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Faculty of
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Department of
TECHNICAL THERMODYNAMICS

# Property Library for Tetradecamethyl-hexasiloxane (MD4M) $C_{14}H_{42}O_5Si_6$

# FluidEXL*Graphics* with LibMD4M for Excel®

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# Property Software for the Calculation of Tetradecamethylhexasiloxane (MD4M)

# FluidEXL*Graphics*
# LibMD4M

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# 0. Package Contents

## 0.1 Zip files for 32-bit Office®

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

**English zip file "CD_FluidEXL_Graphics_LibMD4M_Eng.zip" including the following files:**

| | |
|---|---|
| FluidEXL_Graphics_Eng_Setup.exe | - Self-extracting and self-installing program for FluidEXL*Graphics* |
| FluidEXL_Graphics_Eng.xla | - FluidEXL*Graphics* Add-In |
| LibMD4M_Eng.hlp | - Help file for the LibMD4M property library |
| LibMD4M.dll | - Dynamic link library with functions for the LibMD4M property library |
| FluidEXL_Graphics_LibMD4M_Docu_Eng.pdf | - User's Guide |

**German zip file "CD_FluidEXL_Graphics_LibMD4M.zip" including the following files:**

| | |
|---|---|
| FluidEXL_Graphics_Setup.exe | - Self-extracting and self-installing program for FluidEXL*Graphics* |
| FluidEXL_Graphics.xla | - German Add-In for FluidEXL*Graphics* |
| LibMD4M_Eng.hlp | - Help file for the LibMD4M property library |
| LibMD4M.dll | - Dynamic link library with functions for the LibMD4M property library |
| FluidEXL_Graphics_LibMD4M_Docu_Eng.pdf | - User's Guide |

## 0.2 Zip files for 64-bit Office®

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

**English zip file "CD_FluidEXL_Graphics_LibMD4M_x64_Eng.zip" including the following files and folders:**

**Files:**

| | |
|---|---|
| Setup.exe | - Self-extracting and self-installing program for FluidEXL*Graphics* |
| FluidEXL_Graphics_Eng_64_Setup.msi | - Self-extracting and self-installing program |
| FluidEXL_Graphics_Eng.xla | - FluidEXL*Graphics* Add-In |
| FluidEXL_Graphics_LibMD4M_Docu_Eng.pdf | - User's Guide |
| LibMD4M.dll | - Dynamic link library with functions the LibMD4M property library |
| LibMD4M_Eng.hlp | - Help file for the LibMD4M property library |

**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_LibMD4M_x64.zip" including the following files and folders:**

**Files:**

| | |
|---|---|
| Setup.exe | - Self-extracting and self-installing program for FluidEXL*Graphics* |
| FluidEXL_Graphics_64_Setup.msi | - Self-extracting and self-installing program |
| FluidEXL_Graphics.xla | - German FluidEXL*Graphics* Add-In |
| FluidEXL_Graphics_LibMD4M_Docu_Eng.pdf | - User's Guide |
| LibMD4M.dll | - Dynamic link library with functions the LibMD4M property library |
| LibMD4M_Eng.hlp | - Help file for the LibMD4M property library |

**Folders:**

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

# 1. Property Functions

## 1.1 Calculation Programs

“MD4M” means Tetradecamethylhexasiloxane ( $C_{14}H_{42}O_5Si_6$ )

| Functional Dependence | Function Name | Call from Fortran program | Call in DLL LibMD4M as parameter | Property or Function | Unit of the result |
|---|---|---|---|---|---|
| $c_p = f(p,t,x)$ | cp_ptx_MD4M | CPPTXMD4M(P,T,X) | C_CPPTXMD4M(CP,P,T,X) | Specific isobaric heat capacity | kJ/(kg K) |
| $c_v = f(p,t,x)$ | cv_ptx_MD4M | CVPTXMD4M(P,T,X) | C_CVPTXMD4M(CV,P,T,X) | Specific isochoric heat capacity | kJ/(kg K) |
| $\left(\frac{\partial p}{\partial T}\right)_v = f(p,t,x)$ | dpdtv_ptx_MD4M | DPDTVMD4M(P,T,X) | C_DPDTVMD4M(DPDT,P,T,X) | Derivative of pressure with respect to temperature (at constant specific volume) | kPa/K |
| $\left(\frac{\partial p}{\partial v}\right)_T = f(p,t,x)$ | dpdvt_ptx_MD4M | DPDVTMD4M(P,T,X) | C_DPDVTMD4M(DPDV,P,T,X) | Derivative of pressure with respect to specific volume (at constant temperature) | kPa/(m³/kg) |
| $h = f(p,t,x)$ | h_ptx_MD4M | HPTXMD4M(P,T,X) | C_HPTXMD4M(H,P,T,X) | Specific enthalpy | kJ/kg |
| $\kappa = f(p,t,x)$ | kappa_ptx_MD4M | KAPPAPTXMD4M(P,T,X) | C_KAPPAPTXMD4M(KAPPA,P,T,X) | Isentropic exponent | - |
| $p_s = f(t)$ | ps_t_MD4M | PSTMD4M(T) | C_PSTMD4M(PS,T) | Vapor pressure from temperature | bar |
| $\rho = f(p,t,x)$ | rho_ptx_MD4M | RHOPTXMD4M(P,T,X) | C_RHOPTXMD4M(RHO,P,T,X) | Density | kg/m³ |
| $s = f(p,t,x)$ | s_ptx_MD4M | SPTXMD4M(P,T,X) | C_SPTXMD4M(S,P,T,X) | Specific entropy | kJ/(kg K) |
| $t = f(p,h)$ | t_ph_MD4M | TPHMD4M(P,H) | C_TPHMD4M(T,P,H) | Backward function: Temperature from pressure and enthalpy | °C |
| $t = f(p,s)$ | t_ps_MD4M | TPSMD4M(P,S) | C_TPSMD4M(T,P,S) | Backward function: Temperature from pressure and entropy | °C |
| $t_s = f(p)$ | ts_p_MD4M | TSPMD4M(P) | C_TSPMD4M(TS,P) | Saturation temperature from pressure | °C |
| $u = f(p,t,x)$ | u_ptx_MD4M | UPTXMD4M(P,T,X) | C_UPTXMD4M(U,P,T,X) | Specific internal energy | kJ/kg |
| $v = f(p,t,x)$ | v_ptx_MD4M | VPTXMD4M(P,T,X) | C_VPTXMD4M(V,P,T,X) | Specific volume | m³/kg |
| $w = f(p,t,x)$ | w_ptx_MD4M | WPTXMD4M(P,T,X) | C_WPTXMD4M(W,P,T,X) | Isentropic speed of sound | m/s |
| $x = f(p,h)$ | x_ph_MD4M | XPHMD4M(P,H) | C_XPHMD4M(X,P,H) | Backward function: Vapor fraction from pressure and enthalpy | kg/kg |

| Functional Dependence | Function Name | Call from Fortran program | Call in DLL LibMD4M as parameter | Property or Function | Unit of the result |
|---|---|---|---|---|---|
| $x = f(p,s)$ | x_ps_MD4M | XPSMD4M(P,S) | C_XPSMD4M(X,P,S) | Backward function: Vapor fraction from pressure and entropy | kg/kg |
| $Z = f(p,t,x)$ | Z_ptx_MD4M | ZPTXMD4M(P,T,X) | C_ZPTXMD4M(W,P,T,X) | Compression factor | - |

**Units:**

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

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 bar

## Reference state

$h$ = 0 kJ/kg and $s$ = 0 kJ/(kg K) at $t_B$ = 259.573 °C on the boiling curve ($x$ = 0; $p_s = p_N$ = 1.01325 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:

Single-phase region

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

Wet-steam region

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

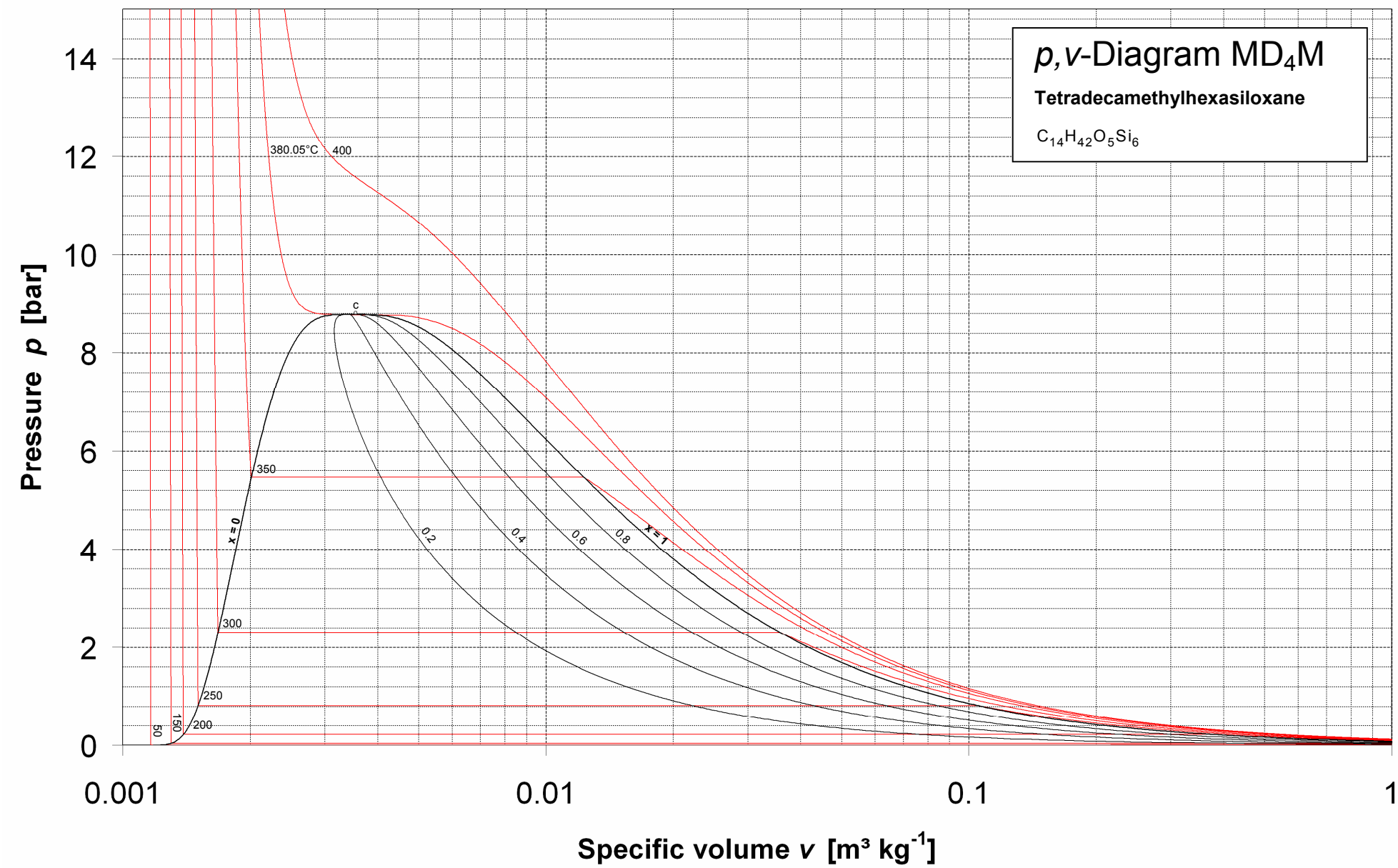
If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in –1000.

Wet steam region: Temperature range from $t$ = 26.85 °C to $t_c$ = 379.05 °C
Pressure range from $p_s$ (26.85 °C) = 0.00001093377 bar to $p_c$ = 8.7747391 bar

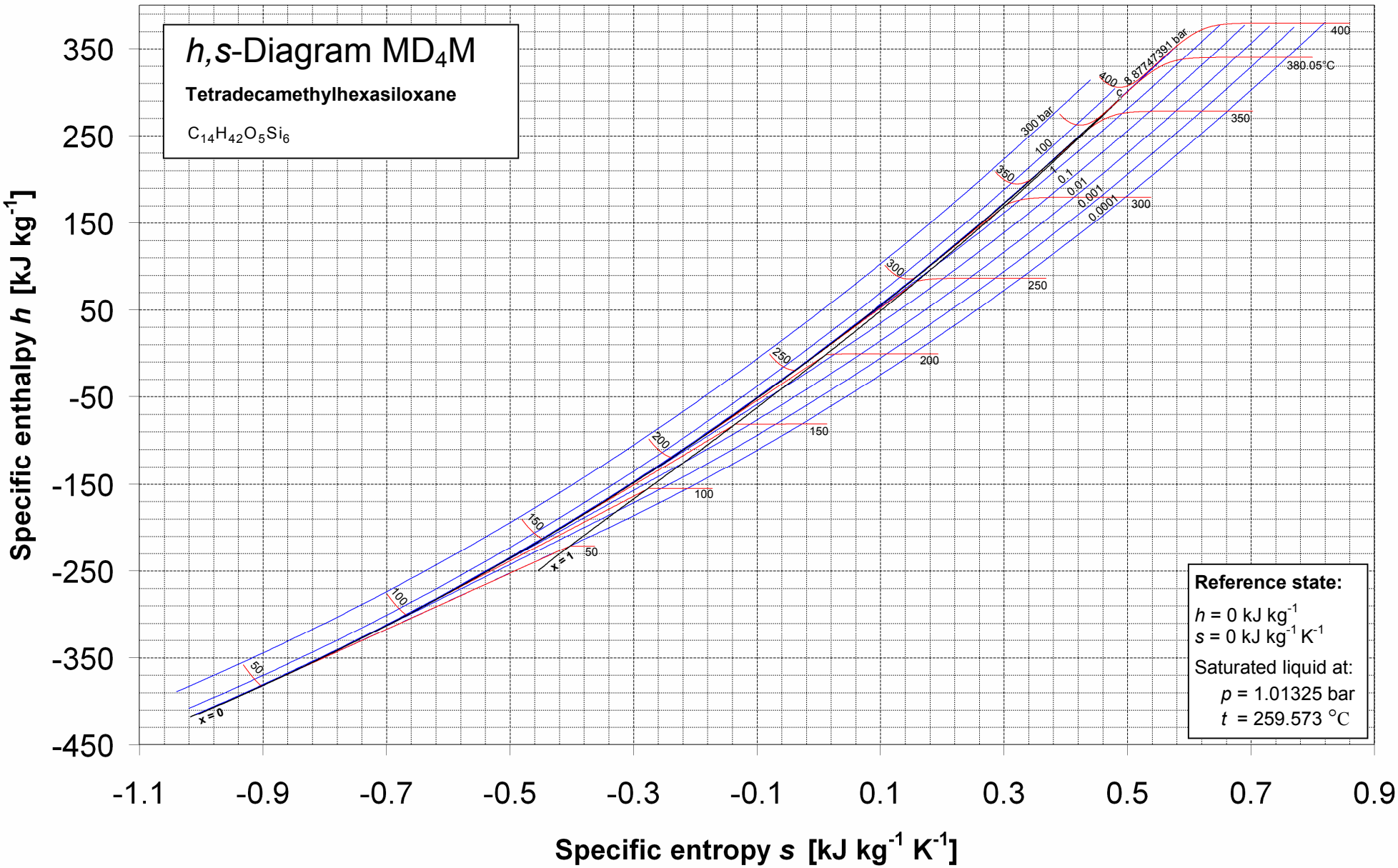
**Note.**

*If the calculation results in –1000, the values entered represent a state point beyond the range of validity of MD4M. 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.*

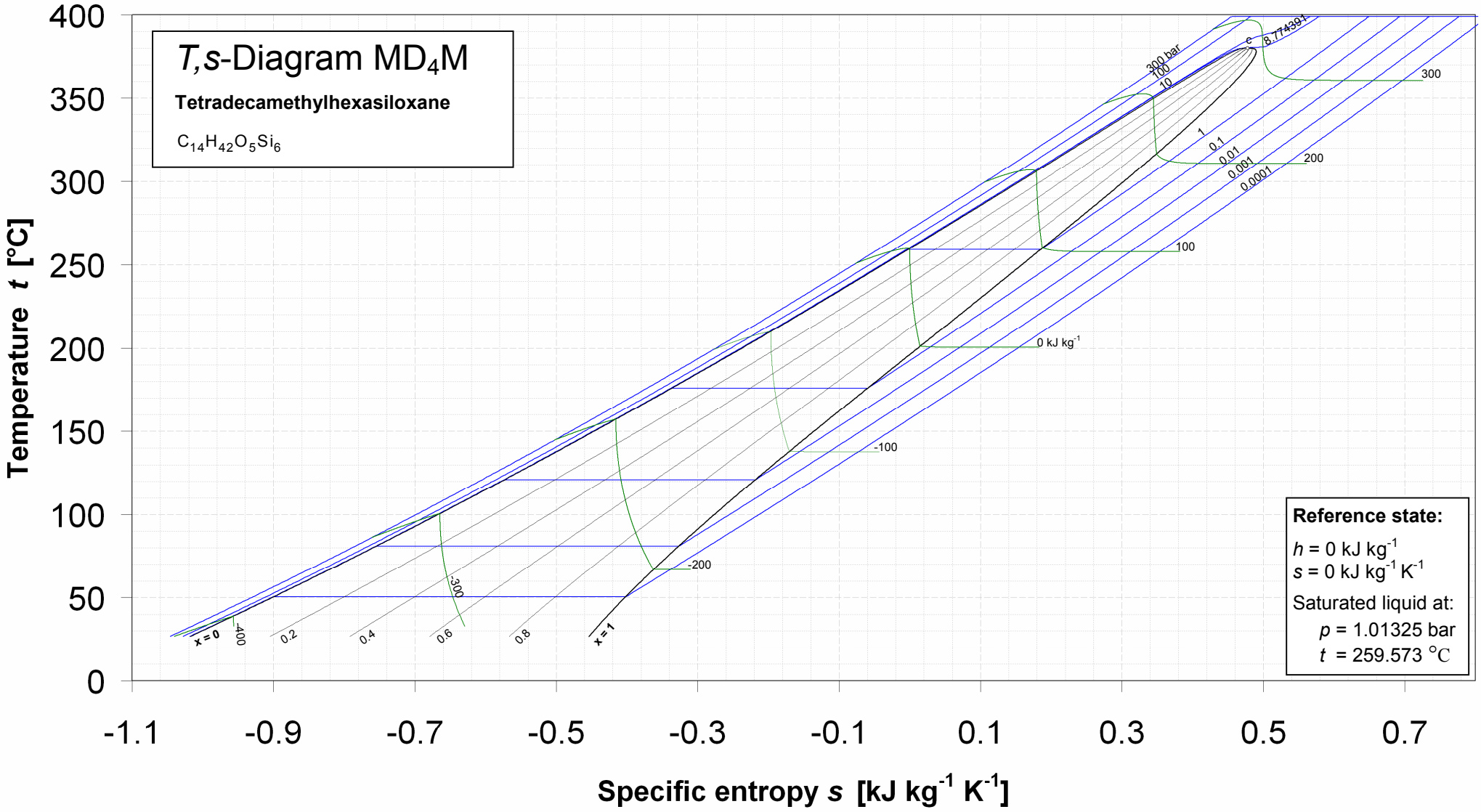
## 1.2 *p,v*-Diagram



## 1.3 *h,s*-Diagram



## 1.4 *T,s*-Diagram



# 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 Tetradecamethylhexasiloxane from the LibMD4M 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 LibMD4M library. In this case, follow the subsection "Adding the LibMD4M 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_LibMD4M_Eng.zip" | (for English version of Windows) |
| "CD_FluidEXL_Graphics_LibMD4M.zip" | (for German version of Windows) |

you will see the folder

| | |
|---|---|
| CD_FluidEXL_Graphics_LibMD4M_Eng | (for English version of Windows) |
| CD_FluidEXL_Graphics_LibMD4M | (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_LibMD4M_Docu_Eng.pdf | |
| LibMD4M.dll | |
| LibMD4M_Eng.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).

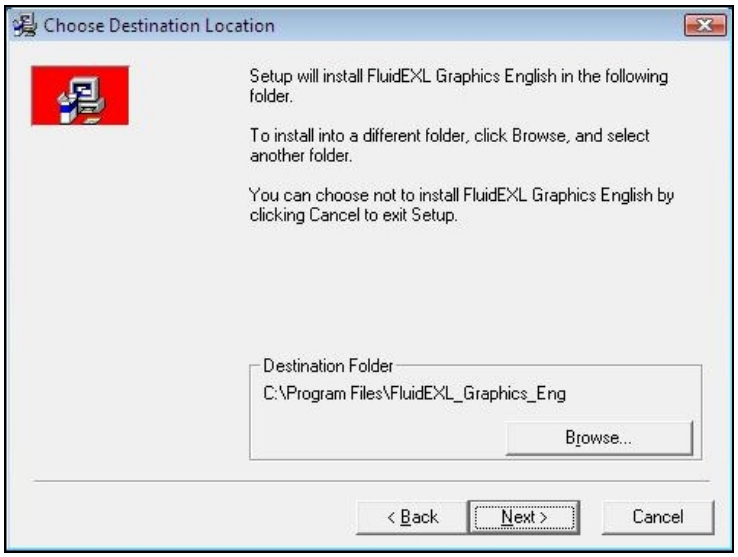



**Figure 2.1:** Choose Destination Location

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 addition, the two subdirectories \FORMULATION97 and \FLuft have been compiled in the destination folder.

In the next step, the following files

| | |
|---|---|
| FluidEXL_Graphics_Eng.xla | (for English version of Windows) |
| FluidEXL_Graphics.xla | (for German version of Windows) |
| LibMD4M.dll | |
| LibMD4M_Eng.hlp | |

from the extracted folder

| | |
|---|---|
| CD_FluidEXL_Graphics_LibMD4M_Eng | (for English version of Windows) |
| CD_FluidEXL_Graphics_LibMD4M | (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®

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_LibMD4M_x64_Eng.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibMD4M_x64.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibMD4M_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibMD4M (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_LibMD4M_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)
LibMD4M.dll
LibMD4M_Eng.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).

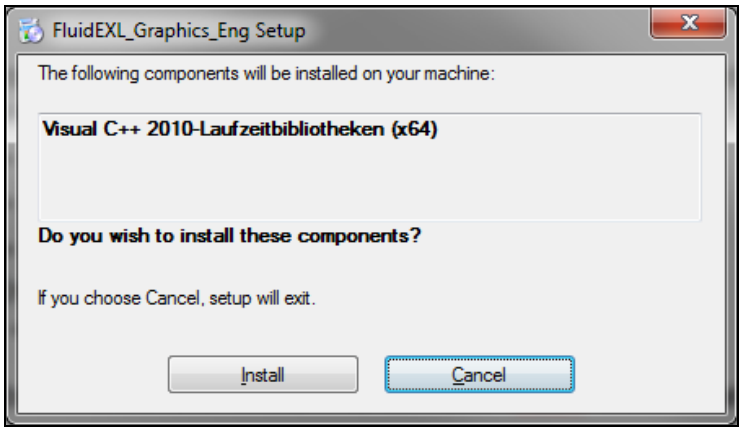



**Figure 2.2:** Installing the "Visual C++ 2010 runtime library (x64)"

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).

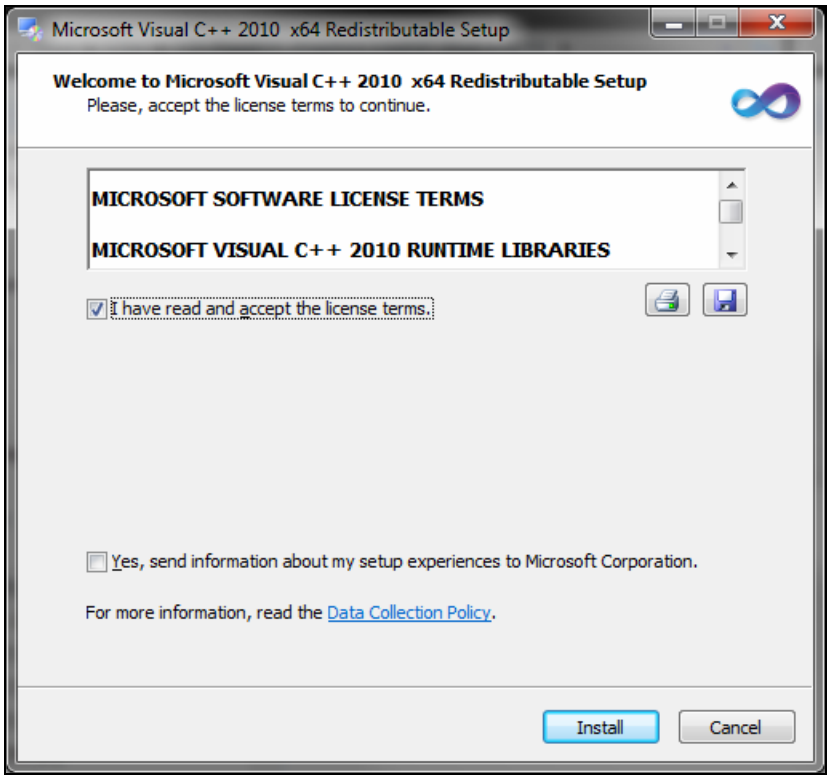



**Figure 2.3:** Accepting the license terms

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).

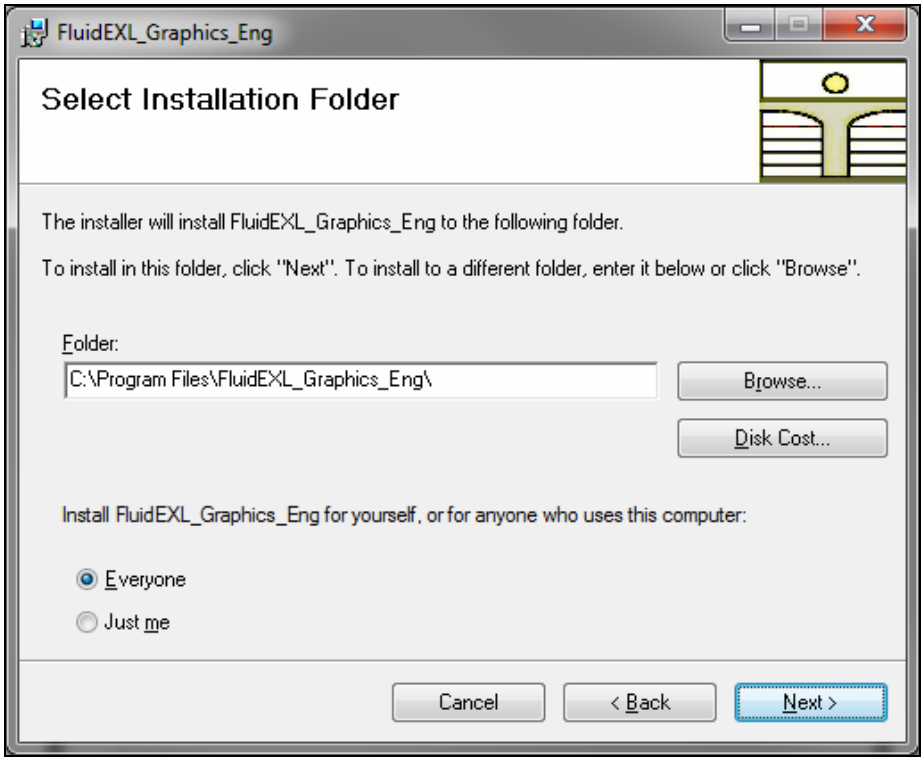



**Figure 2.4:** Choosing the Installation Folder of FluidEXL*Graphics*

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)
LibMD4M.dll
LibMD4M_Eng.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.

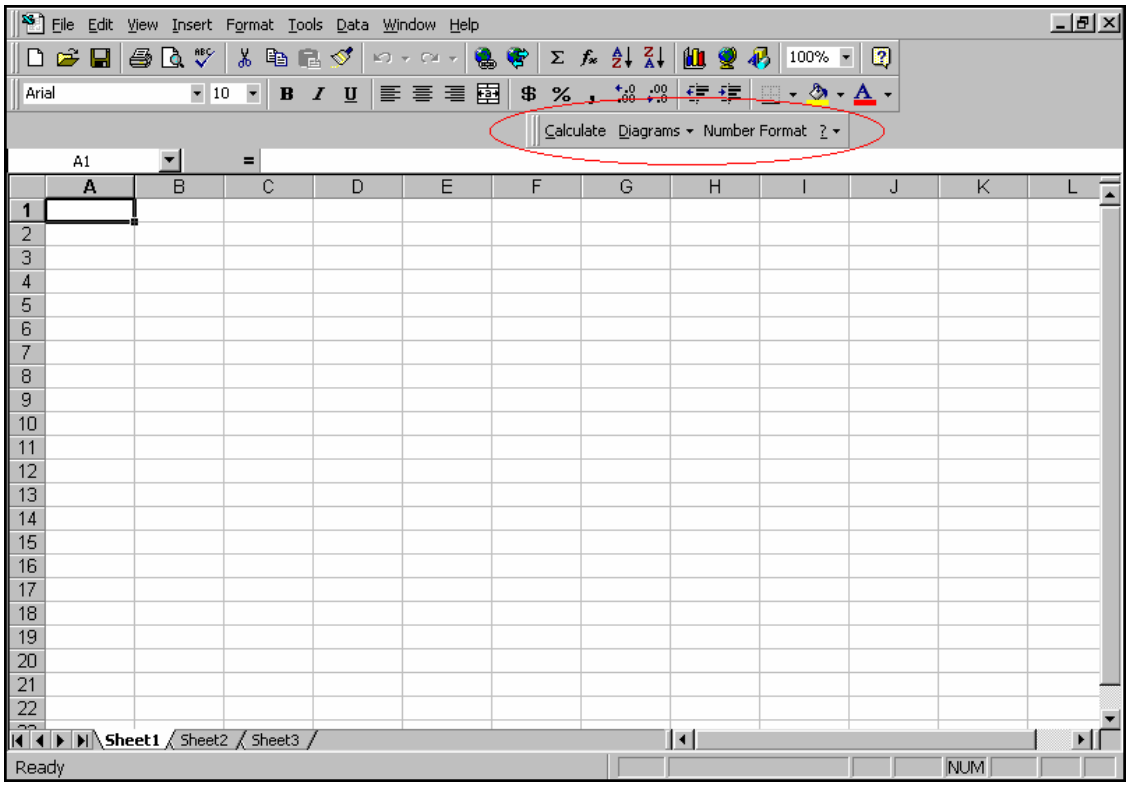



**Figure 2.5:** Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "Siloxane_MD4M" DLL library property functions via this menu bar (see part 2.5 on page 2/19).

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

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

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

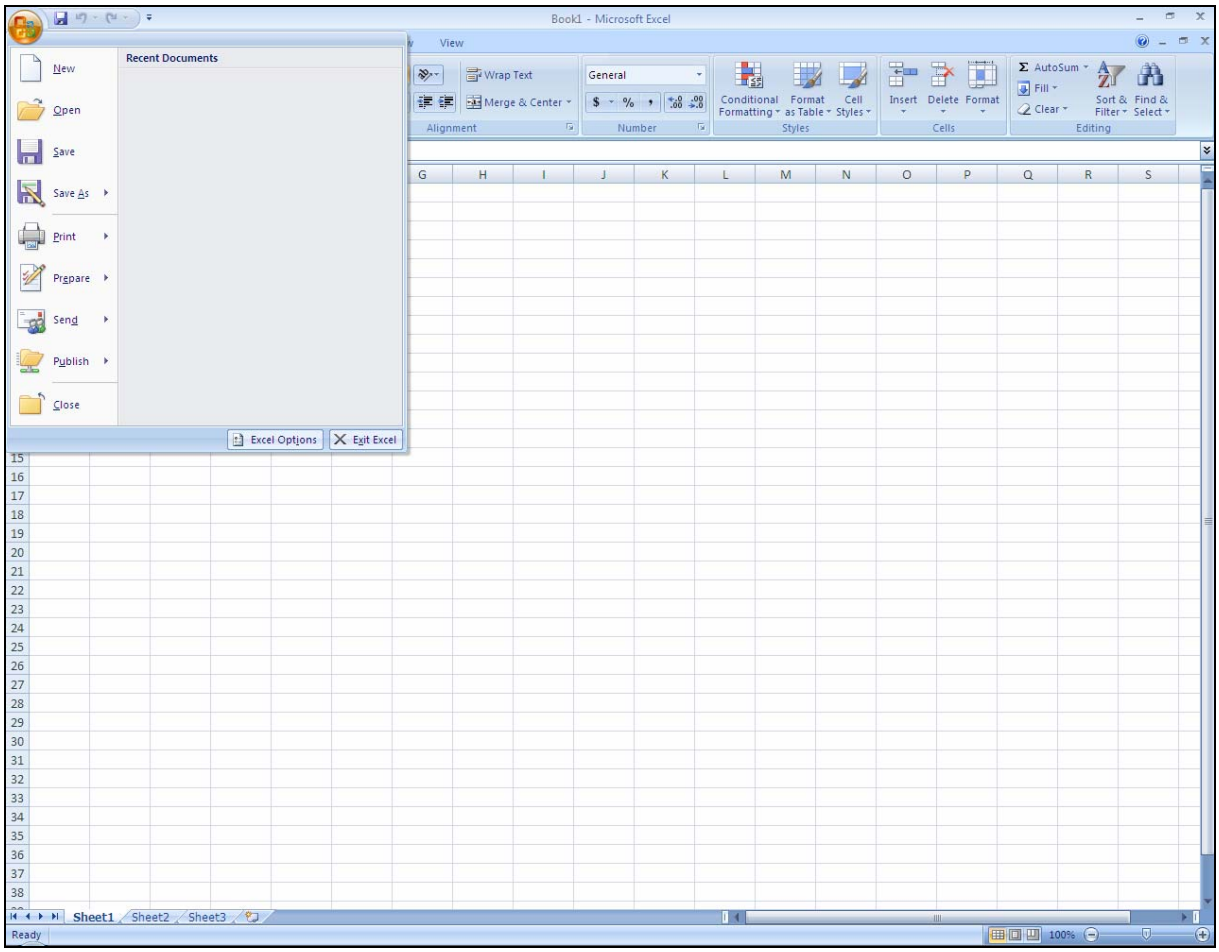



**Figure 2.6:** Registering FluidEXL*Graphics* as Add-In in Excel® 2007

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

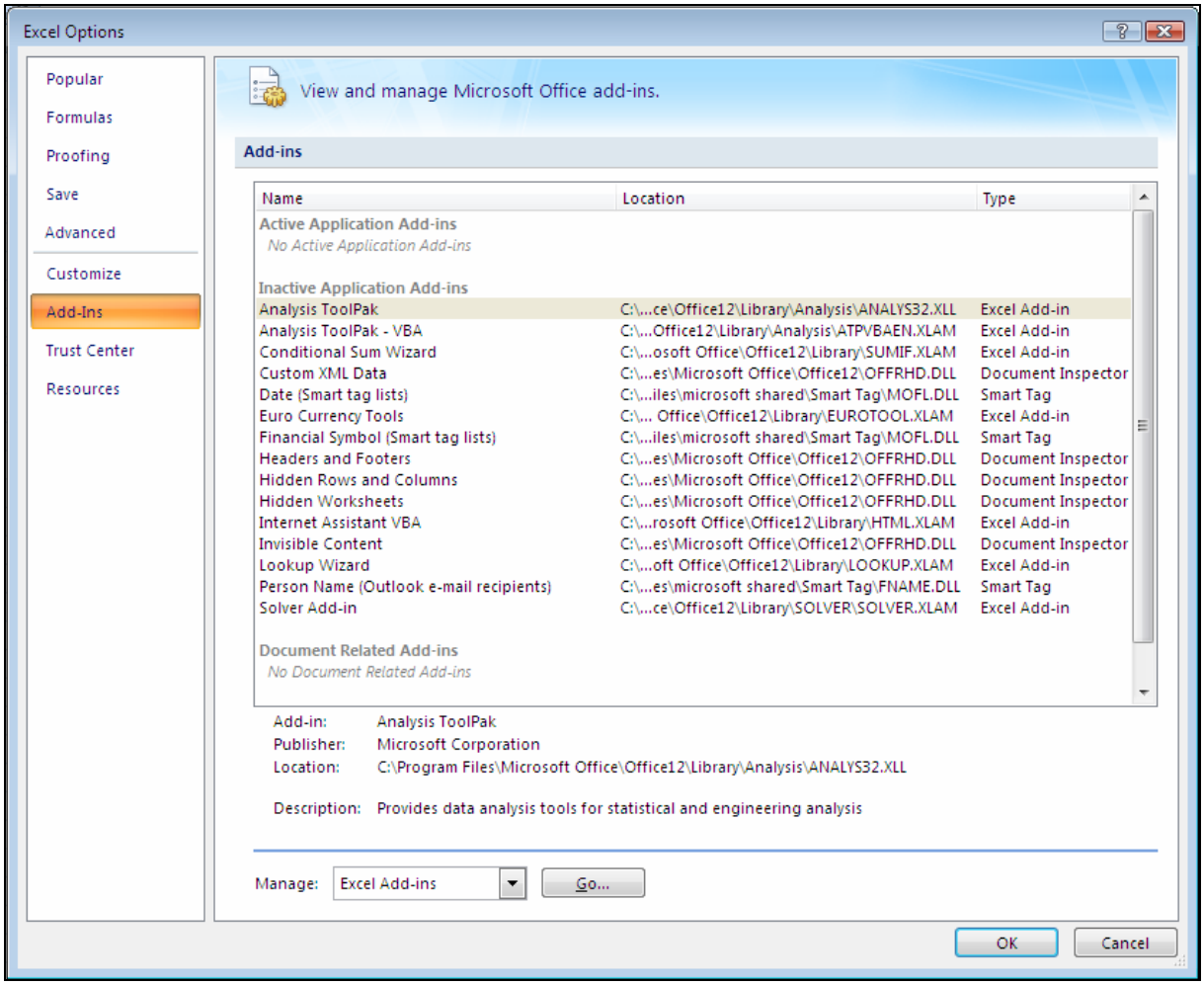



**Figure 2.7:** Dialog window "Excel Options"

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

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

  within that folder click on the file named

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

  and then hit "OK."

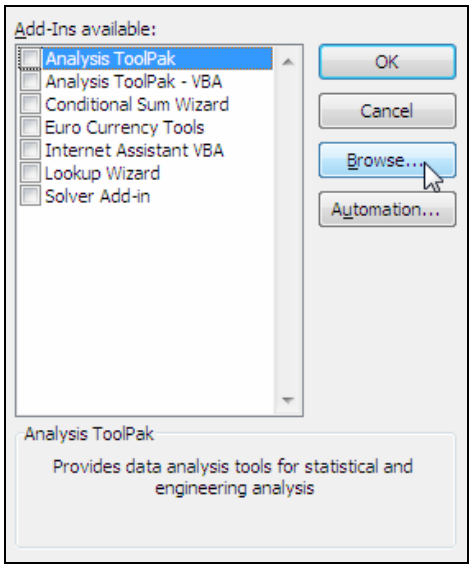



**Figure 2.8:** Dialog window "Add-Ins available"

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

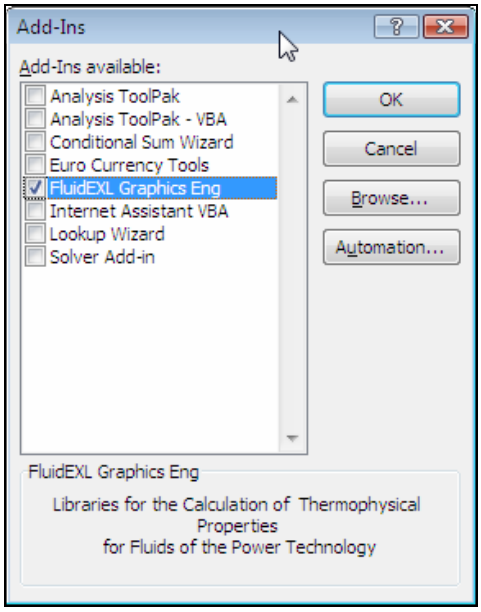



**Figure 2.9:** Dialog window "Add-Ins"

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

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

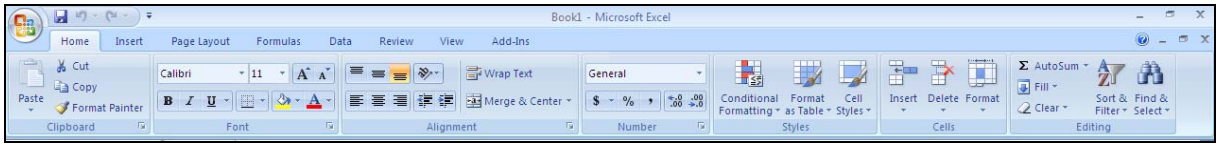



**Figure 2.10:** Menu item "Add-Ins"

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

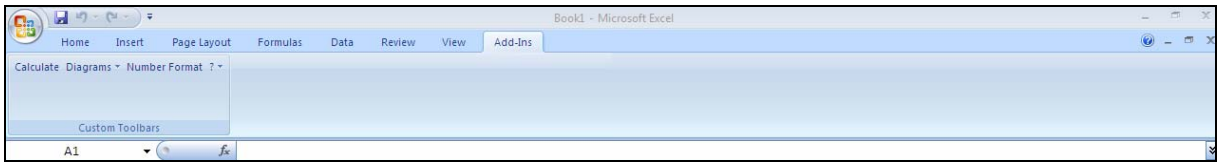



**Figure 2.11:** FluidEXL*Graphics* menu bar

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

### Adding the LibMD4M 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) |
| LibMD4M.dll | |
| LibMD4M_Eng.hlp | |

provided in the extracted folder

| | |
|---|---|
| CD_FluidEXL_Graphics_LibMD4M_Eng | (for English version of Windows) |
| CD_FluidEXL_Graphics_LibMD4M | (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 "Siloxane_MD4M" DLL library property functions via this menu bar (the example calculation can be found in chapter 2.5 on page 2/19).

## 2.3 The FluidEXL*Graphics* Help System

As mentioned earlier, FluidEXL*Graphics* also provides detailed online help functions.

If you are running Windows Vista or Windows 7, please note the paragraph

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

For general information in Excel®

- Click on "?" and then "Help" in the FluidEXL*Graphics* menu bar.

Information on individual property functions may be accessed via the following steps:

- Click "Calculate" in the FluidEXL*Graphics* menu bar.
- Click on the "Siloxane_MD4M" 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 LibMD4M_Eng.hlp function help cannot be found, confirm the question whether you want to look for it yourself with "Yes". Select the LibMD4M_Eng.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.

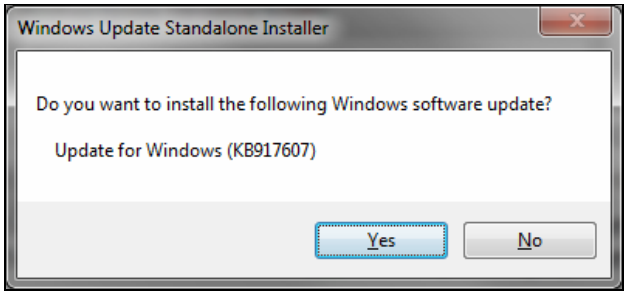



**Figure 2.18:** Windows Update Standalone Installer

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)

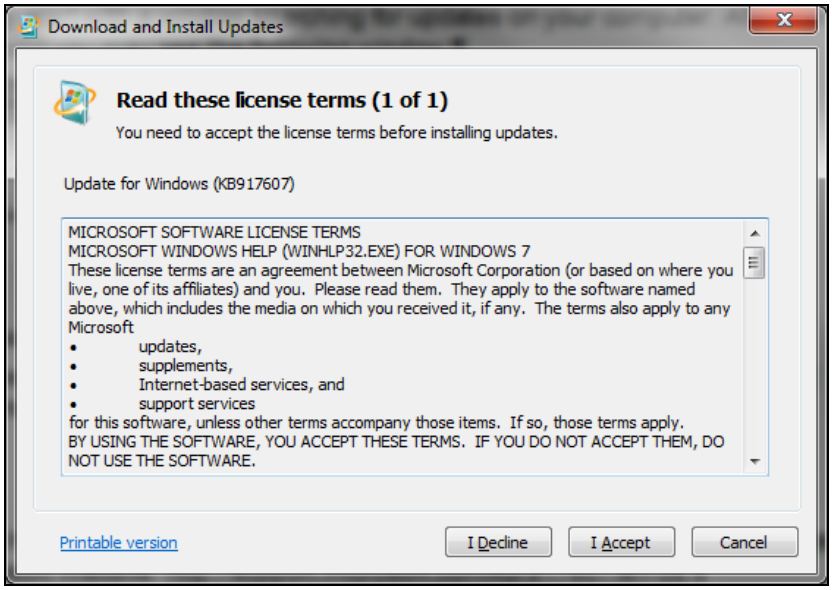


**Figure 2.19:** Windows License Terms

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

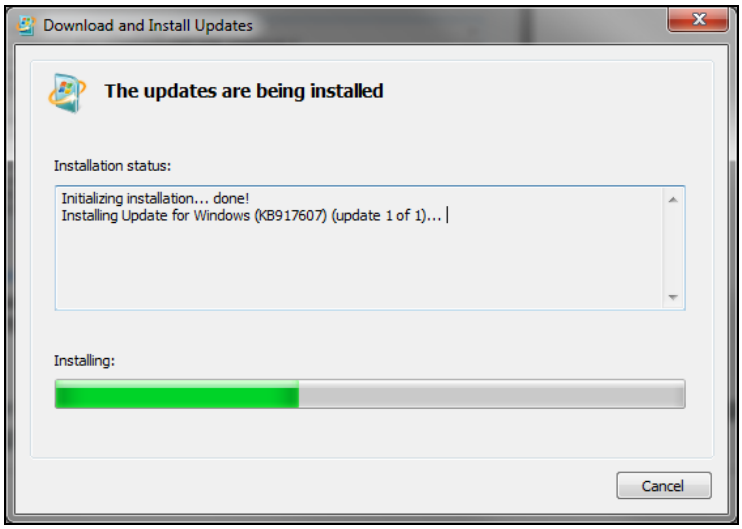



**Figure 2.20:** Installation process

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 LibMD4M 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).

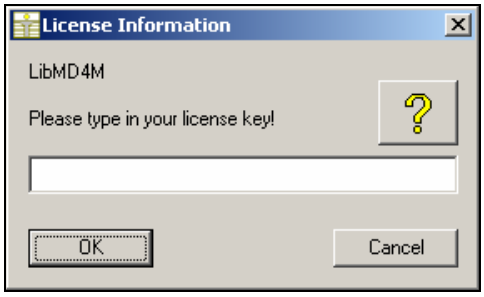



**Figure 2.21:** "License Information" window

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:

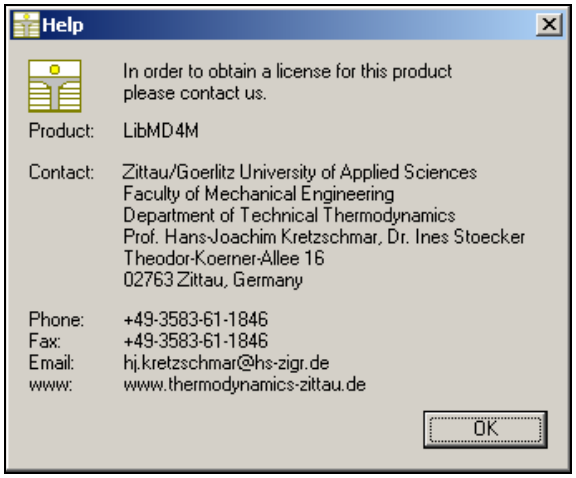



**Figure 2.22:** "Help" window

If you do not enter a valid license it is still possible to start Excel by clicking "Cancel" twice. In this case, the LibMD4M 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 LibMD4M property library, you have to delete the files

LibMD4M.dll
LibMD4M_Eng.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:

- Start Excel®
- Enter a value for *p* in bar in a cell
  (Range of validity: $p$ = 0.00001 bar to 300 bar)

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

- Enter a value for *t* in °C in a cell
  (Range of validity: $t$ = 26.85°C to 399.85 °C)
  ⇒ e. g.: Enter the value 300 into cell B2

- Enter a 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:

  Single-phase region

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

  Wet-steam region

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

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

  If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1000.

  (MD4M Saturation pressure curve:

  $t$ = 26.85 °C to $t_C$ = 379.05 °C

  $p_S$(26.85 °C) = 0.00001093377 bar to $p_C$ = 8.7747391 bar)

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

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

  ⇒ e.g.: Click the D2 cell

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

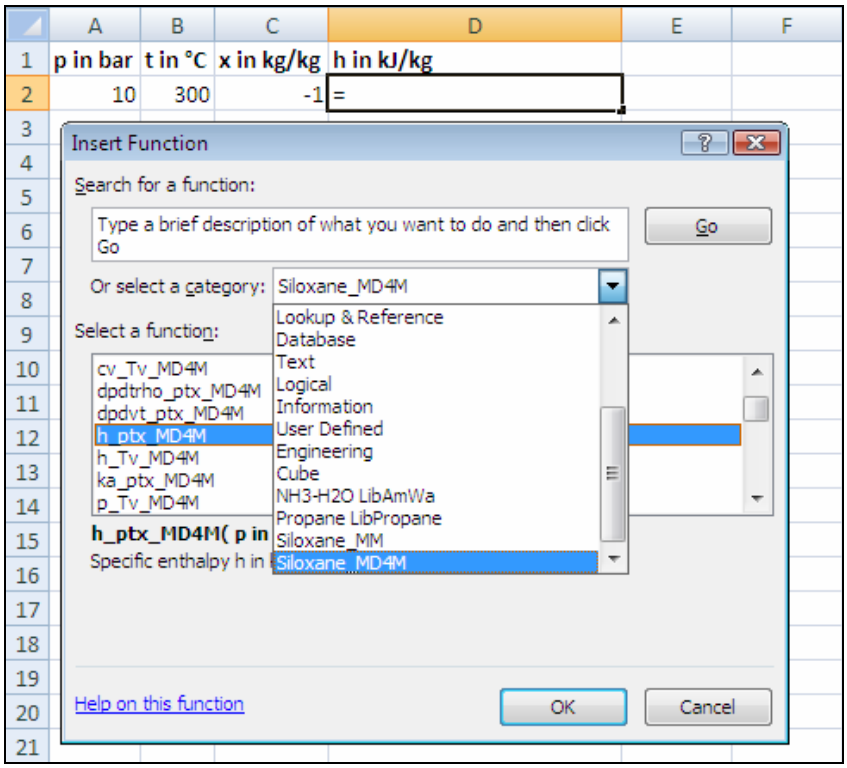



**Figure 2.23:** Choice of library and function name

- In the drop-down menu in the middle, next to "Or select a category:" locate and click the library "Siloxane_MD4M"
- Below this drop-down menu under "Select a function:" choose and click the function h_ptx_MD4M
  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 the "OK" button.
  The window shown in the next figure will now appear.

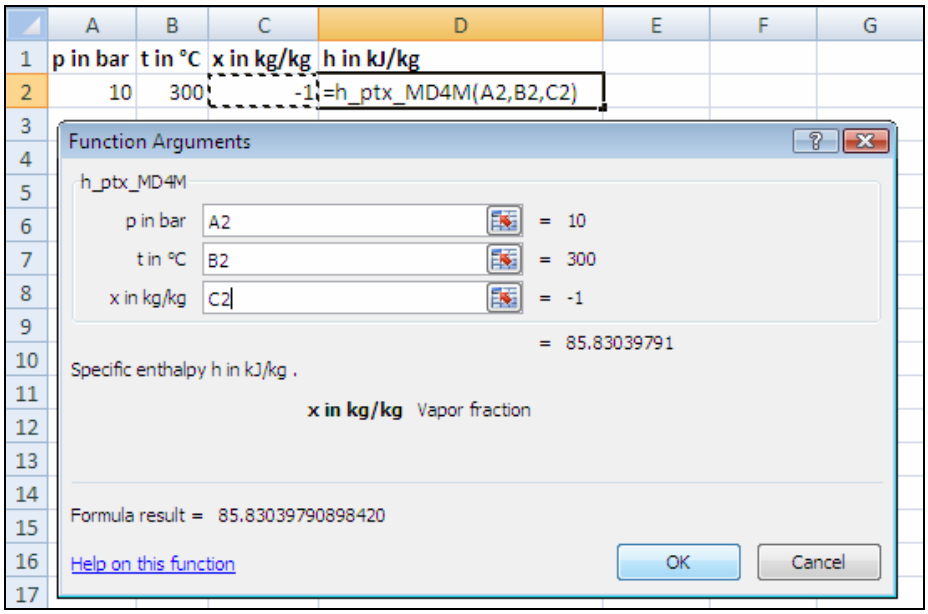



**Figure 2.24:** Enter the given values for the property calculation

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

  ⇒ e. g.: Click on the cell A2

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

  ⇒ e. g.: Type B2 into the window next to "t in °C"

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

  ⇒ e. g.: Click on the cell C2

- Click the "OK" button.

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

⇒ The result of this example must be h = 85.83039790898420 kJ/kg

The calculation of *h* = f(*p*,*t*,*x*) has been carried out. You can now arbitrarily change the values for *p*, *t*, or *x* in the appropriate cells. The specific 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 LibMD4M. More detailed information on each function and its range of validity is available in Chapter 3.

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

## 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 LibMD4M library, delete the files

LibMD4M.dll

LibMD4M_Eng.hlp

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

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

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

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

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

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

has to be cancelled in Excel®.

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

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

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

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

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

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

Within the next step delete the files

LibMD4M.dll

LibMD4M_Eng.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

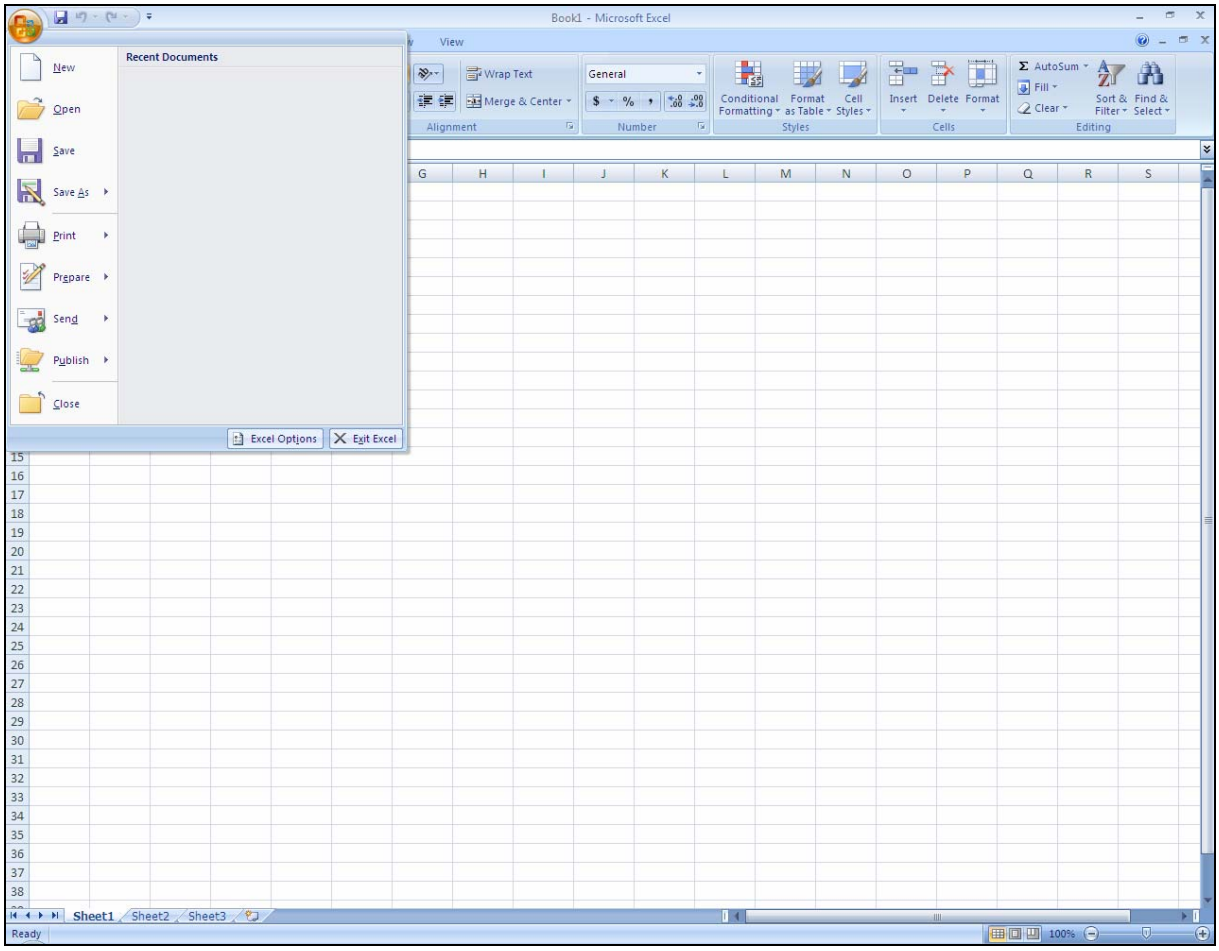



**Figure 2.25:** Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007

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

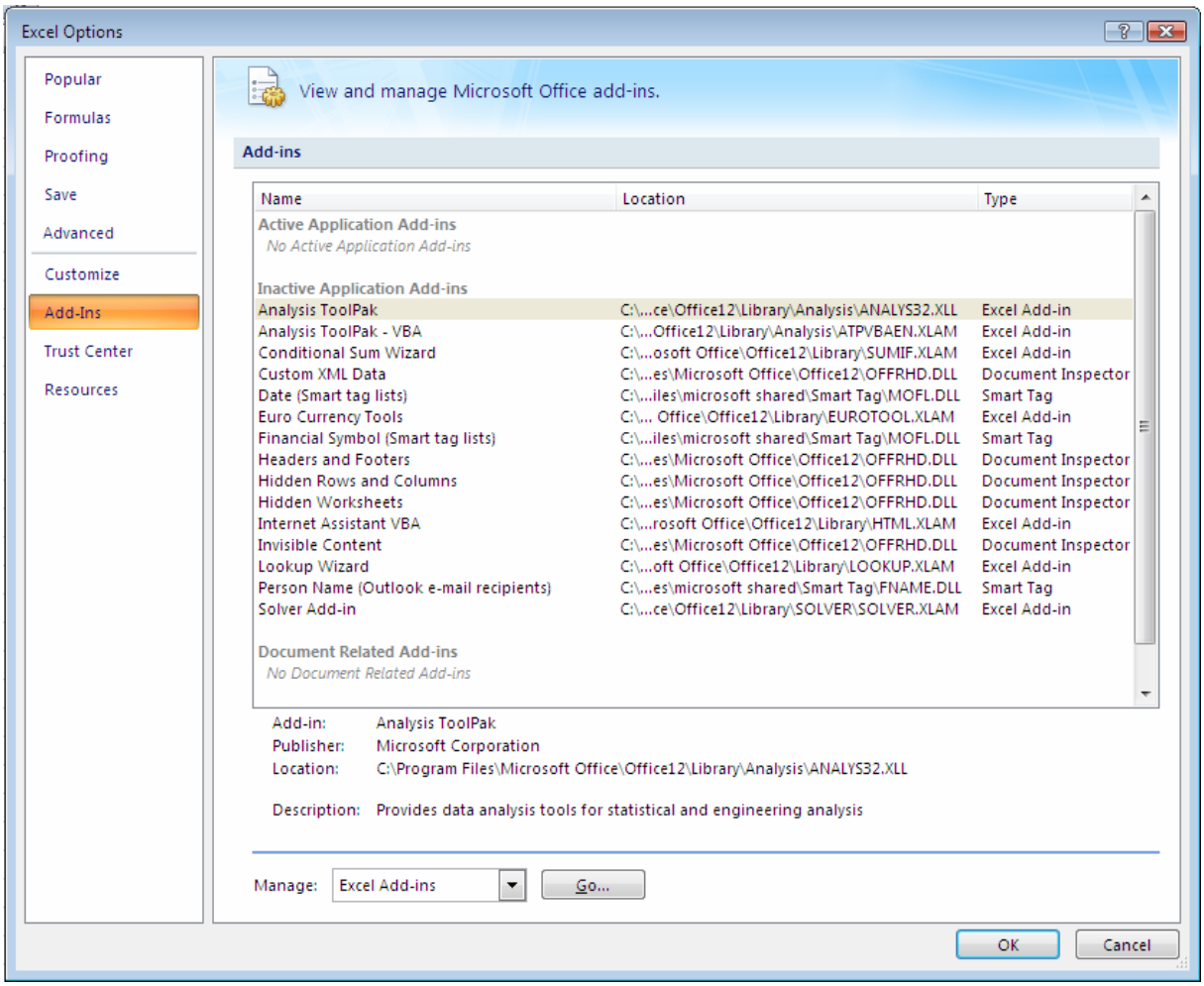



**Figure 2.26:** Dialog window "Add-Ins"

- 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.

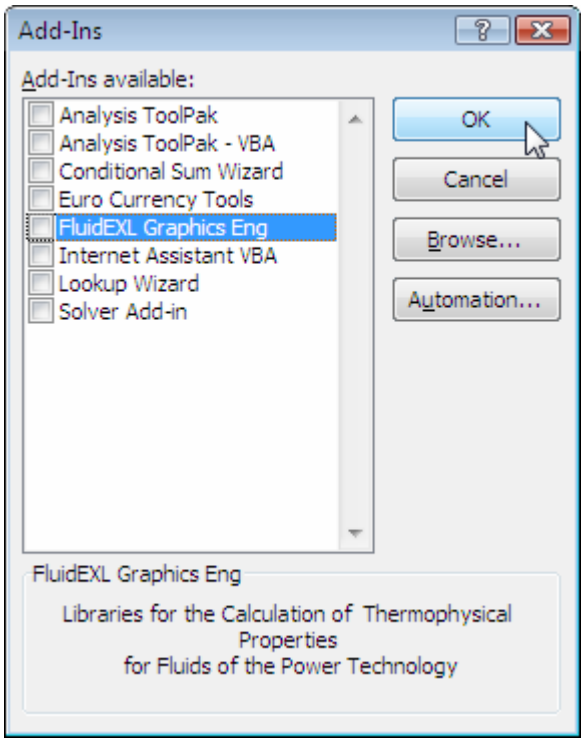



**Figure 2.27:** Dialog window "Add-Ins"

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

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

| | |
|---|---|
| Function Name: | **cp_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION CPPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_CPPTXMD4M(CP,P,T,X)**<br>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

**CPPTXMD4M**, **CP** or **cp_ptx_MD4M** - specific isobaric heat capacity $c_p$ in kJ/(kg K)

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **CPPTXMD4M = -1000**, **CP = -1000** or **cp_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Saturation lines:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

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

| | |
|---|---|
| Function Name: | **cv_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION CVPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_CVPTXMD4M(CV,P,T,X)**<br>REAL*8 CV,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

**CVPTXMD4M**, **CV** or **cv_ptx_MD4M** - specific isochoric heat capacity $c_v$ in kJ/(kg K)

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **CVPTXMD4M = -1000**, **CV = -1000** or **cv_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Saturation lines:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s(26.85°C)$ = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s(26.85°C)$ = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

# Derivative of Pressure with Respect to Temperature (at Constant Specific Volume) $\left(\frac{\partial p}{\partial T}\right)_v = f(p,t,x)$

| | |
|---|---|
| Function Name: | **dpdtv_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION DPDTVPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_DPDTVPTXMD4M(DPDTV,P,T,X)**<br>REAL*8 DPDTV,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

**DPDTVPTXMD4M**, **DPDTV** or **dpdtv_ptx_MD4M** - Derivative of pressure with respect to temperature (at constant specific volume) dpdtv in kPa/K

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **DPDTVPTXMD4M = -1000**, **DPDTV = -1000** or **dpdtvo_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Saturation lines:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

# Derivative of Pressure with Respect to Specific Volume (at Constant Temperature) $\left(\frac{\partial p}{\partial v}\right)_T = f(p,t,x)$

| | |
|---|---|
| Function Name: | **dpdvt_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION DPDVTPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_DPDVTPTXMD4M(DPDVT,P,T,X)**<br>REAL*8 DPDVT,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

**DPDVTPTXMD4M**, **DPDVT** or **dpdvt_ptx_MD4M** - Derivative of pressure with respect to temperature (at constant specific volume) dpdvt in kPa/K

### Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

### Results for wrong input values

Result **DPDVTPTXMD4M = -1000**, **DPDVT = -1000** or **dpdvt_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Saturation lines:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

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

| | |
|---|---|
| Function Name: | **h_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION HPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_HPTXMD4M(H,P,T,X)**<br>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

**HPTXMD4M**, **H** or **h_ptx_MD4M** - specific enthalpy *h* in kJ/kg

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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.

Wet steam region: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **HPTXMD4M = -1000**, **H = -1000** or **h_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Wet steam region:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

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

| | |
|---|---|
| Function Name: | **kappa_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION KAPPAPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_KAPPAPTXMD4M(KAPPA, P,T,X)**<br>REAL*8 KAPPA,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

**KAPPAPTXMD4M**, **KAPPA** or **kappa_ptx_MD4M** - Isentropic exponent $\kappa = \frac{w^2}{p \cdot v}$

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 $t = 26.85°C$ to $t_c = 379.05°C$<br>Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar |

## Results for wrong input values

Result **KAPPAPTXMD4M**, **KAPPA = -1000** or **kappa_ptx_MD4M = -1000** for input values:

| | |
|---|---|
| Single phase region:<br>($x$ = -1) | $p$ > 300 bar or $p$ < 0.00001 bar or<br>$t$ > 399.85 °C or $t$ < 26.85°C |
| Saturation lines: | at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C<br>at $t$ = -1000 and $p > p_c$ = 8.7747391 bar<br>or $p < p_s(26.85°C)$ = 0.00001093377 bar or<br>at $p > p_c$ = 8.7747391 bar or $p < p_s(26.85°C)$ = 0.00001093377 bar and<br>$t > t_c$ = 379.05 °C or $t$ < 26.85°C |

**References:** [1]

# Vapor Pressure $p_s$ = f($t$)

| | |
|---|---|
| Function Name: | **ps_t_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION PSTMD4M(T)**<br>REAL*8 T |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_PSTMD4M(PS,T)**<br>REAL*8 PS,T |

## Input Values:

**T** - Temperature $t$ in °C

## Result

**PSTMD4M**, **PS** or **ps_t_MD4M** - Vapor pressure $p_s$ in bar

## Range of validity

Temperature range: from $t = 26.85$°C to $t_c = 379.05$ °C

## Results for wrong input values

Result **PSTMD4M = -1000**, **PS = -1000**or **ps_t_MD4M = -1000**for input values:

$t < 26.85$°C or $t > t_c = 379.05$ °C

**References:** [1]

# Density $\rho$ = f($p$,$t$,$x$)

| | |
|---|---|
| Function Name: | **rho_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION RHOPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_RHOPTXMD4M(RHO,P,T,X)**<br>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_MD4M**, **RHO** or **rho_ptx_MD4M** - Density $\rho$ in kg/m$^3$

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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.

Wet steam region: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **RHOPTXMD4M = -1000**, **RHO = -1000** or **rho_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Wet steam region:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

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

| | |
|---|---|
| Function Name: | **s_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION SPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_SPTXMD4M(S,P,T,X)**<br>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

**SPTXMD4M**, **S** or **s_ptx_MD4M** - Specific entropy *s* in kJ/kg K

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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.

Wet steam region: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **SPTXMD4M = -1000**, **S = -1000** or **s_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Wet steam region:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

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

| | |
|---|---|
| Function Name: | **t_ph_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION TPHMD4M(P,H)**<br>REAL*8 P,H |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_TPHMD4M(T,P,H)**<br>REAL*8 T,P,H |

## Input Values:

**P** - Pressure *p* in bar

**H -** Specific enthalpy *h* in kJ/kg

## Result

**TPHMD4M**, **T** or **t_ph_MD4M -** Temperature *t* in °C

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 $p_S(26.85°C) = 0.00001093377$ bar to $p_C = 8.7747391$ bar

## Results for wrong input values

Result **T_PH_MD4M**, **T = -1000** or **t_ph_MD4M = -1000** for input values:

Single phase region: at $p$ > 300 bar or $p < p_S$(26.85°C) = 0.00001093377 bar or
($x$ = -1) at result $t$ > 399.85 °C, $t$ < 26.85°C

Boiling or dew curve: at $p > p_C$ = 8.7747391 bar or $p < p_S$ 26.85°C = 0.00001093377 bar
at result $t > t_C$ = 379.05 °C or $t$ < 26.85 °C

**References:** [1]

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

| | |
|---|---|
| Function Name: | **t_ps_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION TPSMD4M(P,S)**<br>REAL*8 P,S |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_TPSMD4M(T,P,S)**<br>REAL*8 T,P,S |

## Input Values:

**P** - Pressure *p* in bar

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

## Result

**TPSMD4M**, **T** or **t_ps_MD4M -** Temperature *t* in °C

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 $p_S(26.85°C) = 0.00001093377$ bar to $p_C = 8.7747391$ bar

## Results for wrong input values

Result **T_PS_MD4M**, **T = -1000** or **t_ps_MD4M = -1000** for input values:

| | |
|---|---|
| Single phase region:<br>($x$ = -1) | at $p$ > 300 bar or $p < p_S$(26.85°C) = 0.00001093377 bar or<br>at result $t$ > 399.85 °C, $t$ < 26.85°C |
| Boiling or dew curve: | at $p > p_C$ = 8.7747391 bar or $p < p_S$ 26.85°C = 0.00001093377 bar<br>at result $t > t_C$ = 379.05 °C or $t$ < 26.85 °C |

**References:** [1]

# Saturation Temperature $t_s$ = f($p$)

| | |
|---|---|
| Function Name: | **ts_p_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION TSPMD4M(P)**<br>REAL*8 P |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_TSPMD4M(TS,P)**<br>REAL*8 TS,P |

## Input Values:

**P** - Pressure $p$ in bar

## Result

**TSPMD4M**, **TS** or **ts_p_MD4M** - Saturation temperature $t_s$ in °C

## Range of validity

Pressure range: from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **TSPMD4M = -1000**, **TS = -1000** or **ts_p_MD4M = -1000** for input values:

$p < p_s(26.85°C) = 0.00001093377$ bar or $p > p_c = 8.7747391$ bar

**References:** [1]

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

| | |
|---|---|
| Function Name: | **u_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION UPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_UPTXMD4M(U,P,T,X)**<br>REAL*8 U,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

**UPTXMD4M**, **U** or **u_ptx_MD4M** - Specific internal energy *u* in kJ/kg

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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.

Wet steam region: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **UPTXMD4M = -1000**, **U = -1000** or **u_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Wet steam region:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

# Specific Volume $v$ = f($p$,$t$,$x$)

| | |
|---|---|
| Function Name: | **v_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION VPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_VPTXMD4M(V,P,T,X)**<br>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

**VPTXMD4M**, **V** or **v_ptx_MD4M** - Specific volume $v$ in $m^3/kg$

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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.

Wet steam region: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **VPTXMD4M = -1000**, **V = -1000** or **v_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Wet steam region:
at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s$(26.85°C) = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and
$t > t_c$ = 379.05 °C or $t$ < 26.85°C

**References:** [1]

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

| | |
|---|---|
| Function Name: | **w_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION WPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_WPTXMD4M(W,P,T,X)**<br>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

**WPTXMD4M**, **W** or **w_ptx_MD4M -** Speed of sound *w* in m/s

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 | Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$ |
| saturated vapor line: | Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar |

## Results for wrong input values

Result **WPTXMD4M = -1000, W = -1000** or **w_ptx_MD4M = -1000** for input values:

| | |
|---|---|
| Single phase region:<br>($x$ = -1) | $p$ > 300 bar or $p$ < 0.00001 bar or<br>$t$ > 399.85 °C or $t$ < 26.85°C |
| Boiling or dew curve: | at $p$ = -1000 and $t > t_c$ = 379.05 °C or $t$ < 26.85 °C<br>at $t$ = -1000 and $p > p_c$ = 8.7747391 bar<br>or $p < p_s$(26.85°C) = 0.00001093377 bar or<br>at $p > p_c$ = 8.7747391 bar or $p < p_s$(26.85°C) = 0.00001093377 bar and<br>$t > t_c$ = 379.05 °C or $t$ < 26.85°C |

**References:** [1]

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

| | |
|---|---|
| Function Name: | **x_ph_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION XPHMD4M(P,H)**<br>REAL*8 P,H |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_XPHMD4M(X,P,H)**<br>REAL*8 X,P,H |

## Input Values:

**P** - Pressure *p* in bar

**H -** Specific enthalpy *h* in kJ/kg

## Result

**XPHMD4M**, **X** or **x_ph_MD4M -** Vapor fraction *x* in (kg saturated steam/kg wet steam)

## Range of validity

Temperature range: from $t = 26.85°C$ to $t_c = 380.05$ °C

Pressure range: from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ 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 $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **X_PH_MD4M**, **X =** -1 or **x_ph_MD4M =** -1 for input values:

If the state point is located in the single phase region:
$p > p_c = 8.7747391$ bar or $p < 0.00001093377$ bar

**References:** [1]

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

| | |
|---|---|
| Function Name: | **x_ps_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION XPSMD4M(P,S)**<br>REAL*8 P,S |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_XPSMD4M(X,P,S)**<br>REAL*8 X,P,S |

## Input Values:

**P** - Pressure *p* in bar

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

## Result

**XPSMD4M**, **X** or **x_ps_MD4M -** Vapor fraction *x* in (kg saturated steam/kg wet steam)

## Range of validity

Temperature range: from $t = 26.85°C$ to $t_c = 380.05\ °C$

Pressure range: from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ 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. 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 $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **X_PS_MD4M**, **X = -1** or **x_ps_MD4M = -1** for input values:

If the state point is located in the single phase region:
$p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar

**References:** [1]

# Compression Factor $Z = f(p,t,x)$

| | |
|---|---|
| Function Name: | **Z_ptx_MD4M** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION ZPTXMD4M(P,T,X)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_ZPTXMD4M(Z,P,T,X)**<br>REAL*8 Z,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

**ZPTXMD4M**, **Z** or **Z_ptx_MD4M -** Compression Factor

## Range of validity

Temperature range: from $t$ = 26.85°C to 399.85 °C
Pressure range: from $p$ = 0.00001 bar to 300 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 on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for $x$ values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, 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 calculating wet steam and $p$ <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.

Boiling and dew curve: Temperature ranges from $t = 26.85°C$ to $t_c = 380.05°C$

Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

## Results for wrong input values

Result **ZPTXMD4M = -1000, Z = -1000** or **Z_ptx_MD4M = -1000** for input values:

Single phase region: ($x$ = -1)
$p$ > 300 bar or $p$ < 0.00001 bar or
$t$ > 399.85 °C or $t$ < 26.85°C

Boiling or dew curve:
at $p$ = -1000 and $t > t_c$ = 380.05 °C or $t$ < 26.85 °C
at $t$ = -1000 and $p > p_c$ = 8.7747391 bar
or $p < p_s(26.85°C)$ = 0.00001093377 bar or
at $p > p_c$ = 8.7747391 bar or $p < p_s(26.85°C)$ = 0.00001093377 bar and
$t > t_c$ = 380.05 °C or $t$ < 26.85°C

**References:** [1]

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Department of Technical Thermodynamics
www.thermodynamics-zittau.de

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

## Water and Steam

### Library LibIF97

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

## Humid Combustion Gas Mixtures

### Library LibHuGas

Model: Ideal mixture of the real fluids:

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

and of the ideal gases:

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

Consideration of:

Dissociation from VDI 4670 and Poynting effect

## Humid Air

### Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

## Carbon Dioxide including Dry Ice

### Library LibCO2

Formulation of Span and Wagner (1994)

## Seawater

### Library LibSeaWa

IAPWS Formulation 2008 of Feistel and IAPWS-IF97

## Ice

### Library LibICE

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

## Ideal Gas Mixtures

### Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

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

Consideration of:

- Dissociation from the VDI Guideline 4670

### Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

## Dry Air including Liquid Air

### Library LibRealAir

Formulation of Lemmon et al. (2000)

## Nitrogen

### Library LibN2

Formulation of Span et al. (2000)

## Hydrogen

### Library LibH2

Formulation of Leachman et al. (2007)

## Refrigerants

### Ammonia

**Library LibNH3**

Formulation of Tillner-Roth (1995)

### R134a

**Library LibR134a**

Formulation of Tillner-Roth and Baehr (1994)

### Iso-Butane

**Library LibButane_Iso**

Formulation of Bücker et al. (2003)

### n-Butane

**Library LibButane_n**

Formulation of Bücker et al. (2003)

## Mixtures for Absorption Processes

### Ammonia/Water Mixtures

**Library LibAmWa**

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

Helmholtz energy equation for the mixing term

(also useable for calculating Kalina Cycle)

### Water/Lithium Bromide Mixtures

**Library LibWaLi**

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

## Liquid Coolants

### Liquid Secondary Refrigerants

**Library LibSecRef**

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (1997)

### Siloxanes as ORC Working Fluids

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

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

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

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

### Propane

**Library LibPropane**

Formulation of Lemmon et al. (2007)

### Methanol

**Library LibCH3OH**

Formulation of de Reuck and Craven (1993)

### Ethanol

**Library LibC2H5OH**

Formulation of Schroeder et al. (2012)

### Helium

**Library LibHe**

Formulation of Arp et al. (1998)

### Hydrocarbons

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

Isopentane $C_5H_{12}$ **Library LibC5H12_ISO**

Neopentane $C_5H_{12}$ **Library LibC5H12_NEO**

Isohexane $C_5H_{14}$ **Library LibC5H14**

Toluene $C_7H_8$ **Library LibC7H8**

Formulation of Lemmon and Span (2006)

### Further Fluids

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

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

Hydrogen sulfide $H_2S$ **Library LibH2S**

Dinitrogen monooxide $N_2O$ **Library LibN2O**

Sulfur dioxide $SO_2$ **Library LibSO2**

Acetone $C_3H_6O$ **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

## For more information please contact:

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

### Thermodynamic Properties

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

### Transport Properties

- Dynamic viscosity $\eta$
- Kinematic viscosity $\nu$
- Thermal conductivity $\lambda$
- Prandtl-number $Pr$

### Backward Functions

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

### Thermodynamic Derivatives

- Partial derivatives can be calculated.

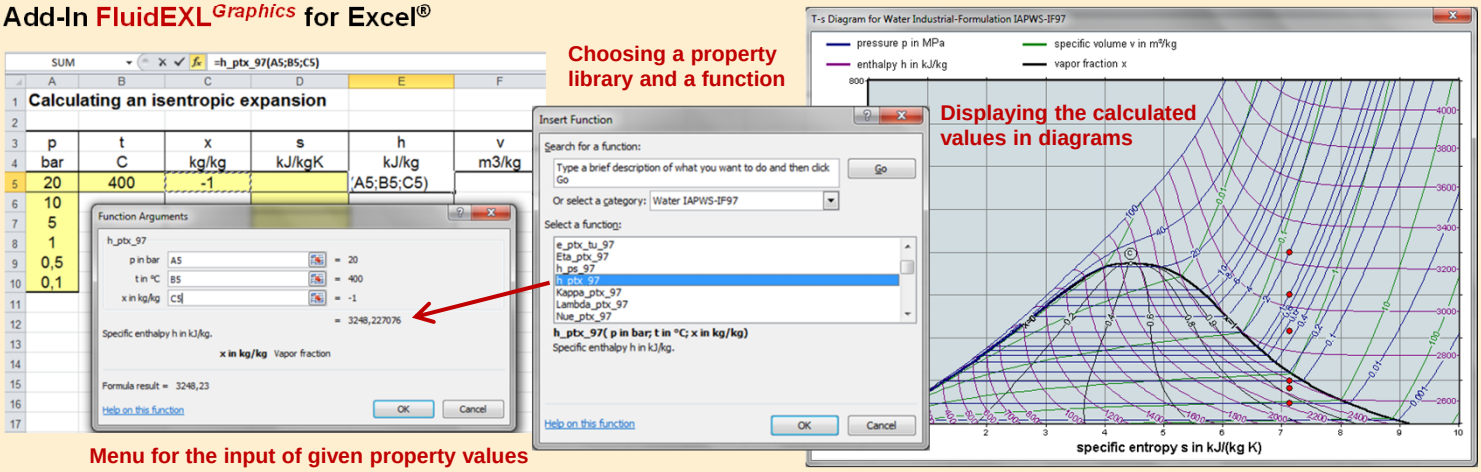
[a] Not all of these property functions are available in all property libraries.

**www.thermodynamic-property-libraries.com**

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

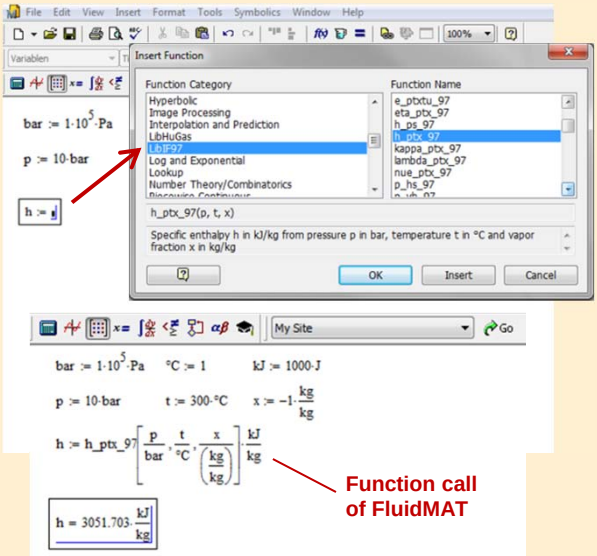
# Property Software for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

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



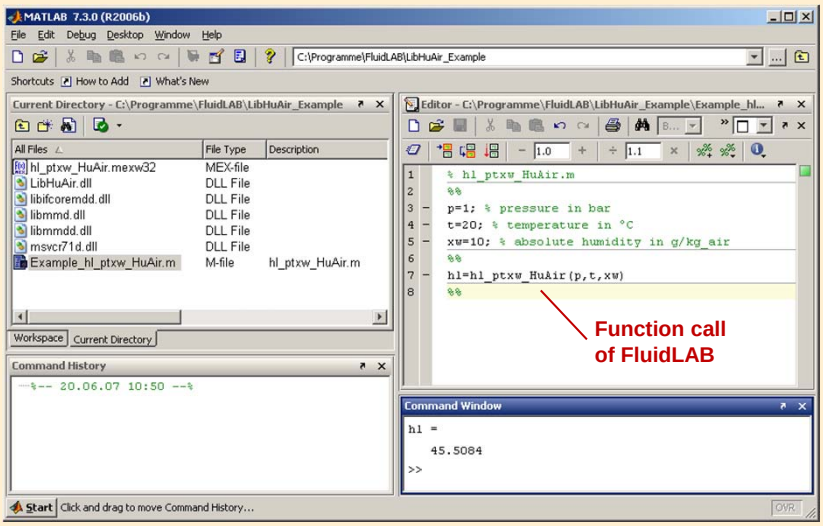

## Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



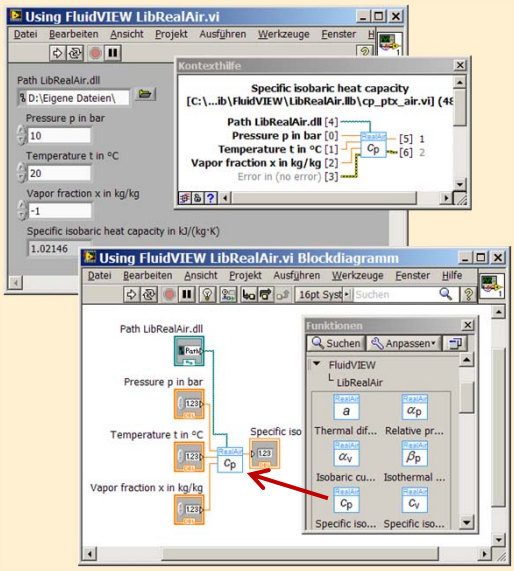

## Add-In FluidLAB for MATLAB®

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



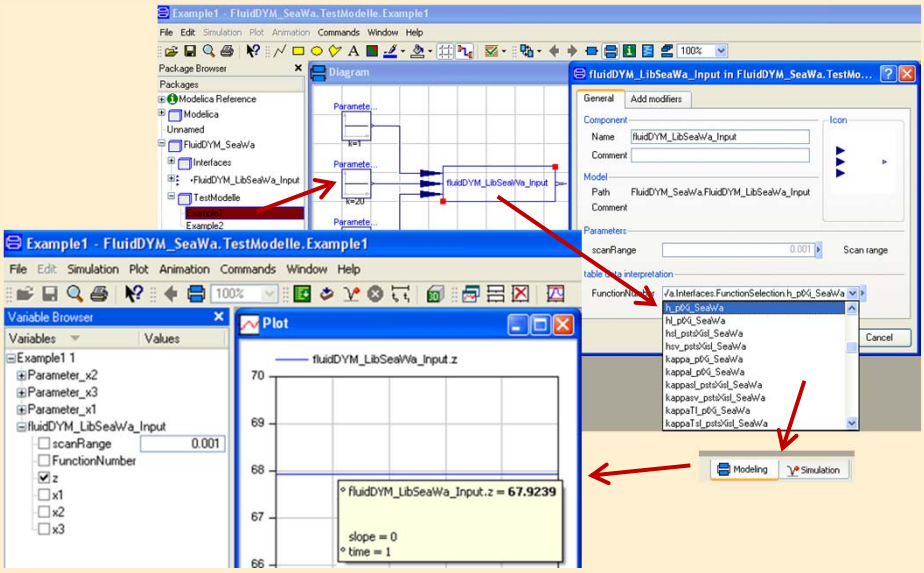

## Add-On FluidVIEW for LabVIEW®

The property functions can be calculated in LabVIEW®.

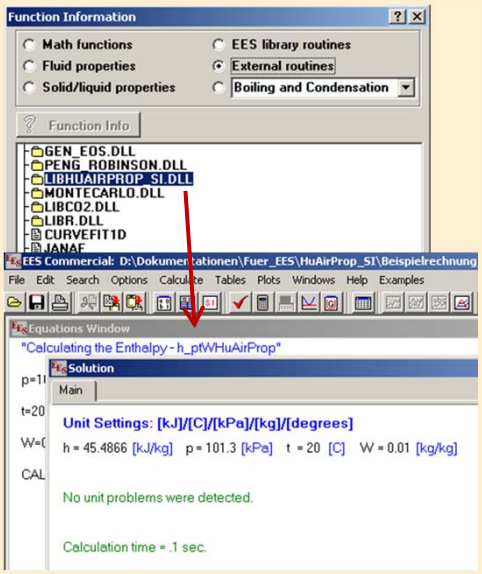



## Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

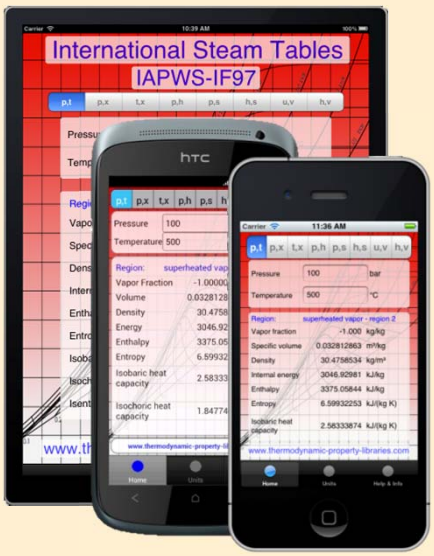
The property functions can be called in DYMOLA® and SimulationX®



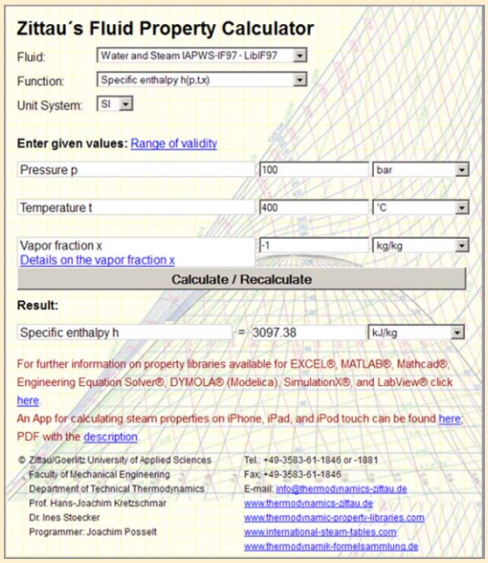
## Add-In FluidEES for Engineering Equation Solver®




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




## Online Property Calculator at www.thermodynamics-zittau.de




## Property Software for Pocket Calculators

### FluidCasio

fx 9750 G II | CFX 9850 fx-GG20 | CFX 9860 G Graph 85 | ALGEBRA FX 2.0

### FluidHP

HP 48 | HP 49

### FluidTI

TI 83, TI 84, TI 89 | TI Voyage 200 | TI 92

## For more information please contact:

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02763 Zittau, Germany

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Internet: www.thermodynamics-zittau.de
Phone: +49-3583-61-1846
Fax.: +49-3583-61-1846

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

### Thermodynamic Properties

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

### Transport Properties

- Dynamic viscosity $\eta$
- Kinematic viscosity $\nu$
- Thermal conductivity $\lambda$
- Prandtl-number $Pr$

### Backward Functions

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

### Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

**www.thermodynamic-property-libraries.com**

# 5. References

[1] Colonna, P.; Nannan, N. R.; Guardone, A.;Lemmon, E. W.
Multiparameter equations of state for selected siloxanes
Fluid Phase Equilibria, 244, (2006) S. 193-211

# 6. Satisfied Customers

Date: 10/2011

The following companies and institutions use the property libraries

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

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| SPG TECH, Montreuil Cedex, France | 09/2011 |
| Voith, Heidenheim-Mergelstetten | 09/2011 |
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| RWE, Essen | 07/2011 |
| Fels, Elingerode | 07/2011 |
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| RWTH Aachen University | 07/2011, 08/2011 |
| Voith, Zschopau | 07/2011 |
| 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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| Helbling Beratung & Bauplanung, Zurich, Switzerland | 05/2011 |
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**2003**

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| 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 |
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| SOFBID, Zwingenberg<br>(general EBSILON program license) | 01/2000 |
| AG KKK - PGW Turbo, Leipzig | 01/2000 |

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| 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<br>(general license for training test benches) | 11/2000 |
| Steinhaus Informationssysteme, Datteln<br>(general license for process data software) | 12/2000 |

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| Bayernwerk, Munich | 01/1999 |
| DREWAG, Dresden (company license) | 02/1999 |
| KEMA IEV, Dresden | 03/1999 |
| Regensburg University of Applied Sciences | 04/1999 |
| Fichtner Consulting & IT, Stuttgart<br>(company licenses and distribution) | 07/1999 |
| Technical University of Cottbus, Chair in Power Plant Engineering | 07/1999 |
| Technical University of Graz, Department of Thermal Engineering, Austria | 11/1999 |
| Ostendorf Engineering, Gummersbach | 12/1999 |

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| Technical University of Cottbus, Chair in Power Plant Engineering | 05/1998 |
| Fichtner Consulting & IT (CADIS information systems) Stuttgart<br>(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 |

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| VEAG Berlin (group license) | 09/1998 |
| NUTEC Engineering, Bisikon, Switzerland | 10/1998 |
| SCA Hygiene Products, Munich | 10/1998 |
| RWE Energie, Neurath | 10/1998 |
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| BASF, Ludwigshafen (group license) | 11/1998 |
| Energieversorgung, Offenbach | 11/1998 |

**1997**

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