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Faculty of
MECHANICAL ENGINEERING
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TECHNICAL THERMODYNAMICS

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

FluidVIEW
with LibIF97
for LabVIEW™

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Property Library for the Industrial Formulation IAPWS-IF97 of Water and Steam Including DLL and Add-on for LabVIEW™

FluidVIEW

LibIF97

Contents

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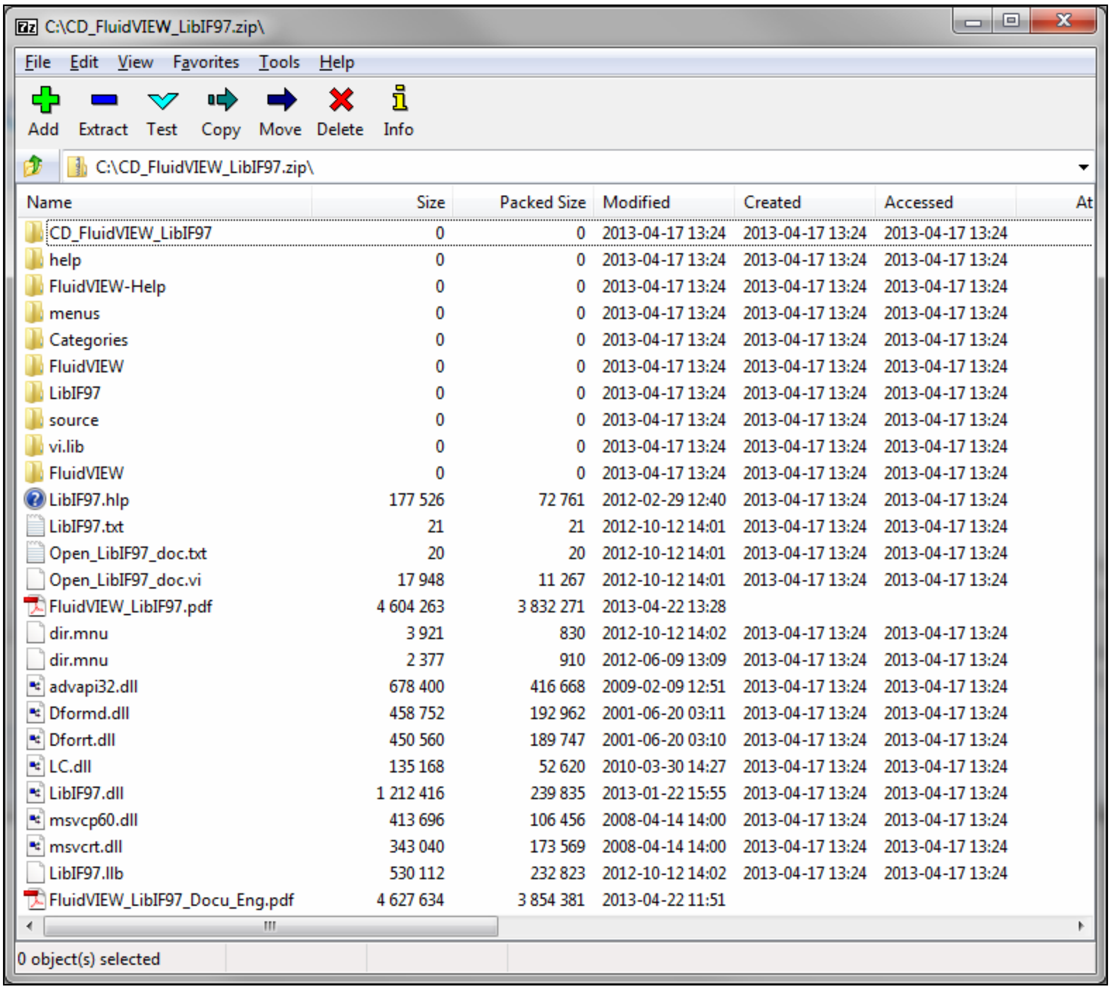
0. Package Contents

0.1 Zip files for 32-bit Windows®

In order to install FluidVIEW on a computer running a 32-bit version of Windows® the zip file **CD_FluidVIEW_LibIF97.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™. All contained files, their paths and the structure of the archive are shown in the screenshot of the 7-zip file archiver and compression tool illustrated in Figure 0.1.



Name	Size	Packed Size	Modified	Created	Accessed	At
CD_FluidVIEW_LibIF97	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
help	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
FluidVIEW-Help	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
menus	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
Categories	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
FluidVIEW	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
LibIF97	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
source	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
vi.lib	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
FluidVIEW	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24	
LibIF97.hlp	177 526	72 761	2012-02-29 12:40	2013-04-17 13:24	2013-04-17 13:24	
LibIF97.txt	21	21	2012-10-12 14:01	2013-04-17 13:24	2013-04-17 13:24	
Open_LibIF97_doc.txt	20	20	2012-10-12 14:01	2013-04-17 13:24	2013-04-17 13:24	
Open_LibIF97_doc.vi	17 948	11 267	2012-10-12 14:01	2013-04-17 13:24	2013-04-17 13:24	
FluidVIEW_LibIF97.pdf	4 604 263	3 832 271	2013-04-22 13:28			
dir.mnu	3 921	830	2012-10-12 14:02	2013-04-17 13:24	2013-04-17 13:24	
dir.mnu	2 377	910	2012-06-09 13:09	2013-04-17 13:24	2013-04-17 13:24	
advapi32.dll	678 400	416 668	2009-02-09 12:51	2013-04-17 13:24	2013-04-17 13:24	
Dformd.dll	458 752	192 962	2001-06-20 03:11	2013-04-17 13:24	2013-04-17 13:24	
Dforrt.dll	450 560	189 747	2001-06-20 03:10	2013-04-17 13:24	2013-04-17 13:24	
LC.dll	135 168	52 620	2010-03-30 14:27	2013-04-17 13:24	2013-04-17 13:24	
LibIF97.dll	1 212 416	239 835	2013-01-22 15:55	2013-04-17 13:24	2013-04-17 13:24	
msvcp60.dll	413 696	106 456	2008-04-14 14:00	2013-04-17 13:24	2013-04-17 13:24	
msvcrt.dll	343 040	173 569	2008-04-14 14:00	2013-04-17 13:24	2013-04-17 13:24	
LibIF97.llb	530 112	232 823	2012-10-12 14:02	2013-04-17 13:24	2013-04-17 13:24	
FluidVIEW_LibIF97_Docu_Eng.pdf	4 627 634	3 854 381	2013-04-22 11:51			

Figure 0.1 Screenshot of WinRAR showing the **CD_FluidVIEW_LibIF97.zip** archive.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.1, 0.2, 0.3 and 0.4.

Table 0.1 Effects of the files located in the archive directory **CD_FluidVIEW_LibIF97\vi.lib \FluidVIEW\LibIF97**

Filename	Effects
LibIF97.llb	LabVIEW™ library file, containing every function of the LibIF97 property library in the form of subprograms (SubVIs)

Table 0.2 Effects of the files located in the archive directory CD_FluidVIEW_LibIF97\menus \Categories\FluidVIEW

Filename	Effects
dir.mnu	The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items)

Table 0.3 Effects of the files located in the archive directory **CD_FluidVIEW_LibIF97\source**

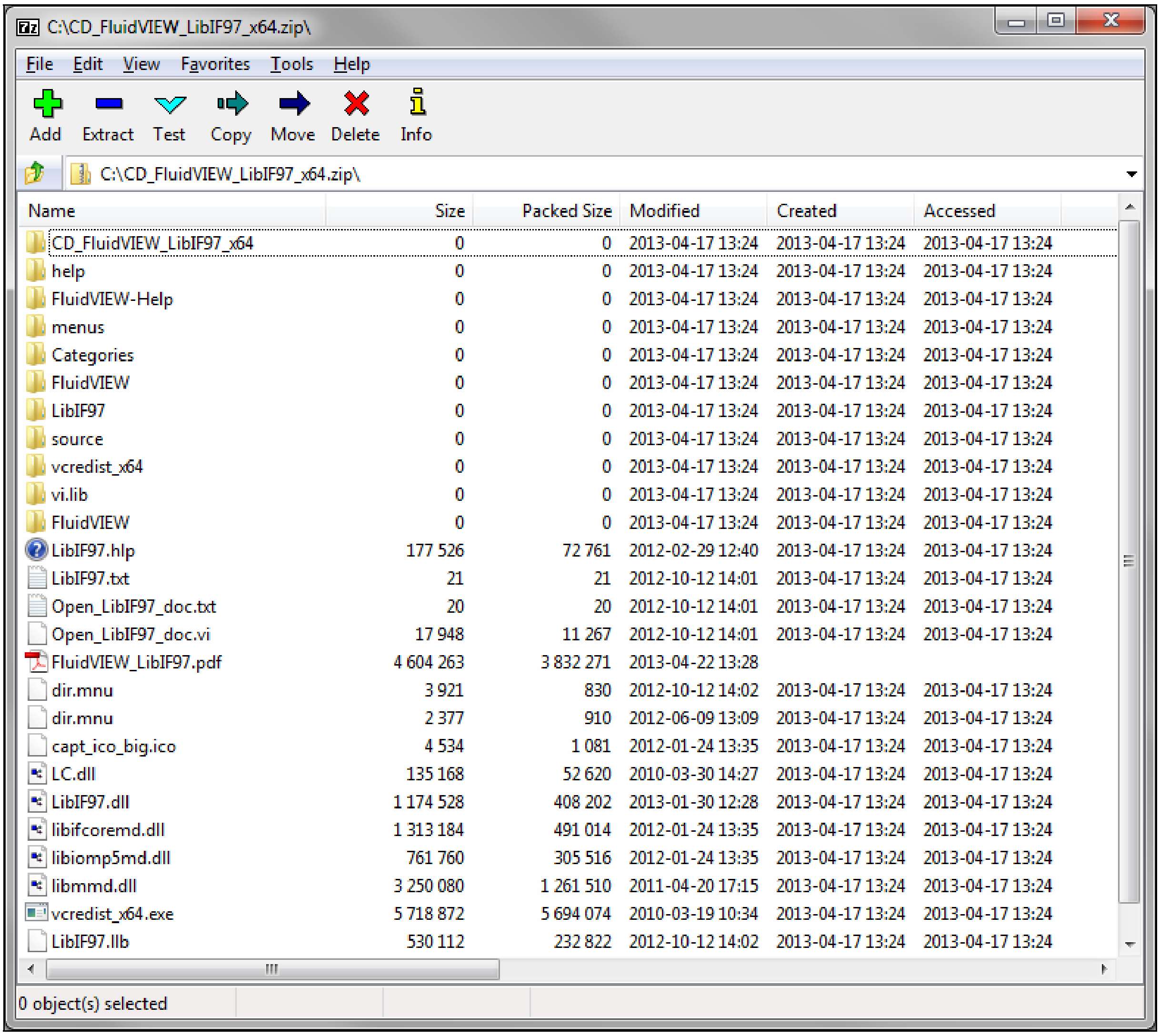
Filename	Effects
LibIF97.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of water and steam
advapi32.dll	Runtime library
Dformd.dll	Runtime library for the Fortran DLL
Dforrt.dll	Runtime library for the Fortran DLL
LC.dll	Auxiliary library
msvcp60.dll	Runtime library
msvcrt.dll	Runtime library

Table 0.4 Effects of the files located in the archive directory **CD_FluidVIEW_LibIF97\help \FluidVIEW-help**

Filename	Effects
FluidVIEW_LibIF97.pdf	User’s guide of the property library LibIF97 for the LabVIEW™ Add-On FluidVIEW
LibIF97.hlp	Help file with descriptions for each function
OpenLibIF97_doc.vi	LabVIEW™ instrument to open the user’s guide via the help menu
LibIF97.txt	Text file to change the name of the menu item of the help file
OpenLibIF97_doc.txt	Text file to change the name of the menu item of the file OpenLibIF97_doc.vi

0.2 Zip files for 64-bit Windows®

In order to install FluidVIEW on a computer running a 64-bit version of Windows® the zip file **CD_FluidVIEW_LibIF97_x64.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™. All contained files, their paths and the structure of the archive are shown in the screenshot of the 7-zip file archiver and compression tool illustrated in Figure 0.2.



Name	Size	Packed Size	Modified	Created	Accessed
CD_FluidVIEW_LibIF97_x64	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
help	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
FluidVIEW-Help	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
menus	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
Categories	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
FluidVIEW	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
LibIF97	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
source	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
vcredist_x64	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
vi.lib	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
FluidVIEW	0	0	2013-04-17 13:24	2013-04-17 13:24	2013-04-17 13:24
LibIF97.hlp	177 526	72 761	2012-02-29 12:40	2013-04-17 13:24	2013-04-17 13:24
LibIF97.txt	21	21	2012-10-12 14:01	2013-04-17 13:24	2013-04-17 13:24
Open_LibIF97_doc.txt	20	20	2012-10-12 14:01	2013-04-17 13:24	2013-04-17 13:24
Open_LibIF97_doc.vi	17 948	11 267	2012-10-12 14:01	2013-04-17 13:24	2013-04-17 13:24
FluidVIEW_LibIF97.pdf	4 604 263	3 832 271	2013-04-22 13:28		
dir.mnu	3 921	830	2012-10-12 14:02	2013-04-17 13:24	2013-04-17 13:24
dir.mnu	2 377	910	2012-06-09 13:09	2013-04-17 13:24	2013-04-17 13:24
capt_ico_big.ico	4 534	1 081	2012-01-24 13:35	2013-04-17 13:24	2013-04-17 13:24
LC.dll	135 168	52 620	2010-03-30 14:27	2013-04-17 13:24	2013-04-17 13:24
LibIF97.dll	1 174 528	408 202	2013-01-30 12:28	2013-04-17 13:24	2013-04-17 13:24
libifcoremd.dll	1 313 184	491 014	2012-01-24 13:35	2013-04-17 13:24	2013-04-17 13:24
libiomp5md.dll	761 760	305 516	2012-01-24 13:35	2013-04-17 13:24	2013-04-17 13:24
libmmd.dll	3 250 080	1 261 510	2011-04-20 17:15	2013-04-17 13:24	2013-04-17 13:24
vcredist_x64.exe	5 718 872	5 694 074	2010-03-19 10:34	2013-04-17 13:24	2013-04-17 13:24
LibIF97.llb	530 112	232 822	2012-10-12 14:02	2013-04-17 13:24	2013-04-17 13:24

Figure 0.2 Screenshot of WinRAR showing the **CD_FluidVIEW_LibIF97_x64.zip** archive.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.5, 0.6, 0.7 and 0.8.

Table 0.5 Effects of the files located in the archive directory **CD_FluidVIEW_LibIF97_x64\vi.lib \FluidVIEW\LibIF97**

Filename	Effects
LibIF97.llb	LabVIEW™ library file, containing every function of the LibIF97 property library in the form of subprograms (SubVIs)

Table 0.6 Effects of the files located in the archive directory CD_FluidVIEW_LibIF97_x64\menus \Categories\FluidVIEW

Filename	Effects
dir.mnu	The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items)

Table 0.7 Effects of the files located in the archive directory **CD_FluidVIEW_LibIF97_x64\source**

Filename	Effects
LibIF97.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of water and steam
Capt_ico_big.ico	Icon file
Libmmd.dll	Runtime library
Libifcoremd.dll	Runtime library
LC.dll	Auxiliary library
Libiomp5md.dll	Runtime library

Table 0.8 Effects of the files located in the archive directory **CD_FluidVIEW_LibIF97_x64\help \FluidVIEW-help**

Filename	Effects
FluidVIEW_LibIF97.pdf	User's guide of the LibIF97 property library for the LabVIEW™ Add-On FluidVIEW
LibIF97.hlp	Help file with descriptions for each function
OpenLibIF97_doc.vi	LabVIEW™ instrument to open the user's guide via the help menu
LibIF97.txt	Text file to change the name of the menu item of the help file
OpenLibIF97_doc.txt	Text file to change the name of the menu item of the file OpenLibIF97_doc.vi

Table 0.9 Effects of the files located in the archive directory **CD_FluidVIEW_LibIF97_x64 \vcredist_x64**

Filename	Effects
vcredist_x64.exe	Executable file to install the Microsoft Visual C++ 2008 Redistributable Package (x64). Within runtime components of Visual C++ Libraries required to run 64-bit applications developed with Visual C++ on a computer that does not have Visual C++ 2010 installed.

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.

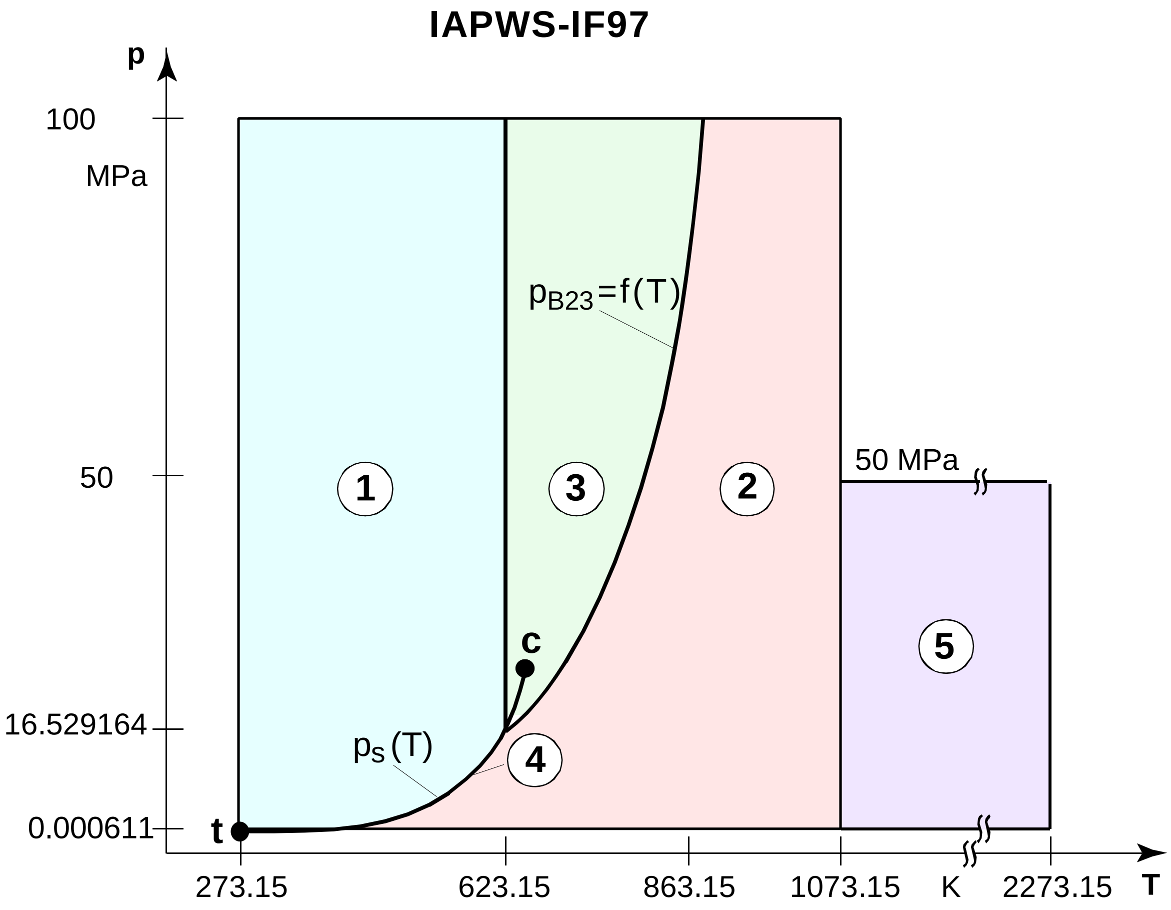


Figure 1.1 Entire Range of Validity of the IF97

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 · 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 · 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 · kPa^{-1})
$\left(\frac{\partial v}{\partial p}\right)_T = \mathrm{f}(p,t,x)$	dv_dp_T_ptx_97	= DVDPT97(P,T,X)	= C_DVDPT97(DVP,P,T,X)	Differential quotient $\left(\frac{\partial v}{\partial p}\right)_\mathrm{T} (p,t,x)$	m^3/(kg · kPa)
$\left(\frac{\partial v}{\partial T}\right)_p = \mathrm{f}(p,t,x)$	dv_dT_p_ptx_97	= DVDTP97(P,T,X)	= C_DVDTP97(DVT,P,T,X)	Differential quotient $\left(\frac{\partial v}{\partial T}\right)_\mathrm{p} (p,t,x)$	m^3/(kg · K)
$e = \mathrm{f}(p,t,x,t_\mathrm{U})$	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 · s = kg/(m · 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**
$\kappa = \mathrm{f}(p,t,x)$	kappa_ptx_97	= KAPPTX97(P,T,X)	= C_KAPPTX97(KAP,P,T,X)	Isentropic exponent	-
$\kappa_T = \mathrm{f}(p,t,x)$	kappat_ptx_97	= KAPPATPTX97(P,T,X)	= C_KAPPATPTX97 (KAPPAT,P,T,X)	Isothermal compressibility	kPa^{-1}
$\lambda = \mathrm{f}(p,t,x)$	lambda_ptx_97	= LAMPTX97(P,T,X)	= C_LAMPTX97(LAM,P,T,X)	Heat conductivity	W/(m · K)
$\mu = \mathrm{f}(p,t,x)$	my_ptx_97	= MYPTX97(P,T,X)	= C_ MYPTX97(MY,P,T,X)	Joule-Thomson coefficient	K kPa^{-1}
$n = \mathrm{f}(p,t,x,wl)$	n_ptxwl_97	= NPTXWL97(P,T,X,WL)	= C_NPTXWL97(N,P,T,X,WL)	Refractive index	-
$\nu = \mathrm{f}(p,t,x)$	ny_ptx_97	= NYPTX97(P,T,X)	= C_NYPTX97(NUE,P,T,X)	Kinematic viscosity	m^2/s
$p = \mathrm{f}(h,s)$	p_hs_97	= PHS97(H,S)	= C_PHS97(PHS,H,S)	Backward function: Pressure from enthalpy and entropy	bar
$p = \mathrm{f}(v,h)$	p_vh_97	= PVH97(H,S)	= C_PVH97(PHS,H,S)	Backward function: Pressure from volume and enthalpy	bar
$p = \mathrm{f}(v,u)$	p_vu_97	= PVU97(H,S)	= C_PVU97(PHS,H,S)	Backward function: Pressure from volume and internal energy	bar
$Pr = \mathrm{f}(p,t,x)$	Pr_ptx_97	= PRPTX97(P,T,X)	= C_PRPTX97(PR,P,T,X)	*Prandtl*-number	-
$p_\mathrm{s} = \mathrm{f}(t)$	ps_t_97	= PST97(T)	= C_PST97(PS,T)	Vapor pressure	bar
$\rho = \mathrm{f}(p,t,x)$	rho_ptx_97	= RHOPTX97(P,T,X)	= C_RHOPTX97(RHO,P,T,X)	Density	kg/m^3
$s = \mathrm{f}(p,h)$	s_ph_97	= SPH97(P,H)	= C_SPH97(SPH,P,H)	Backward function: Specific entropy from pressure and enthalpy	kJ/(kg · K)
$s = \mathrm{f}(p,t,x)$	s_ptx_97	= SPTX97(P,T,X)	= C_SPTX97(S,P,T,X)	Specific entropy	kJ/(kg · K)
$\sigma = \mathrm{f}(p)$	sigma_p_97	= SIGMAP97(P)	= C_SIGMAP97(SIG,P)	Surface tension from pressure	mN/m = mPa · m
$\sigma = \mathrm{f}(t)$	sigma_t_97	= SIGMAT97(T)	= C_SIGMAT97(SIG,T)	Surface tension from temperature	mN/m = mPa · m
$t = \mathrm{f}(h,s)$	t_hs_97	= THS97(H,S)	= C_THS97(THS,H,S)	Backward function: Temperature from enthalpy and entropy	°C
$t = \mathrm{f}(p,h)$	t_ph_97	= TPH97(P,H)	= C_TPH97(TPH,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = \mathrm{f}(p,s)$	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
$t = \mathrm{f}(v,h)$	t_vh_97	= TVH97(P,H)	= C_TVH97(TPH,P,H)	Backward function: Temperature from volume and enthalpy	°C
$t = \mathrm{f}(v,u)$	t_vu_97	= TVU97(P,H)	= C_TVU97(TPH,P,H)	Backward function: Temperature from volume and internal energy	°C
$t_s = \mathrm{f}(p)$	ts_p_97	= TSP97(P)	= C_TSP97(TS,P)	Saturation temperature	°C
$u = \mathrm{f}(p,t,x)$	u_ptx_97	= UPTX97(P,T,X)	= C_UPTX97(U,P,T,X)	Specific internal energy	kJ/kg
$v = \mathrm{f}(p,h)$	v_ph_97	= VPH97(P,S)	= C_VPH97(VPS,P,S)	Backward function: Specific volume from pressure and enthalpy	m^3/kg
$v = \mathrm{f}(p,s)$	v_ps_97	= VPS97(P,S)	= C_VPS97(VPS,P,S)	Backward function: Specific volume from pressure and entropy	m^3/kg
$v = \mathrm{f}(p,t,x)$	v_ptx_97	= VPTX97(P,T,X)	= C_VPTX97(V,P,T,X)	Specific volume	m^3/kg
$w = \mathrm{f}(p,t,x)$	w_ptx_97	= WPTX97(P,T,X)	= C_WPTX97(W,P,T,X)	Isentropic speed of sound	m/s
$x = \mathrm{f}(h,s)$	x_hs_97	= XHS97(H,S)	= C_XHS97(XHS,H,S)	Backward function: Vapor fraction from enthalpy and entropy	kg/kg
$x = \mathrm{f}(p,h)$	x_ph_97	= XPH97(P,H)	= C_XPH97(XPH,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = \mathrm{f}(p,s)$	x_ps_97	= XPS97(P,S)	= C_XPS97(XPS,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
$x = \mathrm{f}(v,h)$	x_vh_97	= XVH97(P,H)	= C_XVH97(XPH,P,H)	Backward function: Vapor fraction from volume and enthalpy	kg/kg
$x = \mathrm{f}(v,u)$	x_vu_97	= XVU97(P,H)	= C_XVU97(XPH,P,H)	Backward function: Vapor fraction from volume and internal energy	kg/kg
$z = \mathrm{f}(p,t,x)$	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:

Single-phase region

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

Wet-steam region

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

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

(Wet steam region of the IAPWS-IF97: t_t = 0 °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 FluidVIEW in LabVIEW™

The FluidVIEW Add-on has been developed to calculate thermodynamic properties in LabVIEW™ (version 10.0 or higher) more conveniently. Within LabVIEW™, it enables the direct call of functions relating to water and steam from the LibIF97 property library.

2.1 Installing FluidVIEW

If a FluidVIEW property library has not yet been installed, please complete the initial installation procedure described below.

If a FluidVIEW property library has already been installed, you only need to copy several files which belong to the LibIF97 library. In this case, follow the subsection "Adding the LibIF97 Library" on page 2/3.

In both cases folders and files from the zip archive

CD_FluidVIEW_LibIF97.zip	(for 32-bit version of Windows®)
CD_FluidVIEW_LibIF97_x64.zip	(for 64-bit version of Windows®)

have to be copied into the default directory of the LabVIEW™ development environment. In the following text these zipped directories for the 32-bit or 64-bit operating system will be symbolised with the term **<CD>**.

You can see the current default directory of LabVIEW™ in the paths page (options dialog box). To display this page please select *Tools* and click on *Options* to open the options dialog box and then select *Paths* from the category list.

By choosing *Default Directory* from the drop-down list the absolute pathname to the default directory, where LabVIEW™ automatically stores information, is displayed. In the following sections the pathname of the default directory will be symbolised by the term **<LV>**.

Additional Requirement When Using the 64-bit Operating System

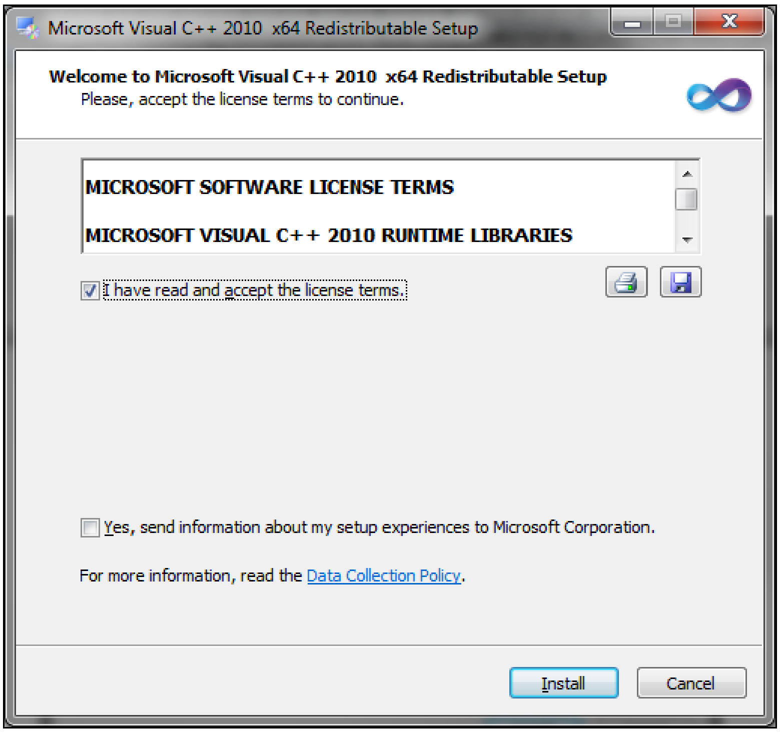
If you want to use FluidVIEW on a 64-bit computer that does not have Visual C++ installed, please make sure the Microsoft Visual C++ 2010 x64 Redistributable Package is installed.

If it is not the case, please install it by double clicking the file

vcredist_x64.exe

which you find in the folder **\vcredist_x64** in the **64-bit** CD folder "CD_FluidVIEW_LibIF97_x64."

In the following window you are required to accept the Microsoft® license terms to install the Microsoft Visual C++ 2010 runtime libraries by ticking the box next to "I have read and accept the license terms" (see Figure 2.1).



Microsoft Visual C++ 2010 x64 Redistributable Setup

Welcome to Microsoft Visual C++ 2010 x64 Redistributable Setup

Please, accept the license terms to continue.

MICROSOFT SOFTWARE LICENSE TERMS

MICROSOFT VISUAL C++ 2010 RUNTIME LIBRARIES

☑ I have read and accept the license terms.

☐ Yes, send information about my setup experiences to Microsoft Corporation.

For more information, read the Data Collection Policy.

Figure 2.1 Accepting the license terms to install the Microsoft Visual C++ 2010 x64 Redistributable Package

Now click on "Install" to continue installation.

After the "Microsoft Visual C++ 2010 x64 Redistributable Pack" has been installed, you will see the sentence "Microsoft Visual C++ 2010 x64 Redistributable has been installed." Confirm this by clicking "Finish."

Now you can use the FluidVIEW Add-On on your 64-bit operating system. Please follow the instructions below to install FluidVIEW.

Initial Installation of FluidVIEW

The initial installation of FluidVIEW is carried out by copying three directories with its contents from the zip archive to the standard directory of LabVIEW™.

The directories that have to be copied, their paths in the zip archive and their target paths are listed in Table 2.1.

The installation is complete after copying the files and restarting LabVIEW™.

Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory **<CD>\source** can be stored in a random directory on the hard disk. The pathname of LibIF97.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9).

All source files have to be stored in the same directory to make the property functions of the LibIF97 library work. These files are for the

- **32-bit system**: LibIF97.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system**: LibIF97.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll.

Table 2.1 Directories which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for the initial installation of FluidVIEW

Name of the directory	Parent directory in the zip archive	Target path in the default directory of LabVIEW (<LV>)
FluidVIEW	<CD>\vi.lib	<LV>\vi.lib
FluidVIEW	<CD>\menus\Categories	<LV>\menus\Categories
FluidVIEW-Help	<CD>\help	<LV>\help

Adding the LibIF97 Library

In order to add the LibIF97 property library to an existing FluidVIEW installation, one folder with its contents and five files have to be copied from the zip archive to the standard directory of LabVIEW™. This directory, the files plus their pathnames in the zip archive and their target paths are listed in Table 2.2.

The installation is complete after copying the files and restarting LabVIEW™.

Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory **<CD>\source** can stored in a random directory on the hard disk. The pathname of LibHuAir.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9). All source files have to be stored in the same directory to make the property functions of the LibIF97 library work. These files are for the

- **32-bit system**: LibIF97.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system**: LibIF97.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll

Table 2.2 Data which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for adding the LibIF97 property library to an existing installation of FluidVIEW

File name with file extension or name of the directory	Parent directory in the zip archive	Target path in the default directory of LabVIEW (<LV>)
LibIF97.llb	<CD>\vi.lib\FluidVIEW	<LV>\vi.lib\FluidVIEW
LibIF97	<CD>\menus\Categories \FluidVIEW	<LV>\menus\Categories \FluidVIEW
LibIF97.hlp	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
LibIF97.txt	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
FluidVIEW_LibIF97.pdf	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
Open_LibIF97_doc.vi	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
Open_LibIF97_doc.txt	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help

After you have restarted LabVIEW™ you will find the functions of the LibIF97 property library in the functions palette under the sub palette FluidVIEW. An example calculation of the specific enthalpy *h* and the specific entropy *s* is shown in section 2.4.

2.2 The FluidVIEW Help System

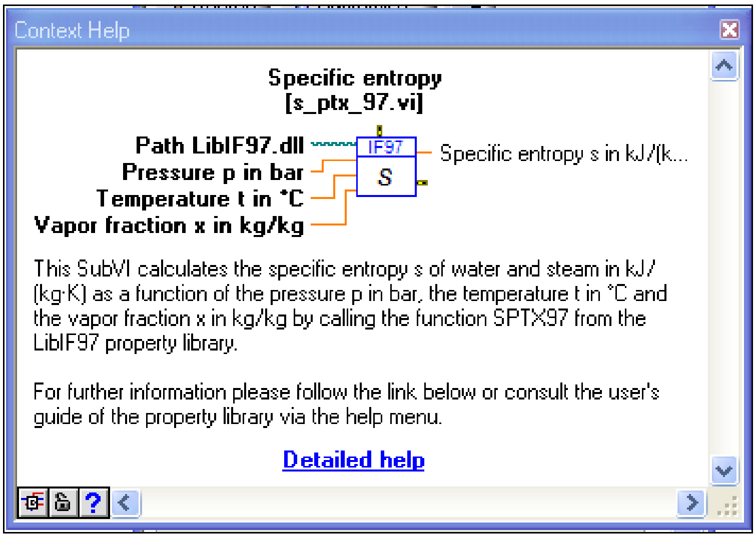
FluidVIEW provides detailed online help functions. If you are running Windows Vista or Windows 7, please note the paragraph
"Using the FluidVIEW Online-Help in Windows Vista or Windows 7."

General Information

The FluidVIEW Help System consists of the Microsoft WinHelp file **LibIF97.hlp** and this user's guide as PDF document **FluidVIEW_LibIF97_Docu_Eng.pdf**. Both files can be opened via the help menu. To do this please click *Help* in the menu bar. In the submenu *FluidVIEW-Help* you will find the commands *LibIF97 Help File* and *LibIF97 User's Guide* to open an appropriate file.

Context-Sensitive Help

If you have activated the context help function in LabVIEW™ (Ctrl-H) and move the cursor over a FluidVIEW object basic information is displayed in the context help window. The in- and output parameters plus a short information text are displayed for a property function. By clicking the **Detailed help** button in the **Context help** window the online help will be opened. The context help window of the function v_ptx_97.vi is shown in Figure 2.2.



Specific entropy
[s_ptx_97.vi]

This SubVI calculates the specific entropy s of water and steam in kJ/(kg·K) as a function of the pressure p in bar, the temperature t in °C and the vapor fraction x in kg/kg by calling the function SPTX97 from the LibIF97 property library.

For further information please follow the link below or consult the user's guide of the property library via the help menu.

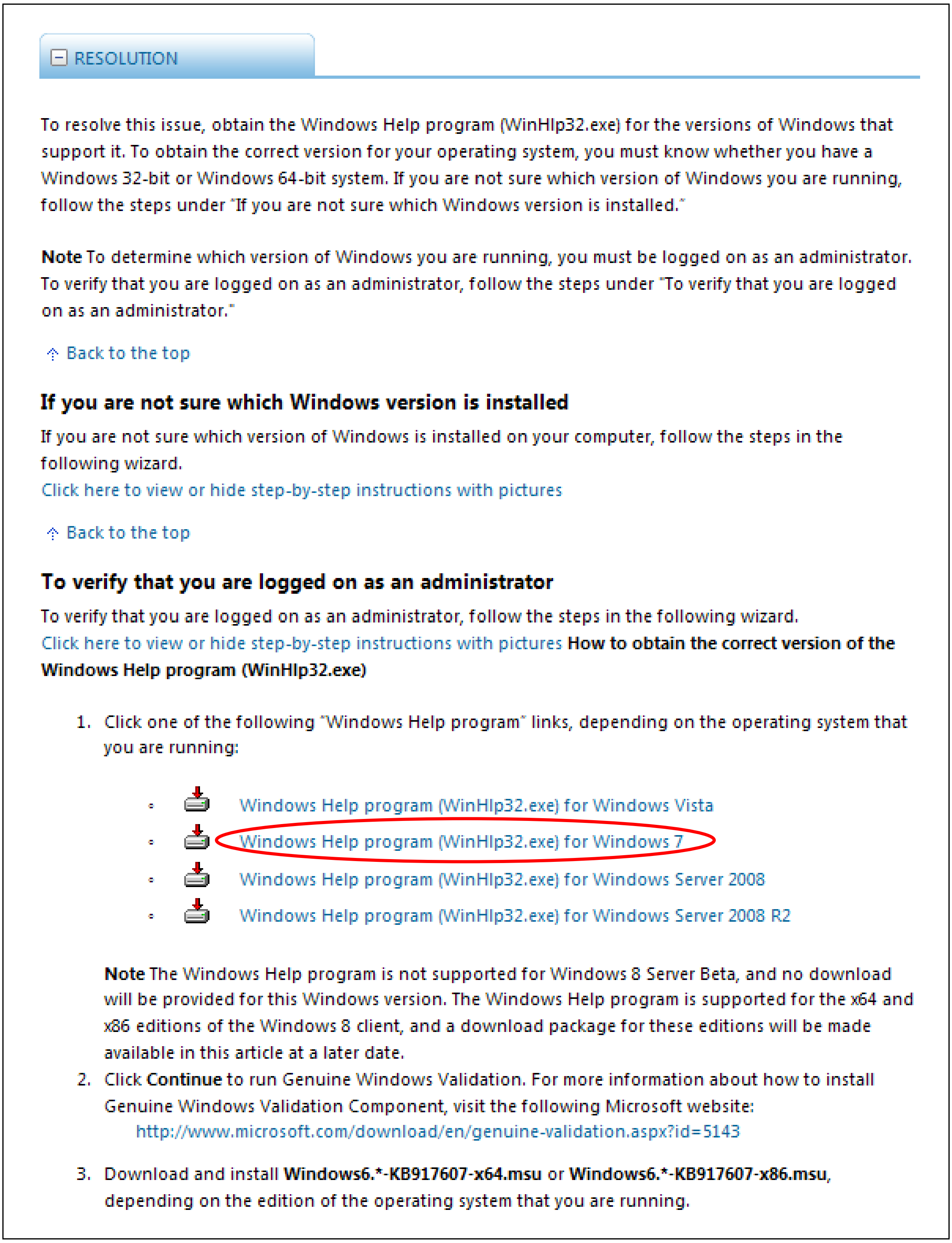
Figure 2.2 Context help window of the function v_ptx_97.vi

Using the FluidVIEW Online-Help in Windows Vista or Windows 7

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

The procedure is analogous for Windows® Vista.

Open Microsoft Internet Explorer® and go to http://support.microsoft.com/kb/917607. Scroll down until you see the headline "Resolution". Under the first Point you'll find the links to download the Windows Help program. Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.3)



To resolve this issue, obtain the Windows Help program (WinHlp32.exe) for the versions of Windows that support it. To obtain the correct version for your operating system, you must know whether you have a Windows 32-bit or Windows 64-bit system. If you are not sure which version of Windows you are running, follow the steps under "If you are not sure which Windows version is installed."

Note To determine which version of Windows you are running, you must be logged on as an administrator. To verify that you are logged on as an administrator, follow the steps under "To verify that you are logged on as an administrator."

If you are not sure which Windows version is installed

If you are not sure which version of Windows is installed on your computer, follow the steps in the following wizard.
Click here to view or hide step-by-step instructions with pictures

To verify that you are logged on as an administrator

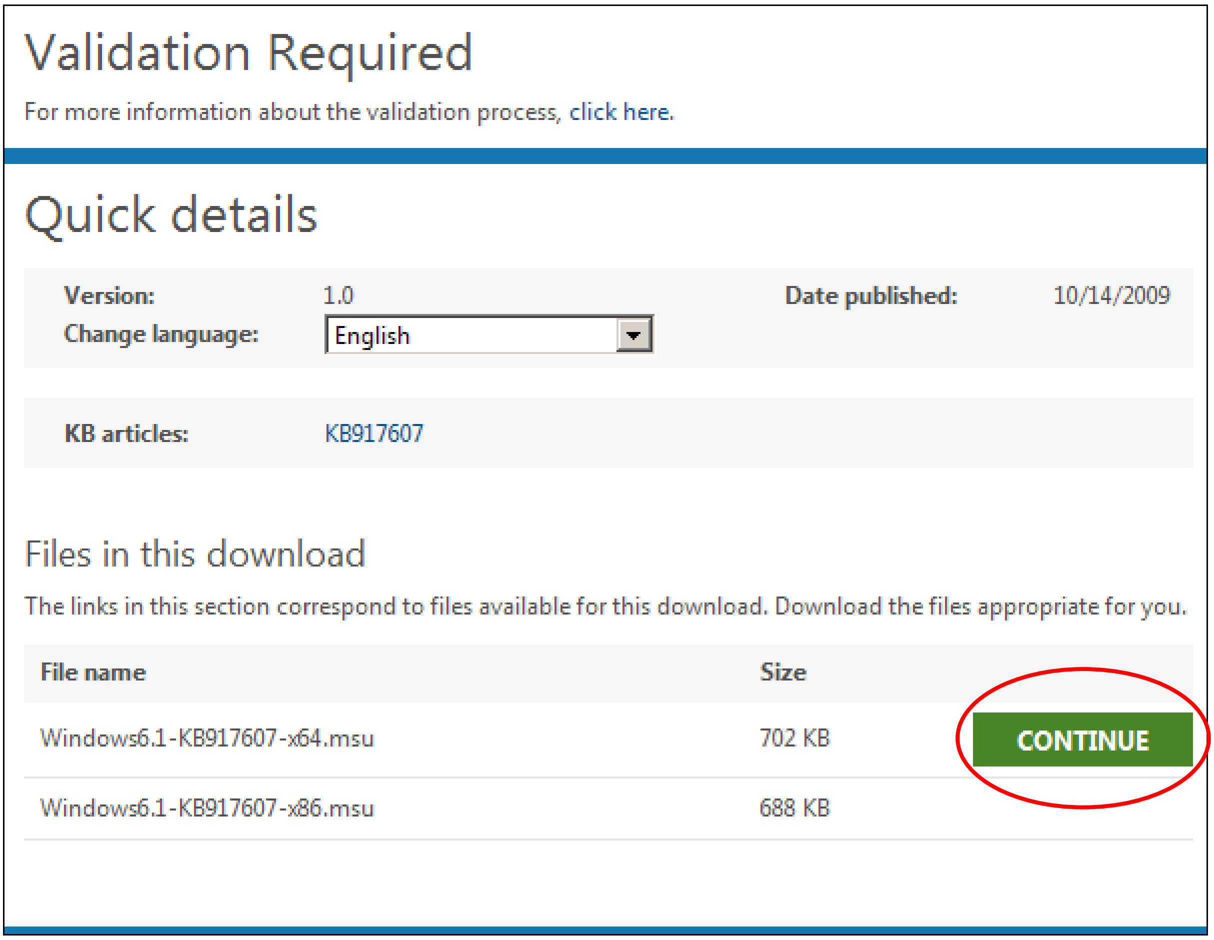
To verify that you are logged on as an administrator, follow the steps in the following wizard.
Click here to view or hide step-by-step instructions with pictures **How to obtain the correct version of the Windows Help program (WinHlp32.exe)**

1. Click one of the following "Windows Help program" links, depending on the operating system that you are running:
   - Windows Help program (WinHlp32.exe) for Windows Vista
   - Windows Help program (WinHlp32.exe) for Windows 7
   - Windows Help program (WinHlp32.exe) for Windows Server 2008
   - Windows Help program (WinHlp32.exe) for Windows Server 2008 R2

   Note The Windows Help program is not supported for Windows 8 Server Beta, and no download will be provided for this Windows version. The Windows Help program is supported for the x64 and x86 editions of the Windows 8 client, and a download package for these editions will be made available in this article at a later date.
2. Click **Continue** to run Genuine Windows Validation. For more information about how to install Genuine Windows Validation Component, visit the following Microsoft website:
   http://www.microsoft.com/download/en/genuine-validation.aspx?id=5143
3. Download and install **Windows6.*-KB917607-x64.msu** or **Windows6.*-KB917607-x86.msu**, depending on the edition of the operating system that you are running.

Figure 2.3 Selecting your Windows® Version

You will be forwarded to the Microsoft Download Center where you can download the Microsoft Windows Help program. First, a validation of your Windows License is required. To do this click on the "Continue" button (see Figure 2.4).



Validation Required

For more information about the validation process, click here.

Quick details

Version: 1.0

Date published: 10/14/2009

Change language: English

KB articles: KB917607

Files in this download

The links in this section correspond to files available for this download. Download the files appropriate for you.

File name	Size
Windows6.1-KB917607-x64.msu	702 KB
Windows6.1-KB917607-x86.msu	688 KB

Figure 2.4 Microsoft® Download Center

Afterwards a web page with instructions on how to install the Genuine Windows Validation Component opens. At the top of your Windows Internet Explorer you will see a yellow information bar. It reads

> *"This website wants to install the following add-on: 'Windows Genuine Advantage' from 'Microsoft Corporation'. If you trust this website and the add-on and want to install it, click here."*

Right-click this bar and select "Install ActiveX Control" in the context menu. A dialog window appears in which you are asked if you want to install the software. Click the "Install" button to continue. After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.5).

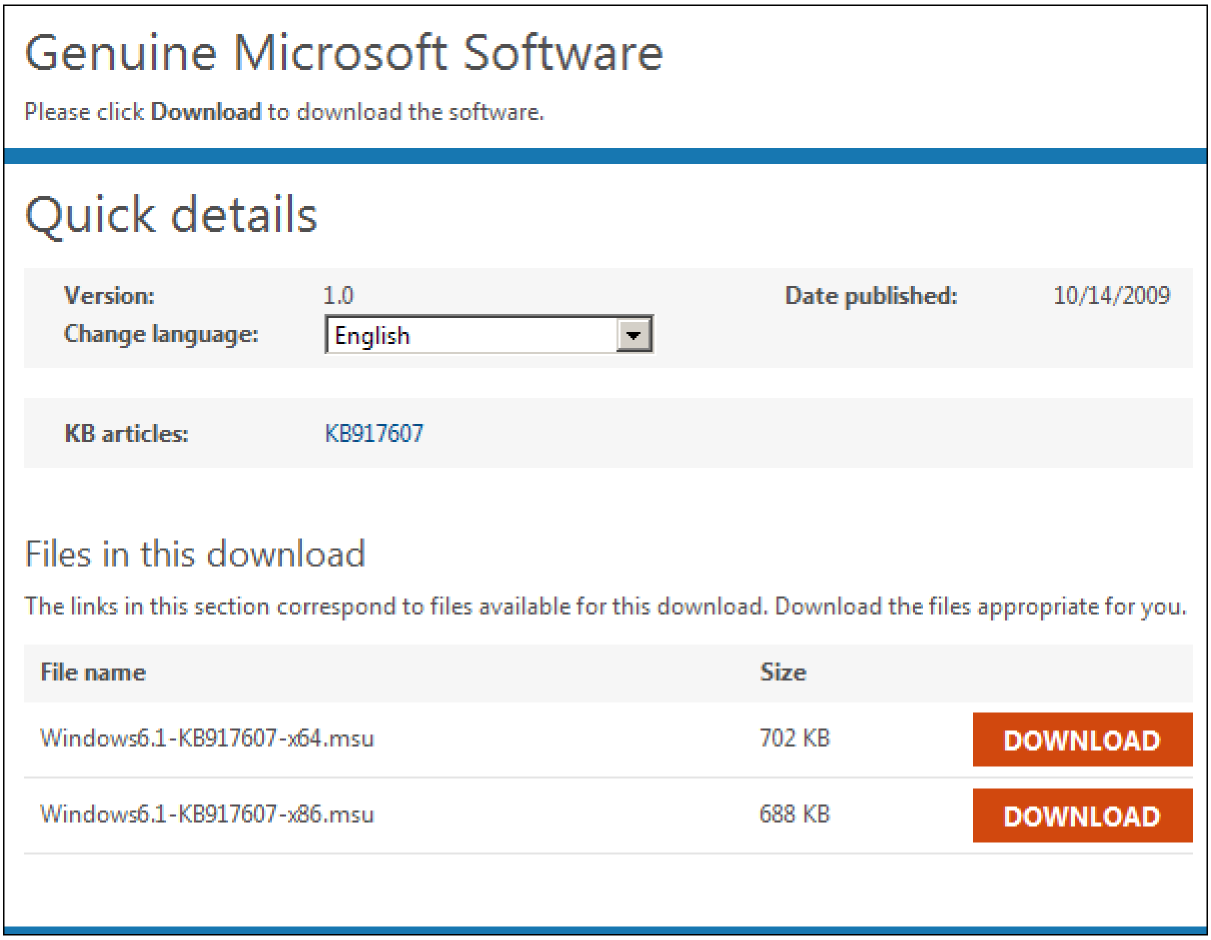
To download and install the correct file you need to know which Windows version (32-bit or 64-bit) you are running on your computer.

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

Windows6.1-KB917607-x64.msu.

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

Windows6.1-KB917607-x86.msu.



Genuine Microsoft Software

Please click **Download** to download the software.

Quick details

Version: 1.0

Change language: English

Date published: 10/14/2009

KB articles: KB917607

Files in this download

The links in this section correspond to files available for this download. Download the files appropriate for you.

File name	Size	
Windows6.1-KB917607-x64.msu	702 KB	DOWNLOAD
Windows6.1-KB917607-x86.msu	688 KB	DOWNLOAD

Figure 2.5 Downloading the Windows Help Program

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

Installation starts with a window searching for updates on your computer.

After the program has finished searching you may be asked, if you want to install the "Update for Windows (KB917607)."

(If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.")

The installation can be continued by clicking the "Yes" button.

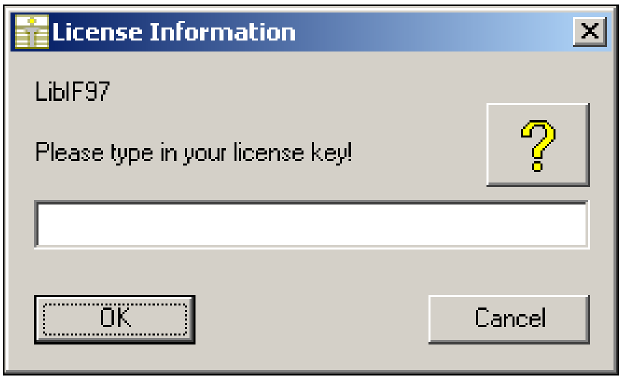
In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept".

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

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

2.3 Licensing the LibIF97 Property Library

The licensing procedure has to be carried out when calculating a LibIF97 function and a FluidVIEW prompt message appears. In this case, you will see the "License Information" window (see figure below).

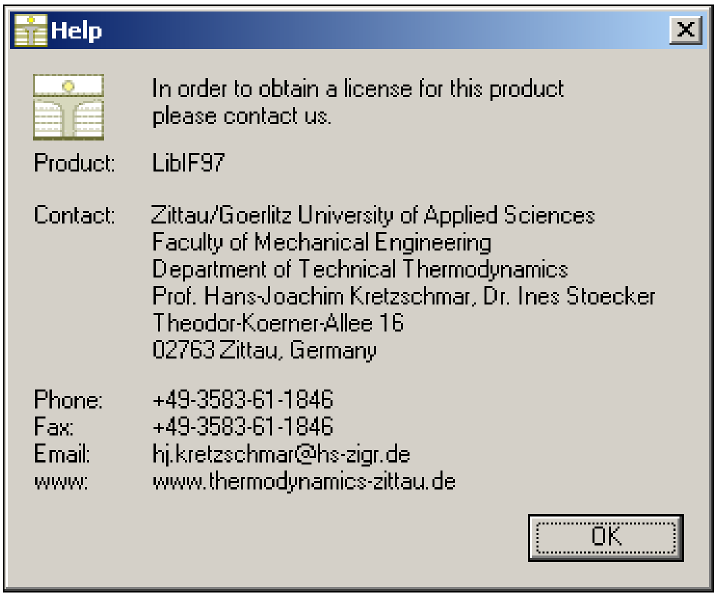


LibIF97

Please type in your license key!

Figure 2.6 "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:



In order to obtain a license for this product
please contact us.

Product: LibIF97

Contact: Zittau/Goerlitz University of Applied Sciences
Faculty of Mechanical Engineering
Department of Technical Thermodynamics
Prof. Hans-Joachim Kretzschmar, Dr. Ines Stoecker
Theodor-Koerner-Allee 16
02763 Zittau, Germany

Phone: +49-3583-61-1846
Fax: +49-3583-61-1846
Email: hj.kretzschmar@hs-zigr.de
www: www.thermodynamics-zittau.de

Figure 2.7 "Help" window

If you do not enter a valid license it is still possible to run your VI by clicking "Cancel". In this case, the LibIF97 property library will display the result "-1.11111E+7" for every calculation.

The "License Information" window will appear every time you reopen your Virtual Instrument (VI) or reload the path of the LibIF97.dll. Should you not wish to license the LibIF97 property library, you have to uninstall FluidVIEW according to the description in section 2.5 of this User's Guide.

2.4 Example: Calculation of *h* = f(*p*,*t*,*x*) and *s* = f(*p*,*t*,*x*)

After the delivered files have been copied in the appropriate folders of the default directory LabVIEW™ (described in section 2.1), the LibIF97 property library is ready to use. The function nodes of the LibIF97 property library can be used by dragging them from the functions palette into the block diagram and connecting them with the wires representing the required input parameters.

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

- Start LabVIEW™ and wait for the *Getting Started* window to be displayed. Then select *Blank VI*. The *Blank VI* will be displayed in two windows, the front panel and the block diagram.
- Open the functions palette in the block diagram **via view / Functions Palette** (or by clicking the right mouse button anywhere in the free area of the block diagram) if not yet displayed.
- In addition to the default LabVIEW™ palettes the functions palette contains the sub palette *FluidVIEW* (see Figure 2.8) with the sub palette *LibIF97* (see Figure 2.9).

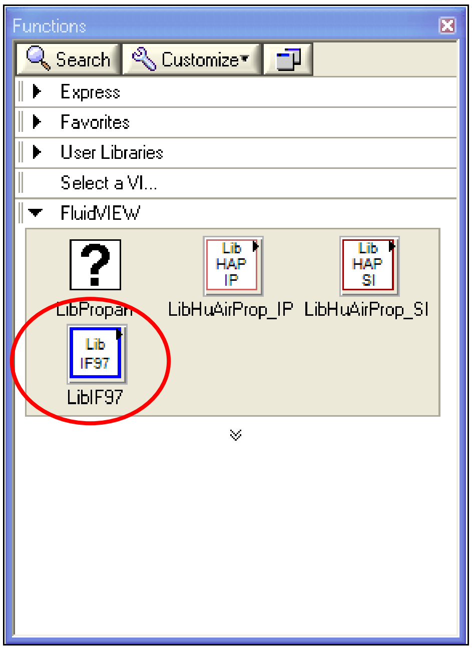


Figure 2.8
Functions palette with the sub palettes FluidVIEW and LibIF97

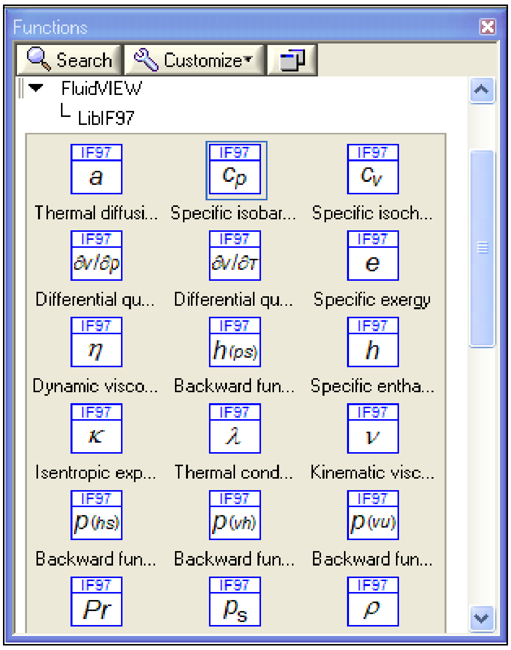


Figure 2.9
Functions palette with the property functions of the LibIF97 library

In order to calculate the specific enthalpy *h*, drag the function (SubVI) whose symbol shows the *h* from the functions palette into the block diagram.
While the short names of the SubVIs behind the symbols will be shown in the control tip, the full names and brief descriptions of the property functions are displayed in the *Context Help* window (see Figure 2.2). To use the context help press <Ctrl>+<H> on your keyboard.

- After placing the node of the SubVI **h_ptx_97.vi** on your block diagram the required input parameters have to be defined.
  The input parameters which are set as required appear in bold type in the Context Help

window. In this case these input parameters are **Path LibIF97.dll** (LabVIEW™ data type: Path), **Pressure p in bar** (LabVIEW™ data type: Double precision, floating-point), **Temperature t in °C** (LabVIEW™ data type: Double precision, floating-point) and **Vapor fraction x in kg/kg** (LabVIEW™ data type: Double precision, floating-point).

- To define these variables wire their input terminals with input elements on the front panel. You can accomplish this in one step by choosing **Create / Control** in the context menu of all required input terminals. In order to wire the output terminal of the function node with an output element on the front panel, choose **Create / Indicator** in the context menu of the output terminal **Specific enthalpy h in kJ/kg** (LabVIEW™ data type: Double precision, floating-point). After cleaning up the block diagram by pressing <Ctrl>+<U> it has the appearance illustrated in Figure 2.10. The same input and output elements are available on the appropriate front panel (see Figure 2.11).

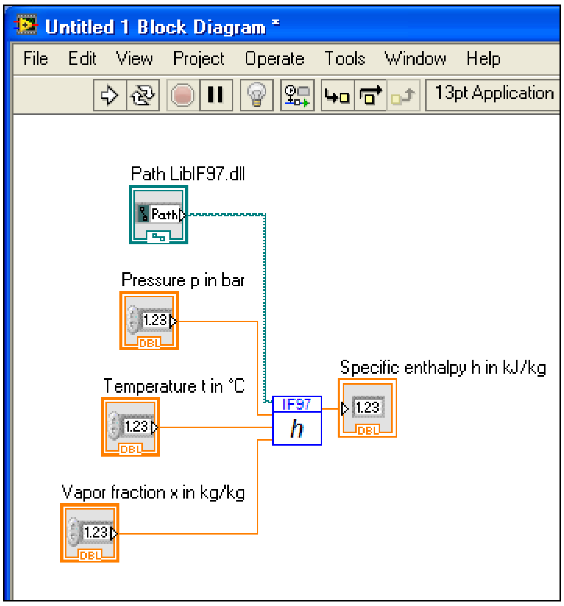


Figure 2.10
Block diagram of the example calculation

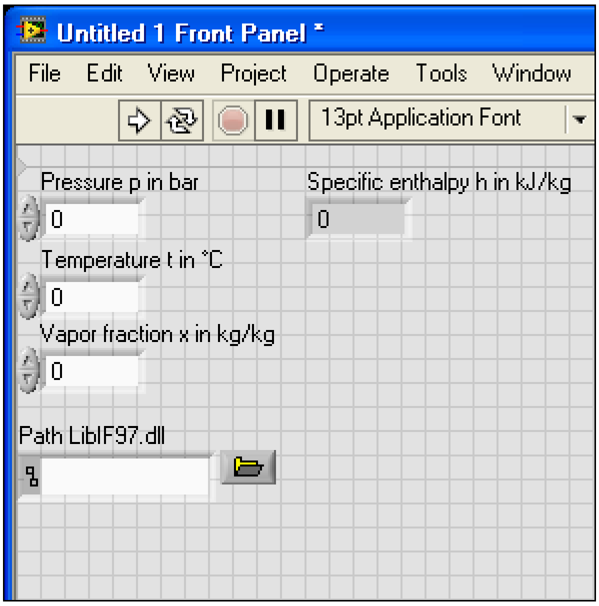


Figure 2.11
Front panel of the example calculation

- Enter a value in the input element *pressure p in bar* on the front panel

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

⇒ e. g.: Enter the value 100.

- Enter a value in the input element *temperature t in °C* on the front panel

(Range of validity of IAPWS-IF97: t = 0 ... 800 °C high temperature region to 2000 °C)

⇒ e. g.: Enter the value 400.

Enter a value in the input element *vapor fraction x in kg/kg* on the front panel.
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.

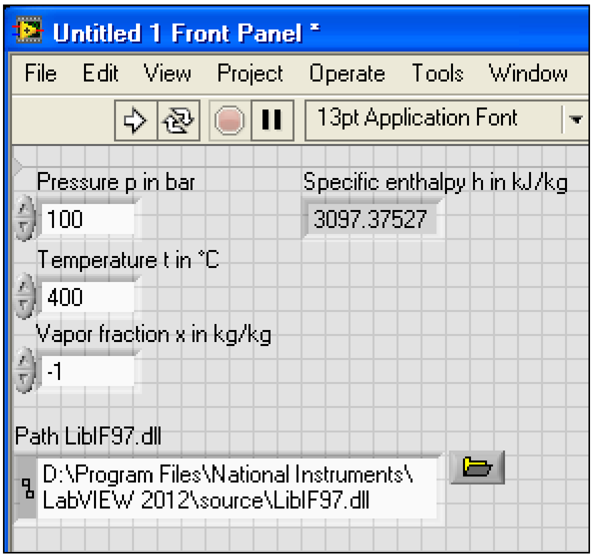
If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1.

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)

- ⇒ e. g.: Enter the value -1.
- Enter the path of the LibIF97.dll in the input element *Path LibIF97.dll* on the front panel (as explained in section 2.1 the LibIF97.dll and the other library files from the directory **<CD>\source** have to be stored in the same directory which is arbitrary). To do this you can use the *File Open Dialog* which appears by clicking the yellow folder symbol on the right of the input element.
- To run the calculation of the specific enthalpy click on the *Run* button or press <Ctrl>+<R>. The result for *h* in kJ/kg appears in the output element (see Figure 2.12).

  ⇒ The result for *h* in our sample calculation is h = 3097.37527 kJ/kg.



Pressure p in bar: 100
Temperature t in °C: 400
Vapor fraction x in kg/kg: -1
Specific enthalpy h in kJ/kg: 3097.37527
Path LibIF97.dll: D:\Program Files\National Instruments\LabVIEW 2012\source\LibIF97.dll

Figure 2.12 Result of the example calculation of *h*

The calculation of *h* = f(*p*,*t*,*x*) has thus been completed.

Correspondingly, the specific entropy *s* = f(*p*,*t*,*x*) can be calculated with the same values for *p*, *t*, and *x*. The following changes need to be implemented.

- Open the context menu of the function node *specific enthalpy* on the block diagram. Under **Replace / Palette LibIF97** you will find the function **Specific entropy** symbolized with *s*. The node on the block diagram changes to **Specific entropy** by clicking on this symbol. Since the input parameters are the same as before their labels need not be changed. Only the label of the output parameter can be changed from *specific enthalpy h in kJ/kg* to *specific entropy s in kJ/(kg·K)* by double clicking on it and typing the new name.
- On the front panel you can see that the new label for the output element *specific entropy s in kJ/(kg·K)* was taken automatically. Since the values in the input elements are still present the calculation can be started now by pressing <Ctrl>+<R> or clicking the *Run* button. The result for *s* in kJ/(kg·K) appears in the output element.

  ⇒ The result for *s* in our sample calculation is 6.21392889 in kJ/(kg·K).

The calculation of *s* = f(*p*,*t*,*x*) has been carried out. You can now arbitrarily change the values for *p*, *t*, or *x* in the appropriate input elements.

Note:

If the calculation results in –1000, this indicates that the values entered are located outside the range of validity. More detailed information on each function and its range of validity is available in chapter 3. For further property functions calculable with FluidVIEW, see the function table in chapter 1.

Removing FluidVIEW

Should you wish to remove the LibIF97 library or the complete FluidVIEW Add-on you have to delete the files that have been copied in the default directory of the LabVIEW™ development environment **<LV>**.

Removing the FluidVIEW Add-on

To remove the FluidVIEW Add-on please delete the folders listed in Table 2.3 from the default directory of LabVIEW™.

Table 2.3 Directories that have to be deleted from the default directory of LabVIEW™ to remove the FluidVIEW Add-on

Name of the directory	Parent directory in the default directory of LabVIEW™ (<LV>)
FluidVIEW	<LV>\vi.lib
FluidVIEW	<LV>\menus\Categories
FluidVIEW-Help	<LV>\help

Removing only the LibIF97 library

To remove only the LibIF97 library please delete the folders or files listed in Table 2.4 from the default directory of LabVIEW™.

Table 2.4 Data that have to be deleted from the default directory of LabVIEW™ (<LV>) to remove only the LibIF97 library.

File name with file extension or name of the directory	Parent directory in the default directory of LabVIEW (<LV>)
LibIF97.llb	<LV>\vi.lib\FluidVIEW
LibIF97	<LV>\menus\Categories\FluidVIEW
LibIF97.hlp	<LV>\help\FluidVIEW-Help
LibIF97.txt	<LV>\help\FluidVIEW-Help
FluidVIEW_LibIF97.pdf	<LV>\help\FluidVIEW-Help
Open_LibIF97_doc.vi	<LV>\help\FluidVIEW-Help
Open_LibIF97_doc.txt	<LV>\help\FluidVIEW-Help

The changes will take effect after restarting LabVIEW™.

3. Program Documentation

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

Function Name:	**a_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION APTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_APTX97(A,P,T,X)** REAL*8 A,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

APTX97, **A** or **a_ptx_97** - Thermal diffusivity $a = \dfrac{\lambda}{\rho \cdot c_p} = \dfrac{\lambda \cdot v}{c_p}$ 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: (*x* = –1)	*p* > 1000 bar or *p* < 0.00611 bar or *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 $\lvert t - t_s(p)\rvert$ > 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 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 **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: for call from Fortran	**REAL*8 FUNCTION ALPHAVPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ ALPHAVPTX97 (ALPHAV,P,T,X)** REAL*8 ALPHAV,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ALPHAVPTX97, **ALPHAV** or **alphav_ptx_97** - Isobaric cubic 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: (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 $\lvert t-t_s(p)\rvert > 0.1$ 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 <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 **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 $\lvert t\text{-}t_s(p)\rvert > 0.1$ K

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

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

Function Name:	**cp_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION CPPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CPPTX97(CP,P,T,X)** REAL*8 CP,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

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

Results for wrong input values

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

Single phase region: (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 $\lvert t-t_s(p)\rvert > 0.1$ K

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

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

Function Name:	**cv_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION CVPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CVPTX97(CV,P,T,X)** REAL*8 CV,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from	t_t = 0 °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: (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 $\lvert t-t_s(p)\rvert > 0.1$ K

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

Isothermal Throttling Coefficient δ_T = f(p,t,x)

Function Name:	**deltat_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION DELTATPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_DELTATPTX97 (DELTAT,P,T,X)** REAL*8 DELTAT,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

DELTATPTX97, **DELTAT** or **deltat_ptx_97** - Isothermal throttling coefficient δ_T in 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 <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 **DELTATPTX97, DELTAT = –1** or **deltat_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]

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

Function Name:	**dv_dp_T_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION DVDPT97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_DVDPT97(DVDPT,P,T,X)** REAL*8 DVDPT,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

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

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* 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_dp_T_ptx_97** or **DVDPT97 = –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]

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

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

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 $|t-t_s(p)|$ > 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: for call from Fortran	**REAL*8 FUNCTION EPTXTU97(P,T,X,TU)** REAL*8 P,T,X,TU
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_EPTXTU97(E,P,T,X,TU)** REAL*8 E,P,T,X,TU

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

TU - Environment temperature t_U in °C

Result

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

Range of validity

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

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

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

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

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

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

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

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

Results for wrong input values

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

Single phase region: ($x = -1$)	$p > 1000$ 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 $\lvert t - t_s(p)\rvert > 0.1$ K

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

Dielectric Constant ε = f(p,t,x)

Function Name:	**epsilon_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION EPSPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ EPSPTX97 (BETAP,P,T,X)** REAL*8 EPS,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from	t_t = 0 °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: (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 $\lvert t-t_s(p)\rvert$ > 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 ≤ *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]

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

Function Name:	**fug_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION FUGPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ FUGPTX97 (FUG,P,T,X)** REAL*8 DELTAT,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from	$t_t = 0$ °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: ($0 \le x \le 1$)	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]

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

Function Name:	**g_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION GPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ GPTX97 (G,P,T,X)** REAL*8 G,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from	$t_t = 0$ °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: ($x = –1$)	$p > 1000$ 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]

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 and p = -1, or the given value for p and t = -1, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

(Saturated liquid and saturated vapor line:

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

Results for wrong input values

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

Single phase region: (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: for call from Fortran	**REAL*8 FUNCTION HPS97(P,S)** REAL*8 P,S
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_HPS97(H,P,S)** REAL*8 H,P,S

Input values

P - Pressure p in bar

S - Specific entropy s in kJ/kg K

Result

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

Range of validity

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

Details on the calculation of wet steam

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

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

Results for wrong input values

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

Single phase region:	$p > 1000$ bar or $p < 0.00611$ bar or at internal calculation result $t > 2000$ °C or $t < 0$ °C or $t > 800$ °C at $p > 500$ bar
Wet steam region:	$p > 220.64$ bar or $p < 0.00611$ bar or at internal calculation result $t > 373.946$ °C or $t < 0$ °C

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

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

Function Name:	**h_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION HPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_HPTX97(H,P,T,X)** REAL*8 H,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

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

(Wet steam region of the IAPWS-IF97: t_t = 0 °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 $\lvert t - t_s(p) \rvert > 0.1$ K

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

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

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 $\kappa = -\frac{v}{p}\left(\frac{\partial p}{\partial v}\right)_s = \frac{w^2}{p \cdot v}$

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

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

Results for wrong input values

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

Single phase region: (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 $\lvert t-t_s(p)\rvert$ > 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* 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 **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 $\lvert t - t_s(p)\rvert$ > 0.1 K

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

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

Function Name:	**Lambda_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION LAMPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_LAMPTX97(LAM,P,T,X)** REAL*8 LAM,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

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

Results for wrong input values

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

Single phase region: (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:

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

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

Function Name:	**my_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION MYPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_MYPTX97 (MY,P,T,X)** REAL*8 MY,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

MYPTX97, **MY** or **my_ptx_97** - Joule-Thomson coefficient μ in K kPa^{-1}

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from	t_t = 0 °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 $\lvert t - t_s(p)\rvert > 0.1$ 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 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 **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 $\lvert t - t_s(p)\rvert > 0.1$ K

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

Kinematic Viscosity ν = f(p,t,x)

Function Name:	**Ny_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION NYPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_NYPTX97(NY,P,T,X)** REAL*8 NY,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from	t_t = 0 °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: (*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:

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

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

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

Input values

H - Specific enthalpy *h* in kJ/kg

S - Specific entropy *s* in kJ/kg K

Result

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

Range of validity

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

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

Details on the calculation of wet steam

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

Results for wrong input values

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

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

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

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

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

Input values

V - Specific volume v in m^3/kg

H - Specific enthalpy h in kJ/kg

Result

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

Range of validity

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

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

Details on the calculation of wet steam

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

Results for wrong input values

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

$v < 0.0009$ m^3/kg

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

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

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

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

Input values

V - Specific volume *h* in kJ/kg

U - Specific internal energy *u* in kJ/kg

Result

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

Range of validity

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

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

Details on the calculation of wet steam

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

Results for wrong input values

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

$v < 0.0009$ m^3/kg

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

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

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

Function Name:	**Pr_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION PRPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PRPTX97(PR,P,T,X)** REAL*8 PR,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

Temperature range: from 0 °C to 900 °C

Pressure range: from 0.00611 bar to 1000 bar

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = 0 °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: (*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 $\|t-t_s(p)\|$ > 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: for call from Fortran	**REAL*8 FUNCTION RHOPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_RHOPTX97(RHO,P,T,X)** REAL*8 RHO,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

RHOPTX97, **RHO** or **rho_ptx_97** - Density $\rho = \frac{1}{v}$ in $\mathrm{kg/m^3}$

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: (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 $\lvert t - t_s(p) \rvert$ > 0.1 K

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

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

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

Input values

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

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

Range of validity

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

Details on the calculation of wet steam

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

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

Results for wrong input values

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

Single phase region:	p > 1000 bar or p < 0.00611 bar or at internal calculation result t > 2000 °C or t < 0 °C or t > 800 °C at p > 500 bar
Wet steam region:	p > 220.64 bar or p < 0.00611 bar or at internal calculation result t > 373.946 °C or t < 0 °C

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

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

Function Name:	**s_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION SPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_SPTX97(S,P,T,X)** REAL*8 S,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

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

(Wet steam region of the IAPWS-IF97: t_t = 0 °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: (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]

Surface Tension σ = f(p)

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

Input values

P - Pressure p in bar

Result

SIGMAP97, **SIGMA** or **sigma_p_97** - Surface tension σ in mN/m = mPa$\cdot$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 σ = 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: for call from Fortran	**REAL*8 FUNCTION THS97(H,S)** REAL*8 H,S
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_THS97(T,H,S)** REAL*8 T,H,S

Input values

H - Specific enthalpy h in kJ/kg

S - Specific entropy s in kJ/kg K

Result

THS97, T or **t_hs_97** - Temperature t in °C

Range of validity

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

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

Details on the calculation of wet steam

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

Results for wrong input values

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

$s < -\ 0.009$ kJ/kg K

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

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

[#] [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]

[#] FUNC_97_200

[K] Backward function: Temperature t = f(p,h)

[$] Backward function: Temperature, t = f(p,h)

[+] SUCH:200

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

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

Input values

P - Pressure *p* in bar

S - Specific entropy *s* in kJ/kg K

Result

TPS97, T or **t_ps_97** - Temperature *t* in °C

Range of validity

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

Details on the calculation of wet steam

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

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

Results for wrong input values

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

Single phase region:	p > 1000 bar or p < 0.00611 bar or at internal calculation result t > 2000 °C or t < 0 °C or t > 800 °C at p > 500 bar
Wet steam region:	p > 220.64 bar or p < 0.00611 bar or at internal calculation result t > 373.946 °C or t < 0 °C

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

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

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

Input values

V - Specific volume *v* in m^3/kg

H - Specific enthalpy *h* in kJ/kg

Result

TVH97, T or **t_vh_97** - Temperature *t* in °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:

$v < 0.0009$ m^3/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

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

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

Input values

V - Specific volume *v* in m^3/kg

U - Specific internal energy *u* in kJ/kg

Result

TVU97, T or **t_vu_97** - Temperature *t* in °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: for call from Fortran	**REAL*8 FUNCTION UPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_UPTX97(U,P,T,X)** REAL*8 U,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

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

Range of validity

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

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

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

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

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

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

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

(Wet steam region of the IAPWS-IF97: t_t = 0 °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: (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]

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

Input values

P - Pressure p in bar

S - Specific entropy s in kJ/kg K

Result

VPS97, **V** or **v_ps_97** - Specific volume v in 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 $v = f(p,t,x)$

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

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

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

Results for wrong input values

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

Single phase region: ($x = -1$)	$p > 1000$ 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 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 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 **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 $\|t-t_s(p)\|$ > 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: for call from Fortran	**REAL*8 FUNCTION XHS97(H,S)** REAL*8 H,S
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_XHS97(X,H,S)** REAL*8 X,H,S

Input values

H - Specific enthalpy *h* in kJ/kg

S - Specific entropy *s* in kJ/kg K

Result

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

Range of validity

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

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

Details on the calculation of wet steam

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

Results for wrong input values

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

$s < -0.009$ kJ/kg K

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

if the state point is located in the single phase region

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

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

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

Input values

P - Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

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

Range of validity

Pressure range: from 0.00611 bar to 1000 bar

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

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

Details on the calculation of wet steam

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

Results for wrong input values

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

if the state point is located in the single phase region

p > 220.64 bar or p < 0.00611 bar

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

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

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

Input values

V - Specific volume v in m^3/kg

H - Specific enthalpy h in kJ/kg

Result

XVH97, X or **x_vh_97** - Vapor fraction x in (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: for call from Fortran	**REAL*8 FUNCTION XVU97(V,U)** REAL*8 V,U
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_XVU97(X,V,U)** REAL*8 X,V,U

Input values

V - Specific volume *v* in m^3/kg

U - Specific internal energy *u* in kJ/kg

Result

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

Range of validity

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

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

Details on the calculation of wet steam

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

Results for wrong input values

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

if the state point is located in the single phase region

$p > 220.64$ 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: for call from Fortran	**REAL*8 FUNCTION XPS97(P,S)** REAL*8 P,S
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_XPS97(X,P,S)** REAL*8 X,P,S

Input values

P - Pressure *p* in bar

S - Specific entropy *s* in kJ/kg K

Result

XPS97, X or **x_ps_97** - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Range of validity

Pressure range: from 0.00611 bar to 1000 bar

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

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

Details on the calculation of wet steam

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

Results for wrong input values

Result **XPS97, X = –1** or **x_ps_97 = –1** for input values:

if the state point is located in the single phase region

p > 220.64 bar or *p* < 0.00611 bar

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

Compression Factor $z = f(p,t,x)$

Function Name:	**z_ptx_97**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION ZPTX97(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ ZPTX97 (Z,P,T,X)** REAL*8 Z,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

ZPTX97, **Z** or **z_ptx_97** - Compression factor *z*

Range of validity

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

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

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

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

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

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

(Saturated liquid and saturated vapor line:

Temperature ranges from	t_t = 0 °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 $\lvert t - t_s(p) \rvert > 0.1$ K

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

4. Property Libraries for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

Water and Steam

Library LibIF97

- Industrial Formulation IAPWS-IF97 (Revision 2007)
- Supplementary Standards
  - IAPWS-IF97-S01
  - IAPWS-IF97-S03rev
  - IAPWS-IF97-S04
  - IAPWS-IF97-S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

CO_2 - Span and Wagner
H_2O - IAPWS-95
N_2 - Span et al.
O_2 - Schmidt and Wagner
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 and Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

- Dry Air from Lemmon et al.
- Steam, water and ice from IAPWS-IF97 and IAPWS-06

Consideration of:

- Condensation and freezing of steam
- Dissociation from the VDI 4670
- Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Formulation 2008 of Feistel and IAPWS-IF97

Ice

Library LibICE

Ice from IAPWS-06, Melting and sublimation pressures from IAPWS-08, Water from IAPWS-IF97, Steam from IAPWS-95 and -IF97

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

Ar
Ne
N_2
O_2
CO
CO_2
Air
NO
H_2O
SO_2
H_2
H_2S
OH
He
F_2
NH_3
Methane
Ethane
Ethylene
Propylene
Propane
Iso-Butane
n-Butane
Benzene
Methanol

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bücker et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

IAPWS Guideline 2001 of Tillner-Roth and Friend (1998)

Helmholtz energy equation for the mixing term

(also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

$C_2H_6O_2$	Ethylene glycol
$C_3H_8O_2$	Propylene glycol
C_2H_5OH	Ethyl alcohol
CH_3OH	Methyl alcohol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $C_8H_{24}O_4Si_4$ **Library LibD4**

Decamethylcyclopentasiloxane $C_{10}H_{30}O_5Si_5$ **Library LibD5**

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

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

Decane $C_{10}H_{22}$ **Library LibC10H22**

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_5H_{14} **Library LibC5H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide CO **Library LibCO**

Carbonyl sulfide COS **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monooxide 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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02763 Zittau, Germany

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Fax.: +49-3583-61-1846

The following thermodynamic and transport properties can be calculated[a]:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl-number Pr

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

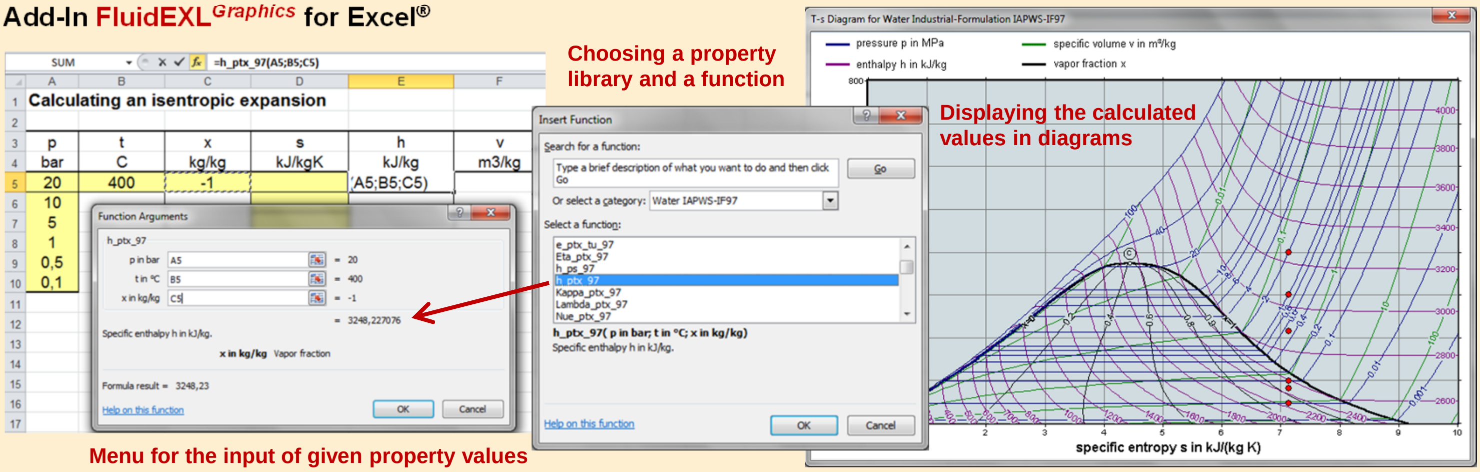
www.thermodynamic-property-libraries.com

---

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

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

Add-In **FluidEXL***Graphics* for Excel®



SUM =h_ptx_97(A5;B5;C5)

	A	B	C	D	E	F
1	Calculating an isentropic expansion					
2						
3	p	t	x	s	h	v
4	bar	C	kg/kg	kJ/kgK	kJ/kg	m3/kg
5	20	400	-1		(A5;B5;C5)	
6	10					
7	5					
8	1					
9	0,5					
10	0,1					

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: Type a brief description of what you want to do and then click Go

Or select a category: Water IAPWS-IF97

Select a function:
- e_ptx_tu_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.

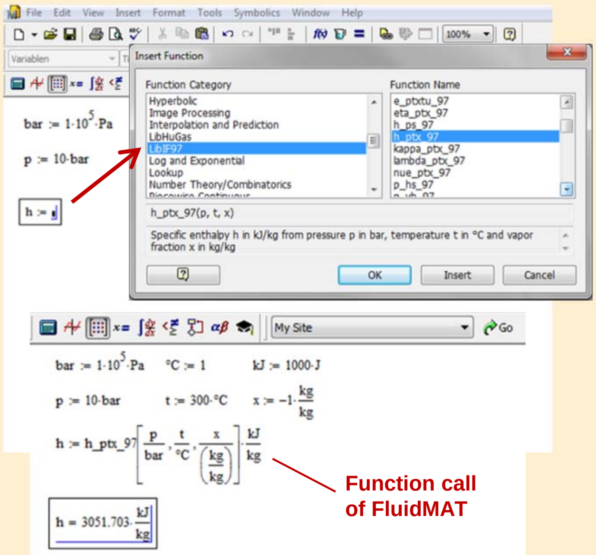
Choosing a property library and a function

Displaying the calculated values in diagrams

Menu for the input of given property values

Add-In **FluidMAT** for Mathcad®

The property libraries can be used in Mathcad®.



Insert Function

Function Category: LibIF97

Function Name: h_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

$bar := 1\cdot10^5\cdot Pa$ $°C := 1$ $kJ := 1000\cdot J$

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

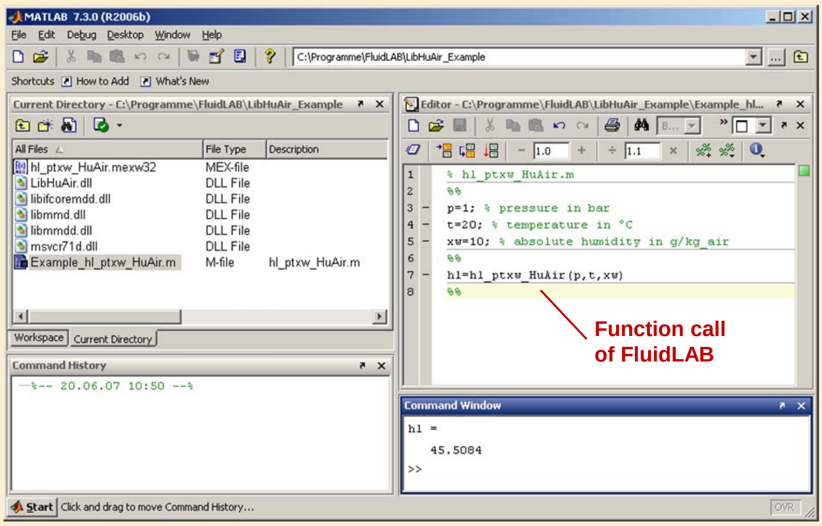
$h := h\_ptx\_97\left[\frac{p}{bar},\frac{t}{°C},\frac{x}{\left(\frac{kg}{kg}\right)}\right]\cdot\frac{kJ}{kg}$

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

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)

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)
%%
```

Command History

```
%-- 20.06.07 10:50 --%
```

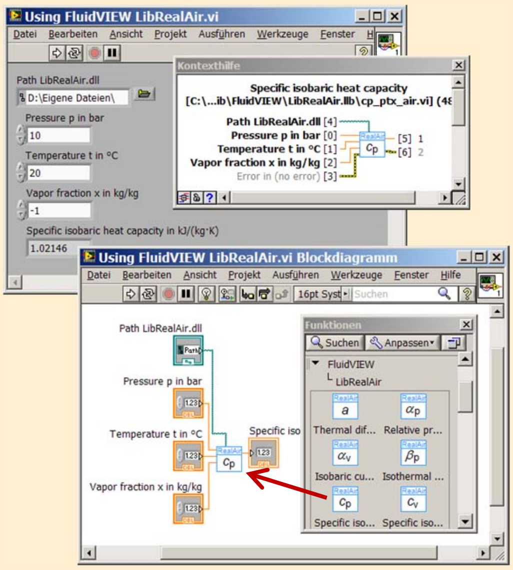
Command Window

```
hl =

   45.5084

>>
```

Function call of FluidLAB

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

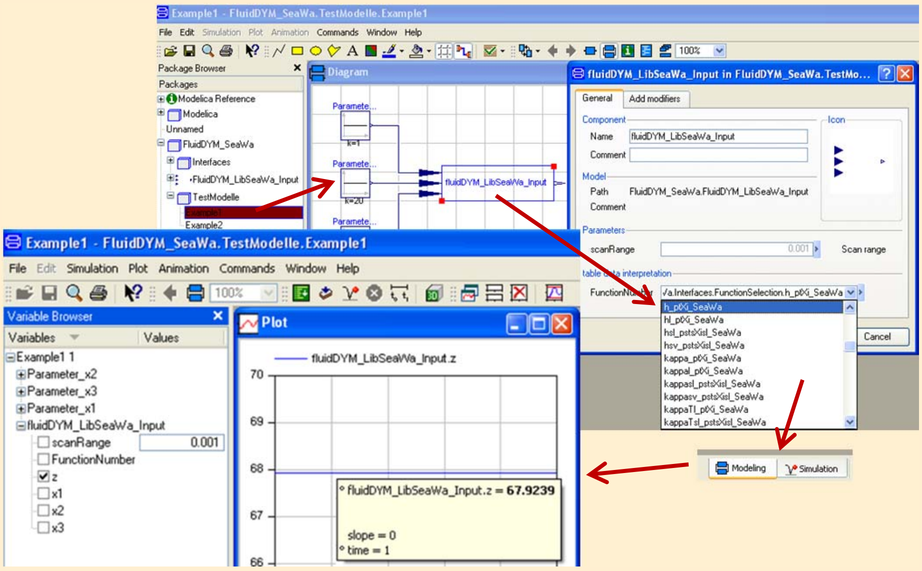
Specific isobaric heat capacity
[C:\...ib\FluidVIEW\LibRealAir.llb\cp_ptx_air.vi] (48

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]

Using FluidVIEW LibRealAir.vi Blockdiagramm

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

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



Example1 - FluidDYM_SeaWa.TestModelle.Example1

fluidDYM_LibSeaWa_Input in FluidDYM_SeaWa.TestMo...

Component
Name: fluidDYM_LibSeaWa_Input
Comment:

Model
Path: FluidDYM_SeaWa.FluidDYM_LibSeaWa_Input
Comment:

Parameters
scanRange: 0.001 Scan range

table data interpretation
FunctionNumber: ...a.Interfaces.FunctionSelection.h_pXi_SeaWa

Variable Browser

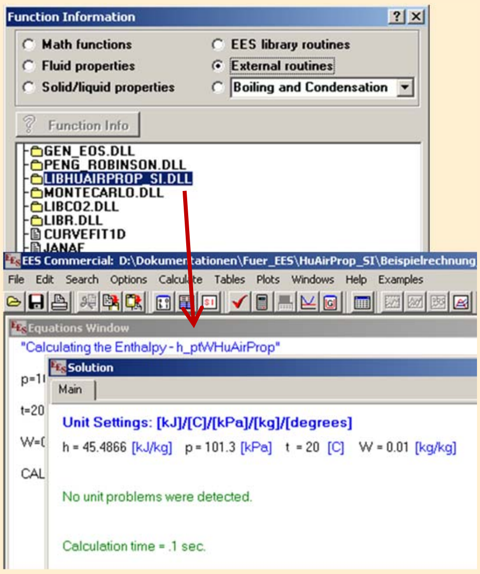
Variables	Values
Example1 1	
Parameter_x2	
Parameter_x3	
Parameter_x1	
fluidDYM_LibSeaWa_Input	
☐ scanRange	0.001
☐ FunctionNumber	
☑ z	
☐ x1	
☐ x2	
☐ x3	

Plot

fluidDYM_LibSeaWa_Input.z = **67.9239**

slope = 0
time = 1

Add-In FluidEES for Engineering Equation Solver®


Function Information

○ Math functions
○ Fluid properties
○ Solid/liquid properties
○ EES library routines
● External routines
○ Boiling and Condensation

GEN_EOS.DLL
PENG_ROBINSON.DLL
LIBHUAIRPROP_SI.DLL
MONTECARLO.DLL
LIBCO2.DLL
LIBR.DLL
CURVEFIT1D
JANAF

EES Commercial: D:\Dokumentationen\Fuer_EES\HuAirProp_SI\Beispielrechnung

Equations Window

"Calculating the Enthalpy - h_ptWHuAirProp"

Solution

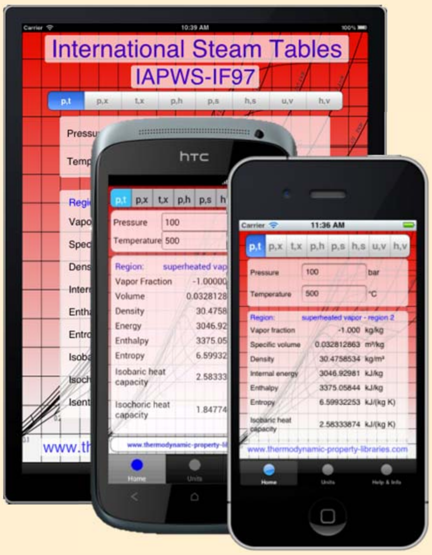
Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

h = 45.4866 [kJ/kg] p = 101.3 [kPa] t = 20 [C] W = 0.01 [kg/kg]

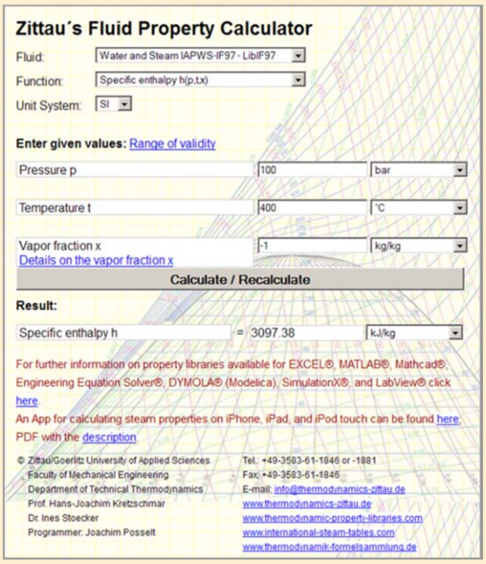
No unit problems were detected.

Calculation time = .1 sec.

App International Steam Tables for iPhone, iPad, iPod touch, Android smart phones and tablets



Online Property Calculator at www.thermodynamics-zittau.de


Zittau´s Fluid Property Calculator

Fluid: Water and Steam IAPWS-IF97 - LibIF97
Function: Specific enthalpy h(p,t,x)
Unit System: SI

Enter given values: Range of validity

Pressure p: 100 bar
Temperature t: 400 °C
Vapor fraction x: -1 kg/kg
Details on the vapor fraction x

Result:

Specific enthalpy h = 3097.38 kJ/kg

For further information on property libraries available for EXCEL®, MATLAB®, Mathcad®, Engineering Equation Solver®, DYMOLA® (Modelica), SimulationX®, and LabView® click here.

An App for calculating steam properties on iPhone, iPad, and iPod touch can be found here; PDF with the description.

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www.thermodynamics-zittau.de
www.thermodynamic-property-libraries.com
www.international-steam-tables.com
www.thermodynamik-formelsammlung.de

Property Software for Pocket Calculators

FluidCasio


fx 9750 G II


CFX 9850
fx-GG20


CFX 9860 G
Graph 85


ALGEBRA
FX 2.0

FluidHP


HP 48


HP 49

FluidTI


TI 83
TI 84
TI 89


TI Voyage 200


TI 92

For more information please contact:

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Fax.: +49-3583-61-1846

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 ν
- Thermal conductivity λ
- Prandtl-number Pr

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

---

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

www.thermodynamic-property-libraries.com

5. References

[1] Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam IAPWS-IF97.
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Transport Properties of Air.
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Formulations for the Thermodynamic Properties of Saturated Phases of H_2O from 173.15 K to 473.15 K.
Report No. 2793 (RP-216), National Bureau of Standards, Washington, D.C. (1983)

6. Satisfied Customers

Date: 10/2011

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)
- FluidVIEW for LabVIEW®:

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
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TUEV Sued, Munich	01/2011
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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
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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
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Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
VER, Dresden	04/2010
CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
Technical University of Dresden	02/2010
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
RWE, Neurath	02/2009
Brandenburg University of Technology, Cottbus	02/2009
Hamburg University of Applied Sciences	02/2009
Kehrein, Moers	03/2009
EPP Software, Marburg	03/2009
Bernd Münstermann, Telgte	03/2009
Suedzucker, Zeitz	03/2009
CPP, Marburg	03/2009
Gelsenkirchen University of Applied Sciences	04/2009
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
Intraserv, Wiesbaden	06/2009
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RWTH Aachen University	09/2009
Vattenfall, Hamburg	10/2009
AIC, Chemnitz	10/2009
Midiplan, Bietigheim-Bissingen	11/2009
Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
FZD, Rossendorf	11/2009
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
University of Karlsruhe	01/2008
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	02/2008
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008
WEBASTO, Neubrandenburg	04/2008
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
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
VER, Dresden	02/2007
Technical University of Dresden, Chair in Jet Propulsion Systems	02/2007
Redacom, Nidau, Switzerland	02/2007
Universität der Bundeswehr, Munich	02/2007
Maxxtec, Sinsheim	03/2007
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, Chair in Power Plant Engineering	06/2007
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

2006

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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M&M Turbine Technology, Bielefeld	06/2006
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006
Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
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
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005
Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

2004

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MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
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Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
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
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
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
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
Ingenieurbuero Ostendorf, Gummersbach	05/2003
TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	06/2003
University of Cali, Colombia	07/2003
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

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
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Stadtwerke Duisburg	08/2002

Stadtwerke Hannover	09/2002
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Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

2001

ALSTOM Power, Baden, Switzerland	01/2001, 06/2001, 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
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
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000

IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
UMAG W. UDE, Husum	03/2000
VEAG, Berlin (group license)	03/2000
Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
Steinhaus Informationssysteme, Datteln (general license for process data software)	12/2000

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Bayernwerk, Munich	01/1999
DREWAG, Dresden (company license)	02/1999
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

1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998

SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

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Gerb, Dresden	06/1997
Siemens Power Generation, Goerlitz	07/1997