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

FluidDYM
with LibIF97
for DYMOLA®

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Software for the Industrial Formulation IAPWS-IF97 of Water and Steam Including DLL and Add-In for DYMOLA®

FluidDYM

LibIF97

Contents

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0 Package Contents

0.1   Zip file for 32-bit DYMOLA®

"CD_FluidDYM_LibCO2.zip"

Including the following files:

FluidDYM_LibCO2_Setup.exe	Installation Program for the FluidDYM Add-In for use in DYMOLA®
LibCO2.dll	Dynamic Link Library f
FluidDYM_LibCO2_Docu.pdf	User's Guide
Folder "Users_Guide"	Includes the complete User's Guide

0.2   Zip file for 64-bit MATLAB®

"CD_FluidDYM_LibCO2_64.zip"

Including the following files and folders:

Files:

Setup.exe	- Self-extracting and self-installing program for FluidLAB
FluidDYM_LibCO2_64.msi	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibCO2.dll	- Dynamic Link Library for carbon dioxide for use in MATLAB®
FluidLAB_LibCO2_Docu.pdf	- User's Guide

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

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.
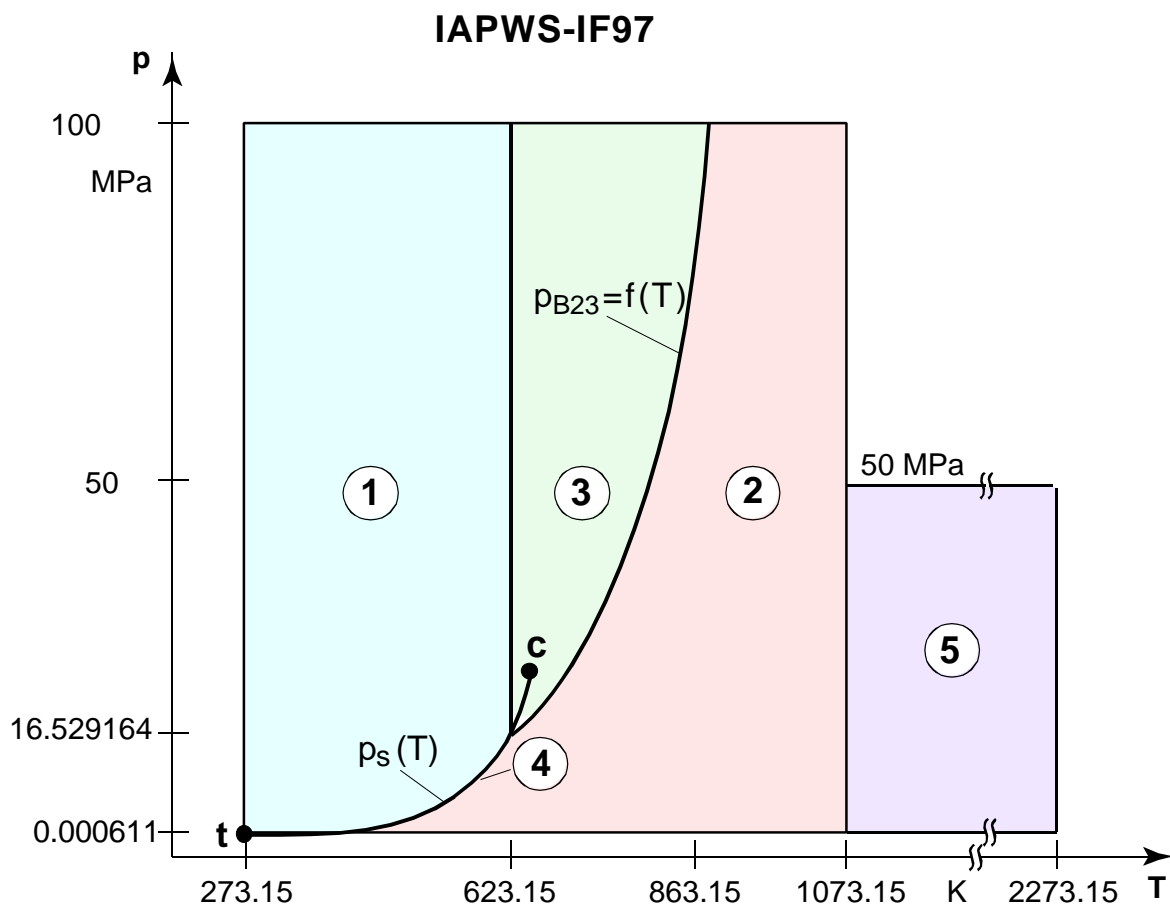

Figure 1.1 Entire Range of Validity of the IF97

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
$a = \mathrm{f}(p,t,x)$	a_ptx_97	= APTX97(P,T,X)	= C_APTX97(A,P,T,X)	Thermal diffusivity	m^2/s
$\alpha_p = \mathrm{f}(p,t,x)$	alphap_ptx_97	= ALPHAPPTX97(P,T,X)	=C_ALPHAPPTX97 (ALPHAP,P,T,X)	Relative pressure coefficient	K^{-1}
$\alpha_v = \mathrm{f}(p,t,x)$	alphav_ptx_97	= ALPHAVPTX97(P,T,X)	=C_ALPHAVPTX97 (ALPHAV,P,T,X)	Isobaric cubic expansion coefficient	K^{-1}
$b = \mathrm{f}(p)$	b_p_97	= BP97(P)	=C_BP97 (B,P)	Laplace coefficient	m
$b = \mathrm{f}(t)$	b_t_97	= BT97(T)	=C_BT97 (B,T)	Laplace coefficient	m
$\beta_p = \mathrm{f}(p,t,x)$	betap_ptx_97	= BETAPPTX97(P,T,X)	= C_BETAPPTX97 (BETAP,P,T,X)	Isothermal stress coefficient	kg/m^3
$c_p = \mathrm{f}(p,t,x)$	cp_ptx_97	= CPPTX97(P,T,X)	= C_CPPTX97(CP,P,T,X)	Specific isobaric heat capacity	$kJ/(kg \cdot K)$
$c_v = \mathrm{f}(p,t,x)$	cv_ptx_97	= CVPTX97(P,T,X)	= C_CVPTX97(CV,P,T,X)	Specific isochoric heat capacity	$kJ/(kg \cdot K)$
$\delta_T = \mathrm{f}(p,t,x)$	deltat_ptx_97	= DELTATPTX97 (P,T,X)	= C_DELTATPTX97 (DELTAT,P,T,X)	Isothermal throttling coefficient	$kJ/(kg \cdot kPa^{-1})$
$\left(\dfrac{\partial v}{\partial p}\right)_T = \mathrm{f}(p,t,x)$	dv_dp_T_ptx_97	= DVDPT97(P,T,X)	= C_DVDPT97(DVP,P,T,X)	Differential quotient $\left(\dfrac{\partial v}{\partial p}\right)_T (p,t,x)$	$m^3/(kg \cdot kPa)$
$\left(\dfrac{\partial v}{\partial T}\right)_p = \mathrm{f}(p,t,x)$	dv_dT_p_ptx_97	= DVDTP97(P,T,X)	= C_DVDTP97(DVT,P,T,X)	Differential quotient $\left(\dfrac{\partial v}{\partial T}\right)_p (p,t,x)$	$m^3/(kg \cdot K)$
$e = \mathrm{f}(p,t,x,t_U)$	e_ptx_tu_97	= EPTXTU97(P,T,X,TU)	= C_EPTXTU97(E;P,T,X,TU)	Specific exergy	kJ/kg
$\varepsilon = \mathrm{f}(p,t,x)$	epsilon_ptx_97	= EPSPTX97 (P,T,X)	= C_EPSPTX97(EPS,P,T,X)	Dielectric constant	-
$\eta = \mathrm{f}(p,t,x)$	eta_ptx_97	= ETAPTX97(P,T,X)	= C_ETAPTX97(ETA,P,T,X)	Dynamic viscosity	$Pa \cdot s = kg/(m \cdot s)$
$f = \mathrm{f}(p,t,x)$	f_ptx_97	= FPTX97 (P,T,X)	= C_FPTX97(F,P,T,X)	Specific Helmholtz energy	kJ/kg
$f^* = \mathrm{f}(p,t,x)$	fug_ptx_97	= FUGPTX97 (P,T,X)	= C_FUGPTX97(FUG,P,T,X)	Fugacity	bar
$g = \mathrm{f}(p,t,x)$	g_ptx_97	= GPTX97 (P,T,X)	= C_GPTX97(G,P,T,X)	Specific Gibbs energy	kJ/kg
$h = \mathrm{f}(p,s)$	h_ps_97	= HPS97(P,S)	= C_HPS97(HPS,P,S)	Backward function: Specific enthalpy from pressure and entropy	kJ/kg
$h = \mathrm{f}(p,t,x)$	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)	*Prandtl*-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/m³
$s = f(p,h)$	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	m^3/kg
$v = f(p,s)$	v_ps_97	= VPS97(P,S)	= C_VPS97(VPS,P,S)	Backward function: Specific volume from pressure and entropy	m^3/kg
$v = f(p,t,x)$	v_ptx_97	= VPTX97(P,T,X)	= C_VPTX97(V,P,T,X)	Specific volume	m^3/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 a, η, λ, v, 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:

<u>Single-phase region</u>

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.

<u>Wet-steam region</u>

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 <u>and</u> p = -1 or the given value for p <u>and</u> t = -1 and in both cases the value for x between 0 and 1 must be entered.

If p <u>and</u> t <u>and</u> 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 °C ... t_c = 373.946 °C

p_t = 0.00611 bar ... p_c = 220.64 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. Application of FluidDYM in Dymola®

The FluidDYM Add-In has been developed to calculate thermodynamic properties in Dymola® more conveniently. Within Dymola® it enables the direct call of functions relating to water and steam from the LibIF97 property library. The 32-bit version of FluidDYM LibIF97 runs on both the 32-bit and 64-bit version of DYMOLA®.

2.1 Installing FluidDYM

In this section, the installation of FluidDYM and LibIF97 is described.

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

After you have downloaded and extracted the zip-file

      "CD_FluidDYM_LibIF97.zip,"   (32-bit version)

      "CD_FluidDYM_LibIF97_64.zip,"   (64-bit version)

you will see the folder

      CD_FluidDYM_LibIF97   (32-bit version)

      CD_FluidDYM_LibIF97_64   (64-bit version)

in your Windows Explorer®, Norton Commander® etc.

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

Within the folder for the **32-bit version** you will see the following files

      FluidDYM_LibIF97_Users_Guide.pdf

      FluidDYM_LibIF97_Setup.exe   (32-bit version)

and the folder

      "Users_Guide."

Within the folder for the **64-bit version** you will see the following files

      FluidDYM_LibIF97_Users_Guide.pdf

      FluidDYM_LibIF97_64_Setup.msi

      Setup.exe

and the folder

      "Users_Guide."

In order to run the installation of **32-bit** FluidDYM including the LibIF97 property library double-click the file

      FluidDYM_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 "Continue" button.

In the following dialog box, "Choose Destination Location," the default path offered automatically for the installation of FluidDYM is

      C:\Program Files\FluidDYM\LibIF97.

By clicking the "Browse…" button, you can change the installation directory before installation (see figure below).
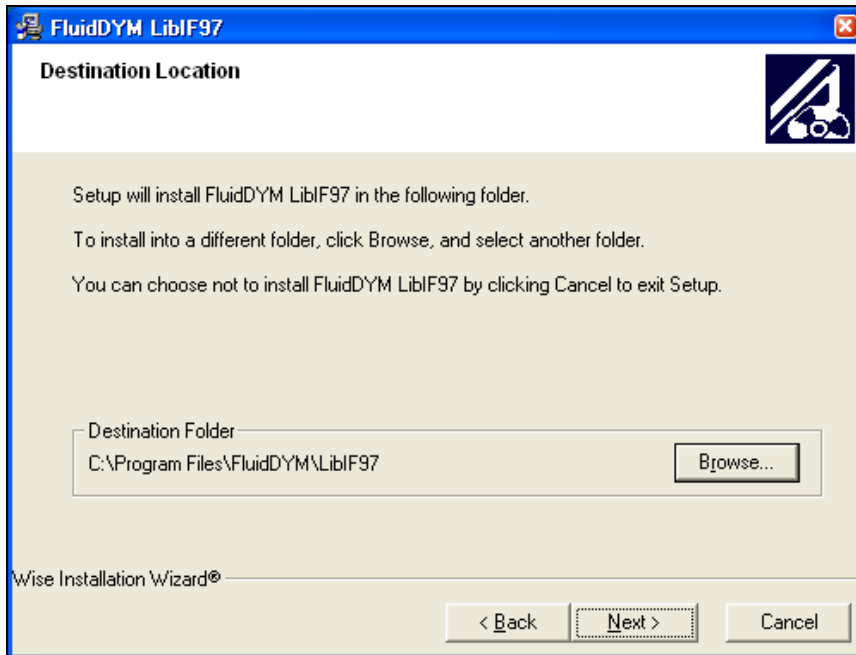

Figure 2.1: Dialog window "Destination Location"

Finally, click on "Next >" to continue installation; click "Next >" again in the "Start Installation" window which follows in order to start the installation of FluidDYM.

After FluidDYM has been installed, you will see the sentence "FluidDYM LibIF97 has been successfully installed." Confirm this by clicking the "Finish" button.

The installation of FluidDYM 32-bit has been completed.

In order to run the installation of **64-bit** FluidDYM including the LibIF97 property library double-click the file

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 "Continue" button.

In the following dialog box, "Choose Destination Location," the default path offered automatically for the installation of FluidDYM is

C:\Users\...\Documents\FluidDYM_64\LibIF97.

By clicking the "Browse…" button, you can change the installation directory before installation (see figure below).

Finally, click on "Next >" to continue installation; click "Next >" again in the "Start Installation" window which follows in order to start the installation of FluidDYM.

After FluidDYM has been installed, you will see the sentence "FluidDYM LibIF97 has been successfully installed." Confirm this by clicking the "Finish" button.

The installation of FluidDYM 64-bit has been completed.

The installation program has copied the following files into the directory

C:\Program Files\FluidDYM\LibIF97 (for English version of Windows)
C:\Programme\FluidDYM\LibIF97   (for German version of Windows)):

- Dynamic link library "LibIF97.dll"

- Folder "Users_Guide"

- Link up Dynamic link library "LibIF97_Dymola.dll" and other necessary system DLL files

- Library File "LibIF97_Dymola.lib"

- Header File "LibIF97_Dymola.h" and other necessary system DLL files

- Modelica File "FluidDYM_LibIF97.mo", includes the following property functions:

a_ptx_97	p_vh_97
alphap_ptx_97	p_vu_97
alphav_ptx_97	Prandtl_ptx_97
b_p_97	ps_t_97
b_t_97	rho_ptx_97
betap_ptx_97	s_ph_97
cp_ptx_97	s_ptx_97
cv_ptx_97	sigma_p_97
deltat_ptx_97	sigma_t_97
dv_dp_T_ptx_97	t_hs_97
dv_dT_p_ptx_97	t_ph_97
e_ptx_97	t_ps_97
epsilon_ptx_97	t_vh_97
eta_ptx_97	t_vu_97
f_ptx_97	ts_p_97
fug_ptx_97	u_ptx_97
g_ptx	v_ph_97
h_ps_97	v_ps_97
h_ptx_97	v_ptx_97
kappa_ptx_97	w_ptx_97
kappat_ptx_97	x_hs_97
lambda_ptx_97	x_ph_97
my_ptx_97	x_ps_97
n_ptxwl_97	x_vh_97
ny_ptx_97	x_vu_97
p_hs_97	z_ptx_97

Now, you have to overwrite the file "LibIF97.dll" and the folder "Users_Guide" in your LibIF97 directory with the files of the same names provided in your CD folder with FluidDYM.
To do this, open the CD folder "CD_FluidDYM_LibIF97" in "My Computer" and click on the file "LibIF97.dll" in order to highlight it. Hold Ctrl and click on the folder "Users_Guide" to mark it as well.

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

Now, open your LibIF97 directory (the standard being

C:\Program Files\FluidDYM\LibIF97 (for English version of Windows)
C:\Programme\FluidDYM\LibIF97   (for German version of Windows))

and insert the "LibIF97.dll" and the "Users_Guide" folder by clicking the "Edit" menu in your Explorer and then select "Paste".

Answer the question whether you want to replace the files by clicking the "Yes" button. Now, you have overwritten the file "LibIF97.dll" and the folder "Users_Guide" successfully.

2.2   Licensing the LibIF97 Property Library

The licensing procedure has to be carried out when Dymola® is running and a model
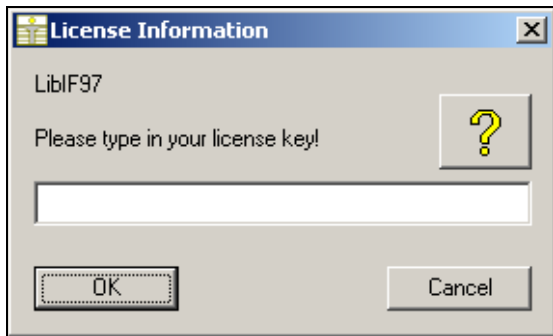simulation starts. In this case, you will see the "License Information" window (see Figure 2.2).

Figure 2.2: "License Information" window

Here you will have to type in the license key which you have obtained from the Zittau/Goerlitz
University of Applied Sciences. You can find contact information on the "Content" page of
this User's Guide or by clicking the yellow question mark in the "License Information" window.
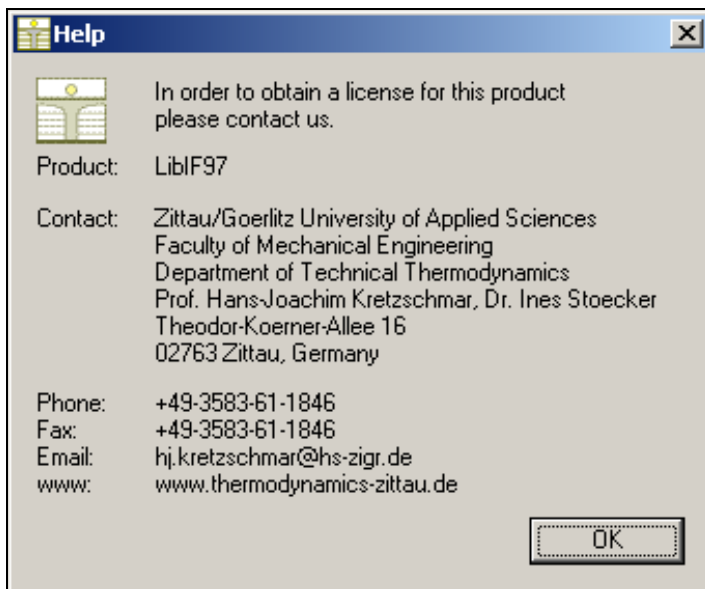Then the following window will appear:

Figure 2.3: "Help" window

If you do not enter a valid license it is still possible to use Dymola® 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 start Dymola.

Should you not wish to license the LibIF97 property library, you have to uninstall the
FluidDYM LibIF97 property library following the description in section 2.4 of this User's Guide.

2.3   Example: Calculation of *h* = f(*p,t,x*)

Now we will calculate, step by step, the specific enthalpy *h* as a function of pressure *p*, temperature *t* and vapor fraction *x,* using Dymola[®].

Please carry out the following instructions:

- Start Windows Explorer[®], Total Commander[®], My Computer or another file manager program.
  The description here refers to Windows Explorer.

- Your Windows Explorer should be set to Details for a better view. Click the "View" button and select "Details".

- Switch into the program directory of FluidDYM in which you will find the folder "\LibIF97"; the standard location is:

    C:\Program Files\FluidDYM\LibIF97 (for English version of Windows)
    C:\Programme\FluidDYM\LibIF97   (for German version of Windows))

- Create the folder "\LibIF97_Example" by clicking on "File" in the Explorer menu, then "New" in the menu which appears, and then selecting "Folder". Name the new folder "\LibIF97_Example".
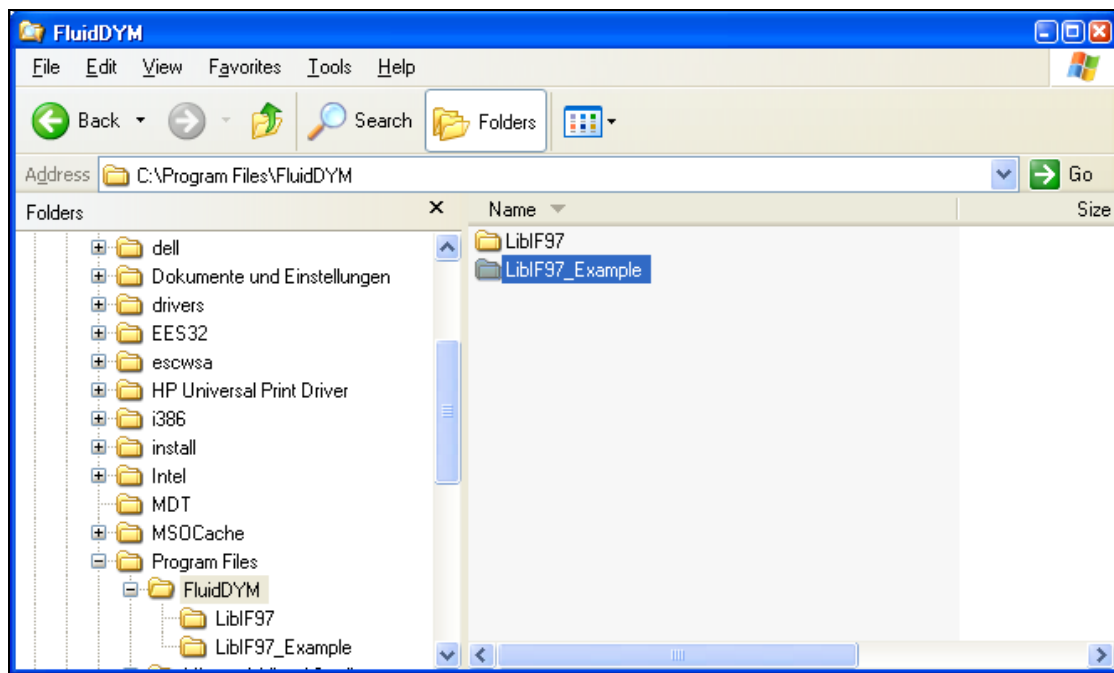
- You will see the following window:

Figure 2.4: "LibIF97_Example" and "LibIF97" directory in FluidDYM

- Switch into the directory "\LibIF97" within "\FluidDYM", the standard being:

    C:\Program Files\FluidDYM\LibIF97 (for English version of Windows)
    C:\Programme\FluidDYM\LibIF97   (for German version of Windows)).
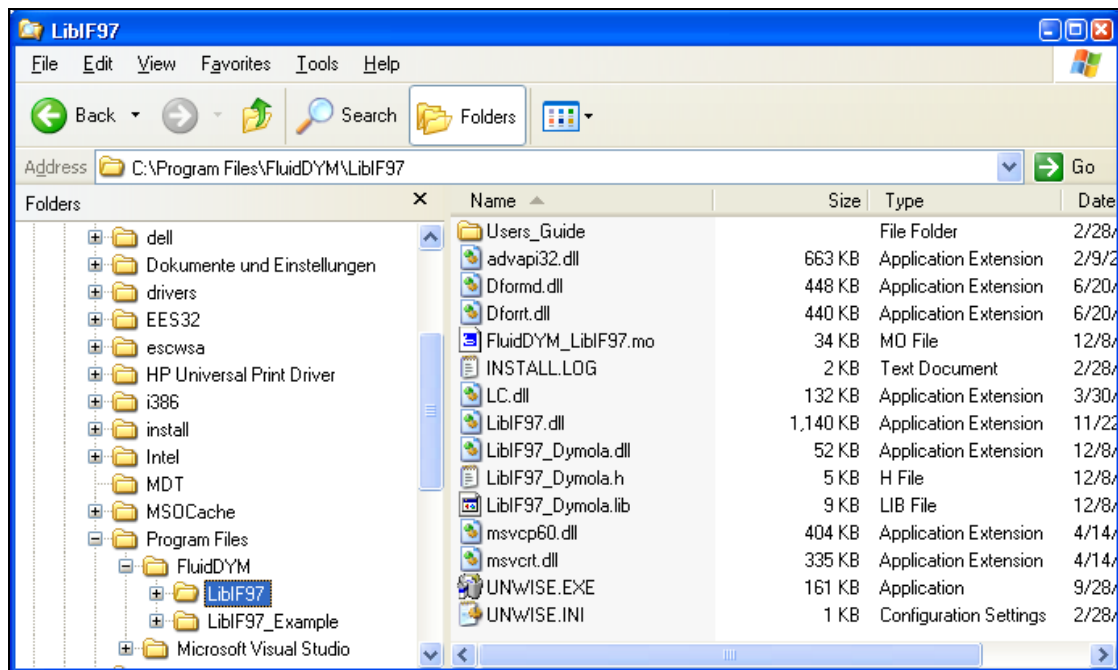
- You will see the following window:

Figure 2.5: "LibIF97" directory including installed files

In order to calculate the function $h = f(p,t,x)$, the following files are necessary. Copy them into the directory

    C:\Program Files\FluidDYM\LibIF97   (for English version of Windows)
    C:\Programme\FluidDYM\LibIF97   (for German version of Windows)):

- • "advapi32.dll"

- • "Dformd.dll"

- • "Dforrt.dll"

- • "FluidDYM_LibIF97.mo"

- • "LC.dll"

- • "LibIF97.dll"

- • "LibIF97_Dymola.dll"

- • "LibIF97_Dymola.h"

- • "LibIF97_Dymola.lib"

- • "msvcp60.dll"

- • "Msvcrt.dll"

- • the folder "Users_Guide"

- Mark up these files, then click "Edit" in the upper menu bar and select "Copy".

- Switch into the directory

    C:\Program Files\FluidDYM\LibIF97_Example   (for English version of Windows)
    C:\Programme\FluidDYM\LibIF97_Example   (for German version of Windows)),

click "Edit" and then "Paste".

- You will see the following window:
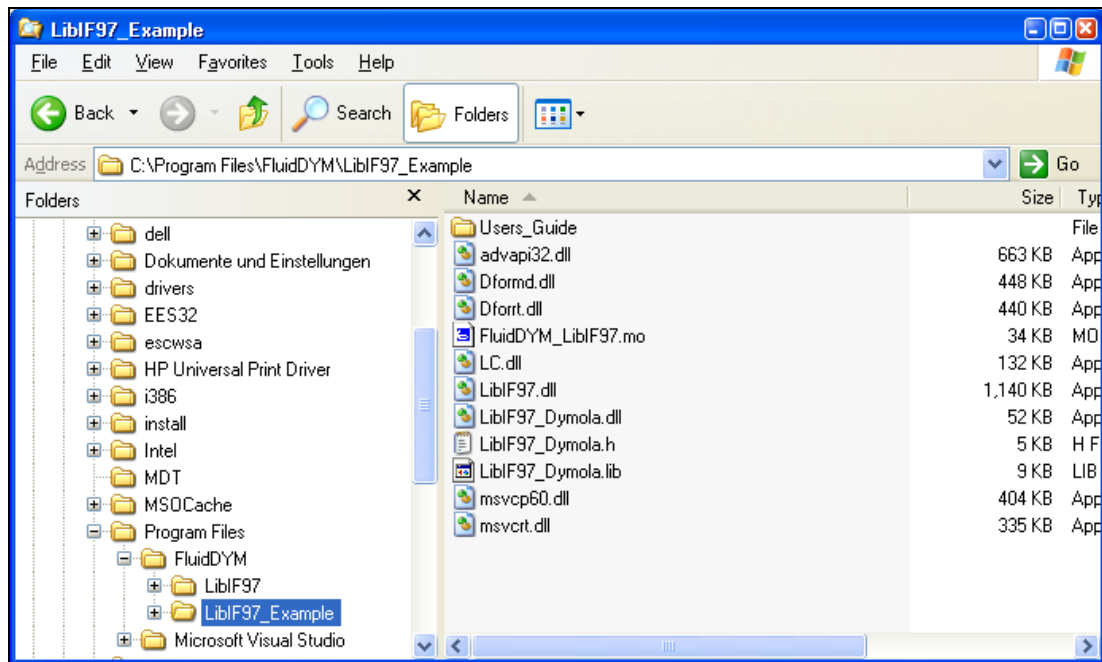
Figure 2.6: "LibIF97_Example" directory including the newly-copied files

- Start Dymola®.
- Now click on "File" in the Dymola® menu bar and select "Open" (see Figure 2.7).

Figure 2.7: Selecting the menu entry "Open"

- Search and click on the directory

    "C:\Program Files\FluidDYM\LibIF97_Example"   (for English version of Windows)
    "C:\Programme\FluidDYM\LibIF97_Example"   (for German version of Windows)

    in the appearing menu.

- Select the "FluidDYM_LibIF97.mo" file and click on the "Open" button (see Figure 2.8).
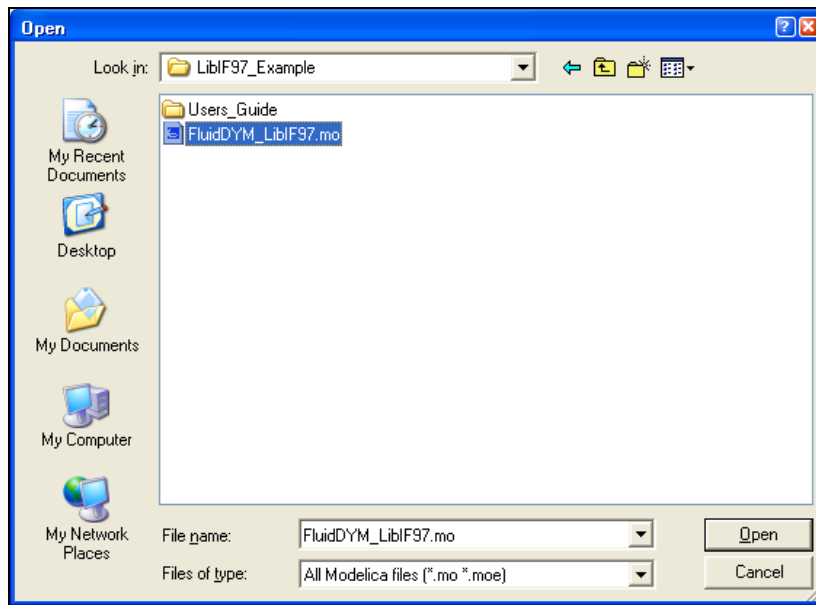
Figure 2.8: Selecting the "FluidDYM_LibIF97.mo" file

- The library will be loaded by Dymola which may take a few seconds.
- After Dymola has finished loading the LibIF97 library, you will see the window shown in Figure 2.9.
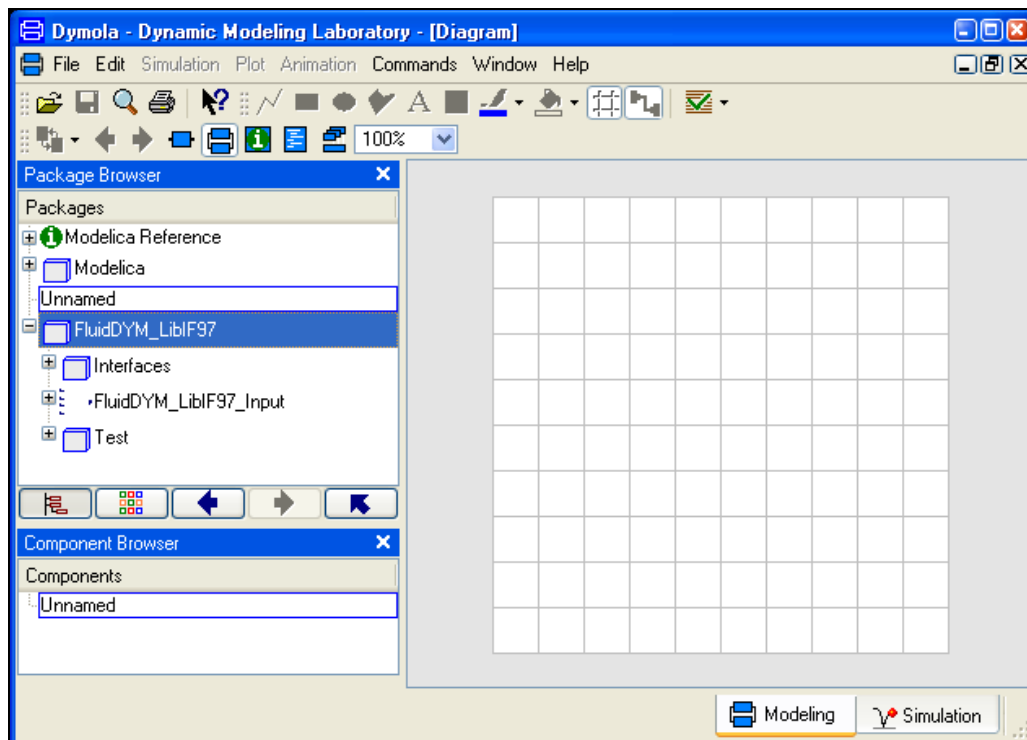
Figure 2.9: Dymola window after loading the "LibIF97" library

- Now, click on "File" in the Dymola menu bar and select "Change Directory…" in order to open the folder "\LibIF97_Example" (see Figure 2.10).
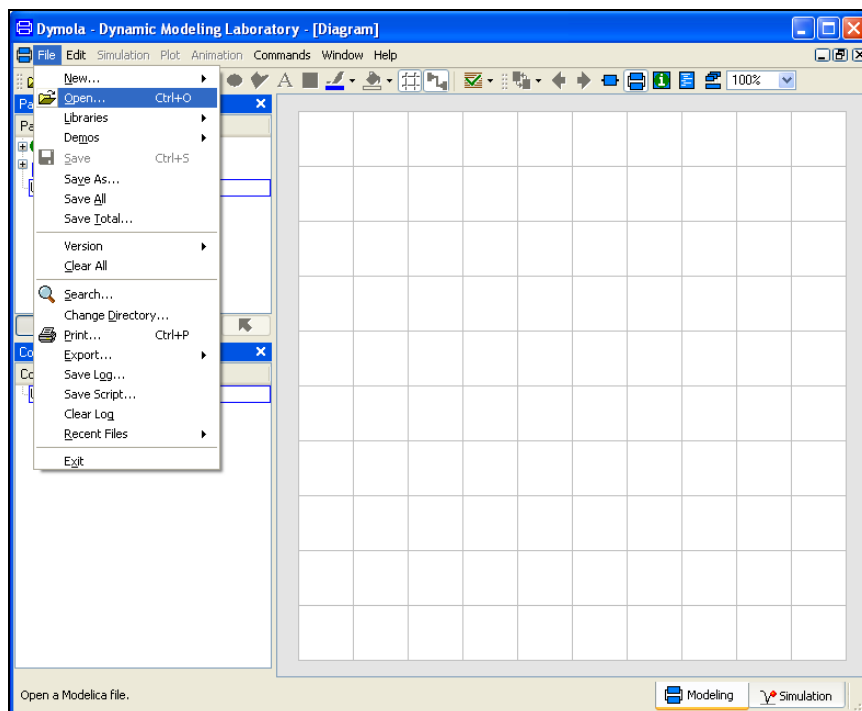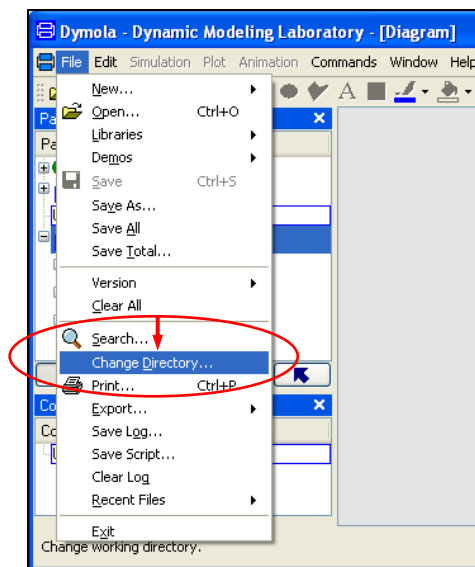
Figure 2.10: Selecting the menu entry "Change Directory…"

- Search and click on the directory
  - "C:\Program Files\FluidDYM\LibIF97_Example" (for English version of Windows)
    "C:\Programme\FluidDYM\LibIF97_Example" (for German version of Windows)

  in the menu that appears (see Figure 2.11).
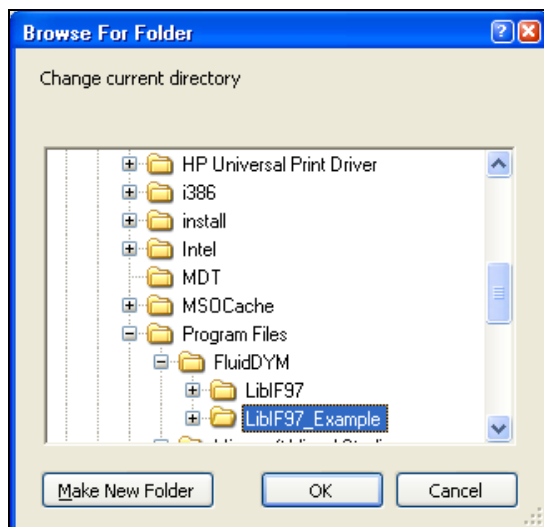
Figure 2.11: Selecting the "LibIF97_Example" directory

- Confirm your selection by clicking the "OK" button.

As indicated in the table of property functions in Chapter 1, you have to call up the function "h_ptx_97" as follows for calculating $h = f(p,t,x)$.

- Click on the Dymola-Block "Testmodelle," which can be found in the FluidDYM_LibIF97 package in the "Package Browser" on the left hand side of the Dymola window. Here choose Example1 by double-clicking on it.

- Now click on the ⊞ button in the Dymola menu bar in order to switch to the Diagram Mode. You will see the following window:
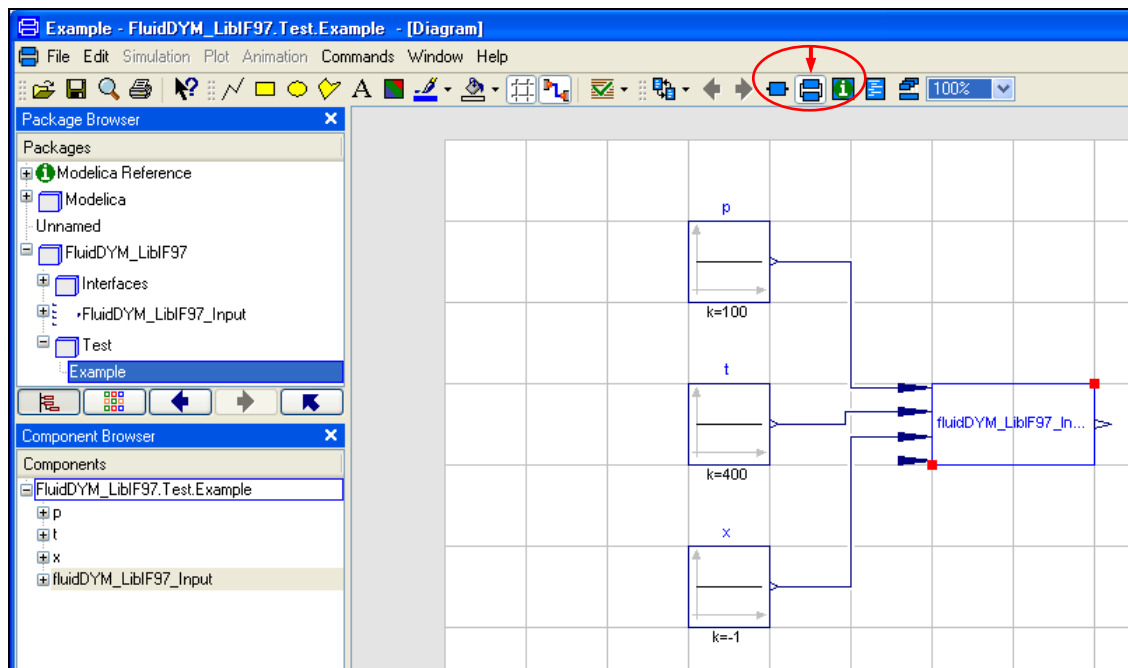
Figure 2.12: Dymola in Diagram Mode

- Now double-click on the "fluidDYM_LibIF97_Input" block on the right hand side of the Dymola window.

- Search and click the "h_ptx_97" function next to "Function Number" in the menu that appears (see Figure 2.13).
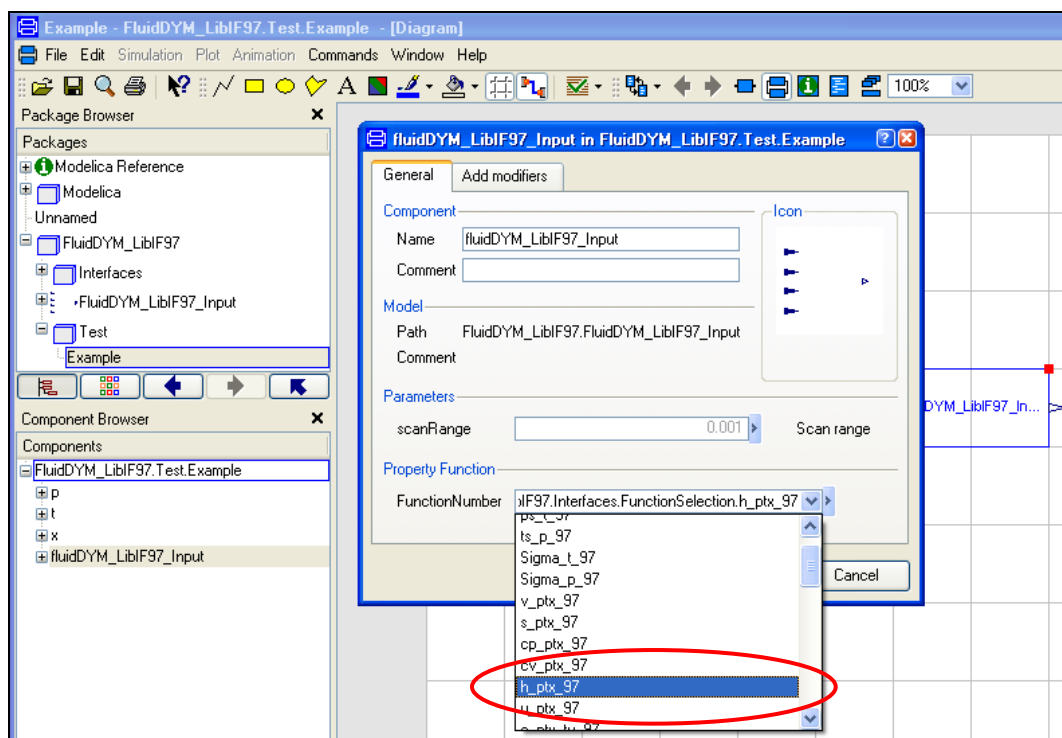
Figure 2.13: Choosing the function "h_ptx_*97*"

- You can set the scan range (how many times the property will be calculated per second) next to "scanRange". The preset value 0.001 means that the property will be calculated 1000 times per second. E.g. if you enter the value 1, the property will be calculated once per second. Do not change the preset value of 0.001 for our example calculation.
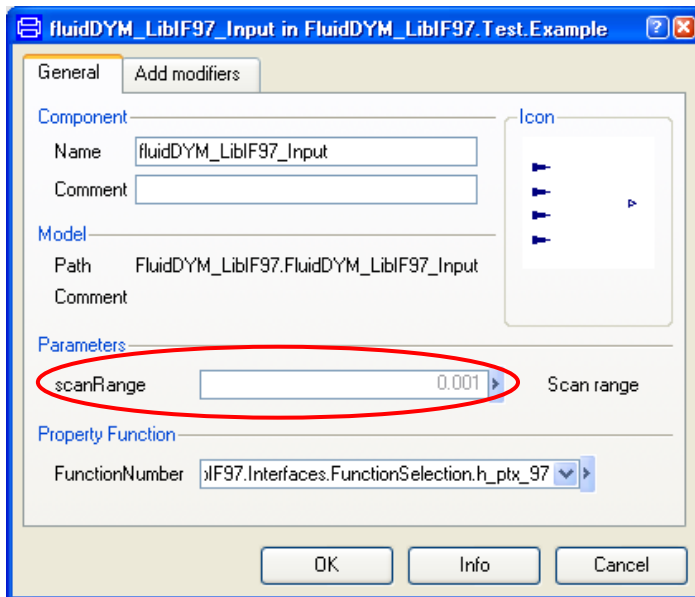
Figure 2.14: Setting the scan range

- Now we will configure the input parameters x1 to x3, where x1 represents the pressure *p*, x2 represents the temperature *t,* and x3 represents the vapor fraction *x*. When calculating a function with only one or two input parameters, the other input parameter(s) will not be defined.

- First, double click on the "Parameter_x1" block which represents the first input parameter, here the pressure *p* in bar.
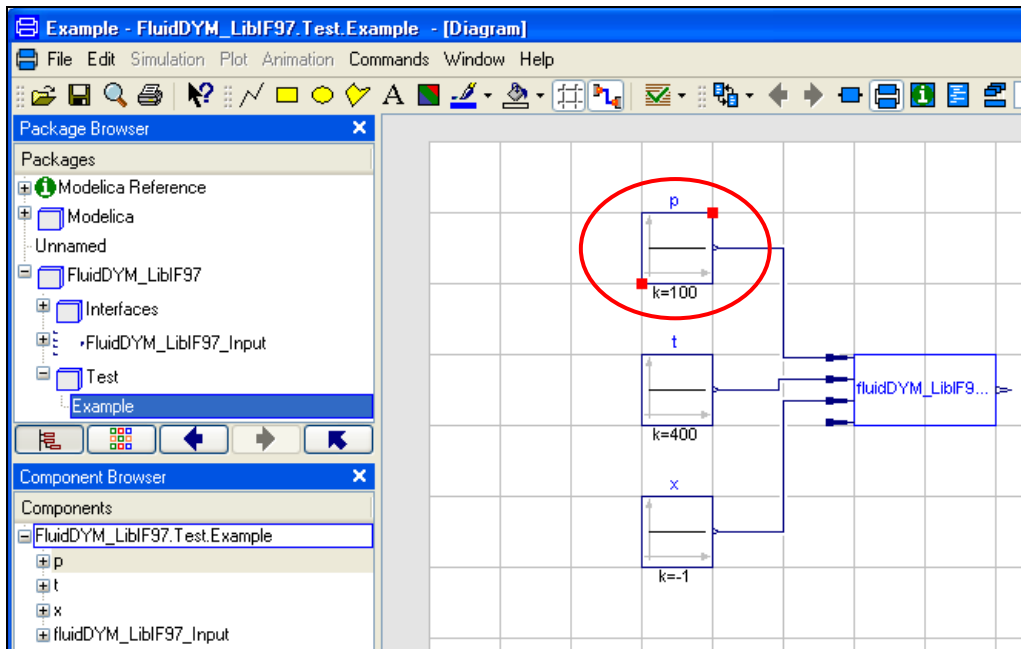
Figure 2.15: "Parameter_x1" block in Dymola

- Enter the value 100 on the line next to "k" in the dialog window which appears

   (Range of validity of the IF97:   p = 0.00611 ... 1000 bar
                                      p = 0.00611 ... 500 bar for high temperature region)

- Then click the "OK" button (see Figure 2.16).

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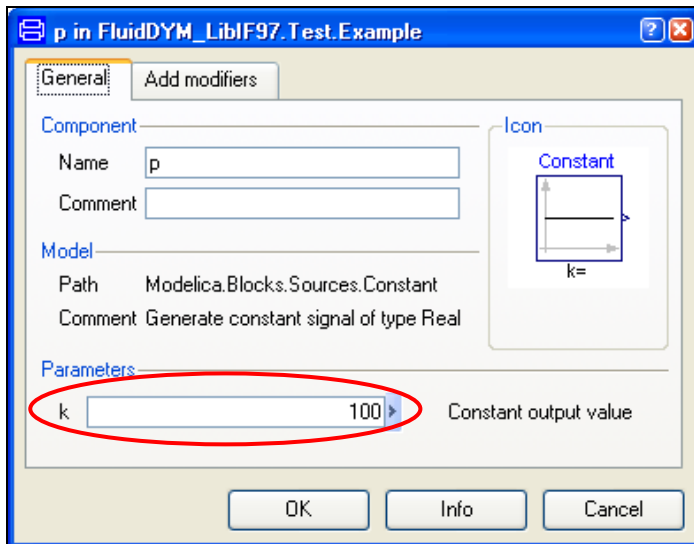
Figure 2.16: Entering the value for the pressure *p*

- Now, double click on the "Parameter_x2" block which represents the second input parameter, here the temperature *t* in °C.

- Enter the value 400 on the line next to "k" in the dialog window which appears

  (Range of validity of the IF97:   t = 0 ... 800 °C

  high temperature region up to 2000 °C

- Then click the "OK" button (see Figure 2.17).
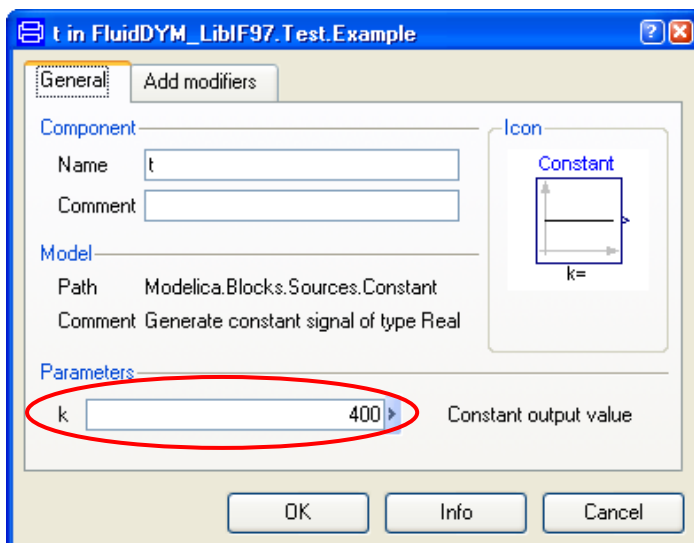
Figure 2.17: Entering the value for the temperature *t*

- Now, double click on the "Parameter_x3" block which represents the third input parameter, here the vapor fraction *x* in kg/kg.

  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.

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.

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 it is not the case the calculation for the property of the chosen function to be calculated results in –1.

- Enter the value -1 on the line next to "k" in the dialog window which appears

- Then click the "OK" button (see Figure 2.18)
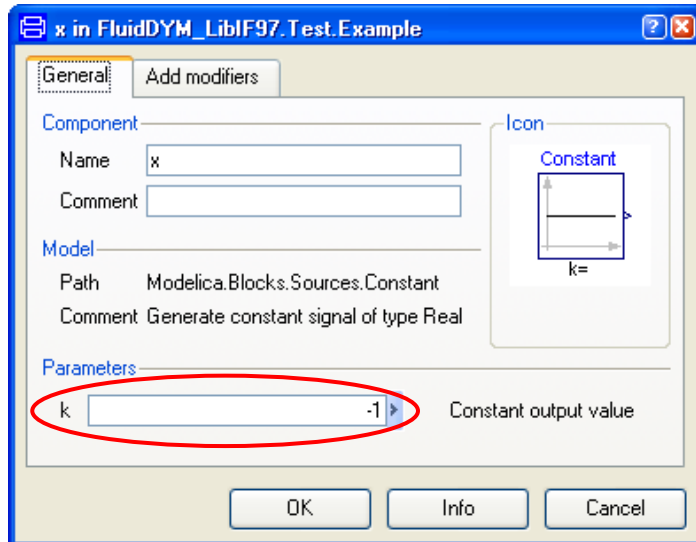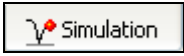
Figure 2.18: Entering the value for the vapor fraction x

All parameters have now been defined.

- Click on the [⋎ Simulation] button in the lower right area of Dymola in order to switch into the "Simulation Mode".

In Figure 2.19 you can see how the Dymola "Simulation Mode" looks like.
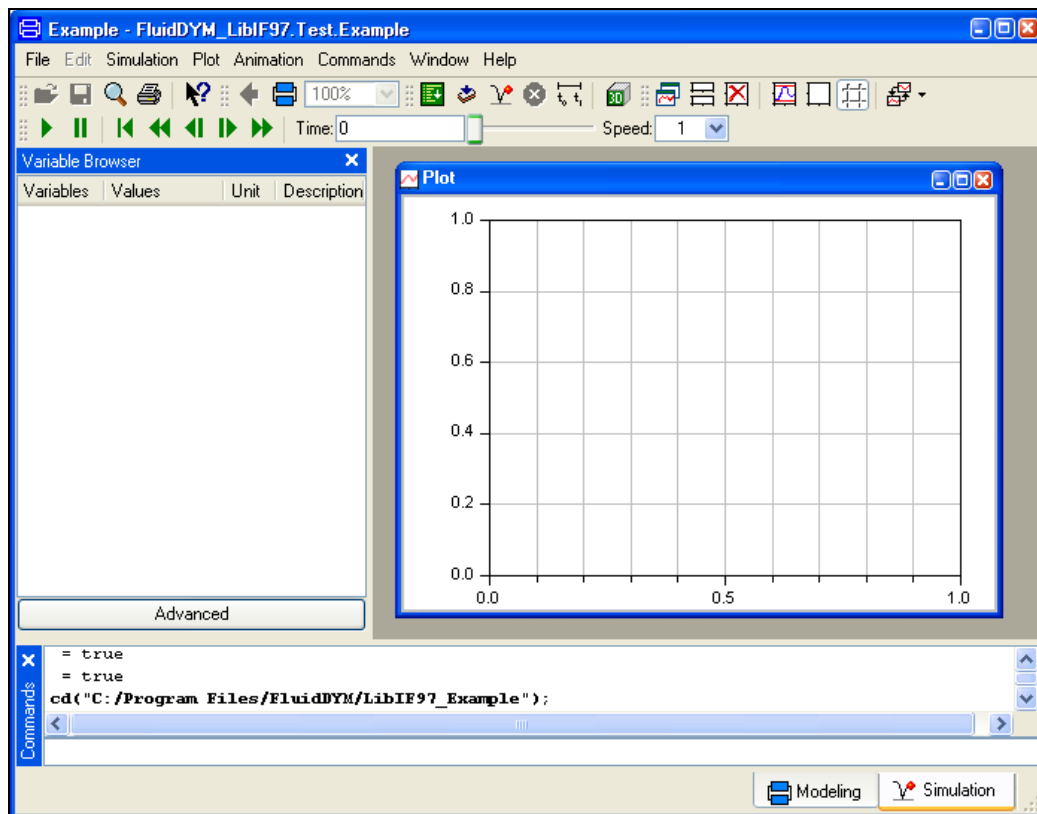
Figure 2.19: "Simulation Mode" window

IMPORTANT NOTICE:

Per default the 64-bit version of Dymola creates a 32-bit simulation process. If you want to create a 64-bit simulation process you must have installed the 64-bit version of FluidDYM and you now need to enter the following command into the command line of Dymola and confirm your entry by pressing the Enter key:

"Advanced.CompileWith64=2"
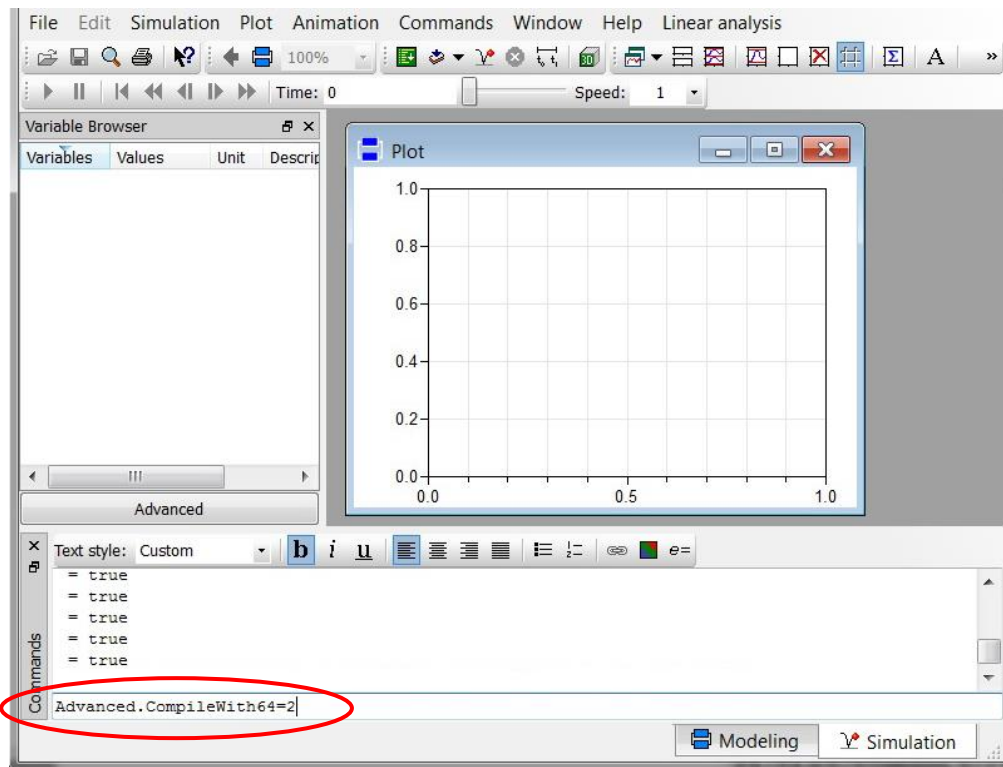
Figure 2.20: "Simulation Mode" window with 64-bit command

Now, your 64-bit Dymola creates 64-bit simulation processes with FluidDYM.

Please note that if you restart Dymola and want to create 64-bit simulation processes again, you will always have to enter this command anew.

For further information concerning this matter, please see the Dymola user's guide.

- Click on the "Simulate" Button [icon] in the Dymola menu bar to start the calculation. Now the model will be compiled and the simulation started.

- Afterwards you will see the following entries within the "Variable Browser" window in Dymola (see Figure 2.21):
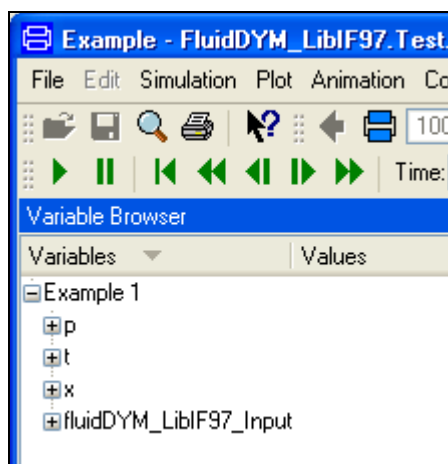
Figure 2.21: "Variable Browser" with new entries

- By clicking on the "New Plot Window" button [icon], a new diagram window will be opened.

- Click on "fluidDYM_LibIF97_Input" within the "Variable Browser"; then you will see the input and output parameters "scanRange", "FunctionNumber", "z", "x1", "x2" and "x3" (see Figure 2.22).
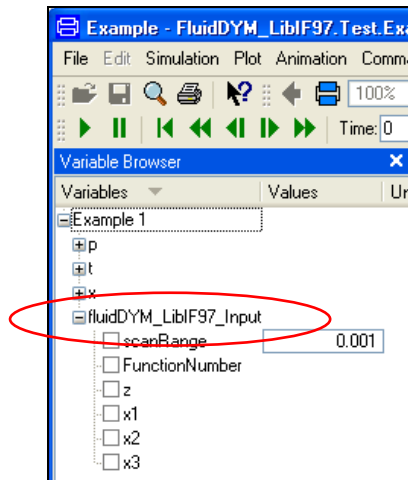
Figure 2.22: Parameters of "fluidDYM_LibIF97_Input"

- After clicking on the output parameter "z", the calculated property will be represented graphically in the "PlotWindow".

- Move the mouse over the curve to see the result of the simulation at a specific point in time (see Figure 2.23).
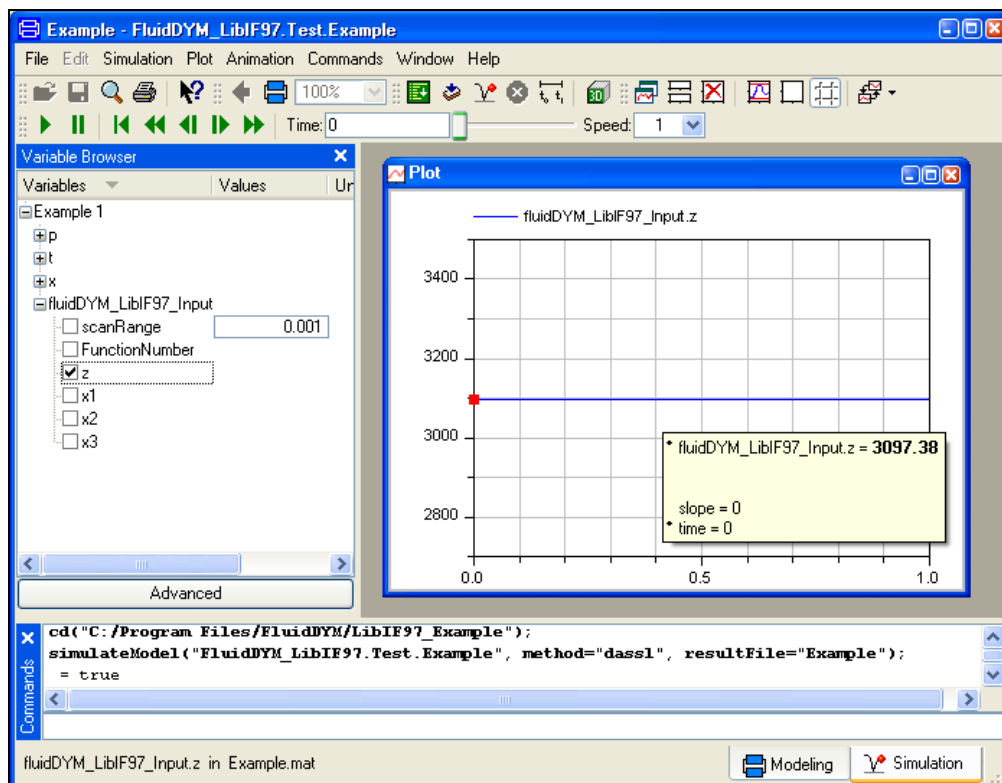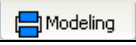
Figure 2.23: "DiagramWindow" showing the result

The result for *h* appears in the "DiagramWindow"

⇒ The result in our sample calculation here is: "h = 3097.38".
The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

- Now click on the Modeling button ⬚Modeling in the lower right area of Dymola in order to switch into the "Modeling Mode". Here you can arbitrarily change the values for *p*, *t*, and *x* in the appropriate blocks.

Help Systems in Dymola®

Dymola® provides detailed help functions. You can choose to read the program documentation or the help page of a specific property function, as desired.

Within the "Modeling-Mode" ⬚Modeling the help may be accessed via two different steps.

First we will show you how to access the program documentation of the property library.

- Make sure Dymola is set to the "Modeling-Mode".

- Now click the 🔲 button in the Dymola menu bar to choose the "Documentation Mode".

- Double-click on the "FluidDYM_LibIF97" Block at the left and then click on "Users_Guide" (see Figure 2.24).
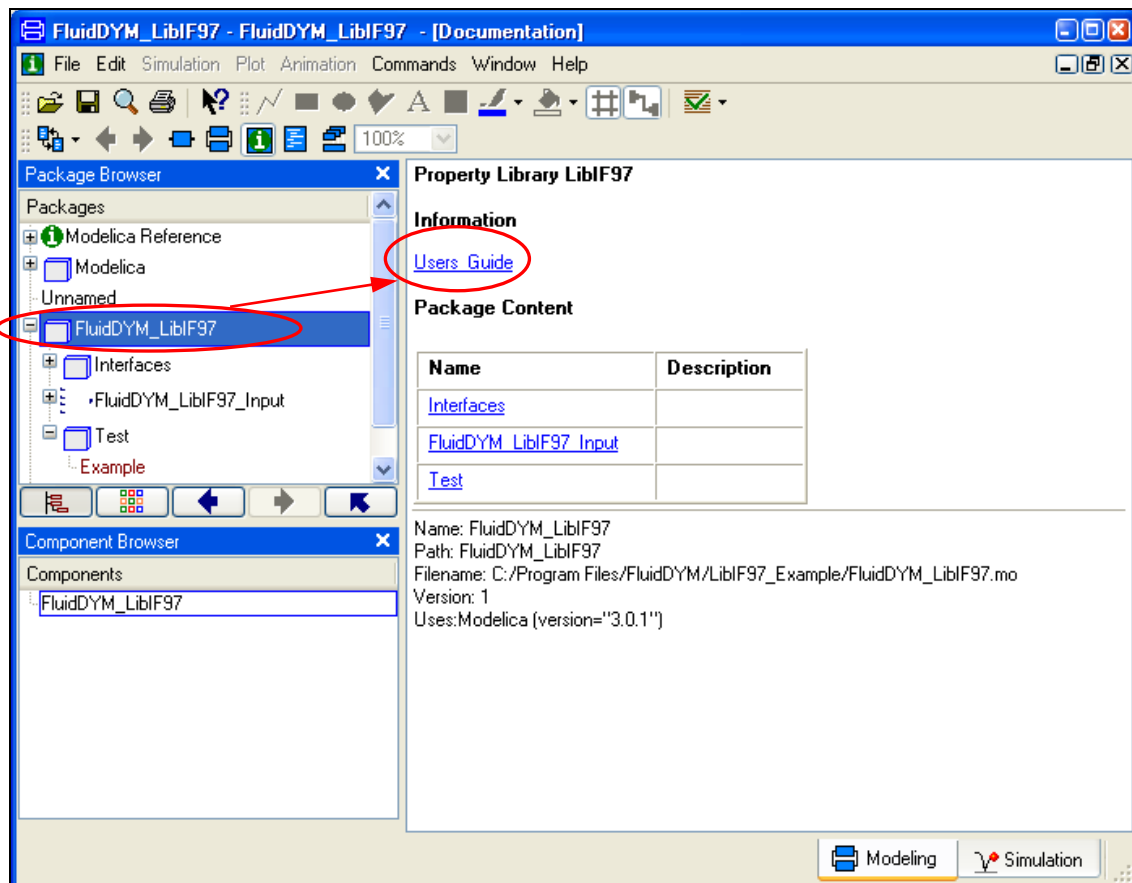
Figure 2.24: Selecting the "Users_Guide"

- The program documentation will be displayed within your default web browser.

Now, we will show you how to access the help page of a specific property function.

- Make sure Dymola is set to the "Modeling-Mode".

- Now click the ▣ button in the Dymola menu bar to choose the "Documentation Mode".

- Double-click on the "FluidDYM_LibIF97_Input" block on the left (see Figure 2.25).
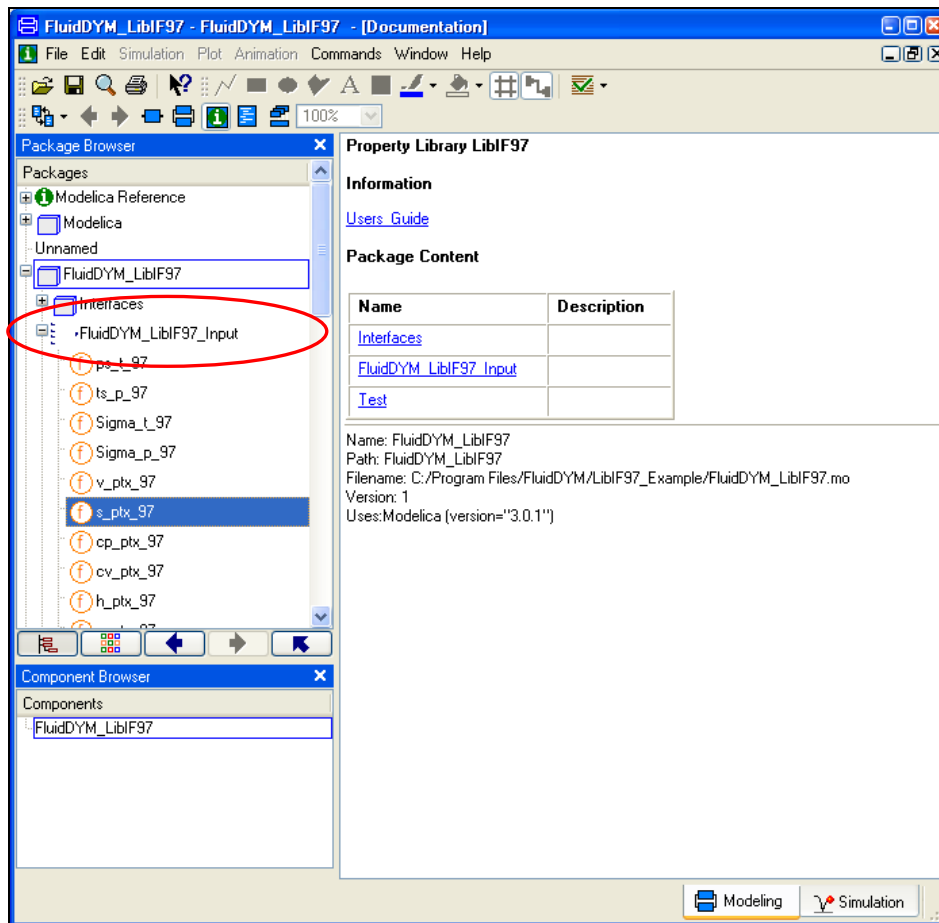
Figure 2.25: Selected "FluidDYM_LibIF97_Input" Block

- Below "FluidDYM_LibIF97_Input" you will see all functions of the LibIF97 property function (see Figure 2.24).

- Now select a function, e.g. "h_ptx_97", and then click on "Users_Guide" (see Figure 2.26).
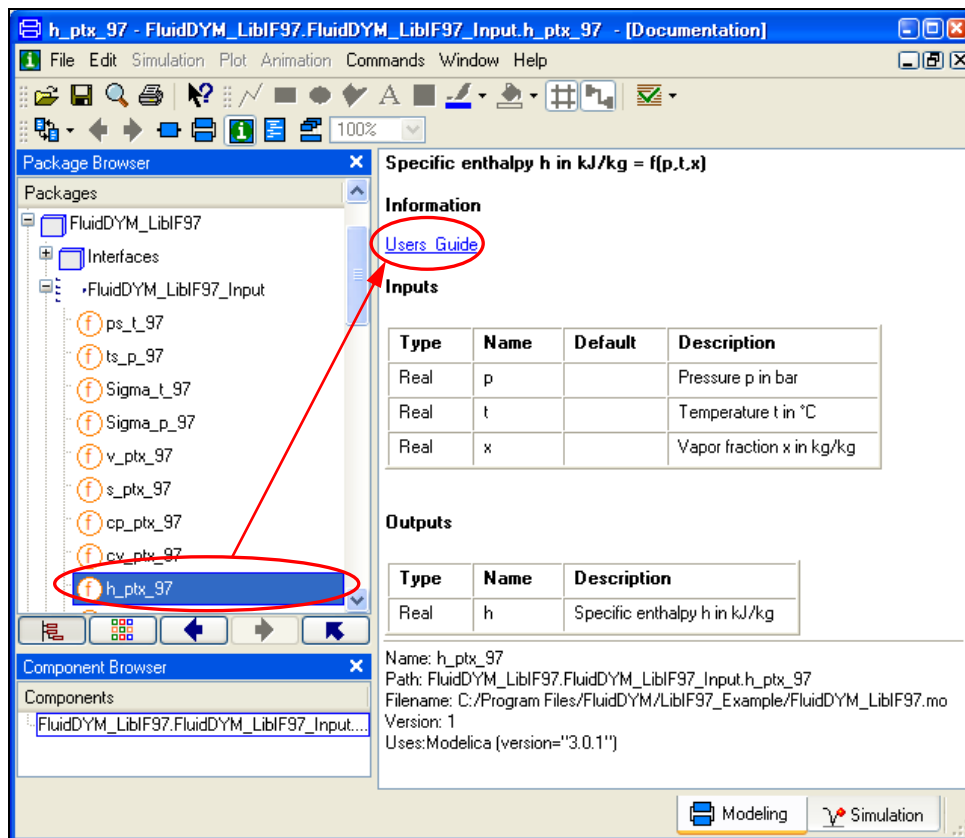
Figure 2.26: Marking the "h_ptx_97" function and selecting the "Users_Guide"

- You will now see the help page of the selected function, here "h_ptx_97", in your default web browser (see Figure 2.27).
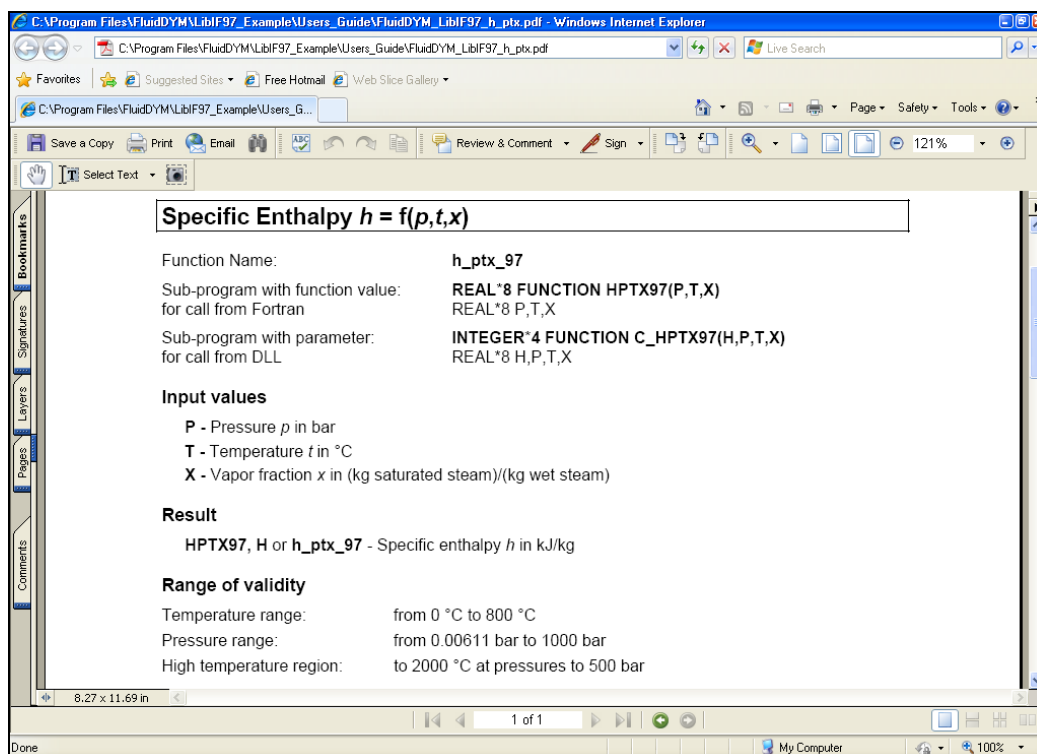
Figure 2.27: Help page of the function "h_ptx_97" in the web browser

2.4   Removing LibIF97 in Dymola

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 "FluidDYM LibIF97" by clicking on it and then clicking the "Change/Remove" button.

In the following dialogue box click "Automatic" and then "Next>".

Confirm the "Perform Uninstall" menu which appears by clicking the "Finish" button.

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

"FluidDYM LibIF97" has now been removed.

If LibIF97 is the only library installed, the directory "FluidDYM" will be removed as well.

3. Program Documentation

Thermal Diffusivity $a = \mathrm{f}(p,t,x)$

Function Name: **a_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_APTX97(A,P,T,X)**
for call from DLL 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 $a = \dfrac{\lambda}{\rho \cdot c_p} = \dfrac{\lambda \cdot v}{c_p}$ 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	$t_t = 0$ °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 α_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* <u>and</u> p = -1, or the given value for *p* <u>and</u> t = -1, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *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 **ALPHAPPTX97, ALPHAP = –1** or **alphap_ptx_97 = –1** for input values:

Single phase region: (*x* = –1)	*p* > 1000 bar or *p* < 0.00611 bar or *t* > 800 °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]

Isobaric Cubic Expansion Coefficient α_v = f(p,t,x)

Function Name: **alphav_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_ ALPHAVPTX97 (ALPHAV,P,T,X)**
for call from DLL 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 expansioncoefficient 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 $|t\text{-}t_s(p)| > 0.1$ 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 $p_t = 0.00611$ bar to $p_c = 220.64$ bar

Results for wrong input values

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

Saturation lines: at $p > 220.64$ bar or $p < 0.00611$ 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 $t_t = 0$ °C to $t_c = 373.946$ °C

Results for wrong input values

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

Saturation lines: $t > 373.946$ °C or $t < 0$ °C

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

Isothermal Stress Coefficient β_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: ($x = -1$)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Saturation lines: ($x = 0$ or $x = 1$)	at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or 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* <u>and</u> p = -1, or the given value for *p* <u>and</u> t = -1, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *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: ($x = -1$)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Saturation lines: ($x = 0$ or $x = 1$)	at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or 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: **REAL*8 FUNCTION CVPTX97(P,T,X)**
for call from Fortran   REAL*8 P,T,X

Sub-program with parameter: **INTEGER*4 FUNCTION C_CVPTX97(CV,P,T,X)**
for call from DLL   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 $t_t = 0$ °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 **CVPTX97, CV = –1** or **cv_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 Throttling Coefficient δ_T = f(p,t,x)

Function Name: **deltat_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_DELTATPTX97 (DELTAT,P,T,X)**
for call from DLL 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 kJ kg^{-1} 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 °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 **DELTATPTX97, DELTAT = –1** or **deltat_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]

Differential Quotient $\left(\dfrac{\partial \boldsymbol{v}}{\partial \boldsymbol{p}}\right)_{\boldsymbol{T}} = \mathbf{f}\left(\boldsymbol{p}, \boldsymbol{t}, \boldsymbol{x}\right)$

Function Name: **dv_dp_T_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_DVDPT97(DVDPT,P,T,X)**
for call from DLL   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 $\left(\dfrac{\partial v}{\partial p}\right)_{T}$ in $m^3 \cdot kg^{-1} \cdot kPa^{-1}$

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* <u>and</u> p = -1, or the given value for *p* <u>and</u> t = -1, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *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 **dv_dp_T_ptx_97** or **DVDPT97 = –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 $|t \text{-} t_s(p)| > 0.1$ K

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

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

Function Name: **dv_dT_p_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_DVDTP97(DVDTP,P,T,X)**
for call from DLL 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 $\left(\dfrac{\partial v}{\partial T}\right)_p$ in $m^3 \cdot kg^{-1} \cdot K^{-1}$

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 **dv_dT_p_ptx_97** or **DVDTP97 = –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 $|t\text{-}t_s(p)| > 0.1$ 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: **REAL*8 FUNCTION EPTXTU97(P,T,X,TU)**
for call from Fortran REAL*8 P,T,X,TU

Sub-program with parameter: **INTEGER*4 FUNCTION C_EPTXTU97(E,P,T,X,TU)**
for call from DLL 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
($0 \le x \le 1$) 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 ε = f(p,t,x)

Function Name: **epsilon_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_ EPSPTX97 (BETAP,P,T,X)**
for call from DLL   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 <u>and</u> p = -1, or the given value for p <u>and</u> t = -1, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> 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 **EPSPTX97, EPS = –1** or **epsilon_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 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	$t_t = 0$ °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 **FPTX97, F = –1** or **f_ptx_97 = –1** for input values:

Single phase region: ($x = -1$)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Saturation lines: ($0 \leq x \leq 1$)	at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or 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]

Fugacity $f^* = \text{f}(p,t,x)$

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	$t_t = 0$ °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 **FUGPTX97, FUG = –1** or **fug_ptx_97 = –1** for input values:

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

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

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

Function Name: **g_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_ GPTX97 (G,P,T,X)**
for call from DLL   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 $t_t = 0$ °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 **GPTX97, G = –1** or **g_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
($0 \leq x \leq 1$)   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]

KCE Kretzschmar Consulting Engineers

Dynamic Viscosity η = 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* <u>and</u> p = -1, or the given value for *p* <u>and</u> t = -1, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *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: (x = –1)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 900$ °C or $t < 0$ °C
Saturation lines: (x = 0 or x = 1)	at $p = –1$ and $t > 373.946$ °C or $t < 0$ °C or 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 $\lvert t - t_s(p) \rvert > 0.1$ 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: **REAL*8 FUNCTION HPS97(P,S)**
for call from Fortran REAL*8 P,S

Sub-program with parameter: **INTEGER*4 FUNCTION C_HPS97(H,P,S)**
for call from DLL 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]

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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 <u>and</u> p = -1 or the given value for p <u>and</u> t = -1 and in both cases the value for x between 0 and 1 must be entered.

If p <u>and</u> t <u>and</u> 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 **HPTX97, H = –1** or **h_ptx_97 = –1** for input values:

Single phase region: ($x = -1$)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Wet steam region: ($0 \le x \le 1$)	at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or 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 Exponent $\kappa = \mathbf{f}(p,t,x)$

Function Name:	**Kappa_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION KAPPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_KAPPTX97(KAPPA,P,T,X)** 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 $\kappa = -\dfrac{v}{p}\left(\dfrac{\partial p}{\partial v}\right)_s = \dfrac{w^2}{p \cdot v}$

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 <u>and</u> p = -1, or the given value for p <u>and</u> t = -1, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> 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: ($x = -1$)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Saturation lines: ($x = 0$ or $x = 1$)	at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or 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 κ_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* <u>and</u> p = -1, or the given value for *p* <u>and</u> t = -1, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *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 **KAPPATPTX97, KAPPAT = –1** or **kappat_ptx_97 = –1** for input values:

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

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

Thermal Conductivity λ = f(p,t,x)

Function Name:	**Lambda_ptx_97**
Sub-program with function value:	**REAL*8 FUNCTION LAMPTX97(P,T,X)**
for call from Fortran	REAL*8 P,T,X
Sub-program with parameter:	**INTEGER*4 FUNCTION C_LAMPTX97(LAM,P,T,X)**
for call from DLL	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* <u>and</u> p = -1, or the given value for *p* <u>and</u> t = -1, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *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 $|t\text{-}t_s(p)| > 0.1$ 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 <u>and</u> p = -1, or the given value for p <u>and</u> t = -1, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> 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 **MYPTX97, MY = –1** or **my_ptx_97 = –1** for input values:

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

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

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 <u>and</u> p = -1, or the given value for p <u>and</u> t = -1, plus the value for x ($x = 0$ or $x = 1$). If p <u>and</u> t <u>and</u> 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 **NPTXWL97, N = –1** or **n_ptxwl_97 = –1** for input values:

Single phase region: ($x = –1$)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Saturation lines: ($x = 0$ or $x = 1$)	at $p = –1$ and $t > 373.946$ °C or $t < 0$ °C or 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]

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

Function Name: **Ny_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_NYPTX97(NY,P,T,X)**
for call from DLL   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 $\nu = \dfrac{\eta}{\rho} = \eta \cdot v$ 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 °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 **NYPTX97, NY = –1** or **ny_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:

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: **REAL*8 FUNCTION PHS97(H,S)**
for call from Fortran REAL*8 H,S

Sub-program with parameter: **INTEGER*4 FUNCTION C_PHS97(P,H,S)**
for call from DLL 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
$h < h(0.00611$ bar, x) at $h'(0.00611$ bar$) < h < h''(0.00611$ bar$)$

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

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

Function Name: **p_vh_97**

Sub-program with function value: **REAL*8 FUNCTION PVH97(V,H)**
for call from Fortran   REAL*8 V,H

Sub-program with parameter: **INTEGER*4 FUNCTION C_PVH97(P,H)**
for call from DLL   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 m^3/kg
$h < h$(0.00611 bar, x) at h'(0.00611 bar) $< h < h''$(0.00611 bar)

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

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

Function Name: **p_vu_97**

Sub-program with function value: **REAL*8 FUNCTION PVU97(V,U)**
for call from Fortran REAL*8 V,U

Sub-program with parameter: **INTEGER*4 FUNCTION C_VU97(P,V,U)**
for call from DLL 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:

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

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

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

Function Name: **Pr_ptx_97**

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

Sub-program with parameter: **INTEGER*4 FUNCTION C_PRPTX97(PR,P,T,X)**
for call from DLL   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 $Pr = \dfrac{v}{a} = \dfrac{\eta \cdot c_p}{\lambda}$

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 °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 **PRPTX97, Pr = –1** or **Pr_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 $|t\text{-}t_s(p)|$ > 0.1 K

References:

Internal calculation of η [7], [6], and ρ or *v* 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: **REAL*8 FUNCTION RHOPTX97(P,T,X)**
for call from Fortran   REAL*8 P,T,X

Sub-program with parameter: **INTEGER*4 FUNCTION C_RHOPTX97(RHO,P,T,X)**
for call from DLL   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 $\rho = \dfrac{1}{v}$ in kg/m^3

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 $|t\text{-}t_s(p)| > 0.1$ K

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

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

Function Name: **s_ph_97**

Sub-program with function value: **REAL*8 FUNCTION SPH97(P,H)**
for call from Fortran   REAL*8 P,H

Sub-program with parameter: **INTEGER*4 FUNCTION C_SPH97(S,P,H)**
for call from DLL   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: **REAL*8 FUNCTION SPTX97(P,T,X)**
for call from Fortran   REAL*8 P,T,X

Sub-program with parameter: **INTEGER*4 FUNCTION C_SPTX97(S,P,T,X)**
for call from DLL   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 <u>and</u> p = -1 or the given value for p <u>and</u> t = -1 and in both cases the value for x between 0 and 1 must be entered.

If p <u>and</u> t <u>and</u> 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 **SPTX97, S = –1** or **s_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]

Surface Tension σ = f(p)

Function Name: **Sigma_p_97**

Sub-program with function value: **REAL*8 FUNCTION SIGMAP97(P)**
for call from Fortran REAL*8 P

Sub-program with parameter: **INTEGER*4 FUNCTION C_SIGMAP97(SIGMA,P)**
for call from DLL 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$\cdot$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: **REAL*8 FUNCTION THS97(H,S)**
for call from Fortran REAL*8 H,S

Sub-program with parameter: **INTEGER*4 FUNCTION C_THS97(T,H,S)**
for call from DLL 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

$h < h(0.00611$ bar, $x)$ at $h'(0.00611$ bar$) < h < h''(0.00611$ bar$)$

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

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

Function Name:	**t_ph_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION TPH97(P,H)** REAL*8 P,H
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TPH97(T,P,H)** 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]

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

Function Name: **t_ps_97**

Sub-program with function value: **REAL*8 FUNCTION TPS97(P,S)**
for call from Fortran   REAL*8 P,S

Sub-program with parameter: **INTEGER*4 FUNCTION C_TPS97(T,P,S)**
for call from DLL   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]

[#K$+] Backward Function: Temperature t = f(v,h)

Function Name:	**t_vh_97**
Sub-program with function value:	**REAL*8 FUNCTION TVH97(V,H)**
for call from Fortran	REAL*8 V,H
Sub-program with parameter:	**INTEGER*4 FUNCTION C_TVH97(T,V,H)**
for call from DLL	REAL*8 T,V,H

Input values

   V - Specific volume v in m³/kg

   H - Specific enthalpy h in kJ/kg

Result

   TVH97, T or **t_vh_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 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 bar to p_c = 220.64 bar

Results for wrong input values

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

v < 0.0009 m³/kg
h < h(0.00611 bar, x) at h'(0.00611 bar) < h < h''(0.00611 bar)

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

FUNC_97_212
K Backward function: Temperature t = f(v,h)
$ Backward function: Temperature, t = f(v,h)
+ SUCH:212

KCE Kretzschmar Consulting Engineers

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

Function Name:	**t_vu_97**
Sub-program with function value:	**REAL*8 FUNCTION TVU97(V,U)**
for call from Fortran	REAL*8 V,U
Sub-program with parameter:	**INTEGER*4 FUNCTION C_TVU97(T,V,U)**
for call from DLL	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 °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 bar to p_c = 220.64 bar

Results for wrong input values

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

v < 0.0009 m^3/kg
u < u(0.00611 bar, x) at u'(0.00611 bar) < u < u''(0.00611 bar)

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

[#] FUNC_97_214
[K] Backward function: Temperature t = f(v,u)
[$] 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: **REAL*8 FUNCTION UPTX97(P,T,X)**
for call from Fortran   REAL*8 P,T,X

Sub-program with parameter: **INTEGER*4 FUNCTION C_UPTX97(U,P,T,X)**
for call from DLL   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: $t_t = 0$ °C ... $t_c = 373.946$ °C

$p_t = 0.00611$ bar ... $p_c = 220.64$ bar)

Results for wrong input values

Result **UPTX97, U = –1** or **u_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 $|t\text{-}t_s(p)| > 0.1$ 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 m^3/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: **REAL*8 FUNCTION VPS97(P,S)**
for call from Fortran   REAL*8 P,S

Sub-program with parameter: **INTEGER*4 FUNCTION C_VPS97(V,P,S)**
for call from DLL   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 m^3/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 $v = \mathrm{f}(p,t,x)$

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 m^3/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 <u>and</u> p = -1 or the given value for p <u>and</u> t = -1 and in both cases the value for x between 0 and 1 must be entered.

   If p <u>and</u> t <u>and</u> 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: ($x = -1$)	$p > 1000$ bar or $p < 0.00611$ bar or $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Wet steam region: ($0 \leq x \leq 1$)	at $p = -1$ and $t > 373.946$ °C or $t < 0$ °C or 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 $|t\text{-}t_s(p)| > 0.1$ K

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

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

Function Name:	**w_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION WPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_WPTX97(W,P,T,X)** 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* <u>and</u> p = -1, or the given value for *p* <u>and</u> t = -1, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *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 **WPTX97, W = –1** or **w_ptx_97 = –1** for input values:

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

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

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

Function Name: **x_hs_97**

Sub-program with function value: **REAL*8 FUNCTION XHS97(H,S)**
for call from Fortran REAL*8 H,S

Sub-program with parameter: **INTEGER*4 FUNCTION C_XHS97(X,H,S)**
for call from DLL 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 bar, x) at h'(0.00611 bar) < h < h''(0.00611 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: **REAL*8 FUNCTION XPH97(P,H)**
for call from Fortran   REAL*8 P,H

Sub-program with parameter: **INTEGER*4 FUNCTION C_XPH97(X,P,H)**
for call from DLL   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: **REAL*8 FUNCTION XVH97(V,H)**
for call from Fortran   REAL*8 V,H

Sub-program with parameter: **INTEGER*4 FUNCTION C_XVH97(X,V,H)**
for call from DLL   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 (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 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
   $p > 220.64$ bar or $p < 0.00611$ bar

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

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

Function Name: **x_vu_97**

Sub-program with function value: **REAL*8 FUNCTION XVU97(V,U)**
for call from Fortran   REAL*8 V,U

Sub-program with parameter: **INTEGER*4 FUNCTION C_XVU97(X,V,U)**
for call from DLL   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 bar or p < 0.00611 bar

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

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

Function Name: **x_ps_97**

Sub-program with function value: **REAL*8 FUNCTION XPS97(P,S)**
for call from Fortran   REAL*8 P,S

Sub-program with parameter: **INTEGER*4 FUNCTION C_XPS97(X,P,S)**
for call from DLL   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 <u>and</u> p = -1, or the given value for p <u>and</u> t = -1, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> 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 **ZPTX97, Z = –1** or **z_ptx_97 = –1** for input values:

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

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)

Library LibSBTL_IF97
Library LibSBTL_95

Extremely fast property calculations according to the IAPWS Guideline 2015 Spline-based Table Look-up Method (SBTL) applied to the Industrial Formulation IAPWS-IF97 and to the Scientific Formulation IAPWS-95 for Computational Fluid Dynamics and simulating non-stationary processes

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

CO_2 - Span, Wagner H_2O - IAPWS-95
O_2 - Schmidt, Wagner N_2 - Span et al.
Ar - Tegeler et al.

and of the ideal gases:

SO_2, CO, Ne
(Scientific Formulation of Bücker et al.)

Consideration of:
- Dissociation from VDI 4670
- 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 VDI 4670
- Poynting effect from ASHRAE RP-1485

Carbon Dioxide Including Dry Ice
Library LibCO2

Formulation of Span and Wagner (1996)

Seawater
Library LibSeaWa

IAPWS Industrial Formulation 2013

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_2O	F_2	Propane
N_2	SO_2	NH_3	Iso-Butane
O_2	H_2	Methane	n-Butane
CO	H_2S	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

Humid Air
Library ASHRAE LibHuAirProp

Model: Virial equation from ASHRAE Report RP-1485 for real mixture of the real fluids:
  - Dry air
  - Steam

Consideration of:
- Enhancement of the partial saturation pressure of water vapor at elevated total pressures

www.ashrae.org/bookstore

Dry Air Including Liquid Air
Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia
Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a
Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane
Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane
Library LibButane_n

Formulation of Bücker and Wagner (2006)

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 the 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

$C_2H_6O_2$	Ethylene glycol
$C_3H_8O_2$	Propylene glycol
C_2H_5OH	Ethanol
CH_3OH	Methanol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate
$CHKO_2$	Potassium formate
LiCl	Lithium chloride
NH_3	Ammonia

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol
Library LibC2H5OH
Formulation of
Schroeder (2012)

Methanol
Library LibCH3OH
Formulation of
de Reuck and Craven (1993)

Propane
Library LibPropane
Formulation of
Lemmon et al. (2009)

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 $C_{14}H_{42}O_5Si_6$ **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)

Nitrogen and Oxygen
Libraries LibN2 and LibO2
Formulations of Span et al. (2000)
and Schmidt and Wagner (1985)

Hydrogen
Library LibH2
Formulation of
Leachman et al. (2009)

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 LibC6H14**

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 H_2S **Library LibH2S**

Nitrous oxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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Fax: +49-3222-4262250

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 v
- 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.

www.thermofluidprop.com

KCE-ThermoFluidProperties
www.thermofluidprop.com

Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL^Graphics for Excel®
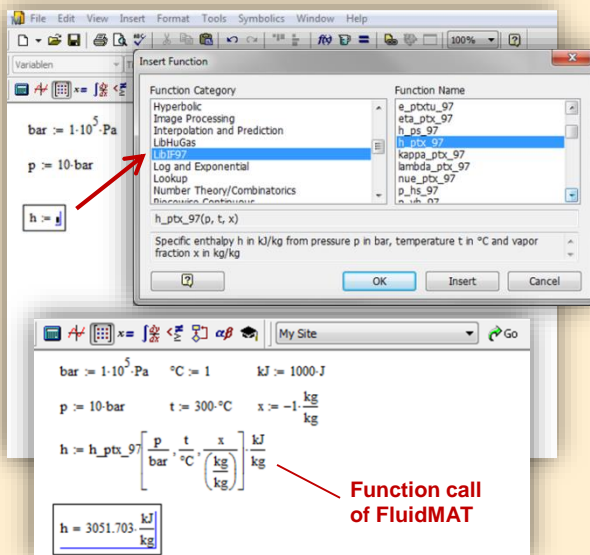
Choosing a property library and a function

Displaying the calculated values in diagrams

Menu for the input of given property values

Calculating an isentropic expansion

	p	t	x	s	h	v
	bar	C	kg/kg	kJ/kgK	kJ/kg	m3/kg
	20	400	-1		(A5;B5;C5)	
	10					
	5					
	1					
	0,5					
	0,1					

SUM =h_ptx_97(A5;B5;C5)

Function Arguments

h_ptx_97

p in bar A5 = 20
t in °C B5 = 400
x in kg/kg C5 = -1

= 3248,227076

Specific enthalpy h in kJ/kg.

x in kg/kg Vapor fraction

Formula result = 3248,23

Insert Function

Search for a function:

Or select a category: Water IAPWS-IF97

Select a function:

e_ptx_97
Eta_ptx_97
h_ps_97
h_ptx_97
Kappa_ptx_97
Lambda_ptx_97
Nue_ptx_97

h_ptx_97(p in bar; t in °C; x in kg/kg)
Specific enthalpy h in kJ/kg.

T-s Diagram for Water Industrial-Formulation IAPWS-IF97

pressure p in MPa
enthalpy h in kJ/kg
specific volume v in m³/kg
vapor fraction x

specific entropy s in kJ/(kg K)

Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.

Insert Function

Function Category
Hyperbolic
Image Processing
Interpolation and Prediction
LibHuGas
LibIF-97
Log and Exponential
Lookup
Number Theory/Combinatorics

Function Name
e_ptxtu_97
eta_ptx_97
h_ps_97
h_ptx_97
kappa_ptx_97
lambda_ptx_97
nue_ptx_97

h_ptx_97(p, t, x)

Specific enthalpy h in kJ/kg from pressure p in bar, temperature t in °C and vapor fraction x in kg/kg

$$bar := 1 \cdot 10^5 \cdot Pa \quad °C := 1 \quad kJ := 1000 \cdot J$$

$$p := 10 \cdot bar \quad t := 300 \cdot °C \quad x := -1 \cdot \frac{kg}{kg}$$

$$h := h\_ptx\_97 \left[\frac{p}{bar}, \frac{t}{°C}, \frac{x}{\left(\frac{kg}{kg}\right)} \right] \cdot \frac{kJ}{kg}$$

$$h = 3051.703 \cdot \frac{kJ}{kg}$$

Function call of FluidMAT

Add-In FluidLAB for MATLAB®
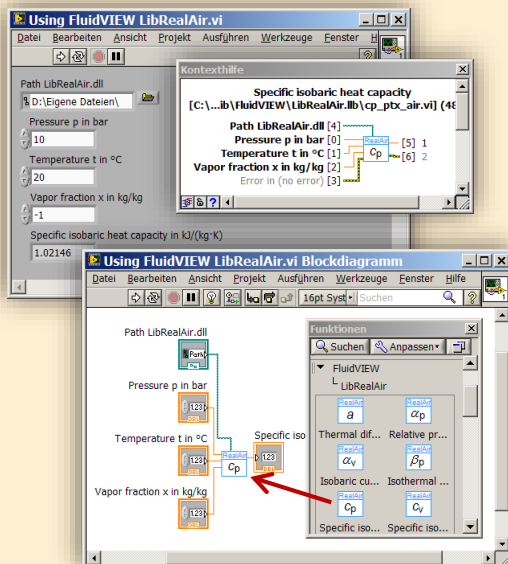
Using the Add-In FluidLAB the property functions can be called in MATLAB®.

MATLAB 7.3.0 (R2006b)

C:\Programme\FluidLAB\LibHuAir_Example

Current Directory - C:\Programme\FluidLAB\LibHuAir_Example

All Files | File Type | Description
hl_ptxw_HuAir.mexw32 | MEX-file
LibHuAir.dll | DLL File
libifcoremdd.dll | DLL File
libmmd.dll | DLL File
libmmdd.dll | DLL File
msvcr71d.dll | DLL File
Example_hl_ptxw_HuAir.m | M-file | hl_ptxw_HuAir.m

Editor - C:\Programme\FluidLAB\LibHuAir_Example\Example_hl_...

```
% hl_ptxw_HuAir.m
%%
p=1; % pressure in bar
t=20; % temperature in °C
xw=10; % absolute humidity in g/kg_air
%%
hl=hl_ptxw_HuAir(p,t,xw)
%%
```

Function call of FluidLAB

Command History
--%-- 20.06.07 10:50 --%

Command Window
hl =
    45.5084
>>

Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

Using FluidVIEW LibRealAir.vi

Path LibRealAir.dll
D:\Eigene Dateien\

Pressure p in bar
10

Temperature t in °C
20

Vapor fraction x in kg/kg
-1

Specific isobaric heat capacity in kJ/(kg·K)
1.02146

Kontexthilfe

Specific isobaric heat capacity
[C:\...ib\FluidVIEW\LibRealAir.llb\cp_ptx_air.vi] (48

Path LibRealAir.dll [4]
Pressure p in bar [0]
Temperature t in °C [1]
Vapor fraction x in kg/kg [2]
Error in (no error) [3]

[5] 1
[6] 2

Using FluidVIEW LibRealAir.vi Blockdiagramm

Path LibRealAir.dll

Pressure p in bar

Temperature t in °C

Vapor fraction x in kg/kg

Specific iso

Funktionen

FluidVIEW
LibRealAir

Thermal dif... Relative pr...
Isobaric cu... Isothermal ...
Specific iso... Specific iso...

Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

The property functions can be called in DYMOLA® and SimulationX®.

Example1 - FluidDYM_SeaWa.TestModelle.Example1

Package Browser
Packages
Modelica Reference
Modelica
Unnamed
FluidDYM_SeaWa
Interfaces
FluidDYM_LibSeaWa_Input
TestModelle
Example1
Example2

Diagram

fluidDYM_LibSeaWa_Input

fluidDYM_LibSeaWa_Input in FluidDYM_SeaWa.TestMo...

General | Add modifiers

Component
Name fluidDYM_LibSeaWa_Input
Comment

Model
Path FluidDYM_SeaWa.FluidDYM_LibSeaWa_Input
Comment

Parameters
scanRange 0.00T

FunctionNo Va.Interfaces.FunctionSelection.h_ptXi_SeaWa

h_ptXi_SeaWa
hl_ptXi_SeaWa
hsl_pstXisl_SeaWa
hsv_pstXisl_SeaWa
kappa_ptXi_SeaWa
kappal_ptXi_SeaWa
kappas_pstXisl_SeaWa
kappasv_pstXisl_SeaWa
kappaTl_ptXi_SeaWa
kappaTsl_pstXisl_SeaWa

Example1 - FluidDYM_SeaWa.TestModelle.Example1

Variable Browser
Variables | Values
Example1 1
Parameter_x2
Parameter_x3
Parameter_x1
fluidDYM_LibSeaWa_Input
scanRange 0.001
FunctionNumber
z
x1
x2
x3

Plot
fluidDYM_LibSeaWa_Input.z

fluidDYM_LibSeaWa_Input.z = 67.9239
slope = 0
time = 1

Modeling | Simulation

Add-In FluidEES for Engineering Equation Solver®

App International Steam Tables for iPhone, iPad, iPod touch, Android Smartphones and Tablets
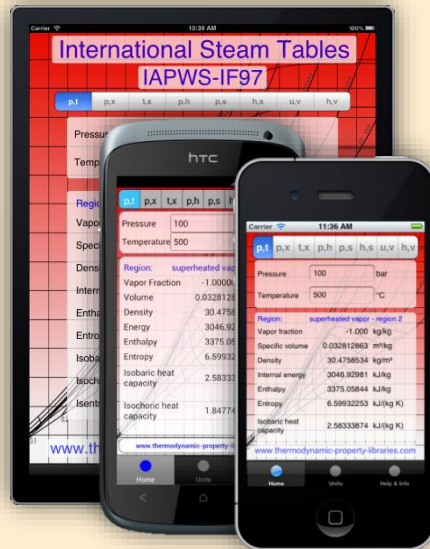
Online Property Calculator at www.thermofluidprop.com

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 Nspire CX CAS   TI 83
TI Nspire CAS   TI 84
   TI 89

TI Voyage 200

TI 92

For more information please contact:

KCE-ThermoFluidProperties UG (limited liability) & Co. KG
Professor Hans-Joachim Kretzschmar

Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
E-mail: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-4262250

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
- Kinematic viscosity v
- Thermal conductivity λ
- Prandtl number Pr

Backward Functions

- $T, v, s\,(p,h)$
- $T, v, h\,(p,s)$
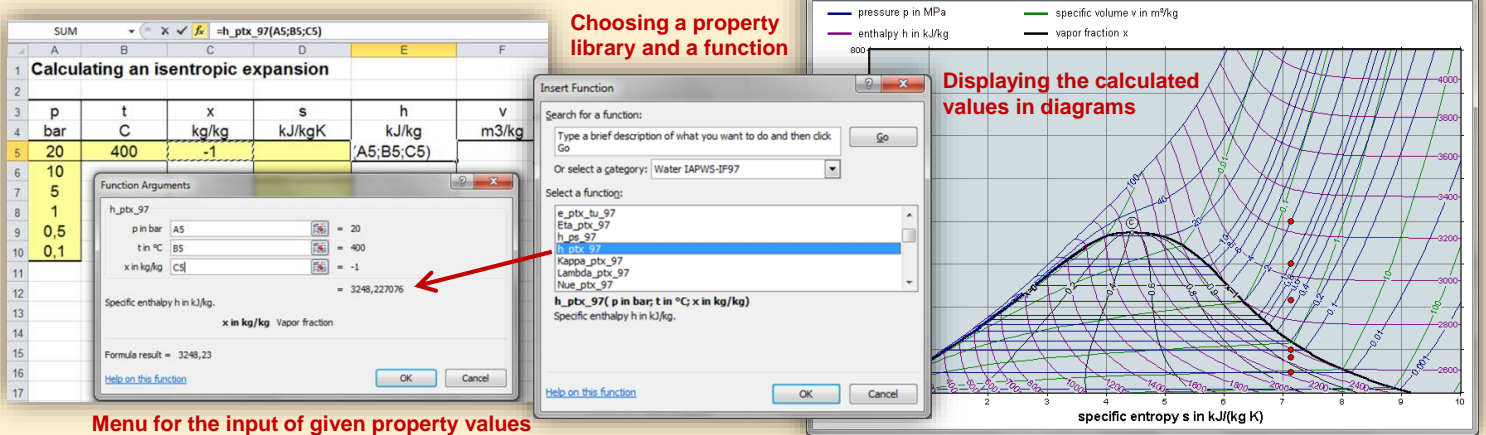- $p, T, v\,(h,s)$
- $p, T\,(v,h)$
- $p, T\,(v,u)$

Thermodynamic Derivatives

- Partial derivatives can be calculated.

[a] Not all of these property functions are available in all property libraries.

www.thermofluidprop.com

5. References

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6. Satisfied Customers

Date: 05/2018

The following companies and institutions use the property libraries

- FluidEXL*Graphics* for Excel®

- FluidLAB for MATLAB®

- FluidMAT for Mathcad®

- FluidEES for Engineering Equation Solver® EES

- FluidDYM for Dymola® (Modelica) and SimulationX®

- FluidVIEW for LabVIEW™.

2018

Universität Madrid, Madrid, Spanien	05/2018
HS Zittau/ Görlitz, Fakultät Wirtschaft, Zittau	05/2018
HS Niederrhein, Krefeld	05/2018
GRS, Köln	03/2018
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	02/2018
AIXPROCESS, Aachen	02/2018
KRONES, Neutraubling	02/2018
Doosan Lentjes, Ratingen	01/2018

2017

Compact Kältetechnik, Dresden	12/2017
Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	12/2017
TH Mittelhessen, Gießen	11/2017
Haarslev Industries, Søndersø, Denmark	11/2017
Hochschule Zittau/Görlitz, Fachgebiet Energiesystemtechnik	11/2017
ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	10/2017
Fels-Werke GmbH, Elbingerode	10/2017
KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik	09/2017
Air-Consult, Jena	09/2017
Papierfabrik Koehler, Oberkirch	09/2017
ZWILAG, Würenlingen, Switzerland	09/2017
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017
Fichtner IT Consulting AG, Stuttgart	07/2017
Hochschule Ansbach, Ansbach	06/2017
RONAL, Härkingen, Switzerland	06/2017
BORSIG Service, Berlin	06/2017

BOGE Kompressoren, Bielefeld	06/2017
STEAG Energy Services, Zwingenberg	06/2017
CES clean energy solutions, Wien, Austria	04/2017
Princeton University, Princeton, USA	04/2017
B2P Bio-to-Power, Wadersloh	04/2017
TU Dresden, Institute for Energy Engineering, Dresden	04/2017
SAINT-GOBAIN, Vaujours, France	03/2017
TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
SCHMIDT + PARTNER, Therwil, Switzerland	03/2017
KAESER Kompressoren, Gera	03/2017
F&R, Praha, Czech Republic	03/2017
ULT Umwelt-Lufttechnik, Löbau	02/2017
JS Energie & Beratung, Erding	02/2017
Kelvion Brazed PHE, Nobitz-Wilchwitz	02/2017
MTU Aero Engines, München	02/2017
Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	01/2017
SHELL Deutschland Oil, Wesseling	01/2017
MARTEC Education Center, Frederikshaven, Denmark	01/2017
SynErgy Thermal Management, Krefeld	01/2017

2016

BOGE Druckluftsysteme, Bielefeld	12/2016
BFT Planung, Aachen	11/2016
Midiplan, Bietigheim-Bissingen	11/2016
BBE Barnich IB	11/2016
Wenisch IB,	11/2016
INL, Idaho Falls	11/2016
TU Kältetechnik, Dresden	11/2016
Kopf SynGas, Sulz	11/2016
INTVEN, Bellevne (USA)	11/2016
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AGO AG Energie+Anlagen, Kulmbach	10/2016
Universität Stuttgart, ITW, Stuttgart	09/2016
Pöyry Deutschland GmbH, Dresden	09/2016
Siemens AG, Erlangen	09/2016
BASF über Fichtner IT Consulting AG	09/2016
B+B Engineering GmbH, Magdeburg	09/2016
Wilhelm Büchner Hochschule, Pfungstadt	08/2016

Webasto Thermo & Comfort SE, Gliching	08/2016
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Planungsbüro Waidhas GmbH, Chemnitz	07/2016
EEB Enerko, Aldershoven	07/2016
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	07/2016
SSP Kälteplaner AG, Wolfertschwenden	07/2016
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	07/2016
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
Universidad Carlos III de Madrid, Madrid, Spain	04/2016
INWAT, Lodzi, Poland	04/2016
Planungsbüro WAIDHAS GmbH, Chemnitz	04/2016
STEAG Energy Services GmbH, Laszlo Küppers, Zwingenberg	03/2016
WULFF & UMAG Energy Solutions GmbH, Husum	03/2016
FH Bielefeld, Bielefeld	03/2016
EWT Eckert Wassertechnik GmbH, Celle	03/2016
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016, 06/2016 (2x)
IEV KEMA - DNV GV – Energie, Dresden	02/2016
Allborg University, Department of Energie, Aalborg, Denmark	02/2016
G.A.M. Heat GmbH, Gräfenhainichen	02/2016
Institut für Luft- und Kältetechnik, Dresden	02/2016, 05/2016, 06/2016
Bosch, Stuttgart	02/2016
INL Idaho National Laboratory, Idaho, USA	11/2016, 01/2016
Friedl ID, Wien, Austria	01/2016
Technical University of Dresden, Dresden	01/2016

2015

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Ruldolf IB, Strau, Austria	12/2015
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2014

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for RWE Essen	12/2013
University of Budapest, Hungary	08/2013
Siemens, Frankenthal	08/2013, 10/2013
	11/2013
VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
Technical University of Deggendorf	07/2013
University of Maryland, USA	07/2013, 08/2013
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BHR Bilfinger, Essen	06/2013
SÜDSALZ, Bad Friedrichshall	06/2013, 12/2013
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KIER, Gajeong-ro, Südkorea	05/2013
Schwing/Stetter GmbH, Memmingen	05/2013
Vattenfall, Berlin	05/2013
AUTARK, Kleinmachnow	05/2013
STEAG, Zwingenberg	05/2013
Hochtief, Düsseldorf	05/2013
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Technical University -Bundeswehr, Munich	04/2013
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Kältetechnik Dresen + Bremen, Alfhausen	04/2013
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ENTEC, Auerbach	02/2013
Caterpillar, Kiel	02/2013
Technical University of Wismar	02/2013
Technical University of Dusseldorf	02/2013

ILK, Dresden	01/2013, 08/2013
Fichtner IT, Stuttgart	01/2013, 11/2013
Schnepf Ingeniuerbüro, Nagold	01/2013
Schütz Engineering, Wadgassen	01/2013
Endress & Hauser, Reinach, Switzerland	01/2013
Oschatz GmbH, Essen	01/2013
frischli Milchwerke, Rehburg-Loccum	01/2013

2012

Voith, Bayreuth	12/2012
Technical University of Munich	12/2012
Dillinger Huette	12/2012
University of Stuttgart	11/2012
Siemens, Muehlheim	11/2012
Sennheiser, Hannover	11/2012
Oschatz GmbH, Essen	10/2012
Fichtner IT, Stuttgart	10/2012, 11/2012
Helbling Technik AG, Zurich, Switzerland	10/2012
University of Duisburg	10/2012
Rerum Cognitio Forschungszentrum, Frankfurt	09/2012
Pöyry Deutschland GmbH, Dresden	08/2012
Extracciones, Guatemala	08/2012
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GKS, Schweinfurt	07/2012
COMPAREX, Leipzig for RWE Essen	07/2012
GEA, Nobitz	07/2012
Meyer Werft, Papenburg	07/2012
STEAG, Herne	07/2012
GRS, Cologne	06/2012
Fichtner IT Consult, Chennai, India	06/2012
Siemens, Freiburg	06/2012
Nikon Research of America, Belmont, USA	06/2012
Niederrhein University of Applied Sciences, Krefeld	06/2012
STEAG, Zwingenberg	06/2012
Mainova, Frankfurt on Main via Fichtner IT Consult	05/2012
Endress & Hauser	05/2012
PEU, Espenheim	05/2012
Luzern University of Applied Sciences, Switzerland	05/2012

BASF, Ludwigshafen (general license) via Fichtner IT Consult	05/2012
SPX Balcke-Dürr, Ratingen	05/2012, 07/2012
Gruber-Schmidt, Wien, Austria	04/2012
Vattenfall, Berlin	04/2012
ALSTOM, Baden	04/2012
SKW, Piesteritz	04/2012
TERA Ingegneria, Trento, Italy	04/2012
Siemens, Erlangen	04/2012, 05/2012
LAWI Power, Dresden	04/2012
Stadtwerke Leipzig	04/2012
SEITZ, Wetzikon, Switzerland	03/2012, 07/2012
M & M, Bielefeld	03/2012
Sennheiser, Wedemark	03/2012
SPG, Montreuil Cedex, France	02/2012
German Destilation, Sprendlingen	02/2012
Lopez, Munguia, Spain	02/2012
Endress & Hauser, Hannover	02/2012
Palo Alto Research Center, USA	02/2012
WIPAK, Walsrode	02/2012
Freudenberg, Weinheim	01/2012
Fichtner, Stuttgart	01/2012
airinotec, Bayreuth	01/2012, 07/2012
University Auckland, New Zealand	01/2012
VPC, Vetschau	01/2012
Franken Guss, Kitzingen	01/2012

2011

XRG-Simulation, Hamburg	12/2011
Smurfit Kappa PPT, AX Roermond, Netherlands	12/2011
AWTEC, Zurich, Switzerland	12/2011
eins-energie, Bad Elster	12/2011
BeNow, Rodenbach	11/2011
Luzern University of Applied Sciences, Switzerland	11/2011
GMVA, Oberhausen	11/2011
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	10/2011
PLANAIR, La Sagne, Switzerland	10/2011
LAWI, Dresden	10/2011
Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011

Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011
	10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011,
	08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011
	06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010

University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010
Vaillant, Remscheid	10/2010
PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
Saacke, Bremen	09/2010
WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	08/2010
ERGION, Mannheim	07/2010
Fichtner IT Consulting, Stuttgart	07/2010
TF Design, Matieland, South Africa	07/2010
MCE, Berlin	07/2010, 12/2010
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	06/2010
RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010
Universitaet der Bundeswehr, Munich	04/2010

Technical University of Hamburg-Harburg	04/2010
Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
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CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
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Siemens Energy, Nuremberg	02/2010
Augsburg University of Applied Sciences	02/2010
ALSTOM Power, Baden, Switzerland	02/2010, 05/2010
MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	01/2010, 12/2010
Technical University of Freiberg	01/2010
ILK, Dresden	01/2010, 12/2010
Fischer-Uhrig Consulting Engineers, Berlin	01/2010

2009

ALSTOM Power, Baden, Schweiz	01/2009, 03/2009 05/2009
Nordostschweizerische Kraftwerke AG, Doettingen, Switzerland	02/2009
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Hamburg University of Applied Sciences	02/2009
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Bernd Münstermann, Telgte	03/2009
Suedzucker, Zeitz	03/2009
CPP, Marburg	03/2009
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Regensburg University of Applied Sciences	05/2009
Gatley & Associates, Atlanta, USA	05/2009
BOSCH, Stuttgart	06/2009, 07/2009
Dr. Nickolay, Consulting Engineers, Gommersheim	06/2009
Ferrostal Power, Saarlouis	06/2009
BHR Bilfinger, Essen	06/2009
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Techsoft, Linz, Austria	08/2009
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Wienstrom, Vienna, Austria	08/2009
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Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
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Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
EC, Heidelberg	11/2009
MCI, Innsbruck, Austria	12/2009
Saacke, Bremen	12/2009
ENERKO, Aldenhoven	12/2009

2008

Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	01/2008
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MAAG, Kuesnacht, Switzerland	02/2008
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Lentjes, Ratingen	03/2008
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CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008

Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008
Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
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Technical University of Dresden,	10/2008, 11/2008
Professorship of Thermic Energy Machines and Plants	
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

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Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
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Universität der Bundeswehr, Munich	02/2007
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University of Rostock, Chair in Technical Thermodynamics	03/2007
AGO, Kulmbach	03/2007
University of Stuttgart, Chair in Aviation Propulsions	03/2007
Siemens Power Generation, Duisburg	03/2007
ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
Technical University of Cottbus,	06/2007
Chair in Power Plant Engineering	
Voith Paper Air Systems, Bayreuth	06/2007
Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
National Energy Technology Laboratory, Pittsburg, USA	10/2007
Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007

Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

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STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006
Technical University of Munich, Chair in Apparatus and Plant Engineering	02/2006
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Department of USET Merseburg incorporated society	05/2006
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	05/2006
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
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ThyssenKrupp Marine Systems, Kiel	07/2006

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Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden Professorship of Thermic Energy Machines and Plants	04/2005
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
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Stadtwerke Leipzig	07/2005
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Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

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Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
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h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
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STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
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Enertech EUT, Radebeul (company license)	11/2004
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Freudenberg Service, Weinheim	12/2004

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003

Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
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VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
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Pettersson+Ahrends, Ober-Moerlen	05/2003
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Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003
Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

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Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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Siemens, Karlsruhe (general license for the WinIS information system)	02/2002

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G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
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Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001

h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
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AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000
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GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
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Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
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VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
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Bayernwerk, Munich	01/1999
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KEMA IEV, Dresden	03/1999
Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
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Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
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SCA Hygiene Products, Munich	10/1998
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Gerb, Dresden	06/1997
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