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Property Library for N-Butane

FluidEXL*Graphics* with LibButane_n for Excel®

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Software for the Calculation of the Properties of N-Butane

LibButane_n

FluidEXL*Graphics*

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0. Package Contents

0.1 Zip files for 32-bit Windows®

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

English zip file "CD_FluidEXL_Graphics_LibButan_n_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*
LibButan_n.dll	- Dynamic Link Library for use in Windows programs
LibButan_n.hlp	- Help file for the LibButane_n property library
FluidEXL_Graphics_LibButan_n_Docu_Eng.pdf	- User's Guide

German zip file "CD_FluidEXL_Graphics_LibButan_n.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*
LibButan_n.dll	- Dynamic Link Library for use in Windows programs
LibButan_n.hlp	- Help file for the LibButane_n property library
FluidEXL_Graphics_LibButan_n_Docu_Eng.pdf	- User's Guide

0.2 Zip files for 64-bit Windows®

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

English zip file "CD_FluidEXL_Graphics_LibButan_n_x64_Eng.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibButan_n_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
LibButan_n.dll	- Dynamic link library for use in Windows® programs

LibButan_n.hlp	- Help file for the LibButane_n 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_LibButan_n_x64.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibButan_n_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
LibButan_n.dll	- Dynamic link library for use in Windows® programs
LibButan_n.hlp	- Help file for the LibButane_n 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	Call in DLL LibButan_n as parameter	Property or Function	Unit of the result
$a = f(p,t,x)$	a_ptx_BUTN	APTXBUTN(P,T,X)	C_APTXBUTN(A,P,T,X)	Thermal diffusivity	m^2/s
$c_p = f(p,t,x)$	cp_ptx_BUTN	CPPTXBUTN(P,T,X)	C_CPPTXBUTN(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$\eta = f(p,t,x)$	eta_ptx_BUTN	ETAPTXBUTN(P,T,X)	C_ETAPTXBUTN(ETA,P,T,X)	Dynamic viscosity	Pa s
$h = f(p,t,x)$	h_ptx_BUTN	HPTXBUTN(P,T,X)	C_HPTXBUTN(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_BUTN	KAPTXBUTN(P,T,X)	C_KAPTXBUTN(KAP,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lambda_ptx_BUTN	LAMPTXBUTN(P,T,X)	C_LAMPTXBUTN(LAM,P,T,X)	Thermal conductivity	W/(m K)
$\nu = f(p,t,x)$	ny_ptx_BUTN	NYPTXBUTN(P,T,X)	C_NYPTXBUTN(NY,P,T,X)	Kinematic viscosity	m^2/s
$p_{mel} = f(t)$	pmel_t_BUTN	PMELBUTN(T)	C_PMELBUTN(PMEL,T)	Melting pressure from temperature	bar
$p_s = f(t)$	ps_t_BUTN	PSTBUTN(T)	C_PSTBUTN(PS,T)	Vapor pressure from temperature	bar
$Pr = f(p,t,x)$	Pr_ptx_BUTN	PRPTXBUTN(P,T,X)	C_PRPTXBUTN(PR,P,T,X)	*Prandtl*-Number	-
$\rho = f(p,t,x)$	rho_ptx_BUTN	ROPTXBUTN(P,T,X)	C_ROPTXBUTN(RHO,P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_BUTN	SPTXBUTN(P,T,X)	C_SPTXBUTN(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_BUTN	TPHBUTN(P,H)	C_TPHBUTN(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_BUTN	TPSBUTN(P,S)	C_TPSBUTN(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_{mel} = f(p)$	tmel_p_BUTN	TMELBUTN(P)	C_TMELBUTN(TMEL,P)	Melting temperature from pressure	°C
$t_s = f(p)$	ts_p_BUTN	TSPBUTN(P)	C_TSPBUTN(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_BUTN	UPTXBUTN(P,T,X)	C_UPTXBUTN(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_BUTN	VPTXBUTN(P,T,X)	C_VPTXBUTN(V,P,T,X)	Specific volume	m^3/kg
$w = f(p,t,x)$	w_ptx_BUTN	WPTXBUTN(P,T,X)	C_WPTXBUTN(W,P,T,X)	Isentropic speed of sound	m/s
$x = f(p,h)$	x_ph_BUTN	XPHBUTN(P,H)	C_XPHBUTN(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	x_ps_BUTN	XPSBUTN(P,S)	C_XPSBUTN(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg

Units:

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

Range of validity

Temperature range: from $t_{mel}(p)$ to 301.85 °C
Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Reference state

h = 200 kJ/kg and s = 1 kJ/(kg K) at t = 0 °C on the boiling curve (x = 0)

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

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

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

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

When calculating wet steam either the given value for t <u>and</u> p = -1000 or the given value for p <u>and</u> t = -1000 and in both cases the value for x between 0 and 1 must be entered.

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

If it is not true, the calculated result will be –1000.

Wet steam region: Temperature range from t_t = –138.255 °C to t_c = 151.975 °C
Pressure range from $p_t = 6.53 \times 10^{-6}$ bar to 37.96 bar

Hint!

If the input values are located outside the range of validity, the result for the calculated function will always be –1000. Please find more exact details on every function and its corresponding range of validity in the enclosed program 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 n butane from the LibButane_n 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 LibButane_n library. In this case, follow the subsection "Adding the LibButane_n Library" on page 2/11.

Installing FluidEXL*Graphics* for 32-bit Windows®

In this section, the installation of FluidEXL*Graphics* for a 32-bit Windows® version is described.

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_LibButan_n_Eng.zip"	(for English version of Windows)
"CD_FluidEXL_Graphics_LibButan_n.zip"	(for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibButan_n_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibButan_n	(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_LibButan_n_Docu_Eng.pdf	
LibButan_n.dll	
LibButan_n.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 "Next >" 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 2.1).

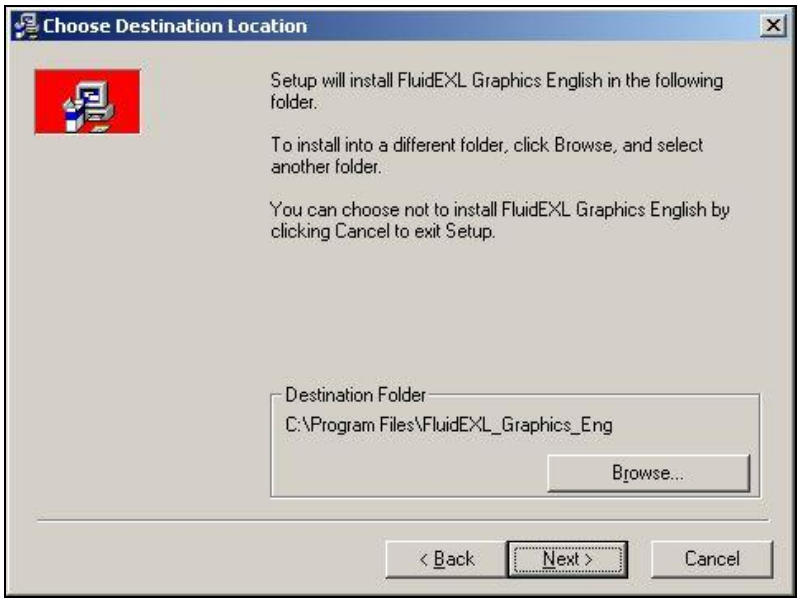


Figure 2.1: Choose Destination Location

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.

Close the "Control Panel" window. The installation of FluidEXL*Graphics* has been completed.

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)
LibButan_n.dll	
LibButan_n.hlp	

from the extracted folder

CD_FluidEXL_Graphics_LibButan_n_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibButan_n (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 Explorer or Norton Commander.

Installing FluidEXL*Graphics* for 64-bit Windows®

In this section, the installation of FluidEXL*Graphics* for a 64-bit Windows® version is described.

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

After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibButan_n_x64_Eng.zip" (for Englisch version of Windows)
"CD_FluidEXL_Graphics_LibButan_n_x64.zip," (for German version of Windows

you will see the folder

"CD_FluidEXL_Graphics_LibButan_n_Eng" (for English version of Windows)
"CD_FluidEXL_Graphics_LibButan_n" (for German version of Windows)

in your Windows Explorer®, Norton Commander®, or any other similar program you may be using.

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

Within this folder you will see the following files

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

and the folders

vcredist_x64
WindowsInstaller3_1.

In order to run the installation of FluidEXL*Graphics*, double-click on 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 2.2).

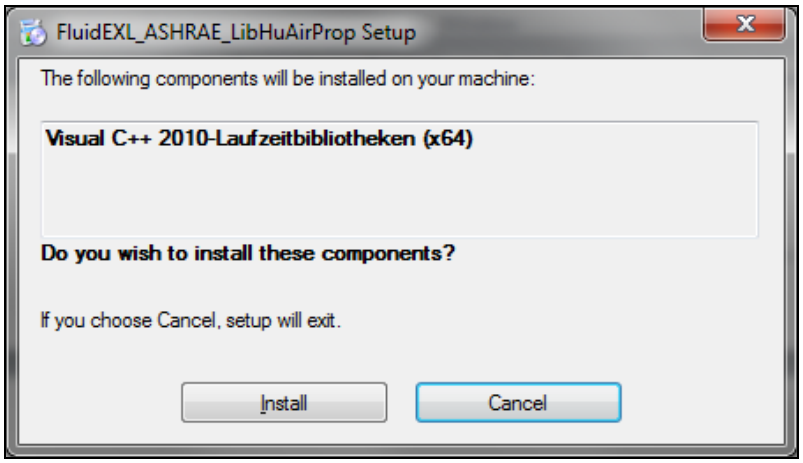


Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

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 2.3).

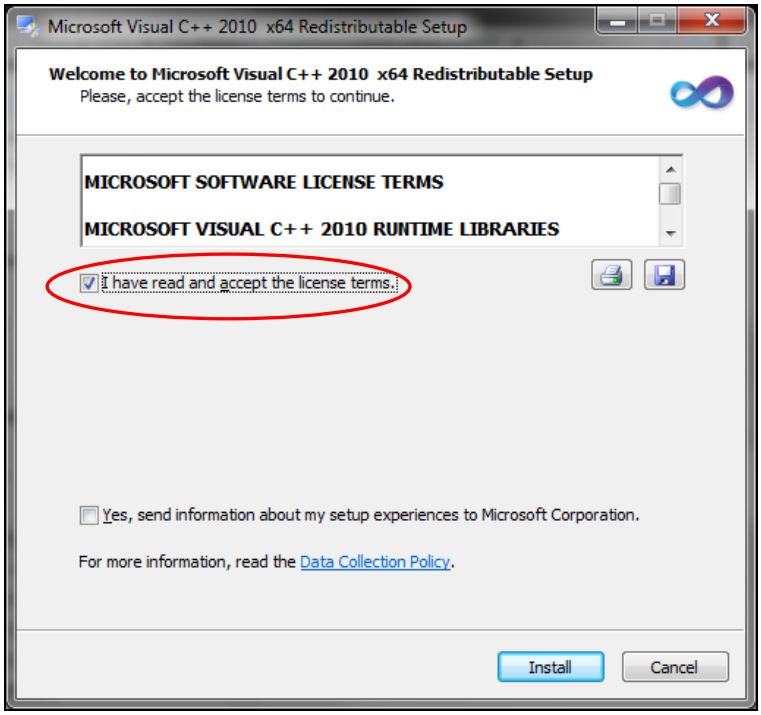


Figure 2.3: Accepting the license terms

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* 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).

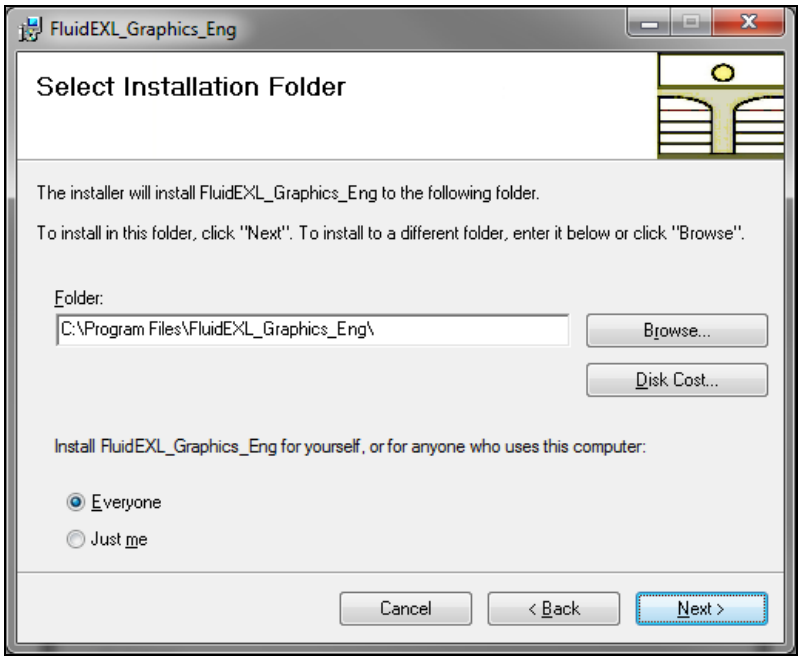


Figure 2.4: Choosing the installation folder

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.
The installation of FluidEXL*Graphics* has been completed.

During the installation process the following files

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

will have been copied into the destination folder chosen, the standard being

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

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)
LibButan_n.dll
LibButan_n.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 on "Add-Ins..." in the menu.

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

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 the next figure.

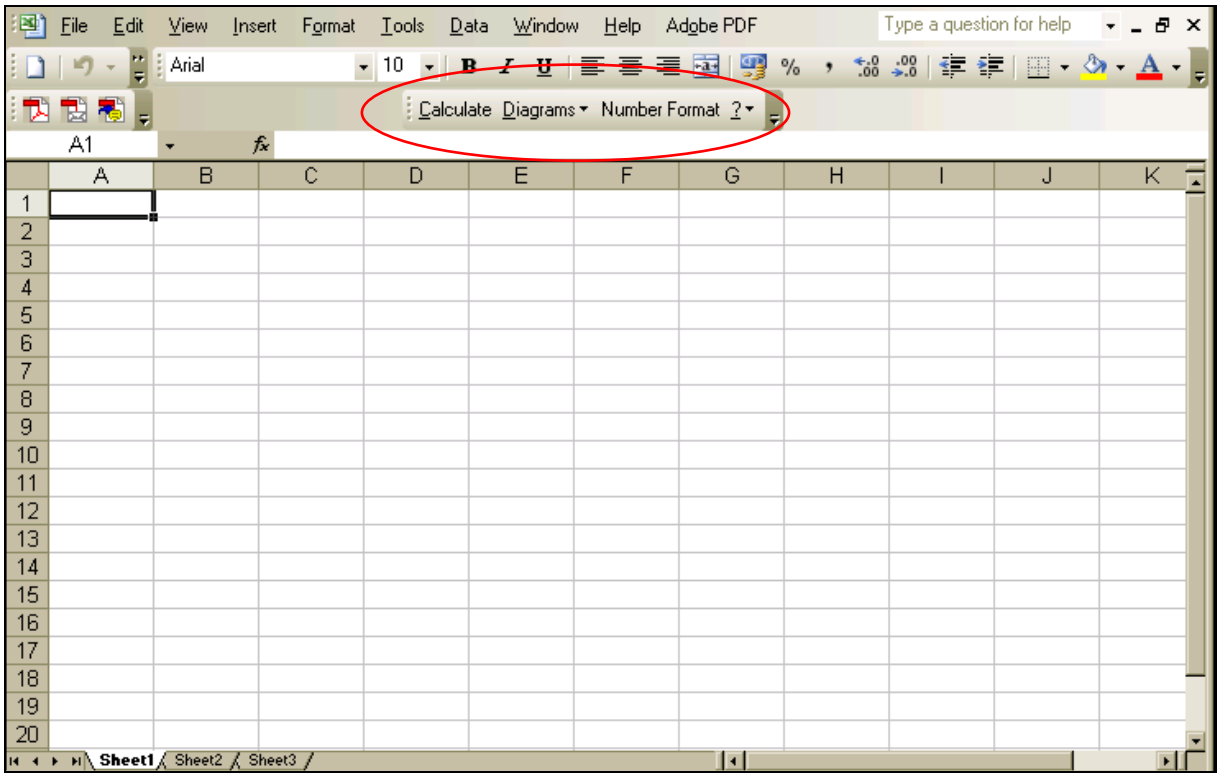


Figure 2.5: Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "N_Butane LibButane_N" library property functions via this menu bar (see section 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® 2007 as an Add-In. For 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 below)

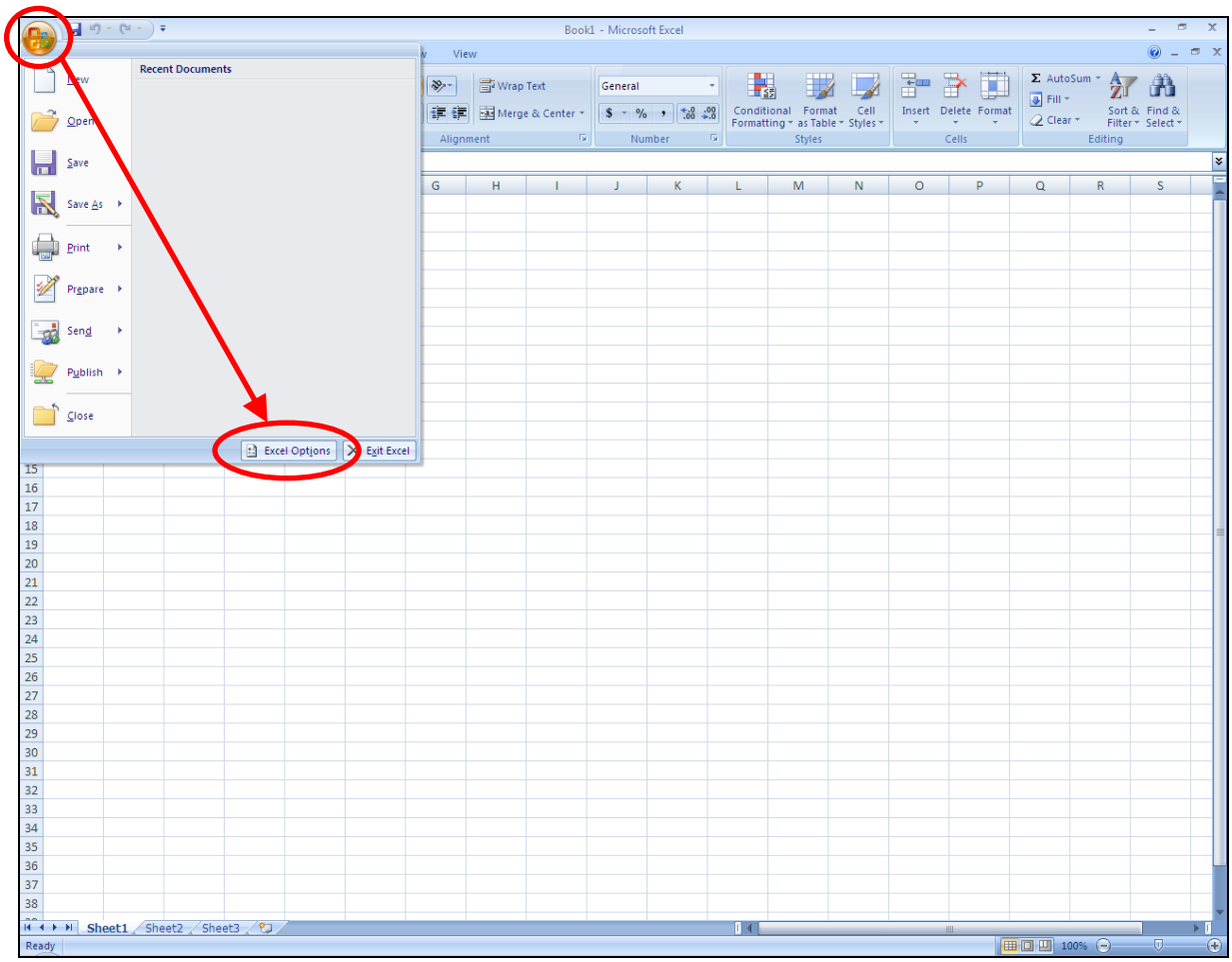


Figure 2.6: Registering FluidEXL*Graphics* as Add-In in Excel® 2007

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

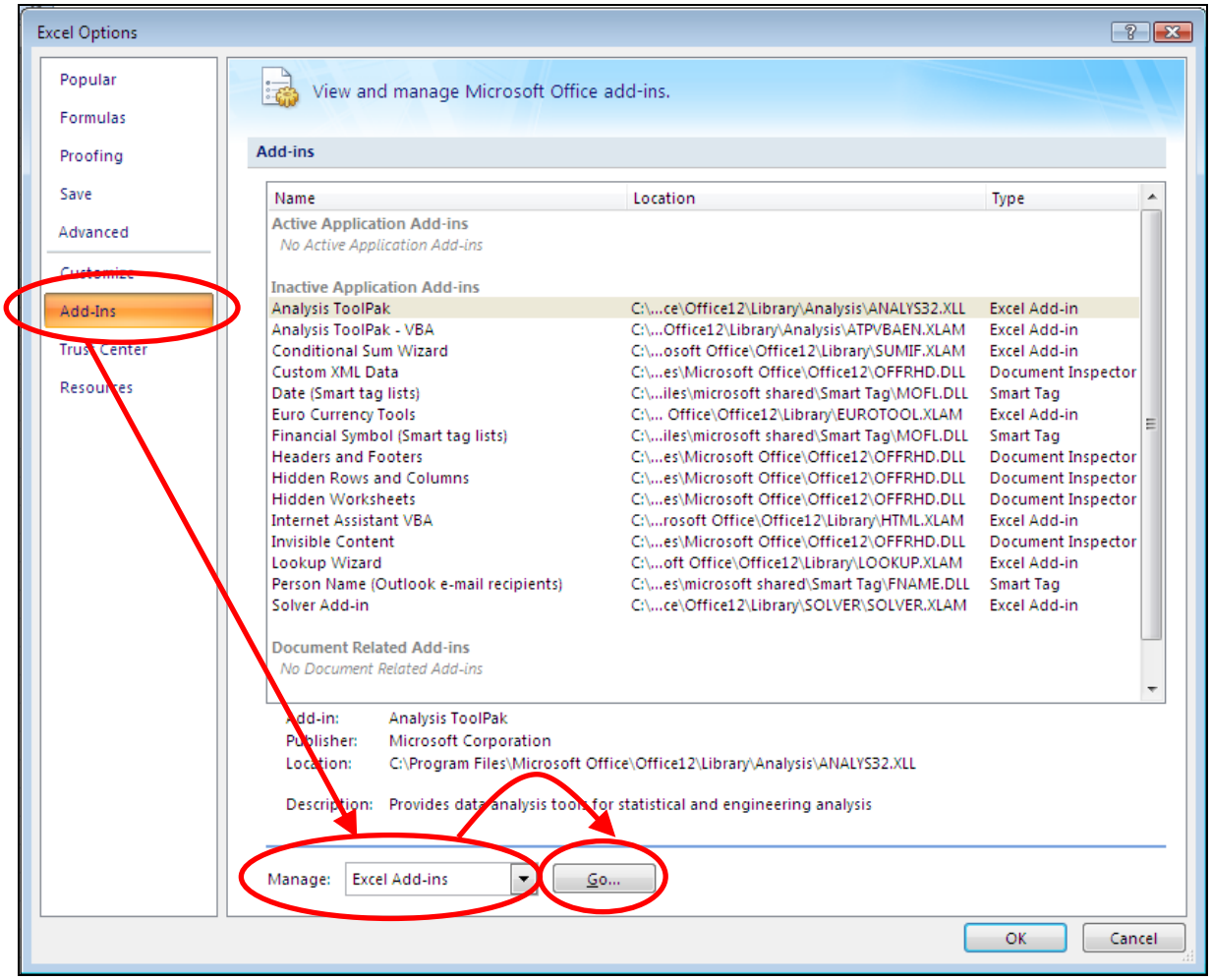


Figure 2.7: Dialog window "Add-Ins"

- 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."

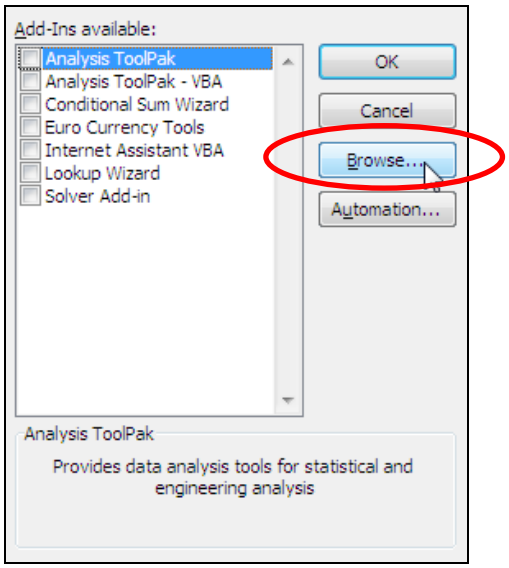


Figure 2.8: Dialog window "Add-Ins available"

- 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", 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.)

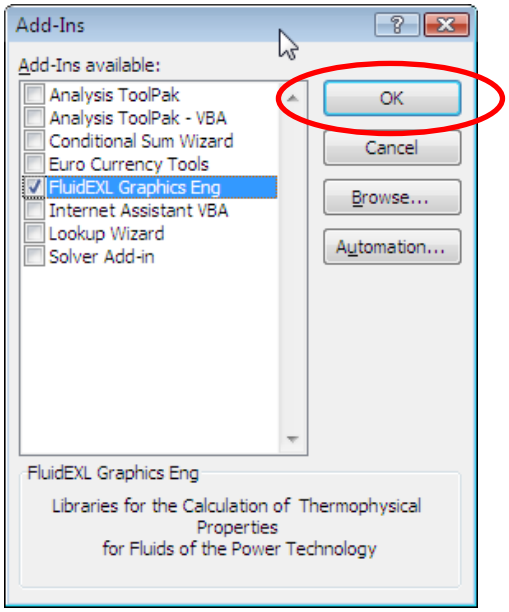


Figure 2.9: Dialog window "Add-Ins"

- 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 the next figure.

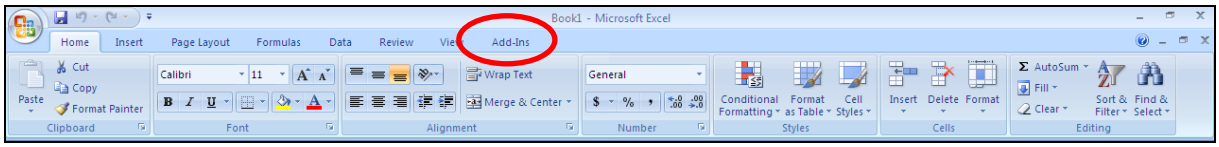


Figure 2.10: Menu item "Add-Ins"

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

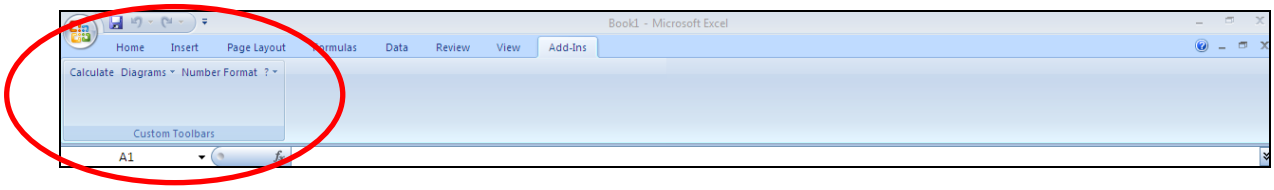


Figure 2.11: FluidEXL*Graphics* menu bar

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 library LibButane_n

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)
LibButan_n.dll	
LibButan_n.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibButan_n_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibButan_n	(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 "n_Butane LibButane_n" library property functions via this menu bar (see section 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.
- Select the "N_Butane LibButane_N" library under "Or select a category:" in the "Insert Function" window which will appear.
- Click the "Help on this function" link 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 "LibButan_n.hlp" cannot be found, you will be asked whether you want to look for it yourself – answer with "Yes." Click on the "LibButan_n.hlp" file in the installation menu of FluidEXLGraphics in the window which is opened, the standard being

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

and click "OK" 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).

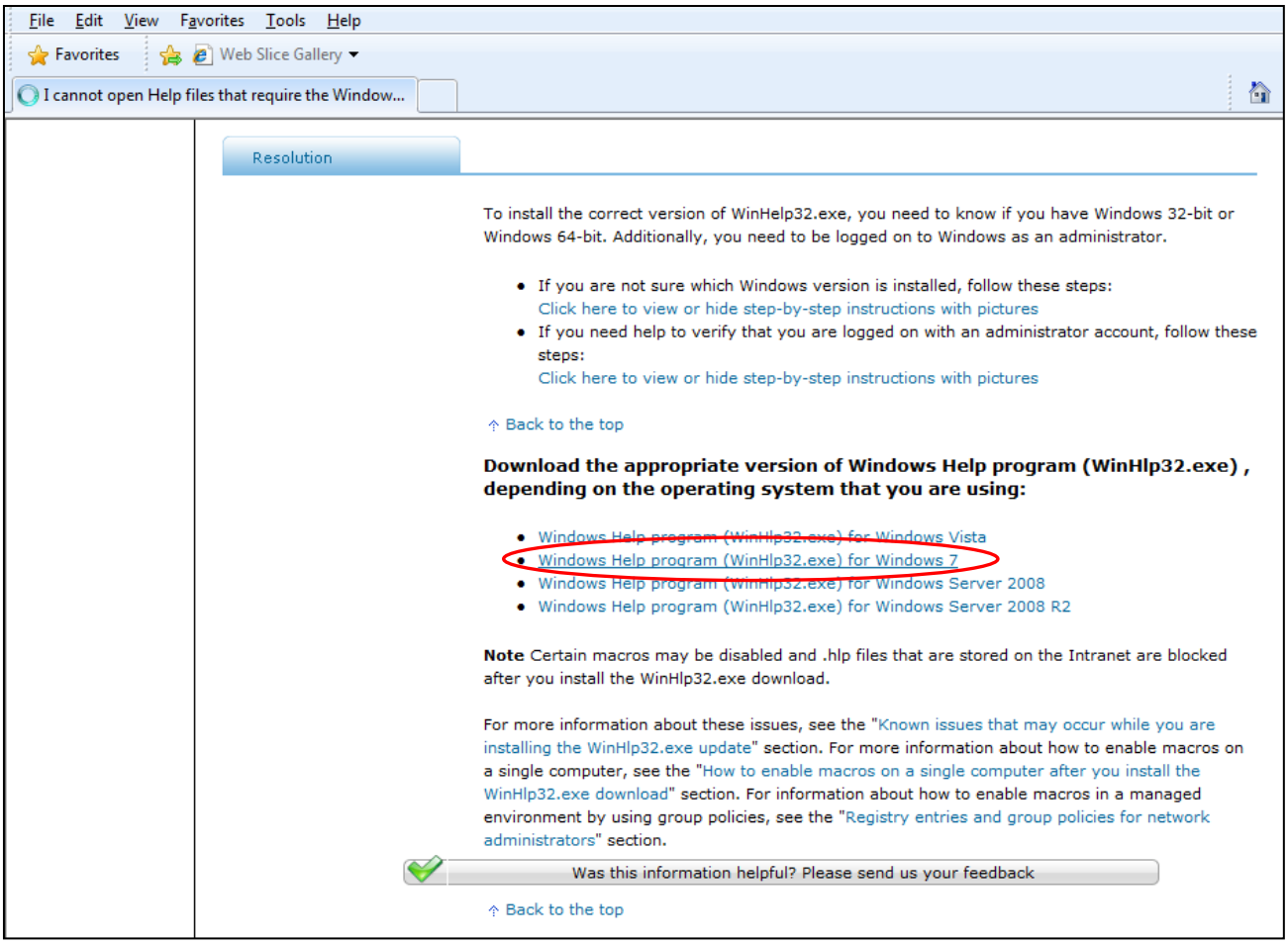


Figure 2.13: Selecting your Windows version

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).

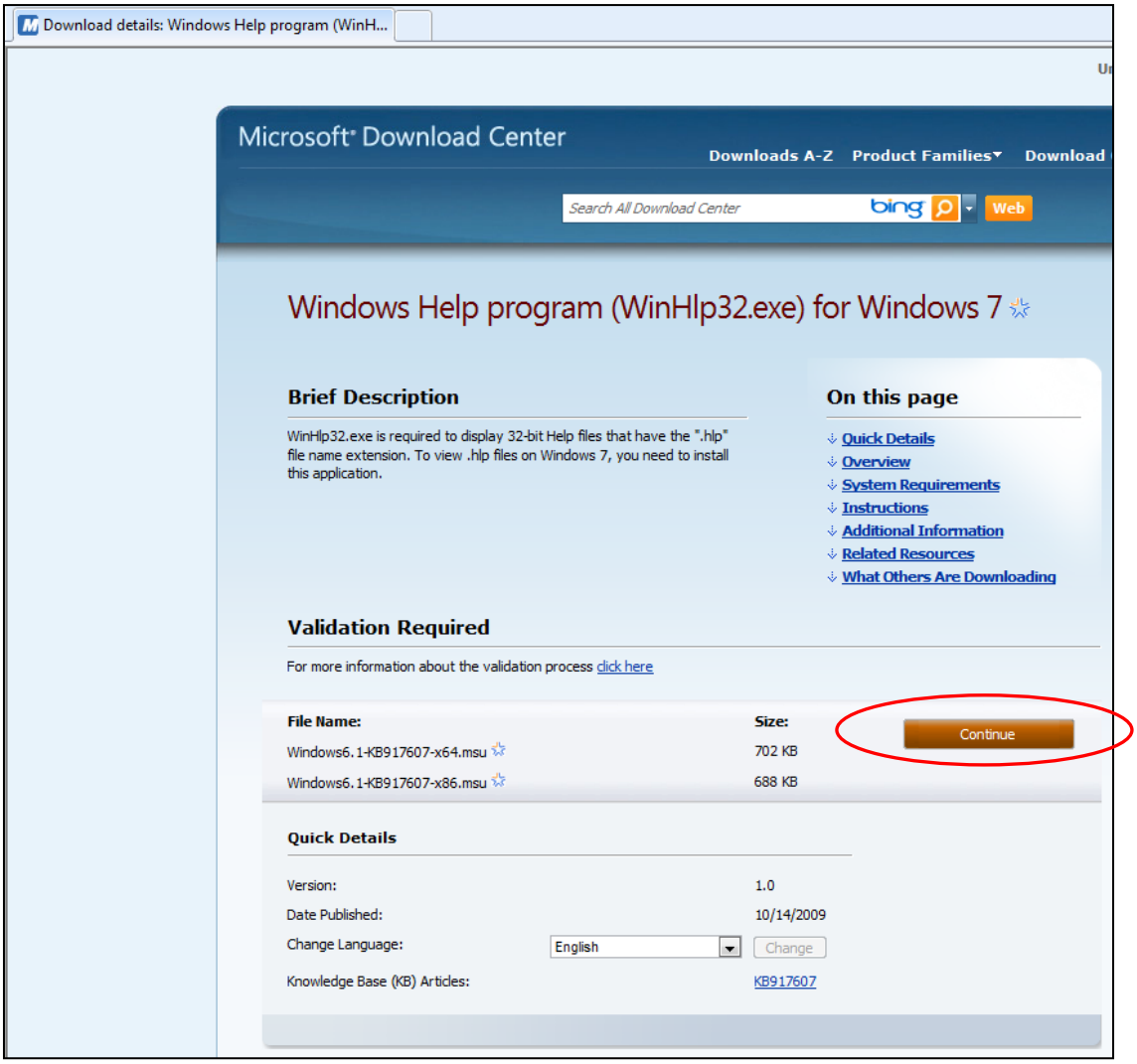


Figure 2.14: Microsoft® Download Center

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).

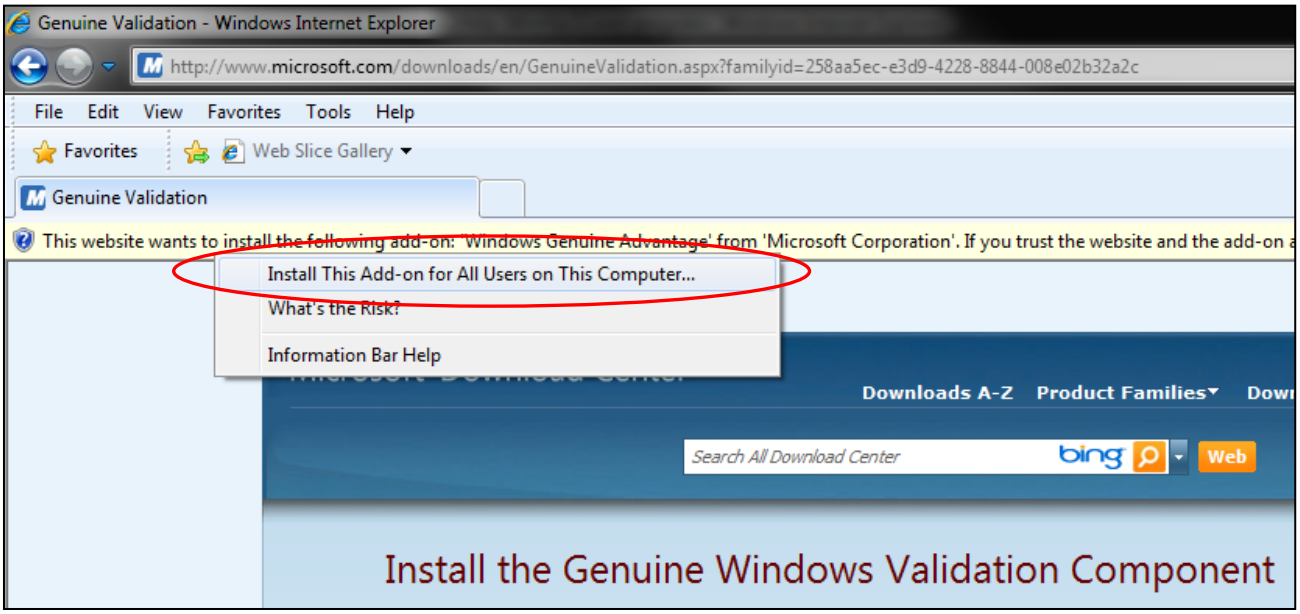


Figure 2.15: Installing the Genuine Windows Validation Component

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).

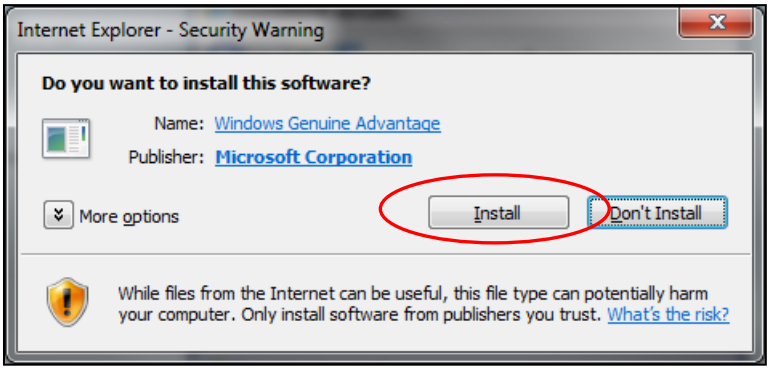


Figure 2.16: Internet Explorer – Security Warning

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

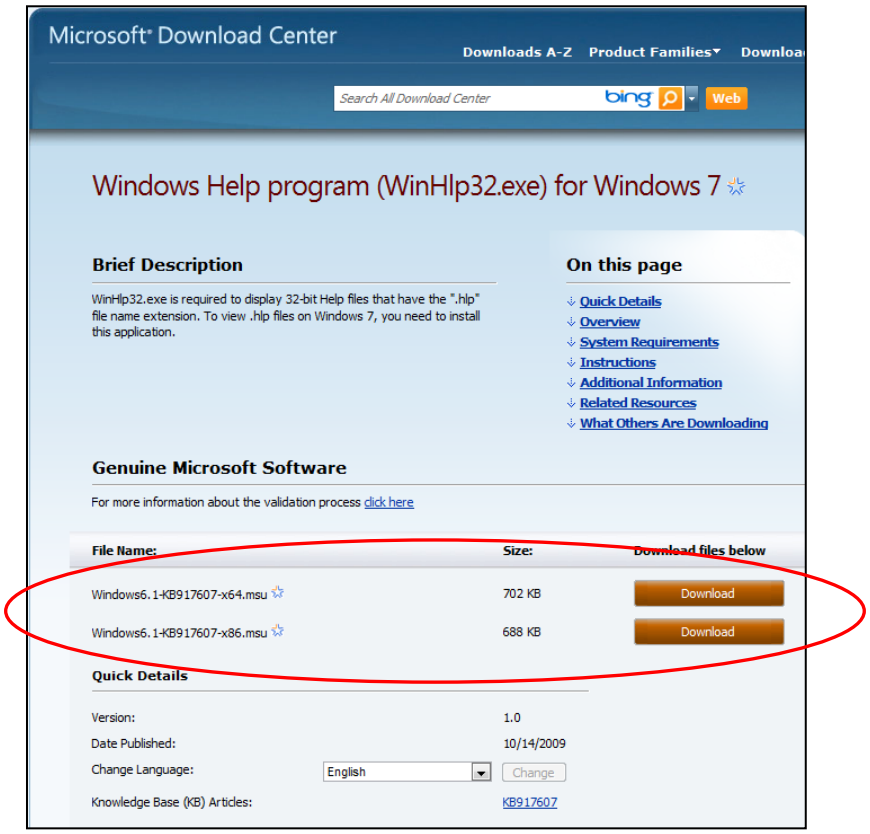


Figure 2.17: Downloading the Windows Help program

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.

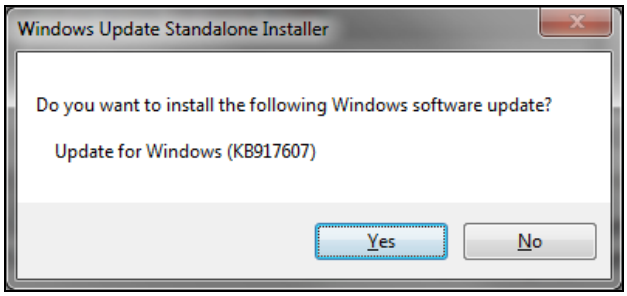


Figure 2.18: Windows Update Standalone Installer

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)

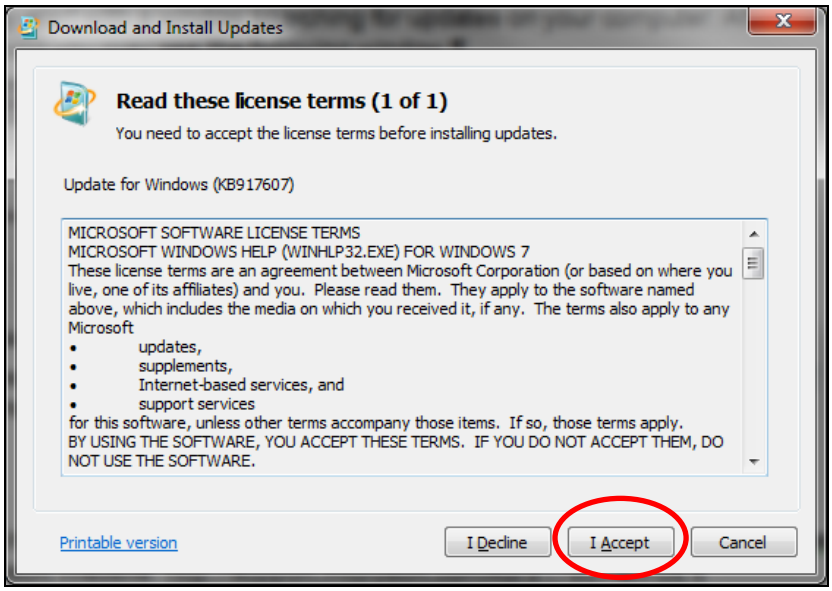


Figure 2.19: Windows License Terms

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

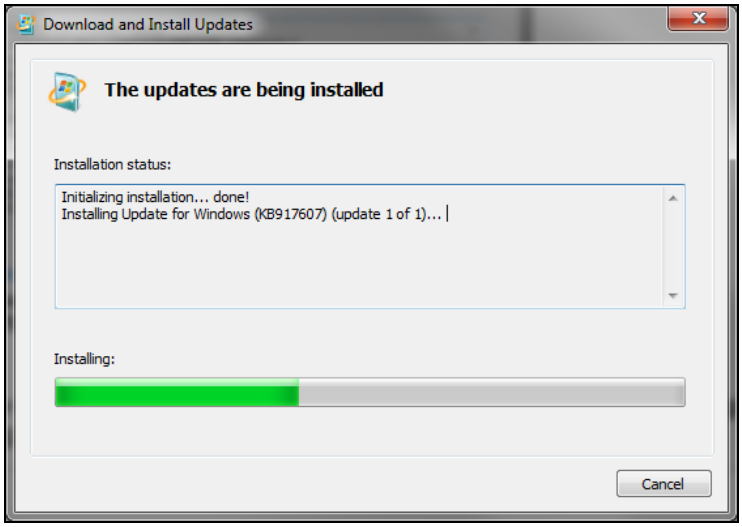


Figure 2.20: Installation process

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 LibButane_N 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).

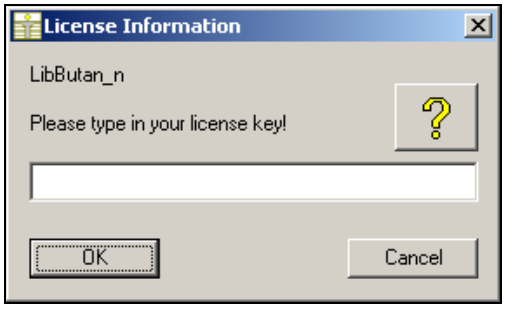


Figure 2.21: "License Information" window

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:

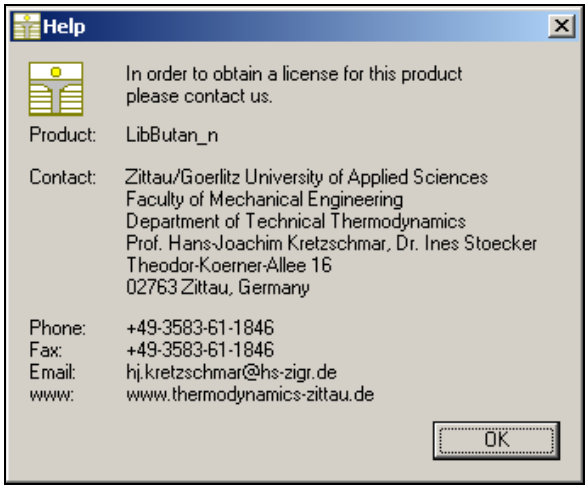


Figure 2.22: "Help" window

If you do not enter a valid license it is still possible to start Excel by clicking "Cancel" twice. In this case, the LibButane_n 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 LibButane_n property library, you have to delete the files

LibButan_n.dll
LibButan_n.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*. Please carry out the following steps:

- Enter the value for *p* in bar in a cell
  (Range of validity: p_t = 6.53 x 10^{-6} bar … 690 bar)

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

- Enter the value for *t* in °C in a cell
  (Range of validity: $t = t_{mel}(p)$ … 301.85 °C)

  ⇒ e. g.: Enter the value 25 into cell B2

- Enter the value for *x* in kg saturated steam/kg wet steam into 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:

  <u>Single-phase region</u>

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

  <u>Wet-steam region</u>

  When calculating wet steam, a value between 0 and 1 (x = 0 for boiling liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for *x*. It is adequate to enter either the given value for *t* <u>and</u> p = –1000, or the given value for *p* <u>and</u> t = –1000, plus the value for *x* between 0 and 1. When 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 saturation-pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1000.

  (Saturation line of n-Butane: t_t = –138.255 °C ... t_c = 151.975 °C
  p_t = 6.53 x 10^{-6} bar … p_c = 37.96 bar)

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

- Click the cell into which the calculated enthalpy *h* in kJ/kg should be entered

  ⇒ e.g.: Click cell D2

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

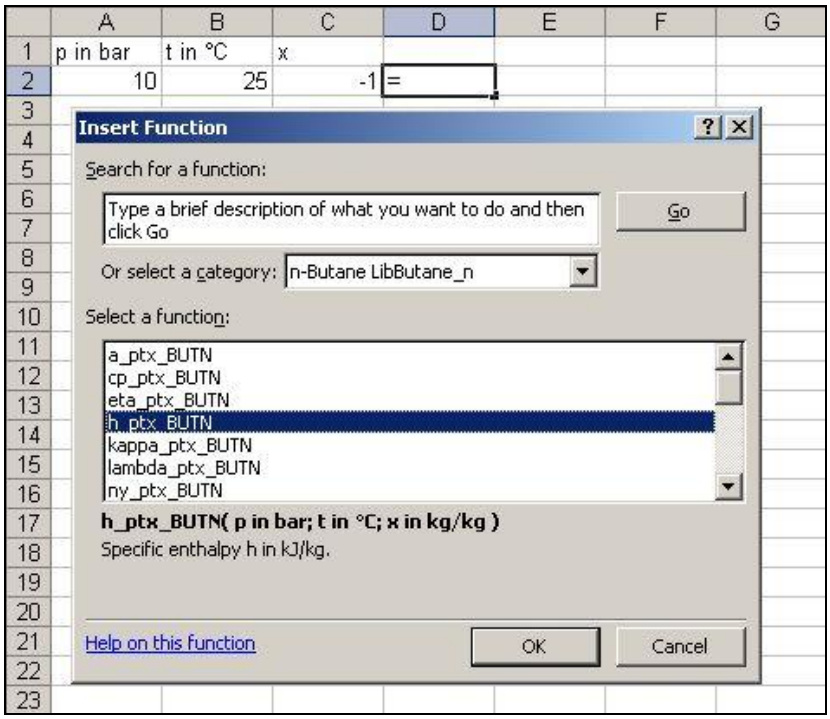


Figure 2.23: Selecting library and function

- Search and click the "n-Butane LibButane_n" library in the upper list box next to "Or select a category:"
- Search and click the "h_ptx_BUTN" function in the lower list box under "Select a function:".

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

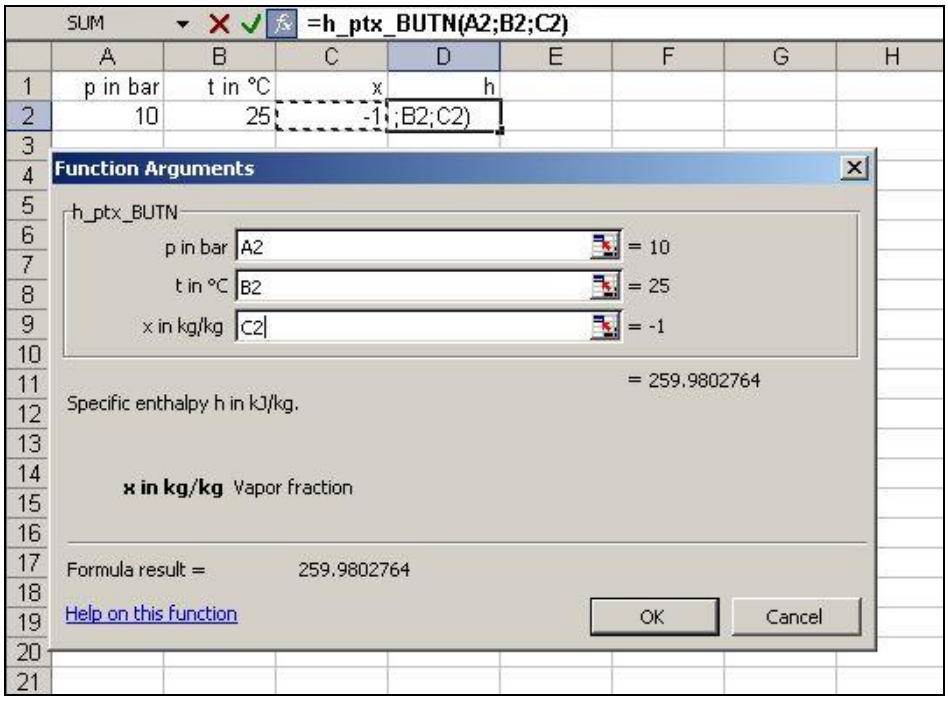


Figure 2.24: Entering the given values for the property calculation

- The cursor is 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.
- 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.
- 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.
- Click the "OK" button.

The result for *h* in kJ/kg appears in the cell selected above.

⇒ The result in our sample calculation here is: h = 259.980276361451 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. The enthalpy is recalculated and updated every time you change the data. 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 of LibButane_n. More detailed information on each function and its range of validity is available in Chapter 3.

For further property functions calculable in FluidEXL*Graphics*, please see the function table in Chapter 1.

Number Formats

When using FluidEXL*Graphics* you have the option of choosing special number formats in advance.
Changes can be made as follows:

- Click the cell or select and click on the cells you wish to format.
  (In empty cells the new format will be applied once a value has been entered.)
- Click "Number Format" in the FluidEXL*Graphics* menu bar.
- Select the desired number format in the dialog box which appears:

"STD – Standard":	Insignificant zeros behind the decimal point are not shown.
"FIX – Fixed Number of Digits":	All set decimal places are shown, including insignificant zeros.
"SCI – Scientific Format":	Numbers are always shown in the exponential form with the set number of decimal places.

- Set the "Number of decimal places" by entering the number into the appropriate window.
- Confirm this by clicking the "OK" button.

As an example, the table below shows the three formats for the number 1.230 adjusted for three decimal places:

STD	1.23
FIX	1.230
SCI	1.230E+00

This formatting can also be applied to cells which have already been calculated.

2.6 Removing FluidEXL*Graphics*

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

LibButan_n.dll

LibButan_n.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.

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

LibButan_n.dll

LibButan_n.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

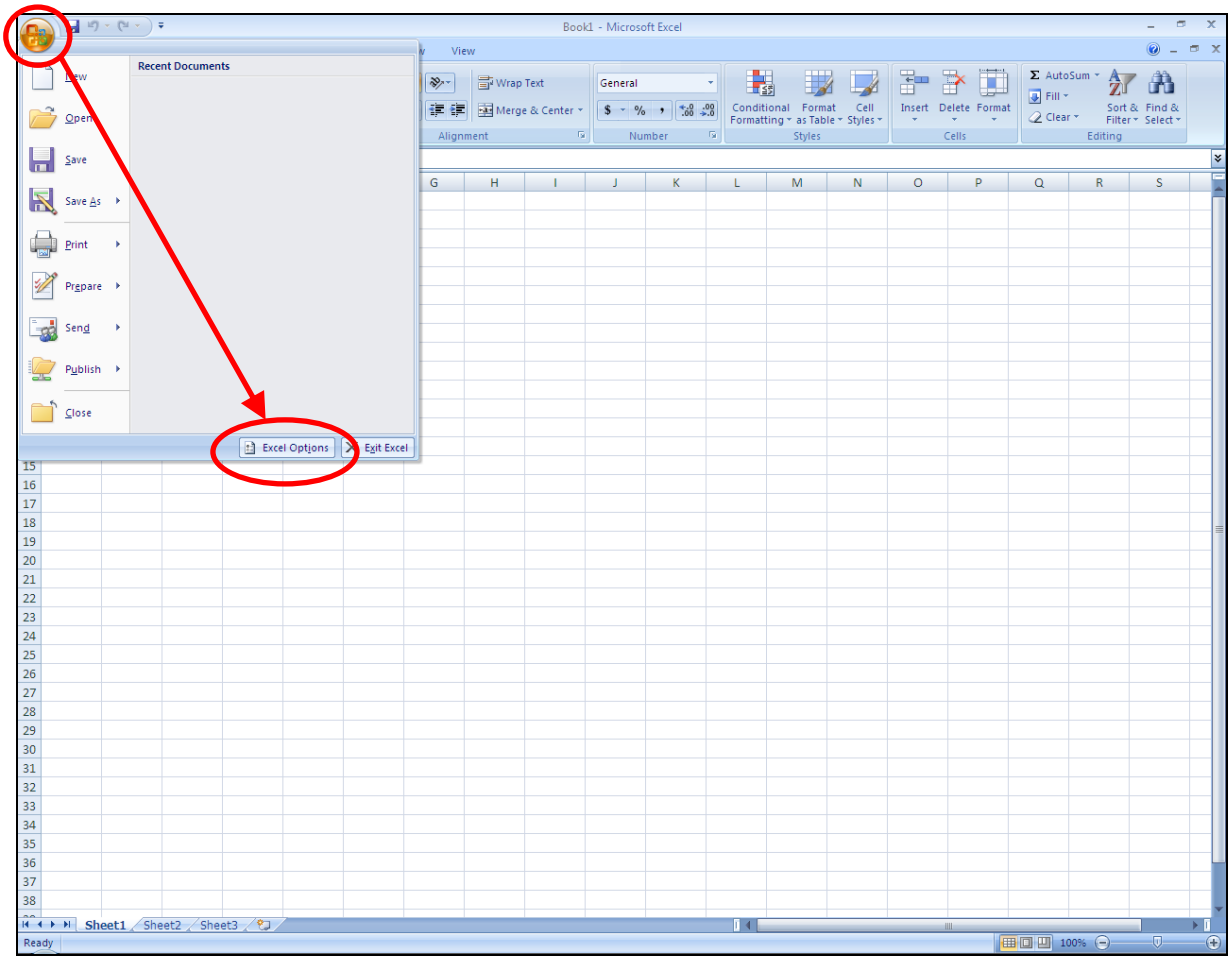


Figure 2.25: Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007

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

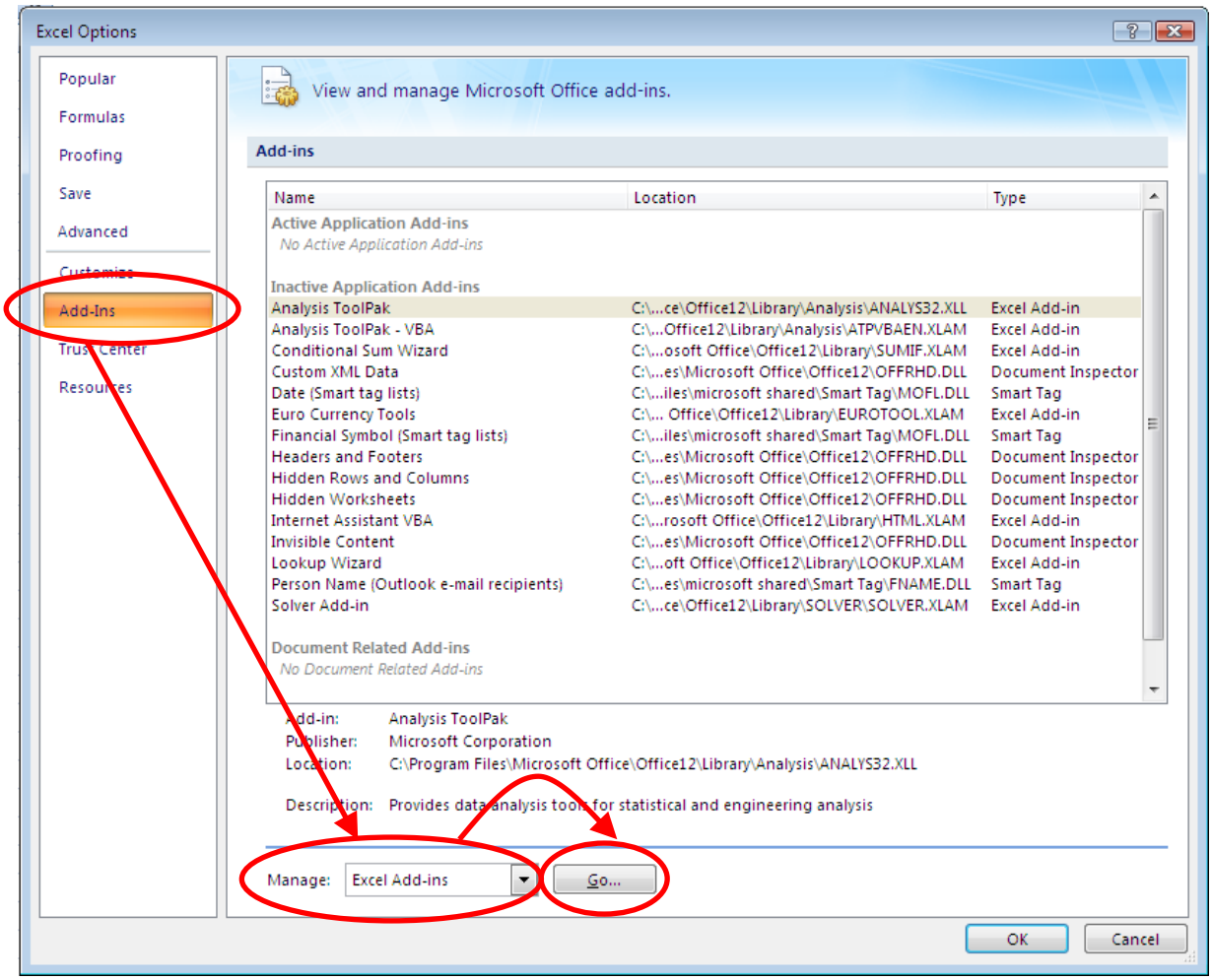


Figure 2.26: Dialog window "Add-Ins"

- 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.

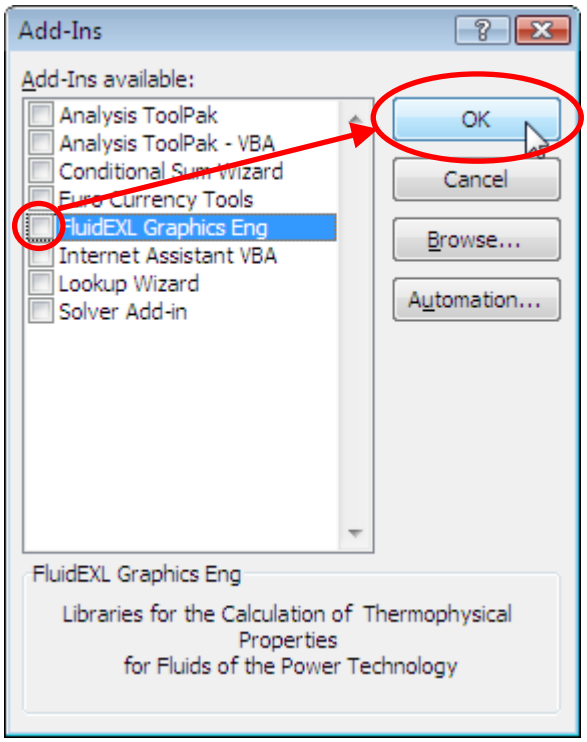


Figure 2.27: Dialog window "Add-Ins"

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_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION APTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_APTXBUTN(A,P,T,X)** REAL*8 A,P,T,X

Input Values:

P – Pressure *p* in bar

T - Temperature *t* in °C

X – Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

APTXBUTN, **A** or **a_ptx_BUTN** – Thermal diffusivity $a = \frac{\lambda * v}{c_p}$ in m^2 / s

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from $p_t = 6.53 \times 10^{-6}$ bar to p_c = 37.96 bar)

Results for wrong input values

Result **APTXBUTN = –1000**, **A = –1000** or **a_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [24], [25]

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

Function Name:	**cp_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION CPPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CPPTXBUTN(CP,P,T,X)** REAL*8 CP,P,T,X

Input Values:

P – Pressure p in bar

T - Temperature t in °C

X – Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

CPTXBUTN, **CP** or **cp_ptx_BUTN** – Specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **CPPTXBUTN = –1000**, **CP = –1000** or **cp_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Dynamic Viscosity η = f(p,t,x)

Function Name:	**eta_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION ETAPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ETAPTXBUTN(ETA,P,T,X)** REAL*8 ETA,P,T,X

Input Values:

P – Pressure p in bar

T - Temperature t in °C

X – Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

ETAPTXBUTN, **ETA** or **eta_ptx_BUTN** – Dynamic viscosity η in Pa s

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **ETAPTXBUTN= –1000**, **ETA = –1000** or **eta_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [23], [25]

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

Function Name:	**h_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION HPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_HPTXBUTN(H,P,T,X)** REAL*8 H,P,T,X

Input Values:

P – Pressure *p* in bar

T - Temperature *t* in °C

X – Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

HPTXBUTN, **H** or **h_ptx_BUTN** - Specific enthalpy *h* in kJ/kg

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

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

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

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

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

When calculating wet steam either the given value for *t* <u>and</u> p = -1000 or the given value for *p* <u>and</u> t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

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

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **HPTXBUTN = –1000**, **H = –1000** or **h_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Isentropic Exponent κ = f(p,t,x)

Function Name:	**kappa_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION KAPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_KAPTXBUTN(KAP,P,T,X)** REAL*8 KAP,P,T,X

Input Values:

P – Pressure p in bar

T - Temperature t in °C

X – Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

KAPPTXBUTN, **KAP** or **kappa_ptx_BUTN** – Isentropic exponent $\kappa = \dfrac{w^2}{p^*v}$

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **KAPTXBUTN**, **KAP = –1000** or **kappa_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Thermal Conductivity λ = f(p,t,x)

Function Name:	**lambda_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION LAMPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_LAMPTXBUTN(LAM,P,T,X)** REAL*8 LAM,P,T,X

Input Values:

P – Pressure p in bar

T - Temperature t in °C

X – Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

LAMPTXBUTN, **LAM** or **lambda_ptx_BUTN** – Thermal conductivity λ in W / m K

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **LAMPTXBUTN = –1000**, **LAM = –1000** or **lambda_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [24], [25]

Kinematic Viscosity ν = f(p,t,x)

Function Name:	**ny_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION NYPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_NYPTXBUTN(NY,P,T,X)** REAL*8 NY,P,T,X

Input Values:

P – Pressure p in bar

T - Temperature t in °C

X – Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

NYPTXBUTN, **NY** or **ny_ptx_BUTN** – Kinematic viscosity $\nu = \eta \cdot v$ in m^2 / s

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **NYPTXBUTN = –1000**, **NY = –1000** or **ny_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [23], [25]

Melting Pressure p_{mel} = f(t)

Function Name:	**pmel_t_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION PMELBUTN(T)** REAL*8 T
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PMELBUTN(PMEL,T)** REAL*8 PMEL,P,T,X

Input Values:

T - Temperature t in °C

Result

PMELTBUTN, **PMEL** or **pmel_t_BUTN** – Melting pressure p_{mel} in bar

Range of validity

Temperature range : from $t_t = -138.255$°C to -127.233°C

Results for wrong input values

Result **PMELBUTN = –1000**, **PMEL = –1000** or **pmel_t_BUTN = –1000** for input values:

$t < t_t = -138.255$°C or $t > -127.233$°C

References: [22], [25]

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

Function Name:	**Pr_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION PRPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PRPTXBUTN(PR,P,T,X)** REAL*8 PR,P,T,X

Input Values:

P – Pressure *p* in bar

T - Temperature *t* in °C

X – Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

PRPTXBUTN, **PR** or **Pr _ptx _BUTN** – Prandtl – Number $Pr = \frac{\eta * c_p}{\lambda}$

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **PRPTXBUTN = –1000**, **PR = –1000** or **Pr_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [23], [24], [25]

Vapor Pressure p_s = f(t)

Function Name:	**ps_t_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION PSTBUTN(T)** REAL*8 T
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PSTBUTN(PS,T)** REAL*8 PS,T

Input Values:

T - Temperature t in °C

Result

PSTBUTN, **PS** or **ps_t_BUTN** – Vapor pressure p_s in bar

Range of validity

Temperature range: from $t_t = -138.255$°C to $t_c = 151.975$°C

Results for wrong input values

Result **PSTBUTN = –1000**, **PS = –1000** or **ps_t_BUTN = –1000** for input values:

$t < t_t = -138.255$°C or $t > t_c = 151.975$°C

References: [22], [25]

Density ρ = f(p,t,x)

Function Name:	**rho_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION ROPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ROPTXBUTN(RHO,P,T,X)** REAL*8 RHO,P,T,X

Input Values:

P – Pressure p in bar

T - Temperature t in °C

X – Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

RHO_PTX_BUTN, **RHO** or **rho_ptx_BUTN** - Density ρ in kg/m^3

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

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

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

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

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

When calculating wet steam either the given value for t <u>and</u> p = -1000 or the given value for p <u>and</u> t = -1000 and in both cases the value for x between 0 and 1 must be entered.

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

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **ROPTXBUTN = –1000**, **RHO = –1000** or **rho_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**s_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION SPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_SPTXBUTN(S,P,T,X)** REAL*8 S,P,T,X

Input Values:

P – Pressure *p* in bar

T - Temperature *t* in °C

X – Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

SPTXBUTN, **S** or **s_ptx_BUTN** - Specific entropy *s* in kJ/kg K

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

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

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

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

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

When calculating wet steam either the given value for *t* <u>and</u> p = -1000 or the given value for *p* <u>and</u> t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

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

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **SPTXBUTN = –1000**, **S = –1000** or **s_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**t_ph_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TPHBUTN(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TPHBUTN(T,P,H)** REAL*8 T,P,H

Input Values:

P – Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

TPHBUTN, **T** or **t_ph_BUTN** – Temperature *t* in °C

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **T_PH_BUTN**, **T = –1000** or **t_ph_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > 301.85$°C, $t < t_t = -138.255$°C or $t < t_{mel}(p)$
Saturated liquid or saturated vapor line:	at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**t_ps_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TPSBUTN(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TPSBUTN(T,P,S)** REAL*8 T,P,S

Input Values:

P – Pressure *p* in bar

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

Result

TPSBUTN, **T** or **t_ps_BUTN** – Temperature *t* in °C

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar

Results for wrong input values

Result **T_PS_BUTN, T = –1000** or **t_ps_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > 301.85$°C, $t < t_t = -138.255$°C or $t < t_{mel}(p)$
Saturated liquid or saturated vapor line:	at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Saturation Temperature t_s = f(p)

Function Name:	**ts_p_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TSPBUTN(P)** REAL*8 P
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TSPBUTN(TS,P)** REAL*8 TS,P

Input Values:

P – Pressure p in bar

Result

TSPBUTN, **TS** or **ts_p_BUTN** - Saturation temperature t_s in °C

Range of validity

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to $p_c = 37.96$ bar

Results for wrong input values

Result **TSPBUTN = –1000**, **TS = –1000** or **ts_p_BUTN = –1000** for input values:

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

Melting Temperature t_{mel} = f(p)

Function Name:	**tmel_p_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TMELBUTN(P)** REAL*8 P
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TMELBUTN(TMEL,P)** REAL*8 TMEL,P

Input Values:

P – Pressure p in bar

Result

TMELPBUTN, **TMEL** or **tmel_p_BUTN** - Melting temperature t_{mel} in °C

Range of validity

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Results for wrong input values

Result **TMELBUTN = –1000**, **TMEL = –1000** or **tmel_p_BUTN = –1000** for input values:

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

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

Function Name:	**u_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION UPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_UPTXBUTN(H,P,T,X)** REAL*8 H,P,T,X

Input Values:

P – Pressure *p* in bar

T - Temperature *t* in °C

X – Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

UPTXBUTN, **U** or **u_ptx_BUTN** - Specific internal energy *u* in kJ/kg

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

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

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

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

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

When calculating wet steam either the given value for *t* <u>and</u> p = -1000 or the given value for *p* <u>and</u> t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

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

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **UPTXBUTN = –1000**, **U = –1000** or **u_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**v_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION VPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_VPTXBUTN(V,P,T,X)** REAL*8 V,P,T,X

Input Values:

P – Pressure *p* in bar

T - Temperature *t* in °C

X – Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

VPTXBUTN, **V** or **v_ptx_BUTN** - Specific volume *v* in m^3/kg

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

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

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

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

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

When calculating wet steam either the given value for *t* <u>and</u> p = -1000 or the given value for *p* <u>and</u> t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

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

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **VPTXBUTN = –1000**, **V = –1000** or **v_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**w_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION WPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_WPTXBUTN(W,P,T,X)** REAL*8 W,P,T,X

Input Values:

P – Pressure *p* in bar

T - Temperature *t* in °C

X – Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

WPTXBUTN, **W** or **w_ptx_BUTN** – Speed of sound *w* in m/s

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **WPTXBUTN = –1000** or **w_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**x_ph_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION XPHBUTN(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_XPHBUTN(T,P,H)** REAL*8 X,P,H

Input Values:

P – Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

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

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar

Results for wrong input values

Result **X_PH_BUTN**, **X = –1** or **x_ph_BUTN = –1** for input values:

In case the state point is located in the single phase region

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

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

Function Name:	**x_ps_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION XPSBUTN(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_XPSBUTN(X,P,S)** REAL*8 X,P,S

Input Values:

P – Pressure *p* in bar

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

Result

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

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar

Results for wrong input values

Result **X_PS_BUTN**, **X = –1** or **x_ps_BUTN = –1** for input values:

In case the state point is located in the single phase region

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

Ideal mixture of the real fluids:

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

and of the ideal gases:

SO_2, CO, Ne (scientific equations of Bücker et al.)
Consideration of

Dissociation from VDI 4670 and Poynting effect

Library LibIDGAS

Ideal gas mixture calculated from the VDI-Guideline 4670

Humid Air

Library LibHuAir

Ideal mixture of the real fluids:

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

Consideration of

- Dissociation from VDI-Guideline 4670
- Poynting effect

Library LibIdAir

Ideal gas mixture calculated from VDI-Guideline 4670

Carbon Dioxide

Library LibCO2

Formulation of Span and Wagner (1994)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Helium

Library LibHe

Formulation of McCarty and Arp (1990)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ideal Gas Mixtures

Library LibIdGasMix

Ideal mixture of the ideal gases:

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

Consideration of

- Dissociation from VDI-Guideline 4670

Seawater

Library LibSeaWa

IAPWS Formulation (2008) and IAPWS-IF97

Refrigerant R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Refrigerant NH_3

Library LibNH3

Formulation of Tillner-Roth (1995)

ORC Working Fluids

Library LibMM

Siloxane $C_6H_{18}OSi_2$ (MM)

Formulation of Colonna et al. (2006)

Library LibD4

Siloxane $C_8H_{24}O_4Si_4$ (D4)

Formulation of Colonna et al. (2006)

Library LibD5

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

Formulation of Colonna et al. (2006)

Library LibMD4M

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

Formulation of Colonna et al. (2006)

Mixtures for Absorption Processes

Library LibAmWa

Ammonia/Water Mixtures

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

Helmholtz energy formulation for the mixing term

Library LibWaLi

Water/Lithium Bromide Mixtures

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Refrigerants

Library LibPropan

Refrigerant Propane

Formulation of Lemmon et al. (2008)

Library LibButan_Iso

Refrigerant Iso-Butane

Formulation of Bücker et al. (2003)

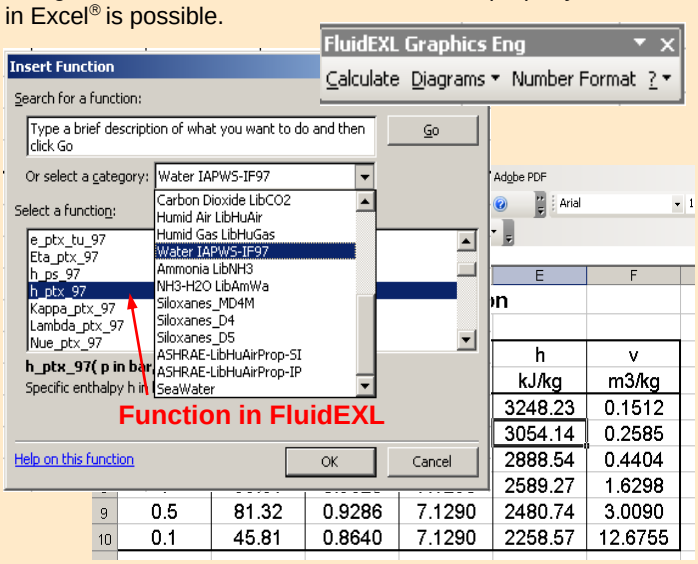
Library LibButan_n

Refrigerant n-Butane

Formulation of Bücker et al. (2003)

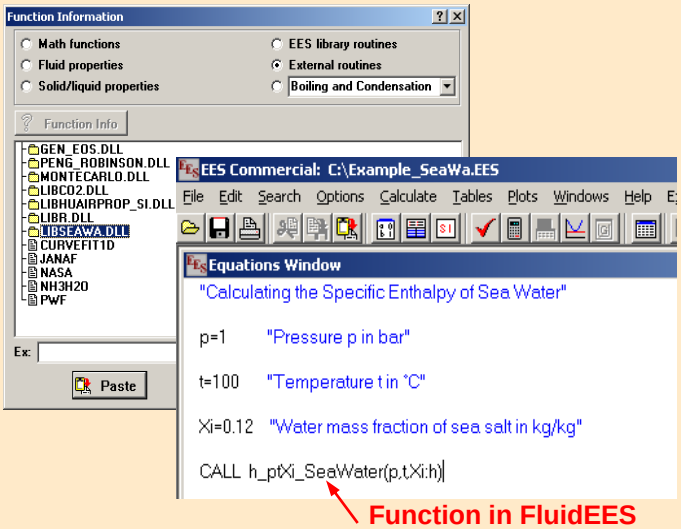
Add-In FluidEXL for Excel®

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



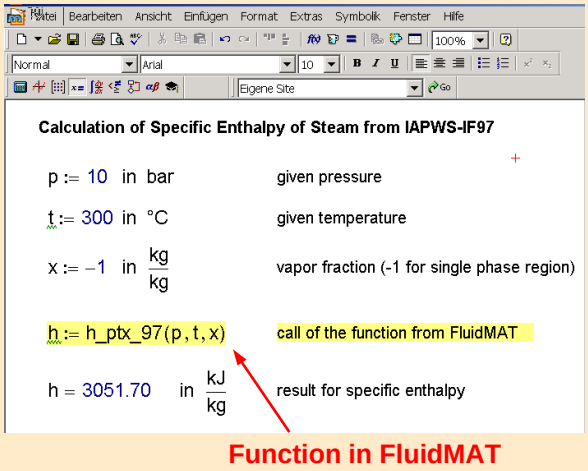
Add-In FluidEES for EES®

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



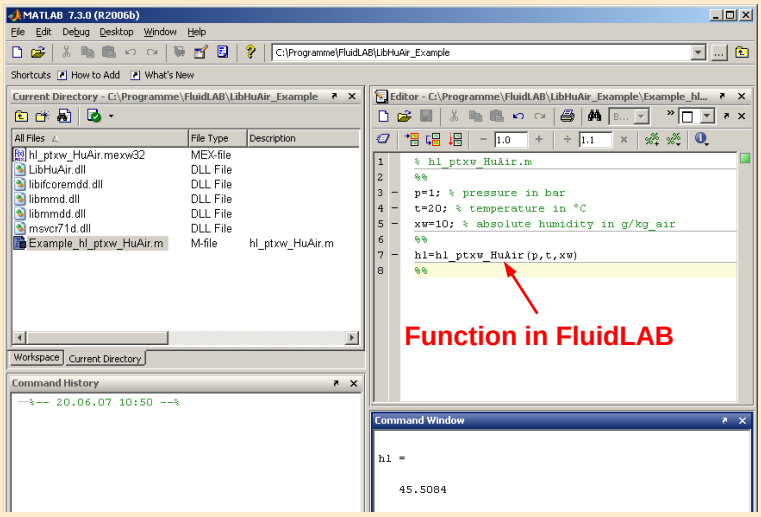
Add-In FluidMAT for Mathcad®

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



Add-In FluidLAB for MATLAB®

The property functions can be called in MATLAB®.



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

Thermodynamic Properties

- Saturation pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e

- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Thermodynamic Derivatives

- Partial derivatives can be calculated

Transport Properties

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

Backward Functions

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

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Fax.: +49-3583-61-1846

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

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6. Satisfied Customers

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