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Property Library for Isopentane

FluidEXL*Graphics* with LibC5H12 for Excel®

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Property Library for Isopentane

Including DLL and Add-In for Excel®

FluidEXL*Graphics*
LibC5H12_ISO

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0. Package Contents

0.1 Zip files for 32-bit Office®

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

English zip file "CD_FluidEXL_Graphics_LibC5H12_ISO_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*
LibC5H12_ISO.dll	- Dynamic Link Library for use in Windows programs
LibC5H12_ISO.hlp	- Help file for the LibC5H12_ISO property library
FluidEXL_Graphics_LibC5H12_ISO_Docu_Eng.pdf	- User's Guide

German zip file "CD_FluidEXL_Graphics_LibC5H12_ISO.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*
LibC5H12_ISO.dll	- Dynamic Link Library for use in Windows® programs
LibC5H12_ISO.hlp	- Help file for the LibC5H12_ISO property library
FluidEXL_Graphics_LibC5H12_ISO_Docu_Eng.pdf	- User's Guide

0.2 Zip files for 64-bit Office®

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

English zip file "CD_FluidEXL_Graphics_LibC5H12_ISO_x64_Eng.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibC5H12_ISO_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics_Eng.xla	- English FluidEXL*Graphics* Add-In
FluidEXL_Graphics_Eng_64_Setup.msi	- Self-extracting and self-installing program
LibC5H12_ISO.dll	- Dynamic link library for use in Windows® programs
LibC5H12_ISO.hlp	- Help file for the LibC5H12_ISO 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_LibC5H12_ISO_x64.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibC5H12_ISO_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics.xla	- German FluidEXL*Graphics* Add-In
FluidEXL_Graphics_64_Setup.msi	- Self-extracting and self-installing program
LibC5H12_ISO.dll	- Dynamic link library for use in Windows® programs
LibC5H12_ISO.hlp	- Help file for the LibC5H12_ISO 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

Functional Dependence	Function Name	Call from Fortran Program	Property or Function	Unit of the Result
$a = f(p,t,x)$	a_ptx_C5H12_ISO	A_PTX_C5H12_ISO(P,T,X)	Thermal diffusivity	m²/s
$c_p = f(p,t,x)$	cp_ptx_C5H12_ISO	CP_PTX_C5H12_ISO(P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_C5H12_ISO	CV_PTX_C5H12_ISO(P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\varepsilon = f(p,t,x)$	eps_ptx_C5H12_ISO	EPS_PTX_C5H12_ISO(P,T,X)	Dielectric constant	-
$\eta = f(p,t,x)$	eta_ptx_C5H12_ISO	ETA_PTX_C5H12_ISO(P,T,X)	Dynamic viscosity	Pa . s
$h = f(p,t,x)$	h_ptx_C5H12_ISO	H_PTX_C5H12_ISO(P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	ka_ptx_C5H12_ISO	KA_PTX_C5H12_ISO(P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lam_ptx_C5H12_ISO	LAM_PTX_C5H12_ISO(P,T,X)	Thermal conductivity	W/(m . K)
$\nu = f(p,t,x)$	ny_ptx_C5H12_ISO	NY_PTX_C5H12_ISO(P,T,X)	Kinematic viscosity	m²/s
$p_{mel} = f(t)$	pmel_t_C5H12_ISO	PMEL_T_C5H12_ISO (T)	Melting pressure from temperature	bar
$Pr = f(p,t,x)$	pr_ptx_C5H12_ISO	PR_PTX_C5H12_ISO(P,T,X)	*Prandtl*-number	-
$p_s = f(t)$	ps_t_C5H12_ISO	PS_T_C5H12_ISO(T)	Vapor pressure from temperature	bar
$\rho = f(p,t,x)$	rho_ptx_C5H12_ISO	RHO_PTX_C5H12_ISO(P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_C5H12_ISO	S_PTX_C5H12_ISO(P,T,X)	Specific entropy	kJ/(kg K)
$\sigma = f(t)$	sigma_t_C5H12_ISO	SIGMA_T_C5H12_ISO(T)	Surface tension from temperature	N/m
$t = f(p,h)$	t_ph_C5H12_ISO	T_PH_C5H12_ISO(P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_C5H12_ISO	T_PS_C5H12_ISO(P,S)	Backward function: Temperature from pressure and entropy	°C
$t_{mel} = f(p)$	tmel_p_C5H12_ISO	TMEL_P_C5H12_ISO (P)	Melting Temperature from pressure	°C
$t_s = f(p)$	ts_p_C5H12_ISO	TS_P_C5H12_ISO(P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_C5H12_ISO	U_PTX_C5H12_ISO(P,T,X)	Specific internal energy	kJ/kg

Functional Dependence	Function Name	Call from Fortran Program	Property or Function	Unit of the Result
v = f(p,t,x)	v_ptx_C5H12_ISO	V_PTX_C5H12_ISO(P,T,X)	Specific volume	m³/kg
w = f(p,t,x)	w_ptx_C5H12_ISO	W_PTX_C5H12_ISO(P,T,X)	Isentropic speed of sound	m/s
x = f(p,h)	x_ph_C5H12_ISO	X_PH_C5H12_ISO(P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
x = f(p,s)	x_ps_C5H12_ISO	X_PS_C5H12_ISO(P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg

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

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

Reference state

h = 0 kJ/kg and s = 0 kJ/(kg K) at p = 1,01325 bar on the saturated liquid line (x = 0)

Details on the vapor fraction *x*

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

Single-phase region

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

Wet-steam region

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for *x*. When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

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

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 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 software documentation in Chapter 3.

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 Isopentane from the LibC5H12_ISO 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 LibC5H12_ISO library. In this case, follow the subsection "Adding the LibC5H12_ISO 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_LibC5H12_ISO_Eng.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibC5H12_ISO.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibC5H12_ISO_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_ISO (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_LibC5H12_ISO_Docu_Eng.pdf
LibC5H12_ISO.dll
LibC5H12_ISO.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).

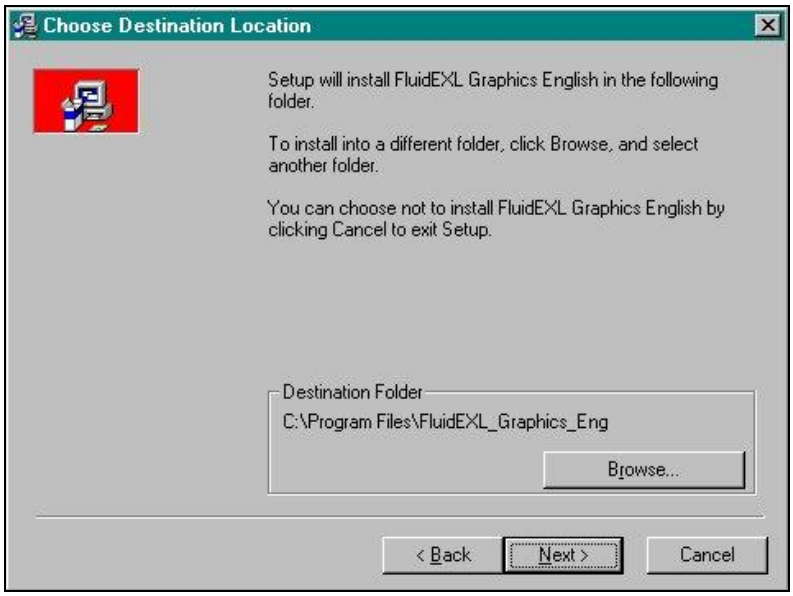

Figure 2.1: Choose Destination Location

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*Graphics*. After FluidEXL*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	LC.dll
DFORMD.dll	Msvcp60.dll
Dforrt.dll	Msvcrt.dll
UNWISE.EXE	UNWISE.INI
INSTALL_EXL.LOG	

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)
LibC5H12_ISO.dll	
LibC5H12_ISO.hlp	

from the extracted folder

CD_FluidEXL_Graphics_LibC5H12_ISO_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_ISO	(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_LibC5H12_ISO_x64_Eng.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibC5H12_ISO_x64.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibC5H12_ISO_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_ISO (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_LibC5H12_ISO_Docu
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)
LibC5H12_ISO.dll
LibC5H12_ISO.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).

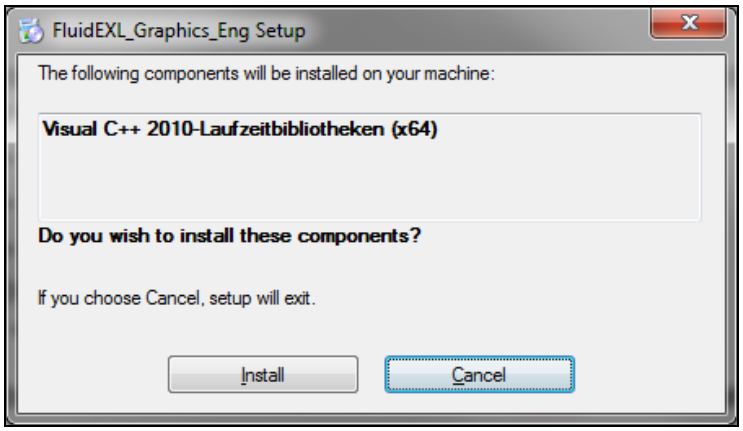

Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

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).

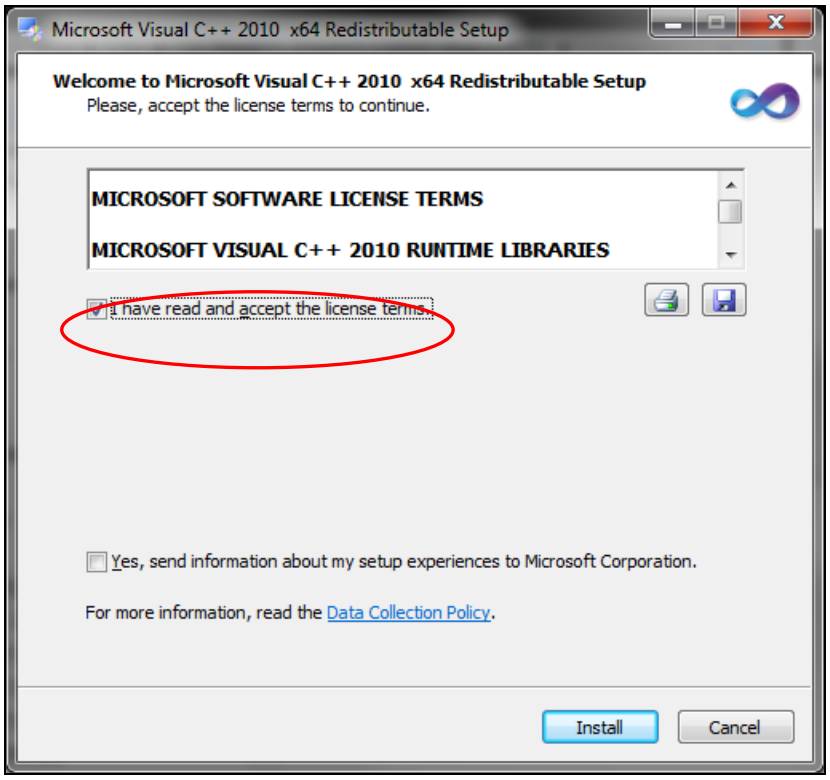

Figure 2.3: Accepting the license terms

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*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).

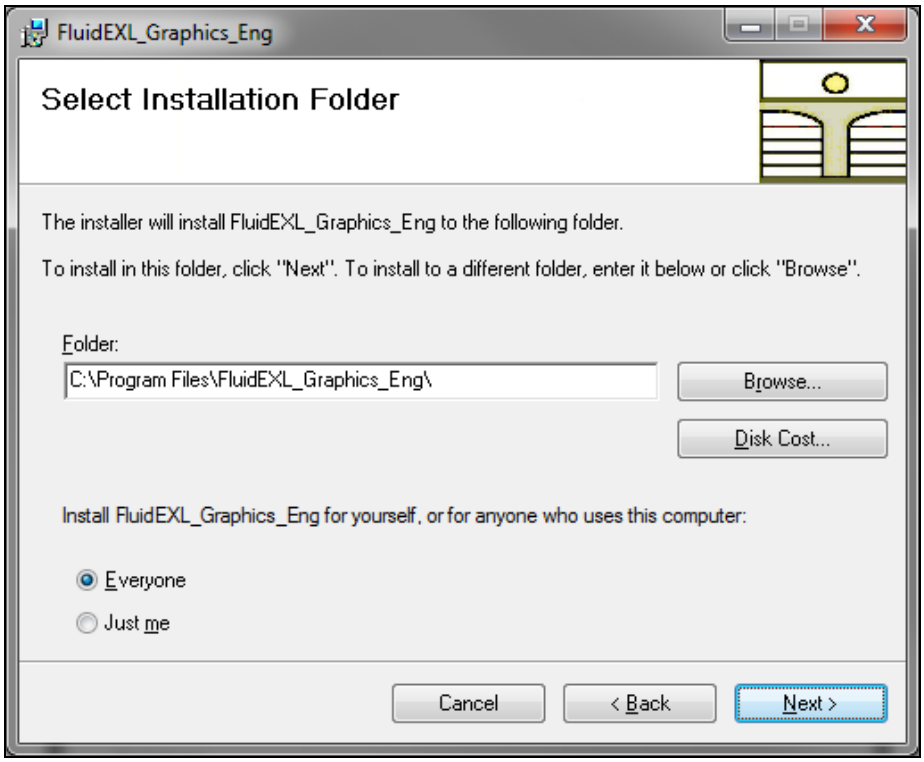

Figure 2.4: Choosing the Installation Folder of FluidEXL*Graphics*

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*Graphics*.

After FluidEXL*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	libmmd.dll
libifcoremd.dll	LC.dll
libiomp5md.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)
LibC5H12_ISO.dll	
LibC5H12_ISO.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.

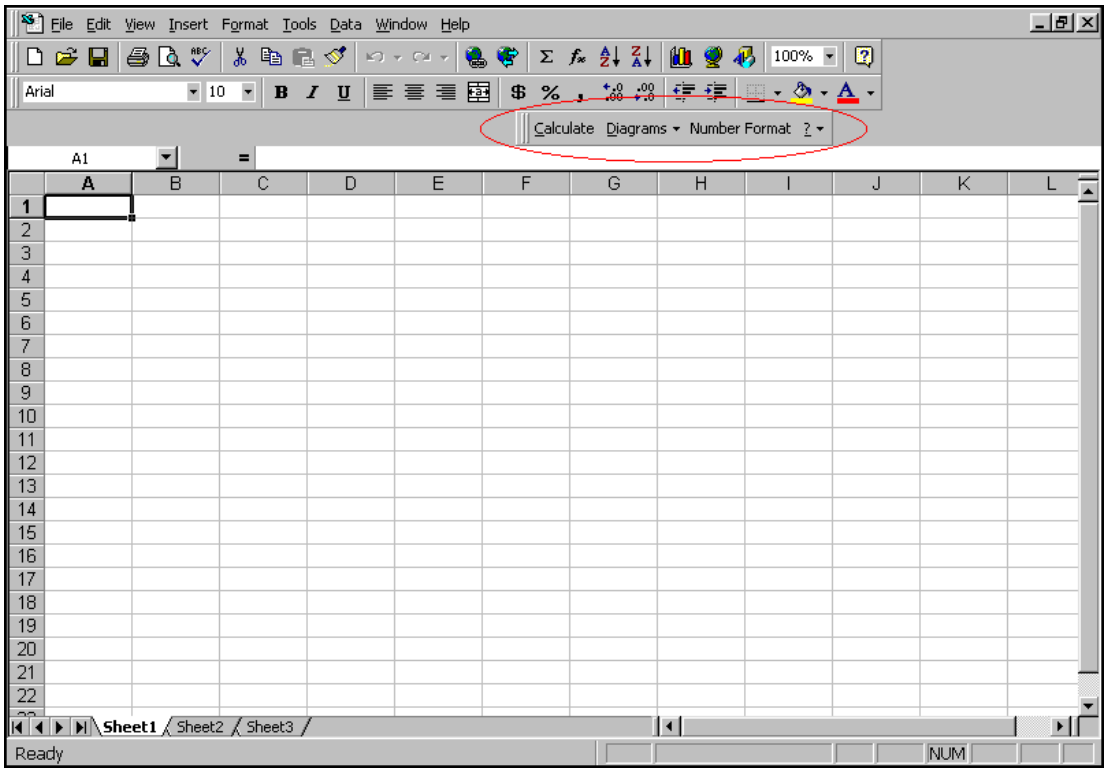

Figure 2.5: Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "LibC5H12_ISO" DLL library property functions via this menu bar (see part 2.5 on page 2/19).

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)

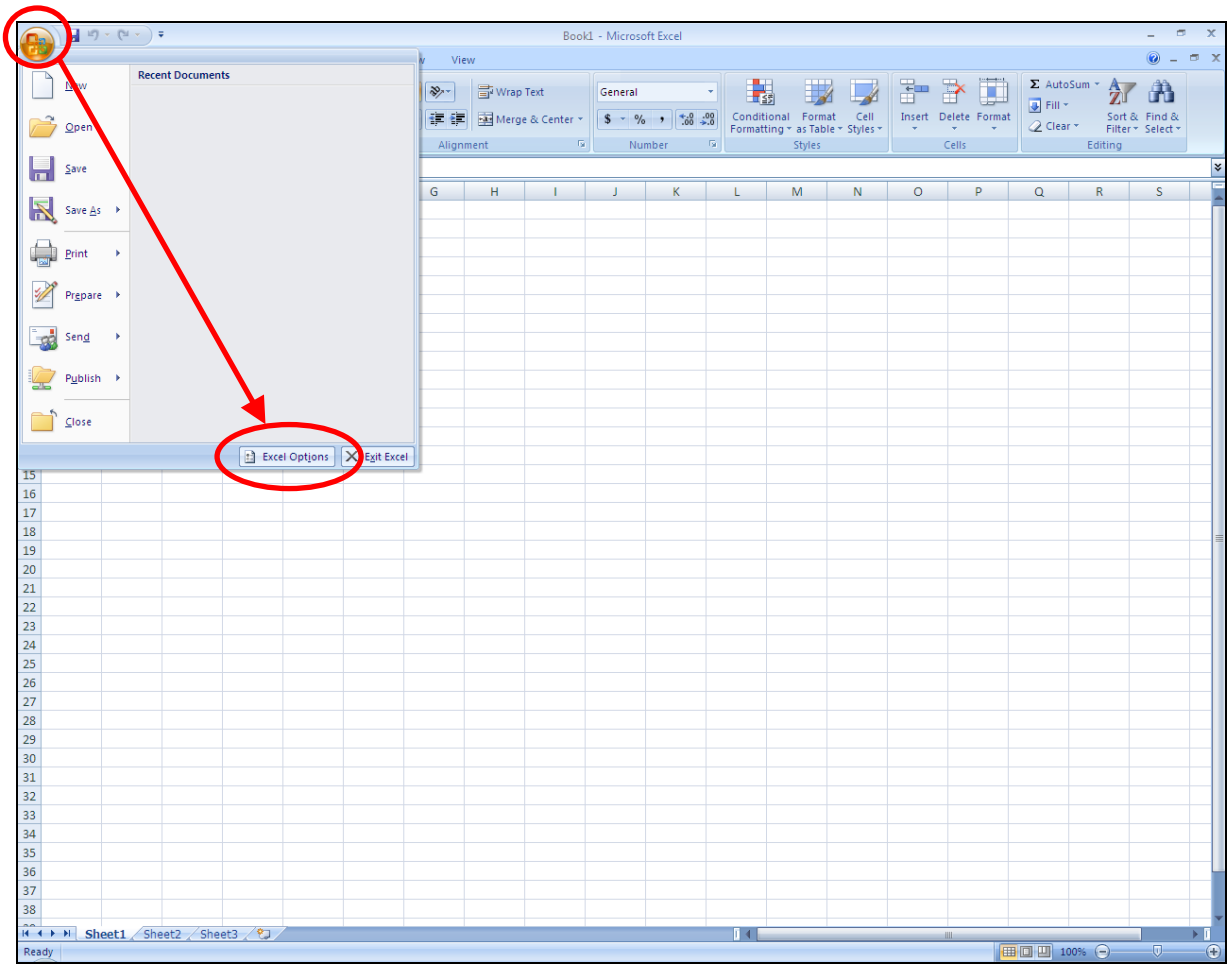

Figure 2.6: Registering FluidEXL*Graphics* as Add-In in Excel® 2007

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

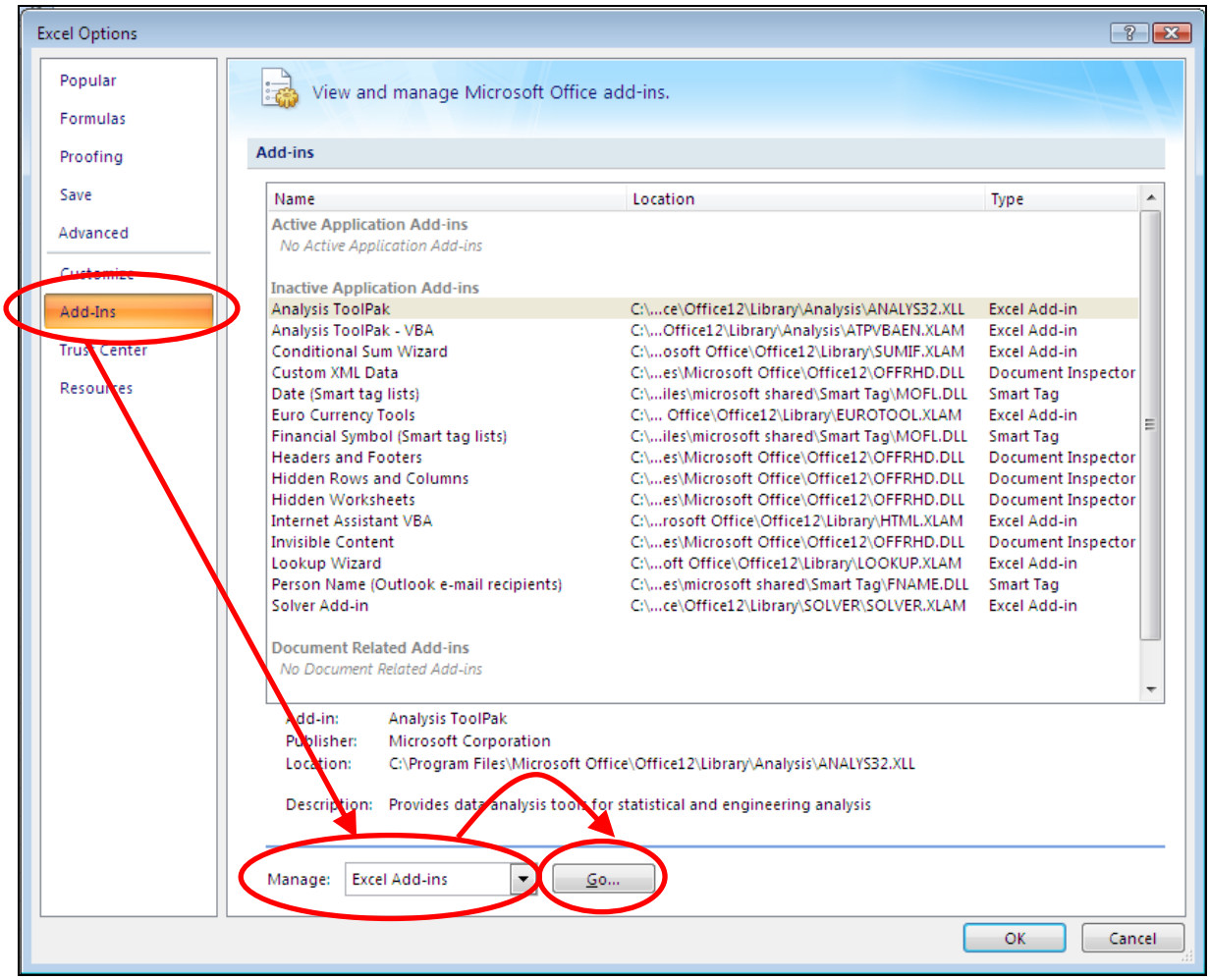

Figure 2.7: Dialog window "Excel Options"

- 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."

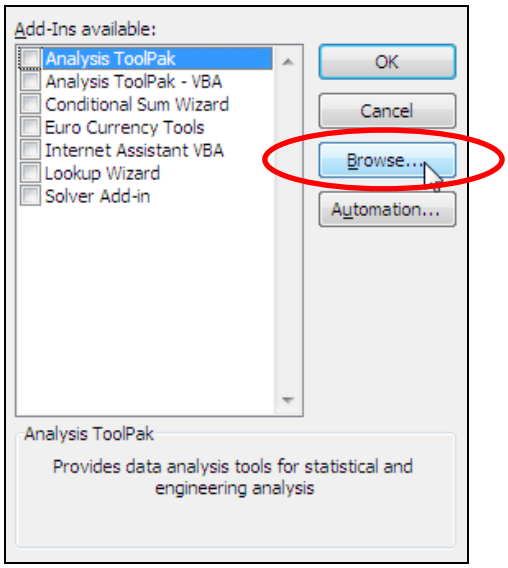

Figure 2.8: Dialog window "Add-Ins available"

- 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.)

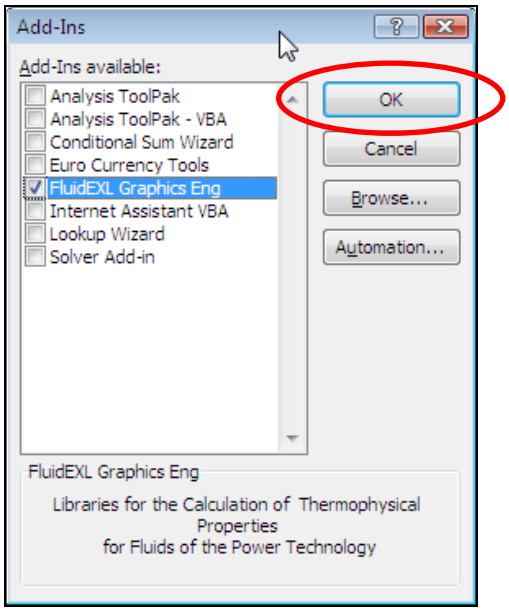

Figure 2.9: Dialog window "Add-Ins"

- 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.

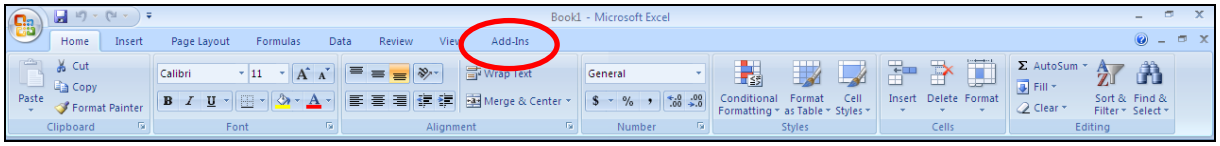

Figure 2.10: Menu item "Add-Ins"

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

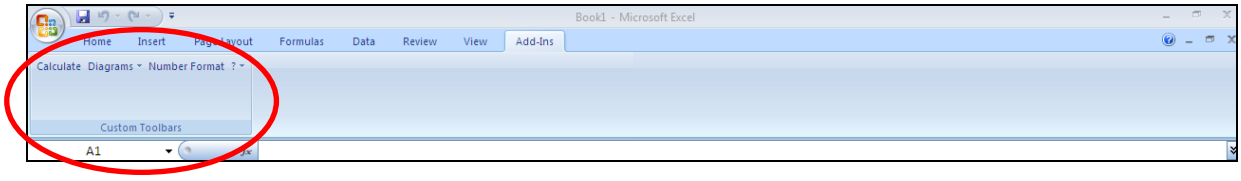

Figure 2.11: FluidEXL*Graphics* menu bar

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 LibC5H12_ISO 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)
LibC5H12_ISO.dll	
LibC5H12_ISO.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibC5H12_ISO_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_ISO	(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 "LibC5H12_ISO" DLL library property functions for isopentane via this menu bar (the example calculation can be found in chapter 2.5 on page 2/19).

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 "Isopentane LibC5H12_ISO" 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 LibC5H12_ISO.hlp function help cannot be found, confirm the question whether you want to look for it yourself with "Yes". Select the LibC5H12_ISO.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:

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).

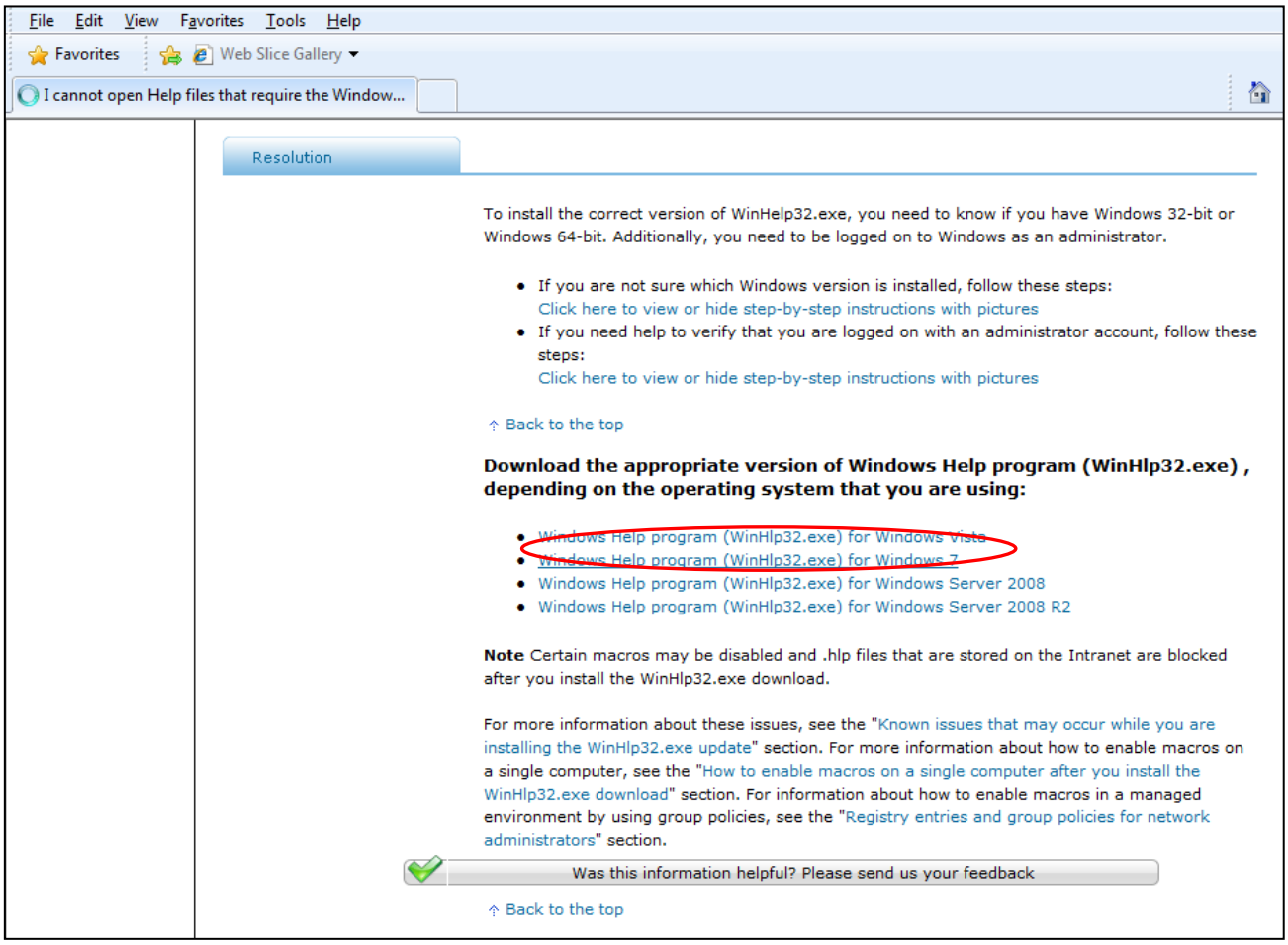

Figure 2.13: Selecting your Windows version

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).

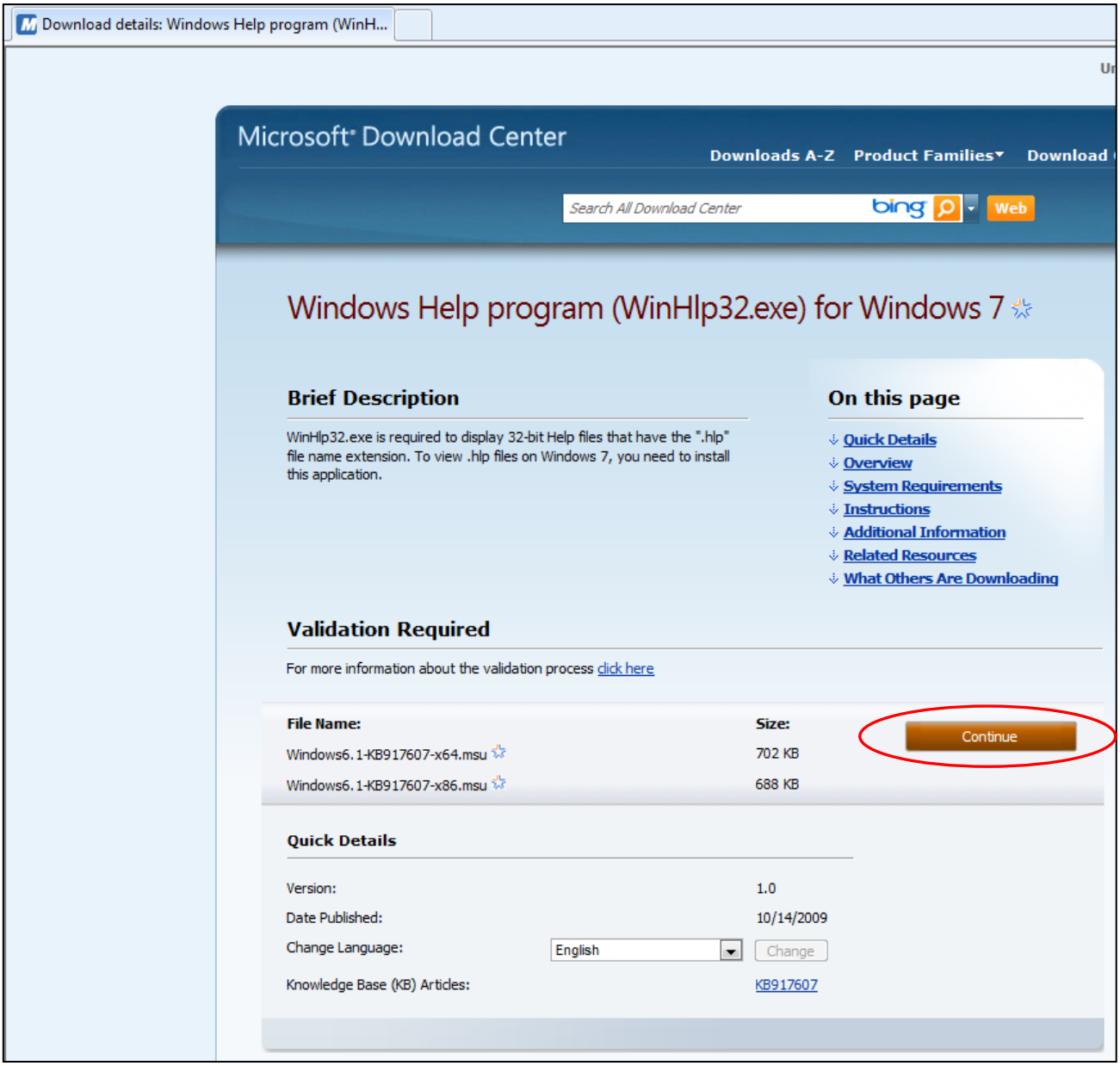

Figure 2.14: Microsoft® Download Center

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).

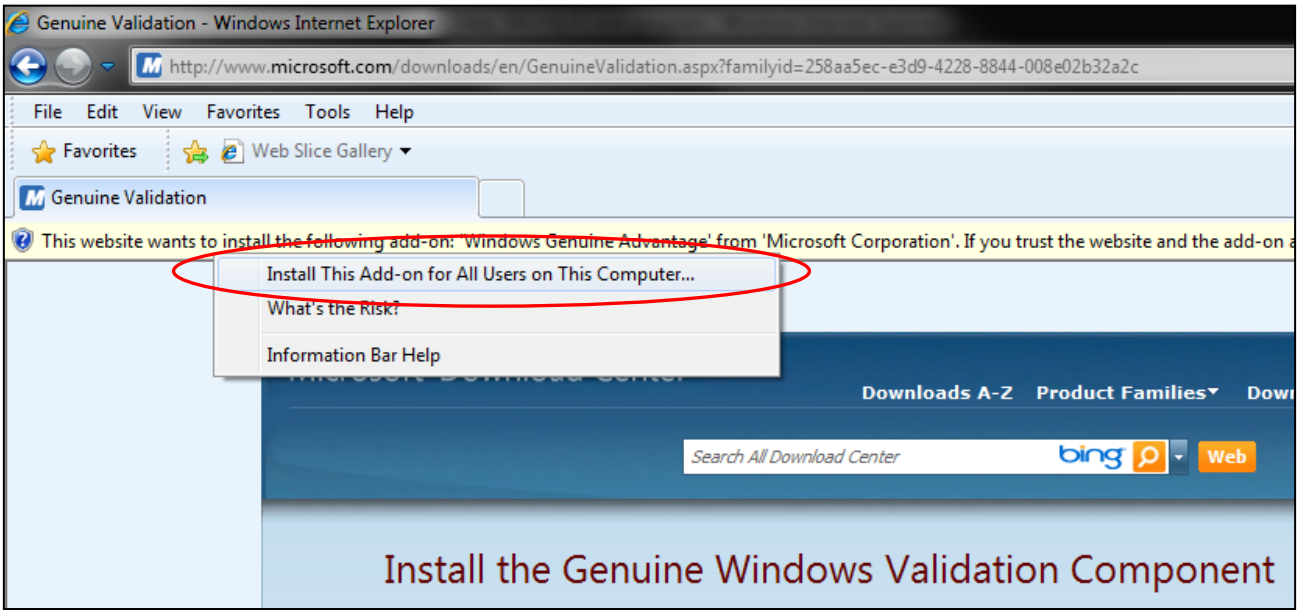

Figure 2.15: Installing the Genuine Windows Validation Component

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).

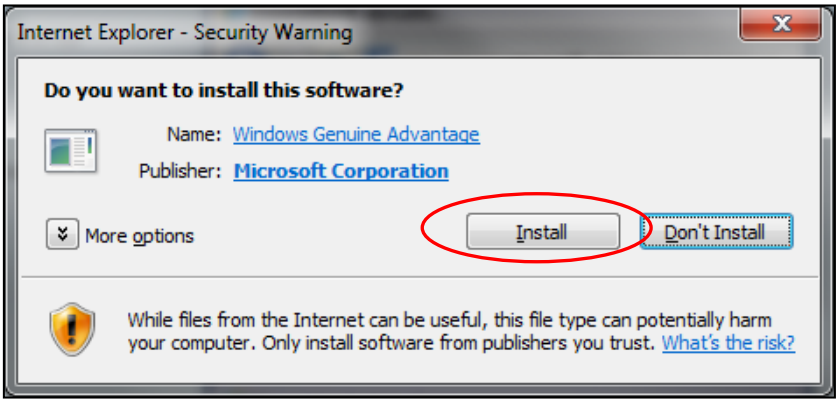

Figure 2.16: Internet Explorer – Security Warning

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

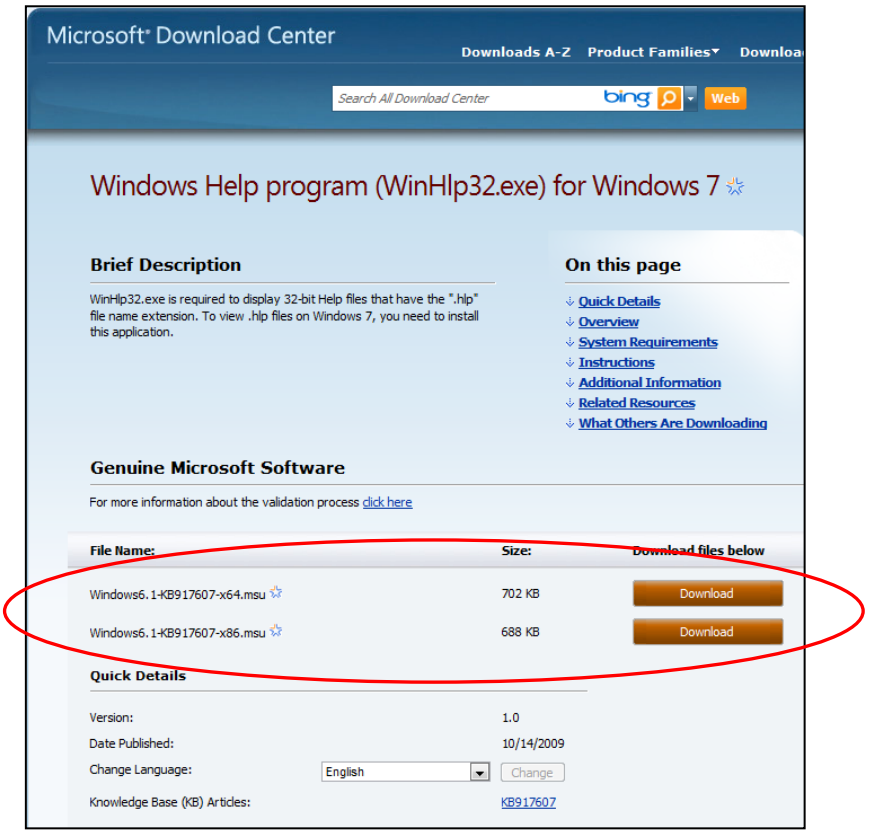

Figure 2.17: Downloading the Windows Help program

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.

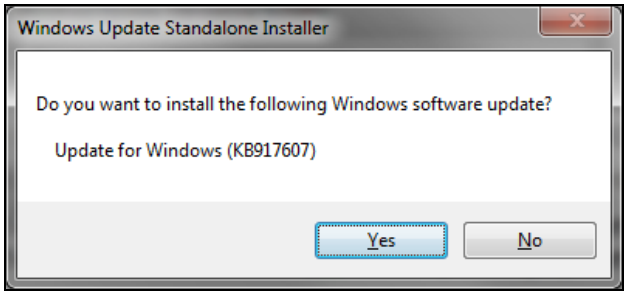

Figure 2.18: Windows Update Standalone Installer

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)

Figure 2.19: Windows License Terms

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

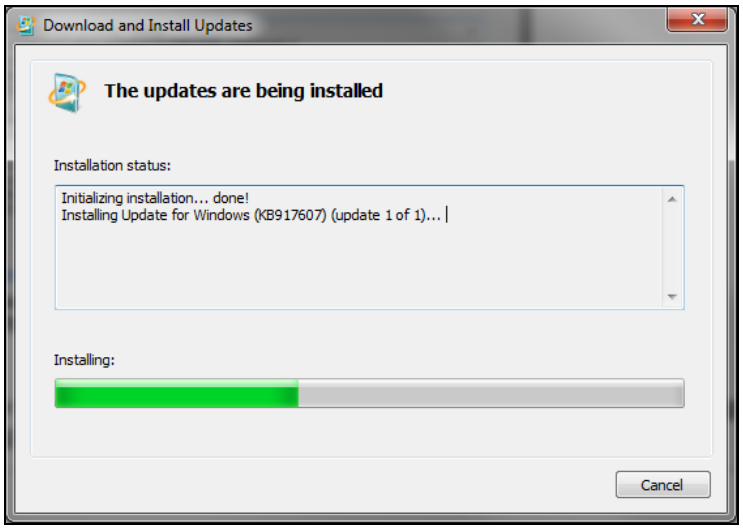

Figure 2.20: Installation process

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 LibC5H12_ISO Property Library

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

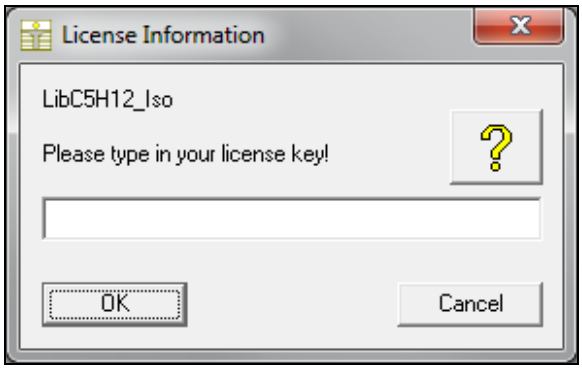

Figure 2.21: "License Information" window

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:

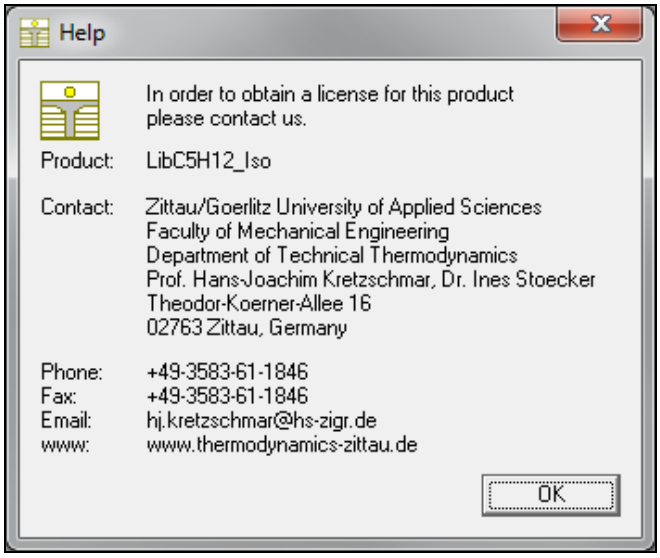

Figure 2.22: "Help" window

If you do not enter a valid license it is still possible to start Excel by clicking "Cancel" twice. In this case, the LibC5H12_ISO 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*Graphics* according to the description in section 2.6 of this User's Guide. Should you not wish to license the LibC5H12_ISO property library, you have to delete the files

LibC5H12_ISO.dll
LibC5H12_ISO.hlp

in the installation folder 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.

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 pressure *p*, temperature *t*, and vapor fraction *x*, using FluidEXL*Graphics*.

- Start Excel®
- Enter a value for *p* in bar in a cell
  (Range of validity: p_t = 8.95275 x 10^{-10} bar to 1 x 10^4 bar)

  ⇒ e. g.: Enter the value 10 into cell A2
- Enter a value for *t* in °C in a cell
  (Range of validity: t = - 160.5 °C to 226.85 °C)

  ⇒ e. g.: Enter the value 200 into cell B2
- Enter a value for *x* in kg saturated steam/kg wet steam in a cell

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

  Single-phase region

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

  Wet-steam region

  If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.
  If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.
  When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.
  If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve.

  (Vapor-pressure curve of ethanol: t_{min} = - 160.5 °C to t_c = 187.2 °C
  p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

  ⇒ e.g.: Enter –1 into the C2 cell.
- Click the cell in which the 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).

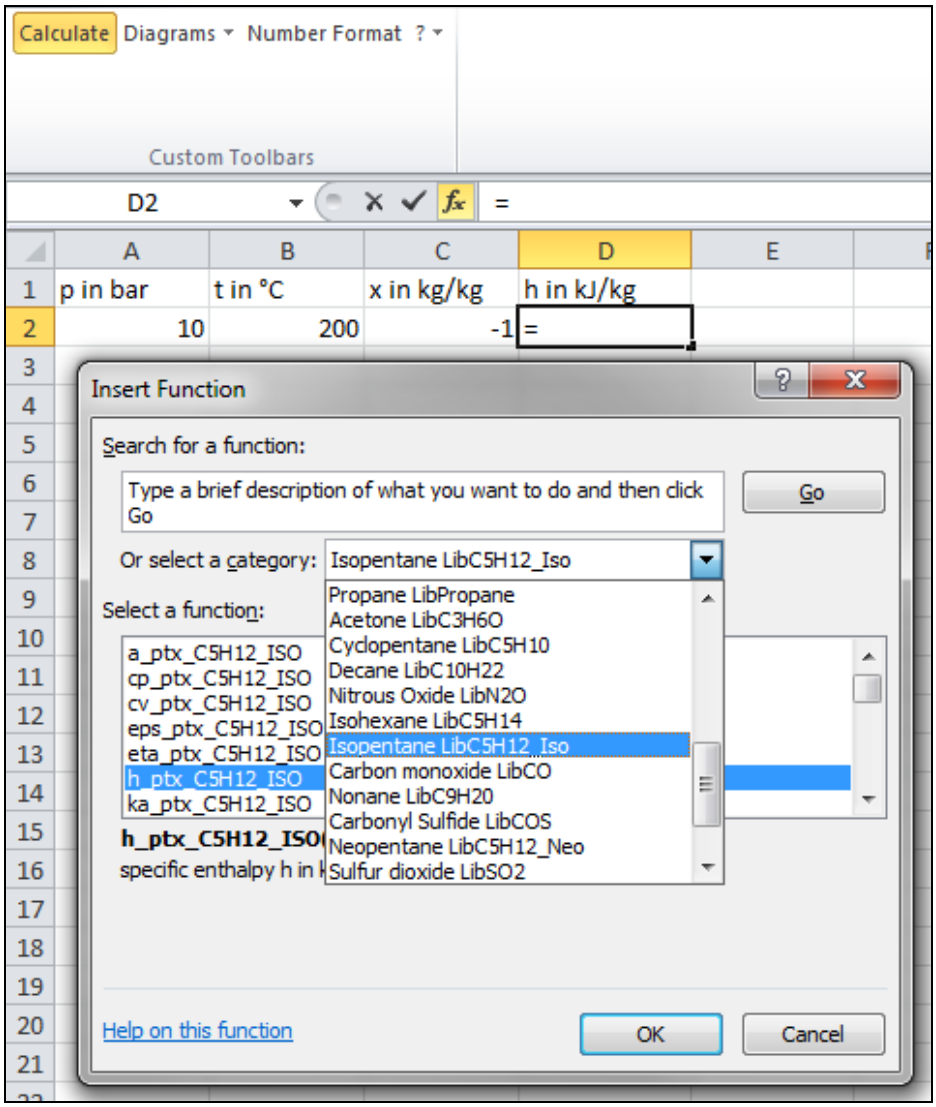

Figure 2.23: Choice of library and function name

- Search and click the "Isopentane LibC5H12_Iso" library under "Or select a category:" in the upper part of the window.
- Search and click the h_ptx_C5H12_Iso 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 the next figure will now appear.

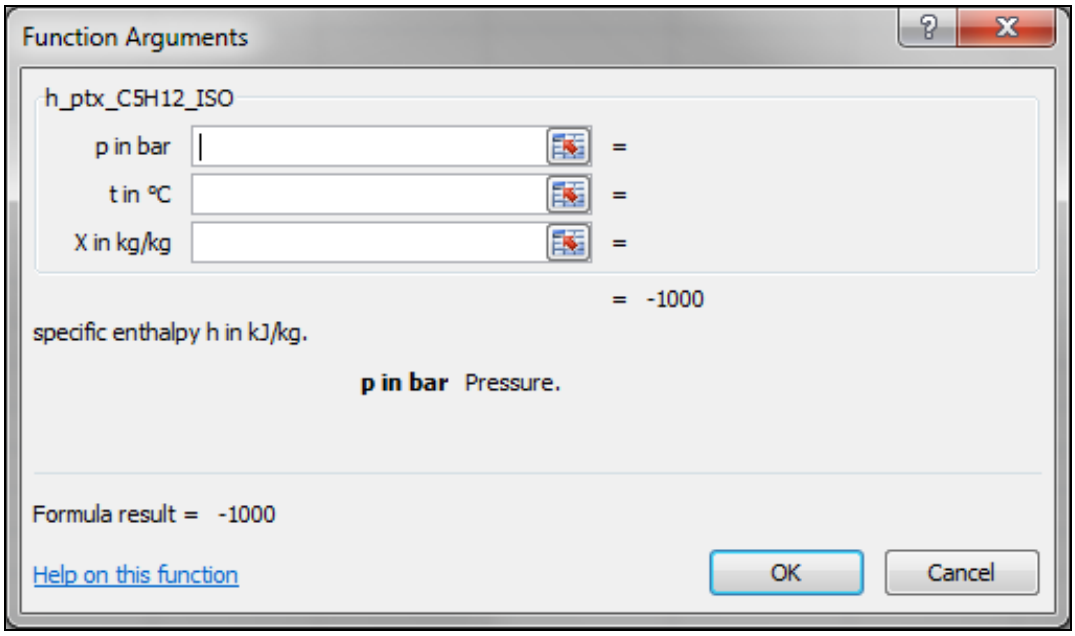

Figure 2.24: Input menu for the function

- The cursor is now situated on the line next to " p in bar ". You can now enter the value for *p* either 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.: Click on the cell A2

- 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.: Type B2 into the window next to "p"

- 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.: Click on the cell C2

  The window should now look like the following figure:

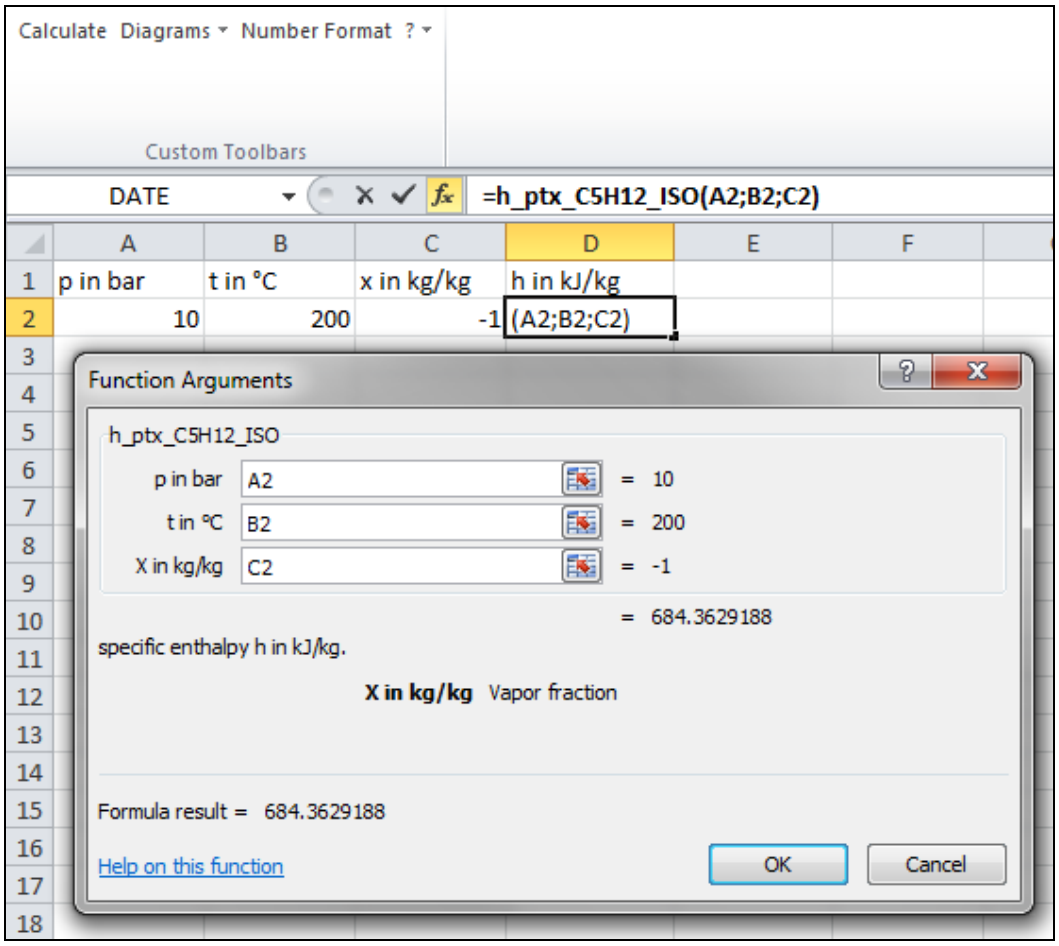

Figure 2.25: Input menu showing the result

- 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: 684.3629188 kJ/kg.

The calculation of $h = f(p,t,x)$ has thus 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 shown in Chapter 1. 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 LibC5H12_ISO library, delete the files

LibC5H12_ISO.dll
LibC5H12_ISO.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))

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

LibC5H12_ISO.dll,
LibC5H12_ISO.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

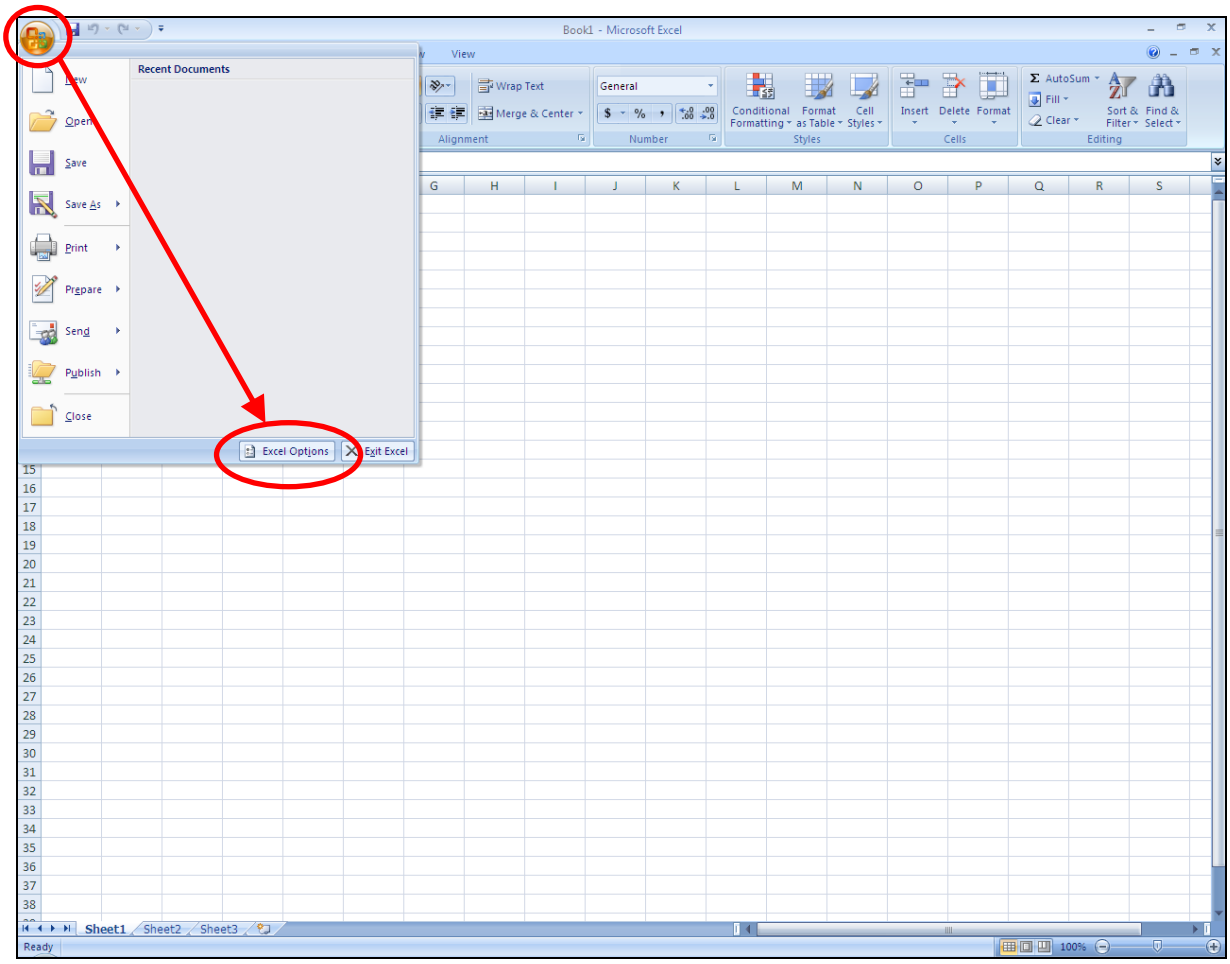

Figure 2.26: Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007

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

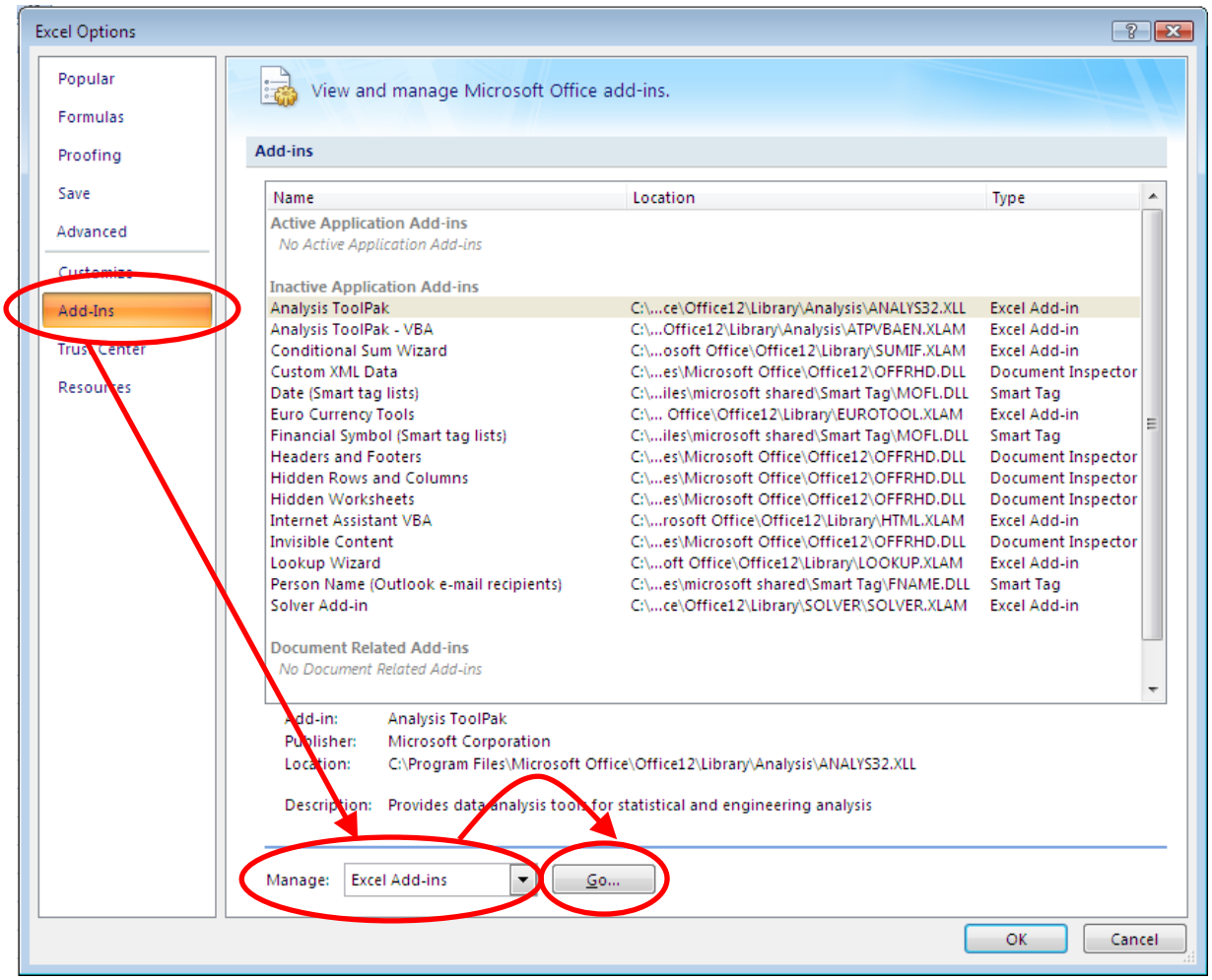

Figure 2.27: Dialog window "Add-Ins"

- 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.

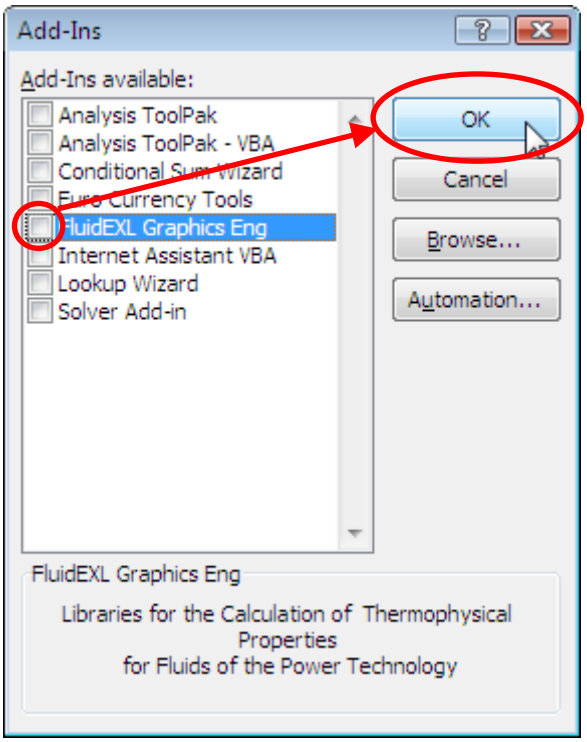

Figure 2.28: Dialog window "Add-Ins"

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_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION A_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

a_ptx_C5H12_ISO or A_PTX_C5H12_ISO - Thermal diffusivity $a = \frac{\lambda}{\rho \cdot c_p} = \frac{\lambda \cdot v}{c_p}$ in m²/s

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^4 bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **A_PTX_C5H12_ISO = –1000 or a_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^4 bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1], [5]

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

Function Name:	**cp_ptx_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION CP_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

cp_ptx_C5H12_ISO or CP_PTX_C5H12_ISO - Specific isobaric heat capacity cp in kJ/ (kg K)

Range of validity

Temperature range:	from - 160.5 °C to 226.85 °C
Pressure range:	from 8.95275 x 10^{-10} bar to 1 x 10^4 bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **CP_PTX_C5H12_ISO = –1000 or cp_ptx_C5H12_ISO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):

- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^4 bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

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

Function Name: **cv_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION CV_PTX_C5H12_ISO (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 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

cv_ptx_C5H12_ISO or CV_PTX_C5H12_ISO - Specific isochoric heat capacity cv in kJ/ (kg K)

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^4 bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **CV_PTX_C5H12_ISO = –1000 or cv_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^4 bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Dielectric Constant ε = f(p,t,x)

Function Name: **eps_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION EPS_PTX_C5H12_ISO (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 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

eps_ptx_C5H12_ISO or EPS_PTX_C5H12_ISO – Dielectric constant ε

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **EPS_PTX_C5H12_ISO = –1000 or eps_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1], [4]

Dynamic Viscosity η = f(p,t,x)

Function Name: **eta_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION ETA_PTX_C5H12_ISO (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 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

eta_ptx_C5H12_ISO or ETA_PTX_C5H12_ISO - Dynamic viscosity η in Pa s

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **ETA_PTX_C5H12_ISO = –1000 or eta_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1], [5]

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

Function Name:	**h_ptx_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION H_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

h_ptx_C5H12_ISO or H_PTX_C5H12_ISO – specific enthalpy h in kJ/kg

Range of validity

Temperature range:	from - 160.5 °C to 226.85 °C
Pressure range:	from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **H_PTX_C5H12_ISO = –1000 or h_ptx_C5H12_ISO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):

- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

Wet steam region (0 ≤ x ≤ 1):

- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Isentropic Exponent κ = f(p,t,x)

Function Name: **ka_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION KA_PTX_C5H12_ISO (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 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ka_ptx_C5H12_ISO or KA_PTX_C5H12_ISO – Isentropic exponent κ

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **KA_PTX_C5H12_ISO = –1000 or ka_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Thermal Conductivity λ = f(p,t,x)

Function Name: **lam_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION LAM_PTX_C5H12_ISO (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 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

lam_ptx_C5H12_ISO or LAM_PTX_C5H12_ISO – Thermal conductivity λ in W/ (m K)

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **LAM_PTX_C5H12_ISO = –1000 or lam_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1], [5]

Kinematic Viscosity v = f(p,t,x)

Function Name: **ny_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION NY_PTX_C5H12_ISO (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 - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ny_ptx_C5H12_ISO or NY_PTX_C5H12_ISO – kinematic viscosity v in m²/s

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275×10^{-10} bar to 1×10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275×10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **NY_PTX_C5H12_ISO = –1000 or ny_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at $p < 8.95275 \times 10^{-10}$ bar or $p > 1 \times 10^{4}$ bar or $p > p_{mel}(t)$
- at $t < -160.5$ °C or $t > 226.85$ °C or $t < t_{mel}(p)$

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and $t < t_{min}$ or $t > t_c$
- at t = –1000 and $p < p_{min}$ or $p > p_c$
- at $p < p_{min}$ or $p > p_c$ or at $t < t_{min}$ or $t > t_c$

References: [1], [5]

Melting Pressure p_{mel} = f(t)

Function Name:	**pmel_t_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION PMEL_T_C5H12_ISO (T)**
for call from Fortran	REAL*8 T

Input values

T - Temperature *t* in °C

Result

ts_t_C5H12_ISO or TS_P_C5H12_ISO - Melting pressure p_{mel} in bar

Range of validity

Temperature range: from t_{min} = - 160.5 °C to - 60.963 °C

Results for wrong input values

Result **PMEL_T_C5H12_ISO = –1000 or pmel_t_C5H12_ISO = –1000** for input values:

Wet steam region (0 ≤ x ≤ 1):

- at $t < t_{min}$ or $t >$ - 60.963 °C

References: [3]

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

Function Name: **pr_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION PR_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

pr_ptx_C5H12_ISO or PR_PTX_C5H12_ISO - Prandtl-number- $\mathrm{Pr} = \frac{\eta \cdot c_p}{\lambda}$

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^4 bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **PR_PTX_C5H12_ISO = –1000 or pr_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^4 bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1], [5]

Vapor Pressure p_s = f(t)

Function Name:	**ps_t_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION PS_T_C5H12_ISO (T)**
for call from Fortran	REAL*8 T

Input values

T - Temperature *t* in °C

Result

ps_t_C5H12_ISO or PS_T_C5H12_ISO - Vapor pressure p_s in bar

Range of validity

Temperature range: from t_{min} = - 160.5 °C to t_c = 187.2 °C

Results for wrong input values

Result **PS_T_C5H12_ISO = –1000 or ps_t_C5H12_ISO = –1000** for input values:

Wet steam region (0 ≤ x ≤ 1):

- at $t < t_{min}$ or $t > t_c$

References: [1]

Density ρ = f(p,t,x)

Function Name: **rho_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION RHO_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

rho_ptx_C5H12_ISO or RHO_PTX_C5H12_ISO - Density ρ in kg/m³

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^4 bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **RHO_PTX_C5H12_ISO = –1000 or rho_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^4 bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

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

Function Name: **s_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION S_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

s_ptx_C5H12_ISO or S_PTX_C5H12_ISO – specific entropy s in kJ/(kg K)

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275×10^{-10} bar to 1×10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	$p_{min} = 8.95275 \times 10^{-10}$ bar to p_c = 33.7822 bar

Results for wrong input values

Result **S_PTX_C5H12_ISO = –1000 or s_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at $p < 8.95275 \times 10^{-10}$ bar or $p > 1 \times 10^{4}$ bar or $p > p_{mel}(t)$
- at $t < -160.5$ °C or $t > 226.85$ °C or $t < t_{mel}(p)$

Wet steam region (0 ≤ x ≤ 1):
- at $x < 0$ or $x > 1$
- at p = –1000 and $t < t_{min}$ or $t > t_c$
- at t = –1000 and $p < p_{min}$ or $p > p_c$
- at $p < p_{min}$ or $p > p_c$ or at $t < t_{min}$ or $t > t_c$

References: [1]

Surface Tension σ = f(p,t,x)

Function Name:	**sigma_t_C5H12_ISO**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION SIGMA_T_C5H12_ISO (T)** REAL*8 T

Input values

T - Temperature *t* in °C

Result

Sigma_t_C5H12_ISO or SIGMA_T_C5H12_ISO – Surface tension σ in N/m

Range of validity

Temperature range: from t_{min} = - 160.5 °C to t_c = 187.2 °C

Results for wrong input values

Result **SIGMA_T_C5H12_ISO = –1000 or sigma_t_C5H12_ISO = –1000** for input values:

Wet steam region (0 ≤ x ≤ 1):

- at $t < t_{min}$ or $t > t_c$

References: [2]

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

Function Name:	**t_ph_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION T_PH_C5H12_ISO (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

t_ph_C5H12_ISO or T_PH_C5H12_ISO – Temperature t in °C

Range of validity

Temperature range:	from - 160.5 °C to 226.85 °C
Pressure range:	from 8.95275×10^{-10} bar to 1×10^{4} bar

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

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

Wet steam region: Pressure ranges from $p_{min} = 8.95275 \times 10^{-10}$ bar to $p_c = 33.7822$ bar

Results for wrong input values

Result **T_PH_C5H12_ISO = –1000 or t_ph_C5H12_ISO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):

- at $p < 8.95275 \times 10^{-10}$ bar or $p > 1 \times 10^{4}$ bar or $p > p_{mel}(t)$
- at $t < -160.5$ °C or $t > 226.85$ °C or $t < t_{mel}(p)$

Wet steam region (0 ≤ x ≤ 1):

- at $x < 0$ or $x > 1$
- at $p = -1000$ and $t < t_{min}$ or $t > t_c$
- at $t = -1000$ and $p < p_{min}$ or $p > p_c$
- at $p < p_{min}$ or $p > p_c$ or at $t < t_{min}$ or $t > t_c$

References: [1]

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

Function Name:	**t_ps_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION T_PH_C5H12_ISO (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

t_ps_C5H12_ISO or T_PS_C5H12_ISO – Temperature t in °C

Range of validity

Temperature range:	from - 160.5 °C to 226.85 °C
Pressure range:	from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

Wet steam region: Pressure ranges from p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **T_PS_C5H12_ISO = –1000 or t_ps_C5H12_ISO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):

- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

Wet steam region (0 ≤ x ≤ 1):

- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Melting Temperature t_{mel} = f(p)

Function Name:	**tmel_p_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION TMEL_P_C5H12_ISO (P)**
for call from Fortran	REAL*8 P

Input values

P - Pressure p in bar

Result

tmel_p_C5H12_ISO or TMEL_P_C5H12_ISO - Melting temperature t_{mel} in °C

Range of validity

Pressure range: from p_{min} = 8.95275 x 10^{-10} bar to 1 x 10^4 bar

Results for wrong input values

Result **TMEL_P_C5H12_ISO = –1000 or tmel_p_C5H12_ISO = –1000** for input values:

Wet steam region (0 ≤ x ≤ 1):

- at $p < p_{min}$ or $p > 1 \times 10^4$ bar

References: [3]

Saturation Temperature t_s = f(p)

Function Name:	**ts_p_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION TS_P_C5H12_ISO (P)**
for call from Fortran	REAL*8 P

Input values

P - Pressure p in bar

Result

ts_t_C5H12_ISO or TS_P_C5H12_ISO - Saturation temperature t_s in °C

Range of validity

Pressure range: from p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **TS_P_C5H12_ISO = –1000 or ts_p_C5H12_ISO = –1000** for input values:

Wet steam region (0 ≤ x ≤ 1):

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

References: [1]

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

Function Name: **u_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION U_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

u_ptx_C5H12_ISO or U_PTX_C5H12_ISO – specific internal energy u in kJ/kg

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **U_PTX_C5H12_ISO = –1000 or u_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

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

Function Name: **v_ptx_C5H12_ISO**

Sub-program with function value: **REAL*8 FUNCTION V_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

v_ptx_C5H12_ISO or V_PTX_C5H12_ISO – specific volume v in m³/kg

Range of validity

Temperature range: from - 160.5 °C to 226.85 °C
Pressure range: from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **V_PTX_C5H12_ISO = –1000 or v_ptx_C5H12_ISO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

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

Function Name:	**w_ptx_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION W_PTX_C5H12_ISO (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 - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

w_ptx_C5H12_ISO or W_PTX_C5H12_ISO – isentropic speed of sound w in m/s

Range of validity

Temperature range:	from - 160.5 °C to 226.85 °C
Pressure range:	from 8.95275 x 10^{-10} bar to 1 x 10^{4} bar

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

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

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

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

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 160.5 °C to t_c = 187.2 °C
	Pressure ranges from	p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **W_PTX_C5H12_ISO = –1000 or w_ptx_C5H12_ISO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):

- at p < 8.95275 x 10^{-10} bar or p > 1 x 10^{4} bar or p > p_{mel} (t)
- at t < - 160.5 °C or t > 226.85 °C or t < t_{mel} (p)

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_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

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

Function Name:	**x_ph_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION X_PH_C5H12_ISO (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

x_ph_C5H12_ISO or X_PH_C5H12_ISO – Vapor fraction x in kg/kg

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

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

Wet steam region: Pressure ranges from p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **X_PH_C5H12_ISO = –1 or x_ph_C5H12_ISO = –1** for input values:

- at x < 0 or x > 1
- at p < p_{min} or p > p_c
- at t < t_{min} or t > t_c

References: [1]

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

Function Name:	**x_ps_C5H12_ISO**
Sub-program with function value:	**REAL*8 FUNCTION X_PH_C5H12_ISO (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

x_ps_C5H12_ISO or X_PS_C5H12_ISO – Vapor fraction x in kg/kg

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

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

Wet steam region: Pressure ranges from p_{min} = 8.95275 x 10^{-10} bar to p_c = 33.7822 bar

Results for wrong input values

Result **X_PS_C5H12_ISO = –1 or x_ps_C5H12_ISO = –1** for input values:

- at x < 0 or x > 1
- at p < p_{min} or p > p_c
- at t < t_{min} or t > t_c

References: [1]

ZITTAU/GOERLITZ UNIVERSITY OF APPLIED SCIENCES
Department of Technical Thermodynamics
www.thermodynamics-zittau.de

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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

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

and of the ideal gases:

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

Consideration of:

Dissociation from VDI 4670 and Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

- Dissociation from the VDI 4670
- Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Formulation 2008 of Feistel and IAPWS-IF97

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

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

Consideration of:

- Dissociation from the VDI Guideline 4670
- Poynting effect

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Library LibIdAir

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButan_Iso

Formulation of Bücker et al. (2003)

n-Butane

Library LibButan_n

Formulation of Bücker et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term

(also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

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

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

Tetradecamethylhexasiloxane $C_{14}H_{42}O_5Si_6$ **Library LibMD4M**

Hexamethyldisiloxane $C_6H_{18}OSi_2$ **Library LibMM**

Formulation of Colonna et al. (2006)

Dodecamethylcyclohexasiloxane $C_{12}H_{36}O_6Si_6$ **Library LibD6**

Decamethyltetrasiloxane $C_{10}H_{30}O_3Si_4$ **Library LibMD2M**

Dodecamethylpentasiloxane $C_{12}H_{36}O_4Si_5$ **Library LibMD3M**

Octamethyltrisiloxane $C_8H_{24}O_2Si_3$ **Library LibMDM**

Formulation of Colonna et al. (2008)

Propane

Library LibPropan

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_5H_{14} **Library LibC5H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**

Carbonyl sulfide **COS** **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monooxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

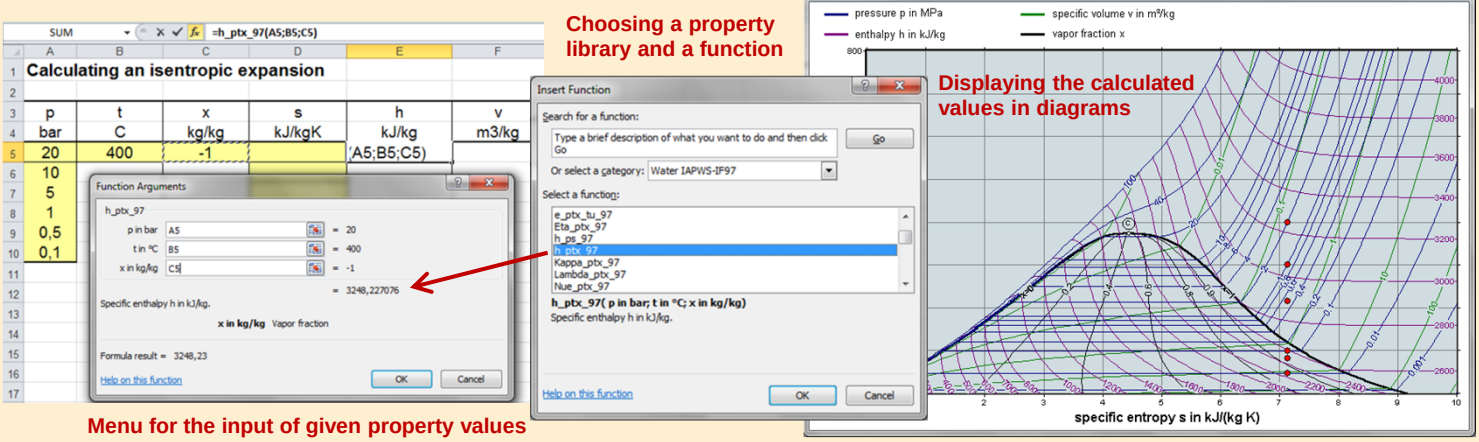
[a] Not all of these property functions are available in all property libraries.

www.thermodynamic-property-libraries.com

ZITTAU/GOERLITZ UNIVERSITY OF APPLIED SCIENCES
Department of Technical Thermodynamics
www.thermodynamics-zittau.de

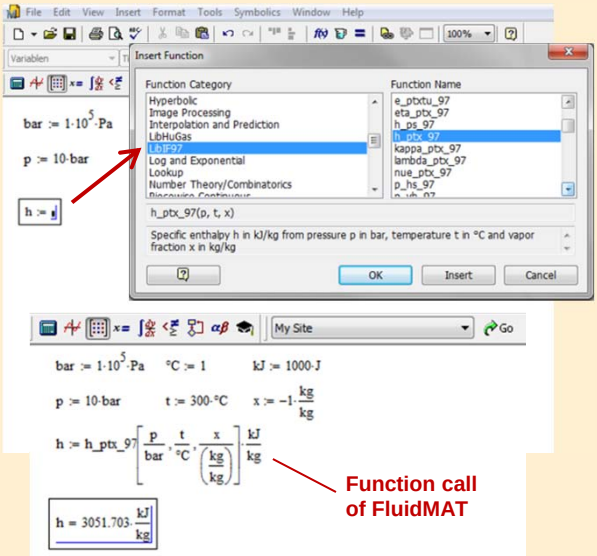
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



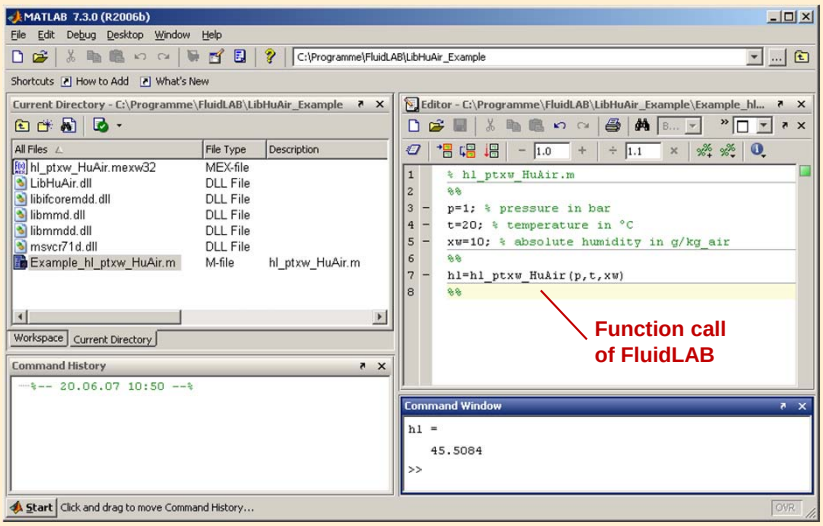
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



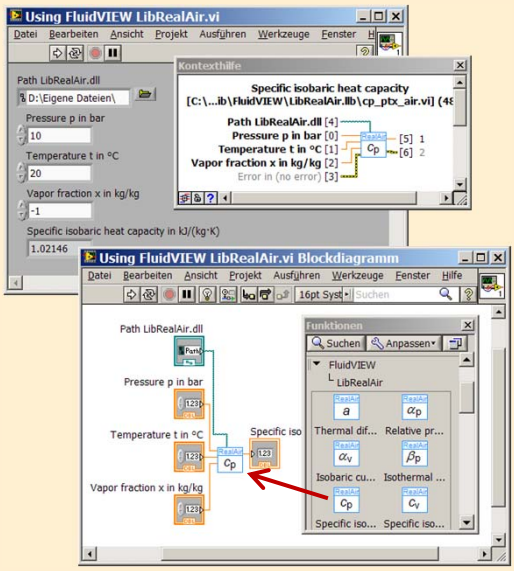
Add-In FluidLAB for MATLAB®

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



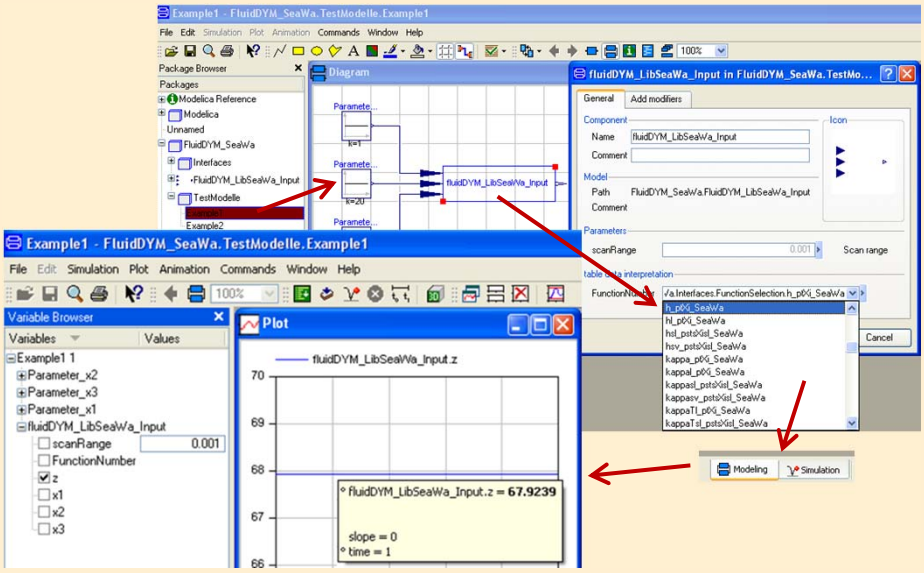
Add-On FluidVIEW for LabVIEW®

The property functions can be calculated in LabVIEW®.

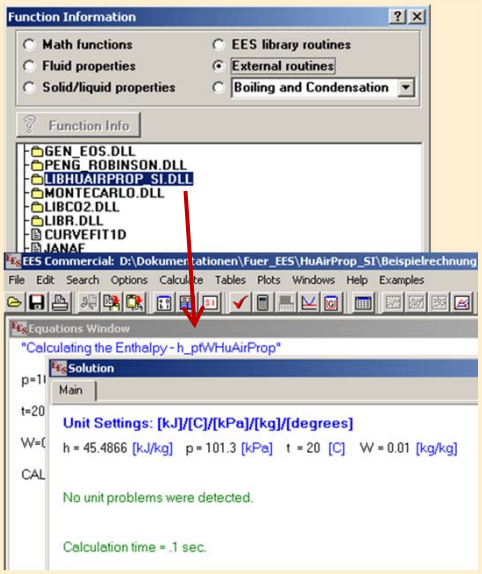


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

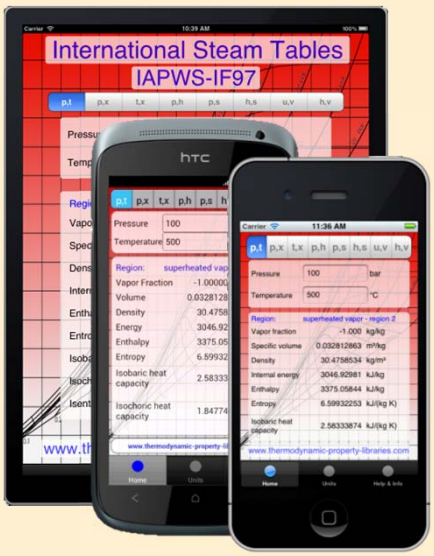
The property functions can be called in DYMOLA® and SimulationX®



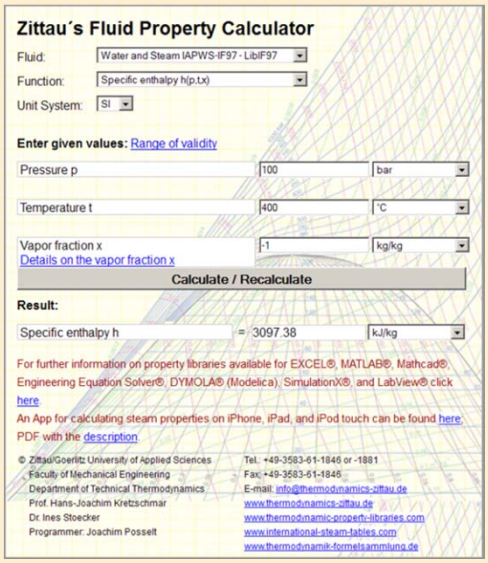
Add-In FluidEES for Engineering Equation Solver®



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



Online Property Calculator at www.thermodynamics-zittau.de



Property Software for Pocket Calculators

FluidCasio

fx 9750 G II

CFX 9850
fx-GG20

CFX 9860 G
Graph 85

ALGEBRA
FX 2.0

FluidHP

HP 48

HP 49

FluidTI

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

For more information please contact:

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

The following thermodynamic and transport properties[a] can be calculated in Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® EES, DYMOLA® (Modelica), SimulationX®, and LabVIEW®:

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

www.thermodynamic-property-libraries.com

5. References

[1] E.W. Lemmon, R.Span:
Short Fundamental Equation of State for 20 Industrial Fluids
J.Chem.Eng.Data, 51, p.785.850,2006

[2] J.J. Jasper:
The Surface Tension of Pure Liquid Compounds
J. Phys. Chem. Ref. Data, 1(4):841-1009, 1972

[3] L.E. Reeves, G.J. Scott, S.E.Jr Babb:
Melting curves of pressure-transmitting fluids
J. Chem. Phys., 40(12):3662-6, 1964

[4] A.H.Harvey, E.W.Lemmon:
Method for Estimating the Dielectric Constant of Natural Gas Mixtures
Int. J. Thermophys., Vol. 26, 31-46,2005

[5] E.W. Lemmon:
Personal Communication with E.W. Lemmon, 2012

6. Satisfied Customers

Date: 10/2011

The following companies and institutions use the property libraries

- FluidEXL*Graphics* for Excel®
- FluidLAB for MATLAB®
- FluidMAT for Mathcad®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica)
- FluidVIEW for LabVIEW®:

2011

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SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
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VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
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Bayernwerk, Munich	01/1999
DREWAG, Dresden (company license)	02/1999
KEMA IEV, Dresden	03/1999
Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
Technical University of Cottbus, Chair in Power Plant Engineering	07/1999
Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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SCA Hygiene Products, Munich	10/1998
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Gerb, Dresden	06/1997
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