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**Property Library for
the Industrial Formulation
IAPWS-IF97
for Water and Steam**

**FluidEES
with LibIF97
for Engineering Equation Solver®**

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Property Library for the Industrial Formulation IAPWS-IF97 of Water and Steam

LibIF97 FluidEES

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0 Package Contents

Zip-file "CD_FluidEES_LibIF97_Eng.zip" including the following files:

FluidEES_LibIF97_Setup.exe	Installation program for the FluidEES add-in for use in Engineering Equation Solver®
LibIF97.dll	Dynamic link library including property algorithms for water and steam
LibIF97.hlp	Help file for the LibIF97 property library
FluidEES_LibIF97_Docu_Eng.pdf	User's Guide

1. Program Functions

1.1 Range of Validity

The International Association for the Properties of Water and Steam IAPWS issued the

"Release on the IAPWS Industrial Formulation 1997

for the Thermodynamic Properties of Water and Steam IAPWS-IF97"

in September 1997 [1], [2], [3]. It will be abbreviated as IAPWS-IF97. This new industrial standard must be applied worldwide in acceptance and guarantees calculations of facilities and plants working with water or steam. The IAPWS-IF97 Formulation replaces the former Industrial Formulation IFC-67 [12].

Figure 1.1 shows the entire range of validity for the equation set of the new Industrial Formulation IAPWS-IF97. It includes temperatures from 0 °C to 800 °C at pressures from 0.00611 bar to 1000 bar and temperatures to 2000 °C for pressures to 500 bar.

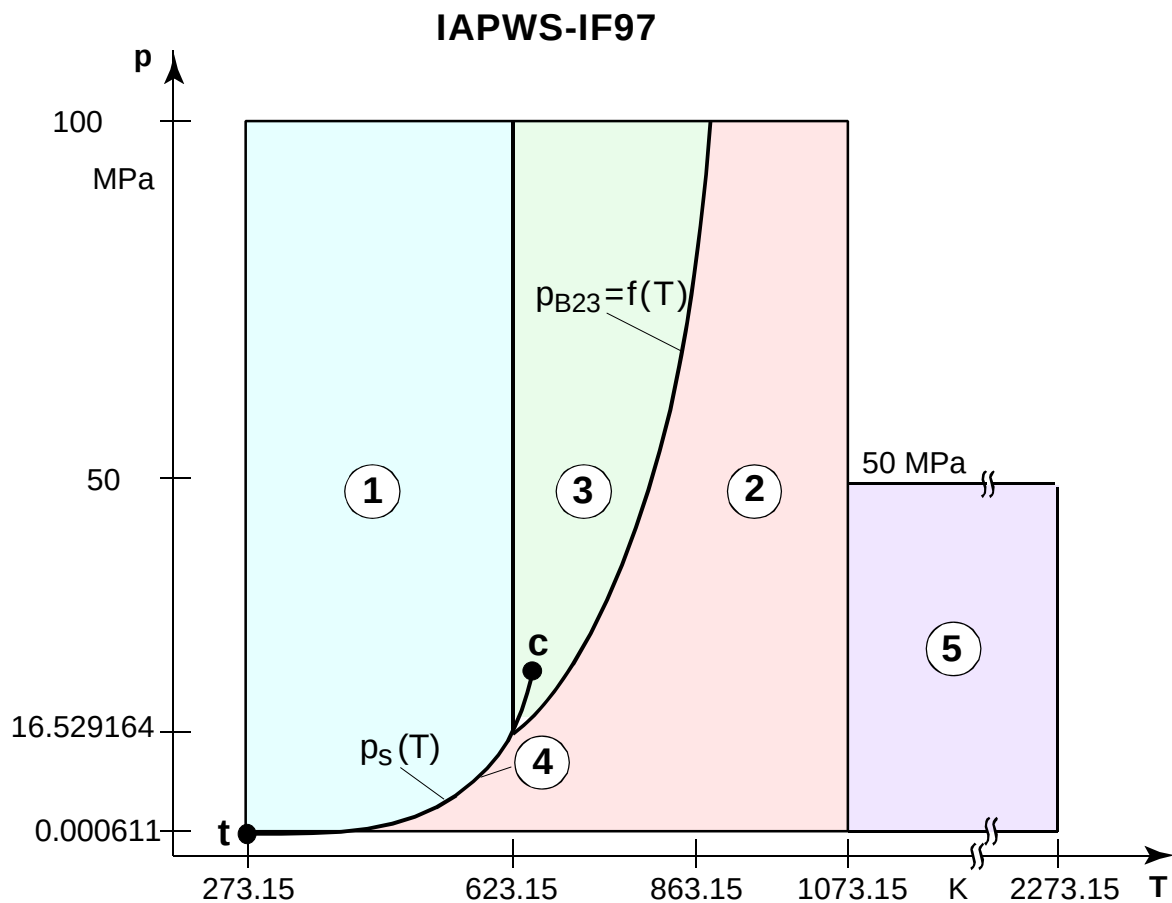


Figure 1.1 Entire Range of Validity of the IF97

The range of validity is divided into five calculation regions. Each of the calculation regions contains its own equations of state. They are described in detail in the official Release of the IAPWS [1] and in the publications by *Wagner et al.* [2] and [3].

The sub-programs of the LibIF97 DLL and the functions of the Add-In FluidEXL *Graphics* for Excel are listed in the following section.

All sub-programs and functions can be applied in the entire range of validity of the IF97. The call of the necessary equation of state for each calculation region will be realized within the program.

1.2 Functions

Functional Dependence	Function Name	Call as Function from DLL LibIF97	Call from DLL LibIF97, Result as Parameter	Property or Function	Unit of the Result
$a = f(p, t, x)$	a_ptx_97	= APTX97(P, T, X)	= C_APTX97(A, P, T, X)	Thermal diffusivity	m ² /s
$\alpha_p = f(p, t, x)$	alphap_ptx_97	= ALPHAPPTX97(P, T, X)	= C_ALPHAPPTX97(ALPHAP, P, T, X)	Relative pressure coefficient	K ⁻¹
$\alpha_v = f(p, t, x)$	alphav_ptx_97	= ALPHAVPTX97(P, T, X)	= C_ALPHAVPTX97(ALPHAV, P, T, X)	Isobaric cubic expansion coefficient	K ⁻¹
$b = f(p)$	b_p_97	= BP97(P)	= C_BP97(B, P)	Laplace coefficient	m
$b = f(t)$	b_t_97	= BT97(T)	= C_BT97(B, T)	Laplace coefficient	m
$\beta_p = f(p, t, x)$	betap_ptx_97	= BETAPPTX97(P, T, X)	= C_BETAPPTX97(BETAP, P, T, X)	Isothermal stress coefficient	kg/m ³
$c_p = f(p, t, x)$	cp_ptx_97	= CPPTX97(P, T, X)	= C_CPPTX97(CP, P, T, X)	Specific isobaric heat capacity	kJ/(kg · K)
$c_v = f(p, t, x)$	cv_ptx_97	= CVPTX97(P, T, X)	= C_CVPTX97(CV, P, T, X)	Specific isochoric heat capacity	kJ/(kg · K)
$\delta_T = f(p, t, x)$	deltat_ptx_97	= DELTATPTX97(P, T, X)	= C_DELTATPTX97(DELTAT, P, T, X)	Isothermal throttling coefficient	kJ/(kg · kPa ⁻¹)
$\left(\frac{\partial v}{\partial p}\right)_T = f(p, t, x)$	dv_dp_T_ptx_97	= DVDPT97(P, T, X)	= C_DVDPT97(DVP, P, T, X)	Differential quotient $\left(\frac{\partial v}{\partial p}\right)_T(p, t, x)$	m ³ /(kg · kPa)
$\left(\frac{\partial v}{\partial T}\right)_p = f(p, t, x)$	dv_dT_p_ptx_97	= DVDTP97(P, T, X)	= C_DVDTP97(DVT, P, T, X)	Differential quotient $\left(\frac{\partial v}{\partial T}\right)_p(p, t, x)$	m ³ /(kg · K)
$e = f(p, t, x, t_U)$	e_ptx_tu_97	= EPTXTU97(P, T, X, TU)	= C_EPTXTU97(E, P, T, X, TU)	Specific exergy	kJ/kg
$\varepsilon = f(p, t, x)$	epsilon_ptx_97	= EPSPTX97(P, T, X)	= C_EPSPTX97(EPS, P, T, X)	Dielectric constant	-
$\eta = f(p, t, x)$	eta_ptx_97	= ETAPTX97(P, T, X)	= C_ETAPTX97(ETA, P, T, X)	Dynamic viscosity	Pa · s = kg/(m · s)
$f = f(p, t, x)$	f_ptx_97	= FPTX97(P, T, X)	= C_FPTX97(F, P, T, X)	Specific Helmholtz energy	kJ/kg
$f^* = f(p, t, x)$	fug_ptx_97	= FUGPTX97(P, T, X)	= C_FUGPTX97(FUG, P, T, X)	Fugacity	bar
$g = f(p, t, x)$	g_ptx_97	= GPTX97(P, T, X)	= C_GPTX97(G, P, T, X)	Specific Gibbs energy	kJ/kg
$h = f(p, s)$	h_ps_97	= HPS97(P, S)	= C_HPS97(HPS, P, S)	Backward function: Specific enthalpy from pressure and entropy	kJ/kg
$h = f(p, t, x)$	h_ptx_97	= HPTX97(P, T, X)	= C_HPTX97(H, P, T, X)	Specific enthalpy	kJ/kg

Functional Dependence	Function Name	Call as Function from DLL LibIF97	Call from DLL LibIF97, Result as Parameter	Property or Function	Unit of the Result
$\kappa = f(p, t, x)$	kappa_ptx_97	= KAPPTX97(P, T, X)	= C_KAPPTX97(KAP, P, T, X)	Isentropic exponent	-
$\kappa_T = f(p, t, x)$	kappat_ptx_97	= KAPPATPTX97(P, T, X)	= C_KAPPATPTX97(KAPPAT, P, T, X)	Isothermal compressibility	kPa ⁻¹
$\lambda = f(p, t, x)$	lambda_ptx_97	= LAMPTX97(P, T, X)	= C_LAMPTX97(LAM, P, T, X)	Heat conductivity	W/(m · K)
$\mu = f(p, t, x)$	my_ptx_97	= MYPTX97(P, T, X)	= C_MYPTX97(MY, P, T, X)	Joule-Thomson coefficient	K kPa ⁻¹
$n = f(p, t, x, wl)$	n_ptxwl_97	= NPTXWL97(P, T, X, WL)	= C_NPTXWL97(N, P, T, X, WL)	Refractive index	-
$\nu = f(p, t, x)$	ny_ptx_97	= NYPTX97(P, T, X)	= C_NYPTX97(NUE, P, T, X)	Kinematic viscosity	m ² /s
$p = f(h, s)$	p_hs_97	= PHS97(H, S)	= C_PHS97(PHS, H, S)	Backward function: Pressure from enthalpy and entropy	bar
$p = f(v, h)$	p_vh_97	= PVH97(H, S)	= C_PVH97(PHS, H, S)	Backward function: Pressure from volume and enthalpy	bar
$p = f(v, u)$	p_vu_97	= PVU97(H, S)	= C_PVU97(PHS, H, S)	Backward function: Pressure from volume and internal energy	bar
$Pr = f(p, t, x)$	Pr_ptx_97	= PRPTX97(P, T, X)	= C_PRPTX97(PR, P, T, X)	<i>Prandtl</i> -number	-
$p_s = f(t)$	ps_t_97	= PST97(T)	= C_PST97(PS, T)	Vapor pressure	bar
$\rho = f(p, t, x)$	rho_ptx_97	= RHOPTX97(P, T, X)	= C_RHOPTX97(RHO, P, T, X)	Density	kg/m ³
$s = f(p, h)$	s_ph_97	= SPH97(P, H)	= C_SPH97(SPH, P, H)	Backward function: Specific entropy from pressure and enthalpy	kJ/(kg · K)
$s = f(p, t, x)$	s_ptx_97	= SPTX97(P, T, X)	= C_SPTX97(S, P, T, X)	Specific entropy	kJ/(kg · K)
$\sigma = f(p)$	sigma_p_97	= SIGMAP97(P)	= C_SIGMAP97(SIG, P)	Surface tension from pressure	mN/m = mPa · m
$\sigma = f(t)$	sigma_t_97	= SIGMAT97(T)	= C_SIGMAT97(SIG, T)	Surface tension from temperature	mN/m = mPa · m
$t = f(h, s)$	t_hs_97	= THS97(H, S)	= C_THS97(THS, H, S)	Backward function: Temperature from enthalpy and entropy	°C
$t = f(p, h)$	t_ph_97	= TPH97(P, H)	= C_TPH97(TPH, P, H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p, s)$	t_ps_97	= TPS97(P, S)	= C_TPS97(TPS, P, S)	Backward function: Temperature from pressure and entropy	°C

Functional Dependence	Function Name	Call as Function from DLL LibIF97	Call from DLL LibIF97, Result as Parameter	Property or Function	Unit of the Result
$t = f(v, h)$	t_vh_97	= TVH97(P,H)	= C_TVH97(TPH,P,H)	Backward function: Temperature from volume and enthalpy	°C
$t = f(v, u)$	t_vu_97	= TVU97(P,H)	= C_TVU97(TPH,P,H)	Backward function: Temperature from volume and internal energy	°C
$t_s = f(p)$	ts_p_97	= TSP97(P)	= C_TSP97(TS,P)	Saturation temperature	°C
$u = f(p, t, x)$	u_ptx_97	= UPTX97(P,T,X)	= C_UPTX97(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p, h)$	v_ph_97	= VPH97(P,S)	= C_VPH97(VPS,P,S)	Backward function: Specific volume from pressure and enthalpy	m³/kg
$v = f(p, s)$	v_ps_97	= VPS97(P,S)	= C_VPS97(VPS,P,S)	Backward function: Specific volume from pressure and entropy	m³/kg
$v = f(p, t, x)$	v_ptx_97	= VPTX97(P,T,X)	= C_VPTX97(V,P,T,X)	Specific volume	m³/kg
$w = f(p, t, x)$	w_ptx_97	= WPTX97(P,T,X)	= C_WPTX97(W,P,T,X)	Isentropic speed of sound	m/s
$x = f(h, s)$	x_hs_97	= XHS97(H,S)	= C_XHS97(XHS,H,S)	Backward function: Vapor fraction from enthalpy and entropy	kg/kg
$x = f(p, h)$	x_ph_97	= XPH97(P,H)	= C_XPH97(XPH,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p, s)$	x_ps_97	= XPS97(P,S)	= C_XPS97(XPS,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
$x = f(v, h)$	x_vh_97	= XVH97(P,H)	= C_XVH97(XPH,P,H)	Backward function: Vapor fraction from volume and enthalpy	kg/kg
$x = f(v, u)$	x_vu_97	= XVU97(P,H)	= C_XVU97(XPH,P,H)	Backward function: Vapor fraction from volume and internal energy	kg/kg
$z = f(p, t, x)$	z_ptx_97	= ZPTX97(P,T,X)	= C_ZPTX97(Z,P,T,X)	Compression factor	-

Units: t in °C p in bar x in kg saturated steam/kg wet steam

Range of validity of IAPWS-IF97

Temperature:	from 0 °C to 800 °C
Pressure:	from 0.00611 bar to 1000 bar
High temperature region:	to 2000 °C for pressures less than 500 bar Exception to 900°C for the functions for α , η , λ , ν , Pr

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single-phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet-steam region

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for x . When calculating wet steam either the given value for t and $p = -1$ or the given value for p and $t = -1$ and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in -1 .

(Wet steam region of the IAPWS-IF97: $t_t = 0\text{ °C} \dots t_c = 373.946\text{ °C}$
 $p_t = 0.00611\text{ bar} \dots p_c = 220.64\text{ bar}$ (c – critical point))

Note.

If the calculation results in -1 , the values entered represent a state point beyond the range of validity of IAPWS-IF97. For further information on each function and its range of validity see Chapter 4. The same information may also be accessed via the online help pages.

2. Add-In FluidEES for Engineering Equation Solver®

The FluidEES Add-In has been developed to conveniently calculate thermodynamic properties in the Engineering Equation Solver® (EES). Within EES®, it enables the direct call of functions relating water and steam from the LibIF97 property library.

2.1 Installing FluidEES including LibIF97

In this section, the installation of FluidEES LibIF97 is described.

Before you begin, it is best to close any Windows® applications you may have open, since Windows® may need to be rebooted during the installation process.

After you have downloaded and extracted the zip-file "CD_FluidEES_LibIF97_Eng.zip", you will see the folder

CD_FluidEES_LibIF97_Eng

in your Windows Explorer®, Norton Commander® or other similar program you are using.

Now, open this folder by double-clicking on it.

Within this folder you will see the following three files:

FluidEES_LibIF97_Docu_Eng.pdf

FluidEES_LibIF97_Setup.exe

LibIF97.dll.

In order to run the installation of FluidEES including the LibIF97 property library, first double-click the file

FluidEES_LibIF97_Setup.exe.

Installation may start with a window noting that all Windows® programs should be closed.

When this is the case, the installation can be continued. Click the "Next >" button.

In the following dialog box, "Destination Location" (see figure below), the default path where Engineering Equation Solver has been installed will be shown (the standard location is:

C:\Program Files\EES32\Userlib\LibIF97 (for English version of Windows)

C:\Programme\EES32\Userlib\LibIF97 (for German version of Windows)).

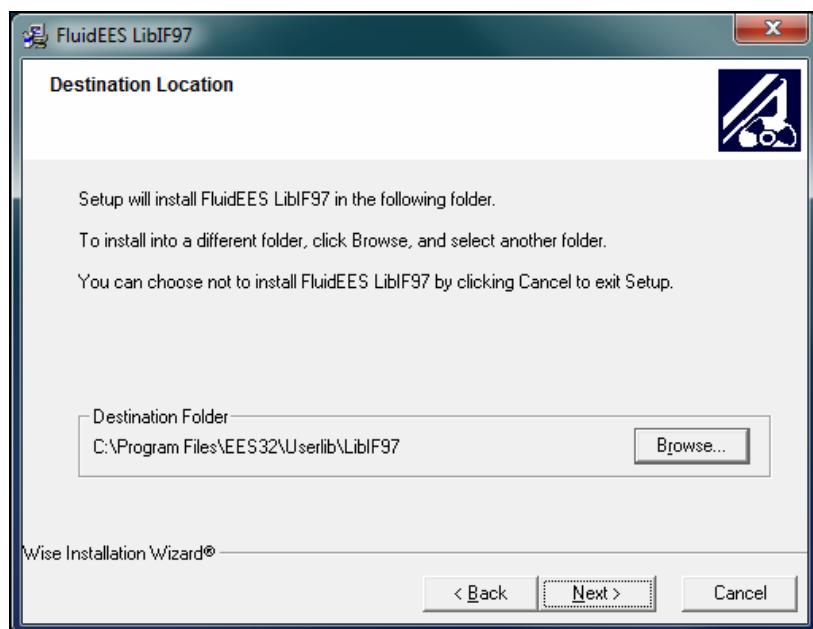


Figure 2.1: "Destination Location"

Click on "Next >" in the window "Destination Location."

Click on the "Next >" button in the "Start Installation" window.

The FluidEES files are now being copied into the "LibIF97" folder on your hard drive.

Click the "Finish >" button in the next window to complete installation.

The installation program has copied the following files into the directory

"C:\Program Files\EES32\Userlib\LibIF97"	(for English version of Windows)
"C:\Programme\EES32\Userlib\LibIF97"	(for German version of Windows):

advapi32.dll	- Dynamic link library for use in Windows® programs
Dformd.dll	- Dynamic link library for use in Windows® programs
Dforrt.dll	- Dynamic link library for use in Windows® programs
INSTALL.LOG	- Log file
LC.dll	- Dynamic link library for use in Windows® programs
LibIF97.ctx	- Interface including property functions of LibIF97 for EES®
LibIF97.dll	- Dynamic link library with property functions of LibIF97
LibIF97.hlp	- Help file of the LibIF97 property library
msvc60.dll	- Dynamic link library for use in Windows® programs
msvcrt.dll	- Dynamic link library for use in Windows® programs
UNWISE.EXE	- File to remove the LibIF97 library
UNWISE.INI	- File to remove the LibIF97 library

Now, you have to overwrite the files

LibIF97.dll

LibIF97.hlp

in your Engineering Equation Solver directory with the file of the same name provided in your CD folder with FluidEES LibIF97.

To do this, open the CD folder in "My Computer" and click on the file "LibIF97.dll" in order to highlight it.

Then click on the "Edit" menu in your Explorer and select "Copy".

Now, open your EES directory (the standard being

"C:\Program Files\EES32\Userlib\LibIF97" (for English version of Windows)

"C:\Programme\EES32\Userlib\LibIF97" (for German version of Windows):

and insert the files "LibIF97.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button.

Please, proceed in the same way to copy the "LibIF97.hlp" file.

Now, you have overwritten the file "LibIF97.dll" successfully.

You can now select the LibIF97 property functions from within Engineering Equation Solver®.

2.2 The FluidEES Help System

As mentioned earlier, FluidEES also provides detailed online help functions.

If you are running Windows Vista or Windows 7, please note the paragraph

"Using the FluidEES Online-Help in Windows Vista or Windows 7."

Information on individual property functions may be accessed via the following steps:

- Click "Options" in the EES menu bar and select "Function Info".
- The "Function Information" window will appear. Select "External routines" and double-click on the entry "LIBIF97.DLL".
- A list with calculable functions of the "LibIF97" library appears.
- Find and select the desired function, e.g. "h_ptx_97" and click the  button above.

If the "LibIF97.hlp" function help cannot be found, confirm the question whether you want to look for it yourself with "Yes." Select the "LibIF97.hlp" file in the installation menu of FluidEES in the window which is opened, the standard being

"C:\Program Files\EES32\Userlib\LibIF97" (for English version of Windows)

"C:\Programme\EES32\Userlib\LibIF97" (for German version of Windows)

and click "Yes" in order to complete the search.

Using the FluidEES Online Help in Windows Vista or Windows 7

If you are running Windows Vista or Windows 7 on your computer, you might not be able to open Help files. To view these files you have to install the Microsoft® Windows Help program which is provided by Microsoft®. Please carry out the following steps in order to download and install the Windows Help program.

Open Microsoft Internet Explorer® and go to the following address:

<http://support.microsoft.com/kb/917607/>

You will see the following web page:



Figure 2.2: Microsoft® Support web page

Scroll down until you see the headline "Resolution." Here you can see the bold hint:

"Download the appropriate version of Windows Help program (WinHlp32.exe), depending on the operating system that you are using:"

The following description relates to Windows® 7. The procedure is analogous for Windows® Vista.

Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.3).

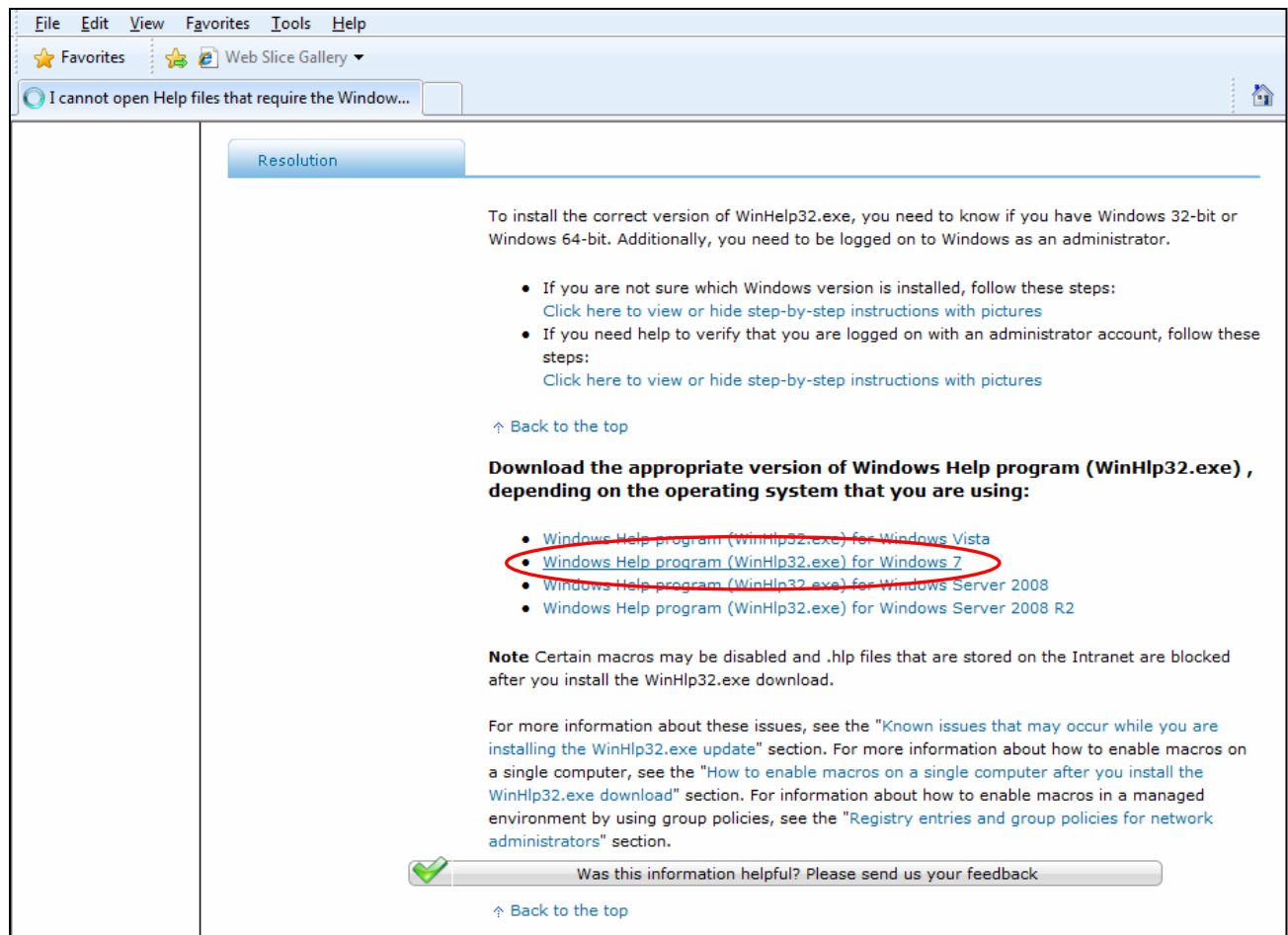


Figure 2.3: Selecting your Windows version

You will be forwarded to the Microsoft Download Center where you can download the Microsoft Windows Help program.

First, a validation of your Windows License is required.

To do this click on the "Continue" button (see Figure 2.4).

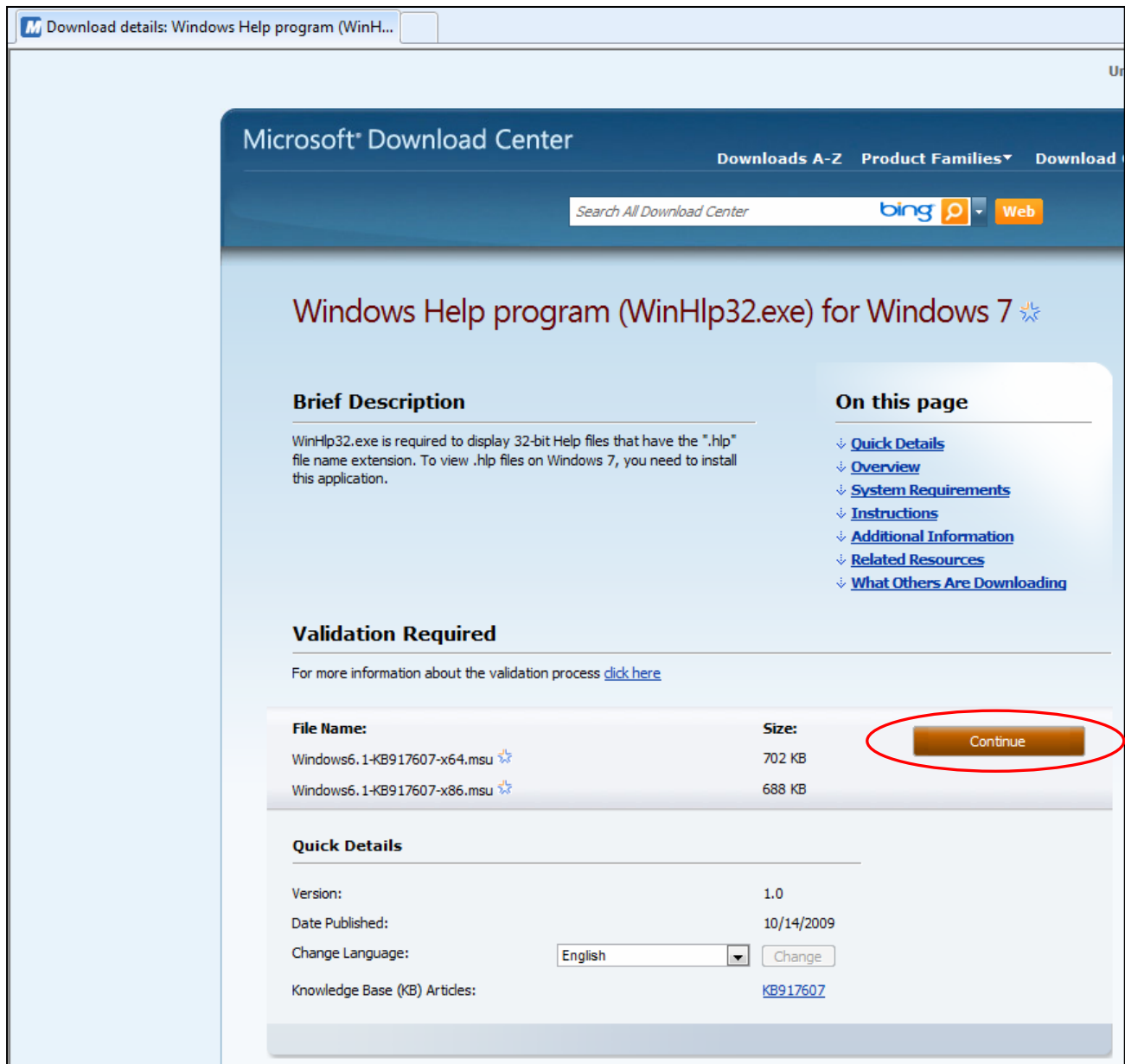


Figure 2.4: Microsoft® Download Center

You will be forwarded to a web page with instructions on how to install the Genuine Windows Validation Component.

At the top of your Windows Internet Explorer you will see a yellow information bar. Right-click this bar and select "Install ActiveX Control" in the context menu (see Figure 2.5).

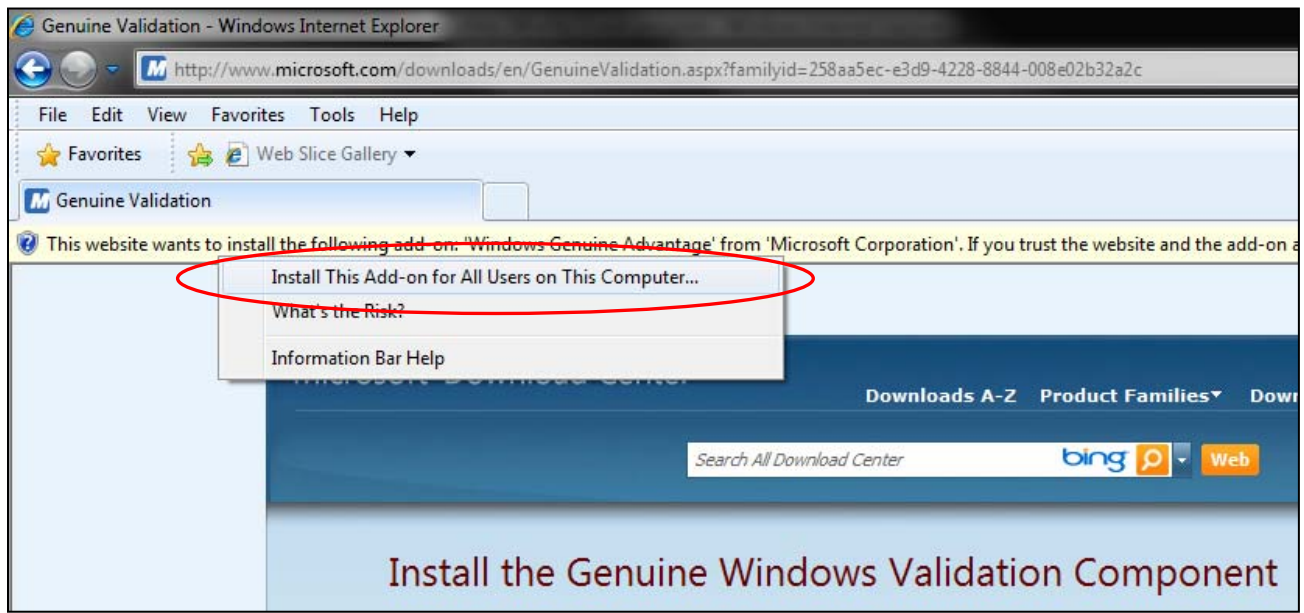


Figure 2.5: Installing the Genuine Windows Validation Component

A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue (see Figure 2.6).

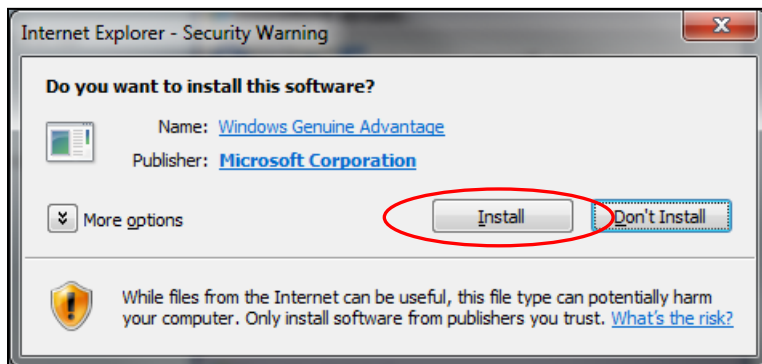


Figure 2.6: Internet Explorer – Security Warning

After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.7).

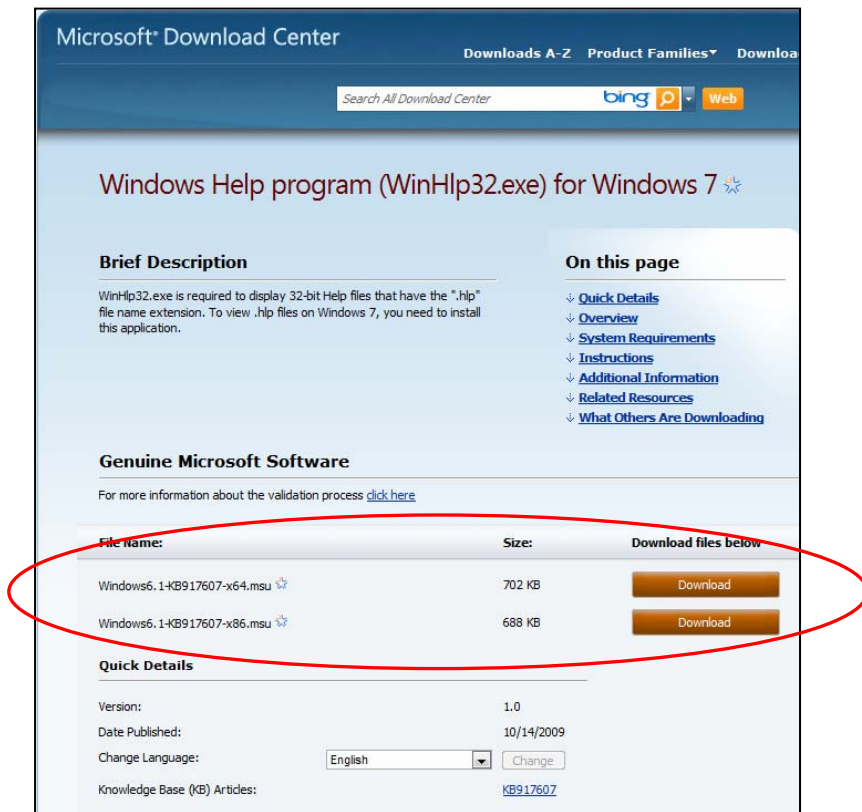


Figure 2.7: Downloading the Windows Help program

To download and install the correct file you need to know which Windows version (32-bit or 64-bit) you are running on your computer.

If you are running a 64-bit operating system, please download the file

Windows6.1-KB917607-x64.msu.

If you are running a 32-bit operating system, please download the file

Windows6.1-KB917607-x86.msu.

In order to run the installation of the Windows Help program double-click the file you have just downloaded on your computer:

Windows6.1-KB917607-x64.msu (for 64-bit operating system)

Windows6.1-KB917607-x86.msu. (for 32-bit operating system).

Installation starts with a window searching for updates on your computer. After the program has finished searching you may see the following window.

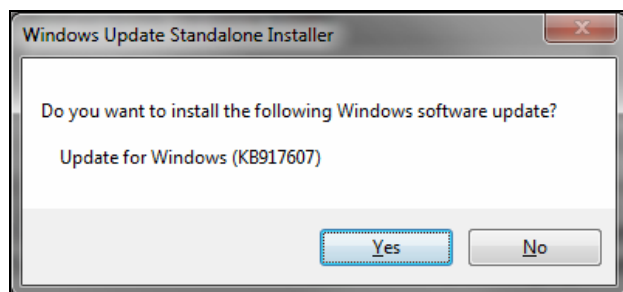


Figure 2.8: Windows Update Standalone Installer

In this case, the installation can be continued by clicking the "Yes" button.
(If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.")

In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept" (see Figure 2.9)

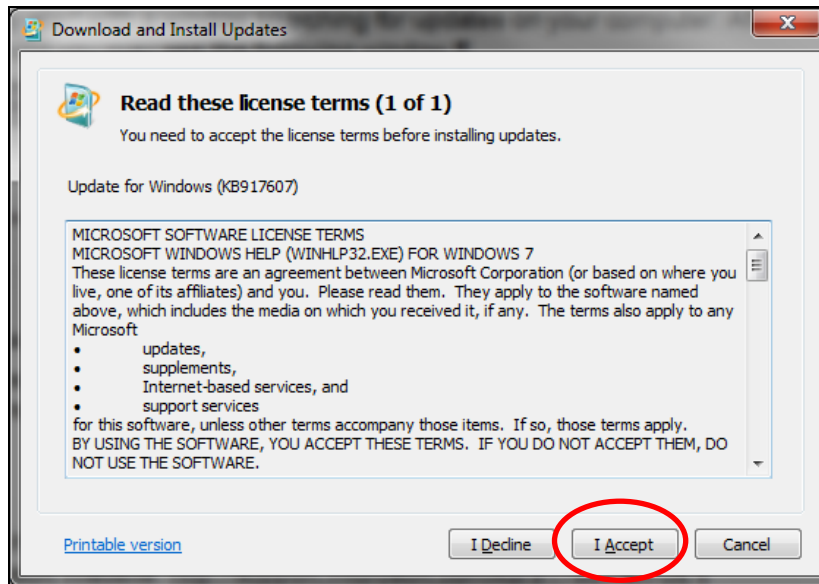


Figure 2.9: Windows License Terms

Installation starts once you have clicked the "I Accept" button (see Figure 2.10).

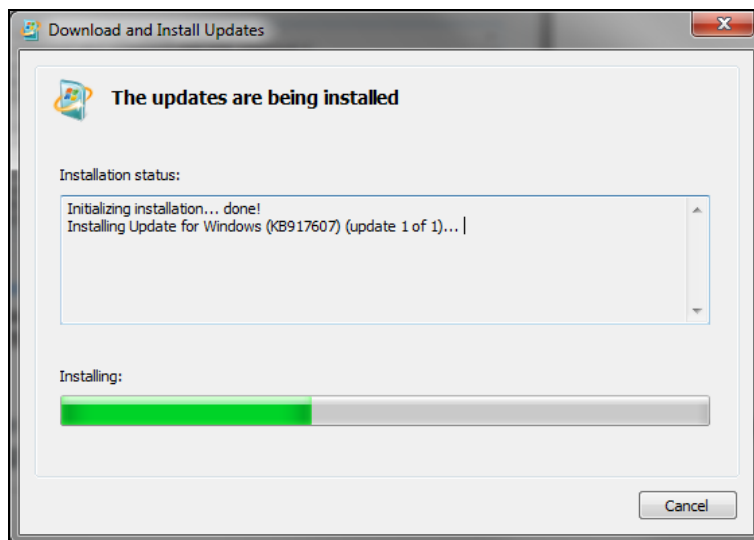


Figure 2.10: Installation process

After the Windows Help program has been installed, the notification "Installation complete" will appear. Confirm this by clicking the "Close" button.

The installation of the Windows Help program has been completed and you will now be able to open the Help files.

2.3 Licensing the LibIF97 Property Library

The licensing procedure must be carried out when Engineering Equation Solver[®] starts up and a FluidEES prompt message appears. In this case, you will see the "License Information" window for LibIF97 (see figure below).

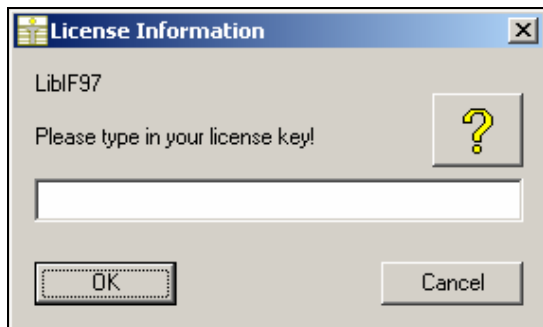


Figure 2.11: "License Information" window

Here you are asked to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. If you do not have this, or have any questions, you will find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:

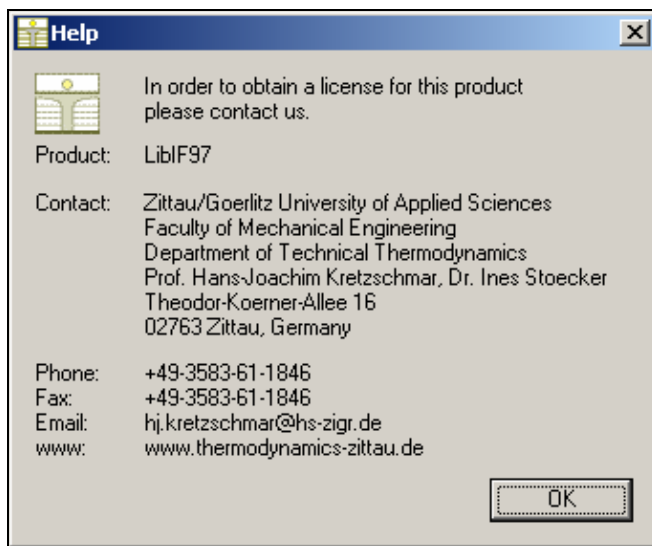


Figure 2.12: "Help" window

If you do not enter a valid license it is still possible to start EES[®] by clicking "Cancel". In this case, the LibIF97 property library will display the result "-11111111" for every calculation.

The "License Information" window will appear every time you use FluidEES LibIF97 until you enter a license code to complete registration. If you decide not to use FluidEES LibIF97, you can uninstall the program following the instructions given in section 2.5 of this User's Guide.

With this procedure the LibIF97 property library has been licensed.

2.4 Example: Calculation of the Specific Enthalpy $h = f(p, t, x)$

Now we will calculate, step by step, the specific enthalpy h as a function of pressure of p , temperature t , and vapor fraction x using FluidEES with LibIF97 in the Engineering Equation Solver®:

How to perform a calculation with FluidEES:

- Start Engineering Equation Solver® (EES).
- The LibIF97 library, if installed, is loaded by the program automatically.
- We recommend preparing an EES® sheet, as shown in Figure 2.13.

Note: The units of p , t , and x must correspond to those in Chapter 1.

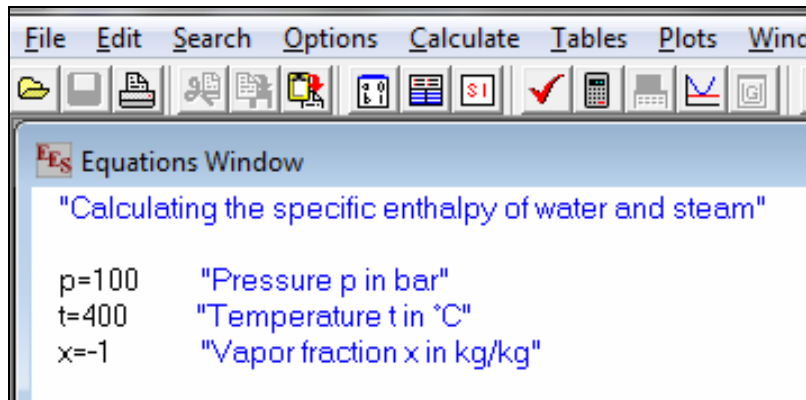


Figure 2.13: Preparing an EES® sheet for the calculation

- The function parameters values stand for:
 - **First operand: Total pressure $p = 1$ bar**
(Range of validity of the IF97: $p = 0.00611 \dots 1000$ bar
 $p = 0.00611 \dots 100$ bar for high temperature region)
 - **Second operand: Temperature $t = 100^\circ\text{C}$**
(Range of validity of the IF97: $t = 0 \dots 800$ °C
high temperature region up to 2000 °C)
 - **Third operand: $x = -1$**

Since the wet steam region is calculated automatically by the subprograms, the following fixed details on the vapor fraction x are to be considered when the value for x is entered:

Single-phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for x . It is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider p and t to be appropriate to

represent the saturation-pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1.

Wet steam region of the IAPWS-IF97:

$$t_t = 0\text{ °C} \dots t_c = 373.946\text{ °C}$$

$$p_t = 0.00611\text{ bar} \dots p_c = 220.64\text{ bar} \quad (c - \text{critical point})$$

- Confirm your entry by pressing the "ENTER" key.

Note:

EES[®] adapts to the language that is set in the "Regional and Language Options," which can be found in the "Control Panel." If you run Engineering Equation Solver[®] on an English version of Windows[®], the standard decimal separator will be a dot. If your computer is set to German, for example, the expected decimal separator will be a comma. In this case enter a comma in the values instead of a dot. To separate the input values of the different gases in a vector use a semicolon. You can find additional information on this issue by clicking on "Help" in the EES[®] menu bar and then select "Help Index". Click on "Search" in the window which appears, type "decimal separator" and press the "ENTER" key.

- For calculating $h = f(p, t, x)$, call up the function "h_ptx_97" of the property library LibIF97 as follows:
- Click on "Options" in the EES[®] menu bar and select "Function Info".
- The "Function Information" window will appear. Select "External routines" and you will see the screen shown here in Figure 2.14.

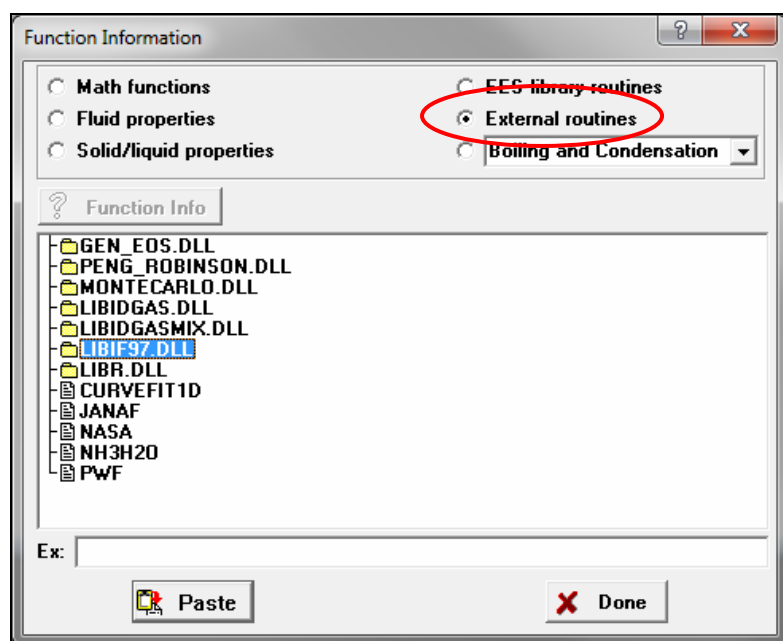


Figure 2.14: "Function Information" window offering different libraries (routines)

- Double-click on the entry "LIBIF97.DLL".
- A list with calculable functions of the "LibIF97" library appears.
- Find and select the desired function, here "h_ptx_97" (see Figure 2.15), and click the "Paste" button below.

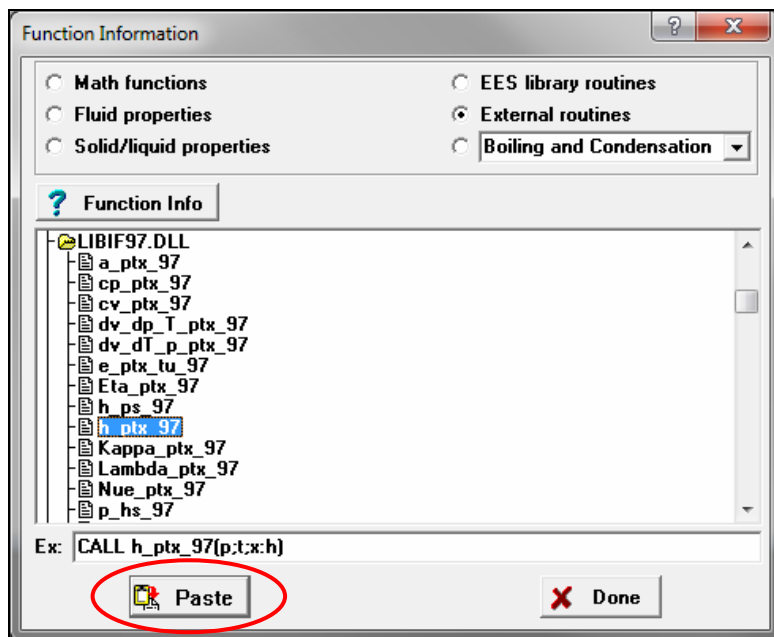


Figure 2.15: Selecting the "h_ptx_97" function

- The selected function will be copied and appears in the "Equations Window" (see Fig. 2.16).

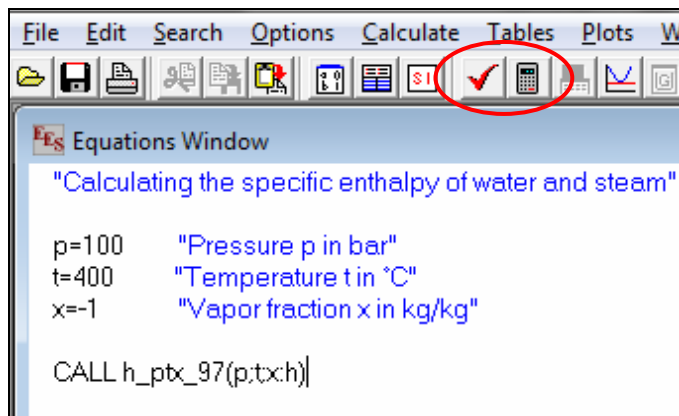


Figure 2.16: "Equations Window" with the call of the property function

- Now, you can check the syntax of the instructions in the "Equations Window" by clicking the  symbol in the upper menu bar of EES®. The program tests whether or not the syntax is correct (e.g. dots as decimal separators versus commas). Confirm the "Information" window which appears by clicking the "OK" button.
- Then click the  symbol in the upper menu bar of EES® to start the calculation.
- Soon you will see the "Calculations Completed" window. Leave this window by clicking the "Continue" button.
- The result for the specific enthalpy h appears in the "Solution" window (see Figure 2.17).

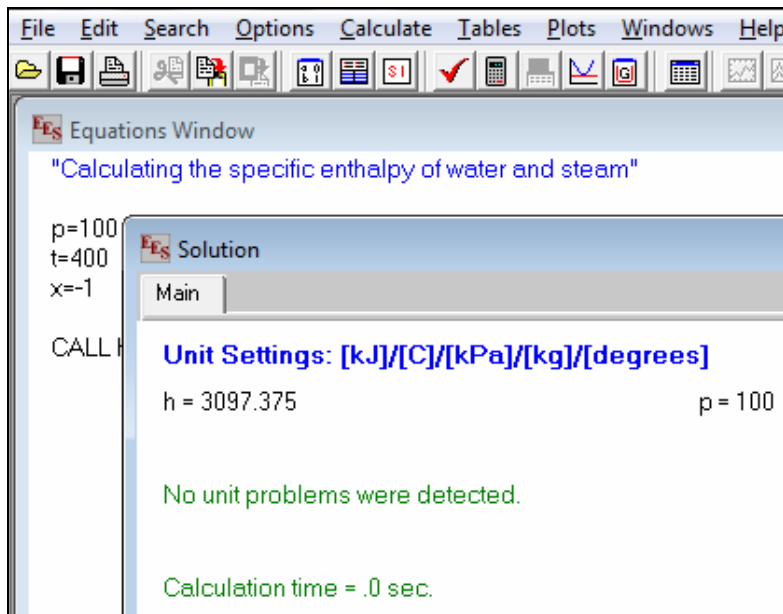


Figure 2.17: "Solution" window showing the result

The calculation of $h = f(p, t, x)$ has thus been carried out.

⇒ The result in our sample calculation here is: "h = 3097.375". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

For further property functions calculable in FluidEES see the function table in Chapter 1.

2.6 Removing FluidEES including LibIF97

In order to remove the property library LibIF97 from your hard drive in Windows®, click "Start" in the lower task bar, then "Settings" and "Control Panel."

Afterwards double-click on "Add or Remove Programs."

In the list box of the "Add or Remove Programs" menu which appears, select "FluidEES LibIF97" by clicking on it and click the "Change/Remove" button.

In the following dialog box select "Automatic" and then click the "Next >" button.

Then confirm the menu "Perform Uninstall" by clicking the "Finish" button.

Finally, close the "Add or Remove Programs" and "Control Panel" windows.

"FluidEES LibIF97" has now been removed.

3. Program Documentation

Thermal Diffusivity $a = f(p, t, x)$

Function Name: **a_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION APTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_APTX97(A,P,T,X)**
REAL*8 A,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

APTX97, A or a_ptx_97 - Thermal diffusivity $a = \frac{\lambda}{\rho \cdot c_p} = \frac{\lambda \cdot v}{c_p}$ in m²/s

Range of validity

Temperature range: from 0 °C to 900 °C
 Pressure range: from 0.00611 bar to 1000 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0$ °C to $t_c = 373.946$ °C
 Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar)

Results for wrong input values

Result **APTX97, A = -1** or **a_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 900$ °C or $t < 0$ °C

Saturation lines: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or

($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64$ bar
 or $p < 0.00611$ bar or at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 or $|t - t_s(p)| > 0.1$ K

References:

Internal calculation from ρ or v and c_p [1], [2], [3] and λ [6]

Relative Pressure Coefficient $\alpha_p = f(p, t, x)$

Function Name: **alphap_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION ALPHAPPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ALPHAPPTX97 (ALPHAP,P,T,X)**
REAL*8 ALPHAP,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ALPHAPPTX97, ALPHAP or alphap_ptx_97 - Relative pressure coefficient α_p in K^{-1}

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$

Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **ALPHAPPTX97, ALPHAP = -1** or **alphap_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 800\text{ °C}$ or $t < 0\text{ °C}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or

($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$
 or $p < 0.00611\text{ bar}$ or at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 or $|t - t_s(p)| > 0.1\text{ K}$

References:

Internal calculation from ρ or v and c_p [1], [2], [3] and λ [6]

Isobaric Cubic Expansion Coefficient $\alpha_v = f(p, t, x)$

Function Name: **alphav_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION ALPHAVPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ ALPHAVPTX97 (ALPHAV,P,T,X)**
REAL*8 ALPHAV,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ALPHAVPTX97, ALPHAV or alphav_ptx_97 - Isobaric cubic expansion coefficient α_v in K⁻¹

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0$ °C to $t_c = 373.946$ °C

Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar)

Results for wrong input values

Result **ALPHAVPTX97, ALPHAV = -1** or **alphav_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Saturation lines: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3]

Laplace Coefficient $b = f(p)$

Function Name:	b_p_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION BP97(P) REAL*8 P
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_ BP97 (B,P) REAL*8 B,P

Input values

P - Pressure p in bar

Result

BPTX97, B or **b_pt_97** - Laplace coefficient b in m

Range of validity

Pressure ranges from $p_t = 0.00611 \text{ bar}$ to $p_c = 220.64 \text{ bar}$

Results for wrong input values

Result **BP97, B = -1** or **b_p_97 = -1** for input values:

Saturation lines: at $p > 220.64 \text{ bar}$ or $p < 0.00611 \text{ bar}$

References: [1], [2], [3]

Laplace Coefficient $b = f(t)$

Function Name:	b_t_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION BT97(T) REAL*8 T
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_ BT97 (B,T) REAL*8 B,T

Input values

T - Temperature t in °C

Result

BPTX97, B or **b_pt_97** - Laplace coefficient b in m

Range of validity

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$

Results for wrong input values

Result **BT97, B = -1** or **b_t_97 = -1** for input values:

Saturation lines: $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$

References: [1], [2], [3]

Isothermal Stress Coefficient $\beta_p = f(p, t, x)$

Function Name: **betap_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION BETAPPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ BETAPPTX97 (BETAP,P,T,X)**
REAL*8 BETAP,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

BETAPPTX97, BETAP or **betap_ptx_97** - Isothermal stress coefficient β_p in kg/m³

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0$ °C to $t_c = 373.946$ °C

Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar)

Results for wrong input values

Result **BETAPPTX97, BETAP = -1** or **betap_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Saturation lines: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3]

Specific Isobaric Heat Capacity $c_p = f(p, t, x)$

Function Name: **cp_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION CPPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_CPPTX97(CP,P,T,X)**
REAL*8 CP,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

CPPTX97, CP or cp_ptx_97 - Specific isobaric heat capacity c_p in kJ/kg K

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0$ °C to $t_c = 373.946$ °C

Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar)

Results for wrong input values

Result **CPPTX97, CP = -1** or **cp_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Saturation lines: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3]

Specific Isochoric Heat Capacity $c_v = f(p, t, x)$

Function Name: **cv_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION CVPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_CVPTX97(CV,P,T,X)**
REAL*8 CV,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

CVPTX97, CV or cv_ptx_97 - Specific isochoric heat capacity c_v in kJ/kg K

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **CVPTX97, CV = -1** or **cv_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [[1], [2], [3]

Isothermal Throttling Coefficient $\delta_T = f(p, t, x)$

Function Name: **deltat_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION DELTATPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_DELTATPTX97 (DELTAT,P,T,X)**
REAL*8 DELTAT,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

DELTATPTX97, DELTAT or **deltat_ptx_97** - Isothermal throttling coefficient δ_T in $\text{kJ kg}^{-1} \text{kPa}^{-1}$

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$

Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **DELTATPTX97, DELTAT = -1** or **deltat_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Differential Quotient $\left(\frac{\partial v}{\partial p}\right)_T = f(p, t, x)$

Function Name: **dv_dp_T_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION DVDPT97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_DVDPT97(DVDPT,P,T,X)**
REAL*8 DVDPT,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

DVDPT97 - Differential quotient $\left(\frac{\partial v}{\partial p}\right)_T$ in $\text{m}^3 \cdot \text{kg}^{-1} \cdot \text{kPa}^{-1}$

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$

Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **dv_dp_T_ptx_97** or **DVDPT97** = **-1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

$$\text{Differential Quotient } \left(\frac{\partial v}{\partial T} \right)_p = f(p, t, x)$$

Function Name: **dv_dT_p_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION DVDTP97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_DVDTP97(DVDTP,P,T,X)**
REAL*8 DVDTP,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

DVDTP97 - Differential quotient $\left(\frac{\partial v}{\partial T} \right)_p$ in $\text{m}^3 \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0 \text{ °C}$ to $t_c = 373.946 \text{ °C}$

Pressure ranges from $p_t = 0.00611 \text{ bar}$ to $p_c = 220.64 \text{ bar}$)

Results for wrong input values

Result **dv_dT_p_ptx_97** or **DVDTP97** = **-1** for input values:

Single phase region: $p > 1000 \text{ bar}$ or $p < 0.00611 \text{ bar}$ or
 ($x = -1$) $t > 2000 \text{ °C}$ or $t < 0 \text{ °C}$ or
 $t > 800 \text{ °C}$ at $p > 500 \text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946 \text{ °C}$ or $t < 0 \text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64 \text{ bar}$ or $p < 0.00611 \text{ bar}$ or
 at $p > 220.64 \text{ bar}$ or $p < 0.00611 \text{ bar}$
 and $t > 373.946 \text{ °C}$ or $t < 0 \text{ °C}$
 at $|t - t_s(p)| > 0.1 \text{ K}$

References: [1], [2], [3]

Specific Exergy $e = f(p, t, x, t_u)$

Function Name: **e_ptx_tu_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION EPTXTU97(P,T,X,TU)**
REAL*8 P,T,X,TU

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_EPTXTU97(E,P,T,X,TU)**
REAL*8 E,P,T,X,TU

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)
TU - Environment temperature t_u in °C

Result

EPTXTU97, E or **e_ptx_tu_97** - Specific exergy (of the enthalpy) e in kJ/kg

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t and $p = -1$ or the given value for p and $t = -1$ and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

(Wet steam region of the IAPWS-IF97: $t_t = 0$ °C ... $t_c = 373.946$ °C
 $p_t = 0.00611$ bar ... $p_c = 220.64$ bar)

Results for wrong input values

Result **EPTXTU97, E = -1** or **e_ptx_tu_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3]

Dielectric Constant $\varepsilon = f(p, t, x)$

Function Name: **epsilon_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION EPSPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ EPSPTX97 (BETAP,P,T,X)**
REAL*8 EPS,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

EPSPTX97, EPS or **epsilon_ptx_97** - Dielectric constant ε

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **EPSPTX97, EPS = -1** or **epsilon_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Specific Helmholtz Energy $f = f(p, t, x)$

Function Name: **f_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION FPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ FPTX97 (F,P,T,X)**
REAL*8 F,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

FPTX97, F or f_ptx_97 - Specific Helmholtz energy f in kJ/kg

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **FPTX97, F = -1** or **f_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Fugacity $f^* = f(p, t, x)$

Function Name: **fug_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION FUGPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_FUGPTX97 (FUG,P,T,X)**
REAL*8 DELTAT,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

FUGPTX97, FUG or **fug_ptx_97** - Fugacity f^* in bar

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$

Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **FUGPTX97, FUG = -1** or **fug_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Specific Gibbs Energy $g = f(p, t, x)$

Function Name: **g_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION GPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ GPTX97 (G,P,T,X)**
REAL*8 G,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

GPTX97, G or g_ptx_97 - Specific Gibbs energy g in kJ/kg

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **GPTX97, G = -1** or **g_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Dynamic Viscosity $\eta = f(p, t, x)$

Function Name: **Eta_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION ETAPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ETAPTX97(ETA,P,T,X)**
REAL*8 ETA,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ETAPTX97, ETA or eta_ptx_97 - Dynamic viscosity η in Pa s

Range of validity

Temperature range: from 0 °C to 900 °C
 Pressure range: from 0.00611 bar to 1000 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0$ °C to $t_c = 373.946$ °C
 Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar)

Results for wrong input values

Result **ETAPTX97, ETA = -1** or **eta_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 900$ °C or $t < 0$ °C

Saturation lines: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References:

[7], internal calculation from ρ or v [1], [2], [3]

Backward Function: Specific Enthalpy $h = f(p,s)$

Function Name:	h_ps_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION HPS97(P,S) REAL*8 P,S
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_HPS97(H,P,S) REAL*8 H,P,S

Input values

P - Pressure p in bar
S - Specific entropy s in kJ/kg K

Result

HPS97, H or h_ps_97 - Specific enthalpy h in kJ/kg

Range of validity

Pressure range: from 0.00611 bar to 1000 bar
 Entropy range: according to temperatures from 0 °C to 800 °C
 High temperature region: to 500 bar and to entropy regarding 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of h in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **HPS97, H = -1** or **h_ps_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: $p > 220.64$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 373.946$ °C or $t < 0$ °C

References: [1], [2], [3]

Specific Enthalpy $h = f(p, t, x)$

Function Name: **h_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION HPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_HPTX97(H,P,T,X)**
REAL*8 H,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

HPTX97, H or h_ptx_97 - Specific enthalpy h in kJ/kg

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t and $p = -1$ or the given value for p and $t = -1$ and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

(Wet steam region of the IAPWS-IF97: $t_t = 0\text{ °C} \dots t_c = 373.946\text{ °C}$
 $p_t = 0.00611\text{ bar} \dots p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **HPTX97, H = -1** or **h_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Wet steam region: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Isentropic Exponent $\kappa = f(p, t, x)$

Function Name: **Kappa_ptx_97**
 Sub-program with function value: **REAL*8 FUNCTION KAPPTX97(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**
 Sub-program with parameter: **INTEGER*4 FUNCTION C_KAPPTX97(KAPPA,P,T,X)**
 for call from DLL **REAL*8 KAPPA,P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

KAPPTX97, KAPPA or **kappa_ptx_97** - Isentropic exponent $\kappa = -\frac{v}{p} \left(\frac{\partial p}{\partial v} \right)_s = \frac{w^2}{p \cdot v}$

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0$ °C to $t_c = 373.946$ °C
 Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar)

Results for wrong input values

Result **KAPPTX97, KAPPA = -1** or **kappa_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar
 Saturation lines: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3]

Isothermal Compressibility $\kappa_T = f(p, t, x)$

Function Name: **kappat_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION KAPPATPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ KAPPATPTX97 (KAPPAT,P,T,X)**
REAL*8 KAPPAT,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

KAPPATPTX97, KAPPAT or **kappat_ptx_97** - Isothermal compressibility κ_T in kPa^{-1}

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$

Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **KAPPATPTX97, KAPPAT = -1** or **kappat_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Thermal Conductivity $\lambda = f(p, t, x)$

Function Name: **Lambda_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION LAMPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_LAMPTX97(LAM,P,T,X)**
REAL*8 LAM,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

LAMPTX97, LAM or **lambda_ptx_97** - Thermal conductivity λ in W/m·K

Range of validity

Temperature range: from 0 °C to 900 °C
 Pressure range: from 0.00611 bar to 1000 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0$ °C to $t_c = 373.946$ °C
 Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar)

Results for wrong input values

Result **LAMPTX97, LAM** = **-1** or **lambda_ptx_97** = **-1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 900$ °C or $t < 0$ °C

Saturation lines: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References:

[6], Internal calculation from ρ or v [1], [2], [3]

Joule-Thomson Coefficient $\mu = f(p, t, x)$

Function Name: **my_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION MYPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_MYPTX97 (MY,P,T,X)**
REAL*8 MY,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

MYPTX97, MY or my_ptx_97 - Joule-Thomson coefficient μ in K kPa⁻¹

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$

Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **MYPTX97, MY = -1** or **my_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Refractive Index $n = f(p, t, x, w_l)$

Function Name: **n_ptxwl_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION NPTXWL97(P,T,X,WL)**
REAL*8 P,T,X,WL

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ NPTXWL97 (N,P,T,X,WL)**
REAL*8 N,P,T,X,WL

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

NPTXWL97, N or **n_ptxwl_97** - Refractive index n

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar
 Wavelength region: from 0.2 μm to 1.1 μm

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **NPTXWL97, N = -1** or **n_ptxwl_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Kinematic Viscosity $\nu = f(p, t, x)$

Function Name: **Ny_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION NYPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_NYPTX97(NY,P,T,X)**
REAL*8 NY,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

NYPTX97, NY or ny_ptx_97 - Kinematic viscosity $\nu = \frac{\eta}{\rho} = \eta \cdot v$ in m^2 / s

Range of validity

Temperature range: from 0 °C to 900 °C
 Pressure range: from 0.00611 bar to 1000 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **NYPTX97, NY = -1 or ny_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 900\text{ °C}$ or $t < 0\text{ °C}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References:

Internal calculation from η [7] and ρ or v [1], [2], [3]

Backward Function: Pressure $p = f(h,s)$

Function Name:	p_hs_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION PHS97(H,S) REAL*8 H,S
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_PHS97(P,H,S) REAL*8 P,H,S

Input values

H - Specific enthalpy h in kJ/kg
S - Specific entropy s in kJ/kg K

Result

PHS97, p or **p_hs_97** - Pressure p in bar

Range of validity

Enthalpy range and entropy range according to pressures from 0.00611 bar to 1000 bar and
 Temperatures from 0 °C to 800 °C

High temperature region: according to pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of h and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of p in the appropriate region will be carried out.

Results for wrong input values

Result **PHS97, P = -1** or **p_hs_97 = -1** for input values:

$s < -0.009$ kJ/kg K
 $h < h'(0.00611 \text{ bar}, x)$ at $h'(0.00611 \text{ bar}) < h < h''(0.00611 \text{ bar})$

References: [1], [2], [3]

Backward Function: Pressure $p = f(v, h)$

Function Name:	p_vh_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION PVH97(V,H) REAL*8 V,H
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_PVH97(P,H) REAL*8 P,V,H

Input values

V - Specific volume v in m^3/kg

H - Specific enthalpy h in kJ/kg

Result

PVH97, p or **p_vh_97** - Pressure p in bar

Range of validity

Enthalpy range and entropy range: according to pressures from 0.00611 bar to 1000 bar and
Temperatures from 0 °C to 800 °C

High temperature region: according to pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of v and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of p in the appropriate region will be carried out.

Results for wrong input values

Result **PVH97, P = -1** or **p_vh_97 = -1** for input values:

$v < 0.0009 \text{ m}^3/\text{kg}$

$h < h'(0.00611 \text{ bar}, x)$ at $h'(0.00611 \text{ bar}) < h < h''(0.00611 \text{ bar})$

References: [1], [2], [3]

Backward Function: Pressure $p = f(v, u)$

Function Name:	p_vu_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION PVU97(V,U) REAL*8 V,U
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_VU97(P,V,U) REAL*8 P,V,U

Input values

V - Specific volume h in kJ/kg
U - Specific internal energy u in kJ/kg

Result

PVU97, p or **p_vu_97** - Pressure p in bar

Range of validity

Enthalpy range and entropy range: according to pressures from 0.00611 bar to 1000 bar and temperatures from 0 °C to 800 °C

High temperature region: according to pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of v and u the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of p in the appropriate region will be carried out.

Results for wrong input values

Result **PVU97, P = -1** or **p_vu_97 = -1** for input values:

$v < 0.0009 \text{ m}^3/\text{kg}$
 $u < u(0.00611 \text{ bar}, x)$ at $u'(0.00611 \text{ bar}) < u < u''(0.00611 \text{ bar})$

References: [1], [2], [3]

Prandtl-Number $Pr = f(p, t, x)$

Function Name: **Pr_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION PRPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_PRPTX97(PR,P,T,X)**
REAL*8 PR,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

PRPTX97, Pr or Pr_ptx_97 - Prandtl-number $Pr = \frac{\nu}{a} = \frac{\eta \cdot c_p}{\lambda}$

Range of validity

Temperature range: from 0 °C to 900 °C
 Pressure range: from 0.00611 bar to 1000 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **PRPTX97, Pr = -1** or **Pr_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 900\text{ °C}$ or $t < 0\text{ °C}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References:

Internal calculation of η [7], [6], and ρ or ν and c_p [1], [2], [3]

Vapor Pressure $p_s = f(t)$

Function Name:	ps_t_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION PST97(T) REAL*8 T
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_PST97(PS,T) REAL*8 PS,T

Input values

T - Temperature t in °C

Result

PST97, PS or **ps_t_97** - Vapor pressure p_s in bar

Range of validity

from $t_t = 0$ °C to $t_c = 373.946$ °C

Results for wrong input values

Result **PST97, PS = -1** or **ps_t_97 = -1** for input values:
 $t < 0$ °C or $t > 373.946$ °C

References: [1], [2], [3]

Density $\rho = f(p, t, x)$

Function Name:	Rho_ptx_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION RHOPTX97(P,T,X) REAL*8 P,T,X
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_RHOPTX97(RHO,P,T,X) REAL*8 RHO,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

RHOPTX97, RHO or rho_ptx_97 - Density $\rho = \frac{1}{v}$ in kg/m³

Range of validity

Temperature range:	from 0 °C to 800 °C
Pressure range:	from 0.00611 bar to 1000 bar
High temperature region:	to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t and $p = -1$ or the given value for p and $t = -1$ and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

(Wet steam region of the IAPWS-IF97: $t_t = 0$ °C ... $t_c = 373.946$ °C
 $p_t = 0.00611$ bar ... $p_c = 220.64$ bar)

Results for wrong input values

Result **RHOPTX97, RHO = -1 or rho_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 $(x = -1)$ $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 $(0 \leq x \leq 1)$ at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
at $p > 220.64$ bar or $p < 0.00611$ bar
and $t > 373.946$ °C or $t < 0$ °C
at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3]

Backward Function: Specific Entropy $s = f(p, h)$

Function Name:	s_ph_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION SPH97(P,H) REAL*8 P,H
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_SPH97(S,P,H) REAL*8 S,P,H

Input values

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

SPH97, S or **s_ph_97** - Specific entropy s in kJ/kg K

Range of validity

Pressure range:	from 0.00611 bar to 1000 bar
Enthalpy range:	according temperatures from 0 °C to 800 °C
High temperature region:	to 500 bar and to enthalpy regarding 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of s in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **SPH97, S** = -1 or **s_ph_97** = -1 for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: $p > 220.64$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 373.946$ °C or $t < 0$ °C

References: [1], [2], [3]

Specific Entropy $s = f(p, t, x)$

Function Name: **s_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION SPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_SPTX97(S,P,T,X)**
REAL*8 S,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

SPTX97, S or **s_ptx_97** - Specific entropy s in kJ/kg K

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t and $p = -1$ or the given value for p and $t = -1$ and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

(Wet steam region of the IAPWS-IF97: $t_t = 0\text{ °C} \dots t_c = 373.946\text{ °C}$
 $p_t = 0.00611\text{ bar} \dots p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **SPTX97, S = -1** or **s_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Wet steam region: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Surface Tension $\sigma = f(p)$

Function Name:	Sigma_p_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION SIGMAP97(P) REAL*8 P
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_SIGMAP97(SIGMA,P) REAL*8 SIGMA,P

Input values

P - Pressure p in bar

Result

SIGMAP97, SIGMA or **sigma_p_97** - Surface tension σ in mN/m = mPa · m

Range of validity

from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **SIGMAP97, SIGMA = -1** or **sigma_p_97 = -1** for input values:

$p < 0.00611$ bar or $p > 220.64$ bar

References:

[8], internal calculation with $t_s = f(p)$ [1], [2], [3]

Surface Tension $\sigma = f(t)$

Function Name:	Sigma_t_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION SIGMAT97(T) REAL*8 T
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_SIGMAT97(SIGMA,T) REAL*8 SIGMA,T

Input values

T - Temperature t in °C

Result

SIGMAT97, SIGMA or **sigma_t_97** - Surface tension σ in mN/m = mPa·m

Range of validity

from $t_t = 0$ °C to $t_c = 373.946$ °C

Results for wrong input values

Result **SIGMAT97, SIGMA** = **-1** or **sigma_t_97** = **-1** for input values:
 $t < 0$ °C or $t > 373.946$ °C

References: [8]

Backward Function: Temperature $t = f(h,s)$

Function Name:	t_hs_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION THS97(H,S) REAL*8 H,S
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_THS97(T,H,S) REAL*8 T,H,S

Input values

H - Specific enthalpy h in kJ/kg
S - Specific entropy s in kJ/kg K

Result

THS97, T or t_hs_97 - Temperature t in °C

Range of validity

Enthalpy range and entropy range: according to pressures from 0.00611 bar to 1000 bar and temperatures from 0 °C to 800 °C

High temperature region: according to pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of h and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Results for wrong input values

Result **THS97, T = -1** or **t_hs_97 = -1** for input values:

$s < -0.009$ kJ/kg K

$h < h(0.00611 \text{ bar}, x)$ at $h'(0.00611 \text{ bar}) < h < h''(0.00611 \text{ bar})$

References: [1], [2], [3]

#KS+ **Backward Function: Temperature $t = f(p,h)$**

Function Name: **t_ph_97**

Sub-program with function value: **REAL*8 FUNCTION TPH97(P,H)**
for call from Fortran **REAL*8 P,H**

Sub-program with parameter: **INTEGER*4 FUNCTION C_TPH97(T,P,H)**
for call from DLL **REAL*8 T,P,H**

Input values

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

TPH97, T or **t_ph_97** - Temperature t in °C

Range of validity

Pressure range: from 0.00611 bar to 1000 bar
 Enthalpy range: according temperatures from 0 °C to 800 °C
 High temperature region: to 500 bar and to enthalpy regarding 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **TPH97, T = -1** or **t_ph_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: $p > 220.64$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 373.946$ °C or $t < 0$ °C

References: [1], [2], [3]

FUNC_97_200

^K Backward function: Temperature $t = f(p,h)$

^S Backward function: Temperature, $t = f(p,h)$

⁺ SUCH:200

Backward Function: Temperature $t = f(p,s)$

Function Name:	t_ps_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION TPS97(P,S) REAL*8 P,S
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_TPS97(T,P,S) REAL*8 T,P,S

Input values

P - Pressure p in bar
S - Specific entropy s in kJ/kg K

Result

TPS97, T or t_ps_97 - Temperature t in °C

Range of validity

Pressure range:	from 0.00611 bar to 1000 bar
Entropy range:	according temperatures from 0 °C to 800 °C
High temperature region:	to 500 bar and to entropy regarding 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **TPS97, T = -1** or **t_ps_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: $p > 220.64$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 373.946$ °C or $t < 0$ °C

References: [1], [2], [3]

#KS+ **Backward Function: Temperature $t = f(v, h)$**

Function Name: **t_vh_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION TVH97(V,H)**
REAL*8 V,H

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_TVH97(T,V,H)**
REAL*8 T,V,H

Input values

V - Specific volume v in m^3/kg

H - Specific enthalpy h in kJ/kg

Result

TVH97, T or **t_vh_97** - Temperature t in $^{\circ}\text{C}$

Range of validity

Pressure range: from 0.00611 bar to 1000 bar

Enthalpy range: according temperatures from 0°C to 800°C

High temperature region: to 500 bar and to enthalpy regarding 2000°C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of v and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611 \text{ bar}$ to $p_c = 220.64 \text{ bar}$

Results for wrong input values

Result **TVH97, T = -1** or **t_vh_97 = -1** for input values:

$v < 0.0009 \text{ m}^3/\text{kg}$

$h < h(0.00611 \text{ bar}, x)$ at $h'(0.00611 \text{ bar}) < h < h''(0.00611 \text{ bar})$

References: [1], [2], [3]

FUNC_97_212

^K Backward function: Temperature $t = f(v, h)$

^S Backward function: Temperature, $t = f(v, h)$

⁺ SUCH:212

#KS+ **Backward Function: Temperature $t = f(v,u)$**

Function Name: **t_vu_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION TVU97(V,U)**
REAL*8 V,U

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_TVU97(T,V,U)**
REAL*8 T,V,U

Input values

V - Specific volume v in m^3/kg
U - Specific internal energy u in kJ/kg

Result

TVU97, T or **t_vu_97** - Temperature t in $^{\circ}\text{C}$

Range of validity

Pressure range: from 0.00611 bar to 1000 bar
 Enthalpy range: according temperatures from 0°C to 800°C
 High temperature region: to 500 bar and to enthalpy regarding 2000°C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of v and u the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611 \text{ bar}$ to $p_c = 220.64 \text{ bar}$

Results for wrong input values

Result **TVU97, T = -1** or **t_vu_97 = -1** for input values:

$v < 0.0009 \text{ m}^3/\text{kg}$
 $u < u(0.00611 \text{ bar}, x)$ at $u'(0.00611 \text{ bar}) < u < u''(0.00611 \text{ bar})$

References: [1], [2], [3]

FUNC_97_214

^K Backward function: Temperature $t = f(v,u)$

^S Backward function: Temperature, $t = f(v,u)$

⁺ SUCH:214

Saturation Temperature $t_s = f(p)$

Function Name:	ts_p_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION TSP97(P) REAL*8 P
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_TSP97(TS,P) REAL*8 TS,P

Input values

P - Pressure p in bar

Result

TSP97, T or **ts_p_97** - Saturation temperature t_s in °C

Range of validity

from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **TSP97, T** = **-1** or **ts_p_97** = **-1** for input values:
 $p < 0.00611$ bar or $p > 220.64$ bar

References: [1], [2], [3]

Specific Internal Energy $u = f(p, t, x)$

Function Name: **u_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION UPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_UPTX97(U,P,T,X)**
REAL*8 U,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

UPTX97, U or u_ptx_97 - Specific internal energy u in kJ/kg

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t and $p = -1$ or the given value for p and $t = -1$ and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

(Wet steam region of the IAPWS-IF97: $t_t = 0\text{ °C} \dots t_c = 373.946\text{ °C}$
 $p_t = 0.00611\text{ bar} \dots p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **UPTX97, U = -1** or **u_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Wet steam region: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Backward Function: Specific Volume $v = f(p, h)$

Function Name:	v_ph_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION VPH97(P,H) REAL*8 P,H
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_VPH97(V,P,H) REAL*8 V,P,H

Input values

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

VPH97, V or **v_ph_97** - Specific volume v in m³/kg

Range of validity

Pressure range:	from 0.00611 bar to 1000 bar
Enthalpy range:	according to temperatures from 0 °C to 800 °C
High temperature region:	to 500 bar and to enthalpy regarding 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of v in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **VPH97, V = -1** or **v_ph_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: $p > 220.64$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 373.946$ °C or $t < 0$ °C

References: [1], [2], [3]

Backward Function: Specific Volume $v = f(p,s)$

Function Name:	v_ps_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION VPS97(P,S) REAL*8 P,S
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_VPS97(V,P,S) REAL*8 V,P,S

Input values

P - Pressure p in bar
S - Specific entropy s in kJ/kg K

Result

VPS97, V or v_ps_97 - Specific volume v in m³/kg

Range of validity

Pressure range:	from 0.00611 bar to 1000 bar
Entropy range:	according to temperatures from 0 °C to 800 °C
High temperature region:	to 500 bar and to entropy regarding 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of v in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

Result **VPS97, V = -1** or **v_ps_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: $p > 220.64$ bar or $p < 0.00611$ bar or
 at internal calculation result $t > 373.946$ °C or $t < 0$ °C

References: [1], [2], [3]

Specific Volume $v = f(p, t, x)$

Function Name: **v_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION VPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_VPTX97(V,P,T,X)**
REAL*8 V,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

VPTX97, V or v_ptx_97 - Specific volume v in m³/kg

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t and $p = -1$ or the given value for p and $t = -1$ and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

(Wet steam region of the IAPWS-IF97: $t_t = 0$ °C ... $t_c = 373.946$ °C
 $p_t = 0.00611$ bar ... $p_c = 220.64$ bar)

Results for wrong input values

Result **VPTX97, V = -1** or **v_ptx_97 = -1** for input values:

Single phase region: $p > 1000$ bar or $p < 0.00611$ bar or
 ($x = -1$) $t > 2000$ °C or $t < 0$ °C or
 $t > 800$ °C at $p > 500$ bar

Wet steam region: at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or
 ($0 \leq x \leq 1$) at $t = -1$ and $p > 220.64$ bar or $p < 0.00611$ bar or
 at $p > 220.64$ bar or $p < 0.00611$ bar
 and $t > 373.946$ °C or $t < 0$ °C
 at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3]

Isentropic Speed of Sound $w = f(p, t, x)$

Function Name: **w_ptx_97**

Sub-program with function value: **REAL*8 FUNCTION WPTX97(P,T,X)**
for call from Fortran **REAL*8 P,T,X**

Sub-program with parameter: **INTEGER*4 FUNCTION C_WPTX97(W,P,T,X)**
for call from DLL **REAL*8 W,P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

WPTX97, W or **w_ptx_97** - Isentropic speed of sound w in m/s

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **WPTX97, W = -1** or **w_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]

Backward Function: Vapor Fraction $x = f(h,s)$

Function Name:	x_hs_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION XHS97(H,S) REAL*8 H,S
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_XHS97(X,H,S) REAL*8 X,H,S

Input values

H - Specific enthalpy h in kJ/kg
S - Specific entropy s in kJ/kg K

Result

XHS97, X or x_hs_97 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Range of validity

Enthalpy range and entropy range according to pressures from 0.00611 bar to 1000 bar and
 Temperatures from 0 °C to 800 °C

High temperature region: according pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of h and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result $x = -1$ will be returned.

Results for wrong input values

Result **XHS97, X = -1** or **x_hs_97 = -1** for input values:

$s < -0.009$ kJ/kg K
 $h < h(0.00611 \text{ bar}, x)$ at $h'(0.00611 \text{ bar}) < h < h''(0.00611 \text{ bar})$
 if the state point is located in the single phase region

References: [1], [2], [3]

Backward Function: Vapor Fraction $x = f(p, h)$

Function Name:	x_ph_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION XPH97(P,H) REAL*8 P,H
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_XPH97(X,P,H) REAL*8 X,P,H

Input values

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

XPH97, X or x_ph_97 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Range of validity

Pressure range: from 0.00611 bar to 1000 bar

Enthalpy range: according to pressures from 0.00611 bar to 1000 bar and
 Temperatures from 0 °C to 800 °C

High temperature region: according pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result $x = -1$ will be returned.

Results for wrong input values

Result **XPH97, X = -1** or **x_ph_97 = -1** for input values:

if the state point is located in the single phase region
 $p > 220.64$ bar or $p < 0.00611$ bar

References: [1], [2], [3]

Backward Function: Vapor Fraction $x = f(v, h)$

Function Name:	x_vh_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION XVH97(V,H) REAL*8 V,H
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_XVH97(X,V,H) REAL*8 X,V,H

Input values

V - Specific volume v in m^3/kg

H - Specific enthalpy h in kJ/kg

Result

XVH97, X or x_vh_97 - Vapor fraction x in $(\text{kg saturated steam})/(\text{kg wet steam})$

Range of validity

Enthalpy range: according to pressures from 0.00611 bar to 1000 bar and temperatures from 0 °C to 800 °C

High temperature region: according to pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of v and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result $x = -1$ will be returned.

Results for wrong input values

Result **XVH97, X = -1** or **x_vh_97 = -1** for input values:

if the state point is located in the single phase region

$p > 220.64 \text{ bar}$ or $p < 0.00611 \text{ bar}$

References: [1], [2], [3]

Backward Function: Vapor Fraction $x = f(v,u)$

Function Name:	x_vu_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION XVU97(V,U) REAL*8 V,U
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_XVU97(X,V,U) REAL*8 X,V,U

Input values

V - Specific volume v in m^3/kg

U - Specific internal energy u in kJ/kg

Result

XVU97, X or **x_vu_97** - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Range of validity

Enthalpy range: according to pressures from 0.00611 bar to 1000 bar and temperatures from 0 °C to 800 °C

High temperature region: according to pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of v and u the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result $x = -1$ will be returned.

Results for wrong input values

Result **XVU97, X = -1** or **x_vu_97 = -1** for input values:

if the state point is located in the single phase region

$p > 220.64 \text{ bar}$ or $p < 0.00611 \text{ bar}$

References: [1], [2], [3]

Backward Function: Vapor Fraction $x = f(p,s)$

Function Name:	x_ps_97
Sub-program with function value: for call from Fortran	REAL*8 FUNCTION XPS97(P,S) REAL*8 P,S
Sub-program with parameter: for call from DLL	INTEGER*4 FUNCTION C_XPS97(X,P,S) REAL*8 X,P,S

Input values

P - Pressure p in bar
S - Specific entropy s in kJ/kg K

Result

XPS97, X or x_ps_97 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Range of validity

Pressure range: from 0.00611 bar to 1000 bar

Entropy range: according to pressures from 0.00611 bar to 1000 bar and
 temperatures from 0 °C to 800 °C

High temperature region: according pressures to 500 bar and temperatures to 2000 °C

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result $x = -1$ will be returned.

Results for wrong input values

Result **XPS97, X = -1** or **x_ps_97 = -1** for input values:

if the state point is located in the single phase region
 $p > 220.64$ bar or $p < 0.00611$ bar

References: [1], [2], [3]

Compression Factor $z = f(p, t, x)$

Function Name: **z_ptx_97**

Sub-program with function value:
for call from Fortran **REAL*8 FUNCTION ZPTX97(P,T,X)**
REAL*8 P,T,X

Sub-program with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ZPTX97 (Z,P,T,X)**
REAL*8 Z,P,T,X

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ZPTX97, Z or z_ptx_97 - Compression factor z

Range of validity

Temperature range: from 0 °C to 800 °C
 Pressure range: from 0.00611 bar to 1000 bar
 High temperature region: to 2000 °C at pressures to 500 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

Temperature ranges from $t_t = 0\text{ °C}$ to $t_c = 373.946\text{ °C}$
 Pressure ranges from $p_t = 0.00611\text{ bar}$ to $p_c = 220.64\text{ bar}$)

Results for wrong input values

Result **ZPTX97, Z = -1** or **z_ptx_97 = -1** for input values:

Single phase region: $p > 1000\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 ($x = -1$) $t > 2000\text{ °C}$ or $t < 0\text{ °C}$ or
 $t > 800\text{ °C}$ at $p > 500\text{ bar}$

Saturation lines: at $p = -1$ and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$ or
 ($x = 0$ or $x = 1$) at $t = -1$ and $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$ or
 at $p > 220.64\text{ bar}$ or $p < 0.00611\text{ bar}$
 and $t > 373.946\text{ °C}$ or $t < 0\text{ °C}$
 at $|t - t_s(p)| > 0.1\text{ K}$

References: [1], [2], [3]



4. Property Libraries for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

Water and Steam

Library LibIF97

- Industrial Formulation IAPWS-IF97 (Revision 2007)
- Supplementary Standards
 - IAPWS-IF97-S01
 - IAPWS-IF97-S03rev
 - IAPWS-IF97-S04
 - IAPWS-IF97-S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)

Humid Combustion Gas Mixtures

Library LibHuGas

- Model: Ideal mixture of the real fluids:
- CO₂ - Span and Wagner O₂ - Schmidt and Wagner
H₂O - IAPWS-95 Ar - Tegeler et al.
N₂ - Span et al.
- and of the ideal gases:
- SO₂, CO, Ne (Scientific Formulation of Bückner et al.)
- Consideration of:
- Dissociation from VDI 4670 and Poynting effect

Humid Air

Library LibHuAir

- Model: Ideal mixture of the real fluids:
- Dry Air from Lemmon et al.
 - Steam, water and ice from IAPWS-IF97 and IAPWS-06
- Consideration of:
- Condensation and freezing of steam
 - Dissociation from the VDI 4670
 - Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Formulation 2008 of Feistel and IAPWS-IF97

Ice

Library LibICE

Ice from IAPWS-06, Melting and sublimation pressures from IAPWS-08, Water from IAPWS-IF97, Steam from IAPWS-95 and -IF97

Ideal Gas Mixtures

Library LibIdGasMix

- Model: Ideal mixture of the ideal gases:
- | | | | |
|-----------------|------------------|-----------------|------------|
| Ar | NO | He | Propylene |
| Ne | H ₂ O | F ₂ | Propane |
| N ₂ | SO ₂ | NH ₃ | Iso-Butane |
| O ₂ | H ₂ | Methane | n-Butane |
| CO | H ₂ S | Ethane | Benzene |
| CO ₂ | OH | Ethylene | Methanol |
| Air | | | |

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bückner et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bückner et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

IAPWS Guideline 2001 of Tillner-Roth and Friend (1998)

Helmholtz energy equation for the mixing term (also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

- | | |
|---|---------------------|
| C ₂ H ₆ O ₂ | Ethylene glycol |
| C ₃ H ₈ O ₂ | Propylene glycol |
| C ₂ H ₅ OH | Ethyl alcohol |
| CH ₃ OH | Methyl alcohol |
| C ₃ H ₈ O ₃ | Glycerol |
| K ₂ CO ₃ | Potassium carbonate |
| CaCl ₂ | Calcium chloride |
| MgCl ₂ | Magnesium chloride |
| NaCl | Sodium chloride |
| C ₂ H ₃ KO ₂ | Potassium acetate |

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $C_8H_{24}O_4Si_4$ **Library LibD4**

Decamethylcyclopentasiloxane $C_{10}H_{30}O_5Si_5$ **Library LibD5**

Tetradecamethylhexasiloxane $C_{14}H_{42}O_6Si_6$ **Library LibMD4M**

Hexamethyldisiloxane $C_6H_{18}OSi_2$ **Library LibMM**

Formulation of Colonna et al. (2006)

Dodecamethylcyclohexasiloxane $C_{12}H_{36}O_6Si_6$ **Library LibD6**

Decamethyltetrasiloxane $C_{10}H_{30}O_3Si_4$ **Library LibMD2M**

Dodecamethylpentasiloxane $C_{12}H_{36}O_4Si_5$ **Library LibMD3M**

Octamethyltrisiloxane $C_8H_{24}O_2Si_3$ **Library LibMDM**

Formulation of Colonna et al. (2008)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

Decane $C_{10}H_{22}$ **Library LibC10H22**

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC5H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**

Carbonyl sulfide **COS** **Library LibCOS**

Hydrogen sulfide **H₂S** **Library LibH2S**

Dinitrogen monoxide **N₂O** **Library LibN2O**

Sulfur dioxide **SO₂** **Library LibSO2**

Acetone **C₃H₆O** **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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The following thermodynamic and transport properties can be calculated^a:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl-number Pr

Backward Functions

- $T, v, s(p, h)$
- $T, v, h(p, s)$
- $p, T, v(h, s)$
- $p, T(v, h)$
- $p, T(v, u)$

Thermodynamic Derivatives

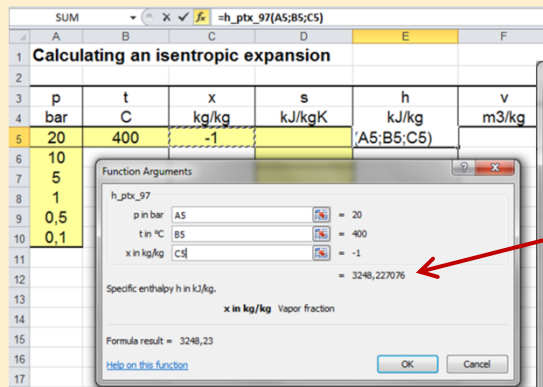
- Partial derivatives can be calculated.

^a Not all of these property functions are available in all property libraries.



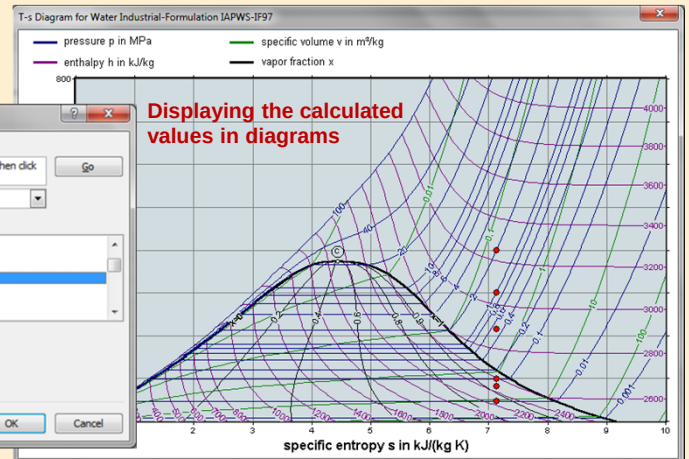
Property Software for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function

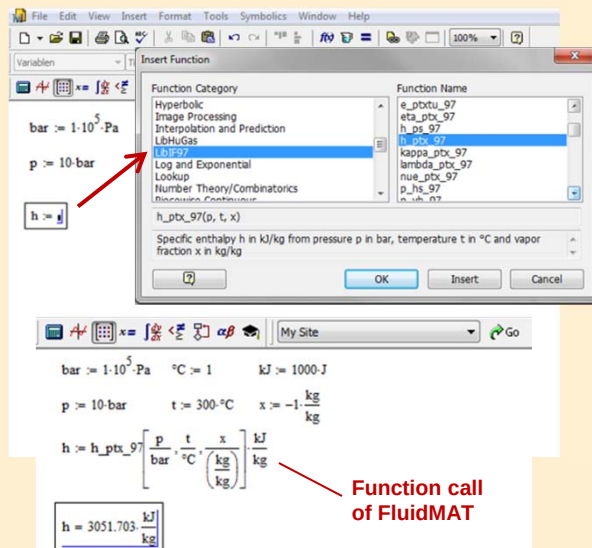
Displaying the calculated values in diagrams



Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

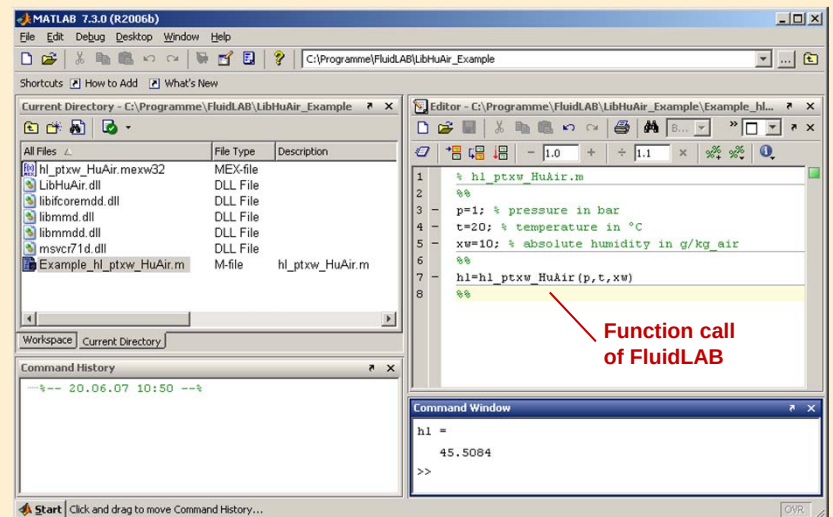
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

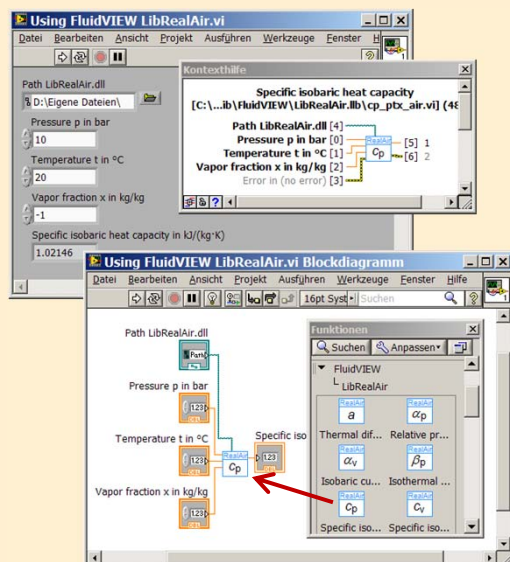
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

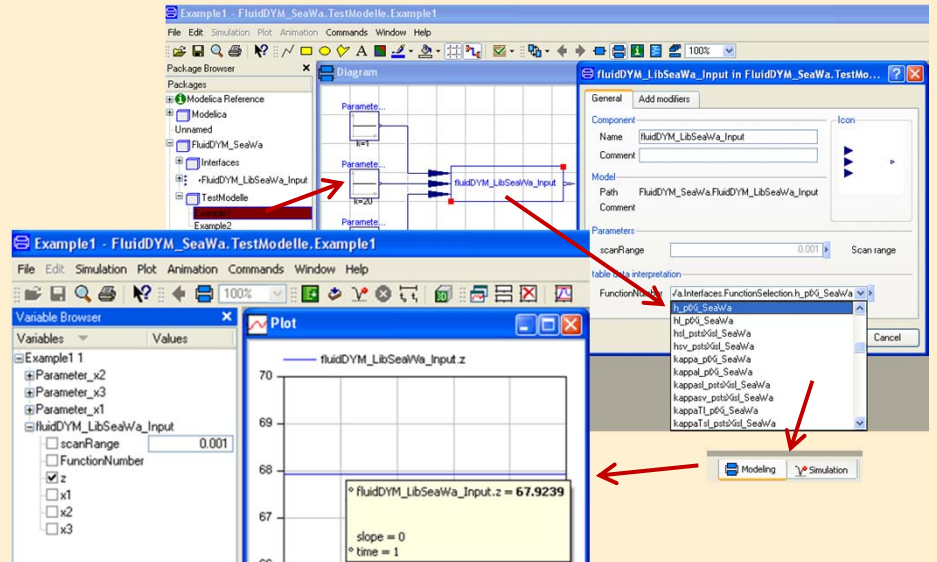
Add-On FluidVIEW for LabVIEW[®]

The property functions can be calculated in LabVIEW[®].

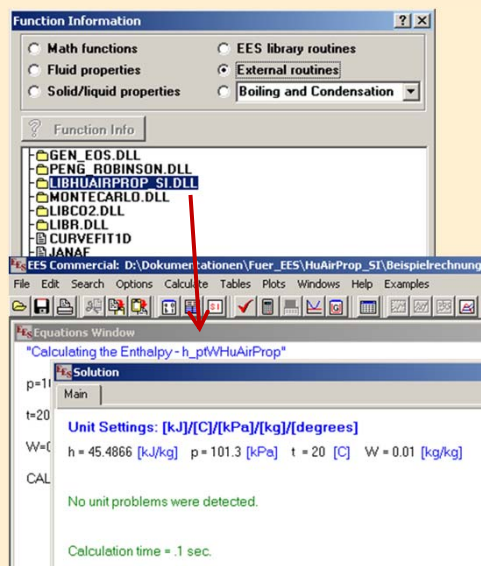


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

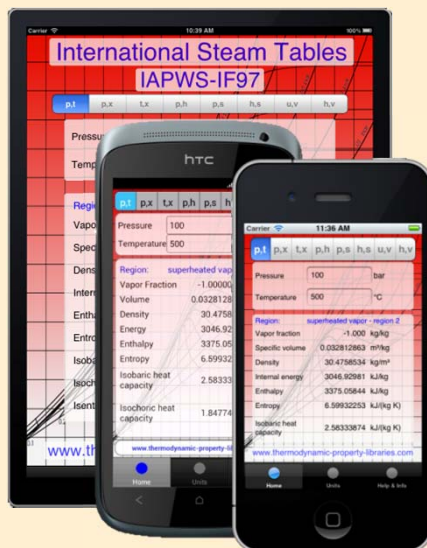
The property functions can be called in DYMOLA[®] and SimulationX[®].



Add-In FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android smart phones and tablets



Online Property Calculator at www.thermodynamics-zittau.de

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

Enter given values: [Range of validity](#)

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = kJ/kg

For further information on property libraries available for EXCEL®, MATLAB®, Mathcad®, Engineering Equation Solver®, DYMOLA® (Modelica), SimulationX®, and LabView® click [here](#)

An App for calculating steam properties on iPhone, iPad, and iPod touch can be found [here](#)

PDF with the description

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www.thermodynamic-property-libraries.com
www.international-steam-tables.com
www.thermodynamic-formelsammlung.de

Property Software for Pocket Calculators

FluidCasio



fx 9750 G II CFX 9850 fx-GG20 CFX 9860 G Graph 85 ALGEBRA FX 2.0

FluidHP



HP 48 HP 49

FluidTI



TI 83 TI Voyage 200 TI 92

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The following thermodynamic and transport properties^a can be calculated in Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® EES, DYMOLA® (Modelica), SimulationX®, and LabVIEW®:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
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- Thermal conductivity λ
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Backward Functions

- $T, v, s(p, h)$
- $T, v, h(p, s)$
- $p, T, v(h, s)$
- $p, T(v, h)$
- $p, T(v, u)$

Thermodynamic Derivatives

- Partial derivatives can be calculated.

^a Not all of these property functions are available in all property libraries.

5. References

- [1] Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam IAPWS-IF97.
Available at the IAPWS website <http://www.iapws.org>
- [2] Wagner, W.; Kretzschmar, H.-J.:
International Steam Tables.
Springer-Verlag, Berlin (2008)
- [3] Wagner, W.; Cooper, J.R.; Dittmann, A.; Kijima, J.; Kretzschmar, H.-J.; Kruse, A.; Mares, R.; Oguchi, K.; Sato, H.; Stöcker, I.; Sifner, O.; Takaishi, Y.; Tanishita, I.; Trübenbach, J.; Willkommen, Th.:
The IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam.
Journal of Eng. for Gas Turbines and Power 122 (2000) No 1, pp. 150-182
- [4] Advisory Note No. 3, Calculation of Thermodynamic Derivatives for Water and Steam from the IAPWS Formulations 2007. Available at the IAPWS website
<http://www.iapws.org>
- [5] Kretzschmar, H.-J.:
Mollier h-s Diagram.
Springer-Verlag, Berlin (1998, 2008)
- [6] Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance. Available at the IAPWS website <http://www.iapws.org>
- [7] Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance. Available at the IAPWS website <http://www.iapws.org>
- [8] Release on Surface Tension of Ordinary Water Substance 1994.
Available at the IAPWS website <http://www.iapws.org>
- [9] 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 2005. Available at the IAPWS website <http://www.iapws.org>
- [10] Supplementary Release on Backward Equations $p(h,s)$ for Region 3, Equations as a Function of h and s for the Region Boundaries, and an Equation $T_{\text{sat}}(h,s)$ for Region 4 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam 2004. Available at the IAPWS website <http://www.iapws.org>

- [11] Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. Available at the IAPWS website <http://www.iapws.org>
- [12] Grigull, U.:
Properties of Water and Steam in SI Units.
Springer-Verlag, Berlin (1989)
- [13] Kretzschmar, H.-J.:
Zur Aufbereitung und Darbietung thermophysikalischer Stoffdaten für die Energietechnik.
Habilitation, TU Dresden, Fakultät Maschinenwesen (1990)
- [14] Baehr, H.D.; Diederichsen, Ch.:
Berechnungsgleichungen für Enthalpie und Entropie der Komponenten von Luft und Verbrennungsgasen.
BWK 40 (1988) No 1/2, pp. 30-33
- [15] Brandt, F.:
Wärmeübertragung in Dampferzeugern und Wärmetauschern.
FDBR-Fachbuchreihe, 2nd edition, Vulkan Verlag Essen (1995)
- [16] VDI-Wärmeatlas, 7. Auflage.
VDI-Verlag, Düsseldorf (1995)
- [17] Blanke, W.:
Thermophysikalische Stoffgrößen.
Springer-Verlag, Berlin (1989)
- [18] VDI-Richtlinie 4670
Thermodynamische Stoffwerte von feuchter Luft und Verbrennungsgasen.
VDI-Handbuch Energietechnik, VDI-Gesellschaft Energietechnik, Düsseldorf (2000)
- [19] Lemmon, E. W.; Jacobsen, R. T.; Penoncello, S. G.; Friend, D. G.:
Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon and Oxygen from 60 to 2000 K at Pressures to 2000 MPa.
J. Phys. Chem. Ref. Data 29 (2000) No 2, pp. 331-385
- [20] Lemmon, E. W.; Jacobsen, R. T.:
Transport Properties of Air.
National Institute of Standards and Technology, Boulder CO, (2000),
private communication
- [21] Revised Supplementary Release on Saturation Properties of Ordinary Water Substance 1992. Available at the IAPWS website <http://www.iapws.org>
- [22] Hyland, R. W.; Wexler, A.:
Formulations for the Thermodynamic Properties of Saturated Phases of H₂O from 173.15 K to 473.15 K.
Report No. 2793 (RP-216), National Bureau of Standards, Washington, D.C. (1983)

6. Satisfied Customers

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