Hochschule
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Faculty of
MECHANICAL ENGINEERING

Department of
TECHNICAL THERMODYNAMICS

Property Library for Ice, Water, and Steam

FluidEXL*Graphics*
with LibICE
for Excel®

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Property Library for Ice, Water, and Steam

Including DLL and Add-In for Excel®

FluidEXL*Graphics*
LibIce

Contents

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0. Package Contents

0.1 Zip files for 32-bit Windows®

The following zip files are delivered for your computer running a 32-bit version of Windows®.

English zip file "CD_FluidEXL_Graphics_LibIce_Eng.zip" including the following files:

FluidEXL_Graphics_Eng_Setup.exe	- English installation program for the Add-In FluidEXL*Graphics* for use in Excel®
FluidEXL_Graphics_Eng.xla	- English Add-In for FluidEXL*Graphics*
LibIce.dll	- Dynamic Link Library for use in Windows programs
LibIce.hlp	- Help file for the LibIce property library
FluidEXL_Graphics_LibIce_Docu_Eng.pdf	- User's guide

German zip file "CD_FluidEXL_Graphics_LibIce.zip" including the following files:

FluidEXL_Graphics_Setup.exe	- German installation program for the Add-In FluidEXL*Graphics* for application in Excel®.
FluidEXL_Graphics.xla	- German Add-In for FluidEXL*Graphics*
LibIce.dll	- Dynamic Link Library for use in Windows® programs
LibIce.hlp	- Help file for the LibIce property library
FluidEXL_Graphics_LibIce_Docu_Eng.pdf	- User's guide

0.2 Zip files for 64-bit Windows®

The following zip files are delivered for your computer running a 64-bit version of Windows®.

English zip file "CD_FluidEXL_Graphics_LibIce_x64_Eng.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibIce_Docu_Eng.pdf	- User's guide
FluidEXL_Graphics_Eng.xla	- English Add-In for FluidEXL*Graphics*
FluidEXL_Graphics_Eng_64_Setup.msi	- Self-extracting and self-installing program
LibIce.dll	- Dynamic link library for use in Windows® programs
LibIce.hlp	- Help file for the LibIce property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL*Graphics*

Folders:

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

German zip file "CD_FluidEXL_Graphics_LibIce_x64.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibIce_Docu_Eng.pdf	- User's guide
FluidEXL_Graphics.xla	- German Add-In for FluidEXL*Graphics*
FluidEXL_Graphics_64_Setup.msi	- Self-extracting and self-installing program
LibIce.dll	- Dynamic link library for use in Windows® programs
LibIce.hlp	- Help file for the LibIce property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL*Graphics*

Folders:

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

1. Property Functions

1.1 Property Functions of LibICE

Functional Dependence	Function Name	Fortran Program	Property or Function	Unit of the Result
$a = \mathrm{f}(p,t,x)$	a_ptx_ICE	APTXICE(P,T,X)	Thermal diffusivity	m^2/s
$\alpha_v = \mathrm{f}(p,t,x)$	alphav_ptx_ICE	ALPHAVPTXICE(P,T,X)	Isobaric cubic expansion coefficient	1/K
$c_p = \mathrm{f}(p,t,x)$	cp_ptx_ICE	CPPTXICE(P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = \mathrm{f}(p,t,x)$	cv_ptx_ICE	CVPTXICE(P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\eta = \mathrm{f}(p,t,x)$	eta_ptx_ICE	ETAPTXICE(P,T,X)	Dynamic viscosity (only for liquid and steam)	Pa s
$h = \mathrm{f}(p,t,x)$	h_ptx_ICE	HPTXICE(P,T,X)	Specific enthalpy	kJ/kg
$\kappa = \mathrm{f}(p,t,x)$	kappa_ptx_ICE	KAPPAPTXICE(P,T,X)	Isentropic exponent	-
$\kappa_T = \mathrm{f}(p,t,x)$	kappaT_ptx_ICE	KAPPATPTXICE(P,T,X)	Isothermal compressibility	1/kPa
$\lambda = \mathrm{f}(p,t,x)$	lambda_ptx_ICE	LAMBDAPTXICE(P,T,X)	Thermal conductivity	W/(m K)
$p_{\mathrm{mel}} = \mathrm{f}(t)$	pmel_t_08_ICE	PMEL_T_08_ICE(T)	Melting pressure	bar
$p_{\mathrm{s}} = \mathrm{f}(t)$	ps_t_97_ICE	PS_T_97_ICE(T)	Vapor pressure	bar
$p_{\mathrm{sub}} = \mathrm{f}(t)$	psub_t_08_ICE	PSUB_T_08_ICE(T)	Sublimation pressure	bar
$\rho = \mathrm{f}(p,t,x)$	rho_ptx_ICE	RHOPTXICE(P,T,X)	Density	$\mathrm{kg/m}^3$

Functional Dependence	Function Name	Fortran Program	Property or Function	Unit of the Result
$s = \mathrm{f}(p,t,x)$	s_ptx_ICE	SPTXICE(P,T,X)	Specific entropy	kJ/(kg K)
$t = \mathrm{f}(p,h)$	t_ph_ICE	TPHICE(P,H)	Backward function: Temperature from pressure and specific enthalpy	°C
$t = \mathrm{f}(p,s)$	t_ps_ICE	TPSICE(P,S)	Backward function: Temperature from pressure and specific entropy	°C
$t_{\mathrm{mel}} = \mathrm{f}(p)$	tmel_p_08_ICE	TMEL_P_08_ICE(P)	Melting temperature	°C
$t_{\mathrm{s}} = \mathrm{f}(p)$	ts_p_97_ICE	TS_P_97_ICE(P)	Saturation temperature	°C
$t_{\mathrm{sub}} = \mathrm{f}(p)$	tsub_p_08_ICE	TSUB_P_08_ICE(P)	Sublimation temperature	°C
$u = \mathrm{f}(p,t,x)$	u_ptx_ICE	UPTXICE(P,T,X)	Specific internal energy	kJ/kg
$v = \mathrm{f}(p,t,x)$	v_ptx_ICE	VPTXICE(P,T,X)	Specific volume	m³/kg
$w = \mathrm{f}(p,t,x)$	w_ptx_ICE	WPTXICE(P,T,X)	Isentropic speed of sound	m/s
$x = \mathrm{f}(p,h)$	x_ph_ICE	XPHICE(P,H)	Backward function: Phase fraction from pressure and specific enthalpy	kg/kg
$x = \mathrm{f}(p,s)$	x_ps_ICE	XPSICE(P,S)	Backward function: Phase fraction from pressure and specific entropy	kg/kg

Units:

p in bar
t in °C
x in kg/kg (Phase fraction; see description in the following)

Reference State:

h = 0.0006118 kJ/kg and s = 0 kJ/(kg K)
at $p_{\mathrm{t}} = 6.11657 \cdot 10^{-3}$ bar and $t_{\mathrm{t}} = 0.01$ °C (273.16 K)

Details on the Phase Fraction x

If the state point to be calculated is located in one of the single phase regions ice, liquid, superheated steam or gas, $x = -1$ must be entered as a pro-forma value. Here the backward functions will result in $x = -1$.

The two phase regions wet stem region, melting region and sublimation region (see log p-h diagram in Chapter 1.2) are divided automatically by the subprograms. Please consider the following facts:

1. Wet Stem Region ($0 \le x \le 1$):

The phase fraction x equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).

When calculating properties of wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) has to be entered for x. In this case, the backward functions result in the appropriate value between 0 and 1 for x.

In this case it is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 0 and 1. If values for both p and t are entered when calculating wet steam, the program will consider p and t to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function results in –1000.

Wet steam region: Temperature ranges from $t_t = 0.01$ °C (273.16 K) to $t_{max} = 350$ °C (623.15 K)
Pressure ranges from $p_t = 6.11657 \cdot 10^{-3}$ bar to $p_s\ (t_{max}) = 165.291643$ bar

2. Melting Region ($10 \le x \le 11$):

The phase fraction x equates to the liquid fraction x in the melting region $x = 10 + \frac{m_{liq}}{(m_{ice} + m_{liq})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.

When calculating properties of the melting region, a value between 10 and 11 ($x = 10$ for melted solid, $x = 11$ for solidified liquid) has to be entered for x. In this case, the backward functions result in the appropriate value between 10 and 11 for x.

In this case it is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 10 and 11. If values for both p and t are entered, the program will consider p and t to be appropriate to represent the melting pressure curve. If it is not the case the calculation for the quantity of the chosen function results in –1000.

Melting region: Temperature ranges from $t_{mel}(p_{max}) = -8.9412$ °C (264.2088 K) to $t_t = 0.01$ °C (273.16 K)
Pressure ranges from $p_t = 6.11657 \cdot 10^{-3}$ bar to $p_{max} = 1000$ bar

3. Sublimation Region (100 ≤ x ≤ 101):

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{\text{gas}}}{\left(m_{\text{ice}} + m_{\text{gas}}\right)}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimated ice and desublimated gas.

When calculating properties of sublimation region, a value between 100 and 101 (*x* = 100 for sublimated ice, *x* = 101 for desublimated gas) has to be entererd for *x*. In this case, the backward functions result in the appropriate value between 100 and 101 for *x*.

In this case it is adequate to enter either the given value for *t* and *p* = –1000, or the given value for *p* and *t* = –1000, plus the value for *x* between 100 and 101. If values for both *p* and *t* are entered, the program will consider *p* and *t* to be appropriate to represent the sublimation pressure curve. If it is not the case the calculation for the quantity of the chosen function results in –1000.

Sublimation region: Temperature ranges from t_{min} = –223.15 °C (50 K) to t_{t} = 0.01 °C (273.16 K)
Pressure ranges from $p_{\text{min}} = p_{\text{sub}}(t_{\text{min}}) = 1.9349584868 \cdot 10^{-45}$ bar to $p_{\text{t}} = 6.11657 \cdot 10^{-3}$ bar

Note:

If the input values are located outside the range of validity, the calculated function will always result in –1000. Please find more exact details on every function and its corresponding range of validity in the enclosed program documentation in Chapter 3. The same information may also be accessed via the online help pages.

1.2 Range of Validity of LibICE

The LibICE property library calculates the thermodynamic and transport properties of ice Ih, water and steam. As shown in the following *p*-*T* and log *p*-*h* diagrams, different formulations are used to describe the entire Range of validity of LibICE.

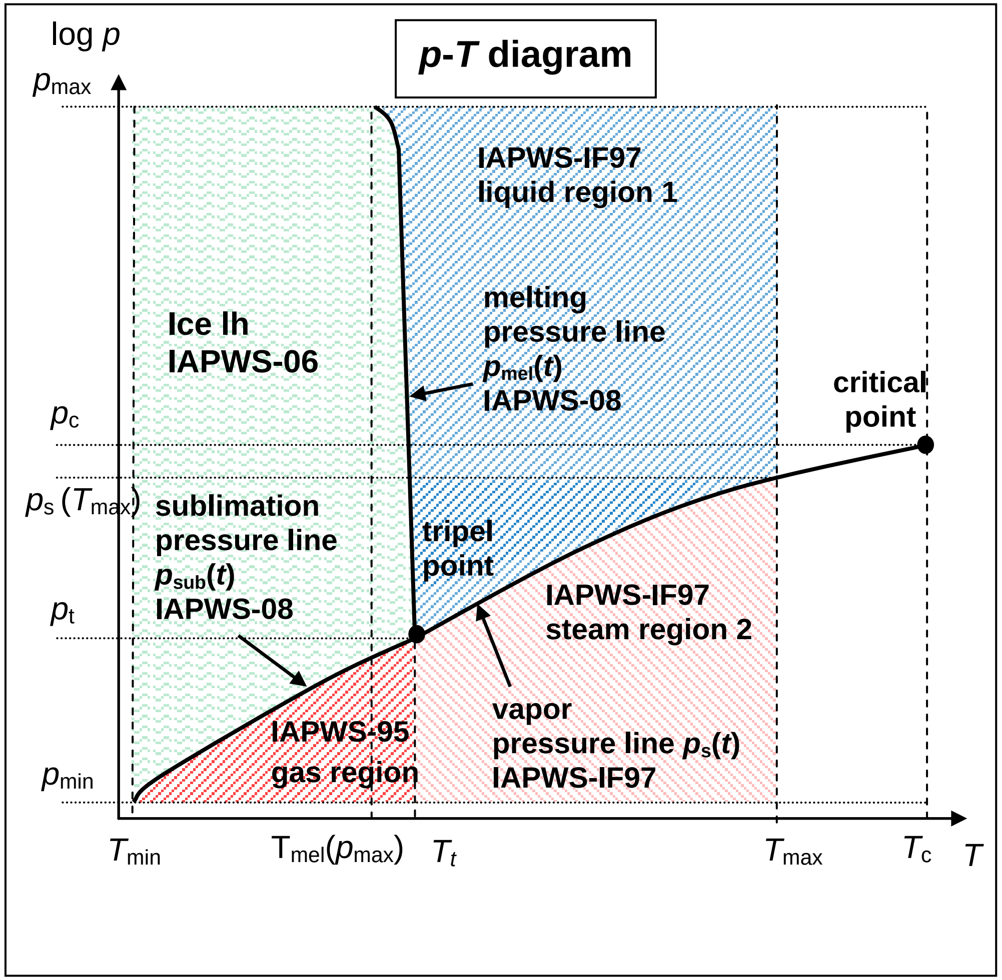
The thermodynamic properties of ice Ih are calculated by the IAPWS Formulation 2006 [7]. This region is marked with green color in the following log *p*-*T* diagram. This region ranges from minimum pressure to maximum pressure and from minimum temperature to the melting temperature for pressures $p \geq p_\mathrm{t}$ and to the sublimation temperature for pressures $p < p_\mathrm{t}$. The melting and sublimation pressures are calculated from the IAPWS 2008 Formulation [8].

The liquid-water region ranges from triple point pressure to maximum pressure and from melting temperature to saturation temperature for $p \leq p_\mathrm{s}(T_\mathrm{max})$ and the maximum temperature for $p > p_\mathrm{s}(T_\mathrm{max})$. In this region, the fundamental equation of IAPWS-IF97 Region 1 [1,2] is used. This region is marked with blue color in the following *p*-*T* diagram.

The vapor region covers the range from minimum pressure to saturation pressure and from triple point temperature to the maximum temperature for pressures $p < p_\mathrm{t}$ and from saturation temperature to maximum temperature for pressures $p \geq p_\mathrm{t}$. The thermodynamic properties are calculated by the fundamental equation of IAPWS-IF97 Region 2 [1,2]. This region is marked with light red color in the following *p*-*T* diagram.

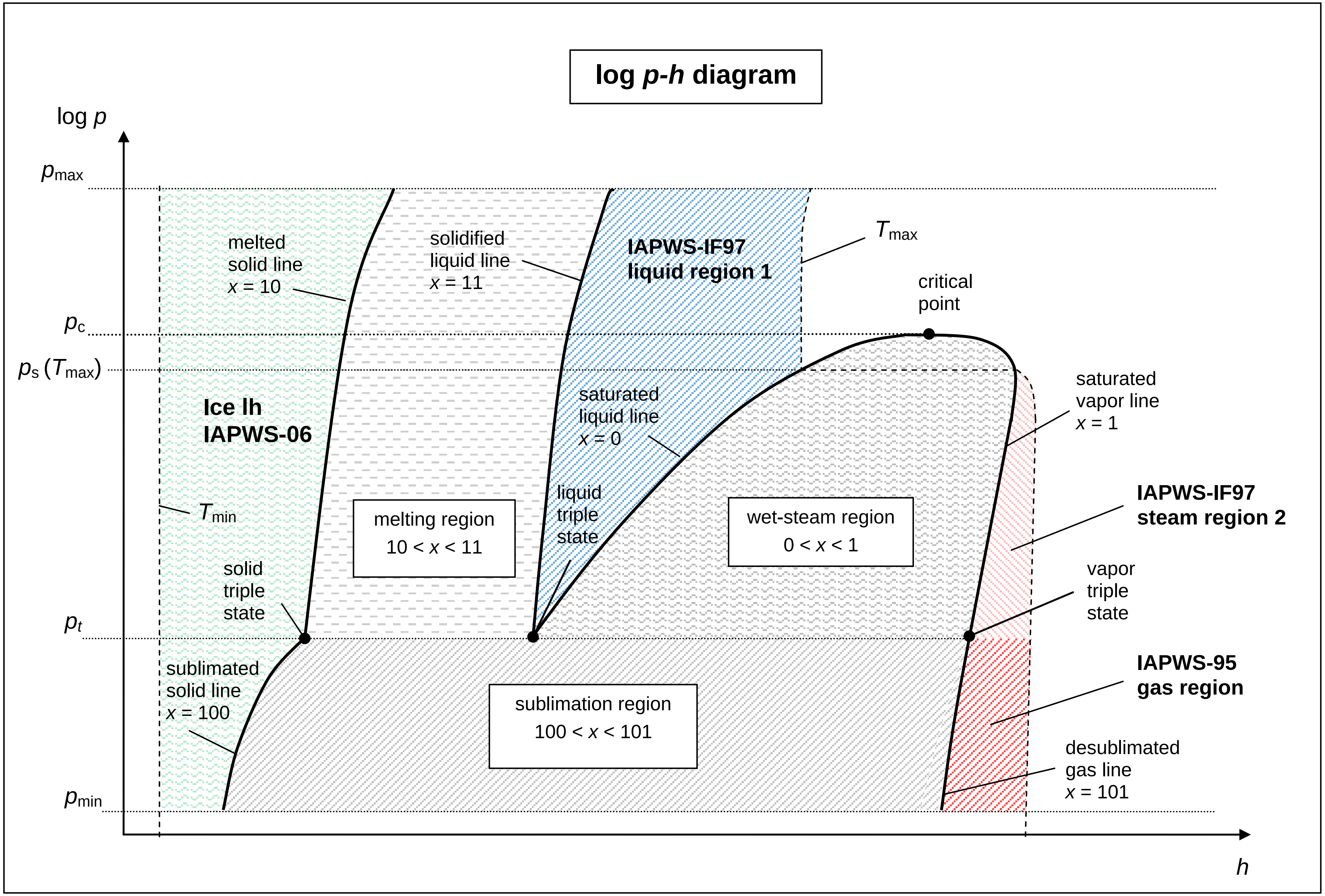
The red region in the *p*-*T* diagram is covered by the Scientific Formulation IAPWS-95 [6]. This region covers the range from minimum pressure to the sublimation pressure and from sublimation temperature to the triple point temperature.

For given property values, the region is chosen automatically by the subprograms. The two-phase regions wet steam region, melting region and sublimation region are also chosen automatically.



Values at Important State Points

Property	Variable	Value and Unit
Minimum temperature	T_{min}	50 K (– 223.15 °C)
Maximum temperature	T_{max}	623.15 K (350 °C)
Triple temperature	T_t	273.16 K (0.01 °C)
Temperature at the critical point	T_c	647.096 K (373.946 °C)
Melting temperature at maximum pressure	$T_{mel}(p_{max})$	264.2088 K (–8.9412 °C)
Minimum pressure	$p_{min}=p_{sub}(T_{min})$	$1.9349584868 \cdot 10^{-46}$ MPa
Maximum pressure	p_{max}	100 MPa
Triple pressure	p_t	$6.11657 \cdot 10^{-4}$ MPa
Pressure at the critical point	p_c	22.064 MPa
Vapor pressure at maximum temperature	$p_s(T_{max})$	16.5291643 MPa


log p-h diagram
log p
h
p_max
p_c
p_s (T_max)
p_t
p_min
melted solid line x = 10
solidified liquid line x = 11
IAPWS-IF97 liquid region 1
T_max
critical point
Ice Ih IAPWS-06
saturated liquid line x = 0
saturated vapor line x = 1
T_min
melting region 10 < x < 11
liquid triple state
wet-steam region 0 < x < 1
IAPWS-IF97 steam region 2
solid triple state
vapor triple state
sublimated solid line x = 100
sublimation region 100 < x < 101
IAPWS-95 gas region
desublimated gas line x = 101

2. Application of FluidEXL^{Graphics} in Excel®

The FluidEXL^{Graphics} Add-In has been developed to calculate thermodynamic properties in Excel more conveniently. Within Excel®, it enables the direct call of functions relating to Water and Water-Ice Ih from the LibIce property library.

2.1 Installing FluidEXL^{Graphics}

If FluidEXL^{Graphics} has not yet been installed or if there is a version installed which has been delivered before June 2010, please complete the initial installation procedure described below.

If FluidEXL^{Graphics} has already been installed in a version which has been delivered after June 2010, you simply need to copy the files which belong to the LibIce library. In this case, follow the subsection "Adding the LibIce Library" on page 2/11.

Installing FluidEXL^{Graphics} for 32-bit Windows®

Complete the following steps for initial installation of FluidEXL^{Graphics}. Before you begin, it is best to uninstall any trial version or full version of FluidEXL^{Graphics} delivered before June 2010. After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibIce_Eng.zip"	(for English version of Windows)
"CD_FluidEXL_Graphics_LibIce.zip"	(for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibIce_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibIce	(for German version of Windows)

in your Windows Explorer, Norton Commander etc. Now, open this folder by double-clicking on it. Within this folder you will see the following files:

FluidEXL_Graphics_Eng_Setup.exe	(for English version of Windows)
FluidEXL_Graphics_Setup.exe	(for German version of Windows)
FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
FluidEXL_Graphics_LibIce_Docu_Eng.pdf	
LibIce.dll	
LibIce.hlp.	

In order to run the installation of FluidEXL^{Graphics} double-click the file

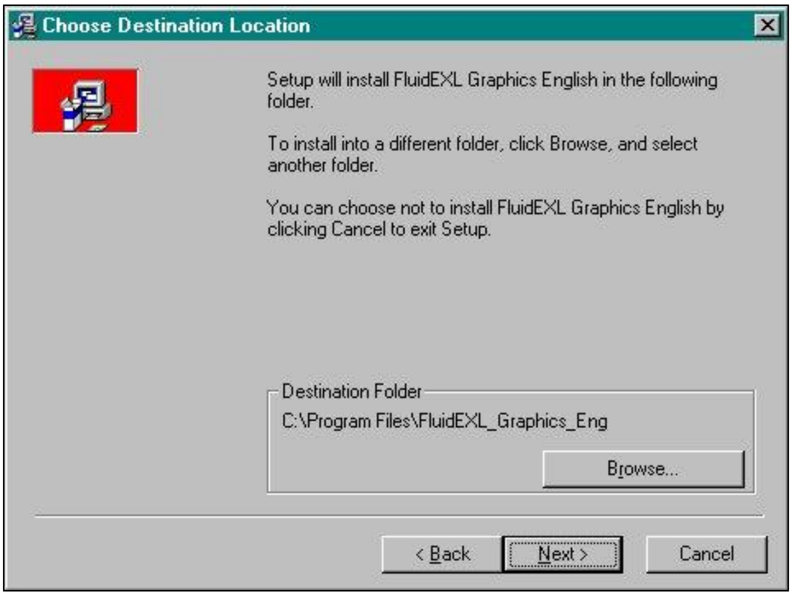
FluidEXL_Graphics_Eng_Setup.exe	(for English version of Windows)
FluidEXL_Graphics_Setup.exe	(for German version of Windows).

Installation may start with a window noting that all Windows programs should be closed. When this is the case, the installation can be continued. Click the "Continue" button.

In the following dialog box, "Choose Destination Location", the default path offered automatically for the installation of FluidEXL^{Graphics} is

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

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



Setup will install FluidEXL Graphics English in the following folder.

To install into a different folder, click Browse, and select another folder.

You can choose not to install FluidEXL Graphics English by clicking Cancel to exit Setup.

Destination Folder
C:\Program Files\FluidEXL_Graphics_Eng

Figure 2.1: Choose Destination Location

Finally, click on "Next" to continue installation; click "Next" again in the "Start Installation" window which follows in order to start the installation of FluidEXL$^{\mathit{Graphics}}$. After FluidEXL$^{\mathit{Graphics}}$ has been installed, the sentence

"FluidEXL Graphics English has been successfully installed."

will be shown. Confirm this by clicking the "Finish" button. During the installation process the following files

Advapi32.dll
DFORMD.dll
Dforrt.dll
UNWISE.EXE
INSTALL_EXL.LOG
LC.dll
Msvcp60.dll
Msvcrt.dll
UNWISE.INI

have been copied into the chosen destination folder, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

In the next step, the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibIce.dll	
LibIce.hlp	

from the extracted folder

CD_FluidEXL_Graphics_LibIce_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibIce	(for German version of Windows)

must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)),

using an appropriate program such as Windows Explorer or Norton Commander.

Installing FluidEXL^{Graphics} for 64-bit Windows®

Complete the following steps for initial installation of FluidEXL^{Graphics}. Before you begin, it is best to uninstall any trial version or full version of FluidEXL^{Graphics} delivered before June 2010. After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibIce_x64_Eng.zip"	(for English version of Windows)
"CD_FluidEXL_Graphics_LibIce_x64.zip"	(for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibIce_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibIce	(for German version of Windows)

in your Windows Explorer, Norton Commander etc. Now, open this folder by double-clicking on it. Within this folder you will see the following files

FluidEXL_Graphics_LibIce_Docu_Eng	
FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
FluidEXL_Graphics_Eng_Setup_64.msi	(for English version of Windows)
FluidEXL_Graphics_Setup_64.msi	(for German version of Windows)
LibIce.dll	
LibIce.hlp	
Setup.exe	

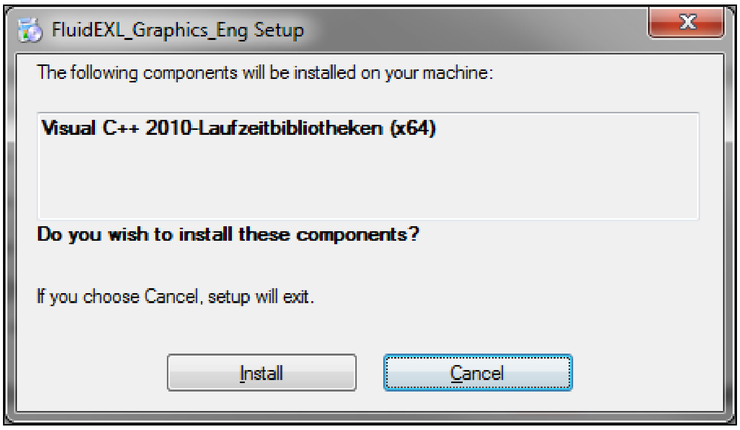
and the folders

vcredist_x64
WindowsInstaller3_1.

In order to run the installation of FluidEXL^{Graphics} double-click the file

Setup.exe.

If the "Microsoft Visual C++ 2010 x64 Redistributable Pack" is not running on your computer yet, installation will start with a window noting that the "Visual C++ 2010 runtime library (x64)" will be installed on your machine (see figure below).


FluidEXL_Graphics_Eng Setup

The following components will be installed on your machine:

Visual C++ 2010-Laufzeitbibliotheken (x64)

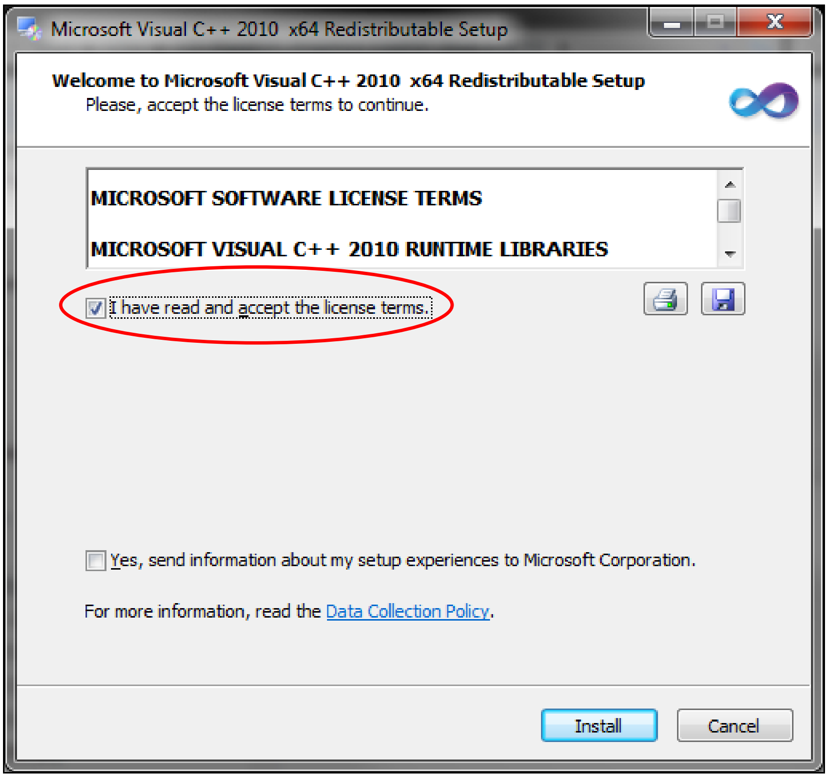
Do you wish to install these components?

If you choose Cancel, setup will exit.

Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

Click on "Install" to continue.

In the following window you are required to accept the Microsoft$^{®}$ license terms to install the "Microsoft Visual C++ 2010 x64 Redistributable Pack" by ticking the box next to "I have read and accept the license terms" (see figure below).



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 2.3: Accepting the license terms

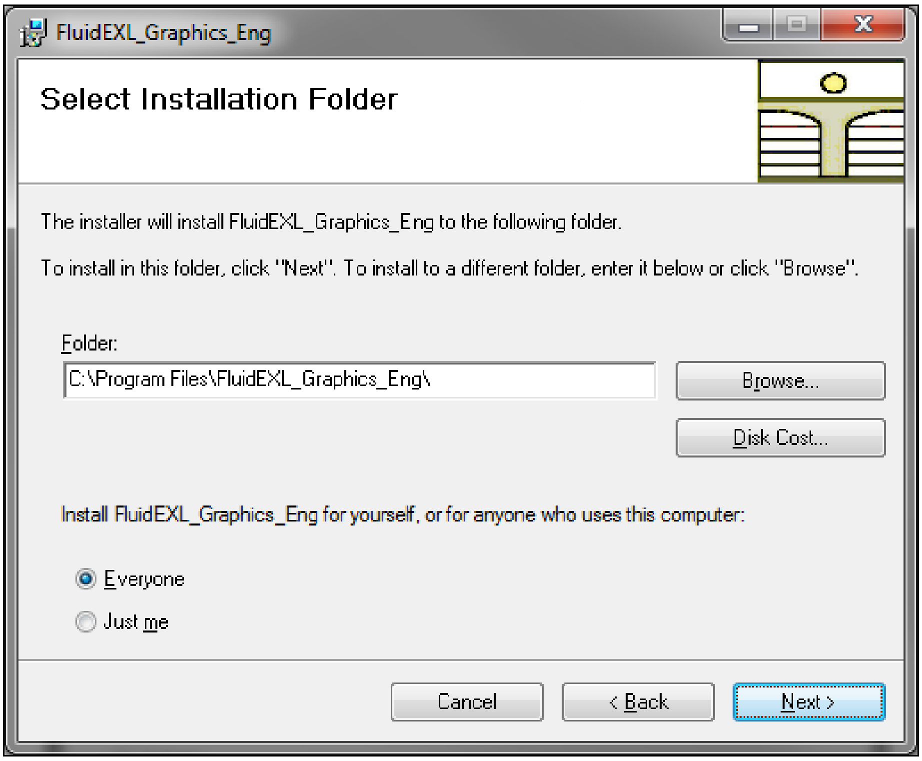
Now click on "Install" to continue installation.

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 the installation of FluidEXL_Graphics_Eng_64 starts with a window noting that the installer will guide you through the installation. Click the "Next >" button to continue.
In the following dialog box, "Select Installation Folder," the default path offered automatically for the installation of FluidEXL$^{\textit{Graphics}}$ is

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows).
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.4).



Select Installation Folder

The installer will install FluidEXL_Graphics_Eng to the following folder.

To install in this folder, click "Next". To install to a different folder, enter it below or click "Browse".

Folder: C:\Program Files\FluidEXL_Graphics_Eng\

Install FluidEXL_Graphics_Eng for yourself, or for anyone who uses this computer:

● Everyone

○ Just me

Figure 2.4: Choosing the Installation Folder of FluidEXL$^{\textit{Graphics}}$

Finally, click on "Next >" to continue installation; click "Next >" again in the "Confirm Installation" window which follows in order to start the installation of FluidEXL$^{\textit{Graphics}}$.

After FluidEXL$^{\textit{Graphics}}$ has been installed, you will see the sentence "FluidEXL_Graphics_Eng has been successfully installed." Confirm this by clicking the "Close" button.

During the installation process the following files will have been copied into the destination folder chosen, the standard being C:\Program Files\FluidEXL_Graphics_Eng:

capt_ico_big.ico
libifcoremd.dll
libiomp5md.dll.
libmmd.dll
LC.dll

In addition, the two subdirectories \FORMULATION97 and \FLuft were created in the destination folder.

In the next step, the files below,

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibIce.dll	
LibIce.hlp	

found in your CD folder, must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows))

using an appropriate program such as Explorer or Norton Commander.

2.2 Registering FluidEXL^{Graphics} as Add-In in Excel®

Registering FluidEXL^{Graphics} as Add-In in Excel®, versions 2003 or earlier

After the installation of FluidEXL^{Graphics}, the program must be registered as an Add-In in Excel®. In order to do so, start Excel® and carry out the following steps:

- Click "Tools" in the upper menu bar of Excel®.
- Here, click the "Add-Ins..." menu item.
  After a short delay the "Add-Ins" dialog box will appear.
- Click "Browse...."
- In the following dialog box, choose your chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows))

  here select

"FluidEXL_Graphics_Eng.xla"	(for English version of Windows)
"FluidEXL_Graphics.xla"	(for German version of Windows)

  and afterwards click "OK".

- Now, the entry

"FluidEXL_Graphics_Eng"	(for English version of Windows)
"FluidEXL_Graphics"	(for German version of Windows)

  will appear in the Add-Ins list.

Note:
As long as the check box next to the file name "FluidEXL Graphics Eng" is checked, this Add-In will be loaded automatically every time you start Excel® until you unmark the box by clicking on it again.

In order to register FluidEXL^{Graphics} as an Add-In, click "OK" in the "Add-Ins" dialog box. Now, the new FluidEXL^{Graphics} menu bar will appear in the upper menu area of your Excel® screen, marked with a red circle in Figure 2.5.

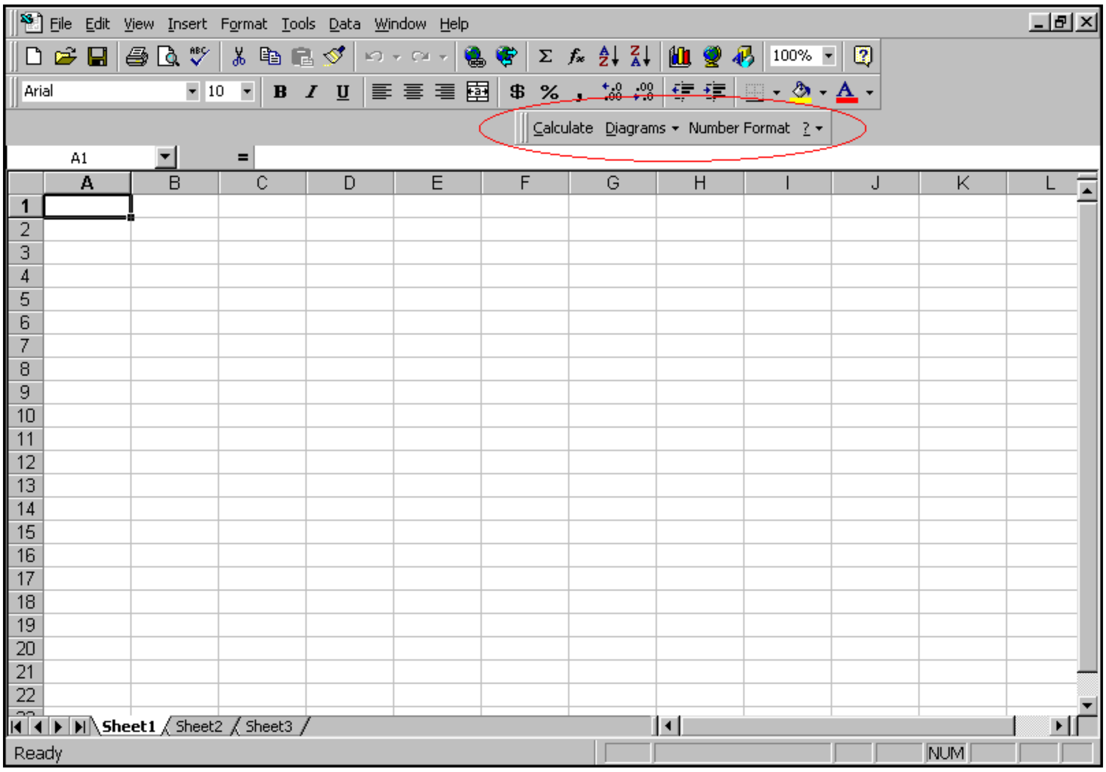


Figure 2.5: Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "LibIce" DLL library property functions via this menu bar (see section 2.5 on page 2/20).

Registering FluidEXL*Graphics* as Add-In in Excel® 2007 (or later versions)

After installation in Windows®, FluidEXL*Graphics* must be registered in Excel® versions 2007 and later as an Add-In. To do this, start Excel® and carry out the following steps:

- Click the Windows Office® button in the upper left hand corner of Excel®
- Click on the "Excel Options" button in the menu which appears (see Figure 2.6)

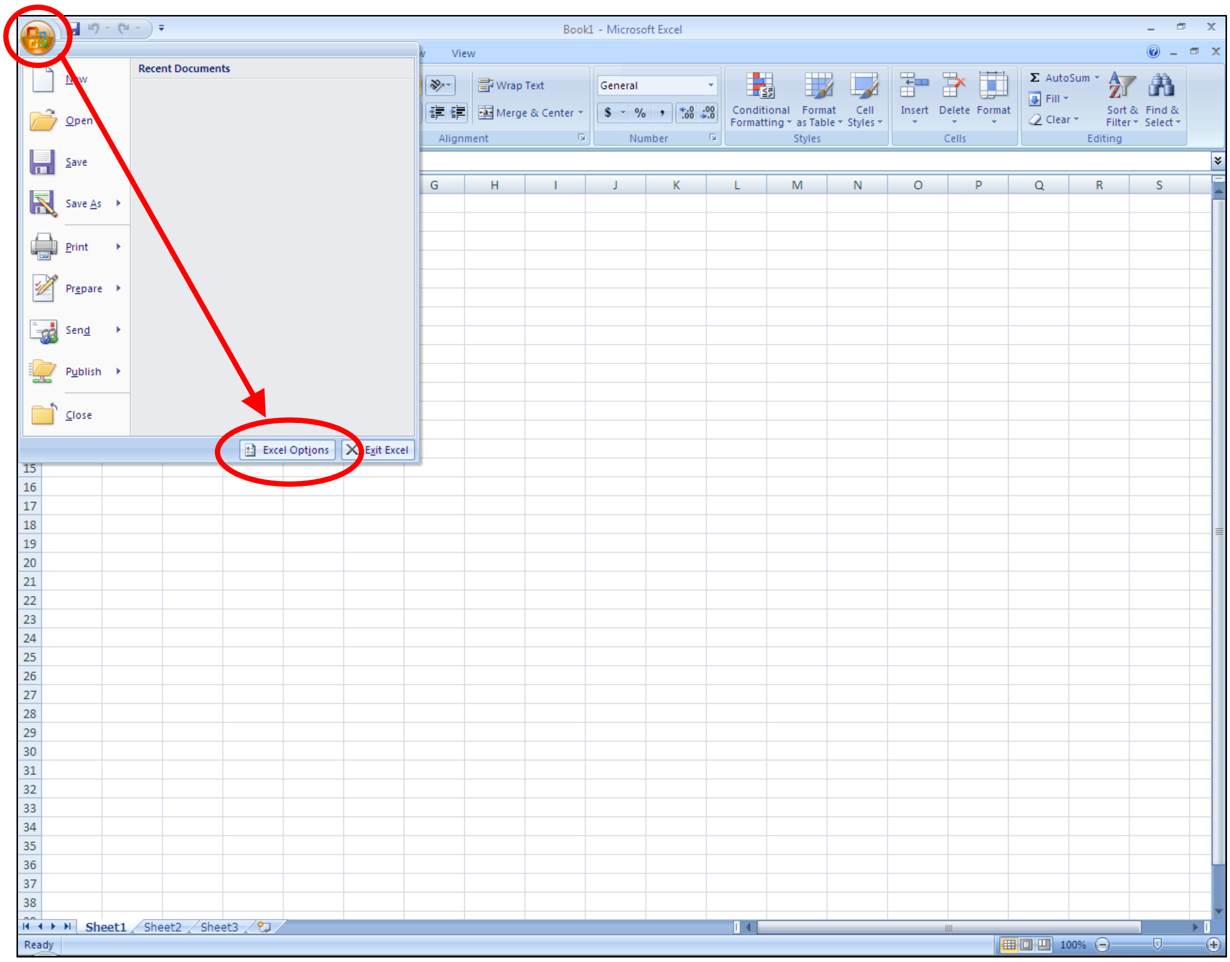
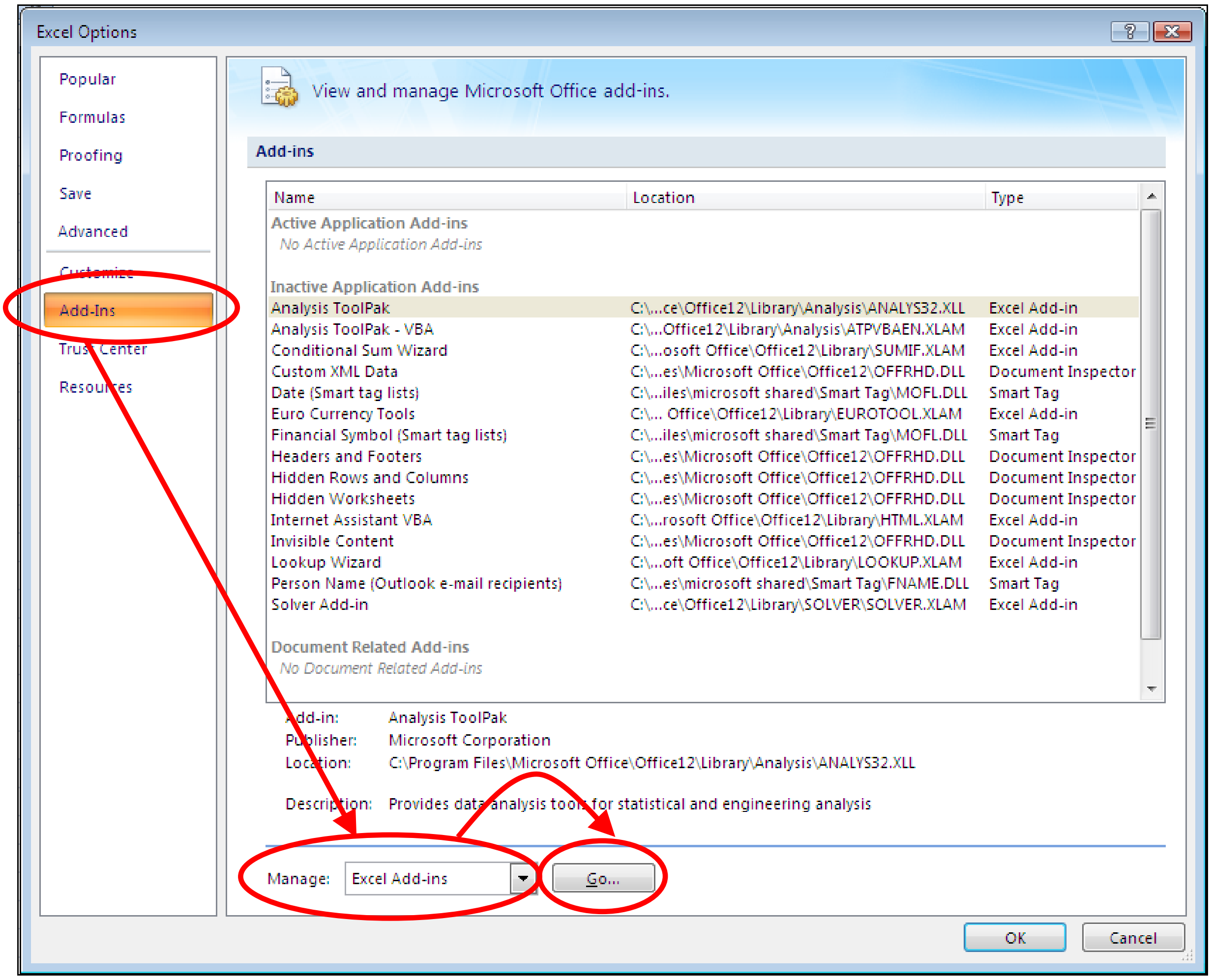


Figure 2.6: Registering FluidEXL*Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu



Name	Location	Type
Active Application Add-ins		
No Active Application Add-ins		
Inactive Application Add-ins		
Analysis ToolPak	C:\...ce\Office12\Library\Analysis\ANALYS32.XLL	Excel Add-in
Analysis ToolPak - VBA	C:\...Office12\Library\Analysis\ATPVBAEN.XLAM	Excel Add-in
Conditional Sum Wizard	C:\...osoft Office\Office12\Library\SUMIF.XLAM	Excel Add-in
Custom XML Data	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Date (Smart tag lists)	C:\...iles\microsoft shared\Smart Tag\MOFL.DLL	Smart Tag
Euro Currency Tools	C:\... Office\Office12\Library\EUROTOOL.XLAM	Excel Add-in
Financial Symbol (Smart tag lists)	C:\...iles\microsoft shared\Smart Tag\MOFL.DLL	Smart Tag
Headers and Footers	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Hidden Rows and Columns	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Hidden Worksheets	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Internet Assistant VBA	C:\...rosoft Office\Office12\Library\HTML.XLAM	Excel Add-in
Invisible Content	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Lookup Wizard	C:\...oft Office\Office12\Library\LOOKUP.XLAM	Excel Add-in
Person Name (Outlook e-mail recipients)	C:\...es\microsoft shared\Smart Tag\FNAME.DLL	Smart Tag
Solver Add-in	C:\...ce\Office12\Library\SOLVER\SOLVER.XLAM	Excel Add-in
Document Related Add-ins		
No Document Related Add-ins		

Add-in: Analysis ToolPak
Publisher: Microsoft Corporation
Location: C:\Program Files\Microsoft Office\Office12\Library\Analysis\ANALYS32.XLL

Description: Provides data analysis tools for statistical and engineering analysis

Figure 2.7: Dialog window "Excel Options"

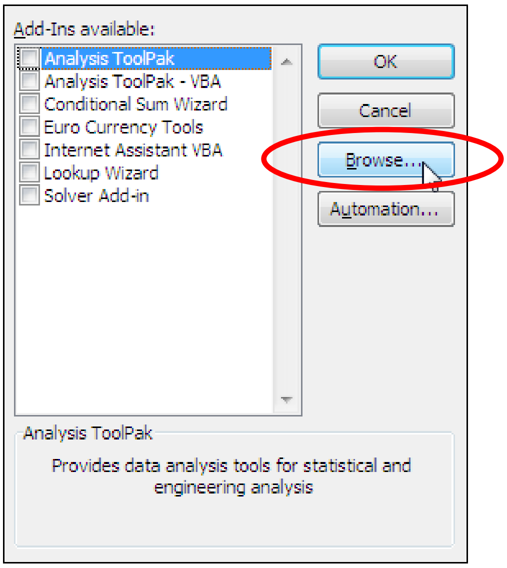
- Should it not be shown in the list automatically, select "Excel Add-ins" (found next to "Manage:" in the lower area of the menu)
- Then click the "Go…" button
- Click "Browse" in the following window and locate the destination folder, generally

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows);

within that folder click on the file named

"FluidEXL_Graphics_Eng.xla"	(for English version of Windows)
"FluidEXL_Graphics.xla"	(for German version of Windows)

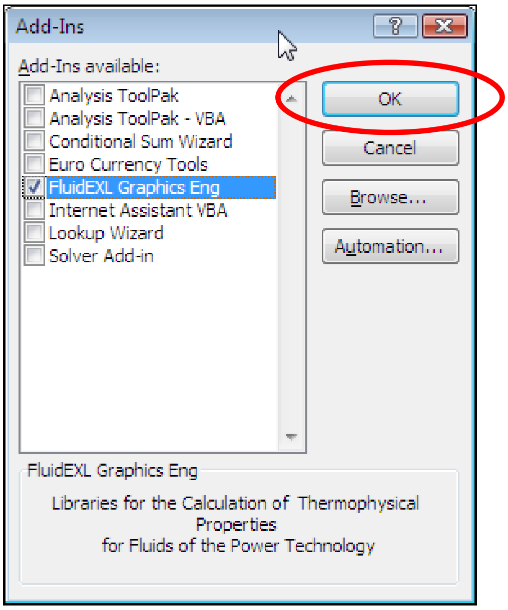
and then hit "OK."



Provides data analysis tools for statistical and engineering analysis

Figure 2.8: Dialog window "Add-Ins available"

- Now, "FluidEXL Graphics Eng" will be shown in your list of Add-Ins.
  (If a check-mark is situated in the box next to the name "FluidEXL Graphics Eng," this Add-In will automatically be loaded whenever Excel® starts. This will continue to occur unless the check-mark is removed from the box by clicking on it.)



Libraries for the Calculation of Thermophysical Properties
for Fluids of the Power Technology

Figure 2.9: Dialog window "Add-Ins"

- In order to register the Add-In click the "OK" button in the "Add-Ins" window.

In order to use FluidEXL*Graphics* in the following example, click on the menu item "Add-Ins" shown in Figure 2.10.

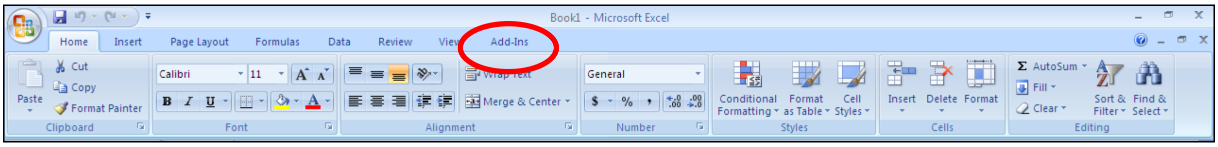


Figure 2.10: Menu item "Add-Ins"

In the upper menu region of Excel, the FluidEXL*Graphics* menu bar will appear as marked with the red circle in the next figure.

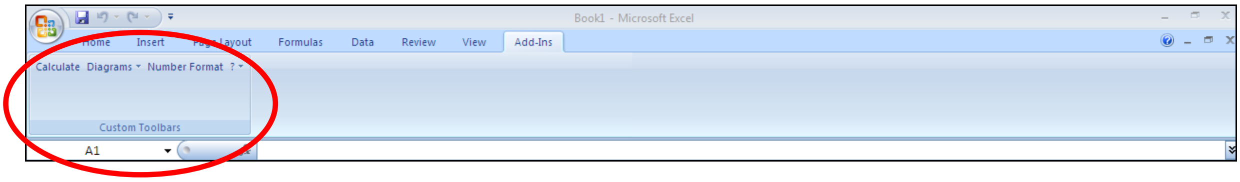


Figure 2.11: FluidEXL*Graphics* menu bar

Installation of FluidEXL*Graphics* in Excel® (versions 2007 and later) is now finished. FluidEXL*Graphics* can be used analogous to the description for using with earlier Excel® versions.

Adding the LibIce Library (FluidEXL*Graphics* is already installed)

If FluidEXL*Graphics* has already been installed in the June 2010 version, you only have to copy the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibIce.dll	
LibIce.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibIce_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibIce	(for German version of Windows)

into the folder you have chosen for the installation of FluidEXL*Graphics* (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)

using an appropriate program such as Explorer® or Norton Commander.

From within Excel you can now select the "LibIce" DLL library property functions for nitrogen via this menu bar (the example calculation can be found in section 2.5 on page 2/20).

2.3 The FluidEXL*Graphics* Help System

As mentioned earlier, FluidEXL*Graphics* also provides detailed online help functions. If you are running Windows Vista or Windows 7, please note the paragraph
"Using the FluidEXL*Graphics* Online-Help in Windows Vista or Windows 7."

For general information in Excel® click on "?" and then "Help" in the FluidEXL*Graphics* menu bar. Information on individual property functions may be accessed via the following steps:

- Click "Calculate" in the FluidEXL*Graphics* menu bar.
- Click on the "ICE LibIce" library under "Or select a category:" in the "Insert Function" window which will appear.
- Click the "Help on this function" button in the lower left-hand edge of the "Insert Function" window.
- If the "Office Assistant" is active, first double-click "Help on this feature" and in the next menu click "Help on selected function".

If the LibIce.hlp function help cannot be found, confirm the question whether you want to look for it yourself with "Yes". Select the LibIce.hlp file in the installation folder of FluidEXL*Graphics* in the window which is opened, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows)

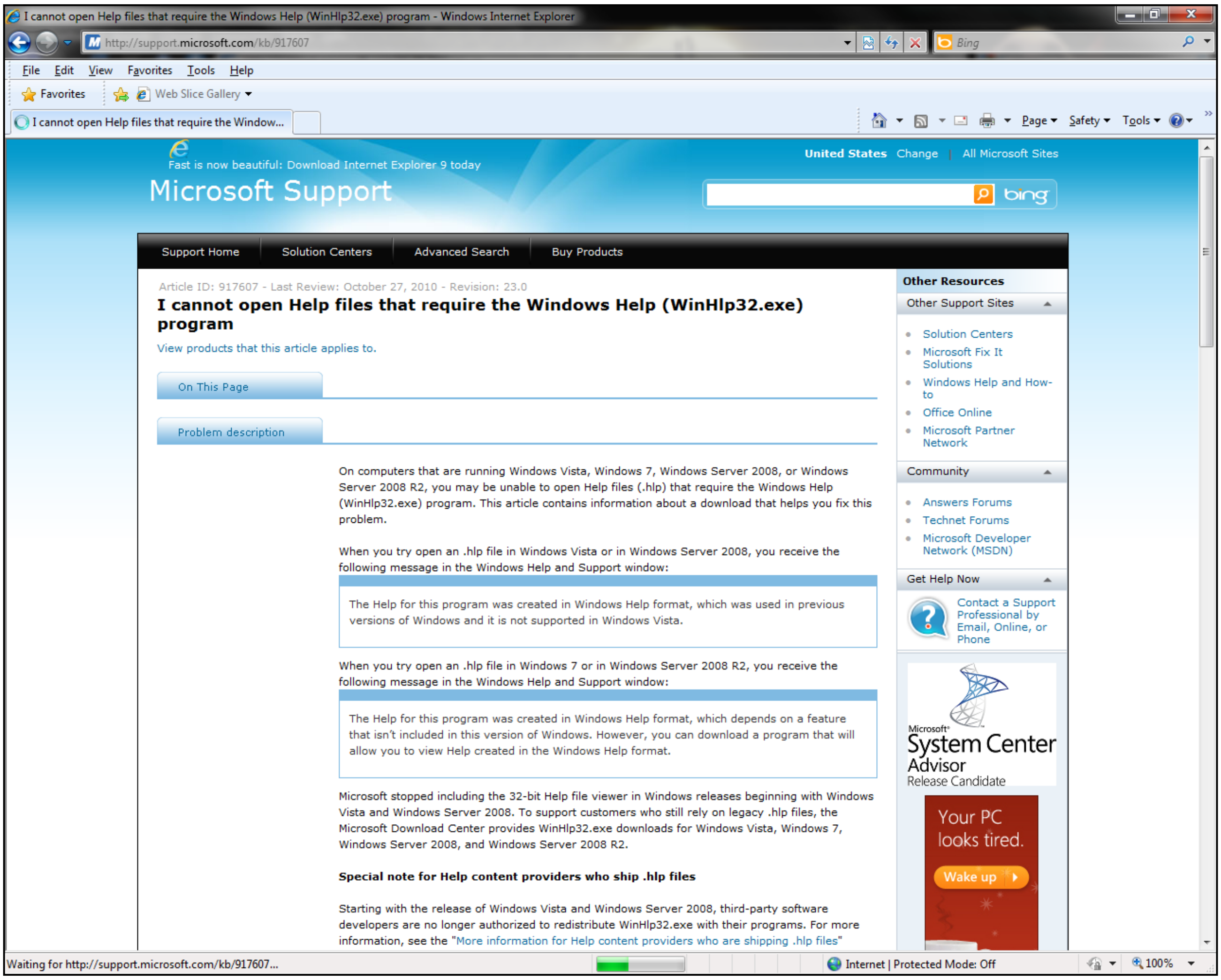
and click "Yes" in order to complete the search.

Using the FluidEXL*Graphics* Online Help in Windows Vista or Windows 7

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

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

You will see the following web page:



Article ID: 917607 - Last Review: October 27, 2010 - Revision: 23.0

I cannot open Help files that require the Windows Help (WinHlp32.exe) program

View products that this article applies to.

On This Page

Problem description

On computers that are running Windows Vista, Windows 7, Windows Server 2008, or Windows Server 2008 R2, you may be unable to open Help files (.hlp) that require the Windows Help (WinHlp32.exe) program. This article contains information about a download that helps you fix this problem.

When you try open an .hlp file in Windows Vista or in Windows Server 2008, you receive the following message in the Windows Help and Support window:

> The Help for this program was created in Windows Help format, which was used in previous versions of Windows and it is not supported in Windows Vista.

When you try open an .hlp file in Windows 7 or in Windows Server 2008 R2, you receive the following message in the Windows Help and Support window:

> The Help for this program was created in Windows Help format, which depends on a feature that isn't included in this version of Windows. However, you can download a program that will allow you to view Help created in the Windows Help format.

Microsoft stopped including the 32-bit Help file viewer in Windows releases beginning with Windows Vista and Windows Server 2008. To support customers who still rely on legacy .hlp files, the Microsoft Download Center provides WinHlp32.exe downloads for Windows Vista, Windows 7, Windows Server 2008, and Windows Server 2008 R2.

Special note for Help content providers who ship .hlp files

Starting with the release of Windows Vista and Windows Server 2008, third-party software developers are no longer authorized to redistribute WinHlp32.exe with their programs. For more information, see the "More information for Help content providers who are shipping .hlp files"

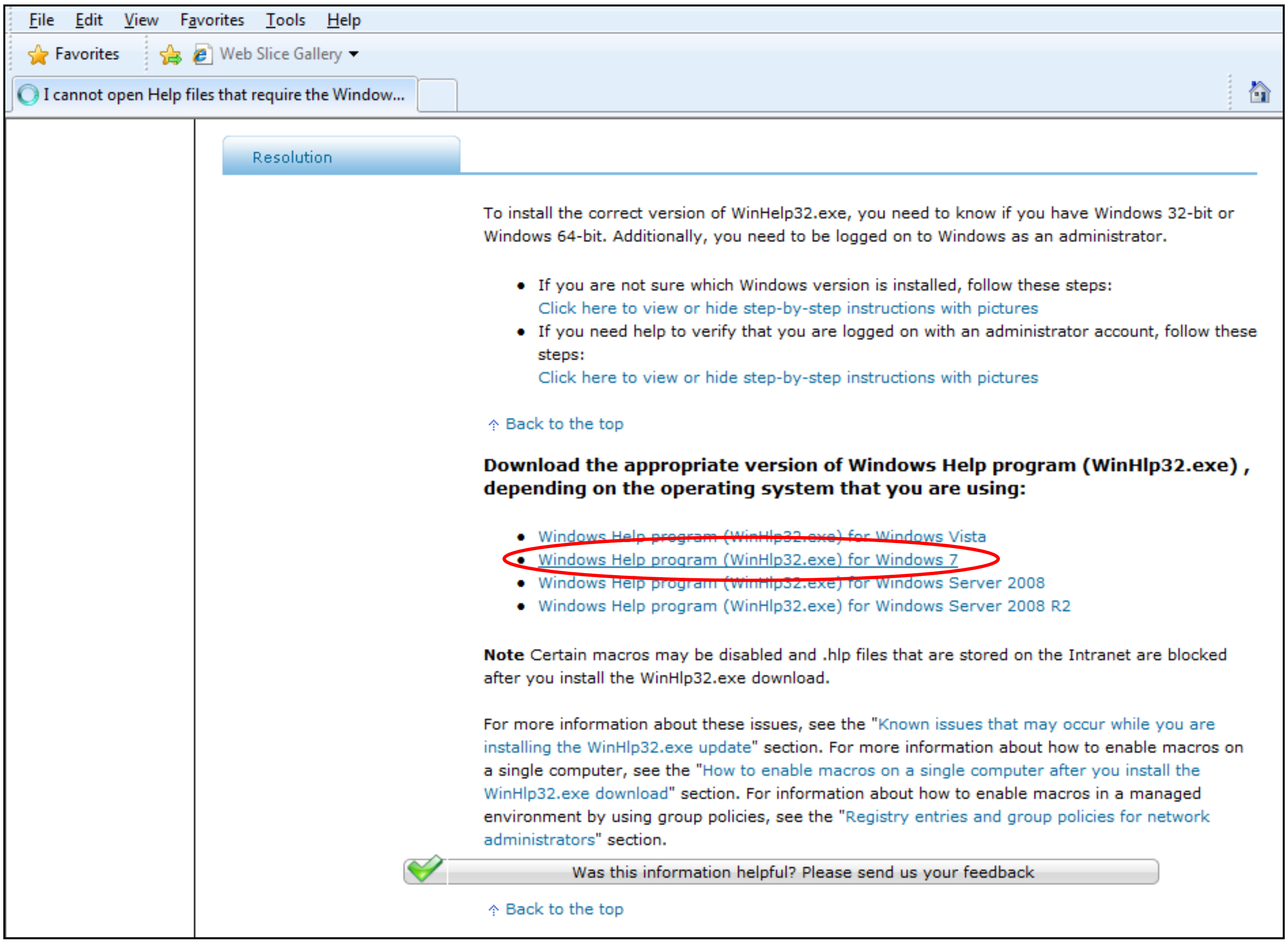
Figure 2.12: Microsoft® Support web page

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

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

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

Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.13).



To install the correct version of WinHelp32.exe, you need to know if you have Windows 32-bit or Windows 64-bit. Additionally, you need to be logged on to Windows as an administrator.

- If you are not sure which Windows version is installed, follow these steps:
  Click here to view or hide step-by-step instructions with pictures
- If you need help to verify that you are logged on with an administrator account, follow these steps:
  Click here to view or hide step-by-step instructions with pictures

↑ Back to the top

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

- 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 Certain macros may be disabled and .hlp files that are stored on the Intranet are blocked after you install the WinHlp32.exe download.

For more information about these issues, see the "Known issues that may occur while you are installing the WinHlp32.exe update" section. For more information about how to enable macros on a single computer, see the "How to enable macros on a single computer after you install the WinHlp32.exe download" section. For information about how to enable macros in a managed environment by using group policies, see the "Registry entries and group policies for network administrators" section.

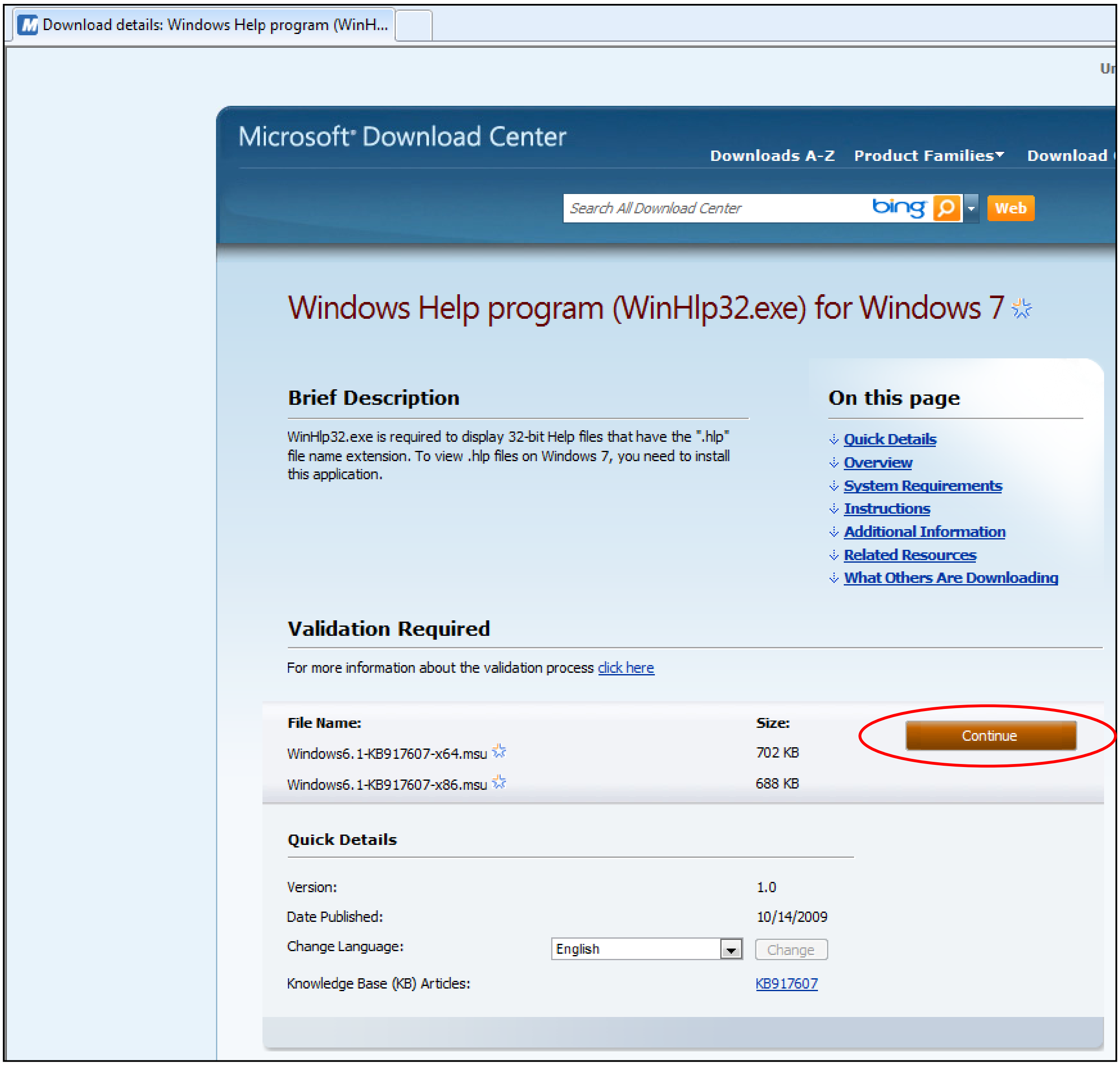
↑ Back to the top

Figure 2.13: 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 2.14).



Windows Help program (WinHlp32.exe) for Windows 7

Brief Description

WinHlp32.exe is required to display 32-bit Help files that have the ".hlp" file name extension. To view .hlp files on Windows 7, you need to install this application.

Validation Required

For more information about the validation process click here

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

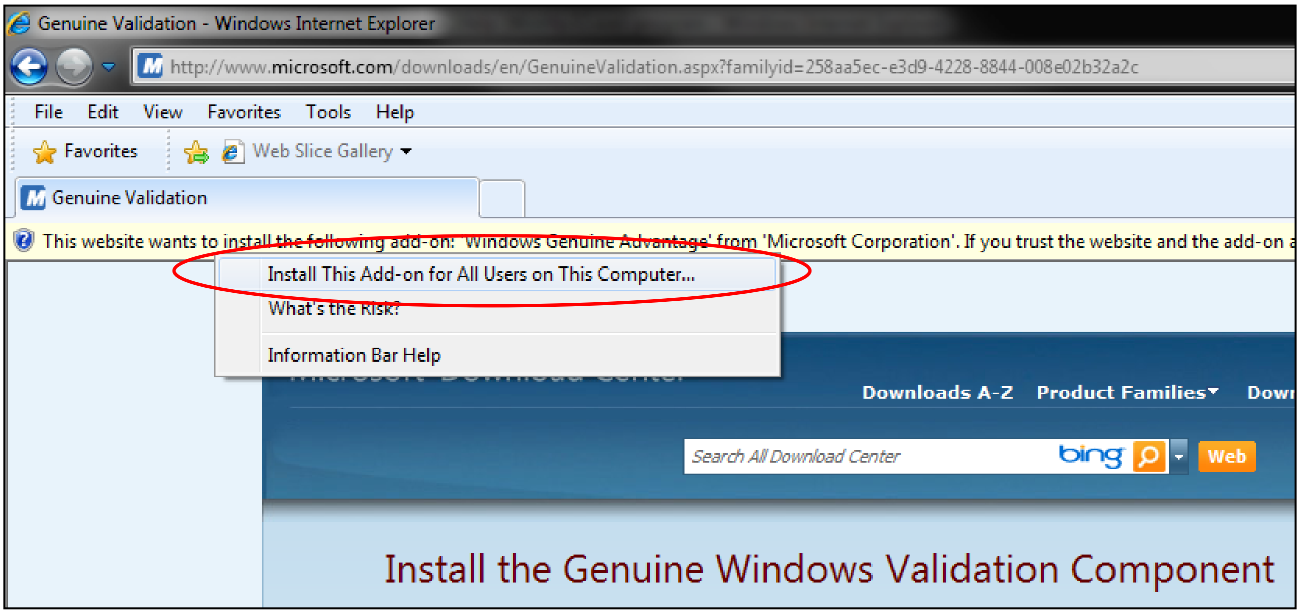
Quick Details

Version:	1.0
Date Published:	10/14/2009
Change Language:	English
Knowledge Base (KB) Articles:	KB917607

Figure 2.14: Microsoft® Download Center

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

At the top of your Windows Internet Explorer you will see a yellow information bar. Right-click this bar and select "Install ActiveX Control" in the context menu (see Figure 2.15).



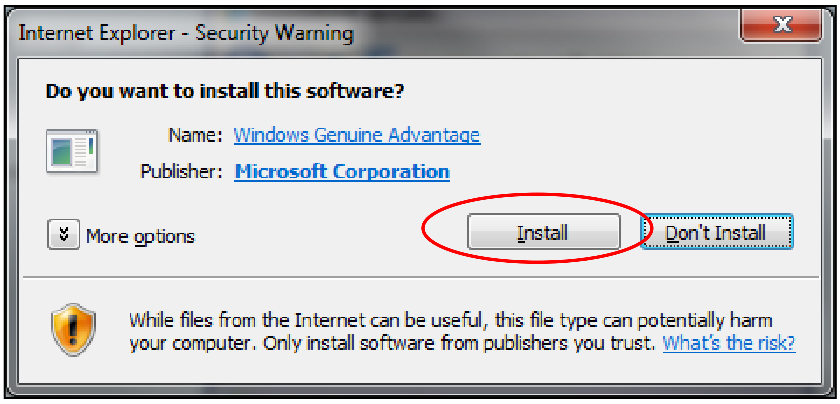
http://www.microsoft.com/downloads/en/GenuineValidation.aspx?familyid=258aa5ec-e3d9-4228-8844-008e02b32a2c

This website wants to install the following add-on: 'Windows Genuine Advantage' from 'Microsoft Corporation'. If you trust the website and the add-on a

Install the Genuine Windows Validation Component

Figure 2.15: Installing the Genuine Windows Validation Component

A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue (see Figure 2.16).



Do you want to install this software?

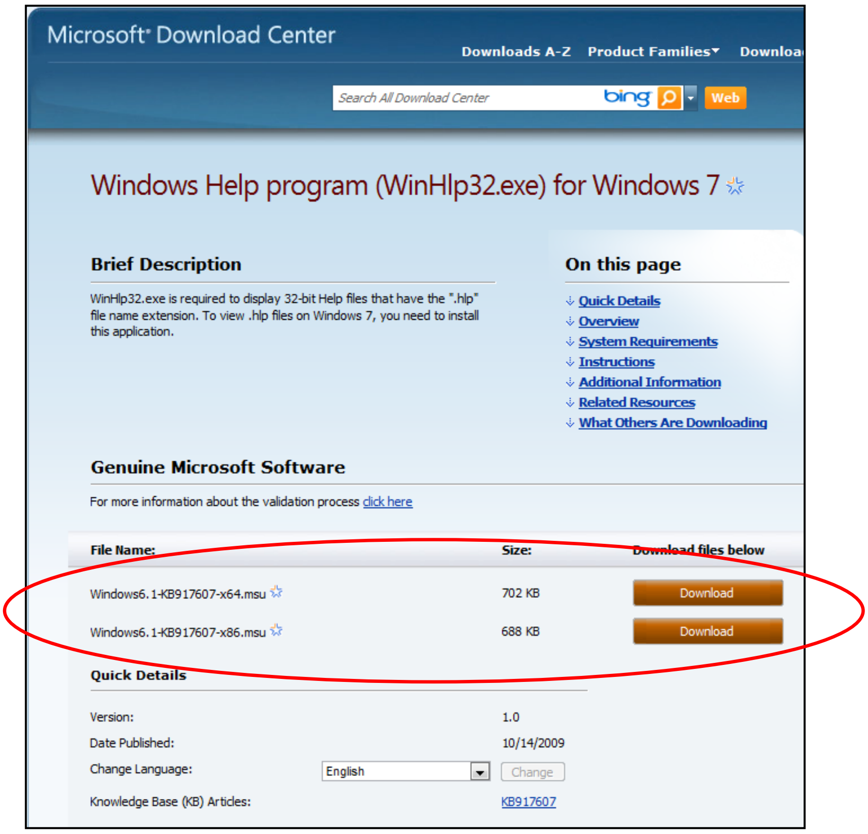
Name: Windows Genuine Advantage

Publisher: Microsoft Corporation

While files from the Internet can be useful, this file type can potentially harm your computer. Only install software from publishers you trust. What's the risk?

Figure 2.16: Internet Explorer – Security Warning

After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.17).



Windows Help program (WinHlp32.exe) for Windows 7

Brief Description

WinHlp32.exe is required to display 32-bit Help files that have the ".hlp" file name extension. To view .hlp files on Windows 7, you need to install this application.

Genuine Microsoft Software

For more information about the validation process click here

File Name:	Size:	Download files below
Windows6.1-KB917607-x64.msu	702 KB	Download
Windows6.1-KB917607-x86.msu	688 KB	Download

Quick Details

Version:	1.0
Date Published:	10/14/2009
Change Language:	English
Knowledge Base (KB) Articles:	KB917607

Figure 2.17: Downloading the Windows Help program

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

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

Windows6.1-KB917607-x64.msu.

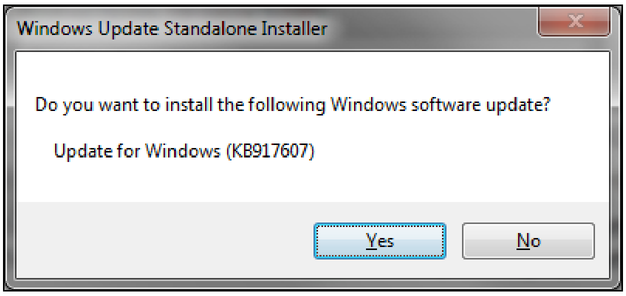
If you are running a 32-bit operating system, please download the file

Windows6.1-KB917607-x86.msu.

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

Windows6.1-KB917607-x64.msu	(for 64-bit operating system)
Windows6.1-KB917607-x86.msu.	(for 32-bit operating system).

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

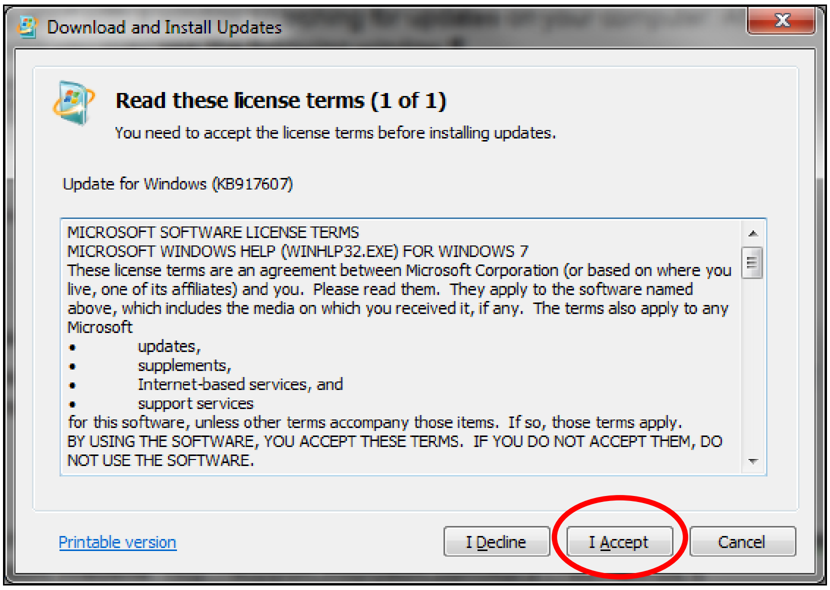


Do you want to install the following Windows software update?

Update for Windows (KB917607)

Figure 2.18: Windows Update Standalone Installer

In this case, the installation can be continued by clicking the "Yes" button.
(If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.")
In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept" (see Figure 2.19)



Read these license terms (1 of 1)

You need to accept the license terms before installing updates.

Update for Windows (KB917607)

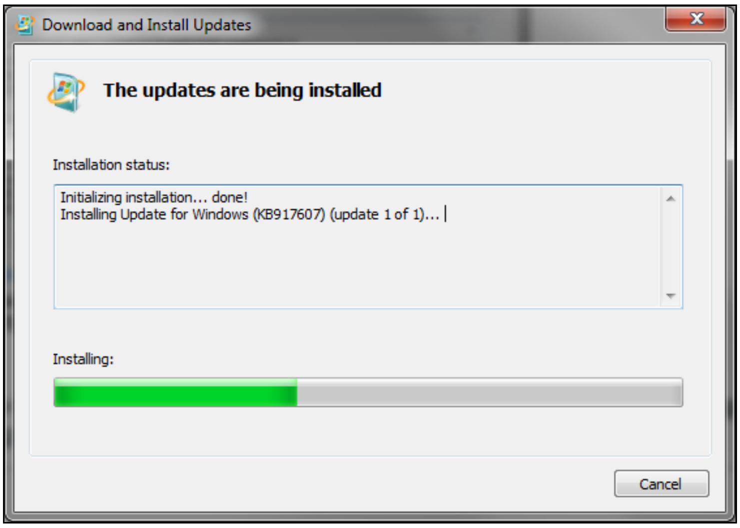
MICROSOFT SOFTWARE LICENSE TERMS
MICROSOFT WINDOWS HELP (WINHLP32.EXE) FOR WINDOWS 7
These license terms are an agreement between Microsoft Corporation (or based on where you live, one of its affiliates) and you. Please read them. They apply to the software named above, which includes the media on which you received it, if any. The terms also apply to any Microsoft

- updates,
- supplements,
- Internet-based services, and
- support services

for this software, unless other terms accompany those items. If so, those terms apply.
BY USING THE SOFTWARE, YOU ACCEPT THESE TERMS. IF YOU DO NOT ACCEPT THEM, DO NOT USE THE SOFTWARE.

Figure 2.19: Windows License Terms

Installation starts once you have clicked the "I Accept" button (see Figure 2.20).



Initializing installation... done!
Installing Update for Windows (KB917607) (update 1 of 1)...

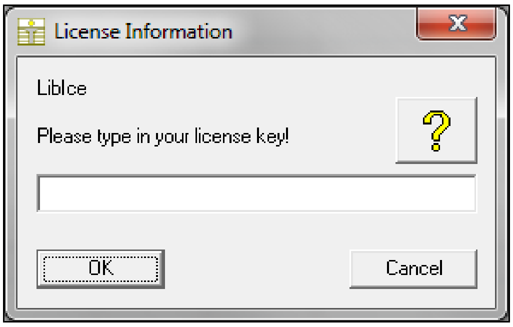
Figure 2.20: Installation process

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

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

2.4 Licensing the LibIce Property Library

The licensing procedure has to be carried out when Excel® starts up and a FluidEXL$^{\mathit{Graphics}}$ prompt message appears. In this case, you will see the "License Information" window (see figure below).

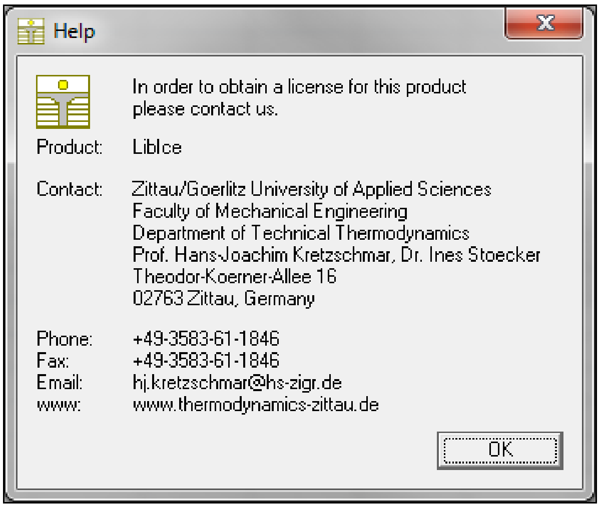


LibIce

Please type in your license key!

Figure 2.21: "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: LibIce

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 2.22: "Help" window

If you do not enter a valid license it is still possible to start Excel by clicking "Cancel" twice. In this case, the LibIce property library will display the result "–11111111" for every calculation. The "License Information" window will appear every time you start Excel unless you uninstall FluidEXL$^{\mathit{Graphics}}$ according to the description in section 2.6 of this user's guide. Should you not wish to license the LibIce property library, you have to delete the files

LibIce.dll
LibIce.hlp

in the installation folder of FluidEXL$^{\mathit{Graphics}}$ (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows))

using an appropriate program such as Explorer® or Norton Commander.

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

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

- Start Excel®
- Enter a value for *p* in bar in a cell

⇒ e. g.: Enter the value 10 into cell A2

- Enter a value for *t* in °C in a cell

  ⇒ e. g.: Enter the value -50 into cell B2

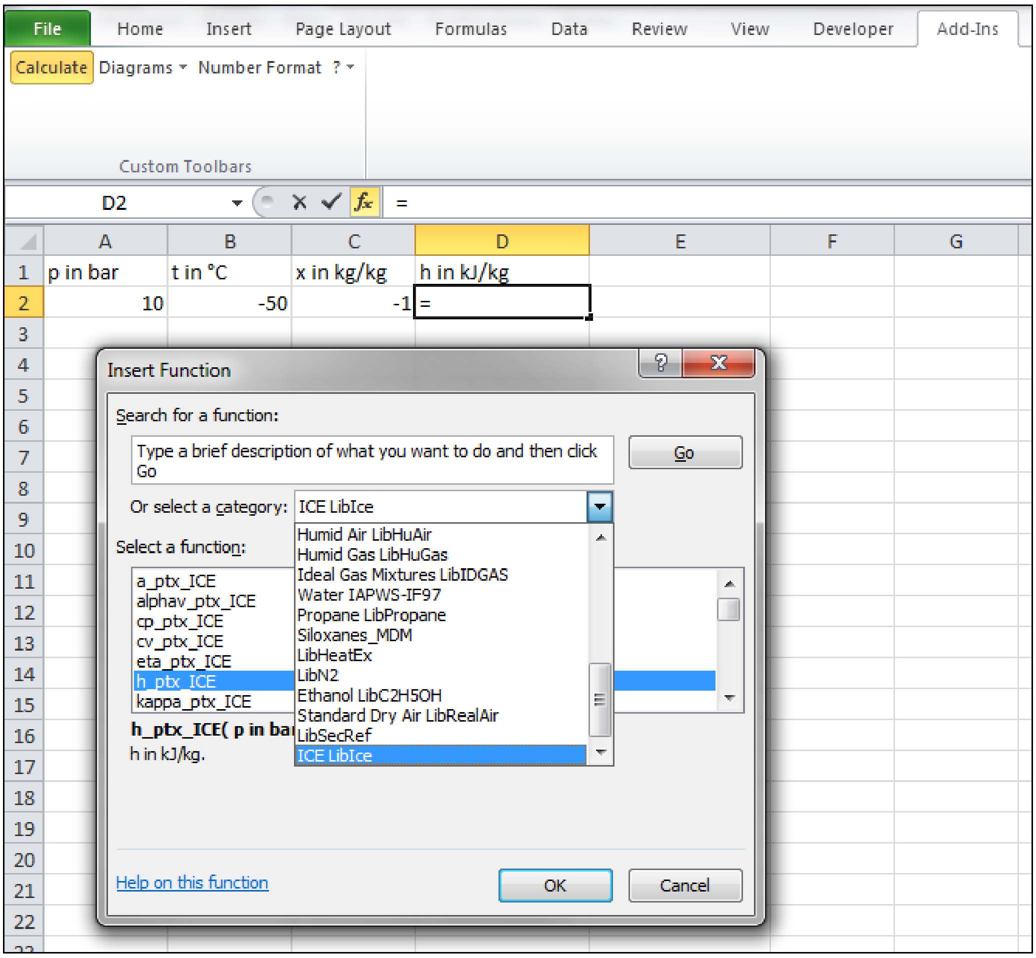
- Enter a value for *x* in kg/kg in a cell.
  In this example we want to calculate the specific enthalpy in the single phase region, we therefore need to insert the value -1 for *x*.

  ⇒ e. g.: Enter the value -1 into cell C2

- Click the cell in which the specific enthalpy *h* in kJ/kg is to be displayed.

  ⇒ e.g.: Click the D2 cell.

- Click "Calculate" in the menu bar of FluidEXL*Graphics*.
  Now the "Insert Function" window appears (see Figure 2.23).



	A	B	C	D
1	p in bar	t in °C	x in kg/kg	h in kJ/kg
2	10	-50	-1	=

Search for a function:

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

Or select a category: ICE LibIce

Humid Air LibHuAir
Humid Gas LibHuGas
Ideal Gas Mixtures LibIDGAS
Water IAPWS-IF97
Propane LibPropane
Siloxanes_MDM
LibHeatEx
LibN2
Ethanol LibC2H5OH
Standard Dry Air LibRealAir
LibSecRef
ICE LibIce

Select a function:

a_ptx_ICE
alphav_ptx_ICE
cp_ptx_ICE
cv_ptx_ICE
eta_ptx_ICE
h_ptx_ICE
kappa_ptx_ICE

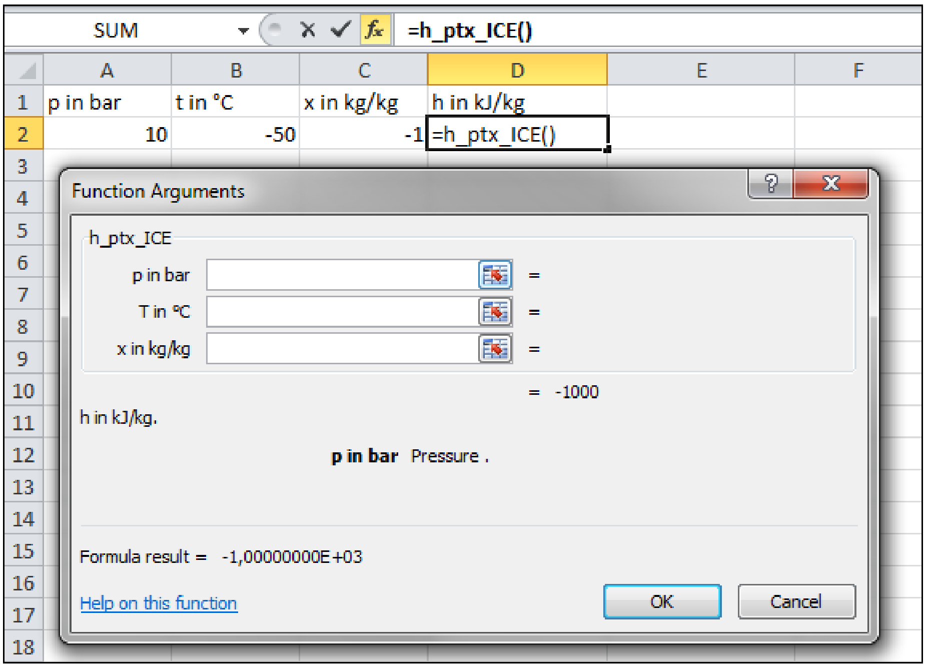
h_ptx_ICE(p in bai

h in kJ/kg.

Figure 2.23: Choice of library and function name

- Search and click the "Ice LibIce" library under "Or select a category:" in the upper part of the window.
- Search and click the h_ptx_Ice function under "Select a function:" right below.

  Here it is possible to get more information on the range of validity, measuring units, error responses, etc. by clicking the "Help on this function" button.
- Click "OK".
  The window shown in Figure 2.24 will now appear.



=h_ptx_ICE()

	A	B	C	D	E	F
1	p in bar	t in °C	x in kg/kg	h in kJ/kg		
2	10	-50	-1	=h_ptx_ICE()		

p in bar =
T in °C =
x in kg/kg =
= -1000
h in kJ/kg.
p in bar Pressure .
Formula result = -1,00000000E+03

Figure 2.24: Input menu for the function

- Situate the cursor next to "p in bar" and enter the value for *p* by clicking the cell with the value for *p,* by entering the name of the cell with the value for *p,* or by entering the value for *p* directly.

  ⇒ e. g.: Type A2 into the window next to "p"

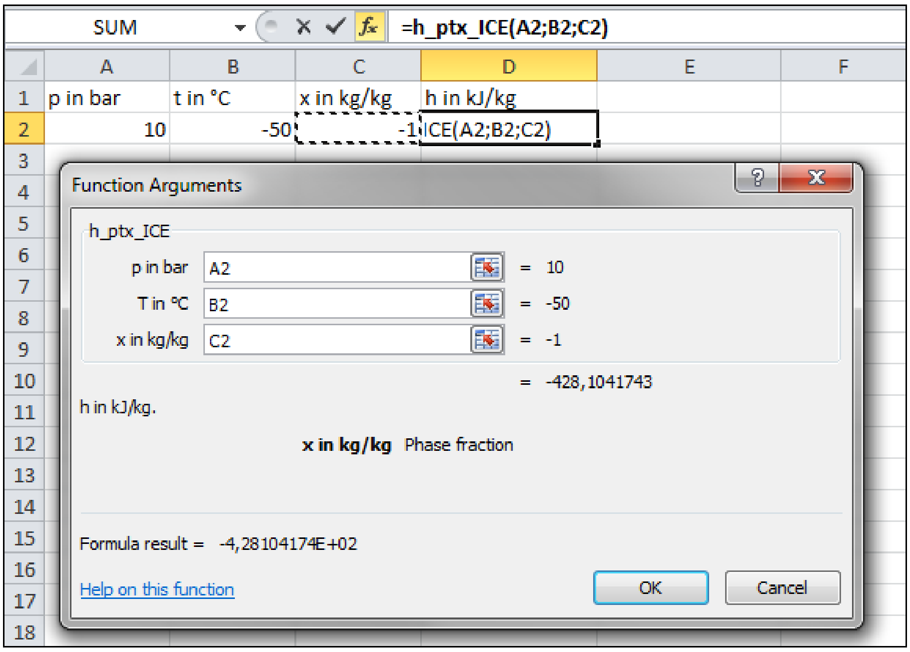
- Situate the cursor next to "T in °C" and enter the value for *T* by clicking the cell with the value for T, by entering the name of the cell with the value for *T*, or by entering the value for *t* directly.

  ⇒ e. g.: Click on the cell B2

- Situate the cursor next to "x in kg/kg" and enter the value for *x* by clicking the cell with the value for x, by entering the name of the cell with the value for *x,* or by entering the value for *x* directly.

  ⇒ e. g.: Type C2 into the window next to "x"

The window should now look like the following figure:



=h_ptx_ICE(A2;B2;C2)

p in bar	t in °C	x in kg/kg	h in kJ/kg
10	-50	-1	ICE(A2;B2;C2)

h_ptx_ICE

p in bar A2 = 10
T in °C B2 = -50
x in kg/kg C2 = -1
= -428,1041743

h in kJ/kg.

x in kg/kg Phase fraction

Formula result = -4,28104174E+02

Figure 2.25: Input menu showing the result

- Click the "OK" button.
  The result for *h* in kJ/kg appears in the cell selected above.

  ⇒ The result for *h* in our sample calculation here is: - 428.1041743 kJ/kg.

The calculation of h = f(p,t,x) has been carried out. You can now arbitrarily change the values for p, t or x in the appropriate cells. This shows that the Excel® data flow and the DLL calculations are working together successfully.

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 in FluidEXL*Graphics*, see the function table in Chapter 1.

2.6 Removing FluidEXL*Graphics*

Should you wish to remove only the LibIce library, delete the files

LibIce.dll
LibIce.hlp

in the directory selected for the installation of FluidEXL*Graphics* (in the standard case

C:\Programme\FluidEXL_Graphics

by using an appropriate program such as Explorer®, Windows, or Norton Commander.

Unregistering FluidEXL*Graphics* as Add-In in Excel®, versions 2003 or earlier

To remove FluidEXL*Graphics* completely, proceed as follows: First the registration of

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)

has to be cancelled in Excel®.

In order to do that, click "Tools" in the upper menu bar of Excel and here "Add-Ins…". Untick the box on the left-hand side of

"FluidEXL Graphics Eng"	(for English version of Windows)
"FluidEXL Graphics"	(for German version of Windows)

in the window that appears and click the "OK" button. The additional menu bar of FluidEXL*Graphics* disappears from the upper part of the Excel window. Afterwards, we recommend closing Excel.

If the FluidEXL*Graphics* menu bar does not disappear, take the following steps:
Click "View" in the upper menu bar of Excel, then "Toolbars" and then "Customize…" in the list box which appears.

"FluidEXL Graphics Eng"	(for English version of Windows)
"FluidEXL Graphics"	(for German version of Windows),

is situated at the bottom of the "Toolbars" entries, which must be selected by clicking on it. Delete the entry by clicking "Delete". You will be asked whether you really want to delete the toolbar – click "OK".

Within the next step delete the files

LibIce.dll,
LibIce.hlp

in the directory selected for the installation of FluidEXL*Graphics* (in the standard case

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows),

using an appropriate program such as Explorer® or Norton Commander.

In order to remove FluidEXL*Graphics* from Windows and the hard disk drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel". Now double-click on "Add or Remove Programs". In the list box of the "Add/Remove Programs" window that appears select

"FluidEXL Graphics Eng"	(for English version of Windows)
"FluidEXL Graphics"	(for German version of Windows)

by clicking on it and click the "Add/Remove…" button. In the following dialog box click "Automatic" and thereafter "Next >". Click "Finish" in the "Perform Uninstall" window. Answer the question whether all shared components shall be removed with "Yes to All". Finally, close the "Add/Remove Programs" and "Control Panel" windows.

Now FluidEXL*Graphics* has been removed.

Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007 (or later versions)

In order to unregister the FluidEXL*Graphics* Add-In in Excel® 2007 start Excel and carry out the following commands:

- Click the Windows Office® button in the upper left corner of Excel
- Click on the "Excel Options" button in the menu which appears

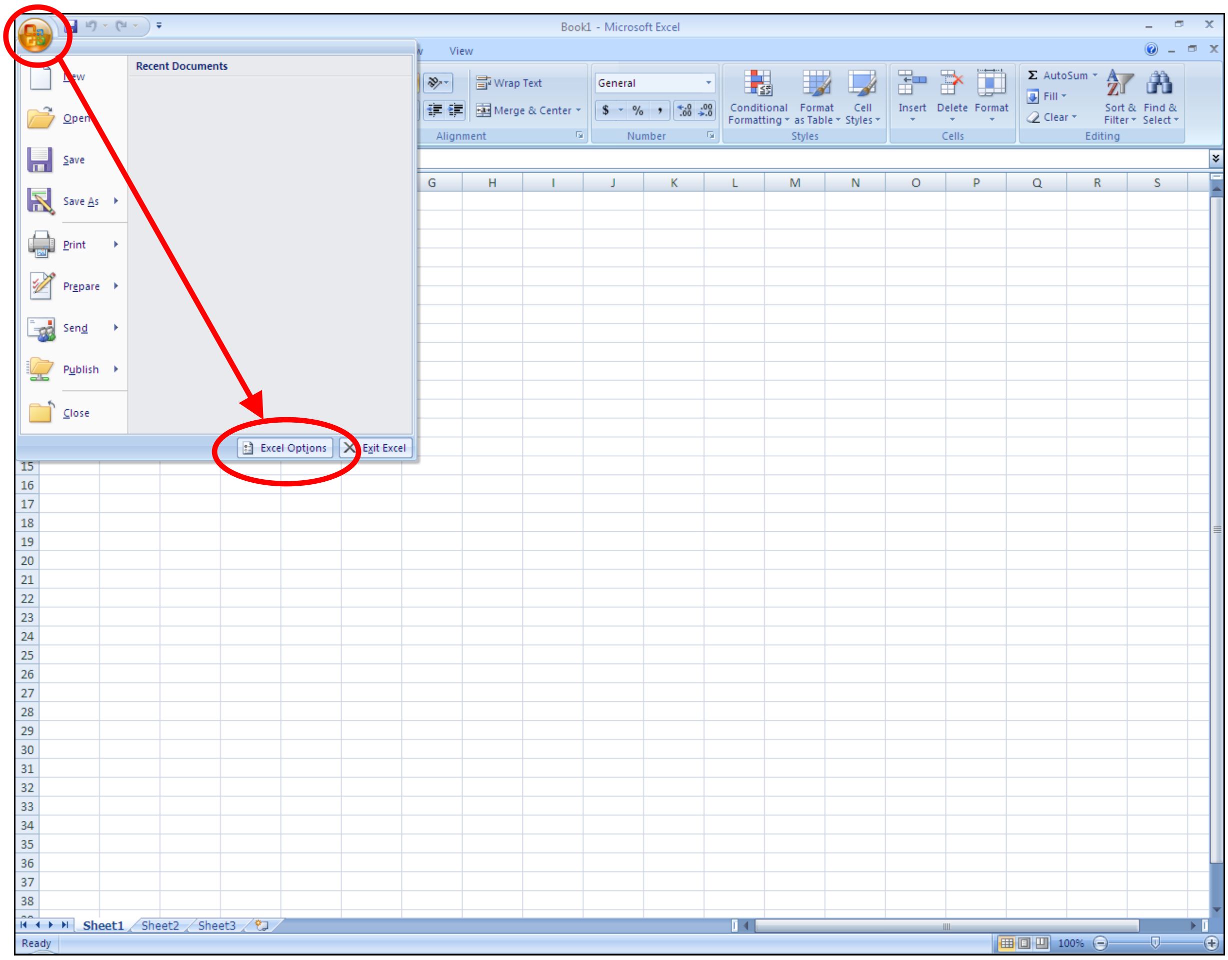
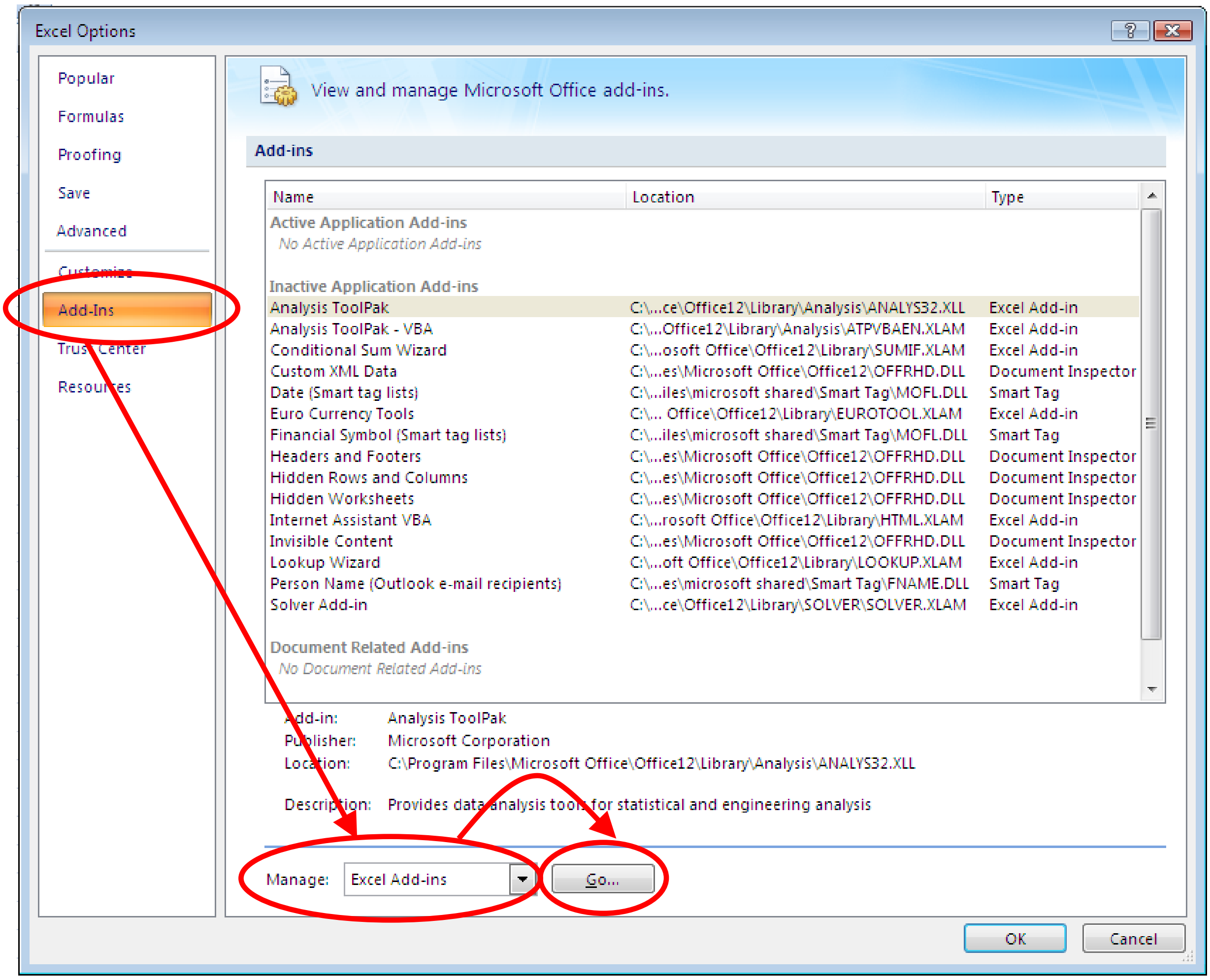


Figure 2.26: Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu



Name	Location	Type
Active Application Add-ins		
No Active Application Add-ins		
Inactive Application Add-ins		
Analysis ToolPak	C:\...ce\Office12\Library\Analysis\ANALYS32.XLL	Excel Add-in
Analysis ToolPak - VBA	C:\...Office12\Library\Analysis\ATPVBAEN.XLAM	Excel Add-in
Conditional Sum Wizard	C:\...osoft Office\Office12\Library\SUMIF.XLAM	Excel Add-in
Custom XML Data	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Date (Smart tag lists)	C:\...iles\microsoft shared\Smart Tag\MOFL.DLL	Smart Tag
Euro Currency Tools	C:\... Office\Office12\Library\EUROTOOL.XLAM	Excel Add-in
Financial Symbol (Smart tag lists)	C:\...iles\microsoft shared\Smart Tag\MOFL.DLL	Smart Tag
Headers and Footers	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Hidden Rows and Columns	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Hidden Worksheets	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Internet Assistant VBA	C:\...rosoft Office\Office12\Library\HTML.XLAM	Excel Add-in
Invisible Content	C:\...es\Microsoft Office\Office12\OFFRHD.DLL	Document Inspector
Lookup Wizard	C:\...oft Office\Office12\Library\LOOKUP.XLAM	Excel Add-in
Person Name (Outlook e-mail recipients)	C:\...es\microsoft shared\Smart Tag\FNAME.DLL	Smart Tag
Solver Add-in	C:\...ce\Office12\Library\SOLVER\SOLVER.XLAM	Excel Add-in
Document Related Add-ins		
No Document Related Add-ins		

Add-in: Analysis ToolPak
Publisher: Microsoft Corporation
Location: C:\Program Files\Microsoft Office\Office12\Library\Analysis\ANALYS32.XLL

Description: Provides data analysis tools for statistical and engineering analysis

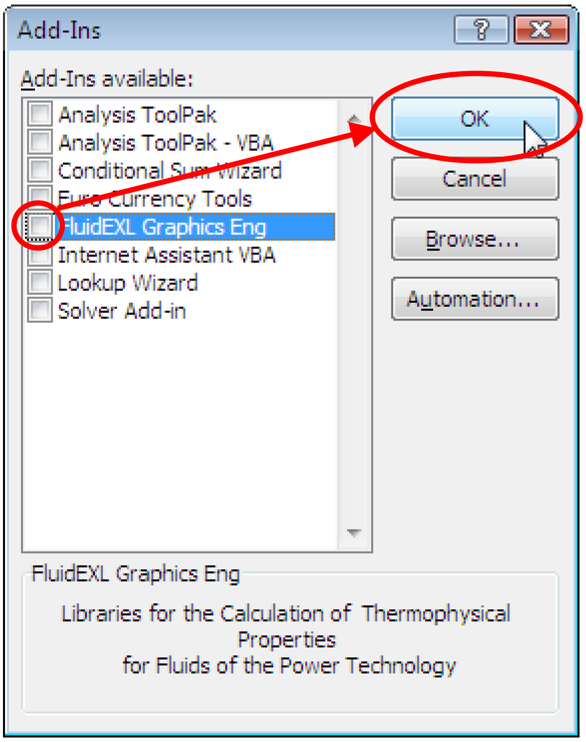
Manage: Excel Add-ins
Go...

Figure 2.27: Dialog window "Add-Ins"

- If it is not shown in the list automatically, chose and click "Excel Add-ins" next to "Manage:" in the lower area of the menu
- Afterwards click the "Go…" button
- Remove the checkmark in front of

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

in the window which now appears. Click the "OK" button to confirm your entry.



☐ Analysis ToolPak
☐ Analysis ToolPak - VBA
☐ Conditional Sum Wizard
☐ Euro Currency Tools
☐ FluidEXL Graphics Eng
☐ Internet Assistant VBA
☐ Lookup Wizard
☐ Solver Add-in

FluidEXL Graphics Eng

Libraries for the Calculation of Thermophysical Properties
for Fluids of the Power Technology

Figure 2.28: Dialog window "Add-Ins"

In order to remove FluidEXL^{Graphics} from Windows and the hard drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel."

Now, double click on "Add or Remove Programs."

In the list box of the "Add or Remove Programs" window that appears, select

"FluidEXL Graphics Eng"	(for English version of Windows)
"FluidEXL Graphics"	(for German version of Windows)

by clicking on it and then clicking the "Add/Remove…" button.

Click "Automatic" in the following dialog box and then the "Next >" button.

Click "Finish" in the "Perform Uninstall" window.

Answer the question of whether all shared components should be removed with "Yes to All."
Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidEXL^{Graphics} has been completely removed from your computer.

3. Program Documentation

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

Function Name: **a_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION APTXICE(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure p in bar

T – Temperature T in °C

X - x in kg / kg (Phase fraction, see the following explanations)

Result

APTXICE or **a_ptx_ICE** – Thermal diffusivity $a = \dfrac{\lambda * v}{c_p}$ in m²/s

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from $T_{\min}$ to $T_{\max}$
Pressure range: from $p_{\min}$ to $p_{\max}$

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*-*h* diagram chapter 1.2):

1. Wet Vapor Region $(0 \le x \le 1)$:

The phase fraction x equates to the vapor fraction x in the wet steam region $x = \dfrac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for x values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for x. In case of dry saturated steam (dew curve) x = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_t to $T_{\max}$
Pressure range from p_t to $p_s(T_{\max})$

2. Melting Region $(10 \le x \le 11)$:

The phase fraction x equates to the liquid fraction x in the melting region $x = 10 + \dfrac{m_{\mathrm{liq}}}{(m_{\mathrm{ice}} + m_{\mathrm{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for x values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for x. In case of solidifying liquid (solidification curve) x = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.
The calculation for *x* values between 100 and 101 is not possible.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam *x* = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 100 or *x* = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Sublimation and
desublimation curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **APTXICE = –1000** or **a_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = -1000$ and $T < T_t$ or $T > T_{max}$
- at $t = -1000$ and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region ($10 \le x \le 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = -1000$ and $T > T_t$ or $T < T_{mel}$ (p_{max})
- at $t = -1000$ and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}$ (p_{max})

Sublimation region ($100 \le x \le 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = -1000$ and $T < T_{min}$ or $T > T_t$
- at $t = -1000$ and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [3], [6], [7], [8]

Isobaric cubic expansion coefficient α_v = f(p,t,x)

Function Name: **alphav_ptx_ICE**

Subprogram with value of the function: for call from Fortran **REAL*8 FUNCTION ALPHAVPTXICE (P,T,X)**
REAL*8 P,T,X

Input Values

P – Pressure p in bar

T – Temperature T in °C

X - x in kg / kg (Phase fraction, see the following explanations)

Result

ALPHAVPTXICE or **alphav_ptx_ICE** – Isobaric cubic expansion coefficient α_v in 1/K

Range of Validity (cp. p,t-diagram in chapter 1.2)

Temperature range: from $T_{\min}$ to $T_{\max}$
Pressure range: from $p_{\min}$ to $p_{\max}$

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg p-h diagram chapter 1.2):

1. Wet Vapor Region $(0 \le x \le 1)$:

The phase fraction x equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for x values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for x. In case of dry saturated steam (dew curve) x = 1 has to be entered.
Concerning pressure and temperature either the given value for t and p = -1000 or the given value for p and t = -1000 and in both cases the value 0 or 1 for x must be entered when calculating boiling liquid or dry saturated steam If p and t and x are entered, the program will consider p and t to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_t to $T_{\max}$
Pressure range from p_t to $p_s\,(T_{\max})$

2. Melting Region $(10 \le x \le 11)$:

The phase fraction x equates to the liquid fraction x in the melting region $x = 10 + \frac{m_{\text{liq}}}{(m_{\text{ice}} + m_{\text{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for x values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for x. In case of solidifying liquid (solidification curve) x = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for t and p = -1000 or the value given for p and t = -1000 and the value for x (x = 10 or x = 11). If p and t and x are entered as given values, the program tests whether p and t fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to $T_{\text{mel}}\,(p_{\max})$
Pressure range from p_t to $p_{\max}$

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{\text{gas}}}{\left(m_{\text{ice}} + m_{\text{gas}}\right)}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.
The calculation for *x* values between 100 and 101 is not possible.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam *x* = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 100 or *x* = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Sublimation and desublimation curve:	Temperatur range from T_{min} to T_{t}
	Pressure range from p_{min} to p_{t}

Results for wrong input values

Result **ALPHAVPTXICE = –1000** or **alphav_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{\text{min}}$ or $p > p_{\text{max}}$
- at $T < T_{\text{min}}$ or $T > T_{\text{max}}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = –1000$ and $T < T_{\text{t}}$ or $T > T_{\text{max}}$
- at $t = –1000$ and $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $T < T_{\text{t}}$ or $T > T_{\text{max}}$

Melting region ($10 \le x \le 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = –1000$ and $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$
- at $t = –1000$ and $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$

Sublimation region ($100 \le x \le 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = –1000$ and $T < T_{\text{min}}$ or $T > T_{\text{t}}$
- at $t = –1000$ and $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $T < T_{\text{min}}$ *or* $T > T_{\text{t}}$

References: [1], [2], [6], [7], [8]

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

Function Name:	**cp_ptx_ICE**
Subprogram with value of the function: for call from Fortran	**REAL*8 FUNCTION CPPTXICE(P,T,X)** REAL*8 P,T,X

Input Values

P – Pressure p in bar

T – Temperature T in °C

X - x in kg / kg (Phase fraction, see the following explanations)

Result

CPPTXICE or **cp_ptx_ICE** - specific isobaric heat capacity c_p in kJ/(kg K)

Range of Validity (cp. p,t-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg p-h diagram chapter 1.2):

1. Wet Vapor Region $(\mathbf{0 \le x \le 1})$:

The phase fraction x equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for x values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for x. In case of dry saturated steam (dew curve) x = 1 has to be entered.
Concerning pressure and temperature either the given value for t and p = -1000 or the given value for p and t = -1000 and in both cases the value 0 or 1 for x must be entered when calculating boiling liquid or dry saturated steam If p and t and x are entered, the program will consider p and t to represent the vapor pressure curve.

Boiling and dew curve:	Temperature range from T_{t} to T_{max} Pressure range from p_{t} to $p_{\text{s}}(T_{\text{max}})$

2. Melting Region $(\mathbf{10 \le x \le 11})$:

The phase fraction x equates to the liquid fraction x in the melting region $x = 10 + \frac{m_{\text{liq}}}{(m_{\text{ice}} + m_{\text{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for x values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for x. In case of solidifying liquid (solidification curve) x = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for t and p = -1000 or the value given for p and t = -1000 and the value for x (x = 10 or x = 11). If p and t and x are entered as given values, the program tests whether p and t fulfil the melting pressure curve.

Melting and Solidification curve:	Temperature range from T_{t} to T_{mel} (p_{max}) Pressure range from p_{t} to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{\text{gas}}}{\left(m_{\text{ice}} + m_{\text{gas}}\right)}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.

The calculation for *x* values between 100 and 101 is not possible.

If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam *x* = 101 has to be entered.

When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 100 or *x* = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Sublimation and desublimation curve:	Temperatur range from T_{min} to T_{t}
	Pressure range from p_{min} to p_{t}

Results for wrong input values

Result **CPPTXICE = –1000** or **cp_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{\text{min}}$ or $p > p_{\text{max}}$
- at $T < T_{\text{min}}$ or $T > T_{\text{max}}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = –1000$ and $T < T_{\text{t}}$ or $T > T_{\text{max}}$
- at $t = –1000$ and $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $T < T_{\text{t}}$ or $T > T_{\text{max}}$

Melting region ($10 \le x \le 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = –1000$ and $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$
- at $t = –1000$ and $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$

Sublimation region ($100 \le x \le 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = –1000$ and $T < T_{\text{min}}$ or $T > T_{\text{t}}$
- at $t = –1000$ and $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $T < T_{\text{min}}$ *or* $T > T_{\text{t}}$

References: [1], [2], [6], [7], [8]

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

Function Name: **cv_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION CVPTXICE(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure p in bar

T – Temperature T in °C

X - x in kg / kg (Phase fraction, see the following explanations)

Result

CVPTXICE or **cv_ptx_ICE** - specific isochoric heat capacity c_v in kJ/(kg K)

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p-h* diagram chapter 1.2):

1. Wet Vapor Region $(0 \leq x \leq 1)$:

The phase fraction x equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for x values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for x. In case of dry saturated steam (dew curve) x = 1 has to be entered.
Concerning pressure and temperature either the given value for t and p = -1000 or the given value for p and t = -1000 and in both cases the value 0 or 1 for x must be entered when calculating boiling liquid or dry saturated steam If p and t and x are entered, the program will consider p and t to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_t to T_{max}
Pressure range from p_t to $p_s(T_{\mathrm{max}})$

2. Melting Region $(10 \leq x \leq 11)$:

The phase fraction x equates to the liquid fraction x in the melting region $x = 10 + \frac{m_{\mathrm{liq}}}{(m_{\mathrm{ice}} + m_{\mathrm{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for x values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for x. In case of solidifying liquid (solidification curve) x = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for t and p = -1000 or the value given for p and t = -1000 and the value for x (x = 10 or x = 11). If p and t and x are entered as given values, the program tests whether p and t fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \leq x \leq 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{\text{gas}}}{(m_{\text{ice}} + m_{\text{gas}})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.
The calculation for *x* values between 100 and 101 is not possible.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam *x* = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 100 or *x* = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Sublimation and desublimation curve:	Temperatur range from T_{min} to T_{t}
	Pressure range from p_{min} to p_{t}

Results for wrong input values

Result **CVPTXICE = –1000** or **cv_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{\text{min}}$ or $p > p_{\text{max}}$
- at $T < T_{\text{min}}$ or $T > T_{\text{max}}$

Two phase regions:

Wet steam region ($0 \leq x \leq 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = –1000$ and $T < T_{\text{t}}$ or $T > T_{\text{max}}$
- at $t = –1000$ and $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $T < T_{\text{t}}$ or $T > T_{\text{max}}$

Melting region ($10 \leq x \leq 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = –1000$ and $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$
- at $t = –1000$ and $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$

Sublimation region ($100 \leq x \leq 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = –1000$ and $T < T_{\text{min}}$ or $T > T_{\text{t}}$
- at $t = –1000$ and $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $T < T_{\text{min}}$ *or* $T > T_{\text{t}}$

References: [1], [2], [6], [7], [8]

Dynamic Viscosity η = f(*p*,*t*,*x*)

Function Name: **eta_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION ETAPTXICE(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

ETAPTXICE or **eta_ptx_ICE** – dynamic viscosity η in Pa s

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (liquid or superheated steam), *x* = -1000 must be entered as a pro-forma value. This function can only by used for liquid and steam region.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*,*h*-diagram chapter 1.2):

1. Wet Vapor Region $(0 \le x \le 1)$:

The phase fraction *x* equates to the vapor fraction *x* in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for *x* values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_t to T_{max}
Pressure range from p_t to $p_s(T_{\text{max}})$

2. Melting Region $(10 \le x \le 11)$:

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\text{liq}}}{(m_{\text{ice}} + m_{\text{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for *x* values unequal to 11 is not possible .
For solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a solidifying liquid it it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{\text{gas}}}{\left(m_{\text{ice}} + m_{\text{gas}}\right)}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.

The calculation for *x* values unequal to 101 is not possible .

If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam *x* = 101 has to be entered.

When calculating a desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* <u>and</u> p = -1000 or the value given for *p* <u>and</u> t = -1000 and the value for *x* (*x* = 101). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Desublimation curve:	Temperatur range from T_{min} to T_{t}
	Pressure range from p_{min} to p_{t}

Results for wrong input values

Result **ETAPTXICE = –1000** or **eta_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (*x* = –1000):
- at $p < p_{\text{min}}$ or $p > p_{\text{max}}$
- at $T < T_{\text{min}}$ or $T > T_{\text{max}}$

Two phase regions:

Wet steam region (0 ≤ *x* ≤ 1):
- at 0 < *x* < 1 , i.e. calculation in the wet steam region not possible!
- at *p* = –1000 and $T < T_{\text{t}}$ or $T > T_{\text{max}}$
- at *t* = –1000 and $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $T < T_{\text{t}}$ or $T > T_{\text{max}}$

Melting region (10 ≤ *x* ≤ 11):
- at *x* < 11 , i.e. calculation in the melting region not possible!
- at *p* = –1000 and $T > T_{\text{t}}$ or $T < T_{\text{mel}}\ (p_{\text{max}})$
- at *t* = –1000 and $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $T > T_{\text{t}}$ or $T < T_{\text{mel}}\ (p_{\text{max}})$

Sublimation region (100 ≤ *x* ≤ 101):
- at *x* < 101 , i.e. calculation in the sublimation region not possible!
- at *p* = –1000 and $T < T_{\text{min}}$ or $T > T_{\text{t}}$
- at *t* = –1000 and $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $T < T_{\text{min}}$ *or* $T > T_{\text{t}}$

References: [1], [2], [4], [6], [7], [8]

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

Function Name: **h_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION HPTXICE(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

HPTXICE or **h_ptx_ICE** - specific enthalpy *h* in kJ/kg

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x= -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*,*h*-diagram chapter 1.2):

1. Wet Vapor Region $(0 \le x \le 1)$:

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
If the state point to be calculated is located in the wet steam region, a value between 0 and 1 must be entered for *x*. If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam. If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\mathrm{s}}(T_{\mathrm{max}})$

2. Melting Region $(10 \le x \le 11)$:

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\mathrm{liq}}}{(m_{\mathrm{ice}} + m_{\mathrm{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
If the state point to be calculated is located in the melting region, a value between 10 and 11 must be entered for *x*. If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \leq x \leq 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas. If the state point to be calculated is located in the melting region, a value between 100 and 101 must be entered for x.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam x = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for x (x = 100 or x = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Melting and
Solidification curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **HPTXICE = –1000** or **h_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:

Wet steam region ($0 \leq x \leq 1$):
- at p = –1000 and $T < T_t$ or $T > T_{max}$
- at t = –1000 and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region ($10 \leq x \leq 11$):
- at p = –1000 and $T > T_t$ or $T < T_{mel}$ (p_{max})
- at t = –1000 and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}$ (p_{max})

Sublimation region ($100 \leq x \leq 101$):
- at p = –1000 and $T < T_{min}$ or $T > T_t$
- at t = –1000 and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [6], [7], [8]

Isentropic Exponent κ = f(*p*,*t*,*x*)

Function Name: **kappa_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION KAPPAPTXICE (P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

KAPPAPTXICE or **kappa_ptx_ICE** – Isentropic exponent $\kappa = \dfrac{w^2}{p * v}$

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), *x* = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p-h* diagram chapter 1.2):

1. Wet Vapor Region $(\mathbf{0 \le x \le 1})$:

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \dfrac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for *x* values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\mathrm{s}}(T_{\mathrm{max}})$

2. Melting Region $(\mathbf{10 \le x \le 11})$:

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \dfrac{m_{\mathrm{liq}}}{(m_{\mathrm{ice}} + m_{\mathrm{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for *x* values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \leq x \leq 101)$:

The phase fraction x equates to the gas fraction x in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.
The calculation for x values between 100 and 101 is not possible.
If sublimating solid is to be calculated, the value 100 has to be entered for x. In case of desublimating steam x = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for t and p = -1000 or the value given for p and t = -1000 and the value for x (x = 100 or x = 101). If p and t and x are entered as given values the program tests whether p and t fulfil the sublimation-pressure-curve.

Sublimation and
desublimation curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **KAPPAPTXICE = –1000** or **kappa_ptx_ICE = –1000** for input values:

Single phase region:
Solid, liquid, overheated steam (x = –1000):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:
Wet steam region ($0 \leq x \leq 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = –1000$ and $T < T_t$ or $T > T_{max}$
- at $t = –1000$ and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region ($10 \leq x \leq 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = –1000$ and $T > T_t$ or $T < T_{mel}$ (p_{max})
- at $t = –1000$ and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}$ (p_{max})

Sublimation region ($100 \leq x \leq 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = –1000$ and $T < T_{min}$ or $T > T_t$
- at $t = –1000$ and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [6], [7], [8]

Isothermal compressibility $\kappa_t = f(p,t,x)$

Function Name:	**kappaT_ptx_ICE**
Subprogram with value of the function: for call from Fortran	**REAL*8 FUNCTION KAPPATPTXICE (P,T,X)** REAL*8 P,T,X

Input Values

P – Pressure p in bar

T – Temperature T in °C

X - x in kg / kg (Phase fraction, see the following explanations)

Result

KAPPATPTXICE or **kappaT_ptx_ICE** – Isothermal compressibility κ_T in 1/kPa

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*-*h* diagram chapter 1.2):

1. **Wet Vapor Region $(0 \leq x \leq 1)$:**

The phase fraction x equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for x values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for x. In case of dry saturated steam (dew curve) x = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for x must be entered when calculating boiling liquid or dry saturated steam If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\text{s}}(T_{\text{max}})$

2. **Melting Region $(10 \leq x \leq 11)$:**

The phase fraction x equates to the liquid fraction x in the melting region $x = 10 + \frac{m_{\text{liq}}}{(m_{\text{ice}} + m_{\text{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for x values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for x. In case of solidifying liquid (solidification curve) x = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for x (x = 10 or x = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_{t} to $T_{\text{mel}}(p_{\text{max}})$
Pressure range from p_{t} to p_{max}

3. Sublimation Region $(100 \leq x \leq 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{\text{gas}}}{(m_{\text{ice}} + m_{\text{gas}})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.
The calculation for *x* values between 100 and 101 is not possible.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam *x* = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 100 or *x* = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Sublimation and desublimation curve:	Temperatur range from T_{min} to T_{t}
	Pressure range from p_{min} to p_{t}

Results for wrong input values

Result **KAPPATPTXICE = –1000** or **kappaT_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{\text{min}}$ or $p > p_{\text{max}}$
- at $T < T_{\text{min}}$ or $T > T_{\text{max}}$

Two phase regions:

Wet steam region ($0 \leq x \leq 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = -1000$ and $T < T_{\text{t}}$ or $T > T_{\text{max}}$
- at $t = -1000$ and $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $p < p_{\text{t}}$ or $p > p_{\text{s}}(T_{\text{max}})$
- at $T < T_{\text{t}}$ or $T > T_{\text{max}}$

Melting region ($10 \leq x \leq 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = -1000$ and $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$
- at $t = -1000$ and $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $p < p_{\text{t}}$ or $p > p_{\text{max}}$
- at $T > T_{\text{t}}$ or $T < T_{\text{mel}}(p_{\text{max}})$

Sublimation region ($100 \leq x \leq 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = -1000$ and $T < T_{\text{min}}$ or $T > T_{\text{t}}$
- at $t = -1000$ and $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $p < p_{\text{min}}$ or $p > p_{\text{t}}$
- at $T < T_{\text{min}}$ *or* $T > T_{\text{t}}$

References: [1], [2], [6], [7], [8]

Thermal Conductivity λ = f(*p*,*t*,*x*)

Function Name: **lambda_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION LAMBDAPTXICE (P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

LAMBDAPTXICE or **lambda_ptx_ICE** – Thermal conductivity λ in W/(m K)

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), *x* = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*-*h* diagram chapter 1.2):

1. **Wet Vapor Region $(\mathbf{0 \le x \le 1})$:**

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for *x* values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\mathrm{s}}(T_{\mathrm{max}})$

2. **Melting Region $(\mathbf{10 \le x \le 11})$:**

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\mathrm{liq}}}{(m_{\mathrm{ice}} + m_{\mathrm{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for *x* values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction x equates to the gas fraction x in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.
The calculation for x values between 100 and 101 is not possible.
If sublimating solid is to be calculated, the value 100 has to be entered for x. In case of desublimating steam $x = 101$ has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for x ($x = 100$ or $x = 101$). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Sublimation and
desublimation curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **LAMBDAPTXICE = –1000** or **lambda_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = -1000$ and $T < T_t$ or $T > T_{max}$
- at $t = -1000$ and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region ($10 \le x \le 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = -1000$ and $T > T_t$ or $T < T_{mel}$ (p_{max})
- at $t = -1000$ and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}$ (p_{max})

Sublimation region ($100 \le x \le 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = -1000$ and $T < T_{min}$ or $T > T_t$
- at $t = -1000$ and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [3], [6], [7], [8]

Melting Pressure $p_{mel} = f(t)$

Function Name: **pmel_t_08_ICE**

Subprogram with value of the function: for call from Fortran **REAL*8 FUNCTION PMEL_T_08_ICE (T)**
REAL*8 T

Input Values

T - Temperature T in °C

Result

PMEL_T_08_ICE or **pmel_t_08_ICE** – Melting pressure p_{mel} in bar

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range from T_t to T_{mel} (p_{max})

Results for wrong input values

Result **PMEL_T_08_ICE = –1000** or **pmel_t_08_ICE = –1000** for input values:

- at T > T_t or T < T_{mel} (p_{max})

References: [8]

Vapor Pressure p_s = f(t)

Function Name:	**ps_t_97_ICE**
Subprogram with value of the function: for call from Fortran	**REAL*8 FUNCTION PS_T_97_ICE (T)** REAL*8 T

Input Values

T - Temperature T in °C

Result

PS_T_97_ICE or **ps_t_97_ICE** – vapor pressure p_s in bar

Range of Validity (cp. p,t-diagram in chapter 1.2)

Temperature range: from T_t to T_c

Results for wrong input values

Result **PS_T_97_ICE = –1000** or **ps_t_97_ICE = –1000** for input values:

- at $T < T_t$ or $T > T_c$

References: [1], [2]

Sublimation Pressure p_{sub} = f(t)

Function Name:	**psub_t_08_ICE**
Subprogram with value of the function: for call from Fortran	**REAL*8 FUNCTION PSUB_T_08_ICE (T)** REAL*8 T

Input Values

T - Temperature T in °C

Result

PSUB_T_08_ICE or **psub_t_08_ICE** – Sublimation pressure p_{sub} in bar

Range of Validity (cp. p,t-diagram in chapter 1.2)

Temperature range: from T_{min} to T_t

Results for wrong input values

Result **PSUB_T_08_ICE = –1000** or **psub_t_08_ICE = –1000** for input values:

- at $T < T_{min}$ or $T > T_t$

References: [8]

Density ρ = f(p,t,x)

Function Name: **rho_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION RHOPTXICE (P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure p in bar

T – Temperature T in °C

X - x in kg / kg (Phase fraction, see the following explanations)

Result

RHOPTXICE or **rho_ptx_ICE** - Density ρ in kg/m^3

Range of Validity (cp. p,t-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x= -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg p,h-diagram chapter 1.2):

1. **Wet Vapor Region $(\mathbf{0 \le x \le 1})$:**

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
If the state point to be calculated is located in the wet steam region, a value between 0 and 1 must be entered for *x*. If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam. If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\mathrm{s}}(T_{\mathrm{max}})$

2. **Melting Region $(\mathbf{10 \le x \le 11})$:**

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\mathrm{liq}}}{(m_{\mathrm{ice}} + m_{\mathrm{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
If the state point to be calculated is located in the melting region, a value between 10 and 11 must be entered for *x*. If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas. If the state point to be calculated is located in the melting region, a value between 100 and 101 must be entered for x.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam x = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* <u>and</u> p = -1000 or the value given for *p* <u>and</u> t = -1000 and the value for x (x = 100 or x = 101). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Melting and
Solidification curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **RHOPTXICE = –1000** or **rho_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam ($x = –1000$):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at $p = –1000$ and $T < T_t$ or $T > T_{max}$
- at $t = –1000$ and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region ($10 \le x \le 11$):
- at $p = –1000$ and $T > T_t$ or $T < T_{mel}(p_{max})$
- at $t = –1000$ and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}(p_{max})$

Sublimation region ($100 \le x \le 101$):
- at $p = –1000$ and $T < T_{min}$ or $T > T_t$
- at $t = –1000$ and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [6], [7], [8]

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

Function Name: **s_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION SPTXICE (P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

SPTXICE or **s_ptx_ICE** - Specific entropy *s* in kJ/(kg K)

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x= -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*,*h*-diagram chapter 1.2):

1. **Wet Vapor Region** $(\mathbf{0 \le x \le 1})$**:**

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
If the state point to be calculated is located in the wet steam region, a value between 0 and 1 must be entered for *x*. If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam. If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\text{s}}\,(T_{\text{max}})$

2. **Melting Region** $(\mathbf{10 \le x \le 11})$**:**

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\text{liq}}}{(m_{\text{ice}} + m_{\text{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
If the state point to be calculated is located in the melting region, a value between 10 and 11 must be entered for *x*. If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas. If the state point to be calculated is located in the melting region, a value between 100 and 101 must be entered for x.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam x = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for x (x = 100 or x = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Melting and
Solidification curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **SPTXICE = –1000** or **s_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (*x* = –1000):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:

Wet steam region (0 ≤ *x* ≤ 1):
- at $p = -1000$ and $T < T_t$ or $T > T_{max}$
- at $t = -1000$ and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region (10 ≤ *x* ≤ 11):
- at $p = -1000$ and $T > T_t$ or $T < T_{mel}(p_{max})$
- at $t = -1000$ and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}(p_{max})$

Sublimation region (100 ≤ *x* ≤ 101):
- at $p = -1000$ and $T < T_{min}$ or $T > T_t$
- at $t = -1000$ and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [6], [7], [8]

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

Function Name: **t_ph_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION TPHICE (P,H)**
for call from Fortran REAL*8 P,H

Input Values

P – Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

TPHICE or **t_ph_ICE** – Temperature t in °C

Range of Validity (cp. p,t-diagram in chapter 1.2)

Pressure range: from p_{min} to p_{max}
Enthalpy range: from $h < h_{\mathrm{max}} = h(p_{\mathrm{min}}, T_{\mathrm{max}})$ to $h > h_{\mathrm{min}} = h(p_{\mathrm{min}}, T_{\mathrm{min}})$

Temperature range: from T_{min} to T_{max} (resulting from internal calculation of the subprograms)

Details on calculating the two phase regions

Using the given values for p and h, the program determines whether the point of state to be calculated is located in the single phase region (solid, liquid or steam) or in the two phase region. The two phase regions wet steam region, melting region and sublimation region (cp. lg p,h-diagram chapter 1.2) are calculated automatically by the subprograms. After that, the calculation is realized for the certain region.

Results for wrong input values

Result **TPHICE = –1000** or **t_ph_ICE = –1000** for input values:

Single phase region:
Solid, liquid, overheated steam:
- at $p < p_{\mathrm{min}}$ or $p > p_{\mathrm{max}}$
- at calculation result $T < T_{\mathrm{min}}$ or $T > T_{\mathrm{max}}$ or $T > T_{\mathrm{mel}}(p_{\mathrm{max}})$ when calculating melting region

Two phase regions:
Wet steam region:
- at $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{s}}(T_{\mathrm{max}})$
- at calculation result $T < T_{\mathrm{t}}$ or $T > T_{\mathrm{max}}$

Melting region:
- at $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{max}}$
- at calculation result $T > T_{\mathrm{t}}$ or $T < T_{\mathrm{mel}}(p_{\mathrm{max}})$

Sublimation region:
- at $p < p_{\mathrm{min}}$ or $p > p_{\mathrm{t}}$
- at calculation result $T < T_{\mathrm{min}}$ or $T > T_{\mathrm{t}}$

References: [1], [2], [6], [7], [8]

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

Function Name: **t_ps_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION TPSICE (P,S)**
for call from Fortran REAL*8 P,S

Input Values

P – Pressure p in bar

S - Specific entropy s in kJ/(kg K)

Result

TPSICE or **t_ps_ICE** – Temperature t in °C

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Pressure range: from p_{min} to p_{max}
Entropy range: from $s < s_{\mathrm{max}} = s(p_{\mathrm{min}}, T_{\mathrm{max}})$ to $s > s_{\mathrm{min}} = s(p_{\mathrm{min}}, T_{\mathrm{min}})$

Temperature range: from T_{min} to T_{max} (resulting from internal calculation of the subprograms)

Details on calculating the two phase regions

Using the given values for p and s, the program determines whether the point of state to be calculated is located in the single phase region (solid, liquid or steam) or in the two phase region. The two phase regions wet steam region, melting region and sublimation region (cp. lg *p,h*-diagram chapter 1.2) are calculated automatically by the subprograms. After that, the calculation is realized for the certain region.

Results for wrong input values

Result **TPSICE = –1000** or **t_ps_ICE = –1000** for input values:

Single phase region:
Solid, liquid, overheated steam:
- at $p < p_{\mathrm{min}}$ or $p > p_{\mathrm{max}}$
- at calculation result $T < T_{\mathrm{min}}$ or $T > T_{\mathrm{max}}$ or $T > T_{\mathrm{mel}}(p_{\mathrm{max}})$ when calculating melting region

Two phase regions:
Wet steam region:
- at $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{s}}(T_{\mathrm{max}})$
- at calculation result $T < T_{\mathrm{t}}$ or $T > T_{\mathrm{max}}$

Melting region:
- at $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{max}}$
- at calculation result $T > T_{\mathrm{t}}$ or $T < T_{\mathrm{mel}}(p_{\mathrm{max}})$

Sublimation region:
- at $p < p_{\mathrm{min}}$ or $p > p_{\mathrm{t}}$
- at calculation result $T < T_{\mathrm{mel}}(p_{\mathrm{max}})$ or $T > T_{\mathrm{t}}$

References: [1], [2], [6], [7], [8]

Melting Temperature t_{mel} = f(p)

Function Name: **tmel_p_08_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION TMEL_P_08_ICE (P)**
for call from Fortran REAL*8 P

Input Values

P – Pressure p in bar

Result

TMEL_P_08_ICE or **tmel_p_08_ICE** – Melting temperature t_{mel} in °C

Range of Validity (cp. p,t-diagram in chapter 1.2)

Pressure range: from p_t to p_{max}

Results for wrong input values

Result **TMELICE = –1000** or **tmel_p_ICE = –1000** for input values:

- at $p < p_t$ or $p > p_{max}$

References: [8]

Saturation Temperature $t_s = f(p)$

Function Name:	**ts_p_97_ICE**
Subprogram with value of the function: for call from Fortran	**REAL*8 FUNCTION TS_P_97_ICE (P)** REAL*8 P

Input Values

P – Pressure *p* in bar

Result

TS_P_97_ICE or **ts_p_97_ICE** – Saturation temperature t_s in °C

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Pressure range: from p_t to p_c

Results for wrong input values

Result **TS_P_97_ICE = –1000** or **ts_p_97_ICE = –1000** for input values:

- at $p < p_t$ or $p > p_c$

References: [1], [2]

Sublimation Temperature $t_{sub} = f(p)$

Function Name:	**tsub_p_08_ICE**
Subprogram with value of the function: for call from Fortran	**REAL*8 FUNCTION TSUB_P_08_ICE (P)** REAL*8 P

Input Values

P – Pressure p in bar

Result

TSUB_P_08_ICE or **tsub_p_08_ICE** – Sublimation temperature t_{sub} in °C

Range of Validity (cp. p,t-diagram in chapter 1.2)

Pressure range: from p_{min} to p_t

Results for wrong input values

Result **TSUB_P_08_ICE = –1000** or **tsub_p_08_ICE = –1000** for input values:

- at $p < p_{min}$ or $p > p_t$

References: [8]

Specific inner energy u = f(*p*,*t*,*x*)

Function Name: **u_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION UPTXICE (P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

UPTXICE or **u_ptx_ICE** – Specific inner energy *u* in kJ/kg

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x= -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*,*h*-diagram chapter 1.2):

1. Wet Vapor Region $(0 \le x \le 1)$:

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
If the state point to be calculated is located in the wet steam region, a value between 0 and 1 must be entered for *x*. If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam. If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\text{s}}(T_{\text{max}})$

2. Melting Region $(10 \le x \le 11)$:

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\text{liq}}}{(m_{\text{ice}} + m_{\text{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
If the state point to be calculated is located in the melting region, a value between 10 and 11 must be entered for *x*. If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas. If the state point to be calculated is located in the melting region, a value between 100 and 101 must be entered for x.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam x = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for x (x = 100 or x = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Melting and
Solidification curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **UPTXICE = –1000** or **u_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (*x* = –1000):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at p = –1000 and $T < T_t$ or $T > T_{max}$
- at t = –1000 and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region ($10 \le x \le 11$):
- at p = –1000 and $T > T_t$ or $T < T_{mel}(p_{max})$
- at t = –1000 and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}(p_{max})$

Sublimation region ($100 \le x \le 101$):
- at p = –1000 and $T < T_{min}$ or $T > T_t$
- at t = –1000 and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [6], [7], [8]

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

Function Name: **v_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION VPTXICE (P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

VPTXICE or **v_ptx_ICE** – Specific volume *v* in m^3/kg

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), x= -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*,*h*-diagram chapter 1.2):

1. Wet Vapor Region $(0 \le x \le 1)$:

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
If the state point to be calculated is located in the wet steam region, a value between 0 and 1 must be entered for *x*. If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam. If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\mathrm{s}}(T_{\mathrm{max}})$

2. Melting Region $(10 \le x \le 11)$:

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\mathrm{liq}}}{(m_{\mathrm{ice}} + m_{\mathrm{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
If the state point to be calculated is located in the melting region, a value between 10 and 11 must be entered for *x*. If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_t to T_{mel} (p_{max})
Pressure range from p_t to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction x equates to the gas fraction x in the sublimation region $x = 100 + \frac{m_{gas}}{(m_{ice} + m_{gas})}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas. If the state point to be calculated is located in the melting region, a value between 100 and 101 must be entered for x.
If sublimating solid is to be calculated, the value 100 has to be entered for x. In case of desublimating steam x = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for t and p = -1000 or the value given for p and t = -1000 and the value for x (x = 100 or x = 101). If p and t and x are entered as given values the program tests whether p and t fulfil the sublimation-pressure-curve.

Melting and
Solidification curve: Temperatur range from T_{min} to T_t
Pressure range from p_{min} to p_t

Results for wrong input values

Result **VPTXICE = –1000** or **v_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{min}$ or $p > p_{max}$
- at $T < T_{min}$ or $T > T_{max}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at p = –1000 and $T < T_t$ or $T > T_{max}$
- at t = –1000 and $p < p_t$ or $p > p_s(T_{max})$
- at $p < p_t$ or $p > p_s(T_{max})$
- at $T < T_t$ or $T > T_{max}$

Melting region ($10 \le x \le 11$):
- at p = –1000 and $T > T_t$ or $T < T_{mel}$ (p_{max})
- at t = –1000 and $p < p_t$ or $p > p_{max}$
- at $p < p_t$ or $p > p_{max}$
- at $T > T_t$ or $T < T_{mel}$ (p_{max})

Sublimation region ($100 \le x \le 101$):
- at p = –1000 and $T < T_{min}$ or $T > T_t$
- at t = –1000 and $p < p_{min}$ or $p > p_t$
- at $p < p_{min}$ or $p > p_t$
- at $T < T_{min}$ *or* $T > T_t$

References: [1], [2], [6], [7], [8]

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

Function Name: **w_ptx_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION WPTXICE (P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P – Pressure *p* in bar

T – Temperature *T* in °C

X - *x* in kg / kg (Phase fraction, see the following explanations)

Result

WPTXICE or **w_ptx_ICE** – Speed of sound *w* in m/s

Range Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Temperature range: from T_{min} to T_{max}
Pressure range: from p_{min} to p_{max}

Details on the phase fraction *x*

If the state point to be calculated is located in the single phase region (solid, liquid or superheated steam), *x* = -1000 must be entered as a pro-forma value.

The two phase regions wet steam region, melting region and sublimation region are calculated automatically by the subprograms. For this purpose the following facts have to be considered (cp. lg *p*-*h* diagram chapter 1.2):

1. Wet Vapor Region $(\mathbf{0 \le x \le 1})$:

The phase fraction *x* equates to the vapor fraction x in the wet steam region $x = \frac{m''}{(m' + m'')}$. Its unit is (kg saturated steam)/(kg wet steam).
The calculation for *x* values between 0 and 1 is not possible.
If boiling liquid (boiling curve) is to be calculated, the value 0 has to be entered for *x*. In case of dry saturated steam (dew curve) *x* = 1 has to be entered.
Concerning pressure and temperature either the given value for *t* and *p* = -1000 or the given value for *p* and *t* = -1000 and in both cases the value 0 or 1 for *x* must be entered when calculating boiling liquid or dry saturated steam If *p* and *t* and *x* are entered, the program will consider *p* and *t* to represent the vapor pressure curve.

Boiling and dew curve: Temperature range from T_{t} to T_{max}
Pressure range from p_{t} to $p_{\text{s}}\,(T_{\text{max}})$

2. Melting Region $(\mathbf{10 \le x \le 11})$:

The phase fraction *x* equates to the liquid fraction *x* in the melting region $x = 10 + \frac{m_{\text{liq}}}{(m_{\text{ice}} + m_{\text{liq}})}$. Its unit is (kg solidified liquid)/(kg melt), whereas melt is a mixture of melting ice and solidified liquid.
The calculation for *x* values between 10 and 11 is not possible.
If melting solid (melting curve) is to be calculated, the value 10 has to be entered for *x*. In case of solidifying liquid (solidification curve) *x* = 11 has to be entered.
When calculating a melting solid or solidifying liquid it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 10 or *x* = 11). If *p* and *t* and *x* are entered as given values, the program tests whether *p* and *t* fulfil the melting pressure curve.

Melting and
Solidification curve: Temperature range from T_{t} to $T_{\text{mel}}\,(p_{\text{max}})$
Pressure range from p_{t} to p_{max}

3. Sublimation Region $(100 \le x \le 101)$:

The phase fraction *x* equates to the gas fraction *x* in the sublimation region $x = 100 + \frac{m_{\mathrm{gas}}}{\left(m_{\mathrm{ice}} + m_{\mathrm{gas}}\right)}$. Its unit is (kg desublimated gas)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating ice and desublimated gas.
The calculation for *x* values between 100 and 101 is not possible.
If sublimating solid is to be calculated, the value 100 has to be entered for *x*. In case of desublimating steam *x* = 101 has to be entered.
When calculating a sublimating solid or desublimating steam it is adequate, Concerning pressure and temperature, to put in either the value given for *t* and p = -1000 or the value given for *p* and t = -1000 and the value for *x* (*x* = 100 or *x* = 101). If *p* and *t* and *x* are entered as given values the program tests whether *p* and *t* fulfil the sublimation-pressure-curve.

Sublimation and
desublimation curve: Temperatur range from T_{min} to T_{t}
Pressure range from p_{min} to p_{t}

Results for wrong input values

Result **WPTXICE = –1000** or **w_ptx_ICE = –1000** for input values:

Single phase region:

Solid, liquid, overheated steam (x = –1000):
- at $p < p_{\mathrm{min}}$ or $p > p_{\mathrm{max}}$
- at $T < T_{\mathrm{min}}$ or $T > T_{\mathrm{max}}$

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at $0 < x < 1$, i.e. calculation in the wet steam region not possible!
- at $p = -1000$ and $T < T_{\mathrm{t}}$ or $T > T_{\mathrm{max}}$
- at $t = -1000$ and $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{s}}(T_{\mathrm{max}})$
- at $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{s}}(T_{\mathrm{max}})$
- at $T < T_{\mathrm{t}}$ or $T > T_{\mathrm{max}}$

Melting region ($10 \le x \le 11$):
- at $10 < x < 11$, i.e. calculation in the melting region not possible!
- at $p = -1000$ and $T > T_{\mathrm{t}}$ or $T < T_{\mathrm{mel}}(p_{\mathrm{max}})$
- at $t = -1000$ and $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{max}}$
- at $p < p_{\mathrm{t}}$ or $p > p_{\mathrm{max}}$
- at $T > T_{\mathrm{t}}$ or $T < T_{\mathrm{mel}}(p_{\mathrm{max}})$

Sublimation region ($100 \le x \le 101$):
- at $100 < x < 101$, i.e. calculation in the sublimation region not possible!
- at $p = -1000$ and $T < T_{\mathrm{min}}$ or $T > T_{\mathrm{t}}$
- at $t = -1000$ and $p < p_{\mathrm{min}}$ or $p > p_{\mathrm{t}}$
- at $p < p_{\mathrm{min}}$ or $p > p_{\mathrm{t}}$
- at $T < T_{\mathrm{min}}$ *or* $T > T_{\mathrm{t}}$

References: [1], [2], [6], [7], [8]

Backward Function: Vapor Fraction $x = \mathrm{f}(p,h)$

Function Name: **x_ph_ICE**

Subprogram with value of the function: **REAL*8 FUNCTION XPHICE (P,H)**
for call from Fortran REAL*8 P,H

Input Values

P – Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

XPHICE, **X** or **x_ph_ICE** – Vapor fraction x in (kg saturated steam/kg wet steam)

Range of Validity (cp. *p*,*t*-diagram in chapter 1.2)

Pressure range: from p_t to $p_s(T_{max})$ for wet steam region
from p_t to p_{max} for melting region
from p_{min} to p_t for sublimation region

Enthalpy range: from $h < h_{max} = h(p_{min}, T_{max})$ to $h > h_{min} = h(p_{min}, T_{min})$

Temperature range: from T_{min} to T_{max} (resulting from internal calculation of the subprograms)

Details on calculating the two phase regions

The two phase regions are calculated automatically by the subprograms. Using the given values for p and h, the program determines whether the point of state to be calculated is located in the single phase region (solid, liquid or steam) or in one of the two phase regions wet steam region, melting region and sublimation region (cp. lg *p,h*-diagram in chapter 1.2). When calculating a two phase mixture, x will be calculated. If the state point to be calculated is located in the single-phase region the result is set to $x = -1$.

Results for wrong input values

Result **XPHICE = –1** or **x_ph_ICE = –1** for input values:

If the state point to be calculated is located in the single phase region (cp. lg *p,h*-diagram in chapter 1.2).

Two phase regions:

Wet steam region ($0 \le x \le 1$):
- at $p < p_t$ or $p > p_s(T_{max})$
- at calculation result $T < T_t$ or $T > T_{max}$

Melting region ($10 \le x \le 11$):
- at $p < p_t$ or $p > p_{max}$
- at calculation result $T > T_t$ or $T < T_{mel}(p_{max})$

Sublimation region ($100 \le x \le 101$):
- at $p < p_{min}$ or $p > p_t$
- at calculation result $T < T_{min}$ or $T > T_t$

References: [1], [2], [6], [7], [8]

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

Function Name:	**x_ps_ICE**
Subprogram with value of the function: for call from Fortran	**REAL*8 FUNCTION XPSICE (P,S)** REAL*8 P,S

Input Values

P – Pressure p in bar

S - Specific entropy s in kJ/(kg K)

Result

XPSICE or **x_ps_ICE** – Vapor fraction x in (kg saturated steam/kg wet steam)

Range of Validity (cp. p,t-diagram in chapter 1.2)

Pressure range:	from p_t to $p_s(T_{max})$	for wet steam region
	from p_t to p_{max}	for melting region
	from p_{min} to p_t	for sublimation region
Entropy range:	from $s < s_{max} = s(p_{min}, T_{max})$ to $s > s_{min} = s(p_{min}, T_{min})$	
Temperature range:	from T_{min} to T_{max} (resulting from internal calculation of the subprograms)	

Details on calculating the two phase regions

The two phase regions are calculated automatically by the subprograms. Using the given values for p and s, the program determines whether the point of state to be calculated is located in the single phase region (solid, liquid or steam) or in one of the two phase regions wet steam region, melting region and sublimation region (cp. lg p,h-diagram in chapter 1.2). When calculating a two phase mixture, x will be calculated. If the state point to be calculated is located in the single-phase region the result is set to $x = -1$.

Results for wrong input values

Result **XPSICE = –1** or **x_ps_ICE = –1** for input values:

If the state point to be calculated is located in the single phase region (cp. lg p,h-diagram in chapter 1.2).

Two phase regions:

Wet steam region ($0 \leq x \leq 1$):
- at $p < p_t$ or $p > p_s(T_{max})$
- at calculation result $T < T_t$ or $T > T_{max}$

Melting region ($10 \leq x \leq 11$):
- at $p < p_t$ or $p > p_{max}$
- at calculation result $T > T_t$ or $T < T_{mel}(p_{max})$

Sublimation region ($100 \leq x \leq 101$):
- at $p < p_{min}$ or $p > p_t$
- at calculation result $T < T_{min}$ or $T > T_t$

References: [1], [2], [6], [7], [8]

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

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 equations of Bücker et al.)

Consideration of

Dissociation from VDI 4670 and Poynting effect

Library LibIDGAS

Ideal gas mixture calculated from the VDI-Guideline 4670

Humid Air

Library LibHuAir

Ideal mixture of the real fluids:

- Dry air from Lemmon et al.
- Steam and water from IAPWS-IF97

Consideration of

- Dissociation from VDI-Guideline 4670
- Poynting effect

Library LibIdAir

Ideal gas mixture calculated from VDI-Guideline 4670

Carbon Dioxide

Library LibCO2

Formulation of Span and Wagner (1994)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Helium

Library LibHe

Formulation of McCarty and Arp (1990)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ideal Gas Mixtures

Library LibIdGasMix

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 VDI-Guideline 4670

Seawater

Library LibSeaWa

IAPWS Formulation (2008) and IAPWS-IF97

Refrigerant R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Refrigerant NH_3

Library LibNH3

Formulation of Tillner-Roth (1995)

ORC Working Fluids

Library LibMM

Siloxane $C_6H_{18}OSi_2$ (MM)

Formulation of Colonna et al. (2006)

Library LibD4

Siloxane $C_8H_{24}O_4Si_4$ (D4)

Formulation of Colonna et al. (2006)

Library LibD5

Siloxane $C_{10}H_{30}O_5Si_5$ (D5)

Formulation of Colonna et al. (2006)

Library LibMD4M

Siloxane $C_{14}H_{42}O_5Si_6$ (MD4M)

Formulation of Colonna et al. (2006)

Mixtures for Absorption Processes

Library LibAmWa

Ammonia/Water Mixtures

IAPWS Guideline 2005 of Tillner-Roth and Friend (1998)

Helmholtz energy formulation for the mixing term

Library LibWaLi

Water/Lithium Bromide Mixtures

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Refrigerants

Library LibPropan

Refrigerant Propane

Formulation of Lemmon et al. (2008)

Library LibButan_Iso

Refrigerant Iso-Butane

Formulation of Bücker et al. (2003)

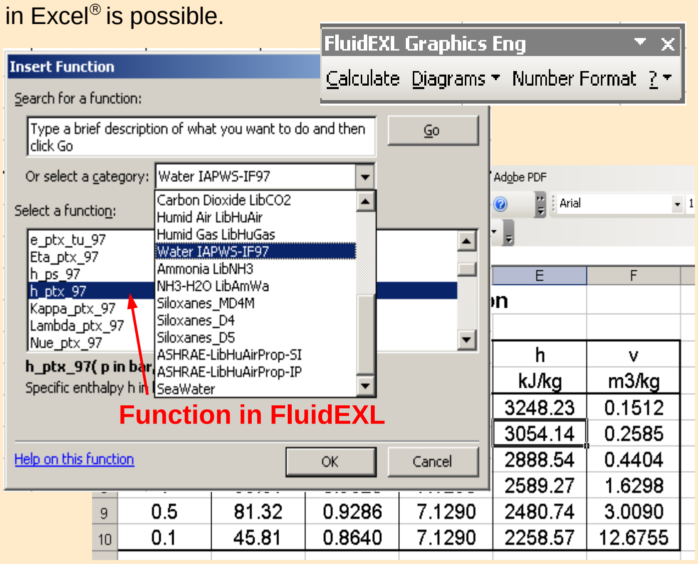
Library LibButan_n

Refrigerant n-Butane

Formulation of Bücker et al. (2003)

Add-In FluidEXL for Excel®

Using the Add-In FluidEXL a direct call of the property functions in Excel® is possible.



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

Or select a category: Water IAPWS-IF97

Carbon Dioxide LibCO2
Humid Air LibHuAir
Humid Gas LibHuGas
Water IAPWS-IF97
Ammonia LibNH3
NH3-H2O LibAmWa
Siloxanes_MD4M
Siloxanes_D4
Siloxanes_D5
ASHRAE-LibHuAirProp-SI
ASHRAE-LibHuAirProp-IP
SeaWater

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

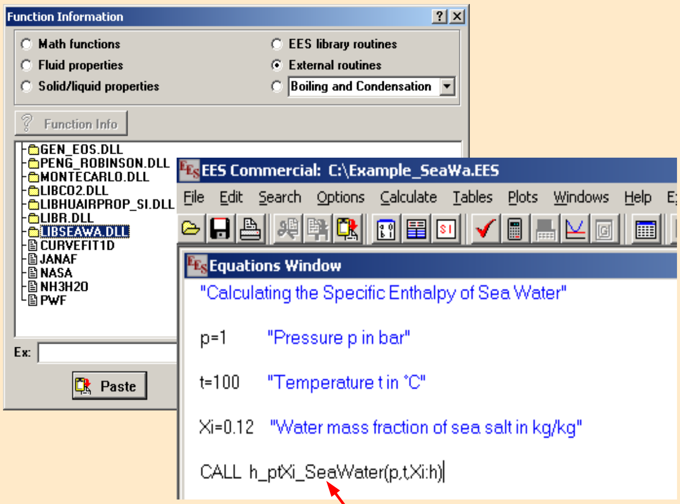
h_ptx_97(p in bar,
Specific enthalpy h in

					h kJ/kg	v m3/kg
					3248.23	0.1512
					3054.14	0.2585
					2888.54	0.4404
					2589.27	1.6298
9	0.5	81.32	0.9286	7.1290	2480.74	3.0090
10	0.1	45.81	0.8640	7.1290	2258.57	12.6755

Function in FluidEXL

Add-In FluidEES for EES®

The Add-In FluidEES allows to call the functions of the property libraries within the Engineering Equation Solver EES®.



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

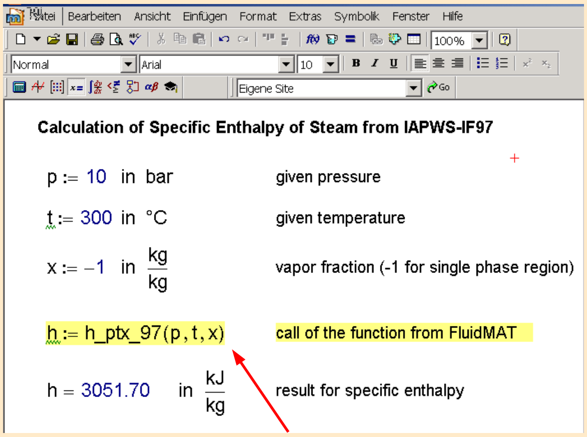
GEN_EOS.DLL
PENG_ROBINSON.DLL
MONTECARLO.DLL
LIBCO2.DLL
LIBHUAIRPROP_SI.DLL
LIBR.DLL
LIBSEAWA.DLL
CURVEFIT1D
JANAF
NASA
NH3H2O
PWF

```
"Calculating the Specific Enthalpy of Sea Water"

p=1     "Pressure p in bar"

t=100   "Temperature t in °C"

Xi=0.12 "Water mass fraction of sea salt in kg/kg"

CALL h_ptXi_SeaWater(p,t,Xi:h)
```

Function in FluidEES

Add-In FluidMAT for Mathcad®

Using the Add-on FluidMAT, the functions of the property libraries can be used in Mathcad®.



Calculation of Specific Enthalpy of Steam from IAPWS-IF97

$p := 10$ in bar — given pressure

$t := 300$ in °C — given temperature

$x := -1$ in $\frac{kg}{kg}$ — vapor fraction (-1 for single phase region)

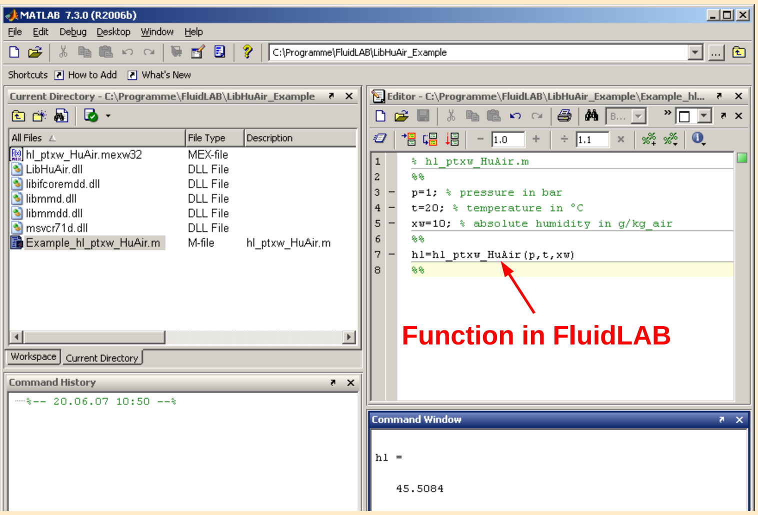
$h := h\_ptx\_97(p,t,x)$ — call of the function from FluidMAT

$h = 3051.70$ in $\frac{kJ}{kg}$ — result for specific enthalpy

Function in FluidMAT

Add-In FluidLAB for MATLAB®

The property functions can be called in MATLAB®.



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

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

```
% 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)
%%
```

```
hl =

   45.5084
```

Function in FluidLAB

The following thermodynamic and transport properties can be calculated[1]:

Thermodynamic Properties

- Saturation 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

Thermodynamic Derivatives

- Partial derivatives can be calculated

Transport Properties

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

Backward Functions

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

For information please contact:

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Phone: +49-3583-61-1846
Fax.: +49-3583-61-1846

---

[1] Not all of these property functions are available in all property libraries listed before.

5. References

[1] IAPWS:
Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam IAPWS-IF97.
Available at the IAPWS Website http://www.iapws.org

[2] Wagner, W.; Kretzschmar, H.-J.:
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Springer-Verlag, Berlin (2008)

[3] IAPWS:
Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance.
Available at the IAPWS Website http://www.iapws.org.

[4] IAPWS:
Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance.
IAPWS Secretariat, Dooley, B., EPRI, Palo Alto CA, (1997)

[5] IAPWS:
Release on Surface Tension of Ordinary Water Substance 1994.
Available at the IAPWS Website http://www.iapws.org.

[6] IAPWS:
Revised Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use.
Available at the IAPWS Website http://www.iapws.org

[7] IAPWS:
Revised Release on the Equation of State 2006 for H2O Ice Ih.
Available at the IAPWS Website http://www.iapws.org

[8] IAPWS:
Revised Release 2008 on the Pressure along the Melting and Sublimation Curves of Ordinary Water Substance.
Available at the IAPWS Website http://www.iapws.org

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®:

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Fels, Elingerode	07/2011
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Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

1997

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