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Property Library for Liquid Secondary Refrigerants

FluidEXL*Graphics* with LibSecRef for Excel®

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Property Library for Liquid Secondary Refrigerants

Including DLL and Add-In for Excel®

FluidEXL*Graphics*
LibSecRef

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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_LibSecRef_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*
LibSecRef.dll	- Dynamic Link Library for use in Windows programs
LibSecRef.hlp	- Help file for the LibSecRef property library
FluidEXL_Graphics_LibSecRef_Docu_Eng.pdf	- User's Guide

German zip file "CD_FluidEXL_Graphics_LibSecRef.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*
LibSecRef.dll	- Dynamic Link Library for use in Windows® programs
LibSecRef.hlp	- Help file for the LibSecRef property library
FluidEXL_Graphics_LibSecRef_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_LibSecRef_x64_Eng.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibSecRef_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
LibSecRef.dll	- Dynamic link library for use in Windows® programs
LibSecRef.hlp	- Help file for the LibSecRef 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_LibSecRef_x64.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibSecRef_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
LibSecRef.dll	- Dynamic link library for use in Windows® programs
LibSecRef.hlp	- Help file for the LibSecRef 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 Program Functions

1.1 Property Functions

The LibSecRef property library uses the formulation for liquid secondary refrigerants by *MELINDER* [1,2]. The secondary refrigerants presented in this library are water solutions (without other additives) of ethylene glycol, propylene glycol, ethyl alcohol, methyl alcohol, glycerol, potassium carbonate, calcium chloride, magnesium chloride, sodium chloride, as well as potassium acetate. The chemical symbols and the range of validities for these solutions are given in Tables 1.1 and 1.2. For all liquid secondary refrigerants the reference pressure is the atmospheric pressure (101.325 kPa).

The thermodynamic and transport property functions and subfunctions of the LibSecRef shown in Table 1.3 are available as functions of the pressure p in bar, the temperature of the solution t in °C and the mass fraction of the non water-component ξ. Also there is a function too calculate the mass fraction ξ as a function of the freezing temperature of the solution t_f *in °C* and a function to calculate the freezing temperature as a function of the Mass fraction ξ. The temperature t must be always between the freezing temperature *tf* and the maximum temperature t_{max}. The temperature- and mass fraction range for the functions are shown in Table 1.2. To call a specific kind of solution, the value I_TYPE is used. All functions can be applied in the entire range of validity shown in Table 1.2.

Table 1.1: Chemical symbol and value of I_TYPE

Name of non-water component	Chemical Symbol	I_TYPE
Ethylene glycol	$C_2H_6O_2$	1
Propylene glycol	$C_3H_8O_2$	2
Ethyl alcohol	C_2H_5OH	3
Methyl alcohol	CH_3OH	4
Glycerol	$C_3H_8O_3$	5
Potassium carbonate	K_2CO_3	6
Calcium chloride	$CaCl_2$	7
Magnesium chloride	$MgCl_2$	8
Sodium chloride	NaCl	9
Potassium acetate	$C_2H_3KO_2$	10

In the thermodynamic property library LibSecRef there are also implemented backwards equations for the calculation of the solution temperature as a function of pressure, mass fraction and specific volume, specific entropy or specific enthalpy.

The reference state is at a mass fraction ξ of 0 (pure Water), a temperature of 0°C and a pressure p of 101,325kPa. The reference values are calculated by the IAPWS-IF97 standard [4.] These values are a specific enthalpy of 6.1012E-2 kJ/kg and a specific entropy of –1.477E-4 kJ/(kg K).

Table 1.2: Range of validity for mass fraction and temperatures

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	tf_{max}
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	0 °C
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	- 5 °C
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	- 5 °C
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	- 5 °C
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	- 5 °C
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	0 °C
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	- 5 °C
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	0 °C
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	0 °C
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	- 5 °C

Units:

Symbol	Name	Unit
I_TYPE	Type of solution	–
t	Solution temperature	°C
t_{min}	Minimal solution temperature	°C
t_{max}	Maximum solution temperature	°C
tf	Freezing temperature	°C
tf_{min}	Minimal freezing temperature	°C
tf_{max}	Maximum freezing temperature	°C
ξ	Mass fraction of the non-water component	kg kg^{-1}
ξ_{min}	Minimal mass fraction of the non-water component	kg kg^{-1}
ξ_{min}	Maximum mass fraction of the non-water component	kg kg^{-1}

Range of validity:

The Input parameters must always be between:

I_TYPE : $I_TYPE \geq 1$ and $I_TYPE \leq 10$

ξ : $\xi \geq \xi_{min}$ and $\xi \leq \xi_{max}$

tf : $tf \geq tf_{min}$ and $tf \leq tf_{max}$

t : $t \geq tf_{min}$ and $t \leq t_{max}$ and $t \geq tf$

p : $p > 0$ bar

Note:

If the calculation results in –1000, the values entered represent a state point beyond the range of validity. For further information on each function and its range of validity see Chapter 3. The same information may also be accessed via the online help pages

Table 1.3: Functions of the LibSecRef property library

Functional dependence	Function Name	Call from DLL LibSecRef, Result as Parameter	Property	Unit
a = f (I_TYPE, p, t, xi)	a_ptxi_SecRef	= A_PTXI_SECREF(I_TYPE,P,T,XI)	Thermal diffusity	m² / s
α_v = f (I_TYPE, p, t, xi)	alfav_ptxi_SecRef	= ALFAV_PTXI_SECREF(I_TYPE,P,T,XI)	Isobaric cubic expansion coefficient	1 / K
c_p = f (I_TYPE, p, t, xi)	cp_ptxi_SecRef	= CP_PTXI_SECREF(I_TYPE,P,T,XI)	Specific isobaric heat capacity	kJ / (kg K)
η = f (I_TYPE, p, t, xi)	eta_ptxi_SecRef	= ETA_ PTXI_SECREF(I_TYPE,P,T,XI)	Dynamic viscosity	Pa s
h = f (I_TYPE, p, t, xi)	h_ptxi_SecRef	= H_ PTXI_SECREF(I_TYPE,P,T,XI)	Specific enthalpy	kJ / kg
λ = f (I_TYPE, p, t, xi)	lam_ptxi_SecRef	= LAM_ PTXI_SECREF(I_TYPE,P,T,XI)	Thermal conductivity	W / (m K)
v = f (I_TYPE, p, t, xi)	ny_ptxi_SecRef	= NY_ PTXI_SECREF(I_TYPE,P,T,XI)	Kinematic viscosity	m² / s
Pr = f (I_TYPE, p, t, xi)	pr_ptxi_SecRef	= PR_ PTXI_SECREF(I_TYPE,P,T,XI)	Prandtl-number	-
ρ = f (I_TYPE, p, t, xi)	rho_ptxi_SecRef	= RHO_ PTXI_SECREF(I_TYPE,P,T,XI)	Density	kg / m³
s = f (I_TYPE, p, t, xi)	s_ptxi_SecRef	= S_ PTXI_SECREF(I_TYPE,P,T,XI)	Specific entropy	kJ / (kg K)
t = f (I_TYPE, p, h, xi)	t_phxi_SecRef	= T_ PHXI_SECREF(I_TYPE,P,H,XI)	Backwards equation: Temperature from pressure, specific enthalpy and mass fraction	°C
t = f (I_TYPE, p, s, xi)	t_psxi_SecRef	= T_ PSXI_SECREF(I_TYPE,P,S,XI)	Backwards equation: Temperature from pressure, specific entropy and mass fraction	°C
t = f (I_TYPE, p, v, xi)	t_pvxi_SecRef	= T_ PVXI_SECREF(I_TYPE,P,V,XI)	Backwards equation: Temperature from pressure, specific volume and mass fraction	°C
tf = f(I_TYPE, xi)	tf_xi_SecRef	= TF_XI_SECREF(I_TYPE,XI)	Freezing temperature	°C
u = f (I_TYPE, p, t, xi)	u_ptxi_SecRef	= U_ PTXI_SECREF(I_TYPE,P,T,XI)	Specific inner energy	kJ / kg
v = f (I_TYPE, p, t, xi)	v_ptxi_SecRef	= V_ PTXI_SECREF(I_TYPE,P,T,XI)	Specific volume	m³ / kg
ξ = f (I_TYPE, tf)	xi_tf_SecRef	= XI_TF_SECREF(I_TYPE,TF)	Mass fraction of the non-water part	kg / kg

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 Secondary Refrigerants from the LibSecRef 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 LibSecRef library. In this case, follow the subsection "Adding the LibSecRef 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_LibSecRef_Eng.zip"	(for English version of Windows)
"CD_FluidEXL_Graphics_LibSecRef.zip"	(for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibSecRef_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibSecRef	(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_LibSecRef_Docu_Eng.pdf	
LibSecRef.dll	
LibSecRef.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).

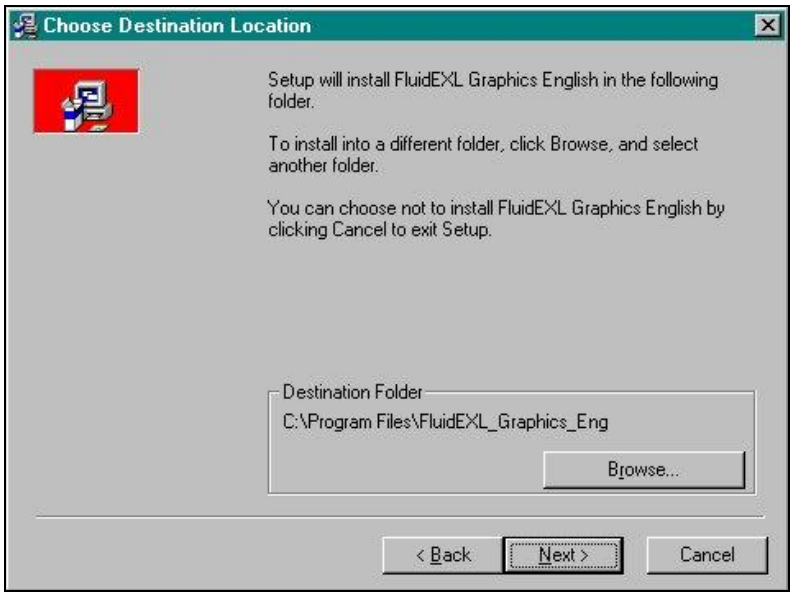


Figure 2.1: Choose Destination Location

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)
LibSecRef.dll	
LibSecRef.hlp	

from the extracted folder

CD_FluidEXL_Graphics_LibSecRef_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibSecRef	(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_LibSecRef_x64_Eng.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibSecRef_x64.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibSecRef_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibSecRef (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_LibSecRef_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)
LibSecRef.dll
LibSecRef.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).

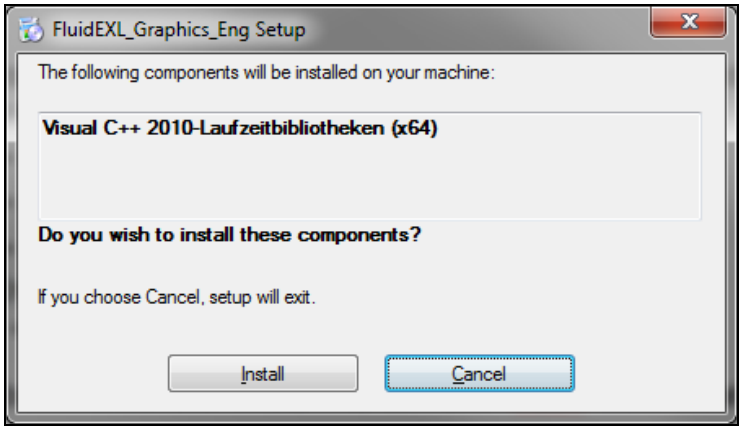


Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

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).

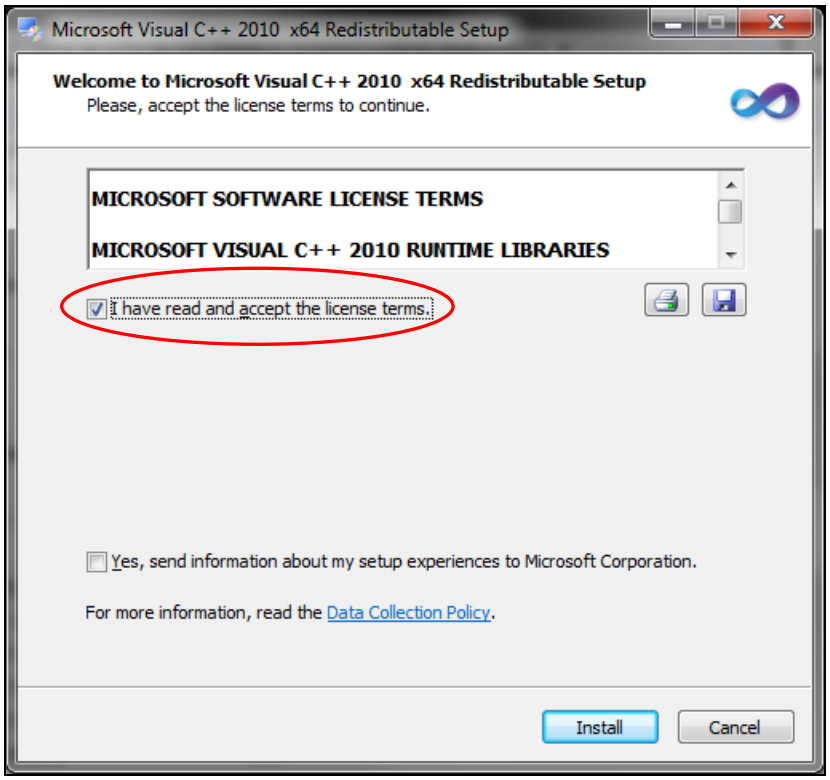


Figure 2.3: Accepting the license terms

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).

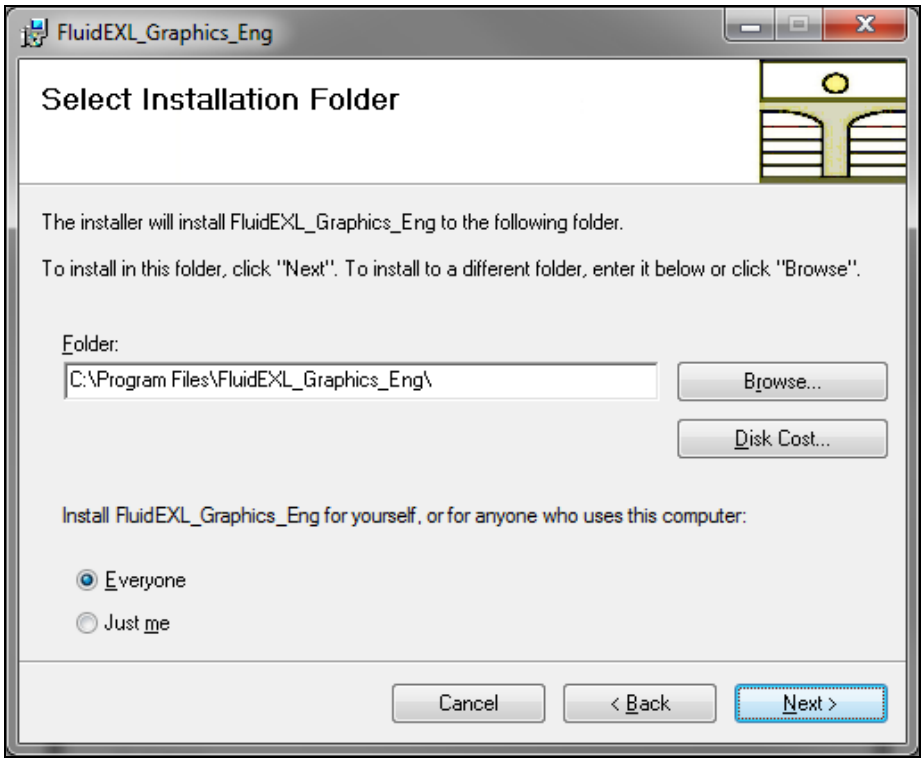


Figure 2.4: Choosing the Installation Folder of FluidEXL*Graphics*

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)
LibSecRef.dll	
LibSecRef.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.

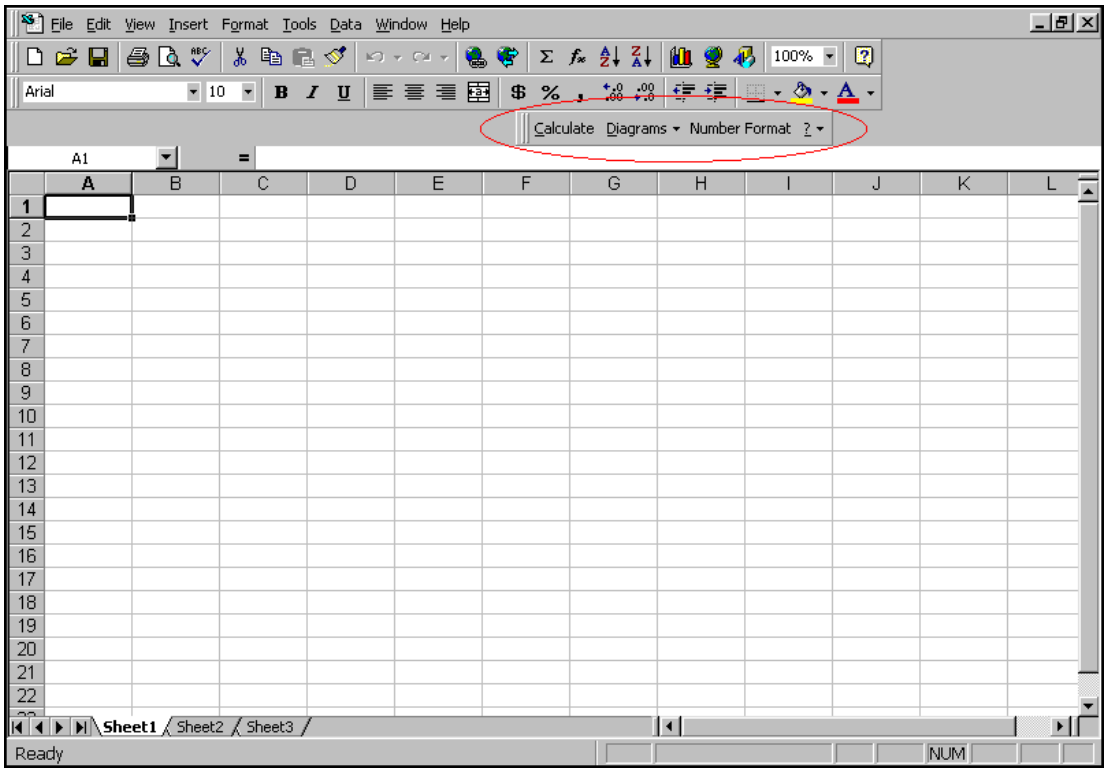


Figure 2.5: Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "LibSecRef" DLL 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® 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)

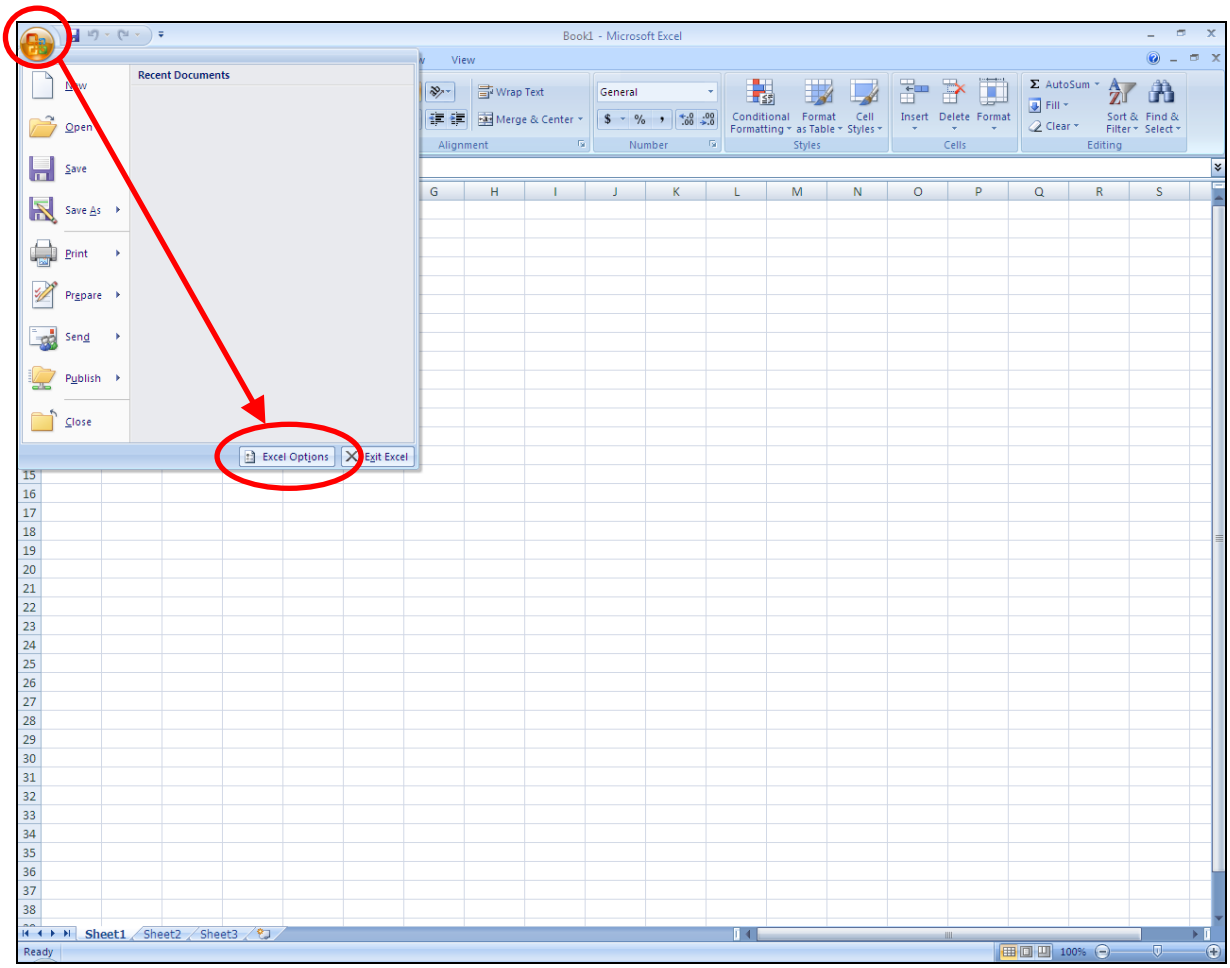


Figure 2.6: Registering FluidEXL*Graphics* as Add-In in Excel® 2007

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

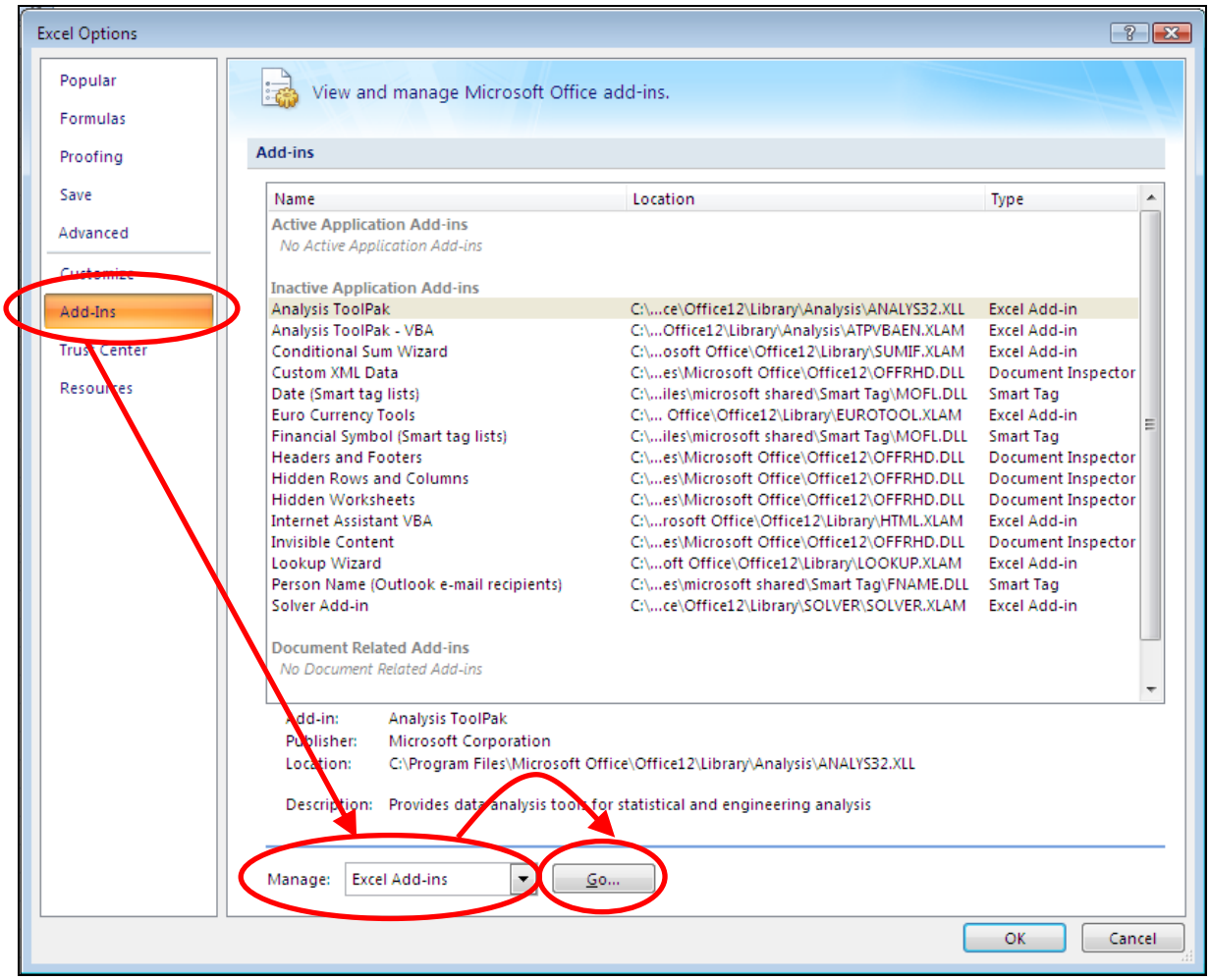


Figure 2.7: Dialog window "Excel Options"

- 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."

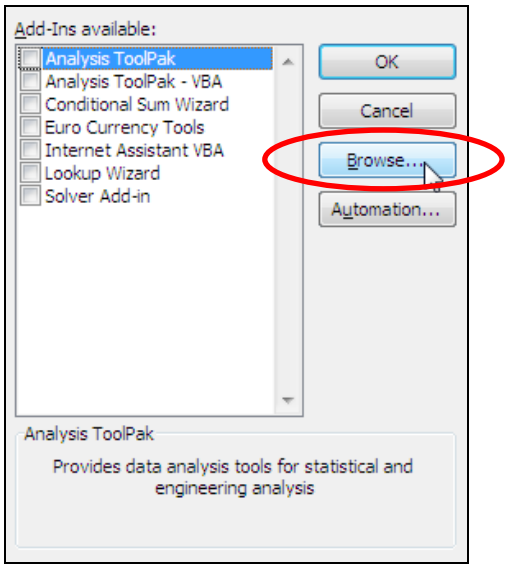


Figure 2.8: Dialog window "Add-Ins available"

- 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.)

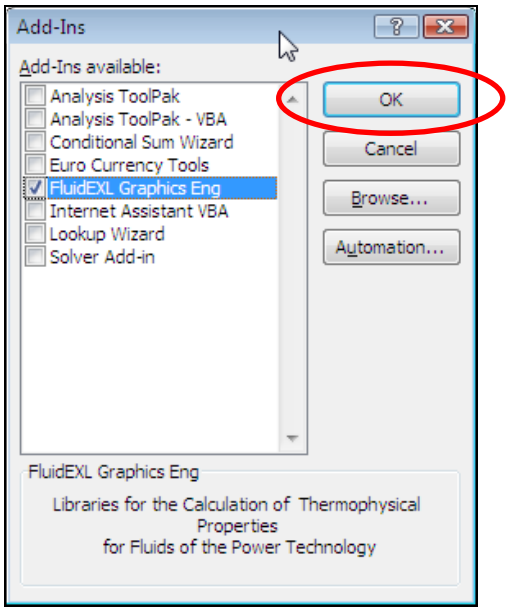


Figure 2.9: Dialog window "Add-Ins"

- 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.

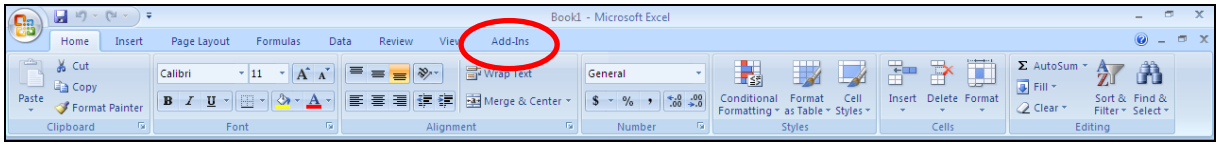


Figure 2.10: Menu item "Add-Ins"

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

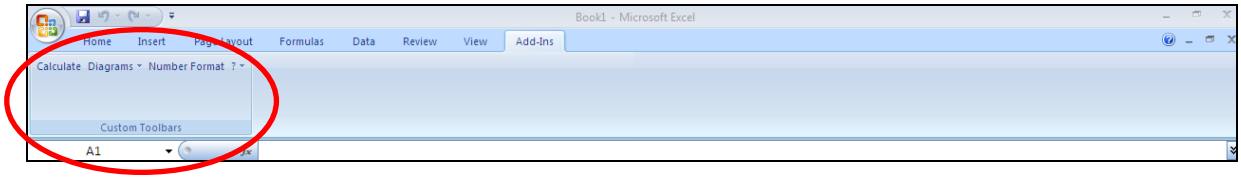


Figure 2.11: FluidEXL*Graphics* menu bar

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 LibSecRef 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)
LibSecRef.dll	
LibSecRef.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibSecRef_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibSecRef	(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 "LibSecRef" DLL library property functions for nitrogen via this menu bar (the example calculation can be found in 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.
- Click on the "Nitrogen LibSecRef" 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 LibSecRef.hlp function help cannot be found, confirm the question whether you want to look for it yourself with "Yes". Select the LibSecRef.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).

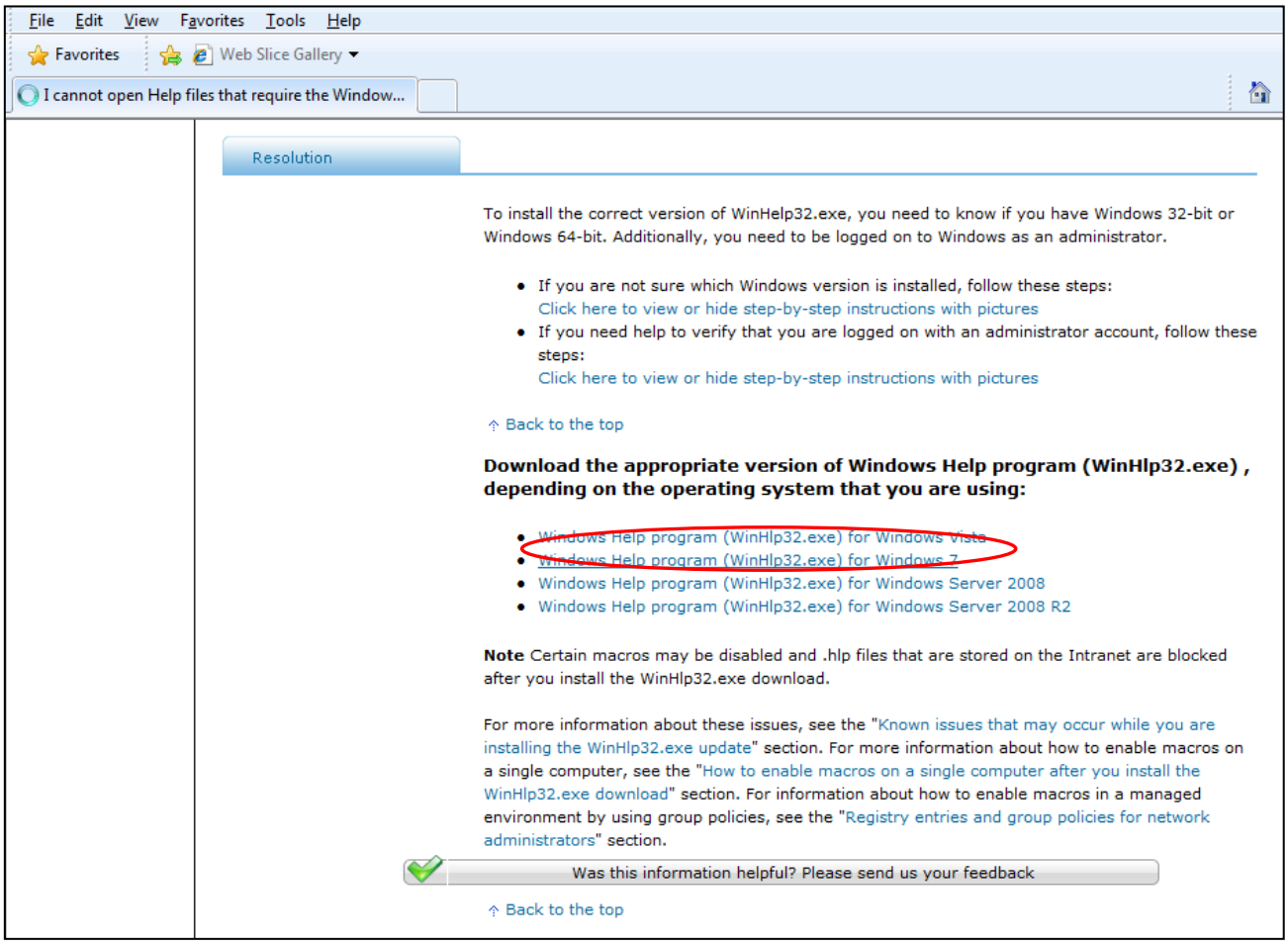


Figure 2.13: Selecting your Windows version

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).

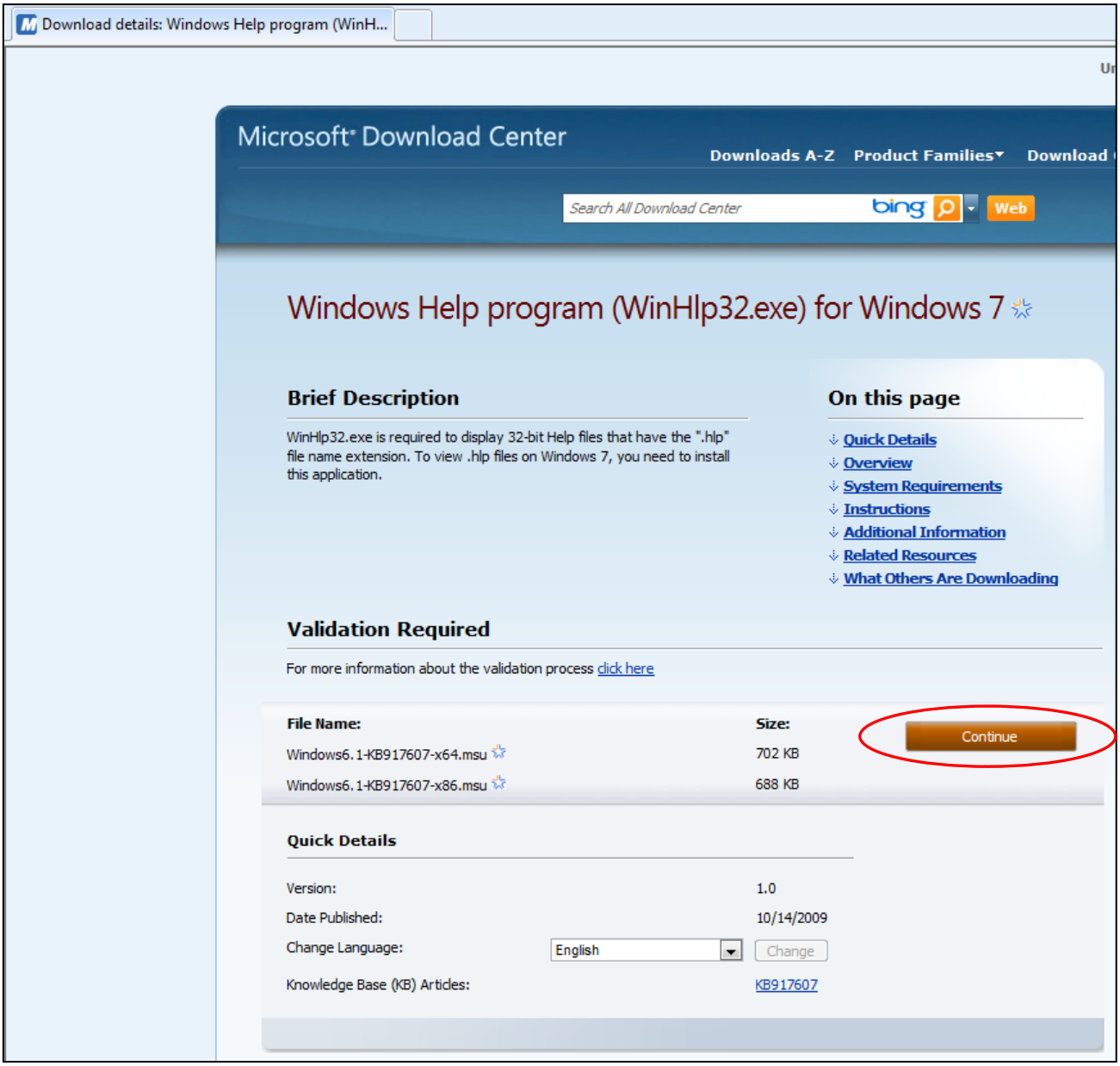


Figure 2.14: Microsoft® Download Center

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).

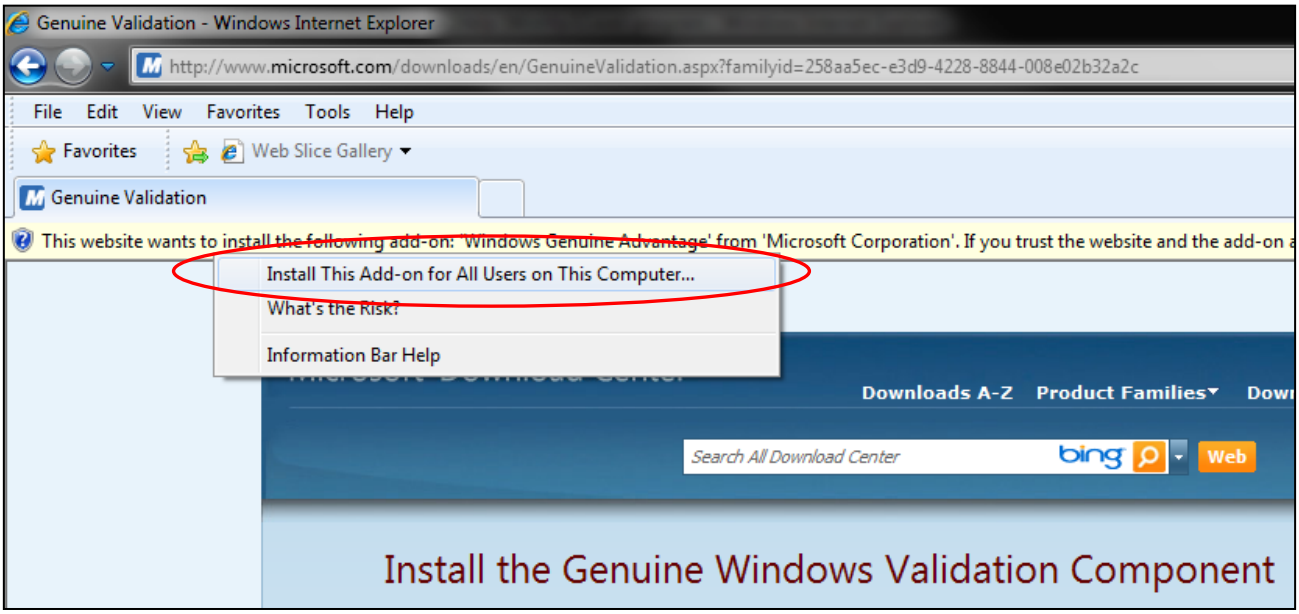


Figure 2.15: Installing the Genuine Windows Validation Component

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).

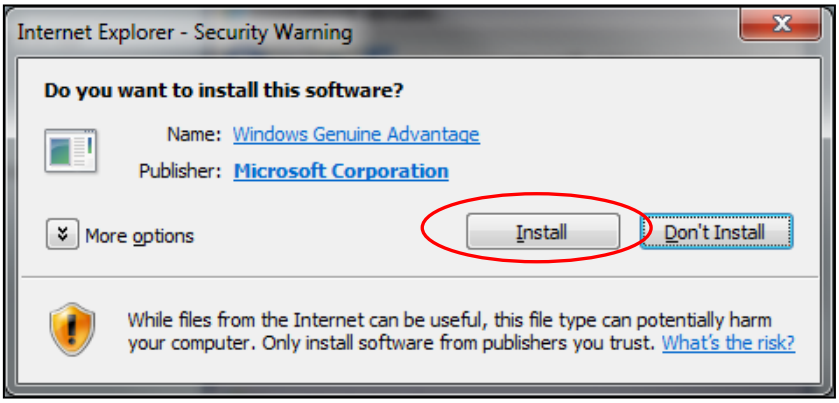


Figure 2.16: Internet Explorer – Security Warning

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

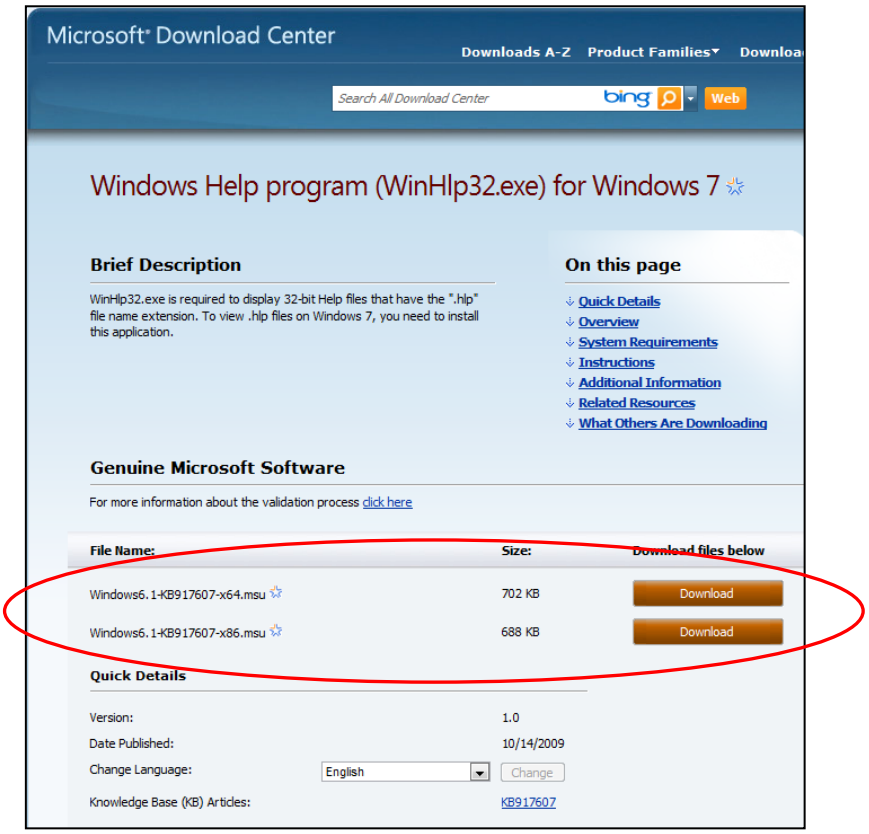


Figure 2.17: Downloading the Windows Help program

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.

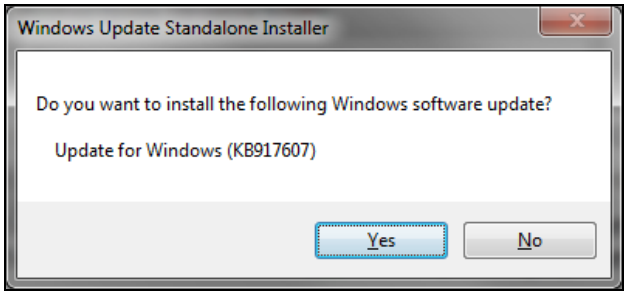


Figure 2.18: Windows Update Standalone Installer

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).

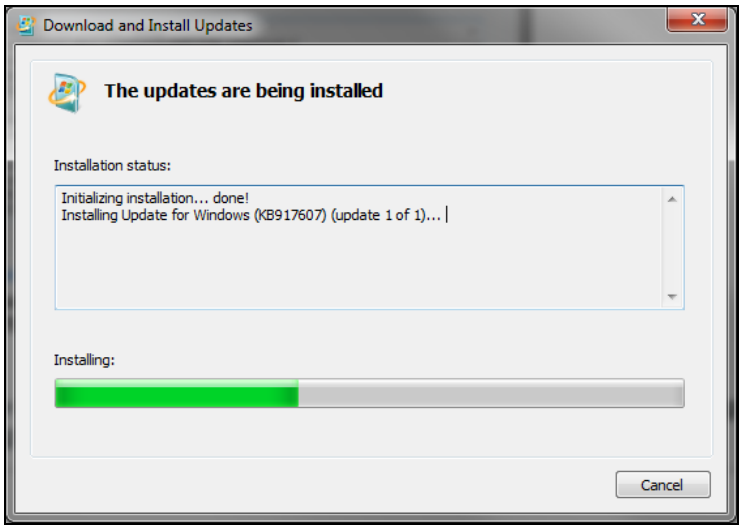


Figure 2.20: Installation process

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 LibSecRef 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).

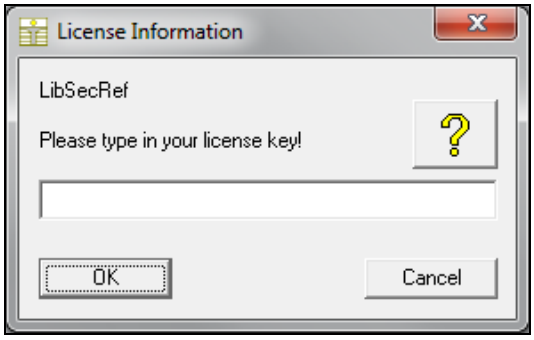


Figure 2.21: "License Information" window

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:

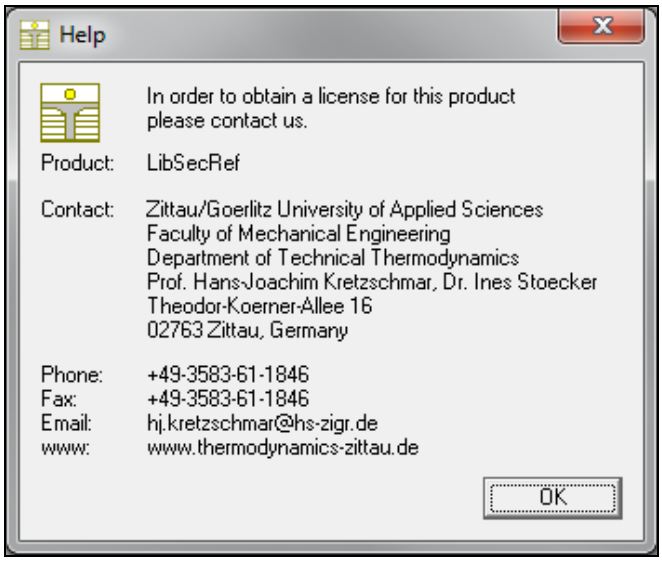


Figure 2.22: "Help" window

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

LibSecRef.dll and LibSecRef.hlp

in the installation folder of FluidEXLGraphics (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 c_p = f (*I_TYPE*,*p*,*t*,*xi*)

Now we will calculate, step by step, the specific isobaric heat capacity c_p as a function of the Type of solution *I_TYPE*, the pressure *p*, the solution temperature *t* and the mass fraction of the non-water part ξ using FluidEXL*Graphics*.

- Start Excel®
- Enter a value for *I_TYPE* in a cell
  (I_TYPE must be between 1 and 10)
  ⇒ e. g.: Enter the value 1 into cell A2

  ⇒ With the value 1 we select a mixture of water and ethylene glycol
- Enter a value for *p* in bar in a cell

⇒ e. g.: Enter the value 100 into cell B2
  (Range of validity corresponding to *MELINDER:* $p \geq 0$ bar)

- Enter a value for *t* in °C in a cell
  (Range of validity corresponding to *MELINDER for I_TYPE = 1*: $t = tf$ ... 40 °C)
  ⇒ e. g.: Enter the value 10 into cell C2
- Enter a value for ξ in a cell
  (Range of validity corresponding to *MELINDER for I_TYPE = 1:* $0 < \xi < 0.56$)
  ⇒ e. g.: Enter the value 0.2 into cell D2
- Click the cell in which the specific isobaric heat capacity c_p in kJ/(kg K) is to be displayed.
  ⇒ e.g.: Click the E2 cell.
- Click "Calculate" in the menu bar of FluidEXL*Graphics*.
  Now the "Insert Function" window appears (see Figure 2.23).

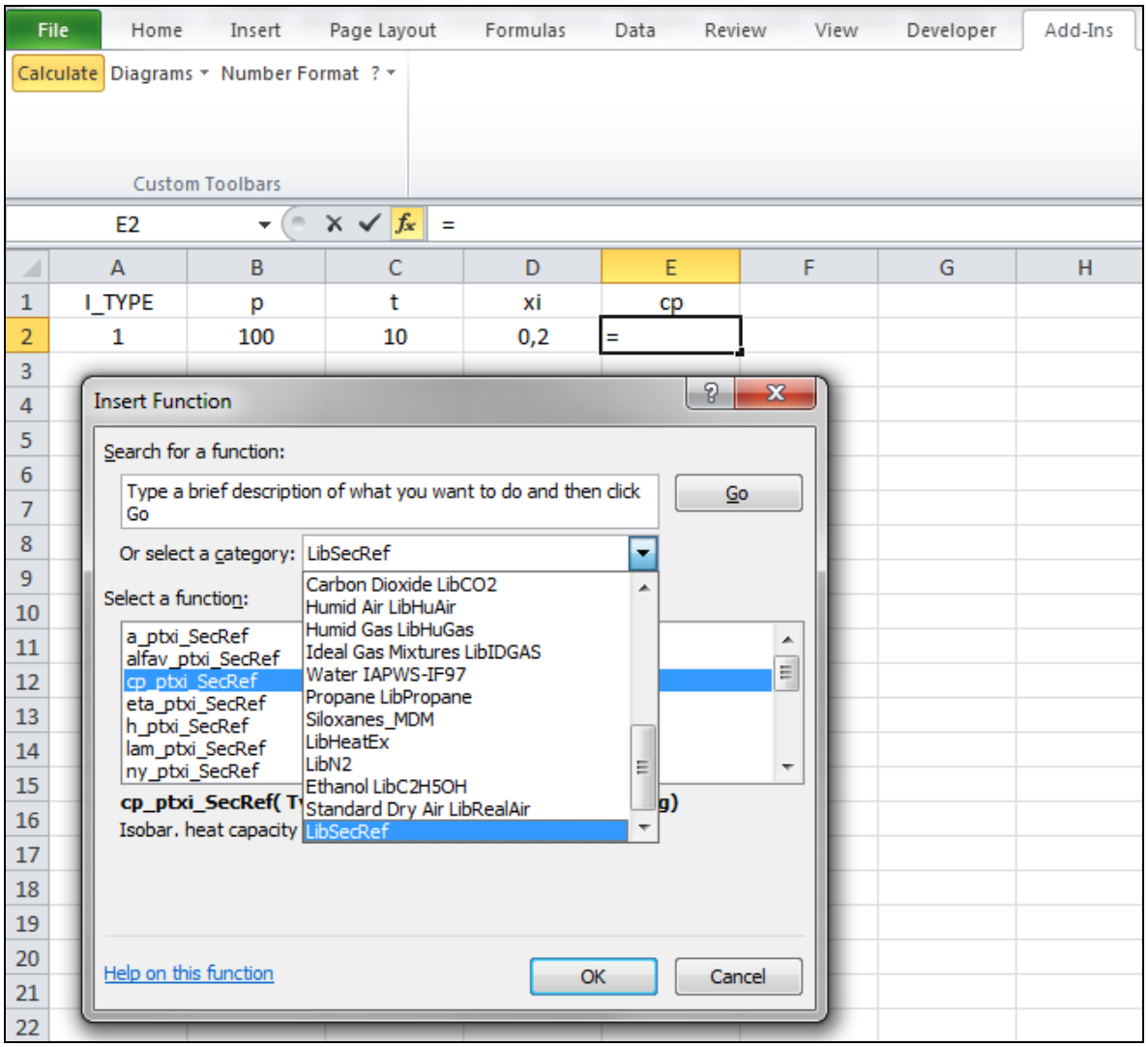


Figure 2.23: Choice of library and function name

- Search and click the "LibSecRef" library under "Or select a category:" in the upper part of the window.
- Search and click the cp_ptxi_SecRef 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 Figure 2.24 will now appear.

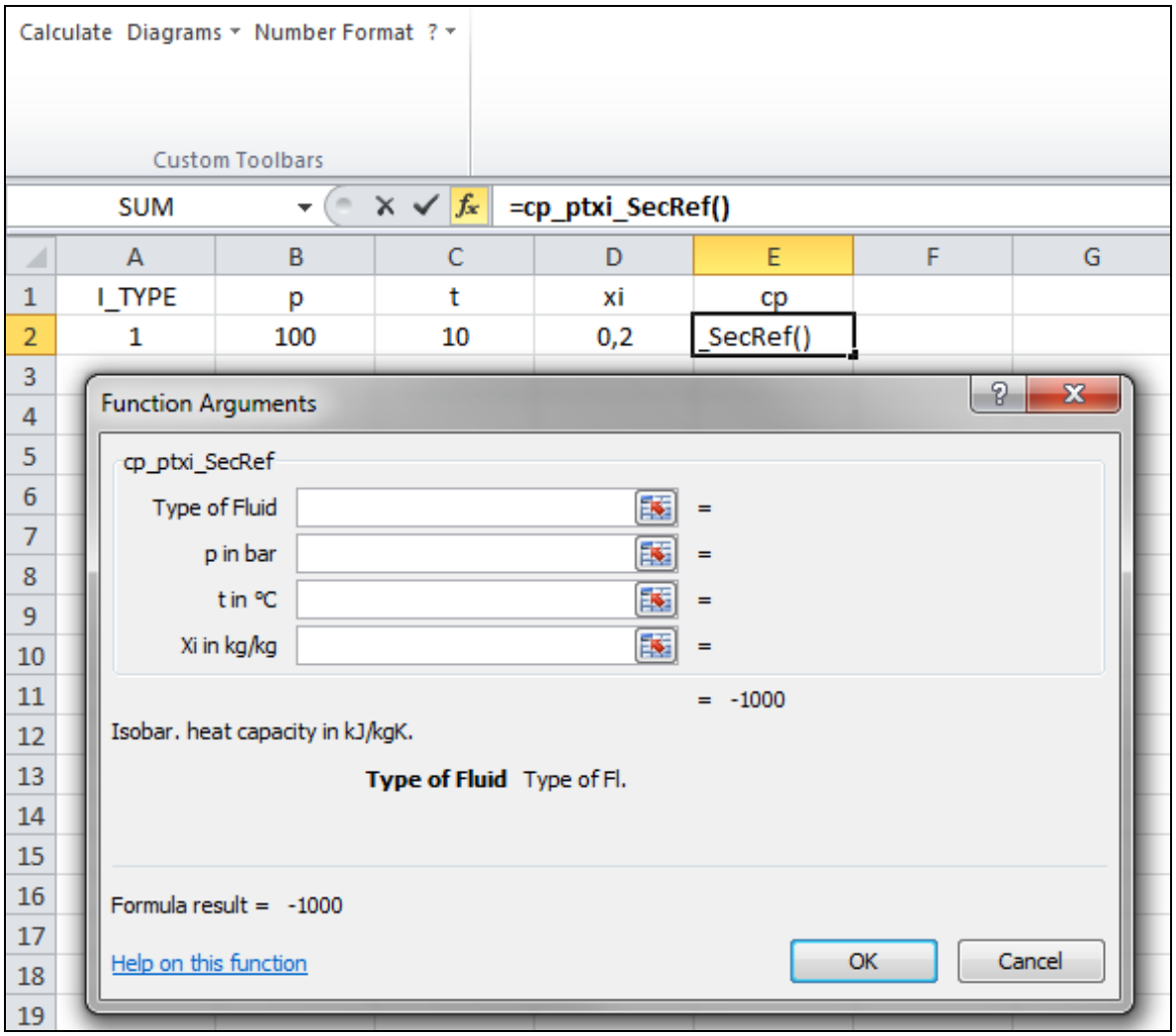


Figure 2.24: Input menu for the function

- The Cursor is now situated on the line next to "*I_TYPE*". You can now enter the value for *I_TYPE* either by clicking the cell with the value for *I_TYPE* by entering the name of the cell with the value for *I_TYPE*, or by entering the value for *I_TYPE* directly.

  ⇒ e. g.: Click on the cell A2

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

⇒ e. g.: Type B2 into the window next to "p"

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

  ⇒ e. g.: Click on the cell C2

- Situate the cursor next to "mass fraction xi" and enter the value for *xi* by clicking the cell with the value for *xi*, by entering the name of the cell with the value for *xi,* or by entering the value for *xi* directly.

  ⇒ e. g.: Type D2 into the window next to "xi"

  The window should now look like in Figure 2.25:

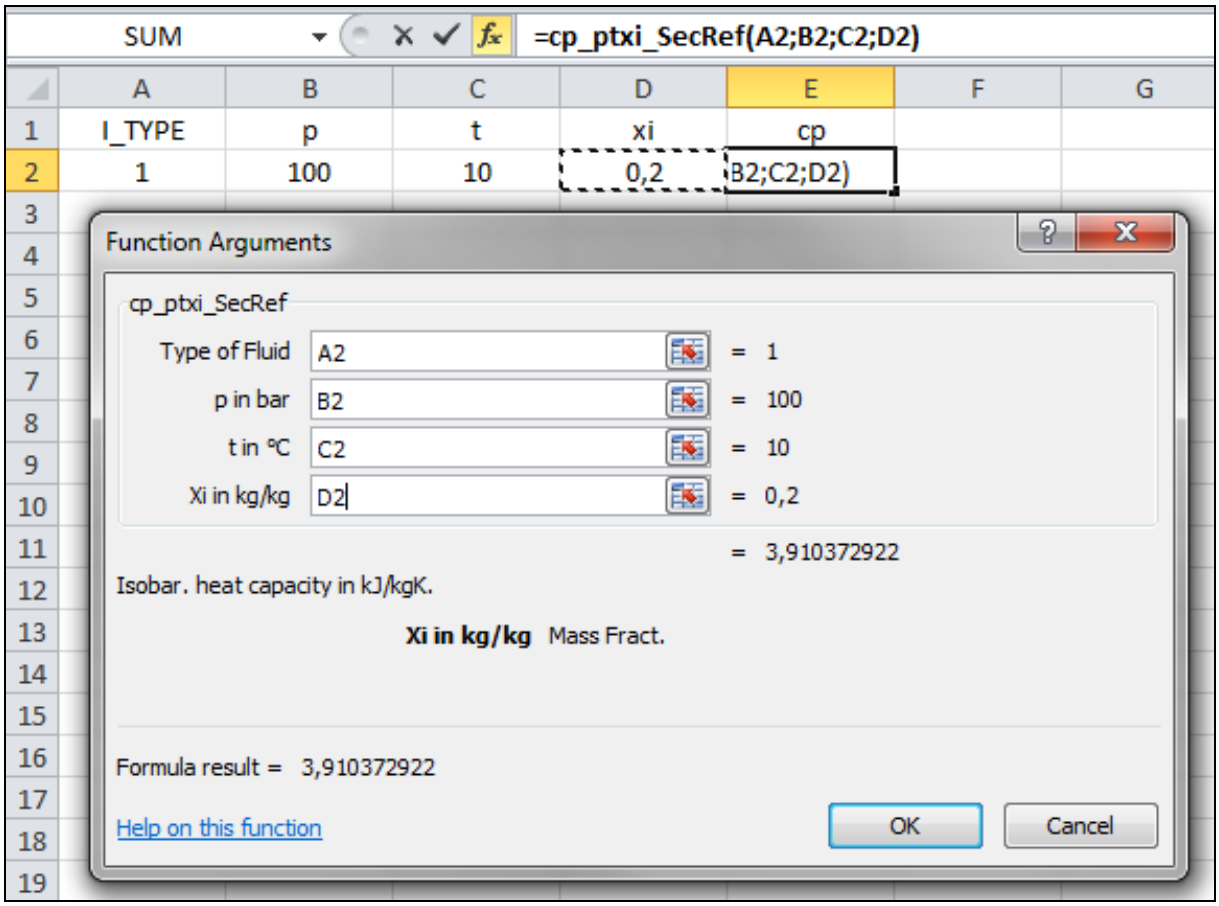


Figure 2.25: Input menu showing the result

- Click the "OK" button.
  The result for *cp* in kJ/(kg K) appears in the cell selected above.

  ⇒ The result for *cp* in our sample calculation here is: 3.910372922 kJ/kgK.

The calculation of *cp* = f(I_TYPE,p,t,xi) has thus been carried out. You can now arbitrarily change the values for *I_TYPE*, *p*, *t* or *xi* 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 of *MELINDER*. More detailed information on each function and its range of validity is available in Chapter 3 or in the help-file.

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 LibSecRef library, delete the files

LibSecRef.dll
LibSecRef.hlp

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

C:\Programme\FluidEXL_Graphics

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

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

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

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

has to be cancelled in Excel®.

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

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

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

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

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

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

Within the next step delete the files

LibSecRef.dll,

LibSecRef.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

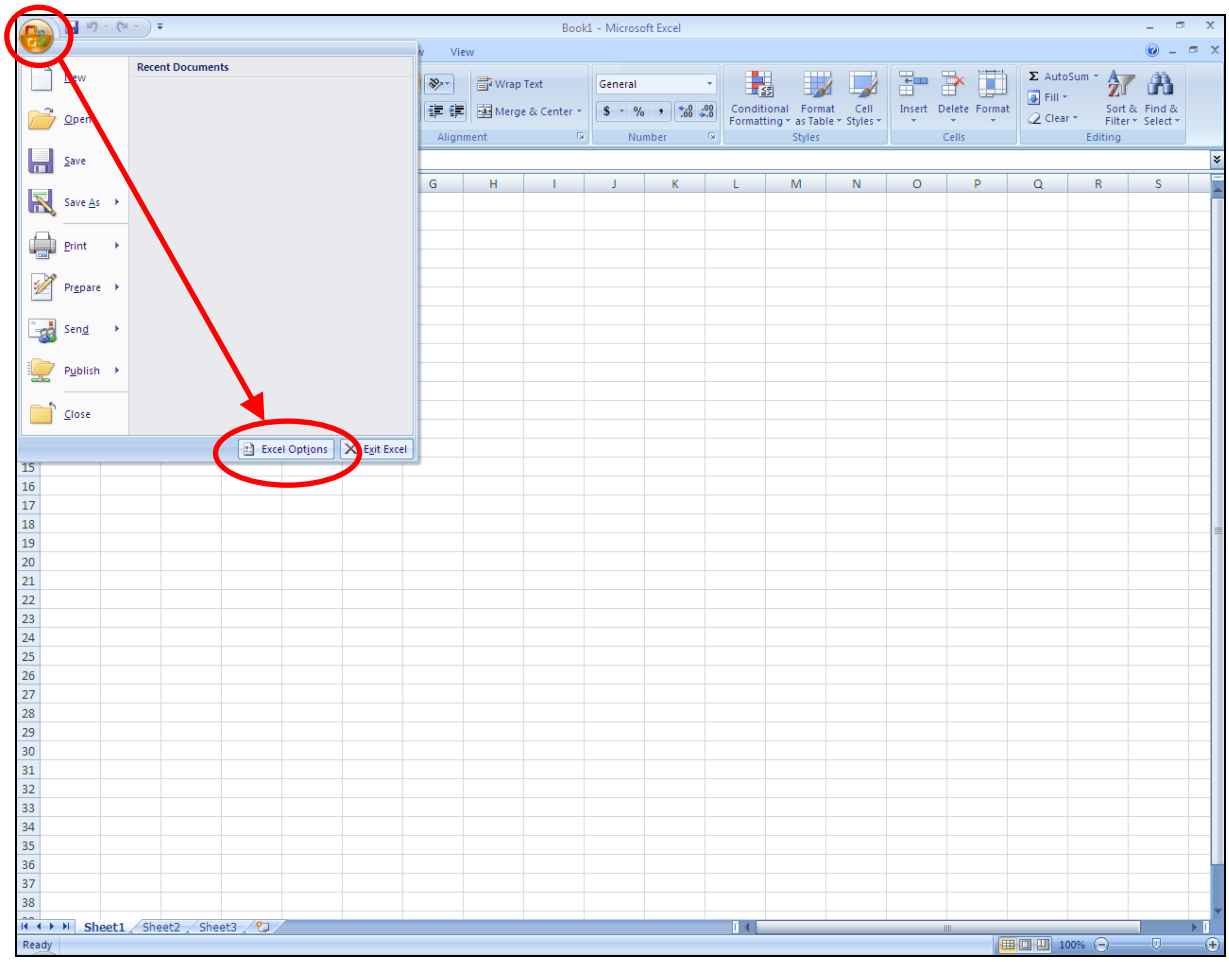


Figure 2.26: Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007

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

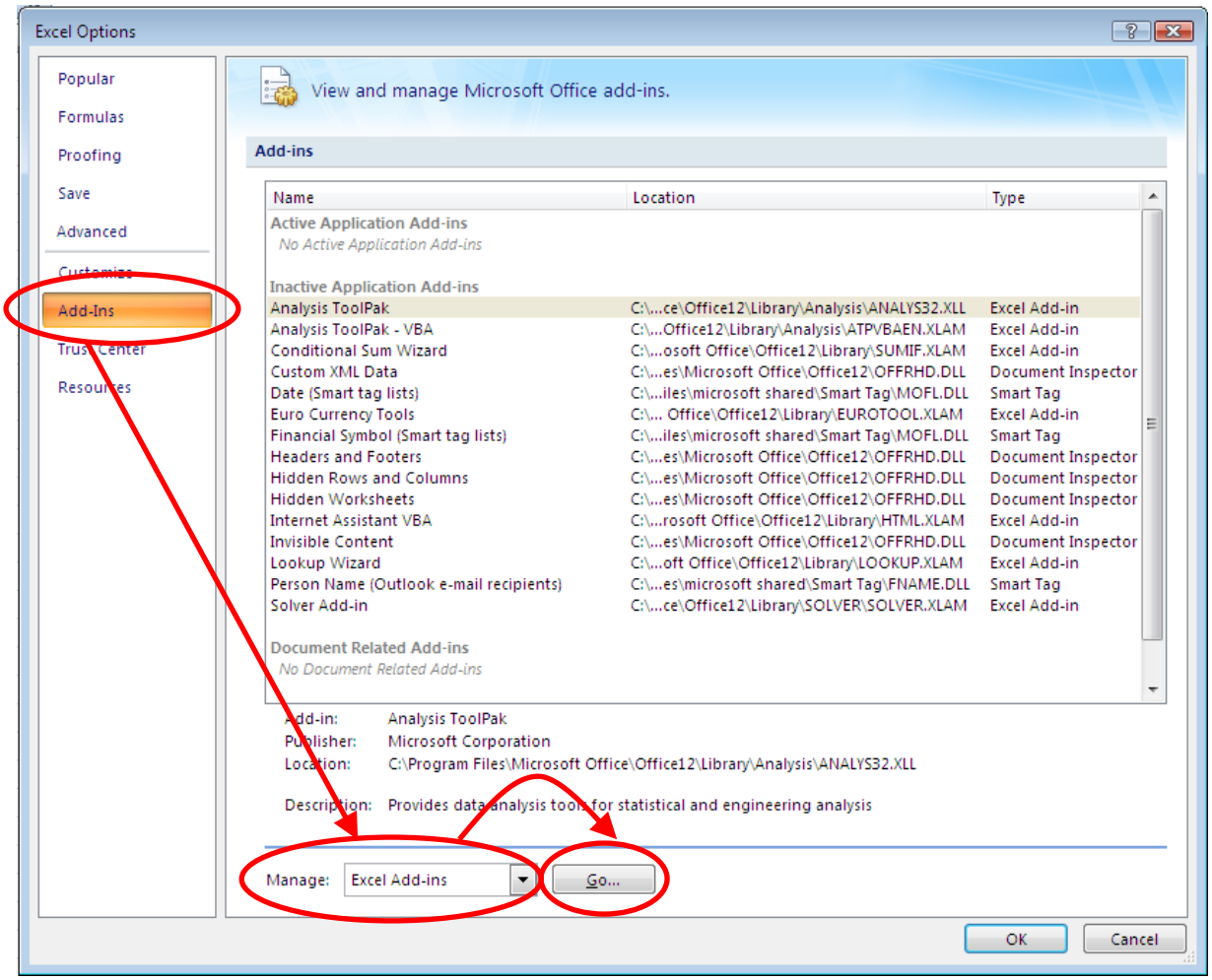


Figure 2.27: Dialog window "Add-Ins"

- 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.

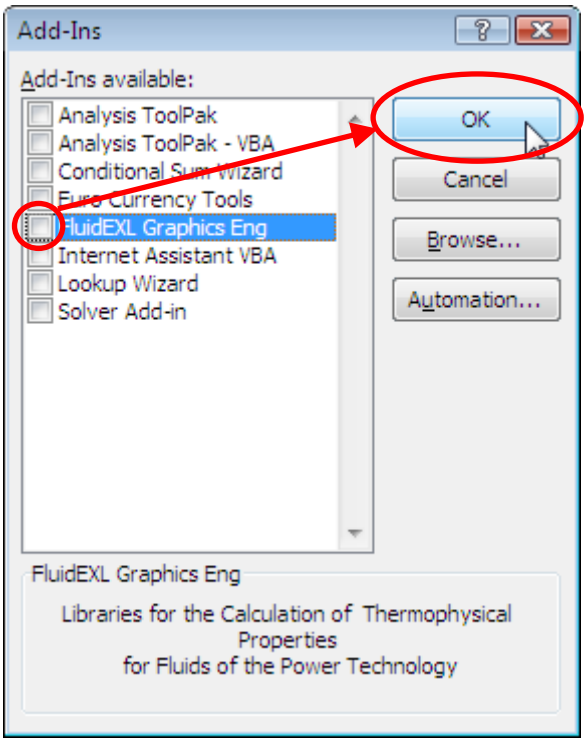


Figure 2.28: Dialog window "Add-Ins"

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(I_TYPE,p,t,ξ)

Function Name: **a_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION A_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

a_ptxi_SecRef or A_PTXI_SECREF – Thermal diffusivity $a = \frac{\lambda}{\rho \cdot c_p} = \frac{\lambda \cdot v}{c_p}$ in m^2 / s

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **a_ptxi_SecRef = –1000** or **A_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References: [1], [2]

Isobaric Cubic Expansion Coefficient α_V = f(I_TYPE,p,t,ξ)

Function Name: **alfav_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION ALFAV_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

alfav_ptxi_SecRef or ALFAV_PTXI_SECREF – Isobaric cubic expansion coefficient in 1/K

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **alfav_ptxi_SecRef = –1000** or **ALFAV_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

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

Function Name: **cp_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION CP_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

cp_ptxi_SecRef or CP_PTXI_SECREF – specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **cp_ptxi_SecRef = –1000** or **CP_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2]

Dynamic Viscosity η = f(I_TYPE,p,t,ξ)

Function Name: **eta_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION ETA_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P,T,XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

eta_ptxi_SecRef or ETA_PTXI_SECREF – Dynamic viscosity η in Pa s

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **eta_ptxi_SecRef = –1000** or **ETA_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2]

Specific Enthalpy h = f(I_TYPE,p,t,ξ)

Function Name: **h_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION H_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

h_ptxi_SecRef or H_PTXI_SECREF – specific enthalpy h in kJ/kg

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **h_ptxi_SecRef = –1000** or **H_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

Thermal Conductivity λ = f(I_TYPE,p,t,ξ)

Function Name: **lam_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION LAM_PTXI_SECREF(I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

lam_ptxi_SecRef or LAM_PTXI_SECREF – thermal conductivity λ in W / (m K)

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **lam_ptxi_SecRef = –1000** or **LAM_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2]

Kinematic Viscosity ν = f(I_TYPE,p,t,ξ)

Function Name: **ny_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION NY_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

ny_ptxi_SecRefor NY_PTXI_SECREF – Kinematic viscosity $\nu = \eta / \rho = \eta \cdot \nu$ in m^2 /s

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **ny_ptxi_SecRef = –1000** or **NY_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

Prandtl-Number Pr = f(*I _TYPE*,*p*,*t*,ξ)

Function Name: **Pr_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION PR_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

pr_ptxi_SecRef or **PR_PTXI_SECREF** – Prandtl-Number Pr $= \eta \cdot c_p / \lambda$

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **pr_ptxi_SecRef = –1000** or **PR_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

Density ρ = f(I_TYPE,p,t,ξ)

Function Name: **rho_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION RHO_PTXI_SECREF(I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

rho_ptxi_SecRefor RHO_PTXI_SECREF – Density ρ in kg/m^3

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **rho_ptxi_SecRef = –1000** or **RHO_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2]

Specific Entropy $s = f(I_TYPE, p, t, \xi)$

Function Name: **s_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION S_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

s_ptxi_SecRef or S_PTXI_SECREF – Specific entropy s in kJ/(kg K)

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **s_ptxi_SecRef = –1000** or **S_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

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

Function Name: **t_phxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION T_PHXI_SECREF (I_TYPE, P, H, XI)**
Variable Types: REAL*8 P, H, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
H – Specific enthalpy in kJ/kg
XI – Mass fraction of the non-water part in kg/kg

Result

t_phxi_SecRef or T_PHXI_SECREF – Solution temperature t in °C

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

The result is **t_phxi_SecRef = –1000** or **T_PHXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	I_TYPE
Ethylene glycol	0	0.56	1
Propylene glycol	0.15	0.57	2
Ethyl alcohol	0.11	0.6	3
Methyl alcohol	0.078	0.474	4
Glycerol	0.195	0.63	5
Potassium carbonate	0	0.39	6
Calcium chloride	0.09	0.294	7
Magnesium chloride	0	0.205	8
Sodium chloride	0	0.23	9
Potassium acetate	0.11	0.41	10

References

[1], [2], [3]

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

Function Name: **t_psxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION T_PSXI_SECREF (I_TYPE, P, S, XI)**
Variable Types: REAL*8 P, S, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
S – Specific entropy in kJ/ (kg K)
XI – Mass fraction of the non-water part in kg/kg

Result

t_psxi_SecRef or T_PSXI_SECREF – Solution temperature t in °C

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

The result is **t_psxi_SecRef = –1000** or **T_PSXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	I_TYPE
Ethylene glycol	0	0.56	1
Propylene glycol	0.15	0.57	2
Ethyl alcohol	0.11	0.6	3
Methyl alcohol	0.078	0.474	4
Glycerol	0.195	0.63	5
Potassium carbonate	0	0.39	6
Calcium chloride	0.09	0.294	7
Magnesium chloride	0	0.205	8
Sodium chloride	0	0.23	9
Potassium acetate	0.11	0.41	10

References

[1], [2], [3]

Backward Function: Temperature t = f(I_TYPE,p,v,ξ)

Function Name: **t_pvxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION T_PVXI_SECREF (I_TYPE, P, V, XI)**
Variable Types: REAL*8 P, V, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
V – Specific volume in m³ / kg
XI – Mass fraction of the non-water part in kg/kg

Result

t_pvxi_SecRef or T_PVXI_SECREF – Solution temperature *t* in °C

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

The result is **t_pvxi_SecRef = –1000** or **T_PVXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	I_TYPE
Ethylene glycol	0	0.56	1
Propylene glycol	0.15	0.57	2
Ethyl alcohol	0.11	0.6	3
Methyl alcohol	0.078	0.474	4
Glycerol	0.195	0.63	5
Potassium carbonate	0	0.39	6
Calcium chloride	0.09	0.294	7
Magnesium chloride	0	0.205	8
Sodium chloride	0	0.23	9
Potassium acetate	0.11	0.41	10

References

[1], [2], [3]

Freezing Temperature *tf* = f(*I_TYPE*,ξ)

Function Name: **tf_xi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION TF_XI_SECREF (I_TYPE, XI)**
Variable Types: REAL*8 XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
XI – Mass fraction of the non-water part

Result

tf_xi_SecRef or TF_XI_SECREF – Freezing Temperature *tf* in °C

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

The result is **tf_xi_SecRef = –1000** or **TF_XI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	10

References

[1], [2]

Specific Internal Energy u = f(I_TYPE,p,t,ξ)

Function Name: **u_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION U_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

u_ptxi_SecRef or U_PTXI_SECREF – Specific internalo energy u in kJ/kg

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **u_ptxi_SecRef = –1000** or **U_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

Specific Volume v = f(I_TYPE,p,t,ξ)

Function Name: **v_ptxi_SecRef**
Subroutine with function value: **REAL*8 FUNCTION V_PTXI_SECREF (I_TYPE, P, T, XI)**
Variable Types: REAL*8 P, T, XI
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution
P – Pressure in bar
T – Solution temperature in °C
XI – Mass fraction of the non-water part in kg/kg

Result

v_ptxi_SecRef or V_PTXI_SECREF – Specific volume v in m³/kg

Range of validity

Type of solution range: from 1 to 10

Mass fraction range: from $\xi_{min} \leq \xi \leq \xi_{max}$

Solution temperature range: from $t_{min} \leq t \leq t_{max}$ and $t \geq tf$

The result is **v_ptxi_SecRef = –1000** or **V_PTXI_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$\xi < \xi_{min}$ or $\xi > \xi_{max}$ or
$t < t_{min}$ or $t > t_{max}$ or $t < tf$ or
$p \leq 0$ bar

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

Mass Fraction of the Non-Water Part ξ = f(I_TYPE,tf)

Function Name: **xi_tf_SecRef**
Subroutine with function value: **REAL*8 FUNCTION XI_TF_SECREF (I_TYPE, TF)**
Variable Types: REAL*8 TF
INTEGER*4 I_TYPE

Input values

I_TYPE – Type of solution

TF – Freezing Solution temperature in °C

Result

xi_tf_SecRef or XI_TF_SECREF – Mass fraction ξ in kg/kg

Range of validity

Type of solution range: from 1 to 10

Freezing temperature range: from $tf_{min} \leq tf \leq tf_{max}$

The result is **xi_tf_SecRef = –1000** or **XI_TF_SECREF = –1000** for the following input values:

$I_TYPE < 1$ or $I_TYPE > 10$ or
$tf < tf_{min}$ or $tf > tf_{max}$

The boundary values are given in the following Table:

Name of non-water component	ξ_{min}	ξ_{max}	t_{min}	t_{max}	tf_{min}	I_TYPE
Ethylene glycol	0	0.56	- 45 °C	40 °C	- 45 °C	1
Propylene glycol	0.15	0.57	- 45 °C	40 °C	- 45 °C	2
Ethyl alcohol	0.11	0.6	- 45 °C	20 °C	- 45 °C	3
Methyl alcohol	0.078	0.474	- 50 °C	20 °C	- 50 °C	4
Glycerol	0.195	0.63	- 40 °C	40 °C	- 40 °C	5
Potassium carbonate	0	0.39	- 35 °C	30 °C	- 35 °C	6
Calcium chloride	0.09	0.294	- 45 °C	30 °C	- 45 °C	7
Magnesium chloride	0	0.205	- 30 °C	30 °C	- 30 °C	8
Sodium chloride	0	0.23	- 20.7 °C	30 °C	- 20.7 °C	9
Potassium acetate	0.11	0.41	- 45 °C	30 °C	- 45 °C	10

References

[1], [2], [3]

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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

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)

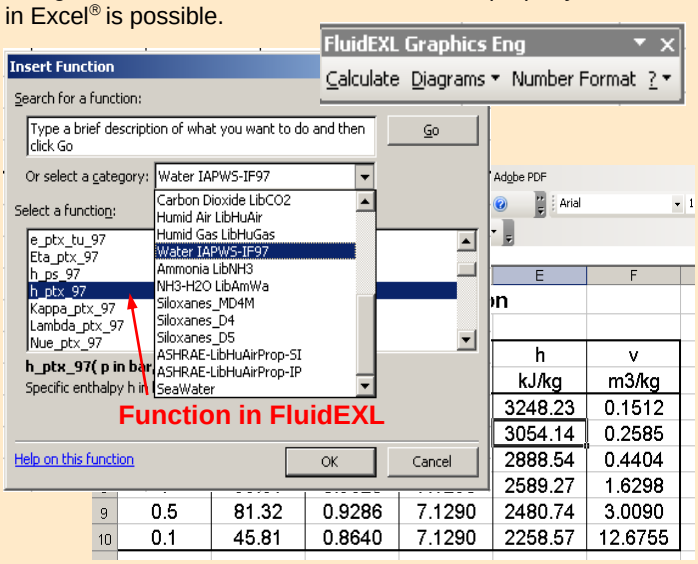
Library LibButan_n

Refrigerant n-Butane

Formulation of Bücker et al. (2003)

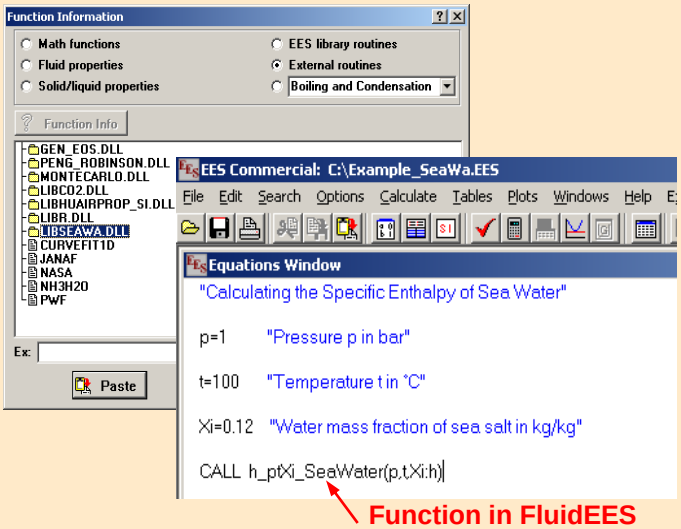
Add-In FluidEXL for Excel®

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



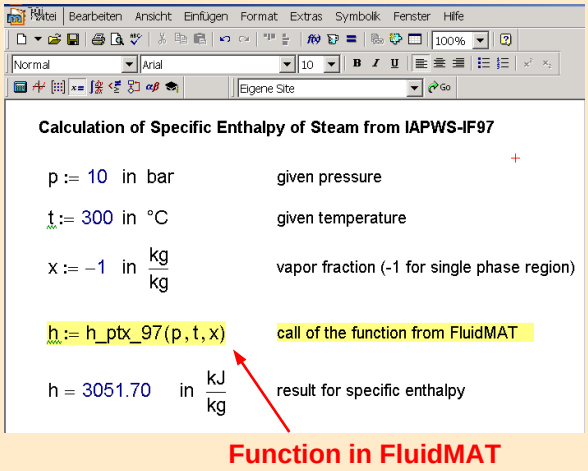
Add-In FluidEES for EES®

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



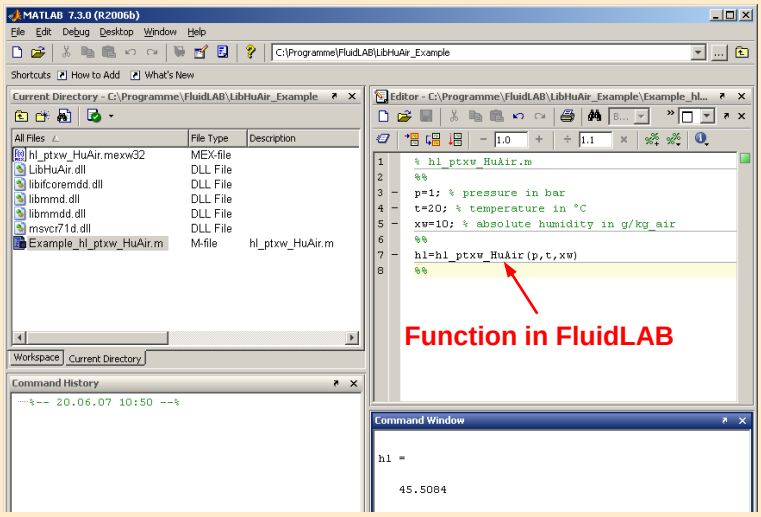
Add-In FluidMAT for Mathcad®

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

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

For information please contact:

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Fax.: +49-3583-61-1846

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

5. References

[1] Melinder, Åke:
Thermopyhsical Properties of Liquid Secondary Refrigerants.
International Institute of Refrigeration, 1997.

[2] Melinder, Åke:
Thermophysical Properties of Aqueous Solutions Used as Secondary Working Fluids.
Doctoral Thesis, 2007.

[3] Kretzschmar, H.-J.:
Zur Aufbereitung und Darbietung thermophysikalischer Stoffdaten für die Energietechnik.
Habilitation, TU Dresden, Fakultät Maschinenwesen (1990)

[4] Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam IAPWS-IF97.
IAPWS Sekretariat, Dooley, B, EPRI, Palo Alto CA (1997)

[5] Wagner, W.; Cooper, J.R.; Dittmann, A.; Kijima, J.; Kretzschmar, H.-J.; Kruse, A.; Mareš, R.; Oguchi, K.; Sato, H.; Stöcker, I.; Šifner, O.; Takaishi, Y.; Tanishita, I.; Trübenbach, J.; Willkommen, Th.:
The IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam.
ASME Journal of Eng. for Gas Turbines and Power 122 (2000) Nr. 1, S. 150-182

6. Satisfied Customers

Date: 10/2011

The following companies and institutions use the property libraries

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

2011

Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011
Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011, 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
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Witt Consulting Engineers, Stade	03/2011

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MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
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2010

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HS Cooler, Wittenburg	12/2010
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Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010
Universitaet der Bundeswehr, Munich	04/2010
Technical University of Hamburg-Harburg	04/2010
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Fischer-Uhrig Consulting Engineers, Berlin	01/2010

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Techgroup, Ratingen	11/2009
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MCI, Innsbruck, Austria	12/2009
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2008

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MAAG, Kuesnacht, Switzerland	02/2008
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RWE IT, Essen	04/2008
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Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
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Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
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Siemens Power Generation, Berlin	11/2006
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BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
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Technical University of Dresden, Waste Management	05/2005
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STORA ENSO Sachsen, Eilenburg	12/2005
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KEMA IEV, Dresden	12/2005

2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	01/2004
University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004

Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003
Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
Ingenieurbuero Ostendorf, Gummersbach	05/2003
TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	06/2003
University of Cali, Colombia	07/2003
Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003

Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
FZR Forschungszentrum, Rossendorf/Dresden	03/2002
CompAir, Simmern	03/2002
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
ALSTOM Power Baden, Switzerland (group licenses)	05/2002
InfraServ, Gendorf	05/2002
SoftSolutions, Muehlhausen (company license)	05/2002
DREWAG, Dresden (company license)	05/2002
SOFBID, Zwingenberg (general EBSILON program license)	06/2002
Kleemann Engineering, Dresden	06/2002
Caliqua, Basel, Switzerland (company license)	07/2002
PCK Raffinerie, Schwedt (group license)	07/2002
Fischer-Uhrig Engineering, Berlin	08/2002
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	08/2002
Stadtwerke Duisburg	08/2002

Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

2001

ALSTOM Power, Baden, Switzerland	01/2001, 06/2001, 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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SOFBID, Zwingenberg (general EBSILON program license)	01/2000
AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000

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

1999

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

1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
M&M Turbine Technology Bielefeld	06/1998
B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998

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

1997

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