\delta - 1)^{I_i} (\theta^{-1} - 1)^{J_i} \right], \quad (3.3)$$

where $\delta = \rho/\rho_c$ and $\theta = T/T_c$ with the critical density $\rho_c = 322$ kg m⁻³ and the critical temperature $T_c = 647.096$ K according to Eqs. (1.6) and (1.4). Table 3.2 contains the coefficients n_i and exponents I_i and J_i of Eq. (3.3).

Table 3.1 Coefficients of Eq. (3.2)

i	n_i	i	n_i
1	$0.167\ 752 \times 10^{-1}$	3	$0.636\ 656\ 4 \times 10^{-2}$
2	$0.220\ 462 \times 10^{-1}$	4	$-0.241\ 605 \times 10^{-2}$

Table 3.2 Coefficients and exponents of Eq. (3.3)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	0	0.520 094	12	2	2	-0.772 479
2	0	1	$0.850\ 895 \times 10^{-1}$	13	2	3	-0.489 837
3	0	2	$-0.108\ 374 \times 10^1$	14	2	4	-0.257 040
4	0	3	-0.289 555	15	3	0	0.161 913
5	1	0	0.222 531	16	3	1	0.257 399
6	1	1	0.999 115	17	4	0	$-0.325\ 372 \times 10^{-1}$
7	1	2	$0.188\ 797 \times 10^1$	18	4	3	$0.698\ 452 \times 10^{-1}$
8	1	3	$0.126\ 613 \times 10^1$	19	5	4	$0.872\ 102 \times 10^{-2}$
9	1	5	0.120 573	20	6	3	$-0.435\ 673 \times 10^{-2}$
10	2	0	-0.281 378	21	6	5	$-0.593\ 264 \times 10^{-3}$
11	2	1	-0.906 851				

If the dynamic viscosity is calculated from Eq. (3.1) for given values of *pressure* and *temperature*, then the input quantity reduced *density* δ has to be calculated first. According to the release [33], this density does not have to be calculated from the IAPWS-95 formulation [8, 9], but can also be determined from the IAPWS-IF97 basic equations, Eq. (2.3), (2.6), (2.11), or (2.15), as described in Sec. 2.2. With this approach, the error is much smaller than the uncertainty of Eq. (3.1) as long as the state point given by the values for the input pressure and temperature is outside the near-critical region defined in the subpoint “Estimated Uncertainty”

given later. Accordingly, the viscosity values listed in the corresponding tables in Part B are based on the density calculation from IAPWS-IF97.

Range of Validity. Figure 3.1 illustrates the range of validity of the viscosity equation for industrial applications, Eq. (3.1), in a p - T diagram. Thus, for pressures up to 50 MPa, Eq. (3.1) can be also used for temperatures above 1073.15 K up to 1273.15 K. Outside the IAPWS-IF97 range of validity with respect to pressure, the viscosity equation for scientific use [33] in combination with the scientific formulation IAPWS-95 [8, 9] for the density calculation should be used.

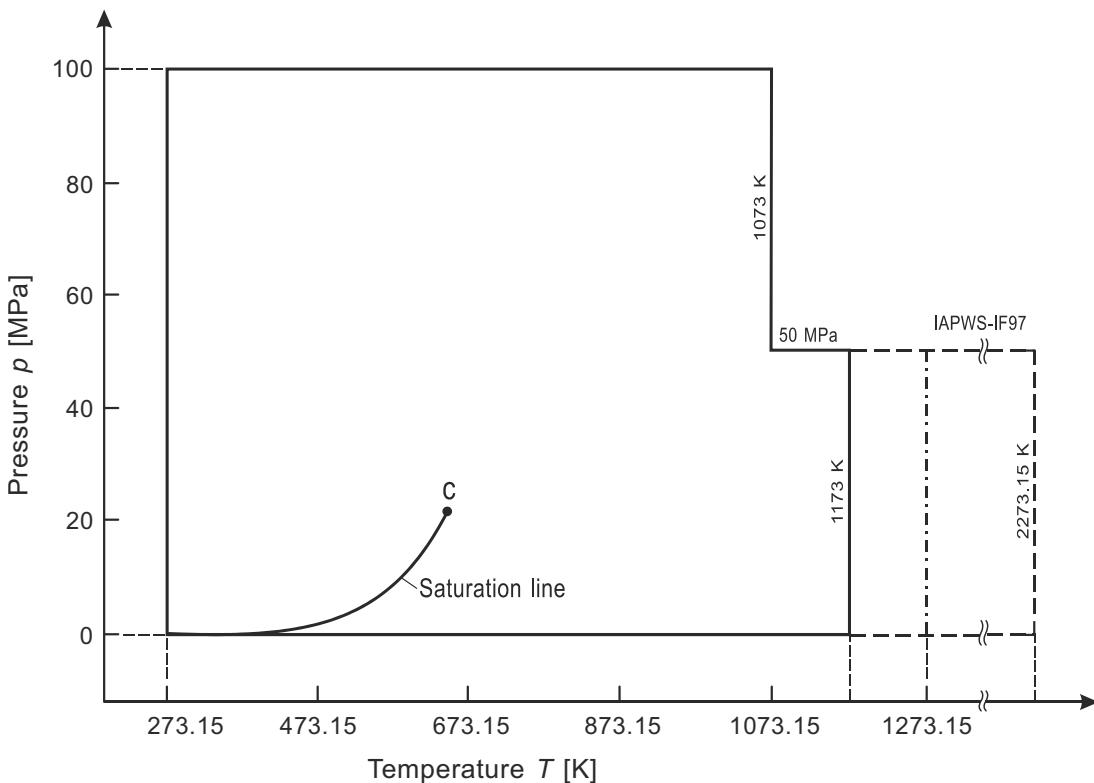


Fig. 3.1 Range of validity of the viscosity equation for industrial applications, Eq. (3.1); its extrapolation range is given by the dashed-dotted line. The validity range of IAPWS-IF97 shown by dashed lines is plotted for comparison.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (3.1), Table 3.3 contains corresponding test values.

Table 3.3 Dynamic viscosity values calculated from Eq. (3.1) for selected temperatures and pressures^a

Property	$T = 298.15 \text{ K}$ $p = 0.1 \text{ MPa}$	$T = 873.15 \text{ K}$ $p = 20 \text{ MPa}$	$T = 673.15 \text{ K}$ $p = 60 \text{ MPa}$	$T = 1173.15 \text{ K}$ $p = 20 \text{ MPa}$
$\rho [\text{kg m}^{-3}]$	$0.997\ 047\ 435 \times 10^3$	$0.549\ 921\ 814 \times 10^2$	$0.612\ 391\ 201 \times 10^3$ ^b	$0.377\ 584\ 847 \times 10^2$
$\Psi_0 [-]$	$0.970\ 904\ 522 \times 10$	$0.326\ 046\ 811 \times 10^2$	$0.244\ 558\ 002 \times 10^2$	$0.441\ 936\ 611 \times 10^2$
$\Psi_1 [-]$	$0.916\ 694\ 207 \times 10^2$	$0.104\ 200\ 938 \times 10$	$0.296\ 900\ 349 \times 10$	$0.102\ 422\ 324 \times 10$
$\eta [\text{Pa s}]$	$0.890\ 022\ 551 \times 10^{-3}$	$0.339\ 743\ 835 \times 10^{-4}$	$0.726\ 093\ 560 \times 10^{-4}$	$0.452\ 641\ 750 \times 10^{-4}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

^bThe density value of this test point, which is located in region 3 of IAPWS-IF97, was calculated from Eq. (2.11) via iteration.

Estimated Uncertainty. The uncertainties in viscosity calculated from Eq. (3.1) are summarized in Fig. 3.2; they can be considered as estimates of a combined expanded uncertainty with a coverage factor of two corresponding to a confidence level of 95%. The viscosity equation reproduces the ISO recommended value of the viscosity at 20 °C (293.15 K) and standard atmospheric pressure within the number of digits given in [35]; it also agrees with all values from 288.15 K to 313.15 K at atmospheric pressure in [35] within the stated uncertainty of 0.17% at 293.15 K.

The uncertainty value of 2%, shown in Fig. 3.2 for temperatures between 573 K and 613 K (for pressures below 45 MPa up to 773 K) is only valid outside the near-critical region. This region, where for the viscosity the so-called critical enhancement occurs, is defined by the temperature and density range given by

$$645.91 \text{ K} \leq T \leq 650.77 \text{ K} \quad 245.8 \text{ kg m}^{-3} \leq \rho \leq 405.3 \text{ kg m}^{-3},$$

see also Fig. 3.2. In this region, the uncertainty of the viscosity equation for industrial applications, Eq. (3.1), is greater than 2%. If one is interested in viscosity calculations in this region, the viscosity equation for scientific use according to Eqs. (14) to (21) in the release [33] should be used together with the IAPWS-95 formulation [8, 9] for the density calculation. In the extrapolation region of Eq. (3.1), no uncertainty estimate is possible.

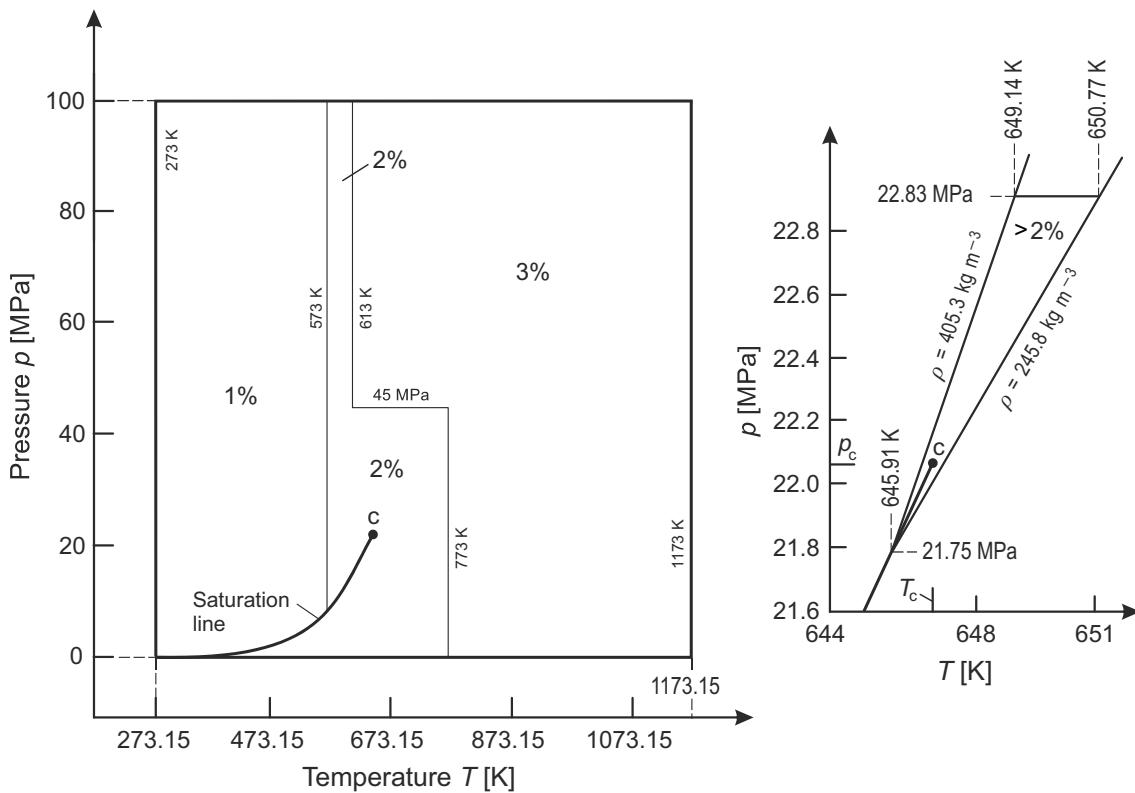


Fig. 3.2 Percentage uncertainties in viscosity estimated for the viscosity equation, Eq. (3.1). In the near-critical region, shown in the enlarged diagram on the right, the uncertainty of Eq. (3.1) is greater than 2%, see text. The positions of the lines separating the uncertainty regions are approximate.

3.2 Equation for the Thermal Conductivity for Industrial Use

The correlation equation for the thermal conductivity for industrial use is based on the IAPWS “Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance” [36] which was adopted at the IAPWS Meeting in 2011. A discussion of the background, development, and validation of this thermal conductivity equation is presented in the background paper [37].

According to the IAPWS Release [36], the correlation equation for the thermal conductivity λ for industrial use is given in dimensionless form, $\Lambda = \lambda/\lambda^*$, and consists of three functions. The equation reads

$$\frac{\lambda(\rho, T)}{\lambda^*} = \Lambda(\rho, T) = \Lambda_0(\theta) \Lambda_1(\delta, \theta) + \Lambda_2(\delta, \theta), \quad (3.4)$$

where $\delta = \rho/\rho_c$ and $\theta = T/T_c$ with $\lambda^* = 1 \times 10^{-3} \text{ W m}^{-1} \text{ K}^{-1}$, and Λ_0 , Λ_1 , and Λ_2 according to Eqs. (3.5) to (3.7). This equation is valid for IAPWS-IF97 regions 1-3 and 5. For region 5, only the functions $\Lambda_0(\theta)$ and $\Lambda_1(\delta, \theta)$ are used. The function $\Lambda_0(\theta)$ represents the thermal conductivity in the dilute-gas limit and has the form

$$\Lambda_0(\theta) = \frac{\theta^{0.5}}{\sum_{i=1}^5 n_i \theta^{1-i}}, \quad (3.5)$$

where $\theta = T/T_c$ with $T_c = 647.096$ K; the coefficients n_i are listed in Table 3.4. The correlation equation for the second function of Eq. (3.4), $\Lambda_1(\delta, \theta)$, reads

$$\Lambda_1(\delta, \theta) = \exp \left[\delta \sum_{i=1}^5 \left(\left(\frac{1}{\theta} - 1 \right)^{i-1} \sum_{j=1}^6 n_{ij} (\delta - 1)^{j-1} \right) \right], \quad (3.6)$$

where $\delta = \rho/\rho_c$ and $\theta = T/T_c$ with $\rho_c = 322 \text{ kg m}^{-3}$ and $T_c = 647.096$ K. The coefficients n_{ij} are given in Table 3.5. The function $\Lambda_2(\delta, \theta)$ represents the critical enhancement of the thermal conductivity. This additive contribution is defined for IAPWS-IF97 regions 1-2 and 3 by

$$\Lambda_2(\delta, \theta) = n_1 \frac{\delta \theta}{\Psi} \frac{c_p}{R} A, \quad (3.7)$$

where $\delta = \rho/\rho_c$ and $\theta = T/T_c$ with $\rho_c = 322 \text{ kg m}^{-3}$ and $T_c = 647.096$ K. The numerical constant n_1 is given in Table 3.6. The variable $\Psi = \eta/\eta^*$ with $\eta^* = 1 \times 10^{-6} \text{ Pa s}$ represents the dimensionless dynamic viscosity calculated from Eq. (3.1); see Section 3.1. The calculation of the enclosed specific isobaric heat capacity c_p depends on the region where the given state point is located. Its calculation will be described later in this section. The variable R in Eq. (3.7) represents the specific gas constant of water and is given in [36] by $R = 0.416\,518\,05 \text{ kJ kg}^{-1} \text{ K}^{-1}$. This value for R is different from the value given in Sec. 1 but is consistent with Eq. (3.7). The function A^{23} is defined by

$$A = \frac{n_2}{a} \left[\left(1 - \frac{1}{b} \right) \arctan(a) + \frac{a}{b} - 1 + \exp \left(-\frac{1}{a^{-1} + \frac{1}{3} a^2 \delta^{-2}} \right) \right], \quad (3.7a)$$

$$\text{with } a = n_3 (\delta B)^{n_4}, \quad (3.7b)$$

$$B = p_c \delta \kappa_T - n_5 \theta^{-1} C, \quad (3.7.c)$$

$$C = \frac{1}{\sum_{i=1}^6 n_i \delta^{i-1}}, \quad (3.7d)$$

$$\text{and } b = c_p/c_v, \quad (3.7e)$$

²³The quantity A corresponds to the quantity $Z(y)$, Eq. (19), in the release [36]. The quantity $\Delta \bar{\chi}$ in Eq. (23) of [36] was replaced by the quantity B , Eq. (3.7c), which contains the isothermal compressibility κ_T . Thus, the calculation of the partial derivative $(\partial \bar{\rho}/\partial \bar{p})_{\bar{T}}$, Eq. (24) of [36], is avoided. The isothermal compressibility κ_T can be straightforward calculated from the IAPWS-IF97 basic equations as described below Eq. (3.7e).

where $\rho_c = 322 \text{ kg m}^{-3}$, $T_c = 647.096 \text{ K}$, $p_c = 22.064 \text{ MPa}$, $\delta = \rho/\rho_c$ and $\theta = T/T_c$. The numerical coefficients n_2 to n_5 of Eqs. (3.7a) to (3.7c) are listed in Table 3.6. The coefficients n_i of Eq. (3.7d) depend on the value for the reduced density. Table 3.7 contains the coefficients n_i for certain ranges of the reduced density δ . The formulas for calculating the specific isobaric heat capacity c_p in Eqs. (3.7) and (3.7e), the specific isochoric heat capacity c_v in Eq. (3.7e), and the isothermal compressibility κ_T in Eq. (3.7c) are listed in Table 2.3 for region 1, in Table 2.8 for region 2, and in Table 2.16 for region 3, respectively.

The following restrictions should be noticed for the calculation of $A_2(\delta, \theta)$ in Eq. (3.7):

- Specific heat capacity c_p in Eqs. (3.7) and (3.7e), in region 3: If $c_p < 0$ or $c_p > 1 \times 10^{13} \text{ kJ kg}^{-1} \text{ K}^{-1}$, it should be set to $c_p = 1 \times 10^{13} \text{ kJ kg}^{-1} \text{ K}^{-1}$.
- Isothermal compressibility κ_T in Eq. (3.7c) in region 3: If $\kappa_T < 0$ or $\kappa_T > 1 \times 10^{13} \text{ MPa}^{-1}$, it should be set to $\kappa_T = 1 \times 10^{13} \text{ MPa}^{-1}$.
- Value of B , Eq. (3.7c): If $B < 0$, it should be set to $B = 0$.
- Value of a , Eq. (3.7b): If $a < 1.2 \times 10^{-7}$, the function A , Eq. (3.7a), should be set to $A = 0$. Thus, the term A_2 in Eq. (3.4) is zero.

If the thermal conductivity is calculated from Eq. (3.4) for given values of *pressure* p and *temperature* T , then the quantity *density* ρ has to be calculated from the IAPWS-IF97 basic equations, Eq. (2.3) for region 1, Eq. (2.6) for region 2, Eq. (2.11) for region 3, and Eq. (2.17), respectively, for region 5, as described in Sec. 2.2. Note the different value for R used for the basic equations in Section 2.2 und in this section.

Range of Validity. IAPWS endorses the validity of Eq. (3.4) for the thermal conductivity for industrial use in the following range of pressures and temperatures

$$\begin{array}{ll} 0 < p \leq 50 \text{ MPa} & 273.15 \text{ K} \leq T \leq 1173.15 \text{ K} \\ 50 \text{ MPa} < p \leq 100 \text{ MPa} & 273.15 \text{ K} \leq T \leq 1073.15 \text{ K}, \end{array}$$

which is illustrated in Fig. 3.3. For comparison, the range of validity of IAPWS-IF97 is also shown.

Table 3.4 Coefficients of Eq. (3.5)

i	n_i	i	n_i
1	$0.244\ 322\ 1 \times 10^{-2}$	4	$-0.345\ 458\ 6 \times 10^{-2}$
2	$0.132\ 309\ 5 \times 10^{-1}$	5	$0.409\ 626\ 6 \times 10^{-3}$
3	$0.677\ 035\ 7 \times 10^{-2}$		

Table 3.5 Coefficients of Eq. (3.6)

i	n_{i1}	n_{i2}	n_{i3}
1	$0.160\ 397\ 357 \times 10^1$	$-0.646\ 013\ 523$	$0.111\ 443\ 906$
2	$0.233\ 771\ 842 \times 10^1$	$-0.278\ 843\ 778 \times 10^1$	$0.153\ 616\ 167 \times 10^1$
3	$0.219\ 650\ 529 \times 10^1$	$-0.454\ 580\ 785 \times 10^1$	$0.355\ 777\ 244 \times 10^1$
4	$-0.121\ 051\ 378 \times 10^1$	$0.160\ 812\ 989 \times 10^1$	$-0.621\ 178\ 141$
5	$-0.272\ 033\ 700 \times 10^1$	$0.457\ 586\ 331 \times 10^1$	$-0.318\ 369\ 245 \times 10^1$

i	n_{i4}	n_{i5}	n_{i6}
1	$0.102\ 997\ 357$	$-0.504\ 123\ 634 \times 10^{-1}$	$0.609\ 859\ 258 \times 10^{-2}$
2	$-0.463\ 045\ 512$	$0.832\ 827\ 019 \times 10^{-1}$	$-0.719\ 201\ 245 \times 10^{-2}$
3	$-0.140\ 944\ 978 \times 10^1$	$0.275\ 418\ 278$	$-0.205\ 938\ 816 \times 10^{-1}$
4	$0.716\ 373\ 224 \times 10^{-1}$	0	0
5	$0.111\ 683\ 480 \times 10^1$	$-0.192\ 683\ 050$	$0.129\ 138\ 420 \times 10^{-1}$

Table 3.6 Coefficients of Eqs. (3.7), (3.7a), (3.7b) and (3.7c)

i	n_i	i	n_i
1	$0.177\ 851\ 4 \times 10^3$	4	$0.508\ 474\ 576\ 271$
2	$0.636\ 619\ 772\ 367\ 581$	5	1.5
3	$0.135\ 882\ 142\ 589\ 674 \times 10^1$		

Table 3.7 Coefficients of Eq. (3.7d) for certain ranges of the reduced density δ

i	n_i	n_i
	$\delta \leq 0.310\ 559\ 006$	$0.310\ 559\ 006 < \delta \leq 0.776\ 397\ 516$
1	$0.653\ 786\ 807\ 199\ 516 \times 10^1$	$0.652\ 717\ 759\ 281\ 799 \times 10^1$
2	$-0.561\ 149\ 954\ 923\ 348 \times 10^1$	$-0.630\ 816\ 983\ 387\ 575 \times 10^1$
3	$0.339\ 624\ 167\ 361\ 325 \times 10^1$	$0.808\ 379\ 285\ 492\ 595 \times 10^1$
4	$-0.227\ 492\ 629\ 730\ 878 \times 10^1$	$-0.982\ 240\ 510\ 197\ 603 \times 10^1$
5	$0.102\ 631\ 854\ 662\ 709 \times 10^2$	$0.121\ 358\ 413\ 791\ 395 \times 10^2$
6	$0.197\ 815\ 050\ 331\ 519 \times 10^1$	$-0.554\ 349\ 664\ 571\ 295 \times 10^1$
	$0.776\ 397\ 516 < \delta \leq 1.242\ 236\ 025$	$1.242\ 236\ 025 < \delta \leq 1.863\ 354\ 037$
1	$0.535\ 500\ 529\ 896\ 124 \times 10^1$	$0.155\ 225\ 959\ 906\ 681 \times 10^1$
2	$-0.396\ 415\ 689\ 925\ 446 \times 10^1$	$0.464\ 621\ 290\ 821\ 181$
3	$0.891\ 990\ 208\ 918\ 795 \times 10^1$	$0.893\ 237\ 374\ 861\ 479 \times 10^1$
4	$-0.120\ 338\ 729\ 505\ 790 \times 10^2$	$-0.110\ 321\ 960\ 061\ 126 \times 10^2$
5	$0.919\ 494\ 865\ 194\ 302 \times 10^1$	$0.616\ 780\ 999\ 933\ 360 \times 10^1$
6	$-0.216\ 866\ 274\ 479\ 712 \times 10^1$	-0.965458722086812
	$\delta > 1.863\ 354\ 037$	
1	$0.111\ 999\ 926\ 419\ 994 \times 10^1$	
2	$0.595\ 748\ 562\ 571\ 649$	
3	$0.988\ 952\ 565\ 078\ 920 \times 10^1$	
4	$-0.103\ 255\ 051\ 147\ 040 \times 10^2$	
5	$0.466\ 861\ 294\ 457\ 414 \times 10^1$	
6	$-0.503\ 243\ 546\ 373\ 828$	

Figure 3.3 shows that the thermal-conductivity equation for industrial use, Eq. (3.4), covers the main part of IAPWS-IF97, regions 1 to 4 and partly region 5, up to temperatures of 1173.15 K for pressures up to 50 MPa. For higher pressures, the temperature range of Eq. (3.4) is limited to 1073.15 K.

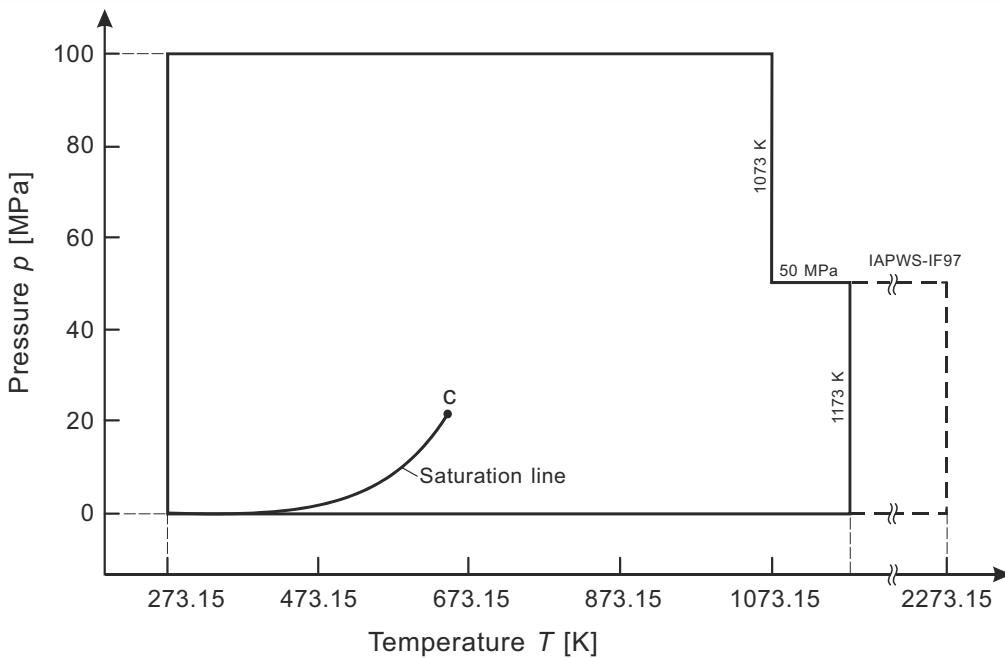


Fig. 3.3 Range of validity of the thermal conductivity equation for industrial use, Eq. (3.4). The greater validity range of IAPWS-IF97 shown by the dashed lines is plotted for comparison.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (3.4), Table 3.8 contains corresponding test values for IAPWS regions 1-3 and 5.

Table 3.8 Thermal conductivity values calculated from Eq. (3.4) and intermediate values for used properties for selected temperatures and pressures^a

Property	$T = 298.15 \text{ K}$ $p = 0.1 \text{ MPa}$	$T = 873.15 \text{ K}$ $p = 10 \text{ MPa}$	$T = 673.15 \text{ K}$ $p = 40 \text{ MPa}$	$T = 1173.15 \text{ K}$ $p = 20 \text{ MPa}$
$\rho [\text{kg m}^{-3}]^b$	$0.997\ 047\ 435 \times 10^3$	$0.260\ 569\ 558 \times 10^2$	$0.523\ 371\ 289 \times 10^3^c$	$0.377\ 584\ 848 \times 10^2$
$A_0 [-]$	$0.184\ 341\ 883 \times 10^2$	$0.791\ 034\ 659 \times 10^2$	$0.545\ 433\ 367 \times 10^2$	$0.119\ 586\ 108 \times 10^3$
$A_1 [-]$	$0.329\ 016\ 833 \times 10^2$	$0.110\ 043\ 337 \times 10^1$	$0.726\ 398\ 725 \times 10^1$	$0.115\ 280\ 540 \times 10^1$
$c_p [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.418\ 190\ 006 \times 10^1$	$0.246\ 001\ 140 \times 10^1$	$0.870\ 121\ 192 \times 10^1$	$0.258\ 078\ 180 \times 10^1$
$c_v [\text{kJ kg}^{-1} \text{ K}^{-1}]$	$0.413\ 819\ 273 \times 10^1$	$0.184\ 023\ 271 \times 10^1$	$0.295\ 154\ 130 \times 10^1$	$0.200\ 782\ 005 \times 10^1$
$\kappa_T [\text{MPa}^{-1}]$	$0.451\ 570\ 597 \times 10^{-3}$	$0.105\ 138\ 803 \times 10^0$	$0.141\ 857\ 631 \times 10^{-1}$	$0.510\ 625\ 539 \times 10^{-1}$
$\Psi [-]$	$0.890\ 022\ 551 \times 10^3$	$0.331\ 172\ 515 \times 10^2$	$0.614\ 968\ 090 \times 10^2$	$0.452\ 641\ 750 \times 10^2$
$b [-]$	$0.101\ 056\ 194 \times 10^1$	$0.133\ 679\ 365 \times 10^1$	$0.294\ 802\ 310 \times 10^1$	$0.128\ 536\ 509 \times 10^1$
$C [-]$	$0.129\ 592\ 952 \times 10^{-1}$	$0.163\ 793\ 337 \times 10^0$	$0.940\ 881\ 573 \times 10^{-1}$	$0.168\ 780\ 175 \times 10^0$
$B [-]$	— ^d	$5.639\ 822\ 730 \times 10^{-3}$	$0.373\ 064\ 478 \times 10^0$	— ^d
$a [-]$	— ^d	$0.271\ 968\ 296 \times 10^{-1}$	$0.105\ 363\ 489 \times 10^1$	— ^d

Continued on next page

Table 3.8 – Continued

Property	$T = 298.15 \text{ K}$ $p = 0.1 \text{ MPa}$	$T = 873.15 \text{ K}$ $p = 10 \text{ MPa}$	$T = 673.15 \text{ K}$ $p = 40 \text{ MPa}$	$T = 1173.15 \text{ K}$ $p = 20 \text{ MPa}$
$A [-]$	– ^d	$0.917\ 330\ 648 \times 10^{-2}$	$0.176\ 976\ 803 \times 10^0$	– ^d
$A_2 [-]$	– ^d	$0.286\ 724\ 816 \times 10^{-1}$	$0.163\ 158\ 335 \times 10^2$	– ^d
$\lambda [\text{W m}^{-1} \text{ K}^{-1}]$	$0.606\ 515\ 827 \times 10^0$	$0.870\ 767\ 659 \times 10^{-1}$	$0.412\ 517\ 936 \times 10^0$	$0.137\ 859\ 512 \times 10^0$

^aProgrammed functions should be verified using 8 byte real values for all variables.

^bThe density values were calculated from IAPWS-IF97.

^cThe density value of this test point, which is located in region 3 of IAPWS-IF97, was calculated from Eq. (2.11) via iteration.

^dThis test point is out of the range of validity of the part A_2 for the critical enhancement in Eq. (3.4).

Estimated Uncertainty. The uncertainty in thermal conductivity calculated from Eq. (3.4) is given in Fig. 3.4.

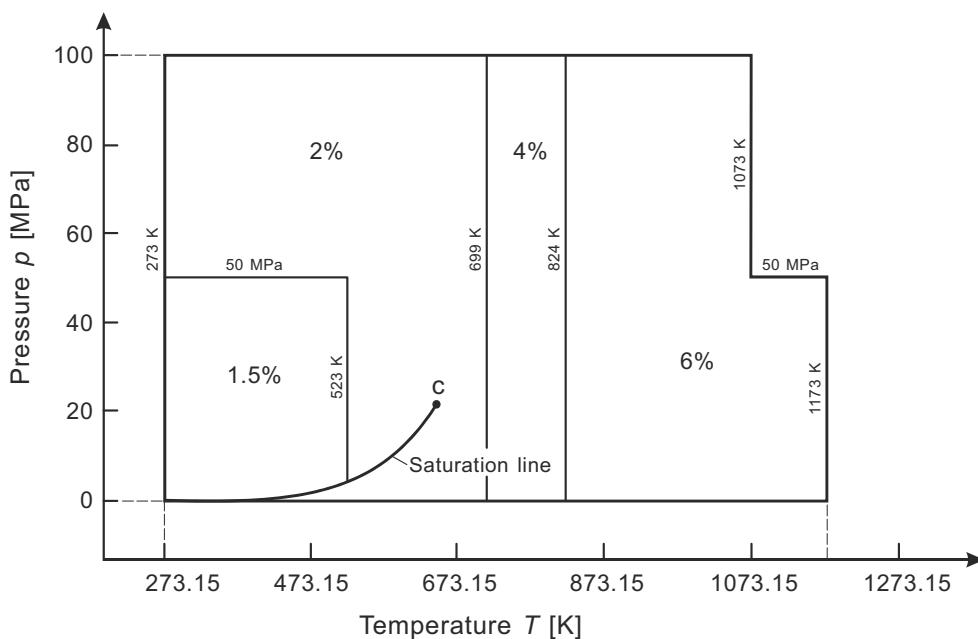


Fig. 3.4 Percentage uncertainties in thermal conductivity estimated for the thermal conductivity equation for industrial use, Eq. (3.4). In a small region near the critical point, the uncertainty of Eq. (3.4) becomes larger.

3.3 Equation for the Surface Tension

In 1975, the experimental results of the surface tension σ of the interface between the liquid and vapour phases of water were critically examined by IAPWS. As a result, IAPWS recommended table values of surface tension, which were adjusted to ITS-90 [6] in 1994 [38]. An equation for the surface tension as a function of temperature was fitted to these table values and is given in the “IAPWS Release on Surface Tension of Ordinary Water Substance” [38].

The equation for the surface tension has the following form:

$$\frac{\sigma}{\sigma^*} = 235.8(1-\theta)^{1.256} [1 - 0.625(1-\theta)], \quad (3.8)$$

where $\sigma^* = 1 \times 10^{-3} \text{ N m}^{-1}$ and $\theta = T/T_c$, where the critical temperature $T_c = 647.096 \text{ K}$ according to Eq. (1.4).

Range of Validity. Equation (3.8) is valid along the entire vapour-liquid saturation line from the triple-point temperature T_t , Eq. (1.7), to the critical temperature T_c , Eq. (1.4), and can be extrapolated to $T = 273.15 \text{ K}$ so that it covers the temperature range

$$273.15 \text{ K} \leq T \leq 647.096 \text{ K}.$$

Computer-Program Verification. To assist the user in computer-program verification of Eq. (3.8), Table 3.9 contains corresponding test values.

Table 3.9 Surface tension values calculated from Eq. (3.8) for selected temperatures^a

$T \text{ [K]}$	$\sigma \text{ [N m}^{-1}\text{]}$
300	$0.716\ 859\ 625 \times 10^{-1}$
450	$0.428\ 914\ 992 \times 10^{-1}$
600	$0.837\ 561\ 087 \times 10^{-2}$

^aProgrammed functions should be verified using 8 byte real values for all variables.

Estimated Uncertainty. The estimated uncertainty in surface tension calculated from Eq. (3.8) is based on the uncertainty of the corresponding input data point used for the development of Eq. (3.8). These uncertainty values are given in Table 1 of the release [38].

3.4 Equation for the Dielectric Constant

A collection of experimental data available for the dielectric constant ε (relative static dielectric constant or relative static permittivity) was published in 1995 [39]. Based on a selected set of these data, an equation for the dielectric constant was developed [40]. This equation, which has its physical basis in the so-called \bar{g} -factor proposed by Harris and Alder [41], was approved by IAPWS in 1997 and is given in the “Release on the Static Dielectric Constant of Ordinary Water Substance for Temperatures from 238 K to 873 K and Pressures up to 1000 MPa” [42].

The equation for the dielectric constant reads

$$\varepsilon(\rho, T) = \frac{1 + A + 5B + (9 + 2A + 18B + A^2 + 10AB + 9B^2)^{0.5}}{4(1 - B)}, \quad (3.9)$$

where the functions A and B are given by

$$A(\rho, T) = \frac{N_A \mu^2 \rho \bar{g}}{M \varepsilon_0 k T} , \quad (3.9a)$$

and

$$B(\rho) = \frac{N_A \alpha \rho}{3 M \varepsilon_0} . \quad (3.9b)$$

The values of the quantities k , N_A , α , ε_0 , μ , and M used in Eqs. (3.9a) and (3.9b) are given in Table 3.10. The correlation equation for the Harris-Alder \bar{g} -factor in Eq. (3.9a) reads

$$\bar{g}(\delta, \tau) = 1 + \sum_{i=1}^{11} n_i \delta^{I_i} \tau^{J_i} + n_{12} \delta \left(\frac{T_c}{228 \text{ K}} \tau^{-1} - 1 \right)^{-1.2} , \quad (3.9c)$$

where $\delta = \rho / \rho_c$ and $\tau = T_c / T$, where the critical density $\rho_c = 322 \text{ kg m}^{-3}$ and the critical temperature $T_c = 647.096 \text{ K}$ according to Eqs. (1.6) and (1.4). Table 3.10 contains the coefficients n_i and exponents I_i and J_i of Eq. (3.9c).

Table 3.10 Quantities used in Eqs. (3.9a) and (3.9b)

Boltzmann's constant k	$1.380\ 658 \times 10^{-23} \text{ J K}^{-1}$
Avogadro's number N_A	$6.022\ 136\ 7 \times 10^{23} \text{ mol}^{-1}$
Mean molecular polarizability α	$1.636 \times 10^{-40} \text{ C}^2 \text{ J}^{-1} \text{ m}^2$
Permittivity of vacuum ε_0	$8.854\ 187\ 817 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$
Molecular dipole moment μ	$6.138 \times 10^{-30} \text{ C m}$
Molar mass M^a	$0.018\ 015\ 268 \text{ kg mol}^{-1}$

^aThis value for M is in accordance with the release [42] and must be used in Eqs. (3.9a) and (3.9b), although it differs slightly from the current value for the molar mass given as Eq. (1.3).

Table 3.11 Coefficients and exponents of Eq. (3.9c)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	1	0.25	0.978 224 486 826	7	4	2	$0.949\ 327\ 488\ 264 \times 10^{-1}$
2	1	1	-0.957 771 379 375	8	5	2	$-0.980\ 469\ 816\ 509 \times 10^{-2}$
3	1	2.5	0.237 511 794 148	9	6	5	$0.165\ 167\ 634\ 970 \times 10^{-4}$
4	2	1.5	0.714 692 244 396	10	7	0.5	$0.937\ 359\ 795\ 772 \times 10^{-4}$
5	3	1.5	-0.298 217 036 956	11	10	10	$-0.123\ 179\ 218\ 720 \times 10^{-9}$
6	3	2.5	-0.108 863 472 196	12	-	-	$0.196\ 096\ 504\ 426 \times 10^{-2}$

If the dielectric constant is calculated from Eq. (3.9) for given values of *pressure* and temperature, then the input quantity density ρ has to be calculated first. For this density calculation, the use of the IAPWS-95 formulation [8, 9] is recommended in the release [42]. However, as mentioned at the beginning of Chap. 3, for industrial use it is recommended that the IAPWS-IF97 basic equations, Eqs (2.3), (2.6), or (2.11), be used for calculating the input density for Eq. (3.9). For this application, the difference between IAPWS-IF97 and IAPWS-95 is negligible

compared with the estimated uncertainty of Eq. (3.9). Accordingly, the values of the dielectric constant listed in the corresponding tables in Part B were calculated in this manner.

Range of Validity. Equation (3.9) covers the following range of temperatures and pressures:

$$\begin{aligned} 273.15 \text{ K} \leq T \leq 323.15 \text{ K} \quad 0 < p \leq p_{\max} \\ 323.15 \text{ K} < T \leq 873.15 \text{ K} \quad 0 < p \leq 600 \text{ MPa}. \end{aligned}$$

The value of p_{\max} corresponds to the ice VI melting pressure [20] at the corresponding temperature or 1000 MPa, whichever is smaller. Equation (3.9) is also valid for the metastable subcooled liquid at atmospheric pressure (0.101325 MPa) for temperatures from 273.15 K down to 238.15 K. Furthermore, Eq. (3.9) extrapolates smoothly up to at least 1200 K and 1200 MPa [42]. The dielectric constant can also be calculated within this extrapolation range with the "Steam Properties Calculator" [28] or the Apps "International Steam Tables" at IOS or Android smart phones or tablets [29], assuming that it is within the range of validity of IAPWS-IF97. For the tables in Part B, ε was calculated up to 1073.15 K.

Computer-Program Verification. To assist the user in computer-program verification of Eq. (3.9), Table 3.12 contains corresponding test values.

Table 3.12 Dielectric constant values calculated from Eq. (3.9) for selected temperatures and pressures^a

Property	$T = 298.15 \text{ K}$ $p = 5 \text{ MPa}$	$T = 873.15 \text{ K}$ $p = 10 \text{ MPa}$	$T = 673.15 \text{ K}$ $p = 40 \text{ MPa}$
$\rho [\text{kg m}^{-3}]$ (IAPWS-IF97)	$0.999\ 242\ 866 \times 10^3$	$0.260\ 569\ 558 \times 10^2$	$0.523\ 371\ 289 \times 10^3$ ^b
$\varepsilon [-]$	$0.785\ 907\ 250 \times 10^2$	$0.112\ 620\ 970 \times 10^1$	$0.103\ 126\ 058 \times 10^2$

^aProgrammed functions should be verified using 8 byte real values for all variables.

^bThe density value of this test point, which is located in region 3 of IAPWS-IF97, was calculated from Eq. (2.11) via iteration.

Estimated Uncertainty. The estimated uncertainty in dielectric constant ε calculated from Eq. (3.9) is based on the uncertainty of the corresponding input data point used for the development of Eq. (3.9). These uncertainty values are given in Table 3 of the release [42].

3.5 Equation for the Refractive Index

Based on a comprehensive collection of experimental data of the refractive index n of water and steam [43], an equation for the Lorentz-Lorenz function dependent on density, temperature, and wavelength was developed in 1990 [44, 45]. This equation was refitted to the experimental data after converting the temperatures to the ITS-90 temperature scale [6] and calculating densities from IAPWS-95 [8, 9]. The refitted equation was approved by IAPWS in 1997 and is given in the "Release on the Refractive Index of Ordinary Water Substance as a Function of Wavelength, Temperature and Pressure" [46].

The equation for the refractive index n from the release was rearranged into a form explicit in n and has then the following form:

$$n(\rho, T, \bar{\lambda}) = \left(\frac{2A+1}{1-A} \right)^{0.5}, \quad (3.10)$$

where the function A is given by

$$A(\delta, \theta, \bar{\lambda}) = \delta \left(n_0 + n_1 \delta + n_2 \theta + n_3 \bar{\lambda}^2 \theta + n_4 \bar{\lambda}^{-2} + \frac{n_5}{\bar{\lambda}^2 - \bar{\lambda}_{\text{UV}}^2} + \frac{n_6}{\bar{\lambda}^2 - \bar{\lambda}_{\text{IR}}^2} + n_7 \delta^2 \right) \quad (3.10a)$$

with $\delta = \rho/\rho^*$, $\theta = T/T^*$, and $\bar{\lambda} = \bar{\lambda}/\bar{\lambda}^*$, where $\rho^* = 1000 \text{ kg m}^{-3}$, $T^* = 273.15 \text{ K}$, and $\bar{\lambda}^* = 0.589 \mu\text{m}$. The values of the reduced effective infrared resonance $\bar{\lambda}_{\text{IR}}$ and the reduced effective ultraviolet resonance $\bar{\lambda}_{\text{UV}}$ are given by $\bar{\lambda}_{\text{IR}} = 5.432\,937$ and $\bar{\lambda}_{\text{UV}} = 0.229\,202$. The coefficients n_i of Eq. (3.10a) are listed in Table 3.13.

Table 3.13 Coefficients of Eq. (3.10a)

i	n_i	i	n_i
0	0.244 257 733	4	$0.158\,920\,570 \times 10^{-2}$
1	$0.974\,634\,476 \times 10^{-2}$	5	$0.245\,934\,259 \times 10^{-2}$
2	$-0.373\,234\,996 \times 10^{-2}$	6	0.900 704 920
3	$0.268\,678\,472 \times 10^{-3}$	7	$-0.166\,626\,219 \times 10^{-1}$

If the refractive index is calculated from Eq. (3.10) for given values of *pressure* and temperature, then the input quantity reduced density δ has to be calculated first. For this density calculation, the use of IAPWS-95 formulation [8, 9] is recommended in the release [46]. However, as mentioned at the beginning of Chap. 3, for industrial use it is recommended that the IAPWS-IF97 basic equations, Eqs. (2.3), (2.6), or (2.11), be used for calculating the input density for Eq. (3.10). For this application, the difference between IAPWS-IF97 and IAPWS-95 is negligible compared with the estimated uncertainty of Eq. (3.10). Accordingly, values of the refractive index listed in the corresponding tables in Part B were calculated in this manner.

Range of Validity. IAPWS endorses Eq. (3.10) in the following validity range regarding temperature, density, and wavelength:

$$\begin{aligned} 261.15 \text{ K} &\leq T \leq 773.15 \text{ K} \\ 0 &< \rho \leq 1060 \text{ kg m}^{-3} \\ 0.2 \mu\text{m} &\leq \lambda \leq 1.1 \mu\text{m}. \end{aligned}$$

The extrapolation of the equation to longer wavelengths seems to be reasonable in liquid water at wavelengths up to $1.9 \mu\text{m}$ [46].

Computer-Program Verification. To assist the user in computer-program verification of Eq. (3.10), Table 3.13 contains corresponding test values.

Table 3.13 Refractive-index values calculated from Eq. (3.10) for selected temperatures, pressures, and wavelengths^a

Property	$T = 298.15 \text{ K}$ $p = 0.1 \text{ MPa}$	$T = 773.15 \text{ K}$ $p = 10 \text{ MPa}$	$T = 673.15 \text{ K}$ $p = 40 \text{ MPa}$
$\rho [\text{kg m}^{-3}]$ (IAPWS-IF97)	$0.997\ 047\ 435 \times 10^3$	$0.304\ 758\ 534 \times 10^2$	$0.523\ 371\ 289 \times 10^3$ ^b
$n [-]$ for $\bar{\lambda} = 0.2265 \text{ } \mu\text{m}$	$0.139\ 277\ 824 \times 10^1$	$0.101\ 098\ 988 \times 10^1$	$0.119\ 757\ 252 \times 10^1$
$n [-]$ for $\bar{\lambda} = 0.5893 \text{ } \mu\text{m}$	$0.133\ 285\ 819 \times 10^1$	$0.100\ 949\ 307 \times 10^1$	$0.116\ 968\ 699 \times 10^1$

^aProgrammed functions should be verified using 8 byte real values for all variables.

^bThe density value of this test point, which is located in region 3 of IAPWS-IF97, was calculated from Eq. (2.11) via iteration.

Estimated Uncertainty. The estimated uncertainty in refractive index calculated from Eq. (3.10) is based on the uncertainty of the corresponding input data point used for the development of Eq. (3.10). These uncertainty values are given in Table 2 of the release [46].

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Part B

Tables of the Properties of Water and Steam

In Part A (equations for the thermodynamic and transport properties), the units K for temperature and MPa for pressure are used. However, for applications in industry, the units °C and bar are usually used. Thus, in the following diagrams the units °C and bar are used.

Table 1 Saturation state (Temperature table)

The temperature table contains values on the saturated liquid ('') and saturated vapour ('') lines for the following thermodynamic and transport properties in the temperature range from 0°C up to the critical temperature $t_c = 373.946^\circ\text{C}$:

- Saturation pressure p_s
- Specific volume v
- Specific enthalpy h
- Specific enthalpy of vaporization Δh_v
- Specific entropy s
- Specific entropy of vaporization Δs_v
- Specific isobaric heat capacity c_p
- Speed of sound w
- Isentropic exponent κ
- Dynamic viscosity η
- Thermal conductivity λ

For given temperatures, the saturation pressures p_s were calculated from the IAPWS-IF97 saturation-pressure equation, Eq. (2.13).

For temperatures $t \leq 350^\circ\text{C}$ and the input values for t and p_s , all of the *thermodynamic* properties on the saturated-liquid and saturated-vapour lines were determined from the basic equations for regions 1 and 2, Eqs. (2.3) and (2.6). The density $\rho (=1/v)$, needed as one of the input quantities of the equations for the transport properties, is then also known.

For $t > 350^\circ\text{C}$, the basic equation of region 3, Eq. (2.11), was used for these calculations. With the (t, p_s) values, the densities ρ' and ρ'' , needed as one of the input quantities of Eq. (2.11), were determined by iterating this equation. With these values for (ρ', t) and (ρ'', t) , the specific volumes $v' (=1/\rho')$ and $v'' (=1/\rho'')$ are known, and the other thermodynamic properties at saturation were determined from Eq. (2.11).

The *transport* properties dynamic viscosity η and thermal conductivity λ were calculated from the equations for industrial use, Eq. (3.1) and Eq. (3.4), respectively. The values of the input quantities ρ' and ρ'' , needed in these equations, were determined from the IAPWS-IF97 basic equations as shown above.

Further saturation properties are listed in Tables 6, 11, 18, and 22.

Table 1 Saturation state
(Temperature table)

<i>t</i> [°C]	<i>T</i> [K]	<i>p_s</i> [bar]	<i>v'</i> [m ³ kg ⁻¹]	<i>v''</i> [m ³ kg ⁻¹]	<i>h'</i>	<i>h''</i> [kJ kg ⁻¹]	Δh_v	<i>s'</i> [kJ kg ⁻¹ K ⁻¹]	<i>s''</i>
0	273.15	0.006112127	0.00100021	206.140	-0.041588	2500.89	2500.93	-0.00015455	9.1558
0.01 ^a	273.16	0.006116570	0.00100021	205.997	0.00061178	2500.91	2500.91	0	9.1555
1	274.15	0.00657088	0.00100015	192.445	4.17665	2502.73	2498.55	0.015260	9.1291
2	275.15	0.00705988	0.00100011	179.764	8.39160	2504.57	2496.17	0.030606	9.1027
3	276.15	0.00758082	0.00100008	168.014	12.6035	2506.40	2493.80	0.045886	9.0765
4	277.15	0.00813549	0.00100007	157.121	16.8127	2508.24	2491.42	0.061101	9.0506
5	278.15	0.00872575	0.00100008	147.017	21.0194	2510.07	2489.05	0.076252	9.0249
6	279.15	0.00935353	0.00100011	137.638	25.2237	2511.91	2486.68	0.091340	8.9994
7	280.15	0.0100209	0.00100014	128.928	29.4258	2513.74	2484.31	0.10637	8.9742
8	281.15	0.0107299	0.00100020	120.834	33.6260	2515.57	2481.94	0.12133	8.9492
9	282.15	0.0114828	0.00100027	113.309	37.8244	2517.40	2479.58	0.13624	8.9244
10	283.15	0.0122818	0.00100035	106.309	42.0211	2519.23	2477.21	0.15109	8.8998
11	284.15	0.0131295	0.00100044	99.7927	46.2162	2521.06	2474.84	0.16587	8.8755
12	285.15	0.0140282	0.00100055	93.7243	50.4100	2522.89	2472.48	0.18061	8.8514
13	286.15	0.0149806	0.00100067	88.0698	54.6024	2524.71	2470.11	0.19528	8.8275
14	287.15	0.0159894	0.00100080	82.7981	58.7936	2526.54	2467.75	0.20990	8.8038
15	288.15	0.0170574	0.00100095	77.8807	62.9837	2528.36	2465.38	0.22447	8.7804
16	289.15	0.0181876	0.00100110	73.2915	67.1727	2530.19	2463.01	0.23898	8.7571
17	290.15	0.0193829	0.00100127	69.0063	71.3608	2532.01	2460.65	0.25344	8.7341
18	291.15	0.0206466	0.00100145	65.0029	75.5479	2533.83	2458.28	0.26785	8.7112
19	292.15	0.0219818	0.00100164	61.2609	79.7343	2535.65	2455.92	0.28220	8.6886
20	293.15	0.0233921	0.00100184	57.7615	83.9199	2537.47	2453.55	0.29650	8.6661
21	294.15	0.0248810	0.00100205	54.4873	88.1048	2539.29	2451.18	0.31075	8.6439
22	295.15	0.0264521	0.00100228	51.4225	92.2890	2541.10	2448.81	0.32495	8.6218
23	296.15	0.0281092	0.00100251	48.5521	96.4727	2542.92	2446.45	0.33910	8.6000
24	297.15	0.0298563	0.00100275	45.8626	100.656	2544.73	2444.08	0.35320	8.5783
25	298.15	0.0316975	0.00100301	43.3414	104.838	2546.54	2441.71	0.36726	8.5568
26	299.15	0.0336369	0.00100327	40.9768	109.021	2548.35	2439.33	0.38126	8.5355
27	300.15	0.0356789	0.00100354	38.7582	113.202	2550.16	2436.96	0.39521	8.5144
28	301.15	0.0378281	0.00100382	36.6754	117.384	2551.97	2434.59	0.40912	8.4934
29	302.15	0.0400892	0.00100411	34.7194	121.565	2553.78	2432.21	0.42298	8.4727
30	303.15	0.0424669	0.00100441	32.8816	125.745	2555.58	2429.84	0.43679	8.4521
31	304.15	0.0449663	0.00100472	31.1540	129.926	2557.39	2427.46	0.45056	8.4317
32	305.15	0.0475925	0.00100504	29.5295	134.106	2559.19	2425.08	0.46428	8.4115
33	306.15	0.0503508	0.00100536	28.0010	138.286	2560.99	2422.70	0.47795	8.3914
34	307.15	0.0532469	0.00100570	26.5624	142.465	2562.79	2420.32	0.49158	8.3715
35	308.15	0.0562862	0.00100604	25.2078	146.645	2564.58	2417.94	0.50517	8.3518
36	309.15	0.0594747	0.00100639	23.9318	150.824	2566.38	2415.56	0.51871	8.3323
37	310.15	0.0628185	0.00100675	22.7292	155.004	2568.17	2413.17	0.53220	8.3129
38	311.15	0.0663237	0.00100712	21.5954	159.183	2569.96	2410.78	0.54566	8.2936
39	312.15	0.0699968	0.00100749	20.5261	163.362	2571.75	2408.39	0.55906	8.2746
40	313.15	0.0738443	0.00100788	19.5170	167.541	2573.54	2406.00	0.57243	8.2557
41	314.15	0.0778731	0.00100827	18.5646	171.720	2575.33	2403.61	0.58575	8.2369
42	315.15	0.0820901	0.00100867	17.6652	175.899	2577.11	2401.21	0.59903	8.2183
43	316.15	0.0865026	0.00100908	16.8155	180.079	2578.89	2398.82	0.61227	8.1999
44	317.15	0.0911180	0.00100949	16.0126	184.258	2580.67	2396.42	0.62547	8.1816

^aTriple-point temperature.

Table 1 Saturation state – Continued
(Temperature table)

<i>t</i> [°C]	<i>c'</i> _{<i>p</i>} [kJ kg ⁻¹ K ⁻¹]	<i>c''</i> _{<i>p</i>} [m s ⁻¹]	<i>w'</i>	<i>w''</i>	<i>κ'</i> [-]	<i>κ''</i>	<i>η'</i> [10 ⁻⁶ Pa s]	<i>η''</i>	<i>λ'</i> [10 ⁻³ W m ⁻¹ K ⁻¹]
0	4.2199	1.8882	1402.3	408.88	3216538	1.3269	1792.0	8.9455	555.57
0.01 ^a	4.2199	1.8882	1402.3	408.89	3214432	1.3269	1791.4	8.9458	555.60
1	4.2165	1.8889	1407.2	409.61	3013281	1.3268	1731.2	8.9741	558.11
2	4.2134	1.8895	1412.1	410.34	2824038	1.3268	1673.7	9.0029	560.59
3	4.2105	1.8902	1416.8	411.07	2647765	1.3267	1619.2	9.0319	563.02
4	4.2078	1.8909	1421.5	411.80	2483500	1.3266	1567.4	9.0610	565.39
5	4.2054	1.8917	1426.0	412.53	2330358	1.3266	1518.3	9.0902	567.72
6	4.2031	1.8924	1430.5	413.25	2187526	1.3265	1471.6	9.1196	570.01
7	4.2011	1.8932	1434.9	413.97	2054253	1.3264	1427.2	9.1491	572.25
8	4.1992	1.8940	1439.1	414.69	1929849	1.3264	1384.8	9.1788	574.44
9	4.1974	1.8949	1443.3	415.41	1813676	1.3263	1344.5	9.2085	576.60
10	4.1958	1.8957	1447.4	416.13	1705145	1.3262	1306.0	9.2384	578.71
11	4.1943	1.8966	1451.4	416.84	1603714	1.3262	1269.2	9.2685	580.79
12	4.1930	1.8975	1455.3	417.55	1508881	1.3261	1234.1	9.2986	582.83
13	4.1917	1.8985	1459.1	418.26	1420182	1.3260	1200.5	9.3289	584.83
14	4.1905	1.8994	1462.8	418.97	1337189	1.3259	1168.4	9.3593	586.80
15	4.1894	1.9004	1466.4	419.68	1259505	1.3258	1137.6	9.3898	588.74
16	4.1884	1.9014	1470.0	420.38	1186764	1.3257	1108.1	9.4204	590.64
17	4.1875	1.9025	1473.4	421.08	1118624	1.3257	1079.9	9.4512	592.51
18	4.1866	1.9035	1476.8	421.79	1054772	1.3256	1052.7	9.4820	594.36
19	4.1858	1.9046	1480.1	422.48	994916	1.3255	1026.7	9.5130	596.17
20	4.1851	1.9057	1483.3	423.18	938786	1.3254	1001.6	9.5441	597.95
21	4.1844	1.9069	1486.4	423.88	886129	1.3253	977.56	9.5752	599.71
22	4.1838	1.9080	1489.4	424.57	836715	1.3252	954.42	9.6065	601.44
23	4.1832	1.9092	1492.4	425.26	790326	1.3251	932.15	9.6379	603.14
24	4.1827	1.9104	1495.2	425.95	746762	1.3250	910.70	9.6694	604.81
25	4.1822	1.9116	1498.0	426.63	705837	1.3249	890.04	9.7009	606.46
26	4.1817	1.9129	1500.7	427.32	667378	1.3248	870.12	9.7326	608.09
27	4.1813	1.9141	1503.4	428.00	631223	1.3247	850.91	9.7643	609.68
28	4.1809	1.9154	1505.9	428.68	597224	1.3246	832.38	9.7962	611.26
29	4.1806	1.9167	1508.4	429.36	565239	1.3245	814.50	9.8281	612.81
30	4.1803	1.9180	1510.8	430.04	535141	1.3244	797.22	9.8602	614.34
31	4.1800	1.9194	1513.2	430.72	506808	1.3243	780.54	9.8923	615.85
32	4.1798	1.9207	1515.4	431.39	480128	1.3242	764.41	9.9245	617.33
33	4.1795	1.9221	1517.6	432.06	454996	1.3241	748.81	9.9567	618.79
34	4.1794	1.9235	1519.8	432.73	431314	1.3240	733.72	9.9891	620.24
35	4.1792	1.9249	1521.8	433.40	408993	1.3239	719.12	10.022	621.66
36	4.1791	1.9263	1523.8	434.07	387946	1.3238	704.99	10.054	623.05
37	4.1790	1.9278	1525.8	434.73	368094	1.3237	691.30	10.087	624.43
38	4.1789	1.9292	1527.6	435.40	349365	1.3235	678.03	10.119	625.79
39	4.1788	1.9307	1529.4	436.06	331688	1.3234	665.18	10.152	627.13
40	4.1788	1.9322	1531.1	436.72	314999	1.3233	652.72	10.185	628.45
41	4.1788	1.9337	1532.8	437.37	299239	1.3232	640.63	10.218	629.74
42	4.1788	1.9353	1534.4	438.03	284351	1.3231	628.91	10.251	631.02
43	4.1788	1.9368	1536.0	438.68	270282	1.3230	617.53	10.284	632.28
44	4.1789	1.9384	1537.5	439.33	256983	1.3229	606.48	10.317	633.53

^a Triple-point temperature.

Table 1 Saturation state – Continued
(Temperature table)

<i>t</i> [°C]	<i>T</i> [K]	<i>p_s</i> [bar]	<i>v'</i>	<i>v''</i>	<i>h'</i>	<i>h''</i>	Δh_v	<i>s'</i>	<i>s''</i>
			[m ³ kg ⁻¹]		[kJ kg ⁻¹]		[kJ kg ⁻¹ K ⁻¹]		
45	318.15	0.0959439	0.00100991	15.2534	188.437	2582.45	2394.02	0.63862	8.1634
46	319.15	0.100988	0.00101034	14.5355	192.617	2584.23	2391.61	0.65174	8.1454
47	320.15	0.106259	0.00101078	13.8562	196.796	2586.00	2389.21	0.66481	8.1276
48	321.15	0.111764	0.00101123	13.2132	200.976	2587.77	2386.80	0.67785	8.1099
49	322.15	0.117512	0.00101168	12.6045	205.156	2589.54	2384.39	0.69084	8.0923
50	323.15	0.123513	0.00101214	12.0279	209.336	2591.31	2381.97	0.70379	8.0749
51	324.15	0.129774	0.00101260	11.4815	213.517	2593.08	2379.56	0.71671	8.0576
52	325.15	0.136305	0.00101308	10.9637	217.697	2594.84	2377.14	0.72958	8.0405
53	326.15	0.143116	0.00101356	10.4726	221.878	2596.60	2374.72	0.74242	8.0235
54	327.15	0.150215	0.00101404	10.0069	226.059	2598.35	2372.30	0.75522	8.0066
55	328.15	0.157614	0.00101454	9.56492	230.241	2600.11	2369.87	0.76798	7.9899
56	329.15	0.165322	0.00101504	9.14543	234.423	2601.86	2367.44	0.78070	7.9733
57	330.15	0.173350	0.00101555	8.74712	238.605	2603.61	2365.01	0.79339	7.9568
58	331.15	0.181708	0.00101606	8.36879	242.788	2605.36	2362.57	0.80603	7.9405
59	332.15	0.190407	0.00101658	8.00932	246.971	2607.10	2360.13	0.81864	7.9243
60	333.15	0.199458	0.00101711	7.66766	251.154	2608.85	2357.69	0.83122	7.9082
61	334.15	0.208873	0.00101765	7.34281	255.338	2610.58	2355.25	0.84375	7.8922
62	335.15	0.218664	0.00101819	7.03384	259.523	2612.32	2352.80	0.85625	7.8764
63	336.15	0.228842	0.00101874	6.73990	263.708	2614.05	2350.35	0.86872	7.8607
64	337.15	0.239421	0.00101929	6.46015	267.893	2615.78	2347.89	0.88115	7.8451
65	338.15	0.250411	0.00101985	6.19383	272.079	2617.51	2345.43	0.89354	7.8296
66	339.15	0.261827	0.00102042	5.94021	276.266	2619.23	2342.97	0.90590	7.8142
67	340.15	0.273680	0.00102100	5.69861	280.453	2620.96	2340.50	0.91823	7.7990
68	341.15	0.285986	0.00102158	5.46840	284.641	2622.67	2338.03	0.93052	7.7839
69	342.15	0.298756	0.00102216	5.24896	288.829	2624.39	2335.56	0.94277	7.7689
70	343.15	0.312006	0.00102276	5.03973	293.018	2626.10	2333.08	0.95499	7.7540
71	344.15	0.325750	0.00102336	4.84018	297.208	2627.81	2330.60	0.96718	7.7392
72	345.15	0.340001	0.00102396	4.64980	301.398	2629.51	2328.11	0.97933	7.7245
73	346.15	0.354775	0.00102458	4.46812	305.589	2631.21	2325.62	0.99146	7.7100
74	347.15	0.370088	0.00102520	4.29469	309.781	2632.91	2323.13	1.0035	7.6955
75	348.15	0.385954	0.00102582	4.12908	313.974	2634.60	2320.63	1.0156	7.6812
76	349.15	0.402389	0.00102645	3.97090	318.167	2636.29	2318.13	1.0276	7.6669
77	350.15	0.419409	0.00102709	3.81978	322.361	2637.98	2315.62	1.0396	7.6528
78	351.15	0.437031	0.00102773	3.67535	326.556	2639.66	2313.11	1.0516	7.6388
79	352.15	0.455271	0.00102838	3.53729	330.752	2641.34	2310.59	1.0635	7.6248
80	353.15	0.474147	0.00102904	3.40527	334.949	2643.01	2308.07	1.0754	7.6110
81	354.15	0.493676	0.00102970	3.27899	339.146	2644.68	2305.54	1.0873	7.5973
82	355.15	0.513875	0.00103037	3.15818	343.345	2646.35	2303.01	1.0991	7.5837
83	356.15	0.534762	0.00103105	3.04257	347.544	2648.01	2300.47	1.1109	7.5701
84	357.15	0.556355	0.00103173	2.93190	351.745	2649.67	2297.93	1.1227	7.5567
85	358.15	0.578675	0.00103242	2.82593	355.946	2651.33	2295.38	1.1344	7.5434
86	359.15	0.601738	0.00103311	2.72445	360.148	2652.98	2292.83	1.1461	7.5301
87	360.15	0.625565	0.00103381	2.62722	364.352	2654.62	2290.27	1.1578	7.5170
88	361.15	0.650174	0.00103451	2.53406	368.556	2656.26	2287.70	1.1694	7.5039
89	362.15	0.675587	0.00103522	2.44476	372.762	2657.90	2285.14	1.1811	7.4909

Table 1 Saturation state – Continued
(Temperature table)

<i>t</i> [°C]	<i>c'</i> _{<i>p</i>} [kJ kg ⁻¹ K ⁻¹]	<i>c''</i> _{<i>p</i>} [m s ⁻¹]	<i>w'</i> [m s ⁻¹]	<i>w''</i> [m s ⁻¹]	<i>κ'</i> [-]	<i>κ''</i> [-]	<i>η'</i> [10 ⁻⁶ Pa s]	<i>η''</i> [10 ⁻⁶ Pa s]	<i>λ'</i> [10 ⁻³ W m ⁻¹ K ⁻¹]	<i>λ''</i> [10 ⁻³ W m ⁻¹ K ⁻¹]
45	4.1790	1.9400	1538.9	439.98	244408	1.3228	595.76	10.350	634.75	19.881
46	4.1791	1.9416	1540.3	440.63	232515	1.3227	585.34	10.383	635.95	19.957
47	4.1792	1.9432	1541.6	441.28	221263	1.3226	575.21	10.416	637.14	20.032
48	4.1794	1.9449	1542.8	441.92	210614	1.3224	565.37	10.450	638.31	20.108
49	4.1796	1.9466	1544.0	442.56	200533	1.3223	555.81	10.483	639.46	20.184
50	4.1798	1.9482	1545.2	443.20	190987	1.3222	546.50	10.516	640.59	20.261
51	4.1800	1.9500	1546.3	443.84	181945	1.3221	537.45	10.550	641.70	20.338
52	4.1802	1.9517	1547.3	444.48	173378	1.3220	528.65	10.583	642.80	20.415
53	4.1805	1.9534	1548.3	445.11	165259	1.3219	520.08	10.617	643.88	20.492
54	4.1808	1.9552	1549.2	445.74	157561	1.3218	511.74	10.651	644.95	20.570
55	4.1811	1.9570	1550.1	446.37	150262	1.3217	503.61	10.684	645.99	20.648
56	4.1814	1.9588	1550.9	447.00	143338	1.3216	495.70	10.718	647.02	20.726
57	4.1818	1.9607	1551.7	447.63	136769	1.3214	487.99	10.752	648.04	20.805
58	4.1821	1.9625	1552.4	448.25	130534	1.3213	480.48	10.786	649.03	20.884
59	4.1825	1.9644	1553.1	448.88	124615	1.3212	473.16	10.820	650.01	20.963
60	4.1829	1.9664	1553.7	449.50	118994	1.3211	466.02	10.854	650.98	21.043
61	4.1834	1.9683	1554.3	450.11	113655	1.3210	459.06	10.887	651.92	21.123
62	4.1838	1.9703	1554.8	450.73	108583	1.3209	452.28	10.921	652.85	21.204
63	4.1843	1.9723	1555.3	451.34	103762	1.3208	445.66	10.956	653.77	21.284
64	4.1848	1.9743	1555.8	451.95	99180	1.3206	439.20	10.990	654.67	21.366
65	4.1853	1.9764	1556.2	452.56	94823	1.3205	432.89	11.024	655.55	21.447
66	4.1859	1.9785	1556.5	453.17	90679	1.3204	426.74	11.058	656.42	21.529
67	4.1864	1.9806	1556.8	453.77	86736	1.3203	420.73	11.092	657.27	21.611
68	4.1870	1.9828	1557.1	454.38	82985	1.3202	414.86	11.126	658.11	21.694
69	4.1876	1.9850	1557.3	454.98	79414	1.3200	409.14	11.160	658.93	21.777
70	4.1882	1.9873	1557.5	455.57	76015	1.3199	403.54	11.195	659.74	21.860
71	4.1889	1.9895	1557.6	456.17	72777	1.3198	398.07	11.229	660.53	21.944
72	4.1896	1.9919	1557.7	456.76	69694	1.3197	392.73	11.263	661.31	22.028
73	4.1902	1.9942	1557.7	457.35	66756	1.3195	387.50	11.298	662.07	22.113
74	4.1910	1.9966	1557.7	457.94	63956	1.3194	382.40	11.332	662.81	22.198
75	4.1917	1.9990	1557.7	458.52	61287	1.3193	377.41	11.367	663.54	22.283
76	4.1924	2.0015	1557.6	459.11	58742	1.3191	372.53	11.401	664.26	22.369
77	4.1932	2.0041	1557.5	459.69	56315	1.3190	367.75	11.435	664.96	22.455
78	4.1940	2.0066	1557.4	460.26	54000	1.3189	363.08	11.470	665.65	22.542
79	4.1948	2.0092	1557.2	460.84	51791	1.3187	358.51	11.504	666.32	22.629
80	4.1956	2.0119	1557.0	461.41	49684	1.3186	354.04	11.539	666.98	22.717
81	4.1965	2.0146	1556.7	461.98	47671	1.3185	349.67	11.573	667.62	22.805
82	4.1974	2.0174	1556.4	462.55	45750	1.3183	345.39	11.608	668.25	22.893
83	4.1983	2.0202	1556.1	463.11	43915	1.3182	341.19	11.643	668.87	22.982
84	4.1992	2.0231	1555.7	463.67	42163	1.3180	337.09	11.677	669.47	23.072
85	4.2001	2.0260	1555.3	464.23	40488	1.3179	333.07	11.712	670.06	23.162
86	4.2011	2.0290	1554.8	464.79	38888	1.3177	329.13	11.746	670.63	23.252
87	4.2020	2.0321	1554.4	465.34	37359	1.3176	325.28	11.781	671.19	23.343
88	4.2030	2.0352	1553.8	465.89	35896	1.3174	321.50	11.816	671.73	23.434
89	4.2041	2.0383	1553.3	466.44	34498	1.3173	317.80	11.850	672.26	23.526

Table 1 Saturation state – Continued
(Temperature table)

<i>t</i> [°C]	<i>T</i> [K]	<i>p_s</i> [bar]	<i>v'</i>	<i>v''</i>	<i>h'</i>	<i>h''</i>	Δh_v	<i>s'</i>	<i>s''</i>
			[m ³ kg ⁻¹]		[kJ kg ⁻¹]		[kJ kg ⁻¹ K ⁻¹]		
90	363.15	0.701824	0.00103594	2.35915	376.968	2659.53	2282.56	1.1927	7.4781
91	364.15	0.728904	0.00103667	2.27705	381.176	2661.16	2279.98	1.2042	7.4653
92	365.15	0.756849	0.00103740	2.19830	385.385	2662.78	2277.39	1.2158	7.4526
93	366.15	0.785681	0.00103813	2.12275	389.595	2664.39	2274.80	1.2273	7.4400
94	367.15	0.815420	0.00103887	2.05025	393.806	2666.01	2272.20	1.2387	7.4275
95	368.15	0.846089	0.00103962	1.98065	398.019	2667.61	2269.60	1.2502	7.4150
96	369.15	0.877711	0.00104038	1.91383	402.232	2669.22	2266.98	1.2616	7.4027
97	370.15	0.910308	0.00104114	1.84965	406.447	2670.81	2264.37	1.2730	7.3904
98	371.15	0.943902	0.00104190	1.78801	410.663	2672.40	2261.74	1.2844	7.3782
99	372.15	0.978518	0.00104268	1.72878	414.880	2673.99	2259.11	1.2957	7.3661
100	373.15	1.01418	0.00104346	1.67186	419.099	2675.57	2256.47	1.3070	7.3541
102	375.15	1.08873	0.00104503	1.56454	427.541	2678.72	2251.18	1.3296	7.3303
104	377.15	1.16776	0.00104663	1.46529	435.988	2681.84	2245.85	1.3520	7.3068
106	379.15	1.25147	0.00104826	1.37342	444.440	2684.94	2240.50	1.3743	7.2836
108	381.15	1.34007	0.00104991	1.28831	452.899	2688.02	2235.12	1.3965	7.2607
110	383.15	1.43376	0.00105158	1.20939	461.363	2691.07	2229.70	1.4187	7.2380
112	385.15	1.53277	0.00105328	1.13615	469.834	2694.09	2224.26	1.4407	7.2157
114	387.15	1.63734	0.00105500	1.06813	478.312	2697.09	2218.78	1.4626	7.1937
116	389.15	1.74768	0.00105675	1.00489	486.796	2700.07	2213.27	1.4844	7.1719
118	391.15	1.86404	0.00105853	0.946070	495.287	2703.02	2207.73	1.5062	7.1504
120	393.15	1.98665	0.00106033	0.891304	503.785	2705.93	2202.15	1.5278	7.1291
122	395.15	2.11578	0.00106215	0.840276	512.290	2708.82	2196.53	1.5494	7.1081
124	397.15	2.25168	0.00106400	0.792695	520.803	2711.69	2190.88	1.5708	7.0873
126	399.15	2.39460	0.00106588	0.748294	529.323	2714.52	2185.19	1.5922	7.0668
128	401.15	2.54481	0.00106778	0.706832	537.851	2717.32	2179.47	1.6134	7.0465
130	403.15	2.70260	0.00106971	0.668084	546.388	2720.09	2173.70	1.6346	7.0264
132	405.15	2.86823	0.00107167	0.631849	554.933	2722.83	2167.89	1.6557	7.0066
134	407.15	3.04199	0.00107365	0.597939	563.486	2725.53	2162.04	1.6767	6.9869
136	409.15	3.22417	0.00107566	0.566183	572.048	2728.20	2156.15	1.6977	6.9675
138	411.15	3.41508	0.00107770	0.536425	580.620	2730.84	2150.22	1.7185	6.9483
140	413.15	3.61501	0.00107976	0.508519	589.200	2733.44	2144.24	1.7393	6.9293
142	415.15	3.82427	0.00108185	0.482334	597.790	2736.01	2138.22	1.7600	6.9105
144	417.15	4.04318	0.00108397	0.457748	606.390	2738.54	2132.15	1.7806	6.8918
146	419.15	4.27205	0.00108612	0.434648	615.000	2741.04	2126.04	1.8011	6.8734
148	421.15	4.51122	0.00108830	0.412931	623.621	2743.50	2119.88	1.8216	6.8551
150	423.15	4.76101	0.00109050	0.392502	632.252	2745.92	2113.67	1.8420	6.8370
152	425.15	5.02177	0.00109274	0.373273	640.893	2748.30	2107.41	1.8623	6.8191
154	427.15	5.29383	0.00109501	0.355162	649.546	2750.64	2101.10	1.8825	6.8014
156	429.15	5.57755	0.00109730	0.338095	658.211	2752.95	2094.74	1.9027	6.7838
158	431.15	5.87329	0.00109963	0.322002	666.887	2755.21	2088.32	1.9228	6.7664
160	433.15	6.18139	0.00110199	0.306818	675.575	2757.43	2081.86	1.9428	6.7491
162	435.15	6.50224	0.00110438	0.292486	684.275	2759.61	2075.33	1.9627	6.7320
164	437.15	6.83619	0.00110680	0.278948	692.988	2761.75	2068.76	1.9826	6.7150
166	439.15	7.18364	0.00110925	0.266155	701.714	2763.84	2062.13	2.0025	6.6982
168	441.15	7.54495	0.00111174	0.254059	710.453	2765.89	2055.44	2.0222	6.6815

Table 1 Saturation state – Continued
(Temperature table)

<i>t</i> [°C]	<i>c'</i> _{<i>p</i>} [kJ kg ⁻¹ K ⁻¹]	<i>c''</i> _{<i>p</i>} [m s ⁻¹]	<i>w'</i> [m s ⁻¹]	<i>w''</i> [m s ⁻¹]	<i>κ'</i> [-]	<i>κ''</i> [-]	<i>η'</i> [10 ⁻⁶ Pa s]	<i>η''</i> [10 ⁻⁶ Pa s]	<i>λ'</i> [10 ⁻³ W m ⁻¹ K ⁻¹]	<i>λ''</i> [10 ⁻³ W m ⁻¹ K ⁻¹]
90	4.2051	2.0415	1552.7	466.98	33160	1.3171	314.17	11.885	672.78	23.618
91	4.2062	2.0448	1552.1	467.52	31881	1.3169	310.62	11.920	673.29	23.711
92	4.2072	2.0482	1551.4	468.06	30656	1.3168	307.13	11.954	673.78	23.804
93	4.2083	2.0516	1550.8	468.60	29484	1.3166	303.72	11.989	674.25	23.898
94	4.2095	2.0551	1550.0	469.13	28363	1.3164	300.37	12.024	674.72	23.993
95	4.2106	2.0586	1549.3	469.66	27288	1.3163	297.09	12.059	675.17	24.088
96	4.2118	2.0623	1548.5	470.18	26260	1.3161	293.86	12.093	675.60	24.183
97	4.2130	2.0660	1547.7	470.71	25275	1.3159	290.71	12.128	676.03	24.279
98	4.2142	2.0697	1546.9	471.23	24331	1.3157	287.61	12.163	676.44	24.375
99	4.2154	2.0736	1546.0	471.74	23426	1.3155	284.57	12.197	676.83	24.473
100	4.2166	2.0775	1545.1	472.26	22559	1.3153	281.59	12.232	677.22	24.570
102	4.2192	2.0856	1543.2	473.27	20931	1.3150	275.79	12.302	677.95	24.767
104	4.2219	2.0940	1541.2	474.28	19434	1.3146	270.20	12.371	678.62	24.967
106	4.2246	2.1027	1539.0	475.26	18056	1.3142	264.81	12.441	679.25	25.168
108	4.2274	2.1118	1536.8	476.24	16786	1.3137	259.62	12.510	679.82	25.373
110	4.2304	2.1212	1534.4	477.20	15616	1.3133	254.61	12.580	680.35	25.579
112	4.2334	2.1310	1532.0	478.15	14537	1.3128	249.78	12.649	680.83	25.788
114	4.2365	2.1411	1529.4	479.08	13541	1.3124	245.11	12.718	681.25	26.000
116	4.2397	2.1517	1526.7	480.00	12620	1.3119	240.60	12.788	681.63	26.215
118	4.2430	2.1626	1523.9	480.90	11769	1.3114	236.24	12.857	681.96	26.432
120	4.2464	2.1740	1521.0	481.79	10982	1.3109	232.03	12.927	682.24	26.652
122	4.2499	2.1858	1518.0	482.66	10254	1.3104	227.96	12.996	682.48	26.874
124	4.2535	2.1979	1514.9	483.52	9579.0	1.3098	224.02	13.065	682.66	27.100
126	4.2571	2.2105	1511.7	484.36	8953.5	1.3093	220.21	13.134	682.80	27.329
128	4.2609	2.2236	1508.4	485.19	8373.3	1.3087	216.52	13.204	682.90	27.560
130	4.2648	2.2370	1505.0	486.00	7834.9	1.3082	212.94	13.273	682.95	27.795
132	4.2689	2.2509	1501.5	486.79	7334.8	1.3076	209.48	13.342	682.95	28.032
134	4.2730	2.2653	1497.9	487.57	6870.2	1.3070	206.12	13.411	682.91	28.273
136	4.2772	2.2800	1494.3	488.34	6438.1	1.3064	202.86	13.480	682.83	28.517
138	4.2816	2.2953	1490.5	489.08	6036.2	1.3057	199.71	13.549	682.70	28.765
140	4.2860	2.3109	1486.6	489.81	5662.0	1.3051	196.64	13.618	682.52	29.015
142	4.2906	2.3270	1482.7	490.53	5313.5	1.3044	193.67	13.686	682.31	29.269
144	4.2953	2.3436	1478.6	491.22	4988.6	1.3038	190.78	13.755	682.05	29.527
146	4.3002	2.3606	1474.5	491.90	4685.7	1.3031	187.98	13.824	681.75	29.788
148	4.3052	2.3780	1470.3	492.57	4403.1	1.3024	185.26	13.893	681.40	30.053
150	4.3103	2.3959	1466.0	493.22	4139.3	1.3018	182.61	13.961	681.01	30.321
152	4.3155	2.4142	1461.6	493.85	3892.9	1.3011	180.04	14.030	680.59	30.593
154	4.3209	2.4329	1457.1	494.46	3662.7	1.3004	177.54	14.098	680.12	30.869
156	4.3264	2.4521	1452.5	495.06	3447.4	1.2997	175.10	14.167	679.61	31.149
158	4.3321	2.4717	1447.9	495.64	3246.0	1.2990	172.73	14.235	679.20	31.433
160	4.3379	2.4918	1443.2	496.21	3057.5	1.2982	170.43	14.304	678.73	31.720
162	4.3439	2.5123	1438.4	496.75	2881.0	1.2975	168.19	14.372	678.18	32.012
164	4.3501	2.5332	1433.5	497.28	2715.7	1.2968	166.00	14.440	677.58	32.308
166	4.3564	2.5545	1428.5	497.80	2560.8	1.2961	163.87	14.508	676.94	32.608
168	4.3628	2.5763	1423.4	498.30	2415.5	1.2953	161.80	14.577	676.25	32.912

Table 1 Saturation state – Continued
(Temperature table)

<i>t</i> [°C]	<i>T</i> [K]	<i>p_s</i> [bar]	<i>v'</i>	<i>v''</i>	<i>h'</i>	<i>h''</i>	Δh_v	<i>s'</i>	<i>s''</i>
			[m ³ kg ⁻¹]		[kJ kg ⁻¹]		[kJ kg ⁻¹ K ⁻¹]		
170	443.15	7.92053	0.00111426	0.242616	719.206	2767.89	2048.69	2.0419	6.6649
172	445.15	8.31077	0.00111682	0.231785	727.973	2769.85	2041.88	2.0616	6.6485
174	447.15	8.71606	0.00111941	0.221528	736.755	2771.77	2035.01	2.0811	6.6322
176	449.15	9.13681	0.00112203	0.211810	745.551	2773.63	2028.08	2.1007	6.6161
178	451.15	9.57343	0.00112469	0.202598	754.362	2775.45	2021.09	2.1201	6.6000
180	453.15	10.0263	0.00112739	0.193862	763.188	2777.22	2014.03	2.1395	6.5841
182	455.15	10.4960	0.00113012	0.185572	772.030	2778.94	2006.91	2.1589	6.5682
184	457.15	10.9827	0.00113289	0.177703	780.889	2780.61	1999.72	2.1782	6.5525
186	459.15	11.4871	0.00113570	0.170229	789.764	2782.23	1992.47	2.1974	6.5369
188	461.15	12.0094	0.00113855	0.163127	798.656	2783.80	1985.14	2.2166	6.5214
190	463.15	12.5502	0.00114144	0.156377	807.566	2785.31	1977.74	2.2358	6.5060
192	465.15	13.1099	0.00114437	0.149957	816.494	2786.77	1970.28	2.2549	6.4907
194	467.15	13.6889	0.00114734	0.143848	825.440	2788.18	1962.74	2.2739	6.4755
196	469.15	14.2877	0.00115036	0.138034	834.405	2789.53	1955.12	2.2929	6.4603
198	471.15	14.9069	0.00115341	0.132497	843.389	2790.82	1947.44	2.3119	6.4453
200	473.15	15.5467	0.00115651	0.127222	852.393	2792.06	1939.67	2.3308	6.4303
202	475.15	16.2078	0.00115966	0.122195	861.417	2793.24	1931.82	2.3497	6.4154
204	477.15	16.8906	0.00116285	0.117402	870.463	2794.36	1923.90	2.3685	6.4006
206	479.15	17.5955	0.00116609	0.112830	879.529	2795.42	1915.89	2.3873	6.3858
208	481.15	18.3231	0.00116937	0.108467	888.618	2796.42	1907.80	2.4060	6.3711
210	483.15	19.0739	0.00117271	0.104302	897.729	2797.35	1899.62	2.4248	6.3565
212	485.15	19.8483	0.00117609	0.100325	906.863	2798.22	1891.36	2.4434	6.3420
214	487.15	20.6470	0.00117953	0.0965249	916.021	2799.03	1883.01	2.4621	6.3275
216	489.15	21.4702	0.00118302	0.0928934	925.203	2799.77	1874.57	2.4807	6.3130
218	491.15	22.3187	0.00118656	0.0894214	934.409	2800.45	1866.04	2.4993	6.2986
220	493.15	23.1929	0.00119016	0.0861007	943.642	2801.05	1857.41	2.5178	6.2842
222	495.15	24.0933	0.00119381	0.0829236	952.900	2801.59	1848.69	2.5363	6.2699
224	497.15	25.0205	0.00119752	0.0798826	962.185	2802.05	1839.87	2.5548	6.2557
226	499.15	25.9749	0.00120129	0.0769710	971.498	2802.45	1830.95	2.5733	6.2414
228	501.15	26.9572	0.00120512	0.0741823	980.839	2802.76	1821.93	2.5917	6.2272
230	503.15	27.9679	0.00120901	0.0715102	990.210	2803.01	1812.80	2.6102	6.2131
232	505.15	29.0075	0.00121297	0.0689492	999.609	2803.18	1803.57	2.6285	6.1989
234	507.15	30.0767	0.00121699	0.0664936	1009.04	2803.27	1794.23	2.6469	6.1848
236	509.15	31.1758	0.00122108	0.0641385	1018.50	2803.28	1784.78	2.6653	6.1707
238	511.15	32.3056	0.00122523	0.0618788	1028.00	2803.21	1775.22	2.6836	6.1566
240	513.15	33.4665	0.00122946	0.0597101	1037.52	2803.06	1765.54	2.7019	6.1425
242	515.15	34.6592	0.00123376	0.0576280	1047.08	2802.82	1755.74	2.7203	6.1285
244	517.15	35.8843	0.00123814	0.0556284	1056.68	2802.50	1745.82	2.7385	6.1144
246	519.15	37.1423	0.00124259	0.0537073	1066.31	2802.10	1735.78	2.7568	6.1003
248	521.15	38.4338	0.00124712	0.0518612	1075.98	2801.60	1725.62	2.7751	6.0863
250	523.15	39.7594	0.00125174	0.0500866	1085.69	2801.01	1715.33	2.7934	6.0722
252	525.15	41.1197	0.00125644	0.0483801	1095.43	2800.33	1704.90	2.8117	6.0582
254	527.15	42.5154	0.00126122	0.0467386	1105.22	2799.56	1694.34	2.8299	6.0441
256	529.15	43.9471	0.00126610	0.0451592	1115.04	2798.69	1683.64	2.8482	6.0300
258	531.15	45.4153	0.00127107	0.0436390	1124.91	2797.71	1672.80	2.8664	6.0158

Table 1 Saturation state – Continued
(Temperature table)

<i>t</i> [°C]	<i>c'</i> _{<i>p</i>} [kJ kg ⁻¹ K ⁻¹]	<i>c''</i> _{<i>p</i>} [m s ⁻¹]	<i>w'</i> [m s ⁻¹]	<i>w''</i> [m s ⁻¹]	<i>κ'</i> [-]	<i>κ''</i> [-]	<i>η'</i> [10 ⁻⁶ Pa s]	<i>η''</i> [10 ⁻⁶ Pa s]	<i>λ'</i> [10 ⁻³ W m ⁻¹ K ⁻¹]	<i>λ''</i> [10 ⁻³ W m ⁻¹ K ⁻¹]
170	4.3695	2.5985	1418.3	498.78	2279.1	1.2946	159.78	14.645	675.52	33.221
172	4.3763	2.6212	1413.0	499.24	2151.2	1.2939	157.80	14.713	674.75	33.534
174	4.3833	2.6443	1407.7	499.68	2031.1	1.2931	155.88	14.781	673.94	33.851
176	4.3906	2.6679	1402.3	500.11	1918.3	1.2924	154.00	14.849	673.09	34.173
178	4.3980	2.6919	1396.9	500.52	1812.2	1.2916	152.17	14.917	672.21	34.500
180	4.4056	2.7164	1391.3	500.92	1712.5	1.2909	150.38	14.985	671.28	34.832
182	4.4134	2.7414	1385.7	501.29	1618.8	1.2902	148.64	15.053	670.32	35.168
184	4.4214	2.7669	1380.0	501.65	1530.5	1.2894	146.93	15.121	669.32	35.509
186	4.4296	2.7928	1374.2	501.99	1447.5	1.2887	145.27	15.189	668.29	35.855
188	4.4381	2.8193	1368.3	502.31	1369.3	1.2879	143.64	15.257	667.21	36.206
190	4.4468	2.8464	1362.4	502.61	1295.7	1.2872	142.05	15.325	666.11	36.563
192	4.4557	2.8739	1356.4	502.90	1226.3	1.2864	140.49	15.394	664.96	36.924
194	4.4649	2.9021	1350.3	503.16	1160.8	1.2857	138.96	15.462	663.78	37.291
196	4.4743	2.9308	1344.1	503.41	1099.1	1.2850	137.47	15.530	662.56	37.664
198	4.4840	2.9601	1337.8	503.63	1040.9	1.2842	136.02	15.598	661.31	38.042
200	4.4940	2.9900	1331.5	503.84	986.01	1.2835	134.59	15.666	660.03	38.426
202	4.5043	3.0206	1325.1	504.03	934.17	1.2827	133.19	15.735	658.71	38.815
204	4.5148	3.0518	1318.6	504.19	885.21	1.2820	131.82	15.803	657.35	39.211
206	4.5256	3.0837	1312.0	504.34	838.97	1.2812	130.48	15.872	655.96	39.612
208	4.5368	3.1163	1305.4	504.46	795.28	1.2804	129.16	15.940	654.53	40.020
210	4.5482	3.1496	1298.7	504.57	753.98	1.2797	127.87	16.009	653.07	40.434
212	4.5600	3.1837	1291.9	504.65	714.94	1.2789	126.60	16.078	651.58	40.855
214	4.5722	3.2186	1285.0	504.71	678.02	1.2782	125.36	16.147	650.05	41.282
216	4.5846	3.2542	1278.1	504.75	643.09	1.2774	124.14	16.216	648.49	41.716
218	4.5975	3.2907	1271.0	504.76	610.04	1.2766	122.95	16.285	646.90	42.157
220	4.6107	3.3280	1263.9	504.76	578.76	1.2759	121.77	16.354	645.27	42.605
222	4.6243	3.3662	1256.8	504.73	549.14	1.2751	120.62	16.424	643.61	43.060
224	4.6383	3.4053	1249.5	504.68	521.09	1.2743	119.48	16.494	641.92	43.523
226	4.6528	3.4453	1242.2	504.60	494.52	1.2735	118.37	16.564	640.19	43.994
228	4.6676	3.4863	1234.8	504.50	469.35	1.2728	117.27	16.634	638.43	44.472
230	4.6829	3.5283	1227.3	504.38	445.49	1.2720	116.19	16.705	636.63	44.959
232	4.6987	3.5713	1219.8	504.23	422.87	1.2712	115.13	16.776	634.81	45.454
234	4.7150	3.6154	1212.2	504.05	401.43	1.2704	114.09	16.847	632.95	45.958
236	4.7317	3.6606	1204.5	503.85	381.09	1.2696	113.06	16.918	631.05	46.470
238	4.7490	3.7070	1196.7	503.63	361.80	1.2688	112.05	16.990	629.13	46.992
240	4.7668	3.7545	1188.8	503.38	343.49	1.2680	111.06	17.062	627.17	47.523
242	4.7852	3.8033	1180.9	503.10	326.12	1.2672	110.07	17.135	625.18	48.065
244	4.8042	3.8534	1172.9	502.79	309.63	1.2664	109.11	17.208	623.15	48.616
246	4.8238	3.9048	1164.8	502.46	293.97	1.2656	108.15	17.281	621.09	49.178
248	4.8441	3.9576	1156.6	502.10	279.10	1.2648	107.21	17.355	619.00	49.751
250	4.8650	4.0119	1148.4	501.71	264.98	1.2640	106.28	17.429	616.88	50.336
252	4.8866	4.0677	1140.0	501.30	251.56	1.2632	105.37	17.504	614.72	50.932
254	4.9089	4.1251	1131.6	500.85	238.81	1.2624	104.46	17.580	612.54	51.541
256	4.9320	4.1843	1123.1	500.38	226.70	1.2616	103.57	17.656	610.31	52.162
258	4.9560	4.2452	1114.5	499.87	215.179	1.2608	102.68	17.732	608.06	52.797

Table 1 Saturation state – Continued
 (Temperature table)

<i>t</i> [°C]	<i>T</i> [K]	<i>p_s</i> [bar]	<i>v'</i>	<i>v''</i>	<i>h'</i>	<i>h''</i>	Δh_v	<i>s'</i>	<i>s''</i>
			[m ³ kg ⁻¹]		[kJ kg ⁻¹]		[kJ kg ⁻¹ K ⁻¹]		
260	533.15	46.9207	0.00127613	0.0421755	1134.83	2796.64	1661.82	2.8847	6.0017
262	535.15	48.4640	0.00128129	0.0407660	1144.78	2795.47	1650.68	2.9030	5.9875
264	537.15	50.0457	0.00128656	0.0394082	1154.79	2794.19	1639.40	2.9213	5.9733
266	539.15	51.6666	0.00129193	0.0380997	1164.84	2792.80	1627.96	2.9396	5.9590
268	541.15	53.3273	0.00129741	0.0368385	1174.94	2791.30	1616.36	2.9579	5.9448
270	543.15	55.0284	0.00130301	0.0356224	1185.09	2789.69	1604.60	2.9762	5.9304
272	545.15	56.7706	0.00130872	0.0344496	1195.30	2787.96	1592.66	2.9945	5.9160
274	547.15	58.5547	0.00131455	0.0333180	1205.55	2786.11	1580.56	3.0129	5.9016
276	549.15	60.3812	0.00132052	0.0322260	1215.87	2784.14	1568.28	3.0312	5.8871
278	551.15	62.2510	0.00132661	0.0311719	1226.24	2782.05	1555.81	3.0496	5.8725
280	553.15	64.1646	0.00133285	0.0301540	1236.67	2779.82	1543.15	3.0681	5.8578
282	555.15	66.1228	0.00133922	0.0291708	1247.16	2777.47	1530.30	3.0865	5.8431
284	557.15	68.1264	0.00134575	0.0282208	1257.72	2774.97	1517.25	3.1050	5.8283
286	559.15	70.1760	0.00135243	0.0273027	1268.34	2772.34	1504.00	3.1236	5.8134
288	561.15	72.2724	0.00135928	0.0264152	1279.03	2769.56	1490.53	3.1421	5.7984
290	563.15	74.4164	0.00136629	0.0255568	1289.80	2766.63	1476.84	3.1608	5.7832
292	565.15	76.6087	0.00137349	0.0247265	1300.63	2763.55	1462.92	3.1794	5.7680
294	567.15	78.8502	0.00138087	0.0239231	1311.54	2760.31	1448.76	3.1982	5.7526
296	569.15	81.1415	0.00138844	0.0231454	1322.54	2756.90	1434.37	3.2170	5.7372
298	571.15	83.4835	0.00139622	0.0223924	1333.61	2753.33	1419.72	3.2358	5.7215
300	573.15	85.8771	0.00140422	0.0216631	1344.77	2749.57	1404.80	3.2547	5.7058
305	578.15	92.0919	0.00142524	0.0199370	1373.07	2739.38	1366.30	3.3024	5.6656
310	583.15	98.6475	0.00144788	0.0183389	1402.00	2727.92	1325.92	3.3506	5.6243
315	588.15	105.558	0.00147239	0.0168557	1431.63	2715.08	1283.45	3.3994	5.5816
320	593.15	112.839	0.00149906	0.0154759	1462.05	2700.67	1238.62	3.4491	5.5373
325	598.15	120.505	0.00152830	0.0141887	1493.37	2684.48	1191.11	3.4997	5.4911
330	603.15	128.575	0.00156060	0.0129840	1525.74	2666.25	1140.51	3.5516	5.4425
335	608.15	137.067	0.00159667	0.0118522	1559.34	2645.60	1086.26	3.6048	5.3910
340	613.15	146.002	0.00163751	0.0107838	1594.45	2622.07	1027.62	3.6599	5.3359
345	618.15	155.401	0.00168460	0.0097698	1631.44	2595.01	963.57	3.7175	5.2763
350	623.15	165.292	0.00174007	0.0088009	1670.86	2563.59	892.73	3.7783	5.2109
355	628.15	175.701	0.00180780	0.0078660	1713.71	2526.45	812.74	3.8438	5.1377
360	633.15	186.664	0.00189451	0.0069449	1761.49	2480.99	719.50	3.9164	5.0527
365	638.15	198.222	0.00201561	0.0060044	1817.59	2422.00	604.41	4.0011	4.9482
370	643.15	210.434	0.00222209	0.0049462	1892.64	2333.50	440.86	4.1142	4.7996
371	644.15	212.964	0.00229020	0.0046914	1913.25	2307.45	394.20	4.1453	4.7573
372	645.15	215.528	0.00238170	0.0043985	1938.54	2274.69	336.15	4.1836	4.7046
373	646.15	218.132	0.00252643	0.0040212	1974.14	2227.55	253.42	4.2377	4.6299
373.946 ^a	647.096	220.640	0.00310559		2087.55	0		4.4120	

^aCritical temperature.

Table 1 Saturation state – Continued
(Temperature table)

t [°C]	c'_p [$\text{kJ kg}^{-1} \text{K}^{-1}$]	c''_p [m s^{-1}]	w'	w''	κ' [–]	κ''	η' [10^{-6}Pa s]	η''	λ' [$10^{-3} \text{W m}^{-1} \text{K}^{-1}$]	λ''
260	4.9807	4.3080	1105.8	499.33	204.228	1.2600	101.81	17.810	605.77	53.446
262	5.0064	4.3728	1097.0	498.77	193.814	1.2592	100.95	17.888	603.45	54.109
264	5.0330	4.4398	1088.2	498.17	183.910	1.2583	100.09	17.966	601.09	54.788
266	5.0605	4.5090	1079.2	497.53	174.488	1.2575	99.249	18.046	598.70	55.483
268	5.0891	4.5806	1070.1	496.87	165.523	1.2567	98.413	18.126	596.28	56.195
270	5.1188	4.6547	1061.0	496.16	156.993	1.2559	97.584	18.208	593.82	56.925
272	5.1496	4.7316	1051.7	495.43	148.874	1.2550	96.764	18.290	591.33	57.673
274	5.1817	4.8114	1042.3	494.65	141.145	1.2542	95.950	18.373	588.81	58.441
276	5.2150	4.8942	1032.8	493.84	133.788	1.2533	95.144	18.457	586.25	59.230
278	5.2497	4.9804	1023.2	493.00	126.782	1.2525	94.344	18.543	583.65	60.041
280	5.2859	5.0701	1013.5	492.11	120.111	1.2516	93.550	18.630	581.02	60.876
282	5.3236	5.1636	1003.7	491.18	113.759	1.2508	92.761	18.717	578.35	61.735
284	5.3629	5.2611	993.72	490.21	107.709	1.2499	91.978	18.807	575.65	62.620
286	5.4040	5.3629	983.64	489.20	101.947	1.2490	91.200	18.897	572.91	63.534
288	5.4469	5.4693	973.44	488.14	96.459	1.2481	90.427	18.989	570.13	64.478
290	5.4918	5.5806	963.12	487.04	91.232	1.2472	89.657	19.083	567.32	65.453
292	5.5389	5.6971	952.67	485.89	86.255	1.2463	88.891	19.179	564.46	66.463
294	5.5882	5.8192	942.10	484.69	81.516	1.2454	88.128	19.276	561.57	67.510
296	5.6399	5.9473	931.42	483.45	77.005	1.2445	87.369	19.375	558.64	68.595
298	5.6943	6.0818	920.61	482.16	72.710	1.2436	86.611	19.476	555.66	69.723
300	5.7515	6.2231	909.69	480.81	68.623	1.2427	85.856	19.580	552.65	70.896
305	5.9083	6.6096	881.91	477.21	59.257	1.2404	83.973	19.849	544.92	74.052
310	6.0883	7.0513	853.50	473.27	51.002	1.2381	82.092	20.135	536.92	77.580
315	6.2968	7.5610	824.43	468.96	43.732	1.2360	80.207	20.442	528.62	81.568
320	6.5414	8.1575	794.58	464.25	37.325	1.2342	78.308	20.773	520.00	86.131
325	6.8331	8.8689	763.55	459.12	31.656	1.2328	76.386	21.133	511.05	91.429
330	7.1888	9.7381	730.70	453.52	26.609	1.2320	74.429	21.531	501.75	97.687
335	7.6354	10.830	695.31	447.37	22.090	1.2320	72.418	21.974	492.06	105.23
340	8.2166	12.241	657.03	440.59	18.056	1.2329	70.332	22.476	481.98	114.52
345	9.0023	14.112	616.71	433.05	14.528	1.2352	68.139	23.055	471.46	126.21
350	10.102	16.641	576.91	424.63	11.572	1.2395	65.797	23.740	460.46	141.18
355	11.858	20.714	531.75	414.79	8.9021	1.2449	63.229	24.573	449.40	162.00
360	14.874	27.570	483.70	402.76	6.6159	1.2513	60.319	25.640	438.94	192.01
365	21.476	42.013	430.66	387.25	4.6421	1.2600	56.806	27.120	432.46	240.61
370	47.096	93.401	370.01	364.77	2.9278	1.2784	51.902	29.596	447.05	345.01
371	64.099	125.06	356.40	358.38	2.6044	1.2855	50.515	30.396	460.07	387.62
372	101.16	190.33	342.02	350.51	2.2788	1.2959	48.798	31.456	486.32	454.50
373	231.91	401.13	326.59	339.58	1.9354	1.3146	46.378	33.106	560.02	595.59
373.946 ^a	— ^b	— ^b	— ^b	— ^b	— ^b	— ^b	— ^c	— ^c	— ^c	— ^c

^aCritical temperature.

^bIn the near-critical region, values for c_p , w , and κ calculated from IAPWS-IF97 are not accurate enough.

^cIn the near-critical region, values for η and λ calculated from the industrial equations, Eqs. (3.1) and (3.4), are not accurate enough.

Table 2 Saturation state (Pressure table)

The pressure table contains values on the saturated liquid ('') and saturated vapour ('') lines for the following thermodynamic properties in the pressure range from $p = 0.006\ 112\ 127$ bar up to the critical pressure $p_c = 220.64$ bar:

- Saturation temperature t_s
- Specific volume v
- Specific enthalpy h
- Specific enthalpy of vaporization Δh_v
- Specific entropy s
- Specific entropy of vaporization Δs_v

For given pressures p , the saturation temperatures t_s were calculated from the IAPWS-IF97 saturation-temperature equation, Eq. (2.14).

For pressures $p \leq 165.292$ bar and the input values for p and t_s , the properties on the saturated-liquid and saturated-vapour lines were determined from the basic equations for regions 1 and 2, Eqs. (2.3) and (2.6).

For $p > 165.292$ bar, the basic equation of region 3, Eq. (2.11), was used for these calculations. With the (p, t_s) values, the densities ρ' and ρ'' , needed as one of the input quantities of Eq. (2.11), were determined by iterating this equation. With these values for (ρ', t) and (ρ'', t) , the specific volumes $v' (=1/\rho')$ and $v'' (=1/\rho'')$ are known, and the other thermodynamic properties at saturation were determined from Eq. (2.11).

Further saturation properties are listed in Tables 6, 11, 18, and 22.

Table 2 **Saturation state**
 (Pressure table)

<i>p</i>	<i>t_s</i>	<i>v'</i>	<i>v''</i>	<i>h'</i>	<i>h''</i>	<i>Δh_v</i>	<i>s'</i>	<i>s''</i>	<i>Δs_v</i>
[bar]	[°C]	[m ³ kg ⁻¹]		[kJ kg ⁻¹]		[kJ kg ⁻¹ K ⁻¹]			
0.006112127	0	0.00100021	206.140	-0.041586	2500.89	2500.93	-0.00015454	9.1558	9.1559
0.006116570 ^a	0.01	0.00100021	205.997	0.00061178	2500.91	2500.91	0	9.1555	9.1555
0.007	1.88090	0.00100011	181.223	7.88979	2504.35	2496.46	0.028782	9.1058	9.0770
0.008	3.76142	0.00100007	159.646	15.8087	2507.80	2491.99	0.057477	9.0567	8.9992
0.009	5.44443	0.00100009	142.763	22.8881	2510.89	2488.00	0.082965	9.0135	8.9305
0.01	6.96963	0.00100014	129.183	29.2982	2513.68	2484.38	0.10591	8.9749	8.8690
0.02	17.4953	0.00100136	66.9896	73.4346	2532.91	2459.48	0.26058	8.7227	8.4621
0.03	24.0799	0.00100277	45.6550	100.990	2544.88	2443.89	0.35433	8.5766	8.2222
0.04	28.9615	0.00100410	34.7925	121.404	2553.71	2432.31	0.42245	8.4735	8.0510
0.05	32.8755	0.00100532	28.1863	137.765	2560.77	2423.00	0.47625	8.3939	7.9177
0.06	36.1603	0.00100645	23.7342	151.494	2566.67	2415.17	0.52087	8.3291	7.8083
0.07	39.0009	0.00100749	20.5252	163.366	2571.76	2408.39	0.55908	8.2746	7.7155
0.08	41.5101	0.00100847	18.0994	173.852	2576.24	2402.39	0.59253	8.2274	7.6349
0.09	43.7618	0.00100939	16.1997	183.262	2580.25	2396.99	0.62233	8.1859	7.5636
0.1	45.8075	0.00101026	14.6706	191.812	2583.89	2392.07	0.64922	8.1489	7.4997
0.2	60.0586	0.00101714	7.64815	251.400	2608.95	2357.55	0.83195	7.9072	7.0753
0.3	69.0954	0.00102222	5.22856	289.229	2624.55	2335.32	0.94394	7.7675	6.8235
0.4	75.8568	0.00102636	3.99311	317.566	2636.05	2318.48	1.0259	7.6690	6.6431
0.5	81.3167	0.00102991	3.24015	340.476	2645.21	2304.74	1.0910	7.5930	6.5020
0.6	85.9258	0.00103306	2.73183	359.837	2652.85	2293.02	1.1452	7.5311	6.3859
0.7	89.9315	0.00103589	2.36490	376.680	2659.42	2282.74	1.1919	7.4790	6.2871
0.8	93.4854	0.00103849	2.08719	391.639	2665.18	2273.54	1.2328	7.4339	6.2011
0.9	96.6870	0.00104090	1.86946	405.128	2670.31	2265.19	1.2694	7.3942	6.1248
1.0	99.6059	0.00104315	1.69402	417.436	2674.95	2257.51	1.3026	7.3588	6.0562
1.01325 ^b	99.9743	0.00104344	1.67330	418.991	2675.53	2256.54	1.3067	7.3544	6.0477
1.1	102.292	0.00104526	1.54955	428.775	2679.18	2250.40	1.3328	7.3268	5.9940
1.2	104.784	0.00104727	1.42845	439.299	2683.06	2243.76	1.3608	7.2976	5.9369
1.3	107.109	0.00104917	1.32541	449.132	2686.65	2237.52	1.3867	7.2708	5.8842
1.4	109.292	0.00105098	1.23665	458.367	2689.99	2231.62	1.4109	7.2460	5.8352
1.5	111.350	0.00105272	1.15936	467.081	2693.11	2226.03	1.4335	7.2229	5.7894
1.6	113.298	0.00105440	1.09143	475.336	2696.04	2220.71	1.4549	7.2014	5.7464
1.7	115.149	0.00105601	1.03124	483.184	2698.81	2215.62	1.4752	7.1811	5.7059
1.8	116.912	0.00105756	0.977534	490.668	2701.42	2210.75	1.4944	7.1620	5.6677
1.9	118.597	0.00105906	0.929299	497.825	2703.89	2206.07	1.5127	7.1440	5.6313
2.0	120.212	0.00106052	0.885735	504.684	2706.24	2201.56	1.5301	7.1269	5.5968
2.1	121.761	0.00106193	0.846187	511.273	2708.48	2197.21	1.5468	7.1106	5.5638
2.2	123.251	0.00106331	0.810119	517.615	2710.62	2193.00	1.5628	7.0951	5.5323
2.3	124.688	0.00106464	0.777086	523.731	2712.66	2188.93	1.5782	7.0802	5.5021
2.4	126.074	0.00106595	0.746716	529.637	2714.62	2184.98	1.5930	7.0660	5.4731
2.5	127.414	0.00106722	0.718697	535.350	2716.50	2181.15	1.6072	7.0524	5.4452
2.6	128.711	0.00106846	0.692763	540.884	2718.31	2177.42	1.6210	7.0393	5.4183
2.7	129.968	0.00106968	0.668687	546.251	2720.04	2173.79	1.6343	7.0267	5.3924
2.8	131.188	0.00107087	0.646274	551.462	2721.72	2170.26	1.6472	7.0146	5.3674
2.9	132.373	0.00107203	0.625355	556.527	2723.33	2166.81	1.6597	7.0029	5.3432
3.0	133.525	0.00107318	0.605785	561.455	2724.89	2163.44	1.6718	6.9916	5.3198
3.1	134.647	0.00107430	0.587436	566.255	2726.40	2160.14	1.6835	6.9806	5.2971
3.2	135.740	0.00107540	0.570196	570.935	2727.86	2156.92	1.6950	6.9700	5.2751
3.3	136.806	0.00107648	0.553966	575.500	2729.27	2153.77	1.7061	6.9597	5.2537
3.4	137.845	0.00107754	0.538658	579.957	2730.64	2150.68	1.7169	6.9498	5.2329

^a Pressure at the triple point.^b This pressure corresponds to 1 atm.

Table 2 **Saturation state** – Continued
(Pressure table)

<i>p</i> [bar]	<i>t_s</i> [°C]	<i>v'</i> [m ³ kg ⁻¹]	<i>v''</i>	<i>h'</i>	<i>h''</i> [kJ kg ⁻¹]	Δ<i>h_v</i>	<i>s'</i>	<i>s''</i> [kJ kg ⁻¹ K ⁻¹]	Δ<i>s_v</i>
3.5	138.861	0.00107858	0.524196	584.311	2731.97	2147.65	1.7275	6.9401	5.2126
3.6	139.853	0.00107961	0.510510	588.569	2733.25	2144.68	1.7378	6.9307	5.1929
3.7	140.823	0.00108062	0.497539	592.735	2734.51	2141.77	1.7478	6.9215	5.1737
3.8	141.773	0.00108161	0.485228	596.813	2735.72	2138.91	1.7576	6.9126	5.1550
3.9	142.702	0.00108259	0.473527	600.808	2736.91	2136.10	1.7672	6.9039	5.1367
4.0	143.613	0.00108356	0.462392	604.723	2738.06	2133.33	1.7766	6.8954	5.1188
4.1	144.505	0.00108451	0.451781	608.563	2739.18	2130.62	1.7858	6.8872	5.1014
4.2	145.380	0.00108545	0.441658	612.330	2740.27	2127.94	1.7948	6.8791	5.0843
4.3	146.238	0.00108638	0.431990	616.027	2741.33	2125.31	1.8036	6.8712	5.0676
4.4	147.081	0.00108729	0.422747	619.657	2742.37	2122.72	1.8122	6.8635	5.0513
4.5	147.908	0.00108820	0.413900	623.224	2743.39	2120.16	1.8206	6.8560	5.0353
4.6	148.721	0.00108909	0.405425	626.730	2744.38	2117.65	1.8289	6.8486	5.0197
4.7	149.519	0.00108997	0.397299	630.177	2745.34	2115.16	1.8371	6.8414	5.0043
4.8	150.305	0.00109084	0.389499	633.567	2746.28	2112.72	1.8450	6.8343	4.9892
4.9	151.077	0.00109170	0.382007	636.902	2747.21	2110.30	1.8529	6.8274	4.9745
5.0	151.836	0.00109256	0.374804	640.185	2748.11	2107.92	1.8606	6.8206	4.9600
5.5	155.462	0.00109668	0.342592	655.877	2752.33	2096.45	1.8972	6.7885	4.8913
6.0	158.832	0.00110061	0.315575	670.501	2756.14	2085.64	1.9311	6.7592	4.8281
6.5	161.986	0.00110436	0.292581	684.216	2759.60	2075.38	1.9626	6.7321	4.7695
7.0	164.953	0.00110797	0.272764	697.143	2762.75	2065.61	1.9921	6.7070	4.7149
7.5	167.755	0.00111144	0.255503	709.384	2765.64	2056.26	2.0198	6.6835	4.6637
8.0	170.414	0.00111479	0.240328	721.018	2768.30	2047.28	2.0460	6.6615	4.6156
8.5	172.943	0.00111803	0.226878	732.113	2770.76	2038.65	2.0708	6.6408	4.5700
9.0	175.358	0.00112118	0.214874	742.725	2773.04	2030.31	2.0944	6.6212	4.5268
9.5	177.669	0.00112425	0.204090	752.901	2775.15	2022.25	2.1169	6.6027	4.4857
10.0	179.886	0.00112723	0.194349	762.683	2777.12	2014.44	2.1384	6.5850	4.4465
10.5	182.017	0.00113015	0.185504	772.105	2778.95	2006.85	2.1591	6.5681	4.4091
11.0	184.070	0.00113299	0.177436	781.198	2780.67	1999.47	2.1789	6.5520	4.3731
11.5	186.050	0.00113578	0.170045	789.988	2782.27	1992.28	2.1979	6.5365	4.3386
12.0	187.965	0.00113850	0.163250	798.499	2783.77	1985.27	2.2163	6.5217	4.3054
12.5	189.817	0.00114118	0.156979	806.751	2785.17	1978.42	2.2340	6.5074	4.2734
13.0	191.613	0.00114380	0.151175	814.764	2786.49	1971.73	2.2512	6.4936	4.2425
13.5	193.355	0.00114638	0.145786	822.552	2787.73	1965.18	2.2678	6.4804	4.2126
14.0	195.047	0.00114892	0.140768	830.132	2788.89	1958.76	2.2839	6.4675	4.1836
14.5	196.693	0.00115141	0.136084	837.516	2789.98	1952.47	2.2995	6.4551	4.1556
15.0	198.295	0.00115387	0.131702	844.717	2791.01	1946.29	2.3147	6.4431	4.1284
15.5	199.856	0.00115629	0.127593	851.745	2791.97	1940.23	2.3294	6.4314	4.1019
16.0	201.378	0.00115868	0.123732	858.610	2792.88	1934.27	2.3438	6.4200	4.0762
16.5	202.864	0.00116103	0.120097	865.322	2793.73	1928.41	2.3578	6.4090	4.0512
17.0	204.315	0.00116336	0.116668	871.888	2794.53	1922.64	2.3715	6.3983	4.0268
17.5	205.733	0.00116565	0.113428	878.316	2795.28	1916.96	2.3848	6.3878	4.0030
18.0	207.120	0.00116792	0.110362	884.614	2795.99	1911.37	2.3978	6.3776	3.9798
18.5	208.477	0.00117016	0.107456	890.788	2796.65	1905.86	2.4105	6.3676	3.9571
19.0	209.806	0.00117238	0.104698	896.844	2797.26	1900.42	2.4229	6.3579	3.9350
19.5	211.108	0.00117458	0.102076	902.786	2797.84	1895.06	2.4351	6.3484	3.9133

Table 2 **Saturation state** – Continued
 (Pressure table)

<i>p</i> [bar]	<i>t_s</i> [°C]	<i>v'</i> [m ³ kg ⁻¹]	<i>v''</i> [m ³ kg ⁻¹]	<i>h'</i> [kJ kg ⁻¹]	<i>h''</i> [kJ kg ⁻¹]	Δ<i>h_v</i>	<i>s'</i> [kJ kg ⁻¹ K ⁻¹]	<i>s''</i> [kJ kg ⁻¹ K ⁻¹]	Δ<i>s_v</i>
20.0	212.385	0.00117675	0.0995805	908.622	2798.38	1889.76	2.4470	6.3392	3.8921
20.5	213.637	0.00117890	0.0972026	914.355	2798.89	1884.53	2.4587	6.3301	3.8714
21.0	214.865	0.00118103	0.0949339	919.989	2799.36	1879.37	2.4701	6.3212	3.8511
21.5	216.071	0.00118314	0.0927671	925.530	2799.80	1874.27	2.4814	6.3125	3.8311
22.0	217.256	0.00118524	0.0906953	930.981	2800.20	1869.22	2.4924	6.3040	3.8116
22.5	218.420	0.00118731	0.0887123	936.345	2800.58	1864.23	2.5032	6.2956	3.7924
23.0	219.564	0.00118937	0.0868125	941.626	2800.92	1859.30	2.5138	6.2874	3.7736
23.5	220.689	0.00119141	0.0849906	946.827	2801.24	1854.42	2.5242	6.2793	3.7551
24.0	221.795	0.00119343	0.0832421	951.952	2801.54	1849.58	2.5344	6.2714	3.7370
24.5	222.885	0.00119544	0.0815623	957.003	2801.80	1844.80	2.5445	6.2636	3.7191
25.0	223.956	0.00119744	0.0799474	961.983	2802.04	1840.06	2.5544	6.2560	3.7015
25.5	225.012	0.00119942	0.0783935	966.895	2802.26	1835.37	2.5642	6.2485	3.6843
26.0	226.052	0.00120139	0.0768973	971.740	2802.45	1830.71	2.5738	6.2411	3.6673
26.5	227.076	0.00120334	0.0754556	976.521	2802.63	1826.11	2.5832	6.2338	3.6506
27.0	228.086	0.00120528	0.0740653	981.241	2802.78	1821.54	2.5925	6.2266	3.6341
27.5	229.081	0.00120721	0.0727238	985.901	2802.91	1817.01	2.6017	6.2196	3.6179
28.0	230.063	0.00120913	0.0714285	990.503	2803.02	1812.51	2.6107	6.2126	3.6019
28.5	231.031	0.00121104	0.0701770	995.050	2803.11	1808.06	2.6196	6.2058	3.5861
29.0	231.986	0.00121294	0.0689671	999.542	2803.18	1803.63	2.6284	6.1990	3.5706
29.5	232.928	0.00121482	0.0677968	1003.98	2803.23	1799.25	2.6371	6.1924	3.5553
30.0	233.858	0.00121670	0.0666641	1008.37	2803.26	1794.89	2.6456	6.1858	3.5402
30.5	234.777	0.00121857	0.0655672	1012.71	2803.28	1790.57	2.6541	6.1793	3.5253
31.0	235.684	0.00122042	0.0645044	1017.00	2803.28	1786.28	2.6624	6.1729	3.5105
31.5	236.580	0.00122227	0.0634741	1021.25	2803.27	1782.02	2.6706	6.1666	3.4960
32.0	237.464	0.00122411	0.0624748	1025.45	2803.24	1777.79	2.6787	6.1604	3.4817
32.5	238.339	0.00122594	0.0615052	1029.61	2803.19	1773.58	2.6867	6.1542	3.4675
33.0	239.203	0.00122777	0.0605639	1033.72	2803.13	1769.41	2.6946	6.1481	3.4535
33.5	240.057	0.00122958	0.0596497	1037.79	2803.05	1765.26	2.7025	6.1421	3.4397
34.0	240.901	0.00123139	0.0587614	1041.83	2802.96	1761.14	2.7102	6.1362	3.4260
34.5	241.736	0.00123319	0.0578979	1045.82	2802.86	1757.04	2.7178	6.1303	3.4125
35.0	242.562	0.00123498	0.0570582	1049.78	2802.74	1752.97	2.7254	6.1245	3.3991
35.5	243.378	0.00123677	0.0562413	1053.69	2802.61	1748.92	2.7329	6.1188	3.3859
36.0	244.186	0.00123855	0.0554463	1057.57	2802.47	1744.90	2.7403	6.1131	3.3728
36.5	244.986	0.00124032	0.0546722	1061.42	2802.31	1740.89	2.7476	6.1075	3.3599
37.0	245.776	0.00124209	0.0539183	1065.23	2802.15	1736.91	2.7548	6.1019	3.3471
37.5	246.559	0.00124385	0.0531837	1069.01	2801.97	1732.96	2.7619	6.0964	3.3345
38.0	247.334	0.00124560	0.0524678	1072.76	2801.78	1729.02	2.7690	6.0910	3.3219
38.5	248.101	0.00124735	0.0517698	1076.47	2801.57	1725.10	2.7760	6.0856	3.3095
39.0	248.861	0.00124910	0.0510890	1080.15	2801.36	1721.21	2.7830	6.0802	3.2973
39.5	249.613	0.00125084	0.0504248	1083.80	2801.13	1717.33	2.7898	6.0749	3.2851
40.0	250.358	0.00125257	0.0497766	1087.43	2800.90	1713.47	2.7967	6.0697	3.2731
40.5	251.095	0.00125430	0.0491438	1091.02	2800.65	1709.63	2.8034	6.0645	3.2611
41.0	251.826	0.00125602	0.0485259	1094.58	2800.39	1705.81	2.8101	6.0594	3.2493
41.5	252.550	0.00125774	0.0479223	1098.12	2800.13	1702.01	2.8167	6.0543	3.2376
42.0	253.267	0.00125946	0.0473326	1101.63	2799.85	1698.22	2.8232	6.0492	3.2260

Table 2 **Saturation state** – Continued
(Pressure table)

<i>p</i> [bar]	<i>t_s</i> [°C]	<i>v'</i> [m ³ kg ⁻¹]	<i>v''</i> [m ³ kg ⁻¹]	<i>h'</i> [kJ kg ⁻¹]	<i>h''</i> [kJ kg ⁻¹]	Δ<i>h_v</i>	<i>s'</i> [kJ kg ⁻¹ K ⁻¹]	<i>s''</i> [kJ kg ⁻¹ K ⁻¹]	Δ<i>s_v</i>
42.5	253.978	0.00126117	0.0467562	1105.11	2799.57	1694.46	2.8297	6.0442	3.2145
43.0	254.683	0.00126288	0.0461927	1108.57	2799.27	1690.70	2.8362	6.0393	3.2031
43.5	255.381	0.00126458	0.0456417	1112.00	2798.97	1686.97	2.8425	6.0343	3.1918
44.0	256.073	0.00126628	0.0451027	1115.40	2798.65	1683.25	2.8488	6.0294	3.1806
44.5	256.759	0.00126797	0.0445754	1118.79	2798.33	1679.54	2.8551	6.0246	3.1695
45.0	257.439	0.00126966	0.0440593	1122.14	2798.00	1675.85	2.8613	6.0198	3.1585
45.5	258.114	0.00127135	0.0435542	1125.48	2797.66	1672.18	2.8675	6.0150	3.1475
46.0	258.783	0.00127304	0.0430596	1128.79	2797.31	1668.52	2.8736	6.0103	3.1367
46.5	259.446	0.00127472	0.0425753	1132.08	2796.95	1664.87	2.8797	6.0056	3.1260
47.0	260.104	0.00127639	0.0421009	1135.34	2796.59	1661.24	2.8857	6.0010	3.1153
47.5	260.757	0.00127807	0.0416361	1138.59	2796.21	1657.62	2.8916	5.9963	3.1047
48.0	261.404	0.00127974	0.0411806	1141.81	2795.83	1654.02	2.8975	5.9917	3.0942
48.5	262.046	0.00128141	0.0407341	1145.01	2795.44	1650.43	2.9034	5.9872	3.0838
49.0	262.683	0.00128308	0.0402964	1148.20	2795.04	1646.85	2.9092	5.9827	3.0734
49.5	263.316	0.00128474	0.0398672	1151.36	2794.64	1643.28	2.9150	5.9782	3.0632
50	263.943	0.00128641	0.0394463	1154.50	2794.23	1639.73	2.9207	5.9737	3.0530
51	265.183	0.00128972	0.0386282	1160.73	2793.38	1632.65	2.9321	5.9649	3.0328
52	266.405	0.00129303	0.0378403	1166.88	2792.51	1625.62	2.9433	5.9562	3.0129
53	267.610	0.00129633	0.0370811	1172.97	2791.60	1618.64	2.9543	5.9475	2.9933
54	268.797	0.00129962	0.0363488	1178.98	2790.67	1611.69	2.9652	5.9390	2.9739
55	269.967	0.00130291	0.0356422	1184.92	2789.72	1604.79	2.9759	5.9307	2.9548
56	271.121	0.00130619	0.0349597	1190.81	2788.74	1597.93	2.9865	5.9224	2.9359
57	272.260	0.00130947	0.0343003	1196.63	2787.73	1591.10	2.9969	5.9141	2.9173
58	273.383	0.00131274	0.0336627	1202.39	2786.70	1584.31	3.0072	5.9060	2.8988
59	274.492	0.00131601	0.0330458	1208.09	2785.64	1577.55	3.0174	5.8980	2.8806
60	275.586	0.00131927	0.0324487	1213.73	2784.56	1570.83	3.0274	5.8901	2.8626
61	276.667	0.00132253	0.0318703	1219.32	2783.46	1564.14	3.0374	5.8822	2.8448
62	277.734	0.00132579	0.0313098	1224.86	2782.33	1557.48	3.0472	5.8744	2.8272
63	278.788	0.00132905	0.0307664	1230.34	2781.19	1550.84	3.0569	5.8667	2.8098
64	279.830	0.00133231	0.0302392	1235.78	2780.02	1544.24	3.0665	5.8591	2.7926
65	280.859	0.00133557	0.0297276	1241.17	2778.83	1537.66	3.0760	5.8515	2.7755
66	281.876	0.00133882	0.0292308	1246.51	2777.62	1531.11	3.0854	5.8440	2.7586
67	282.881	0.00134208	0.0287482	1251.81	2776.39	1524.58	3.0947	5.8366	2.7419
68	283.875	0.00134534	0.0282792	1257.06	2775.13	1518.07	3.1039	5.8292	2.7253
69	284.858	0.00134860	0.0278231	1262.27	2773.86	1511.59	3.1130	5.8219	2.7089
70	285.830	0.00135186	0.0273796	1267.44	2772.57	1505.13	3.1220	5.8146	2.6926
71	286.791	0.00135512	0.0269479	1272.57	2771.26	1498.69	3.1309	5.8074	2.6765
72	287.743	0.00135839	0.0265277	1277.65	2769.93	1492.27	3.1398	5.8003	2.6605
73	288.684	0.00136165	0.0261185	1282.70	2768.58	1485.87	3.1485	5.7932	2.6447
74	289.615	0.00136493	0.0257198	1287.72	2767.21	1479.49	3.1572	5.7862	2.6290
75	290.537	0.00136820	0.0253313	1292.70	2765.82	1473.12	3.1658	5.7792	2.6134
76	291.449	0.00137149	0.0249525	1297.64	2764.41	1466.78	3.1743	5.7722	2.5979
77	292.352	0.00137477	0.0245831	1302.55	2762.99	1460.44	3.1827	5.7653	2.5826
78	293.247	0.00137806	0.0242227	1307.42	2761.55	1454.12	3.1911	5.7584	2.5673
79	294.132	0.00138136	0.0238709	1312.27	2760.09	1447.82	3.1994	5.7516	2.5522

Table 2 **Saturation state** – Continued
 (Pressure table)

<i>p</i> [bar]	<i>t_s</i> [°C]	<i>v'</i> [m ³ kg ⁻¹]	<i>v''</i> [m ³ kg ⁻¹]	<i>h'</i> [kJ kg ⁻¹]	<i>h''</i> [kJ kg ⁻¹]	Δ<i>h_v</i>	<i>s'</i> [kJ kg ⁻¹ K ⁻¹]	<i>s''</i> [kJ kg ⁻¹ K ⁻¹]	Δ<i>s_v</i>
80	295.009	0.00138466	0.0235275	1317.08	2758.61	1441.53	3.2077	5.7448	2.5372
81	295.878	0.00138797	0.0231922	1321.86	2757.12	1435.25	3.2158	5.7381	2.5223
82	296.738	0.00139129	0.0228646	1326.61	2755.60	1428.99	3.2239	5.7314	2.5075
83	297.591	0.00139461	0.0225446	1331.34	2754.07	1422.74	3.2320	5.7247	2.4928
84	298.435	0.00139795	0.0222317	1336.03	2752.52	1416.49	3.2399	5.7181	2.4782
85	299.272	0.00140129	0.0219258	1340.70	2750.96	1410.26	3.2478	5.7115	2.4637
86	300.102	0.00140464	0.0216266	1345.34	2749.38	1404.04	3.2557	5.7050	2.4493
87	300.924	0.00140799	0.0213340	1349.96	2747.78	1397.82	3.2635	5.6984	2.4349
88	301.738	0.00141136	0.0210476	1354.54	2746.16	1391.62	3.2712	5.6919	2.4207
89	302.546	0.00141474	0.0207673	1359.11	2744.53	1385.42	3.2789	5.6855	2.4065
90	303.347	0.00141812	0.0204929	1363.65	2742.88	1379.23	3.2866	5.6790	2.3924
91	304.141	0.00142152	0.0202242	1368.17	2741.22	1373.05	3.2942	5.6726	2.3784
92	304.928	0.00142493	0.0199610	1372.66	2739.53	1366.87	3.3017	5.6662	2.3645
93	305.709	0.00142834	0.0197031	1377.14	2737.83	1360.70	3.3092	5.6598	2.3507
94	306.483	0.00143177	0.0194503	1381.59	2736.12	1354.53	3.3166	5.6535	2.3369
95	307.251	0.00143522	0.0192026	1386.02	2734.38	1348.37	3.3240	5.6472	2.3232
96	308.013	0.00143867	0.0189597	1390.43	2732.64	1342.21	3.3313	5.6409	2.3095
97	308.768	0.00144214	0.0187214	1394.81	2730.87	1336.06	3.3386	5.6346	2.2960
98	309.518	0.00144562	0.0184878	1399.18	2729.09	1329.90	3.3459	5.6283	2.2824
99	310.262	0.00144911	0.0182585	1403.54	2727.29	1323.75	3.3531	5.6221	2.2690
100	310.999	0.00145262	0.0180336	1407.87	2725.47	1317.61	3.3603	5.6159	2.2556
105	314.606	0.00147038	0.0169687	1429.27	2716.14	1286.88	3.3956	5.5850	2.1895
110	318.081	0.00148855	0.0159939	1450.28	2706.39	1256.12	3.4300	5.5545	2.1246
115	321.436	0.00150718	0.0150972	1470.95	2696.21	1225.26	3.4636	5.5243	2.0607
120	324.678	0.00152633	0.0142689	1491.33	2685.58	1194.26	3.4965	5.4941	1.9977
125	327.816	0.00154607	0.0135006	1511.46	2674.49	1163.02	3.5288	5.4640	1.9353
130	330.857	0.00156649	0.0127851	1531.40	2662.89	1131.49	3.5606	5.4339	1.8733
135	333.806	0.00158766	0.0121163	1551.19	2650.77	1099.58	3.5920	5.4036	1.8116
140	336.669	0.00160971	0.0114889	1570.88	2638.09	1067.21	3.6230	5.3730	1.7500
145	339.452	0.00163276	0.0108981	1590.51	2624.81	1034.29	3.6538	5.3422	1.6884
150	342.158	0.00165696	0.0103401	1610.15	2610.86	1000.71	3.6844	5.3108	1.6264
155	344.792	0.00168249	0.00981114	1629.85	2596.22	966.37	3.7150	5.2789	1.5638
160	347.357	0.00170954	0.00930813	1649.67	2580.80	931.13	3.7457	5.2463	1.5006
165	349.856	0.00173833	0.00882826	1669.68	2564.57	894.88	3.7765	5.2129	1.4364
170	352.293	0.00176934	0.00836934	1690.04	2547.41	857.38	3.8077	5.1785	1.3708
175	354.671	0.00180286	0.00792681	1710.76	2529.11	818.35	3.8393	5.1428	1.3035
180	356.992	0.00183949	0.00749867	1732.02	2509.53	777.51	3.8717	5.1055	1.2339
185	359.258	0.00188000	0.00708178	1753.99	2488.41	734.42	3.9050	5.0663	1.1613
190	361.471	0.00192545	0.00667261	1776.89	2465.41	688.52	3.9396	5.0246	1.0849
195	363.633	0.00197747	0.00626677	1801.08	2440.00	638.92	3.9762	4.9795	1.0034
200	365.746	0.00203865	0.00585828	1827.10	2411.39	584.29	4.0154	4.9299	0.9145
205	367.811	0.00211358	0.00543777	1855.90	2378.16	522.26	4.0588	4.8736	0.8148
210	369.827	0.00221186	0.00498768	1889.40	2337.54	448.15	4.1093	4.8062	0.6970
215	371.795	0.00236016	0.00446300	1932.81	2282.18	349.38	4.1749	4.7166	0.5417
220	373.707	0.00275039	0.00357662	2021.92	2164.18	142.27	4.3109	4.5308	0.2199
220.640 ^a	373.946	0.00310559		2087.55	0		4.4120	0	

^a Pressure at the critical point.

Table 3 Single-phase region (0 °C to 800 °C)

This table contains values for the following thermodynamic and transport properties in the single-phase region for temperatures from 0°C to 800°C and for pressures from 0.006 112 127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97):

- Specific volume v
- Specific enthalpy h
- Specific entropy s
- Specific isobaric heat capacity c_p
- Speed of sound w
- Isentropic exponent κ
- Dynamic viscosity η
- Thermal conductivity λ

In region 1 and 2 and for the given values of p and t , the *thermodynamic* properties v , h , s , c_p , w , and κ were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6). The density ρ ($=1/v$), needed as one of the input quantities of the equations for the transport properties, is then also known.

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities of Eq. (2.11), was determined by iterating this equation. With these (ρ, t) values, the specific volume v ($=1/\rho$) is known and the other thermodynamic properties were determined from Eq. (2.11).

The calculation of the saturation properties is described in the introduction to Table 1. Values for the properties v , h , s , c_p , and w for temperatures above 800°C up to 2000°C and up to 500 bar (high temperature region 5) are listed in Table 4.

The *transport* properties dynamic viscosity η and thermal conductivity λ were calculated from the equations for industrial use, Eq. (3.1) and Eq. (3.4), respectively. The values of the input quantities ρ , needed in these equations, were determined from the IAPWS-IF97 basic equations as shown above.

Table 3 Single-phase region
(0 °C to 800 °C)

$p = 0.006112127 \text{ bar}$								
t	v	h	s	c_p	w	κ	η	λ
[°C]	[$\text{m}^3 \text{kg}^{-1}$]	[kJ kg^{-1}]	[$\text{kJ kg}^{-1} \text{K}^{-1}$]	[$\text{kJ kg}^{-1} \text{K}^{-1}$]	[m s^{-1}]	[-]	[10^{-6} Pa s]	[$10^{-3} \text{ W m}^{-1} \text{K}^{-1}$]
$t_s = 0 \text{ °C}$								Saturation
Liquid	0.00100021	- 0.04159	- 0.0001545	4.2199	1402.3	3216538	1792.0	555.57
Vapour	206.140	2500.89	9.1558	1.8882	408.88	1.3269	8.9455	16.760
2	207.657	2504.66	9.1695	1.8822	410.50	1.3277	9.0033	16.889
4	209.173	2508.42	9.1831	1.8780	412.08	1.3282	9.0617	17.019
6	210.688	2512.18	9.1966	1.8750	413.63	1.3286	9.1207	17.150
8	212.203	2515.92	9.2100	1.8730	415.15	1.3288	9.1803	17.282
10	213.717	2519.67	9.2233	1.8716	416.65	1.3289	9.2404	17.414
12	215.231	2523.41	9.2364	1.8706	418.13	1.3290	9.3011	17.548
14	216.744	2527.15	9.2495	1.8700	419.60	1.3290	9.3622	17.682
16	218.258	2530.89	9.2625	1.8696	421.06	1.3290	9.4239	17.817
18	219.771	2534.63	9.2754	1.8694	422.51	1.3290	9.4861	17.953
20	221.284	2538.37	9.2882	1.8693	423.95	1.3289	9.5488	18.089
25	225.065	2547.71	9.3198	1.8695	427.53	1.3287	9.7075	18.434
30	228.846	2557.06	9.3509	1.8701	431.07	1.3285	9.8689	18.784
35	232.626	2566.42	9.3815	1.8708	434.57	1.3282	10.033	19.138
40	236.406	2575.77	9.4116	1.8718	438.03	1.3279	10.199	19.498
45	240.185	2585.13	9.4413	1.8728	441.47	1.3276	10.368	19.862
50	243.964	2594.50	9.4705	1.8740	444.87	1.3272	10.538	20.231
55	247.743	2603.87	9.4993	1.8753	448.25	1.3269	10.711	20.604
60	251.521	2613.25	9.5276	1.8767	451.59	1.3265	10.885	20.982
65	255.299	2622.64	9.5556	1.8781	454.90	1.3262	11.061	21.364
70	259.077	2632.03	9.5832	1.8797	458.19	1.3258	11.239	21.751
75	262.855	2641.44	9.6104	1.8813	461.44	1.3254	11.419	22.142
80	266.632	2650.85	9.6372	1.8831	464.67	1.3249	11.599	22.537
85	270.409	2660.27	9.6637	1.8849	467.88	1.3245	11.782	22.936
90	274.186	2669.70	9.6898	1.8867	471.05	1.3240	11.965	23.339
95	277.963	2679.14	9.7157	1.8887	474.20	1.3236	12.150	23.747
100	281.740	2688.58	9.7411	1.8907	477.33	1.3231	12.336	24.158
110	289.294	2707.51	9.7912	1.8949	483.51	1.3221	12.712	24.993
120	296.847	2726.48	9.8401	1.8993	489.59	1.3211	13.092	25.843
130	304.399	2745.50	9.8878	1.9039	495.58	1.3201	13.475	26.708
140	311.952	2764.56	9.9346	1.9087	501.49	1.3190	13.862	27.587
150	319.504	2783.67	9.9803	1.9137	507.31	1.3179	14.252	28.481
160	327.056	2802.84	10.025	1.9188	513.05	1.3168	14.645	29.388
170	334.608	2822.05	10.069	1.9240	518.72	1.3156	15.040	30.309
180	342.160	2841.32	10.112	1.9294	524.31	1.3145	15.438	31.242
190	349.712	2860.64	10.154	1.9348	529.83	1.3133	15.838	32.189
200	357.264	2880.01	10.195	1.9404	535.28	1.3121	16.240	33.148
210	364.816	2899.45	10.236	1.9460	540.66	1.3109	16.643	34.119
220	372.367	2918.93	10.276	1.9517	545.98	1.3097	17.048	35.102
230	379.919	2938.48	10.315	1.9575	551.23	1.3085	17.454	36.096
240	387.470	2958.08	10.354	1.9633	556.43	1.3073	17.862	37.102

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

$p = 0.006112127 \text{ bar}$								
t	v	h	s	c_p	w	κ	η	λ
[°C]	[$\text{m}^3 \text{ kg}^{-1}$]	[kJ kg^{-1}]	[$\text{kJ kg}^{-1} \text{ K}^{-1}$]	[$\text{kJ kg}^{-1} \text{ K}^{-1}$]	[m s^{-1}]	[-]	[10^{-6} Pa s]	[$10^{-3} \text{ W m}^{-1} \text{ K}^{-1}$]
250	395.022	2977.75	10.392	1.9692	561.56	1.3061	18.270	38.119
260	402.573	2997.47	10.429	1.9752	566.64	1.3049	18.680	39.147
270	410.125	3017.25	10.466	1.9812	571.67	1.3037	19.090	40.185
280	417.676	3037.09	10.502	1.9873	576.64	1.3025	19.501	41.234
290	425.227	3057.00	10.538	1.9934	581.56	1.3013	19.913	42.292
300	432.779	3076.96	10.573	1.9996	586.43	1.3001	20.325	43.361
310	440.330	3096.99	10.608	2.0058	591.25	1.2989	20.737	44.439
320	447.881	3117.08	10.642	2.0120	596.02	1.2977	21.150	45.527
330	455.432	3137.23	10.675	2.0183	600.74	1.2965	21.563	46.623
340	462.984	3157.44	10.709	2.0247	605.42	1.2953	21.977	47.729
350	470.535	3177.72	10.741	2.0310	610.06	1.2941	22.390	48.844
360	478.086	3198.07	10.774	2.0374	614.65	1.2929	22.803	49.967
370	485.637	3218.47	10.806	2.0439	619.20	1.2917	23.217	51.099
380	493.188	3238.94	10.837	2.0504	623.70	1.2905	23.630	52.239
390	500.740	3259.48	10.869	2.0569	628.17	1.2893	24.043	53.388
400	508.291	3280.08	10.899	2.0635	632.60	1.2881	24.456	54.544
410	515.842	3300.75	10.930	2.0701	636.99	1.2869	24.868	55.708
420	523.393	3321.48	10.960	2.0767	641.34	1.2858	25.281	56.880
430	530.944	3342.28	10.990	2.0834	645.65	1.2846	25.692	58.059
440	538.495	3363.15	11.019	2.0901	649.93	1.2834	26.104	59.245
450	546.046	3384.08	11.048	2.0968	654.18	1.2822	26.515	60.438
460	553.598	3405.09	11.077	2.1036	658.39	1.2811	26.925	61.639
470	561.149	3426.16	11.106	2.1103	662.56	1.2799	27.335	62.846
480	568.700	3447.29	11.134	2.1172	666.70	1.2788	27.745	64.060
490	576.251	3468.50	11.162	2.1240	670.81	1.2776	28.154	65.281
500	583.802	3489.77	11.190	2.1309	674.89	1.2765	28.562	66.508
510	591.353	3511.12	11.217	2.1378	678.94	1.2753	28.969	67.741
520	598.904	3532.53	11.244	2.1447	682.96	1.2742	29.376	68.981
530	606.455	3554.01	11.271	2.1517	686.95	1.2731	29.783	70.226
540	614.006	3575.56	11.298	2.1586	690.90	1.2720	30.188	71.478
550	621.557	3597.18	11.324	2.1656	694.83	1.2708	30.593	72.735
560	629.108	3618.88	11.351	2.1726	698.74	1.2697	30.997	73.998
570	636.660	3640.64	11.376	2.1796	702.61	1.2686	31.400	75.266
580	644.211	3662.47	11.402	2.1867	706.46	1.2675	31.802	76.540
590	651.762	3684.37	11.428	2.1937	710.29	1.2664	32.204	77.819
600	659.313	3706.34	11.453	2.2008	714.08	1.2654	32.605	79.104
650	697.068	3817.27	11.577	2.2362	732.71	1.2601	34.595	85.600
700	734.823	3929.96	11.695	2.2716	750.77	1.2550	36.564	92.212
750	772.578	4044.43	11.810	2.3070	768.31	1.2501	38.508	98.926
800	810.333	4160.66	11.921	2.3423	785.38	1.2454	40.428	105.73

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 0.01 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.00100021	-0.04119	-0.0001545	4.2199	1402.3	1965991	1792.0	555.58
2	0.00100011	8.39190	0.030607	4.2133	1412.1	1993738	1673.7	560.59
4	0.00100007	16.8129	0.061101	4.2078	1421.5	2020451	1567.4	565.39
6	0.00100011	25.2237	0.091340	4.2031	1430.5	2046110	1471.6	570.01
<i>t_s = 6.96963 °C</i>								
Liquid	0.00100014	29.2982	0.10591	4.2011	1434.7	2058167	1428.5	572.18
Vapour	129.183	2513.68	8.9749	1.8932	413.95	1.3265	9.1482	17.212
8	129.662	2515.63	8.9819	1.8898	414.78	1.3269	9.1790	17.280
10	130.590	2519.41	8.9953	1.8846	416.36	1.3275	9.2392	17.413
12	131.517	2523.17	9.0085	1.8810	417.91	1.3279	9.2999	17.547
14	132.444	2526.93	9.0216	1.8784	419.42	1.3282	9.3611	17.681
16	133.370	2530.68	9.0347	1.8765	420.91	1.3284	9.4228	17.816
18	134.296	2534.44	9.0476	1.8752	422.39	1.3285	9.4850	17.952
20	135.222	2538.19	9.0604	1.8743	423.85	1.3285	9.5477	18.089
25	137.536	2547.55	9.0921	1.8732	427.45	1.3285	9.7065	18.434
30	139.849	2556.92	9.1233	1.8730	431.00	1.3283	9.8679	18.784
35	142.162	2566.28	9.1539	1.8733	434.51	1.3281	10.032	19.139
40	144.474	2575.65	9.1841	1.8739	437.99	1.3278	10.198	19.499
45	146.785	2585.02	9.2138	1.8747	441.43	1.3275	10.367	19.863
50	149.096	2594.40	9.2430	1.8757	444.83	1.3272	10.537	20.232
55	151.407	2603.78	9.2718	1.8768	448.21	1.3268	10.710	20.605
60	153.717	2613.17	9.3002	1.8780	451.56	1.3265	10.885	20.983
65	156.027	2622.56	9.3282	1.8793	454.87	1.3261	11.061	21.365
70	158.337	2631.96	9.3558	1.8808	458.16	1.3257	11.239	21.752
75	160.647	2641.37	9.3830	1.8823	461.42	1.3253	11.418	22.143
80	162.957	2650.79	9.4099	1.8840	464.65	1.3249	11.599	22.538
85	165.266	2660.21	9.4364	1.8857	467.85	1.3245	11.781	22.937
90	167.575	2669.64	9.4625	1.8875	471.03	1.3240	11.965	23.341
95	169.884	2679.08	9.4883	1.8894	474.19	1.3236	12.150	23.748
100	172.193	2688.54	9.5138	1.8913	477.31	1.3231	12.336	24.160
110	176.811	2707.47	9.5639	1.8954	483.49	1.3221	12.712	24.994
120	181.428	2726.44	9.6128	1.8997	489.58	1.3211	13.091	25.844
130	186.045	2745.46	9.6606	1.9043	495.57	1.3201	13.475	26.709
140	190.662	2764.53	9.7073	1.9090	501.48	1.3190	13.862	27.589
150	195.279	2783.65	9.7530	1.9140	507.30	1.3179	14.252	28.482
160	199.895	2802.81	9.7978	1.9190	513.04	1.3168	14.645	29.389
170	204.512	2822.03	9.8416	1.9242	518.71	1.3156	15.040	30.310
180	209.128	2841.30	9.8846	1.9295	524.30	1.3145	15.438	31.244
190	213.744	2860.62	9.9268	1.9350	529.82	1.3133	15.838	32.190
200	218.360	2880.00	9.9682	1.9405	535.27	1.3121	16.240	33.149
210	222.976	2899.43	10.009	1.9461	540.65	1.3109	16.643	34.120
220	227.592	2918.92	10.049	1.9518	545.97	1.3097	17.048	35.103
230	232.208	2938.47	10.088	1.9576	551.23	1.3085	17.454	36.097
240	236.823	2958.07	10.127	1.9634	556.42	1.3073	17.862	37.103

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 0.01 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	241.439	2977.73	10.165	1.9693	561.56	1.3061	18.270	38.120
260	246.055	2997.46	10.202	1.9753	566.64	1.3049	18.680	39.148
270	250.670	3017.24	10.239	1.9813	571.67	1.3037	19.090	40.186
280	255.286	3037.08	10.275	1.9874	576.64	1.3025	19.501	41.234
290	259.902	3056.99	10.310	1.9935	581.56	1.3013	19.913	42.293
300	264.517	3076.95	10.346	1.9996	586.43	1.3001	20.325	43.361
310	269.133	3096.98	10.380	2.0058	591.24	1.2989	20.737	44.440
320	273.748	3117.07	10.414	2.0121	596.02	1.2977	21.150	45.527
330	278.364	3137.22	10.448	2.0184	600.74	1.2965	21.563	46.624
340	282.979	3157.44	10.481	2.0247	605.42	1.2953	21.977	47.730
350	287.595	3177.72	10.514	2.0311	610.05	1.2941	22.390	48.845
360	292.210	3198.06	10.547	2.0375	614.65	1.2929	22.803	49.968
370	296.826	3218.47	10.579	2.0439	619.20	1.2917	23.217	51.100
380	301.441	3238.94	10.610	2.0504	623.70	1.2905	23.630	52.240
390	306.057	3259.47	10.641	2.0569	628.17	1.2893	24.043	53.388
400	310.672	3280.08	10.672	2.0635	632.60	1.2881	24.456	54.544
410	315.288	3300.74	10.703	2.0701	636.99	1.2869	24.868	55.708
420	319.903	3321.48	10.733	2.0767	641.34	1.2858	25.281	56.880
430	324.518	3342.28	10.763	2.0834	645.65	1.2846	25.692	58.059
440	329.134	3363.15	10.792	2.0901	649.93	1.2834	26.104	59.245
450	333.749	3384.08	10.821	2.0968	654.18	1.2822	26.515	60.439
460	338.365	3405.08	10.850	2.1036	658.38	1.2811	26.925	61.639
470	342.980	3426.15	10.879	2.1104	662.56	1.2799	27.335	62.847
480	347.595	3447.29	10.907	2.1172	666.70	1.2788	27.745	64.061
490	352.211	3468.50	10.935	2.1240	670.81	1.2776	28.154	65.281
500	356.826	3489.77	10.962	2.1309	674.89	1.2765	28.562	66.508
510	361.441	3511.11	10.990	2.1378	678.94	1.2753	28.969	67.742
520	366.057	3532.53	11.017	2.1447	682.96	1.2742	29.376	68.981
530	370.672	3554.01	11.044	2.1517	686.94	1.2731	29.783	70.227
540	375.288	3575.56	11.071	2.1586	690.90	1.2720	30.188	71.478
550	379.903	3597.18	11.097	2.1656	694.83	1.2708	30.593	72.735
560	384.518	3618.87	11.123	2.1726	698.74	1.2697	30.997	73.998
570	389.134	3640.63	11.149	2.1797	702.61	1.2686	31.400	75.267
580	393.749	3662.47	11.175	2.1867	706.46	1.2675	31.802	76.541
590	398.364	3684.37	11.201	2.1937	710.29	1.2664	32.204	77.820
600	402.980	3706.34	11.226	2.2008	714.08	1.2654	32.605	79.104
650	426.056	3817.26	11.349	2.2362	732.71	1.2601	34.596	85.601
700	449.133	3929.96	11.468	2.2716	750.77	1.2550	36.564	92.212
750	472.209	4044.43	11.583	2.3070	768.31	1.2501	38.508	98.926
800	495.286	4160.66	11.694	2.3423	785.38	1.2454	40.428	105.73

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 0.1 bar</i>									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.00100020	-0.03202	-0.0001539	4.2199	1402.3	196604	1792.0	555.58	
2	0.00100010	8.40098	0.030607	4.2133	1412.1	199379	1673.7	560.60	
4	0.00100007	16.8219	0.061101	4.2078	1421.5	202050	1567.4	565.40	
6	0.00100010	25.2326	0.091339	4.2031	1430.5	204616	1471.6	570.01	
8	0.00100019	33.6348	0.12133	4.1991	1439.2	207075	1384.8	574.45	
10	0.00100034	42.0296	0.15108	4.1958	1447.4	209428	1306.0	578.72	
12	0.00100054	50.4183	0.18061	4.1929	1455.3	211674	1234.1	582.83	
14	0.00100080	58.8017	0.20990	4.1905	1462.8	213814	1168.4	586.81	
16	0.00100110	67.1805	0.23898	4.1884	1470.0	215848	1108.1	590.65	
18	0.00100145	75.5555	0.26785	4.1866	1476.8	217779	1052.7	594.36	
20	0.00100184	83.9271	0.29650	4.1851	1483.3	219606	1001.6	597.96	
25	0.00100300	104.845	0.36725	4.1822	1498.0	223737	890.04	606.46	
30	0.00100441	125.750	0.43679	4.1803	1510.8	227261	797.22	614.35	
35	0.00100604	146.649	0.50517	4.1792	1521.8	230209	719.12	621.66	
40	0.00100788	167.543	0.57243	4.1788	1531.2	232610	652.72	628.45	
45	0.00100991	188.438	0.63862	4.1790	1538.9	234495	595.76	634.75	
<i>t_s = 45.8075 °C</i>									
Saturation									
Liquid	0.00101026	191.812	0.64922	4.1791	1540.0	234753	587.32	635.72	
Vapour	14.6706	2583.89	8.1489	1.9413	440.51	1.3227	10.377	19.942	
50	14.8674	2591.99	8.1741	1.9272	443.67	1.3240	10.521	20.255	
55	15.1015	2601.60	8.2037	1.9178	447.26	1.3246	10.694	20.631	
60	15.3353	2611.18	8.2326	1.9124	450.74	1.3248	10.870	21.011	
65	15.5687	2620.73	8.2611	1.9091	454.14	1.3247	11.047	21.396	
70	15.8018	2630.27	8.2891	1.9071	457.50	1.3246	11.226	21.784	
75	16.0347	2639.80	8.3167	1.9058	460.81	1.3243	11.406	22.176	
80	16.2674	2649.33	8.3438	1.9051	464.09	1.3240	11.587	22.572	
85	16.4999	2658.86	8.3706	1.9048	467.33	1.3236	11.770	22.972	
90	16.7323	2668.38	8.3970	1.9048	470.55	1.3233	11.955	23.376	
95	16.9646	2677.90	8.4231	1.9051	473.73	1.3229	12.140	23.784	
100	17.1967	2687.43	8.4488	1.9057	476.89	1.3225	12.327	24.196	
110	17.6607	2706.50	8.4992	1.9074	483.12	1.3216	12.703	25.030	
120	18.1243	2725.58	8.5484	1.9098	489.25	1.3207	13.084	25.880	
130	18.5876	2744.69	8.5964	1.9128	495.28	1.3197	13.468	26.744	
140	19.0507	2763.84	8.6433	1.9163	501.22	1.3187	13.856	27.622	
150	19.5136	2783.02	8.6892	1.9201	507.07	1.3176	14.247	28.515	
160	19.9763	2802.24	8.7340	1.9243	512.83	1.3166	14.640	29.420	
170	20.4389	2821.51	8.7780	1.9288	518.52	1.3154	15.036	30.340	
180	20.9013	2840.82	8.8211	1.9336	524.13	1.3143	15.434	31.272	
190	21.3637	2860.18	8.8634	1.9385	529.66	1.3132	15.834	32.217	
200	21.8260	2879.59	8.9048	1.9436	535.13	1.3120	16.236	33.175	
210	22.2882	2899.05	8.9455	1.9489	540.52	1.3108	16.640	34.145	
220	22.7504	2918.57	8.9855	1.9543	545.85	1.3097	17.045	35.126	
230	23.2124	2938.14	9.0248	1.9598	551.12	1.3085	17.452	36.119	
240	23.6745	2957.76	9.0634	1.9654	556.32	1.3073	17.859	37.124	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 0.1 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	24.1365	2977.45	9.1014	1.9711	561.46	1.3061	18.268	38.14
260	24.5985	2997.19	9.1388	1.9769	566.55	1.3049	18.678	39.17
270	25.0604	3016.98	9.1756	1.9827	571.58	1.3037	19.089	40.20
280	25.5223	3036.84	9.2118	1.9887	576.56	1.3025	19.500	41.25
290	25.9842	3056.76	9.2475	1.9947	581.48	1.3013	19.912	42.31
300	26.4460	3076.73	9.2827	2.0007	586.36	1.3001	20.324	43.38
310	26.9078	3096.77	9.3173	2.0069	591.18	1.2989	20.736	44.45
320	27.3696	3116.87	9.3515	2.0130	595.96	1.2977	21.149	45.54
330	27.8314	3137.03	9.3852	2.0192	600.68	1.2965	21.563	46.64
340	28.2932	3157.26	9.4185	2.0255	605.37	1.2953	21.976	47.74
350	28.7550	3177.54	9.4513	2.0318	610.00	1.2941	22.389	48.86
360	29.2167	3197.89	9.4837	2.0382	614.60	1.2929	22.803	49.98
370	29.6785	3218.31	9.5157	2.0446	619.15	1.2917	23.216	51.11
380	30.1402	3238.79	9.5473	2.0510	623.66	1.2905	23.630	52.25
390	30.6019	3259.33	9.5785	2.0575	628.13	1.2893	24.043	53.40
400	31.0636	3279.94	9.6093	2.0641	632.56	1.2881	24.456	54.55
410	31.5253	3300.61	9.6398	2.0706	636.95	1.2869	24.868	55.72
420	31.9870	3321.35	9.6699	2.0772	641.30	1.2857	25.280	56.89
430	32.4486	3342.15	9.6997	2.0839	645.62	1.2846	25.692	58.07
440	32.9103	3363.03	9.7292	2.0905	649.90	1.2834	26.104	59.25
450	33.3720	3383.96	9.7584	2.0972	654.15	1.2822	26.515	60.45
460	33.8336	3404.97	9.7872	2.1040	658.36	1.2811	26.925	61.65
470	34.2953	3426.04	9.8158	2.1107	662.53	1.2799	27.335	62.85
480	34.7569	3447.19	9.8440	2.1175	666.68	1.2788	27.745	64.07
490	35.2185	3468.40	9.8720	2.1244	670.79	1.2776	28.154	65.29
500	35.6802	3489.67	9.8997	2.1312	674.87	1.2765	28.562	66.52
510	36.1418	3511.02	9.9271	2.1381	678.92	1.2753	28.970	67.75
520	36.6034	3532.44	9.9543	2.1450	682.94	1.2742	29.377	68.99
530	37.0650	3553.92	9.9812	2.1520	686.92	1.2731	29.783	70.23
540	37.5267	3575.48	10.008	2.1589	690.88	1.2720	30.188	71.48
550	37.9883	3597.10	10.034	2.1659	694.82	1.2708	30.593	72.74
560	38.4499	3618.79	10.061	2.1729	698.72	1.2697	30.997	74.00
570	38.9115	3640.56	10.086	2.1799	702.60	1.2686	31.400	75.27
580	39.3731	3662.39	10.112	2.1869	706.45	1.2675	31.803	76.55
590	39.8347	3684.30	10.138	2.1940	710.27	1.2664	32.204	77.83
600	40.2963	3706.27	10.163	2.2010	714.07	1.2654	32.605	79.11
650	42.6042	3817.20	10.287	2.2364	732.70	1.2601	34.596	85.61
700	44.9121	3929.91	10.405	2.2718	750.76	1.2550	36.564	92.22
750	47.2199	4044.38	10.520	2.3071	768.31	1.2501	38.508	98.93
800	49.5278	4160.62	10.631	2.3424	785.38	1.2454	40.429	105.74

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 1 bar</i>									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.00100016	0.05966	-0.0001478	4.2194	1402.4	19665	1791.8	555.65	
2	0.00100006	8.49179	0.030610	4.2129	1412.2	19943	1673.5	560.66	
4	0.00100003	16.9119	0.061101	4.2074	1421.6	20210	1567.3	565.47	
6	0.00100006	25.3219	0.091336	4.2027	1430.7	20467	1471.5	570.08	
8	0.00100015	33.7233	0.12133	4.1988	1439.3	20713	1384.7	574.51	
10	0.00100030	42.1174	0.15108	4.1955	1447.6	20948	1305.9	578.78	
12	0.00100050	50.5054	0.18060	4.1926	1455.4	21172	1234.0	582.89	
14	0.00100076	58.8881	0.20989	4.1902	1463.0	21386	1168.3	586.86	
16	0.00100106	67.2664	0.23897	4.1881	1470.1	21590	1108.1	590.70	
18	0.00100141	75.6407	0.26783	4.1863	1476.9	21783	1052.7	594.42	
20	0.00100180	84.0118	0.29648	4.1848	1483.4	21966	1001.6	598.01	
25	0.00100296	104.928	0.36723	4.1819	1498.2	22379	890.02	606.52	
30	0.00100437	125.833	0.43676	4.1800	1511.0	22731	797.22	614.39	
35	0.00100600	146.730	0.50513	4.1790	1522.0	23026	719.13	621.71	
40	0.00100784	167.623	0.57239	4.1786	1531.3	23266	652.73	628.49	
45	0.00100987	188.516	0.63859	4.1788	1539.0	23455	595.77	634.80	
50	0.00101210	209.412	0.70375	4.1796	1545.3	23595	546.52	640.64	
55	0.00101450	230.313	0.76794	4.1809	1550.2	23689	503.63	646.04	
60	0.00101708	251.222	0.83117	4.1828	1553.9	23739	466.04	651.02	
65	0.00101982	272.141	0.89350	4.1852	1556.3	23749	432.91	655.59	
70	0.00102273	293.074	0.95495	4.1881	1557.6	23722	403.56	659.78	
75	0.00102579	314.023	1.0156	4.1915	1557.8	23658	377.42	663.58	
80	0.00102902	334.991	1.0754	4.1955	1557.1	23561	354.06	667.01	
85	0.00103239	355.979	1.1344	4.2000	1555.4	23432	333.08	670.08	
90	0.00103593	376.992	1.1926	4.2050	1552.8	23275	314.18	672.80	
95	0.00103962	398.030	1.2502	4.2106	1549.3	23090	297.09	675.17	
<i>t_s = 99.6059 °C</i>									
Saturation									
Liquid	0.00104315	417.436	1.3026	4.2161	1545.5	22896	282.75	677.07	
Vapour	1.69402	2674.95	7.3588	2.0759	472.05	1.3154	12.218	24.532	
100	1.69596	2675.77	7.3610	2.0741	472.34	1.3155	12.234	24.564	
110	1.74482	2696.32	7.4154	2.0399	479.27	1.3165	12.620	25.397	
120	1.79324	2716.61	7.4676	2.0187	485.89	1.3166	13.009	26.240	
130	1.84132	2736.72	7.5181	2.0039	492.31	1.3163	13.401	27.096	
140	1.88913	2756.70	7.5671	1.9933	498.57	1.3158	13.796	27.963	
150	1.93673	2776.59	7.6147	1.9857	504.70	1.3152	14.192	28.843	
160	1.98414	2796.42	7.6610	1.9805	510.70	1.3145	14.591	29.736	
170	2.03140	2816.21	7.7062	1.9772	516.59	1.3137	14.992	30.642	
180	2.07853	2835.97	7.7503	1.9755	522.38	1.3129	15.394	31.560	
190	2.12556	2855.72	7.7934	1.9751	528.07	1.3119	15.798	32.491	
200	2.17249	2875.48	7.8356	1.9757	533.67	1.3110	16.204	33.436	
210	2.21935	2895.24	7.8769	1.9772	539.19	1.3099	16.611	34.392	
220	2.26614	2915.02	7.9174	1.9793	544.62	1.3089	17.019	35.361	
230	2.31287	2934.83	7.9572	1.9821	549.98	1.3078	17.428	36.342	
240	2.35955	2954.66	7.9962	1.9854	555.27	1.3067	17.838	37.335	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>t</i> [°C]	<i>p = 1 bar</i>							
	<i>v</i> [m ³ kg ⁻¹]	<i>h</i> [kJ kg ⁻¹]	<i>s</i> [kJ kg ⁻¹ K ⁻¹]	<i>c_p</i> [kJ kg ⁻¹ K ⁻¹]	<i>w</i> [m s ⁻¹]	<i>κ</i> [-]	<i>η</i> [10 ⁻⁶ Pa s]	<i>λ</i> [10 ⁻³ W m ⁻¹ K ⁻¹]
250	2.40619	2974.54	8.0346	1.9891	560.49	1.3056	18.249	38.340
260	2.45279	2994.45	8.0723	1.9932	565.65	1.3045	18.661	39.356
270	2.49935	3014.40	8.1094	1.9975	570.74	1.3033	19.073	40.383
280	2.54588	3034.40	8.1458	2.0022	575.77	1.3022	19.486	41.421
290	2.59239	3054.45	8.1818	2.0070	580.75	1.3010	19.899	42.470
300	2.63887	3074.54	8.2171	2.0121	585.67	1.2998	20.313	43.530
310	2.68533	3094.69	8.2520	2.0173	590.54	1.2987	20.727	44.599
320	2.73176	3114.89	8.2863	2.0227	595.35	1.2975	21.141	45.679
330	2.77818	3135.14	8.3202	2.0282	600.11	1.2963	21.555	46.768
340	2.82458	3155.45	8.3536	2.0338	604.83	1.2951	21.969	47.867
350	2.87097	3175.82	8.3865	2.0396	609.50	1.2939	22.384	48.975
360	2.91735	3196.24	8.4190	2.0454	614.12	1.2928	22.798	50.093
370	2.96371	3216.73	8.4511	2.0514	618.70	1.2916	23.212	51.219
380	3.01006	3237.27	8.4828	2.0574	623.23	1.2904	23.626	52.354
390	3.05639	3257.87	8.5141	2.0635	627.73	1.2892	24.040	53.498
400	3.10272	3278.54	8.5451	2.0697	632.18	1.2881	24.453	54.649
410	3.14904	3299.27	8.5756	2.0759	636.59	1.2869	24.866	55.809
420	3.19535	3320.06	8.6059	2.0822	640.96	1.2857	25.279	56.977
430	3.24165	3340.91	8.6357	2.0886	645.30	1.2845	25.692	58.153
440	3.28795	3361.83	8.6653	2.0950	649.59	1.2834	26.103	59.336
450	3.33424	3382.81	8.6945	2.1015	653.85	1.2822	26.515	60.527
460	3.38052	3403.86	8.7234	2.1080	658.08	1.2811	26.926	61.725
470	3.42679	3424.97	8.7520	2.1146	662.27	1.2799	27.336	62.930
480	3.47306	3446.15	8.7803	2.1212	666.43	1.2788	27.746	64.142
490	3.51932	3467.40	8.8083	2.1279	670.55	1.2776	28.155	65.361
500	3.56558	3488.71	8.8361	2.1345	674.64	1.2765	28.564	66.586
510	3.61184	3510.09	8.8635	2.1413	678.70	1.2753	28.971	67.818
520	3.65809	3531.53	8.8907	2.1480	682.73	1.2742	29.379	69.056
530	3.70433	3553.05	8.9177	2.1548	686.73	1.2731	29.785	70.300
540	3.75057	3574.63	8.9444	2.1617	690.70	1.2720	30.191	71.551
550	3.79681	3596.28	8.9709	2.1685	694.64	1.2709	30.596	72.807
560	3.84304	3618.00	8.9971	2.1754	698.55	1.2698	31.000	74.069
570	3.88928	3639.79	9.0231	2.1823	702.44	1.2687	31.403	75.337
580	3.93550	3661.65	9.0489	2.1892	706.29	1.2676	31.806	76.611
590	3.98173	3683.58	9.0744	2.1962	710.12	1.2665	32.207	77.889
600	4.02795	3705.57	9.0998	2.2031	713.93	1.2654	32.608	79.173
650	4.25902	3816.60	9.2234	2.2381	732.59	1.2601	34.600	85.670
700	4.49004	3929.38	9.3424	2.2732	750.68	1.2550	36.568	92.282
750	4.72101	4043.92	9.4571	2.3083	768.24	1.2502	38.512	98.999
800	4.95196	4160.21	9.5681	2.3434	785.34	1.2455	40.433	105.81

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 2 bar</i>									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.00100011	0.16152	-0.0001411	4.2189	1402.6	9835.3	1791.5	555.73	
2	0.00100001	8.59268	0.030613	4.2124	1412.4	9974.1	1673.3	560.74	
4	0.00099998	17.0119	0.061101	4.2069	1421.8	10108	1567.1	565.54	
6	0.00100001	25.4210	0.091333	4.2023	1430.8	10236	1471.3	570.14	
8	0.00100010	33.8216	0.12132	4.1984	1439.5	10359	1384.6	574.57	
10	0.00100025	42.2150	0.15107	4.1951	1447.7	10477	1305.8	578.84	
12	0.00100045	50.6022	0.18058	4.1922	1455.6	10589	1234.0	582.95	
14	0.00100071	58.9842	0.20988	4.1898	1463.1	10696	1168.3	586.93	
16	0.00100101	67.3618	0.23895	4.1878	1470.3	10798	1108.0	590.76	
18	0.00100136	75.7355	0.26781	4.1860	1477.1	10894	1052.6	594.48	
20	0.00100175	84.1059	0.29646	4.1845	1483.6	10986	1001.6	598.07	
25	0.00100292	105.021	0.36721	4.1816	1498.3	11192	890.01	606.57	
30	0.00100432	125.924	0.43673	4.1798	1511.1	11369	797.22	614.45	
35	0.00100595	146.820	0.50510	4.1787	1522.1	11516	719.13	621.76	
40	0.00100779	167.712	0.57235	4.1783	1531.5	11636	652.74	628.55	
45	0.00100983	188.604	0.63854	4.1785	1539.2	11730	595.79	634.85	
50	0.00101205	209.498	0.70371	4.1793	1545.5	11800	546.54	640.69	
55	0.00101446	230.398	0.76789	4.1807	1550.4	11847	503.65	646.09	
60	0.00101703	251.306	0.83112	4.1825	1554.0	11873	466.07	651.07	
65	0.00101977	272.224	0.89344	4.1849	1556.5	11878	432.94	655.64	
70	0.00102268	293.156	0.95489	4.1879	1557.8	11864	403.58	659.83	
75	0.00102575	314.104	1.0155	4.1913	1558.0	11832	377.45	663.63	
80	0.00102897	335.070	1.0753	4.1953	1557.2	11784	354.08	667.06	
85	0.00103235	356.058	1.1343	4.1998	1555.6	11720	333.11	670.13	
90	0.00103588	377.069	1.1926	4.2048	1553.0	11641	314.21	672.85	
95	0.00103957	398.107	1.2501	4.2103	1549.5	11548	297.12	675.23	
100	0.00104341	419.173	1.3069	4.2164	1545.3	11443	281.61	677.27	
110	0.00105155	461.405	1.4186	4.2302	1534.6	11197	254.63	680.38	
120	0.00106033	503.786	1.5278	4.2464	1521.0	10909	232.03	682.24	
<i>t_s = 120.212 °C</i>									
Saturation									
Liquid	0.00106052	504.684	1.5301	4.2467	1520.7	10903	231.60	682.27	
Vapour	0.885735	2706.24	7.1269	2.1752	481.88	1.3108	12.934	26.675	
130	0.910412	2727.25	7.1796	2.1232	488.81	1.3122	13.326	27.500	
140	0.935281	2748.31	7.2312	2.0902	495.51	1.3126	13.728	28.354	
150	0.959894	2769.09	7.2809	2.0667	501.97	1.3125	14.132	29.218	
160	0.984303	2789.66	7.3290	2.0492	508.26	1.3122	14.537	30.095	
170	1.00854	2810.09	7.3756	2.0359	514.39	1.3118	14.943	30.984	
180	1.03265	2830.39	7.4209	2.0261	520.39	1.3112	15.350	31.887	
190	1.05663	2850.62	7.4650	2.0189	526.26	1.3105	15.759	32.802	
200	1.08052	2870.78	7.5081	2.0139	532.02	1.3098	16.168	33.730	
210	1.10432	2890.90	7.5502	2.0106	537.68	1.3089	16.578	34.672	
220	1.12805	2911.00	7.5914	2.0089	543.23	1.3080	16.990	35.626	
230	1.15172	2931.08	7.6317	2.0083	548.70	1.3071	17.402	36.593	
240	1.17534	2951.17	7.6712	2.0087	554.09	1.3061	17.814	37.572	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 2 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	1.19891	2971.26	7.7100	2.0100	559.40	1.3050	18.228	38.564
260	1.22244	2991.37	7.7481	2.0120	564.63	1.3040	18.642	39.568
270	1.24593	3011.50	7.7855	2.0145	569.80	1.3029	19.056	40.584
280	1.26939	3031.66	7.8223	2.0176	574.89	1.3018	19.471	41.612
290	1.29282	3051.85	7.8584	2.0211	579.93	1.3007	19.885	42.651
300	1.31623	3072.08	7.8940	2.0250	584.90	1.2996	20.301	43.701
310	1.33962	3092.35	7.9291	2.0291	589.81	1.2984	20.716	44.761
320	1.36298	3112.67	7.9636	2.0336	594.67	1.2973	21.131	45.833
330	1.38632	3133.03	7.9977	2.0383	599.48	1.2961	21.547	46.915
340	1.40965	3153.43	8.0312	2.0432	604.23	1.2950	21.962	48.007
350	1.43296	3173.89	8.0643	2.0483	608.93	1.2938	22.377	49.108
360	1.45626	3194.40	8.0970	2.0535	613.59	1.2927	22.793	50.219
370	1.47955	3214.96	8.1292	2.0590	618.20	1.2915	23.208	51.340
380	1.50282	3235.58	8.1610	2.0645	622.76	1.2903	23.622	52.470
390	1.52608	3256.25	8.1924	2.0702	627.28	1.2892	24.037	53.609
400	1.54934	3276.98	8.2235	2.0760	631.75	1.2880	24.451	54.756
410	1.57258	3297.77	8.2541	2.0818	636.19	1.2868	24.865	55.912
420	1.59581	3318.62	8.2844	2.0878	640.58	1.2857	25.278	57.076
430	1.61904	3339.53	8.3144	2.0939	644.93	1.2845	25.691	58.248
440	1.64226	3360.50	8.3440	2.1000	649.25	1.2834	26.103	59.428
450	1.66547	3381.53	8.3733	2.1062	653.53	1.2822	26.515	60.616
460	1.68868	3402.62	8.4022	2.1125	657.77	1.2811	26.926	61.812
470	1.71187	3423.78	8.4309	2.1189	661.97	1.2799	27.337	63.014
480	1.73507	3445.00	8.4593	2.1253	666.14	1.2788	27.747	64.224
490	1.75825	3466.29	8.4873	2.1317	670.28	1.2776	28.157	65.441
500	1.78144	3487.64	8.5151	2.1382	674.39	1.2765	28.565	66.665
510	1.80462	3509.05	8.5426	2.1448	678.46	1.2754	28.973	67.895
520	1.82779	3530.53	8.5699	2.1514	682.50	1.2742	29.381	69.132
530	1.85096	3552.08	8.5969	2.1580	686.51	1.2731	29.787	70.375
540	1.87412	3573.69	8.6236	2.1647	690.49	1.2720	30.193	71.624
550	1.89728	3595.37	8.6501	2.1715	694.44	1.2709	30.599	72.880
560	1.92044	3617.12	8.6764	2.1782	698.36	1.2698	31.003	74.141
570	1.94360	3638.94	8.7024	2.1850	702.26	1.2687	31.406	75.408
580	1.96675	3660.82	8.7282	2.1918	706.12	1.2676	31.809	76.681
590	1.98990	3682.77	8.7538	2.1986	709.96	1.2665	32.211	77.960
600	2.01304	3704.79	8.7792	2.2055	713.78	1.2654	32.612	79.244
650	2.12873	3815.93	8.9029	2.2400	732.47	1.2602	34.604	85.740
700	2.24437	3928.80	9.0220	2.2748	750.59	1.2551	36.572	92.354
750	2.35996	4043.41	9.1368	2.3096	768.18	1.2502	38.517	99.073
800	2.47553	4159.76	9.2479	2.3445	785.29	1.2455	40.437	105.89

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 4 bar</i>									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.00100000	0.36519	-0.0001277	4.2179	1402.9	4920.4	1791.1	555.88	
2	0.000999906	8.79442	0.030619	4.2115	1412.7	4989.8	1673.0	560.88	
4	0.000999877	17.2118	0.061101	4.2061	1422.1	5056.6	1566.8	565.68	
6	0.000999911	25.6192	0.091327	4.2015	1431.1	5120.8	1471.1	570.28	
8	0.00100001	34.0182	0.12131	4.1976	1439.8	5182.3	1384.4	574.71	
10	0.00100016	42.4100	0.15105	4.1943	1448.0	5241.1	1305.6	578.97	
12	0.00100036	50.7957	0.18056	4.1915	1455.9	5297.3	1233.8	583.08	
14	0.00100061	59.1763	0.20985	4.1891	1463.4	5350.8	1168.2	587.05	
16	0.00100092	67.5525	0.23892	4.1871	1470.6	5401.7	1107.9	590.89	
18	0.00100127	75.9249	0.26777	4.1854	1477.4	5450.0	1052.6	594.60	
20	0.00100166	84.2941	0.29642	4.1839	1483.9	5495.7	1001.5	598.19	
25	0.00100283	105.206	0.36715	4.1810	1498.6	5599.0	889.98	606.69	
30	0.00100423	126.106	0.43667	4.1792	1511.5	5687.2	797.22	614.56	
35	0.00100586	146.999	0.50503	4.1782	1522.5	5761.0	719.15	621.87	
40	0.00100770	167.889	0.57228	4.1778	1531.8	5821.1	652.77	628.65	
45	0.00100974	188.778	0.63846	4.1781	1539.5	5868.3	595.82	634.95	
50	0.00101196	209.671	0.70361	4.1789	1545.8	5903.3	546.58	640.79	
55	0.00101437	230.568	0.76779	4.1802	1550.7	5926.8	503.70	646.19	
60	0.00101694	251.474	0.83101	4.1821	1554.4	5939.6	466.11	651.17	
65	0.00101968	272.390	0.89333	4.1845	1556.8	5942.2	432.99	655.75	
70	0.00102259	293.320	0.95477	4.1874	1558.1	5935.3	403.63	659.93	
75	0.00102565	314.265	1.0154	4.1909	1558.4	5919.4	377.50	663.74	
80	0.00102887	335.229	1.0752	4.1949	1557.6	5895.2	354.14	667.17	
85	0.00103225	356.215	1.1342	4.1993	1555.9	5863.2	333.16	670.24	
90	0.00103578	377.224	1.1924	4.2044	1553.4	5823.9	314.26	672.96	
95	0.00103947	398.259	1.2499	4.2099	1549.9	5777.7	297.17	675.34	
100	0.00104330	419.323	1.3068	4.2160	1545.7	5725.1	281.67	677.39	
110	0.00105144	461.550	1.4185	4.2297	1535.0	5602.3	254.68	680.50	
120	0.00106021	503.926	1.5276	4.2459	1521.5	5458.4	232.09	682.36	
130	0.00106963	546.476	1.6345	4.2645	1505.3	5296.2	212.97	683.03	
140	0.00107974	589.225	1.7392	4.2859	1486.7	5117.8	196.65	682.55	
<i>t_s = 143.613 °C</i>									
Saturation									
Liquid	0.00108356	604.723	1.7766	4.2944	1479.4	5049.8	191.34	682.10	
Vapour	0.462392	2738.06	6.8954	2.3403	491.09	1.3039	13.742	29.477	
150	0.470887	2752.78	6.9305	2.2749	495.98	1.3060	14.009	30.006	
160	0.483935	2775.19	6.9828	2.2121	503.07	1.3074	14.426	30.845	
170	0.496761	2797.09	7.0328	2.1708	509.78	1.3078	14.844	31.697	
180	0.509418	2818.64	7.0809	2.1403	516.24	1.3079	15.261	32.563	
190	0.521938	2839.92	7.1274	2.1167	522.51	1.3077	15.678	33.442	
200	0.534345	2860.99	7.1724	2.0984	528.61	1.3073	16.096	34.336	
210	0.546656	2881.90	7.2161	2.0841	534.56	1.3068	16.513	35.245	
220	0.558886	2902.69	7.2587	2.0732	540.38	1.3062	16.931	36.168	
230	0.571047	2923.37	7.3002	2.0649	546.08	1.3055	17.349	37.105	
240	0.583149	2943.99	7.3408	2.0588	551.68	1.3048	17.767	38.056	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 4 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.595199	2964.56	7.3805	2.0546	557.17	1.3039	18.185	39.021
260	0.607205	2985.09	7.4194	2.0519	562.57	1.3030	18.603	40.000
270	0.619173	3005.60	7.4575	2.0504	567.88	1.3021	19.022	40.993
280	0.631106	3026.10	7.4949	2.0500	573.11	1.3011	19.440	41.998
290	0.643008	3046.60	7.5316	2.0505	578.26	1.3001	19.858	43.016
300	0.654884	3067.11	7.5677	2.0518	583.34	1.2990	20.277	44.047
310	0.666736	3087.64	7.6032	2.0537	588.36	1.2980	20.695	45.090
320	0.678566	3108.19	7.6381	2.0561	593.31	1.2969	21.113	46.145
330	0.690376	3128.76	7.6725	2.0591	598.19	1.2958	21.530	47.211
340	0.702170	3149.37	7.7064	2.0624	603.02	1.2947	21.948	48.288
350	0.713947	3170.01	7.7398	2.0661	607.80	1.2936	22.365	49.376
360	0.725709	3190.69	7.7728	2.0702	612.52	1.2924	22.782	50.475
370	0.737458	3211.42	7.8052	2.0745	617.18	1.2913	23.199	51.584
380	0.749196	3232.18	7.8373	2.0790	621.80	1.2902	23.615	52.703
390	0.760921	3253.00	7.8689	2.0838	626.37	1.2890	24.031	53.832
400	0.772637	3273.86	7.9001	2.0887	630.90	1.2879	24.446	54.971
410	0.784343	3294.77	7.9310	2.0938	635.38	1.2868	24.861	56.118
420	0.796040	3315.74	7.9614	2.0991	639.81	1.2856	25.275	57.275
430	0.807729	3336.76	7.9915	2.1046	644.20	1.2845	25.689	58.440
440	0.819410	3357.83	8.0213	2.1101	648.56	1.2833	26.103	59.614
450	0.831084	3378.96	8.0507	2.1158	652.87	1.2822	26.515	60.796
460	0.842751	3400.15	8.0798	2.1216	657.14	1.2810	26.927	61.986
470	0.854413	3421.39	8.1086	2.1275	661.38	1.2799	27.339	63.184
480	0.866068	3442.69	8.1371	2.1334	665.58	1.2788	27.750	64.389
490	0.877718	3464.06	8.1652	2.1395	669.75	1.2776	28.160	65.602
500	0.889363	3485.49	8.1931	2.1456	673.88	1.2765	28.569	66.823
510	0.901003	3506.97	8.2207	2.1519	677.98	1.2754	28.978	68.050
520	0.912638	3528.52	8.2481	2.1581	682.04	1.2743	29.386	69.284
530	0.924269	3550.14	8.2752	2.1645	686.07	1.2732	29.793	70.525
540	0.935896	3571.81	8.3020	2.1709	690.07	1.2720	30.199	71.772
550	0.947520	3593.55	8.3286	2.1773	694.04	1.2709	30.604	73.026
560	0.959139	3615.36	8.3549	2.1838	697.99	1.2698	31.009	74.286
570	0.970756	3637.23	8.3810	2.1904	701.90	1.2688	31.413	75.552
580	0.982369	3659.17	8.4069	2.1969	705.78	1.2677	31.816	76.824
590	0.993979	3681.17	8.4325	2.2036	709.64	1.2666	32.218	78.101
600	1.00559	3703.24	8.4579	2.2102	713.47	1.2655	32.619	79.384
650	1.06359	3814.59	8.5819	2.2439	732.23	1.2603	34.612	85.880
700	1.12153	3927.63	8.7012	2.2779	750.40	1.2552	36.581	92.497
750	1.17944	4042.38	8.8161	2.3122	768.04	1.2504	38.526	99.221
800	1.23731	4158.85	8.9273	2.3466	785.19	1.2457	40.446	106.04

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 6 bar</i>									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.000999902	0.56879	-0.0001144	4.2169	1403.2	3282.0	1790.6	556.03	
2	0.000999806	8.99610	0.030625	4.2105	1413.0	3328.3	1672.6	561.03	
4	0.000999778	17.4117	0.061100	4.2052	1422.4	3372.9	1566.5	565.82	
6	0.000999814	25.8173	0.091320	4.2006	1431.4	3415.7	1470.8	570.42	
8	0.000999909	34.2147	0.12129	4.1968	1440.1	3456.7	1384.2	574.84	
10	0.00100006	42.6050	0.15103	4.1936	1448.3	3495.9	1305.5	579.10	
12	0.00100027	50.9892	0.18054	4.1908	1456.2	3533.4	1233.7	583.21	
14	0.00100052	59.3684	0.20982	4.1884	1463.8	3569.1	1168.0	587.17	
16	0.00100082	67.7432	0.23889	4.1864	1470.9	3603.0	1107.8	591.01	
18	0.00100117	76.1143	0.26774	4.1847	1477.7	3635.2	1052.5	594.71	
20	0.00100157	84.4823	0.29638	4.1832	1484.2	3665.7	1001.4	598.30	
25	0.00100274	105.391	0.36710	4.1805	1499.0	3734.6	889.95	606.80	
30	0.00100414	126.288	0.43661	4.1787	1511.8	3793.4	797.21	614.67	
35	0.00100578	147.179	0.50496	4.1777	1522.8	3842.6	719.16	621.97	
40	0.00100762	168.066	0.57220	4.1773	1532.1	3882.7	652.79	628.76	
45	0.00100965	188.953	0.63837	4.1776	1539.9	3914.2	595.86	635.06	
50	0.00101188	209.843	0.70352	4.1784	1546.2	3937.6	546.62	640.90	
55	0.00101428	230.738	0.76769	4.1798	1551.1	3953.3	503.74	646.30	
60	0.00101685	251.642	0.83091	4.1817	1554.7	3961.8	466.16	651.28	
65	0.00101959	272.556	0.89322	4.1841	1557.2	3963.6	433.04	655.85	
70	0.00102250	293.483	0.95465	4.1870	1558.5	3959.0	403.69	660.04	
75	0.00102556	314.426	1.0152	4.1905	1558.7	3948.5	377.56	663.84	
80	0.00102878	335.388	1.0750	4.1944	1558.0	3932.4	354.19	667.28	
85	0.00103215	356.372	1.1340	4.1989	1556.3	3911.1	333.22	670.35	
90	0.00103568	377.378	1.1923	4.2039	1553.7	3884.9	314.32	673.07	
95	0.00103937	398.412	1.2498	4.2094	1550.3	3854.2	297.22	675.45	
100	0.00104320	419.474	1.3066	4.2155	1546.1	3819.1	281.72	677.50	
110	0.00105134	461.696	1.4183	4.2293	1535.4	3737.3	254.73	680.62	
120	0.00106010	504.067	1.5275	4.2453	1521.9	3641.5	232.14	682.48	
130	0.00106952	546.611	1.6343	4.2639	1505.8	3533.5	213.03	683.16	
140	0.00107961	589.355	1.7390	4.2853	1487.2	3414.6	196.70	682.68	
150	0.00109042	632.328	1.8418	4.3099	1466.3	3286.3	182.64	681.10	
<i>t_s = 158.832 °C</i>									
Liquid	0.00110061	670.501	1.9311	4.3345	1445.9	3166.0	171.77	679.02	
Vapour	0.315575	2756.14	6.7592	2.4800	495.88	1.2987	14.264	31.552	
160	0.316666	2759.02	6.7658	2.4597	496.87	1.2994	14.314	31.645	
170	0.325824	2782.97	6.8205	2.3427	504.69	1.3029	14.743	32.450	
180	0.334744	2806.04	6.8720	2.2759	511.81	1.3042	15.171	33.273	
190	0.343496	2828.55	6.9211	2.2295	518.55	1.3047	15.597	34.111	
200	0.352116	2850.66	6.9684	2.1942	525.04	1.3048	16.023	34.967	
210	0.360628	2872.46	7.0139	2.1666	531.32	1.3047	16.448	35.839	
220	0.369050	2894.01	7.0581	2.1446	537.43	1.3044	16.873	36.727	
230	0.377395	2915.37	7.1010	2.1273	543.38	1.3039	17.296	37.632	
240	0.385675	2936.57	7.1427	2.1136	549.19	1.3034	17.720	38.553	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 6 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.393899	2957.65	7.1834	2.1030	554.88	1.3027	18.143	39.490
260	0.402075	2978.64	7.2231	2.0949	560.45	1.3020	18.566	40.442
270	0.410209	2999.56	7.2620	2.0888	565.91	1.3012	18.988	41.410
280	0.418307	3020.42	7.3001	2.0845	571.28	1.3003	19.410	42.392
290	0.426372	3041.25	7.3374	2.0817	576.56	1.2994	19.831	43.389
300	0.434409	3062.06	7.3740	2.0800	581.76	1.2985	20.253	44.399
310	0.442420	3082.86	7.4100	2.0794	586.88	1.2975	20.673	45.424
320	0.450409	3103.65	7.4453	2.0797	591.92	1.2965	21.094	46.461
330	0.458378	3124.45	7.4801	2.0807	596.89	1.2954	21.514	47.511
340	0.466328	3145.27	7.5143	2.0823	601.80	1.2944	21.934	48.573
350	0.474262	3166.10	7.5480	2.0845	606.65	1.2933	22.353	49.648
360	0.482181	3186.96	7.5812	2.0872	611.43	1.2922	22.772	50.734
370	0.490086	3207.85	7.6140	2.0903	616.16	1.2911	23.190	51.831
380	0.497979	3228.77	7.6463	2.0938	620.84	1.2900	23.608	52.939
390	0.505860	3249.72	7.6781	2.0976	625.46	1.2889	24.025	54.058
400	0.513731	3270.72	7.7095	2.1017	630.04	1.2878	24.442	55.187
410	0.521592	3291.76	7.7405	2.1060	634.56	1.2867	24.858	56.326
420	0.529444	3312.84	7.7712	2.1106	639.04	1.2855	25.273	57.475
430	0.537287	3333.97	7.8014	2.1154	643.47	1.2844	25.688	58.633
440	0.545123	3355.15	7.8314	2.1203	647.86	1.2833	26.102	59.801
450	0.552952	3376.38	7.8609	2.1255	652.21	1.2822	26.516	60.977
460	0.560774	3397.66	7.8901	2.1307	656.52	1.2810	26.929	62.162
470	0.568589	3418.99	7.9190	2.1362	660.79	1.2799	27.341	63.355
480	0.576399	3440.38	7.9476	2.1417	665.02	1.2788	27.752	64.556
490	0.584203	3461.83	7.9759	2.1473	669.21	1.2776	28.163	65.765
500	0.592002	3483.33	8.0039	2.1531	673.37	1.2765	28.573	66.982
510	0.599796	3504.89	8.0316	2.1590	677.49	1.2754	28.982	68.206
520	0.607586	3526.51	8.0591	2.1649	681.58	1.2743	29.390	69.437
530	0.615371	3548.19	8.0862	2.1709	685.63	1.2732	29.798	70.676
540	0.623153	3569.93	8.1131	2.1770	689.66	1.2721	30.205	71.921
550	0.630930	3591.73	8.1398	2.1832	693.65	1.2710	30.610	73.173
560	0.638704	3613.59	8.1662	2.1895	697.61	1.2699	31.015	74.431
570	0.646475	3635.52	8.1923	2.1958	701.54	1.2688	31.420	75.696
580	0.654242	3657.51	8.2183	2.2021	705.44	1.2677	31.823	76.967
590	0.662006	3679.56	8.2439	2.2085	709.31	1.2667	32.225	78.243
600	0.669768	3701.68	8.2694	2.2150	713.16	1.2656	32.627	79.526
650	0.708536	3813.24	8.3937	2.2477	731.99	1.2604	34.620	86.021
700	0.747253	3926.46	8.5131	2.2811	750.22	1.2553	36.590	92.640
750	0.785928	4041.36	8.6282	2.3148	767.91	1.2505	38.535	99.369
800	0.824571	4157.95	8.7395	2.3488	785.10	1.2459	40.455	106.19

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 8 bar</i>									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.000999801	0.77234	-0.0001013	4.2160	1403.5	2462.9	1790.2	556.18	
2	0.000999706	9.19771	0.030632	4.2096	1413.3	2497.6	1672.2	561.18	
4	0.000999679	17.6115	0.061100	4.2043	1422.7	2531.0	1566.2	565.96	
6	0.000999716	26.0154	0.091314	4.1998	1431.8	2563.1	1470.6	570.56	
8	0.000999812	34.4111	0.12128	4.1960	1440.4	2593.9	1384.0	574.98	
10	0.000999965	42.7999	0.15101	4.1928	1448.7	2623.4	1305.3	579.23	
12	0.00100017	51.1827	0.18052	4.1901	1456.5	2651.5	1233.5	583.34	
14	0.00100043	59.5605	0.20979	4.1878	1464.1	2678.2	1167.9	587.30	
16	0.00100073	67.9339	0.23885	4.1858	1471.2	2703.7	1107.7	591.13	
18	0.00100108	76.3037	0.26770	4.1841	1478.0	2727.8	1052.4	594.83	
20	0.00100148	84.6704	0.29634	4.1826	1484.5	2750.7	1001.4	598.42	
25	0.00100264	105.576	0.36705	4.1799	1499.3	2802.4	889.93	606.91	
30	0.00100405	126.471	0.43655	4.1781	1512.1	2846.5	797.21	614.78	
35	0.00100569	147.359	0.50489	4.1772	1523.1	2883.4	719.17	622.08	
40	0.00100753	168.243	0.57212	4.1768	1532.4	2913.5	652.82	628.86	
45	0.00100956	189.128	0.63829	4.1771	1540.2	2937.1	595.89	635.16	
50	0.00101179	210.015	0.70343	4.1779	1546.5	2954.7	546.66	641.00	
55	0.00101419	230.908	0.76759	4.1793	1551.4	2966.5	503.79	646.40	
60	0.00101676	251.809	0.83080	4.1812	1555.1	2972.9	466.21	651.38	
65	0.00101950	272.721	0.89311	4.1836	1557.5	2974.3	433.09	655.96	
70	0.00102240	293.647	0.95453	4.1866	1558.8	2970.9	403.74	660.14	
75	0.00102547	314.588	1.0151	4.1900	1559.1	2963.0	377.61	663.95	
80	0.00102868	335.548	1.0749	4.1940	1558.4	2951.0	354.25	667.38	
85	0.00103206	356.529	1.1339	4.1985	1556.7	2935.0	333.27	670.46	
90	0.00103559	377.533	1.1921	4.2035	1554.1	2915.4	314.37	673.18	
95	0.00103927	398.564	1.2496	4.2090	1550.7	2892.4	297.28	675.57	
100	0.00104310	419.624	1.3065	4.2150	1546.5	2866.1	281.77	677.61	
110	0.00105123	461.841	1.4181	4.2288	1535.9	2804.9	254.79	680.73	
120	0.00105999	504.207	1.5273	4.2448	1522.4	2733.1	232.19	682.61	
130	0.00106940	546.746	1.6341	4.2634	1506.3	2652.1	213.08	683.28	
140	0.00107948	589.484	1.7388	4.2847	1487.7	2563.0	196.76	682.81	
150	0.00109029	632.451	1.8416	4.3092	1466.9	2466.9	182.69	681.24	
160	0.00110186	675.681	1.9426	4.3373	1443.7	2364.5	170.48	678.85	
170	0.00111426	719.211	2.0419	4.3695	1418.3	2256.6	159.78	675.53	
<i>t_s = 170.414 °C</i>									
Saturation									
Liquid	0.00111479	721.018	2.0460	4.3709	1417.2	2252.0	159.36	675.37	
Vapour	0.240328	2768.30	6.6615	2.6032	498.87	1.2944	14.659	33.285	
180	0.247183	2792.44	6.7154	2.4499	506.90	1.2994	15.079	34.022	
190	0.254105	2816.46	6.7678	2.3621	514.34	1.3013	15.516	34.813	
200	0.260868	2839.77	6.8176	2.3030	521.29	1.3021	15.950	35.624	
210	0.267506	2862.57	6.8653	2.2586	527.95	1.3024	16.382	36.455	
220	0.274043	2884.97	6.9112	2.2236	534.36	1.3025	16.814	37.306	
230	0.280496	2907.06	6.9555	2.1956	540.58	1.3023	17.244	38.176	
240	0.286878	2928.90	6.9985	2.1732	546.63	1.3020	17.673	39.064	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 8 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.293199	2950.54	7.0403	2.1553	552.52	1.3015	18.101	39.971
260	0.299469	2972.02	7.0810	2.1411	558.28	1.3010	18.528	40.895
270	0.305693	2993.37	7.1206	2.1298	563.91	1.3003	18.954	41.836
280	0.311878	3014.63	7.1594	2.1211	569.42	1.2996	19.380	42.794
290	0.318030	3035.80	7.1974	2.1145	574.84	1.2988	19.805	43.768
300	0.324151	3056.92	7.2345	2.1097	580.15	1.2979	20.229	44.758
310	0.330245	3078.00	7.2710	2.1063	585.37	1.2970	20.653	45.762
320	0.336316	3099.05	7.3068	2.1042	590.51	1.2961	21.076	46.782
330	0.342366	3120.09	7.3420	2.1031	595.58	1.2951	21.498	47.815
340	0.348397	3141.12	7.3765	2.1029	600.57	1.2941	21.920	48.862
350	0.354411	3162.15	7.4106	2.1035	605.49	1.2930	22.341	49.922
360	0.360409	3183.19	7.4441	2.1048	610.34	1.2920	22.762	50.995
370	0.366393	3204.25	7.4771	2.1066	615.14	1.2909	23.182	52.081
380	0.372365	3225.33	7.5096	2.1090	619.87	1.2899	23.601	53.178
390	0.378324	3246.43	7.5416	2.1117	624.55	1.2888	24.019	54.286
400	0.384273	3267.56	7.5733	2.1149	629.17	1.2877	24.437	55.406
410	0.390212	3288.73	7.6045	2.1184	633.74	1.2866	24.855	56.537
420	0.396142	3309.93	7.6353	2.1223	638.26	1.2855	25.271	57.678
430	0.402063	3331.17	7.6657	2.1264	642.74	1.2844	25.687	58.829
440	0.407977	3352.46	7.6958	2.1307	647.17	1.2832	26.102	59.989
450	0.413883	3373.79	7.7255	2.1352	651.55	1.2821	26.517	61.159
460	0.419783	3395.16	7.7548	2.1400	655.89	1.2810	26.930	62.339
470	0.425676	3416.59	7.7839	2.1449	660.19	1.2799	27.343	63.527
480	0.431563	3438.06	7.8126	2.1500	664.45	1.2788	27.755	64.724
490	0.437444	3459.59	7.8410	2.1553	668.67	1.2777	28.167	65.929
500	0.443321	3481.17	7.8690	2.1606	672.86	1.2766	28.577	67.142
510	0.449192	3502.80	7.8969	2.1661	677.00	1.2754	28.987	68.363
520	0.455059	3524.49	7.9244	2.1717	681.12	1.2743	29.395	69.592
530	0.460921	3546.24	7.9516	2.1774	685.19	1.2732	29.803	70.828
540	0.466780	3568.04	7.9786	2.1833	689.24	1.2721	30.210	72.071
550	0.472635	3589.90	8.0053	2.1892	693.25	1.2711	30.617	73.321
560	0.478486	3611.82	8.0318	2.1951	697.23	1.2700	31.022	74.577
570	0.484333	3633.81	8.0580	2.2012	701.18	1.2689	31.426	75.841
580	0.490178	3655.85	8.0840	2.2073	705.10	1.2678	31.830	77.110
590	0.496019	3677.95	8.1098	2.2135	708.99	1.2667	32.233	78.386
600	0.501857	3700.12	8.1353	2.2197	712.85	1.2657	32.634	79.668
650	0.531012	3811.90	8.2598	2.2516	731.75	1.2605	34.628	86.162
700	0.560113	3925.29	8.3794	2.2843	750.04	1.2555	36.599	92.784
750	0.589174	4040.33	8.4947	2.3175	767.77	1.2506	38.544	99.518
800	0.618202	4157.04	8.6060	2.3510	785.00	1.2460	40.464	106.35

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 10 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000999699	0.97582	-0.00008842	4.2150	1403.8	1971.4	1789.7	556.33
2	0.000999606	9.39927	0.030637	4.2087	1413.6	1999.2	1671.8	561.32
4	0.000999581	17.8112	0.061099	4.2034	1423.1	2025.9	1565.9	566.10
6	0.000999618	26.2135	0.091307	4.1990	1432.1	2051.6	1470.3	570.70
8	0.000999716	34.6076	0.12127	4.1952	1440.7	2076.2	1383.7	575.11
10	0.000999870	42.9948	0.15100	4.1921	1449.0	2099.8	1305.1	579.36
12	0.00100008	51.3761	0.18049	4.1894	1456.9	2122.3	1233.4	583.46
14	0.00100033	59.7525	0.20977	4.1871	1464.4	2143.7	1167.8	587.42
16	0.00100064	68.1246	0.23882	4.1851	1471.5	2164.1	1107.6	591.25
18	0.00100099	76.4931	0.26766	4.1834	1478.4	2183.4	1052.3	594.95
20	0.00100139	84.8585	0.29630	4.1820	1484.8	2201.7	1001.3	598.54
25	0.00100255	105.761	0.36700	4.1793	1499.6	2243.1	889.90	607.02
30	0.00100396	126.653	0.43649	4.1776	1512.4	2278.4	797.20	614.89
35	0.00100560	147.538	0.50482	4.1766	1523.4	2307.9	719.18	622.19
40	0.00100744	168.421	0.57204	4.1763	1532.8	2332.0	652.84	628.97
45	0.00100947	189.303	0.63820	4.1766	1540.5	2350.9	595.93	635.27
50	0.00101170	210.188	0.70334	4.1775	1546.8	2365.0	546.70	641.10
55	0.00101410	231.079	0.76749	4.1789	1551.7	2374.4	503.83	646.50
60	0.00101667	251.977	0.83070	4.1808	1555.4	2379.6	466.26	651.49
65	0.00101941	272.887	0.89299	4.1832	1557.9	2380.7	433.14	656.06
70	0.00102231	293.810	0.95441	4.1861	1559.2	2378.0	403.79	660.25
75	0.00102537	314.749	1.0150	4.1896	1559.5	2371.7	377.66	664.06
80	0.00102859	335.707	1.0748	4.1935	1558.7	2362.1	354.30	667.49
85	0.00103196	356.686	1.1338	4.1980	1557.1	2349.4	333.32	670.57
90	0.00103549	377.688	1.1920	4.2030	1554.5	2333.7	314.42	673.29
95	0.00103917	398.717	1.2495	4.2085	1551.1	2315.3	297.33	675.68
100	0.00104300	419.774	1.3063	4.2146	1546.9	2294.3	281.83	677.73
110	0.00105112	461.987	1.4179	4.2283	1536.3	2245.4	254.84	680.85
120	0.00105988	504.348	1.5271	4.2443	1522.8	2188.0	232.25	682.73
130	0.00106928	546.882	1.6339	4.2629	1506.8	2123.3	213.13	683.41
140	0.00107936	589.614	1.7386	4.2841	1488.3	2052.1	196.81	682.94
150	0.00109015	632.575	1.8414	4.3086	1467.4	1975.2	182.74	681.37
160	0.00110171	675.797	1.9423	4.3366	1444.3	1893.4	170.53	678.99
170	0.00111410	719.320	2.0417	4.3687	1418.9	1807.1	159.83	675.67
<i>t_s</i> = 179.886 °C								
Saturation								
Liquid	0.00112723	762.683	2.1384	4.4051	1391.6	1718.1	150.48	671.34
Vapour	0.194349	2777.12	6.5850	2.7150	500.89	1.2910	14.981	34.812
180	0.194418	2777.43	6.5857	2.7119	501.00	1.2911	14.986	34.821
190	0.200319	2803.52	6.6426	2.5285	509.69	1.2969	15.433	35.552
200	0.206004	2828.27	6.6955	2.4288	517.32	1.2991	15.876	36.312
210	0.211542	2852.20	6.7455	2.3614	524.41	1.3000	16.316	37.097
220	0.216966	2875.55	6.7934	2.3105	531.18	1.3005	16.755	37.906
230	0.222297	2898.45	6.8393	2.2702	537.69	1.3006	17.191	38.737
240	0.227551	2920.98	6.8837	2.2378	543.99	1.3005	17.625	39.590

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 10 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.232739	2943.22	6.9266	2.2116	550.11	1.3002	18.058	40.464
260	0.237871	2965.23	6.9683	2.1905	556.06	1.2999	18.490	41.358
270	0.242955	2987.05	7.0088	2.1735	561.86	1.2994	18.920	42.272
280	0.247998	3008.71	7.0484	2.1600	567.53	1.2988	19.350	43.204
290	0.253004	3030.25	7.0870	2.1492	573.08	1.2981	19.778	44.154
300	0.257979	3051.70	7.1247	2.1408	578.51	1.2973	20.205	45.122
310	0.262926	3073.08	7.1617	2.1344	583.85	1.2965	20.632	46.107
320	0.267848	3094.40	7.1979	2.1297	589.09	1.2956	21.058	47.108
330	0.272749	3115.68	7.2335	2.1263	594.25	1.2947	21.482	48.124
340	0.277629	3136.93	7.2685	2.1242	599.32	1.2938	21.906	49.155
350	0.282492	3158.16	7.3028	2.1231	604.32	1.2928	22.329	50.201
360	0.287339	3179.39	7.3366	2.1228	609.24	1.2918	22.752	51.260
370	0.292172	3200.62	7.3699	2.1233	614.10	1.2907	23.173	52.333
380	0.296991	3221.86	7.4026	2.1245	618.89	1.2897	23.594	53.419
390	0.301799	3243.11	7.4349	2.1262	623.62	1.2886	24.014	54.517
400	0.306595	3264.39	7.4668	2.1284	628.30	1.2876	24.433	55.627
410	0.311381	3285.68	7.4982	2.1311	632.92	1.2865	24.852	56.749
420	0.316158	3307.01	7.5292	2.1341	637.48	1.2854	25.269	57.882
430	0.320927	3328.37	7.5598	2.1375	642.00	1.2843	25.686	59.025
440	0.325687	3349.76	7.5900	2.1412	646.47	1.2832	26.102	60.179
450	0.330440	3371.19	7.6198	2.1451	650.89	1.2821	26.518	61.344
460	0.335186	3392.66	7.6493	2.1494	655.26	1.2810	26.932	62.517
470	0.339926	3414.18	7.6785	2.1538	659.59	1.2799	27.346	63.701
480	0.344659	3435.74	7.7073	2.1584	663.88	1.2788	27.758	64.893
490	0.349387	3457.35	7.7358	2.1632	668.13	1.2777	28.170	66.094
500	0.354110	3479.00	7.7640	2.1682	672.34	1.2766	28.581	67.303
510	0.358828	3500.71	7.7919	2.1733	676.52	1.2755	28.991	68.521
520	0.363541	3522.47	7.8195	2.1786	680.65	1.2744	29.401	69.747
530	0.368250	3544.28	7.8468	2.1840	684.75	1.2733	29.809	70.980
540	0.372955	3566.15	7.8739	2.1895	688.82	1.2722	30.216	72.221
550	0.377656	3588.07	7.9007	2.1951	692.85	1.2711	30.623	73.469
560	0.382354	3610.05	7.9272	2.2008	696.85	1.2700	31.029	74.725
570	0.387048	3632.09	7.9535	2.2066	700.82	1.2690	31.433	75.987
580	0.391738	3654.19	7.9795	2.2125	704.76	1.2679	31.837	77.255
590	0.396426	3676.34	8.0054	2.2185	708.66	1.2668	32.240	78.530
600	0.401111	3698.56	8.0309	2.2245	712.54	1.2658	32.642	79.811
650	0.424497	3810.55	8.1557	2.2555	731.51	1.2606	34.637	86.305
700	0.447829	3924.12	8.2755	2.2875	749.86	1.2556	36.607	92.929
750	0.471121	4039.31	8.3909	2.3201	767.64	1.2508	38.553	99.667
800	0.494380	4156.14	8.5024	2.3532	784.91	1.2462	40.473	106.50

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 20 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000999193	1.99229	-0.00002608	4.2100	1405.4	988.40	1787.5	557.09
2	0.000999107	10.4062	0.030665	4.2041	1415.2	1002.3	1670.0	562.05
4	0.000999088	18.8091	0.061094	4.1990	1424.6	1015.7	1564.3	566.81
6	0.000999132	27.2029	0.091271	4.1948	1433.7	1028.6	1469.0	571.38
8	0.000999235	35.5890	0.12121	4.1913	1442.3	1040.9	1382.7	575.78
10	0.000999394	43.9685	0.15090	4.1883	1450.6	1052.7	1304.2	580.01
12	0.000999605	52.3425	0.18038	4.1858	1458.4	1063.9	1232.6	584.10
14	0.000999866	60.7118	0.20962	4.1836	1466.0	1074.7	1167.2	588.04
16	0.00100018	69.0772	0.23865	4.1818	1473.1	1084.9	1107.2	591.86
18	0.00100053	77.4392	0.26747	4.1802	1479.9	1094.5	1051.9	595.55
20	0.00100093	85.7984	0.29609	4.1789	1486.4	1103.7	1001.0	599.12
25	0.00100210	106.686	0.36674	4.1764	1501.2	1124.4	889.76	607.59
30	0.00100352	127.564	0.43618	4.1749	1514.0	1142.1	797.19	615.44
35	0.00100515	148.437	0.50447	4.1741	1525.0	1156.9	719.25	622.73
40	0.00100700	169.306	0.57166	4.1739	1534.4	1169.0	652.97	629.50
45	0.00100903	190.177	0.63778	4.1743	1542.2	1178.5	596.10	635.79
50	0.00101125	211.050	0.70287	4.1752	1548.5	1185.6	546.90	641.62
55	0.00101365	231.929	0.76699	4.1766	1553.4	1190.3	504.06	647.02
60	0.00101622	252.817	0.83016	4.1786	1557.1	1193.0	466.50	652.01
65	0.00101896	273.716	0.89243	4.1810	1559.6	1193.6	433.39	656.59
70	0.00102185	294.628	0.95382	4.1840	1561.0	1192.3	404.05	660.78
75	0.00102491	315.556	1.0144	4.1874	1561.3	1189.2	377.93	664.59
80	0.00102812	336.503	1.0741	4.1914	1560.6	1184.4	354.57	668.03
85	0.00103148	357.471	1.1331	4.1958	1559.0	1178.1	333.59	671.11
90	0.00103500	378.462	1.1913	4.2008	1556.5	1170.3	314.69	673.84
95	0.00103867	399.479	1.2487	4.2063	1553.1	1161.2	297.60	676.24
100	0.00104249	420.526	1.3055	4.2123	1549.0	1150.8	282.10	678.29
110	0.00105059	462.715	1.4171	4.2259	1538.4	1126.4	255.11	681.44
120	0.00105932	505.051	1.5262	4.2418	1525.1	1097.8	232.51	683.33
130	0.00106869	547.559	1.6329	4.2601	1509.2	1065.6	213.39	684.04
140	0.00107873	590.263	1.7376	4.2812	1490.8	1030.1	197.06	683.59
150	0.00108948	633.193	1.8403	4.3053	1470.1	991.86	183.00	682.05
160	0.00110099	676.382	1.9411	4.3330	1447.2	951.08	170.78	679.66
170	0.00111332	719.867	2.0404	4.3647	1422.0	908.11	160.08	676.39
180	0.00112654	763.691	2.1382	4.4011	1394.6	863.22	150.64	672.04
190	0.00114075	807.906	2.2347	4.4430	1365.0	816.67	142.23	666.70
200	0.00115606	852.572	2.3301	4.4914	1333.2	768.70	134.70	660.40
210	0.00117260	897.760	2.4246	4.5476	1299.0	719.55	127.89	653.16

<i>t_s</i> = 212.385 °C	Saturation							
Liquid	0.00117675	908.622	2.4470	4.5623	1290.6	707.68	126.36	651.29
Vapour	0.0995805	2798.38	6.3392	3.1904	504.66	1.2788	16.091	40.936
220	0.102167	2821.67	6.3868	2.9487	512.58	1.2858	16.454	41.313
230	0.105394	2850.17	6.4440	2.7665	521.47	1.2901	16.924	41.874
240	0.108488	2877.21	6.4972	2.6481	529.47	1.2920	17.388	42.492

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 20 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.111484	2903.23	6.5474	2.5602	536.96	1.2931	17.848	43.158
260	0.114400	2928.47	6.5952	2.4909	544.07	1.2938	18.303	43.866
270	0.117251	2953.09	6.6410	2.4349	550.89	1.2941	18.755	44.612
280	0.120046	2977.21	6.6850	2.3890	557.44	1.2943	19.203	45.393
290	0.122794	3000.90	6.7274	2.3512	563.78	1.2942	19.649	46.206
300	0.125501	3024.25	6.7685	2.3201	569.91	1.2940	20.092	47.048
310	0.128174	3047.32	6.8084	2.2944	575.87	1.2937	20.533	47.919
320	0.130816	3070.16	6.8472	2.2733	581.67	1.2932	20.971	48.815
330	0.133431	3092.80	6.8851	2.2559	587.33	1.2926	21.408	49.736
340	0.136023	3115.28	6.9221	2.2417	592.86	1.2920	21.842	50.681
350	0.138594	3137.64	6.9582	2.2301	598.27	1.2913	22.275	51.647
360	0.141147	3159.89	6.9937	2.2207	603.57	1.2905	22.706	52.633
370	0.143683	3182.06	7.0284	2.2133	608.77	1.2897	23.136	53.639
380	0.146205	3204.16	7.0625	2.2074	613.88	1.2888	23.564	54.664
390	0.148712	3226.21	7.0960	2.2030	618.91	1.2879	23.991	55.706
400	0.151208	3248.23	7.1290	2.1997	623.85	1.2869	24.417	56.765
410	0.153693	3270.21	7.1614	2.1974	628.72	1.2860	24.841	57.840
420	0.156167	3292.18	7.1933	2.1961	633.52	1.2850	25.264	58.931
430	0.158632	3314.14	7.2248	2.1955	638.25	1.2840	25.686	60.036
440	0.161088	3336.09	7.2558	2.1957	642.92	1.2830	26.106	61.154
450	0.163537	3358.05	7.2863	2.1964	647.52	1.2819	26.525	62.286
460	0.165978	3380.02	7.3165	2.1976	652.08	1.2809	26.944	63.431
470	0.168413	3402.01	7.3463	2.1994	656.57	1.2799	27.361	64.588
480	0.170841	3424.01	7.3757	2.2015	661.02	1.2788	27.776	65.757
490	0.173263	3446.04	7.4048	2.2041	665.41	1.2777	28.191	66.937
500	0.175680	3468.09	7.4335	2.2069	669.76	1.2767	28.605	68.127
510	0.178092	3490.18	7.4619	2.2101	674.06	1.2756	29.017	69.328
520	0.180499	3512.30	7.4899	2.2136	678.32	1.2746	29.429	70.539
530	0.182902	3534.45	7.5177	2.2173	682.54	1.2735	29.839	71.759
540	0.185300	3556.64	7.5451	2.2212	686.71	1.2725	30.249	72.988
550	0.187694	3578.88	7.5723	2.2254	690.85	1.2714	30.657	74.226
560	0.190085	3601.15	7.5992	2.2297	694.95	1.2704	31.064	75.473
570	0.192472	3623.47	7.6258	2.2342	699.01	1.2693	31.470	76.728
580	0.194856	3645.84	7.6522	2.2389	703.04	1.2683	31.875	77.990
590	0.197237	3668.25	7.6783	2.2437	707.03	1.2672	32.279	79.260
600	0.199614	3690.71	7.7042	2.2486	710.99	1.2662	32.682	80.538
650	0.211464	3803.79	7.8301	2.2750	730.32	1.2611	34.681	87.025
700	0.223260	3918.24	7.9509	2.3035	748.96	1.2562	36.653	93.660
750	0.235015	4034.16	8.0670	2.3333	766.98	1.2515	38.600	100.42
800	0.246737	4151.59	8.1791	2.3642	784.44	1.2470	40.520	107.29

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 40 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000998184	4.02062	0.00008726	4.2003	1408.6	496.92	1783.2	558.60
2	0.000998113	12.4157	0.030710	4.1949	1418.4	503.90	1666.3	563.51
4	0.000998107	20.8009	0.061075	4.1904	1427.8	510.62	1561.3	568.22
6	0.000998163	29.1779	0.091192	4.1867	1436.8	517.07	1466.5	572.75
8	0.000998277	37.5481	0.12107	4.1835	1445.5	523.25	1380.6	577.10
10	0.000998446	45.9125	0.15071	4.1809	1453.7	529.16	1302.4	581.30
12	0.000998666	54.2720	0.18013	4.1787	1461.6	534.79	1231.2	585.36
14	0.000998936	62.6275	0.20933	4.1768	1469.1	540.17	1166.0	589.28
16	0.000999252	70.9796	0.23832	4.1753	1476.3	545.28	1106.2	593.07
18	0.000999613	79.3288	0.26709	4.1739	1483.1	550.13	1051.2	596.74
20	0.00100002	87.6755	0.29566	4.1728	1489.6	554.72	1000.4	600.29
25	0.00100120	108.534	0.36622	4.1708	1504.4	565.10	889.51	608.71
30	0.00100263	129.385	0.43557	4.1696	1517.2	573.97	797.16	616.53
35	0.00100427	150.231	0.50378	4.1690	1528.2	581.40	719.39	623.79
40	0.00100611	171.076	0.57088	4.1691	1537.6	587.48	653.23	630.55
45	0.00100815	191.923	0.63692	4.1696	1545.4	592.27	596.44	636.83
50	0.00101037	212.773	0.70195	4.1706	1551.8	595.84	547.31	642.66
55	0.00101276	233.630	0.76600	4.1722	1556.8	598.28	504.51	648.06
60	0.00101533	254.495	0.82910	4.1742	1560.5	599.64	466.98	653.04
65	0.00101806	275.372	0.89130	4.1767	1563.1	599.98	433.89	657.63
70	0.00102094	296.263	0.95263	4.1796	1564.5	599.38	404.57	661.82
75	0.00102398	317.169	1.0131	4.1831	1564.9	597.90	378.46	665.64
80	0.00102718	338.095	1.0728	4.1871	1564.3	595.57	355.10	669.10
85	0.00103053	359.041	1.1317	4.1915	1562.8	592.47	334.13	672.19
90	0.00103403	380.010	1.1898	4.1964	1560.3	588.64	315.23	674.94
95	0.00103768	401.006	1.2473	4.2018	1557.1	584.12	298.14	677.35
100	0.00104148	422.029	1.3040	4.2078	1553.0	578.97	282.64	679.42
110	0.00104953	464.172	1.4154	4.2212	1542.7	566.91	255.64	682.60
120	0.00105821	506.460	1.5244	4.2368	1529.6	552.75	233.04	684.54
130	0.00106751	548.916	1.6310	4.2548	1513.9	536.76	213.91	685.29
140	0.00107748	591.564	1.7355	4.2754	1495.9	519.17	197.58	684.90
150	0.00108814	634.433	1.8380	4.2990	1475.5	500.17	183.51	683.40
160	0.00109956	677.555	1.9388	4.3260	1452.9	479.92	171.29	681.00
170	0.00111177	720.966	2.0378	4.3569	1428.1	458.59	160.58	677.83
180	0.00112486	764.707	2.1354	4.3923	1401.1	436.30	151.14	673.55
190	0.00113892	808.829	2.2317	4.4330	1372.0	413.18	142.74	668.28
200	0.00115404	853.387	2.3269	4.4799	1340.6	389.35	135.21	662.06
210	0.00117037	898.451	2.4212	4.5342	1307.1	364.93	128.41	654.90
220	0.00118806	944.102	2.5147	4.5975	1271.2	340.03	122.21	646.82
230	0.00120732	990.438	2.6077	4.6717	1232.9	314.76	116.52	637.81
240	0.00122842	1037.58	2.7005	4.7595	1192.1	289.22	111.24	627.85

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 40 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00125169	1085.69	2.7933	4.8646	1148.5	263.45	106.3	616.9
<i>t_s = 250.358 °C</i>								
Liquid	0.00125257	1087.43	2.7967	4.8688	1146.9	262.53	106.12	616.50
Vapour	0.0497766	2800.90	6.0697	4.0217	501.64	1.2639	17.443	50.441
260	0.0517770	2837.19	6.1384	3.5536	513.78	1.2746	17.936	50.343
270	0.0536916	2871.20	6.2016	3.2702	524.26	1.2797	18.436	50.459
280	0.0554948	2902.88	6.2594	3.0774	533.58	1.2826	18.927	50.722
290	0.0572145	2932.91	6.3132	2.9332	542.18	1.2844	19.409	51.098
300	0.0588680	2961.65	6.3638	2.8199	550.23	1.2857	19.885	51.565
310	0.0604671	2989.38	6.4118	2.7285	557.85	1.2866	20.355	52.107
320	0.0620211	3016.28	6.4575	2.6536	565.10	1.2872	20.820	52.715
330	0.0635367	3042.49	6.5014	2.5915	572.04	1.2876	21.280	53.381
340	0.0650195	3068.14	6.5435	2.5399	578.71	1.2877	21.736	54.097
350	0.0664740	3093.32	6.5843	2.4967	585.14	1.2877	22.188	54.859
360	0.0679040	3118.10	6.6237	2.4604	591.35	1.2875	22.637	55.663
370	0.0693123	3142.55	6.6620	2.4299	597.38	1.2871	23.083	56.505
380	0.0707017	3166.71	6.6993	2.4042	603.23	1.2867	23.525	57.381
390	0.0720743	3190.64	6.7357	2.3825	608.93	1.2862	23.965	58.289
400	0.0734318	3214.37	6.7712	2.3642	614.49	1.2855	24.403	59.227
410	0.0747759	3237.94	6.8059	2.3488	619.92	1.2849	24.838	60.193
420	0.0761079	3261.36	6.8400	2.3359	625.24	1.2841	25.271	61.184
430	0.0774290	3284.66	6.8734	2.3251	630.45	1.2833	25.702	62.199
440	0.0787401	3307.87	6.9061	2.3162	635.56	1.2825	26.130	63.237
450	0.0800422	3330.99	6.9383	2.3088	640.58	1.2816	26.557	64.295
460	0.0813360	3354.05	6.9700	2.3027	645.51	1.2807	26.982	65.374
470	0.0826222	3377.05	7.0012	2.2979	650.36	1.2798	27.405	66.471
480	0.0839015	3400.01	7.0318	2.2941	655.14	1.2789	27.827	67.586
490	0.0851742	3422.94	7.0621	2.2913	659.84	1.2780	28.247	68.717
500	0.0864410	3445.84	7.0919	2.2892	664.48	1.2770	28.666	69.865
510	0.0877022	3468.72	7.1213	2.2879	669.06	1.2760	29.082	71.027
520	0.0889583	3491.60	7.1503	2.2872	673.58	1.2751	29.498	72.203
530	0.0902096	3514.47	7.1790	2.2871	678.04	1.2741	29.912	73.393
540	0.0914564	3537.34	7.2073	2.2875	682.44	1.2731	30.324	74.596
550	0.0926990	3560.22	7.2353	2.2883	686.80	1.2721	30.736	75.811
560	0.0939376	3583.11	7.2629	2.2896	691.10	1.2711	31.145	77.037
570	0.0951726	3606.01	7.2902	2.2913	695.36	1.2701	31.554	78.274
580	0.0964041	3628.93	7.3172	2.2933	699.58	1.2692	31.961	79.522
590	0.0976323	3651.88	7.3440	2.2956	703.75	1.2682	32.367	80.780
600	0.0988574	3674.85	7.3704	2.2982	707.87	1.2672	32.772	82.047
650	0.104943	3790.15	7.4989	2.3149	727.94	1.2624	34.777	88.513
700	0.110973	3906.41	7.6215	2.3360	747.17	1.2577	36.752	95.162
750	0.116961	4023.80	7.7391	2.3601	765.68	1.2531	38.699	101.96
800	0.122915	4142.46	7.8523	2.3865	783.55	1.2487	40.618	108.88

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 60 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000997183	6.04286	0.0001856	4.1908	1411.8	333.11	1778.9	560.09
2	0.000997126	14.4195	0.030741	4.1860	1421.6	337.78	1662.8	564.95
4	0.000997133	22.7873	0.061042	4.1820	1431.0	342.27	1558.3	569.61
6	0.000997201	31.1478	0.091100	4.1787	1440.0	346.58	1464.0	574.10
8	0.000997326	39.5024	0.12092	4.1759	1448.7	350.71	1378.5	578.42
10	0.000997504	47.8519	0.15051	4.1737	1456.9	354.65	1300.7	582.59
12	0.000997733	56.1973	0.17988	4.1718	1464.8	358.42	1229.8	586.61
14	0.000998011	64.5391	0.20904	4.1702	1472.3	362.01	1164.9	590.50
16	0.000998335	72.8781	0.23798	4.1689	1479.5	365.42	1105.3	594.27
18	0.000998702	81.2147	0.26671	4.1678	1486.3	368.66	1050.4	597.91
20	0.000999112	89.5493	0.29524	4.1668	1492.8	371.73	999.86	601.45
25	0.00100031	110.379	0.36569	4.1652	1507.6	378.67	889.26	609.83
30	0.00100174	131.203	0.43496	4.1643	1520.4	384.60	797.14	617.61
35	0.00100339	152.024	0.50308	4.1641	1531.5	389.58	719.54	624.86
40	0.00100524	172.844	0.57010	4.1643	1540.9	393.65	653.49	631.60
45	0.00100727	193.667	0.63607	4.1650	1548.7	396.87	596.79	637.87
50	0.00100949	214.495	0.70103	4.1661	1555.1	399.28	547.72	643.69
55	0.00101188	235.329	0.76501	4.1678	1560.2	400.93	504.96	649.09
60	0.00101444	256.173	0.82805	4.1698	1564.0	401.87	467.46	654.07
65	0.00101716	277.028	0.89018	4.1724	1566.6	402.13	434.40	658.66
70	0.00102004	297.898	0.95145	4.1754	1568.1	401.76	405.09	662.87
75	0.00102307	318.783	1.0119	4.1788	1568.5	400.81	378.98	666.70
80	0.00102625	339.687	1.0715	4.1828	1568.0	399.29	355.64	670.16
85	0.00102958	360.612	1.1303	4.1872	1566.5	397.26	334.67	673.27
90	0.00103307	381.559	1.1884	4.1921	1564.2	394.74	315.77	676.04
95	0.00103670	402.533	1.2458	4.1974	1561.0	391.77	298.68	678.46
100	0.00104048	423.535	1.3024	4.2033	1557.1	388.37	283.17	680.55
110	0.00104849	465.632	1.4138	4.2165	1547.0	380.41	256.17	683.77
120	0.00105710	507.871	1.5226	4.2318	1534.1	371.05	233.56	685.75
130	0.00106635	550.276	1.6291	4.2495	1518.7	360.47	214.43	686.54
140	0.00107624	592.869	1.7335	4.2697	1500.9	348.83	198.09	686.19
150	0.00108682	635.679	1.8358	4.2927	1480.8	336.25	184.01	684.75
160	0.00109814	678.735	1.9364	4.3191	1458.5	322.85	171.79	682.26
170	0.00111024	722.073	2.0353	4.3492	1434.1	308.72	161.08	679.26
180	0.00112321	765.733	2.1327	4.3837	1407.5	293.96	151.64	675.05
190	0.00113711	809.763	2.2289	4.4232	1378.8	278.65	143.24	669.85
200	0.00115205	854.217	2.3238	4.4687	1348.0	262.87	135.71	663.71
210	0.00116817	899.160	2.4178	4.5213	1314.9	246.69	128.92	656.64
220	0.00118561	944.671	2.5110	4.5823	1279.7	230.19	122.73	648.65
230	0.00120456	990.841	2.6037	4.6537	1242.0	213.45	117.05	639.75
240	0.00122528	1037.79	2.6961	4.7378	1202.0	196.52	111.79	629.91

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 60 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00124808	1085.65	2.7885	4.8379	1159.3	179.46	106.86	619.12
260	0.00127338	1134.61	2.8812	4.9589	1113.5	162.29	102.21	607.32
270	0.00130177	1184.92	2.9747	5.1082	1064.2	145.00	97.744	594.46
<i>t_s = 275.586 °C</i>								
Liquid	0.00131927	1213.73	3.0274	5.2080	1034.8	135.28	95.310	586.78
Vapour	0.0324487	2784.56	5.8901	4.8768	494.01	1.2535	18.440	59.065
280	0.0331998	2805.25	5.9276	4.5160	501.07	1.2604	18.677	58.553
290	0.0347631	2847.50	6.0033	3.9812	514.56	1.2694	19.202	57.841
300	0.0361911	2885.49	6.0702	3.6378	526.04	1.2743	19.713	57.515
310	0.0375230	2920.58	6.1309	3.3929	536.29	1.2775	20.213	57.442
320	0.0387819	2953.55	6.1870	3.2078	545.69	1.2797	20.705	57.552
330	0.0399833	2984.87	6.2393	3.0626	554.43	1.2813	21.188	57.804
340	0.0411378	3014.89	6.2887	2.9459	562.64	1.2825	21.665	58.171
350	0.0422535	3043.86	6.3356	2.8504	570.41	1.2834	22.135	58.633
360	0.0433364	3071.96	6.3803	2.7714	577.79	1.2839	22.601	59.178
370	0.0443912	3099.33	6.4232	2.7054	584.85	1.2842	23.061	59.793
380	0.0454220	3126.10	6.4645	2.6499	591.62	1.2843	23.517	60.470
390	0.0464317	3152.36	6.5044	2.6030	598.14	1.2842	23.969	61.202
400	0.0474230	3178.18	6.5431	2.5632	604.44	1.2840	24.417	61.984
410	0.0483980	3203.64	6.5806	2.5293	610.54	1.2837	24.862	62.810
420	0.0493586	3228.79	6.6171	2.5004	616.47	1.2832	25.304	63.677
430	0.0503063	3253.66	6.6528	2.4757	622.23	1.2827	25.743	64.581
440	0.0512425	3278.31	6.6876	2.4545	627.84	1.2821	26.179	65.519
450	0.0521683	3302.76	6.7216	2.4364	633.32	1.2814	26.612	66.489
460	0.0530847	3327.05	6.7550	2.4209	638.68	1.2807	27.043	67.487
470	0.0539925	3351.19	6.7877	2.4077	643.93	1.2799	27.472	68.513
480	0.0548925	3375.21	6.8198	2.3964	649.07	1.2791	27.898	69.563
490	0.0557854	3399.12	6.8513	2.3868	654.12	1.2783	28.323	70.637
500	0.0566717	3422.95	6.8824	2.3787	659.07	1.2775	28.745	71.733
510	0.0575519	3446.70	6.9129	2.3719	663.95	1.2766	29.165	72.849
520	0.0584266	3470.39	6.9429	2.3663	668.74	1.2757	29.584	73.984
530	0.0592960	3494.03	6.9726	2.3616	673.46	1.2748	30.001	75.138
540	0.0601607	3517.63	7.0018	2.3579	678.11	1.2739	30.416	76.308
550	0.0610209	3541.19	7.0306	2.3550	682.70	1.2730	30.830	77.495
560	0.0618769	3564.73	7.0590	2.3528	687.22	1.2721	31.242	78.696
570	0.0627290	3588.25	7.0870	2.3512	691.69	1.2712	31.652	79.912
580	0.0635775	3611.76	7.1148	2.3503	696.09	1.2702	32.061	81.141
590	0.0644225	3635.26	7.1421	2.3498	700.45	1.2693	32.468	82.383
600	0.0652644	3658.76	7.1692	2.3499	704.75	1.2684	32.874	83.637
650	0.0694316	3776.36	7.3002	2.3559	725.58	1.2638	34.883	90.068
700	0.0735419	3894.47	7.4248	2.3692	745.42	1.2593	36.859	96.719
750	0.0776087	4013.37	7.5439	2.3874	764.42	1.2549	38.805	103.547
800	0.0816416	4133.27	7.6583	2.4092	782.69	1.2506	40.721	110.512

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 80 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000996188	8.05907	0.0002693	4.1814	1414.9	251.22	1774.7	561.56
2	0.000996145	16.4176	0.030758	4.1772	1424.8	254.73	1659.3	566.37
4	0.000996165	24.7683	0.060998	4.1737	1434.2	258.10	1555.4	571.00
6	0.000996245	33.1127	0.090998	4.1708	1443.2	261.34	1461.5	575.44
8	0.000996380	41.4519	0.12076	4.1685	1451.9	264.44	1376.5	579.73
10	0.000996568	49.7868	0.15031	4.1665	1460.1	267.41	1299.1	583.86
12	0.000996806	58.1182	0.17963	4.1649	1468.0	270.24	1228.4	587.85
14	0.000997092	66.4467	0.20873	4.1636	1475.5	272.94	1163.7	591.72
16	0.000997423	74.7728	0.23763	4.1625	1482.7	275.50	1104.4	595.46
18	0.000997797	83.0970	0.26632	4.1617	1489.5	277.94	1049.7	599.08
20	0.000998213	91.4196	0.29480	4.1609	1496.0	280.24	999.31	602.60
25	0.000999424	112.221	0.36516	4.1597	1510.7	285.46	889.03	610.94
30	0.00100086	133.018	0.43434	4.1592	1523.6	289.92	797.14	618.69
35	0.00100252	153.814	0.50238	4.1591	1534.7	293.67	719.69	625.91
40	0.00100437	174.610	0.56932	4.1596	1544.1	296.74	653.76	632.64
45	0.00100640	195.410	0.63522	4.1604	1552.0	299.17	597.14	638.90
50	0.00100862	216.215	0.70011	4.1617	1558.5	301.00	548.13	644.72
55	0.00101101	237.028	0.76402	4.1634	1563.6	302.26	505.41	650.11
60	0.00101356	257.850	0.82699	4.1656	1567.4	302.99	467.95	655.10
65	0.00101627	278.684	0.88906	4.1681	1570.1	303.21	434.90	659.70
70	0.00101913	299.532	0.95027	4.1712	1571.6	302.96	405.61	663.91
75	0.00102215	320.396	1.0106	4.1746	1572.2	302.26	379.51	667.75
80	0.00102532	341.279	1.0702	4.1786	1571.7	301.15	356.17	671.23
85	0.00102864	362.183	1.1290	4.1829	1570.3	299.66	335.21	674.35
90	0.00103211	383.109	1.1870	4.1878	1568.1	297.79	316.31	677.13
95	0.00103572	404.061	1.2443	4.1931	1565.0	295.59	299.22	679.56
100	0.00103948	425.041	1.3009	4.1989	1561.1	293.07	283.71	681.67
110	0.00104745	467.093	1.4121	4.2119	1551.2	287.15	256.71	684.93
120	0.00105601	509.285	1.5208	4.2269	1538.5	280.19	234.09	686.95
130	0.00106519	551.639	1.6272	4.2442	1523.4	272.32	214.95	687.78
140	0.00107502	594.178	1.7314	4.2640	1505.8	263.65	198.60	687.48
150	0.00108552	636.929	1.8337	4.2866	1486.0	254.29	184.52	686.10
160	0.00109674	679.921	1.9341	4.3123	1464.1	244.30	172.29	683.66
170	0.00110874	723.187	2.0328	4.3417	1440.0	233.78	161.58	680.69
180	0.00112157	766.768	2.1301	4.3752	1413.8	222.78	152.13	676.54
190	0.00113533	810.708	2.2260	4.4137	1385.6	211.37	143.73	671.41
200	0.00115010	855.061	2.3207	4.4578	1355.2	199.61	136.21	665.35
210	0.00116601	899.887	2.4145	4.5087	1322.7	187.55	129.42	658.36
220	0.00118320	945.262	2.5074	4.5677	1288.0	175.25	123.25	650.47
230	0.00120186	991.273	2.5998	4.6363	1251.0	162.77	117.58	641.67
240	0.00122222	1038.03	2.6918	4.7169	1211.6	150.15	112.33	631.95

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 80 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00124457	1085.66	2.7837	4.8125	1169.8	137.43	107.43	621.30
260	0.00126930	1134.34	2.8759	4.9272	1125.0	124.65	102.80	609.67
270	0.00129694	1184.29	2.9687	5.0674	1077.0	111.80	98.376	597.01
280	0.00132823	1235.81	3.0627	5.2431	1024.9	98.865	94.090	583.23
290	0.00136429	1289.33	3.1586	5.4713	967.72	85.803	89.866	568.18
<i>t_s = 295.009 °C</i>								
Liquid	0.00138466	1317.08	3.2077	5.6140	936.73	79.212	87.745	560.09
Vapour	0.0235275	2758.61	5.7448	5.8831	484.07	1.2450	19.326	68.052
300	0.0242802	2786.38	5.7935	5.2870	493.56	1.2541	19.596	66.709
310	0.0256318	2835.27	5.8781	4.5559	509.11	1.2640	20.125	65.007
320	0.0268425	2878.35	5.9514	4.0905	522.16	1.2697	20.640	64.029
330	0.0279551	2917.53	6.0169	3.7620	533.69	1.2736	21.145	63.489
340	0.0289946	2953.87	6.0766	3.5176	544.12	1.2764	21.639	63.247
350	0.0299776	2988.06	6.1319	3.3288	553.71	1.2785	22.126	63.223
360	0.0309152	3020.57	6.1837	3.1789	562.64	1.2800	22.605	63.370
370	0.0318155	3051.73	6.2325	3.0573	571.02	1.2811	23.078	63.652
380	0.0326848	3081.79	6.2789	2.9572	578.94	1.2818	23.546	64.048
390	0.0335276	3110.93	6.3232	2.8738	586.46	1.2823	24.008	64.539
400	0.0343477	3139.31	6.3657	2.8037	593.65	1.2825	24.465	65.111
410	0.0351482	3167.04	6.4066	2.7444	600.54	1.2826	24.918	65.755
420	0.0359315	3194.23	6.4461	2.6939	607.17	1.2825	25.367	66.462
430	0.0366996	3220.95	6.4843	2.6507	613.56	1.2822	25.812	67.225
440	0.0374543	3247.26	6.5215	2.6136	619.75	1.2819	26.254	68.039
450	0.0381970	3273.23	6.5577	2.5817	625.75	1.2814	26.693	68.898
460	0.0389290	3298.91	6.5929	2.5541	631.59	1.2809	27.128	69.798
470	0.0396513	3324.33	6.6274	2.5303	637.27	1.2803	27.561	70.736
480	0.0403649	3349.53	6.6611	2.5097	642.82	1.2796	27.992	71.708
490	0.0410706	3374.53	6.6940	2.4919	648.24	1.2789	28.419	72.713
500	0.0417691	3399.37	6.7264	2.4765	653.54	1.2782	28.845	73.746
510	0.0424609	3424.07	6.7581	2.4631	658.73	1.2774	29.268	74.807
520	0.0431467	3448.64	6.7893	2.4516	663.82	1.2766	29.689	75.893
530	0.0438269	3473.11	6.8199	2.4416	668.82	1.2758	30.108	77.003
540	0.0445019	3497.48	6.8501	2.4331	673.73	1.2750	30.525	78.135
550	0.0451721	3521.77	6.8798	2.4258	678.56	1.2741	30.940	79.287
560	0.0458379	3546.00	6.9091	2.4196	683.31	1.2733	31.353	80.458
570	0.0464996	3570.17	6.9379	2.4144	687.99	1.2724	31.764	81.647
580	0.0471574	3594.29	6.9663	2.4101	692.60	1.2715	32.174	82.853
590	0.0478117	3618.37	6.9944	2.4066	697.15	1.2707	32.582	84.075
600	0.0484625	3642.42	7.0221	2.4038	701.64	1.2698	32.989	85.312
650	0.0516732	3762.42	7.1557	2.3983	723.25	1.2654	34.999	91.692
700	0.0548251	3882.42	7.2823	2.4032	743.70	1.2610	36.974	98.333
750	0.0579325	4002.86	7.4030	2.4152	763.20	1.2568	38.918	105.18
800	0.0610054	4124.02	7.5186	2.4322	781.88	1.2526	40.831	112.19

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 100 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000995200	10.0693	0.0003384	4.1723	1418.2	202.09	1770.6	563.03
2	0.000995171	18.4100	0.030762	4.1686	1428.0	204.90	1655.8	567.79
4	0.000995203	26.7440	0.060942	4.1655	1437.4	207.61	1552.5	572.37
6	0.000995294	35.0726	0.090884	4.1631	1446.4	210.21	1459.1	576.77
8	0.000995440	43.3967	0.12060	4.1611	1455.1	212.69	1374.5	581.02
10	0.000995638	51.7173	0.15009	4.1595	1463.3	215.07	1297.4	585.12
12	0.000995884	60.0349	0.17936	4.1582	1471.2	217.34	1227.1	589.09
14	0.000996178	68.3503	0.20842	4.1572	1478.7	219.50	1162.6	592.92
16	0.000996516	76.6637	0.23727	4.1563	1485.9	221.56	1103.5	596.64
18	0.000996897	84.9757	0.26592	4.1557	1492.7	223.51	1049.0	600.24
20	0.000997318	93.2865	0.29437	4.1551	1499.2	225.36	998.78	603.74
25	0.000998541	114.060	0.36463	4.1543	1514.0	229.54	888.81	612.04
30	0.000999989	134.831	0.43372	4.1541	1526.8	233.12	797.14	619.76
35	0.00100165	155.601	0.50168	4.1543	1537.9	236.13	719.85	626.96
40	0.00100350	176.374	0.56855	4.1549	1547.4	238.60	654.03	633.67
45	0.00100554	197.151	0.63437	4.1559	1555.3	240.56	597.49	639.92
50	0.00100775	217.934	0.69919	4.1573	1561.8	242.04	548.54	645.74
55	0.00101013	238.725	0.76303	4.1591	1566.9	243.06	505.86	651.13
60	0.00101268	259.526	0.82594	4.1613	1570.8	243.66	468.43	656.13
65	0.00101538	280.339	0.88795	4.1639	1573.6	243.86	435.41	660.73
70	0.00101824	301.166	0.94909	4.1670	1575.2	243.67	406.13	664.95
75	0.00102125	322.009	1.0094	4.1705	1575.8	243.14	380.04	668.80
80	0.00102441	342.871	1.0689	4.1744	1575.4	242.27	356.71	672.29
85	0.00102771	363.754	1.1276	4.1787	1574.1	241.09	335.75	675.42
90	0.00103116	384.659	1.1856	4.1835	1571.9	239.62	316.85	678.21
95	0.00103475	405.590	1.2428	4.1888	1568.9	237.88	299.76	680.67
100	0.00103850	426.548	1.2994	4.1945	1565.1	235.89	284.25	682.79
110	0.00104641	468.555	1.4105	4.2073	1555.4	231.20	257.24	686.08
120	0.00105493	510.701	1.5190	4.2221	1543.0	225.68	234.61	688.14
130	0.00106405	553.005	1.6253	4.2391	1528.0	219.43	215.46	689.02
140	0.00107380	595.491	1.7294	4.2585	1510.7	212.54	199.11	688.77
150	0.00108422	638.184	1.8315	4.2806	1491.2	205.10	185.02	687.44
160	0.00109535	681.112	1.9318	4.3057	1469.6	197.16	172.79	685.06
170	0.00110724	724.309	2.0304	4.3343	1445.8	188.80	162.07	682.10
180	0.00111996	767.812	2.1274	4.3670	1420.1	180.06	152.62	678.03
190	0.00113357	811.665	2.2232	4.4044	1392.2	170.99	144.23	672.97
200	0.00114818	855.918	2.3177	4.4472	1362.3	161.64	136.71	666.98
210	0.00116389	900.631	2.4112	4.4965	1330.3	152.05	129.92	660.08
220	0.00118085	945.874	2.5039	4.5535	1296.1	142.27	123.76	652.28
230	0.00119922	991.731	2.5959	4.6196	1259.8	132.34	118.10	643.58
240	0.00121923	1038.30	2.6876	4.6970	1221.1	122.30	112.87	633.98

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 100 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00124116	1085.72	2.7791	4.7883	1180.0	112.19	107.99	623.46
260	0.00126534	1134.13	2.8708	4.8972	1136.3	102.03	103.38	611.99
270	0.00129228	1183.74	2.9629	5.0293	1089.4	91.840	98.995	599.52
280	0.00132264	1234.82	3.0561	5.1931	1038.9	81.605	94.755	585.97
290	0.00135739	1287.75	3.1510	5.4023	983.78	71.300	90.596	571.21
300	0.00139804	1343.10	3.2484	5.6816	922.76	60.905	86.434	555.07
310	0.00144710	1401.77	3.3498	6.0782	854.92	50.507	82.156	537.19
<i>t_s = 310.999 °C</i>								
Liquid	0.00145262	1407.87	3.3603	6.1275	847.74	49.474	81.716	535.29
Vapour	0.0180336	2725.47	5.6159	7.1472	472.44	1.2377	20.194	78.338
320	0.0192716	2782.66	5.7131	5.7468	491.71	1.2546	20.664	74.148
330	0.0204462	2835.67	5.8017	4.9228	508.20	1.2632	21.177	71.580
340	0.0214897	2882.06	5.8780	4.3885	522.16	1.2688	21.682	70.040
350	0.0224422	2923.96	5.9458	4.0118	534.45	1.2728	22.177	69.104
360	0.0233274	2962.61	6.0073	3.7324	545.52	1.2757	22.665	68.570
370	0.0241605	2998.82	6.0641	3.5174	555.64	1.2779	23.146	68.323
380	0.0249522	3033.11	6.1170	3.3471	565.02	1.2794	23.621	68.293
390	0.0257099	3065.87	6.1668	3.2092	573.79	1.2806	24.089	68.434
400	0.0264393	3097.38	6.2139	3.0958	582.04	1.2813	24.553	68.715
410	0.0271447	3127.85	6.2589	3.0013	589.86	1.2818	25.011	69.111
420	0.0278294	3157.45	6.3019	2.9217	597.31	1.2820	25.465	69.606
430	0.0284963	3186.32	6.3432	2.8542	604.44	1.2821	25.914	70.186
440	0.0291475	3214.57	6.3831	2.7965	611.28	1.2820	26.360	70.840
450	0.0297850	3242.28	6.4217	2.7470	617.87	1.2817	26.802	71.560
460	0.0304102	3269.53	6.4591	2.7043	624.24	1.2814	27.241	72.338
470	0.0310246	3296.38	6.4955	2.6674	630.41	1.2810	27.676	73.167
480	0.0316292	3322.89	6.5310	2.6354	636.39	1.2804	28.109	74.044
490	0.0322250	3349.11	6.5655	2.6076	642.21	1.2799	28.539	74.964
500	0.0328129	3375.06	6.5993	2.5833	647.89	1.2792	28.966	75.922
510	0.0333935	3400.78	6.6324	2.5622	653.42	1.2786	29.391	76.916
520	0.0339675	3426.31	6.6648	2.5437	658.83	1.2779	29.813	77.943
530	0.0345355	3451.67	6.6965	2.5275	664.12	1.2771	30.233	79.000
540	0.0350979	3476.87	6.7277	2.5134	669.31	1.2764	30.651	80.085
550	0.0356552	3501.94	6.7584	2.5011	674.39	1.2756	31.067	81.195
560	0.0362078	3526.90	6.7885	2.4904	679.39	1.2748	31.480	82.330
570	0.0367561	3551.75	6.8182	2.4811	684.29	1.2740	31.892	83.487
580	0.0373002	3576.52	6.8474	2.4730	689.11	1.2731	32.302	84.665
590	0.0378406	3601.22	6.8761	2.4660	693.86	1.2723	32.711	85.862
600	0.0383775	3625.84	6.9045	2.4600	698.54	1.2715	33.117	87.077
650	0.0410163	3748.32	7.0409	2.4420	720.95	1.2672	35.126	93.387
700	0.0435944	3870.27	7.1696	2.4380	742.03	1.2630	37.098	100.00
750	0.0461269	3992.28	7.2918	2.4435	762.03	1.2589	39.038	106.87
800	0.0486242	4114.73	7.4087	2.4555	781.12	1.2548	40.947	113.90

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 120 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000994218	12.0737	0.0003931	4.1633	1421.4	169.34	1766.6	564.48
2	0.000994202	20.3970	0.030754	4.1601	1431.2	171.70	1652.5	569.19
4	0.000994247	28.7145	0.060873	4.1575	1440.6	173.96	1549.7	573.72
6	0.000994350	37.0275	0.090760	4.1555	1449.7	176.12	1456.8	578.09
8	0.000994506	45.3369	0.12042	4.1539	1458.3	178.20	1372.5	582.30
10	0.000994713	53.6433	0.14986	4.1526	1466.6	180.19	1295.8	586.37
12	0.000994968	61.9475	0.17909	4.1516	1474.4	182.08	1225.8	590.31
14	0.000995269	70.2499	0.20810	4.1508	1481.9	183.88	1161.6	594.12
16	0.000995614	78.5509	0.23691	4.1502	1489.1	185.60	1102.6	597.81
18	0.000996001	86.8509	0.26551	4.1498	1495.9	187.23	1048.4	601.40
20	0.000996429	95.1500	0.29392	4.1494	1502.4	188.77	998.27	604.87
25	0.000997663	115.896	0.36409	4.1490	1517.2	192.26	888.60	613.13
30	0.000999120	136.641	0.43309	4.1491	1530.0	195.26	797.15	620.83
35	0.00100078	157.387	0.50097	4.1495	1541.2	197.78	720.02	628.01
40	0.00100264	178.136	0.56777	4.1503	1550.6	199.84	654.31	634.70
45	0.00100468	198.891	0.63352	4.1515	1558.6	201.49	597.85	640.95
50	0.00100689	219.652	0.69827	4.1530	1565.1	202.73	548.95	646.76
55	0.00100927	240.421	0.76205	4.1549	1570.3	203.60	506.32	652.15
60	0.00101181	261.201	0.82489	4.1571	1574.2	204.11	468.92	657.15
65	0.00101450	281.993	0.88684	4.1598	1577.0	204.29	435.91	661.75
70	0.00101735	302.800	0.94792	4.1629	1578.7	204.15	406.65	665.98
75	0.00102035	323.622	1.0082	4.1664	1579.4	203.72	380.57	669.84
80	0.00102349	344.464	1.0676	4.1703	1579.1	203.02	357.24	673.34
85	0.00102678	365.326	1.1263	4.1746	1577.8	202.05	336.28	676.49
90	0.00103022	386.210	1.1842	4.1793	1575.7	200.85	317.39	679.30
95	0.00103379	407.120	1.2414	4.1845	1572.8	199.41	300.30	681.77
100	0.00103751	428.056	1.2978	4.1902	1569.1	197.77	284.78	683.91
110	0.00104539	470.020	1.4088	4.2028	1559.6	193.89	257.76	687.24
120	0.00105385	512.119	1.5173	4.2174	1547.4	189.33	235.13	689.34
130	0.00106291	554.374	1.6234	4.2340	1532.6	184.16	215.98	690.26
140	0.00107260	596.807	1.7274	4.2530	1515.6	178.46	199.62	690.06
150	0.00108294	639.443	1.8294	4.2746	1496.4	172.30	185.52	688.77
160	0.00109398	682.309	1.9295	4.2992	1475.0	165.73	173.28	686.44
170	0.00110577	725.438	2.0279	4.3271	1451.6	158.80	162.57	683.51
180	0.00111836	768.865	2.1248	4.3590	1426.2	151.56	153.11	679.50
190	0.00113184	812.632	2.2204	4.3953	1398.8	144.05	144.72	674.52
200	0.00114628	856.788	2.3147	4.4369	1369.3	136.31	137.20	668.60
210	0.00116180	901.391	2.4080	4.4847	1337.8	128.36	130.42	661.78
220	0.00117853	946.506	2.5004	4.5397	1304.1	120.26	124.26	654.07
230	0.00119664	992.215	2.5921	4.6035	1268.4	112.04	118.61	645.47
240	0.00121632	1038.61	2.6834	4.6779	1230.4	103.72	113.40	635.98

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 120 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00123783	1085.81	2.7745	4.7652	1190.1	95.346	108.53	625.59
260	0.00126151	1133.97	2.8657	4.8688	1147.2	86.937	103.96	614.27
270	0.00128779	1183.26	2.9573	4.9936	1101.5	78.508	99.600	601.98
280	0.00131728	1233.94	3.0498	5.1467	1052.4	70.063	95.403	588.65
290	0.00135084	1286.33	3.1436	5.3398	999.16	61.587	91.302	574.18
300	0.00138976	1340.93	3.2397	5.5924	940.65	53.056	87.222	558.39
310	0.00143614	1398.49	3.3393	5.9411	875.62	44.489	83.067	541.03
320	0.00149369	1460.31	3.4444	6.4621	803.26	35.998	78.695	521.62
<i>t_s = 324.678 °C</i>								
Liquid	0.00152633	1491.33	3.4965	6.8126	765.59	32.001	76.511	511.64
Vapour	0.0142689	2685.58	5.4941	8.8189	459.46	1.2329	21.109	91.062
330	0.0150236	2728.14	5.5650	7.3313	474.22	1.2474	21.357	85.827
340	0.0162112	2793.47	5.6725	5.8968	494.92	1.2591	21.837	80.374
350	0.0172227	2848.01	5.7607	5.0746	511.54	1.2661	22.321	77.304
360	0.0181226	2895.87	5.8369	4.5309	525.77	1.2711	22.804	75.413
370	0.0189442	2939.15	5.9047	4.1447	538.33	1.2748	23.283	74.222
380	0.0197077	2979.09	5.9664	3.8563	549.63	1.2774	23.756	73.494
390	0.0204258	3016.49	6.0232	3.6329	559.97	1.2793	24.225	73.096
400	0.0211077	3051.90	6.0762	3.4551	569.54	1.2806	24.689	72.948
410	0.0217597	3085.70	6.1261	3.3106	578.47	1.2815	25.149	72.995
420	0.0223867	3118.19	6.1733	3.1912	586.89	1.2821	25.604	73.200
430	0.0229924	3149.59	6.2182	3.0914	594.85	1.2825	26.054	73.536
440	0.0235799	3180.07	6.2613	3.0071	602.43	1.2826	26.501	73.982
450	0.0241515	3209.77	6.3027	2.9353	609.68	1.2826	26.944	74.522
460	0.0247091	3238.81	6.3425	2.8737	616.64	1.2824	27.384	75.145
470	0.0252545	3267.28	6.3811	2.8207	623.34	1.2821	27.820	75.840
480	0.0257890	3295.25	6.4185	2.7748	629.81	1.2817	28.253	76.598
490	0.0263138	3322.79	6.4548	2.7349	636.07	1.2813	28.683	77.414
500	0.0268298	3349.97	6.4902	2.7002	642.14	1.2807	29.111	78.281
510	0.0273378	3376.81	6.5247	2.6698	648.04	1.2801	29.536	79.193
520	0.0278387	3403.37	6.5584	2.6432	653.79	1.2795	29.958	80.148
530	0.0283331	3429.69	6.5914	2.6199	659.39	1.2788	30.378	81.142
540	0.0288215	3455.78	6.6237	2.5993	664.86	1.2781	30.796	82.170
550	0.0293045	3481.68	6.6553	2.5813	670.22	1.2774	31.211	83.231
560	0.0297824	3507.41	6.6864	2.5654	675.46	1.2766	31.625	84.321
570	0.0302557	3533.00	6.7169	2.5514	680.60	1.2758	32.036	85.438
580	0.0307247	3558.45	6.7469	2.5391	685.64	1.2751	32.446	86.581
590	0.0311897	3583.78	6.7764	2.5283	690.60	1.2743	32.853	87.748
600	0.0316511	3609.02	6.8055	2.5188	695.46	1.2734	33.259	88.936
650	0.0339104	3734.07	6.9448	2.4871	718.70	1.2693	35.264	95.158
700	0.0361069	3858.03	7.0756	2.4737	740.40	1.2652	37.231	101.74
750	0.0382567	3981.64	7.1994	2.4723	760.90	1.2612	39.165	108.60
800	0.0403706	4105.40	7.3175	2.4793	780.40	1.2571	41.068	115.66

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 140 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000993243	14.0723	0.0004338	4.1545	1424.7	145.96	1762.6	565.91
2	0.000993240	22.3784	0.030732	4.1518	1434.5	147.98	1649.2	570.58
4	0.000993298	30.6799	0.060793	4.1497	1443.9	149.92	1546.9	575.07
6	0.000993411	38.9776	0.090625	4.1481	1452.9	151.78	1454.5	579.40
8	0.000993577	47.2724	0.12023	4.1468	1461.6	153.57	1370.6	583.58
10	0.000993794	55.5650	0.14962	4.1458	1469.8	155.27	1294.2	587.62
12	0.000994058	63.8559	0.17880	4.1451	1477.7	156.90	1224.5	591.52
14	0.000994366	72.1456	0.20777	4.1446	1485.2	158.45	1160.5	595.31
16	0.000994718	80.4344	0.23654	4.1442	1492.3	159.92	1101.8	598.98
18	0.000995112	88.7225	0.26510	4.1439	1499.1	161.32	1047.7	602.54
20	0.000995544	97.0102	0.29347	4.1438	1505.6	162.64	997.77	606.00
25	0.000996790	117.729	0.36355	4.1438	1520.4	165.64	888.41	614.22
30	0.000998255	138.448	0.43247	4.1441	1533.3	168.22	797.17	621.89
35	0.000999923	159.170	0.50027	4.1448	1544.4	170.38	720.19	629.05
40	0.00100178	179.897	0.56699	4.1458	1553.9	172.16	654.59	635.73
45	0.00100382	200.629	0.63267	4.1471	1561.9	173.58	598.21	641.96
50	0.00100603	221.368	0.69735	4.1487	1568.4	174.66	549.37	647.77
55	0.00100840	242.116	0.76106	4.1507	1573.7	175.41	506.78	653.17
60	0.00101094	262.875	0.82385	4.1530	1577.7	175.87	469.40	658.16
65	0.00101363	283.647	0.88573	4.1557	1580.5	176.03	436.42	662.77
70	0.00101647	304.433	0.94675	4.1588	1582.3	175.93	407.17	667.01
75	0.00101945	325.235	1.0069	4.1623	1583.0	175.57	381.10	670.88
80	0.00102258	346.056	1.0663	4.1662	1582.7	174.98	357.78	674.39
85	0.00102586	366.898	1.1249	4.1705	1581.6	174.17	336.82	677.56
90	0.00102928	387.762	1.1828	4.1752	1579.6	173.15	317.93	680.38
95	0.00103284	408.650	1.2399	4.1803	1576.7	171.93	300.83	682.86
100	0.00103654	429.566	1.2963	4.1859	1573.1	170.54	285.31	685.02
110	0.00104437	471.485	1.4072	4.1983	1563.8	167.25	258.29	688.39
120	0.00105278	513.539	1.5155	4.2127	1551.7	163.37	235.65	690.52
130	0.00106179	555.745	1.6215	4.2290	1537.2	158.97	216.49	691.49
140	0.00107141	598.127	1.7254	4.2476	1520.4	154.11	200.12	691.33
150	0.00108168	640.707	1.8272	4.2688	1501.4	148.87	186.02	690.10
160	0.00109263	683.512	1.9272	4.2928	1480.4	143.27	173.77	687.83
170	0.00110432	726.573	2.0255	4.3200	1457.3	137.37	163.05	684.91
180	0.00111679	769.925	2.1222	4.3511	1432.2	131.20	153.60	680.97
190	0.00113013	813.609	2.2176	4.3864	1405.2	124.80	145.20	676.06
200	0.00114442	857.671	2.3117	4.4269	1376.2	118.20	137.69	670.21
210	0.00115975	902.166	2.4048	4.4732	1345.1	111.44	130.91	663.47
220	0.00117627	947.158	2.4969	4.5265	1312.0	104.53	124.76	655.85
230	0.00119411	992.722	2.5884	4.5880	1276.8	97.521	119.12	647.35
240	0.00121347	1038.95	2.6794	4.6595	1239.5	90.434	113.92	637.97

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 140 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00123460	1085.95	2.7701	4.7431	1199.9	83.298	109.08	627.71
260	0.00125779	1133.86	2.8608	4.8419	1157.9	76.136	104.52	616.53
270	0.00128346	1182.85	2.9518	4.9600	1113.2	68.964	100.19	604.41
280	0.00131214	1233.15	3.0436	5.1037	1065.4	61.789	96.036	591.29
290	0.00134461	1285.05	3.1366	5.2826	1013.9	54.609	91.987	577.07
300	0.00138198	1338.97	3.2315	5.5128	957.73	47.409	87.980	561.63
310	0.00142603	1395.56	3.3293	5.8226	895.59	40.176	83.931	544.72
320	0.00147974	1455.87	3.4319	6.2683	826.50	32.974	79.723	525.99
330	0.00154886	1521.80	3.5421	6.9830	748.38	25.829	75.163	504.77
<i>t_s = 336.669 °C</i>								
Saturation								
Liquid	0.00160971	1570.88	3.6230	7.8117	682.84	20.690	71.732	488.74
Vapour	0.0114889	2638.09	5.3730	11.260	445.18	1.2322	22.135	108.11
340	0.0119989	2672.38	5.4291	9.4878	457.16	1.2442	22.240	101.25
350	0.0132316	2752.92	5.5595	7.0059	482.90	1.2588	22.632	90.622
360	0.0142288	2816.39	5.6605	5.7978	502.28	1.2665	23.068	85.311
370	0.0150919	2870.38	5.7452	5.0539	518.43	1.2721	23.520	82.156
380	0.0158666	2918.26	5.8190	4.5496	532.40	1.2761	23.976	80.154
390	0.0165779	2961.83	5.8853	4.1840	544.80	1.2789	24.433	78.860
400	0.0172410	3002.23	5.9457	3.9064	556.02	1.2808	24.889	78.045
410	0.0178661	3040.16	6.0017	3.6884	566.31	1.2822	25.342	77.576
420	0.0184603	3076.14	6.0539	3.5132	575.85	1.2831	25.792	77.369
430	0.0190290	3110.53	6.1032	3.3697	584.79	1.2837	26.239	77.369
440	0.0195762	3143.61	6.1499	3.2504	593.21	1.2840	26.683	77.537
450	0.0201049	3175.60	6.1945	3.1500	601.20	1.2841	27.123	77.844
460	0.0206177	3206.66	6.2371	3.0648	608.81	1.2841	27.561	78.268
470	0.0211167	3236.94	6.2782	2.9920	616.09	1.2839	27.995	78.791
480	0.0216034	3266.54	6.3177	2.9293	623.08	1.2836	28.427	79.402
490	0.0220794	3295.55	6.3560	2.8750	629.81	1.2832	28.855	80.089
500	0.0225457	3324.06	6.3931	2.8278	636.31	1.2828	29.281	80.843
510	0.0230034	3352.13	6.4292	2.7867	642.60	1.2822	29.705	81.658
520	0.0234533	3379.81	6.4643	2.7506	648.71	1.2816	30.126	82.526
530	0.0238961	3407.15	6.4986	2.7190	654.64	1.2810	30.544	83.442
540	0.0243326	3434.20	6.5320	2.6911	660.42	1.2803	30.960	84.402
550	0.0247632	3460.99	6.5648	2.6666	666.05	1.2796	31.375	85.403
560	0.0251885	3487.54	6.5968	2.6449	671.55	1.2789	31.787	86.440
570	0.0256089	3513.89	6.6283	2.6256	676.93	1.2781	32.197	87.510
580	0.0260247	3540.06	6.6591	2.6086	682.20	1.2774	32.605	88.611
590	0.0264364	3566.07	6.6894	2.5936	687.37	1.2766	33.011	89.741
600	0.0268442	3591.94	6.7192	2.5803	692.43	1.2758	33.416	90.897
650	0.0288338	3719.67	6.8615	2.5336	716.49	1.2717	35.413	97.006
700	0.0307586	3845.69	6.9944	2.5103	738.83	1.2676	37.373	103.53
750	0.0326354	3970.94	7.1200	2.5017	759.83	1.2636	39.299	110.39
800	0.0344758	4096.02	7.2393	2.5033	779.72	1.2596	41.195	117.47

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 160 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000992274	16.0651	0.0004606	4.1458	1427.9	128.43	1758.7	567.34
2	0.000992285	24.3545	0.030697	4.1437	1437.7	130.20	1645.9	571.96
4	0.000992354	32.6401	0.060701	4.1420	1447.2	131.90	1544.3	576.41
6	0.000992478	40.9228	0.090479	4.1408	1456.2	133.53	1452.3	580.70
8	0.000992655	49.2033	0.12004	4.1399	1464.8	135.10	1368.8	584.84
10	0.000992880	57.4824	0.14938	4.1392	1473.1	136.59	1292.7	588.85
12	0.000993152	65.7603	0.17851	4.1387	1480.9	138.01	1223.2	592.73
14	0.000993469	74.0374	0.20744	4.1385	1488.4	139.37	1159.5	596.49
16	0.000993828	82.3141	0.23616	4.1383	1495.6	140.66	1101.0	600.14
18	0.000994227	90.5906	0.26469	4.1382	1502.4	141.89	1047.1	603.68
20	0.000994665	98.8671	0.29302	4.1382	1508.8	143.05	997.29	607.12
25	0.000995923	119.559	0.36301	4.1386	1523.6	145.68	888.23	615.30
30	0.000997395	140.253	0.43184	4.1392	1536.5	147.94	797.20	622.94
35	0.000999068	160.952	0.49956	4.1401	1547.6	149.84	720.37	630.08
40	0.00100093	181.655	0.56621	4.1413	1557.2	151.41	654.88	636.75
45	0.00100297	202.365	0.63182	4.1427	1565.2	152.66	598.57	642.98
50	0.00100518	223.083	0.69643	4.1445	1571.8	153.61	549.79	648.78
55	0.00100755	243.810	0.76008	4.1465	1577.0	154.28	507.24	654.17
60	0.00101008	264.549	0.82280	4.1489	1581.1	154.68	469.89	659.17
65	0.00101276	285.300	0.88463	4.1516	1584.0	154.84	436.93	663.79
70	0.00101559	306.066	0.94559	4.1548	1585.8	154.76	407.69	668.04
75	0.00101856	326.848	1.0057	4.1583	1586.6	154.46	381.63	671.92
80	0.00102168	347.649	1.0650	4.1621	1586.4	153.95	358.31	675.44
85	0.00102494	368.470	1.1236	4.1664	1585.3	153.25	337.36	678.62
90	0.00102835	389.314	1.1814	4.1711	1583.4	152.37	318.46	681.45
95	0.00103189	410.182	1.2384	4.1762	1580.6	151.32	301.37	683.95
100	0.00103558	431.076	1.2948	4.1817	1577.1	150.11	285.85	686.13
110	0.00104337	472.953	1.4056	4.1939	1567.9	147.26	258.82	689.53
120	0.00105173	514.961	1.5138	4.2080	1556.1	143.89	236.17	691.71
130	0.00106067	557.120	1.6197	4.2241	1541.8	140.07	217.00	692.72
140	0.00107023	599.450	1.7234	4.2423	1525.2	135.85	200.62	692.61
150	0.00108042	641.975	1.8251	4.2630	1506.5	131.29	186.52	691.42
160	0.00109129	684.720	1.9250	4.2865	1485.7	126.42	174.26	689.20
170	0.00110288	727.715	2.0231	4.3131	1463.0	121.29	163.54	686.29
180	0.00111524	770.994	2.1197	4.3434	1438.2	115.92	154.09	682.44
190	0.00112845	814.596	2.2148	4.3778	1411.6	110.36	145.69	677.59
200	0.00114258	858.566	2.3088	4.4171	1382.9	104.62	138.17	671.81
210	0.00115774	902.956	2.4016	4.4620	1352.3	98.728	131.40	665.15
220	0.00117404	947.828	2.4935	4.5136	1319.8	92.722	125.25	657.61
230	0.00119163	993.254	2.5847	4.5730	1285.1	86.622	119.63	649.21
240	0.00121069	1039.32	2.6754	4.6418	1248.4	80.456	114.44	639.94

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 160 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00123144	1086.13	2.7657	4.7220	1209.5	74.248	109.61	629.80
260	0.00125418	1133.81	2.8560	4.8163	1168.3	68.020	105.07	618.76
270	0.00127926	1182.51	2.9465	4.9284	1124.6	61.787	100.77	606.81
280	0.00130720	1232.45	3.0376	5.0636	1078.0	55.561	96.653	593.88
290	0.00133866	1283.89	3.1297	5.2301	1028.0	49.344	92.652	579.91
300	0.00137464	1337.20	3.2236	5.4411	973.99	43.132	88.709	564.77
310	0.00141664	1392.93	3.3200	5.7190	914.67	36.910	84.752	548.28
320	0.00146711	1451.94	3.4203	6.1063	848.79	30.692	80.683	530.13
330	0.00153049	1515.71	3.5269	6.6932	775.52	24.560	76.351	509.81
340	0.00161627	1587.27	3.6445	7.7439	687.82	18.295	71.469	486.41
<i>t_s = 347.357 °C</i>								
Saturation								
Liquid	0.00170954	1649.67	3.7457	9.4729	597.67	13.059	67.056	466.33
Vapour	0.00930813	2580.80	5.2463	15.207	429.20	1.2369	23.363	132.79
350	0.00976565	2616.99	5.3045	12.413	441.49	1.2475	23.355	121.52
360	0.0110599	2715.63	5.4616	8.1928	472.82	1.2634	23.570	102.25
370	0.0120464	2788.30	5.5755	6.5172	494.85	1.2705	23.922	93.944
380	0.0128781	2848.27	5.6680	5.5538	512.76	1.2760	24.321	89.243
390	0.0136131	2900.49	5.7474	4.9289	527.98	1.2798	24.741	86.301
400	0.0142810	2947.46	5.8177	4.4882	541.32	1.2824	25.171	84.374
410	0.0148991	2990.62	5.8814	4.1588	553.28	1.2841	25.606	83.103
420	0.0154783	3030.88	5.9399	3.9032	564.18	1.2853	26.042	82.290
430	0.0160263	3068.85	5.9943	3.6993	574.24	1.2860	26.478	81.817
440	0.0165486	3104.99	6.0453	3.5333	583.62	1.2864	26.913	81.605
450	0.0170494	3139.61	6.0935	3.3960	592.43	1.2866	27.346	81.600
460	0.0175320	3172.98	6.1393	3.2809	600.76	1.2866	27.777	81.764
470	0.0179988	3205.29	6.1831	3.1835	608.68	1.2865	28.206	82.070
480	0.0184520	3236.70	6.2251	3.1004	616.23	1.2862	28.633	82.494
490	0.0188931	3267.34	6.2655	3.0289	623.47	1.2859	29.057	83.021
500	0.0193237	3297.31	6.3045	2.9671	630.42	1.2854	29.479	83.637
510	0.0197449	3326.71	6.3423	2.9134	637.13	1.2849	29.899	84.330
520	0.0201577	3355.60	6.3790	2.8664	643.61	1.2844	30.317	85.093
530	0.0205628	3384.05	6.4146	2.8253	649.89	1.2837	30.733	85.916
540	0.0209611	3412.12	6.4494	2.7891	655.98	1.2831	31.146	86.795
550	0.0213532	3439.85	6.4832	2.7572	661.91	1.2824	31.558	87.723
560	0.0217396	3467.28	6.5164	2.7290	667.68	1.2816	31.967	88.696
570	0.0221208	3494.44	6.5488	2.7039	673.31	1.2809	32.375	89.710
580	0.0224972	3521.37	6.5805	2.6817	678.81	1.2801	32.780	90.761
590	0.0228693	3548.08	6.6117	2.6620	684.18	1.2793	33.184	91.847
600	0.0232373	3574.61	6.6422	2.6444	689.45	1.2785	33.587	92.963
650	0.0250259	3705.11	6.7876	2.5817	714.35	1.2744	35.573	98.935
700	0.0267475	3833.26	6.9228	2.5477	737.32	1.2703	37.523	105.39
750	0.0284200	3960.18	7.0499	2.5316	758.80	1.2662	39.441	112.23
800	0.0300554	4086.62	7.1706	2.5277	779.09	1.2622	41.328	119.31

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

p = 180 bar									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.000991311	18.0523	0.0004737	4.1373	1431.2	114.80	1755.0	568.75	
2	0.000991335	26.3252	0.030650	4.1357	1441.0	116.37	1642.8	573.32	
4	0.000991416	34.5952	0.060598	4.1344	1450.5	117.89	1541.6	577.73	
6	0.000991551	42.8632	0.090323	4.1336	1459.5	119.34	1450.1	581.98	
8	0.000991738	51.1298	0.11983	4.1330	1468.1	120.73	1367.0	586.09	
10	0.000991972	59.3954	0.14913	4.1327	1476.3	122.06	1291.2	590.07	
12	0.000992253	67.6605	0.17821	4.1325	1484.2	123.33	1222.0	593.92	
14	0.000992576	75.9254	0.20710	4.1324	1491.7	124.54	1158.5	597.66	
16	0.000992942	84.1903	0.23578	4.1325	1498.8	125.69	1100.2	601.28	
18	0.000993347	92.4553	0.26426	4.1326	1505.6	126.78	1046.5	604.81	
20	0.000993791	100.721	0.29256	4.1328	1512.1	127.81	996.84	608.23	
25	0.000995060	121.386	0.36246	4.1335	1526.8	130.16	888.07	616.38	
30	0.000996541	142.056	0.43121	4.1344	1539.7	132.17	797.24	623.99	
35	0.000998219	162.731	0.49885	4.1355	1550.9	133.86	720.56	631.11	
40	0.00100008	183.412	0.56543	4.1369	1560.4	135.26	655.17	637.76	
45	0.00100212	204.100	0.63097	4.1384	1568.5	136.38	598.94	643.98	
50	0.00100433	224.796	0.69552	4.1403	1575.1	137.24	550.22	649.78	
55	0.00100670	245.503	0.75910	4.1424	1580.4	137.84	507.70	655.18	
60	0.00100922	266.221	0.82176	4.1449	1584.5	138.21	470.38	660.18	
65	0.00101189	286.952	0.88353	4.1476	1587.5	138.36	437.44	664.81	
70	0.00101471	307.698	0.94443	4.1508	1589.3	138.30	408.21	669.06	
75	0.00101768	328.461	1.0045	4.1543	1590.2	138.04	382.16	672.95	
80	0.00102079	349.241	1.0638	4.1582	1590.1	137.60	358.84	676.49	
85	0.00102404	370.043	1.1223	4.1624	1589.0	136.99	337.89	679.67	
90	0.00102742	390.866	1.1800	4.1670	1587.2	136.22	319.00	682.52	
95	0.00103095	411.714	1.2370	4.1721	1584.5	135.29	301.90	685.04	
100	0.00103462	432.587	1.2933	4.1775	1581.1	134.23	286.38	687.23	
110	0.00104236	474.421	1.4040	4.1896	1572.1	131.72	259.34	690.67	
120	0.00105068	516.385	1.5121	4.2035	1560.4	128.74	236.69	692.89	
130	0.00105957	558.497	1.6178	4.2192	1546.3	125.37	217.51	693.94	
140	0.00106906	600.777	1.7214	4.2371	1530.0	121.64	201.13	693.88	
150	0.00107918	643.247	1.8230	4.2574	1511.5	117.61	187.01	692.74	
160	0.00108996	685.933	1.9227	4.2803	1491.0	113.31	174.75	690.57	
170	0.00110145	728.864	2.0207	4.3063	1468.5	108.77	164.03	687.67	
180	0.00111371	772.071	2.1171	4.3358	1444.1	104.03	154.57	683.89	
190	0.00112679	815.593	2.2121	4.3693	1417.8	99.113	146.17	679.11	
200	0.00114077	859.473	2.3058	4.4075	1389.6	94.039	138.66	673.41	
210	0.00115575	903.761	2.3985	4.4511	1359.4	88.836	131.89	666.82	
220	0.00117185	948.516	2.4902	4.5011	1327.3	83.527	125.75	659.37	
230	0.00118920	993.807	2.5811	4.5585	1293.3	78.135	120.13	651.06	
240	0.00120796	1039.72	2.6714	4.6248	1257.1	72.685	114.95	641.89	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 180 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00122836	1086.34	2.7614	4.7018	1218.9	67.198	110.1	631.87
260	0.00125066	1133.80	2.8513	4.7919	1178.5	61.694	105.6	620.97
270	0.00127520	1182.23	2.9413	4.8984	1135.7	56.191	101.3	609.17
280	0.00130243	1231.83	3.0317	5.0260	1090.2	50.698	97.26	596.44
290	0.00133297	1282.84	3.1231	5.1816	1041.7	45.223	93.30	582.69
300	0.00136769	1335.60	3.2160	5.3761	989.47	39.769	89.41	567.84
310	0.00140788	1390.56	3.3110	5.6275	932.73	34.330	85.54	551.72
320	0.00145557	1448.44	3.4095	5.9683	870.13	28.898	81.59	534.09
330	0.00151428	1510.43	3.5131	6.4631	800.55	23.512	77.44	514.54
340	0.00159084	1578.71	3.6253	7.2691	722.19	18.214	72.89	492.33
350	0.00170295	1658.65	3.7546	8.9989	619.19	12.508	67.45	466.22
<i>t_s = 356.992 °C</i>								
Liquid	0.00183949	1732.02	3.8717	12.840	513.11	7.9515	62.12	445.07
Vapour	0.00749867	2509.53	5.1055	22.966	410.33	1.2474	24.96	172.52
360	0.00810999	2566.03	5.1950	15.820	428.85	1.2599	24.72	145.53
370	0.00945130	2683.67	5.3795	9.3270	465.42	1.2733	24.64	114.66
380	0.0104189	2764.89	5.5048	7.1712	489.69	1.2786	24.87	102.90
390	0.0112174	2830.24	5.6041	5.9991	509.01	1.2832	25.20	96.497
400	0.0119147	2886.31	5.6881	5.2645	525.21	1.2862	25.57	92.553
410	0.0125434	2936.27	5.7618	4.7572	539.29	1.2881	25.96	89.964
420	0.0131220	2981.89	5.8281	4.3826	551.82	1.2892	26.37	88.221
430	0.0136617	3024.21	5.8887	4.0939	563.20	1.2899	26.78	87.057
440	0.0141706	3063.96	5.9448	3.8649	573.67	1.2902	27.20	86.313
450	0.0146541	3101.65	5.9973	3.6792	583.40	1.2903	27.62	85.886
460	0.0151165	3137.66	6.0468	3.5262	592.52	1.2903	28.04	85.709
470	0.0155610	3172.26	6.0936	3.3983	601.13	1.2901	28.46	85.732
480	0.0159901	3205.69	6.1383	3.2902	609.29	1.2898	28.88	85.920
490	0.0164060	3238.12	6.1811	3.1981	617.07	1.2894	29.29	86.247
500	0.0168102	3269.69	6.2222	3.1190	624.51	1.2889	29.71	86.691
510	0.0172042	3300.53	6.2618	3.0506	631.65	1.2884	30.12	87.237
520	0.0175890	3330.73	6.3002	2.9911	638.52	1.2878	30.53	87.871
530	0.0179656	3360.38	6.3373	2.9391	645.16	1.2871	30.95	88.583
540	0.0183350	3389.54	6.3734	2.8935	651.58	1.2864	31.35	89.363
550	0.0186977	3418.27	6.4085	2.8533	657.80	1.2857	31.76	90.205
560	0.0190544	3446.62	6.4427	2.8179	663.85	1.2849	32.17	91.102
570	0.0194055	3474.64	6.4762	2.7864	669.73	1.2841	32.57	92.049
580	0.0197517	3502.36	6.5089	2.7585	675.47	1.2833	32.97	93.040
590	0.0200933	3529.82	6.5408	2.7336	681.06	1.2825	33.37	94.072
600	0.0204306	3557.04	6.5722	2.7114	686.53	1.2816	33.77	95.142
650	0.0220638	3690.42	6.7208	2.6313	712.27	1.2774	35.75	100.95
700	0.0236279	3820.74	6.8583	2.5859	735.86	1.2732	37.68	107.31
750	0.0251418	3949.37	6.9872	2.5620	757.84	1.2691	39.59	114.12
800	0.0266179	4077.18	7.1091	2.5525	778.51	1.2650	41.47	121.20

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 200 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000990355	20.0338	0.0004733	4.1290	1434.5	103.89	1751.2	570.14
2	0.000990391	28.2906	0.030591	4.1278	1444.3	105.32	1639.7	574.67
4	0.000990484	36.5454	0.060484	4.1270	1453.7	106.68	1539.0	579.04
6	0.000990630	44.7990	0.090157	4.1265	1462.8	107.99	1448.0	583.26
8	0.000990826	53.0518	0.11962	4.1263	1471.4	109.25	1365.2	587.34
10	0.000991070	61.3043	0.14886	4.1262	1479.6	110.45	1289.8	591.28
12	0.000991358	69.5568	0.17791	4.1263	1487.4	111.59	1220.8	595.11
14	0.000991689	77.8096	0.20675	4.1265	1494.9	112.68	1157.6	598.82
16	0.000992062	86.0628	0.23539	4.1267	1502.1	113.71	1099.5	602.42
18	0.000992473	94.3166	0.26384	4.1271	1508.9	114.70	1045.9	605.93
20	0.000992922	102.571	0.29209	4.1274	1515.3	115.63	996.40	609.33
25	0.000994202	123.211	0.36190	4.1285	1530.1	117.74	887.91	617.44
30	0.000995690	143.856	0.43057	4.1297	1543.0	119.55	797.30	625.03
35	0.000997374	164.508	0.49814	4.1310	1554.1	121.09	720.75	632.13
40	0.000999240	185.166	0.56464	4.1325	1563.7	122.35	655.47	638.77
45	0.00100128	205.833	0.63012	4.1342	1571.8	123.36	599.32	644.99
50	0.00100348	226.509	0.69460	4.1361	1578.4	124.14	550.64	650.78
55	0.00100585	247.195	0.75813	4.1384	1583.8	124.69	508.17	656.18
60	0.00100837	267.893	0.82072	4.1409	1587.9	125.03	470.87	661.19
65	0.00101103	288.604	0.88243	4.1437	1590.9	125.17	437.94	665.82
70	0.00101385	309.330	0.94327	4.1468	1592.9	125.13	408.73	670.08
75	0.00101680	330.073	1.0033	4.1503	1593.8	124.91	382.69	673.98
80	0.00101990	350.834	1.0625	4.1542	1593.7	124.52	359.38	677.53
85	0.00102313	371.615	1.1209	4.1584	1592.8	123.98	338.43	680.73
90	0.00102651	392.419	1.1786	4.1630	1591.0	123.29	319.53	683.59
95	0.00103002	413.246	1.2356	4.1680	1588.4	122.47	302.43	686.13
100	0.00103366	434.100	1.2918	4.1734	1585.0	121.52	286.91	688.34
110	0.00104137	475.892	1.4024	4.1853	1576.2	119.28	259.87	691.81
120	0.00104964	517.811	1.5104	4.1989	1564.7	116.63	237.20	694.07
130	0.00105847	559.877	1.6160	4.2144	1550.8	113.61	218.02	695.16
140	0.00106790	602.107	1.7195	4.2320	1534.7	110.28	201.63	695.14
150	0.00107795	644.524	1.8209	4.2518	1516.5	106.67	187.50	694.06
160	0.00108865	687.152	1.9205	4.2742	1496.2	102.82	175.24	691.94
170	0.00110005	730.018	2.0183	4.2996	1474.0	98.760	164.51	689.03
180	0.00111219	773.155	2.1146	4.3284	1450.0	94.516	155.05	685.34
190	0.00112515	816.599	2.2094	4.3610	1424.0	90.112	146.65	680.63
200	0.00113899	860.391	2.3030	4.3982	1396.2	85.571	139.14	675.00
210	0.00115380	904.580	2.3954	4.4405	1366.4	80.914	132.37	668.48
220	0.00116970	949.222	2.4868	4.4889	1334.8	76.162	126.23	661.11
230	0.00118681	994.382	2.5775	4.5444	1301.2	71.336	120.62	652.89
240	0.00120530	1040.14	2.6675	4.6084	1265.7	66.457	115.45	643.83

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 200 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00122536	1086.58	2.7572	4.6824	1228.1	61.546	110.65	633.92
260	0.00124724	1133.83	2.8466	4.7687	1188.5	56.622	106.16	623.15
270	0.00127126	1182.01	2.9362	4.8701	1146.5	51.700	101.91	611.51
280	0.00129784	1231.29	3.0261	4.9908	1102.1	46.792	97.849	598.95
290	0.00132752	1281.91	3.1167	5.1366	1054.8	41.907	93.931	585.42
300	0.00136109	1334.14	3.2087	5.3168	1004.3	37.050	90.098	570.83
310	0.00139965	1388.40	3.3025	5.5459	949.79	32.226	86.293	555.06
320	0.00144494	1445.30	3.3993	5.8491	890.30	27.428	82.443	537.89
330	0.00149977	1505.79	3.5004	6.2740	824.41	22.659	78.450	519.00
340	0.00156931	1571.52	3.6085	6.9239	751.10	17.975	74.159	497.81
350	0.00166487	1645.95	3.7288	8.1062	664.96	13.280	69.266	473.33
360	0.00182472	1740.13	3.8787	11.460	542.74	8.0716	62.790	443.88
<i>t_s = 365.746 °C</i>								
Liquid	0.00203865	1827.10	4.0154	23.200	422.20	4.3719	56.198	432.42
Vapour	0.00585828	2411.39	4.9299	45.677	384.50	1.2618	27.400	250.80
370	0.00692374	2526.48	5.1095	18.660	421.11	1.2806	26.285	168.42
380	0.00825779	2659.19	5.3144	10.221	461.33	1.2886	25.824	126.74
390	0.00918976	2747.17	5.4482	7.6925	487.08	1.2908	25.899	111.72
400	0.00994958	2816.84	5.5525	6.3601	507.34	1.2935	26.137	103.69
410	0.0106082	2876.05	5.6398	5.5410	524.18	1.2951	26.449	98.776
420	0.0111994	2928.51	5.7160	4.9820	538.73	1.2957	26.799	95.542
430	0.0117416	2976.18	5.7843	4.5718	551.66	1.2960	27.172	93.341
440	0.0122459	3020.26	5.8466	4.2568	563.37	1.2959	27.558	91.835
450	0.0127202	3061.53	5.9041	4.0074	574.13	1.2957	27.953	90.827
460	0.0131699	3100.57	5.9577	3.8056	584.12	1.2954	28.353	90.192
470	0.01355992	3137.77	6.0081	3.6395	593.47	1.2950	28.755	89.847
480	0.0140113	3173.45	6.0558	3.5010	602.28	1.2945	29.160	89.733
490	0.0144085	3207.86	6.1012	3.3841	610.63	1.2939	29.565	89.807
500	0.0147929	3241.19	6.1445	3.2845	618.58	1.2933	29.971	90.039
510	0.0151662	3273.59	6.1862	3.1990	626.18	1.2927	30.376	90.404
520	0.0155296	3305.21	6.2263	3.1251	633.46	1.2920	30.780	90.882
530	0.0158842	3336.13	6.2650	3.0608	640.47	1.2912	31.184	91.459
540	0.0162309	3366.45	6.3026	3.0046	647.23	1.2904	31.586	92.122
550	0.0165707	3396.24	6.3390	2.9552	653.76	1.2896	31.987	92.861
560	0.0169040	3425.57	6.3744	2.9116	660.09	1.2888	32.387	93.668
570	0.0172316	3454.49	6.4089	2.8731	666.23	1.2879	32.786	94.534
580	0.0175539	3483.05	6.4426	2.8389	672.20	1.2870	33.183	95.456
590	0.0178714	3511.28	6.4755	2.8084	678.02	1.2862	33.580	96.425
600	0.0181844	3539.23	6.5077	2.7812	683.69	1.2853	33.974	97.440
650	0.0196942	3675.59	6.6596	2.6824	710.26	1.2808	35.929	103.05
700	0.0211327	3808.15	6.7994	2.6251	734.48	1.2764	37.851	109.30
750	0.0225198	3938.52	6.9301	2.5930	756.93	1.2721	39.745	116.07
800	0.0238685	4067.73	7.0534	2.5775	777.99	1.2679	41.610	123.14

Table 3 Single-phase region – Continued
 (0 °C to 800 °C)

p = 220 bar									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.000989405	22.0098	0.0004596	4.1209	1437.8	94.978	1747.6	571.53	
2	0.000989454	30.2508	0.030520	4.1201	1447.7	96.275	1636.6	576.02	
4	0.000989558	38.4907	0.060358	4.1198	1457.1	97.520	1536.5	580.34	
6	0.000989715	46.7300	0.089980	4.1196	1466.1	98.712	1445.9	584.52	
8	0.000989921	54.9693	0.11939	4.1197	1474.7	99.853	1363.5	588.57	
10	0.000990173	63.2089	0.14859	4.1199	1482.9	100.94	1288.4	592.49	
12	0.000990469	71.4491	0.17759	4.1203	1490.7	101.98	1219.7	596.29	
14	0.000990808	79.6900	0.20639	4.1207	1498.2	102.97	1156.7	599.97	
16	0.000991186	87.9318	0.23500	4.1211	1505.3	103.92	1098.7	603.56	
18	0.000991604	96.1745	0.26340	4.1216	1512.1	104.81	1045.3	607.04	
20	0.000992058	104.418	0.29162	4.1221	1518.6	105.66	995.97	610.43	
25	0.000993349	125.032	0.36135	4.1235	1533.3	107.58	887.78	618.50	
30	0.000994845	145.654	0.42994	4.1250	1546.2	109.24	797.36	626.06	
35	0.000996534	166.282	0.49743	4.1265	1557.4	110.63	720.96	633.15	
40	0.000998403	186.919	0.56386	4.1282	1567.0	111.79	655.78	639.78	
45	0.00100044	207.564	0.62927	4.1300	1575.1	112.72	599.69	645.98	
50	0.00100265	228.220	0.69369	4.1321	1581.8	113.43	551.07	651.78	
55	0.00100501	248.885	0.75715	4.1343	1587.2	113.94	508.63	657.17	
60	0.00100752	269.563	0.81969	4.1369	1591.4	114.25	471.36	662.19	
65	0.00101018	290.255	0.88134	4.1398	1594.4	114.39	438.45	666.82	
70	0.00101298	310.962	0.94212	4.1429	1596.4	114.35	409.25	671.09	
75	0.00101593	331.685	1.0021	4.1464	1597.3	114.16	383.22	675.00	
80	0.00101901	352.427	1.0612	4.1503	1597.4	113.82	359.91	678.56	
85	0.00102223	373.188	1.1196	4.1545	1596.5	113.33	338.96	681.78	
90	0.00102559	393.972	1.1772	4.1591	1594.8	112.72	320.07	684.66	
95	0.00102909	414.780	1.2341	4.1640	1592.2	111.98	302.97	687.21	
100	0.00103272	435.613	1.2904	4.1693	1589.0	111.13	287.44	689.43	
110	0.00104038	477.363	1.4008	4.1811	1580.3	109.11	260.39	692.94	
120	0.00104860	519.239	1.5087	4.1945	1569.0	106.71	237.72	695.24	
130	0.00105739	561.259	1.6142	4.2097	1555.3	103.99	218.52	696.38	
140	0.00106675	603.440	1.7175	4.2269	1539.4	100.97	202.12	696.41	
150	0.00107673	645.804	1.8189	4.2463	1521.4	97.713	188.00	695.37	
160	0.00108735	688.375	1.9183	4.2683	1501.4	94.233	175.73	693.30	
170	0.00109866	731.179	2.0160	4.2931	1479.5	90.562	164.99	690.35	
180	0.00111069	774.247	2.1121	4.3211	1455.7	86.725	155.53	686.78	
190	0.00112353	817.614	2.2068	4.3529	1430.1	82.743	147.12	682.14	
200	0.00113723	861.320	2.3001	4.3891	1402.6	78.637	139.61	676.57	
210	0.00115188	905.412	2.3923	4.4302	1373.3	74.426	132.85	670.13	
220	0.00116758	949.944	2.4836	4.4771	1342.2	70.129	126.71	662.84	
230	0.00118447	994.978	2.5740	4.5309	1309.1	65.765	121.11	654.71	
240	0.00120269	1040.59	2.6637	4.5926	1274.1	61.353	115.95	645.75	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 220 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00122242	1086.86	2.7530	4.6638	1237.2	56.913	111.17	635.95
260	0.00124391	1133.90	2.8421	4.7464	1198.2	52.461	106.69	625.31
270	0.00126744	1181.84	2.9312	4.8432	1157.1	48.014	102.46	613.81
280	0.00129340	1230.82	3.0205	4.9576	1113.6	43.583	98.429	601.42
290	0.00132229	1281.06	3.1105	5.0947	1067.5	39.176	94.547	588.10
300	0.00135480	1332.82	3.2016	5.2623	1018.5	34.803	90.762	573.76
310	0.00139190	1386.45	3.2944	5.4724	965.96	30.471	87.020	558.31
320	0.00143507	1442.47	3.3896	5.7448	909.21	26.184	83.258	541.56
330	0.00148663	1501.67	3.4886	6.1153	846.98	21.934	79.394	523.24
340	0.00155059	1565.33	3.5933	6.6555	777.89	17.738	75.307	502.92
350	0.00163487	1635.90	3.7074	7.5429	700.27	13.634	70.788	479.81
360	0.00176017	1719.47	3.8404	9.4598	602.89	9.3863	65.325	452.51
370	0.00202856	1842.65	4.0333	18.352	452.83	4.5948	56.680	421.94
<i>t_s = 373.707 °C</i>								
Liquid	0.00275039	2021.92	4.3109	1163.9	315.24	1.6423	43.221	859.00
Vapour	0.00357662	2164.18	4.5308	1707.2	326.11	1.3516	35.624	1010.2
380	0.00612498	2504.56	5.0556	19.419	420.44	1.3118	27.886	183.60
390	0.00737736	2643.66	5.2671	10.722	460.90	1.3088	27.061	137.30
400	0.00825503	2735.76	5.4050	8.0332	487.13	1.3066	26.976	119.93
410	0.00896956	2808.37	5.5121	6.6169	507.74	1.3064	27.119	110.58
420	0.00958798	2869.89	5.6015	5.7489	524.85	1.3059	27.365	104.83
430	0.0101423	2924.25	5.6794	5.1572	539.62	1.3050	27.668	101.02
440	0.0106498	2973.55	5.7491	4.7230	552.76	1.3041	28.003	98.405
450	0.0111214	3019.05	5.8124	4.3894	564.66	1.3031	28.359	96.583
460	0.0115644	3061.57	5.8708	4.1251	575.59	1.3022	28.728	95.329
470	0.0119839	3101.72	5.9252	3.9113	585.74	1.3014	29.107	94.499
480	0.0123840	3139.92	5.9763	3.7354	595.25	1.3005	29.491	93.996
490	0.0127675	3176.52	6.0246	3.5887	604.20	1.2997	29.879	93.753
500	0.0131370	3211.77	6.0704	3.4649	612.68	1.2988	30.270	93.721
510	0.0134943	3245.88	6.1143	3.3595	620.75	1.2980	30.663	93.863
520	0.0138410	3279.01	6.1563	3.2689	628.46	1.2971	31.056	94.152
530	0.0141782	3311.30	6.1968	3.1906	635.85	1.2962	31.450	94.567
540	0.0145070	3342.86	6.2358	3.1225	642.95	1.2952	31.843	95.089
550	0.0148284	3373.78	6.2736	3.0628	649.79	1.2943	32.236	95.706
560	0.0151431	3404.14	6.3103	3.0104	656.41	1.2933	32.629	96.405
570	0.0154516	3434.01	6.3459	2.9640	662.81	1.2924	33.021	97.178
580	0.0157547	3463.44	6.3806	2.9230	669.02	1.2914	33.413	98.017
590	0.0160527	3492.48	6.4145	2.8864	675.06	1.2904	33.803	98.913
600	0.0163461	3521.18	6.4475	2.8538	680.94	1.2894	34.192	99.863
650	0.0177555	3660.64	6.6029	2.7351	708.34	1.2845	36.124	105.24
700	0.0190916	3795.49	6.7451	2.6651	733.17	1.2798	38.029	111.36
750	0.0203752	3927.63	6.8776	2.6244	756.09	1.2753	39.907	118.07
800	0.0216197	4058.25	7.0022	2.6029	777.51	1.2710	41.760	125.12

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 240 bar									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.000988461	23.9804	0.0004328	4.1129	1441.2	87.552	1744.1	572.90	
2	0.000988522	32.2058	0.030436	4.1126	1451.0	88.743	1633.7	577.34	
4	0.000988638	40.4310	0.060222	4.1126	1460.4	89.885	1534.1	581.63	
6	0.000988805	48.6565	0.089794	4.1128	1469.4	90.980	1443.8	585.78	
8	0.000989020	56.8825	0.11916	4.1132	1478.0	92.027	1361.8	589.79	
10	0.000989281	65.1095	0.14832	4.1137	1486.2	93.028	1287.0	593.68	
12	0.000989585	73.3375	0.17727	4.1143	1494.0	93.982	1218.5	597.46	
14	0.000989931	81.5667	0.20603	4.1149	1501.5	94.891	1155.8	601.12	
16	0.000990316	89.7972	0.23459	4.1156	1508.6	95.756	1098.0	604.68	
18	0.000990739	98.0290	0.26296	4.1162	1515.4	96.577	1044.8	608.14	
20	0.000991199	106.262	0.29115	4.1169	1521.8	97.356	995.57	611.52	
25	0.000992500	126.851	0.36079	4.1186	1536.6	99.122	887.65	619.56	
30	0.000994005	147.449	0.42930	4.1204	1549.5	100.64	797.43	627.09	
35	0.000995698	168.055	0.49672	4.1221	1560.7	101.93	721.17	634.16	
40	0.000997570	188.670	0.56308	4.1239	1570.3	102.99	656.09	640.78	
45	0.000999610	209.294	0.62842	4.1259	1578.4	103.84	600.07	646.98	
50	0.00100181	229.929	0.69278	4.1280	1585.1	104.50	551.50	652.77	
55	0.00100417	250.575	0.75618	4.1304	1590.6	104.97	509.10	658.17	
60	0.00100668	271.233	0.81865	4.1330	1594.8	105.27	471.86	663.18	
65	0.00100933	291.905	0.88024	4.1359	1597.9	105.40	438.97	667.83	
70	0.00101213	312.593	0.94097	4.1391	1599.9	105.38	409.77	672.10	
75	0.00101506	333.297	1.0009	4.1426	1600.9	105.21	383.75	676.03	
80	0.00101813	354.019	1.0600	4.1464	1601.0	104.90	360.44	679.60	
85	0.00102134	374.762	1.1183	4.1506	1600.2	104.46	339.50	682.83	
90	0.00102469	395.526	1.1759	4.1551	1598.5	103.91	320.60	685.72	
95	0.00102817	416.314	1.2327	4.1600	1596.1	103.24	303.50	688.29	
100	0.00103178	437.127	1.2889	4.1653	1592.9	102.47	287.97	690.53	
110	0.00103941	478.836	1.3992	4.1769	1584.4	100.63	260.91	694.08	
120	0.00104758	520.669	1.5070	4.1901	1573.3	98.447	238.23	696.41	
130	0.00105631	562.643	1.6124	4.2050	1559.8	95.965	219.03	697.59	
140	0.00106562	604.776	1.7156	4.2219	1544.0	93.220	202.62	697.66	
150	0.00107552	647.089	1.8168	4.2409	1526.3	90.247	188.49	696.67	
160	0.00108606	689.603	1.9161	4.2624	1506.5	87.075	176.21	694.66	
170	0.00109728	732.346	2.0137	4.2866	1484.9	83.728	165.47	691.66	
180	0.00110922	775.346	2.1096	4.3140	1461.4	80.228	156.00	688.22	
190	0.00112193	818.638	2.2041	4.3450	1436.1	76.597	147.60	683.64	
200	0.00113549	862.260	2.2973	4.3802	1409.0	72.853	140.08	678.14	
210	0.00114998	906.258	2.3893	4.4202	1380.1	69.013	133.32	671.78	
220	0.00116550	950.682	2.4803	4.4657	1349.4	65.094	127.19	664.56	
230	0.00118217	995.593	2.5705	4.5177	1316.8	61.115	121.60	656.52	
240	0.00120013	1041.06	2.6600	4.5773	1282.4	57.092	116.45	647.65	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 240 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00121955	1087.17	2.7490	4.6458	1246.0	53.043	111.67	637.96
260	0.00124066	1134.01	2.8376	4.7252	1207.7	48.984	107.21	627.45
270	0.00126373	1181.72	2.9263	4.8176	1167.4	44.931	103.00	616.09
280	0.00128911	1230.42	3.0151	4.9262	1124.8	40.896	98.999	603.87
290	0.00131725	1280.31	3.1045	5.0555	1079.9	36.887	95.150	590.73
300	0.00134878	1331.62	3.1948	5.2120	1032.2	32.913	91.408	576.64
310	0.00138457	1384.67	3.2866	5.4056	981.37	28.983	87.723	561.47
320	0.00142586	1439.91	3.3805	5.6524	926.94	25.108	84.039	545.10
330	0.00147461	1497.99	3.4776	5.9796	868.05	21.291	80.284	527.29
340	0.00153400	1559.93	3.5794	6.4387	803.19	17.523	76.364	507.71
350	0.00160989	1627.56	3.6888	7.1423	730.87	13.825	72.124	485.74
360	0.00171529	1704.72	3.8116	8.4459	647.89	10.197	67.253	460.32
370	0.00189103	1802.54	3.9649	11.773	538.24	6.3833	60.868	429.53
380	0.00261206	2025.16	4.3076	67.846	355.44	2.0153	45.486	429.81
390	0.00561344	2500.75	5.0320	18.200	426.49	1.3501	29.362	189.95
400	0.00673124	2637.37	5.2366	10.804	463.97	1.3325	28.300	145.67
410	0.00754038	2730.75	5.3744	8.1820	489.68	1.3250	28.072	127.21
420	0.00820459	2804.86	5.4821	6.7651	510.09	1.3214	28.123	116.99
430	0.00878146	2867.81	5.5723	5.8859	527.11	1.3183	28.304	110.61
440	0.00929927	2923.48	5.6509	5.2815	541.87	1.3156	28.557	106.33
450	0.00977372	2973.96	5.7212	4.8354	555.03	1.3133	28.853	103.36
460	0.0102146	3020.53	5.7852	4.4912	566.99	1.3113	29.177	101.26
470	0.0106287	3064.02	5.8441	4.2179	577.99	1.3097	29.519	99.792
480	0.0110207	3105.06	5.8990	3.9963	588.23	1.3082	29.875	98.787
490	0.0113944	3144.08	5.9504	3.8138	597.81	1.3068	30.240	98.141
500	0.0117526	3181.43	5.9991	3.6614	606.84	1.3056	30.611	97.780
510	0.0120975	3217.39	6.0453	3.5328	615.40	1.3044	30.986	97.649
520	0.0124309	3252.15	6.0894	3.4232	623.54	1.3032	31.365	97.709
530	0.0127542	3285.90	6.1317	3.3290	631.32	1.3021	31.745	97.928
540	0.0130686	3318.78	6.1723	3.2474	638.77	1.3009	32.127	98.283
550	0.0133751	3350.89	6.2116	3.1764	645.93	1.2998	32.510	98.755
560	0.0136745	3382.33	6.2496	3.1141	652.83	1.2986	32.894	99.328
570	0.0139675	3413.19	6.2864	3.0593	659.50	1.2975	33.277	99.991
580	0.0142547	3443.54	6.3222	3.0107	665.95	1.2963	33.661	100.73
590	0.0145367	3473.43	6.3570	2.9676	672.21	1.2952	34.044	101.54
600	0.0148139	3502.91	6.3910	2.9292	678.29	1.2940	34.427	102.42
650	0.0161403	3645.56	6.5499	2.7892	706.51	1.2886	36.331	107.53
700	0.0173913	3782.76	6.6946	2.7060	731.93	1.2835	38.215	113.49
750	0.0185887	3916.71	6.8289	2.6564	755.31	1.2788	40.076	120.12
800	0.0197464	4048.76	6.9549	2.6286	777.08	1.2742	41.915	127.14

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 260 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000987523	25.9455	0.0003931	4.1051	1444.5	81.271	1740.6	574.26
2	0.000987597	34.1558	0.030341	4.1052	1454.3	82.372	1630.8	578.66
4	0.000987724	42.3666	0.060074	4.1056	1463.7	83.428	1531.7	582.91
6	0.000987901	50.5784	0.089597	4.1062	1472.7	84.440	1441.8	587.02
8	0.000988125	58.7914	0.11891	4.1069	1481.3	85.408	1360.1	591.00
10	0.000988395	67.0059	0.14803	4.1076	1489.5	86.332	1285.6	594.87
12	0.000988707	75.2220	0.17694	4.1084	1497.3	87.214	1217.4	598.61
14	0.000989059	83.4397	0.20566	4.1093	1504.8	88.054	1154.9	602.26
16	0.000989451	91.6591	0.23419	4.1101	1511.9	88.853	1097.3	605.80
18	0.000989880	99.8802	0.26252	4.1110	1518.7	89.612	1044.3	609.24
20	0.000990345	108.103	0.29067	4.1118	1525.1	90.332	995.19	612.60
25	0.000991657	128.667	0.36022	4.1138	1539.8	91.964	887.54	620.61
30	0.000993169	149.241	0.42866	4.1158	1552.7	93.369	797.51	628.12
35	0.000994867	169.825	0.49600	4.1178	1563.9	94.558	721.38	635.16
40	0.000996742	190.419	0.56230	4.1197	1573.6	95.544	656.40	641.77
45	0.000998783	211.023	0.62757	4.1218	1581.7	96.338	600.46	647.96
50	0.00100098	231.637	0.69186	4.1240	1588.5	96.950	551.94	653.75
55	0.00100334	252.263	0.75520	4.1265	1593.9	97.391	509.57	659.15
60	0.00100584	272.902	0.81762	4.1291	1598.2	97.671	472.35	664.18
65	0.00100849	293.555	0.87916	4.1321	1601.4	97.798	439.48	668.83
70	0.00101127	314.223	0.93983	4.1353	1603.4	97.782	410.30	673.11
75	0.00101420	334.908	0.99967	4.1388	1604.5	97.632	384.28	677.05
80	0.00101726	355.612	1.0587	4.1426	1604.7	97.355	360.98	680.63
85	0.00102046	376.335	1.1170	4.1468	1603.9	96.960	340.03	683.87
90	0.00102379	397.080	1.1745	4.1513	1602.3	96.453	321.14	686.78
95	0.00102725	417.848	1.2313	4.1561	1599.9	95.843	304.03	689.36
100	0.00103084	438.641	1.2874	4.1613	1596.8	95.136	288.50	691.62
110	0.00103843	480.310	1.3976	4.1727	1588.5	93.454	261.44	695.20
120	0.00104656	522.101	1.5053	4.1857	1577.5	91.454	238.75	697.58
130	0.00105524	564.030	1.6106	4.2004	1564.2	89.177	219.53	698.80
140	0.00106449	606.116	1.7137	4.2170	1548.7	86.659	203.12	698.92
150	0.00107433	648.377	1.8148	4.2356	1531.1	83.929	188.97	697.97
160	0.00108479	690.836	1.9140	4.2566	1511.6	81.016	176.69	696.01
170	0.00109592	733.518	2.0114	4.2803	1490.3	77.942	165.94	693.07
180	0.00110775	776.452	2.1072	4.3070	1467.1	74.728	156.47	689.65
190	0.00112035	819.670	2.2015	4.3373	1442.1	71.393	148.07	685.13
200	0.00113378	863.210	2.2945	4.3715	1415.3	67.954	140.55	679.70
210	0.00114812	907.116	2.3863	4.4104	1386.8	64.427	133.79	673.41
220	0.00116346	951.435	2.4771	4.4546	1356.5	60.829	127.67	666.28
230	0.00117991	996.227	2.5671	4.5049	1324.4	57.174	122.08	658.32
240	0.00119762	1041.56	2.6563	4.5625	1290.4	53.479	116.94	649.54

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 260 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00121675	1087.51	2.7449	4.6286	1254.7	49.761	112.17	639.96
260	0.00123750	1134.16	2.8333	4.7048	1217.0	46.034	107.73	629.56
270	0.00126012	1181.64	2.9215	4.7932	1177.4	42.314	103.54	618.34
280	0.00128495	1230.08	3.0099	4.8966	1135.8	38.612	99.558	606.27
290	0.00131240	1279.64	3.0987	5.0188	1091.9	34.938	95.740	593.33
300	0.00134302	1330.53	3.1882	5.1654	1045.4	31.298	92.037	579.45
310	0.00137760	1383.05	3.2791	5.3447	996.13	27.704	88.404	564.56
320	0.00141722	1437.58	3.3718	5.5697	943.68	24.168	84.788	548.54
330	0.00146353	1494.67	3.4672	5.8618	887.58	20.703	81.129	531.19
340	0.00151912	1555.16	3.5667	6.2589	826.76	17.306	77.347	512.24
350	0.00158845	1620.44	3.6723	6.8365	759.34	13.961	73.326	491.22
360	0.00168051	1693.16	3.7880	7.8050	684.72	10.730	68.854	467.32
370	0.00181755	1779.58	3.9234	9.7460	593.74	7.4598	63.465	439.03
380	0.00208694	1901.05	4.1107	16.212	474.65	4.1520	55.603	404.95
390	0.00355176	2242.70	4.6290	47.316	379.01	1.5556	36.836	331.22
400	0.00528668	2510.55	5.0304	16.237	436.89	1.3886	30.653	190.95
410	0.00625640	2639.46	5.2206	10.554	469.97	1.3578	29.495	151.85
420	0.00699044	2731.76	5.3548	8.1627	494.42	1.3450	29.159	133.44
430	0.00760205	2806.08	5.4612	6.8141	514.15	1.3374	29.129	122.82
440	0.00813711	2869.65	5.5510	5.9567	530.78	1.3316	29.249	116.03
450	0.00861924	2926.06	5.6296	5.3574	545.33	1.3270	29.454	111.42
460	0.00906196	2977.30	5.7000	4.9105	558.38	1.3233	29.712	108.17
470	0.00947390	3024.60	5.7640	4.5635	570.28	1.3203	30.004	105.84
480	0.00986106	3068.80	5.8231	4.2866	581.27	1.3178	30.320	104.19
490	0.0102278	3110.51	5.8781	4.0614	591.50	1.3157	30.652	103.04
500	0.0105776	3150.16	5.9298	3.8754	601.10	1.3138	30.996	102.27
510	0.0109128	3188.11	5.9785	3.7198	610.16	1.3121	31.349	101.80
520	0.0112356	3224.64	6.0249	3.5883	618.74	1.3105	31.709	101.58
530	0.0115477	3259.95	6.0691	3.4761	626.91	1.3090	32.073	101.57
540	0.0118502	3294.21	6.1115	3.3796	634.71	1.3075	32.440	101.72
550	0.0121444	3327.58	6.1523	3.2959	642.19	1.3061	32.810	102.02
560	0.0124312	3360.17	6.1917	3.2229	649.38	1.3047	33.182	102.45
570	0.0127112	3392.07	6.2297	3.1587	656.30	1.3033	33.555	102.98
580	0.0129853	3423.37	6.2666	3.1021	662.99	1.3019	33.929	103.61
590	0.0132538	3454.13	6.3025	3.0520	669.47	1.3006	34.304	104.32
600	0.0135174	3484.42	6.3374	3.0073	675.75	1.2993	34.679	105.11
650	0.0147740	3630.36	6.5000	2.8447	704.78	1.2931	36.551	109.91
700	0.0159531	3769.97	6.6473	2.7476	730.78	1.2875	38.411	115.69
750	0.0170777	3905.75	6.7833	2.6888	754.59	1.2824	40.253	122.24
800	0.0181620	4039.25	6.9107	2.6545	776.71	1.2776	42.075	129.21

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 280 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000986591	27.9053	0.0003407	4.0974	1447.9	75.891	1737.2	575.60
2	0.000986677	36.1007	0.030234	4.0980	1457.7	76.915	1628.0	579.97
4	0.000986815	44.2973	0.059917	4.0987	1467.1	77.896	1529.3	584.18
6	0.000987002	52.4957	0.089391	4.0996	1476.1	78.837	1439.9	588.26
8	0.000987236	60.6960	0.11866	4.1006	1484.6	79.736	1358.5	592.21
10	0.000987514	68.8983	0.14773	4.1017	1492.8	80.595	1284.3	596.04
12	0.000987834	77.1026	0.17661	4.1027	1500.6	81.415	1216.4	599.76
14	0.000988193	85.3091	0.20529	4.1037	1508.1	82.196	1154.0	603.38
16	0.000988591	93.5176	0.23377	4.1048	1515.2	82.938	1096.7	606.90
18	0.000989026	101.728	0.26207	4.1058	1521.9	83.644	1043.8	610.33
20	0.000989496	109.941	0.29018	4.1068	1528.4	84.313	994.82	613.67
25	0.000990818	130.480	0.35966	4.1091	1543.1	85.831	887.44	621.65
30	0.000992338	151.032	0.42801	4.1113	1556.0	87.138	797.60	629.13
35	0.000994041	171.594	0.49529	4.1135	1567.2	88.246	721.61	636.16
40	0.000995918	192.166	0.56151	4.1156	1576.8	89.165	656.72	642.76
45	0.000997960	212.749	0.62672	4.1178	1585.0	89.906	600.85	648.95
50	0.00100016	233.344	0.69095	4.1201	1591.8	90.479	552.37	654.74
55	0.00100251	253.951	0.75423	4.1226	1597.3	90.894	510.04	660.14
60	0.00100501	274.570	0.81659	4.1253	1601.6	91.159	472.85	665.16
65	0.00100765	295.204	0.87807	4.1283	1604.8	91.283	439.99	669.82
70	0.00101043	315.853	0.93869	4.1315	1607.0	91.274	410.82	674.12
75	0.00101334	336.520	0.99848	4.1350	1608.1	91.140	384.81	678.06
80	0.00101639	357.204	1.0575	4.1388	1608.3	90.889	361.51	681.66
85	0.00101958	377.909	1.1157	4.1430	1607.6	90.528	340.57	684.91
90	0.00102289	398.634	1.1732	4.1474	1606.1	90.064	321.67	687.84
95	0.00102634	419.383	1.2299	4.1522	1603.8	89.504	304.56	690.43
100	0.00102992	440.157	1.2859	4.1573	1600.7	88.853	289.03	692.71
110	0.00103747	481.785	1.3960	4.1686	1592.5	87.304	261.96	696.33
120	0.00104555	523.534	1.5036	4.1814	1581.7	85.460	239.26	698.74
130	0.00105418	565.420	1.6088	4.1959	1568.6	83.359	220.04	700.01
140	0.00106337	607.458	1.7118	4.2121	1553.3	81.034	203.61	700.17
150	0.00107314	649.668	1.8128	4.2304	1536.0	78.513	189.46	699.27
160	0.00108353	692.073	1.9118	4.2509	1516.7	75.821	177.17	697.36
170	0.00109457	734.696	2.0091	4.2741	1495.6	72.981	166.42	694.47
180	0.00110631	777.564	2.1047	4.3002	1472.6	70.011	156.94	691.06
190	0.00111879	820.710	2.1989	4.3297	1448.0	66.929	148.53	686.62
200	0.00113209	864.170	2.2918	4.3630	1421.6	63.751	141.02	681.26
210	0.00114628	907.986	2.3834	4.4008	1393.4	60.492	134.26	675.04
220	0.00116144	952.204	2.4740	4.4437	1363.5	57.167	128.14	667.98
230	0.00117770	996.880	2.5637	4.4925	1331.8	53.790	122.55	660.10
240	0.00119516	1042.08	2.6526	4.5482	1298.4	50.376	117.42	651.42

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 280 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00121400	1087.87	2.7410	4.6120	1263.2	46.941	112.67	641.94
260	0.00123440	1134.35	2.8290	4.6852	1226.1	43.498	108.24	631.66
270	0.00125661	1181.61	2.9168	4.7699	1187.3	40.061	104.06	620.57
280	0.00128092	1229.79	3.0047	4.8684	1146.4	36.644	100.11	608.65
290	0.00130771	1279.04	3.0929	4.9842	1103.5	33.255	96.318	595.88
300	0.00133750	1329.55	3.1818	5.1219	1058.2	29.902	92.652	582.21
310	0.00137097	1381.57	3.2718	5.2887	1010.3	26.592	89.065	567.58
320	0.00140908	1435.45	3.3634	5.4951	959.59	23.339	85.510	551.88
330	0.00145324	1491.66	3.4574	5.7582	905.78	20.163	81.934	534.95
340	0.00150559	1550.90	3.5548	6.1067	848.38	17.073	78.269	516.55
350	0.00156965	1614.25	3.6573	6.5932	785.84	14.051	74.424	496.33
360	0.00165196	1683.64	3.7677	7.3526	716.33	11.093	70.247	473.68
370	0.00176645	1763.10	3.8922	8.6798	636.68	8.1956	65.453	447.49
380	0.00195213	1862.42	4.0454	11.672	541.56	5.3658	59.355	415.81
390	0.00239786	2022.34	4.2882	23.482	428.02	2.7287	49.488	378.18
400	0.00385452	2334.42	4.7552	27.310	409.44	1.5533	35.669	272.72
410	0.00507063	2529.06	5.0424	14.334	449.43	1.4227	31.774	189.73
420	0.00590405	2648.46	5.2160	10.103	478.15	1.3830	30.623	156.26
430	0.00656344	2738.07	5.3444	8.0188	500.89	1.3652	30.217	138.67
440	0.00712296	2811.60	5.4483	6.7824	519.63	1.3538	30.122	128.05
450	0.00761715	2875.11	5.5367	5.9700	535.67	1.3454	30.190	121.08
460	0.00806487	2931.77	5.6145	5.3900	549.86	1.3389	30.351	116.25
470	0.00847736	2983.38	5.6845	4.9518	562.68	1.3339	30.572	112.80
480	0.00886205	3031.12	5.7483	4.6086	574.44	1.3298	30.834	110.31
490	0.00922415	3075.78	5.8072	4.3330	585.34	1.3266	31.123	108.51
500	0.00956757	3117.94	5.8621	4.1079	595.51	1.3238	31.432	107.23
510	0.00989528	3158.06	5.9136	3.9213	605.06	1.3213	31.756	106.36
520	0.0102096	3196.47	5.9624	3.7649	614.09	1.3191	32.091	105.81
530	0.0105124	3233.44	6.0087	3.6324	622.65	1.3171	32.434	105.51
540	0.0108052	3269.18	6.0529	3.5191	630.80	1.3152	32.784	105.43
550	0.0110891	3303.87	6.0953	3.4214	638.60	1.3134	33.138	105.53
560	0.0113653	3337.65	6.1361	3.3366	646.07	1.3116	33.496	105.78
570	0.0116344	3370.64	6.1755	3.2624	653.25	1.3100	33.856	106.17
580	0.0118973	3402.93	6.2136	3.1971	660.17	1.3083	34.219	106.67
590	0.0121545	3434.61	6.2505	3.1393	666.86	1.3067	34.583	107.26
600	0.0124065	3465.74	6.2863	3.0880	673.34	1.3052	34.948	107.95
650	0.0136035	3615.07	6.4527	2.9016	703.15	1.2980	36.783	112.39
700	0.0147212	3757.13	6.6026	2.7900	729.71	1.2918	38.615	117.96
750	0.0157832	3894.78	6.7405	2.7216	753.95	1.2863	40.436	124.40
800	0.0168046	4029.74	6.8693	2.6808	776.40	1.2811	42.241	131.33

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 300 bar									
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>	
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]	
0	0.000985665	29.8599	0.0002758	4.0899	1451.3	71.230	1733.9	576.94	
2	0.000985763	38.0406	0.030116	4.0909	1461.1	72.187	1625.2	581.26	
4	0.000985912	46.2234	0.059748	4.0920	1470.5	73.104	1527.0	585.43	
6	0.000986109	54.4086	0.089176	4.0932	1479.4	73.983	1438.0	589.48	
8	0.000986352	62.5964	0.11840	4.0945	1488.0	74.823	1357.0	593.40	
10	0.000986638	70.7866	0.14743	4.0958	1496.1	75.626	1283.0	597.21	
12	0.000986965	78.9794	0.17626	4.0970	1503.9	76.391	1215.4	600.91	
14	0.000987332	87.1748	0.20490	4.0983	1511.4	77.120	1153.2	604.50	
16	0.000987736	95.3726	0.23335	4.0995	1518.5	77.814	1096.0	608.00	
18	0.000988176	103.573	0.26161	4.1007	1525.2	78.473	1043.3	611.41	
20	0.000988652	111.775	0.28969	4.1018	1531.7	79.098	994.47	614.74	
25	0.000989984	132.291	0.35908	4.1044	1546.4	80.517	887.35	622.68	
30	0.000991511	152.819	0.42737	4.1069	1559.3	81.739	797.69	630.15	
35	0.000993220	173.360	0.49457	4.1092	1570.5	82.776	721.84	637.16	
40	0.000995099	193.911	0.56073	4.1115	1580.1	83.637	657.04	643.75	
45	0.000997141	214.475	0.62588	4.1138	1588.3	84.333	601.24	649.93	
50	0.000999339	235.050	0.69004	4.1162	1595.1	84.873	552.81	655.71	
55	0.00100169	255.637	0.75326	4.1188	1600.7	85.264	510.51	661.12	
60	0.00100418	276.238	0.81557	4.1215	1605.1	85.516	473.34	666.15	
65	0.00100681	296.853	0.87699	4.1245	1608.3	85.637	440.50	670.81	
70	0.00100958	317.483	0.93755	4.1278	1610.5	85.634	411.34	675.12	
75	0.00101249	338.131	0.99729	4.1313	1611.7	85.515	385.34	679.07	
80	0.00101553	358.797	1.0562	4.1351	1611.9	85.286	362.04	682.68	
85	0.00101870	379.482	1.1144	4.1392	1611.3	84.955	341.10	685.95	
90	0.00102200	400.189	1.1718	4.1436	1609.9	84.528	322.20	688.89	
95	0.00102544	420.919	1.2285	4.1484	1607.6	84.010	305.09	691.50	
100	0.00102900	441.673	1.2845	4.1534	1604.6	83.409	289.56	693.79	
110	0.00103651	483.262	1.3945	4.1646	1596.6	81.975	262.48	697.45	
120	0.00104455	524.970	1.5019	4.1772	1586.0	80.266	239.77	699.90	
130	0.00105313	566.811	1.6070	4.1914	1573.0	78.316	220.54	701.21	
140	0.00106226	608.803	1.7099	4.2073	1557.9	76.158	204.10	701.41	
150	0.00107197	650.964	1.8107	4.2252	1540.7	73.817	189.94	700.56	
160	0.00108228	693.315	1.9097	4.2453	1521.7	71.317	177.65	698.70	
170	0.00109324	735.879	2.0068	4.2680	1500.8	68.679	166.89	695.86	
180	0.00110488	778.683	2.1023	4.2935	1478.2	65.920	157.41	692.48	
190	0.00111725	821.759	2.1964	4.3222	1453.8	63.057	149.00	688.10	
200	0.00113043	865.140	2.2890	4.3547	1427.7	60.105	141.49	682.81	
210	0.00114447	908.867	2.3805	4.3915	1399.9	57.078	134.73	676.65	
220	0.00115946	952.986	2.4709	4.4332	1370.4	53.989	128.61	669.67	
230	0.00117552	997.550	2.5603	4.4805	1339.2	50.852	123.03	661.87	
240	0.00119275	1042.62	2.6490	4.5344	1306.2	47.682	117.90	653.28	

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 300 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00121131	1088.26	2.7371	4.5959	1271.5	44.490	113.16	643.90
260	0.00123138	1134.57	2.8248	4.6664	1235.1	41.293	108.74	633.73
270	0.00125319	1181.63	2.9122	4.7476	1196.9	38.102	104.58	622.77
280	0.00127700	1229.56	2.9997	4.8417	1156.8	34.930	100.65	611.00
290	0.00130318	1278.51	3.0874	4.9516	1114.8	31.788	96.885	598.40
300	0.00133219	1328.66	3.1756	5.0814	1070.6	28.681	93.252	584.93
310	0.00136464	1380.23	3.2648	5.2370	1024.1	25.616	89.708	570.54
320	0.00140138	1433.51	3.3554	5.4272	974.84	22.604	86.208	555.13
330	0.00144362	1488.93	3.4481	5.6659	922.91	19.667	82.705	538.58
340	0.00149319	1547.07	3.5437	5.9753	868.21	16.827	79.141	520.68
350	0.00155290	1608.80	3.6435	6.3935	809.96	14.082	75.440	501.15
360	0.00162769	1675.57	3.7498	7.0110	744.31	11.345	71.492	479.54
370	0.00172705	1750.19	3.8667	7.9986	672.42	8.7269	67.105	455.01
380	0.00187297	1838.26	4.0026	9.8342	590.65	6.2087	61.900	426.10
390	0.00213310	1955.23	4.1802	14.344	497.30	3.8646	54.943	390.64
400	0.00279641	2152.37	4.4750	25.797	419.63	2.0990	44.203	339.93
410	0.00398397	2395.84	4.8342	19.685	432.54	1.5654	35.620	244.78
420	0.00492092	2552.87	5.0625	12.730	462.80	1.4509	32.762	187.87
430	0.00563824	2662.82	5.2201	9.5627	487.80	1.4067	31.674	159.41
440	0.00622812	2748.86	5.3416	7.7964	508.64	1.3847	31.232	143.07
450	0.00673815	2820.91	5.4419	6.6908	526.23	1.3699	31.091	132.73
460	0.00719339	2883.84	5.5284	5.9370	541.56	1.3591	31.115	125.74
470	0.00760843	2940.32	5.6049	5.3861	555.31	1.3510	31.238	120.82
480	0.00799240	2991.99	5.6740	4.9638	567.83	1.3447	31.426	117.25
490	0.00835153	3039.89	5.7372	4.6297	579.37	1.3398	31.659	114.65
500	0.00869030	3084.79	5.7956	4.3597	590.11	1.3357	31.924	112.74
510	0.00901209	3127.24	5.8502	4.1378	600.16	1.3322	32.211	111.37
520	0.00931954	3167.67	5.9015	3.9532	609.62	1.3292	32.515	110.41
530	0.00961471	3206.41	5.9500	3.7979	618.57	1.3265	32.832	109.78
540	0.00989926	3243.71	5.9962	3.6660	627.07	1.3241	33.160	109.42
550	0.0101745	3279.79	6.0403	3.5529	635.17	1.3217	33.494	109.29
560	0.0104416	3314.82	6.0826	3.4552	642.92	1.3196	33.835	109.34
570	0.0107014	3348.94	6.1233	3.3701	650.36	1.3175	34.181	109.55
580	0.0109547	3382.25	6.1626	3.2955	657.51	1.3155	34.530	109.90
590	0.0112021	3414.87	6.2006	3.2296	664.40	1.3135	34.882	110.37
600	0.0114442	3446.87	6.2374	3.1713	671.07	1.3117	35.236	110.94
650	0.0125897	3599.68	6.4077	2.9598	701.63	1.3034	37.027	114.98
700	0.0136542	3744.24	6.5602	2.8331	728.73	1.2964	38.829	120.30
750	0.0146621	3883.78	6.7000	2.7549	753.38	1.2904	40.626	126.63
800	0.0156288	4020.23	6.8303	2.7072	776.14	1.2848	42.412	133.49

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 400 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000981126	39.5556	-0.0002298	4.0544	1468.5	54.946	1718.4	583.43
2	0.000981280	47.6674	0.029359	4.0573	1478.2	55.668	1612.3	587.55
4	0.000981481	55.7849	0.058755	4.0602	1487.5	56.359	1516.4	591.55
6	0.000981726	63.9080	0.087959	4.0629	1496.4	57.020	1429.2	595.44
8	0.000982012	72.0363	0.11697	4.0655	1504.9	57.652	1349.8	599.22
10	0.000982338	80.1697	0.14580	4.0679	1513.0	58.256	1277.2	602.90
12	0.000982701	88.3079	0.17444	4.0702	1520.7	58.831	1210.7	606.48
14	0.000983101	96.4505	0.20290	4.0724	1528.1	59.379	1149.5	609.98
16	0.000983535	104.597	0.23117	4.0744	1535.1	59.901	1093.2	613.38
18	0.000984002	112.748	0.25926	4.0763	1541.8	60.397	1041.2	616.71
20	0.000984502	120.902	0.28717	4.0781	1548.2	60.868	993.00	619.96
25	0.000985884	141.303	0.35618	4.0821	1562.9	61.938	887.12	627.76
30	0.000987447	161.723	0.42410	4.0857	1575.7	62.862	798.34	635.11
35	0.000989180	182.159	0.49096	4.0888	1587.0	63.650	723.10	642.06
40	0.000991072	202.611	0.55680	4.0918	1596.7	64.308	658.75	648.60
45	0.000993117	223.077	0.62164	4.0946	1605.0	64.843	603.26	654.76
50	0.000995309	243.557	0.68551	4.0974	1611.9	65.263	555.06	660.54
55	0.000997641	264.051	0.74844	4.1003	1617.6	65.573	512.92	665.96
60	0.00100011	284.560	0.81047	4.1033	1622.2	65.780	475.85	671.01
65	0.00100271	305.084	0.87162	4.1064	1625.6	65.889	443.09	675.71
70	0.00100545	325.624	0.93191	4.1097	1628.1	65.906	413.97	680.07
75	0.00100831	346.181	0.99139	4.1132	1629.5	65.836	387.99	684.08
80	0.00101130	366.757	1.0501	4.1170	1630.1	65.685	364.71	687.75
85	0.00101441	387.351	1.1080	4.1210	1629.7	65.457	343.77	691.09
90	0.00101765	407.967	1.1651	4.1252	1628.6	65.157	324.86	694.10
95	0.00102101	428.604	1.2216	4.1298	1626.7	64.790	307.74	696.79
100	0.00102449	449.265	1.2773	4.1346	1624.0	64.359	292.18	699.17
110	0.00103183	490.662	1.3868	4.1450	1616.7	63.325	265.06	703.00
120	0.00103966	532.169	1.4937	4.1567	1606.8	62.085	242.30	705.65
130	0.00104800	573.800	1.5983	4.1697	1594.7	60.664	223.03	707.16
140	0.00105685	615.569	1.7006	4.1843	1580.5	59.087	206.55	707.58
150	0.00106625	657.491	1.8009	4.2005	1564.3	57.373	192.35	706.96
160	0.00107622	699.585	1.8992	4.2186	1546.3	55.540	180.01	705.34
170	0.00108677	741.871	1.9957	4.2389	1526.5	53.605	169.22	702.76
180	0.00109796	784.371	2.0906	4.2616	1505.1	51.580	159.72	699.28
190	0.00110982	827.113	2.1839	4.2871	1482.1	49.478	151.29	695.40
200	0.00112241	870.124	2.2758	4.3158	1457.4	47.311	143.77	690.43
210	0.00113577	913.440	2.3663	4.3480	1431.2	45.088	137.01	684.61
220	0.00114999	957.098	2.4558	4.3843	1403.5	42.821	130.90	677.99
230	0.00116514	1001.14	2.5442	4.4252	1374.2	40.519	125.34	670.58
240	0.00118132	1045.62	2.6317	4.4713	1343.4	38.193	120.24	662.41

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 400 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00119864	1090.59	2.7185	4.5234	1311.1	35.852	115.54	653.50
260	0.00121724	1136.11	2.8047	4.5824	1277.3	33.506	111.17	643.85
270	0.00123729	1182.26	2.8905	4.6493	1242.0	31.167	107.09	633.46
280	0.00125898	1229.13	2.9760	4.7254	1205.2	28.845	103.23	622.35
290	0.00128255	1276.80	3.0614	4.8123	1167.0	26.548	99.578	610.49
300	0.00130831	1325.41	3.1469	4.9120	1127.4	24.287	96.077	597.89
310	0.00133664	1375.10	3.2329	5.0272	1086.2	22.068	92.699	584.51
320	0.00136803	1426.02	3.3195	5.1615	1043.4	19.895	89.409	570.33
330	0.00140314	1478.41	3.4070	5.3198	998.69	17.771	86.175	555.29
340	0.00144284	1532.52	3.4960	5.5097	951.99	15.703	82.962	539.31
350	0.00148840	1588.74	3.5870	5.7424	903.62	13.715	79.732	522.26
360	0.00154152	1647.62	3.6807	6.0440	853.45	11.813	76.445	504.00
370	0.00160475	1709.93	3.7783	6.4342	800.77	9.9896	73.054	484.33
380	0.00168216	1776.72	3.8814	6.9509	745.75	8.2653	69.493	462.88
390	0.00178035	1849.61	3.9921	7.6679	688.52	6.6568	65.677	439.18
400	0.00191069	1931.13	4.1141	8.7012	630.14	5.1954	61.497	412.52
410	0.00209341	2025.18	4.2527	10.192	573.76	3.9314	56.829	381.95
420	0.00236117	2136.30	4.4142	12.045	526.61	2.9362	51.663	346.35
430	0.00274238	2263.84	4.5969	13.205	499.08	2.2707	46.484	305.32
440	0.00320965	2394.03	4.7807	12.554	493.66	1.8982	42.273	263.18
450	0.00369271	2511.77	4.9447	10.950	501.50	1.7027	39.444	227.60
460	0.00414901	2613.32	5.0842	9.3909	514.66	1.5960	37.687	201.01
470	0.00456732	2700.69	5.2026	8.1475	528.95	1.5315	36.617	181.89
480	0.00494969	2777.18	5.3048	7.1892	542.92	1.4888	35.972	168.06
490	0.00530040	2845.20	5.3946	6.4475	556.25	1.4594	35.601	157.94
500	0.00562490	2906.69	5.4746	5.8745	568.83	1.4381	35.411	150.41
510	0.00592790	2963.09	5.5471	5.4221	580.67	1.4220	35.345	144.72
520	0.00621295	3015.42	5.6135	5.0563	591.81	1.4093	35.367	140.37
530	0.00648280	3064.43	5.6749	4.7551	602.30	1.3990	35.454	137.02
540	0.00673966	3110.69	5.7322	4.5044	612.21	1.3903	35.589	134.45
550	0.00698531	3154.65	5.7859	4.2938	621.60	1.3828	35.762	132.48
560	0.00722123	3196.67	5.8366	4.1156	630.51	1.3763	35.964	131.00
570	0.007444864	3237.05	5.8848	3.9634	638.99	1.3704	36.189	129.91
580	0.00766855	3276.01	5.9308	3.8324	647.09	1.3651	36.432	129.14
590	0.00788179	3313.75	5.9747	3.7188	654.85	1.3602	36.691	128.65
600	0.00808906	3350.43	6.0170	3.6194	662.31	1.3557	36.962	128.39
650	0.00905378	3521.76	6.2079	3.2666	695.98	1.3375	38.439	129.53
700	0.00993098	3679.42	6.3743	3.0570	725.36	1.3245	40.032	133.16
750	0.0107484	3828.75	6.5239	2.9259	751.76	1.3145	41.676	138.62
800	0.0115229	3972.81	6.6614	2.8428	775.83	1.3059	43.343	144.96

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 500 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000976730	49.1286	-0.001021	4.0225	1485.9	45.212	1704.7	589.62
2	0.000976937	57.1781	0.028341	4.0270	1495.6	45.791	1601.0	593.57
4	0.000977186	65.2365	0.057522	4.0313	1504.8	46.345	1507.0	597.41
6	0.000977475	73.3031	0.086523	4.0353	1513.6	46.875	1421.6	601.15
8	0.000977801	81.3773	0.11534	4.0390	1522.0	47.381	1343.6	604.80
10	0.000978164	89.4588	0.14399	4.0424	1530.0	47.864	1272.2	608.36
12	0.000978561	97.5468	0.17245	4.0456	1537.7	48.324	1206.7	611.84
14	0.000978991	105.641	0.20074	4.0486	1545.0	48.763	1146.5	615.25
16	0.000979453	113.741	0.22885	4.0513	1551.9	49.181	1090.9	618.57
18	0.000979945	121.846	0.25678	4.0538	1558.6	49.578	1039.6	621.83
20	0.000980468	129.956	0.28454	4.0562	1564.9	49.956	991.97	625.01
25	0.000981897	150.250	0.35319	4.0614	1579.5	50.815	887.21	632.68
30	0.000983494	170.569	0.42077	4.0659	1592.3	51.559	799.22	639.94
35	0.000985249	190.908	0.48732	4.0698	1603.5	52.196	724.54	646.82
40	0.000987154	211.266	0.55285	4.0733	1613.3	52.731	660.58	653.33
45	0.000989203	231.640	0.61740	4.0765	1621.6	53.169	605.37	659.47
50	0.000991389	252.031	0.68099	4.0797	1628.7	53.516	557.37	665.26
55	0.000993708	272.437	0.74366	4.0828	1634.6	53.776	515.37	670.70
60	0.000996157	292.859	0.80542	4.0860	1639.3	53.955	478.40	675.78
65	0.000998732	313.297	0.86631	4.0892	1643.0	54.056	445.69	680.53
70	0.00100143	333.751	0.92636	4.0926	1645.6	54.084	416.61	684.93
75	0.00100425	354.223	0.98558	4.0961	1647.3	54.043	390.65	689.00
80	0.00100719	374.713	1.0440	4.0998	1648.1	53.936	367.37	692.73
85	0.00101025	395.221	1.1017	4.1037	1648.0	53.769	346.43	696.14
90	0.00101343	415.750	1.1586	4.1078	1647.2	53.544	327.51	699.23
95	0.00101672	436.300	1.2148	4.1121	1645.5	53.266	310.37	702.00
100	0.00102013	456.872	1.2703	4.1167	1643.2	52.937	294.80	704.46
110	0.00102730	498.087	1.3793	4.1265	1636.5	52.140	267.62	708.47
120	0.00103494	539.405	1.4858	4.1374	1627.4	51.178	244.82	711.31
130	0.00104306	580.838	1.5898	4.1494	1616.0	50.071	225.49	713.02
140	0.00105167	622.397	1.6917	4.1627	1602.5	48.840	208.96	713.65
150	0.00106078	664.096	1.7914	4.1774	1587.2	47.498	194.71	713.25
160	0.00107043	705.951	1.8891	4.1938	1570.1	46.063	182.34	711.86
170	0.00108062	747.979	1.9851	4.2121	1551.4	44.544	171.52	709.53
180	0.00109140	790.199	2.0793	4.2324	1531.0	42.955	161.99	706.30
190	0.00110280	832.635	2.1719	4.2551	1509.1	41.304	153.54	702.51
200	0.00111486	875.311	2.2631	4.2806	1485.8	39.602	146.00	697.88
210	0.00112763	918.256	2.3529	4.3090	1460.9	37.856	139.23	692.38
220	0.00114116	961.503	2.4415	4.3409	1434.7	36.074	133.12	686.09
230	0.00115553	1005.09	2.5290	4.3766	1407.0	34.266	127.57	679.04
240	0.00117080	1049.05	2.6155	4.4165	1378.0	32.439	122.49	671.26

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 500 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00118708	1093.43	2.7012	4.4613	1347.7	30.601	117.81	662.76
260	0.00120446	1138.29	2.7861	4.5115	1316.0	28.759	113.48	653.57
270	0.00122307	1183.68	2.8704	4.5678	1283.1	26.923	109.45	643.69
280	0.00124305	1229.67	2.9543	4.6310	1249.0	25.100	105.66	633.14
290	0.00126459	1276.33	3.0379	4.7020	1213.7	23.298	102.08	621.91
300	0.00128789	1323.74	3.1214	4.7819	1177.3	21.526	98.671	610.02
310	0.00131322	1372.00	3.2049	4.8719	1139.9	19.790	95.406	597.44
320	0.00134088	1421.22	3.2885	4.9736	1101.5	18.097	92.254	584.19
330	0.00137128	1471.52	3.3726	5.0889	1062.1	16.453	89.189	570.23
340	0.00140492	1523.05	3.4574	5.2200	1021.7	14.859	86.187	555.54
350	0.00144244	1575.98	3.5430	5.3700	980.05	13.318	83.221	540.08
360	0.00148475	1630.63	3.6300	5.5620	936.04	11.802	80.264	523.79
370	0.00153293	1687.35	3.7189	5.7866	891.79	10.376	77.296	506.59
380	0.00158849	1746.51	3.8101	6.0531	846.77	9.0278	74.291	488.37
390	0.00165351	1808.60	3.9045	6.3776	801.09	7.7623	71.224	469.01
400	0.00173089	1874.31	4.0028	6.7781	755.14	6.5889	68.068	448.33
410	0.00182467	1944.47	4.1063	7.2713	709.70	5.5207	64.800	426.12
420	0.00194037	2020.07	4.2161	7.8636	666.13	4.5737	61.406	402.17
430	0.00208504	2101.99	4.3334	8.5275	626.51	3.7651	57.904	376.31
440	0.00226604	2190.53	4.4585	9.1599	593.57	3.1096	54.371	348.62
450	0.00248744	2284.44	4.5892	9.5672	569.96	2.6120	50.971	319.72
460	0.00274521	2380.52	4.7212	9.5776	556.72	2.2580	47.928	290.98
470	0.00302709	2474.69	4.8488	9.2032	552.52	2.0170	45.407	264.27
480	0.00331861	2563.86	4.9680	8.6087	554.76	1.8547	43.448	241.00
490	0.00360858	2646.56	5.0770	7.8969	560.89	1.7436	41.985	221.51
500	0.00388941	2722.52	5.1759	7.3090	568.92	1.6644	40.924	205.98
510	0.00415994	2792.70	5.2661	6.7313	578.20	1.6073	40.163	193.40
520	0.00441748	2857.36	5.3482	6.2131	588.07	1.5657	39.633	183.36
530	0.00466236	2917.25	5.4232	5.7787	598.00	1.5340	39.276	175.39
540	0.00489567	2973.16	5.4924	5.4136	607.73	1.5088	39.051	169.04
550	0.00511848	3025.70	5.5566	5.1031	617.16	1.4883	38.925	163.96
560	0.00533183	3075.37	5.6166	4.8372	626.25	1.4711	38.876	159.88
570	0.00553667	3122.57	5.6729	4.6091	634.99	1.4565	38.889	156.62
580	0.00573390	3167.66	5.7261	4.4131	643.38	1.4438	38.951	154.02
590	0.00592433	3210.92	5.7765	4.2440	651.44	1.4327	39.052	151.97
600	0.00610867	3252.61	5.8245	4.0973	659.20	1.4227	39.185	150.36
650	0.00695746	3443.48	6.0372	3.5873	694.26	1.3856	40.168	146.95
700	0.00771757	3614.76	6.2180	3.2881	724.96	1.3620	41.452	147.95
750	0.00841745	3774.13	6.3777	3.1008	752.51	1.3455	42.883	152.05
800	0.00907413	3925.96	6.5226	2.9813	777.37	1.3319	44.391	157.54

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 600 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000972471	58.5861	-0.002077	3.9937	1503.7	38.750	1692.8	595.53
2	0.000972727	66.5794	0.027080	3.9996	1513.2	39.233	1591.2	599.31
4	0.000973021	74.5842	0.056067	4.0051	1522.3	39.695	1499.0	603.01
6	0.000973350	82.5995	0.084884	4.0102	1531.0	40.136	1415.0	606.62
8	0.000973714	90.6246	0.11353	4.0148	1539.3	40.557	1338.3	610.16
10	0.000974111	98.6586	0.14200	4.0191	1547.2	40.959	1268.1	613.62
12	0.000974539	106.701	0.17031	4.0230	1554.8	41.343	1203.5	617.01
14	0.000974998	114.751	0.19844	4.0267	1562.0	41.708	1144.1	620.32
16	0.000975486	122.807	0.22640	4.0300	1568.9	42.056	1089.2	623.58
18	0.000976002	130.870	0.25419	4.0331	1575.5	42.387	1038.4	626.77
20	0.000976545	138.939	0.28181	4.0359	1581.8	42.702	991.37	629.89
25	0.000978019	159.135	0.35012	4.0422	1596.2	43.419	887.62	637.44
30	0.000979648	179.359	0.41739	4.0474	1609.0	44.043	800.34	644.63
35	0.000981425	199.608	0.48364	4.0519	1620.2	44.578	726.16	651.46
40	0.000983342	219.877	0.54889	4.0559	1630.0	45.029	662.55	657.94
45	0.000985394	240.166	0.61316	4.0595	1638.4	45.402	607.59	664.08
50	0.000987575	260.472	0.67649	4.0630	1645.6	45.699	559.76	669.88
55	0.000989883	280.795	0.73890	4.0663	1651.6	45.925	517.88	675.34
60	0.000992312	301.135	0.80042	4.0696	1656.4	46.084	480.98	680.46
65	0.000994862	321.491	0.86107	4.0729	1660.3	46.179	448.33	685.25
70	0.000997528	341.864	0.92087	4.0763	1663.1	46.213	419.28	689.71
75	0.00100031	362.255	0.97987	4.0798	1665.0	46.190	393.32	693.84
80	0.00100321	382.663	1.0381	4.0835	1666.0	46.113	370.04	697.64
85	0.00100621	403.090	1.0955	4.0873	1666.2	45.985	349.09	701.12
90	0.00100933	423.536	1.1522	4.0913	1665.6	45.809	330.15	704.28
95	0.00101256	444.003	1.2082	4.0954	1664.2	45.589	312.99	707.13
100	0.00101591	464.490	1.2634	4.0997	1662.2	45.326	297.40	709.68
110	0.00102292	505.533	1.3720	4.1090	1656.1	44.686	270.17	713.87
120	0.00103039	546.672	1.4780	4.1191	1647.6	43.907	247.31	716.89
130	0.00103830	587.918	1.5816	4.1302	1636.9	43.008	227.92	718.79
140	0.00104668	629.280	1.6829	4.1424	1624.2	42.005	211.34	719.63
150	0.00105553	670.770	1.7822	4.1558	1609.6	40.910	197.05	719.45
160	0.00106488	712.401	1.8794	4.1707	1593.4	39.737	184.63	718.29
170	0.00107475	754.189	1.9748	4.1872	1575.5	38.494	173.77	716.19
180	0.00108516	796.150	2.0684	4.2055	1556.2	37.193	164.21	713.20
190	0.00109614	838.305	2.1604	4.2258	1535.3	35.840	155.74	709.36
200	0.00110773	880.675	2.2509	4.2485	1513.1	34.445	148.18	705.16
210	0.00111996	923.284	2.3400	4.2738	1489.4	33.013	141.40	699.98
220	0.00113289	966.161	2.4279	4.3020	1464.5	31.552	135.29	694.00
230	0.00114657	1009.33	2.5145	4.3334	1438.2	30.068	129.73	687.29
240	0.00116107	1052.84	2.6002	4.3684	1410.8	28.569	124.66	679.86

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 600 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00117644	1096.72	2.6848	4.4073	1382.1	27.061	120.0	671.75
260	0.00119279	1141.00	2.7687	4.4507	1352.2	25.550	115.7	662.97
270	0.00121019	1185.75	2.8518	4.4988	1321.3	24.043	111.7	653.54
280	0.00122878	1231.00	2.9344	4.5523	1289.3	22.548	108.0	643.48
290	0.00124867	1276.81	3.0165	4.6117	1256.4	21.070	104.4	632.79
300	0.00127003	1323.25	3.0982	4.6775	1222.6	19.616	101.1	621.49
310	0.00129303	1370.38	3.1797	4.7504	1188.0	18.192	97.906	609.59
320	0.00131791	1418.28	3.2612	4.8309	1152.7	16.804	94.852	597.08
330	0.00134492	1467.03	3.3427	4.9198	1116.8	15.456	91.903	583.96
340	0.00137438	1516.71	3.4244	5.0175	1080.4	14.154	89.039	570.24
350	0.00140668	1567.41	3.5064	5.1244	1043.5	12.901	86.239	555.90
360	0.00144230	1619.30	3.5890	5.2592	1004.8	11.666	83.486	540.96
370	0.00148191	1672.64	3.6726	5.4109	965.62	10.487	80.759	525.33
380	0.00152621	1727.58	3.7573	5.5800	926.26	9.3691	78.045	509.02
390	0.00157615	1784.32	3.8435	5.7733	886.78	8.3153	75.333	491.98
400	0.00163294	1843.15	3.9316	5.9975	847.38	7.3289	72.609	474.17
410	0.00169811	1904.39	4.0219	6.2571	808.45	6.4149	69.865	455.54
420	0.00177352	1968.41	4.1149	6.5524	770.53	5.5794	67.095	436.03
430	0.00186141	2035.54	4.2111	6.8777	734.35	4.8286	64.304	415.61
440	0.00196432	2106.01	4.3106	7.2170	700.87	4.1678	61.509	394.31
450	0.00208469	2179.82	4.4134	7.5398	671.18	3.6015	58.741	372.22
460	0.00222434	2256.60	4.5188	7.7999	646.41	3.1309	56.057	349.62
470	0.00238359	2335.44	4.6256	7.9454	627.42	2.7526	53.527	326.97
480	0.00256059	2415.00	4.7319	7.9414	614.48	2.4577	51.227	304.91
490	0.00275152	2493.77	4.8358	7.7888	607.17	2.2330	49.215	284.14
500	0.00295158	2570.40	4.9356	7.5220	604.53	2.0636	47.514	265.22
510	0.00315612	2643.99	5.0302	7.1881	605.44	1.9357	46.116	248.48
520	0.00336069	2713.90	5.1189	6.7994	608.68	1.8374	44.998	233.98
530	0.00356327	2780.22	5.2020	6.4533	613.85	1.7625	44.114	221.70
540	0.00376176	2842.90	5.2796	6.0859	620.17	1.7040	43.429	211.28
550	0.00395482	2902.06	5.3519	5.7534	627.13	1.6574	42.908	202.58
560	0.00414208	2958.09	5.4195	5.4575	634.37	1.6192	42.520	195.33
570	0.00432345	3011.32	5.4830	5.1919	641.73	1.5875	42.241	189.30
580	0.00449897	3062.02	5.5428	4.9539	649.10	1.5609	42.051	184.30
590	0.00466889	3110.48	5.5993	4.7424	656.43	1.5382	41.933	180.16
600	0.00483355	3156.95	5.6528	4.5557	663.64	1.5186	41.876	176.74
650	0.00559084	3366.76	5.8867	3.9007	697.48	1.4502	42.189	167.15
700	0.00626511	3551.39	6.0815	3.5151	728.16	1.4105	43.069	164.61
750	0.00688181	3720.64	6.2512	3.2730	756.11	1.3846	44.229	166.83
800	0.00745681	3880.15	6.4034	3.1193	781.16	1.3639	45.541	171.13

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 700 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000968343	67.9346	-0.003378	3.9678	1521.6	34.155	1682.5	601.17
2	0.000968644	75.8774	0.025594	3.9749	1531.0	34.569	1582.8	604.81
4	0.000968980	83.8338	0.054406	3.9814	1540.0	34.964	1492.2	608.37
6	0.000969347	91.8027	0.083056	3.9874	1548.6	35.341	1409.6	611.87
8	0.000969746	99.7830	0.11154	3.9928	1556.8	35.702	1334.0	615.30
10	0.000970175	107.774	0.13986	3.9978	1564.6	36.045	1264.7	618.67
12	0.000970632	115.774	0.16802	4.0024	1572.1	36.373	1201.0	621.97
14	0.000971117	123.783	0.19601	4.0066	1579.2	36.686	1142.3	625.22
16	0.000971629	131.800	0.22383	4.0104	1586.0	36.983	1088.0	628.40
18	0.000972167	139.824	0.25149	4.0139	1592.5	37.267	1037.8	631.54
20	0.000972730	147.856	0.27898	4.0172	1598.7	37.536	991.20	634.61
25	0.000974245	167.960	0.34698	4.0242	1613.0	38.151	888.35	642.06
30	0.000975905	188.096	0.41395	4.0301	1625.7	38.688	801.69	649.18
35	0.000977702	208.259	0.47992	4.0351	1636.9	39.149	727.95	655.98
40	0.000979630	228.446	0.54491	4.0395	1646.7	39.541	664.66	662.44
45	0.000981686	248.654	0.60893	4.0435	1655.1	39.865	609.91	668.58
50	0.000983863	268.881	0.67201	4.0472	1662.4	40.126	562.23	674.40
55	0.000986160	289.125	0.73418	4.0507	1668.5	40.327	520.44	679.89
60	0.000988572	309.387	0.79546	4.0541	1673.5	40.471	483.61	685.05
65	0.000991097	329.666	0.85588	4.0575	1677.5	40.560	450.99	689.89
70	0.000993734	349.962	0.91546	4.0609	1680.5	40.598	421.95	694.40
75	0.000996480	370.275	0.97423	4.0644	1682.6	40.586	396.00	698.59
80	0.000999335	390.606	1.0322	4.0680	1683.8	40.529	372.72	702.46
85	0.00100230	410.955	1.0894	4.0717	1684.2	40.429	351.75	706.02
90	0.00100536	431.323	1.1459	4.0755	1683.8	40.287	332.79	709.26
95	0.00100854	451.711	1.2017	4.0795	1682.7	40.107	315.61	712.19
100	0.00101181	472.118	1.2567	4.0836	1680.9	39.892	299.98	714.82
110	0.00101869	512.997	1.3648	4.0923	1675.3	39.361	272.70	719.18
120	0.00102598	553.967	1.4704	4.1018	1667.4	38.712	249.78	722.39
130	0.00103371	595.035	1.5735	4.1120	1657.3	37.959	230.34	724.49
140	0.00104188	636.211	1.6744	4.1233	1645.3	37.117	213.70	725.52
150	0.00105049	677.504	1.7732	4.1355	1631.5	36.197	199.36	725.55
160	0.00105957	718.926	1.8699	4.1491	1616.0	35.210	186.90	724.61
170	0.00106913	760.490	1.9648	4.1640	1599.0	34.163	176.00	722.74
180	0.00107920	802.211	2.0579	4.1805	1580.5	33.066	166.40	719.99
190	0.00108981	844.106	2.1493	4.1988	1560.6	31.926	157.90	716.40
200	0.00110097	886.194	2.2392	4.2191	1539.4	30.748	150.32	712.23
210	0.00111273	928.496	2.3277	4.2417	1516.9	29.539	143.52	707.40
220	0.00112512	971.037	2.4149	4.2668	1493.1	28.305	137.39	701.73
230	0.00113819	1013.84	2.5008	4.2947	1468.1	27.052	131.84	695.33
240	0.00115199	1056.94	2.5856	4.3256	1442.0	25.785	126.77	688.23

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 700 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00116659	1100.36	2.6694	4.3598	1414.7	24.509	122.12	680.47
260	0.00118204	1144.15	2.7523	4.3976	1386.4	23.231	117.83	672.07
270	0.00119842	1188.33	2.8344	4.4393	1357.2	21.957	113.86	663.05
280	0.00121583	1232.95	2.9158	4.4853	1327.0	20.692	110.14	653.42
290	0.00123436	1278.05	2.9966	4.5358	1296.1	19.442	106.66	643.21
300	0.00125413	1323.68	3.0769	4.5912	1264.4	18.212	103.37	632.43
310	0.00127529	1369.89	3.1569	4.6516	1232.2	17.007	100.25	621.09
320	0.00129798	1416.73	3.2365	4.7174	1199.4	15.832	97.265	609.21
330	0.00132241	1464.26	3.3160	4.7885	1166.2	14.691	94.399	596.79
340	0.00134877	1512.52	3.3953	4.8648	1132.6	13.587	91.633	583.84
350	0.00137734	1561.57	3.4747	4.9456	1098.8	12.523	88.947	570.37
360	0.00140839	1611.49	3.5541	5.0456	1064.4	11.492	86.329	556.40
370	0.00144236	1662.50	3.6341	5.1581	1028.9	10.485	83.758	541.91
380	0.00147965	1714.68	3.7146	5.2776	993.30	9.5259	81.226	526.89
390	0.00152079	1768.09	3.7957	5.4083	957.83	8.6180	78.724	511.36
400	0.00156639	1822.89	3.8778	5.5547	922.59	7.7629	76.244	495.31
410	0.00161722	1879.25	3.9609	5.7192	887.84	6.9631	73.778	478.73
420	0.00167415	1937.34	4.0453	5.9017	853.87	6.2214	71.324	461.62
430	0.00173821	1997.33	4.1312	6.0990	821.07	5.5407	68.883	444.00
440	0.00181047	2059.35	4.2188	6.3049	789.90	4.9233	66.460	425.88
450	0.00189208	2123.43	4.3080	6.5096	760.87	4.3710	64.070	407.32
460	0.00198407	2189.49	4.3987	6.6990	734.52	3.8846	61.731	388.43
470	0.00208719	2257.30	4.4906	6.8558	711.40	3.4639	59.471	369.39
480	0.00220176	2326.43	4.5830	6.9619	691.97	3.1068	57.321	350.42
490	0.00232737	2396.31	4.6752	7.0021	676.51	2.8092	55.316	331.81
500	0.00246294	2466.23	4.7662	6.9693	665.04	2.5653	53.485	313.90
510	0.00260674	2535.47	4.8552	6.8670	657.31	2.3678	51.849	297.02
520	0.00275670	2603.38	4.9413	6.7073	652.87	2.2088	50.418	281.41
530	0.00291072	2669.48	5.0242	6.5070	651.17	2.0811	49.189	267.24
540	0.00306666	2733.39	5.1032	6.2797	652.00	1.9803	48.152	254.58
550	0.00322318	2795.01	5.1786	6.0369	654.19	1.8968	47.287	243.39
560	0.00337846	2854.09	5.2499	5.7814	657.60	1.8286	46.580	233.63
570	0.00353176	2910.72	5.3175	5.5472	661.76	1.7714	46.007	225.19
580	0.00368255	2965.08	5.3816	5.3277	666.47	1.7231	45.550	217.92
590	0.00383038	3017.31	5.4424	5.1190	671.62	1.6823	45.192	211.67
600	0.00397492	3067.51	5.5003	4.9233	677.13	1.6478	44.919	206.33
650	0.00464832	3293.57	5.7522	4.1825	706.51	1.5341	44.447	189.70
700	0.00525194	3490.45	5.9600	3.7267	735.57	1.4717	44.849	182.87
750	0.00580362	3668.96	6.1390	3.4357	762.99	1.4330	45.689	182.78
800	0.00631671	3835.81	6.2982	3.2526	787.58	1.4028	46.774	185.60

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

p = 800 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000964341	77.1804	-0.004907	3.9446	1539.6	30.724	1673.7	606.55
2	0.000964684	85.0779	0.023900	3.9527	1548.9	31.086	1575.7	610.06
4	0.000965058	92.9907	0.052555	3.9600	1557.8	31.431	1486.5	613.51
6	0.000965460	100.918	0.081053	3.9667	1566.2	31.760	1405.1	616.90
8	0.000965892	108.857	0.10939	3.9728	1574.3	32.074	1330.6	620.23
10	0.000966350	116.809	0.13758	3.9784	1582.0	32.374	1262.2	623.52
12	0.000966834	124.770	0.16560	3.9835	1589.4	32.659	1199.2	626.75
14	0.000967344	132.742	0.19345	3.9881	1596.4	32.932	1141.1	629.93
16	0.000967879	140.723	0.22115	3.9923	1603.1	33.192	1087.4	633.06
18	0.000968437	148.711	0.24868	3.9962	1609.6	33.439	1037.7	636.14
20	0.000969019	156.707	0.27605	3.9998	1615.7	33.674	991.45	639.17
25	0.000970572	176.726	0.34377	4.0076	1629.9	34.212	889.39	646.54
30	0.000972260	196.781	0.41047	4.0140	1642.4	34.682	803.28	653.61
35	0.000974076	216.865	0.47618	4.0194	1653.6	35.088	729.92	660.38
40	0.000976016	236.974	0.54092	4.0242	1663.3	35.434	666.89	666.84
45	0.000978074	257.106	0.60469	4.0284	1671.8	35.721	612.33	672.98
50	0.000980249	277.257	0.66754	4.0322	1679.1	35.954	564.77	678.82
55	0.000982535	297.427	0.72948	4.0359	1685.3	36.135	523.06	684.35
60	0.000984931	317.616	0.79054	4.0394	1690.4	36.266	486.28	689.55
65	0.000987434	337.821	0.85074	4.0428	1694.5	36.350	453.68	694.44
70	0.000990043	358.044	0.91010	4.0463	1697.7	36.389	424.65	699.02
75	0.000992756	378.284	0.96866	4.0497	1699.9	36.386	398.70	703.27
80	0.000995572	398.542	1.0264	4.0533	1701.3	36.343	375.40	707.21
85	0.000998489	418.817	1.0834	4.0569	1701.9	36.262	354.41	710.84
90	0.00100151	439.110	1.1397	4.0605	1701.7	36.145	335.43	714.16
95	0.00100463	459.422	1.1953	4.0643	1700.8	35.994	318.22	717.17
100	0.00100785	479.754	1.2501	4.0683	1699.3	35.812	302.57	719.88
110	0.00101459	520.477	1.3578	4.0765	1694.2	35.362	275.22	724.42
120	0.00102173	561.286	1.4630	4.0853	1686.7	34.808	252.24	727.81
130	0.00102928	602.186	1.5657	4.0948	1677.2	34.164	232.73	730.10
140	0.00103724	643.185	1.6661	4.1052	1665.8	33.441	216.04	731.34
150	0.00104564	684.292	1.7645	4.1164	1652.7	32.651	201.64	731.56
160	0.00105447	725.517	1.8607	4.1287	1637.9	31.802	189.13	730.83
170	0.00106375	766.871	1.9551	4.1423	1621.6	30.901	178.19	729.19
180	0.00107351	808.368	2.0477	4.1572	1604.0	29.957	168.55	726.67
190	0.00108377	850.022	2.1387	4.1738	1585.0	28.975	160.02	723.31
200	0.00109454	891.849	2.2280	4.1921	1564.7	27.960	152.41	719.16
210	0.00110587	933.870	2.3159	4.2124	1543.2	26.918	145.60	714.65
220	0.00111778	976.104	2.4024	4.2348	1520.5	25.854	139.46	709.29
230	0.00113031	1018.57	2.4877	4.2597	1496.7	24.773	133.89	703.19
240	0.00114350	1061.31	2.5718	4.2872	1471.8	23.679	128.82	696.40

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p = 800 bar</i>								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00115740	1104.33	2.6548	4.3174	1445.8	22.577	124.17	688.97
260	0.00117207	1147.67	2.7368	4.3508	1419.0	21.473	119.90	680.91
270	0.00118757	1191.35	2.8180	4.3873	1391.2	20.371	115.93	672.26
280	0.00120397	1235.42	2.8984	4.4273	1362.6	19.277	112.25	663.03
290	0.00122135	1279.91	2.9781	4.4708	1333.4	18.195	108.79	653.25
300	0.00123981	1324.85	3.0572	4.5181	1303.5	17.131	105.54	642.93
310	0.00125944	1370.29	3.1358	4.5692	1273.2	16.088	102.46	632.08
320	0.00128038	1416.25	3.2140	4.6241	1242.5	15.071	99.531	620.73
330	0.00130275	1462.78	3.2918	4.6825	1211.5	14.083	96.728	608.90
340	0.00132672	1509.91	3.3693	4.7440	1180.3	13.126	94.033	596.58
350	0.00135245	1557.67	3.4465	4.8076	1149.0	12.203	91.430	583.81
360	0.00138016	1606.10	3.5236	4.8842	1117.3	11.305	88.906	570.61
370	0.00141010	1655.38	3.6008	4.9727	1084.6	10.428	86.445	556.99
380	0.00144256	1705.56	3.6783	5.0634	1051.8	9.5864	84.037	542.94
390	0.00147784	1756.67	3.7559	5.1586	1019.2	8.7860	81.675	528.49
400	0.00151632	1808.76	3.8339	5.2623	986.85	8.0282	79.351	513.66
410	0.00155843	1861.95	3.9123	5.3768	954.96	7.3147	77.061	498.46
420	0.00160468	1916.33	3.9913	5.5024	923.76	6.6472	74.799	482.91
430	0.00165561	1972.03	4.0711	5.6371	893.49	6.0274	72.565	467.01
440	0.00171181	2029.10	4.1517	5.7774	864.44	5.4566	70.362	450.81
450	0.00177388	2087.58	4.2331	5.9181	836.91	4.9356	68.196	434.35
460	0.00184240	2147.44	4.3153	6.0528	811.19	4.4645	66.076	417.70
470	0.00191784	2208.59	4.3982	6.1737	787.59	4.0430	64.017	400.94
480	0.00200054	2270.84	4.4814	6.2727	766.40	3.6701	62.033	384.21
490	0.00209065	2333.94	4.5646	6.3420	747.86	3.3440	60.143	367.66
500	0.00218803	2397.56	4.6474	6.3749	732.12	3.0622	58.365	351.44
510	0.00229222	2461.31	4.7294	6.3679	719.27	2.8212	56.713	335.75
520	0.00240251	2524.78	4.8099	6.3205	709.24	2.6172	55.202	320.76
530	0.00251797	2587.59	4.8886	6.2361	701.86	2.4454	53.839	306.63
540	0.00263750	2649.40	4.9651	6.1206	696.86	2.3015	52.625	293.49
550	0.00276004	2709.93	5.0391	5.9817	693.95	2.1810	51.557	281.41
560	0.00288461	2768.96	5.1103	5.8423	692.89	2.0804	50.630	270.45
570	0.00301014	2826.43	5.1789	5.6505	693.29	1.9960	49.833	260.51
580	0.00313543	2882.02	5.2445	5.4708	694.79	1.9245	49.159	251.69
590	0.00326009	2935.89	5.3072	5.3034	696.96	1.8625	48.593	243.90
600	0.00338369	2988.09	5.3674	5.1372	699.81	1.8092	48.123	237.03
650	0.00397500	3225.67	5.6321	4.4081	721.80	1.6384	46.863	213.77
700	0.00451614	3432.92	5.8509	3.9135	747.63	1.5471	46.747	202.35
750	0.00501331	3619.74	6.0382	3.5834	773.31	1.4911	47.237	199.65
800	0.00547622	3793.32	6.2039	3.3765	796.77	1.4491	48.071	200.75

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 1000 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
0	0.000956687	95.3860	-0.008582	3.9057	1575.5	25.947	1660.6	616.60
2	0.000957105	103.207	0.019946	3.9150	1584.6	26.235	1565.3	619.89
4	0.000957548	111.046	0.048331	3.9235	1593.2	26.509	1478.5	623.13
6	0.000958014	118.900	0.076571	3.9312	1601.4	26.770	1399.1	626.35
8	0.000958503	126.770	0.10466	3.9382	1609.3	27.020	1326.2	629.53
10	0.000959015	134.653	0.13260	3.9446	1616.8	27.257	1259.3	632.67
12	0.000959548	142.548	0.16038	3.9503	1624.0	27.484	1197.5	635.78
14	0.000960102	150.454	0.18801	3.9556	1630.8	27.700	1140.5	638.85
16	0.000960677	158.370	0.21549	3.9604	1637.3	27.906	1087.7	641.89
18	0.000961273	166.295	0.24280	3.9649	1643.6	28.103	1038.7	644.89
20	0.000961888	174.229	0.26996	3.9689	1649.6	28.290	993.14	647.86
25	0.000963510	194.096	0.33716	3.9777	1663.4	28.718	892.36	655.10
30	0.000965249	214.003	0.40337	3.9849	1675.8	29.094	807.13	662.10
35	0.000967101	233.943	0.46861	3.9909	1686.8	29.419	734.37	668.84
40	0.000969061	253.911	0.53289	3.9961	1696.4	29.698	671.75	675.31
45	0.000971126	273.903	0.59623	4.0007	1704.9	29.932	617.46	681.49
50	0.000973294	293.917	0.65864	4.0048	1712.2	30.122	570.07	687.39
55	0.000975562	313.950	0.72016	4.0086	1718.5	30.272	528.47	693.00
60	0.000977929	334.003	0.78081	4.0122	1723.7	30.383	491.74	698.31
65	0.000980392	354.072	0.84061	4.0157	1728.0	30.456	459.16	703.31
70	0.000982950	374.160	0.89957	4.0191	1731.3	30.494	430.12	708.01
75	0.000985603	394.264	0.95774	4.0225	1733.8	30.498	404.14	712.40
80	0.000988348	414.385	1.0151	4.0259	1735.4	30.471	380.79	716.49
85	0.000991185	434.523	1.0717	4.0293	1736.2	30.413	359.75	720.27
90	0.000994115	454.678	1.1276	4.0327	1736.3	30.327	340.71	723.75
95	0.000997135	474.850	1.1828	4.0362	1735.7	30.214	323.43	726.92
100	0.00100025	495.040	1.2373	4.0397	1734.4	30.075	307.71	729.80
110	0.00100674	535.473	1.3442	4.0471	1730.0	29.730	280.23	734.69
120	0.00101361	575.982	1.4486	4.0548	1723.4	29.302	257.11	738.44
130	0.00102084	616.571	1.5505	4.0630	1714.7	28.803	237.48	741.11
140	0.00102844	657.245	1.6502	4.0718	1704.3	28.242	220.66	742.73
150	0.00103643	698.010	1.7477	4.0813	1692.1	27.627	206.15	743.35
160	0.00104482	738.873	1.8431	4.0916	1678.5	26.966	193.54	743.03
170	0.00105361	779.845	1.9366	4.1028	1663.6	26.266	182.50	741.80
180	0.00106282	820.934	2.0283	4.1152	1647.3	25.532	172.78	739.72
190	0.00107246	862.152	2.1183	4.1288	1629.8	24.768	164.18	736.82
200	0.00108256	903.513	2.2066	4.1437	1611.2	23.979	156.51	733.14
210	0.00109313	945.032	2.2935	4.1603	1591.5	23.169	149.64	728.72
220	0.00110421	986.725	2.3789	4.1785	1570.7	22.342	143.46	723.92
230	0.00111581	1028.61	2.4630	4.1987	1548.9	21.501	137.87	718.42
240	0.00112796	1070.70	2.5458	4.2207	1526.2	20.649	132.78	712.21

Table 3 Single-phase region – Continued
(0 °C to 800 °C)

<i>p</i> = 1000 bar								
<i>t</i>	<i>v</i>	<i>h</i>	<i>s</i>	<i>c_p</i>	<i>w</i>	<i>κ</i>	<i>η</i>	<i>λ</i>
[°C]	[m ³ kg ⁻¹]	[kJ kg ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[kJ kg ⁻¹ K ⁻¹]	[m s ⁻¹]	[-]	[10 ⁻⁶ Pa s]	[10 ⁻³ W m ⁻¹ K ⁻¹]
250	0.00114071	1113.03	2.6275	4.2449	1502.5	19.791	128.12	705.37
260	0.00115408	1155.61	2.7081	4.2714	1478.1	18.930	123.85	697.94
270	0.00116813	1198.47	2.7878	4.3001	1452.8	18.069	119.90	689.94
280	0.00118289	1241.62	2.8665	4.3311	1426.9	17.212	116.23	681.41
290	0.00119843	1285.10	2.9444	4.3646	1400.4	16.364	112.81	672.36
300	0.00121480	1328.92	3.0215	4.4003	1373.4	15.527	109.61	662.82
310	0.00123207	1373.11	3.0980	4.4382	1346.1	14.707	106.59	652.81
320	0.00125031	1417.69	3.1738	4.4781	1318.5	13.904	103.73	642.36
330	0.00126961	1462.68	3.2490	4.5197	1290.8	13.124	101.01	631.47
340	0.00129006	1508.09	3.3236	4.5622	1263.0	12.366	98.409	620.18
350	0.00131176	1553.92	3.3978	4.6048	1235.2	11.632	95.915	608.50
360	0.00133481	1600.21	3.4715	4.6541	1207.4	10.922	93.513	596.47
370	0.00135934	1647.05	3.5449	4.7144	1179.3	10.232	91.191	584.11
380	0.00138548	1694.50	3.6181	4.7739	1150.7	9.5566	88.940	571.45
390	0.00141337	1742.53	3.6910	4.8320	1121.9	8.9058	86.751	558.52
400	0.00144317	1791.14	3.7638	4.8917	1093.3	8.2826	84.619	545.33
410	0.00147508	1840.37	3.8364	4.9557	1065.0	7.6892	82.537	531.93
420	0.00150929	1890.27	3.9089	5.0253	1037.2	7.1273	80.500	518.33
430	0.00154605	1940.90	3.9814	5.1001	1010.0	6.5981	78.505	504.56
440	0.00158559	1992.29	4.0540	5.1784	983.70	6.1028	76.550	490.63
450	0.00162815	2044.47	4.1267	5.2581	958.43	5.6419	74.637	476.60
460	0.00167397	2097.44	4.1994	5.3363	934.37	5.2154	72.766	462.50
470	0.00172324	2151.18	4.2722	5.4102	911.66	4.8230	70.945	448.38
480	0.00177614	2205.62	4.3450	5.4766	890.42	4.4639	69.177	434.30
490	0.00183278	2260.68	4.4176	5.5326	870.75	4.1369	67.471	420.34
500	0.00189324	2316.23	4.4899	5.5757	852.73	3.8407	65.833	406.56
510	0.00195750	2372.14	4.5618	5.6038	836.42	3.5740	64.272	393.05
520	0.00202548	2428.25	4.6330	5.6155	821.87	3.3348	62.794	379.88
530	0.00209703	2484.39	4.7033	5.6101	809.07	3.1215	61.404	367.14
540	0.00217192	2540.40	4.7726	5.5877	798.03	2.9322	60.108	354.89
550	0.00224984	2596.09	4.8407	5.5490	788.69	2.7647	58.908	343.20
560	0.00233047	2651.33	4.9074	5.4954	780.97	2.6172	57.806	332.12
570	0.00241341	2705.96	4.9726	5.4288	774.80	2.4874	56.800	321.69
580	0.00249829	2759.87	5.0361	5.3512	770.05	2.3735	55.889	311.94
590	0.00258472	2812.94	5.0980	5.2687	769.69	2.2920	55.070	302.88
600	0.00267226	2865.07	5.1580	5.1706	766.53	2.1988	54.339	294.51
650	0.00311448	3110.60	5.4316	4.6275	767.31	1.8904	51.825	262.56
700	0.00354616	3330.76	5.6640	4.1910	784.08	1.7336	50.711	242.89
750	0.00395319	3530.68	5.8644	3.8235	801.50	1.6250	50.478	234.84
800	0.00433551	3715.19	6.0405	3.5762	821.00	1.5547	50.781	232.24

Table 4 High-temperature region (800 °C to 2000 °C)

This table contains values for the following thermodynamic properties in the high-temperature region (region 5 of IAPWS-IF97) for temperatures from 800 °C to 2000 °C and for pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 500 bar:

- Specific volume v
- Specific enthalpy h
- Specific entropy s
- Specific isobaric heat capacity c_p
- Isentropic exponent κ

These thermodynamic properties were calculated from the IAPWS-IF97 basic equation for region 5, Eq. (2.15), except for the temperature $t = 800^\circ\text{C}$. At 800 °C, the properties were determined from the basic equation of region 2, Eq. (2.6), because the boundary $t = 800^\circ\text{C}$ between regions 2 and 5 belongs to region 2; see the comment at the beginning of Sec. 2.2.

With the values for v and κ given in this table, the speed of sound w can be calculated from the relation $w = [\kappa/(pv)]^{0.5}$.

Table 4 High-temperature region
(800 °C to 2000 °C)

t [°C]	p = 0.006112127 bar					p = 0.01 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	810.333	4160.66	11.921	2.3423	1.2454	495.286	4160.66	11.694	2.3423	1.2454
820	825.435	4207.69	11.964	2.3573	1.2435	504.516	4207.69	11.737	2.3573	1.2435
840	840.538	4254.97	12.007	2.3707	1.2417	513.747	4254.97	11.780	2.3707	1.2417
860	855.640	4302.52	12.050	2.3841	1.2401	522.977	4302.51	11.822	2.3841	1.2401
880	870.742	4350.33	12.091	2.3975	1.2384	532.208	4350.33	11.864	2.3975	1.2384
900	885.844	4398.42	12.133	2.4109	1.2368	541.439	4398.42	11.906	2.4109	1.2368
920	900.946	4446.77	12.174	2.4243	1.2351	550.669	4446.77	11.946	2.4243	1.2351
940	916.048	4495.39	12.214	2.4376	1.2336	559.900	4495.39	11.987	2.4376	1.2336
960	931.150	4544.27	12.254	2.4508	1.2320	569.130	4544.27	12.027	2.4508	1.2320
980	946.252	4593.42	12.294	2.4639	1.2305	578.361	4593.42	12.066	2.4639	1.2305
1000	961.354	4642.82	12.333	2.4769	1.2290	587.591	4642.82	12.106	2.4769	1.2290
1020	976.456	4692.49	12.371	2.4898	1.2275	596.822	4692.49	12.144	2.4898	1.2275
1040	991.558	4742.42	12.410	2.5025	1.2261	606.053	4742.41	12.183	2.5025	1.2261
1060	1006.66	4792.59	12.448	2.5152	1.2247	615.283	4792.59	12.220	2.5152	1.2247
1080	1021.76	4843.02	12.485	2.5276	1.2234	624.514	4843.02	12.258	2.5276	1.2234
1100	1036.86	4893.70	12.522	2.5400	1.2221	633.744	4893.70	12.295	2.5400	1.2221
1120	1051.97	4944.62	12.559	2.5521	1.2208	642.975	4944.62	12.332	2.5521	1.2208
1140	1067.07	4995.78	12.596	2.5641	1.2195	652.205	4995.78	12.368	2.5641	1.2195
1160	1082.17	5047.18	12.632	2.5759	1.2183	661.436	5047.18	12.405	2.5759	1.2183
1180	1097.27	5098.82	12.668	2.5876	1.2171	670.666	5098.82	12.440	2.5876	1.2171
1200	1112.37	5150.68	12.703	2.5991	1.2159	679.897	5150.68	12.476	2.5991	1.2159
1220	1127.48	5202.78	12.738	2.6104	1.2148	689.128	5202.78	12.511	2.6104	1.2148
1240	1142.58	5255.10	12.773	2.6215	1.2137	698.358	5255.10	12.546	2.6215	1.2137
1260	1157.68	5307.64	12.807	2.6325	1.2126	707.589	5307.64	12.580	2.6325	1.2126
1280	1172.78	5360.40	12.842	2.6432	1.2115	716.819	5360.40	12.614	2.6432	1.2115
1300	1187.88	5413.37	12.876	2.6538	1.2105	726.050	5413.37	12.648	2.6538	1.2105
1320	1202.99	5466.55	12.909	2.6642	1.2095	735.280	5466.55	12.682	2.6642	1.2095
1340	1218.09	5519.93	12.942	2.6745	1.2086	744.511	5519.93	12.715	2.6745	1.2086
1360	1233.19	5573.52	12.975	2.6845	1.2076	753.741	5573.52	12.748	2.6845	1.2076
1380	1248.29	5627.31	13.008	2.6944	1.2067	762.972	5627.31	12.781	2.6944	1.2067
1400	1263.39	5681.30	13.041	2.7041	1.2058	772.202	5681.30	12.813	2.7041	1.2058
1420	1278.50	5735.48	13.073	2.7136	1.2049	781.433	5735.48	12.846	2.7136	1.2049
1440	1293.60	5789.84	13.105	2.7230	1.2041	790.663	5789.84	12.878	2.7230	1.2041
1460	1308.70	5844.39	13.136	2.7322	1.2033	799.894	5844.39	12.909	2.7322	1.2033
1480	1323.80	5899.13	13.168	2.7412	1.2025	809.125	5899.13	12.941	2.7412	1.2025
1500	1338.90	5954.04	13.199	2.7501	1.2017	818.355	5954.04	12.972	2.7501	1.2017
1550	1376.66	6092.08	13.276	2.7715	1.1998	841.431	6092.08	13.048	2.7715	1.1998
1600	1414.41	6231.18	13.351	2.7921	1.1980	864.508	6231.18	13.124	2.7921	1.1980
1650	1452.17	6371.27	13.425	2.8117	1.1964	887.584	6371.27	13.198	2.8117	1.1964
1700	1489.92	6512.33	13.497	2.8305	1.1948	910.660	6512.33	13.270	2.8305	1.1948
1750	1527.68	6654.32	13.568	2.8486	1.1933	933.737	6654.32	13.341	2.8486	1.1933
1800	1565.43	6797.19	13.638	2.8661	1.1919	956.813	6797.19	13.411	2.8661	1.1919
1850	1603.19	6940.91	13.707	2.8829	1.1906	979.889	6940.91	13.479	2.8829	1.1906
1900	1640.94	7085.47	13.774	2.8992	1.1893	1002.966	7085.47	13.547	2.8992	1.1893
1950	1678.70	7230.83	13.840	2.9152	1.1881	1026.042	7230.83	13.613	2.9152	1.1881
2000	1716.45	7376.98	13.905	2.9307	1.1869	1049.118	7376.98	13.678	2.9307	1.1869

Table 4 High-temperature region – Continued
(800 °C to 2000 °C)

t [°C]	p = 0.1 bar					p = 1 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	49.5278	4160.62	10.631	2.3424	1.2454	4.95196	4160.21	9.5681	2.3434	1.2455
820	50.4509	4207.65	10.675	2.3573	1.2435	5.04434	4207.26	9.6115	2.3582	1.2435
840	51.3740	4254.93	10.717	2.3707	1.2418	5.13670	4254.56	9.6544	2.3716	1.2418
860	52.2971	4302.48	10.760	2.3842	1.2401	5.22907	4302.12	9.6968	2.3850	1.2401
880	53.2202	4350.30	10.802	2.3976	1.2384	5.32143	4349.96	9.7386	2.3983	1.2385
900	54.1433	4398.38	10.843	2.4110	1.2368	5.41379	4398.06	9.7800	2.4117	1.2368
920	55.0664	4446.74	10.884	2.4243	1.2352	5.50614	4446.42	9.8208	2.4250	1.2352
940	55.9895	4495.36	10.924	2.4376	1.2336	5.59850	4495.06	9.8613	2.4383	1.2337
960	56.9126	4544.24	10.964	2.4508	1.2320	5.69085	4543.95	9.9012	2.4515	1.2321
980	57.8357	4593.39	11.004	2.4639	1.2305	5.78319	4593.11	9.9408	2.4645	1.2306
1000	58.7588	4642.80	11.043	2.4770	1.2290	5.87554	4642.54	9.9799	2.4775	1.2291
1020	59.6819	4692.47	11.082	2.4898	1.2276	5.96788	4692.21	10.019	2.4904	1.2276
1040	60.6050	4742.39	11.120	2.5026	1.2261	6.06023	4742.15	10.057	2.5031	1.2262
1060	61.5281	4792.57	11.158	2.5152	1.2247	6.15257	4792.34	10.095	2.5157	1.2248
1080	62.4512	4843.00	11.195	2.5277	1.2234	6.24491	4842.78	10.132	2.5281	1.2235
1100	63.3742	4893.67	11.232	2.5400	1.2221	6.33724	4893.46	10.170	2.5404	1.2221
1120	64.2973	4944.60	11.269	2.5522	1.2208	6.42958	4944.39	10.206	2.5526	1.2209
1140	65.2204	4995.76	11.306	2.5642	1.2195	6.52191	4995.56	10.243	2.5646	1.2196
1160	66.1435	5047.16	11.342	2.5760	1.2183	6.61425	5046.97	10.279	2.5764	1.2184
1180	67.0666	5098.80	11.378	2.5876	1.2171	6.70658	5098.62	10.315	2.5880	1.2172
1200	67.9896	5150.67	11.413	2.5991	1.2159	6.79891	5150.49	10.350	2.5995	1.2160
1220	68.9127	5202.76	11.448	2.6104	1.2148	6.89124	5202.60	10.385	2.6108	1.2149
1240	69.8358	5255.08	11.483	2.6215	1.2137	6.98357	5254.92	10.420	2.6219	1.2138
1260	70.7589	5307.62	11.518	2.6325	1.2126	7.07590	5307.47	10.455	2.6328	1.2127
1280	71.6819	5360.38	11.552	2.6433	1.2116	7.16822	5360.23	10.489	2.6436	1.2116
1300	72.6050	5413.35	11.586	2.6538	1.2105	7.26055	5413.21	10.523	2.6541	1.2106
1320	73.5281	5466.53	11.619	2.6643	1.2095	7.35287	5466.40	10.556	2.6645	1.2096
1340	74.4512	5519.92	11.652	2.6745	1.2086	7.44520	5519.79	10.590	2.6748	1.2086
1360	75.3742	5573.51	11.686	2.6845	1.2076	7.53752	5573.39	10.623	2.6848	1.2077
1380	76.2973	5627.30	11.718	2.6944	1.2067	7.62985	5627.18	10.655	2.6947	1.2068
1400	77.2204	5681.29	11.751	2.7041	1.2058	7.72217	5681.17	10.688	2.7044	1.2059
1420	78.1434	5735.46	11.783	2.7136	1.2049	7.81449	5735.36	10.720	2.7139	1.2050
1440	79.0665	5789.83	11.815	2.7230	1.2041	7.90681	5789.73	10.752	2.7232	1.2042
1460	79.9896	5844.38	11.846	2.7322	1.2033	7.99913	5844.28	10.784	2.7324	1.2033
1480	80.9126	5899.12	11.878	2.7412	1.2025	8.09145	5899.02	10.815	2.7414	1.2025
1500	81.8357	5954.03	11.909	2.7501	1.2017	8.18377	5953.94	10.846	2.7503	1.2018
1550	84.1434	6092.08	11.986	2.7715	1.1998	8.41457	6091.99	10.923	2.7717	1.1999
1600	86.4510	6231.17	12.061	2.7921	1.1980	8.64536	6231.10	10.998	2.7922	1.1981
1650	88.7587	6371.27	12.135	2.8117	1.1964	8.87615	6371.20	11.072	2.8119	1.1965
1700	91.0663	6512.33	12.207	2.8306	1.1948	9.10694	6512.27	11.145	2.8307	1.1949
1750	93.3740	6654.31	12.278	2.8487	1.1933	9.33773	6654.26	11.216	2.8488	1.1934
1800	95.6816	6797.18	12.348	2.8661	1.1919	9.56851	6797.14	11.285	2.8662	1.1920
1850	97.9893	6940.91	12.417	2.8829	1.1906	9.79930	6940.87	11.354	2.8830	1.1907
1900	100.297	7085.47	12.484	2.8993	1.1893	10.0301	7085.43	11.421	2.8994	1.1894
1950	102.605	7230.83	12.550	2.9152	1.1881	10.2609	7230.80	11.487	2.9153	1.1882
2000	104.912	7376.98	12.615	2.9307	1.1869	10.4916	7376.95	11.552	2.9308	1.1870

Table 4 High-temperature region – Continued
 (800 °C to 2000 °C)

t [°C]	p = 2 bar					p = 4 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	2.47553	4159.76	9.2479	2.3445	1.2455	1.23731	4158.85	8.9273	2.3466	1.2457
820	2.52175	4206.83	9.2913	2.3592	1.2436	1.26046	4205.96	8.9708	2.3612	1.2438
840	2.56797	4254.14	9.3342	2.3725	1.2419	1.28360	4253.31	9.0137	2.3744	1.2421
860	2.61418	4301.73	9.3766	2.3859	1.2402	1.30673	4300.93	9.0561	2.3877	1.2404
880	2.66039	4349.58	9.4184	2.3992	1.2386	1.32986	4348.82	9.0980	2.4009	1.2388
900	2.70659	4397.69	9.4598	2.4125	1.2369	1.35299	4396.97	9.1394	2.4141	1.2371
920	2.75279	4446.08	9.5007	2.4258	1.2353	1.37612	4445.38	9.1803	2.4273	1.2355
940	2.79899	4494.73	9.5411	2.4390	1.2337	1.39924	4494.06	9.2208	2.4404	1.2339
960	2.84519	4543.64	9.5811	2.4521	1.2322	1.42237	4543.00	9.2608	2.4535	1.2324
980	2.89139	4592.81	9.6207	2.4652	1.2307	1.44548	4592.20	9.3003	2.4665	1.2309
1000	2.93758	4642.24	9.6598	2.4781	1.2292	1.46860	4641.66	9.3395	2.4794	1.2294
1020	2.98377	4691.93	9.6985	2.4910	1.2277	1.49172	4691.38	9.3782	2.4922	1.2279
1040	3.02996	4741.88	9.7369	2.5037	1.2263	1.51483	4741.35	9.4166	2.5048	1.2265
1060	3.07615	4792.08	9.7748	2.5162	1.2249	1.53794	4791.57	9.4546	2.5173	1.2251
1080	3.12234	4842.53	9.8124	2.5287	1.2236	1.56105	4842.04	9.4921	2.5297	1.2238
1100	3.16852	4893.23	9.8496	2.5409	1.2222	1.58416	4892.75	9.5293	2.5419	1.2224
1120	3.21470	4944.17	9.8864	2.5531	1.2210	1.60727	4943.71	9.5662	2.5540	1.2211
1140	3.26089	4995.35	9.9229	2.5650	1.2197	1.63037	4994.91	9.6027	2.5659	1.2199
1160	3.30707	5046.77	9.9590	2.5768	1.2185	1.65348	5046.35	9.6388	2.5777	1.2186
1180	3.35325	5098.42	9.9948	2.5884	1.2173	1.67658	5098.02	9.6746	2.5893	1.2175
1200	3.39942	5150.30	10.030	2.5999	1.2161	1.69968	5149.92	9.7101	2.6007	1.2163
1220	3.44560	5202.41	10.065	2.6111	1.2150	1.72278	5202.05	9.7452	2.6119	1.2151
1240	3.49178	5254.75	10.100	2.6222	1.2139	1.74588	5254.39	9.7801	2.6230	1.2140
1260	3.53795	5307.30	10.135	2.6332	1.2128	1.76898	5306.96	9.8146	2.6339	1.2130
1280	3.58413	5360.07	10.169	2.6439	1.2117	1.79208	5359.75	9.8488	2.6446	1.2119
1300	3.63030	5413.06	10.203	2.6545	1.2107	1.81518	5412.74	9.8827	2.6551	1.2109
1320	3.67647	5466.25	10.236	2.6648	1.2097	1.83827	5465.95	9.9163	2.6655	1.2099
1340	3.72265	5519.65	10.270	2.6751	1.2087	1.86137	5519.36	9.9496	2.6757	1.2089
1360	3.76882	5573.25	10.303	2.6851	1.2078	1.88446	5572.98	9.9826	2.6857	1.2080
1380	3.81499	5627.05	10.335	2.6949	1.2069	1.90756	5626.79	10.015	2.6955	1.2071
1400	3.86116	5681.05	10.368	2.7046	1.2060	1.93065	5680.79	10.048	2.7052	1.2062
1420	3.90733	5735.23	10.400	2.7141	1.2051	1.95374	5734.99	10.080	2.7146	1.2053
1440	3.95350	5789.61	10.432	2.7235	1.2043	1.97684	5789.38	10.112	2.7240	1.2044
1460	3.99966	5844.17	10.464	2.7326	1.2034	1.99993	5843.95	10.144	2.7331	1.2036
1480	4.04583	5898.92	10.495	2.7417	1.2026	2.02302	5898.70	10.175	2.7421	1.2028
1500	4.09200	5953.84	10.526	2.7505	1.2018	2.04611	5953.63	10.206	2.7509	1.2020
1550	4.20741	6091.90	10.603	2.7719	1.2000	2.10383	6091.72	10.283	2.7723	1.2001
1600	4.32282	6231.01	10.678	2.7924	1.1982	2.16156	6230.85	10.358	2.7928	1.1984
1650	4.43823	6371.13	10.752	2.8121	1.1965	2.21927	6370.99	10.432	2.8124	1.1967
1700	4.55364	6512.21	10.825	2.8309	1.1950	2.27699	6512.08	10.505	2.8312	1.1951
1750	4.66905	6654.20	10.896	2.8489	1.1935	2.33471	6654.09	10.576	2.8492	1.1937
1800	4.78445	6797.09	10.965	2.8663	1.1921	2.39242	6796.99	10.645	2.8666	1.1923
1850	4.89985	6940.83	11.034	2.8832	1.1908	2.45013	6940.74	10.714	2.8834	1.1909
1900	5.01525	7085.40	11.101	2.8995	1.1895	2.50784	7085.33	10.781	2.8997	1.1896
1950	5.13065	7230.77	11.167	2.9154	1.1883	2.56555	7230.71	10.847	2.9156	1.1884
2000	5.24605	7376.93	11.232	2.9309	1.1871	2.62326	7376.88	10.912	2.9311	1.1872

Table 4 High-temperature region – Continued
(800 °C to 2000 °C)

t [°C]	p = 6 bar					p = 8 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.824571	4157.95	8.7395	2.3488	1.2459	0.618202	4157.04	8.6060	2.3510	1.2460
820	0.840027	4205.09	8.7830	2.3632	1.2440	0.629812	4204.22	8.6496	2.3653	1.2442
840	0.855474	4252.48	8.8260	2.3763	1.2423	0.641412	4251.65	8.6926	2.3782	1.2425
860	0.870917	4300.14	8.8684	2.3894	1.2406	0.653010	4299.35	8.7350	2.3912	1.2408
880	0.886357	4348.06	8.9103	2.4026	1.2389	0.664604	4347.30	8.7770	2.4043	1.2391
900	0.901794	4396.24	8.9517	2.4157	1.2373	0.676195	4395.52	8.8184	2.4173	1.2375
920	0.917229	4444.69	8.9927	2.4288	1.2357	0.687783	4444.00	8.8594	2.4304	1.2359
940	0.932660	4493.40	9.0332	2.4419	1.2341	0.699369	4492.73	8.8999	2.4433	1.2343
960	0.948090	4542.37	9.0732	2.4549	1.2326	0.710952	4541.73	8.9400	2.4563	1.2328
980	0.963517	4591.59	9.1128	2.4678	1.2311	0.722533	4590.98	8.9796	2.4691	1.2312
1000	0.978942	4641.08	9.1520	2.4806	1.2296	0.734112	4640.49	9.0188	2.4819	1.2298
1020	0.994365	4690.82	9.1907	2.4933	1.2281	0.745689	4690.26	9.0576	2.4945	1.2283
1040	1.00979	4740.81	9.2291	2.5059	1.2267	0.757264	4740.28	9.0960	2.5071	1.2269
1060	1.02521	4791.05	9.2671	2.5184	1.2253	0.768838	4790.54	9.1340	2.5195	1.2255
1080	1.04062	4841.55	9.3047	2.5307	1.2239	0.780410	4841.05	9.1716	2.5318	1.2241
1100	1.05604	4892.28	9.3419	2.5429	1.2226	0.791980	4891.81	9.2088	2.5439	1.2228
1120	1.07145	4943.26	9.3787	2.5549	1.2213	0.803549	4942.81	9.2457	2.5559	1.2215
1140	1.08687	4994.48	9.4152	2.5668	1.2201	0.815116	4994.05	9.2822	2.5677	1.2203
1160	1.10228	5045.93	9.4514	2.5785	1.2188	0.826683	5045.52	9.3184	2.5794	1.2190
1180	1.11769	5097.62	9.4872	2.5901	1.2176	0.838248	5097.22	9.3542	2.5909	1.2178
1200	1.13310	5149.54	9.5227	2.6015	1.2165	0.849812	5149.15	9.3897	2.6023	1.2167
1220	1.14851	5201.68	9.5579	2.6127	1.2153	0.861374	5201.31	9.4248	2.6134	1.2155
1240	1.16392	5254.04	9.5927	2.6237	1.2142	0.872936	5253.69	9.4597	2.6244	1.2144
1260	1.17933	5306.62	9.6272	2.6346	1.2131	0.884497	5306.29	9.4942	2.6353	1.2133
1280	1.19473	5359.42	9.6614	2.6453	1.2121	0.896057	5359.10	9.5284	2.6459	1.2123
1300	1.21014	5412.43	9.6953	2.6558	1.2111	0.907616	5412.12	9.5624	2.6564	1.2113
1320	1.22554	5465.65	9.7290	2.6661	1.2101	0.919174	5465.35	9.5960	2.6667	1.2103
1340	1.24094	5519.08	9.7623	2.6763	1.2091	0.930732	5518.79	9.6293	2.6769	1.2093
1360	1.25635	5572.70	9.7953	2.6862	1.2082	0.942288	5572.43	9.6624	2.6868	1.2083
1380	1.27175	5626.52	9.8281	2.6961	1.2072	0.953844	5626.26	9.6951	2.6966	1.2074
1400	1.28715	5680.54	9.8606	2.7057	1.2063	0.965400	5680.29	9.7276	2.7062	1.2065
1420	1.30255	5734.75	9.8928	2.7152	1.2055	0.976954	5734.51	9.7598	2.7157	1.2056
1440	1.31795	5789.15	9.9247	2.7245	1.2046	0.988508	5788.92	9.7918	2.7250	1.2048
1460	1.33335	5843.73	9.9564	2.7336	1.2038	1.00006	5843.51	9.8235	2.7341	1.2040
1480	1.34875	5898.49	9.9878	2.7426	1.2030	1.01161	5898.28	9.8549	2.7430	1.2032
1500	1.36415	5953.43	10.019	2.7514	1.2022	1.02317	5953.23	9.8860	2.7518	1.2024
1550	1.40264	6091.54	10.096	2.7727	1.2003	1.05205	6091.36	9.9629	2.7732	1.2005
1600	1.44113	6230.69	10.171	2.7932	1.1985	1.08092	6230.53	10.038	2.7936	1.1987
1650	1.47962	6370.84	10.245	2.8127	1.1969	1.10980	6370.70	10.112	2.8131	1.1970
1700	1.51811	6511.95	10.317	2.8315	1.1953	1.13867	6511.82	10.184	2.8318	1.1955
1750	1.55659	6653.98	10.388	2.8495	1.1938	1.16754	6653.87	10.256	2.8498	1.1940
1800	1.59508	6796.89	10.458	2.8669	1.1924	1.19640	6796.79	10.325	2.8672	1.1926
1850	1.63356	6940.66	10.527	2.8837	1.1911	1.22527	6940.57	10.394	2.8839	1.1912
1900	1.67204	7085.25	10.594	2.9000	1.1898	1.25413	7085.18	10.461	2.9002	1.1899
1950	1.71051	7230.65	10.660	2.9158	1.1886	1.28300	7230.59	10.527	2.9160	1.1887
2000	1.74899	7376.83	10.725	2.9313	1.1874	1.31186	7376.78	10.592	2.9315	1.1875

Table 4 High-temperature region – Continued
 (800 °C to 2000 °C)

t [°C]	p = 10 bar					p = 20 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.494380	4156.14	8.5024	2.3532	1.2462	0.246737	4151.59	8.1791	2.3642	1.2470
820	0.503682	4203.35	8.5459	2.3673	1.2443	0.251424	4199.00	8.2228	2.3774	1.2452
840	0.512975	4250.82	8.5890	2.3801	1.2426	0.256102	4246.67	8.2660	2.3897	1.2435
860	0.522265	4298.56	8.6315	2.3930	1.2410	0.260776	4294.58	8.3087	2.4021	1.2419
880	0.531551	4346.55	8.6735	2.4060	1.2393	0.265447	4342.75	8.3508	2.4145	1.2402
900	0.540835	4394.79	8.7149	2.4189	1.2377	0.270116	4391.17	8.3925	2.4270	1.2386
920	0.550116	4443.30	8.7559	2.4319	1.2361	0.274781	4439.83	8.4336	2.4396	1.2370
940	0.559394	4492.07	8.7965	2.4448	1.2345	0.279444	4488.75	8.4742	2.4521	1.2354
960	0.568669	4541.09	8.8366	2.4577	1.2329	0.284105	4537.92	8.5144	2.4646	1.2339
980	0.577943	4590.38	8.8762	2.4704	1.2314	0.288763	4587.33	8.5542	2.4770	1.2324
1000	0.587214	4639.91	8.9154	2.4831	1.2299	0.293419	4637.00	8.5935	2.4894	1.2309
1020	0.596484	4689.70	8.9542	2.4957	1.2285	0.298073	4686.91	8.6324	2.5017	1.2294
1040	0.605751	4739.74	8.9926	2.5082	1.2271	0.302726	4737.06	8.6709	2.5139	1.2280
1060	0.615017	4790.03	9.0306	2.5206	1.2257	0.307376	4787.46	8.7090	2.5260	1.2266
1080	0.624281	4840.56	9.0682	2.5328	1.2243	0.312025	4838.10	8.7467	2.5380	1.2253
1100	0.633544	4891.34	9.1055	2.5449	1.2230	0.316673	4888.98	8.7840	2.5498	1.2239
1120	0.642805	4942.36	9.1424	2.5568	1.2217	0.321319	4940.10	8.8210	2.5616	1.2226
1140	0.652065	4993.61	9.1789	2.5686	1.2204	0.325963	4991.44	8.8576	2.5732	1.2214
1160	0.661324	5045.10	9.2151	2.5803	1.2192	0.330607	5043.02	8.8938	2.5846	1.2201
1180	0.670581	5096.82	9.2509	2.5917	1.2180	0.335249	5094.83	8.9297	2.5959	1.2189
1200	0.679837	5148.77	9.2864	2.6031	1.2168	0.339890	5146.86	8.9653	2.6070	1.2178
1220	0.689093	5200.94	9.3216	2.6142	1.2157	0.344530	5199.11	9.0005	2.6180	1.2166
1240	0.698347	5253.34	9.3565	2.6252	1.2146	0.349169	5251.58	9.0354	2.6288	1.2155
1260	0.707600	5305.95	9.3910	2.6360	1.2135	0.353806	5304.26	9.0700	2.6395	1.2144
1280	0.716852	5358.77	9.4252	2.6466	1.2125	0.358443	5357.15	9.1043	2.6500	1.2134
1300	0.726104	5411.81	9.4592	2.6571	1.2114	0.363080	5410.26	9.1382	2.6603	1.2124
1320	0.735354	5465.06	9.4928	2.6673	1.2104	0.367715	5463.56	9.1719	2.6705	1.2113
1340	0.744604	5518.50	9.5261	2.6775	1.2095	0.372349	5517.07	9.2053	2.6805	1.2104
1360	0.753853	5572.15	9.5592	2.6874	1.2085	0.376983	5570.78	9.2384	2.6903	1.2094
1380	0.763101	5626.00	9.5920	2.6972	1.2076	0.381616	5624.68	9.2712	2.6999	1.2085
1400	0.772349	5680.04	9.6245	2.7068	1.2067	0.386249	5678.78	9.3037	2.7094	1.2076
1420	0.781596	5734.27	9.6567	2.7162	1.2058	0.390880	5733.06	9.3360	2.7188	1.2067
1440	0.790843	5788.68	9.6886	2.7255	1.2050	0.395512	5787.53	9.3679	2.7279	1.2059
1460	0.800088	5843.28	9.7203	2.7346	1.2041	0.400142	5842.18	9.3997	2.7370	1.2050
1480	0.809334	5898.07	9.7517	2.7435	1.2033	0.404772	5897.00	9.4311	2.7458	1.2042
1500	0.818578	5953.02	9.7829	2.7523	1.2025	0.409402	5952.01	9.4623	2.7545	1.2034
1550	0.841688	6091.17	9.8597	2.7736	1.2007	0.420973	6090.27	9.5392	2.7756	1.2015
1600	0.864795	6230.37	9.9351	2.7939	1.1989	0.432542	6229.55	9.6146	2.7958	1.1997
1650	0.887900	6370.55	10.009	2.8134	1.1972	0.444108	6369.83	9.6885	2.8152	1.1980
1700	0.911002	6511.70	10.081	2.8321	1.1956	0.455672	6511.06	9.7610	2.8337	1.1965
1750	0.934102	6653.75	10.152	2.8501	1.1941	0.467234	6653.19	9.8321	2.8516	1.1950
1800	0.957200	6796.70	10.222	2.8674	1.1927	0.478794	6796.21	9.9019	2.8688	1.1935
1850	0.980297	6940.49	10.291	2.8842	1.1914	0.490353	6940.07	9.9705	2.8855	1.1922
1900	1.00339	7085.11	10.358	2.9004	1.1901	0.501910	7084.74	10.038	2.9016	1.1909
1950	1.02649	7230.53	10.424	2.9163	1.1889	0.513466	7230.22	10.104	2.9173	1.1896
2000	1.04958	7376.73	10.489	2.9317	1.1877	0.525020	7376.47	10.169	2.9328	1.1884

Table 4 High-temperature region – Continued
(800 °C to 2000 °C)

t [°C]	p = 40 bar					p = 60 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.122915	4142.46	7.8523	2.3865	1.2487	0.0816416	4133.27	7.6583	2.4092	1.2506
820	0.125295	4190.26	7.8964	2.3980	1.2471	0.0832519	4181.48	7.7028	2.4190	1.2490
840	0.127665	4238.33	7.9400	2.4091	1.2454	0.0848536	4229.95	7.7468	2.4288	1.2474
860	0.130032	4286.62	7.9830	2.4204	1.2438	0.0864518	4278.63	7.7901	2.4390	1.2457
880	0.132396	4335.14	8.0255	2.4318	1.2421	0.0880467	4327.52	7.8329	2.4494	1.2441
900	0.134757	4383.89	8.0674	2.4434	1.2405	0.0896384	4376.61	7.8751	2.4600	1.2425
920	0.137115	4432.88	8.1088	2.4551	1.2389	0.0912274	4425.92	7.9167	2.4708	1.2409
940	0.139471	4482.10	8.1497	2.4668	1.2374	0.0928137	4475.44	7.9579	2.4816	1.2393
960	0.141824	4531.55	8.1901	2.4785	1.2358	0.0943976	4525.18	7.9986	2.4926	1.2378
980	0.144174	4581.24	8.2301	2.4903	1.2343	0.0959791	4575.14	8.0388	2.5036	1.2363
1000	0.146523	4631.16	8.2696	2.5020	1.2328	0.0975585	4625.33	8.0785	2.5147	1.2348
1020	0.148869	4681.32	8.3087	2.5137	1.2314	0.0991359	4675.73	8.1178	2.5258	1.2334
1040	0.151214	4731.71	8.3474	2.5253	1.2299	0.100711	4726.36	8.1566	2.5368	1.2319
1060	0.153557	4782.33	8.3856	2.5369	1.2286	0.102285	4777.21	8.1951	2.5479	1.2305
1080	0.155898	4833.19	8.4235	2.5484	1.2272	0.103857	4828.27	8.2331	2.5588	1.2292
1100	0.158238	4884.27	8.4610	2.5598	1.2259	0.105428	4879.56	8.2707	2.5697	1.2278
1120	0.160577	4935.58	8.4981	2.5711	1.2246	0.106997	4931.06	8.3079	2.5806	1.2265
1140	0.162914	4987.11	8.5348	2.5822	1.2233	0.108565	4982.78	8.3448	2.5913	1.2252
1160	0.165249	5038.86	8.5712	2.5933	1.2221	0.110131	5034.71	8.3813	2.6020	1.2240
1180	0.167584	5090.84	8.6072	2.6042	1.2208	0.111697	5086.86	8.4174	2.6125	1.2228
1200	0.169917	5143.03	8.6429	2.6150	1.2197	0.113261	5139.22	8.4532	2.6230	1.2216
1220	0.172249	5195.44	8.6782	2.6256	1.2185	0.114824	5191.78	8.4886	2.6333	1.2204
1240	0.174581	5248.06	8.7132	2.6362	1.2174	0.116386	5244.55	8.5237	2.6435	1.2193
1260	0.176911	5300.88	8.7479	2.6465	1.2163	0.117947	5297.52	8.5585	2.6535	1.2182
1280	0.179240	5353.92	8.7822	2.6567	1.2152	0.119507	5350.69	8.5930	2.6635	1.2171
1300	0.181569	5407.15	8.8163	2.6668	1.2142	0.121066	5404.05	8.6271	2.6733	1.2161
1320	0.183896	5460.59	8.8501	2.6767	1.2132	0.122625	5457.62	8.6610	2.6829	1.2151
1340	0.186223	5514.22	8.8835	2.6864	1.2122	0.124182	5511.37	8.6945	2.6924	1.2141
1360	0.188549	5568.04	8.9167	2.6960	1.2112	0.125739	5565.31	8.7277	2.7018	1.2131
1380	0.190875	5622.06	8.9495	2.7055	1.2103	0.127295	5619.44	8.7607	2.7110	1.2121
1400	0.193199	5676.26	8.9821	2.7148	1.2094	0.128851	5673.75	8.7933	2.7201	1.2112
1420	0.195524	5730.65	9.0144	2.7239	1.2085	0.130406	5728.25	8.8257	2.7291	1.2103
1440	0.197847	5785.22	9.0465	2.7329	1.2076	0.131960	5782.92	8.8578	2.7379	1.2094
1460	0.200170	5839.97	9.0783	2.7417	1.2068	0.133514	5837.76	8.8896	2.7465	1.2086
1480	0.202492	5894.89	9.1098	2.7504	1.2060	0.135067	5892.78	8.9212	2.7551	1.2078
1500	0.204814	5949.98	9.1410	2.7590	1.2052	0.136619	5947.96	8.9525	2.7634	1.2069
1550	0.210617	6088.45	9.2180	2.7797	1.2032	0.140499	6086.65	9.0296	2.7838	1.2050
1600	0.216416	6227.94	9.2935	2.7996	1.2014	0.144375	6226.33	9.1052	2.8033	1.2031
1650	0.222213	6368.40	9.3675	2.8186	1.1997	0.148249	6366.96	9.1793	2.8221	1.2014
1700	0.228008	6509.79	9.4401	2.8369	1.1981	0.152121	6508.52	9.2520	2.8401	1.1998
1750	0.233801	6652.08	9.5113	2.8545	1.1966	0.155991	6650.97	9.3232	2.8575	1.1982
1800	0.239592	6795.23	9.5812	2.8715	1.1951	0.159859	6794.26	9.3932	2.8743	1.1967
1850	0.245382	6939.22	9.6498	2.8880	1.1937	0.163725	6938.38	9.4619	2.8905	1.1953
1900	0.251170	7084.02	9.7172	2.9040	1.1924	0.167590	7083.31	9.5294	2.9063	1.1940
1950	0.256956	7229.61	9.7835	2.9195	1.1911	0.171453	7229.01	9.5957	2.9217	1.1927
2000	0.262741	7375.97	9.8486	2.9348	1.1899	0.175316	7375.47	9.6608	2.9368	1.1914

Table 4 High-temperature region – Continued
 (800 °C to 2000 °C)

t [°C]	p = 80 bar					p = 100 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.0610054	4124.02	7.5186	2.4322	1.2526	0.0486242	4114.73	7.4087	2.4555	1.2548
820	0.0622309	4172.66	7.5635	2.4404	1.2511	0.0496189	4163.82	7.4539	2.4621	1.2532
840	0.0634484	4221.55	7.6078	2.4489	1.2494	0.0506058	4213.13	7.4986	2.4693	1.2516
860	0.0646622	4270.62	7.6515	2.4578	1.2478	0.0515890	4262.59	7.5427	2.4770	1.2499
880	0.0658726	4319.87	7.6946	2.4672	1.2462	0.0525689	4312.21	7.5861	2.4851	1.2483
900	0.0670799	4369.31	7.7371	2.4767	1.2446	0.0535456	4362.00	7.6289	2.4937	1.2467
920	0.0682844	4418.94	7.7790	2.4866	1.2430	0.0545194	4411.96	7.6711	2.5026	1.2451
940	0.0694862	4468.77	7.8205	2.4966	1.2414	0.0554905	4462.10	7.7128	2.5117	1.2435
960	0.0706855	4518.81	7.8614	2.5068	1.2399	0.0564591	4512.43	7.7540	2.5211	1.2420
980	0.0718825	4569.05	7.9018	2.5171	1.2383	0.0574253	4562.95	7.7946	2.5306	1.2404
1000	0.0730773	4619.49	7.9417	2.5275	1.2368	0.0583894	4613.66	7.8347	2.5403	1.2389
1020	0.0742701	4670.15	7.9812	2.5379	1.2354	0.0593515	4664.56	7.8744	2.5501	1.2375
1040	0.0754611	4721.01	8.0202	2.5484	1.2339	0.0603117	4715.66	7.9136	2.5600	1.2360
1060	0.0766503	4772.08	8.0588	2.5589	1.2325	0.0612701	4766.96	7.9524	2.5699	1.2346
1080	0.0778378	4823.36	8.0970	2.5693	1.2312	0.0622268	4818.46	7.9907	2.5798	1.2332
1100	0.0790238	4874.85	8.1348	2.5797	1.2298	0.0631820	4870.16	8.0287	2.5898	1.2319
1120	0.0802083	4926.55	8.1722	2.5901	1.2285	0.0641358	4922.05	8.0662	2.5997	1.2305
1140	0.0813914	4978.46	8.2092	2.6005	1.2272	0.0650881	4974.14	8.1033	2.6096	1.2292
1160	0.0825733	5030.57	8.2458	2.6107	1.2260	0.0660392	5026.43	8.1400	2.6194	1.2280
1180	0.0837539	5082.89	8.2820	2.6209	1.2247	0.0669890	5078.92	8.1764	2.6292	1.2267
1200	0.0849334	5135.41	8.3179	2.6310	1.2235	0.0679377	5131.60	8.2124	2.6390	1.2255
1220	0.0861118	5188.12	8.3535	2.6409	1.2224	0.0688853	5184.48	8.2481	2.6486	1.2244
1240	0.0872891	5241.04	8.3887	2.6508	1.2212	0.0698319	5237.55	8.2834	2.6582	1.2232
1260	0.0884655	5294.16	8.4235	2.6606	1.2201	0.0707775	5290.80	8.3183	2.6676	1.2221
1280	0.0896410	5347.47	8.4581	2.6702	1.2190	0.0717221	5344.25	8.3530	2.6770	1.2210
1300	0.0908156	5400.97	8.4923	2.6798	1.2180	0.0726659	5397.88	8.3873	2.6863	1.2199
1320	0.0919894	5454.65	8.5262	2.6892	1.2169	0.0736089	5451.70	8.4213	2.6954	1.2189
1340	0.0931624	5508.53	8.5598	2.6984	1.2159	0.0745511	5505.70	8.4550	2.7044	1.2178
1360	0.0943346	5562.59	8.5931	2.7076	1.2150	0.0754926	5559.88	8.4883	2.7133	1.2168
1380	0.0955062	5616.83	8.6261	2.7166	1.2140	0.0764333	5614.23	8.5214	2.7221	1.2159
1400	0.0966770	5671.25	8.6589	2.7255	1.2131	0.0773734	5668.76	8.5542	2.7308	1.2149
1420	0.0978473	5725.85	8.6913	2.7342	1.2122	0.0783129	5723.46	8.5867	2.7394	1.2140
1440	0.0990169	5780.62	8.7235	2.7428	1.2113	0.0792517	5778.34	8.6189	2.7478	1.2131
1460	0.100186	5835.56	8.7554	2.7513	1.2104	0.0801900	5833.37	8.6509	2.7561	1.2122
1480	0.101354	5890.67	8.7870	2.7597	1.2095	0.0811277	5888.58	8.6825	2.7643	1.2114
1500	0.102522	5945.95	8.8183	2.7679	1.2087	0.0820649	5943.94	8.7139	2.7723	1.2105
1550	0.105440	6084.85	8.8956	2.7879	1.2067	0.0844057	6083.05	8.7913	2.7919	1.2085
1600	0.108355	6224.72	8.9713	2.8071	1.2049	0.0867437	6223.13	8.8671	2.8108	1.2066
1650	0.111268	6365.54	9.0454	2.8255	1.2031	0.0890792	6364.12	8.9414	2.8290	1.2048
1700	0.114178	6507.26	9.1182	2.8433	1.2014	0.0914125	6506.01	9.014	2.8465	1.2031
1750	0.117086	6649.86	9.1896	2.8604	1.1999	0.0937437	6648.76	9.086	2.8634	1.2015
1800	0.119993	6793.30	9.2596	2.8770	1.1984	0.0960732	6792.34	9.156	2.8797	1.2000
1850	0.122897	6937.55	9.3284	2.8930	1.1969	0.0984010	6936.72	9.225	2.8956	1.1985
1900	0.125801	7082.59	9.3959	2.9087	1.1955	0.100727	7081.89	9.292	2.9110	1.1971
1950	0.128703	7228.41	9.4622	2.9239	1.1942	0.103052	7227.82	9.359	2.9261	1.1958
2000	0.131603	7374.98	9.5274	2.9389	1.1929	0.105376	7374.49	9.424	2.9409	1.1945

Table 4 High-temperature region – Continued
(800 °C to 2000 °C)

t [°C]	p = 120 bar					p = 140 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.0403706	4105.40	7.3175	2.4793	1.2571	0.0344758	4096.02	7.2393	2.5033	1.2596
820	0.0412113	4154.94	7.3632	2.4842	1.2555	0.0352065	4146.04	7.2854	2.5067	1.2579
840	0.0420447	4204.68	7.4083	2.4900	1.2538	0.0359302	4196.21	7.3309	2.5109	1.2562
860	0.0428743	4254.54	7.4527	2.4964	1.2522	0.0366500	4246.48	7.3757	2.5160	1.2545
880	0.0437004	4304.54	7.4964	2.5033	1.2505	0.0373664	4296.86	7.4197	2.5217	1.2528
900	0.0445234	4354.68	7.5395	2.5108	1.2489	0.0380796	4347.35	7.4632	2.5281	1.2512
920	0.0453434	4404.97	7.5820	2.5187	1.2473	0.0387898	4397.98	7.5060	2.5350	1.2496
940	0.0461607	4455.43	7.6240	2.5270	1.2457	0.0394973	4448.75	7.5482	2.5423	1.2480
960	0.0469755	4506.05	7.6654	2.5355	1.2441	0.0402022	4499.68	7.5898	2.5500	1.2464
980	0.0477880	4556.85	7.7062	2.5443	1.2426	0.0409048	4550.76	7.6309	2.5580	1.2448
1000	0.0485982	4607.83	7.7466	2.5532	1.2411	0.0416052	4602.00	7.6714	2.5662	1.2433
1020	0.0494065	4658.98	7.7865	2.5624	1.2396	0.0423035	4653.41	7.7115	2.5747	1.2418
1040	0.0502128	4710.32	7.8259	2.5716	1.2381	0.0430000	4704.99	7.7511	2.5833	1.2403
1060	0.0510173	4761.85	7.8648	2.5810	1.2367	0.0436946	4756.74	7.7902	2.5921	1.2389
1080	0.0518202	4813.56	7.9033	2.5904	1.2353	0.0443876	4808.67	7.8289	2.6010	1.2375
1100	0.0526216	4865.46	7.9414	2.5998	1.2340	0.0450790	4860.78	7.8671	2.6099	1.2361
1120	0.0534214	4917.55	7.9790	2.6093	1.2326	0.0457689	4913.07	7.9049	2.6189	1.2347
1140	0.0542199	4969.83	8.0163	2.6188	1.2313	0.0464575	4965.53	7.9423	2.6279	1.2334
1160	0.0550171	5022.30	8.0532	2.6282	1.2300	0.0471448	5018.18	7.9793	2.6370	1.2321
1180	0.0558130	5074.96	8.0897	2.6376	1.2288	0.0478308	5071.01	8.0159	2.6460	1.2308
1200	0.0566079	5127.81	8.1258	2.6470	1.2276	0.0485157	5124.02	8.0521	2.6550	1.2296
1220	0.0574016	5180.84	8.1615	2.6563	1.2264	0.0491995	5177.21	8.0880	2.6639	1.2284
1240	0.0581943	5234.06	8.1969	2.6655	1.2252	0.0498823	5230.58	8.1235	2.6729	1.2272
1260	0.0589860	5287.46	8.2320	2.6747	1.2241	0.0505641	5284.13	8.1586	2.6817	1.2261
1280	0.0597768	5341.05	8.2667	2.6838	1.2229	0.0512449	5337.85	8.1935	2.6905	1.2249
1300	0.0605667	5394.81	8.3011	2.6927	1.2219	0.0519249	5391.75	8.2279	2.6992	1.2238
1320	0.0613559	5448.75	8.3352	2.7016	1.2208	0.0526041	5445.82	8.2621	2.7079	1.2228
1340	0.0621442	5502.87	8.3689	2.7104	1.2198	0.0532825	5500.06	8.2959	2.7164	1.2217
1360	0.0629318	5557.17	8.4024	2.7191	1.2188	0.0539602	5554.47	8.3295	2.7249	1.2207
1380	0.0637186	5611.64	8.4355	2.7277	1.2178	0.0546372	5609.05	8.3627	2.7332	1.2197
1400	0.0645049	5666.28	8.4684	2.7361	1.2168	0.0553134	5663.80	8.3956	2.7415	1.2187
1420	0.0652904	5721.08	8.5010	2.7445	1.2159	0.0559891	5718.71	8.4282	2.7496	1.2178
1440	0.0660754	5776.06	8.5332	2.7527	1.2150	0.0566641	5773.79	8.4605	2.7577	1.2168
1460	0.0668598	5831.19	8.5652	2.7609	1.2141	0.0573386	5829.02	8.4926	2.7656	1.2159
1480	0.0676436	5886.49	8.5970	2.7689	1.2132	0.0580125	5884.41	8.5244	2.7735	1.2150
1500	0.0684269	5941.95	8.6284	2.7768	1.2123	0.0586859	5939.96	8.5559	2.7812	1.2142
1550	0.0703831	6081.27	8.7059	2.7960	1.2103	0.0603673	6079.49	8.6335	2.8001	1.2121
1600	0.0723364	6221.54	8.7818	2.8145	1.2084	0.0620458	6219.95	8.7095	2.8183	1.2102
1650	0.0742873	6362.71	8.8562	2.8324	1.2066	0.0637219	6361.31	8.7840	2.8358	1.2083
1700	0.0762359	6504.77	8.9291	2.8496	1.2048	0.0653958	6503.53	8.8570	2.8528	1.2065
1750	0.0781825	6647.67	9.0006	2.8663	1.2032	0.0670676	6646.58	8.9286	2.8692	1.2049
1800	0.0801273	6791.39	9.0708	2.8824	1.2016	0.0687376	6790.44	8.9988	2.8851	1.2033
1850	0.0820705	6935.90	9.1397	2.8981	1.2001	0.0704060	6935.08	9.0677	2.9006	1.2018
1900	0.0840121	7081.19	9.2073	2.9133	1.1987	0.0720730	7080.49	9.1354	2.9157	1.2003
1950	0.0859525	7227.23	9.2737	2.9283	1.1973	0.0737386	7226.65	9.2019	2.9304	1.1989
2000	0.0878916	7374.01	9.3390	2.9429	1.1960	0.0754029	7373.53	9.2673	2.9450	1.1975

Table 4 High-temperature region – Continued
 (800 °C to 2000 °C)

t [°C]	p = 160 bar					p = 180 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.0300554	4086.62	7.1706	2.5277	1.2622	0.0266179	4077.18	7.1091	2.5525	1.2650
820	0.0307035	4137.11	7.2172	2.5295	1.2603	0.0272017	4128.17	7.1561	2.5526	1.2630
840	0.0313449	4187.73	7.2630	2.5322	1.2586	0.0277792	4179.23	7.2024	2.5536	1.2612
860	0.0319825	4238.41	7.3082	2.5358	1.2569	0.0283528	4230.32	7.2479	2.5558	1.2595
880	0.0326166	4289.16	7.3526	2.5403	1.2553	0.0289229	4281.47	7.2927	2.5590	1.2578
900	0.0332474	4340.02	7.3963	2.5455	1.2536	0.0294897	4332.69	7.3367	2.5631	1.2561
920	0.0338753	4390.99	7.4394	2.5514	1.2519	0.0300535	4384.00	7.3801	2.5679	1.2544
940	0.0345004	4442.08	7.4818	2.5577	1.2503	0.0306145	4435.41	7.4228	2.5733	1.2527
960	0.0351229	4493.30	7.5237	2.5646	1.2487	0.0311729	4486.93	7.4649	2.5792	1.2511
980	0.0357431	4544.66	7.5650	2.5717	1.2471	0.0317290	4538.58	7.5065	2.5856	1.2495
1000	0.0363610	4596.17	7.6058	2.5793	1.2456	0.0322828	4590.36	7.5475	2.5923	1.2479
1020	0.0369769	4647.84	7.6461	2.5870	1.2441	0.0328346	4642.28	7.5879	2.5994	1.2464
1040	0.0375909	4699.66	7.6858	2.5950	1.2426	0.0333845	4694.34	7.6279	2.6068	1.2448
1060	0.0382031	4751.64	7.7251	2.6032	1.2411	0.0339325	4746.55	7.6673	2.6144	1.2434
1080	0.0388137	4803.79	7.7640	2.6116	1.2397	0.0344789	4798.91	7.7063	2.6222	1.2419
1100	0.0394226	4856.10	7.8023	2.6200	1.2383	0.0350237	4851.44	7.7448	2.6301	1.2405
1120	0.0400301	4908.59	7.8403	2.6285	1.2369	0.0355671	4904.12	7.7829	2.6381	1.2391
1140	0.0406362	4961.24	7.8778	2.6371	1.2355	0.0361091	4956.96	7.8206	2.6463	1.2377
1160	0.0412410	5014.07	7.9149	2.6457	1.2342	0.0366497	5009.97	7.8578	2.6545	1.2364
1180	0.0418446	5067.07	7.9517	2.6544	1.2329	0.0371892	5063.14	7.8947	2.6627	1.2351
1200	0.0424470	5120.25	7.9880	2.6630	1.2317	0.0377275	5116.48	7.9311	2.6710	1.2338
1220	0.0430484	5173.59	8.0240	2.6716	1.2305	0.0382647	5169.98	7.9672	2.6793	1.2326
1240	0.0436487	5227.11	8.0596	2.6802	1.2293	0.0388008	5223.65	8.0029	2.6875	1.2313
1260	0.0442481	5280.80	8.0948	2.6888	1.2281	0.0393360	5277.48	8.0383	2.6958	1.2302
1280	0.0448465	5334.66	8.1297	2.6973	1.2270	0.0398703	5331.48	8.0733	2.7040	1.2290
1300	0.0454440	5388.69	8.1643	2.7057	1.2258	0.0404037	5385.64	8.1079	2.7122	1.2279
1320	0.0460408	5442.89	8.1985	2.7141	1.2248	0.0409363	5439.97	8.1422	2.7203	1.2268
1340	0.0466367	5497.25	8.2324	2.7224	1.2237	0.0414681	5494.46	8.1762	2.7284	1.2257
1360	0.0472319	5551.78	8.2660	2.7306	1.2227	0.0419992	5549.10	8.2099	2.7364	1.2246
1380	0.0478264	5606.48	8.2993	2.7388	1.2216	0.0425296	5603.91	8.2432	2.7443	1.2236
1400	0.0484203	5661.33	8.3323	2.7468	1.2206	0.0430593	5658.87	8.2763	2.7521	1.2226
1420	0.0490135	5716.35	8.3650	2.7548	1.2197	0.0435884	5713.99	8.3090	2.7599	1.2216
1440	0.0496061	5771.52	8.3974	2.7626	1.2187	0.0441168	5769.27	8.3415	2.7676	1.2207
1460	0.0501981	5826.85	8.4295	2.7704	1.2178	0.0446447	5824.69	8.3736	2.7751	1.2197
1480	0.0507896	5882.34	8.4613	2.7781	1.2169	0.0451720	5880.27	8.4055	2.7826	1.2188
1500	0.0513805	5937.97	8.4929	2.7856	1.2160	0.0456989	5936.00	8.4371	2.7901	1.2179
1550	0.0528558	6077.72	8.5706	2.8041	1.2139	0.0470138	6075.96	8.5150	2.8082	1.2158
1600	0.0543282	6218.38	8.6467	2.8220	1.2119	0.0483259	6216.81	8.5912	2.8257	1.2137
1650	0.0557982	6359.91	8.7213	2.8393	1.2100	0.0496356	6358.52	8.6659	2.8427	1.2118
1700	0.0572660	6502.29	8.7944	2.8560	1.2083	0.0509430	6501.07	8.7390	2.8591	1.2100
1750	0.0587317	6645.50	8.8660	2.8721	1.2066	0.0522485	6644.42	8.8108	2.8750	1.2083
1800	0.0601957	6789.50	8.9363	2.8878	1.2049	0.0535521	6788.56	8.8812	2.8905	1.2066
1850	0.0616580	6934.27	9.0053	2.9031	1.2034	0.0548541	6933.47	8.9502	2.9056	1.2050
1900	0.0631188	7079.80	9.0731	2.9180	1.2019	0.0561547	7079.12	9.0180	2.9203	1.2035
1950	0.0645783	7226.07	9.1396	2.9326	1.2005	0.0574539	7225.49	9.0846	2.9348	1.2020
2000	0.0660366	7373.06	9.2050	2.9470	1.1991	0.0587519	7372.59	9.1500	2.9490	1.2006

Table 4 High-temperature region – Continued
(800 °C to 2000 °C)

t [°C]	p = 200 bar					p = 220 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.0238685	4067.73	7.0534	2.5775	1.2679	0.0216197	4058.25	7.0022	2.6029	1.2710
820	0.0244009	4119.21	7.1008	2.5759	1.2657	0.0221100	4110.24	7.0501	2.5996	1.2686
840	0.0249273	4170.72	7.1475	2.5753	1.2639	0.0225945	4162.21	7.0972	2.5973	1.2667
860	0.0254497	4222.23	7.1934	2.5761	1.2621	0.0230751	4214.14	7.1435	2.5965	1.2649
880	0.0259686	4273.77	7.2385	2.5779	1.2604	0.0235520	4266.07	7.1889	2.5970	1.2631
900	0.0264841	4325.36	7.2828	2.5808	1.2586	0.0240256	4318.03	7.2336	2.5986	1.2613
920	0.0269966	4377.01	7.3265	2.5845	1.2569	0.0244962	4370.02	7.2775	2.6012	1.2595
940	0.0275064	4428.74	7.3695	2.5889	1.2552	0.0249639	4422.08	7.3208	2.6046	1.2578
960	0.0280135	4480.57	7.4118	2.5939	1.2535	0.0254291	4474.21	7.3634	2.6087	1.2561
980	0.0285183	4532.50	7.4536	2.5995	1.2519	0.0258919	4526.43	7.4054	2.6134	1.2544
1000	0.0290208	4584.55	7.4948	2.6055	1.2503	0.0263524	4578.75	7.4468	2.6186	1.2528
1020	0.0295213	4636.72	7.5355	2.6119	1.2487	0.0268109	4631.18	7.4877	2.6243	1.2512
1040	0.0300198	4689.03	7.5756	2.6186	1.2472	0.0272674	4683.73	7.5280	2.6304	1.2496
1060	0.0305166	4741.47	7.6153	2.6256	1.2457	0.0277222	4736.40	7.5678	2.6368	1.2481
1080	0.0310116	4794.05	7.6544	2.6328	1.2442	0.0281752	4789.20	7.6072	2.6434	1.2465
1100	0.0315051	4846.78	7.6931	2.6402	1.2427	0.0286267	4842.14	7.6460	2.6503	1.2451
1120	0.0319972	4899.66	7.7313	2.6478	1.2413	0.0290767	4895.21	7.6844	2.6574	1.2436
1140	0.0324878	4952.69	7.7691	2.6555	1.2399	0.0295254	4948.43	7.7223	2.6647	1.2422
1160	0.0329771	5005.88	7.8065	2.6632	1.2386	0.0299727	5001.80	7.7598	2.6720	1.2408
1180	0.0334652	5059.22	7.8435	2.6711	1.2373	0.0304188	5055.31	7.7969	2.6795	1.2395
1200	0.0339522	5112.72	7.8800	2.6790	1.2360	0.0308638	5108.98	7.8335	2.6870	1.2382
1220	0.0344381	5166.38	7.9162	2.6869	1.2347	0.0313076	5162.79	7.8698	2.6946	1.2369
1240	0.0349229	5220.20	7.9520	2.6949	1.2335	0.0317505	5216.76	7.9057	2.7022	1.2356
1260	0.0354068	5274.18	7.9874	2.7028	1.2323	0.0321923	5270.88	7.9413	2.7098	1.2344
1280	0.0358898	5328.31	8.0225	2.7107	1.2311	0.0326333	5325.16	7.9764	2.7175	1.2332
1300	0.0363719	5382.61	8.0573	2.7186	1.2299	0.0330734	5379.58	8.0113	2.7251	1.2320
1320	0.0368531	5437.06	8.0917	2.7265	1.2288	0.0335127	5434.16	8.0457	2.7327	1.2309
1340	0.0373336	5491.67	8.1257	2.7343	1.2277	0.0339512	5488.89	8.0799	2.7403	1.2298
1360	0.0378134	5546.43	8.1595	2.7421	1.2266	0.0343889	5543.77	8.1137	2.7478	1.2287
1380	0.0382924	5601.35	8.1929	2.7498	1.2256	0.0348260	5598.80	8.1472	2.7553	1.2276
1400	0.0387708	5656.42	8.2260	2.7574	1.2246	0.0352624	5653.98	8.1804	2.7627	1.2266
1420	0.0392486	5711.65	8.2588	2.7650	1.2236	0.0356981	5709.31	8.2132	2.7701	1.2255
1440	0.0397257	5767.02	8.2913	2.7725	1.2226	0.0361333	5764.79	8.2458	2.7774	1.2246
1460	0.0402023	5822.55	8.3235	2.7799	1.2216	0.0365679	5820.41	8.2781	2.7846	1.2236
1480	0.0406783	5878.22	8.3555	2.7872	1.2207	0.0370019	5876.17	8.3101	2.7918	1.2226
1500	0.0411538	5934.03	8.3871	2.7945	1.2198	0.0374354	5932.08	8.3418	2.7989	1.2217
1550	0.0423405	6074.20	8.4651	2.8122	1.2176	0.0385171	6072.46	8.4199	2.8162	1.2195
1600	0.0435243	6215.25	8.5414	2.8294	1.2156	0.0395960	6213.69	8.4963	2.8331	1.2174
1650	0.0447057	6357.14	8.6162	2.8461	1.2136	0.0406724	6355.76	8.5711	2.8495	1.2154
1700	0.0458849	6499.85	8.6894	2.8623	1.2117	0.0417466	6498.63	8.644	2.8654	1.2135
1750	0.0470621	6643.35	8.7612	2.8780	1.2100	0.0428189	6642.29	8.716	2.8809	1.2117
1800	0.0482375	6787.63	8.8317	2.8932	1.2083	0.0438893	6786.71	8.787	2.8959	1.2100
1850	0.0494112	6932.67	8.9008	2.9081	1.2067	0.0449582	6931.87	8.856	2.9106	1.2083
1900	0.0505835	7078.44	8.9687	2.9226	1.2051	0.0460255	7077.76	8.924	2.9249	1.2067
1950	0.0517545	7224.93	9.0353	2.9369	1.2036	0.0470915	7224.36	8.991	2.9391	1.2052
2000	0.0529243	7372.13	9.1008	2.9510	1.2022	0.0481564	7371.67	9.056	2.9530	1.2037

Table 4 High-temperature region – Continued
 (800 °C to 2000 °C)

t [°C]	p = 240 bar					p = 260 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.0197464	4048.76	6.9549	2.6286	1.2742	0.0181620	4039.25	6.9107	2.6545	1.2776
820	0.0202015	4101.26	7.0033	2.6235	1.2716	0.0185873	4092.28	6.9596	2.6476	1.2748
840	0.0206512	4153.69	7.0508	2.6194	1.2697	0.0190074	4145.17	7.0075	2.6417	1.2727
860	0.0210968	4206.05	7.0974	2.6170	1.2678	0.0194235	4197.96	7.0546	2.6377	1.2708
880	0.0215388	4258.38	7.1432	2.6161	1.2659	0.0198359	4250.69	7.1007	2.6354	1.2688
900	0.0219774	4310.70	7.1882	2.6165	1.2640	0.0202450	4303.39	7.1460	2.6345	1.2669
920	0.0224130	4363.05	7.2324	2.6179	1.2622	0.0206510	4356.08	7.1905	2.6348	1.2650
940	0.0228458	4415.43	7.2760	2.6203	1.2605	0.0210541	4408.78	7.2343	2.6361	1.2632
960	0.0232760	4467.86	7.3188	2.6235	1.2587	0.0214547	4461.53	7.2775	2.6383	1.2614
980	0.0237038	4520.37	7.3611	2.6274	1.2570	0.0218528	4514.32	7.3199	2.6414	1.2596
1000	0.0241293	4572.96	7.4027	2.6318	1.2553	0.0222487	4567.19	7.3618	2.6450	1.2579
1020	0.0245527	4625.65	7.4438	2.6368	1.2537	0.0226425	4620.13	7.4030	2.6493	1.2562
1040	0.0249743	4678.44	7.4843	2.6422	1.2521	0.0230344	4673.16	7.4437	2.6540	1.2546
1060	0.0253940	4731.34	7.5243	2.6480	1.2505	0.0234244	4726.29	7.4839	2.6592	1.2530
1080	0.0258120	4784.36	7.5637	2.6541	1.2489	0.0238128	4779.53	7.5235	2.6647	1.2514
1100	0.0262285	4837.50	7.6027	2.6605	1.2474	0.0241996	4832.88	7.5627	2.6706	1.2498
1120	0.0266435	4890.78	7.6412	2.6670	1.2460	0.0245850	4886.35	7.6013	2.6767	1.2483
1140	0.0270571	4944.19	7.6793	2.6738	1.2445	0.0249690	4939.95	7.6395	2.6830	1.2469
1160	0.0274694	4997.73	7.7169	2.6808	1.2431	0.0253516	4993.68	7.6773	2.6895	1.2454
1180	0.0278805	5051.42	7.7541	2.6878	1.2417	0.0257331	5047.53	7.7146	2.6962	1.2440
1200	0.0282904	5105.25	7.7909	2.6950	1.2404	0.0261134	5101.52	7.7515	2.7030	1.2427
1220	0.0286993	5159.22	7.8273	2.7022	1.2391	0.0264926	5155.65	7.7880	2.7099	1.2413
1240	0.0291071	5213.34	7.8633	2.7095	1.2378	0.0268708	5209.92	7.8241	2.7168	1.2400
1260	0.0295140	5267.60	7.8989	2.7169	1.2365	0.0272480	5264.33	7.8598	2.7239	1.2387
1280	0.0299199	5322.01	7.9342	2.7242	1.2353	0.0276243	5318.87	7.8952	2.7309	1.2375
1300	0.0303250	5376.57	7.9691	2.7316	1.2341	0.0279997	5373.56	7.9301	2.7380	1.2363
1320	0.0307293	5431.27	8.0036	2.7389	1.2330	0.0283744	5428.39	7.9648	2.7451	1.2351
1340	0.0311327	5486.12	8.0379	2.7462	1.2318	0.0287482	5483.37	7.9991	2.7522	1.2339
1360	0.0315355	5541.12	8.0717	2.7535	1.2307	0.0291213	5538.48	8.0330	2.7592	1.2328
1380	0.0319375	5596.26	8.1053	2.7608	1.2296	0.0294938	5593.73	8.0667	2.7663	1.2317
1400	0.0323389	5651.55	8.1385	2.7680	1.2286	0.0298655	5649.13	8.1000	2.7733	1.2306
1420	0.0327397	5706.98	8.1715	2.7752	1.2275	0.0302366	5704.67	8.1330	2.7803	1.2296
1440	0.0331398	5762.56	8.2041	2.7823	1.2265	0.0306072	5760.34	8.1656	2.7872	1.2285
1460	0.0335394	5818.27	8.2364	2.7893	1.2255	0.0309771	5816.15	8.1980	2.7941	1.2275
1480	0.0339385	5874.13	8.2685	2.7963	1.2246	0.0313466	5872.10	8.2301	2.8009	1.2265
1500	0.0343370	5930.13	8.3003	2.8033	1.2236	0.0317154	5928.19	8.2619	2.8076	1.2256
1550	0.0353312	6070.72	8.3784	2.8203	1.2214	0.0326356	6068.99	8.3403	2.8243	1.2233
1600	0.0363226	6212.15	8.4550	2.8368	1.2192	0.0335530	6210.61	8.4169	2.8405	1.2211
1650	0.0373115	6354.39	8.5299	2.8529	1.2172	0.0344679	6353.03	8.4919	2.8563	1.2190
1700	0.0382983	6497.43	8.6033	2.8685	1.2153	0.0353806	6496.23	8.5654	2.8716	1.2170
1750	0.0392831	6641.23	8.6753	2.8837	1.2134	0.0362914	6640.19	8.6375	2.8866	1.2152
1800	0.0402660	6785.79	8.7459	2.8986	1.2117	0.0372003	6784.88	8.7081	2.9012	1.2134
1850	0.0412474	6931.09	8.8151	2.9131	1.2100	0.0381077	6930.30	8.7774	2.9155	1.2117
1900	0.0422273	7077.10	8.8831	2.9273	1.2084	0.0390136	7076.43	8.8455	2.9296	1.2100
1950	0.0432059	7223.81	8.9499	2.9412	1.2068	0.0399182	7223.26	8.9123	2.9434	1.2084
2000	0.0441833	7371.21	9.0154	2.9550	1.2053	0.0408215	7370.77	8.9779	2.9570	1.2069

Table 4 High-temperature region – Continued
(800 °C to 2000 °C)

t [°C]	p = 280 bar					p = 300 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.0168046	4029.74	6.8693	2.6808	1.2811	0.0156288	4020.23	6.8303	2.7072	1.2848
820	0.0172043	4083.29	6.9187	2.6719	1.2781	0.0160064	4074.31	6.8801	2.6964	1.2816
840	0.0175991	4136.65	6.9670	2.6641	1.2760	0.0163792	4128.14	6.9289	2.6868	1.2793
860	0.0179898	4189.87	7.0144	2.6586	1.2739	0.0167480	4181.80	6.9767	2.6795	1.2772
880	0.0183769	4243.01	7.0609	2.6548	1.2719	0.0171130	4235.33	7.0235	2.6743	1.2750
900	0.0187606	4296.08	7.1065	2.6526	1.2699	0.0174747	4288.78	7.0695	2.6707	1.2730
920	0.0191412	4349.12	7.1514	2.6517	1.2679	0.0178332	4342.17	7.1146	2.6686	1.2710
940	0.0195189	4402.15	7.1955	2.6520	1.2661	0.0181889	4395.53	7.1589	2.6679	1.2690
960	0.0198940	4455.20	7.2388	2.6532	1.2642	0.0185420	4448.89	7.2026	2.6682	1.2671
980	0.0202667	4508.29	7.2815	2.6554	1.2624	0.0188926	4502.27	7.2455	2.6694	1.2652
1000	0.0206372	4561.42	7.3236	2.6583	1.2606	0.0192411	4555.67	7.2878	2.6715	1.2634
1020	0.0210056	4614.62	7.3651	2.6618	1.2589	0.0195874	4609.13	7.3294	2.6743	1.2616
1040	0.0213720	4667.90	7.4059	2.6659	1.2572	0.0199318	4662.65	7.3705	2.6777	1.2598
1060	0.0217367	4721.26	7.4463	2.6704	1.2555	0.0202744	4716.24	7.4110	2.6816	1.2581
1080	0.0220996	4774.72	7.4861	2.6754	1.2539	0.0206153	4769.92	7.4510	2.6860	1.2565
1100	0.0224610	4828.28	7.5254	2.6807	1.2523	0.0209546	4823.68	7.4904	2.6908	1.2548
1120	0.0228210	4881.95	7.5642	2.6863	1.2508	0.0212925	4877.55	7.5294	2.6959	1.2533
1140	0.0231795	4935.73	7.6025	2.6922	1.2493	0.0216290	4931.52	7.5678	2.7013	1.2517
1160	0.0235367	4989.63	7.6404	2.6983	1.2478	0.0219642	4985.61	7.6058	2.7070	1.2502
1180	0.0238928	5043.66	7.6778	2.7045	1.2464	0.0222982	5039.80	7.6434	2.7129	1.2487
1200	0.0242476	5097.82	7.7148	2.7109	1.2450	0.0226310	5094.12	7.6805	2.7189	1.2473
1220	0.0246014	5152.10	7.7514	2.7175	1.2436	0.0229627	5148.56	7.7172	2.7251	1.2459
1240	0.0249542	5206.52	7.7876	2.7241	1.2423	0.0232935	5203.13	7.7535	2.7314	1.2446
1260	0.0253060	5261.07	7.8234	2.7308	1.2410	0.0236233	5257.82	7.7894	2.7378	1.2432
1280	0.0256569	5315.75	7.8589	2.7376	1.2397	0.0239521	5312.64	7.8250	2.7443	1.2419
1300	0.0260069	5370.57	7.8939	2.7444	1.2385	0.0242801	5367.59	7.8601	2.7508	1.2407
1320	0.0263562	5425.53	7.9287	2.7512	1.2372	0.0246073	5422.67	7.8949	2.7574	1.2394
1340	0.0267046	5480.62	7.9630	2.7581	1.2361	0.0249337	5477.88	7.9293	2.7640	1.2382
1360	0.0270523	5535.85	7.9971	2.7649	1.2349	0.0252594	5533.23	7.9634	2.7706	1.2370
1380	0.0273993	5591.22	8.0307	2.7717	1.2338	0.0255844	5588.71	7.9972	2.7772	1.2359
1400	0.0277457	5646.72	8.0641	2.7785	1.2327	0.0259088	5644.32	8.0306	2.7838	1.2348
1420	0.0280914	5702.36	8.0972	2.7853	1.2316	0.0262325	5700.06	8.0638	2.7904	1.2337
1440	0.0284366	5758.13	8.1299	2.7921	1.2305	0.0265556	5755.93	8.0966	2.7969	1.2326
1460	0.0287811	5814.04	8.1624	2.7988	1.2295	0.0268781	5811.94	8.1291	2.8034	1.2315
1480	0.0291251	5870.08	8.1945	2.8054	1.2285	0.0272001	5868.07	8.1613	2.8099	1.2305
1500	0.0294686	5926.26	8.2264	2.8120	1.2275	0.0275216	5924.33	8.1932	2.8164	1.2295
1550	0.0303253	6067.26	8.3048	2.8283	1.2252	0.0283232	6065.55	8.2717	2.8323	1.2271
1600	0.0311792	6209.08	8.3815	2.8442	1.2230	0.0291221	6207.55	8.3486	2.8478	1.2248
1650	0.0320307	6351.67	8.4567	2.8597	1.2208	0.0299186	6350.33	8.4238	2.8630	1.2227
1700	0.0328799	6495.03	8.5303	2.8748	1.2188	0.0307128	6493.85	8.4975	2.8779	1.2206
1750	0.0337272	6639.14	8.6024	2.8895	1.2169	0.0315051	6638.11	8.5697	2.8924	1.2187
1800	0.0345727	6783.98	8.6731	2.9039	1.2151	0.0322956	6783.08	8.6404	2.9066	1.2168
1850	0.0354167	6929.53	8.7425	2.9180	1.2134	0.0330846	6928.76	8.7099	2.9205	1.2150
1900	0.0362591	7075.78	8.8106	2.9318	1.2117	0.0338720	7075.12	8.7780	2.9341	1.2133
1950	0.0371002	7222.71	8.8774	2.9455	1.2101	0.0346582	7222.17	8.8449	2.9476	1.2117
2000	0.0379402	7370.32	8.9431	2.9590	1.2085	0.0354431	7369.88	8.9106	2.9610	1.2101

Table 4 High-temperature region – Continued
 (800 °C to 2000 °C)

t [°C]	p = 400 bar					p = 500 bar				
	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]	v [m ³ kg ⁻¹]	h [kJ kg ⁻¹]	s [kJ kg ⁻¹ K ⁻¹]	c _p [kJ kg ⁻¹ K ⁻¹]	κ [-]
800	0.0115229	3972.81	6.6614	2.8428	1.3059	0.00907413	3925.96	6.5226	2.9813	1.3319
820	0.0118223	4029.55	6.7137	2.8210	1.3016	0.00932613	3985.35	6.5774	2.9475	1.3268
840	0.0121179	4085.77	6.7647	2.8015	1.2986	0.00957460	4043.99	6.6306	2.9174	1.3224
860	0.0124093	4141.63	6.8144	2.7855	1.2957	0.00981891	4102.08	6.6823	2.8921	1.3184
880	0.0126970	4197.20	6.8630	2.7725	1.2929	0.0100595	4159.70	6.7327	2.8709	1.3145
900	0.0129812	4252.55	6.9106	2.7620	1.2902	0.0102966	4216.94	6.7819	2.8533	1.3110
920	0.0132623	4307.70	6.9572	2.7538	1.2877	0.0105307	4273.85	6.8300	2.8387	1.3076
940	0.0135406	4362.71	7.0030	2.7475	1.2852	0.0107619	4330.51	6.8771	2.8267	1.3043
960	0.0138162	4417.61	7.0478	2.7429	1.2829	0.0109905	4386.94	6.9232	2.8170	1.3013
980	0.0140894	4472.44	7.0919	2.7396	1.2806	0.0112167	4443.20	6.9685	2.8091	1.2984
1000	0.0143604	4527.21	7.1353	2.7376	1.2784	0.0114408	4499.31	7.0129	2.8029	1.2956
1020	0.0146292	4581.95	7.1780	2.7366	1.2762	0.0116628	4555.32	7.0566	2.7982	1.2929
1040	0.0148962	4636.68	7.2200	2.7366	1.2742	0.0118829	4611.25	7.0995	2.7947	1.2904
1060	0.0151614	4691.42	7.2613	2.7374	1.2721	0.0121012	4667.12	7.1417	2.7924	1.2879
1080	0.0154249	4746.18	7.3021	2.7389	1.2702	0.0123180	4722.95	7.1833	2.7910	1.2856
1100	0.0156869	4800.98	7.3423	2.7410	1.2683	0.0125332	4778.77	7.2242	2.7904	1.2833
1120	0.0159474	4855.82	7.3820	2.7437	1.2665	0.0127470	4834.57	7.2646	2.7906	1.2811
1140	0.0162065	4910.73	7.4211	2.7468	1.2647	0.0129594	4890.39	7.3044	2.7915	1.2790
1160	0.0164644	4965.70	7.4597	2.7503	1.2630	0.0131706	4946.24	7.3436	2.7929	1.2770
1180	0.0167211	5020.74	7.4979	2.7542	1.2613	0.0133807	5002.11	7.3823	2.7948	1.2750
1200	0.0169766	5075.87	7.5355	2.7584	1.2597	0.0135896	5058.03	7.4205	2.7971	1.2731
1220	0.0172311	5131.08	7.5728	2.7628	1.2581	0.0137975	5114.00	7.4583	2.7999	1.2713
1240	0.0174846	5186.38	7.6096	2.7675	1.2565	0.0140044	5170.03	7.4956	2.8029	1.2695
1260	0.0177371	5241.78	7.6459	2.7724	1.2550	0.0142103	5226.12	7.5324	2.8063	1.2678
1280	0.0179887	5297.28	7.6819	2.7774	1.2536	0.0144154	5282.28	7.5688	2.8099	1.2661
1300	0.0182395	5352.88	7.7175	2.7826	1.2521	0.0146197	5338.52	7.6047	2.8137	1.2645
1320	0.0184895	5408.58	7.7526	2.7879	1.2508	0.0148232	5394.83	7.6403	2.8178	1.2629
1340	0.0187387	5464.39	7.7875	2.7932	1.2494	0.0150260	5451.23	7.6755	2.8220	1.2613
1360	0.0189872	5520.31	7.8219	2.7987	1.2481	0.0152280	5507.71	7.7103	2.8263	1.2598
1380	0.0192350	5576.34	7.8560	2.8042	1.2468	0.0154294	5564.28	7.7447	2.8308	1.2584
1400	0.0194822	5632.48	7.8898	2.8098	1.2455	0.0156301	5620.94	7.7788	2.8353	1.2570
1420	0.0197287	5688.73	7.9232	2.8154	1.2443	0.0158303	5677.70	7.8125	2.8400	1.2556
1440	0.0199747	5745.10	7.9563	2.8210	1.2431	0.0160298	5734.54	7.8459	2.8447	1.2542
1460	0.0202201	5801.57	7.9891	2.8267	1.2420	0.0162288	5791.48	7.8789	2.8495	1.2529
1480	0.0204650	5858.16	8.0215	2.8323	1.2408	0.0164273	5848.52	7.9117	2.8543	1.2516
1500	0.0207094	5914.87	8.0537	2.8380	1.2397	0.0166253	5905.66	7.9441	2.8592	1.2504
1550	0.0213182	6057.12	8.1328	2.8520	1.2370	0.0171183	6048.92	8.0237	2.8715	1.2474
1600	0.0219244	6200.07	8.2101	2.8660	1.2345	0.0176086	6192.80	8.1016	2.8838	1.2446
1650	0.0225282	6343.71	8.2858	2.8797	1.2321	0.0180966	6337.30	8.1777	2.8961	1.2419
1700	0.0231298	6488.04	8.3599	2.8933	1.2299	0.0185824	6482.42	8.2522	2.9084	1.2394
1750	0.0237294	6633.03	8.4325	2.9066	1.2277	0.0190664	6628.14	8.3252	2.9206	1.2370
1800	0.0243274	6778.69	8.5036	2.9197	1.2256	0.0195486	6774.47	8.3966	2.9327	1.2347
1850	0.0249237	6925.00	8.5733	2.9327	1.2237	0.0200293	6921.41	8.4666	2.9447	1.2325
1900	0.0255186	7071.96	8.6417	2.9455	1.2218	0.0205086	7068.94	8.5353	2.9567	1.2304
1950	0.0261123	7219.55	8.7089	2.9582	1.2199	0.0209866	7217.07	8.6027	2.9686	1.2284
2000	0.0267047	7367.77	8.7748	2.9708	1.2182	0.0214634	7365.80	8.6689	2.9805	1.2265

Table 5 Ideal-gas state

This table contains values for the following thermodynamic properties in the ideal-gas state for temperatures from 0°C to 2000°C:

- Specific isobaric heat capacity c_p^o
- Specific isochoric heat capacity c_v^o
- Specific enthalpy h^o
- Specific entropy s^o ($p_0 = 0.006\,112\,127$ bar)
- Speed of sound w^o
- Isentropic exponent κ^o
- Mean specific isobaric heat capacity $c_{p,m}^o = c_p^o \Big|_{t_0}^t = \frac{1}{t-t_0} \int_{T_0}^T c_p^o(T) dT$ between the reference temperature $t_0 = 0^\circ\text{C}$ and the tabulated temperature t

These thermodynamic properties were calculated from Eq. (2.7) for temperatures $t \leq 800^\circ\text{C}$ and from Eq. (2.16) for temperatures $t > 800^\circ\text{C}$.

The listed values for the specific enthalpy h^o , the specific entropy s^o , and the mean specific isobaric heat capacity $c_{p,m}^o$ relate to the reference temperature $t_0 = 0^\circ\text{C}$, and for s^o , in addition, to the reference pressure $p_0 = p_s(t_0) = 0.006\,112\,127$ bar. Due to this very low pressure, the difference (arising from the real-gas contribution) between the values for s given in Table 3 (for this pressure) and for s^o listed in this table is very small. The reference values for $h^o(t_0)$ and $s^o(p_0, t_0)$ are in accordance with the zero points of the specific internal energy and specific entropy given by Eq. (2.4).

Specific entropy values for pressures $p \neq p_0$ can be calculated from the equation

$$s^o(p, t) = s^o(p_0, t) - R \ln \left(\frac{p}{p_0} \right),$$

where the values $s^o(p_0, t)$ are listed in the table, and $R = 0.461\,526 \text{ kJ kg}^{-1} \text{ K}^{-1}$ is the specific gas constant of water according to Eq. (1.1).

Table 5 Ideal-gas state

<i>t</i> [°C]	<i>c_p⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>c_v⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>h⁰</i> [kJ kg ⁻¹]	<i>s⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>w⁰</i> [m s ⁻¹]	<i>κ⁰</i> [-]	<i>c_{p,m}⁰</i> [kJ kg ⁻¹ K ⁻¹]
	<i>p₀</i> = 0.006112127 bar						
0	1.8589	1.3974	2501.42	9.1574	409.52	1.3303	1.8589
2	1.8593	1.3978	2505.14	9.1710	411.00	1.3302	1.8591
4	1.8598	1.3983	2508.86	9.1845	412.47	1.3301	1.8593
6	1.8602	1.3987	2512.58	9.1978	413.94	1.3300	1.8596
8	1.8607	1.3991	2516.30	9.2111	415.40	1.3299	1.8598
10	1.8611	1.3996	2520.02	9.2243	416.86	1.3298	1.8600
12	1.8615	1.4000	2523.74	9.2374	418.32	1.3297	1.8602
14	1.8620	1.4005	2527.47	9.2504	419.76	1.3296	1.8604
16	1.8624	1.4009	2531.19	9.2634	421.21	1.3294	1.8607
18	1.8629	1.4014	2534.92	9.2762	422.64	1.3293	1.8609
20	1.8634	1.4018	2538.64	9.2890	424.08	1.3292	1.8611
25	1.8646	1.4030	2547.96	9.3205	427.63	1.3289	1.8617
30	1.8658	1.4043	2557.29	9.3515	431.16	1.3287	1.8623
35	1.8671	1.4056	2566.62	9.3820	434.65	1.3284	1.8629
40	1.8685	1.4069	2575.96	9.4121	438.11	1.3280	1.8635
45	1.8699	1.4083	2585.30	9.4417	441.54	1.3277	1.8641
50	1.8714	1.4098	2594.66	9.4709	444.93	1.3274	1.8648
55	1.8729	1.4114	2604.02	9.4996	448.30	1.3270	1.8654
60	1.8745	1.4130	2613.39	9.5279	451.64	1.3266	1.8661
65	1.8762	1.4147	2622.76	9.5559	454.95	1.3262	1.8668
70	1.8780	1.4164	2632.15	9.5834	458.23	1.3258	1.8676
75	1.8798	1.4182	2641.54	9.6106	461.49	1.3254	1.8683
80	1.8816	1.4201	2650.95	9.6374	464.71	1.3250	1.8691
85	1.8836	1.4221	2660.36	9.6639	467.91	1.3245	1.8699
90	1.8856	1.4240	2669.78	9.6900	471.09	1.3241	1.8707
95	1.8876	1.4261	2679.21	9.7158	474.24	1.3236	1.8715
100	1.8897	1.4282	2688.66	9.7413	477.36	1.3232	1.8724
105	1.8919	1.4303	2698.11	9.7665	480.46	1.3227	1.8733
110	1.8941	1.4326	2707.58	9.7913	483.53	1.3222	1.8742
115	1.8963	1.4348	2717.05	9.8159	486.58	1.3217	1.8751
120	1.8986	1.4371	2726.54	9.8402	489.61	1.3211	1.8760
130	1.9034	1.4418	2745.55	9.8879	495.60	1.3201	1.8779
135	1.9058	1.4443	2755.07	9.9114	498.57	1.3196	1.8789
140	1.9082	1.4467	2764.61	9.9346	501.51	1.3190	1.8799
145	1.9107	1.4492	2774.16	9.9576	504.43	1.3185	1.8809
150	1.9133	1.4517	2783.72	9.9803	507.33	1.3179	1.8820
160	1.9184	1.4569	2802.87	10.025	513.07	1.3168	1.8841
170	1.9237	1.4622	2822.08	10.069	518.73	1.3156	1.8863
180	1.9291	1.4676	2841.35	10.112	524.32	1.3145	1.8885
190	1.9346	1.4731	2860.67	10.154	529.84	1.3133	1.8908
200	1.9402	1.4786	2880.04	10.195	535.29	1.3121	1.8931
210	1.9458	1.4843	2899.47	10.236	540.67	1.3109	1.8955
220	1.9516	1.4900	2918.96	10.276	545.99	1.3097	1.8979
230	1.9573	1.4958	2938.50	10.315	551.24	1.3085	1.9004
240	1.9632	1.5017	2958.10	10.354	556.43	1.3073	1.9029

Table 5 Ideal-gas state – Continued

<i>t</i> [°C]	<i>c_p⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>c_v⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>h⁰</i> [kJ kg ⁻¹]	<i>s⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>w⁰</i> [m s ⁻¹]	<i>κ⁰</i> [–]	<i>c_{p,m}⁰</i> [kJ kg ⁻¹ K ⁻¹]
	<i>p₀</i> = 0.006112127 bar						
250	1.9691	1.5076	2977.77	10.392	561.57	1.3061	1.9054
260	1.9751	1.5136	2997.49	10.429	566.65	1.3049	1.9080
270	1.9811	1.5196	3017.27	10.466	571.68	1.3037	1.9106
280	1.9872	1.5257	3037.11	10.502	576.65	1.3025	1.9132
290	1.9933	1.5318	3057.01	10.538	581.56	1.3013	1.9158
300	1.9995	1.5380	3076.98	10.573	586.43	1.3001	1.9185
310	2.0057	1.5442	3097.00	10.608	591.25	1.2989	1.9212
320	2.0120	1.5504	3117.09	10.642	596.02	1.2977	1.9240
330	2.0183	1.5567	3137.24	10.675	600.75	1.2965	1.9267
340	2.0246	1.5631	3157.46	10.709	605.43	1.2953	1.9295
350	2.0310	1.5695	3177.73	10.741	610.06	1.2941	1.9323
360	2.0374	1.5759	3198.08	10.774	614.65	1.2929	1.9352
370	2.0438	1.5823	3218.48	10.806	619.20	1.2917	1.9380
380	2.0503	1.5888	3238.95	10.837	623.71	1.2905	1.9409
390	2.0569	1.5953	3259.49	10.869	628.17	1.2893	1.9438
400	2.0634	1.6019	3280.09	10.899	632.60	1.2881	1.9467
410	2.0700	1.6085	3300.76	10.930	636.99	1.2869	1.9496
420	2.0767	1.6151	3321.49	10.960	641.34	1.2858	1.9526
430	2.0833	1.6218	3342.29	10.990	645.66	1.2846	1.9555
440	2.0900	1.6285	3363.16	11.019	649.94	1.2834	1.9585
450	2.0968	1.6352	3384.09	11.048	654.18	1.2822	1.9615
460	2.1035	1.6420	3405.09	11.077	658.39	1.2811	1.9645
470	2.1103	1.6488	3426.16	11.106	662.56	1.2799	1.9675
480	2.1171	1.6556	3447.30	11.134	666.71	1.2788	1.9706
490	2.1240	1.6625	3468.51	11.162	670.82	1.2776	1.9736
500	2.1309	1.6693	3489.78	11.190	674.89	1.2765	1.9767
510	2.1378	1.6763	3511.12	11.217	678.94	1.2753	1.9798
520	2.1447	1.6832	3532.54	11.244	682.96	1.2742	1.9829
530	2.1517	1.6901	3554.02	11.271	686.95	1.2731	1.9860
540	2.1586	1.6971	3575.57	11.298	690.91	1.2720	1.9892
550	2.1656	1.7041	3597.19	11.324	694.84	1.2708	1.9923
560	2.1726	1.7111	3618.88	11.351	698.74	1.2697	1.9955
570	2.1796	1.7181	3640.64	11.376	702.61	1.2686	1.9986
580	2.1867	1.7251	3662.47	11.402	706.46	1.2675	2.0018
590	2.1937	1.7322	3684.38	11.428	710.29	1.2664	2.0050
600	2.2008	1.7392	3706.35	11.453	714.08	1.2654	2.0082
620	2.2149	1.7534	3750.51	11.503	721.61	1.2632	2.0147
640	2.2291	1.7676	3794.95	11.552	729.03	1.2611	2.0211
660	2.2433	1.7817	3839.67	11.601	736.36	1.2590	2.0277
680	2.2574	1.7959	3884.68	11.648	743.61	1.2570	2.0342
700	2.2716	1.8101	3929.97	11.695	750.77	1.2550	2.0408
720	2.2858	1.8243	3975.54	11.742	757.84	1.2530	2.0474
740	2.2999	1.8384	4021.40	11.788	764.84	1.2510	2.0540
760	2.3141	1.8525	4067.54	11.833	771.76	1.2491	2.0607
780	2.3282	1.8666	4113.96	11.877	778.61	1.2472	2.0674

Table 5 Ideal-gas state – Continued

<i>t</i> [°C]	<i>c_p⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>c_v⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>h⁰</i> [kJ kg ⁻¹]	<i>s⁰</i> [kJ kg ⁻¹ K ⁻¹]	<i>w⁰</i> [m s ⁻¹]	<i>κ⁰</i> [-]	<i>c_{p,m}⁰</i> [kJ kg ⁻¹ K ⁻¹]
	<i>p₀</i> = 0.006112127 bar						
800	2.3423	1.8808	4160.66	11.921	785.38	1.2454	2.0741
820	2.3572	1.8957	4207.69	11.964	792.05	1.2435	2.0808
840	2.3707	1.9091	4254.97	12.007	798.71	1.2417	2.0876
860	2.3841	1.9226	4302.52	12.050	805.31	1.2401	2.0943
880	2.3975	1.9360	4350.33	12.091	811.84	1.2384	2.1010
900	2.4109	1.9494	4398.42	12.133	818.31	1.2368	2.1078
920	2.4243	1.9627	4446.77	12.174	824.72	1.2351	2.1145
940	2.4376	1.9760	4495.39	12.214	831.07	1.2336	2.1212
960	2.4508	1.9892	4544.27	12.254	837.36	1.2320	2.1280
980	2.4639	2.0024	4593.42	12.294	843.60	1.2305	2.1347
1000	2.4769	2.0154	4642.83	12.333	849.80	1.2290	2.1414
1020	2.4898	2.0283	4692.49	12.371	855.94	1.2275	2.1481
1040	2.5025	2.0410	4742.42	12.410	862.03	1.2261	2.1548
1060	2.5152	2.0536	4792.59	12.448	868.08	1.2247	2.1615
1080	2.5276	2.0661	4843.02	12.485	874.08	1.2234	2.1682
1100	2.5400	2.0784	4893.70	12.522	880.04	1.2221	2.1748
1120	2.5521	2.0906	4944.62	12.559	885.96	1.2208	2.1814
1140	2.5641	2.1026	4995.78	12.596	891.83	1.2195	2.1880
1160	2.5759	2.1144	5047.18	12.632	897.67	1.2183	2.1946
1180	2.5876	2.1261	5098.82	12.668	903.47	1.2171	2.2012
1200	2.5991	2.1376	5150.69	12.703	909.23	1.2159	2.2077
1220	2.6104	2.1489	5202.78	12.738	914.95	1.2148	2.2142
1240	2.6215	2.1600	5255.10	12.773	920.64	1.2137	2.2207
1260	2.6325	2.1709	5307.64	12.807	926.29	1.2126	2.2272
1280	2.6432	2.1817	5360.40	12.842	931.91	1.2115	2.2336
1300	2.6538	2.1923	5413.37	12.876	937.50	1.2105	2.2400
1320	2.6642	2.2027	5466.55	12.909	943.05	1.2095	2.2463
1340	2.6745	2.2129	5519.94	12.942	948.57	1.2086	2.2526
1360	2.6845	2.2230	5573.53	12.975	954.06	1.2076	2.2589
1380	2.6944	2.2329	5627.31	13.008	959.52	1.2067	2.2651
1400	2.7041	2.2426	5681.30	13.041	964.95	1.2058	2.2713
1420	2.7136	2.2521	5735.48	13.073	970.35	1.2049	2.2775
1440	2.7230	2.2614	5789.84	13.105	975.72	1.2041	2.2836
1460	2.7322	2.2706	5844.39	13.136	981.06	1.2033	2.2897
1480	2.7412	2.2797	5899.13	13.168	986.37	1.2025	2.2957
1500	2.7501	2.2885	5954.04	13.199	991.66	1.2017	2.3017
1550	2.7715	2.3100	6092.08	13.276	1004.76	1.1998	2.3166
1600	2.7921	2.3305	6231.18	13.351	1017.70	1.1980	2.3311
1650	2.8117	2.3502	6371.28	13.425	1030.48	1.1964	2.3454
1700	2.8305	2.3690	6512.33	13.497	1043.11	1.1948	2.3594
1750	2.8486	2.3871	6654.32	13.568	1055.59	1.1933	2.3731
1800	2.8661	2.4045	6797.19	13.638	1067.92	1.1919	2.3865
1850	2.8829	2.4214	6940.91	13.707	1080.12	1.1906	2.3997
1900	2.8992	2.4377	7085.47	13.774	1092.18	1.1893	2.4127
1950	2.9152	2.4536	7230.83	13.840	1104.10	1.1881	2.4253
2000	2.9307	2.4692	7376.98	13.905	1115.89	1.1869	2.4378

Table 6 Saturation state:
Compression factor z ,
Specific isochoric heat capacity c_v ,
Isobaric cubic expansion coefficient α_v ,
Isothermal compressibility κ_T

This table contains values on the saturated liquid ('') and saturated vapour ('') lines for the following thermodynamic properties for temperatures from $t = 0^\circ\text{C}$ up to the critical temperature $t_c = 373.946^\circ\text{C}$:

- Compression factor (real-gas factor) $z = pv/(RT) = p/(\rho RT)$
- Specific isochoric heat capacity c_v
- Isobaric cubic expansion coefficient $\alpha_v = v^{-1}(\partial v/\partial T)_p$
- Isothermal compressibility $\kappa_T = -v^{-1}(\partial v/\partial p)_T$

For given temperatures, the saturation pressures p_s were calculated from the IAPWS-IF97 saturation-pressure equation, Eq. (2.13).

For temperatures $t \leq 350^\circ\text{C}$ and the input values of t and p_s , the properties on the saturated-liquid and saturated-vapour lines were determined from the basic equations for regions 1 and 2, Eqs. (2.3) and (2.6).

For $t > 350^\circ\text{C}$, the basic equation of region 3, Eq. (2.11), was used for these calculations. With the input (t, p_s) values, the densities ρ' and ρ'' , needed as one of the input quantities of Eq. (2.11), were determined by iterating this equation. With these values for (ρ', t) and (ρ'', t) , the other thermodynamic properties at saturation were determined from Eq. (2.11).

The tabulated values of α_v and κ_T can be used to calculate corresponding partial derivatives of thermodynamic properties as described in Sec. 2.4.4.1 by means of an example.

Table 6 Saturation state: Compression factor z , Specific isobaric heat capacity c_v , Isobaric cubic expansion coefficient α_v , Isothermal compressibility κ_T

t [°C]	z' [-]	z''	c_v' [$\text{kJ kg}^{-1} \text{K}^{-1}$]	c_v''	α_v' [10^{-6}K^{-1}]	α_v''	κ_T' [10^{-6}kPa^{-1}]	κ_T''
0	4.8494×10^{-6}	0.99944	4.2174	1.4221	-68.073	3681.2	0.50895	1637128
0.01 ^a	4.8527×10^{-6}	0.99944	4.2174	1.4221	-67.890	3681.1	0.50891	1635939
1	5.1940×10^{-6}	0.99941	4.2151	1.4226	-50.101	3668.4	0.50522	1522872
2	5.5600×10^{-6}	0.99939	4.2128	1.4232	-32.744	3655.7	0.50164	1417432
3	5.9485×10^{-6}	0.99936	4.2103	1.4237	-15.967	3643.2	0.49822	1320068
4	6.3607×10^{-6}	0.99933	4.2078	1.4243	0.26721	3630.7	0.49494	1230105
5	6.7977×10^{-6}	0.99930	4.2052	1.4248	15.989	3618.4	0.49180	1146932
6	7.2609×10^{-6}	0.99927	4.2026	1.4254	31.229	3606.2	0.48880	1069989
7	7.7514×10^{-6}	0.99923	4.1999	1.4261	46.014	3594.1	0.48592	998769
8	8.2708×10^{-6}	0.99920	4.1971	1.4267	60.370	3582.1	0.48317	932806
9	8.8203×10^{-6}	0.99916	4.1942	1.4274	74.321	3570.3	0.48054	871678
10	9.4016×10^{-6}	0.99912	4.1912	1.4280	87.889	3558.5	0.47802	814997
11	1.0016×10^{-5}	0.99909	4.1882	1.4287	101.09	3546.9	0.47562	762411
12	1.0665×10^{-5}	0.99905	4.1851	1.4294	113.96	3535.3	0.47332	713596
13	1.1351×10^{-5}	0.99900	4.1820	1.4302	126.50	3523.9	0.47112	668257
14	1.2075×10^{-5}	0.99896	4.1787	1.4309	138.73	3512.6	0.46903	626124
15	1.2838×10^{-5}	0.99892	4.1754	1.4317	150.67	3501.4	0.46703	586948
16	1.3644×10^{-5}	0.99887	4.1720	1.4325	162.33	3490.3	0.46512	550502
17	1.4493×10^{-5}	0.99882	4.1686	1.4333	173.72	3479.3	0.46330	516579
18	1.5387×10^{-5}	0.99877	4.1650	1.4341	184.87	3468.4	0.46157	484987
19	1.6330×10^{-5}	0.99872	4.1615	1.4350	195.78	3457.6	0.45993	455551
20	1.7321×10^{-5}	0.99867	4.1578	1.4358	206.46	3446.9	0.45836	428109
22	1.9463×10^{-5}	0.99856	4.1503	1.4376	227.18	3425.8	0.45547	378629
24	2.1830×10^{-5}	0.99844	4.1425	1.4394	247.11	3405.2	0.45287	335498
25	2.3105×10^{-5}	0.99838	4.1385	1.4403	256.80	3395.0	0.45168	316031
26	2.4443×10^{-5}	0.99832	4.1345	1.4413	266.31	3384.9	0.45055	297829
28	2.7321×10^{-5}	0.99818	4.1262	1.4432	284.86	3365.0	0.44850	264867
30	3.0487×10^{-5}	0.99804	4.1178	1.4452	302.80	3345.5	0.44671	235969
32	3.3963×10^{-5}	0.99789	4.1091	1.4472	320.18	3326.4	0.44515	210588
34	3.7776×10^{-5}	0.99773	4.1003	1.4493	337.04	3307.7	0.44382	188256
36	4.1950×10^{-5}	0.99757	4.0913	1.4515	353.43	3289.3	0.44271	168572
38	4.6514×10^{-5}	0.99739	4.0821	1.4536	369.38	3271.4	0.44180	151192
40	5.1496×10^{-5}	0.99720	4.0728	1.4558	384.92	3253.7	0.44110	135820
42	5.6928×10^{-5}	0.99700	4.0633	1.4581	400.08	3236.5	0.44058	122202
44	6.2841×10^{-5}	0.99679	4.0537	1.4604	414.88	3219.6	0.44025	110117
46	6.9271×10^{-5}	0.99657	4.0440	1.4627	429.36	3203.0	0.44010	99378
48	7.6251×10^{-5}	0.99634	4.0342	1.4651	443.53	3186.9	0.44011	89817
50	8.3821×10^{-5}	0.99609	4.0243	1.4675	457.42	3171.1	0.44029	81294
52	9.2018×10^{-5}	0.99584	4.0144	1.4699	471.04	3155.6	0.44063	73684
54	1.0089×10^{-4}	0.99556	4.0043	1.4724	484.41	3140.6	0.44113	66879
56	1.1046×10^{-4}	0.99528	3.9942	1.4750	497.54	3125.8	0.44177	60786
58	1.2080×10^{-4}	0.99498	3.9840	1.4776	510.46	3111.5	0.44257	55321

^a Triple-point temperature.

Table 6 Saturation state: **Compression factor z ,**
Specific isobaric heat capacity c_v ,
Isobaric cubic expansion coefficient α_v ,
Isothermal compressibility κ_T – Continued

t [°C]	z' [–]	z''	c'_v [$\text{kJ kg}^{-1} \text{K}^{-1}$]	c''_v	α'_v [10^{-6} K^{-1}]	α''_v	κ'_T [10^{-6} kPa^{-1}]	κ''_T
60	1.3194×10^{-4}	0.99467	3.9738	1.4802	523.17	3097.5	0.44350	50414
62	1.4394×10^{-4}	0.99434	3.9636	1.4829	535.70	3083.9	0.44458	46002
64	1.5683×10^{-4}	0.99400	3.9533	1.4857	548.05	3070.7	0.44579	42029
66	1.7069×10^{-4}	0.99364	3.9430	1.4885	560.23	3057.8	0.44714	38446
68	1.8556×10^{-4}	0.99326	3.9326	1.4915	572.25	3045.3	0.44862	35212
70	2.0149×10^{-4}	0.99287	3.9223	1.4945	584.13	3033.2	0.45023	32289
72	2.1856×10^{-4}	0.99246	3.9119	1.4976	595.88	3021.5	0.45197	29643
74	2.3681×10^{-4}	0.99203	3.9015	1.5008	607.51	3010.2	0.45383	27246
76	2.5632×10^{-4}	0.99158	3.8912	1.5041	619.01	2999.3	0.45582	25070
78	2.7714×10^{-4}	0.99111	3.8808	1.5074	630.42	2988.7	0.45793	23095
80	2.9936×10^{-4}	0.99062	3.8704	1.5110	641.72	2978.6	0.46017	21298
82	3.2303×10^{-4}	0.99012	3.8601	1.5146	652.93	2968.9	0.46252	19662
84	3.4823×10^{-4}	0.98959	3.8497	1.5183	664.07	2959.6	0.46500	18171
86	3.7504×10^{-4}	0.98904	3.8394	1.5222	675.12	2950.7	0.46760	16810
88	4.0354×10^{-4}	0.98847	3.8291	1.5262	686.11	2942.3	0.47032	15568
90	4.3379×10^{-4}	0.98787	3.8188	1.5304	697.04	2934.3	0.47316	14431
92	4.6589×10^{-4}	0.98726	3.8085	1.5347	707.92	2926.7	0.47612	13391
94	4.9992×10^{-4}	0.98662	3.7983	1.5392	718.75	2919.6	0.47920	12438
96	5.3597×10^{-4}	0.98595	3.7880	1.5439	729.53	2912.9	0.48240	11564
98	5.7413×10^{-4}	0.98526	3.7779	1.5487	740.29	2906.7	0.48572	10761
100	6.1448×10^{-4}	0.98454	3.7677	1.5537	751.01	2901.0	0.48917	10023
105	7.2561×10^{-4}	0.98264	3.7424	1.5671	777.74	2888.7	0.49832	8426.2
110	8.5262×10^{-4}	0.98057	3.7174	1.5817	804.42	2879.6	0.50826	7122.2
115	9.9714×10^{-4}	0.97831	3.6926	1.5977	831.13	2873.6	0.51901	6051.8
120	0.00116	0.97587	3.6680	1.6152	857.98	2870.9	0.53060	5168.3
125	0.00135	0.97324	3.6437	1.6342	885.03	2871.5	0.54306	4435.3
130	0.00155	0.97040	3.6197	1.6546	912.38	2875.6	0.55644	3824.1
135	0.00179	0.96735	3.5959	1.6766	940.10	2883.1	0.57078	3312.1
140	0.00205	0.96408	3.5725	1.7001	968.29	2894.2	0.58615	2881.1
145	0.00234	0.96059	3.5493	1.7250	997.03	2908.9	0.60260	2516.8
150	0.00266	0.95687	3.5264	1.7512	1026.4	2927.1	0.62021	2207.5
155	0.00301	0.95291	3.5039	1.7787	1056.5	2949.1	0.63905	1943.8
160	0.00341	0.94871	3.4817	1.8073	1087.5	2974.8	0.65923	1718.1
165	0.00384	0.94426	3.4598	1.8369	1119.3	3004.2	0.68084	1524.2
170	0.00432	0.93956	3.4383	1.8674	1152.2	3037.7	0.70399	1357.0
175	0.00484	0.93461	3.4171	1.8989	1186.3	3075.2	0.72882	1212.4
180	0.00540	0.92939	3.3963	1.9311	1221.7	3117.0	0.75547	1086.8
185	0.00603	0.92390	3.3759	1.9641	1258.4	3163.3	0.78410	977.46
190	0.00670	0.91813	3.3558	1.9978	1296.8	3214.4	0.81490	881.93
195	0.00744	0.91208	3.3362	2.0324	1336.8	3270.6	0.84806	798.24

Table 6 Saturation state: Compression factor z , Specific isobaric heat capacity c_v , Isobaric cubic expansion coefficient α_v , Isothermal compressibility κ_T – Continued

t [°C]	z'	z''	c_v' [kJ kg ⁻¹ K ⁻¹]	c_v''	α_v' [10 ⁻⁶ K ⁻¹]	α_v''	κ_T' [10 ⁻⁶ kPa ⁻¹]	κ_T''
200	0.00823	0.90575	3.3170	2.0677	1378.8	3332.3	0.88383	724.72
205	0.00910	0.89912	3.2982	2.1038	1422.8	3399.9	0.92245	659.96
210	0.01003	0.89218	3.2799	2.1407	1469.2	3473.9	0.96422	602.78
215	0.01104	0.88494	3.2621	2.1785	1518.0	3554.8	1.0095	552.17
220	0.01213	0.87738	3.2447	2.2171	1569.7	3643.1	1.0586	507.27
225	0.01330	0.86949	3.2278	2.2565	1624.4	3739.5	1.1121	467.37
230	0.01456	0.86126	3.2114	2.2967	1682.6	3844.7	1.1704	431.84
235	0.01592	0.85269	3.1956	2.3377	1744.6	3959.5	1.2341	400.14
240	0.01737	0.84376	3.1802	2.3795	1810.8	4084.9	1.3039	371.82
245	0.01894	0.83446	3.1655	2.4220	1881.8	4221.9	1.3807	346.49
250	0.02061	0.82478	3.1513	2.4653	1958.2	4371.9	1.4653	323.81
255	0.02241	0.81471	3.1378	2.5093	2040.7	4536.3	1.5591	303.49
260	0.02433	0.80423	3.1249	2.5543	2130.1	4717.0	1.6634	285.29
265	0.02640	0.79332	3.1127	2.6003	2227.4	4916.4	1.7798	268.98
270	0.02860	0.78198	3.1012	2.6476	2333.8	5137.2	1.9106	254.40
275	0.03097	0.77017	3.0906	2.6964	2450.8	5382.9	2.0583	241.39
280	0.03350	0.75788	3.0809	2.7470	2580.3	5657.6	2.2262	229.82
285	0.03621	0.74508	3.0722	2.7998	2724.3	5966.4	2.4182	219.58
290	0.03912	0.73174	3.0645	2.8549	2885.7	6315.5	2.6396	210.61
295	0.04224	0.71782	3.0579	2.9124	3067.7	6712.6	2.8966	202.82
300	0.04559	0.70329	3.0525	2.9724	3274.5	7166.8	3.1973	196.19
305	0.04919	0.68809	3.0481	3.0347	3511.4	7690.0	3.5520	190.67
310	0.05307	0.67217	3.0447	3.0990	3785.1	8297.5	3.9744	186.29
315	0.05726	0.65547	3.0425	3.1652	4104.6	9010.3	4.4833	183.09
320	0.06179	0.63790	3.0418	3.2332	4482.9	9858.2	5.1060	181.16
325	0.06671	0.61936	3.0437	3.3038	4939.2	10885	5.8851	180.70
330	0.07208	0.59971	3.0499	3.3780	5504.0	12157	6.8895	181.99
335	0.07797	0.57879	3.0629	3.4575	6226.5	13774	8.2330	185.49
340	0.08449	0.55638	3.0851	3.5435	7185.6	15888	10.103	191.91
345	0.09176	0.53217	3.1162	3.6349	8504.5	18732	12.796	202.25
350	0.10001	0.50581	3.1513	3.7257	10365	22660	16.759	218.02
355	0.10956	0.47672	3.2092	3.8564	13414	28945	23.624	245.57
360	0.12102	0.44364	3.2884	4.0060	18809	39736	36.627	294.64
365	0.13566	0.40411	3.4148	4.1910	30979	62943	68.346	401.37
370	0.15753	0.35065	3.6617	4.4328	79652	148007	208.76	783.27
371	0.16406	0.33607	3.7474	4.4926	112324	201421	308.40	1016.8
372	0.17240	0.31838	3.8625	4.5582	183758	312832	533.26	1494.9
373	0.18480	0.29414	4.0389	4.6282	435715	679124	1360.1	3022.4
373.946 ^a	0.22944		— ^b		— ^b		— ^b	

^aCritical temperature.

^bIn the near-critical region, the values for c_v , α_v , and κ_T calculated from IAPWS-IF97 are not accurate enough.

Table 7 Compression factor z

For the single-phase region, this table contains values for the

- Compression factor (real-gas factor) $z = pv/(RT) = p/(\rho RT)$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given values of p and t , the needed specific volume v was determined from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the needed density ρ was determined by iterating this equation.

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the compression factor for temperatures above 800°C up to 2000°C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

Table 7 Compression factor z [-]^a

<i>t</i> [°C]	<i>p</i> [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	4.8494×10^{-6}	7.9340×10^{-6}	7.9340×10^{-5}	7.9336×10^{-4}	0.0015866	0.0031730	0.0047590	0.0063446	0.0079300	0.015852
5	0.99952	7.7904×10^{-6}	7.7904×10^{-5}	7.7900×10^{-4}	0.0015579	0.0031156	0.0046729	0.0062299	0.0077866	0.015566
10	0.99958	0.99930	7.6548×10^{-5}	7.6545×10^{-4}	0.0015308	0.0030614	0.0045916	0.0061216	0.0076512	0.015295
15	0.99963	0.99938	7.5265×10^{-5}	7.5262×10^{-4}	0.0015052	0.0030101	0.0045147	0.0060190	0.0075230	0.015039
20	0.99967	0.99945	7.4048×10^{-5}	7.4045×10^{-4}	0.0014808	0.0029614	0.0044417	0.0059217	0.0074014	0.014796
25	0.99970	0.99951	7.2890×10^{-5}	7.2888×10^{-4}	0.0014577	0.0029151	0.0043723	0.0058292	0.0072858	0.014565
30	0.99973	0.99955	7.1789×10^{-5}	7.1786×10^{-4}	0.0014357	0.0028710	0.0043062	0.0057411	0.0071757	0.014345
35	0.99975	0.99960	7.0739×10^{-5}	7.0736×10^{-4}	0.0014147	0.0028291	0.0042432	0.0056571	0.0070708	0.014135
40	0.99977	0.99963	6.9736×10^{-5}	6.9734×10^{-4}	0.0013946	0.0027890	0.0041831	0.0055770	0.0069706	0.013935
45	0.99979	0.99966	6.8779×10^{-5}	6.8776×10^{-4}	0.0013755	0.0027507	0.0041257	0.0055004	0.0068749	0.013744
50	0.99981	0.99969	0.99686	6.7861×10^{-4}	0.0013572	0.0027141	0.0040708	0.0054272	0.0067834	0.013561
60	0.99984	0.99974	0.99737	6.6148×10^{-4}	0.0013229	0.0026456	0.0039680	0.0052902	0.0066122	0.013219
70	0.99986	0.99978	0.99776	6.4577×10^{-4}	0.0012915	0.0025827	0.0038738	0.0051646	0.0064551	0.012904
80	0.99988	0.99981	0.99807	6.3134×10^{-4}	0.0012626	0.0025250	0.0037872	0.0050491	0.0063108	0.012616
90	0.99990	0.99983	0.99833	6.1808×10^{-4}	0.0012361	0.0024720	0.0037076	0.0049430	0.0061782	0.012351
100	0.99991	0.99985	0.99854	0.98477	<u>0.0012117</u>	<u>0.0024232</u>	0.0036345	0.0048455	0.0060562	0.012107
125	0.99993	0.99989	0.99893	0.98898	<u>0.97722</u>	<u>0.0023179</u>	0.0034765	0.0046349	0.0057930	0.011580
150	0.99995	0.99992	0.99919	0.99169	0.98302	<u>0.96447</u>	<u>0.0033501</u>	<u>0.0044662</u>	0.0055821	0.011157
175	0.99996	0.99994	0.99936	0.99355	0.98689	0.97298	0.95819	0.94237	<u>0.0054180</u>	0.010828
200	0.99997	0.99995	0.99949	0.99486	0.98962	0.97878	0.96748	0.95569	<u>0.94337</u>	<u>0.010588</u>
225	0.99997	0.99996	0.99959	0.99583	0.99161	0.98295	0.97403	0.96483	0.95534	0.90296
250	0.99998	0.99997	0.99966	0.99657	0.99310	0.98605	0.97884	0.97147	0.96393	0.92346
275	0.99998	0.99997	0.99972	0.99714	0.99426	0.98843	0.98250	0.97647	0.97034	0.93804
300	0.99999	0.99998	0.99976	0.99759	0.99517	0.99028	0.98534	0.98033	0.97526	0.94888
325	0.99999	0.99998	0.99980	0.99796	0.99590	0.99177	0.98760	0.98338	0.97913	0.95722
350	0.99999	0.99998	0.99983	0.99825	0.99650	0.99297	0.98942	0.98584	0.98224	0.96380
375	0.99999	0.99998	0.99985	0.99850	0.99699	0.99396	0.99092	0.98785	0.98477	0.96909
400	0.99999	0.99999	0.99987	0.99870	0.99740	0.99478	0.99215	0.98951	0.98686	0.97341
425	0.99999	0.99999	0.99989	0.99887	0.99774	0.99547	0.99319	0.99090	0.98861	0.97699
450	0.99999	0.99999	0.99990	0.99901	0.99803	0.99605	0.99406	0.99207	0.99007	0.97999
475	0.99999	0.99999	0.99991	0.99914	0.99827	0.99654	0.99480	0.99306	0.99132	0.98252
500	1.0000	0.99999	0.99992	0.99924	0.99848	0.99696	0.99544	0.99391	0.99238	0.98468
525	1.0000	0.99999	0.99993	0.99933	0.99866	0.99733	0.99598	0.99464	0.99329	0.98652
550	1.0000	0.99999	0.99994	0.99941	0.99882	0.99764	0.99645	0.99527	0.99408	0.98811
575	1.0000	0.99999	0.99995	0.99948	0.99896	0.99791	0.99686	0.99581	0.99476	0.98949
600	1.0000	1.0000	0.99995	0.99954	0.99907	0.99815	0.99722	0.99629	0.99536	0.99069
625	1.0000	1.0000	0.99996	0.99959	0.99918	0.99835	0.99753	0.99670	0.99588	0.99174
650	1.0000	1.0000	0.99996	0.99963	0.99927	0.99854	0.99780	0.99707	0.99634	0.99265
675	1.0000	1.0000	0.99997	0.99967	0.99935	0.99870	0.99804	0.99739	0.99674	0.99346
700	1.0000	1.0000	0.99997	0.99971	0.99942	0.99884	0.99826	0.99768	0.99709	0.99418
725	1.0000	1.0000	0.99997	0.99974	0.99948	0.99897	0.99845	0.99793	0.99741	0.99482
750	1.0000	1.0000	0.99998	0.99977	0.99954	0.99908	0.99862	0.99815	0.99769	0.99538
775	1.0000	1.0000	0.99998	0.99979	0.99959	0.99918	0.99877	0.99836	0.99794	0.99589
800	1.0000	1.0000	0.99998	0.99982	0.99963	0.99927	0.99890	0.99854	0.99817	0.99634

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 7 Compression factor z [-]^a – Continued

t [°C]	p [bar]									
	40	60	80	100	120	140	160	180	200	220
0	0.031672	0.047460	0.063217	0.078943	0.094638	0.11030	0.12594	0.14154	0.15712	0.17266
5	0.031101	0.046606	0.062081	0.077527	0.092944	0.10833	0.12369	0.13902	0.15432	0.16960
10	0.030561	0.045799	0.061008	0.076188	0.091341	0.10647	0.12156	0.13663	0.15168	0.16669
15	0.030050	0.045034	0.059990	0.074919	0.089821	0.10470	0.11955	0.13437	0.14917	0.16394
20	0.029565	0.044308	0.059024	0.073714	0.088377	0.10302	0.11763	0.13222	0.14678	0.16131
25	0.029104	0.043617	0.058104	0.072566	0.087003	0.10141	0.11580	0.13016	0.14450	0.15882
30	0.028665	0.042959	0.057228	0.071473	0.085693	0.099889	0.11406	0.12821	0.14233	0.15643
35	0.028246	0.042331	0.056393	0.070430	0.084443	0.098432	0.11240	0.12634	0.14026	0.15415
40	0.027846	0.041732	0.055595	0.069433	0.083249	0.097040	0.11081	0.12455	0.13828	0.15198
45	0.027464	0.041160	0.054832	0.068481	0.082107	0.095710	0.10929	0.12285	0.13638	0.14989
50	0.027098	0.040612	0.054102	0.067570	0.081014	0.094436	0.10784	0.12121	0.13457	0.14790
60	0.026414	0.039586	0.052735	0.065862	0.078966	0.092048	0.10511	0.11815	0.13116	0.14416
70	0.025786	0.038644	0.051480	0.064294	0.077085	0.089855	0.10260	0.11533	0.12803	0.14072
80	0.025209	0.037779	0.050326	0.062852	0.075355	0.087836	0.10030	0.11273	0.12515	0.13755
90	0.024678	0.036983	0.049264	0.061524	0.073761	0.085976	0.098170	0.11034	0.12249	0.13462
100	0.024190	0.036250	0.048287	0.060301	0.072293	0.084263	0.096210	0.10814	0.12004	0.13192
125	0.023134	0.034665	0.046171	0.057653	0.069111	0.080547	0.091959	0.10335	0.11472	0.12606
150	0.022287	0.033390	0.044467	0.055517	0.066542	0.077542	0.088516	0.099466	0.11039	0.12129
175	0.021625	0.032392	0.043128	0.053835	0.064514	0.075164	0.085786	0.096381	0.10695	0.11749
200	0.021139	0.031654	0.042134	0.052579	0.062991	0.073370	0.083717	0.094032	0.10432	0.11457
225	0.020834	0.031183	0.041489	0.051753	0.061976	0.072160	0.082305	0.092412	0.10248	0.11252
250	0.020736	0.031015	0.041237	0.051405	0.061521	0.071586	0.081604	0.091575	0.10150	0.11138
275	0.86337	0.031244	0.041491	0.051662	0.061763	0.071796	0.081765	0.091673	0.10152	0.11132
300	0.89017	0.82090	0.73431	0.052851	0.063046	0.073142	0.083147	0.093067	0.10291	0.11268
325	0.90970	0.85609	0.79429	0.72009	0.62239	0.076670	0.086751	0.096711	0.10656	0.11632
350	0.92453	0.88151	0.83387	0.78033	0.71861	0.64410	0.54329	0.10658	0.11578	0.12506
375	0.93615	0.90078	0.86258	0.82106	0.77552	0.72488	0.66736	0.59950	0.51316	0.36029
400	0.94544	0.91587	0.88446	0.85102	0.81529	0.77693	0.73548	0.69031	0.64051	0.58457
425	0.95303	0.92797	0.90169	0.87410	0.84510	0.81457	0.78238	0.74835	0.71231	0.67402
450	0.95930	0.93785	0.91558	0.89243	0.86836	0.84334	0.81734	0.79033	0.76225	0.73309
475	0.96455	0.94605	0.92697	0.90730	0.88701	0.86611	0.84460	0.82247	0.79975	0.77643
500	0.96899	0.95292	0.93645	0.91957	0.90227	0.88457	0.86647	0.84798	0.82913	0.80995
525	0.97277	0.95875	0.94444	0.92984	0.91496	0.89980	0.88438	0.86872	0.85284	0.83676
550	0.97602	0.96373	0.95123	0.93853	0.92564	0.91256	0.89931	0.88590	0.87236	0.85870
575	0.97883	0.96801	0.95705	0.94595	0.93472	0.92336	0.91189	0.90033	0.88868	0.87697
600	0.98126	0.97172	0.96208	0.95234	0.94251	0.93260	0.92261	0.91258	0.90249	0.89238
625	0.98338	0.97495	0.96645	0.95787	0.94924	0.94056	0.93183	0.92308	0.91430	0.90552
650	0.98524	0.97778	0.97026	0.96269	0.95509	0.94746	0.93981	0.93215	0.92448	0.91683
675	0.98688	0.98026	0.97360	0.96692	0.96021	0.95349	0.94676	0.94004	0.93332	0.92662
700	0.98833	0.98245	0.97655	0.97063	0.96471	0.95878	0.95285	0.94694	0.94104	0.93517
725	0.98961	0.98439	0.97915	0.97392	0.96868	0.96344	0.95822	0.95301	0.94782	0.94266
750	0.99075	0.98611	0.98147	0.97683	0.97219	0.96757	0.96296	0.95837	0.95381	0.94927
775	0.99177	0.98765	0.98353	0.97942	0.97532	0.97124	0.96717	0.96313	0.95911	0.95512
800	0.99268	0.98902	0.98538	0.98174	0.97812	0.97451	0.97092	0.96736	0.96383	0.96032

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 7 Compression factor z [-] – Continued

t [°C]	p [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	0.18818	0.20367	0.21913	0.23456	0.31131	0.38739	0.46284	0.53769	0.61196	0.75888
5	0.18484	0.20006	0.21526	0.23042	0.30586	0.38066	0.45485	0.52847	0.60153	0.74609
10	0.18168	0.19665	0.21159	0.22650	0.30068	0.37426	0.44725	0.51968	0.59158	0.73386
15	0.17868	0.19340	0.20810	0.22277	0.29576	0.36816	0.43999	0.51129	0.58207	0.72216
20	0.17583	0.19032	0.20478	0.21922	0.29107	0.36234	0.43307	0.50327	0.57298	0.71095
25	0.17311	0.18737	0.20161	0.21583	0.28659	0.35678	0.42645	0.49560	0.56427	0.70021
30	0.17051	0.18456	0.19859	0.21260	0.28231	0.35147	0.42011	0.48826	0.55593	0.68990
35	0.16803	0.18188	0.19571	0.20951	0.27821	0.34638	0.41405	0.48122	0.54793	0.68001
40	0.16566	0.17931	0.19294	0.20656	0.27429	0.34151	0.40823	0.47447	0.54025	0.67051
45	0.16339	0.17685	0.19030	0.20373	0.27054	0.33684	0.40265	0.46800	0.53289	0.66137
50	0.16121	0.17450	0.18777	0.20102	0.26694	0.33236	0.39730	0.46178	0.52581	0.65259
60	0.15713	0.17008	0.18302	0.19593	0.26018	0.32394	0.38723	0.45006	0.51246	0.63602
70	0.15338	0.16602	0.17864	0.19124	0.25394	0.31616	0.37792	0.43923	0.50011	0.62066
80	0.14992	0.16227	0.17461	0.18692	0.24819	0.30898	0.36931	0.42919	0.48866	0.60639
90	0.14673	0.15882	0.17089	0.18293	0.24287	0.30233	0.36133	0.41989	0.47804	0.59314
100	0.14379	0.15563	0.16745	0.17925	0.23795	0.29617	0.35394	0.41126	0.46817	0.58080
125	0.13738	0.14868	0.15996	0.17122	0.22721	0.28269	0.33771	0.39229	0.44644	0.55354
150	0.13217	0.14303	0.15386	0.16467	0.21839	0.27159	0.32429	0.37653	0.42833	0.53070
175	0.12801	0.13850	0.14896	0.15940	0.21124	0.26252	0.31326	0.36352	0.41331	0.51160
200	0.12480	0.13499	0.14516	0.15530	0.20560	0.25527	0.30436	0.35292	0.40098	0.49574
225	0.12252	0.13249	0.14242	0.15232	0.20137	0.24972	0.29741	0.34453	0.39110	0.48277
250	0.12122	0.13102	0.14078	0.15051	0.19858	0.24583	0.29235	0.33822	0.38349	0.47245
275	0.12106	0.13075	0.14039	0.14999	0.19731	0.24367	0.28919	0.33397	0.37810	0.46462
300	0.12237	0.13201	0.14158	0.15109	0.19784	0.24344	0.28807	0.33188	0.37496	0.45924
325	0.12598	0.13557	0.14507	0.15450	0.20069	0.24555	0.28931	0.33216	0.37423	0.45636
350	0.13434	0.14360	0.15282	0.16199	0.20701	0.25077	0.29347	0.33524	0.37620	0.45611
375	0.16524	0.16709	0.17275	0.17970	0.21948	0.26069	0.30155	0.34178	0.38136	0.45872
400	0.51999	0.44243	0.34739	0.27003	0.24600	0.27857	0.31537	0.35293	0.39046	0.46453
425	0.63325	0.58969	0.54306	0.49349	0.31500	0.31169	0.33811	0.37045	0.40458	0.47401
450	0.70282	0.67146	0.63904	0.60567	0.44257	0.37265	0.37477	0.39684	0.42520	0.48783
475	0.75256	0.72816	0.70329	0.67803	0.55174	0.45939	0.42922	0.43446	0.45371	0.50659
500	0.79047	0.77072	0.75076	0.73063	0.63054	0.54500	0.49630	0.48316	0.49055	0.53057
525	0.82051	0.80413	0.78766	0.77112	0.68949	0.61643	0.56395	0.53841	0.53418	0.55945
550	0.84495	0.83114	0.81730	0.80345	0.73548	0.67365	0.62460	0.59389	0.58121	0.59221
575	0.86522	0.85344	0.84167	0.82992	0.77247	0.71992	0.67626	0.64511	0.62800	0.62733
600	0.88226	0.87213	0.86203	0.85197	0.80292	0.75793	0.71967	0.69046	0.67173	0.66312
625	0.89675	0.88799	0.87927	0.87059	0.82841	0.78966	0.75625	0.72978	0.71129	0.69812
650	0.90919	0.90158	0.89400	0.88648	0.85001	0.81649	0.78734	0.76371	0.74638	0.73100
675	0.91995	0.91331	0.90671	0.90016	0.86849	0.83941	0.81397	0.79305	0.77728	0.76159
700	0.92932	0.92351	0.91775	0.91203	0.88446	0.85916	0.83696	0.81854	0.80442	0.78955
725	0.93753	0.93244	0.92740	0.92240	0.89833	0.87630	0.85694	0.84080	0.82828	0.81470
750	0.94477	0.94030	0.93588	0.93150	0.91048	0.89128	0.87442	0.86032	0.84934	0.83717
775	0.95116	0.94724	0.94337	0.93953	0.92116	0.90444	0.88978	0.87753	0.86798	0.85727
800	0.95685	0.95341	0.95001	0.94665	0.93060	0.91605	0.90333	0.89276	0.88453	0.87535

Table 8 Specific isochoric heat capacity c_v

For the single-phase region, this table contains values for the

- Specific isochoric heat capacity c_v

for temperatures from 0 °C to 800 °C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given values of p and t , the specific isochoric heat capacity c_v was calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities of Eq. (2.11), was calculated by iterating this equation. With these (ρ, t) values, c_v was determined from Eq. (2.11).

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the specific isochoric heat capacity for temperatures above 800 °C up to 2000 °C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

Table 8 Specific isochoric heat capacity c_v [kJ kg⁻¹ K⁻¹]^a

t [°C]	p [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	4.2174	4.2174	4.2174	4.2170	4.2165	4.2156	4.2146	4.2137	4.2127	4.2081
5	4.2118	4.2052	4.2052	4.2048	4.2044	4.2035	4.2026	4.2018	4.2009	4.1966
10	4.2077	4.186	4.186	4.1912	4.1908	4.1904	4.1896	4.1888	4.1880	4.1872
15	4.2063	4.124	4.124	4.1754	4.1750	4.1747	4.1739	4.1731	4.1724	4.1716
20	4.2062	4.100	4.100	4.1578	4.1574	4.1571	4.1564	4.1557	4.1549	4.1542
25	4.2066	4.093	4.1385	4.1382	4.1379	4.1372	4.1365	4.1358	4.1352	4.1318
30	4.2073	4.095	4.1178	4.1175	4.1172	4.1165	4.1159	4.1153	4.1146	4.1115
35	4.2082	4.100	4.0958	4.0955	4.0952	4.0946	4.0940	4.0934	4.0928	4.0898
40	4.2093	4.108	4.0728	4.0725	4.0722	4.0717	4.0711	4.0705	4.0699	4.0671
45	4.2104	4.117	4.0489	4.0486	4.0484	4.0478	4.0473	4.0468	4.0462	4.0435
50	4.2117	4.129	4.4510	4.0241	4.0239	4.0233	4.0228	4.0223	4.0218	4.0193
60	4.2145	4.154	4.4397	3.9736	3.9734	3.9730	3.9725	3.9720	3.9716	3.9693
70	4.2176	4.184	4.4366	3.9221	3.9219	3.9215	3.9211	3.9207	3.9203	3.9183
80	4.2211	4.217	4.4361	3.8703	3.8701	3.8698	3.8694	3.8690	3.8687	3.8669
90	4.2248	4.253	4.4371	3.8187	3.8186	3.8182	3.8179	3.8176	3.8173	3.8156
100	4.2288	4.293	4.4389	1.5514	3.7676	3.7673	3.7670	3.7667	3.7664	3.7649
125	4.2399	4.401	4.4461	1.5100	1.5962	3.6435	3.6433	3.6431	3.6429	3.6417
150	4.2452	4.452	4.4561	1.4969	1.5467	1.6742	3.5263	3.5261	3.5260	3.5250
175	4.2465	4.4652	4.4678	1.4949	1.5274	1.6001	1.6879	1.8129	3.4170	3.4162
200	4.2478	4.4788	4.4806	1.4992	1.5213	1.5696	1.6235	1.6837	1.7526	3.3167
225	4.2493	4.4931	4.4943	1.5075	1.5229	1.5563	1.5929	1.6327	1.6757	1.9604
250	4.2507	4.5077	4.5086	1.5183	1.5294	1.5533	1.5790	1.6067	1.6362	1.8113
275	4.2522	4.5227	4.5234	1.5307	1.5390	1.5566	1.5753	1.5951	1.6161	1.7376
300	4.2538	4.5380	4.5386	1.5442	1.5506	1.5639	1.5780	1.5927	1.6081	1.6955
325	4.2553	4.5536	4.5541	1.5585	1.5636	1.5740	1.5849	1.5961	1.6078	1.6727
350	4.2569	4.5695	4.5699	1.5735	1.5776	1.5859	1.5945	1.6034	1.6126	1.6622
375	4.2585	4.5856	4.5859	1.5889	1.5923	1.5991	1.6062	1.6133	1.6207	1.6598
400	4.2601	4.6019	4.6022	1.6047	1.6076	1.6133	1.6191	1.6251	1.6311	1.6627
425	4.2618	4.6185	4.6187	1.6209	1.6233	1.6282	1.6331	1.6381	1.6432	1.6693
450	4.2635	4.6353	4.6354	1.6373	1.6394	1.6436	1.6478	1.6521	1.6564	1.6785
475	4.2652	4.6522	4.6524	1.6540	1.6558	1.6595	1.6632	1.6669	1.6706	1.6895
500	4.2669	4.6694	4.6695	1.6709	1.6725	1.6758	1.6790	1.6822	1.6854	1.7019
525	4.2687	4.6867	4.6868	1.6881	1.6895	1.6923	1.6951	1.6980	1.7008	1.7152
550	4.2704	4.7041	4.7042	1.7053	1.7066	1.7091	1.7116	1.7141	1.7167	1.7293
575	4.2721	4.7216	4.7217	1.7227	1.7239	1.7261	1.7283	1.7306	1.7328	1.7440
600	4.2739	4.7393	4.7393	1.7402	1.7412	1.7432	1.7452	1.7472	1.7492	1.7592
625	4.2756	4.7569	4.7570	1.7578	1.7587	1.7605	1.7623	1.7641	1.7659	1.7748
650	4.2774	4.7747	4.7747	1.7754	1.7762	1.7779	1.7795	1.7811	1.7827	1.7906
675	4.2792	4.7924	4.7924	1.7931	1.7938	1.7952	1.7967	1.7981	1.7995	1.8067
700	4.2810	4.8101	4.8102	1.8107	1.8114	1.8127	1.8140	1.8152	1.8165	1.8229
725	4.2827	4.8278	4.8278	1.8284	1.8289	1.8301	1.8313	1.8324	1.8336	1.8393
750	4.2845	4.8455	4.8455	1.8460	1.8465	1.8475	1.8486	1.8496	1.8506	1.8558
775	4.2863	4.8631	4.8632	1.8636	1.8640	1.8650	1.8659	1.8668	1.8677	1.8723
800	4.2880	4.8808	4.8808	1.8812	1.8816	1.8824	1.8832	1.8841	1.8849	1.8890

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 8 Specific isochoric heat capacity c_v [kJ kg⁻¹ K⁻¹]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	40	60	80	100	120	140	160	180	200	220
0	4.1988	4.1897	4.1806	4.1717	4.1630	4.1543	4.1458	4.1373	4.1290	4.1208
5	4.1880	4.1796	4.1713	4.1630	4.1549	4.1469	4.1390	4.1312	4.1235	4.1159
10	4.1752	4.1674	4.1596	4.1519	4.1444	4.1369	4.1295	4.1223	4.1151	4.1080
15	4.1604	4.1530	4.1458	4.1386	4.1315	4.1245	4.1175	4.1107	4.1039	4.0973
20	4.1437	4.1367	4.1299	4.1231	4.1164	4.1098	4.1033	4.0968	4.0904	4.0841
25	4.1252	4.1186	4.1122	4.1058	4.0994	4.0932	4.0870	4.0809	4.0748	4.0689
30	4.1052	4.0990	4.0929	4.0868	4.0808	4.0749	4.0690	4.0632	4.0575	4.0518
35	4.0839	4.0780	4.0722	4.0665	4.0608	4.0552	4.0496	4.0441	4.0387	4.0333
40	4.0615	4.0560	4.0505	4.0450	4.0396	4.0343	4.0290	4.0238	4.0186	4.0134
45	4.0382	4.0330	4.0278	4.0226	4.0175	4.0124	4.0074	4.0024	3.9975	3.9926
50	4.0143	4.0093	4.0043	3.9994	3.9946	3.9898	3.9850	3.9803	3.9756	3.9709
60	3.9648	3.9603	3.9559	3.9515	3.9471	3.9428	3.9385	3.9342	3.9300	3.9258
70	3.9142	3.9102	3.9062	3.9023	3.8984	3.8944	3.8906	3.8867	3.8829	3.8791
80	3.8632	3.8597	3.8561	3.8525	3.8490	3.8455	3.8420	3.8385	3.8351	3.8316
90	3.8124	3.8092	3.8060	3.8028	3.7996	3.7964	3.7933	3.7901	3.7870	3.7839
100	3.7620	3.7591	3.7562	3.7533	3.7505	3.7476	3.7448	3.7420	3.7391	3.7363
125	3.6395	3.6372	3.6349	3.6327	3.6305	3.6282	3.6260	3.6238	3.6216	3.6194
150	3.5232	3.5214	3.5196	3.5178	3.5160	3.5142	3.5124	3.5107	3.5089	3.5072
175	3.4146	3.4130	3.4115	3.4100	3.4085	3.4070	3.4055	3.4040	3.4026	3.4012
200	3.3151	3.3137	3.3122	3.3108	3.3095	3.3081	3.3068	3.3056	3.3043	3.3031
225	3.2267	3.2252	3.2237	3.2223	3.2209	3.2196	3.2183	3.2171	3.2159	3.2148
250	<u>3.1513</u>	3.1496	3.1480	3.1464	3.1449	3.1434	3.1420	3.1407	3.1395	3.1383
275	2.0722	<u>3.0905</u>	<u>3.0883</u>	3.0861	3.0841	3.0821	3.0803	3.0786	3.0770	3.0755
300	1.9201	<u>2.2326</u>	<u>2.7311</u>	<u>3.0496</u>	<u>3.0454</u>	3.0414	3.0377	3.0344	3.0315	3.0289
325	1.8331	2.0365	2.3005	2.6626	3.2776	<u>3.0361</u>	<u>3.0288</u>	3.0206	3.0121	3.0044
350	1.7809	1.9251	2.0975	2.3073	2.5702	2.9123	3.4616	<u>3.0957</u>	3.0508	3.0276
375	1.7502	1.8570	1.9798	2.1202	2.2819	2.4702	2.6950	2.9707	3.3234	4.1702
400	1.7337	1.8152	1.9068	2.0085	2.1208	2.2447	2.3812	2.5318	2.7010	2.8942
425	1.7265	1.7904	1.8610	1.9380	2.0211	2.1105	2.2062	2.3081	2.4158	2.5285
450	1.7257	1.7771	1.8329	1.8929	1.9568	2.0245	2.0958	2.1706	2.2488	2.3297
475	1.7292	1.7715	1.8167	1.8646	1.9151	1.9680	2.0231	2.0803	2.1394	2.2002
500	1.7358	1.7713	1.8086	1.8477	1.8885	1.9309	1.9746	2.0196	2.0657	2.1128
525	1.7446	1.7749	1.8063	1.8389	1.8725	1.9071	1.9427	1.9790	2.0159	2.0534
550	1.7550	1.7812	1.8081	1.8356	1.8639	1.8927	1.9221	1.9521	1.9824	2.0130
575	1.7667	1.7896	1.8128	1.8364	1.8605	1.8849	1.9097	1.9348	1.9602	1.9857
600	1.7793	1.7994	1.8197	1.8402	1.8610	1.8820	1.9032	1.9246	1.9461	1.9678
625	1.7926	1.8104	1.8283	1.8462	1.8643	1.8826	1.9009	1.9194	1.9379	1.9566
650	1.8065	1.8223	1.8381	1.8540	1.8699	1.8858	1.9018	1.9179	1.9341	1.9503
675	1.8209	1.8350	1.8490	1.8630	1.8771	1.8911	1.9052	1.9194	1.9336	1.9478
700	1.8356	1.8482	1.8607	1.8732	1.8857	1.8981	1.9106	1.9231	1.9356	1.9481
725	1.8507	1.8619	1.8731	1.8842	1.8953	1.9064	1.9175	1.9286	1.9397	1.9508
750	1.8659	1.8760	1.8860	1.8960	1.9059	1.9158	1.9257	1.9356	1.9455	1.9554
775	1.8815	1.8905	1.8995	1.9084	1.9173	1.9262	1.9350	1.9439	1.9527	1.9616
800	1.8972	1.9053	1.9134	1.9214	1.9294	1.9373	1.9453	1.9533	1.9612	1.9692

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 8 Specific isochoric heat capacity c_v [kJ kg⁻¹ K⁻¹] – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	4.1127	4.1048	4.0969	4.0891	4.0518	4.0170	3.9846	3.9543	3.9261	3.8754
5	4.1085	4.1011	4.0938	4.0866	4.0519	4.0195	3.9892	3.9607	3.9341	3.8858
10	4.1010	4.0941	4.0872	4.0805	4.0480	4.0175	3.9889	3.9620	3.9367	3.8904
15	4.0907	4.0842	4.0777	4.0714	4.0407	4.0119	3.9847	3.9590	3.9348	3.8903
20	4.0779	4.0717	4.0656	4.0596	4.0306	4.0031	3.9772	3.9526	3.9294	3.8865
25	4.0630	4.0571	4.0513	4.0456	4.0180	3.9918	3.9670	3.9434	3.9211	3.8796
30	4.0462	4.0406	4.0351	4.0297	4.0034	3.9783	3.9546	3.9319	3.9104	3.8704
35	4.0279	4.0226	4.0174	4.0122	3.9871	3.9631	3.9403	3.9186	3.8978	3.8592
40	4.0084	4.0033	3.9983	3.9934	3.9694	3.9465	3.9246	3.9037	3.8837	3.8464
45	3.9878	3.9830	3.9782	3.9735	3.9506	3.9287	3.9077	3.8876	3.8683	3.8323
50	3.9663	3.9618	3.9572	3.9527	3.9309	3.9099	3.8898	3.8705	3.8519	3.8171
60	3.9216	3.9175	3.9134	3.9093	3.8894	3.8702	3.8517	3.8339	3.8167	3.7845
70	3.8753	3.8716	3.8679	3.8642	3.8460	3.8285	3.8115	3.7951	3.7793	3.7495
80	3.8282	3.8248	3.8214	3.8181	3.8016	3.7856	3.7700	3.7550	3.7404	3.7129
90	3.7808	3.7778	3.7747	3.7717	3.7567	3.7420	3.7278	3.7140	3.7006	3.6753
100	3.7335	3.7307	3.7280	3.7252	3.7116	3.6982	3.6852	3.6725	3.6602	3.6370
125	3.6172	3.6150	3.6129	3.6107	3.5999	3.5892	3.5788	3.5685	3.5586	3.5400
150	3.5054	3.5037	3.5019	3.5002	3.4916	3.4831	3.4746	3.4663	3.4583	3.4437
175	3.3998	3.3983	3.3969	3.3956	3.3887	3.3818	3.3750	3.3683	3.3618	3.3504
200	3.3019	3.3007	3.2996	3.2984	3.2929	3.2874	3.2820	3.2766	3.2714	3.2627
225	3.2137	3.2127	3.2116	3.2106	3.2060	3.2018	3.1975	3.1933	3.1891	3.1825
250	3.1372	3.1361	3.1351	3.1341	3.1299	3.1264	3.1230	3.1196	3.1162	3.1113
275	3.0740	3.0727	3.0714	3.0703	3.0655	3.0620	3.0589	3.0559	3.0528	3.0488
300	3.0265	3.0242	3.0221	3.0202	3.0127	3.0078	3.0039	3.0004	2.9970	2.9929
325	2.9979	2.9925	2.9881	2.9843	2.9696	2.9602	2.9540	2.9487	2.9439	2.9384
350	3.0097	2.9916	2.9743	2.9598	2.9281	2.9099	2.8990	2.8915	2.8849	2.8786
375	3.2906	3.1280	3.0543	3.0108	2.9216	2.8877	2.8681	2.8550	2.8461	2.8366
400	3.0987	3.3112	3.5147	3.4045	2.9515	2.8732	2.8378	2.8171	2.8046	2.7950
425	2.6462	2.7700	2.8954	3.0080	3.0409	2.8891	2.8252	2.7906	2.7707	2.7567
450	2.4124	2.4956	2.5783	2.6593	2.9363	2.8936	2.8184	2.7718	2.7445	2.7258
475	2.2625	2.3258	2.3891	2.4515	2.7167	2.8125	2.7851	2.7442	2.7157	2.6958
500	2.1608	2.2094	2.2584	2.3075	2.5330	2.6775	2.7087	2.6955	2.6764	2.6625
525	2.0912	2.1294	2.1678	2.2062	2.3912	2.5334	2.6120	2.6269	2.6253	2.6249
550	2.0437	2.0746	2.1055	2.1363	2.2858	2.4144	2.5000	2.5486	2.5664	2.5841
575	2.0114	2.0370	2.0626	2.0881	2.2112	2.3220	2.4106	2.4681	2.5016	2.5414
600	1.9895	2.0113	2.0330	2.0546	2.1592	2.2544	2.3363	2.4014	2.4482	2.4892
625	1.9753	1.9940	2.0127	2.0313	2.1221	2.2060	2.2798	2.3412	2.3892	2.4613
650	1.9665	1.9828	1.9991	2.0153	2.0949	2.1698	2.2369	2.2939	2.3384	2.3917
675	1.9620	1.9762	1.9905	2.0047	2.0749	2.1415	2.2024	2.2552	2.2980	2.3491
700	1.9607	1.9733	1.9858	1.9984	2.0604	2.1196	2.1740	2.2218	2.2623	2.3233
725	1.9620	1.9731	1.9842	1.9954	2.0505	2.1033	2.1518	2.1946	2.2314	2.2976
750	1.9653	1.9753	1.9852	1.9952	2.0445	2.0921	2.1360	2.1749	2.2086	2.2732
775	1.9705	1.9794	1.9883	1.9972	2.0418	2.0853	2.1263	2.1632	2.1954	2.2544
800	1.9772	1.9853	1.9933	2.0014	2.0420	2.0827	2.1222	2.1590	2.1914	2.2410

Table 9 Isobaric cubic expansion coefficient α_v

For the single-phase region, this table contains values for the

- Isobaric cubic expansion coefficient $\alpha_v = v^{-1}(\partial v / \partial T)_p$

for temperatures from 0 °C to 800 °C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given values of p and t , the isobaric cubic expansion coefficient α_v was calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities of Eq. (2.11), was calculated by iterating this equation. With these (ρ, t) values, α_v was determined from Eq. (2.11).

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the isobaric cubic expansion coefficient for temperatures above 800 °C up to 2000 °C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

The tabulated values of α_v can be used to calculate corresponding partial derivatives of thermodynamic properties as described in Sec. 2.4.4.1 by means of an example.

Table 9 Isobaric cubic expansion coefficient α_v [10^{-6} K^{-1}]^a

<i>t</i> [°C]	<i>p</i> [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	-68,073	-68,071	-68,037	-67,694	-67,313	-66,551	-65,790	-65,031	-64,272	-60,492
5	3608.9	15.989	16.017	16.293	16.600	17.213	17.825	18.436	19.047	22.089
10	3542.1	3551.4	87.910	88.132	88.377	88.869	89.359	89.849	90.339	92.778
15	3478.8	3485.3	150.68	150.86	151.05	151.44	151.83	152.22	152.61	154.55
20	3418.3	3423.3	206.47	206.61	206.76	207.06	207.37	207.67	207.98	209.49
25	3360.1	3364.2	256.81	256.91	257.03	257.26	257.49	257.72	257.95	259.10
30	3304.0	3307.5	302.80	302.88	302.96	303.13	303.30	303.46	303.63	304.47
35	3249.8	3252.9	345.30	345.35	345.40	345.51	345.62	345.74	345.85	346.40
40	3197.5	3200.1	384.92	384.95	384.98	385.04	385.10	385.16	385.22	385.53
45	3146.8	3149.2	422.16	422.17	422.18	422.19	422.21	422.22	422.24	422.32
50	3097.8	3099.9	3153.7	457.41	457.39	457.37	457.34	457.32	457.29	457.17
60	3004.2	3005.9	3045.9	523.13	523.08	522.98	522.88	522.78	522.68	522.19
70	2916.3	2917.6	2949.2	584.08	583.99	583.83	583.66	583.49	583.33	582.50
80	2833.4	2834.5	2860.0	641.66	641.55	641.32	641.09	640.86	640.63	639.50
90	2755.1	2756.0	2776.9	697.00	696.85	696.56	696.27	695.98	695.70	694.26
100	2681.0	2681.8	2699.1	2897.3	750.84	750.49	750.14	749.79	749.44	747.70
125	2512.4	2512.9	2524.1	2645.6	2807.5	884.60	884.08	883.56	883.04	880.48
150	2363.7	2364.1	2371.7	2452.4	2552.7	2800.3	1025.9	1025.2	1024.5	1020.8
175	2231.8	2232.0	2237.4	2293.6	2361.5	2515.5	2699.7	2934.9	1185.8	1180.6
200	2113.8	2113.9	2117.9	2158.5	2206.6	2312.4	2431.8	2566.7	2720.5	1375.4
225	2007.6	2007.8	2010.7	2041.1	2076.5	2152.4	2235.8	2327.1	2427.0	3105.9
250	1911.7	1911.8	1914.0	1937.3	1964.1	2020.7	2081.5	2146.7	2216.5	2649.1
275	1824.4	1824.5	1826.3	1844.6	1865.4	1908.8	1954.6	2003.0	2054.1	2355.3
300	1744.8	1744.9	1746.3	1760.9	1777.4	1811.5	1847.0	1884.1	1922.7	2142.7
325	1671.9	1672.0	1673.1	1684.9	1698.2	1725.5	1753.7	1782.8	1812.9	1979.4
350	1604.8	1604.9	1605.8	1615.5	1626.4	1648.5	1671.3	1694.6	1718.5	1848.3
375	1542.9	1542.9	1543.7	1551.8	1560.7	1579.0	1597.6	1616.6	1636.0	1739.4
400	1485.6	1485.6	1486.3	1493.0	1500.5	1515.7	1531.1	1546.8	1562.7	1646.7
425	1432.4	1432.4	1433.0	1438.6	1444.9	1457.7	1470.6	1483.7	1496.9	1566.1
450	1382.9	1382.9	1383.4	1388.2	1393.5	1404.3	1415.2	1426.2	1437.3	1495.0
475	1336.7	1336.7	1337.1	1341.2	1345.7	1354.9	1364.2	1373.5	1382.9	1431.5
500	1293.4	1293.4	1293.8	1297.3	1301.2	1309.1	1317.0	1325.0	1333.0	1374.2
525	1252.9	1252.9	1253.2	1256.3	1259.6	1266.4	1273.2	1280.1	1287.0	1322.2
550	1214.9	1214.9	1215.1	1217.8	1220.7	1226.5	1232.4	1238.3	1244.3	1274.7
575	1179.1	1179.1	1179.3	1181.6	1184.1	1189.2	1194.3	1199.5	1204.6	1230.9
600	1145.3	1145.3	1145.5	1147.5	1149.7	1154.1	1158.6	1163.1	1167.6	1190.5
625	1113.4	1113.4	1113.6	1115.3	1117.3	1121.2	1125.1	1129.0	1133.0	1152.9
650	1083.3	1083.3	1083.4	1085.0	1086.7	1090.1	1093.5	1097.0	1100.5	1118.0
675	1054.7	1054.7	1054.8	1056.2	1057.7	1060.7	1063.8	1066.8	1069.9	1085.3
700	1027.6	1027.6	1027.7	1028.9	1030.3	1032.9	1035.6	1038.3	1041.0	1054.7
725	1001.9	1001.9	1002.0	1003.0	1004.2	1006.6	1009.0	1011.4	1013.8	1025.9
750	977.38	977.38	977.48	978.43	979.49	981.62	983.75	985.89	988.03	998.82
775	954.07	954.07	954.16	955.01	955.96	957.86	959.77	961.68	963.59	973.23
800	931.84	931.84	931.92	932.69	933.54	935.24	936.95	938.67	940.38	949.02

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 9 Isobaric cubic expansion coefficient α_v [10^{-6} K^{-1}]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	40	60	80	100	120	140	160	180	200	220
0	-53,004	-45,611	-38,310	-31,102	-23,986	-16,962	-10,027	-3,1815	3.5753	10.244
5	28.119	34.075	39.959	45.770	51.511	57.180	62.778	68.307	73.767	79.159
10	97.615	102.40	107.12	111.79	116.41	120.97	125.47	129.93	134.33	138.67
15	158.39	162.19	165.96	169.68	173.36	176.99	180.59	184.15	187.67	191.15
20	212.50	215.47	218.42	221.34	224.22	227.08	229.91	232.71	235.49	238.23
25	261.38	263.65	265.90	268.13	270.33	272.52	274.69	276.84	278.98	281.09
30	306.12	307.77	309.41	311.04	312.66	314.26	315.86	317.44	319.01	320.57
35	347.51	348.61	349.72	350.81	351.91	353.00	354.08	355.16	356.24	357.31
40	386.14	386.76	387.38	388.00	388.63	389.26	389.89	390.52	391.16	391.79
45	422.49	422.67	422.85	423.05	423.25	423.47	423.68	423.91	424.14	424.38
50	456.93	456.70	456.49	456.29	456.11	455.94	455.78	455.64	455.50	455.38
60	521.22	520.27	519.35	518.45	517.57	516.72	515.88	515.07	514.28	513.50
70	580.88	579.28	577.72	576.20	574.70	573.23	571.80	570.39	569.01	567.65
80	637.26	635.07	632.92	630.80	628.73	626.70	624.70	622.74	620.81	618.92
90	691.43	688.66	685.93	683.26	680.63	678.05	675.52	673.02	670.58	668.17
100	744.28	740.92	737.62	734.38	731.20	728.07	725.00	721.99	719.02	716.10
125	875.43	870.47	865.62	860.85	856.18	851.60	847.09	842.68	838.34	834.07
150	1013.7	1006.7	999.87	993.19	986.64	980.24	973.97	967.82	961.80	955.90
175	1170.4	1160.5	1150.8	1141.4	1132.3	1123.4	1114.6	1106.1	1097.8	1089.7
200	1360.5	1346.0	1332.0	1318.5	1305.3	1292.6	1280.2	1268.1	1256.4	1245.1
225	1607.7	1585.5	1564.2	1543.7	1524.0	1505.0	1486.7	1469.0	1452.0	1435.5
250	<u>1957.8</u>	1920.6	1885.4	1852.0	1820.3	1790.2	1761.4	1734.0	1707.7	1682.6
275	3300.4	<u>2449.0</u>	<u>2381.7</u>	2319.6	2262.0	2208.5	2158.5	2111.6	2067.6	2026.2
300	2759.7	<u>3799.6</u>	<u>5952.9</u>	<u>3169.9</u>	<u>3036.9</u>	2919.1	2813.8	2719.1	2633.2	2554.7
325	2413.7	3048.8	4055.4	5893.7	10648	<u>4538.6</u>	<u>4210.7</u>	3940.6	3714.0	3521.3
350	2168.8	2599.5	3198.0	4080.4	5506.7	8232.1	16257	<u>8475.0</u>	6982.1	6067.4
375	1984.4	2294.8	2694.4	3222.1	3946.3	4995.4	6647.8	9648.6	16818	88312
400	1839.2	2072.5	2357.8	2710.8	3155.2	3727.7	4487.0	5531.8	7051.9	9449.8
425	1720.8	1901.7	2114.8	2367.4	2668.9	3032.5	3476.6	4027.0	4719.9	5607.7
450	1621.4	1765.3	1929.9	2118.9	2336.7	2588.5	2881.1	3223.2	3625.9	4102.6
475	1536.3	1653.1	1783.5	1929.8	2093.9	2278.4	2485.8	2719.6	2983.4	3281.8
500	1462.2	1558.4	1664.0	1780.2	1907.9	2048.5	2203.0	2372.8	2559.3	2764.0
525	1396.7	1477.1	1564.0	1658.2	1760.1	1870.4	1989.7	2118.5	2257.3	2406.5
550	1338.3	1406.2	1478.7	1556.3	1639.2	1727.9	1822.5	1923.2	2030.3	2143.9
575	1285.6	1343.5	1404.7	1469.5	1538.1	1610.7	1687.3	1768.0	1852.9	1942.0
600	1237.8	1287.5	1339.7	1394.5	1452.0	1512.2	1575.3	1641.2	1710.0	1781.5
625	1194.1	1237.1	1282.0	1328.7	1377.4	1428.1	1480.8	1535.5	1592.1	1650.6
650	1154.0	1191.4	1230.2	1270.4	1312.1	1355.2	1399.7	1445.6	1492.9	1541.4
675	1117.0	1149.7	1183.5	1218.3	1254.2	1291.2	1329.2	1368.2	1408.1	1448.9
700	1082.6	1111.4	1141.0	1171.4	1202.5	1234.5	1267.2	1300.6	1334.6	1369.3
725	1050.7	1076.1	1102.1	1128.7	1156.0	1183.8	1212.1	1240.9	1270.3	1300.0
750	1020.8	1043.3	1066.3	1089.8	1113.7	1138.1	1162.8	1187.9	1213.3	1239.0
775	992.84	1012.9	1033.3	1054.1	1075.2	1096.6	1118.3	1140.2	1162.4	1184.8
800	966.57	984.45	1002.6	1021.1	1039.8	1058.7	1077.9	1097.2	1116.7	1136.3

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 9 Isobaric cubic expansion coefficient α_v [10^{-6} K^{-1}] – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	16.827	23.323	29.734	36.061	66.466	94.908	121.51	146.40	169.71	212.16
5	84.482	89.738	94.927	100.05	124.70	147.80	169.45	189.74	208.76	243.43
10	142.97	147.21	151.40	155.54	175.50	194.25	211.87	228.41	243.96	272.35
15	194.59	197.99	201.35	204.67	220.72	235.85	250.11	263.54	276.20	299.38
20	240.94	243.63	246.29	248.92	261.66	273.71	285.12	295.91	306.11	324.86
25	283.18	285.25	287.30	289.34	299.22	308.63	317.57	326.07	334.14	349.04
30	322.12	323.66	325.18	326.69	334.08	341.16	347.94	354.42	360.61	372.11
35	358.38	359.44	360.50	361.55	366.72	371.74	376.59	381.27	385.77	394.21
40	392.43	393.07	393.70	394.34	397.52	400.68	403.79	406.84	409.81	415.48
45	424.63	424.88	425.13	425.40	426.77	428.23	429.76	431.32	432.89	436.00
50	455.26	455.16	455.07	454.99	454.70	454.60	454.67	454.85	455.13	455.87
60	512.75	512.01	511.29	510.59	507.32	504.43	501.86	499.56	497.50	493.93
70	566.32	565.02	563.74	562.49	556.57	551.18	546.25	541.73	537.58	530.14
80	617.06	615.24	613.45	611.68	603.31	595.62	588.53	581.97	575.88	564.89
90	665.81	663.48	661.19	658.95	648.24	638.37	629.22	620.74	612.84	598.51
100	713.24	710.42	707.65	704.92	691.93	679.92	668.80	658.45	648.80	631.27
125	829.88	825.77	821.72	817.75	798.83	781.39	765.24	750.24	736.27	710.93
150	950.11	944.44	938.87	933.41	907.54	883.85	862.06	841.94	823.30	789.74
175	1081.8	1074.0	1066.4	1059.0	1024.1	992.49	963.73	937.40	913.21	870.17
200	1234.0	1223.2	1212.7	1202.5	1155.0	1112.7	1074.7	1040.4	1009.2	954.48
225	1419.6	1404.2	1389.2	1374.8	1308.5	1250.9	1200.2	1155.1	1114.6	1045.0
250	1658.6	1635.5	1613.3	1592.0	1496.5	1415.9	1346.8	1286.6	1233.6	1144.4
275	1987.1	1950.1	1915.0	1881.7	1737.1	1620.4	1523.6	1441.8	1371.3	1255.9
300	2482.7	2416.3	2354.7	2297.5	2061.8	1884.2	1744.0	1629.8	1534.5	1383.5
325	3355.2	3209.9	3081.4	2966.4	2531.9	2240.8	2028.1	1863.7	1731.9	1531.8
350	5427.9	4945.1	4565.8	4259.5	3293.4	2754.1	2407.8	2160.9	1973.5	1704.2
375	22964	13135	9787.2	8017.7	4700.2	3556.7	2944.1	2552.0	2275.2	1904.5
400	13615	22211	40478	37835	7963.4	4898.9	3716.9	3069.3	2652.2	2135.5
425	6772.2	8344.6	10509	13441	15069	7186.2	4835.1	3753.6	3124.0	2406.0
450	4669.2	5344.8	6152.2	7117.1	12818	9691.5	6226.8	4579.0	3675.7	2711.8
475	3619.6	4001.8	4433.0	4917.1	8024.4	9203.7	7172.4	5346.4	4223.3	3023.8
500	2988.5	3234.3	3502.8	3794.9	5565.8	7107.8	6877.9	5684.7	4610.6	3294.1
525	2566.7	2738.3	2921.6	3116.7	4248.5	5391.0	5855.7	5438.7	4695.6	3472.3
550	2264.0	2390.7	2523.9	2663.6	3443.8	4257.4	4809.1	4843.0	4481.2	3526.3
575	2035.2	2132.5	2233.8	2338.8	2908.6	3498.8	3978.2	4180.7	4077.6	3457.1
600	1855.8	1932.6	2012.0	2093.7	2527.9	2971.1	3354.7	3593.8	3632.5	3294.9
625	1710.9	1772.9	1836.6	1901.7	2242.9	2586.8	2892.5	3113.1	3211.2	3062.1
650	1591.2	1642.2	1694.2	1747.2	2021.3	2295.0	2541.7	2733.6	2848.1	2821.2
675	1490.6	1533.0	1576.2	1619.9	1844.2	2066.2	2268.1	2432.0	2544.0	2595.8
700	1404.6	1440.4	1476.6	1513.2	1699.4	1882.5	2050.0	2189.5	2291.6	2373.1
725	1330.1	1360.6	1391.4	1422.4	1578.9	1732.0	1872.6	1992.0	2083.0	2168.4
750	1265.0	1291.1	1317.5	1344.0	1477.0	1606.4	1725.8	1828.6	1909.4	1991.7
775	1207.3	1230.0	1252.8	1275.6	1389.6	1499.9	1602.0	1691.1	1762.9	1842.4
800	1155.9	1175.7	1195.5	1215.3	1313.7	1408.3	1495.9	1573.2	1637.2	1716.4

Table 10 Isothermal compressibility κ_T

For the single-phase region, this table contains values for the

- Isothermal compressibility $\kappa_T = -v^{-1}(\partial v / \partial p)_T$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given values of p and t , the isothermal compressibility κ_T was calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities for Eq. (2.11), was calculated by iterating this equation. With these values for (ρ, t) , κ_T was determined from Eq. (2.11).

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the isothermal compressibility for temperatures above 800°C up to 2000°C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

The tabulated values of κ_T can be used to calculate corresponding partial derivatives of thermodynamic properties as described in Sec. 2.4.4.1 by means of an example.

Table 10 Isothermal compressibility κ_T [10^{-6} kPa $^{-1}$]^a

<i>t</i> [°C]	<i>p</i> [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	0.50895	0.50895	0.50894	0.50881	0.50867	0.50838	0.50810	0.50781	0.50753	0.50611
5	1636924	0.49180	0.49179	0.49167	0.49154	0.49127	0.49101	0.49075	0.49048	0.48917
10	1636798	1000752	0.47801	0.47790	0.47778	0.47753	0.47728	0.47703	0.47679	0.47555
15	1636709	1000638	0.46702	0.46691	0.46679	0.46656	0.46632	0.46609	0.46585	0.46468
20	1636641	1000559	0.45835	0.45825	0.45814	0.45791	0.45768	0.45746	0.45723	0.45610
25	1636585	1000498	0.45167	0.45157	0.45146	0.45124	0.45102	0.45080	0.45058	0.44948
30	1636538	1000448	0.44670	0.44660	0.44649	0.44628	0.44606	0.44584	0.44563	0.44455
35	1636496	1000406	0.44323	0.44314	0.44303	0.44281	0.44260	0.44238	0.44217	0.44109
40	1636460	1000369	0.44109	0.44100	0.44089	0.44067	0.44046	0.44024	0.44003	0.43895
45	1636428	1000337	0.44015	0.44005	0.43994	0.43973	0.43951	0.43929	0.43907	0.43799
50	1636400	1000309	100324	0.44020	0.44008	0.43986	0.43964	0.43942	0.43920	0.43810
60	1636352	1000261	100267	0.44341	0.44330	0.44306	0.44283	0.44260	0.44237	0.44122
70	1636314	1000223	100226	0.45014	0.45002	0.44977	0.44953	0.44928	0.44904	0.44781
80	1636283	1000192	100194	0.46010	0.45996	0.45969	0.45943	0.45916	0.45890	0.45757
90	1636258	1000166	100168	0.47311	0.47297	0.47268	0.47238	0.47209	0.47180	0.47035
100	1636237	1000145	100147	10163	0.48901	0.48868	0.48836	0.48804	0.48772	0.48612
125	1636198	1000107	100108	10115	5124.8	0.54270	0.54227	0.54185	0.54142	0.53930
150	1636173	1000081	100082	10086	5090.1	2601.1	0.61984	0.61924	0.61865	0.61569
175	1636155	1000064	100064	10066	5068.4	2573.7	1746.3	1337.2	0.72835	0.72401
200	1636142	1000051	100051	10052	5053.6	2556.5	1726.3	1313.0	1066.8	0.88083
225	1636133	1000041	100041	10042	5043.0	2544.7	1713.2	1298.4	1050.4	563.36
250	1636126	1000034	100034	10035	5035.1	2536.1	1703.9	1288.4	1039.6	546.53
275	1636120	1000028	100029	10029	5029.1	2529.7	1697.1	1281.1	1031.9	536.00
300	1636116	1000024	100024	10024	5024.4	2524.8	1691.9	1275.7	1026.2	528.74
325	1636112	1000020	100020	10021	5020.7	2520.9	1687.9	1271.5	1021.8	523.48
350	1636109	1000017	100017	10018	5017.6	2517.8	1684.7	1268.2	1018.4	519.52
375	1636107	1000015	100015	10015	5015.1	2515.3	1682.1	1265.5	1015.7	516.44
400	1636105	1000013	100013	10013	5013.1	2513.2	1679.9	1263.4	1013.5	513.99
425	1636103	1000011	100011	10011	5011.4	2511.4	1678.2	1261.6	1011.6	512.01
450	1636102	1000010	100010	10010	5009.9	2509.9	1676.7	1260.1	1010.1	510.38
475	1636100	1000009	100009	10009	5008.7	2508.7	1675.4	1258.8	1008.8	509.02
500	1636099	1000008	100008	10008	5007.6	2507.6	1674.3	1257.7	1007.7	507.87
525	1636098	1000007	100007	10007	5006.7	2506.7	1673.4	1256.8	1006.8	506.90
550	1636098	1000006	100006	10006	5005.9	2505.9	1672.6	1256.0	1006.0	506.07
575	1636097	1000005	100005	10005	5005.2	2505.2	1671.9	1255.3	1005.3	505.35
600	1636096	1000005	100005	10005	5004.6	2504.6	1671.3	1254.7	1004.7	504.73
625	1636096	1000004	100004	10004	5004.1	2504.1	1670.8	1254.1	1004.1	504.19
650	1636095	1000004	100004	10004	5003.7	2503.7	1670.3	1253.7	1003.7	503.72
675	1636095	1000003	100003	10003	5003.3	2503.3	1669.9	1253.3	1003.3	503.30
700	1636095	1000003	100003	10003	5002.9	2502.9	1669.6	1252.9	1002.9	502.94
725	1636094	1000003	100003	10003	5002.6	2502.6	1669.3	1252.6	1002.6	502.61
750	1636094	1000002	100002	10002	5002.3	2502.3	1669.0	1252.3	1002.3	502.32
775	1636094	1000002	100002	10002	5002.1	2502.1	1668.7	1252.1	1002.1	502.07
800	1636093	1000002	100002	10002	5001.8	2501.8	1668.5	1251.8	1001.8	501.84

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 10 Isothermal compressibility κ_T [10^{-6} kPa $^{-1}$]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	40	60	80	100	120	140	160	180	200	220
0	0.50328	0.50047	0.49767	0.49490	0.49213	0.48939	0.48666	0.48395	0.48126	0.47858
5	0.48655	0.48395	0.48136	0.47878	0.47623	0.47368	0.47115	0.46864	0.46614	0.46366
10	0.47310	0.47065	0.46822	0.46581	0.46340	0.46102	0.45864	0.45628	0.45394	0.45161
15	0.46234	0.46002	0.45771	0.45541	0.45313	0.45086	0.44860	0.44636	0.44413	0.44191
20	0.45385	0.45162	0.44940	0.44719	0.44499	0.44281	0.44064	0.43848	0.43633	0.43420
25	0.44729	0.44512	0.44295	0.44081	0.43867	0.43655	0.43444	0.43234	0.43025	0.42818
30	0.44240	0.44026	0.43813	0.43602	0.43392	0.43184	0.42977	0.42771	0.42566	0.42363
35	0.43896	0.43684	0.43473	0.43264	0.43056	0.42849	0.42644	0.42440	0.42237	0.42036
40	0.43682	0.43469	0.43259	0.43050	0.42842	0.42635	0.42430	0.42227	0.42024	0.41824
45	0.43584	0.43370	0.43158	0.42947	0.42738	0.42530	0.42324	0.42120	0.41916	0.41715
50	0.43592	0.43375	0.43160	0.42947	0.42735	0.42525	0.42316	0.42109	0.41904	0.41700
60	0.43893	0.43667	0.43442	0.43220	0.42999	0.42781	0.42564	0.42349	0.42136	0.41924
70	0.44538	0.44297	0.44058	0.43822	0.43589	0.43357	0.43128	0.42901	0.42676	0.42453
80	0.45495	0.45235	0.44978	0.44725	0.44474	0.44225	0.43980	0.43737	0.43496	0.43258
90	0.46749	0.46466	0.46187	0.45911	0.45638	0.45369	0.45103	0.44840	0.44580	0.44324
100	0.48296	0.47985	0.47678	0.47376	0.47077	0.46783	0.46492	0.46205	0.45922	0.45642
125	0.53512	0.53103	0.52700	0.52305	0.51917	0.51536	0.51161	0.50792	0.50429	0.50072
150	0.60989	0.60423	0.59870	0.59330	0.58801	0.58285	0.57779	0.57284	0.56798	0.56323
175	0.71553	0.70730	0.69931	0.69155	0.68400	0.67666	0.66951	0.66255	0.65577	0.64915
200	0.86769	0.85502	0.84281	0.83102	0.81964	0.80864	0.79801	0.78771	0.77774	0.76808
225	1.0963	1.0754	1.0554	1.0363	1.0180	1.0004	0.9836	0.9674	0.9519	0.9370
250	1.4649	1.4266	1.3905	1.3565	1.3243	1.2939	1.2651	1.2377	1.2117	1.1869
275	298.09	2.0561	1.9787	1.9079	1.8427	1.7824	1.7265	1.6746	1.6261	1.5807
300	285.57	213.11	192.95	3.0590	2.8843	2.7310	2.5955	2.4750	2.3668	2.2691
325	277.65	200.10	167.19	157.57	179.18	5.2606	4.7573	4.3466	4.0057	3.7200
350	272.19	192.29	155.17	136.61	129.95	136.50	179.66	12.912	10.004	8.3061
375	268.21	187.05	148.05	126.42	114.20	108.47	108.86	118.12	149.15	471.54
400	265.20	183.29	143.31	120.29	106.01	97.053	91.859	89.812	91.024	96.560
425	262.85	180.49	139.92	116.18	100.93	90.664	83.639	78.940	76.061	74.745
450	260.98	178.32	137.40	113.22	97.461	86.548	78.713	72.979	68.768	65.720
475	259.45	176.60	135.45	111.01	94.940	83.672	75.418	69.190	64.393	60.650
500	258.19	175.20	133.90	109.29	93.032	81.550	73.059	66.564	61.468	57.392
525	257.14	174.06	132.65	107.93	91.542	79.924	71.287	64.636	59.373	55.116
550	256.25	173.10	131.62	106.82	90.349	78.643	69.912	63.162	57.797	53.436
575	255.49	172.29	130.76	105.90	89.377	77.610	68.816	62.003	56.572	52.145
600	254.83	171.60	130.04	105.14	88.571	76.762	67.926	61.069	55.595	51.126
625	254.27	171.01	129.42	104.49	87.895	76.056	67.190	60.304	54.801	50.303
650	253.78	170.50	128.89	103.94	87.321	75.461	66.574	59.667	54.144	49.627
675	253.35	170.05	128.43	103.46	86.830	74.955	66.053	59.131	53.594	49.063
700	252.97	169.66	128.03	103.05	86.406	74.520	65.607	58.675	53.128	48.588
725	252.63	169.32	127.67	102.69	86.037	74.143	65.222	58.283	52.730	48.184
750	252.34	169.02	127.36	102.37	85.715	73.815	64.889	57.944	52.386	47.836
775	252.08	168.75	127.09	102.10	85.431	73.527	64.597	57.649	52.088	47.534
800	251.84	168.51	126.85	101.85	85.181	73.274	64.341	57.390	51.827	47.272

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 10 Isothermal compressibility κ_T [10^{-6} kPa $^{-1}$] – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	0.47593	0.47328	0.47066	0.46805	0.45528	0.44296	0.43109	0.41969	0.40877	0.38842
5	0.46119	0.45874	0.45631	0.45389	0.44201	0.43054	0.41946	0.40880	0.39856	0.37938
10	0.44929	0.44698	0.44469	0.44242	0.43125	0.42044	0.40999	0.39991	0.39021	0.37198
15	0.43971	0.43752	0.43534	0.43317	0.42255	0.41225	0.40229	0.39267	0.38339	0.36592
20	0.43208	0.42997	0.42788	0.42580	0.41557	0.40566	0.39607	0.38680	0.37786	0.36098
25	0.42612	0.42407	0.42204	0.42001	0.41008	0.40045	0.39113	0.38212	0.37343	0.35701
30	0.42160	0.41959	0.41760	0.41561	0.40587	0.39644	0.38730	0.37848	0.36996	0.35389
35	0.41836	0.41637	0.41439	0.41243	0.40280	0.39348	0.38446	0.37576	0.36736	0.35152
40	0.41624	0.41426	0.41229	0.41033	0.40074	0.39147	0.38251	0.37386	0.36553	0.34983
45	0.41514	0.41315	0.41118	0.40921	0.39960	0.39032	0.38136	0.37272	0.36441	0.34878
50	0.41497	0.41296	0.41097	0.40899	0.39930	0.38995	0.38094	0.37227	0.36394	0.34830
60	0.41714	0.41506	0.41300	0.41095	0.40095	0.39135	0.38212	0.37326	0.36478	0.34894
70	0.42232	0.42013	0.41796	0.41581	0.40533	0.39531	0.38571	0.37653	0.36777	0.35152
80	0.43022	0.42789	0.42558	0.42329	0.41218	0.40159	0.39148	0.38186	0.37271	0.35585
90	0.44069	0.43818	0.43570	0.43324	0.42133	0.41003	0.39930	0.38911	0.37947	0.36181
100	0.45366	0.45093	0.44824	0.44558	0.43271	0.42056	0.40906	0.39820	0.38796	0.36932
125	0.49721	0.49375	0.49034	0.48698	0.47090	0.45589	0.44186	0.42873	0.41647	0.39454
150	0.55857	0.55399	0.54951	0.54510	0.52421	0.50501	0.48727	0.47086	0.45569	0.42898
175	0.64270	0.63640	0.63024	0.62423	0.59605	0.57061	0.54745	0.52629	0.50696	0.47345
200	0.75871	0.74961	0.74078	0.73219	0.69257	0.65760	0.62635	0.59824	0.57289	0.52964
225	0.92257	0.90872	0.89535	0.88246	0.82407	0.77399	0.73032	0.69178	0.65756	0.60030
250	1.1633	1.1408	1.1193	1.0987	1.0078	0.93267	0.86919	0.81459	0.76708	0.68938
275	1.5382	1.4982	1.4606	1.4251	1.2737	1.1548	1.0584	0.97819	0.91026	0.80240
300	2.1802	2.0989	2.0242	1.9554	1.6783	1.4772	1.3230	1.2003	1.1000	0.94689
325	3.4779	3.2699	3.0887	2.9288	2.3420	1.9678	1.7055	1.5090	1.3557	1.1331
350	7.1520	6.2955	5.6344	5.1132	3.5748	2.7714	2.2837	1.9511	1.7071	1.3753
375	50.350	24.883	16.950	13.002	6.2650	4.2260	3.2177	2.6106	2.2033	1.6909
400	109.02	135.82	178.66	120.34	14.186	7.1608	4.8062	3.6285	2.9214	2.1130
425	74.919	76.668	80.079	84.782	41.143	13.659	7.6248	5.2286	3.9681	2.6774
450	63.594	62.220	61.469	61.221	54.754	25.317	12.380	7.6755	5.4612	3.4191
475	57.708	55.386	53.548	52.081	46.613	32.908	18.360	10.985	7.4431	4.3532
500	54.078	51.349	49.073	47.151	40.317	32.802	22.428	14.398	9.7231	5.4524
525	51.611	48.681	46.196	44.060	36.481	30.511	23.552	16.789	11.835	6.6326
550	49.823	46.783	44.188	41.943	33.961	28.404	23.142	17.839	13.358	7.7670
575	48.467	45.362	42.704	40.400	32.203	26.776	22.273	18.018	14.177	8.7348
600	47.406	44.261	41.565	39.225	30.911	25.549	21.401	17.774	14.498	9.4469
625	46.556	43.385	40.664	38.302	29.924	24.607	20.657	17.382	14.518	9.9329
650	45.861	42.673	39.937	37.561	29.145	23.865	20.040	16.979	14.382	10.235
675	45.286	42.086	39.340	36.954	28.518	23.268	19.530	16.608	14.185	10.379
700	44.802	41.595	38.842	36.451	28.005	22.779	19.105	16.281	13.977	10.405
725	44.392	41.180	38.423	36.028	27.578	22.373	18.748	15.997	13.781	10.384
750	44.040	40.825	38.065	35.669	27.218	22.032	18.444	15.749	13.602	10.350
775	43.737	40.520	37.758	35.361	26.913	21.742	18.185	15.532	13.439	10.312
800	43.473	40.254	37.492	35.095	26.651	21.494	17.961	15.342	13.291	10.265

Table 11 Saturation state:
Kinematic viscosity ν ,
Prandtl number Pr ,
Thermal diffusivity a ,
Dielectric constant ε

This table contains values on the saturated liquid ('') and saturated vapour ('') lines for the following properties for temperatures from 0°C up to the critical temperature $t_c = 373.946^\circ\text{C}$:

- Kinematic viscosity $\nu = \eta \rho^{-1}$
- Prandtl number $Pr = \eta c_p \lambda^{-1}$
- Thermal diffusivity $a = \lambda / (\rho c_p)$
- Dielectric constant ε

For given temperatures, the saturation pressures p_s were calculated from the IAPWS-IF97 saturation-pressure equation, Eq. (2.13).

For temperatures $t \leq 350^\circ\text{C}$ and the input values for t and p_s , the required *thermodynamic* properties ρ' ($=1/\nu'$) and ρ'' ($=1/\nu''$), c'_p , and c''_p on the saturated-liquid and saturated-vapour lines were determined from the basic equations for regions 1 and 2, Eqs. (2.3) and (2.6).

For $t > 350^\circ\text{C}$ and the input (t, p_s) values, the saturation densities ρ' and ρ'' were calculated by iterating the basic equation for region 3, Eq. (2.11). With these values for (ρ', t) and (ρ'', t) , the isobaric heat capacities c'_p and c''_p were calculated from Eq. (2.11).

With the values (ρ', t) and (ρ'', t) , the *transport* properties η' and η'' , and λ' and λ'' were determined from Eq. (3.1) and Eq. (3.4), respectively. The dielectric constants ε' and ε'' were calculated from Eq. (3.9).

Table 11 Saturation state: **Kinematic viscosity ν ,**
Prandtl number Pr ,
Thermal diffusivity a ,
Dielectric constant ϵ

t [°C]	ν' [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]	ν''	Pr'	Pr''	a' [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]	a''	ϵ'	ϵ'' [-]
0	1.7923	1844.0	13.611	1.0078	0.13168	1829.7	87.899	1.00006
0.01 ^a	1.7917	1842.8	13.606	1.0078	0.13169	1828.5	87.895	1.00006
1	1.7315	1727.0	13.079	1.0075	0.13238	1714.1	87.498	1.00007
2	1.6739	1618.4	12.579	1.0073	0.13306	1606.7	87.098	1.00007
3	1.6193	1517.5	12.109	1.0070	0.13373	1506.9	86.701	1.00008
4	1.5676	1423.7	11.665	1.0068	0.13438	1414.1	86.305	1.00008
5	1.5184	1336.4	11.247	1.0066	0.13501	1327.7	85.911	1.00009
6	1.4718	1255.2	10.851	1.0064	0.13563	1247.2	85.520	1.00009
7	1.4274	1179.6	10.477	1.0062	0.13623	1172.3	85.130	1.00010
8	1.3851	1109.1	10.123	1.0061	0.13683	1102.4	84.741	1.00011
9	1.3448	1043.4	9.7874	1.0059	0.13740	1037.3	84.355	1.00011
10	1.3064	982.13	9.4688	1.0058	0.13797	976.44	83.970	1.00012
11	1.2698	924.92	9.1662	1.0057	0.13853	919.66	83.588	1.00013
12	1.2348	871.51	8.8785	1.0056	0.13908	866.61	83.207	1.00014
13	1.2013	821.59	8.6047	1.0056	0.13961	817.03	82.827	1.00014
14	1.1693	774.93	8.3439	1.0055	0.14014	770.66	82.450	1.00015
15	1.1387	731.29	8.0953	1.0055	0.14066	727.27	82.074	1.00016
16	1.1094	690.44	7.8581	1.0055	0.14117	686.66	81.699	1.00017
17	1.0812	652.19	7.6317	1.0055	0.14168	648.62	81.327	1.00018
18	1.0542	616.36	7.4153	1.0055	0.14217	612.97	80.956	1.00019
19	1.0283	582.77	7.2084	1.0056	0.14266	579.55	80.586	1.00020
20	1.0035	551.28	7.0104	1.0056	0.14314	548.20	80.219	1.00021
22	0.95659	493.99	6.6393	1.0057	0.14408	491.17	79.488	1.00024
24	0.91320	443.46	6.2981	1.0059	0.14500	440.85	78.764	1.00027
25	0.89271	420.45	6.1377	1.0060	0.14545	417.93	78.405	1.00028
26	0.87296	398.81	5.9837	1.0062	0.14589	396.37	78.047	1.00030
28	0.83556	359.28	5.6934	1.0064	0.14676	356.99	77.336	1.00033
30	0.80074	324.22	5.4247	1.0067	0.14761	322.05	76.631	1.00036
32	0.76826	293.06	5.1755	1.0071	0.14844	291.01	75.932	1.00040
34	0.73790	265.33	4.9441	1.0074	0.14925	263.37	75.239	1.00044
36	0.70949	240.61	4.7286	1.0078	0.15004	238.74	74.553	1.00049
38	0.68286	218.53	4.5277	1.0083	0.15082	216.74	73.872	1.00054
40	0.65786	198.78	4.3402	1.0087	0.15157	197.06	73.198	1.00059
42	0.63436	181.08	4.1648	1.0092	0.15232	179.43	72.529	1.00065
44	0.61224	165.20	4.0005	1.0097	0.15304	163.61	71.867	1.00072
46	0.59139	150.92	3.8465	1.0102	0.15375	149.40	71.210	1.00078
48	0.57172	138.07	3.7018	1.0107	0.15444	136.61	70.559	1.00086
50	0.55314	126.49	3.5659	1.0112	0.15512	125.08	69.914	1.00094
52	0.53556	116.03	3.4379	1.0118	0.15578	114.68	69.274	1.0010
54	0.51892	106.58	3.3173	1.0124	0.15643	105.28	68.641	1.0011
56	0.50316	98.022	3.2035	1.0130	0.15706	96.767	68.012	1.0012
58	0.48820	90.264	3.0961	1.0136	0.15768	89.055	67.390	1.0013

^a Triple-point temperature.

Table 11 Saturation state: **Kinematic viscosity ν ,**
Prandtl number Pr ,
Thermal diffusivity a ,
Dielectric constant ϵ – Continued

t [°C]	ν' [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]	ν''	Pr'	Pr''	a' [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]	a''	ϵ' [–]	ϵ''
60	0.47400	83.221	2.9945	1.0142	0.15829	82.056	66.773	1.0014
62	0.46050	76.820	2.8984	1.0149	0.15888	75.696	66.161	1.0015
64	0.44767	70.994	2.8075	1.0155	0.15946	69.909	65.555	1.0017
66	0.43545	65.686	2.7212	1.0162	0.16002	64.638	64.954	1.0018
68	0.42382	60.843	2.6394	1.0169	0.16057	59.829	64.359	1.0020
70	0.41272	56.419	2.5618	1.0177	0.16111	55.438	63.769	1.0021
72	0.40214	52.373	2.4880	1.0185	0.16163	51.423	63.184	1.0023
74	0.39203	48.668	2.4179	1.0193	0.16214	47.747	62.605	1.0024
76	0.38238	45.272	2.3512	1.0201	0.16263	44.379	62.030	1.0026
78	0.37315	42.156	2.2876	1.0210	0.16312	41.288	61.461	1.0028
80	0.36433	39.293	2.2271	1.0219	0.16359	38.449	60.897	1.0030
82	0.35588	36.660	2.1694	1.0229	0.16404	35.839	60.338	1.0033
84	0.34778	34.236	2.1144	1.0239	0.16449	33.436	59.784	1.0035
86	0.34003	32.002	2.0618	1.0250	0.16492	31.221	59.235	1.0037
88	0.33260	29.942	2.0116	1.0261	0.16534	29.179	58.691	1.0040
90	0.32546	28.039	1.9637	1.0273	0.16574	27.292	58.152	1.0043
92	0.31862	26.279	1.9178	1.0286	0.16614	25.549	57.617	1.0046
94	0.31205	24.652	1.8740	1.0299	0.16652	23.936	57.088	1.0049
96	0.30573	23.144	1.8320	1.0313	0.16689	22.442	56.563	1.0052
98	0.29966	21.747	1.7918	1.0327	0.16724	21.058	56.043	1.0055
100	0.29382	20.450	1.7533	1.0343	0.16758	19.773	55.527	1.0059
105	0.28017	17.597	1.6638	1.0384	0.16839	16.946	54.259	1.0069
110	0.26775	15.214	1.5832	1.0432	0.16912	14.584	53.018	1.0079
115	0.25640	13.211	1.5103	1.0485	0.16978	12.600	51.806	1.0092
120	0.24603	11.521	1.4442	1.0544	0.17036	10.927	50.620	1.0105
125	0.23652	10.088	1.3843	1.0610	0.17086	9.508	49.460	1.0121
130	0.22778	8.8673	1.3298	1.0682	0.17130	8.301	48.326	1.0138
135	0.21974	7.8225	1.2801	1.0761	0.17166	7.269	47.216	1.0156
140	0.21233	6.9248	1.2349	1.0846	0.17194	6.385	46.131	1.0177
145	0.20548	6.1504	1.1935	1.0936	0.17216	5.624	45.069	1.0200
150	0.19914	5.4798	1.1558	1.1032	0.17230	4.967	44.030	1.0225
155	0.19326	4.8970	1.1213	1.1132	0.17236	4.399	43.013	1.0252
160	0.18781	4.3886	1.0893	1.1236	0.17242	3.906	42.018	1.0282
165	0.18275	3.9437	1.0601	1.1344	0.17239	3.476	41.043	1.0315
170	0.17803	3.5531	1.0335	1.1455	0.17226	3.102	40.088	1.0350
175	0.17364	3.2090	1.0092	1.1569	0.17206	2.774	39.153	1.0389
180	0.16954	2.9051	0.9870	1.1686	0.17178	2.486	38.236	1.0431
185	0.16571	2.6358	0.9667	1.1807	0.17142	2.232	37.337	1.0476
190	0.16214	2.3965	0.9483	1.1931	0.17098	2.009	36.456	1.0525
195	0.15879	2.1834	0.9315	1.2058	0.17046	1.811	35.591	1.0578

**Table 11 Saturation state: Kinematic viscosity ν ,
Prandtl number Pr ,
Thermal diffusivity a ,
Dielectric constant ϵ – Continued**

t [°C]	ν' [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]	ν''	Pr'	Pr''	a' [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]	a''	ϵ' [-]	ϵ''
200	0.15565	1.9931	0.9164	1.2190	0.16985	1.6350	34.742	1.0636
205	0.15271	1.8227	0.9027	1.2327	0.16916	1.4786	33.909	1.0698
210	0.14995	1.6698	0.8905	1.2470	0.16839	1.3390	33.091	1.0765
215	0.14736	1.5322	0.8797	1.2619	0.16752	1.2142	32.286	1.0837
220	0.14493	1.4081	0.8701	1.2775	0.16656	1.1023	31.496	1.0915
225	0.14264	1.2961	0.8618	1.2938	0.16551	1.0017	30.718	1.0999
230	0.14048	1.1946	0.8547	1.3110	0.16436	0.91121	29.952	1.1089
235	0.13845	1.1025	0.8488	1.3290	0.16311	0.82956	29.198	1.1187
240	0.13654	1.0188	0.8441	1.3480	0.16176	0.75579	28.455	1.1292
245	0.13474	0.94254	0.8405	1.3680	0.16030	0.68900	27.722	1.1405
250	0.13304	0.87297	0.8382	1.3892	0.15872	0.62842	26.999	1.1527
255	0.13144	0.80937	0.8370	1.4116	0.15703	0.57337	26.285	1.1659
260	0.12992	0.75113	0.8371	1.4355	0.15521	0.52323	25.579	1.1802
265	0.12850	0.69770	0.8385	1.4612	0.15325	0.47749	24.881	1.1957
270	0.12715	0.64860	0.8412	1.4888	0.15116	0.43564	24.190	1.2124
275	0.12588	0.60341	0.8453	1.5188	0.14891	0.39729	23.504	1.2306
280	0.12469	0.56175	0.8511	1.5516	0.14651	0.36205	22.824	1.2505
285	0.12356	0.52329	0.8585	1.5875	0.14392	0.32963	22.148	1.2721
290	0.12250	0.48771	0.8679	1.6270	0.14114	0.29975	21.475	1.2958
295	0.12150	0.45474	0.8795	1.6706	0.13815	0.27220	20.805	1.3217
300	0.12056	0.42416	0.8935	1.7187	0.13493	0.24680	20.135	1.3504
305	0.11968	0.39572	0.9105	1.7716	0.13145	0.22337	19.466	1.3820
310	0.11886	0.36925	0.9309	1.8301	0.12769	0.20177	18.794	1.4172
315	0.11810	0.34456	0.9554	1.8948	0.12361	0.18184	18.119	1.4566
320	0.11739	0.32148	0.9851	1.9674	0.11917	0.16340	17.439	1.5010
325	0.11674	0.29986	1.0213	2.0500	0.11430	0.14627	16.751	1.5514
330	0.11615	0.27956	1.0664	2.1463	0.10892	0.13025	16.053	1.6091
335	0.11563	0.26044	1.1237	2.2616	0.10290	0.11516	15.340	1.6762
340	0.11517	0.24238	1.1990	2.4026	0.096055	0.10088	14.607	1.7552
345	0.11479	0.22525	1.3011	2.5780	0.088224	0.08737	13.844	1.8499
350	0.11449	0.20893	1.4435	2.7983	0.079314	0.07466	13.043	1.9663
355	0.11431	0.19329	1.6684	3.1420	0.068513	0.06152	12.183	2.1138
360	0.11427	0.17807	2.0440	3.6816	0.055908	0.048367	11.233	2.3107
365	0.11450	0.16284	2.8210	4.7353	0.040589	0.034388	10.130	2.5975
370	0.11533	0.14639	5.4677	8.0124	0.021093	0.018270	8.6722	3.1076
371	0.11569	0.14260	7.0380	9.8072	0.016438	0.014540	8.2784	3.2794
372	0.11622	0.13836	10.1504	13.1725	0.011450	0.010504	7.8019	3.5119
373	0.11717	0.13313	19.2053	22.2964	0.0061009	0.0059707	7.1501	3.8834
373.946 ^a	— ^b	— ^b	— ^b	— ^b	— ^b	— ^b	5.3606	

^aCritical temperature.

^bIn the near-critical region, the values for ν , Pr , and a calculated from IAPWS-IF97 and the industrial equations for transport properties are not accurate enough.

Table 12 Kinematic viscosity ν

For the single-phase region, this table contains values for the

- Kinematic viscosity $\nu = \eta \rho^{-1}$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar.

In regions 1 and 2 and the given values of p and t , the density $\rho (=1/\nu)$ was calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities of Eq. (2.11), was determined by iterating this equation.

The dynamic viscosity η was determined from the equation for industrial use, Eq. (3.1). The values of the input quantities ρ , needed in this equation, were determined from the IAPWS-IF97 basic equations as shown above.

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 12 Kinematic viscosity ν [$10^{-6} \text{ m}^2 \text{ s}^{-1}$] ^a

t [°C]	p [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	1.7923	1.7923	1.7923	1.7920	1.7917	1.7911	1.7905	1.7898	1.7892	1.7861
5	1908.5	1.5184	1.5184	1.5182	1.5180	1.5176	1.5171	1.5167	1.5163	1.5141
10	1974.8	1206.5	1.3064	1.3063	1.3061	1.3058	1.3055	1.3052	1.3049	1.3034
15	2043.0	1248.2	1.1387	1.1386	1.1385	1.1383	1.1381	1.1378	1.1376	1.1366
20	2113.0	1291.1	1.0035	1.0034	1.0033	1.0032	1.0030	1.0029	1.0027	1.0020
25	2184.8	1335.0	0.89271	0.89266	0.89260	0.89250	0.89239	0.89228	0.89217	0.89164
30	2258.5	1380.0	0.80074	0.80070	0.80067	0.80059	0.80052	0.80044	0.80036	0.79999
35	2333.9	1426.2	0.72346	0.72344	0.72341	0.72336	0.72331	0.72326	0.72321	0.72296
40	2411.1	1473.4	0.65786	0.65785	0.65783	0.65780	0.65776	0.65773	0.65770	0.65754
45	2490.1	1521.7	0.60166	0.60166	0.60165	0.60163	0.60161	0.60159	0.60157	0.60148
50	2570.9	1571.1	156.42	0.55313	0.55313	0.55312	0.55311	0.55311	0.55310	0.55306
60	2737.9	1673.1	166.69	0.47400	0.47400	0.47401	0.47402	0.47403	0.47403	0.47407
70	2911.8	1779.5	177.38	0.41273	0.41274	0.41275	0.41277	0.41278	0.41280	0.41288
80	3092.8	1890.1	188.50	0.36433	0.36434	0.36436	0.36439	0.36441	0.36443	0.36454
90	3280.7	2005.0	200.03	0.32547	0.32548	0.32551	0.32553	0.32556	0.32558	0.32571
100	3475.7	2124.2	211.98	0.29384	0.29386	0.29389	0.29392	0.29395	0.29408	
125	3993.2	2440.5	243.69	23.998	11.785	0.23655	0.23658	0.23661	0.23664	0.23679
150	4553.6	2783.1	278.00	27.487	13.565	6.5966	0.19916	0.19919	0.19922	0.19937
175	5156.7	3151.7	314.90	31.221	15.458	7.5729	4.9405	3.6206	0.17366	0.17381
200	5801.8	3546.1	354.37	35.203	17.470	8.6007	5.6420	4.1608	3.2705	0.15572
225	6488.8	3966.0	396.39	39.433	19.601	9.6837	6.3765	4.7217	3.7280	1.7324
250	7217.2	4411.1	440.93	43.911	21.853	10.824	7.1465	5.3071	4.2029	1.9897
275	7986.4	4881.3	487.97	48.635	24.227	12.022	7.9533	5.9186	4.6973	2.2520
300	8796.2	5376.3	537.48	53.603	26.720	13.279	8.7979	6.5572	5.2126	2.5216
325	9646.0	5895.7	589.44	58.813	29.334	14.594	9.6805	7.2236	5.7493	2.7997
350	10535	6439.3	643.81	64.263	32.066	15.967	10.601	7.9179	6.3079	3.0872
375	11464	7006.7	700.56	69.950	34.916	17.399	11.560	8.6403	6.8885	3.3846
400	12431	7597.7	759.68	75.872	37.883	18.888	12.556	9.3906	7.4911	3.6920
425	13436	8212.0	821.12	82.025	40.964	20.434	13.591	10.169	8.1158	4.0098
450	14478	8849.3	884.85	88.407	44.160	22.036	14.662	10.975	8.7625	4.3379
475	15558	9509.3	950.86	95.015	47.468	23.695	15.770	11.808	9.4309	4.6764
500	16674	10192	1019.1	101.85	50.887	25.408	16.915	12.669	10.121	5.0253
525	17827	10896	1089.5	108.90	54.417	27.176	18.096	13.556	10.832	5.3846
550	19015	11622	1162.2	116.17	58.054	28.998	19.313	14.470	11.565	5.7541
575	20239	12370	1237.0	123.65	61.799	30.874	20.565	15.411	12.319	6.1339
600	21497	13139	1313.9	131.34	65.649	32.801	21.852	16.378	13.093	6.5238
625	22789	13929	1392.9	139.25	69.604	34.781	23.174	17.370	13.888	6.9238
650	24115	14740	1473.9	147.36	73.662	36.813	24.530	18.388	14.703	7.3338
675	25475	15571	1557.0	155.67	77.821	38.895	25.919	19.431	15.539	7.7536
700	26868	16422	1642.2	164.19	82.081	41.027	27.342	20.499	16.394	8.1833
725	28293	17293	1729.3	172.91	86.441	43.208	28.797	21.592	17.269	8.6226
750	29750	18184	1818.4	181.82	90.898	45.439	30.286	22.709	18.163	9.0715
775	31240	19094	1909.4	190.92	95.453	47.718	31.806	23.850	19.077	9.5299
800	32760	20023	2002.3	200.22	100.10	50.044	33.358	25.015	20.009	9.9977

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 12 Kinematic viscosity ν [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]^a – Continued

t [°C]	p [bar]									
	40	60	80	100	120	140	160	180	200	220
0	1.7799	1.7739	1.7679	1.7621	1.7563	1.7507	1.7451	1.7397	1.7344	1.7291
5	1.5099	1.5057	1.5016	1.4975	1.4935	1.4896	1.4858	1.4820	1.4783	1.4746
10	1.3004	1.2975	1.2946	1.2918	1.2890	1.2862	1.2835	1.2809	1.2783	1.2757
15	1.1344	1.1324	1.1303	1.1283	1.1263	1.1244	1.1225	1.1206	1.1188	1.1169
20	1.0005	0.99898	0.99753	0.99610	0.99470	0.99333	0.99197	0.99065	0.98934	0.98806
25	0.89058	0.88954	0.88852	0.88751	0.88653	0.88556	0.88461	0.88368	0.88277	0.88187
30	0.79926	0.79853	0.79782	0.79713	0.79645	0.79578	0.79513	0.79449	0.79386	0.79325
35	0.72246	0.72198	0.72150	0.72103	0.72058	0.72013	0.71970	0.71927	0.71886	0.71846
40	0.65722	0.65691	0.65661	0.65632	0.65603	0.65576	0.65549	0.65523	0.65497	0.65473
45	0.60130	0.60113	0.60096	0.60080	0.60064	0.60049	0.60035	0.60021	0.60008	0.59996
50	0.55298	0.55291	0.55285	0.55279	0.55273	0.55268	0.55264	0.55260	0.55256	0.55253
60	0.47414	0.47421	0.47429	0.47437	0.47445	0.47454	0.47462	0.47472	0.47481	0.47491
70	0.41304	0.41320	0.41337	0.41353	0.41370	0.41387	0.41404	0.41421	0.41439	0.41457
80	0.36475	0.36497	0.36519	0.36541	0.36563	0.36586	0.36608	0.36630	0.36653	0.36675
90	0.32596	0.32622	0.32647	0.32672	0.32698	0.32723	0.32749	0.32775	0.32800	0.32826
100	0.29436	0.29464	0.29491	0.29519	0.29546	0.29574	0.29602	0.29629	0.29657	0.29685
125	0.23709	0.23739	0.23769	0.23799	0.23829	0.23859	0.23889	0.23919	0.23949	0.23979
150	0.19968	0.19999	0.20030	0.20061	0.20091	0.20121	0.20152	0.20182	0.20212	0.20242
175	0.17412	0.17443	0.17474	0.17505	0.17535	0.17566	0.17596	0.17626	0.17656	0.17686
200	0.15604	0.15635	0.15666	0.15697	0.15727	0.15757	0.15788	0.15818	0.15847	0.15877
225	0.14287	0.14319	0.14350	0.14382	0.14412	0.14443	0.14474	0.14504	0.14534	0.14563
250	<u>0.13304</u>	0.13338	0.13370	0.13403	0.13435	0.13466	0.13498	0.13528	0.13559	0.13589
275	1.0202	<u>0.12589</u>	<u>0.12625</u>	0.12659	0.12693	0.12727	0.12760	0.12792	0.12824	0.12855
300	1.1706	<u>0.71343</u>	<u>0.47579</u>	<u>0.12084</u>	<u>0.12122</u>	0.12159	0.12194	0.12229	0.12263	0.12296
325	1.3216	0.82509	0.57268	0.41590	0.30246	<u>0.11717</u>	<u>0.11759</u>	0.11799	0.11837	0.11873
350	1.4749	0.93529	0.66329	0.49771	0.38444	0.29946	0.22808	<u>0.11487</u>	0.11532	0.11573
375	1.6315	1.0459	0.75192	0.57434	0.45470	0.36782	0.30091	0.24648	0.19900	0.14722
400	1.7919	1.1579	0.84032	0.64915	0.52113	0.42911	0.35947	0.30465	0.26005	0.22269
425	1.9566	1.2719	0.92936	0.72355	0.58612	0.48774	0.41375	0.35602	0.30966	0.27159
450	2.1257	1.3883	1.0196	0.79830	0.65074	0.54531	0.46623	0.40474	0.35557	0.31539
475	2.2994	1.5073	1.1113	0.87384	0.71559	0.60263	0.51801	0.45229	0.39982	0.35703
500	2.4779	1.6290	1.2048	0.95046	0.78104	0.66016	0.56965	0.49940	0.44335	0.39766
525	2.6611	1.7537	1.3002	1.0284	0.84733	0.71820	0.62153	0.54651	0.48666	0.43787
550	2.8492	1.8813	1.3976	1.1077	0.91463	0.77694	0.67385	0.59386	0.53005	0.47802
575	3.0420	2.0119	1.4971	1.1885	0.98306	0.83651	0.72680	0.64165	0.57372	0.51831
600	3.2397	2.1455	1.5987	1.2710	1.0527	0.89702	0.78046	0.69000	0.61780	0.55891
625	3.4422	2.2822	1.7025	1.3550	1.1236	0.95853	0.83493	0.73898	0.66240	0.59991
650	3.6496	2.4219	1.8085	1.4407	1.1958	1.0211	0.89025	0.78868	0.70758	0.64140
675	3.8616	2.5648	1.9167	1.5282	1.2694	1.0848	0.94649	0.83913	0.75340	0.68342
700	4.0785	2.7107	2.0271	1.6173	1.3443	1.1495	1.0037	0.89037	0.79990	0.72603
725	4.3000	2.8596	2.1397	1.7081	1.4206	1.2155	1.0618	0.94243	0.84710	0.76925
750	4.5262	3.0116	2.2546	1.8007	1.4983	1.2825	1.1209	0.99534	0.89504	0.81311
775	4.7571	3.1666	2.3717	1.8950	1.5774	1.3508	1.1810	1.0491	0.94372	0.85763
800	4.9925	3.3246	2.4909	1.9910	1.6579	1.4202	1.2421	1.1037	0.99317	0.90283

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 12 Kinematic viscosity ν [$10^{-6} \text{ m}^2 \text{ s}^{-1}$] – Continued

t [°C]	p [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	1.7239	1.7189	1.7139	1.7090	1.6860	1.6651	1.6462	1.6292	1.6140	1.5887
5	1.4711	1.4675	1.4641	1.4607	1.4447	1.4301	1.4170	1.4052	1.3947	1.3772
10	1.2732	1.2707	1.2683	1.2659	1.2546	1.2444	1.2352	1.2270	1.2197	1.2076
15	1.1152	1.1134	1.1117	1.1100	1.1021	1.0949	1.0885	1.0827	1.0777	1.0695
20	0.98681	0.98558	0.98437	0.98318	0.97761	0.97259	0.96812	0.96417	0.96073	0.95529
25	0.88099	0.88013	0.87929	0.87846	0.87460	0.87115	0.86811	0.86547	0.86321	0.85980
30	0.79265	0.79206	0.79148	0.79092	0.78831	0.78603	0.78405	0.78237	0.78099	0.77908
35	0.71806	0.71768	0.71731	0.71694	0.71527	0.71385	0.71267	0.71172	0.71100	0.71021
40	0.65449	0.65426	0.65404	0.65382	0.65287	0.65210	0.65152	0.65112	0.65090	0.65097
45	0.59984	0.59973	0.59962	0.59952	0.59910	0.59884	0.59872	0.59874	0.59890	0.59963
50	0.55250	0.55248	0.55246	0.55245	0.55245	0.55257	0.55281	0.55315	0.55361	0.55485
60	0.47501	0.47511	0.47521	0.47532	0.47591	0.47656	0.47729	0.47808	0.47895	0.48089
70	0.41474	0.41492	0.41510	0.41529	0.41623	0.41721	0.41824	0.41931	0.42043	0.42279
80	0.36698	0.36721	0.36744	0.36767	0.36883	0.37002	0.37123	0.37247	0.37374	0.37636
90	0.32852	0.32877	0.32903	0.32929	0.33059	0.33191	0.33324	0.33458	0.33594	0.33871
100	0.29712	0.29740	0.29768	0.29795	0.29934	0.30073	0.30213	0.30353	0.30494	0.30779
125	0.24008	0.24038	0.24067	0.24097	0.24244	0.24390	0.24536	0.24681	0.24826	0.25114
150	0.20272	0.20302	0.20332	0.20361	0.20509	0.20655	0.20799	0.20942	0.21084	0.21366
175	0.17715	0.17745	0.17774	0.17804	0.17949	0.18092	0.18233	0.18372	0.18510	0.18781
200	0.15906	0.15936	0.15965	0.15994	0.16137	0.16277	0.16414	0.16549	0.16682	0.16943
225	0.14593	0.14622	0.14651	0.14680	0.14822	0.14959	0.15094	0.15225	0.15354	0.15605
250	0.13619	0.13649	0.13678	0.13707	0.13849	0.13986	0.14118	0.14247	0.14372	0.14615
275	0.12886	0.12916	0.12946	0.12976	0.13120	0.13256	0.13388	0.13515	0.13637	0.13874
300	0.12329	0.12361	0.12392	0.12423	0.12570	0.12708	0.12839	0.12964	0.13085	0.13315
325	0.11908	0.11942	0.11976	0.12008	0.12159	0.12298	0.12428	0.12552	0.12670	0.12895
350	0.11611	0.11647	0.11682	0.11715	0.11867	0.12004	0.12131	0.12251	0.12365	0.12582
375	0.11549	0.11546	0.11562	0.11583	0.11703	0.11822	0.11937	0.12048	0.12154	0.12358
400	0.19049	0.16205	0.13749	0.12361	0.11750	0.11782	0.11857	0.11943	0.12032	0.12212
425	0.23976	0.21280	0.18976	0.17013	0.12438	0.11985	0.11930	0.11954	0.12006	0.12142
450	0.28200	0.25387	0.22996	0.20950	0.14566	0.12679	0.12246	0.12123	0.12097	0.12152
475	0.32152	0.29165	0.26624	0.24446	0.17266	0.14073	0.12929	0.12511	0.12340	0.12254
500	0.35976	0.32787	0.30073	0.27743	0.19918	0.15917	0.14024	0.13173	0.12770	0.12464
525	0.39739	0.36332	0.33431	0.30936	0.22480	0.17910	0.15417	0.14104	0.13406	0.12795
550	0.43483	0.39846	0.36747	0.34079	0.24981	0.19924	0.16969	0.15242	0.14230	0.13253
575	0.47231	0.43355	0.40050	0.37202	0.27447	0.21933	0.18590	0.16510	0.15205	0.13833
600	0.51000	0.46877	0.43358	0.40325	0.29898	0.23937	0.20241	0.17855	0.16283	0.14521
625	0.54800	0.50422	0.46685	0.43460	0.32347	0.25939	0.21908	0.19244	0.17432	0.15297
650	0.58639	0.54000	0.50037	0.46616	0.34802	0.27947	0.23587	0.20660	0.18628	0.16141
675	0.62525	0.57617	0.53422	0.49800	0.37270	0.29963	0.25278	0.22098	0.19857	0.17040
700	0.66461	0.61277	0.56846	0.53017	0.39755	0.31991	0.26983	0.23554	0.21111	0.17983
725	0.70450	0.64984	0.60311	0.56272	0.42263	0.34035	0.28702	0.25027	0.22387	0.18957
750	0.74497	0.68742	0.63821	0.59566	0.44795	0.36096	0.30437	0.26516	0.23681	0.19955
775	0.78601	0.72552	0.67378	0.62904	0.47355	0.38178	0.32189	0.28023	0.24994	0.20975
800	0.82767	0.76417	0.70984	0.66285	0.49944	0.40281	0.33959	0.29546	0.26324	0.22016

Table 13 Prandtl number Pr

For the single-phase region, this table contains values for the

- Prandtl number $Pr = \eta c_p \lambda^{-1}$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar.

In regions 1 and 2 and the given values of p and t , the density $\rho (=1/v)$ and the specific isobaric heat capacity c_p were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities of Eq. (2.11), was determined by iterating this equation. With these (ρ, t) values, c_p was determined from Eq. (2.11).

The transport properties dynamic viscosity η and thermal conductivity λ were calculated from the equations for industrial use, Eq. (3.1) and Eq. (3.4), respectively. The values of the input quantities ρ , needed in these equations, were determined from the IAPWS-IF97 basic equations as shown above.

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 13 Prandtl number Pr [−]^a

t [°C]	p [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	13.611	13.611	13.611	13.606	13.601	13.591	13.580	13.570	13.560	13.509
5	0.99846	11.247	11.247	11.243	11.240	11.232	11.225	11.218	11.211	11.176
10	0.99308	1.0000	9.4686	9.4663	9.4637	9.4586	9.4534	9.4483	9.4432	9.4177
15	0.98949	0.99344	8.0951	8.0934	8.0915	8.0877	8.0839	8.0802	8.0764	8.0577
20	0.98676	0.98932	7.0103	7.0090	7.0076	7.0048	7.0019	6.9991	6.9963	6.9822
25	0.98450	0.98635	6.1377	6.1367	6.1356	6.1334	6.1312	6.1290	6.1269	6.1161
30	0.98252	0.98397	5.4247	5.4239	5.4230	5.4213	5.4196	5.4179	5.4162	5.4078
35	0.98073	0.98193	4.8344	4.8338	4.8331	4.8318	4.8304	4.8291	4.8278	4.8211
40	0.97909	0.98011	4.3402	4.3397	4.3392	4.3381	4.3370	4.3359	4.3349	4.3295
45	0.97758	0.97846	3.9223	3.9219	3.9215	3.9206	3.9197	3.9188	3.9180	3.9137
50	0.97617	0.97693	3.0011	3.5656	3.5652	3.5645	3.5638	3.5631	3.5624	3.5588
60	0.97359	0.97418	0.98933	2.9943	2.9941	2.9936	2.9931	2.9926	2.9921	2.9897
70	0.97129	0.97175	0.98276	2.5617	2.5615	2.5612	2.5608	2.5605	2.5601	2.5584
80	0.96920	0.96956	0.97798	2.2270	2.2269	2.2267	2.2264	2.2262	2.2259	2.2246
90	0.96727	0.96755	0.97412	1.9636	1.9635	1.9634	1.9632	1.9630	1.9628	1.9618
100	0.96548	0.96570	0.97086	1.0330	1.7532	1.7530	1.7529	1.7527	1.7526	1.7519
125	0.96139	0.96151	0.96438	0.99568	1.0403	1.3842	1.3841	1.3840	1.3839	1.3834
150	0.95764	0.95771	0.95935	0.97706	0.99958	1.0621	1.1557	1.1556	1.1556	1.1552
175	0.95408	0.95413	0.95509	0.96543	0.97845	1.0094	1.0495	1.1117	1.0091	1.0087
200	0.95062	0.95065	0.95123	0.95748	0.96532	0.98366	1.0055	1.0311	1.0619	0.91611
225	0.94721	0.94723	0.94760	0.95157	0.95649	0.96789	0.98132	0.99669	1.0140	1.1421
250	0.94385	0.94386	0.94411	0.94678	0.95005	0.95751	0.96618	0.97602	0.98700	1.0588
275	0.94054	0.94054	0.94073	0.94265	0.94496	0.95015	0.95605	0.96268	0.97000	1.0168
300	0.93728	0.93729	0.93743	0.93892	0.94067	0.94451	0.94879	0.95350	0.95865	0.99080
325	0.93411	0.93411	0.93423	0.93544	0.93686	0.93988	0.94317	0.94673	0.95055	0.97370
350	0.93102	0.93103	0.93113	0.93217	0.93336	0.93586	0.93852	0.94135	0.94434	0.96183
375	0.92805	0.92805	0.92814	0.92905	0.93009	0.93223	0.93447	0.93681	0.93926	0.95307
400	0.92519	0.92520	0.92528	0.92609	0.92700	0.92888	0.93081	0.93281	0.93487	0.94616
425	0.92247	0.92247	0.92254	0.92327	0.92408	0.92574	0.92743	0.92916	0.93093	0.94040
450	0.91988	0.91988	0.91995	0.92059	0.92131	0.92278	0.92426	0.92577	0.92730	0.93536
475	0.91743	0.91743	0.91749	0.91806	0.91870	0.91998	0.92128	0.92260	0.92393	0.93082
500	0.91511	0.91511	0.91516	0.91566	0.91622	0.91734	0.91847	0.91961	0.92075	0.92664
525	0.91293	0.91293	0.91297	0.91340	0.91388	0.91485	0.91582	0.91679	0.91777	0.92275
550	0.91087	0.91088	0.91091	0.91128	0.91168	0.91249	0.91331	0.91413	0.91495	0.91911
575	0.90894	0.90894	0.90897	0.90927	0.90960	0.91027	0.91095	0.91162	0.91229	0.91570
600	0.90711	0.90711	0.90714	0.90738	0.90764	0.90818	0.90871	0.90925	0.90979	0.91249
625	0.90539	0.90539	0.90541	0.90559	0.90579	0.90620	0.90661	0.90702	0.90742	0.90947
650	0.90376	0.90376	0.90377	0.90390	0.90404	0.90433	0.90462	0.90491	0.90519	0.90663
675	0.90221	0.90221	0.90222	0.90230	0.90239	0.90256	0.90274	0.90291	0.90309	0.90396
700	0.90074	0.90074	0.90075	0.90078	0.90081	0.90089	0.90096	0.90103	0.90110	0.90146
725	0.89935	0.89935	0.89935	0.89934	0.89932	0.89930	0.89928	0.89925	0.89923	0.89910
750	0.89803	0.89802	0.89802	0.89797	0.89791	0.89780	0.89769	0.89757	0.89746	0.89690
775	0.89677	0.89677	0.89677	0.89668	0.89658	0.89639	0.89619	0.89600	0.89580	0.89484
800	0.89560	0.89560	0.89559	0.89547	0.89533	0.89506	0.89480	0.89453	0.89426	0.89293

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 13 Prandtl number Pr [−]^a – Continued

t [°C]	p [bar]									
	40	60	80	100	120	140	160	180	200	220
0	13.408	13.310	13.215	13.121	13.029	12.940	12.852	12.766	12.683	12.601
5	11.106	11.037	10.970	10.905	10.841	10.778	10.716	10.656	10.597	10.539
10	9.3676	9.3185	9.2703	9.2231	9.1768	9.1314	9.0869	9.0433	9.0006	8.9587
15	8.0208	7.9845	7.9490	7.9141	7.8799	7.8463	7.8133	7.7810	7.7493	7.7182
20	6.9544	6.9271	6.9003	6.8740	6.8481	6.8227	6.7978	6.7733	6.7493	6.7257
25	6.0947	6.0738	6.0532	6.0330	6.0131	5.9935	5.9743	5.9555	5.9369	5.9187
30	5.3912	5.3749	5.3588	5.3430	5.3274	5.3122	5.2971	5.2824	5.2678	5.2536
35	4.8079	4.7950	4.7823	4.7698	4.7574	4.7453	4.7334	4.7217	4.7102	4.6988
40	4.3190	4.3086	4.2984	4.2884	4.2785	4.2688	4.2592	4.2498	4.2405	4.2314
45	3.9051	3.8967	3.8885	3.8803	3.8723	3.8644	3.8566	3.8490	3.8415	3.8341
50	3.5518	3.5450	3.5382	3.5315	3.5250	3.5185	3.5121	3.5059	3.4997	3.4936
60	2.9849	2.9801	2.9755	2.9709	2.9664	2.9619	2.9575	2.9532	2.9490	2.9448
70	2.5550	2.5516	2.5483	2.5451	2.5418	2.5387	2.5356	2.5325	2.5295	2.5265
80	2.2221	2.2197	2.2173	2.2149	2.2125	2.2102	2.2079	2.2057	2.2035	2.2013
90	1.9600	1.9581	1.9563	1.9545	1.9527	1.9510	1.9493	1.9476	1.9459	1.9443
100	1.7504	1.7490	1.7476	1.7462	1.7448	1.7434	1.7421	1.7408	1.7395	1.7383
125	1.3825	1.3816	1.3807	1.3798	1.3790	1.3782	1.3773	1.3765	1.3757	1.3750
150	1.1544	1.1536	1.1528	1.1521	1.1514	1.1507	1.1500	1.1493	1.1487	1.1480
175	1.0078	1.0070	1.0062	1.0054	1.0046	1.0039	1.0032	1.0025	1.0018	1.0012
200	0.91491	0.91374	0.91262	0.91153	0.91048	0.90946	0.90848	0.90752	0.90659	0.90569
225	0.86043	0.85862	0.85689	0.85522	0.85362	0.85208	0.85060	0.84917	0.84779	0.84646
250	<u>0.83815</u>	0.83506	0.83213	0.82935	0.82671	0.82420	0.82181	0.81952	0.81733	0.81524
275	1.1695	<u>0.84518</u>	<u>0.83951</u>	0.83426	0.82939	0.82485	0.82061	0.81662	0.81287	0.80934
300	1.0875	1.2468	1.5531	<u>0.88473</u>	<u>0.87354</u>	0.86358	0.85464	0.84655	0.83918	0.83243
325	1.0402	1.1374	1.2833	1.5208	2.0266	<u>0.98838</u>	<u>0.96117</u>	0.93865	0.91964	0.90331
350	1.0098	1.0761	1.1650	1.2875	1.4653	1.7497	2.3857	<u>1.3019</u>	1.1862	1.1128
375	0.98904	1.0368	1.0974	1.1738	1.2717	1.4005	1.5791	1.8502	2.3504	5.7935
400	0.97411	1.0097	1.0535	1.1062	1.1694	1.2458	1.3390	1.4544	1.6032	1.8069
425	0.96276	0.99012	1.0228	1.0611	1.1054	1.1564	1.2153	1.2835	1.3622	1.4535
450	0.95364	0.97517	1.0002	1.0289	1.0613	1.0976	1.1381	1.1832	1.2333	1.2888
475	0.94597	0.96320	0.98272	1.0046	1.0289	1.0557	1.0848	1.1165	1.1508	1.1877
500	0.93926	0.95321	0.96863	0.98560	1.0041	1.0242	1.0458	1.0688	1.0933	1.1191
525	0.93324	0.94456	0.95681	0.97007	0.98434	0.99960	1.0158	1.0329	1.0508	1.0694
550	0.92775	0.93689	0.94661	0.95697	0.96797	0.97962	0.99187	1.0047	1.0180	1.0317
575	0.92268	0.92996	0.93759	0.94562	0.95406	0.96290	0.97212	0.98170	0.99157	1.0017
600	0.91797	0.92363	0.92949	0.93560	0.94195	0.94856	0.95541	0.96248	0.96973	0.97713
625	0.91359	0.91781	0.92214	0.92662	0.93125	0.93603	0.94097	0.94603	0.95122	0.95649
650	0.90951	0.91244	0.91543	0.91850	0.92167	0.92493	0.92829	0.93173	0.93524	0.93881
675	0.90571	0.90747	0.90927	0.91113	0.91304	0.91501	0.91704	0.91913	0.92127	0.92345
700	0.90216	0.90289	0.90364	0.90443	0.90527	0.90615	0.90708	0.90806	0.90907	0.91012
725	0.89886	0.89862	0.89842	0.89824	0.89809	0.89799	0.89792	0.89789	0.89789	0.89791
750	0.89578	0.89469	0.89362	0.89258	0.89158	0.89061	0.88967	0.88877	0.88790	0.88706
775	0.89293	0.89106	0.88922	0.88742	0.88566	0.88393	0.88224	0.88059	0.87897	0.87738
800	0.89031	0.88773	0.88520	0.88272	0.88029	0.87790	0.87555	0.87325	0.87098	0.86875

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 13 Prandtl number Pr [–] – Continued

t [°C]	p [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	12.521	12.443	12.366	12.291	11.942	11.630	11.352	11.104	10.885	10.518
5	10.483	10.428	10.373	10.320	10.072	9.8483	9.6480	9.4688	9.3086	9.0395
10	8.9177	8.8774	8.8380	8.7994	8.6176	8.4535	8.3057	8.1727	8.0533	7.8512
15	7.6877	7.6577	7.6284	7.5995	7.4636	7.3404	7.2289	7.1282	7.0374	6.8829
20	6.7025	6.6798	6.6575	6.6356	6.5319	6.4377	6.3520	6.2744	6.2043	6.0842
25	5.9008	5.8833	5.8660	5.8490	5.7687	5.6954	5.6286	5.5679	5.5128	5.4182
30	5.2395	5.2258	5.2122	5.1989	5.1357	5.0778	5.0250	4.9769	4.9331	4.8577
35	4.6877	4.6767	4.6659	4.6553	4.6049	4.5587	4.5165	4.4779	4.4427	4.3819
40	4.2224	4.2136	4.2049	4.1964	4.1558	4.1185	4.0843	4.0530	4.0245	3.9751
45	3.8268	3.8196	3.8125	3.8056	3.7725	3.7421	3.7142	3.6886	3.6653	3.6248
50	3.4876	3.4817	3.4760	3.4702	3.4431	3.4181	3.3951	3.3740	3.3547	3.3213
60	2.9406	2.9366	2.9326	2.9286	2.9099	2.8925	2.8766	2.8620	2.8486	2.8254
70	2.5235	2.5207	2.5178	2.5150	2.5017	2.4893	2.4780	2.4676	2.4581	2.4416
80	2.1992	2.1971	2.1950	2.1929	2.1832	2.1742	2.1660	2.1584	2.1515	2.1396
90	1.9427	1.9411	1.9396	1.9380	1.9307	1.9240	1.9179	1.9123	1.9072	1.8984
100	1.7370	1.7358	1.7346	1.7334	1.7278	1.7227	1.7180	1.7137	1.7099	1.7033
125	1.3742	1.3734	1.3727	1.3720	1.3686	1.3655	1.3628	1.3603	1.3581	1.3544
150	1.1474	1.1468	1.1462	1.1456	1.1429	1.1404	1.1382	1.1363	1.1346	1.1318
175	1.0005	0.99995	0.99938	0.99885	0.99608	0.99346	0.99115	0.98911	0.98732	0.98437
200	0.90482	0.90397	0.90315	0.90235	0.89869	0.89552	0.89278	0.89046	0.88844	0.88460
225	0.84517	0.84393	0.84273	0.84157	0.83628	0.83174	0.82781	0.82438	0.82138	0.81643
250	0.81324	0.81131	0.80946	0.80769	0.79974	0.79306	0.78736	0.78243	0.77815	0.77104
275	0.80600	0.80283	0.79982	0.79696	0.78450	0.77440	0.76600	0.75889	0.75277	0.74277
300	0.82620	0.82044	0.81509	0.81010	0.78933	0.77348	0.76083	0.75042	0.74167	0.72766
325	0.88910	0.87656	0.86537	0.85530	0.81674	0.79029	0.77057	0.75507	0.74245	0.72289
350	1.0605	1.0205	0.98864	0.96244	0.87666	0.82746	0.79496	0.77125	0.75291	0.72584
375	2.3444	1.6726	1.4216	1.2824	1.0041	0.90081	0.84318	0.80515	0.77759	0.73947
400	2.0989	2.6066	3.5719	3.3546	1.2971	1.0291	0.91839	0.85504	0.81292	0.75904
425	1.5609	1.6911	1.8502	2.0390	1.9249	1.2548	1.0353	0.92856	0.86379	0.78682
450	1.3498	1.4163	1.4886	1.5673	1.8977	1.5253	1.1899	1.0239	0.92919	0.82342
475	1.2273	1.2695	1.3139	1.3600	1.5876	1.5696	1.3198	1.1220	0.99946	0.86421
500	1.1462	1.1746	1.2041	1.2345	1.3830	1.4522	1.3476	1.1875	1.0587	0.90285
525	1.0887	1.1086	1.1289	1.1496	1.2514	1.3177	1.2981	1.2005	1.0920	0.93351
550	1.0457	1.0599	1.0744	1.0889	1.1591	1.2115	1.2186	1.1729	1.0959	0.95248
575	1.0120	1.0224	1.0328	1.0432	1.0923	1.1298	1.1442	1.1236	1.0744	0.95888
600	0.98463	0.99219	0.99974	1.0072	1.0420	1.0678	1.0794	1.0718	1.0430	0.95399
625	0.96182	0.96718	0.97253	0.97782	1.0021	1.0196	1.0271	1.0222	1.0038	0.93941
650	0.94241	0.94602	0.94962	0.95318	0.96936	0.98058	0.98453	0.97993	0.96635	0.91341
675	0.92564	0.92785	0.93004	0.93220	0.94186	0.94794	0.94883	0.94374	0.93270	0.89372
700	0.91119	0.91227	0.91335	0.91441	0.91901	0.92121	0.91971	0.91395	0.90409	0.87500
725	0.89795	0.89801	0.89807	0.89812	0.89791	0.89606	0.89160	0.88408	0.87369	0.84758
750	0.88623	0.88542	0.88463	0.88383	0.87967	0.87455	0.86773	0.85882	0.84784	0.82182
775	0.87582	0.87428	0.87276	0.87126	0.86381	0.85604	0.84743	0.83759	0.82634	0.79993
800	0.86656	0.86440	0.86227	0.86017	0.84998	0.84007	0.83010	0.81971	0.80854	0.78197

Table 14 Thermal diffusivity a

For the single-phase region, this table contains values for the

- Thermal diffusivity $a = \lambda/(\rho c_p)$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar.

In regions 1 and 2 and the given values of p and t , the density ρ ($=1/v$) and the specific isobaric heat capacity c_p were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities of Eq. (2.11), was determined by iterating this equation. With these (ρ, t) values, the specific isobaric heat capacity c_p was determined.

The thermal conductivity λ was calculated from the equation for industrial use, Eq. (3.4). The values of the input quantities ρ , needed in this equation, were determined from the IAPWS-IF97 basic equations as shown above.

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 14 Thermal diffusivity α [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]^a

<i>t</i> [°C]	<i>p</i> [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	0.13168	0.13168	0.13168	0.13171	0.13174	0.13179	0.13184	0.13190	0.13195	0.13222
5	1911.4	0.13501	0.13501	0.13503	0.13506	0.13511	0.13515	0.13520	0.13525	0.13548
10	1988.6	1206.6	0.13798	0.13799	0.13802	0.13806	0.13810	0.13814	0.13819	0.13840
15	2064.7	1256.5	0.14066	0.14068	0.14070	0.14074	0.14078	0.14082	0.14086	0.14105
20	2141.3	1305.0	0.14314	0.14316	0.14318	0.14321	0.14325	0.14328	0.14332	0.14350
25	2219.2	1353.5	0.14545	0.14546	0.14548	0.14551	0.14555	0.14558	0.14562	0.14579
30	2298.6	1402.5	0.14761	0.14763	0.14764	0.14767	0.14771	0.14774	0.14777	0.14793
35	2379.7	1452.4	0.14965	0.14966	0.14968	0.14971	0.14974	0.14977	0.14980	0.14996
40	2462.6	1503.3	0.15157	0.15159	0.15160	0.15163	0.15166	0.15169	0.15172	0.15187
45	2547.3	1555.2	0.15340	0.15341	0.15342	0.15345	0.15348	0.15351	0.15354	0.15369
50	2633.7	1608.2	156.25	0.15513	0.15515	0.15518	0.15520	0.15523	0.15526	0.15540
60	2812.1	1717.5	168.49	0.15830	0.15831	0.15834	0.15837	0.15840	0.15843	0.15857
70	2997.9	1831.2	180.50	0.16112	0.16113	0.16116	0.16119	0.16121	0.16124	0.16138
80	3191.1	1949.5	192.74	0.16359	0.16361	0.16364	0.16367	0.16369	0.16372	0.16386
90	3391.8	2072.3	205.34	0.16575	0.16576	0.16579	0.16582	0.16585	0.16588	0.16602
100	3599.9	2199.6	218.343	20.086	0.16760	0.16763	0.16766	0.16769	0.16772	0.16787
125	4153.6	2538.2	252.689	24.102	11.329	0.17089	0.17093	0.17096	0.17099	0.17116
150	4755.1	2906.0	289.781	28.132	13.571	6.211	0.17232	0.17236	0.17240	0.17259
175	5404.8	3303.2	329.712	32.339	15.799	7.502	4.707	3.257	0.17209	0.17232
200	6103.2	3730.2	372.543	36.766	18.098	8.744	5.611	4.035	3.080	0.16998
225	6850.4	4186.9	418.310	41.440	20.493	10.005	6.498	4.737	3.677	1.517
250	7646.5	4673.5	467.033	46.379	23.003	11.304	7.397	5.437	4.258	1.879
275	8491.4	5189.9	518.718	51.593	25.638	12.653	8.319	6.148	4.843	2.215
300	9384.8	5736.0	573.357	57.090	28.406	14.059	9.273	6.877	5.437	2.545
325	10326	6311.6	630.936	62.872	31.311	15.527	10.264	7.630	6.048	2.875
350	11316	6916.3	691.428	68.940	34.356	17.062	11.296	8.411	6.680	3.210
375	12352	7549.9	754.804	75.292	37.541	18.664	12.370	9.223	7.334	3.551
400	13436	8212.0	821.027	81.927	40.866	20.334	13.490	10.067	8.013	3.902
425	14565	8902.2	890.057	88.842	44.330	22.073	14.654	10.944	8.718	4.264
450	15739	9620.0	961.852	96.033	47.931	23.881	15.863	11.855	9.449	4.638
475	16958	10365	1036.4	103.50	51.669	25.756	17.118	12.799	10.207	5.024
500	18221	11137	1113.6	111.23	55.541	27.698	18.417	13.776	10.992	5.423
525	19527	11935	1193.4	119.22	59.544	29.706	19.760	14.787	11.803	5.835
550	20876	12759	1275.8	127.48	63.678	31.779	21.146	15.830	12.640	6.261
575	22266	13609	1360.8	135.99	67.940	33.917	22.576	16.905	13.503	6.699
600	23698	14484	1448.4	144.75	72.329	36.118	24.047	18.012	14.391	7.149
625	25171	15385	1538.4	153.77	76.843	38.381	25.561	19.151	15.305	7.613
650	26684	16309	1630.9	163.03	81.480	40.707	27.116	20.320	16.243	8.089
675	28236	17258	1725.8	172.53	86.240	43.094	28.712	21.521	17.206	8.577
700	29829	18232	1823.1	182.28	91.119	45.540	30.347	22.751	18.193	9.078
725	31460	19228	1922.8	192.26	96.118	48.047	32.023	24.011	19.204	9.590
750	33129	20249	2024.9	202.48	101.233	50.611	33.737	25.300	20.238	10.114
775	34836	21292	2129.2	212.92	106.463	53.233	35.490	26.618	21.296	10.650
800	36579	22358	2235.8	223.59	111.805	55.911	37.280	27.964	22.375	11.197

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 14 Thermal diffusivity α [$10^{-6} \text{ m}^2 \text{ s}^{-1}$]^a – Continued

t [°C]	p [bar]									
	40	60	80	100	120	140	160	180	200	220
0	0.13275	0.13327	0.13379	0.13430	0.13480	0.13530	0.13579	0.13627	0.13675	0.13722
5	0.13595	0.13642	0.13687	0.13732	0.13777	0.13821	0.13865	0.13908	0.13950	0.13992
10	0.13882	0.13924	0.13965	0.14006	0.14046	0.14086	0.14125	0.14164	0.14202	0.14240
15	0.14144	0.14182	0.14220	0.14257	0.14294	0.14330	0.14366	0.14402	0.14437	0.14472
20	0.14386	0.14421	0.14456	0.14491	0.14525	0.14559	0.14593	0.14626	0.14659	0.14691
25	0.14612	0.14645	0.14678	0.14711	0.14743	0.14775	0.14807	0.14838	0.14869	0.14900
30	0.14825	0.14857	0.14888	0.14919	0.14950	0.14980	0.15011	0.15040	0.15070	0.15099
35	0.15026	0.15057	0.15087	0.15117	0.15146	0.15176	0.15205	0.15233	0.15262	0.15290
40	0.15217	0.15246	0.15276	0.15305	0.15333	0.15362	0.15390	0.15418	0.15446	0.15473
45	0.15398	0.15426	0.15455	0.15483	0.15511	0.15539	0.15567	0.15594	0.15621	0.15648
50	0.15569	0.15597	0.15625	0.15653	0.15681	0.15708	0.15735	0.15762	0.15789	0.15815
60	0.15885	0.15912	0.15940	0.15967	0.15994	0.16021	0.16048	0.16075	0.16101	0.16127
70	0.16166	0.16194	0.16221	0.16249	0.16276	0.16303	0.16329	0.16356	0.16383	0.16409
80	0.16415	0.16443	0.16470	0.16498	0.16526	0.16553	0.16580	0.16607	0.16634	0.16661
90	0.16631	0.16660	0.16688	0.16717	0.16745	0.16773	0.16801	0.16828	0.16856	0.16883
100	0.16817	0.16846	0.16876	0.16905	0.16934	0.16963	0.16992	0.17020	0.17049	0.17077
125	0.17149	0.17182	0.17215	0.17248	0.17280	0.17313	0.17345	0.17376	0.17408	0.17440
150	0.17298	0.17336	0.17374	0.17412	0.17449	0.17487	0.17523	0.17560	0.17596	0.17632
175	0.17277	0.17322	0.17367	0.17411	0.17454	0.17497	0.17540	0.17582	0.17624	0.17665
200	0.17055	0.17111	0.17166	0.17220	0.17273	0.17326	0.17378	0.17429	0.17480	0.17530
225	0.16604	0.16676	0.16747	0.16816	0.16884	0.16950	0.17016	0.17080	0.17143	0.17205
250	0.15873	0.15972	0.16068	0.16161	0.16251	0.16339	0.16424	0.16508	0.16589	0.16669
275	0.87228	0.14895	0.15038	0.15174	0.15305	0.15429	0.15549	0.15664	0.15776	0.15883
300	1.0764	0.57220	0.30635	0.13658	0.13877	0.14079	0.14268	0.14446	0.14613	0.14772
325	1.2705	0.72539	0.44627	0.27348	0.14924	0.11855	0.12234	0.12570	0.12871	0.13144
350	1.4606	0.86915	0.56936	0.38658	0.26236	0.17115	0.095601	0.088227	0.097214	0.10399
375	1.6496	1.00884	0.68520	0.48931	0.35755	0.26262	0.19056	0.13322	0.084666	0.025411
400	1.8396	1.14679	0.79765	0.58685	0.44565	0.34446	0.26847	0.20947	0.16220	0.12325
425	2.0323	1.28464	0.90863	0.68190	0.53025	0.42177	0.34045	0.27739	0.22732	0.18685
450	2.2290	1.42366	1.01938	0.77590	0.61317	0.49684	0.40967	0.34208	0.28830	0.24471
475	2.4308	1.5649	1.1309	0.86981	0.69546	0.57085	0.47749	0.40509	0.34744	0.30060
500	2.6381	1.7090	1.2438	0.96434	0.77782	0.64455	0.54470	0.46723	0.40552	0.35534
525	2.8515	1.8566	1.3589	1.0601	0.86081	0.71848	0.61185	0.52909	0.46313	0.40944
550	3.0711	2.0080	1.4764	1.1575	0.94489	0.79310	0.67938	0.59110	0.52070	0.46335
575	3.2970	2.1634	1.5968	1.2569	1.0304	0.86874	0.74764	0.65362	0.57860	0.51744
600	3.5292	2.3229	1.7200	1.3584	1.1176	0.94566	0.81688	0.71690	0.63709	0.57199
625	3.7678	2.4866	1.8463	1.4623	1.2066	1.0240	0.88731	0.78114	0.69637	0.62720
650	4.0126	2.6544	1.9756	1.5686	1.2974	1.1040	0.95903	0.84647	0.75658	0.68321
675	4.2637	2.8263	2.1080	1.6772	1.3903	1.1855	1.0321	0.91295	0.81779	0.74008
700	4.5207	3.0022	2.2433	1.7882	1.4850	1.2686	1.1065	0.98052	0.87991	0.79773
725	4.7839	3.1822	2.3817	1.9016	1.5818	1.3535	1.1825	1.0496	0.94344	0.85671
750	5.0528	3.3661	2.5230	2.0174	1.6805	1.4401	1.2599	1.1199	1.0080	0.91664
775	5.3275	3.5537	2.6671	2.1354	1.7811	1.5282	1.3386	1.1914	1.0737	0.97750
800	5.6077	3.7450	2.8139	2.2555	1.8834	1.6178	1.4187	1.2639	1.1403	1.0392

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 14 Thermal diffusivity α [$10^{-6} \text{ m}^2 \text{ s}^{-1}$] – Continued

t [°C]	p [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	0.13769	0.13814	0.13860	0.13904	0.14118	0.14317	0.14501	0.14672	0.14828	0.15103
5	0.14033	0.14074	0.14114	0.14154	0.14344	0.14522	0.14687	0.14840	0.14983	0.15236
10	0.14277	0.14314	0.14350	0.14386	0.14559	0.14721	0.14872	0.15014	0.15145	0.15382
15	0.14506	0.14540	0.14573	0.14606	0.14766	0.14916	0.15057	0.15189	0.15313	0.15538
20	0.14723	0.14755	0.14786	0.14817	0.14967	0.15108	0.15241	0.15367	0.15485	0.15701
25	0.14930	0.14960	0.14990	0.15019	0.15161	0.15296	0.15423	0.15544	0.15658	0.15869
30	0.15128	0.15157	0.15185	0.15213	0.15350	0.15480	0.15603	0.15720	0.15832	0.16038
35	0.15318	0.15346	0.15373	0.15400	0.15533	0.15659	0.15779	0.15894	0.16004	0.16208
40	0.15500	0.15527	0.15554	0.15581	0.15710	0.15833	0.15952	0.16065	0.16173	0.16376
45	0.15675	0.15701	0.15728	0.15754	0.15881	0.16003	0.16120	0.16232	0.16340	0.16543
50	0.15842	0.15868	0.15894	0.15920	0.16045	0.16166	0.16283	0.16395	0.16502	0.16706
60	0.16153	0.16179	0.16205	0.16230	0.16355	0.16476	0.16592	0.16705	0.16814	0.17020
70	0.16435	0.16461	0.16487	0.16512	0.16638	0.16760	0.16878	0.16992	0.17104	0.17316
80	0.16687	0.16714	0.16740	0.16766	0.16894	0.17018	0.17139	0.17257	0.17371	0.17590
90	0.16910	0.16937	0.16964	0.16991	0.17123	0.17251	0.17375	0.17496	0.17614	0.17841
100	0.17105	0.17133	0.17161	0.17189	0.17325	0.17457	0.17586	0.17711	0.17834	0.18070
125	0.17471	0.17502	0.17533	0.17564	0.17715	0.17861	0.18004	0.18144	0.18280	0.18543
150	0.17668	0.17703	0.17739	0.17774	0.17945	0.18112	0.18273	0.18430	0.18583	0.18877
175	0.17706	0.17746	0.17786	0.17824	0.18020	0.18211	0.18396	0.18575	0.18748	0.19080
200	0.17580	0.17629	0.17677	0.17725	0.17956	0.18176	0.18386	0.18585	0.18777	0.19153
225	0.17266	0.17326	0.17385	0.17444	0.17723	0.17986	0.18233	0.18469	0.18693	0.19114
250	0.16747	0.16823	0.16898	0.16971	0.17317	0.17635	0.17931	0.18208	0.18470	0.18955
275	0.15988	0.16089	0.16187	0.16282	0.16724	0.17118	0.17478	0.17808	0.18116	0.18678
300	0.14922	0.15066	0.15203	0.15335	0.15925	0.16429	0.16875	0.17276	0.17642	0.18299
325	0.13394	0.13624	0.13839	0.14039	0.14887	0.15561	0.16129	0.16623	0.17065	0.17838
350	0.10949	0.11413	0.11816	0.12172	0.13537	0.14507	0.15260	0.15885	0.16424	0.17334
375	0.049263	0.069030	0.081329	0.090325	0.11655	0.13124	0.14157	0.14964	0.15631	0.16712
400	0.090758	0.062171	0.038491	0.036848	0.090584	0.11449	0.12910	0.13967	0.14801	0.16089
425	0.15360	0.12583	0.10256	0.083440	0.064612	0.095511	0.11523	0.12873	0.13899	0.15432
450	0.20892	0.17925	0.15448	0.13367	0.076755	0.083125	0.10292	0.11839	0.13019	0.14758
475	0.26197	0.22973	0.20263	0.17975	0.10875	0.089661	0.097966	0.11151	0.12346	0.14179
500	0.31386	0.27913	0.24975	0.22473	0.14402	0.10961	0.10407	0.11093	0.12062	0.13805
525	0.36501	0.32774	0.29615	0.26911	0.17964	0.13591	0.11877	0.11749	0.12277	0.13707
550	0.41584	0.37593	0.34203	0.31298	0.21552	0.16445	0.13925	0.12995	0.12985	0.13915
575	0.46672	0.42406	0.38777	0.35661	0.25128	0.19413	0.16247	0.14694	0.14151	0.14427
600	0.51795	0.47246	0.43370	0.40035	0.28694	0.22417	0.18752	0.16659	0.15612	0.15221
625	0.56975	0.52133	0.48003	0.44445	0.32279	0.25439	0.21330	0.18826	0.17366	0.16284
650	0.62223	0.57081	0.52692	0.48906	0.35902	0.28500	0.23957	0.21083	0.19277	0.17671
675	0.67548	0.62097	0.57441	0.53422	0.39570	0.31608	0.26642	0.23416	0.21290	0.19067
700	0.72939	0.67170	0.62239	0.57980	0.43259	0.34727	0.29339	0.25772	0.23351	0.20552
725	0.78457	0.72365	0.67157	0.62655	0.47068	0.37982	0.32192	0.28308	0.25623	0.22366
750	0.84060	0.77638	0.72145	0.67395	0.50922	0.41274	0.35077	0.30875	0.27932	0.24281
775	0.89746	0.82985	0.77201	0.72198	0.54821	0.44598	0.37985	0.33457	0.30247	0.26221
800	0.95511	0.88404	0.82322	0.77061	0.58759	0.47950	0.40910	0.36044	0.32558	0.28155

Table 15 Dielectric constant ε

For the single-phase region, this table contains values for the

- Dielectric constant ε

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar.

The dielectric constant was calculated from Eq. (3.9). The input quantities of this equation are density and temperature. Thus, for given pressures and temperatures, the values of the density ρ had to be determined first.

In regions 1 and 2 and the given values of p and t , the density ρ ($=1/v$) was calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ was determined by iterating this equation.

Thus, with the values of the input quantities (ρ, t) , the dielectric constant ε was calculated from of Eq. (3.9).

For temperatures $t \geq 600^\circ\text{C}$, the values for ε were obtained by extrapolating Eq. (3.9) as described in Sec. 3.4 under the subsection “Range of Validity.”

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 15 Dielectric constant ϵ [–] ^{a,b}

<i>t</i> [°C]	<i>p</i> [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	87.899	87.899	87.900	87.903	87.908	87.916	87.924	87.933	87.941	87.983
5	1.000062	85.911	85.912	85.915	85.920	85.928	85.936	85.944	85.952	85.993
10	1.000060	1.000010	83.971	83.974	83.978	83.986	83.994	84.002	84.010	84.050
15	1.000058	1.000094	82.074	82.077	82.081	82.089	82.097	82.104	82.112	82.151
20	1.000056	1.000091	80.219	80.222	80.226	80.234	80.241	80.249	80.257	80.295
25	1.000054	1.000088	78.405	78.408	78.412	78.420	78.427	78.435	78.442	78.479
30	1.000052	1.000085	76.631	76.634	76.638	76.645	76.653	76.660	76.667	76.704
35	1.000051	1.000083	74.895	74.899	74.902	74.910	74.917	74.924	74.931	74.968
40	1.000049	1.000080	73.198	73.201	73.205	73.212	73.219	73.226	73.234	73.269
45	1.000048	1.000078	71.538	71.541	71.544	71.552	71.559	71.566	71.573	71.608
50	1.000046	1.000075	1.00076	69.917	69.921	69.928	69.935	69.942	69.949	69.984
60	1.000043	1.000071	1.00071	66.776	66.779	66.786	66.793	66.800	66.807	66.842
70	1.000041	1.000067	1.00067	63.771	63.775	63.782	63.789	63.796	63.803	63.837
80	1.000039	1.000063	1.00064	60.899	60.902	60.909	60.916	60.923	60.930	60.965
90	1.000037	1.000060	1.00060	58.153	58.156	58.163	58.170	58.177	58.184	58.219
100	1.000035	1.000057	1.00057	1.0058	55.531	55.538	55.545	55.552	55.559	55.593
125	1.000031	1.000050	1.00050	1.0051	1.0103	49.466	49.473	49.480	49.488	49.524
150	1.000027	1.000045	1.00045	1.0045	1.0091	1.0187	44.035	44.043	44.050	44.088
175	1.000024	1.000040	1.00040	1.0040	1.0081	1.0166	1.0253	1.0345	39.157	39.197
200	1.000022	1.000036	1.00036	1.0036	1.0073	1.0148	1.0226	1.0306	1.0389	34.762
225	1.000020	1.000033	1.00033	1.0033	1.0066	1.0134	1.0203	1.0274	1.0347	1.0747
250	1.000018	1.000030	1.00030	1.0030	1.0060	1.0121	1.0184	1.0248	1.0313	1.0663
275	1.000017	1.000027	1.00027	1.0027	1.0055	1.0111	1.0167	1.0225	1.0284	1.0595
300	1.000015	1.000025	1.00025	1.0025	1.0050	1.0101	1.0153	1.0206	1.0259	1.0539
325	1.000014	1.000023	1.00023	1.0023	1.0046	1.0093	1.0141	1.0189	1.0238	1.0492
350	1.000013	1.000021	1.00021	1.0021	1.0043	1.0086	1.0130	1.0174	1.0219	1.0451
375	1.000012	1.000020	1.00020	1.0020	1.0040	1.0080	1.0120	1.0161	1.0203	1.0416
400	1.000011	1.000018	1.00018	1.0018	1.0037	1.0074	1.0112	1.0150	1.0188	1.0385
425	1.000011	1.000017	1.00017	1.0017	1.0034	1.0069	1.0104	1.0140	1.0175	1.0358
450	1.000010	1.000016	1.00016	1.0016	1.0032	1.0065	1.0097	1.0130	1.0164	1.0333
475	1.000009	1.000015	1.00015	1.0015	1.0030	1.0061	1.0091	1.0122	1.0153	1.0312
500	1.000009	1.000014	1.00014	1.0014	1.0028	1.0057	1.0086	1.0115	1.0144	1.0292
525	1.000008	1.000013	1.00013	1.0013	1.0027	1.0054	1.0081	1.0108	1.0135	1.0274
550	1.000008	1.000013	1.00013	1.0013	1.0025	1.0051	1.0076	1.0102	1.0128	1.0258
575	1.000007	1.000012	1.00012	1.0012	1.0024	1.0048	1.0072	1.0096	1.0121	1.0244
600	1.000007	1.000011	1.00011	1.0011	1.0023	1.0045	1.0068	1.0091	1.0114	1.0231
625	1.000007	1.000011	1.00011	1.0011	1.0021	1.0043	1.0065	1.0086	1.0108	1.0219
650	1.000006	1.000010	1.00010	1.0010	1.0020	1.0041	1.0061	1.0082	1.0103	1.0207
675	1.000006	1.000010	1.00010	1.0010	1.0019	1.0039	1.0058	1.0078	1.0098	1.0197
700	1.000006	1.000009	1.00009	1.0009	1.0018	1.0037	1.0056	1.0074	1.0093	1.0188
725	1.000005	1.000009	1.00009	1.0009	1.0018	1.0035	1.0053	1.0071	1.0089	1.0179
750	1.000005	1.000008	1.00008	1.0008	1.0017	1.0034	1.0051	1.0068	1.0085	1.0171
775	1.000005	1.000008	1.00008	1.0008	1.0016	1.0032	1.0048	1.0065	1.0081	1.0163
800	1.000005	1.000008	1.00008	1.0008	1.0015	1.0031	1.0046	1.0062	1.0078	1.0156

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.^bThe ϵ values below the dashed line were calculated from Eq. (3.9) by extrapolating this equation in accordance with the IAPWS release [42].

Table 15 Dielectric constant ϵ [-]^{a,b} – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	40	60	80	100	120	140	160	180	200	220
0	88.066	88.149	88.232	88.315	88.398	88.480	88.562	88.644	88.725	88.807
5	86.074	86.154	86.235	86.315	86.396	86.475	86.555	86.635	86.714	86.793
10	84.129	84.207	84.286	84.364	84.442	84.520	84.598	84.676	84.753	84.830
15	82.228	82.305	82.382	82.458	82.535	82.611	82.687	82.763	82.838	82.914
20	80.370	80.446	80.521	80.596	80.671	80.745	80.820	80.894	80.968	81.042
25	78.554	78.628	78.702	78.775	78.849	78.922	78.995	79.068	79.141	79.214
30	76.777	76.850	76.923	76.996	77.068	77.140	77.212	77.284	77.356	77.427
35	75.040	75.112	75.184	75.255	75.327	75.398	75.469	75.540	75.611	75.681
40	73.341	73.412	73.483	73.554	73.625	73.695	73.765	73.835	73.905	73.975
45	71.679	71.750	71.820	71.890	71.960	72.030	72.100	72.169	72.238	72.307
50	70.054	70.124	70.194	70.264	70.333	70.402	70.471	70.540	70.608	70.677
60	66.911	66.981	67.050	67.119	67.187	67.255	67.324	67.391	67.459	67.526
70	63.906	63.975	64.044	64.112	64.180	64.248	64.316	64.383	64.450	64.517
80	61.034	61.102	61.171	61.239	61.307	61.375	61.442	61.509	61.576	61.642
90	58.288	58.357	58.425	58.493	58.561	58.629	58.696	58.763	58.830	58.897
100	55.663	55.732	55.801	55.870	55.938	56.006	56.073	56.140	56.207	56.274
125	49.595	49.666	49.737	49.807	49.877	49.946	50.015	50.083	50.152	50.219
150	44.163	44.237	44.311	44.384	44.456	44.528	44.600	44.671	44.742	44.812
175	39.277	39.357	39.435	39.513	39.590	39.666	39.742	39.817	39.892	39.966
200	34.850	34.937	35.022	35.107	35.191	35.274	35.356	35.437	35.517	35.596
225	30.790	30.888	30.985	31.080	31.174	31.266	31.357	31.447	31.535	31.623
250	<u>27.001</u>	27.117	27.231	27.342	27.451	27.558	27.663	27.766	27.867	27.966
275	1.1333	<u>23.508</u>	<u>23.651</u>	23.789	23.924	24.054	24.181	24.305	24.426	24.543
300	1.1180	1.1982	1.3079	<u>20.271</u>	<u>20.454</u>	20.629	20.796	20.957	21.111	21.260
325	1.1060	1.1737	1.2579	1.3705	1.5453	<u>17.031</u>	<u>17.294</u>	17.536	17.761	17.971
350	1.0961	1.1550	1.2246	1.3099	1.4200	1.5755	1.8431	<u>13.481</u>	13.956	14.351
375	1.0879	1.1400	1.1998	1.2696	1.3534	1.4576	1.5940	1.7881	2.1126	3.1189
400	1.0808	1.1276	1.1801	1.2397	1.3083	1.3888	1.4854	1.6050	1.7589	1.9684
425	1.0746	1.1171	1.1640	1.2160	1.2744	1.3407	1.4168	1.5056	1.6108	1.7382
450	1.0692	1.1081	1.1504	1.1967	1.2476	1.3042	1.3675	1.4388	1.5199	1.6131
475	1.0645	1.1002	1.1387	1.1804	1.2257	1.2751	1.3294	1.3893	1.4557	1.5297
500	1.0602	1.0933	1.1286	1.1665	1.2072	1.2512	1.2988	1.3505	1.4069	1.4685
525	1.0564	1.0872	1.1198	1.1545	1.1915	1.2310	1.2734	1.3189	1.3680	1.4209
550	1.0530	1.0817	1.1119	1.1439	1.1778	1.2137	1.2519	1.2926	1.3360	1.3823
575	1.0500	1.0768	1.1049	1.1345	1.1658	1.1987	1.2334	1.2702	1.3091	1.3503
600	1.0471	1.0723	1.0986	1.1262	1.1551	1.1854	1.2173	1.2508	1.2860	1.3231
625	1.0446	1.0683	1.0930	1.1187	1.1456	1.1737	1.2031	1.2338	1.2660	1.2997
650	1.0423	1.0646	1.0878	1.1120	1.1371	1.1632	1.1905	1.2189	1.2485	1.2793
675	1.0401	1.0612	1.0831	1.1058	1.1294	1.1538	1.1792	1.2056	1.2329	1.2614
700	1.0381	1.0582	1.0789	1.1003	1.1224	1.1453	1.1690	1.1936	1.2190	1.2454
725	1.0363	1.0553	1.0749	1.0952	1.1160	1.1376	1.1598	1.1828	1.2066	1.2311
750	1.0346	1.0527	1.0713	1.0905	1.1102	1.1305	1.1515	1.1730	1.1953	1.2182
775	1.0331	1.0503	1.0680	1.0862	1.1048	1.1241	1.1438	1.1641	1.1850	1.2065
800	1.0316	1.0480	1.0649	1.0822	1.0999	1.1181	1.1368	1.1560	1.1757	1.1959

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.^bThe ϵ values below the dashed line were calculated from Eq. (3.9) by extrapolating this equation in accordance with the IAPWS release [42].

Table 15 Dielectric constant ϵ [–]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	88.888	88.969	89.050	89.131	89.531	89.927	90.318	90.704	91.086	91.838
5	86.872	86.951	87.030	87.108	87.497	87.881	88.261	88.636	89.007	89.736
10	84.907	84.984	85.060	85.137	85.516	85.890	86.260	86.625	86.986	87.696
15	82.989	83.064	83.139	83.213	83.583	83.949	84.310	84.667	85.019	85.712
20	81.116	81.189	81.262	81.336	81.698	82.056	82.410	82.759	83.103	83.781
25	79.286	79.358	79.430	79.502	79.858	80.209	80.556	80.898	81.236	81.900
30	77.498	77.569	77.640	77.711	78.061	78.406	78.747	79.083	79.415	80.067
35	75.751	75.821	75.891	75.961	76.306	76.646	76.982	77.313	77.640	78.281
40	74.044	74.113	74.182	74.251	74.592	74.928	75.259	75.585	75.907	76.539
45	72.375	72.444	72.512	72.580	72.917	73.249	73.577	73.899	74.217	74.840
50	70.745	70.813	70.880	70.948	71.282	71.610	71.934	72.253	72.568	73.184
60	67.594	67.660	67.727	67.794	68.123	68.446	68.765	69.078	69.387	69.990
70	64.583	64.650	64.716	64.782	65.107	65.427	65.742	66.051	66.355	66.950
80	61.709	61.774	61.840	61.906	62.229	62.547	62.859	63.165	63.466	64.054
90	58.963	59.029	59.094	59.160	59.482	59.799	60.109	60.413	60.712	61.295
100	56.340	56.406	56.472	56.537	56.860	57.176	57.486	57.789	58.086	58.665
125	50.287	50.354	50.421	50.487	50.814	51.132	51.443	51.747	52.044	52.620
150	44.882	44.951	45.020	45.088	45.424	45.749	46.066	46.374	46.674	47.254
175	40.039	40.111	40.184	40.255	40.605	40.943	41.269	41.585	41.892	42.481
200	35.675	35.752	35.829	35.906	36.277	36.632	36.974	37.303	37.620	38.225
225	31.709	31.794	31.878	31.962	32.363	32.744	33.107	33.454	33.786	34.414
250	28.064	28.160	28.254	28.347	28.793	29.209	29.601	29.973	30.326	30.986
275	24.658	24.771	24.881	24.989	25.498	25.964	26.397	26.802	27.182	27.885
300	21.403	21.542	21.677	21.808	22.412	22.950	23.439	23.888	24.304	25.062
325	18.169	18.357	18.536	18.706	19.465	20.109	20.675	21.184	21.648	22.474
350	14.693	14.998	15.274	15.527	16.569	17.382	18.060	18.650	19.175	20.087
375	9.6270	10.683	11.365	11.888	13.593	14.697	15.547	16.250	16.855	17.874
400	2.2792	2.8098	3.9330	5.9302	10.313	11.981	13.094	13.953	14.663	15.814
425	1.8962	2.0977	2.3642	2.7299	6.5334	9.1766	10.679	11.746	12.586	13.893
450	1.7214	1.8486	1.9999	2.1820	3.8823	6.4760	8.3525	9.6462	10.629	12.103
475	1.6128	1.7065	1.8129	1.9343	2.8759	4.5285	6.3155	7.7334	8.8284	10.451
500	1.5362	1.6107	1.6930	1.7842	2.4190	3.4609	4.8153	6.1344	7.2504	8.9583
525	1.4781	1.5400	1.6073	1.6804	2.1567	2.8757	3.8480	4.9291	5.9555	7.6491
550	1.4319	1.4850	1.5419	1.6029	1.9831	2.5209	3.2365	4.0811	4.9569	6.5402
575	1.3940	1.4404	1.4897	1.5421	1.8581	2.2835	2.8340	3.4948	4.2152	5.6301
600	1.3622	1.4034	1.4469	1.4928	1.7627	2.1127	2.5535	3.0811	3.6712	4.8999
625	1.3351	1.3721	1.4109	1.4517	1.6870	1.9832	2.3477	2.7797	3.2671	4.3211
650	1.3116	1.3452	1.3802	1.4168	1.6252	1.8812	2.1901	2.5521	2.9607	3.8650
675	1.2909	1.3217	1.3536	1.3868	1.5735	1.7984	2.0653	2.3747	2.7227	3.5012
700	1.2727	1.3010	1.3303	1.3607	1.5296	1.7298	1.9640	2.2327	2.5334	3.2085
725	1.2564	1.2826	1.3097	1.3376	1.4917	1.6717	1.8798	2.1164	2.3797	2.9709
750	1.2418	1.2662	1.2913	1.3171	1.4586	1.6220	1.8088	2.0193	2.2525	2.7754
775	1.2286	1.2514	1.2748	1.2988	1.4295	1.5788	1.7479	1.9371	2.1455	2.6122
800	1.2167	1.2380	1.2598	1.2823	1.4036	1.5409	1.6952	1.8666	2.0544	2.4739

^aThe ϵ values below the dashed line were calculated from Eq. (3.9) by extrapolating this equation in accordance with the IAPWS release [42].

Table 16 Refractive index n (Saturation state)

This table contains values on the saturated liquid ('') and saturated vapour ('') lines for the

- Refractive index n

for temperatures from 0°C up to the critical temperature $t_c = 373.946^\circ\text{C}$ and for the common wavelengths of $\bar{\lambda} = 0.2265 \mu\text{m}$, $0.40466 \mu\text{m}$, $0.5893 \mu\text{m}$, and $0.70652 \mu\text{m}$.

For given temperatures, the saturation pressures p_s were calculated from the IAPWS-IF97 saturation-pressure equation, Eq. (2.13).

The refractive index was calculated from Eq. (3.10). The input quantities of this equation are density, temperature and wavelength. Thus, for input pressures and temperatures, the values of the density $\rho (=1/v)$ had to be determined first.

For temperatures $t \leq 350^\circ\text{C}$ and the input values for t and p_s , the required densities $\rho' (=1/v')$ on the saturated-liquid line and $\rho'' (=1/v'')$ on the saturated-vapour line were determined from the basic equations for regions 1 and 2, Eqs. (2.3) and (2.6).

For $t > 350^\circ\text{C}$ and the input (t, p_s) values, the saturation densities ρ' and ρ'' were calculated by iterating the basic equation for region 3, Eq. (2.11).

Thus, with the values of the input quantities (ρ', t) , (ρ'', t) , and the given wavelengths, the refractive index n at saturation was calculated from Eq. (3.10).

Table 16 Refractive index n [-]
(Saturation state)

t [°C]	$\bar{\lambda} = 0.2265 \mu\text{m}$		$\bar{\lambda} = 0.40466 \mu\text{m}$		$\bar{\lambda} = 0.5893 \mu\text{m}$		$\bar{\lambda} = 0.70652 \mu\text{m}$	
	n'	n''	n'	n''	n'	n''	n'	n''
0	1.3945	1.000002	1.3441	1.000002	1.3343	1.000002	1.3313	1.000002
0.01 ^a	1.3945	1.000002	1.3441	1.000002	1.3343	1.000002	1.3313	1.000002
10	1.3942	1.000003	1.3439	1.000003	1.3340	1.000003	1.3311	1.000003
20	1.3933	1.00001	1.3431	1.00001	1.3333	1.00001	1.3304	1.00001
25	1.3928	1.00001	1.3426	1.00001	1.3328	1.00001	1.3299	1.00001
30	1.3921	1.00001	1.3420	1.00001	1.3323	1.00001	1.3293	1.00001
40	1.3905	1.00002	1.3406	1.00002	1.3309	1.00002	1.3280	1.00002
50	1.3885	1.00003	1.3390	1.00003	1.3294	1.00003	1.3264	1.00003
60	1.3864	1.00005	1.3371	1.00004	1.3276	1.00004	1.3247	1.00004
70	1.3839	1.0001	1.3350	1.0001	1.3256	1.0001	1.3227	1.0001
80	1.3813	1.0001	1.3328	1.0001	1.3234	1.0001	1.3206	1.0001
90	1.3785	1.0002	1.3304	1.0001	1.3211	1.0001	1.3183	1.0001
100	1.3755	1.0002	1.3278	1.0002	1.3186	1.0002	1.3158	1.0002
110	1.3723	1.0003	1.3251	1.0003	1.3159	1.0003	1.3132	1.0003
120	1.3689	1.0004	1.3222	1.0004	1.3132	1.0004	1.3105	1.0004
130	1.3654	1.0005	1.3192	1.0005	1.3103	1.0005	1.3076	1.0005
140	1.3616	1.0007	1.3160	1.0006	1.3072	1.0006	1.3046	1.0006
150	1.3578	1.0009	1.3127	1.0008	1.3040	1.0008	1.3014	1.0008
160	1.3537	1.0012	1.3092	1.0011	1.3007	1.0010	1.2981	1.0010
170	1.3495	1.0015	1.3056	1.0013	1.2972	1.0013	1.2947	1.0013
180	1.3451	1.0019	1.3019	1.0017	1.2936	1.0016	1.2911	1.0016
190	1.3406	1.0023	1.2980	1.0021	1.2898	1.0020	1.2873	1.0020
200	1.3358	1.0029	1.2939	1.0026	1.2858	1.0025	1.2834	1.0025
210	1.3308	1.0035	1.2896	1.0031	1.2817	1.0030	1.2794	1.0030
220	1.3256	1.0042	1.2852	1.0038	1.2774	1.0037	1.2751	1.0036
230	1.3202	1.0051	1.2805	1.0045	1.2729	1.0044	1.2706	1.0044
240	1.3145	1.0061	1.2756	1.0054	1.2682	1.0053	1.2660	1.0053
250	1.3086	1.0073	1.2705	1.0065	1.2632	1.0063	1.2611	1.0063
260	1.3023	1.0087	1.2651	1.0077	1.2580	1.0075	1.2559	1.0074
270	1.2957	1.0103	1.2594	1.0091	1.2525	1.0089	1.2504	1.0088
280	1.2887	1.0121	1.2534	1.0107	1.2466	1.0105	1.2446	1.0104
290	1.2813	1.0143	1.2469	1.0127	1.2404	1.0124	1.2384	1.0123
300	1.2732	1.0169	1.2400	1.0149	1.2336	1.0146	1.2318	1.0145
310	1.2646	1.0199	1.2325	1.0177	1.2264	1.0172	1.2246	1.0171
320	1.2551	1.0236	1.2243	1.0209	1.2184	1.0204	1.2167	1.0203
330	1.2446	1.0282	1.2151	1.0250	1.2095	1.0243	1.2079	1.0242
340	1.2325	1.0339	1.2047	1.0301	1.1994	1.0293	1.1978	1.0291
350	1.2183	1.0417	1.1923	1.0369	1.1873	1.0360	1.1858	1.0357
360	1.1998	1.0529	1.1761	1.0469	1.1716	1.0457	1.1703	1.0454
370	1.1694	1.0746	1.1495	1.0661	1.1457	1.0644	1.1446	1.0640
373.946 ^b		1.1200		1.1061		1.1035		1.1027

^aTriple-point temperature.^bCritical temperature.

Table 17 Refractive index n

For the single-phase region, this table contains values for the

- Refractive index n

for temperatures from 0°C up to 500°C, pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar and for the common wavelengths of $\bar{\lambda} = 0.2265 \mu\text{m}$, $0.40466 \mu\text{m}$, $0.5893 \mu\text{m}$, and $0.70652 \mu\text{m}$.

The refractive index was calculated from Eq. (3.10). The input quantities of this equation are density, temperature and wavelength. Thus, for given pressures and temperatures, the values of the density ρ had to be determined first.

In regions 1 and 2 and the given values of p and t , the density $\rho (=1/v)$ was calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3 and the given (p,t) values, the density ρ was determined by iterating the basic equation for region 3, Eq. (2.11).

Thus, with the values of the input quantities (ρ, t) and the wavelengths $\bar{\lambda}$, the refractive index n was calculated from Eq. (3.10).

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 17 Refractive index n [–]^a

t [°C]	p [bar]										
	0.006112127	0.01	0.1	1	2	5	10	25	50	75	100
$\bar{\lambda} = 0.2265 \mu\text{m}$											
0	1.3945	1.3945	1.3945	1.3945	1.3945	1.3946	1.3947	1.3950	1.3955	1.3960	1.3965
25	1.000002	1.000003	1.3928	1.3928	1.3928	1.3929	1.3929	1.3932	1.3937	1.3941	1.3945
50	1.000002	1.000002	1.00002	1.3885	1.3886	1.3886	1.3887	1.3890	1.3894	1.3898	1.3903
75	1.000001	1.000002	1.00002	1.3827	1.3827	1.3827	1.3828	1.3831	1.3835	1.3840	1.3844
100	1.000001	1.000002	1.00002	1.0002	1.3755	1.3755	1.3756	1.3759	1.3764	1.3768	1.3773
125	1.000001	1.000002	1.00002	1.0002	1.0004	1.3672	1.3673	1.3676	1.3681	1.3686	1.3691
150	1.000001	1.000002	1.00002	1.0002	1.0004	1.3578	1.3579	1.3582	1.3588	1.3593	1.3599
175	1.000001	1.000002	1.00002	1.0002	1.0004	1.0009	1.3474	1.3478	1.3484	1.3490	1.3497
200	1.000001	1.000002	1.00002	1.0002	1.0003	1.0009	1.0018	1.3361	1.3368	1.3376	1.3383
225	1.000001	1.000002	1.00002	1.0002	1.0003	1.0008	1.0017	1.0046	1.3239	1.3248	1.3256
250	1.000001	1.000002	1.00002	1.0002	1.0003	1.0008	1.0016	1.0042	1.3091	1.3102	1.3113
275	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0015	1.0039	1.0088	1.2932	1.2947
300	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0014	1.0037	1.0080	1.0136	1.2745
325	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0013	1.0035	1.0075	1.0122	1.0184
350	1.000001	1.000001	1.00001	1.0001	1.0003	1.0006	1.0013	1.0033	1.0070	1.0112	1.0162
375	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0012	1.0032	1.0066	1.0104	1.0148
400	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0012	1.0030	1.0063	1.0098	1.0137
425	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0011	1.0029	1.0060	1.0093	1.0129
450	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0011	1.0028	1.0057	1.0088	1.0121
475	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0011	1.0027	1.0055	1.0084	1.0115
500	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0026	1.0052	1.0081	1.0110
$\bar{\lambda} = 0.40466 \mu\text{m}$											
0	1.3441	1.3441	1.3441	1.3442	1.3442	1.3442	1.3443	1.3446	1.3450	1.3454	1.3458
25	1.000001	1.000002	1.3426	1.3426	1.3426	1.3427	1.3428	1.3430	1.3434	1.3437	1.3441
50	1.000001	1.000002	1.00002	1.3390	1.3390	1.3390	1.3391	1.3393	1.3397	1.3401	1.3404
75	1.000001	1.000002	1.00002	1.3340	1.3340	1.3340	1.3341	1.3343	1.3347	1.3350	1.3354
100	1.000001	1.000002	1.00002	1.0002	1.3278	1.3279	1.3279	1.3282	1.3286	1.3290	1.3294
125	1.000001	1.000002	1.00002	1.0002	1.0004	1.3207	1.3208	1.3211	1.3215	1.3219	1.3224
150	1.000001	1.000002	1.00002	1.0002	1.0003	1.3127	1.3128	1.3131	1.3136	1.3140	1.3145
175	1.000001	1.000002	1.00002	1.0002	1.0003	1.0008	1.3038	1.3041	1.3047	1.3052	1.3057
200	1.000001	1.000001	1.00001	1.0001	1.0003	1.0008	1.0016	1.2941	1.2948	1.2954	1.2960
225	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0015	1.0040	1.2836	1.2844	1.2852
250	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0014	1.0037	1.2709	1.2719	1.2728
275	1.000001	1.000001	1.00001	1.0001	1.0003	1.0006	1.0013	1.0035	1.0078	1.2573	1.2585
300	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0013	1.0033	1.0071	1.0121	1.2411
325	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0012	1.0031	1.0066	1.0108	1.0163
350	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0011	1.0029	1.0062	1.0099	1.0144
375	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0011	1.0028	1.0058	1.0092	1.0131
400	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0027	1.0055	1.0087	1.0122
425	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0026	1.0053	1.0082	1.0114
450	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0025	1.0051	1.0078	1.0108
475	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0009	1.0024	1.0048	1.0075	1.0102
500	1.000001	1.000001	1.00001	1.0001	1.0002	1.0004	1.0009	1.0023	1.0046	1.0071	1.0097

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 17 Refractive index n [–]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]										
	150	200	250	300	400	500	600	700	800	900	1000
$\bar{\lambda} = 0.2265 \mu\text{m}$											
0	1.3975	1.3985	1.3995	1.4004	1.4023	1.4041	1.4059	1.4077	1.4094	1.4111	1.4127
25	1.3954	1.3963	1.3972	1.3980	1.3997	1.4013	1.4030	1.4045	1.4061	1.4076	1.4091
50	1.3911	1.3919	1.3928	1.3936	1.3952	1.3968	1.3984	1.3999	1.4014	1.4029	1.4043
75	1.3853	1.3861	1.3869	1.3878	1.3894	1.3910	1.3926	1.3941	1.3956	1.3971	1.3985
100	1.3782	1.3791	1.3800	1.3808	1.3825	1.3842	1.3858	1.3874	1.3890	1.3905	1.3920
125	1.3701	1.3710	1.3720	1.3729	1.3747	1.3765	1.3783	1.3799	1.3816	1.3832	1.3847
150	1.3610	1.3620	1.3631	1.3641	1.3661	1.3680	1.3699	1.3717	1.3735	1.3752	1.3769
175	1.3509	1.3521	1.3533	1.3544	1.3566	1.3588	1.3608	1.3628	1.3647	1.3666	1.3684
200	1.3397	1.3411	1.3424	1.3438	1.3463	1.3487	1.3510	1.3532	1.3553	1.3574	1.3593
225	1.3273	1.3290	1.3306	1.3321	1.3350	1.3378	1.3404	1.3429	1.3452	1.3475	1.3497
250	1.3134	1.3154	1.3174	1.3192	1.3227	1.3259	1.3289	1.3318	1.3345	1.3371	1.3395
275	1.2975	1.3001	1.3025	1.3048	1.3091	1.3130	1.3166	1.3199	1.3230	1.3259	1.3287
300	1.2786	1.2822	1.2855	1.2885	1.2939	1.2988	1.3031	1.3070	1.3107	1.3141	1.3173
325	1.2541	1.2601	1.2650	1.2694	1.2767	1.2829	1.2883	1.2931	1.2975	1.3015	1.3051
350	1.0319	1.2285	1.2382	1.2455	1.2565	1.2650	1.2719	1.2779	1.2832	1.2879	1.2923
375	1.0262	1.0478	1.1909	1.2114	1.2315	1.2440	1.2535	1.2612	1.2677	1.2734	1.2786
400	1.0232	1.0367	1.0612	1.1334	1.1976	1.2188	1.2324	1.2426	1.2509	1.2579	1.2640
425	1.0212	1.0317	1.0463	1.0693	1.1473	1.1874	1.2079	1.2219	1.2325	1.2412	1.2486
450	1.0196	1.0286	1.0397	1.0543	1.1001	1.1501	1.1800	1.1990	1.2127	1.2235	1.2324
475	1.0184	1.0263	1.0355	1.0467	1.0771	1.1167	1.1510	1.1747	1.1918	1.2049	1.2155
500	1.0173	1.0245	1.0326	1.0418	1.0650	1.0946	1.1255	1.1512	1.1708	1.1860	1.1983
$\bar{\lambda} = 0.40466 \mu\text{m}$											
0	1.3467	1.3475	1.3483	1.3491	1.3507	1.3523	1.3538	1.3552	1.3567	1.3581	1.3595
25	1.3448	1.3456	1.3463	1.3470	1.3484	1.3498	1.3512	1.3525	1.3538	1.3551	1.3564
50	1.3411	1.3418	1.3425	1.3432	1.3446	1.3459	1.3473	1.3485	1.3498	1.3510	1.3522
75	1.3361	1.3369	1.3376	1.3383	1.3397	1.3410	1.3423	1.3436	1.3449	1.3461	1.3473
100	1.3301	1.3309	1.3316	1.3324	1.3338	1.3352	1.3366	1.3379	1.3392	1.3405	1.3418
125	1.3232	1.3240	1.3248	1.3256	1.3271	1.3286	1.3301	1.3315	1.3329	1.3343	1.3356
150	1.3154	1.3163	1.3172	1.3181	1.3198	1.3214	1.3230	1.3245	1.3260	1.3275	1.3289
175	1.3068	1.3078	1.3088	1.3098	1.3117	1.3135	1.3152	1.3169	1.3185	1.3201	1.3216
200	1.2972	1.2984	1.2996	1.3007	1.3028	1.3049	1.3068	1.3087	1.3105	1.3122	1.3139
225	1.2866	1.2880	1.2894	1.2907	1.2932	1.2955	1.2977	1.2999	1.3019	1.3038	1.3057
250	1.2747	1.2764	1.2780	1.2796	1.2826	1.2853	1.2879	1.2904	1.2927	1.2949	1.2970
275	1.2609	1.2632	1.2653	1.2672	1.2709	1.2742	1.2773	1.2801	1.2828	1.2853	1.2877
300	1.2446	1.2477	1.2506	1.2532	1.2578	1.2620	1.2657	1.2691	1.2722	1.2751	1.2779
325	1.2234	1.2286	1.2329	1.2366	1.2430	1.2483	1.2530	1.2571	1.2608	1.2643	1.2674
350	1.0282	1.2011	1.2096	1.2159	1.2255	1.2328	1.2388	1.2440	1.2485	1.2526	1.2563
375	1.0232	1.0423	1.1684	1.1863	1.2037	1.2146	1.2228	1.2295	1.2351	1.2401	1.2445
400	1.0206	1.0325	1.0542	1.1179	1.1742	1.1927	1.2045	1.2133	1.2205	1.2266	1.2319
425	1.0188	1.0281	1.0410	1.0614	1.1301	1.1652	1.1832	1.1953	1.2046	1.2121	1.2185
450	1.0174	1.0253	1.0352	1.0480	1.0885	1.1325	1.1588	1.1753	1.1873	1.1967	1.2044
475	1.0163	1.0233	1.0315	1.0414	1.0682	1.1032	1.1333	1.1541	1.1690	1.1804	1.1897
500	1.0154	1.0217	1.0288	1.0370	1.0575	1.0837	1.1109	1.1335	1.1506	1.1639	1.1747

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 17 Refractive index n [–]^a – Continued

t [°C]	p [bar]											
	0.006112127	0.01	0.1	1	2	5	10	25	50	75	100	
$\bar{\lambda} = 0.5893 \mu\text{m}$												
0	1.3343	1.3343	1.3343	1.3343	1.3344	1.3344	1.3345	1.3347	1.3351	1.3356	1.3360	
25	1.000001	1.000002	1.328	1.329	1.329	1.329	1.330	1.332	1.336	1.339	1.343	
50	1.000001	1.000002	1.00002	1.3294	1.3294	1.3294	1.3295	1.3297	1.3301	1.3304	1.3308	
75	1.000001	1.000002	1.00002	1.3245	1.3245	1.3246	1.3246	1.3249	1.3252	1.3256	1.3259	
100	1.000001	1.000002	1.00002	1.0002	1.3186	1.3186	1.3187	1.3189	1.3193	1.3197	1.3201	
125	1.000001	1.000002	1.00002	1.0002	1.0004	1.3118	1.3119	1.3121	1.3125	1.3129	1.3133	
150	1.000001	1.000002	1.00002	1.0002	1.0003	1.3040	1.3041	1.3044	1.3048	1.3053	1.3057	
175	1.000001	1.000002	1.00002	1.0002	1.0003	1.2954	1.2957	1.2963	1.2968	1.2973		
200	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0015	1.2861	1.2867	1.2873	1.2879	
225	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0014	1.0039	1.2759	1.2766	1.2774	
250	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0014	1.0036	1.2636	1.2645	1.2655	
275	1.000001	1.000001	1.00001	1.0001	1.0003	1.0006	1.0013	1.0034	1.0076	1.2504	1.2516	
300	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0012	1.0032	1.0069	1.0118	1.2347	
325	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0012	1.0030	1.0064	1.0106	1.0159	
350	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0011	1.0029	1.0060	1.0097	1.0140	
375	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0011	1.0027	1.0057	1.0090	1.0128	
400	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0026	1.0054	1.0085	1.0119	
425	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0025	1.0052	1.0080	1.0111	
450	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0009	1.0024	1.0049	1.0076	1.0105	
475	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0009	1.0023	1.0047	1.0073	1.0100	
500	1.000001	1.000001	1.00001	1.0001	1.0002	1.0004	1.0009	1.0022	1.0045	1.0070	1.0095	
$\bar{\lambda} = 0.70652 \mu\text{m}$												
0	1.3313	1.3313	1.3313	1.3313	1.3314	1.3314	1.3315	1.3317	1.3321	1.3325	1.3330	
25	1.000001	1.000002	1.3299	1.3299	1.3299	1.3299	1.3300	1.3300	1.3302	1.3306	1.3310	1.3313
50	1.000001	1.000002	1.00002	1.3265	1.3265	1.3265	1.3266	1.3268	1.3271	1.3275	1.3278	
75	1.000001	1.000002	1.00002	1.3217	1.3217	1.3217	1.3218	1.3220	1.3224	1.3227	1.3231	
100	1.000001	1.000002	1.00002	1.0002	1.3158	1.3159	1.3160	1.3162	1.3166	1.3169	1.3173	
125	1.000001	1.000002	1.00002	1.0002	1.0004	1.3091	1.3092	1.3094	1.3098	1.3102	1.3106	
150	1.000001	1.000002	1.00002	1.0002	1.0003	1.3014	1.3015	1.3018	1.3022	1.3027	1.3031	
175	1.000001	1.000002	1.00002	1.0002	1.0003	1.0008	1.2929	1.2932	1.2938	1.2943	1.2948	
200	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0015	1.2837	1.2843	1.2849	1.2855	
225	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0014	1.0039	1.2736	1.2744	1.2751	
250	1.000001	1.000001	1.00001	1.0001	1.0003	1.0007	1.0013	1.0036	1.2615	1.2624	1.2633	
275	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0013	1.0034	1.0076	1.2484	1.2496	
300	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0012	1.0032	1.0069	1.0117	1.2328	
325	1.000001	1.000001	1.00001	1.0001	1.0002	1.0006	1.0012	1.0030	1.0064	1.0105	1.0158	
350	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0011	1.0028	1.0060	1.0096	1.0139	
375	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0011	1.0027	1.0057	1.0090	1.0127	
400	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0026	1.0054	1.0084	1.0118	
425	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0010	1.0025	1.0051	1.0080	1.0110	
450	1.000001	1.000001	1.00001	1.0001	1.0002	1.0005	1.0009	1.0024	1.0049	1.0076	1.0104	
475	1.000001	1.000001	1.00001	1.0001	1.0002	1.0004	1.0009	1.0023	1.0047	1.0072	1.0099	
500	1.000001	1.000001	1.00001	1.0001	1.0002	1.0004	1.0009	1.0022	1.0045	1.0069	1.0094	

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the gas phase.

Table 17 Refractive index n [–]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]										
	150	200	250	300	400	500	600	700	800	900	1000
$\bar{\lambda} = 0.5893 \mu\text{m}$											
0	1.3368	1.3376	1.3383	1.3391	1.3407	1.3421	1.3436	1.3450	1.3464	1.3478	1.3491
25	1.3350	1.3357	1.3364	1.3371	1.3385	1.3398	1.3411	1.3424	1.3437	1.3449	1.3461
50	1.3314	1.3321	1.3328	1.3335	1.3348	1.3361	1.3373	1.3386	1.3398	1.3410	1.3421
75	1.3266	1.3273	1.3280	1.3287	1.3300	1.3313	1.3326	1.3338	1.3351	1.3362	1.3374
100	1.3208	1.3215	1.3223	1.3230	1.3244	1.3257	1.3270	1.3283	1.3296	1.3308	1.3320
125	1.3141	1.3149	1.3157	1.3165	1.3180	1.3194	1.3208	1.3222	1.3235	1.3248	1.3261
150	1.3066	1.3075	1.3084	1.3092	1.3108	1.3124	1.3139	1.3154	1.3169	1.3183	1.3196
175	1.2983	1.2993	1.3002	1.3012	1.3030	1.3048	1.3064	1.3081	1.3096	1.3112	1.3126
200	1.2891	1.2902	1.2913	1.2924	1.2945	1.2964	1.2983	1.3001	1.3019	1.3036	1.3052
225	1.2788	1.2801	1.2814	1.2827	1.2851	1.2874	1.2896	1.2916	1.2936	1.2954	1.2972
250	1.2672	1.2689	1.2705	1.2720	1.2749	1.2776	1.2801	1.2824	1.2847	1.2868	1.2888
275	1.2539	1.2561	1.2581	1.2600	1.2636	1.2668	1.2698	1.2725	1.2751	1.2775	1.2798
300	1.2381	1.2411	1.2439	1.2464	1.2509	1.2549	1.2585	1.2618	1.2649	1.2677	1.2703
325	1.2176	1.2225	1.2267	1.2304	1.2365	1.2417	1.2462	1.2502	1.2538	1.2572	1.2602
350	1.0275	1.1959	1.2041	1.2103	1.2195	1.2266	1.2325	1.2375	1.2419	1.2458	1.2495
375	1.0227	1.0413	1.1640	1.1815	1.1984	1.2090	1.2170	1.2234	1.2289	1.2337	1.2380
400	1.0201	1.0317	1.0528	1.1150	1.1697	1.1877	1.1992	1.2078	1.2147	1.2206	1.2258
425	1.0183	1.0274	1.0400	1.0599	1.1268	1.1610	1.1785	1.1903	1.1993	1.2066	1.2128
450	1.0169	1.0247	1.0343	1.0469	1.0863	1.1292	1.1547	1.1708	1.1825	1.1916	1.1991
475	1.0159	1.0227	1.0307	1.0403	1.0665	1.1006	1.1299	1.1502	1.1647	1.1758	1.1848
500	1.0150	1.0211	1.0281	1.0361	1.0561	1.0816	1.1081	1.1301	1.1468	1.1598	1.1702
$\bar{\lambda} = 0.70652 \mu\text{m}$											
0	1.3337	1.3345	1.3353	1.3361	1.3376	1.3391	1.3405	1.3419	1.3433	1.3446	1.3459
25	1.3320	1.3327	1.3334	1.3341	1.3355	1.3368	1.3381	1.3393	1.3406	1.3418	1.3430
50	1.3285	1.3292	1.3299	1.3305	1.3318	1.3331	1.3343	1.3356	1.3368	1.3379	1.3391
75	1.3238	1.3244	1.3251	1.3258	1.3271	1.3284	1.3297	1.3309	1.3321	1.3333	1.3344
100	1.3180	1.3187	1.3195	1.3202	1.3215	1.3229	1.3242	1.3255	1.3267	1.3279	1.3291
125	1.3114	1.3122	1.3130	1.3137	1.3152	1.3166	1.3180	1.3194	1.3207	1.3220	1.3233
150	1.3040	1.3049	1.3057	1.3066	1.3082	1.3097	1.3112	1.3127	1.3141	1.3155	1.3169
175	1.2958	1.2968	1.2977	1.2986	1.3004	1.3022	1.3038	1.3055	1.3070	1.3085	1.3100
200	1.2867	1.2878	1.2889	1.2899	1.2920	1.2939	1.2958	1.2976	1.2993	1.3010	1.3026
225	1.2765	1.2778	1.2791	1.2804	1.2828	1.2850	1.2871	1.2892	1.2911	1.2930	1.2948
250	1.2650	1.2667	1.2683	1.2698	1.2726	1.2753	1.2778	1.2801	1.2823	1.2844	1.2864
275	1.2519	1.2540	1.2560	1.2579	1.2615	1.2646	1.2676	1.2703	1.2729	1.2753	1.2776
300	1.2362	1.2392	1.2419	1.2444	1.2489	1.2529	1.2565	1.2597	1.2627	1.2655	1.2682
325	1.2159	1.2208	1.2249	1.2285	1.2347	1.2398	1.2443	1.2482	1.2518	1.2551	1.2581
350	1.0273	1.1944	1.2026	1.2087	1.2178	1.2249	1.2307	1.2356	1.2400	1.2439	1.2475
375	1.0225	1.0410	1.1628	1.1801	1.1969	1.2074	1.2153	1.2217	1.2271	1.2319	1.2361
400	1.0199	1.0315	1.0524	1.1141	1.1684	1.1863	1.1977	1.2062	1.2131	1.2190	1.2240
425	1.0182	1.0272	1.0397	1.0594	1.1258	1.1598	1.1771	1.1888	1.1978	1.2050	1.2112
450	1.0168	1.0245	1.0341	1.0465	1.0857	1.1282	1.1536	1.1696	1.1811	1.1902	1.1976
475	1.0158	1.0225	1.0305	1.0400	1.0660	1.0999	1.1290	1.1491	1.1635	1.1745	1.1834
500	1.0149	1.0210	1.0279	1.0359	1.0557	1.0810	1.1074	1.1291	1.1457	1.1586	1.1690

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the gas phase.

Table 18 Saturation state:
Relative pressure coefficient α_p ,
Isothermal stress coefficient β_p ,
Fugacity f^*

This table contains values on the saturated liquid ('') and saturated vapour ('') lines for the following thermodynamic properties for temperatures from $t = 0^\circ\text{C}$ up to the critical temperature $t_c = 373.946^\circ\text{C}$:

- Relative pressure coefficient $\alpha_p = p^{-1}(\partial p/\partial T)_v$
- Isothermal stress coefficient $\beta_p = -p^{-1}(\partial p/\partial v)_T$
- Fugacity $f^* = p \exp[(g - g^0)/(RT)]$

For given temperatures, the saturation pressures p_s were calculated from the IAPWS-IF97 saturation-pressure equation, Eq. (2.13).

For temperatures $t \leq 350^\circ\text{C}$ and the input values of t and p_s , the properties relative pressure coefficient α_p , isothermal stress coefficient β_p , and fugacity f^* on the saturated-liquid and saturated-vapour lines were determined from the basic equations for regions 1 and 2, Eqs. (2.3) and (2.6).

For $t > 350^\circ\text{C}$, the basic equation of region 3, Eq. (2.11), was used for the calculations. With the input values (t, p_s) , the densities ρ' and ρ'' , needed as one of the input quantities of Eq. (2.11), were calculated by iterating this equation. With these values for (ρ', t) and (ρ'', t) , α_p , β_p , and f^* were determined from this equation.

It should be noted that, below 350°C , the values of the fugacity of the saturated liquid, $f^{*''}$, and saturated vapour, $f^{*''}$, are partially not completely equal as they should be. This is caused by the fact that $f^{*''}$ and $f^{*''}$ were calculated from two different basic equations, Eq. (2.3) and (2.6). However, these equations are not thermodynamically consistent with each other, because such independent equations do not fulfil the phase-equilibrium condition.

The tabulated values of α_p and β_p can be used to calculate corresponding partial derivatives of thermodynamic properties as described in Sec. 2.4.2.

Table 18 Saturation state: Relative pressure coefficient α_p , Isothermal stress coefficient β_p , Fugacity f^*

t [°C]	α'_p [10^{-3} K $^{-1}$]	α''_p	β'_p	β''_p [kg m $^{-3}$]	$f^{*'}^a$ [bar]	$f^{*''}^a$
0	-218830	3.6789	3.2140×10^9	0.0048480	0.0061091	0.0061089
0.01 ^b	-218100	3.6787	3.2119×10^9	0.0048514	0.0061135	0.0061133
1	-150919	3.6660	3.0119×10^9	0.0051929	0.0065674	0.0065672
2	-92458	3.6532	2.8233×10^9	0.0055590	0.0070559	0.0070558
3	-42274	3.6406	2.6475×10^9	0.0059476	0.0075764	0.0075762
4	663.62	3.6280	2.4833×10^9	0.0063597	0.0081304	0.0081303
5	37259	3.6156	2.3301×10^9	0.0067966	0.0087201	0.0087199
6	68304	3.6033	2.1870×10^9	0.0072595	0.0093471	0.0093469
7	94496	3.5911	2.0534×10^9	0.0077496	0.010014	0.010013
8	116445	3.5790	1.9285×10^9	0.0082684	0.010722	0.010722
9	134689	3.5670	1.8118×10^9	0.0088172	0.011474	0.011474
10	149700	3.5551	1.7027×10^9	0.0093975	0.012272	0.012271
11	161891	3.5433	1.6007×10^9	0.010011	0.013118	0.013118
12	171628	3.5316	1.5052×10^9	0.010658	0.014016	0.014015
13	179232	3.5201	1.4159×10^9	0.011342	0.014967	0.014966
14	184983	3.5086	1.3324×10^9	0.012064	0.015974	0.015973
15	189130	3.4972	1.2541×10^9	0.012825	0.017040	0.017040
16	191890	3.4860	1.1808×10^9	0.013627	0.018168	0.018168
17	193455	3.4748	1.1122×10^9	0.014473	0.019361	0.019361
18	193992	3.4638	1.0478×10^9	0.015363	0.020623	0.020622
19	193649	3.4528	9.8750×10^8	0.016301	0.021955	0.021955
20	192556	3.4420	9.3094×10^8	0.017288	0.023363	0.023362
22	188561	3.4205	8.2813×10^8	0.019417	0.026416	0.026415
24	182758	3.3995	7.3756×10^8	0.021768	0.029812	0.029811
25	179365	3.3891	6.9638×10^8	0.023033	0.031649	0.031648
26	175725	3.3788	6.5769×10^8	0.024360	0.033583	0.033582
28	167900	3.3585	5.8717×10^8	0.027213	0.037763	0.037761
30	159617	3.3386	5.2483×10^8	0.030349	0.042388	0.042386
32	151129	3.3190	4.6965×10^8	0.033789	0.047497	0.047495
34	142621	3.2998	4.2076×10^8	0.037557	0.053131	0.053129
36	134232	3.2809	3.7738×10^8	0.041678	0.059335	0.059333
38	126060	3.2624	3.3886×10^8	0.046179	0.066157	0.066154
40	118173	3.2442	3.0461×10^8	0.051087	0.073644	0.073642
42	110619	3.2263	2.7412×10^8	0.056431	0.081851	0.081849
44	103425	3.2088	2.4694×10^8	0.062241	0.090834	0.090831
46	96607	3.1916	2.2270×10^8	0.068551	0.10065	0.10065
48	90170	3.1747	2.0104×10^8	0.075393	0.11136	0.11136
50	84113	3.1582	1.8168×10^8	0.082802	0.12304	0.12304
52	78427	3.1420	1.6435×10^8	0.090815	0.13575	0.13575
54	73102	3.1261	1.4882×10^8	0.099471	0.14956	0.14956
56	68124	3.1105	1.3489×10^8	0.108809	0.16455	0.16456
58	63476	3.0953	1.2238×10^8	0.118870	0.18081	0.18081

^aRegarding different values for $f^{*'}^a$ and $f^{*''}^a$ see the introductory page of this table.

^bTriple-point temperature.

Table 18 Saturation state:

Relative pressure coefficient α_p ,
Isothermal stress coefficient β_p ,
Fugacity f^*

– Continued

t [°C]	α'_p [10^{-3} K $^{-1}$]	α''_p	β'_p [kg m $^{-3}$]	β''_p	$f^{*'}^a$ [bar]	$f^{*''}^a$
60	59142	3.0804	1.1114×10^8	0.12970	0.19841	0.19841
62	55105	3.0658	1.0103×10^8	0.14134	0.21744	0.21745
64	51348	3.0516	9.1919×10^7	0.15383	0.23800	0.23801
66	47853	3.0377	8.3707×10^7	0.16724	0.26018	0.26019
68	44603	3.0241	7.6297×10^7	0.18159	0.28408	0.28409
70	41583	3.0108	6.9603×10^7	0.19696	0.30981	0.30982
72	38777	2.9979	6.3552×10^7	0.21338	0.33747	0.33748
74	36170	2.9853	5.8076×10^7	0.23092	0.36718	0.36719
76	33749	2.9731	5.3116×10^7	0.24963	0.39905	0.39907
78	31500	2.9612	4.8619×10^7	0.26958	0.43320	0.43323
80	29412	2.9496	4.4539×10^7	0.29081	0.46977	0.46980
82	27471	2.9384	4.0833×10^7	0.31339	0.50888	0.50891
84	25669	2.9276	3.7465×10^7	0.33738	0.55066	0.55070
86	23994	2.9171	3.4401×10^7	0.36286	0.59526	0.59530
88	22438	2.9069	3.1611×10^7	0.38988	0.64282	0.64286
90	20991	2.8971	2.9069×10^7	0.41851	0.69349	0.69353
92	19645	2.8877	2.6751×10^7	0.44883	0.74741	0.74746
94	18394	2.8787	2.4634×10^7	0.48091	0.80476	0.80481
96	17230	2.8700	2.2701×10^7	0.51481	0.86568	0.86574
98	16147	2.8617	2.0934×10^7	0.55061	0.93035	0.93041
100	15138	2.8537	1.9318×10^7	0.58839	0.99894	0.99900
105	12909	2.8356	1.5846×10^7	0.69201	1.1887	1.1888
110	11039	2.8199	1.3050×10^7	0.80973	1.4069	1.4070
115	9465.8	2.8067	1.0786×10^7	0.94285	1.6566	1.6566
120	8139.3	2.7960	8.9469×10^6	1.0927	1.9409	1.9409
125	7017.8	2.7879	7.4460×10^6	1.2607	2.2632	2.2632
130	6067.0	2.7824	6.2163×10^6	1.4483	2.6269	2.6270
135	5258.7	2.7793	5.2052×10^6	1.6569	3.0357	3.0358
140	4569.7	2.7788	4.3707×10^6	1.8881	3.4934	3.4934
145	3980.7	2.7808	3.6797×10^6	2.1433	4.0037	4.0037
150	3476.0	2.7852	3.1055×10^6	2.4242	4.5707	4.5707
155	3042.3	2.7919	2.6270×10^6	2.7322	5.1983	5.1982
160	2668.6	2.8010	2.2269×10^6	3.0689	5.8907	5.8906
165	2345.9	2.8125	1.8915×10^6	3.4359	6.6520	6.6518
170	2066.4	2.8262	1.6095×10^6	3.8348	7.4864	7.4862
175	1823.9	2.8422	1.3718×10^6	4.2669	8.3982	8.3979
180	1612.9	2.8605	1.1710×10^6	4.7338	9.3915	9.3911
185	1428.8	2.8811	1.0010×10^6	5.2369	10.471	10.470
190	1268.0	2.9041	856627	5.7776	11.640	11.639
195	1127.1	2.9296	733875	6.3570	12.903	12.902

^aRegarding different values for $f^{*'}^a$ and $f^{*''}^a$ see the introductory page of this table.

Table 18 Saturation state: Relative pressure coefficient α_p , Isothermal stress coefficient β_p , Fugacity f^* – Continued

t [°C]	α'_p [10^{-3} K $^{-1}$]	α''_p	β'_p	β''_p [kg m $^{-3}$]	$f^{*'}^a$ [bar]	$f^{*''}^a$
200	1003.4	2.9576	629279	6.9764	14.264	14.264
205	894.68	2.9882	539994	7.6367	15.728	15.728
210	798.82	3.0215	463652	8.3390	17.298	17.298
215	714.18	3.0576	398276	9.0838	18.978	18.978
220	639.31	3.0965	342213	9.8718	20.772	20.771
225	572.95	3.1384	294073	10.703	22.683	22.683
230	514.04	3.1833	252688	11.578	24.715	24.715
235	461.65	3.2314	217073	12.497	26.871	26.871
240	414.98	3.2827	186393	13.459	29.155	29.155
245	373.33	3.3374	159943	14.463	31.569	31.569
250	336.11	3.3957	137122	15.508	34.116	34.116
255	302.80	3.4578	117422	16.592	36.799	36.799
260	272.93	3.5239	100405	17.713	39.620	39.620
265	246.10	3.5944	85703	18.868	42.581	42.582
270	221.98	3.6696	72996	20.053	45.685	45.686
275	200.25	3.7502	62014	21.262	48.934	48.934
280	180.64	3.8367	52525	22.489	52.329	52.329
285	162.93	3.9296	44330	23.727	55.871	55.871
290	146.91	4.0297	37261	24.966	59.561	59.561
295	132.40	4.1375	31171	26.194	63.402	63.401
300	119.26	4.2538	25936	27.399	67.392	67.392
305	107.34	4.3794	21449	28.564	71.534	71.534
310	96.541	4.5150	17616	29.672	75.828	75.827
315	86.733	4.6621	14351	30.697	80.273	80.272
320	77.807	4.8224	11578	31.609	84.869	84.869
325	69.646	4.9990	9226.4	32.367	89.617	89.617
330	62.135	5.1956	7233.8	32.915	94.516	94.517
335	55.176	5.4176	5550.0	33.185	99.566	99.567
340	48.716	5.6706	4140.2	33.096	104.77	104.77
345	42.769	5.9597	2985.3	32.566	110.11	110.12
350	37.416	6.2878	2074.5	31.530	115.61	115.61
355	32.316	6.7085	1332.7	29.465	121.26	121.26
360	27.510	7.2248	772.04	26.180	127.04	127.04
365	22.866	7.9114	366.21	20.933	132.97	132.97
370	18.132	8.9796	102.44	12.266	139.04	139.04
371	17.102	9.3013	66.482	9.8432	140.27	140.27
372	15.988	9.7094	36.532	7.0563	141.51	141.51
373	14.687	10.301	13.342	3.7720	142.75	142.75
373.946 ^b	12.158		0		143.93	

^a Regarding different values for $f^{*'}^a$ and $f^{*''}^a$ see the introductory page of this table.

^b Critical temperature.

Table 19 Relative pressure coefficient α_p

For the single-phase region, this table contains values for the

- Relative pressure coefficient $\alpha_p = p^{-1}(\partial p/\partial T)_v$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given values of p and t , the values for the relative pressure coefficient α_p were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities for Eq. (2.11), was calculated by iterating this equation. With these (ρ, t) values, α_p was determined from this equation.

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the relative pressure coefficient for temperatures above 800°C up to 2000°C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

The tabulated values of α_p can be used to calculate corresponding partial derivatives of thermodynamic properties as described in Sec. 2.4.2.

Table 19 Relative pressure coefficient α_p [10^{-3} K^{-1}]^a

t [°C]	p [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	-218830	-133749	-13368	-1330,4	-661,66	-327,27	-215,81	-160,08	-126,64	-59,762
5	3.6071	32512	3256.9	331.39	168.86	87.593	60.505	46.960	38.833	22.579
10	3.5405	3.5488	18391	1844.1	924.88	465.25	312.04	235.44	189.47	97.548
15	3.4775	3.4831	32265	3231.0	1618.0	811.49	542.66	408.25	327.60	166.30
20	3.4171	3.4214	45046	4508.6	2256.5	1130.5	755.14	567.47	454.86	229.65
25	3.3591	3.3625	56857	5689.2	2846.6	1425.3	951.50	714.62	572.48	288.22
30	3.3031	3.3060	67787	6781.8	3392.7	1698.1	1133.2	850.81	681.36	342.44
35	3.2490	3.2515	77904	7793.3	3898.2	1950.7	1301.5	976.92	782.16	392.66
40	3.1968	3.1989	87265	8729.0	4365.9	2184.4	1457.2	1093.6	875.45	439.14
45	3.1462	3.1481	95913	9593.6	4798.1	2400.3	1601.1	1201.4	961.66	482.11
50	3.0972	3.0989	3.1435	10391	5196.7	2599.5	1733.8	1300.9	1041.2	521.76
60	3.0038	3.0051	3.0378	11798	5899.9	2950.9	1967.9	1476.4	1181.5	591.75
70	2.9159	2.9170	2.9425	12975	6488.5	3245.1	2164.0	1623.4	1299.1	650.39
80	2.8330	2.8339	2.8544	13946	6973.9	3487.7	2325.7	1744.6	1396.0	698.79
90	2.7548	2.7555	2.7722	14732	7366.8	3684.2	2456.6	1842.8	1474.6	738.02
100	2.6808	2.6814	2.6952	2.8508	7677.2	3839.3	2560.0	1920.4	1536.6	769.04
125	2.5122	2.5126	2.5213	2.6156	2.7392	4075.0	2717.2	2038.3	1631.0	816.32
150	2.3636	2.3639	2.3697	2.4316	2.5075	2.6915	2.758.6	2069.5	1656.0	829.02
175	2.2317	2.2318	2.2359	2.2786	2.3296	2.4435	2.5766	2.7434	1628.0	815.29
200	2.1137	2.1138	2.1168	2.1473	2.1832	2.2612	2.3477	2.4434	2.5502	780.74
225	2.0076	2.0077	2.0099	2.0325	2.0588	2.1146	2.1751	2.2403	2.3104	2.7566
250	1.9116	1.9117	1.9134	1.9307	1.9505	1.9919	2.0360	2.0827	2.1322	2.4236
275	1.8244	1.8245	1.8258	1.8393	1.8546	1.8864	1.9196	1.9543	1.9907	2.1971
300	1.7448	1.7449	1.7459	1.7567	1.7688	1.7937	1.8195	1.8461	1.8737	2.0262
325	1.6719	1.6719	1.6728	1.6815	1.6912	1.7112	1.7316	1.7526	1.7741	1.8906
350	1.6048	1.6048	1.6055	1.6127	1.6207	1.6369	1.6534	1.6703	1.6875	1.7789
375	1.5429	1.5429	1.5435	1.5494	1.5560	1.5694	1.5830	1.5967	1.6107	1.6841
400	1.4856	1.4856	1.4861	1.4910	1.4966	1.5077	1.5190	1.5304	1.5419	1.6019
425	1.4324	1.4324	1.4328	1.4370	1.4417	1.4510	1.4605	1.4701	1.4797	1.5294
450	1.3829	1.3829	1.3832	1.3868	1.3907	1.3987	1.4067	1.4148	1.4229	1.4646
475	1.3367	1.3367	1.3370	1.3400	1.3434	1.3502	1.3570	1.3639	1.3708	1.4061
500	1.2934	1.2934	1.2937	1.2963	1.2992	1.3051	1.3110	1.3169	1.3228	1.3530
525	1.2529	1.2529	1.2531	1.2554	1.2579	1.2630	1.2681	1.2732	1.2783	1.3042
550	1.2149	1.2149	1.2151	1.2170	1.2192	1.2236	1.2280	1.2325	1.2369	1.2594
575	1.1790	1.1791	1.1792	1.1809	1.1829	1.1867	1.1906	1.1944	1.1983	1.2179
600	1.1453	1.1453	1.1454	1.1470	1.1486	1.1520	1.1554	1.1588	1.1622	1.1793
625	1.1134	1.1134	1.1135	1.1149	1.1164	1.1193	1.1223	1.1253	1.1283	1.1433
650	1.0833	1.0833	1.0834	1.0846	1.0859	1.0885	1.0911	1.0938	1.0964	1.1097
675	1.0547	1.0547	1.0548	1.0558	1.0570	1.0593	1.0617	1.0640	1.0664	1.0782
700	1.0276	1.0276	1.0277	1.0286	1.0297	1.0317	1.0338	1.0359	1.0380	1.0485
725	1.0019	1.0019	1.0019	1.0028	1.0037	1.0056	1.0074	1.0093	1.0112	1.0206
750	0.97738	0.97738	0.97746	0.97821	0.97904	0.98071	0.98239	0.98407	0.98575	0.99420
775	0.95407	0.95407	0.95414	0.95481	0.95557	0.95707	0.95858	0.96009	0.96161	0.96923
800	0.93184	0.93184	0.93190	0.93252	0.93320	0.93456	0.93592	0.93729	0.93866	0.94555

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 19 Relative pressure coefficient α_p [10^{-3} K^{-1}]^a – Continued

t [°C]	p [bar]									
	40	60	80	100	120	140	160	180	200	220
0	-26.330	-15.189	-9.6223	-6.2846	-4.0616	-2.4756	-1.2877	-0.36522	0.37145	0.97298
5	14.448	11.735	10.377	9.5597	9.0137	8.6224	8.3277	8.0976	7.9125	7.7602
10	51.583	36.260	28.598	23.999	20.933	18.742	17.098	15.819	14.796	13.958
15	85.647	58.764	45.322	37.258	31.881	28.041	25.160	22.920	21.128	19.661
20	117.05	79.518	60.753	49.495	41.990	36.630	32.611	29.485	26.985	24.939
25	146.09	98.720	75.035	60.826	51.355	44.591	39.519	35.575	32.420	29.839
30	172.99	116.51	88.276	71.336	60.045	51.981	45.934	41.233	37.473	34.397
35	197.92	133.01	100.56	81.087	68.111	58.844	51.895	46.493	42.172	38.637
40	221.00	148.29	111.94	90.130	75.595	65.214	57.431	51.379	46.539	42.581
45	242.34	162.43	122.47	98.505	82.529	71.120	62.565	55.914	50.594	46.243
50	262.05	175.49	132.21	106.25	88.942	76.584	67.318	60.113	54.351	49.638
60	296.86	198.58	149.44	119.96	100.31	86.273	75.751	67.570	61.026	55.674
70	326.06	217.96	163.91	131.48	109.87	94.437	82.863	73.864	66.666	60.779
80	350.18	233.99	175.89	141.04	117.81	101.22	88.777	79.102	71.364	65.035
90	369.76	247.01	185.64	148.82	124.28	106.75	93.607	83.385	75.210	68.522
100	385.27	257.34	193.38	155.01	129.43	111.16	97.463	86.809	78.287	71.316
125	408.98	273.20	205.32	164.58	137.43	118.03	103.48	92.170	83.120	75.715
150	415.52	277.68	208.76	167.40	139.83	120.13	105.36	93.863	84.668	77.144
175	408.92	273.45	205.71	165.06	137.95	118.58	104.05	92.749	83.704	76.302
200	391.98	262.37	197.56	158.65	132.71	114.17	100.26	89.439	80.775	73.683
225	366.63	245.73	185.26	148.97	124.76	107.45	94.469	84.361	76.268	69.641
250	<u>334.12</u>	224.39	169.49	136.53	114.55	98.825	87.022	77.832	70.471	64.439
275	2.7680	<u>198.51</u>	<u>150.45</u>	121.58	102.30	88.503	78.136	70.056	63.578	58.265
300	2.4160	2.9716	3.8565	<u>103.63</u>	<u>87.743</u>	76.349	67.757	61.035	55.626	51.176
325	2.1733	2.5395	3.0320	3.7405	4.9524	<u>61.626</u>	<u>55.319</u>	50.367	46.359	43.027
350	1.9920	2.2532	2.5762	2.9869	3.5313	4.3078	5.6553	<u>36.465</u>	34.895	33.204
375	1.8497	2.0448	2.2749	2.5487	2.8798	3.2896	3.8166	4.5378	5.6380	8.5129
400	1.7338	1.8845	2.0566	2.2536	2.4802	2.7435	3.0529	3.4218	3.8737	4.4484
425	1.6366	1.7561	1.8892	2.0378	2.2035	2.3891	2.5979	2.8341	3.1027	3.4102
450	1.5532	1.6500	1.7558	1.8715	1.9980	2.1363	2.2876	2.4537	2.6363	2.8375
475	1.4804	1.5601	1.6460	1.7384	1.8380	1.9450	2.0600	2.1837	2.3166	2.4596
500	1.4158	1.4825	1.5534	1.6288	1.7090	1.7942	1.8846	1.9804	2.0818	2.1891
525	1.3580	1.4144	1.4738	1.5364	1.6023	1.6716	1.7445	1.8209	1.9009	1.9847
550	1.3057	1.3539	1.4043	1.4570	1.5120	1.5694	1.6293	1.6916	1.7564	1.8237
575	1.2580	1.2996	1.3428	1.3876	1.4341	1.4824	1.5324	1.5842	1.6376	1.6928
600	1.2143	1.2505	1.2878	1.3263	1.3661	1.4072	1.4495	1.4931	1.5379	1.5839
625	1.1741	1.2057	1.2382	1.2716	1.3059	1.3412	1.3774	1.4146	1.4526	1.4915
650	1.1368	1.1646	1.1931	1.2223	1.2522	1.2828	1.3140	1.3460	1.3786	1.4119
675	1.1022	1.1268	1.1519	1.1776	1.2037	1.2305	1.2577	1.2854	1.3137	1.3423
700	1.0699	1.0917	1.1140	1.1367	1.1598	1.1833	1.2072	1.2314	1.2561	1.2810
725	1.0397	1.0592	1.0790	1.0992	1.1196	1.1404	1.1615	1.1829	1.2045	1.2264
750	1.0113	1.0288	1.0465	1.0645	1.0828	1.1013	1.1200	1.1389	1.1580	1.1773
775	0.98466	1.0004	1.0163	1.0324	1.0488	1.0653	1.0820	1.0988	1.1158	1.1330
800	0.95950	0.97366	0.9880	1.0025	1.0172	1.0321	1.0470	1.0621	1.0773	1.0926

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 19 Relative pressure coefficient α_p [10^{-3} K^{-1}] – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	1.4732	1.8953	2.2563	2.5682	3.6497	4.2852	4.6978	4.9833	5.1898	5.4623
5	7.6325	7.5237	7.4298	7.3477	7.0530	6.8660	6.7328	6.6304	6.5474	6.4167
10	13.259	12.667	12.160	11.719	10.174	9.2404	8.6127	8.1593	7.8149	7.3217
15	18.439	17.405	16.518	15.750	13.059	11.442	10.362	9.5881	9.0051	8.1816
20	23.235	21.793	20.557	19.487	15.741	13.495	11.998	10.929	10.126	8.9994
25	27.690	25.871	24.313	22.963	18.242	15.414	13.532	12.190	11.185	9.7767
30	31.835	29.667	27.810	26.202	20.578	17.211	14.973	13.378	12.184	10.515
35	35.693	33.203	31.069	29.221	22.761	18.895	16.325	14.495	13.126	11.215
40	39.283	36.494	34.104	32.034	24.799	20.470	17.594	15.546	14.014	11.876
45	42.619	39.553	36.927	34.652	26.700	21.943	18.782	16.532	14.849	12.501
50	45.712	42.392	39.547	37.082	28.469	23.316	19.892	17.455	15.632	13.088
60	51.216	47.445	44.214	41.415	31.632	25.779	21.889	19.119	17.048	14.155
70	55.874	51.726	48.171	45.092	34.328	27.886	23.604	20.554	18.271	15.081
80	59.762	55.302	51.480	48.169	36.593	29.663	25.055	21.772	19.314	15.874
90	62.950	58.237	54.198	50.699	38.464	31.137	26.264	22.790	20.187	16.542
100	65.507	60.594	56.383	52.735	39.976	32.335	27.249	23.622	20.905	17.093
125	69.545	64.325	59.851	55.974	42.410	34.279	28.864	24.999	22.098	18.019
150	70.874	65.568	61.020	57.078	43.281	35.004	29.486	25.545	22.584	18.409
175	70.131	64.908	60.430	56.548	42.952	34.787	29.340	25.445	22.517	18.379
200	67.769	62.762	58.468	54.745	41.692	33.841	28.597	24.844	22.020	18.021
225	64.113	59.431	55.414	51.929	39.698	32.324	27.389	23.853	21.188	17.408
250	59.406	55.140	51.479	48.300	37.124	30.363	25.825	22.563	20.102	16.600
275	53.826	50.061	46.825	44.013	34.095	28.063	23.993	21.056	18.831	15.652
300	47.448	44.277	41.545	39.165	30.713	25.511	21.971	19.398	17.437	14.611
325	40.197	37.757	35.630	33.761	27.027	22.775	19.819	17.644	15.969	13.518
350	31.622	30.211	28.941	27.768	23.033	19.875	17.573	15.822	14.450	12.392
375	19.004	20.303	20.622	20.555	18.756	16.832	15.249	13.965	12.908	11.263
400	5.2037	6.2897	8.0916	10.480	14.034	13.682	12.889	12.084	11.348	10.106
425	3.7664	4.1862	4.6867	5.2847	9.1567	10.522	10.569	10.256	9.8410	8.9862
450	3.0592	3.3039	3.5745	3.8751	5.8527	7.6562	8.3828	8.5225	8.4133	7.9312
475	2.6134	2.7789	2.9567	3.1471	4.3037	5.5935	6.5109	6.9529	7.0926	6.9461
500	2.3026	2.4225	2.5492	2.6828	3.4513	4.3337	5.1111	5.6402	5.9274	6.0416
525	2.0722	2.1635	2.2587	2.3579	2.9114	3.5338	4.1438	4.6278	4.9593	5.2352
550	1.8934	1.9655	2.0400	2.1168	2.5352	2.9978	3.4635	3.8783	4.1932	4.5401
575	1.7497	1.8081	1.8681	1.9297	2.2580	2.6134	2.9769	3.3146	3.5952	3.9579
600	1.6311	1.6794	1.7288	1.7792	2.0445	2.3258	2.6126	2.8885	3.1319	3.4878
625	1.5312	1.5718	1.6130	1.6550	1.8739	2.1025	2.3338	2.5586	2.7649	3.0828
650	1.4457	1.4801	1.5151	1.5505	1.7338	1.9233	2.1138	2.3000	2.4754	2.7564
675	1.3715	1.4010	1.4309	1.4612	1.6166	1.7760	1.9356	2.0919	2.2418	2.5009
700	1.3063	1.3319	1.3577	1.3838	1.5171	1.6529	1.7883	1.9211	2.0494	2.2806
725	1.2485	1.2708	1.2933	1.3160	1.4313	1.5483	1.6647	1.7790	1.8893	2.0883
750	1.1968	1.2164	1.2361	1.2560	1.3566	1.4583	1.5594	1.6588	1.7547	1.9243
775	1.1502	1.1675	1.1850	1.2025	1.2908	1.3797	1.4683	1.5554	1.6397	1.7867
800	1.1079	1.1233	1.1388	1.1543	1.2323	1.3104	1.3881	1.4649	1.5397	1.6721

Table 20 Isothermal stress coefficient β_p

For the single-phase region, this table contains values for the

- Isothermal stress coefficient $\beta_p = -p^{-1}(\partial p / \partial v)_T$

for temperatures from 0 °C to 800 °C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given (p, t) values, the values for the isothermal stress coefficient β_p were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities for Eq. (2.11), was calculated by iterating this equation. With these values for (ρ, t) , β_p was determined from this equation.

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the isothermal stress coefficient for temperatures above 800 °C up to 2000 °C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

The tabulated values of β_p can be used to calculate corresponding partial derivatives of thermodynamic properties as described in Sec. 2.4.2.

Table 20 Isothermal stress coefficient β_p [kg m⁻³]^a

t [°C]	p [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	<u>3.2140×10⁹</u>	1.9644×10 ⁹	1.9645×10 ⁸	1.9651×10 ⁷	9.8286×10 ⁶	4.9176×10 ⁶	3.2805×10 ⁶	2.4620×10 ⁶	1.9709×10 ⁶	988733
5	0.0047611	<u>2.0332×10⁹</u>	2.0332×10 ⁸	2.0338×10 ⁷	1.0172×10 ⁷	5.0894×10 ⁶	3.3951×10 ⁶	2.5479×10 ⁶	2.0396×10 ⁶	1.0231×10 ⁶
10	0.0046771	0.0076518	2.0913×10 ⁸	2.0919×10 ⁷	1.0462×10 ⁷	5.2345×10 ⁶	3.4918×10 ⁶	2.6204×10 ⁶	2.0976×10 ⁶	1.0520×10 ⁶
15	0.0045959	0.0075193	2.1392×10 ⁸	2.1398×10 ⁷	1.0702×10 ⁷	5.3543×10 ⁶	3.5717×10 ⁶	2.6804×10 ⁶	2.1456×10 ⁶	1.0760×10 ⁶
20	0.0045176	0.0073911	2.1777×10 ⁸	2.1783×10 ⁷	1.0895×10 ⁷	5.4505×10 ⁶	3.6358×10 ⁶	2.7285×10 ⁶	2.1841×10 ⁶	1.0952×10 ⁶
25	0.0044418	0.0072672	2.2074×10 ⁸	2.2080×10 ⁷	1.1043×10 ⁷	5.5247×10 ⁶	3.6853×10 ⁶	2.7655×10 ⁶	2.2137×10 ⁶	1.1101×10 ⁶
30	0.0043686	0.0071474	2.2288×10 ⁸	2.2294×10 ⁷	1.1150×10 ⁷	5.5783×10 ⁶	3.7210×10 ⁶	2.7923×10 ⁶	2.2352×10 ⁶	1.1208×10 ⁶
35	0.0042977	0.0070314	2.2426×10 ⁸	2.2432×10 ⁷	1.1219×10 ⁷	5.6128×10 ⁶	3.7440×10 ⁶	2.8096×10 ⁶	2.2490×10 ⁶	1.1277×10 ⁶
40	0.0042291	0.0069191	2.2494×10 ⁸	2.2500×10 ⁷	1.1253×10 ⁷	5.6298×10 ⁶	3.7553×10 ⁶	2.8181×10 ⁶	2.2558×10 ⁶	1.1312×10 ⁶
45	0.0041626	0.0068104	<u>2.2496×10⁸</u>	2.2502×10 ⁷	1.1254×10 ⁷	5.6305×10 ⁶	3.7559×10 ⁶	2.8185×10 ⁶	2.2561×10 ⁶	1.1314×10 ⁶
50	0.0040982	0.0067050	0.067044	2.2446×10 ⁷	1.1226×10 ⁷	5.6164×10 ⁶	3.7465×10 ⁶	2.8115×10 ⁶	2.2505×10 ⁶	1.1286×10 ⁶
60	0.0039752	0.0065038	0.065035	2.2174×10 ⁷	1.1090×10 ⁷	5.5485×10 ⁶	3.7013×10 ⁶	2.7777×10 ⁶	2.2235×10 ⁶	1.1151×10 ⁶
70	0.0038593	0.0063142	0.063141	2.1721×10 ⁷	1.0864×10 ⁷	5.4356×10 ⁶	3.6260×10 ⁶	2.7213×10 ⁶	2.1784×10 ⁶	1.0927×10 ⁶
80	0.0037500	0.0061354	0.061353	2.1122×10 ⁷	1.0564×10 ⁷	5.2858×10 ⁶	3.5262×10 ⁶	2.6464×10 ⁶	2.1186×10 ⁶	1.0628×10 ⁶
90	0.0036468	0.0059665	0.059664	<u>2.0404×10⁷</u>	1.0205×10 ⁷	5.1063×10 ⁶	3.4066×10 ⁶	2.5568×10 ⁶	2.0469×10 ⁶	1.0271×10 ⁶
100	0.0035491	0.0058066	0.058065	0.58018	<u>9.7995×10⁶</u>	4.9034×10 ⁶	3.2714×10 ⁶	2.4554×10 ⁶	1.9658×10 ⁶	986625
125	0.0033262	0.0054420	0.054420	0.54401	1.0866	<u>4.3261×10⁶</u>	2.8866×10 ⁶	2.1669×10 ⁶	1.7351×10 ⁶	871426
150	0.0031297	0.0051205	0.051205	0.51195	1.0233	2.0411	<u>2.4659×10⁶</u>	<u>1.8514×10⁶</u>	1.4828×10 ⁶	745396
175	0.0029551	0.0048348	0.048348	0.48343	0.96658	1.9307	2.8894	3.8366	<u>1.2252×10⁶</u>	616707
200	0.0027990	0.0045794	0.045794	0.45791	0.91567	1.8301	2.7418	3.6493	4.5504	491017
225	0.0026585	0.0043495	0.043495	0.43494	0.86980	1.7389	2.6066	3.4720	4.3343	8.5504
250	0.0025315	0.0041417	0.041417	0.41416	0.82828	1.6562	2.4832	3.3091	4.1331	8.2063
275	0.0024160	0.0039528	0.039528	0.39528	0.79052	1.5808	2.3707	3.1598	3.9479	7.8617
300	0.0023106	0.0037804	0.037804	0.37804	0.75605	1.5120	2.2676	3.0228	3.7774	7.5349
325	0.0022140	0.0036224	0.036224	0.36224	0.72446	1.4488	2.1731	2.8970	3.6206	7.2290
350	0.0021252	0.0034771	0.034771	0.34770	0.69540	1.3908	2.0860	2.7811	3.4759	6.9443
375	0.0020432	0.0033429	0.033429	0.33429	0.66858	1.3371	2.0056	2.6740	3.3422	6.6795
400	0.0019674	0.0032188	0.032188	0.32188	0.64375	1.2875	1.9312	2.5748	3.2183	6.4334
425	0.0018969	0.0031035	0.031035	0.31035	0.62070	1.2414	1.8620	2.4827	3.1032	6.2042
450	0.0018313	0.0029962	0.029962	0.29962	0.59924	1.1985	1.7977	2.3969	2.9960	5.9905
475	0.0017701	0.0028961	0.028961	0.28961	0.57922	1.1584	1.7376	2.3168	2.8959	5.7908
500	0.0017129	0.0028025	0.028025	0.28025	0.56049	1.1210	1.6815	2.2419	2.8023	5.6039
525	0.0016592	0.0027147	0.027147	0.27147	0.54294	1.0859	1.6288	2.1717	2.7146	5.4287
550	0.0016089	0.0026322	0.026322	0.26322	0.52645	1.0529	1.5793	2.1058	2.6322	5.2639
575	0.0015614	0.0025546	0.025546	0.25546	0.51093	1.0219	1.5328	2.0437	2.5546	5.1089
600	0.0015167	0.0024815	0.024815	0.24815	0.49630	0.99260	1.4889	1.9852	2.4815	4.9627
625	0.0014745	0.0024124	0.024124	0.24124	0.48249	0.96497	1.4475	1.9299	2.4124	4.8246
650	0.0014346	0.0023471	0.023471	0.23471	0.46942	0.93884	1.4083	1.8777	2.3471	4.6940
675	0.0013968	0.0022852	0.022852	0.22852	0.45704	0.91408	1.3711	1.8282	2.2852	4.5703
700	0.0013609	0.0022265	0.022265	0.22265	0.44530	0.89060	1.3359	1.7812	2.2265	4.4529
725	0.0013268	0.0021707	0.021707	0.21707	0.43415	0.86830	1.3024	1.7366	2.1707	4.3414
750	0.0012944	0.0021177	0.021177	0.21177	0.42354	0.84708	1.2706	1.6942	2.1177	4.2354
775	0.0012635	0.0020672	0.020672	0.20672	0.41344	0.82688	1.2403	1.6538	2.0672	4.1344
800	0.0012341	0.0020190	0.020190	0.20190	0.40381	0.80761	1.2114	1.6152	2.0190	4.0381

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 20 Isothermal stress coefficient β_p [kg m⁻³]^a – Continued

t [°C]	p [bar]									
	40	60	80	100	120	140	160	180	200	220
0	497646	333963	252130	203038	170315	146947	129425	115801	104906	95994
5	514786	345372	260673	209861	175992	151804	133667	119565	108286	99061
10	529257	355005	267887	215622	180784	155905	137249	122742	111140	101650
15	541218	362969	273852	220387	184749	159298	140213	125372	113503	103794
20	550830	369371	278649	224222	187941	162031	142601	127492	115408	105524
25	558247	374317	282359	227189	190413	164149	144454	129138	116888	106868
30	563624	377908	285055	229349	192215	165695	145808	130343	117973	107855
35	567109	380242	286813	230761	193396	166711	146700	131138	118691	108509
40	568846	381414	287703	231481	194003	167236	147164	131554	119069	108856
45	568971	381515	287792	231562	194079	167308	147232	131620	119133	108917
50	567616	380633	287145	231057	193667	166963	146937	131364	118907	108717
60	560962	376244	283888	228478	191540	165158	145374	129987	117680	107612
70	549809	368860	278387	224106	187921	162076	142694	127620	115563	105699
80	534975	359022	271047	218264	183076	157944	139095	124436	112710	103117
90	517174	347205	262222	211232	177240	152960	134751	120590	109261	99993
100	497020	333818	252216	203255	170614	147299	129813	116214	105334	96433
125	439585	295633	223654	180464	151669	131099	115671	103671	94070	86215
150	376704	253797	192337	155456	130865	113298	100119	89868	81665	74952
175	312457	211028	160305	129864	109565	95061	84179	75713	68938	63392
200	249663	169199	128957	104804	88696	77185	68547	61825	56444	52039
225	190433	129706	99334	81103	68943	60252	53729	48652	44586	41257
250	136347	93609	72231	59397	50835	44715	40120	36542	33676	31329
275	15.359	61531	48146	40103	34732	30889	28000	25749	23944	22464
300	14.871	21.609	26.682	23383	20789	18926	17517	16412	15521	14786
325	14.342	21.146	27.278	31.926	32.482	8981.3	8777.3	8617.2	8486.0	8371.4
350	13.817	20.513	26.873	32.618	37.234	39.549	35.622	2526.6	3002.0	3347.3
375	13.314	19.841	26.177	32.206	37.747	42.517	46.014	47.206	43.676	19.677
400	12.838	19.174	25.395	31.442	37.241	42.687	47.643	51.917	55.209	57.025
425	12.389	18.530	24.598	30.562	36.384	42.023	47.427	52.535	57.283	61.603
450	11.968	17.916	23.818	29.653	35.403	41.050	46.572	51.949	57.159	62.190
475	11.573	17.335	23.066	28.755	34.390	39.963	45.466	50.892	56.237	61.500
500	11.202	16.786	22.349	27.885	33.386	38.849	44.271	49.650	54.987	60.288
525	10.853	16.268	21.669	27.051	32.412	37.748	43.059	48.346	53.613	58.863
550	10.525	15.779	21.024	26.256	31.475	36.678	41.866	47.042	52.206	57.366
575	10.215	15.318	20.413	25.501	30.579	35.649	40.710	45.764	50.814	55.864
600	9.9238	14.882	19.835	24.783	29.726	34.664	39.597	44.527	49.457	54.391
625	9.6481	14.469	19.288	24.103	28.915	33.724	38.531	43.338	48.148	52.962
650	9.3872	14.079	18.769	23.457	28.143	32.828	37.513	42.200	46.890	51.586
675	9.1400	13.709	18.276	22.843	27.409	31.975	36.542	41.112	45.685	50.265
700	8.9055	13.357	17.809	22.260	26.711	31.163	35.616	40.073	44.534	49.001
725	8.6826	13.023	17.364	21.705	26.046	30.389	34.733	39.081	43.434	47.792
750	8.4706	12.706	16.941	21.177	25.413	29.651	33.891	38.135	42.383	46.636
775	8.2687	12.403	16.538	20.673	24.809	28.947	33.088	37.231	41.379	45.532
800	8.0762	12.114	16.153	20.193	24.233	28.275	32.320	36.368	40.419	44.476

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 20 Isothermal stress coefficient β_p [kg m⁻³] – Continued

t [°C]	p [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	88571	82292	76913	72253	55967	46227	39756	35152	31710	26911
5	91376	84876	79307	74482	57619	47531	40828	36058	32492	27521
10	93744	87057	81328	76364	59013	48631	41732	36820	33149	28032
15	95706	88864	83002	77923	60169	49544	42482	37454	33695	28456
20	97289	90323	84354	79183	61105	50284	43091	37968	34139	28800
25	98520	91459	85408	80166	61837	50864	43569	38374	34489	29071
30	99425	92294	86184	80890	62379	51296	43926	38677	34751	29275
35	100026	92850	86701	81374	62744	51590	44171	38886	34932	29416
40	100346	93148	86980	81635	62946	51754	44310	39006	35037	29498
45	100406	93207	87037	81691	62996	51800	44351	39043	35071	29524
50	100227	93044	86889	81556	62905	51734	44302	39004	35039	29499
60	99223	92127	86045	80775	62344	51303	43954	38715	34792	29305
70	97480	90526	84568	79404	61343	50521	43318	38180	34330	28942
80	95124	88361	82566	77544	59976	49447	42437	37436	33687	28433
90	92270	85736	80136	75283	58307	48131	41354	36518	32891	27802
100	89016	82741	77362	72702	56394	46618	40106	35457	31969	27070
125	79668	74129	69381	65266	50864	42226	36469	32357	29269	24918
150	69358	64623	60564	57045	44727	37334	32405	28882	26233	22491
175	58769	54855	51499	48590	38399	32277	28192	25271	23074	19961
200	48365	45255	42587	40273	32161	27280	24021	21690	19935	17441
225	38480	36128	34109	32358	26211	22504	20025	18250	16913	15008
250	29370	27709	26284	25047	20696	18064	16299	15033	14079	12716
275	21227	20178	19276	18493	15728	14047	12914	12100	11485	10603
300	14169	13644	13191	12796	11386	10513	9919.3	9490.0	9165.3	8693.5
325	8267.3	8171.7	8084.3	8005.2	7706.9	7497.0	7341.3	7226.9	7139.9	7005.0
350	3618.8	3846.1	4038.2	4198.0	4698.6	5003.1	5188.2	5315.9	5414.2	5543.1
375	401.80	804.06	1141.6	1430.8	2431.2	3034.4	3445.3	3746.7	3978.5	4309.8
400	56.779	53.564	51.861	99.057	922.35	1613.6	2123.6	2513.5	2821.8	3279.2
425	65.417	68.647	71.365	74.178	239.46	728.96	1203.8	1602.3	1933.2	2445.4
450	67.037	71.718	76.277	80.805	123.65	317.59	645.78	983.68	1290.3	1796.3
475	66.686	71.810	76.903	82.015	112.61	191.57	367.50	606.84	857.60	1313.2
500	65.559	70.813	76.067	81.350	110.24	156.76	251.77	402.84	587.56	968.73
525	64.104	69.348	74.607	79.900	107.92	144.34	204.39	300.32	429.40	731.60
550	62.526	67.696	72.886	78.109	105.38	137.57	182.10	248.45	339.03	572.26
575	60.920	65.987	71.075	76.193	102.70	132.52	169.61	219.77	286.93	466.21
600	59.332	64.285	69.258	74.257	99.982	128.15	161.12	202.20	254.81	396.12
625	57.785	62.620	67.472	72.348	97.319	124.15	154.43	190.18	233.62	347.89
650	56.290	61.006	65.738	70.490	94.742	120.45	148.75	181.01	218.65	313.71
675	54.853	59.453	64.066	68.697	92.264	117.00	143.75	173.50	207.27	289.09
700	53.476	57.961	62.459	66.973	89.890	113.77	139.24	167.07	198.03	271.01
725	52.158	56.533	60.920	65.320	87.621	110.72	135.11	161.40	190.17	256.60
750	50.897	55.166	59.445	63.737	85.454	107.84	131.30	156.30	183.31	244.40
775	49.691	53.858	58.035	62.222	83.385	105.12	127.76	151.67	177.21	233.84
800	48.538	52.608	56.686	60.773	81.408	102.54	124.44	147.41	171.74	224.70

Table 21 Fugacity f^*

For the single-phase region, this table contains values for the

- Fugacity $f^* = p \exp[(g - g^0)/(RT)]$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given (p, t) values, the values for the fugacity f^* were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities for Eq. (2.11), was calculated by iterating this equation. With the values for (ρ, t) , the values of f^* were determined from Eq. (2.11).

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the fugacity for temperatures above 800°C up to 2000°C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

Table 21 Fugacity f^* [bar]^a

<i>t</i> [°C]	<i>p</i> [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	0.0061091	0.0061091	0.0061095	0.0061139	0.0061187	0.0061284	0.0061382	0.0061479	0.0061577	0.0062067
5	0.0061093	0.0087201	0.0087207	0.0087268	0.0087336	0.0087472	0.0087609	0.0087745	0.0087882	0.0088569
10	0.0061096	0.0099932	0.012273	0.012281	0.012290	0.012309	0.012328	0.012347	0.012366	0.012461
15	0.0061099	0.0099939	0.017041	0.017053	0.017066	0.017091	0.017117	0.017143	0.017169	0.017298
20	0.00611010	0.0099946	0.023364	0.023380	0.023397	0.023432	0.023466	0.023501	0.023536	0.023711
25	0.00611030	0.0099951	0.031650	0.031671	0.031694	0.031741	0.031787	0.031833	0.031880	0.032113
30	0.00611047	0.0099956	0.042389	0.042417	0.042447	0.042508	0.042569	0.042630	0.042692	0.042999
35	0.00611062	0.0099960	0.056161	0.056197	0.056236	0.056316	0.056396	0.056476	0.056556	0.056957
40	0.00611075	0.0099963	0.073646	0.073692	0.073743	0.073846	0.073949	0.074052	0.074156	0.074674
45	0.00611087	0.0099966	0.095634	0.095693	0.095759	0.095891	0.096023	0.096155	0.096287	0.096951
50	0.00611098	0.0099969	0.099690	0.12311	0.12320	0.12336	0.12353	0.12370	0.12387	0.12471
60	0.00611115	0.0099974	0.099739	0.19851	0.19865	0.19891	0.19917	0.19944	0.19970	0.20102
70	0.00611130	0.0099978	0.099777	0.30995	0.31015	0.31055	0.31095	0.31135	0.31175	0.31377
80	0.00611141	0.0099981	0.099808	0.46993	0.47022	0.47082	0.47141	0.47201	0.47260	0.47559
90	0.00611151	0.0099983	0.099834	0.69361	0.69404	0.69490	0.69576	0.69662	0.69748	0.70180
100	0.00611158	0.0099985	0.099855	0.98525	0.99953	1.0007	1.0020	1.0032	1.0044	1.0105
125	0.00611173	0.0099989	0.099893	0.98921	1.9564	2.2654	2.2680	2.2706	2.2732	2.2864
150	0.00611182	0.0099992	0.099919	0.99182	1.9670	3.8664	4.5739	4.5790	4.5841	4.6097
175	0.00611189	0.0099994	0.099936	0.99362	1.9744	3.8965	5.7651	7.5787	8.4031	8.4487
200	0.00611194	0.0099995	0.099949	0.99490	1.9796	3.9178	5.8140	7.6675	9.4776	14.298
225	0.00611197	0.0099996	0.099959	0.99586	1.9834	3.9334	5.8496	7.7318	9.5794	18.288
250	0.00611200	0.0099997	0.099966	0.99658	1.9863	3.9452	5.8764	7.7799	9.6554	18.607
275	0.00611202	0.0099997	0.099972	0.99715	1.9886	3.9543	5.8971	7.8169	9.7136	18.847
300	0.00611204	0.0099998	0.099976	0.99760	1.9904	3.9616	5.9134	7.8460	9.7593	19.034
325	0.00611205	0.0099998	0.099980	0.99796	1.9918	3.9674	5.9265	7.8694	9.7958	19.182
350	0.00611206	0.0099998	0.099983	0.99826	1.9930	3.9721	5.9372	7.8883	9.8255	19.302
375	0.00611207	0.0099998	0.099985	0.99850	1.9940	3.9760	5.9460	7.9039	9.8499	19.400
400	0.00611208	0.0099999	0.099987	0.99870	1.9948	3.9792	5.9533	7.9169	9.8702	19.481
425	0.00611208	0.0099999	0.099989	0.99887	1.9955	3.9819	5.9594	7.9278	9.8872	19.549
450	0.00611209	0.0099999	0.099990	0.99902	1.9961	3.9842	5.9646	7.9370	9.9016	19.607
475	0.00611209	0.0099999	0.099991	0.99914	1.9966	3.9862	5.9690	7.9448	9.9138	19.656
500	0.00611210	0.0099999	0.099992	0.99924	1.9970	3.9879	5.9727	7.9515	9.9243	19.698
525	0.00611210	0.0099999	0.099993	0.99933	1.9973	3.9893	5.9760	7.9573	9.9333	19.734
550	0.00611210	0.0099999	0.099994	0.99941	1.9976	3.9906	5.9788	7.9623	9.9411	19.765
575	0.00611211	0.0099999	0.099995	0.99948	1.9979	3.9917	5.9812	7.9666	9.9479	19.792
600	0.00611211	0.010000	0.099995	0.99954	1.9981	3.9926	5.9834	7.9704	9.9538	19.815
625	0.00611211	0.010000	0.099996	0.99959	1.9984	3.9934	5.9852	7.9737	9.9589	19.836
650	0.00611211	0.010000	0.099996	0.99963	1.9985	3.9942	5.9868	7.9766	9.9635	19.854
675	0.00611211	0.010000	0.099997	0.99967	1.9987	3.9948	5.9883	7.9792	9.9675	19.870
700	0.00611212	0.010000	0.099997	0.99971	1.9988	3.9954	5.9896	7.9814	9.9710	19.884
725	0.00611212	0.010000	0.099997	0.99974	1.9990	3.9959	5.9907	7.9835	9.9742	19.897
750	0.00611212	0.010000	0.099998	0.99977	1.9991	3.9963	5.9917	7.9853	9.9770	19.908
775	0.00611212	0.010000	0.099998	0.99979	1.9992	3.9967	5.9926	7.9869	9.9795	19.918
800	0.00611212	0.010000	0.099998	0.99982	1.9993	3.9971	5.9934	7.9883	9.9817	19.927

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 21 Fugacity f^* [bar]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	40	60	80	100	120	140	160	180	200	220
0	0.0063058	0.0064064	0.0065085	0.0066121	0.0067173	0.0068241	0.0069324	0.0070423	0.0071539	0.0072671
5	0.0089957	0.0091367	0.0092796	0.0094247	0.0095719	0.0097213	0.0098728	0.010027	0.010183	0.010341
10	0.012653	0.012848	0.013045	0.013246	0.013449	0.013655	0.013864	0.014076	0.014292	0.014510
15	0.017560	0.017826	0.018095	0.018369	0.018646	0.018927	0.019212	0.019501	0.019794	0.020092
20	0.024064	0.024422	0.024786	0.025154	0.025527	0.025906	0.026290	0.026679	0.027074	0.027474
25	0.032584	0.033061	0.033545	0.034036	0.034533	0.035037	0.035548	0.036066	0.036591	0.037124
30	0.043620	0.044249	0.044887	0.045534	0.046189	0.046853	0.047526	0.048208	0.048900	0.049601
35	0.057767	0.058588	0.059421	0.060264	0.061118	0.061984	0.062862	0.063751	0.064652	0.065564
40	0.075722	0.076783	0.077858	0.078947	0.080051	0.081168	0.082301	0.083448	0.084611	0.085789
45	0.098293	0.099651	0.10103	0.10242	0.10383	0.10526	0.10671	0.10818	0.10966	0.11117
50	0.12641	0.12814	0.12988	0.13165	0.13344	0.13525	0.13709	0.13895	0.14083	0.14274
60	0.20370	0.20640	0.20915	0.21192	0.21473	0.21757	0.22045	0.22336	0.22632	0.22930
70	0.31784	0.32197	0.32614	0.33036	0.33464	0.33896	0.34334	0.34777	0.35225	0.35679
80	0.48163	0.48774	0.49391	0.50016	0.50649	0.51289	0.51936	0.52591	0.53253	0.53924
90	0.71052	0.71934	0.72826	0.73728	0.74640	0.75563	0.76496	0.77440	0.78395	0.79361
100	1.0228	1.0352	1.0478	1.0605	1.0734	1.0864	1.0995	1.1128	1.1263	1.1399
125	2.3131	2.3400	2.3671	2.3946	2.4224	2.4504	2.4788	2.5074	2.5363	2.5656
150	4.6614	4.7136	4.7663	4.8196	4.8734	4.9277	4.9826	5.0380	5.0939	5.1504
175	8.5406	8.6334	8.7270	8.8216	8.9170	9.0133	9.1106	9.2087	9.3078	9.4078
200	14.450	14.604	14.758	14.914	15.072	15.231	15.391	15.553	15.716	15.881
225	22.855	23.094	23.335	23.578	23.823	24.071	24.320	24.571	24.824	25.080
250	<u>34.120</u>	34.475	34.833	35.193	35.557	35.923	36.291	36.663	37.037	37.415
275	<u>35.322</u>	48.948	49.459	49.974	50.492	51.013	51.538	52.067	52.599	53.135
300	36.105	<u>51.146</u>	64.042	<u>67.898</u>	68.618	69.341	70.067	70.797	71.531	72.269
325	36.715	52.570	66.699	79.025	89.384	<u>90.584</u>	<u>91.577</u>	92.571	93.567	94.565
350	37.203	53.692	68.749	82.344	94.432	104.93	113.65	<u>116.63</u>	118.01	119.37
375	37.600	54.597	70.384	84.949	98.277	110.34	121.11	130.52	138.44	144.52
400	37.927	55.339	71.716	87.053	101.35	114.59	126.78	137.90	147.93	156.84
425	38.200	55.956	72.818	88.786	103.86	118.04	131.33	143.73	155.24	165.85
450	38.430	56.474	73.741	90.233	105.95	120.90	135.09	148.51	161.17	173.08
475	38.626	56.913	74.522	91.454	107.71	123.30	138.23	152.49	166.10	179.06
500	38.793	57.288	75.188	92.494	109.21	125.34	140.89	155.86	170.26	184.10
525	38.936	57.611	75.760	93.387	110.49	127.09	143.17	158.74	173.82	188.39
550	39.060	57.889	76.254	94.157	111.60	128.59	145.13	161.22	176.87	192.09
575	39.168	58.131	76.683	94.827	112.56	129.90	146.84	163.38	179.52	195.28
600	39.262	58.342	77.057	95.410	113.40	131.04	148.32	165.25	181.83	198.07
625	39.344	58.527	77.386	95.922	114.14	132.04	149.62	166.89	183.86	200.52
650	39.417	58.690	77.674	96.372	114.79	132.92	150.77	168.34	185.64	202.67
675	39.481	58.833	77.929	96.769	115.36	133.69	151.78	169.62	187.21	204.56
700	39.537	58.960	78.155	97.122	115.86	134.38	152.68	170.75	188.61	206.25
725	39.587	59.073	78.355	97.435	116.31	134.99	153.47	171.76	189.85	207.75
750	39.632	59.174	78.534	97.714	116.71	135.54	154.18	172.66	190.96	209.08
775	39.672	59.264	78.694	97.963	117.07	136.03	154.82	173.46	191.95	210.28
800	39.708	59.345	78.837	98.187	117.40	136.46	155.39	174.18	192.84	211.35

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 21 Fugacity f^* [bar] – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	0.0073820	0.0074987	0.0076170	0.0077371	0.0083648	0.0090402	0.0097668	0.010548	0.011389	0.013263
5	0.010501	0.010664	0.010830	0.010997	0.011873	0.012815	0.013826	0.014913	0.016080	0.018678
10	0.014731	0.014956	0.015184	0.015415	0.016621	0.017916	0.019305	0.020796	0.022396	0.025950
15	0.020393	0.020699	0.021009	0.021324	0.022964	0.024722	0.026607	0.028627	0.030792	0.035596
20	0.027879	0.028291	0.028708	0.029131	0.031334	0.033694	0.036221	0.038927	0.041823	0.048238
25	0.037663	0.038210	0.038765	0.039327	0.042254	0.045386	0.048736	0.052319	0.056150	0.064623
30	0.050311	0.051030	0.051760	0.052499	0.056346	0.060458	0.064852	0.069546	0.074560	0.085634
35	0.066489	0.067426	0.068376	0.069338	0.074343	0.079687	0.085391	0.091480	0.097978	0.11231
40	0.086981	0.088190	0.089414	0.090655	0.097103	0.10398	0.11132	0.11914	0.12748	0.14584
45	0.11269	0.11424	0.11580	0.11739	0.12562	0.13439	0.14374	0.15369	0.16430	0.18763
50	0.14467	0.14663	0.14861	0.15061	0.16103	0.17212	0.18393	0.19649	0.20987	0.23924
60	0.23233	0.23539	0.23848	0.24162	0.25789	0.27519	0.29357	0.31311	0.33386	0.37932
70	0.36138	0.36603	0.37073	0.37549	0.40015	0.42632	0.45410	0.48356	0.51481	0.58311
80	0.54602	0.55288	0.55982	0.56685	0.60321	0.64174	0.68257	0.72581	0.77162	0.87149
90	0.80338	0.81326	0.82325	0.83336	0.88564	0.94096	0.99949	1.0614	1.1269	1.2694
100	1.1536	1.1675	1.1816	1.1958	1.2693	1.3469	1.4289	1.5155	1.6071	1.8058
125	2.5951	2.6250	2.6552	2.6857	2.8430	3.0088	3.1834	3.3673	3.5610	3.9797
150	5.2075	5.2651	5.3234	5.3821	5.6850	6.0032	6.3374	6.6885	7.0572	7.8511
175	9.5088	9.6107	9.7136	9.8174	10.351	10.911	11.498	12.112	12.756	14.137
200	16.047	16.215	16.384	16.554	17.431	18.347	19.305	20.306	21.353	23.591
225	25.337	25.597	25.859	26.123	27.478	28.891	30.365	31.902	33.506	36.925
250	37.795	38.178	38.565	38.954	40.947	43.021	45.179	47.425	49.763	54.731
275	53.674	54.218	54.765	55.316	58.132	61.053	64.085	67.233	70.502	77.428
300	73.012	73.758	74.510	75.265	79.116	83.095	87.211	91.472	95.887	105.21
325	95.567	96.572	97.581	98.594	103.73	109.01	114.45	120.05	125.84	138.02
350	120.72	122.07	123.42	124.77	131.53	138.40	145.42	152.63	160.05	175.58
375	147.05	149.01	150.90	152.74	161.71	170.58	179.53	188.64	197.97	217.36
400	164.58	171.06	176.17	179.91	192.94	204.51	215.86	227.26	238.81	262.64
425	175.56	184.37	192.29	199.29	222.88	238.74	253.25	267.44	281.62	310.54
450	184.24	194.66	204.35	213.32	248.12	271.24	290.21	307.94	325.29	360.05
475	191.38	203.07	214.13	224.59	268.23	300.04	325.12	347.40	368.58	410.09
500	197.38	210.10	222.29	233.95	284.72	324.57	356.71	384.56	410.32	459.58
525	202.48	216.08	229.21	241.88	298.57	345.42	384.56	418.55	449.54	507.54
550	206.87	221.22	235.15	248.68	310.42	363.29	408.89	449.07	485.64	553.17
575	210.66	225.66	240.29	254.56	320.65	378.78	430.17	476.23	518.42	595.94
600	213.97	229.54	244.77	259.68	329.57	392.29	448.85	500.35	547.94	635.56
625	216.87	232.93	248.70	264.17	337.38	404.16	465.33	521.78	574.44	671.92
650	219.42	235.92	252.15	268.12	344.27	414.64	479.92	540.85	598.20	705.11
675	221.68	238.55	255.20	271.61	350.35	423.93	492.89	557.87	619.52	735.33
700	223.68	240.89	257.90	274.71	355.76	432.19	504.46	573.10	638.67	762.78
725	225.45	242.98	260.31	277.46	360.58	439.55	514.80	586.76	655.91	787.70
750	227.04	244.83	262.46	279.93	364.89	446.15	524.07	599.03	671.45	810.31
775	228.46	246.50	264.39	282.13	368.74	452.06	532.40	610.09	685.48	830.85
800	229.74	247.99	266.11	284.11	372.21	457.39	539.90	620.06	698.17	849.53

Table 22 Saturation state:
Joule-Thomson coefficient μ ,
Isothermal throttling coefficient δ_T ,
Surface tension σ

This table contains values on the saturated liquid ('') and saturated vapour ('') lines for the following properties for temperatures from 0°C up to the critical temperature $t_c = 373.946^\circ\text{C}$:

- Joule-Thomson coefficient $\mu = (\partial T / \partial p)_h$
- Isothermal throttling coefficient $\delta_T = (\partial h / \partial p)_T$

Furthermore, values of the

- Surface tension σ

are also listed.

For given temperatures, the saturation pressures p_s were calculated from the IAPWS-IF97 saturation-pressure equation, Eq. (2.13).

For temperatures $t \leq 350^\circ\text{C}$ and the input values of t and p_s , the thermodynamic properties Joule-Thomson coefficient μ and isothermal throttling coefficient δ_T on the saturated-liquid and saturated-vapour lines were determined from the basic equations for regions 1 and 2, Eqs. (2.3) and (2.6).

For $t > 350^\circ\text{C}$, the basic equation of region 3, Eq. (2.11), was used for these calculations. With the input (t, p_s) values, the densities ρ' and ρ'' , needed as one of the input quantities of Eq. (2.11), were determined by iterating this equation. With these values for (ρ', t) and (ρ'', t) , μ and δ_T at saturation were determined from Eq. (2.11).

For the given temperatures, the values of the surface tension σ of saturated water were calculated from Eq. (3.8).

Table 22 Saturation state: Joule-Thomson coefficient μ , Isothermal throttling coefficient δ_T , Surface tension σ

t [°C]	μ' [10^{-3} K kPa $^{-1}$]	μ''	δ'_T [10^{-3} kJ kg $^{-1}$ kPa $^{-1}$]	δ''_T	σ [10^{-3} N m $^{-1}$]
0	-0.24143	602.48	1.0188	-1137.6	75.648
0.01 ^a	-0.24142	602.25	1.0188	-1137.2	75.646
1	-0.24046	580.02	1.0139	-1095.6	75.508
2	-0.23950	558.86	1.0091	-1056.0	75.367
3	-0.23857	538.90	1.0045	-1018.6	75.226
4	-0.23765	520.05	1.0000	-983.38	75.084
5	-0.23675	502.22	0.99563	-950.03	74.942
6	-0.23587	485.33	0.99139	-918.45	74.799
7	-0.23500	469.30	0.98725	-888.50	74.655
8	-0.23415	454.09	0.98322	-860.05	74.511
9	-0.23331	439.61	0.97929	-833.01	74.366
10	-0.23248	425.83	0.97545	-807.26	74.221
11	-0.23167	412.69	0.97170	-782.72	74.075
12	-0.23087	400.15	0.96804	-759.30	73.929
13	-0.23009	388.17	0.96445	-736.92	73.782
14	-0.22931	376.70	0.96093	-715.52	73.634
15	-0.22855	365.72	0.95749	-695.03	73.486
16	-0.22780	355.20	0.95411	-675.39	73.337
17	-0.22706	345.10	0.95080	-656.56	73.188
18	-0.22633	335.41	0.94755	-638.47	73.038
19	-0.22561	326.09	0.94435	-621.09	72.887
20	-0.22489	317.13	0.94121	-604.38	72.736
22	-0.22350	300.21	0.93507	-572.80	72.432
24	-0.22214	284.49	0.92912	-543.48	72.126
25	-0.22147	277.04	0.92621	-529.60	71.972
26	-0.22080	269.85	0.92334	-516.20	71.818
28	-0.21950	256.21	0.91771	-490.75	71.507
30	-0.21822	243.47	0.91221	-466.98	71.194
32	-0.21696	231.56	0.90684	-444.76	70.879
34	-0.21572	220.40	0.90158	-423.94	70.562
36	-0.21451	209.95	0.89643	-404.44	70.242
38	-0.21330	200.15	0.89137	-386.14	69.920
40	-0.21212	190.96	0.88639	-368.97	69.596
42	-0.21094	182.32	0.88149	-352.84	69.270
44	-0.20978	174.21	0.87666	-337.70	68.942
46	-0.20863	166.59	0.87190	-323.46	68.611
48	-0.20749	159.43	0.86719	-310.08	68.279
50	-0.20636	152.70	0.86253	-297.49	67.944
52	-0.20523	146.36	0.85792	-285.65	67.607
54	-0.20411	140.40	0.85335	-274.52	67.268
56	-0.20300	134.79	0.84881	-264.03	66.927
58	-0.20188	129.51	0.84431	-254.17	66.584

^a Triple-point temperature.

Table 22 Saturation state:

Joule-Thomson coefficient μ ,
Isothermal throttling coefficient δ_T ,
Surface tension σ

– Continued

t [°C]	μ' [10^{-3} K kPa $^{-1}$]	μ''	δ'_T [10^{-3} kJ kg $^{-1}$ kPa $^{-1}$]	δ''_T	σ [10^{-3} N m $^{-1}$]
60	–0.20078	124.53	0.83983	–244.88	66.238
62	–0.19967	119.84	0.83538	–236.13	65.891
64	–0.19856	115.42	0.83095	–227.88	65.541
66	–0.19746	111.25	0.82654	–220.11	65.190
68	–0.19635	107.31	0.82214	–212.78	64.836
70	–0.19525	103.60	0.81775	–205.88	64.481
72	–0.19414	100.09	0.81337	–199.36	64.123
74	–0.19303	96.768	0.80899	–193.21	63.764
76	–0.19192	93.628	0.80461	–187.40	63.402
78	–0.19080	90.656	0.80022	–181.91	63.038
80	–0.18968	87.842	0.79584	–176.73	62.673
82	–0.18856	85.174	0.79144	–171.83	62.305
84	–0.18743	82.644	0.78703	–167.20	61.936
86	–0.18629	80.242	0.78261	–162.81	61.565
88	–0.18515	77.961	0.77817	–158.66	61.191
90	–0.18399	75.792	0.77371	–154.73	60.816
92	–0.18284	73.728	0.76923	–151.01	60.439
94	–0.18167	71.763	0.76473	–147.48	60.060
96	–0.18049	69.890	0.76020	–144.13	59.679
98	–0.17931	68.103	0.75563	–140.96	59.296
100	–0.17811	66.397	0.75104	–137.94	58.912
105	–0.17508	62.450	0.73939	–131.04	57.943
110	–0.17196	58.900	0.72747	–124.94	56.962
115	–0.16877	55.687	0.71524	–119.52	55.970
120	–0.16547	52.755	0.70266	–114.69	54.968
125	–0.16208	50.062	0.68968	–110.35	53.955
130	–0.15856	47.569	0.67624	–106.41	52.932
135	–0.15492	45.247	0.66230	–102.83	51.899
140	–0.15114	43.072	0.64780	–99.536	50.856
145	–0.14721	41.025	0.63268	–96.492	49.803
150	–0.14312	39.091	0.61687	–93.658	48.741
155	–0.13884	37.261	0.60031	–91.008	47.670
160	–0.13438	35.525	0.58292	–88.521	46.591
165	–0.12970	33.879	0.56461	–86.182	45.503
170	–0.12480	32.318	0.54530	–83.979	44.406
175	–0.11965	30.838	0.52489	–81.906	43.302
180	–0.11423	29.436	0.50326	–79.959	42.190
185	–0.10853	28.108	0.48031	–78.134	41.071
190	–0.10252	26.851	0.45589	–76.428	39.945
195	–0.096172	25.662	0.42985	–74.840	38.813

Table 22 Saturation state:

Joule-Thomson coefficient μ ,
Isothermal throttling coefficient δ_T ,
Surface tension σ

– Continued

t [°C]	μ' [10^{-3} K kPa $^{-1}$]	μ''	δ'_T [10^{-3} kJ kg $^{-1}$ kPa $^{-1}$]	δ''_T	σ [10^{-3} N m $^{-1}$]
200	-0.089460	24.537	0.40203	-73.368	37.675
205	-0.082353	23.473	0.37225	-72.009	36.530
210	-0.074819	22.466	0.34029	-70.761	35.381
215	-0.066820	21.513	0.30592	-69.621	34.226
220	-0.058315	20.609	0.26887	-68.587	33.067
225	-0.049260	19.752	0.22884	-67.655	31.903
230	-0.039604	18.939	0.18546	-66.823	30.736
235	-0.029290	18.167	0.13834	-66.089	29.566
240	-0.018253	17.433	0.087011	-65.452	28.394
245	-0.0064212	16.734	0.030911	-64.911	27.219
250	0.0062905	16.069	-0.030603	-64.468	26.043
255	0.019978	15.436	-0.098302	-64.127	24.866
260	0.034755	14.831	-0.17310	-63.891	23.689
265	0.050751	14.253	-0.25612	-63.770	22.512
270	0.068121	13.701	-0.34870	-63.774	21.337
275	0.087046	13.172	-0.45248	-63.917	20.163
280	0.10774	12.665	-0.56950	-64.212	18.993
285	0.13046	12.178	-0.70230	-64.680	17.826
290	0.15551	11.708	-0.85402	-65.339	16.664
295	0.18324	11.256	-1.0286	-66.211	15.508
300	0.21406	10.818	-1.2312	-67.321	14.360
305	0.24849	10.394	-1.4681	-68.702	13.219
310	0.28710	9.9836	-1.7480	-70.397	12.089
315	0.33066	9.5846	-2.0821	-72.469	10.970
320	0.38019	9.1962	-2.4870	-75.018	9.8644
325	0.43712	8.8166	-2.9869	-78.194	8.7744
330	0.50359	8.4434	-3.6202	-82.222	7.7026
335	0.58272	8.0730	-4.4493	-87.431	6.6518
340	0.67877	7.7012	-5.5771	-94.272	5.6255
345	0.79663	7.3239	-7.1714	-103.36	4.6282
350	0.94029	6.9387	-9.4988	-115.47	3.6654
355	1.1321	6.5247	-13.424	-135.15	2.7448
360	1.3894	6.0857	-20.667	-167.78	1.8772
365	1.7616	5.5976	-37.831	-235.17	1.0801
370	2.3699	4.9880	-111.61	-465.89	0.38822
371	2.5494	4.8295	-163.41	-604.00	0.26921
372	2.7676	4.6411	-279.97	-883.32	0.16007
373	3.0562	4.3890	-708.76	-1760.6	0.064757
373.946 ^a		_b		_b	0

^aCritical temperature.^bIn the near critical region, the values for μ and δ_T calculated from IAPWS-IF97 are not accurate enough.

Table 23 Joule-Thomson coefficient μ

For the single-phase region, this table contains values for the

- Joule-Thomson coefficient $\mu = (\partial T / \partial p)_h$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given (p, t) values, the values for the Joule-Thomson coefficient μ were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities for Eq. (2.11), was calculated by iterating this equation. With these values for (ρ, t) , the values of μ were determined from Eq. (2.11).

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the Joule-Thomson coefficient for temperatures above 800°C up to 2000°C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

Table 23 Joule-Thomson coefficient μ [10^{-3} K kPa $^{-1}$]^a

<i>t</i> [°C]	<i>p</i> [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	-0.24143	-0.24143	-0.24143	-0.24142	-0.24141	-0.24139	-0.24138	-0.24136	-0.24134	-0.24126
5	426.975	-0.23675	-0.23675	-0.23675	-0.23674	-0.23672	-0.23671	-0.23669	-0.23668	-0.23660
10	335.123	387.47	-0.23248	-0.23247	-0.23247	-0.23245	-0.23244	-0.23243	-0.23241	-0.23235
15	281.183	304.43	-0.22855	-0.22854	-0.22854	-0.22853	-0.22852	-0.22850	-0.22849	-0.22844
20	245.227	255.56	-0.22489	-0.22489	-0.22489	-0.22488	-0.22487	-0.22486	-0.22485	-0.22481
25	218.477	223.08	-0.22147	-0.22146	-0.22146	-0.22145	-0.22145	-0.22144	-0.22144	-0.22141
30	196.965	199.01	-0.21822	-0.21822	-0.21821	-0.21821	-0.21821	-0.21820	-0.21820	-0.21818
35	178.811	179.71	-0.21511	-0.21511	-0.21511	-0.21511	-0.21511	-0.21511	-0.21511	-0.21510
40	163.063	163.45	-0.21212	-0.21212	-0.21212	-0.21212	-0.21212	-0.21212	-0.21213	-0.21213
45	149.189	149.35	-0.20921	-0.20921	-0.20921	-0.20921	-0.20922	-0.20922	-0.20923	-0.20925
50	136.858	136.92	147.46	-0.20636	-0.20636	-0.20637	-0.20638	-0.20638	-0.20639	-0.20642
60	115.957	115.96	118.15	-0.20078	-0.20079	-0.20080	-0.20081	-0.20082	-0.20083	-0.20089
70	99.063	99.061	99.492	-0.19525	-0.19526	-0.19528	-0.19530	-0.19531	-0.19533	-0.19541
80	85.291	85.290	85.395	-0.18969	-0.18970	-0.18972	-0.18974	-0.18977	-0.18979	-0.18990
90	73.984	73.985	74.053	-0.18400	-0.18401	-0.18404	-0.18407	-0.18410	-0.18412	-0.18426
100	64.638	64.641	64.717	66.331	-0.17813	-0.17816	-0.17820	-0.17823	-0.17827	-0.17844
125	47.498	47.502	47.580	48.226	49.290	-0.16212	-0.16218	-0.16223	-0.16228	-0.16255
150	36.261	36.263	36.321	36.822	37.246	38.284	-0.14317	-0.14325	-0.14333	-0.14374
175	28.607	28.609	28.646	28.986	29.295	29.732	30.067	30.528	-0.11972	-0.12034
200	23.203	23.204	23.226	23.438	23.642	23.959	24.166	24.289	24.359	-0.089890
225	19.255	19.255	19.268	19.393	19.518	19.727	19.883	19.990	20.053	19.959
250	16.279	16.279	16.286	16.356	16.428	16.555	16.657	16.736	16.793	16.803
275	13.972	13.972	13.976	14.013	14.052	14.122	14.182	14.232	14.272	14.327
300	12.139	12.139	12.141	12.159	12.178	12.214	12.245	12.272	12.294	12.339
325	10.650	10.650	10.651	10.659	10.667	10.682	10.695	10.707	10.716	10.736
350	9.4201	9.4201	9.4202	9.4220	9.4238	9.4272	9.4301	9.4324	9.4340	9.4314
375	8.3873	8.3873	8.3871	8.3859	8.3846	8.3819	8.3791	8.3763	8.3733	8.3554
400	7.5091	7.5091	7.5089	7.5063	7.5035	7.4979	7.4925	7.4872	7.4819	7.4555
425	6.7546	6.7546	6.7543	6.7512	6.7479	6.7413	6.7349	6.7286	6.7224	6.6927
450	6.1005	6.1005	6.1002	6.0971	6.0938	6.0872	6.0807	6.0744	6.0681	6.0383
475	5.5293	5.5293	5.5290	5.5262	5.5231	5.5169	5.5109	5.5050	5.4991	5.4711
500	5.0275	5.0275	5.0272	5.0247	5.0219	5.0165	5.0111	5.0058	5.0005	4.9753
525	4.5843	4.5843	4.5841	4.5819	4.5795	4.5748	4.5701	4.5655	4.5609	4.5388
550	4.1913	4.1913	4.1911	4.1893	4.1872	4.1832	4.1792	4.1753	4.1714	4.1524
575	3.8414	3.8414	3.8412	3.8397	3.8380	3.8347	3.8313	3.8280	3.8248	3.8087
600	3.5289	3.5289	3.5288	3.5275	3.5261	3.5234	3.5206	3.5179	3.5152	3.5018
625	3.2491	3.2491	3.2489	3.2479	3.2468	3.2446	3.2423	3.2401	3.2379	3.2269
650	2.9978	2.9978	2.9977	2.9969	2.9960	2.9942	2.9924	2.9906	2.9888	2.9799
675	2.7717	2.7717	2.7717	2.7710	2.7703	2.7689	2.7675	2.7661	2.7646	2.7574
700	2.5679	2.5679	2.5679	2.5674	2.5668	2.5657	2.5646	2.5635	2.5624	2.5566
725	2.3838	2.3838	2.3838	2.3834	2.3830	2.3821	2.3813	2.3804	2.3796	2.3750
750	2.2172	2.2172	2.2172	2.2169	2.2166	2.2159	2.2153	2.2146	2.2140	2.2105
775	2.0662	2.0662	2.0662	2.0660	2.0657	2.0653	2.0648	2.0643	2.0638	2.0610
800	1.9291	1.9291	1.9291	1.9289	1.9288	1.9284	1.9280	1.9276	1.9273	1.9251

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 23 Joule-Thomson coefficient μ [10^{-3} K kPa $^{-1}$]^a – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	40	60	80	100	120	140	160	180	200	220
0	-0.24109	-0.24091	-0.24073	-0.24055	-0.24037	-0.24019	-0.24000	-0.23981	-0.23962	-0.23942
5	-0.23644	-0.23628	-0.23612	-0.23595	-0.23579	-0.23562	-0.23545	-0.23528	-0.23511	-0.23493
10	-0.23221	-0.23207	-0.23193	-0.23179	-0.23164	-0.23150	-0.23135	-0.23120	-0.23105	-0.23090
15	-0.22832	-0.22821	-0.22809	-0.22797	-0.22786	-0.22773	-0.22761	-0.22749	-0.22736	-0.22724
20	-0.22472	-0.22463	-0.22454	-0.22445	-0.22435	-0.22426	-0.22416	-0.22406	-0.22396	-0.22386
25	-0.22134	-0.22128	-0.22121	-0.22115	-0.22108	-0.22101	-0.22093	-0.22086	-0.22079	-0.22071
30	-0.21815	-0.21811	-0.21807	-0.21803	-0.21798	-0.21794	-0.21789	-0.21784	-0.21779	-0.21774
35	-0.21509	-0.21508	-0.21506	-0.21505	-0.21503	-0.21501	-0.21498	-0.21496	-0.21493	-0.21490
40	-0.21215	-0.21216	-0.21217	-0.21218	-0.21218	-0.21218	-0.21219	-0.21218	-0.21218	-0.21218
45	-0.20929	-0.20932	-0.20936	-0.20939	-0.20942	-0.20944	-0.20947	-0.20949	-0.20951	-0.20953
50	-0.20649	-0.20655	-0.20661	-0.20666	-0.20671	-0.20677	-0.20681	-0.20686	-0.20690	-0.20694
60	-0.20100	-0.20111	-0.20122	-0.20132	-0.20142	-0.20152	-0.20161	-0.20171	-0.20179	-0.20188
70	-0.19558	-0.19574	-0.19589	-0.19604	-0.19619	-0.19634	-0.19648	-0.19661	-0.19675	-0.19688
80	-0.19011	-0.19033	-0.19053	-0.19073	-0.19093	-0.19113	-0.19132	-0.19150	-0.19168	-0.19186
90	-0.18454	-0.18480	-0.18507	-0.18532	-0.18557	-0.18582	-0.18606	-0.18630	-0.18653	-0.18676
100	-0.17877	-0.17910	-0.17942	-0.17974	-0.18005	-0.18035	-0.18065	-0.18094	-0.18123	-0.18151
125	-0.16308	-0.16360	-0.16410	-0.16460	-0.16508	-0.16556	-0.16602	-0.16648	-0.16693	-0.16737
150	-0.14454	-0.14533	-0.14609	-0.14684	-0.14757	-0.14829	-0.14899	-0.14967	-0.15035	-0.15100
175	-0.12156	-0.12275	-0.12390	-0.12503	-0.12613	-0.12720	-0.12824	-0.12926	-0.13026	-0.13123
200	-0.091784	-0.093618	-0.095396	-0.097120	-0.098792	-0.10042	-0.10199	-0.10353	-0.10502	-0.10646
225	-0.051462	-0.054397	-0.057222	-0.059944	-0.062567	-0.065098	-0.067542	-0.069903	-0.072187	-0.074396
250	0.006229	0.001228	-0.003529	-0.008063	-0.012389	-0.016522	-0.020477	-0.024265	-0.027897	-0.031384
275	13.955	0.086796	0.077837	0.069484	0.061669	0.054334	0.047431	0.040918	0.034758	0.028922
300	12.144	11.717	11.077	0.20098	0.18404	0.16873	0.15480	0.14207	0.13035	0.11952
325	10.629	10.362	9.9860	9.5006	8.8394	0.39416	0.35709	0.32517	0.29739	0.27301
350	9.3579	9.1888	8.9412	8.6299	8.2524	7.7998	7.1829	0.81017	0.68821	0.60274
375	8.2921	8.1781	8.0114	7.7991	7.5465	7.2514	6.9059	6.4942	5.9566	4.8603
400	7.3946	7.3097	7.1930	7.0441	6.8663	6.6615	6.4288	6.1644	5.8617	5.5092
425	6.6333	6.5641	6.4772	6.3694	6.2404	6.0916	5.9241	5.7375	5.5307	5.3014
450	5.9817	5.9221	5.8533	5.7717	5.6754	5.5645	5.4394	5.3008	5.1488	4.9833
475	5.4186	5.3661	5.3092	5.2446	5.1703	5.0856	4.9902	4.8844	4.7687	4.6434
500	4.9279	4.8816	4.8331	4.7801	4.7209	4.6544	4.5801	4.4980	4.4081	4.3109
525	4.4970	4.4563	4.4145	4.3700	4.3215	4.2679	4.2087	4.1436	4.0727	3.9960
550	4.1161	4.0807	4.0446	4.0067	3.9660	3.9218	3.8735	3.8209	3.7638	3.7023
575	3.7776	3.7471	3.7160	3.6835	3.6490	3.6118	3.5716	3.5282	3.4813	3.4310
600	3.4756	3.4494	3.4227	3.3947	3.3651	3.3335	3.2995	3.2630	3.2238	3.1819
625	3.2049	3.1827	3.1598	3.1357	3.1102	3.0830	3.0539	3.0228	2.9895	2.9540
650	2.9617	2.9430	2.9234	2.9026	2.8806	2.8570	2.8318	2.8050	2.7763	2.7459
675	2.7425	2.7268	2.7101	2.6922	2.6730	2.6525	2.6306	2.6072	2.5823	2.5559
700	2.5445	2.5313	2.5171	2.5016	2.4850	2.4670	2.4478	2.4273	2.4054	2.3823
725	2.3652	2.3542	2.3420	2.3287	2.3141	2.2984	2.2814	2.2633	2.2440	2.2236
750	2.2025	2.1933	2.1829	2.1713	2.1586	2.1447	2.1296	2.1135	2.0964	2.0782
775	2.0546	2.0468	2.0379	2.0278	2.0166	2.0042	1.9908	1.9764	1.9611	1.9448
800	1.9198	1.9132	1.9055	1.8966	1.8866	1.8756	1.8636	1.8506	1.8368	1.8222

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 23 Joule-Thomson coefficient μ [10^{-3} K kPa $^{-1}$] – Continued

<i>t</i> [°C]	<i>p</i> [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	-0.23923	-0.23903	-0.23883	-0.23863	-0.23760	-0.23652	-0.23542	-0.23429	-0.23314	-0.23075
5	-0.23476	-0.23458	-0.23440	-0.23422	-0.23330	-0.23235	-0.23138	-0.23040	-0.22940	-0.22736
10	-0.23075	-0.23059	-0.23044	-0.23028	-0.22949	-0.22867	-0.22783	-0.22698	-0.22612	-0.22437
15	-0.22711	-0.22698	-0.22685	-0.22672	-0.22605	-0.22535	-0.22465	-0.22392	-0.22319	-0.22171
20	-0.22376	-0.22365	-0.22355	-0.22344	-0.22289	-0.22233	-0.22174	-0.22114	-0.22053	-0.21928
25	-0.22063	-0.22055	-0.22047	-0.22039	-0.21997	-0.21952	-0.21905	-0.21856	-0.21806	-0.21702
30	-0.21768	-0.21763	-0.21757	-0.21752	-0.21721	-0.21687	-0.21651	-0.21614	-0.21574	-0.21490
35	-0.21488	-0.21484	-0.21481	-0.21478	-0.21458	-0.21436	-0.21411	-0.21383	-0.21353	-0.21289
40	-0.21217	-0.21216	-0.21215	-0.21214	-0.21206	-0.21194	-0.21179	-0.21162	-0.21141	-0.21095
45	-0.20955	-0.20956	-0.20957	-0.20958	-0.20961	-0.20960	-0.20955	-0.20947	-0.20936	-0.20907
50	-0.20698	-0.20702	-0.20705	-0.20709	-0.20722	-0.20731	-0.20736	-0.20737	-0.20735	-0.20723
60	-0.20196	-0.20204	-0.20212	-0.20220	-0.20254	-0.20283	-0.20307	-0.20326	-0.20342	-0.20363
70	-0.19701	-0.19713	-0.19726	-0.19737	-0.19793	-0.19841	-0.19884	-0.19922	-0.19954	-0.20008
80	-0.19204	-0.19221	-0.19237	-0.19254	-0.19330	-0.19399	-0.19461	-0.19517	-0.19567	-0.19652
90	-0.18698	-0.18720	-0.18741	-0.18762	-0.18862	-0.18951	-0.19033	-0.19108	-0.19175	-0.19293
100	-0.18178	-0.18205	-0.18232	-0.18258	-0.18381	-0.18493	-0.18596	-0.18690	-0.18776	-0.18928
125	-0.16780	-0.16822	-0.16864	-0.16905	-0.17098	-0.17274	-0.17436	-0.17585	-0.17722	-0.17967
150	-0.15165	-0.15228	-0.15289	-0.15350	-0.15636	-0.15896	-0.16134	-0.16352	-0.16552	-0.16908
175	-0.13218	-0.13311	-0.13401	-0.13490	-0.13906	-0.14281	-0.14621	-0.14930	-0.15212	-0.15710
200	-0.10788	-0.10925	-0.11059	-0.11189	-0.11795	-0.12333	-0.12815	-0.13249	-0.13642	-0.14327
225	-0.076534	-0.078606	-0.080615	-0.082564	-0.091496	-0.099286	-0.106150	-0.112249	-0.117705	-0.127053
250	-0.034736	-0.037959	-0.041063	-0.044054	-0.057531	-0.068982	-0.078858	-0.087477	-0.095071	-0.107842
275	0.023382	0.018113	0.013094	0.0083049	-0.012727	-0.029966	-0.044413	-0.056729	-0.067371	-0.084871
300	0.10945	0.10007	0.091295	0.083063	0.048399	0.021529	-1.100×10^{-4}	-0.017991	-0.033060	-0.057160
325	0.25142	0.23210	0.21465	0.19875	0.13605	0.091744	0.058201	0.031635	0.009974	-0.023462
350	0.53699	0.48364	0.43928	0.40182	0.27275	0.19238	0.13738	0.09652	0.06463	0.01765
375	1.6556	1.2274	1.0049	0.85912	0.50337	0.34425	0.24858	0.18313	0.13491	0.06780
400	5.0874	4.5424	3.7046	2.6524	0.95753	0.58675	0.40897	0.30063	0.22629	0.12908
425	5.0471	4.7633	4.4434	4.0793	1.8846	0.98509	0.64267	0.46067	0.34559	0.20509
450	4.8036	4.6095	4.4005	4.1760	2.7888	1.5622	0.96851	0.67182	0.49699	0.29758
475	4.5087	4.3648	4.2117	4.0497	3.1196	2.0929	1.3543	0.92954	0.67922	0.40554
500	4.2066	4.0957	3.9785	3.8552	3.1628	2.3922	1.6942	1.1998	0.88026	0.52525
525	3.9138	3.8264	3.7341	3.6374	3.0992	2.5057	1.9170	1.4318	1.0758	0.65015
550	3.6364	3.5664	3.4925	3.4151	2.9849	2.5121	2.0337	1.5945	1.2406	0.77143
575	3.3773	3.3203	3.2602	3.1972	2.8466	2.4602	2.0662	1.6895	1.3591	0.88008
600	3.1374	3.0902	3.0404	2.9883	2.6982	2.3768	2.0468	1.7261	1.4304	0.97003
625	2.9164	2.8767	2.8349	2.7912	2.5477	2.2769	1.9970	1.7228	1.4649	1.0306
650	2.7137	2.6798	2.6442	2.6069	2.4002	2.1695	1.9297	1.6932	1.4692	1.0798
675	2.5280	2.4987	2.4680	2.4359	2.2584	2.0604	1.8535	1.6477	1.4511	1.1067
700	2.3579	2.3323	2.3055	2.2777	2.1239	1.9528	1.7733	1.5935	1.4195	1.1079
725	2.2021	2.1795	2.1560	2.1315	1.9971	1.8481	1.6918	1.5341	1.3798	1.0942
750	2.0591	2.0391	2.0182	1.9965	1.8779	1.7472	1.6100	1.4712	1.3341	1.0730
775	1.9277	1.9098	1.8911	1.8717	1.7661	1.6500	1.5284	1.4053	1.2832	1.0478
800	1.8067	1.7906	1.7737	1.7563	1.6610	1.5564	1.4471	1.3366	1.2276	1.0207

Table 24 Isothermal throttling coefficient δ_T

For the single-phase region, this table contains values for the

- Isothermal throttling coefficient $\delta_T = (\partial h / \partial p)_T$

for temperatures from 0°C to 800°C and pressures from 0.006112127 bar, corresponding to $p_s(0^\circ\text{C})$, to 1000 bar (regions 1 to 3 of IAPWS-IF97).

In regions 1 and 2 and the given (p, t) values, the values for the isothermal throttling coefficient δ_T were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3) and (2.6).

In region 3, the basic equation of this region, Eq. (2.11), was used for these calculations. With the given (p, t) values, the density ρ , needed as one of the input quantities for Eq. (2.11), was calculated by iterating this equation. With these values for (ρ, t) , the values of δ_T were determined from Eq. (2.11).

The horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Values for the isothermal throttling coefficient for temperatures above 800°C up to 2000°C and pressures up to 500 bar can be calculated online with the "Steam Properties Calculator" [28].

Table 24 Isothermal throttling coefficient δ_T [10^{-3} kJ kg $^{-1}$ kPa $^{-1}$]^a

t [°C]	p [bar]									
	0.006112127	0.01	0.1	1	2	4	6	8	10	20
0	1.0188	1.0188	1.0188	1.0186	1.0185	1.0182	1.0179	1.0176	1.0172	1.0157
5	-801.16	0.99563	0.99562	0.99550	0.99537	0.99510	0.99483	0.99456	0.99430	0.99296
10	-627.20	-730.24	0.97544	0.97534	0.97522	0.97499	0.97476	0.97452	0.97429	0.97314
15	-525.74	-571.51	0.95748	0.95739	0.95729	0.95709	0.95689	0.95669	0.95648	0.95548
20	-458.40	-479.00	0.94120	0.94112	0.94103	0.94086	0.94068	0.94051	0.94033	0.93946
25	-408.45	-417.87	0.92621	0.92614	0.92606	0.92591	0.92576	0.92560	0.92545	0.92469
30	-368.34	-372.74	0.91221	0.91215	0.91208	0.91195	0.91182	0.91169	0.91155	0.91089
35	-334.53	-336.65	0.89899	0.89894	0.89888	0.89877	0.89866	0.89854	0.89843	0.89786
40	-305.21	-306.29	0.88639	0.88635	0.88630	0.88620	0.88610	0.88601	0.88591	0.88542
45	-279.40	-279.99	0.87427	0.87423	0.87419	0.87411	0.87403	0.87395	0.87387	0.87346
50	-256.47	-256.82	-284.20	0.86250	0.86246	0.86240	0.86233	0.86226	0.86220	0.86186
60	-217.61	-217.78	-225.95	0.83982	0.83980	0.83976	0.83972	0.83968	0.83964	0.83943
70	-186.21	-186.31	-189.74	0.81775	0.81774	0.81772	0.81771	0.81769	0.81768	0.81760
80	-160.61	-160.68	-162.69	0.79584	0.79584	0.79585	0.79586	0.79587	0.79588	0.79593
90	-139.59	-139.65	-141.06	0.77372	0.77374	0.77377	0.77381	0.77384	0.77388	0.77405
100	-122.21	-122.26	-123.33	-137.58	0.75107	0.75113	0.75120	0.75126	0.75132	0.75163
125	-90.323	-90.348	-90.937	-96.968	-105.78	0.68980	0.68995	0.69009	0.69024	0.69095
150	-69.392	-69.406	-69.741	-73.116	-76.976	-87.090	0.61704	0.61730	0.61756	0.61886
175	-55.117	-55.126	-55.321	-57.282	-59.487	-64.058	-69.324	-76.815	0.5251	0.5274
200	-45.022	-45.027	-45.143	-46.306	-47.612	-50.276	-53.027	-55.937	-59.164	0.40373
225	-37.635	-37.638	-37.708	-38.411	-39.201	-40.810	-42.459	-44.154	-45.904	-56.798
250	-32.057	-32.059	-32.102	-32.535	-33.021	-34.013	-35.029	-36.071	-37.140	-43.020
275	-27.724	-27.725	-27.752	-28.024	-28.329	-28.952	-29.591	-30.246	-30.917	-34.538
300	-24.272	-24.273	-24.290	-24.464	-24.660	-25.060	-25.469	-25.889	-26.319	-28.628
325	-21.462	-21.463	-21.474	-21.588	-21.717	-21.978	-22.246	-22.521	-22.803	-24.309
350	-19.132	-19.133	-19.140	-19.217	-19.303	-19.478	-19.657	-19.841	-20.029	-21.033
375	-17.170	-17.170	-17.175	-17.228	-17.287	-17.407	-17.529	-17.655	-17.783	-18.467
400	-15.495	-15.495	-15.499	-15.536	-15.577	-15.661	-15.747	-15.835	-15.924	-16.400
425	-14.050	-14.050	-14.052	-14.079	-14.109	-14.169	-14.231	-14.293	-14.357	-14.695
450	-12.791	-12.792	-12.793	-12.813	-12.835	-12.879	-12.924	-12.970	-13.017	-13.263
475	-11.688	-11.688	-11.689	-11.704	-11.720	-11.753	-11.787	-11.822	-11.856	-12.039
500	-10.713	-10.713	-10.714	-10.725	-10.738	-10.764	-10.789	-10.816	-10.842	-10.980
525	-9.8480	-9.8481	-9.8489	-9.8578	-9.8676	-9.8875	-9.9077	-9.9281	-9.9487	-10.055
550	-9.0767	-9.0768	-9.0775	-9.0845	-9.0924	-9.1082	-9.1242	-9.1404	-9.1567	-9.2406
575	-8.3864	-8.3864	-8.3870	-8.3927	-8.3991	-8.4119	-8.4248	-8.4379	-8.4510	-8.5182
600	-7.7664	-7.7664	-7.7669	-7.7716	-7.7768	-7.7874	-7.7980	-7.8087	-7.8195	-7.8742
625	-7.2079	-7.2079	-7.2083	-7.2123	-7.2167	-7.2255	-7.2344	-7.2433	-7.2523	-7.2975
650	-6.7036	-6.7037	-6.7040	-6.7074	-6.7111	-6.7186	-6.7261	-6.7337	-6.7412	-6.7792
675	-6.2472	-6.2473	-6.2475	-6.2504	-6.2537	-6.2601	-6.2666	-6.2730	-6.2795	-6.3118
700	-5.8333	-5.8333	-5.8336	-5.8361	-5.8389	-5.8446	-5.8502	-5.8558	-5.8613	-5.8891
725	-5.4573	-5.4573	-5.4575	-5.4597	-5.4622	-5.4671	-5.4720	-5.4769	-5.4818	-5.5059
750	-5.1151	-5.1151	-5.1153	-5.1172	-5.1194	-5.1238	-5.1281	-5.1324	-5.1367	-5.1577
775	-4.8032	-4.8032	-4.8033	-4.8051	-4.8070	-4.8108	-4.8147	-4.8184	-4.8222	-4.8406
800	-4.5185	-4.5185	-4.5187	-4.5202	-4.5219	-4.5253	-4.5286	-4.5319	-4.5352	-4.5513

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 24 Isothermal throttling coefficient δ_T [10^{-3} kJ kg $^{-1}$ kPa $^{-1}$]^a – Continued

t [°C]	p [bar]									
	40	60	80	100	120	140	160	180	200	220
0	1.0126	1.0096	1.0066	1.0037	1.0007	0.99784	0.99499	0.99217	0.98939	0.98664
5	0.99032	0.98771	0.98513	0.98257	0.98005	0.97755	0.97508	0.97264	0.97023	0.96784
10	0.97085	0.96858	0.96634	0.96412	0.96193	0.95975	0.95761	0.95548	0.95337	0.95129
15	0.95349	0.95152	0.94956	0.94763	0.94571	0.94381	0.94194	0.94008	0.93823	0.93641
20	0.93772	0.93600	0.93430	0.93261	0.93093	0.92927	0.92763	0.92599	0.92438	0.92278
25	0.92318	0.92168	0.92019	0.91872	0.91725	0.91580	0.91436	0.91293	0.91151	0.91010
30	0.90958	0.90828	0.90698	0.90570	0.90442	0.90315	0.90189	0.90064	0.89940	0.89817
35	0.89673	0.89560	0.89448	0.89337	0.89226	0.89116	0.89006	0.88897	0.88789	0.88681
40	0.88445	0.88349	0.88253	0.88157	0.88062	0.87967	0.87872	0.87778	0.87684	0.87591
45	0.87264	0.87182	0.87101	0.87020	0.86939	0.86858	0.86777	0.86697	0.86617	0.86537
50	0.86118	0.86051	0.85983	0.85916	0.85848	0.85780	0.85713	0.85645	0.85578	0.85510
60	0.83902	0.83861	0.83819	0.83777	0.83734	0.83691	0.83648	0.83604	0.83560	0.83516
70	0.81744	0.81727	0.81710	0.81691	0.81672	0.81652	0.81632	0.81611	0.81589	0.81566
80	0.79602	0.79609	0.79615	0.79620	0.79624	0.79627	0.79629	0.79630	0.79629	0.79628
90	0.77439	0.77471	0.77501	0.77530	0.77558	0.77584	0.77608	0.77631	0.77653	0.77674
100	0.75223	0.75281	0.75337	0.75391	0.75443	0.75493	0.75542	0.75588	0.75633	0.75676
125	0.69234	0.69370	0.69502	0.69630	0.69754	0.69875	0.69993	0.70107	0.70218	0.70326
150	0.62139	0.62385	0.62624	0.62856	0.63082	0.63301	0.63514	0.63722	0.63924	0.64120
175	0.53169	0.53589	0.53996	0.54390	0.54771	0.55142	0.55501	0.55849	0.56188	0.56516
200	0.41118	0.41835	0.42526	0.43191	0.43833	0.44453	0.45051	0.45629	0.46188	0.46728
225	0.23843	0.25113	0.26326	0.27486	0.28596	0.29659	0.30679	0.31658	0.32597	0.33501
250	<u>-0.030301</u>	-0.005941	0.016986	0.038607	0.059034	0.078366	0.096691	0.11409	0.13063	0.14637
275	-44.181	<u>-0.45107</u>	<u>-0.40086</u>	-0.35482	-0.31242	-0.27320	-0.23681	-0.20292	-0.17128	-0.14166
300	-34.246	-42.625	-58.562	<u>-1.1419</u>	<u>-1.0292</u>	-0.93015	-0.84230	-0.76378	-0.69306	-0.62894
325	-27.859	-32.443	-39.078	-50.201	-76.880	<u>-2.5924</u>	<u>-2.2731</u>	-2.0129	-1.7968	-1.6147
350	-23.364	-26.192	-29.763	-34.621	-41.877	-54.645	-89.165	<u>-7.2907</u>	<u>-5.5787</u>	<u>-4.5464</u>
375	-20.038	-21.889	-24.074	-26.732	-30.116	-34.660	-41.284	-52.343	-75.993	-275.51
400	-17.483	-18.736	-20.167	-21.807	-23.724	-26.022	-28.854	-32.452	-37.281	-44.256
425	-15.458	-16.329	-17.304	-18.386	-19.590	-20.943	-22.486	-24.267	-26.340	-28.777
450	-13.810	-14.429	-15.111	-15.855	-16.659	-17.528	-18.472	-19.503	-20.633	-21.873
475	-12.441	-12.888	-13.377	-13.903	-14.461	-15.051	-15.671	-16.324	-17.011	-17.734
500	-11.281	-11.612	-11.969	-12.349	-12.747	-13.162	-13.590	-14.029	-14.478	-14.937
525	-10.285	-10.534	-10.800	-11.080	-11.370	-11.670	-11.974	-12.283	-12.592	-12.901
550	-9.4190	-9.6100	-9.8115	-10.021	-10.237	-10.458	-10.680	-10.902	-11.123	-11.340
575	-8.6593	-8.8083	-8.9635	-9.1236	-9.2868	-9.4517	-9.6166	-9.7802	-9.9408	-10.097
600	-7.9877	-8.1057	-8.2273	-8.3511	-8.4761	-8.6013	-8.7254	-8.8473	-8.9661	-9.0807
625	-7.3902	-7.4852	-7.5817	-7.6788	-7.7758	-7.8718	-7.9662	-8.0581	-8.1468	-8.2315
650	-6.8560	-6.9335	-7.0110	-7.0881	-7.1642	-7.2387	-7.3110	-7.3807	-7.4473	-7.5102
675	-6.3763	-6.4402	-6.5033	-6.5651	-6.6253	-6.6835	-6.7394	-6.7926	-6.8427	-6.8894
700	-5.9439	-5.9973	-6.0491	-6.0991	-6.1471	-6.1929	-6.2362	-6.2768	-6.3145	-6.3491
725	-5.5528	-5.5978	-5.6408	-5.6816	-5.7201	-5.7562	-5.7898	-5.8208	-5.8490	-5.8744
750	-5.1982	-5.2363	-5.2722	-5.3056	-5.3367	-5.3653	-5.3913	-5.4149	-5.4358	-5.4541
775	-4.8756	-4.9081	-4.9382	-4.9657	-4.9908	-5.0134	-5.0335	-5.0512	-5.0665	-5.0793
800	-4.5816	-4.6093	-4.6344	-4.6571	-4.6774	-4.6952	-4.7106	-4.7237	-4.7345	-4.7429

^aThe horizontal lines in the columns indicate the transition from the liquid phase to the vapour phase.

Table 24 Isothermal throttling coefficient δ_T [10^{-3} kJ kg $^{-1}$ kPa $^{-1}$] – Continued

t [°C]	p [bar]									
	240	260	280	300	400	500	600	700	800	1000
0	0.98392	0.98123	0.97858	0.97596	0.96331	0.95141	0.94019	0.92962	0.91964	0.90124
5	0.96548	0.96315	0.96084	0.95857	0.94755	0.93715	0.92731	0.91801	0.90921	0.89293
10	0.94923	0.94720	0.94518	0.94318	0.93352	0.92436	0.91567	0.90743	0.89960	0.88506
15	0.93460	0.93281	0.93104	0.92929	0.92077	0.91267	0.90495	0.89760	0.89060	0.87754
20	0.92119	0.91961	0.91805	0.91651	0.90899	0.90180	0.89492	0.88835	0.88206	0.87028
25	0.90870	0.90732	0.90594	0.90458	0.89793	0.89155	0.88542	0.87953	0.87388	0.86324
30	0.89694	0.89572	0.89451	0.89332	0.88744	0.88178	0.87632	0.87105	0.86597	0.85637
35	0.88574	0.88467	0.88362	0.88256	0.87740	0.87239	0.86753	0.86283	0.85828	0.84962
40	0.87498	0.87405	0.87313	0.87222	0.86770	0.86329	0.85900	0.85482	0.85076	0.84298
45	0.86457	0.86377	0.86298	0.86219	0.85827	0.85443	0.85066	0.84698	0.84337	0.83642
50	0.85443	0.85375	0.85308	0.85241	0.84906	0.84575	0.84248	0.83925	0.83608	0.82991
60	0.83471	0.83427	0.83382	0.83337	0.83108	0.82875	0.82640	0.82405	0.82169	0.81701
70	0.81544	0.81520	0.81496	0.81472	0.81342	0.81202	0.81055	0.80900	0.80741	0.80414
80	0.79627	0.79624	0.79620	0.79616	0.79583	0.79534	0.79470	0.79395	0.79310	0.79118
90	0.77693	0.77711	0.77728	0.77744	0.77808	0.77849	0.77870	0.77873	0.77862	0.77805
100	0.75718	0.75757	0.75796	0.75833	0.75997	0.76131	0.76238	0.76321	0.76385	0.76463
125	0.70431	0.70534	0.70634	0.70731	0.71179	0.71572	0.71916	0.72219	0.72485	0.72925
150	0.64312	0.64498	0.64680	0.64857	0.65678	0.66405	0.67049	0.67623	0.68136	0.69008
175	0.56836	0.57146	0.57448	0.57742	0.59099	0.60293	0.61349	0.62288	0.63125	0.64551
200	0.47252	0.47758	0.48249	0.48725	0.50903	0.52792	0.54445	0.55901	0.57191	0.59366
225	0.34370	0.35207	0.36013	0.36791	0.40296	0.43271	0.45828	0.48047	0.49989	0.53214
250	0.16138	0.17570	0.18938	0.20247	0.26023	0.30775	0.34755	0.38138	0.41046	0.45778
275	-0.11386	-0.087716	-0.063075	-0.039805	0.059641	0.13780	0.20096	0.25311	0.29689	0.36624
300	-0.57048	-0.51690	-0.46761	-0.42207	-0.23774	-0.10295	5.1473×10^{-4}	0.08260	0.14937	0.25152
325	-1.4591	-1.3243	-1.2059	-1.1009	-0.71253	-0.46142	-0.28369	-0.15034	-0.04641	0.10555
350	-3.8354	-3.3064	-2.8963	-2.5690	-1.5663	-1.0331	-0.70397	-0.47733	-0.31074	-0.081283
375	-28.595	-14.444	-9.8622	-7.5198	-3.3589	-2.0358	-1.3654	-0.95535	-0.67693	-0.32169
400	-54.962	-73.758	-101.17	-68.425	-8.3316	-3.9770	-2.4528	-1.6699	-1.1908	-0.63143
425	-31.695	-35.267	-39.599	-44.438	-24.159	-8.0687	-4.3136	-2.7635	-1.9245	-1.0382
450	-23.227	-24.695	-26.271	-27.941	-30.537	-14.946	-7.3024	-4.3732	-2.9413	-1.5647
475	-18.493	-19.282	-20.091	-20.904	-23.830	-18.672	-10.784	-6.4290	-4.2292	-2.2079
500	-15.402	-15.872	-16.343	-16.807	-18.580	-17.485	-12.744	-8.3619	-5.6116	-2.9286
525	-13.206	-13.507	-13.801	-14.085	-15.182	-15.000	-12.720	-9.4659	-6.7586	-3.6506
550	-11.551	-11.755	-11.949	-12.134	-12.817	-12.819	-11.701	-9.6259	-7.4210	-4.2807
575	-10.248	-10.391	-10.526	-10.652	-11.089	-11.089	-10.475	-9.1842	-7.5542	-4.7447
600	-9.1900	-9.2930	-9.3889	-9.4767	-9.7657	-9.7387	-9.3249	-8.4981	-7.3483	-5.0156
625	-8.3115	-8.3862	-8.4549	-8.5170	-8.7089	-8.6636	-8.3483	-7.7615	-6.9440	-5.0649
650	-7.5690	-7.6232	-7.6723	-7.7160	-7.8402	-7.7827	-7.5274	-7.0817	-6.4762	-4.9969
675	-6.9325	-6.9716	-7.0064	-7.0367	-7.1121	-7.0458	-6.8302	-6.4743	-6.0038	-4.8698
700	-6.3804	-6.4082	-6.4324	-6.4528	-6.4928	-6.4208	-6.2334	-5.9384	-5.5553	-4.6432
725	-5.8968	-5.9162	-5.9324	-5.9454	-5.9594	-5.8842	-5.7188	-5.4687	-5.1469	-4.3702
750	-5.4697	-5.4826	-5.4927	-5.5001	-5.4947	-5.4176	-5.2696	-5.0548	-4.7806	-4.1028
775	-5.0896	-5.0975	-5.1030	-5.1061	-5.0856	-5.0067	-4.8719	-4.6847	-4.4497	-3.8616
800	-4.7492	-4.7532	-4.7550	-4.7546	-4.7218	-4.6402	-4.5140	-4.3476	-4.1452	-3.6501



Part C

Diagrams of the Properties of Water and Steam

In Part A (equations for the thermodynamic and transport properties), the units K for temperature and MPa for pressure are used. However, for applications in industry, the units °C and bar are usually used. Thus, in the following diagrams the units °C and bar are used.

Overview Diagrams

The first three diagrams of Part C are overview diagrams, namely:

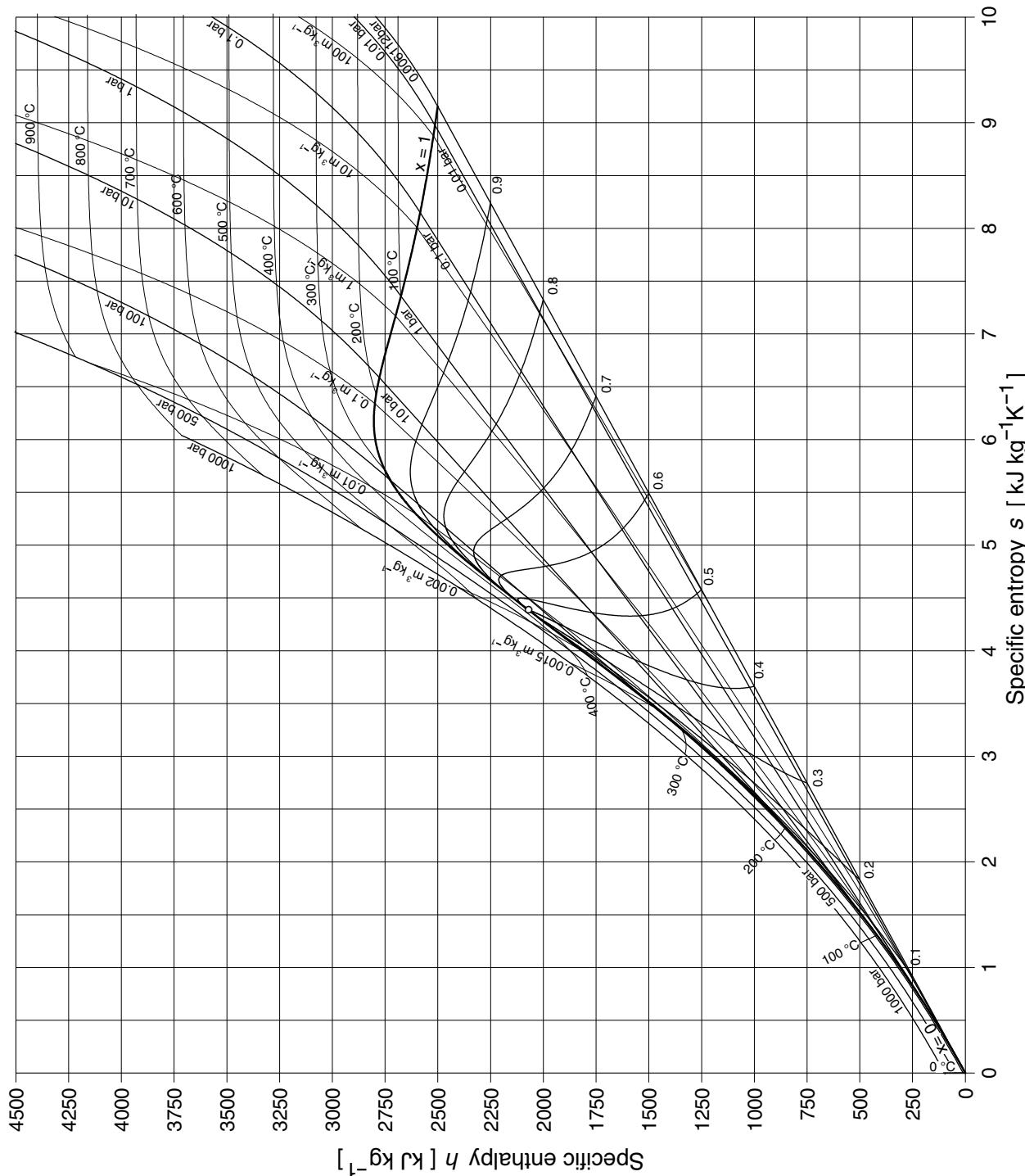
Diagram 1: Mollier h - s diagram

Diagram 2: T - s diagram

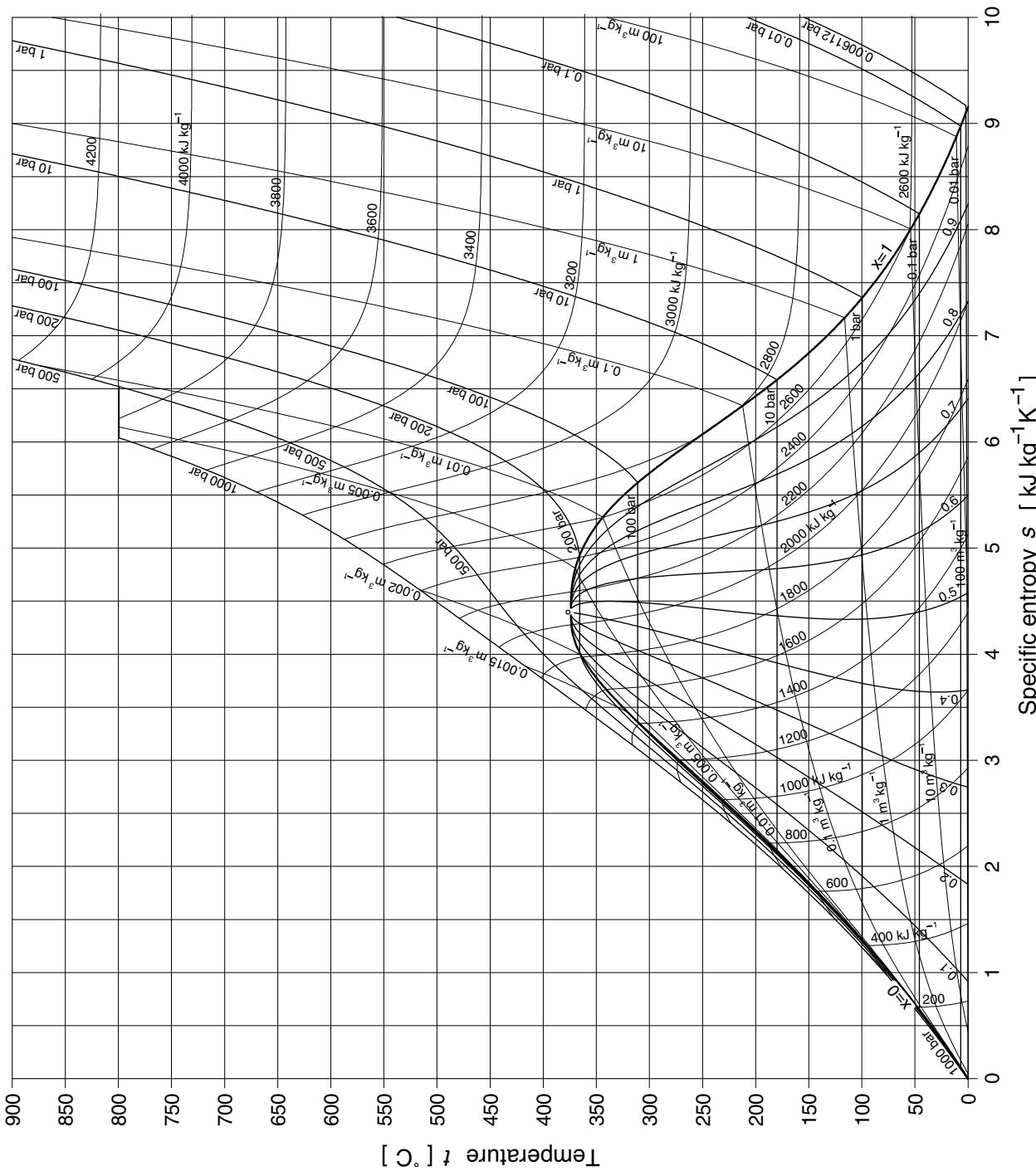
Diagram 3: $\log(p)$ - h diagram

The diagrams were calculated from the IAPWS-IF97 basic equations, Eqs.(2.3), (2.6), (2.11), and (2.15) and plotted using the software FluidDIA [47].

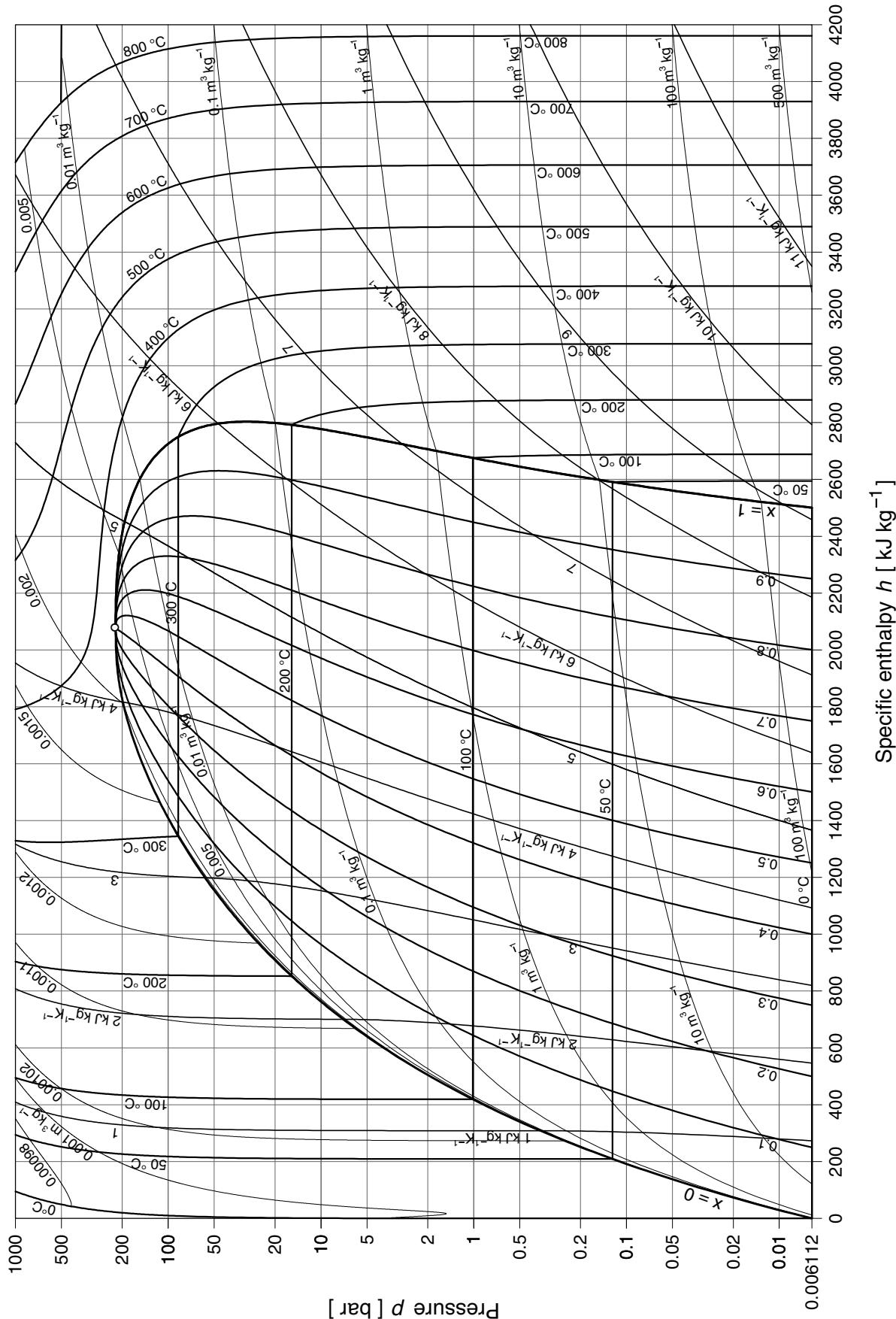
Coloured wall charts of these three diagrams with millimeter raster in the size A2 (42.0 x 59.4 cm) can be obtained via <http://www.international-steam-tables.com>.



Diagr. 1 Mollier enthalpy-entropy diagram with lines of constant pressure, temperature, and specific volume.



Diagr. 2 Temperature-entropy diagram with lines of constant pressure, specific enthalpy, and specific volume.



Diagr. 3 Logarithm pressure-enthalpy diagram with lines of constant specific entropy, temperature, and specific volume.

Pressure-Temperature Diagrams with Lines of Constant Properties

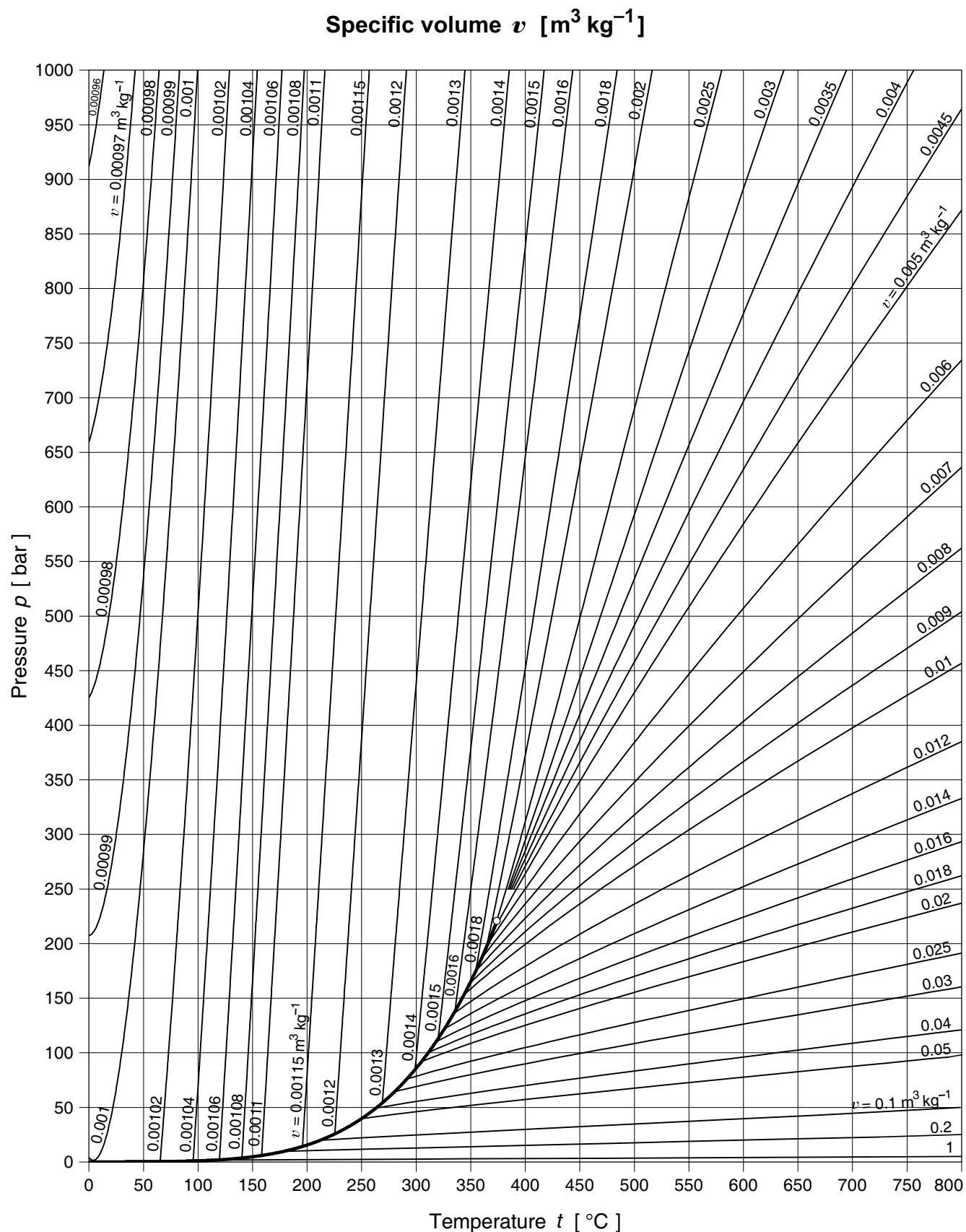
Additional diagrams contained in Part C are pressure-temperature diagrams with isolines of the following properties:

- Diagram 4: Specific volume v
- Diagram 5: Density ρ
- Diagram 6: Compression factor z
- Diagram 7: Specific enthalpy h
- Diagram 8: Specific internal energy u
- Diagram 9: Specific entropy s
- Diagram 10: Specific Gibbs free energy g
- Diagram 11: Specific Helmholtz free energy f
- Diagram 12: Specific isobaric heat capacity c_p
- Diagram 13: Specific isochoric heat capacity c_v
- Diagram 14: Speed of sound w
- Diagram 15: Isentropic exponent κ
- Diagram 16: Isobaric cubic expansion coefficient α_v
- Diagram 17: Isothermal compressibility κ_T
- Diagram 18: Relative pressure coefficient α_p
- Diagram 19: Isothermal stress coefficient β_p
- Diagram 20: Joule-Thomson coefficient μ
- Diagram 21: Isothermal throttling coefficient δ_T
- Diagram 22: Fugacity f^*
- Diagram 23: Dynamic viscosity η
- Diagram 24: Kinematic viscosity ν
- Diagram 25: Thermal conductivity λ
- Diagram 26: Prandtl number Pr
- Diagram 27: Thermal diffusivity a
- Diagram 28: Dielectric constant ε
- Diagram 29: Refractive index n

The thermodynamic properties in the diagrams were calculated from the IAPWS-IF97 basic equations, Eqs. (2.3), (2.6), and (2.11), with the exception of c_p , c_v , w , κ_T , δ_T , and μ . Since the small inconsistencies for these properties at the region boundaries are visible in such diagrams, they were calculated from the scientific formulation IAPWS-95 [8, 9].

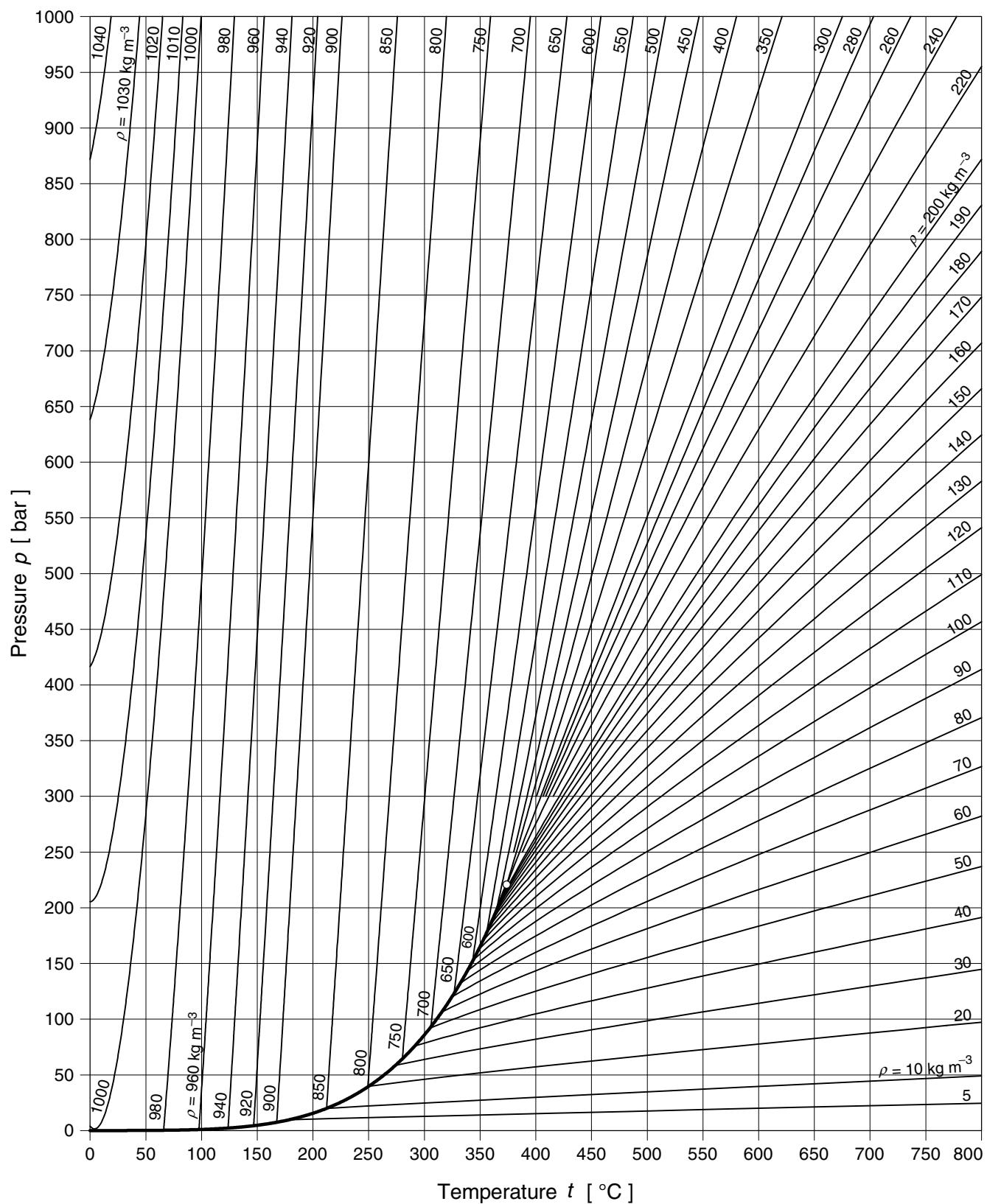
The dynamic viscosity η and the thermal conductivity λ were calculated from the equations for industrial use, Eq. (3.1) and Eq. (3.4). The properties ε and n were calculated from Eqs. (3.9) and (3.10). The densities needed in these equations were determined from the IAPWS-IF97 basic equations, see above.

All of the diagrams were plotted using the software FluidDIA [47].

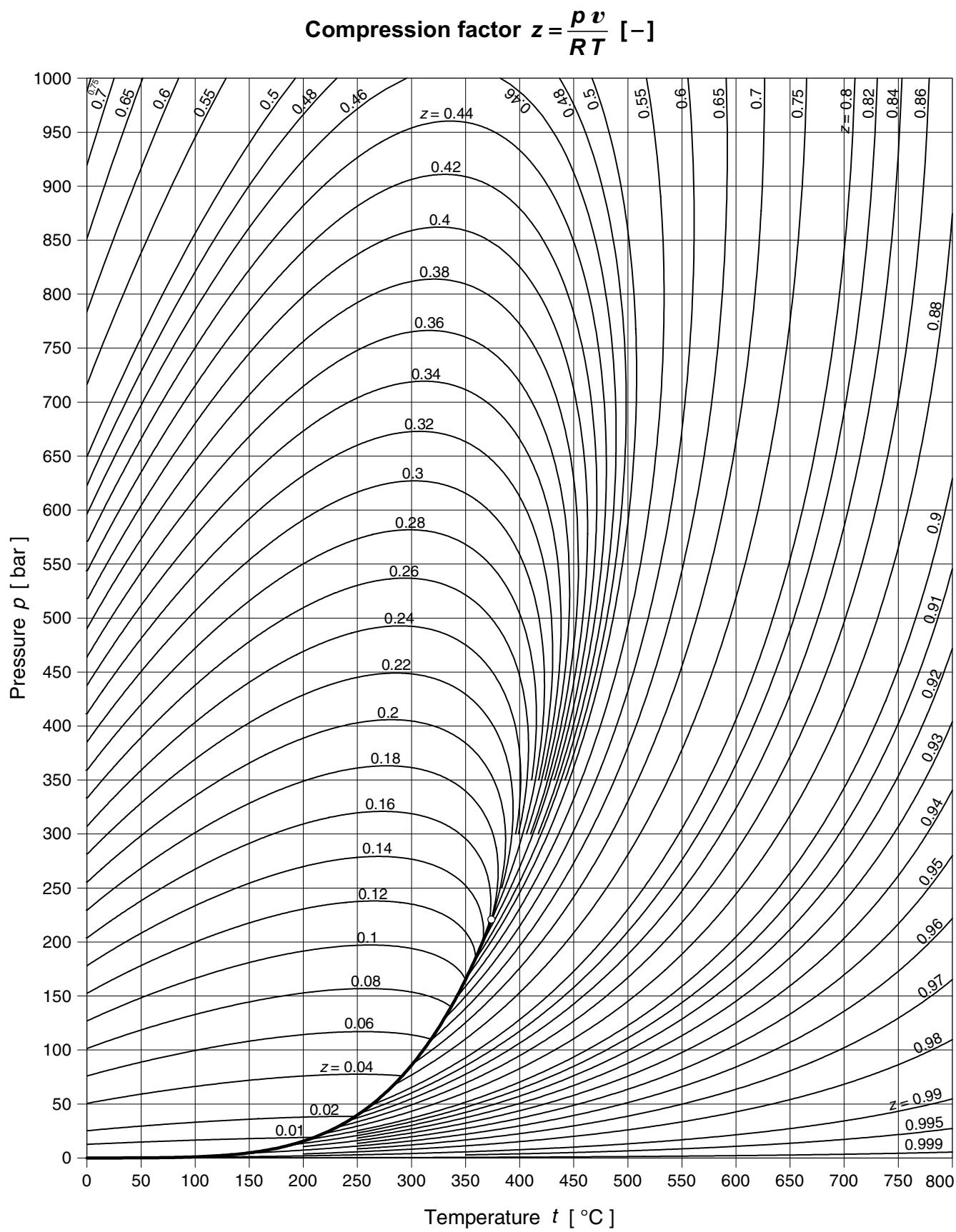


Diagr. 4 Pressure-temperature diagram with lines of constant specific volume.

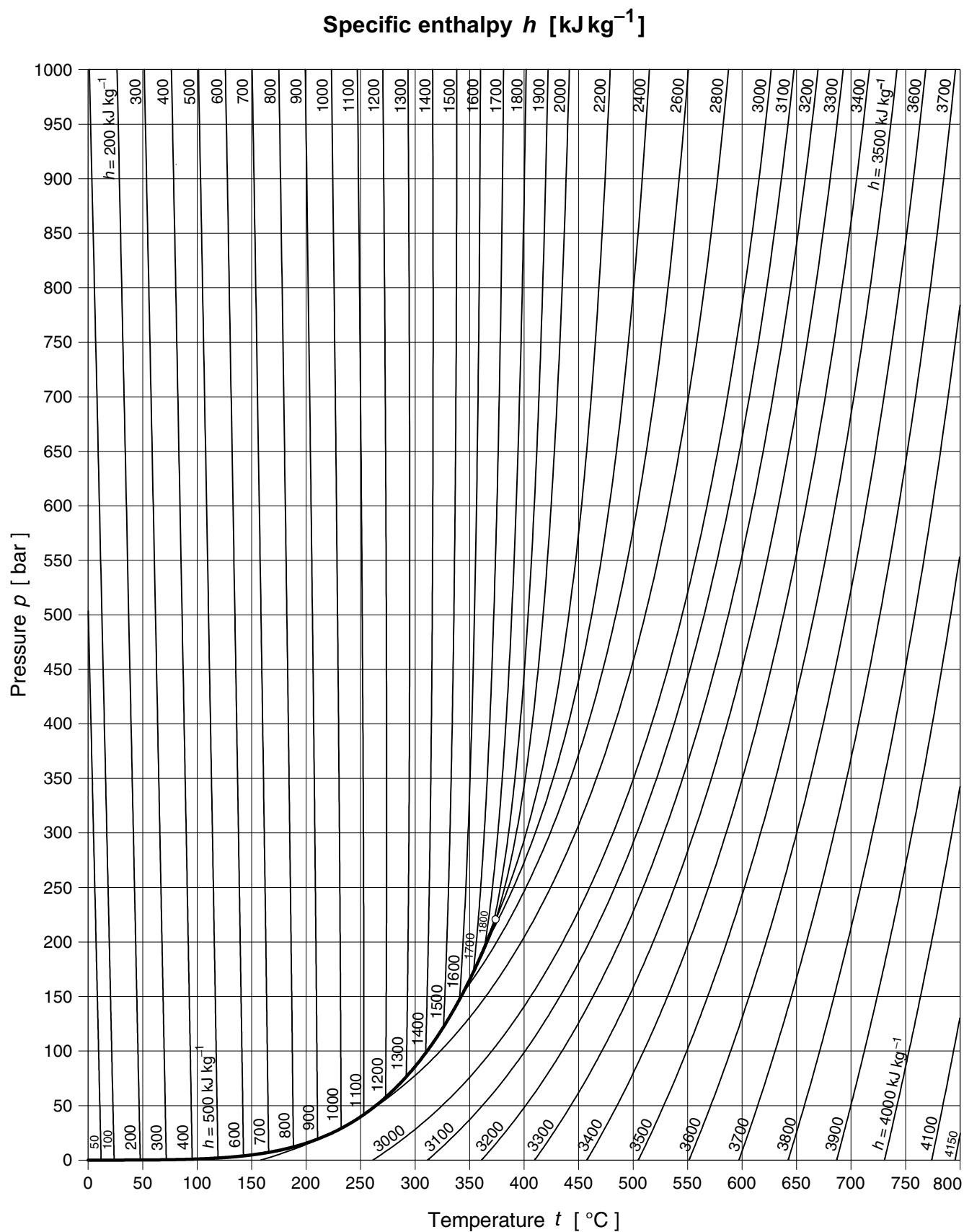
$$\text{Density } \rho = \frac{1}{v} \text{ [kg m}^{-3}\text{]}$$



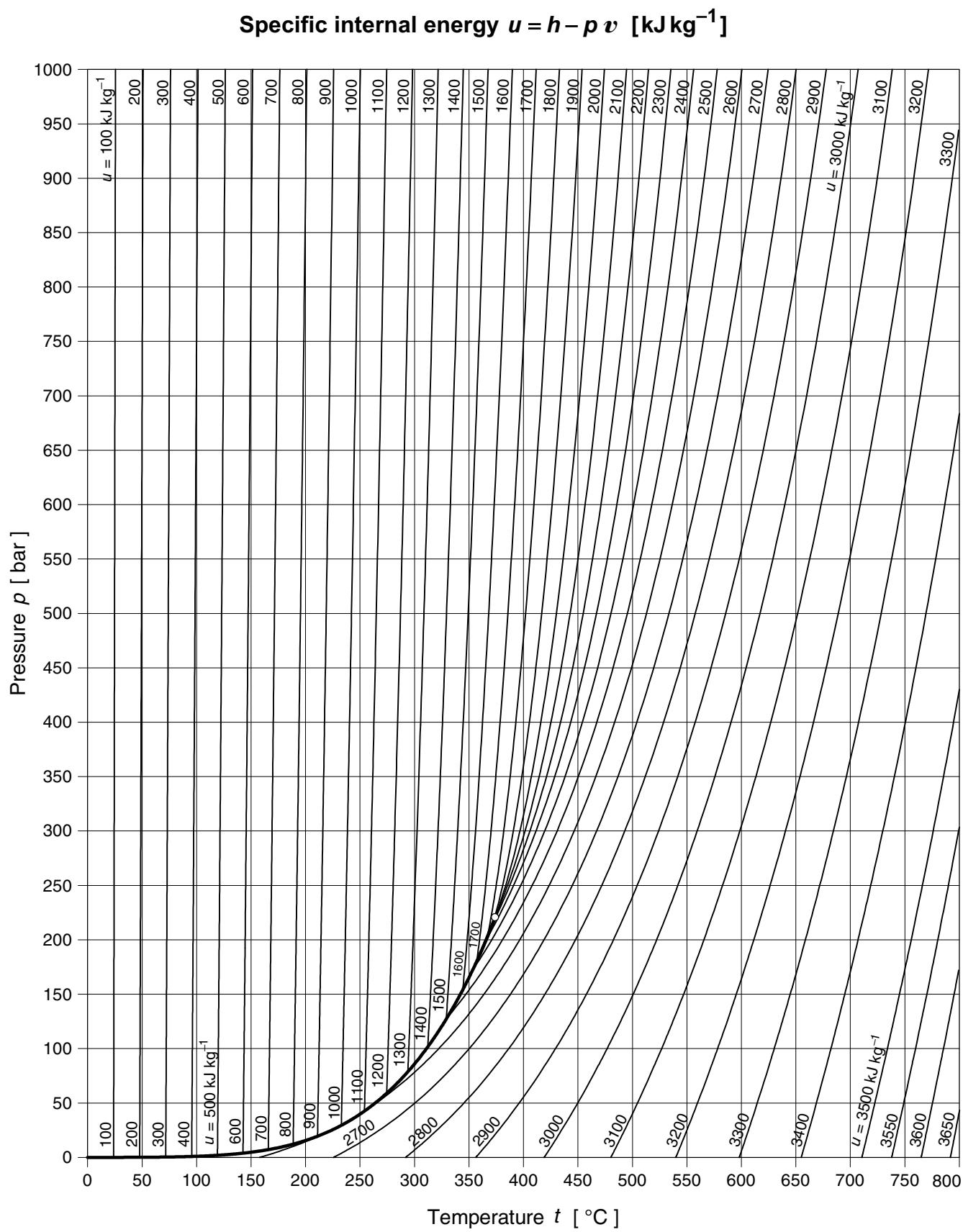
Diagr. 5 Pressure-temperature diagram with lines of constant density.



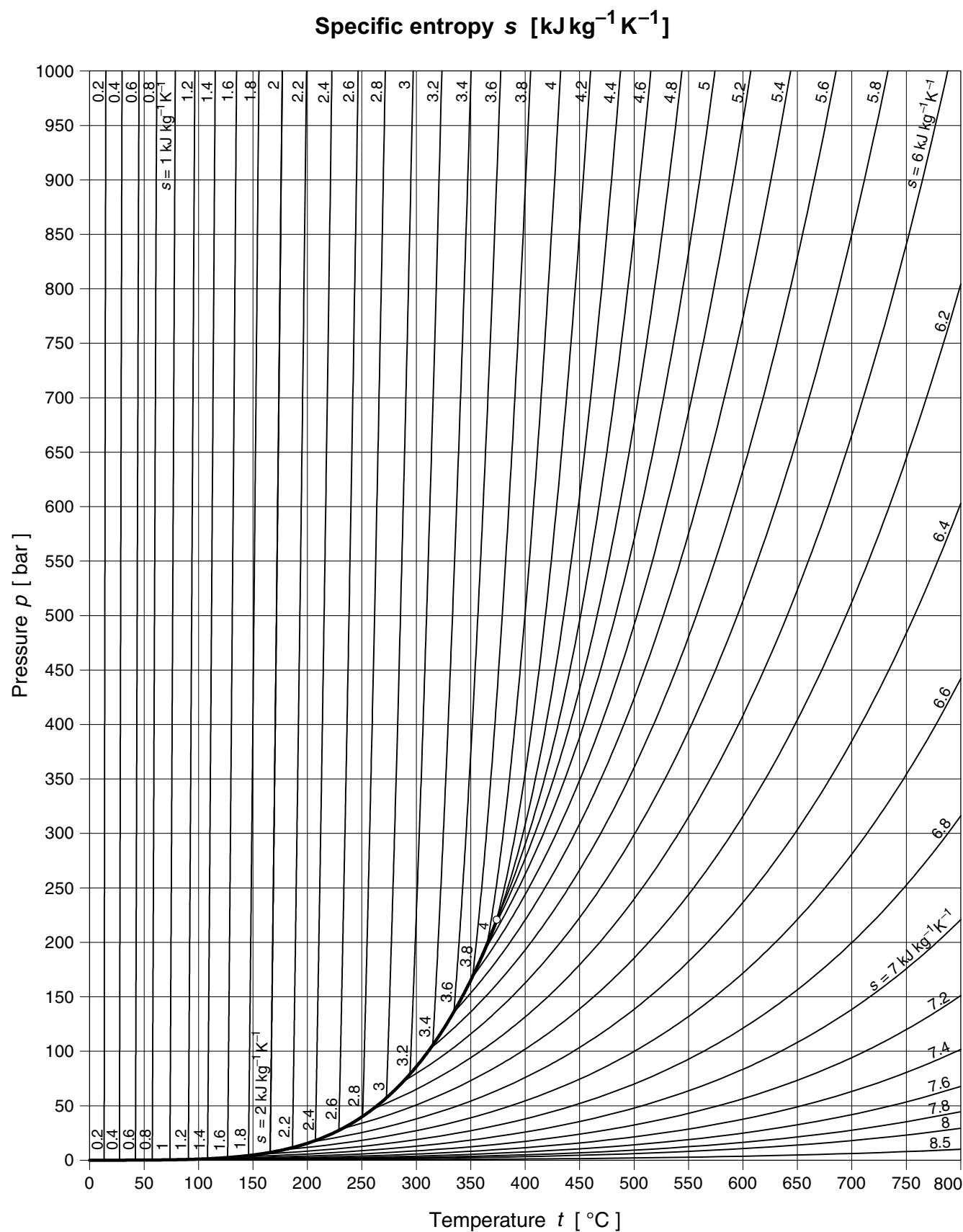
Diagr. 6 Pressure-temperature diagram with lines of constant compression factor.



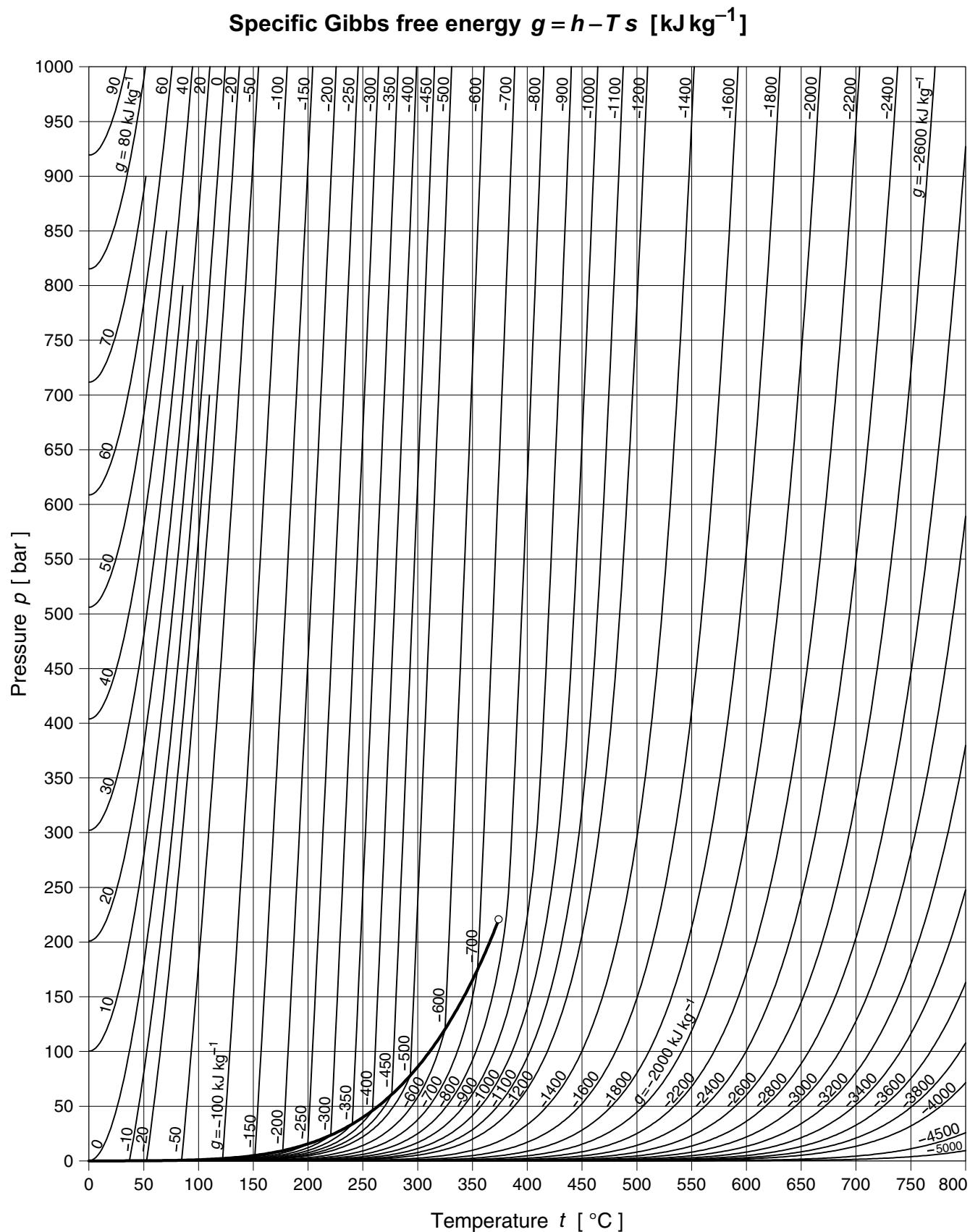
Diagr. 7 Pressure-temperature diagram with lines of constant specific enthalpy.



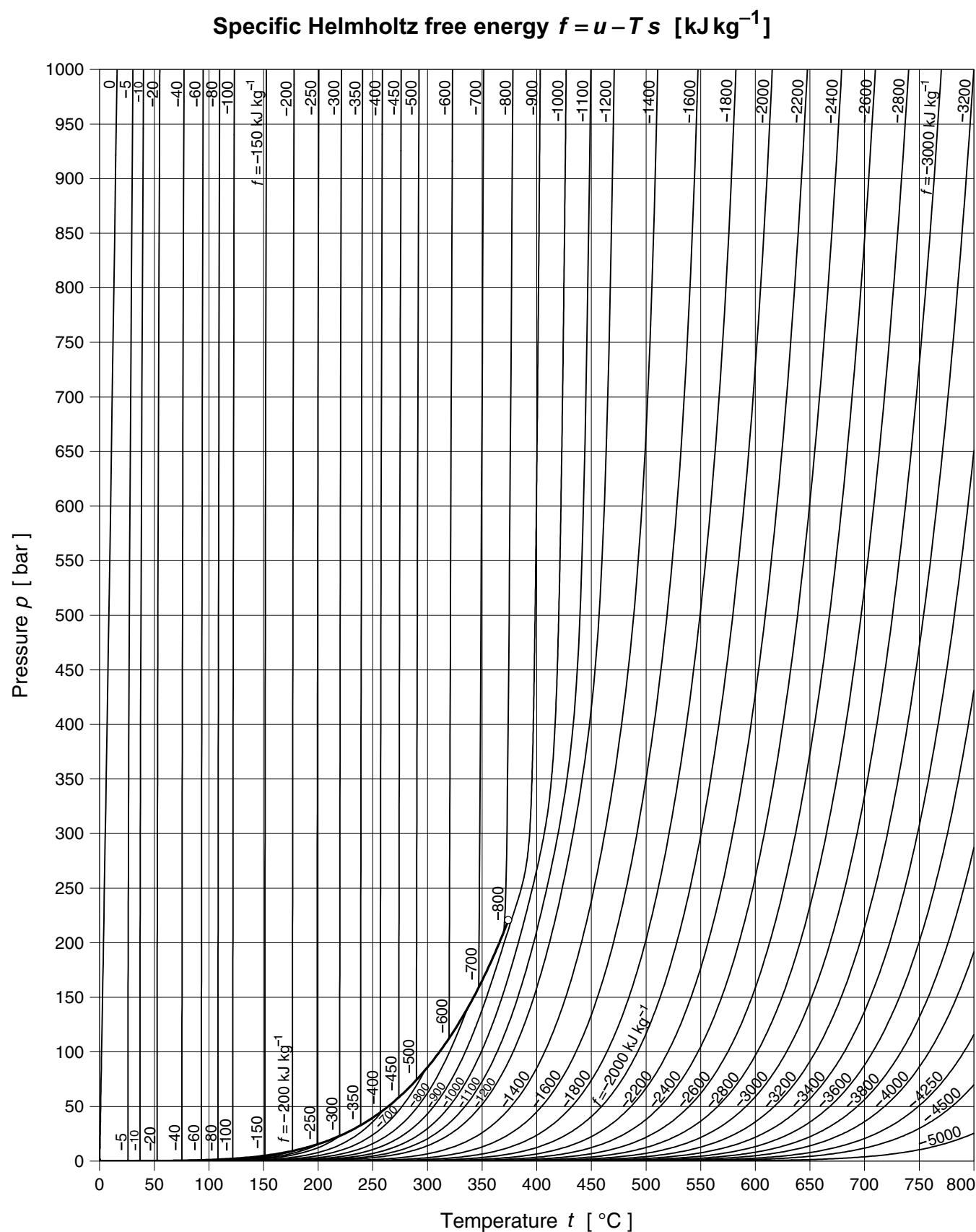
Diagr. 8 Pressure-temperature diagram with lines of constant specific internal energy.



Diagr. 9 Pressure-temperature diagram with lines of constant specific entropy.

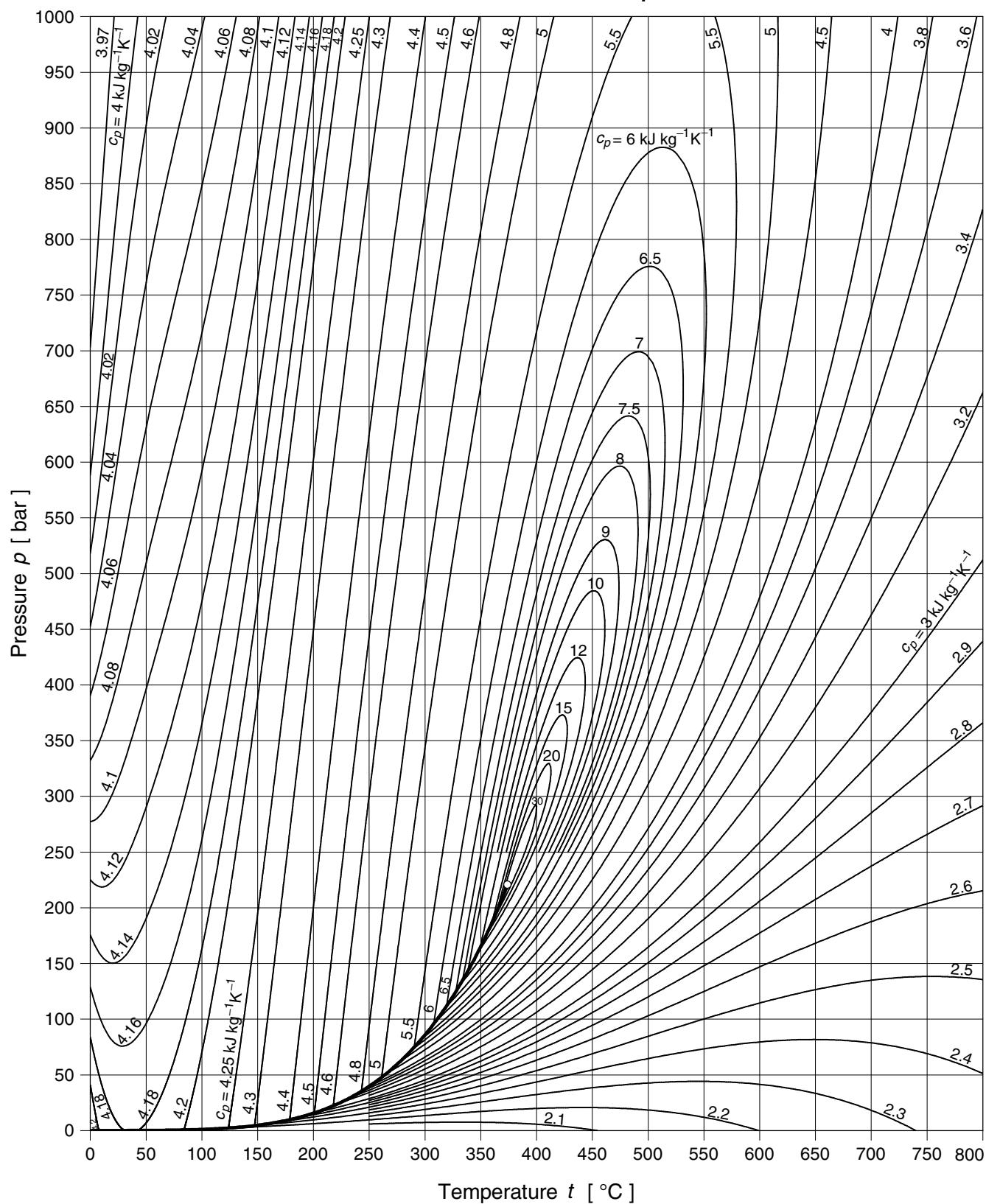


Diagr. 10 Pressure-temperature diagram with lines of constant specific Gibbs free energy.

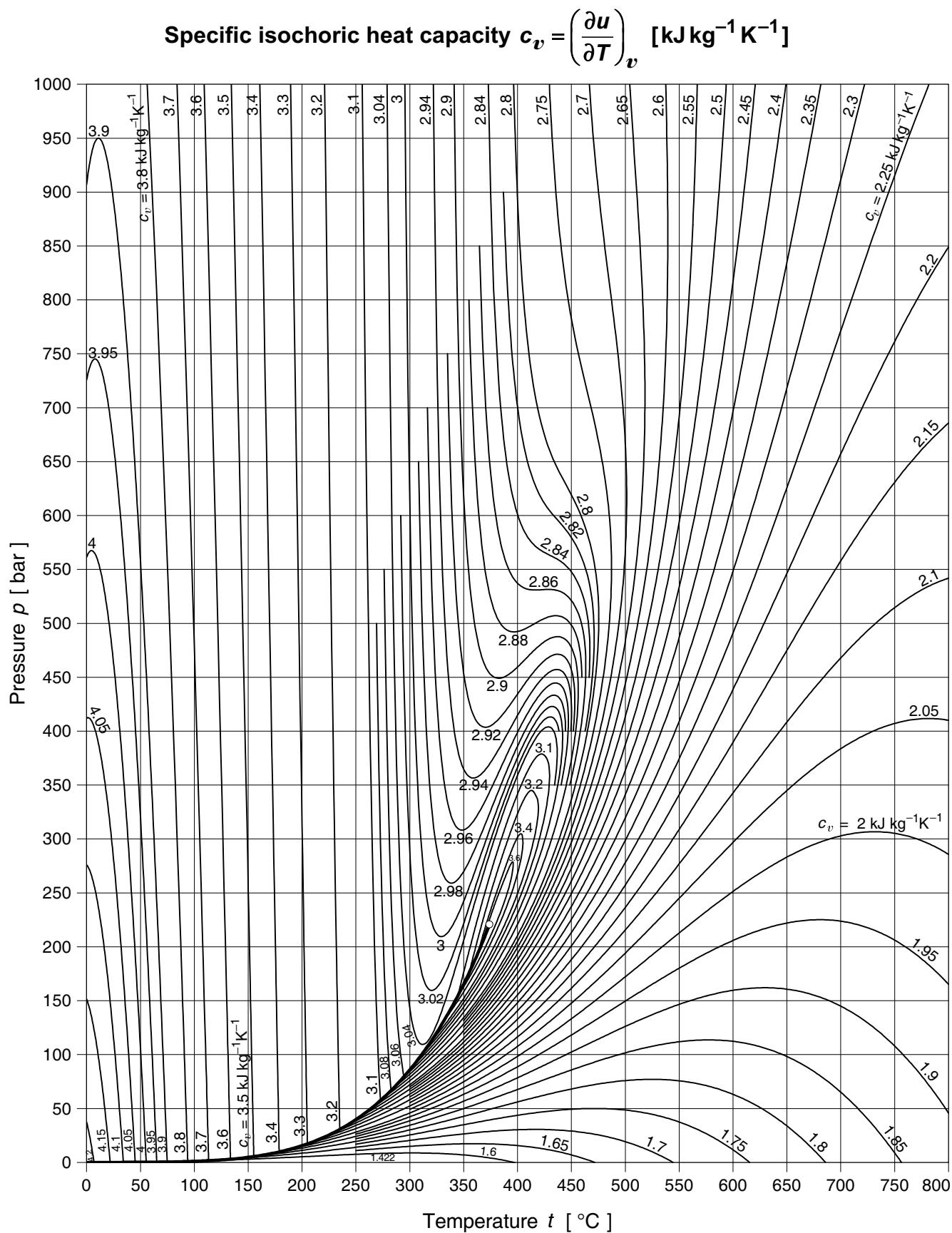


Diagr. 11 Pressure-temperature diagram with lines of constant specific Helmholtz free energy.

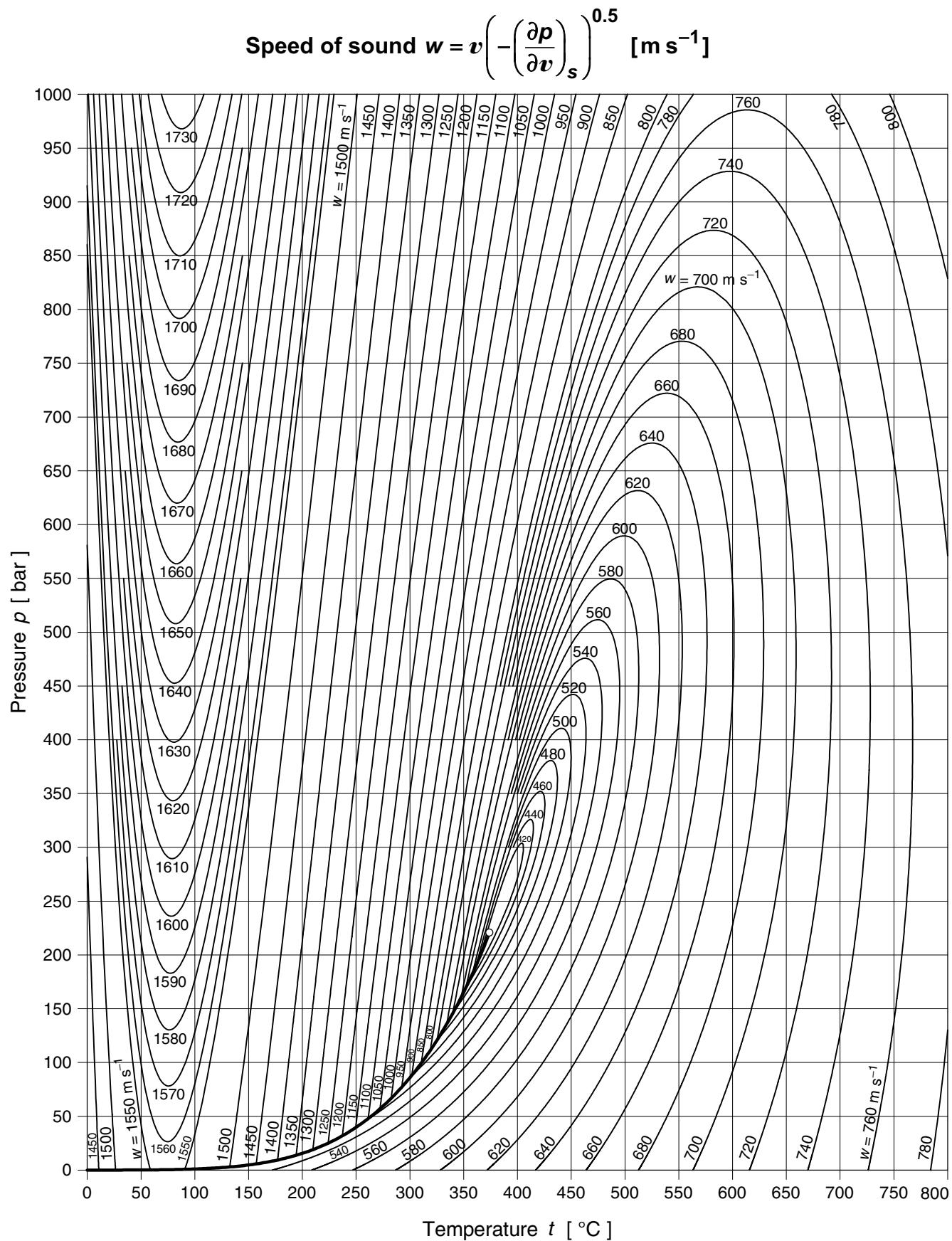
Specific isobaric heat capacity $c_p = \left(\frac{\partial h}{\partial T}\right)_p$ [kJ kg⁻¹ K⁻¹]



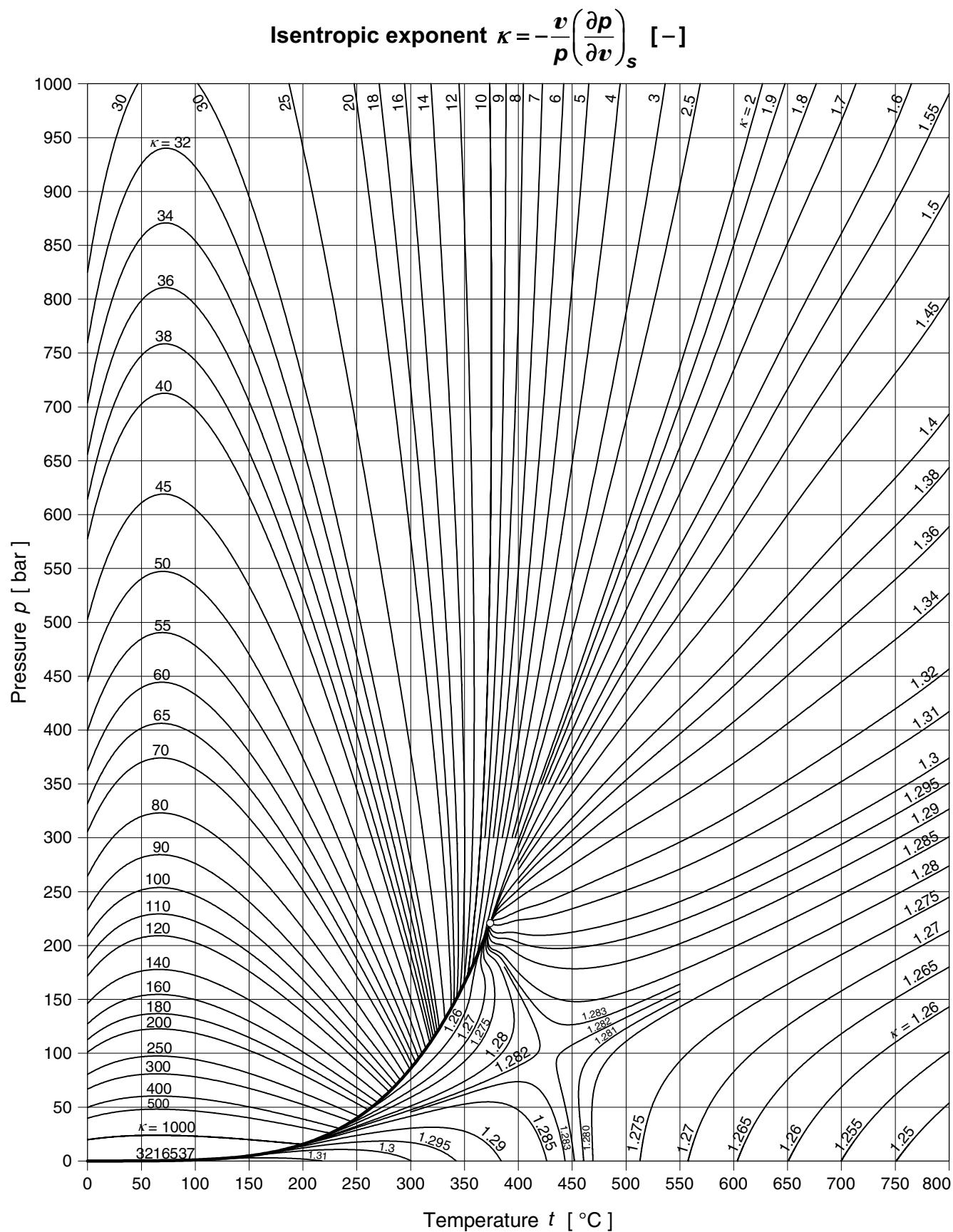
Diagr. 12 Pressure-temperature diagram with lines of constant specific isobaric heat capacity.



Diagr. 13 Pressure-temperature diagram with lines of constant specific isochoric heat capacity.

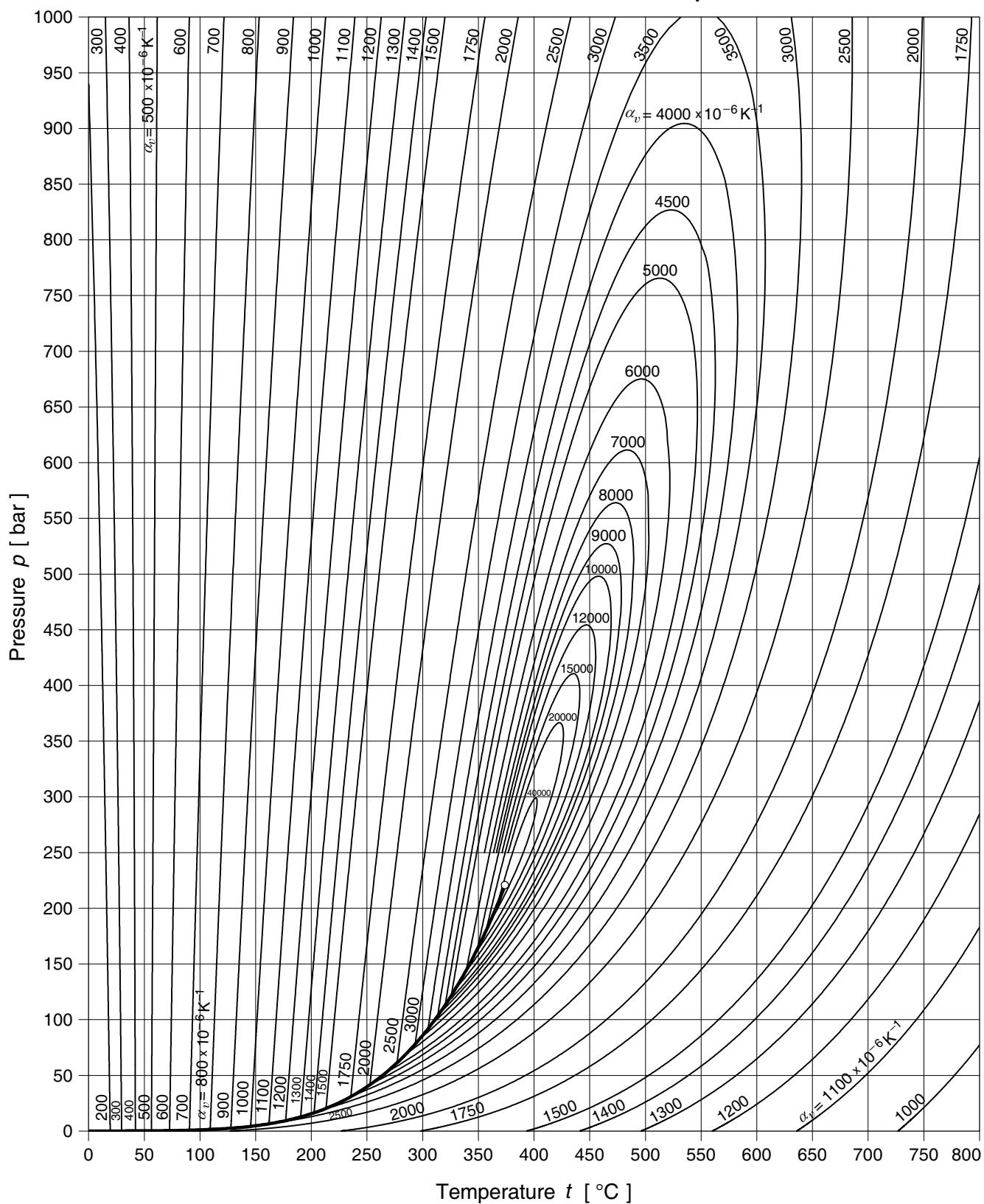


Diagr. 14 Pressure-temperature diagram with lines of constant speed of sound.

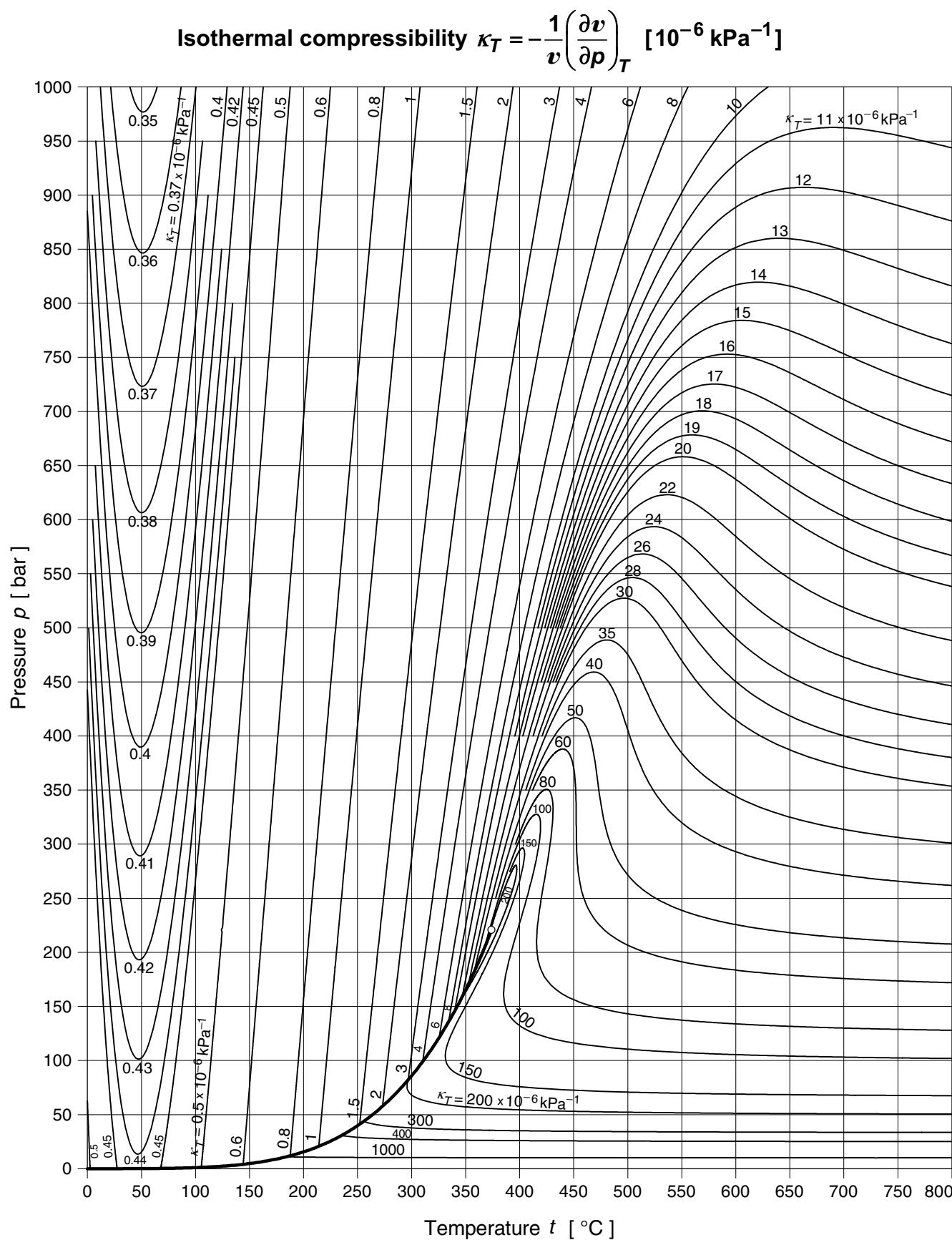


Diagr. 15 Pressure-temperature diagram with lines of constant isentropic exponent.

$$\text{Isobaric cubic expansion coefficient } \alpha_v = \frac{1}{v} \left(\frac{\partial v}{\partial T} \right)_p [10^{-6} \text{ K}^{-1}]$$

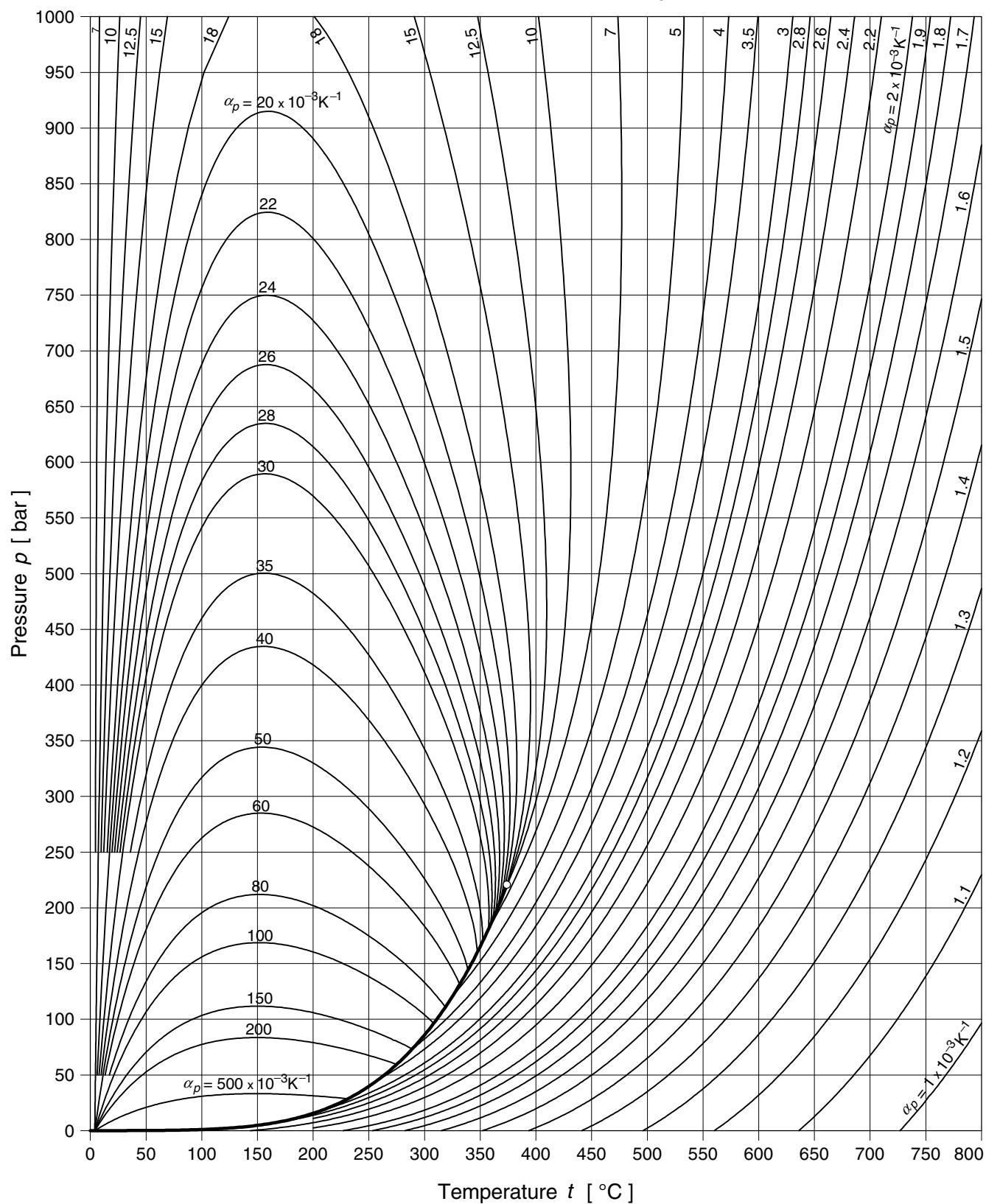


Diagr. 16 Pressure-temperature diagram with lines of const. isobaric cubic expansion coefficient.

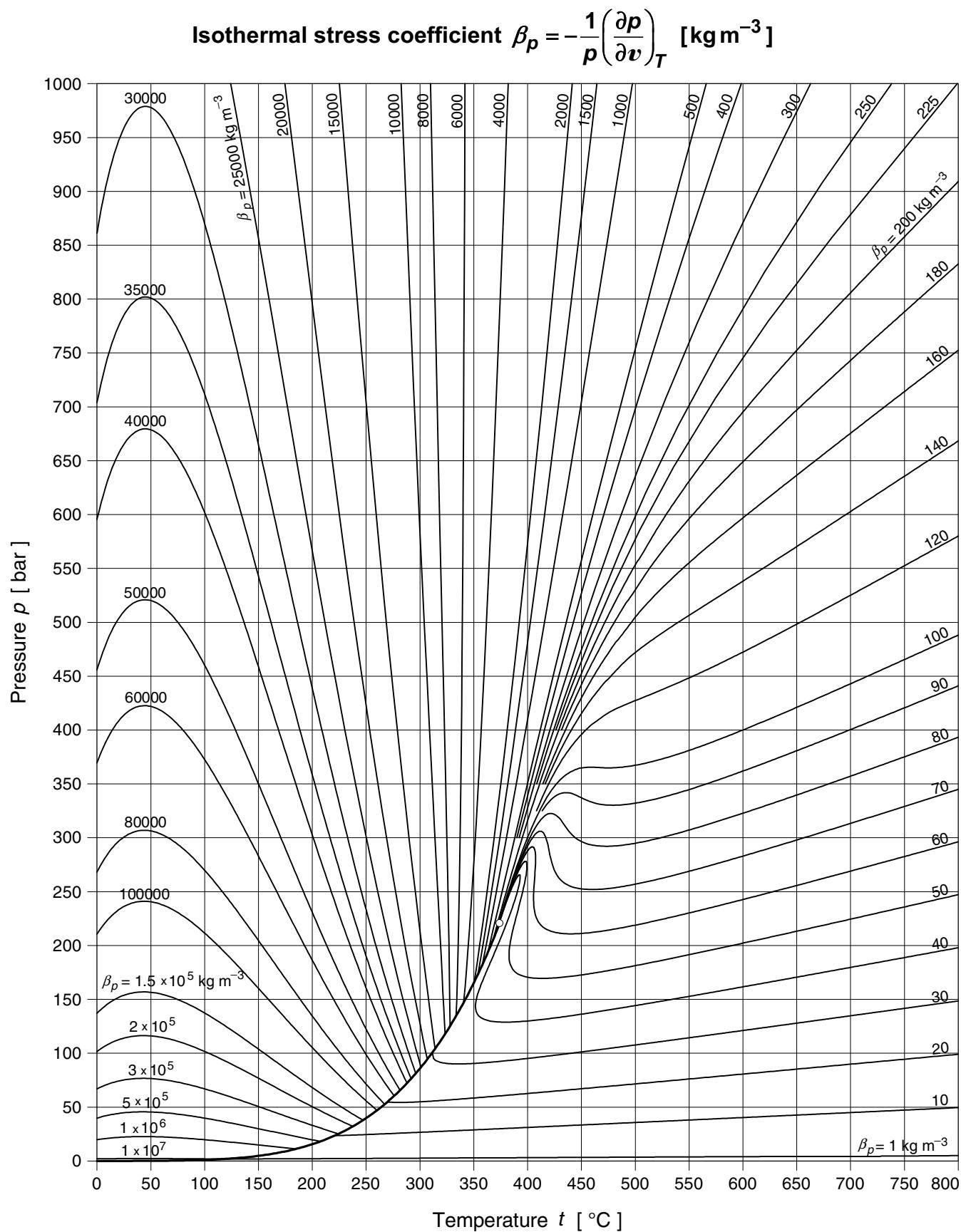


Diagr. 17 Pressure-temperature diagram with lines of constant isothermal compressibility.

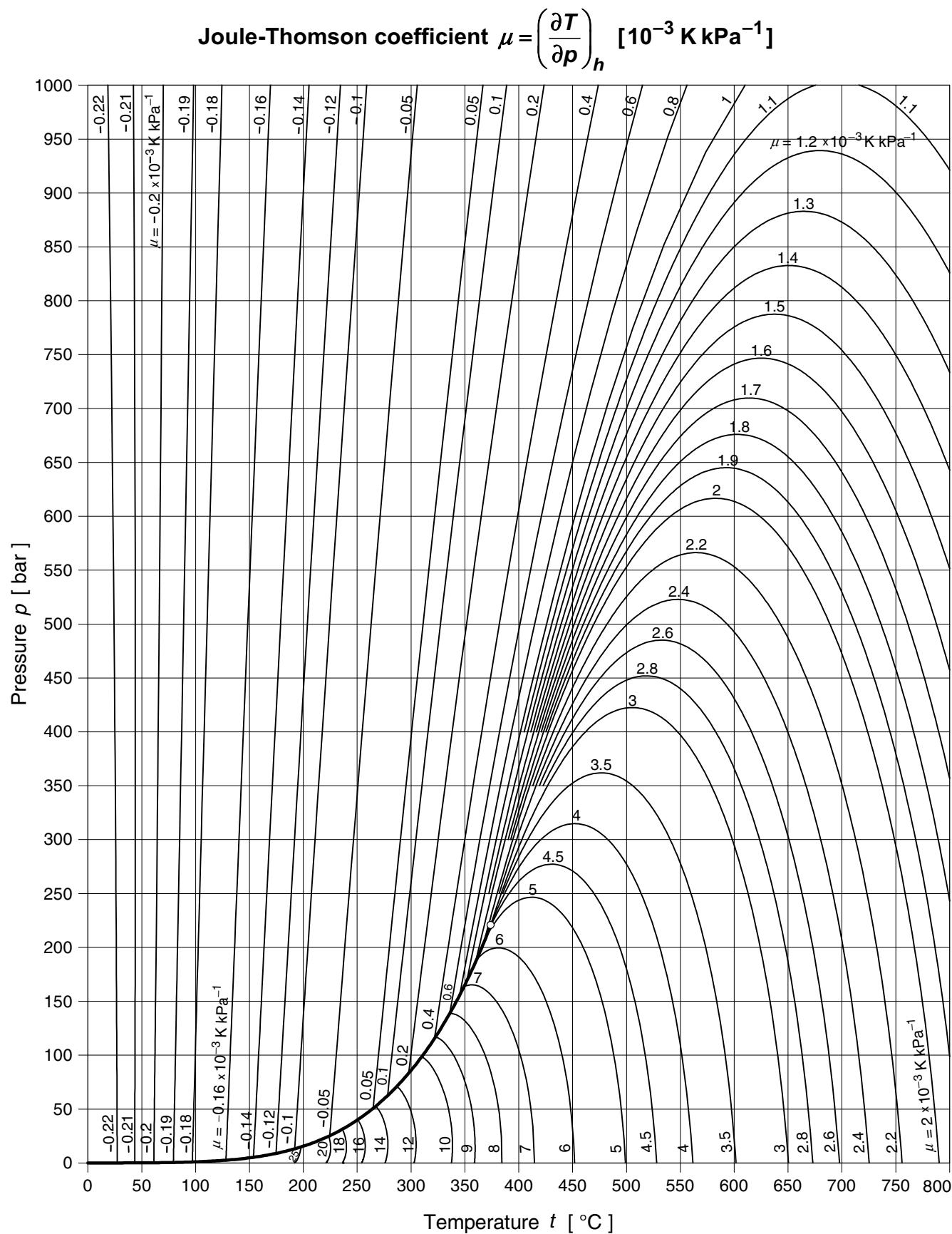
$$\text{Relative pressure coefficient } \alpha_p = \frac{1}{p} \left(\frac{\partial p}{\partial T} \right)_v [10^{-3} \text{ K}^{-1}]$$



Diagr. 18 Pressure-temperature diagram with lines of constant relative pressure coefficient.

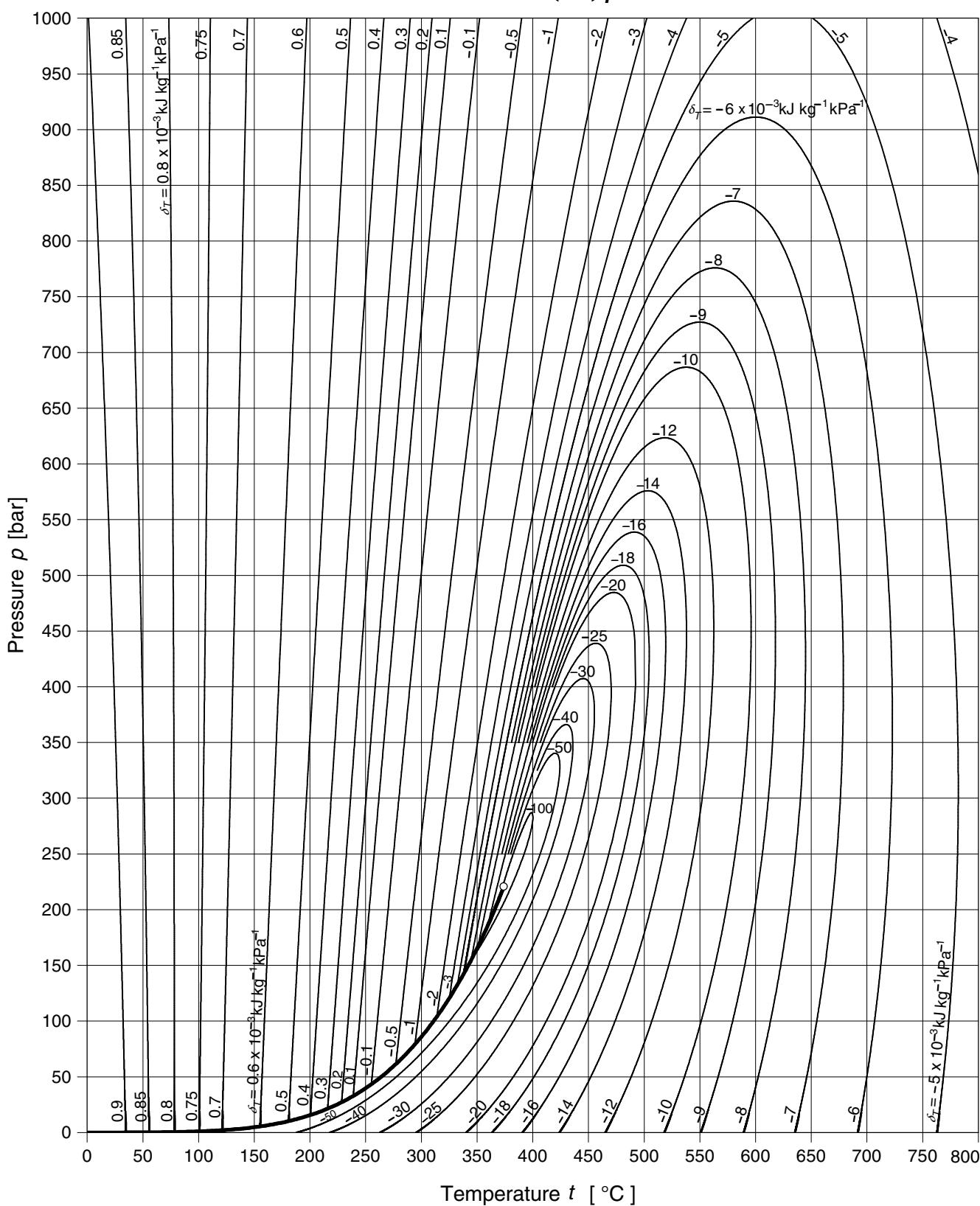


Diagr. 19 Pressure-temperature diagram with lines of constant isothermal stress coefficient.

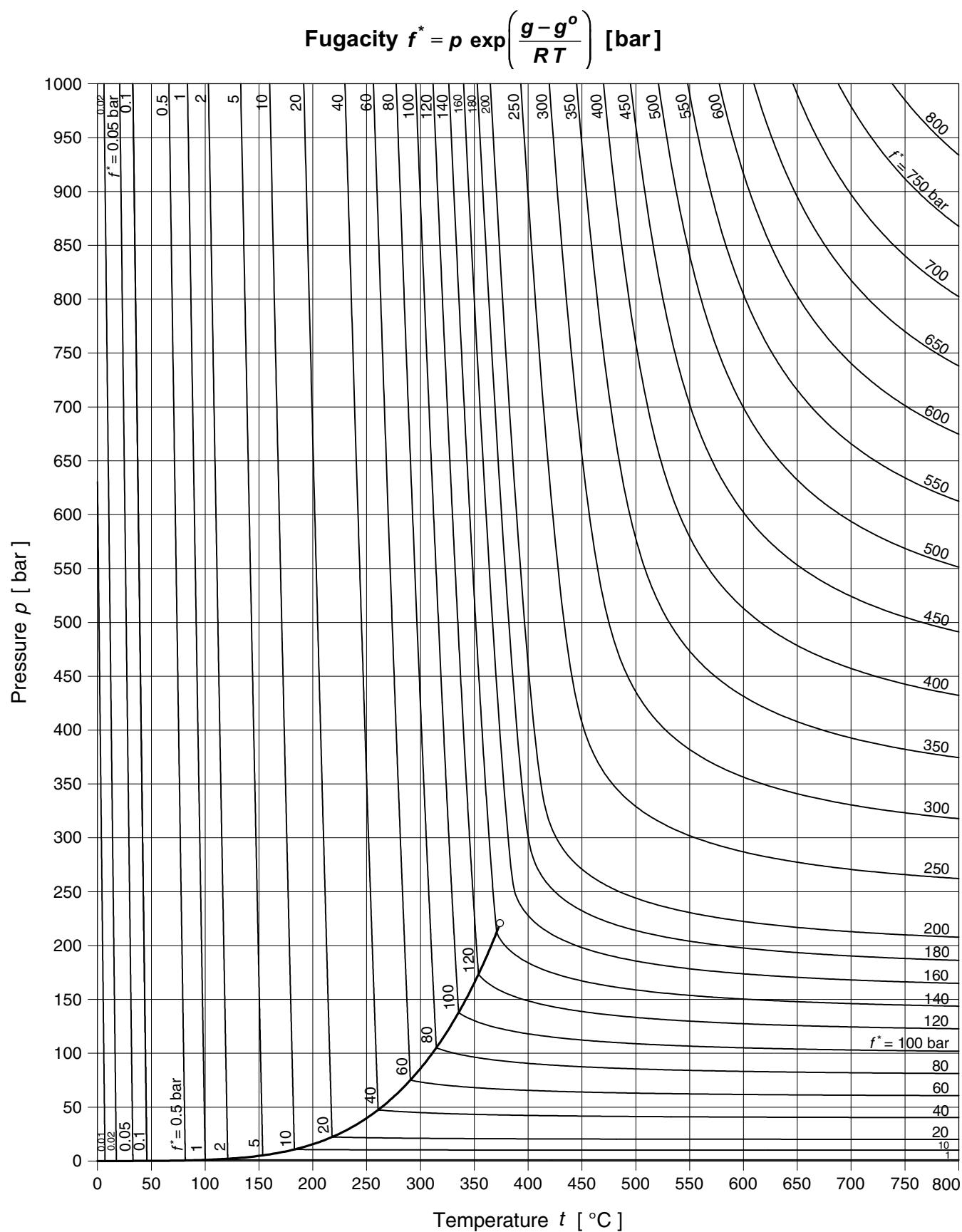


Diagr. 20 Pressure-temperature diagram with lines of constant Joule-Thomson coefficient.

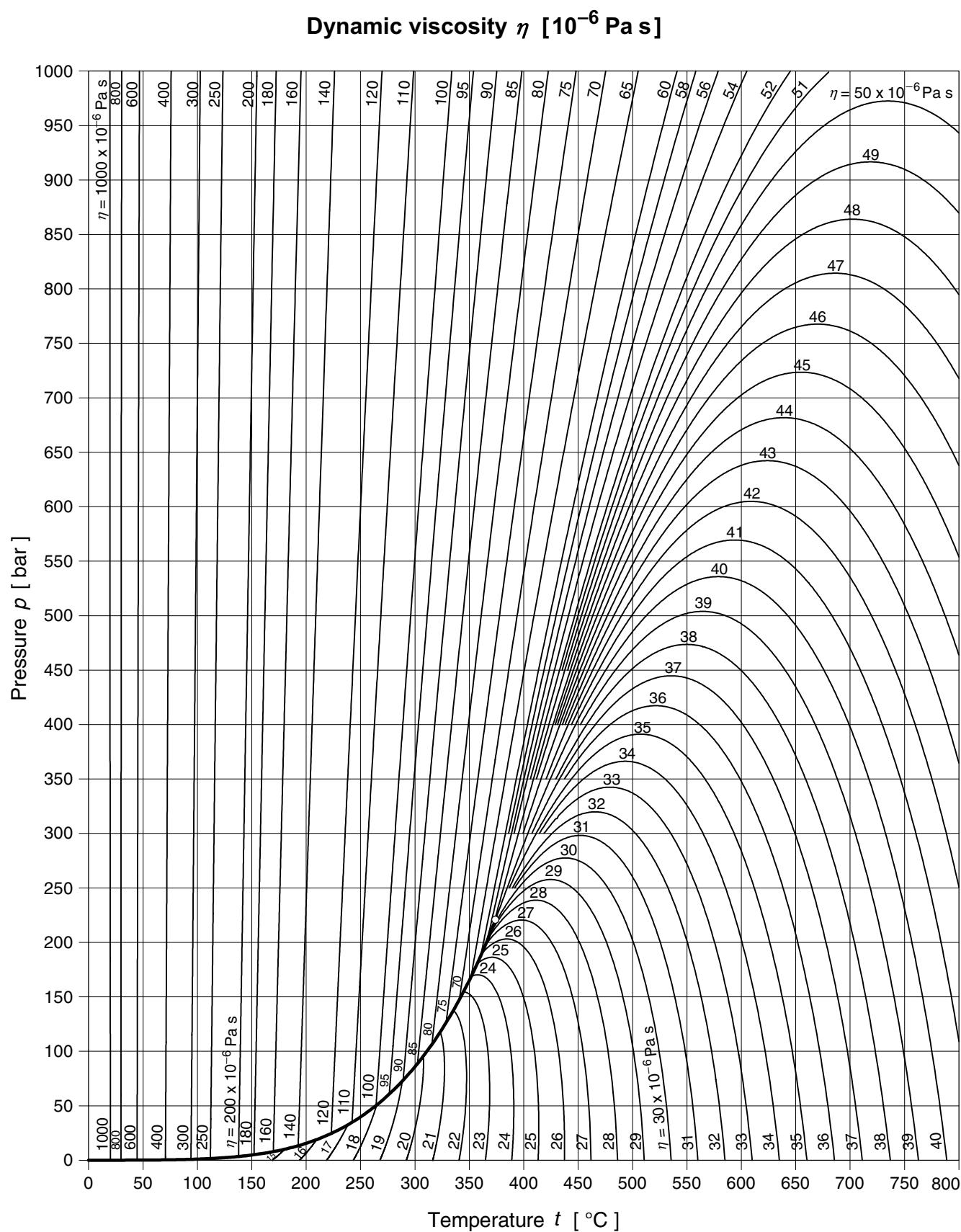
$$\text{Isothermal throttling coefficient } \delta_T = \left(\frac{\partial h}{\partial p} \right)_T [10^{-3} \text{ kJ kg}^{-1} \text{ kPa}^{-1}]$$



Diagr. 21 Pressure-temperature diagram with lines of constant isothermal throttling coefficient.

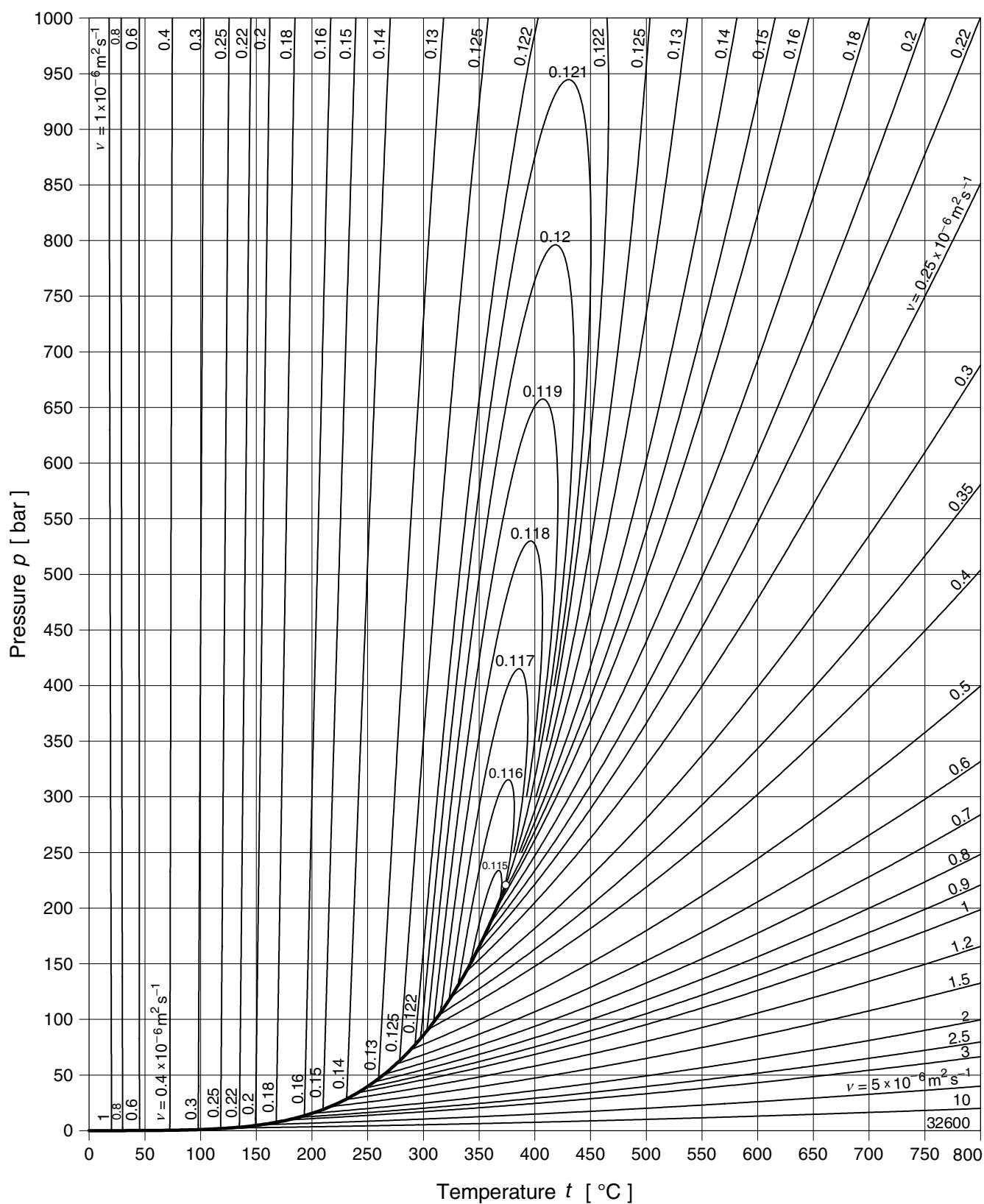


Diagr. 22 Pressure-temperature diagram with lines of constant fugacity.

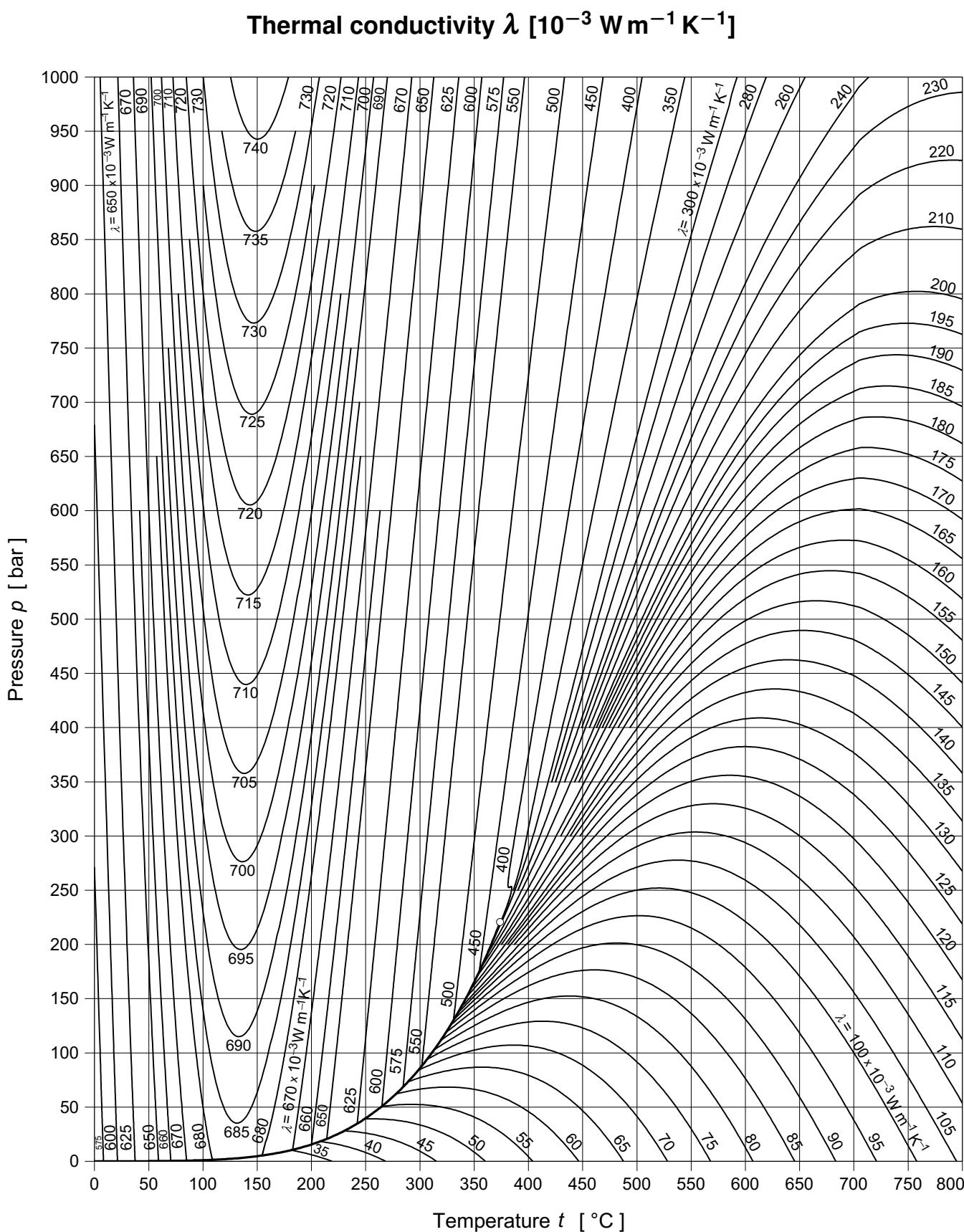


Diagr. 23 Pressure-temperature diagram with lines of constant dynamic viscosity.

$$\text{Kinematic viscosity } \nu = \frac{\eta}{\rho} [10^{-6} \text{ m}^2 \text{ s}^{-1}]$$

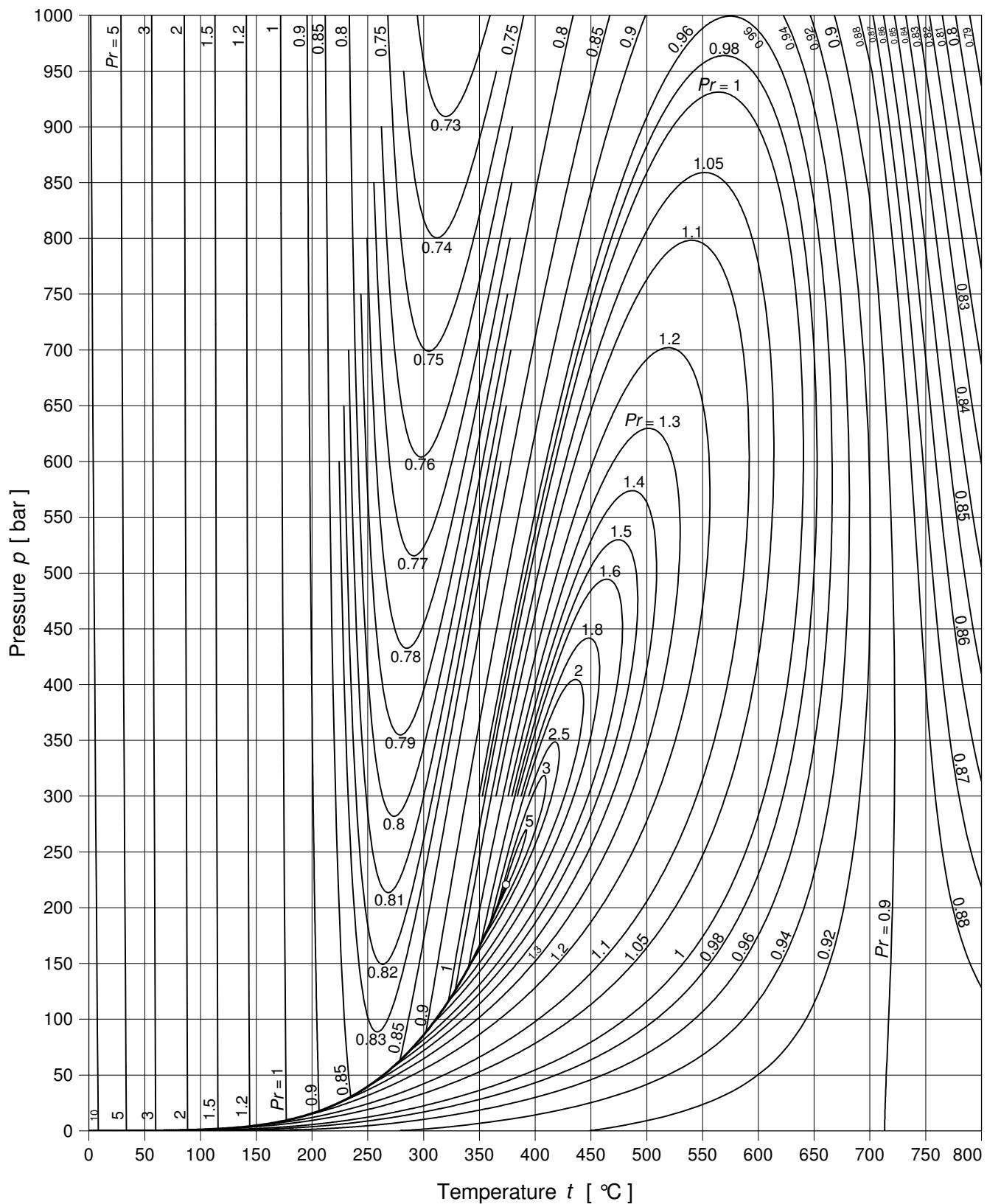


Diagr. 24 Pressure-temperature diagram with lines of constant kinematic viscosity.



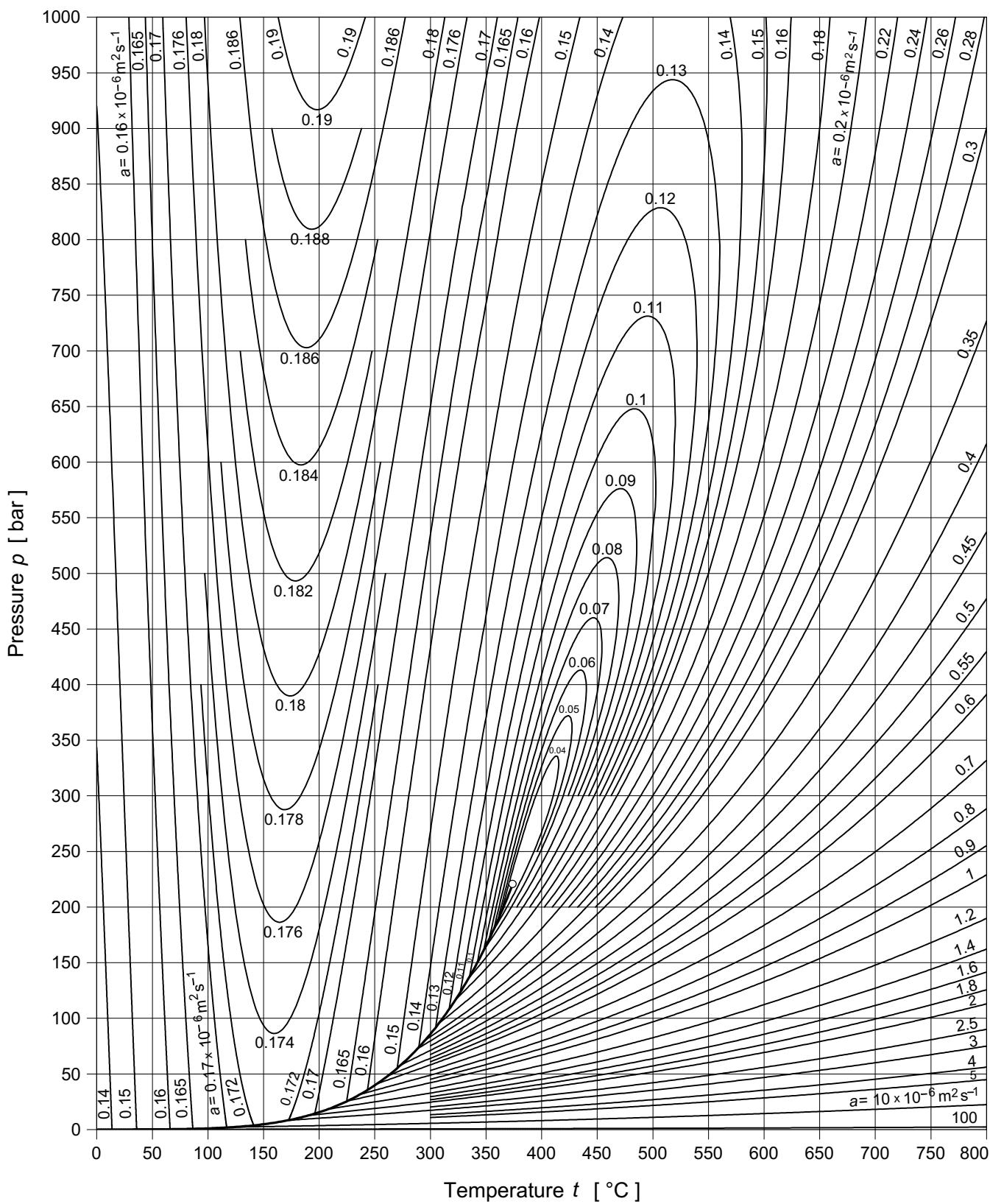
Diagr. 25 Pressure-temperature diagram with lines of constant thermal conductivity.

Prandtl number $Pr = \frac{\eta c_p}{\lambda}$ [-]

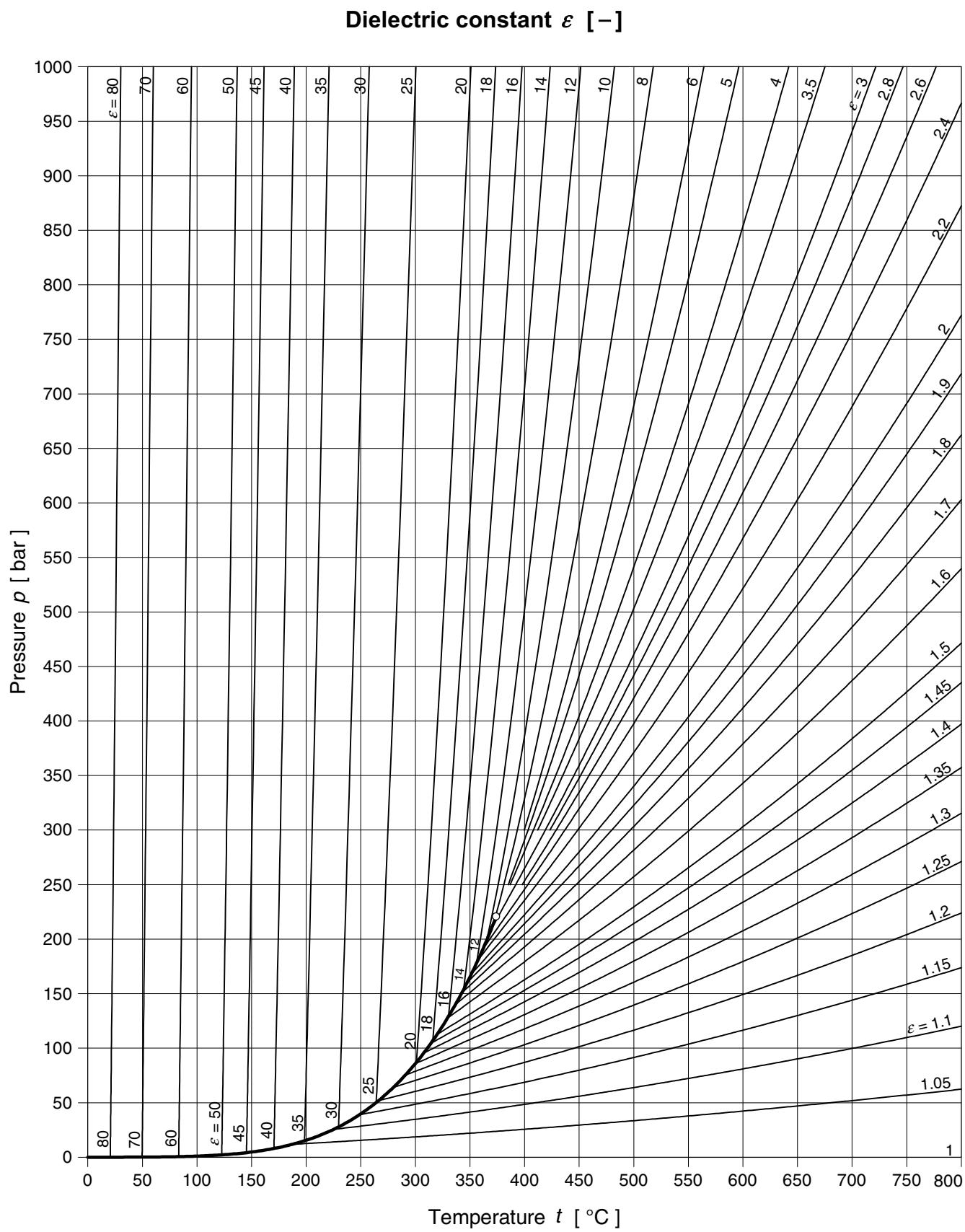


Diagr. 26 Pressure-temperature diagram with lines of constant Prandtl number.

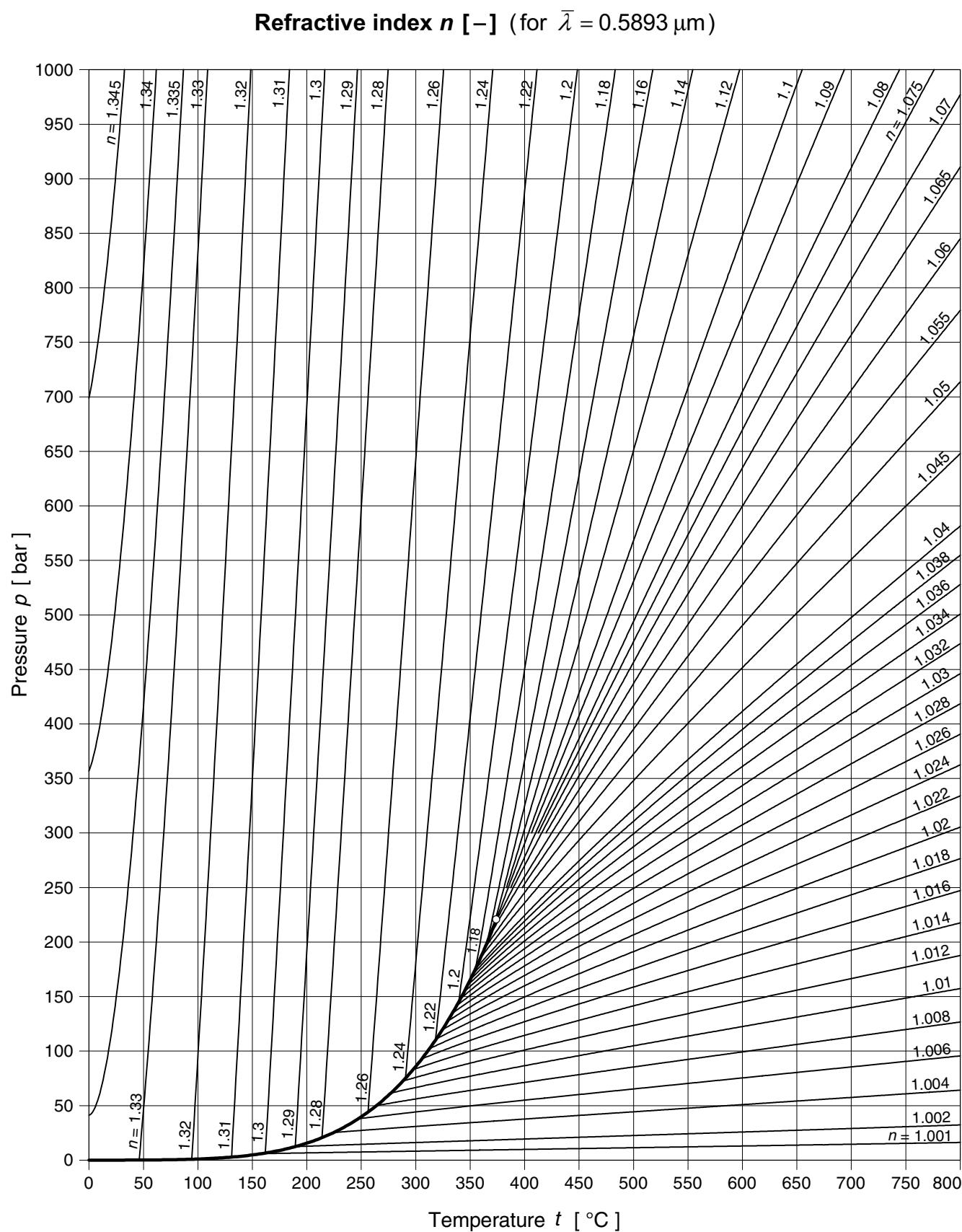
$$\text{Thermal diffusivity } a = \frac{\lambda}{\rho c_p} [10^{-6} \text{ m}^2 \text{ s}^{-1}]$$



Diagr. 27 Pressure-temperature diagram with lines of constant thermal diffusivity.



Diagr. 28 Pressure-temperature diagram with lines of constant dielectric constant.



Diagr. 29 Pressure-temperature diagram with lines of constant refractive index.

