International Steam Tables – IAPWS-IF97

developed by
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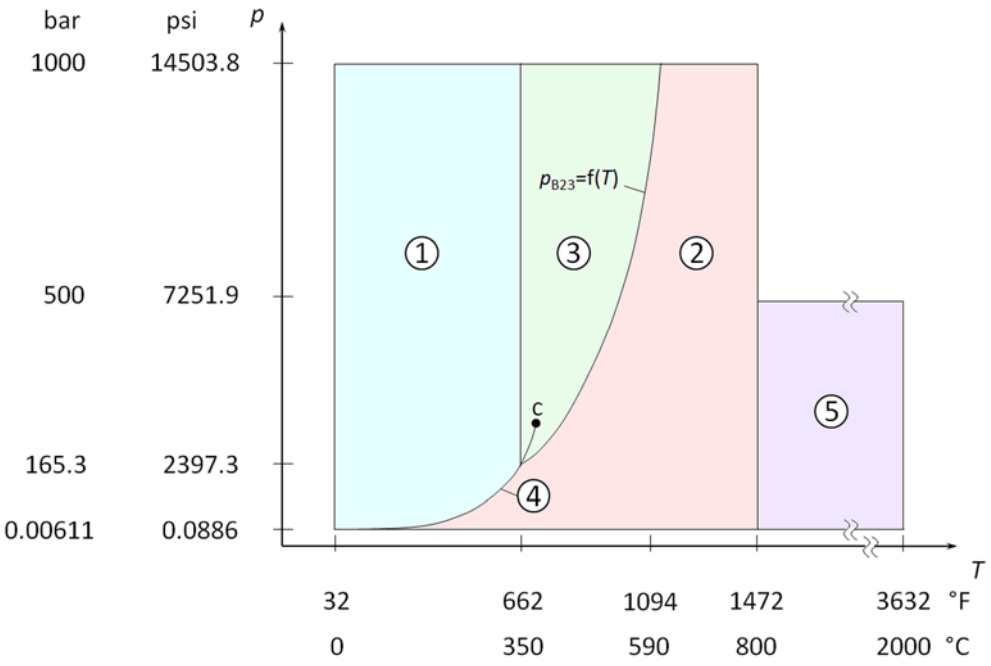
1. IAPWS-IF97 Range of Validity

This application is based on the Industrial Formulation IAPWS-IF97 [1], supplementary backward equations [2,3,4,5] and the latest standards for transport properties [6,7]. A comprehensive description of the entire equation set is given in [8]. The range of validity and the calculation regions are illustrated in this *p*-*T* diagram:



Temperature:	0 °C ≤ *t* ≤ 800 °C	32 °F ≤ *t* ≤ 1472 °F
Pressure:	0.00611 bar ≤ *p* ≤ 1000 bar	0.0886 psi ≤ *p* ≤ 14503.77 psi

High-temperature region 5:

800 °C < *t* ≤ 2000 °C [a]	1472 °F < *t* ≤ 3632 °F [a]
0.00611 bar ≤ *p* ≤ 500 bar	0.0886 psi ≤ *p* ≤ 7251.89 psi

[a] The upper temperature limit of the transport properties (λ, η, ν, *Pr* and *a*) is 900 °C / 1652 °F.

2. User's Guide

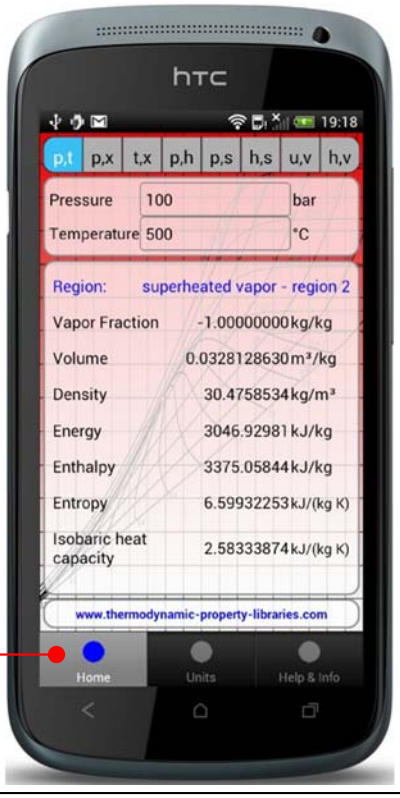
2.1 Navigation within the **International Steam Tables** app

At the bottom of the screen you will find a tab bar to switch between three different views: **Home**, **Units** and **Help & Info**.

Home: Perform calculations (see Section 2.2)

Units: Select units (see Section 2.3)

Help & Info: View this manual and get additional information (see Section 3)

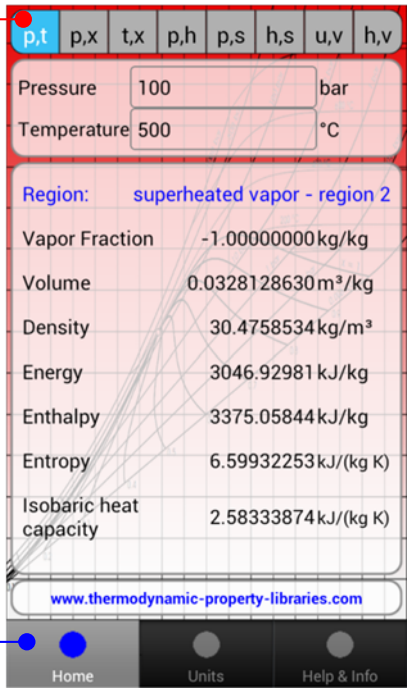


2.2 Calculations

To perform a calculation, carry out the following steps:

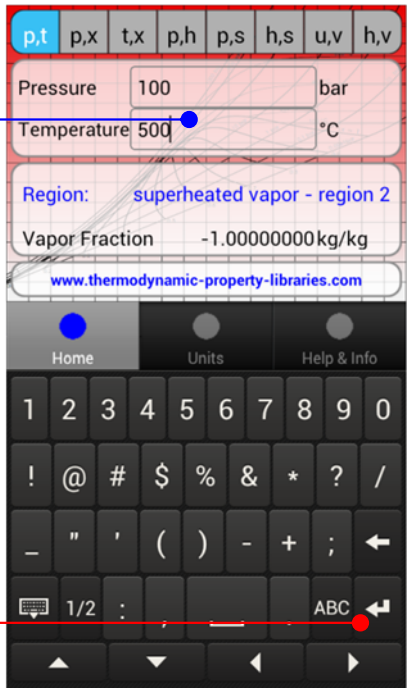
1. Tap the **Home** button on the tab bar to switch to the **Home** view
2. Select the input variables from the input button bar.
   The following combinations of input variables are available:

p,t	Pressure *p* and temperature *t*
p,x	Pressure *p* and vapor fraction *x* for wet steam region
t,x	Temperature *t* and vapor fraction *x* for wet steam region
p,h	Pressure *p* and specific enthalpy *h*
p,s	Pressure *p* and specific entropy *s*
h,s	Specific enthalpy *h* and specific entropy *s*
u,v	Specific internal energy *u* and specific volume *v*
h,v	Specific enthalpy *h* and specific volume *v*



Example: choose ***p,t***

3. Enter the values of the input variables by tapping the corresponding text boxes and typing via the keyboard which appears.
   Please note that, depending on the country and language settings on your device, either a comma "," or a dot "." is used as decimal separator.
   Tap the "Return" button of the keyboard to complete input value editing.
   If you want to change the input units refer to Section 2.3 of this manual.
   Example: - enter a pressure *p* of 100 bar
   - enter a temperature *t* of 500 °C

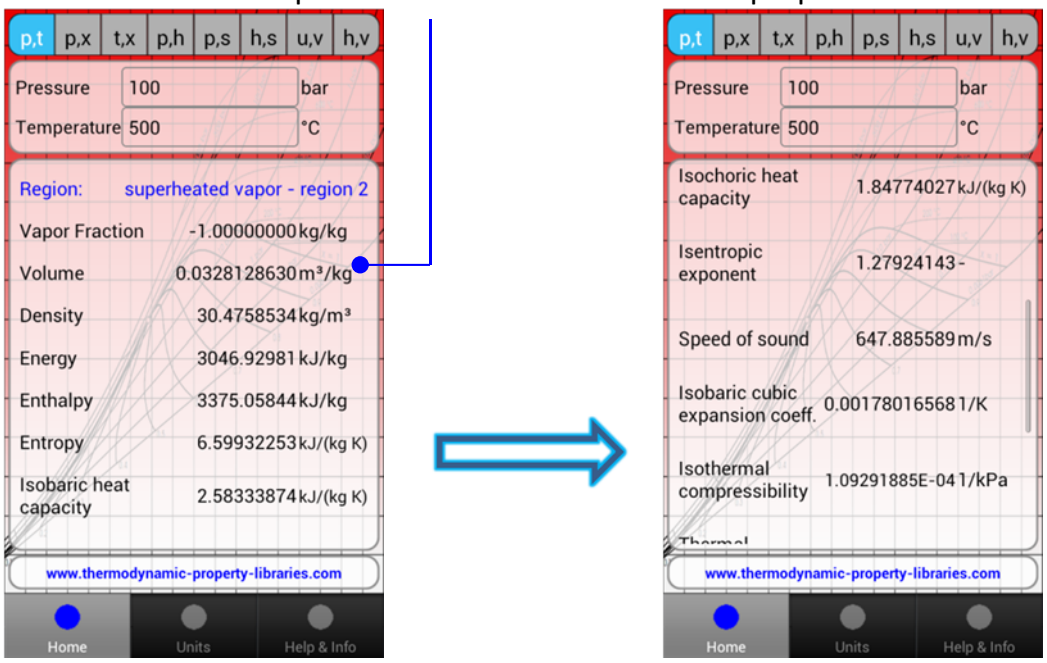


4. Results are shown in the scrollable output view. The calculated properties are shown in this table:

Pressure	p
Saturation pressure	p_s
Temperature	t
Saturation temperature	t_s
Vapor fraction	$x = \frac{m''}{m}$
Specific volume	v
Density	$\rho = 1/v$
Specific internal energy	u
Specific enthalpy	$h = u + p \cdot v$
Specific entropy	s
Specific isobaric heat capacity	$c_p = \left(\frac{\partial h}{\partial T}\right)_p$
Specific isochoric heat capacity	$c_v = \left(\frac{\partial u}{\partial T}\right)_v$

Isentropic exponent	$\kappa = -\frac{v}{p}\left(\frac{\partial p}{\partial v}\right)_s$
Speed of sound	$w = v\sqrt{-\left(\frac{\partial p}{\partial v}\right)_s}$
Isobaric cubic expansion coefficient	$\alpha_v = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$
Isothermal compressibility	$\kappa_T = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T$
Thermal conductivity	λ
Dynamic viscosity	η
Kinematic viscosity	$\nu = \eta/\rho$
Prandtl number	$\mathrm{Pr} = \frac{\eta \cdot c_p}{\lambda}$
Thermal diffusivity	$a = \frac{\lambda}{\rho \cdot c_p}$

Scroll down in the output view to see more calculated properties:



Using the values for v, s, c_p, α_v and κ_T, all thermodynamic derivatives can be calculated. The procedure to obtain all thermodynamic derivatives from these properties is described in [8].

Remarks on results:

- If the input values are outside the range of validity (see Section 1), the values of the properties will appear as -1. Note that the upper temperature limit of the transport properties (λ, η, ν, Pr and a) is 900 °C / 1652 °F
- If input values correspond to a state point in the wet steam region but not exactly to a saturated liquid or saturated vapor state the value -1 will be shown for the following properties:

Specific isobaric heat capacity c_p
Specific isochoric heat capacity c_v
Isentropic exponent κ
Speed of sound w
Isobaric cubic expansion coefficient α_v
Isothermal compressibility κ_T
Thermal conductivity λ
Dynamic viscosity η
Kinematic viscosity ν
Prandtl number Pr
Thermal diffusivity a

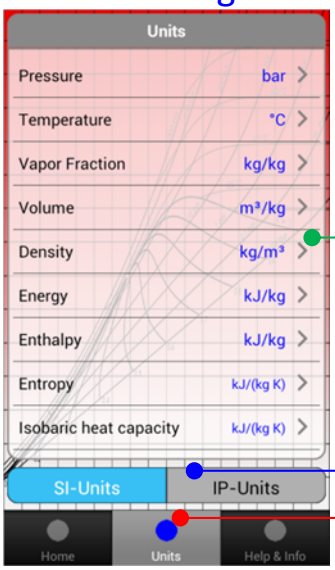
- The vapor fraction x is not defined in the single phase regions (1, 2, 3 and 5 of IAPWS-IF97) and will be set to -1 in these regions.

The results are automatically updated whenever the combination of input variables is changed (via the input button bar), the values of the input variables are changed, or the units are changed (as described in Section 2.3).

Note:

If you switch from one input variable combination to another, the values previously given or calculated will be assigned to the new input values and the output will be calculated automatically. For example, if you calculate a certain state point from pressure p and temperature t and afterwards you switch to a calculation from pressure p and specific entropy s, the previously calculated value for s (from p and t) will be assigned as input value for s. This eases the calculation of thermodynamic processes in which one property is kept constant, e. g. of an isentropic expansion.

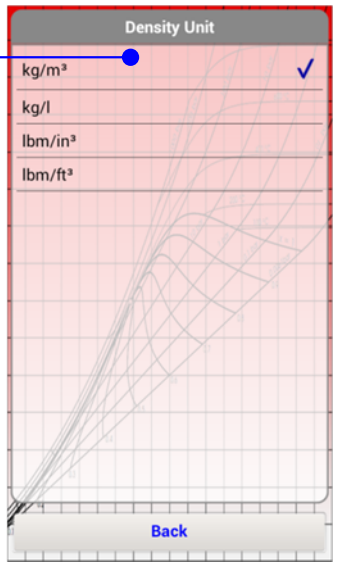
2.3 Unit Settings



1. Select the **Units** view from the tab bar controller.
2. Preselect the unit system (SI and I-P unit systems are available).
3. In order to select a unit for a certain property, tap the property in the scrollable table and select the unit from the table which then appears.

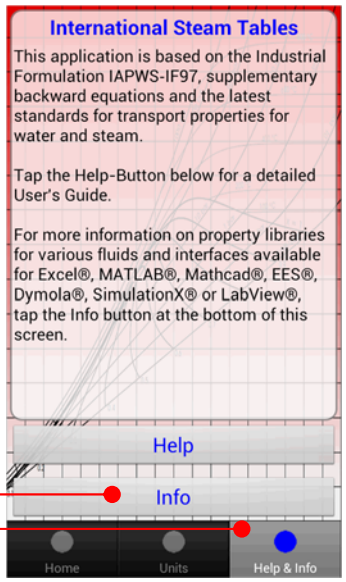
Note:

When units are changed the corresponding values are immediately converted to these new units.



3. Information

For more information on property libraries for various fluids and interfaces available for Excel®, MATLAB®, Mathcad®, EES®, Dymola®, SimulationX® or LabView®, tap the **Help & Info** button on the tab bar and tap the **Info** button at the bottom of the screen (PDF-Reader required).



We recommend visiting the following websites:

For more information on **thermodynamic property libraries** for various fluids and software applications, please visit:

www.thermodynamic-property-libraries.com .

In order to **calculate thermodynamic properties of various fluids online**, please visit:

www.fluid-property-calculator.com .

For details on the **book** and the authors of the **International Steam Tables**, visit the website:

www.international-steam-tables.com .

To learn more about the **International Association for the Properties of Water and Steam (IAPWS)**, visit the official website:

www.iapws.org .

4. Contact

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5. References

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

[2] IAPWS (2001), *Supplementary Release on Backward Equations for Pressure as a Function of Enthalpy and Entropy p(h,s) to the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam*, available at the IAPWS website http://www.iapws.org.

[3] IAPWS (2004), *Revised Supplementary Release on Backward Equations for the Functions T(p,h), v(p,h), and T(p,s), v(p,s) for Region 3 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam*, available at the IAPWS website http://www.iapws.org.

[4] IAPWS (2004), *Supplementary Release on Backward Equations p(h,s) for Region 3, Equations as a Function of h and s for the Region Boundaries, and an Equation Tsat(h,s) for Region 4 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam*, available at the IAPWS website http://www.iapws.org.

[5] IAPWS (2005), *Supplementary Release on Backward Equations for Specific Volume as a Function of Pressure and Temperature v(p,T) for Region 3 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam*, available at the IAPWS website http://www.iapws.org.

[6] IAPWS (2008), *Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance*, available at the IAPWS website http://www.iapws.org.

[7] IAPWS (2011), *Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance*, available at the IAPWS website http://www.iapws.org.

[8] Wagner, W., Kretzschmar, H.-J., *International Steam Tables*, Springer-Verlag, Berlin (2008), see also at http://www.international-stem-tables.com.