KCE
ThermoFluidProperties

Property Library for Ethanol

FluidVIEW
with LibC2H5OH
for LabVIEW™

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Property Library of Ammonia-Water Mixtures
Including DLL and Add-on for LabVIEW™
FluidVIEW
LibC2H5OH

Contents

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0 Package Contents

0.1 Zip files for 32-bit LabVIEW™

In order to install FluidVIEW on a computer running a 32-bit version of LabVIEW™ the zip file **CD_FluidVIEW_LibC2H5OH.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.1, 0.2, 0.3 and 0.4.

Table 0.1 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH\vi.lib \FluidVIEW\LibC2H5OH**

Filename	Effects
LibC2H5OH.llb	LabVIEW™ library file, containing every function of the LibC2H5OH property library in the form of subprograms (SubVIs)

Table 0.2 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH\menus \Categories\FluidVIEW**

Filename	Effects
dir.mnu	The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items)

Table 0.3 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH\source**

Filename	Effects
LibC2H5OH.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of carbon dioxide
advapi32.dll	Runtime library
Dformd.dll	Runtime library for the Fortran DLL
Dforrt.dll	Runtime library for the Fortran DLL
LC.dll	Auxiliary library
msvcp60.dll	Runtime library
msvcrt.dll	Runtime library

Table 0.4 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH\help \FluidVIEW-help**

Filename	Effects
FluidVIEW_LibC2H5OH.pdf	User's guide of the property library LibC2H5OH for the LabVIEW™ Add-On FluidVIEW
LibC2H5OH.chm	Help file with descriptions for each function
OpenLibC2H5OH_doc.vi	LabVIEW™ instrument to open the user's guide via the help menu
LibC2H5OH.txt	Text file to change the name of the menu item of the help file
OpenLibC2H5OH_doc.txt	Text file to change the name of the menu item of the file OpenLibC2H5OH_doc.vi

0.2 Zip files for 64-bit LabVIEW™

In order to install FluidVIEW on a computer running a 64-bit version of LabVIEW™ the zip file **CD_FluidVIEW_LibC2H5OH_x64.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.5, 0.6, 0.7, 0.8 and 0.9.

Table 0.5 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH_x64\vi.lib \FluidVIEW\LibC2H5OH**

Filename	Effects
LibC2H5OH.llb	LabVIEW™ library file, containing every function of the LibC2H5OH property library in the form of subprograms (SubVIs)

Table 0.6 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH_x64\menus \Categories\FluidVIEW**

Filename	Effects
dir.mnu	The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items)

Table 0.7 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH_x64\source**

Filename	Effects
LibC2H5OH.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of carbon dioxide
Capt_ico_big.ico	Icon file
Libmmd.dll	Runtime library
Libifcoremd.dll	Runtime library
LC.dll	Auxiliary library
Libiomp5md.dll	Runtime library

Table 0.8 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH_x64\help \FluidVIEW-help**

Filename	Effects
FluidVIEW_LibC2H5OH.pdf	User's guide of the LibC2H5OH property library for the LabVIEW™ Add-On FluidVIEW
LibC2H5OH.chm	Help file with descriptions for each function
OpenLibC2H5OH_doc.vi	LabVIEW™ instrument to open the user's guide via the help menu
LibC2H5OH.txt	Text file to change the name of the menu item of the help file
OpenLibC2H5OH_doc.txt	Text file to change the name of the menu item of the file OpenLibC2H5OH_doc.vi

Table 0.9 Effects of the files located in the archive directory **CD_FluidVIEW_LibC2H5OH_x64 \vcredist_x64**

Filename	Effects
vcredist_x64.exe	Executable file to install the Microsoft Visual C++ 2008 Redistributable Package (x64). Within runtime components of Visual C++ Libraries required to run 64-bit applications developed with Visual C++ on a computer that does not have Visual C++ 2010 installed.

1. Property Functions

Functional Dependence	Function Name	Call from Fortran Program	Call from the DLL LibC2H5OH as Parameter	Property or Function	Unit of the Result
$a = f(p,t,x)$	a_ptx_C2H5OH	A_PTX_C2H5OH(P,T,X)	C_APTX_C2H5OH(A,P,T,X)	Thermal diffusivity	m²/s
$c_p = f(p,t,x)$	cp_ptx_C2H5OH	CP_PTX_C2H5OH(P,T,X)	C_CPPTX_C2H5OH(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$\eta = f(p,t,x)$	eta_ptx_C2H5OH	ETA_PTX_C2H5OH(P,T,X)	C_ETAPTX_C2H5OH(ETA,P,T,X)	Dynamic viscosity	Pa . s
$h = f(p,t,x)$	h_ptx_C2H5OH	H_PTX_C2H5OH(P,T,X)	C_HPTX_C2H5OH(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	ka_ptx_C2H5OH	KA_PTX_C2H5OH(P,T,X)	C_KAPTX_C2H5OH(KAP,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lam_ptx_C2H5OH	LAM_PTX_C2H5OH(P,T,X)	C_LAMPTX_C2H5OH(LAM,P,T,X)	Thermal conductivity	W/(m . K)
$\nu = f(p,t,x)$	ny_ptx_C2H5OH	NY_PTX_C2H5OH(P,T,X)	C_NYPTX_C2H5OH(NY,P,T,X)	Kinematic viscosity	m²/s
$Pr = f(p,t,x)$	pr_ptx_C2H5OH	PR_PTX_C2H5OH(P,T,X)	C_PRPTX_C2H5OH(PR,P,T,X)	*Prandtl*-number	-
$p_s = f(t)$	ps_t_C2H5OH	PST_C2H5OH(T)	C_PST_C2H5OH(PS,T)	Vapor pressure from temperature	bar
$\rho = f(p,t,x)$	rho_ptx_C2H5OH	RHO_PTX_C2H5OH(P,T,X)	C_RHOPTX_C2H5OH(RHO,P,T,X)	Density	kg/m³
$s = f(p,t,x)$	s_ptx_C2H5OH	S_PTX_C2H5OH(P,T,X)	C_SPTX_C2H5OH(S,P,T,X)	Specific entropy	kJ/(kg K)
$\sigma = f(t)$	sigma_t_C2H5OH	SIGMA_T_C2H5OH(T)	C_SIGMAT_C2H5OH(SIGMA,T)	Surface tension from temperature	N/m
$t = f(p,h)$	t_ph_C2H5OH	T_PH_C2H5OH(P,H)	C_TPH_C2H5OH(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_C2H5OH	T_PS_C2H5OH(P,S)	C_TPS_C2H5OH(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_C2H5OH	TSP_C2H5OH(P)	C_TSP_C2H5OH(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_C2H5OH	U_PTX_C2H5OH(P,T,X)	C_UPTX_C2H5OH(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_C2H5OH	V_PTX_C2H5OH(P,T,X)	C_VPTX_C2H5OH(V,P,T,X)	Specific volume	m³/kg
$w = f(p,t,x)$	w_ptx_C2H5OH	W_PTX_C2H5OH(P,T,X)	C_WPTX_C2H5OH(W,P,T,X)	Isentropic speed of sound	m/s

Functional Dependence	Function Name	Call from Fortran Program	Call from the DLL LibC2H5OH as Parameter	Property or Function	Unit of the Result
$x = f(p,h)$	x_ph_C2H5OH	X_PH_C2H5OH(P,H)	C_XPH_C2H5OH(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	x_ps_C2H5OH	X_PS_C2H5OH(P,S)	C_XPS_C2H5OH(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg

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

Range of validity

Temperature range: from - 114.15°C to 376.85 °C
Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Reference state

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

Details on the vapor fraction *x*

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

Single-phase region

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

Wet-steam region

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

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

Wet steam region: Temperature ranges from t_{min} = - 114.15 °C to t_c = 241.56 °C
Pressure ranges from p_{min} = 7.2 x 10^{-9} bar to p_c = 62.68 bar

Note:

If the input values are located outside the range of validity, the calculated function will always result in –1000. Please find more exact details on every function and its corresponding range of validity in the enclosed software documentation in Chapter 3.

2 Application of FluidVIEW in LabVIEW™

The FluidVIEW Add-on has been developed to calculate thermodynamic properties in LabVIEW™ (version 10.0 or higher) more conveniently. Within LabVIEW™, it enables the direct call of functions relating to ethanol from the LibC2H5OH property library.

2.1 Installing FluidVIEW

If a FluidVIEW property library has not yet been installed, please complete the initial installation procedure described below.

If a FluidVIEW property library has already been installed, you only need to copy several files which belong to the LibC2H5OH library. In this case, follow the subsection "Adding the LibC2H5OH Library" on page 2/3.

In both cases folders and files from the zip archive

CD_FluidVIEW_LibC2H5OH.zip (for 32-bit version of LabVIEW™)

CD_FluidVIEW_LibC2H5OH_x64.zip (for 64-bit version of LabVIEW™)

have to be copied into the default directory of the LabVIEW™ development environment. In the following text these zipped directories for the 32-bit or 64-bit LabVIEW™ version will be symbolised with the term **<CD>**.

You can see the current default directory of LabVIEW™ in the paths page (options dialog box). To display this page please select *Tools* and click on *Options* to open the options dialog box and then select *Paths* from the category list.

By choosing *Default Directory* from the drop-down list the absolute pathname to the default directory, where LabVIEW™ automatically stores information, is displayed. In the following sections the pathname of the default directory will be symbolised by the term **<LV>**.

Additional Requirement When Using a 64-bit Operating System

If you want to use FluidVIEW on a 64-bit computer that does not have Visual C++ installed, please make sure the Microsoft Visual C++ 2010 x64 Redistributable Package is installed.

If it is not the case, please install it by double clicking the file

vcredist_x64.exe

which you find in the folder **\vcredist_x64** in the **64-bit** CD folder "CD_FluidVIEW_LibC2H5OH_x64."

In the following window you are required to accept the Microsoft® license terms to install the Microsoft Visual C++ 2010 runtime libraries by ticking the box next to "I have read and accept the license terms" (see Figure 2.1).

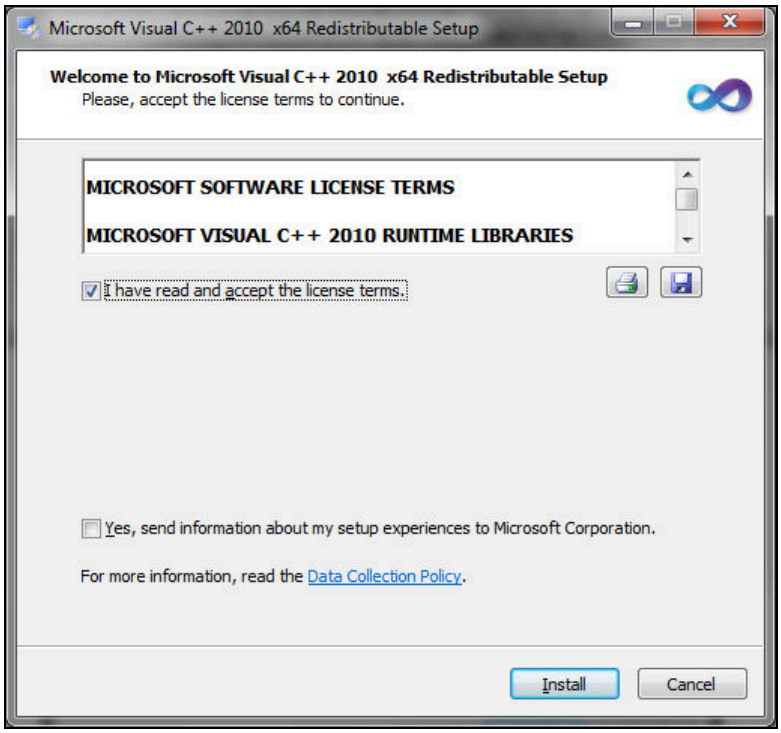


Figure 2.1 Accepting the license terms to install the Microsoft Visual C++ 2010 x64 Redistributable Package

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 you can use the FluidVIEW Add-On on your 64-bit LabVIEW™. Please follow the instructions below to install FluidVIEW.

Initial Installation of FluidVIEW

The initial installation of FluidVIEW is carried out by copying three directories with its contents from the zip archive to the standard directory of LabVIEW™.

The directories that have to be copied, their paths in the zip archive and their target paths are listed in Table 2.1.

The installation is complete after copying the files and restarting LabVIEW™.

Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory **<CD>\source** can be stored in a random directory on the hard disk. The pathname of LibC2H5OH.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9).

All source files have to be stored in the same directory to make the property functions of the LibC2H5OH library work. These files are for the

- **32-bit system**: LibC2H5OH.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system**: LibC2H5OH.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll.

Table 2.1 Directories which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for the initial installation of FluidVIEW

Name of the directory	Parent directory in the zip archive	Target path in the default directory of LabVIEW (<LV>)
FluidVIEW	<CD>\vi.lib	<LV>\vi.lib
FluidVIEW	<CD>\menus\Categories	<LV>\menus\Categories
FluidVIEW-Help	<CD>\help	<LV>\help

Adding the LibC2H5OH Library

In order to add the LibC2H5OH property library to an existing FluidVIEW installation, one folder with its contents and five files have to be copied from the zip archive to the standard directory of LabVIEW™. This directory, the files plus their pathnames in the zip archive and their target paths are listed in Table 2.2.

The installation is complete after copying the files and restarting LabVIEW™.

Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory **<CD>\source** can stored in a random directory on the harddisc. The pathname of LibC2H5OH.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9).
All source files have to be stored in the same directory to make the property functions of the LibC2H5OH library work. These files are for the

- **32-bit system**: LibC2H5OH.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system**: LibC2H5OH.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll

Table 2.2 Data which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for adding the LibC2H5OH property library to an existing installation of FluidVIEW

File name with file extension or name of the directory	Parent directory in the zip archive	Target path in the default directory of LabVIEW (<LV>)
LibC2H5OH.llb	<CD>\vi.lib\FluidVIEW	<LV>\vi.lib\FluidVIEW
LibC2H5OH	<CD>\menus\Categories \FluidVIEW	<LV>\menus\Categories \FluidVIEW
LibC2H5OH.hlp	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
LibC2H5OH.txt	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
FluidVIEW_LibC2H5OH.pdf	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
Open_LibC2H5OH_doc.vi	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
Open_LibC2H5OH_doc.txt	<CD>\\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help

After you have restarted LabVIEW™ you will find the functions of the LibC2H5OH property library in the functions palette under the sub palette FluidVIEW. An example calculation of the specific enthalpy *h* and the specific entropy *s* is shown in section 2.4.

2.2 The FluidVIEW Help System

FluidVIEW provides detailed online help functions.

General Information

The FluidVIEW Help System consists of the Microsoft WinHelp file **LibC2H5OH.chm** and this user's guide as PDF document **FluidVIEW_LibC2H5OH_Docu_Eng.pdf**. Both files can be opened via the help menu. To do this please click *Help* in the menu bar. In the submenu *FluidVIEW-Help* you will find the commands *LibC2H5OH Help File* and *LibC2H5OH User's Guide* to open an appropriate file.

Context-Sensitive Help

If you have activated the context help function in LabVIEW™ (Ctrl-H) and move the cursor over a FluidVIEW object basic information is displayed in the context help window. The in- and output parameters plus a short information text are displayed for a property function. By clicking the **Detailed help** button in the **Context help** window the online help will be opened. The context help window of the function lam_ptx_C2H5OH.vi is shown in Figure 2.2.

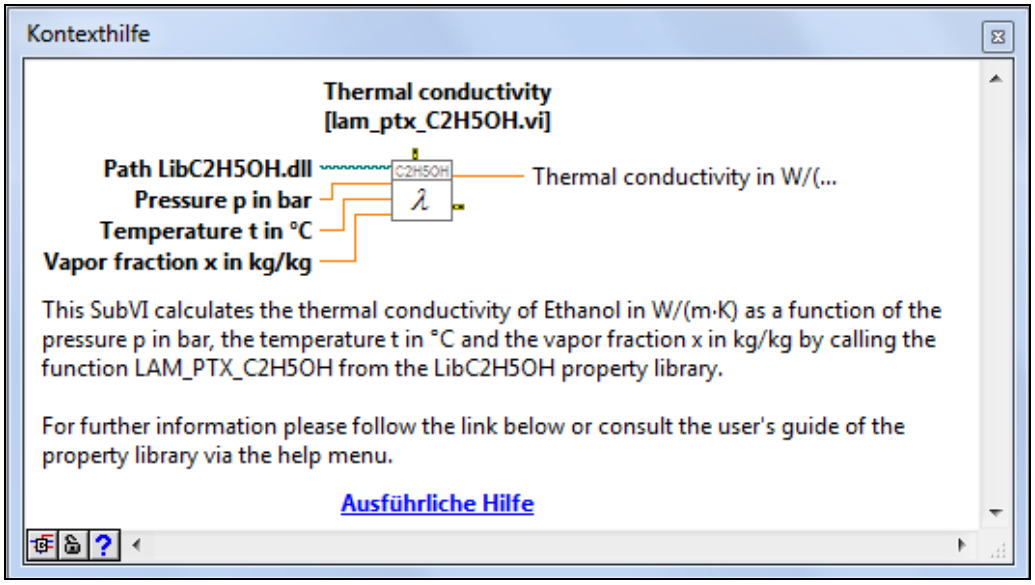


Figure 2.2 Context help window of the function lam_ptx_C2H5OH.vi

2.3 Licensing the LibC2H5OH Property Library

The licensing procedure has to be carried out when calculating a LibC2H5OH function and a FluidVIEW prompt message appears. In this case, you will see the "License Information" window (see figure below).

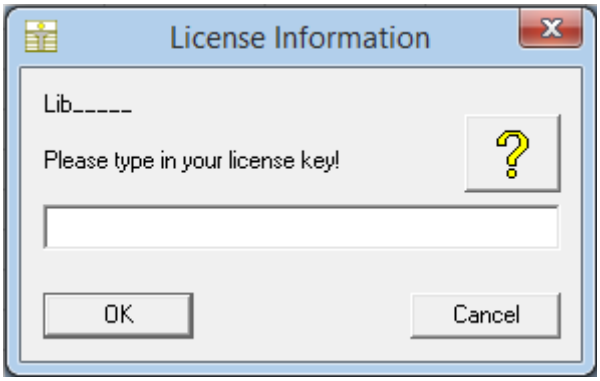


Figure 2.3 "License Information" window

Here you will have to type in the license key. 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:

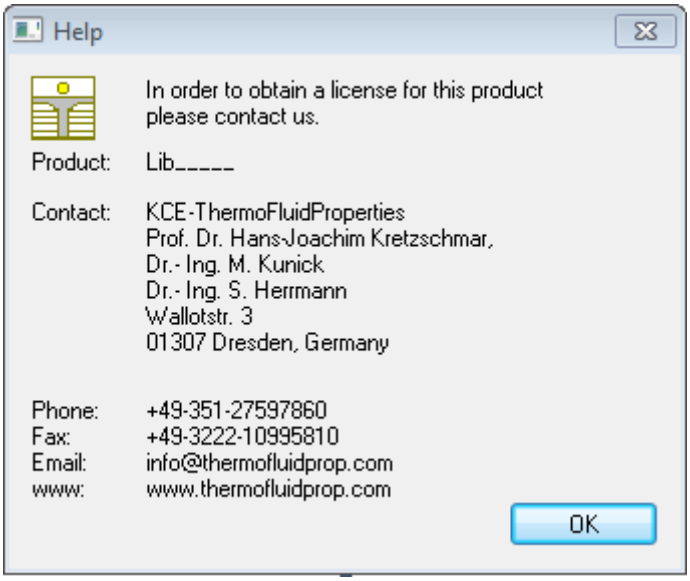


Figure 2.4 "Help" window

If you do not enter a valid license it is still possible to run your VI by clicking "Cancel". In this case, the LibC2H5OH property library will display the result "-1.11111E+7" for every calculation.

The "License Information" window will appear every time you reopen your Virtual Instrument (VI) or reload the path of the LibC2H5OH.dll. Should you not wish to license the LibC2H5OH property library, you have to uninstall FluidVIEW according to the description in section 2.5 of this User's Guide.

Note:

The product name "Lib_ _ _ _ _ in the Figures above stands for the Library you are installing.

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

After the delivered files have been copied in the appropriate folders of the default directory LabVIEW™ (described in section 2.1), the LibC2H5OH property library is ready to use. The function nodes of the LibC2H5OH property library can be used by dragging them from the functions palette into the block diagram and connecting them with the wires representing the required input parameters.

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

- Start LabVIEW™ and wait for the *Getting Started* window to be displayed. Then select *Blank VI*. The *Blank VI* will be displayed in two windows, the front panel and the block diagram.
- Open the functions palette in the block diagram **via view / Functions Palette** (or by clicking the right mouse button anywhere in the free area of the block diagram) if not yet displayed.
- In addition to the default LabVIEW™ palettes the functions palette contains the sub palette *FluidVIEW* (see Figure 2.5) with the sub palette *LibC2H5OH* (see Figure 2.6).

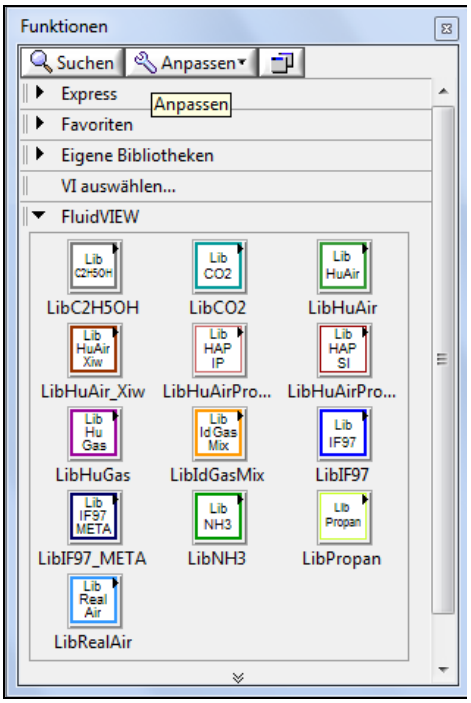


Figure 2.5
Functions palette with the sub palettes FluidVIEW and LibC2H5OH

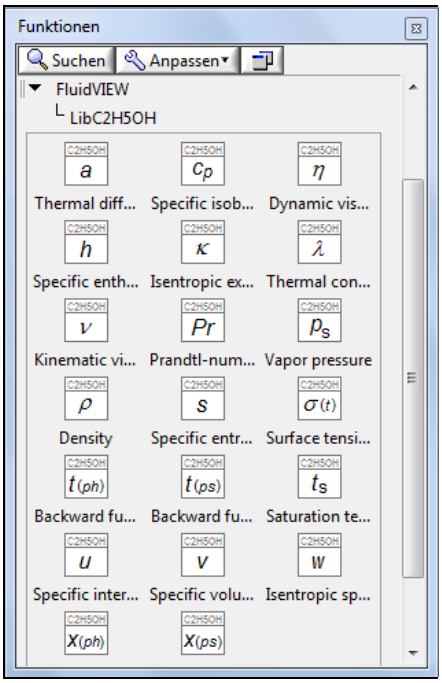


Figure 2.6
Functions palette with the property functions of the LibC2H5OH library

In order to calculate the specific enthalpy *h*, drag the function (SubVI) whose symbol shows the *h* from the functions palette into the block diagram.
While the short names of the SubVIs behind the symbols will be shown in the control tip, the full names and brief descriptions of the property functions are displayed in the *Context Help* window (see Figure 2.2). To use the context help press <Ctrl>+<H> on your keyboard.

- After placing the node of the SubVI **h_ptx_C2H5OH.vi** on your block diagram the required input parameters have to be defined.
  The input parameters which are set as required appear in bold type in the Context Help

window. In this case these input parameters are **Path LibC2H5OH.dll** (LabVIEW™ data type: Path), **Pressure p in bar** (LabVIEW™ data type: Double precision, floating-point), **Temperature t in °C** (LabVIEW™ data type: Double precision, floating-point) and **Vapor fraction x in kg/kg** (LabVIEW™ data type: Double precision, floating-point).

- To define these variables wire their input terminals with input elements on the front panel. You can accomplish this in one step by choosing **Create / Control** in the context menu of all required input terminals. In order to wire the output terminal of the function node with an output element on the front panel, choose **Create / Indicator** in the context menu of the output terminal **Specific enthalpy h in kJ/kg** (LabVIEW™ data type: Double precision, floating-point). After cleaning up the block diagram by pressing <Ctrl>+<U> it has the appearance illustrated in Figure 2.7. The same input and output elements are available on the appropriate front panel (see Figure 2.8).

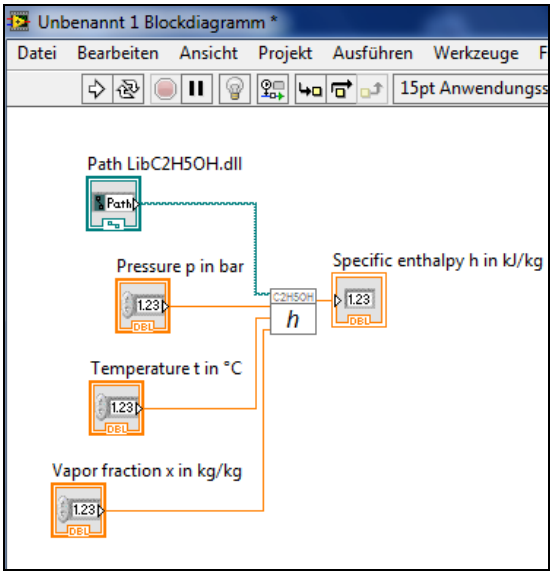


Figure 2.7
Block diagram of the example calculation

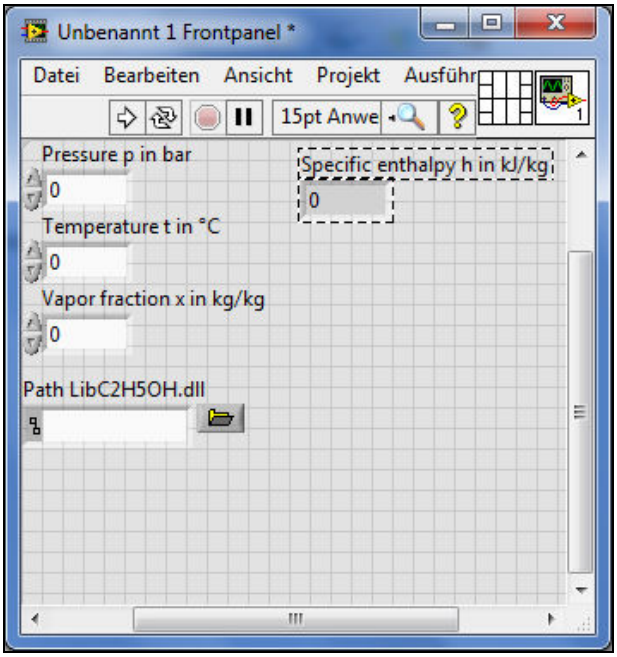


Figure 2.8
Front panel of the example calculation

- Enter a value in the input element *pressure p in bar* on the front panel
  (Range of validity: p_t = 8.8 x 10^{-9} bar to 2800 bar)

  ⇒ e. g.: Enter the value 40 for *p*.

- Enter a value in the input element *temperature t in °C* on the front panel
  (Range of validity: *t* = - 23.15 °C to 376.85 °C)

  ⇒ e. g.: Enter the value 250 for *t*.

Enter a value in the input element *vapor fraction x in kg saturated steam/kg wet steam* on the front panel.

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

<u>Single-phase region</u>

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

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 = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered. If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve.

(Vapor-pressure curve of ethanol: t_{min} = - 23.15 °C ... t_c = 240.75 °C
p_{min} = 2.700744 x 10^{-3} bar … p_c = 61.48 bar)

⇒ e. g.: Enter the value -1000 for *x*.

- Enter the path of the LibC2H5OH.dll in the input element *Path LibC2H5OH.dll* on the front panel (as explained in section 2.1 the LibC2H5OH.dll and the other library files from the directory **<CD>\source** have to be stored in the same directory which is arbitrary). To do this you can use the *File Open Dialog* which appears by clicking the yellow folder symbol on the right of the input element.
- To run the calculation of the specific enthalpy click on the *Run* button or press <Ctrl>+<R>. The result for *h* in kJ/kg appears in the output element (see Figure 2.9).

  ⇒ The result for *h* in our sample calculation is h = 1483.19 kJ/kg.

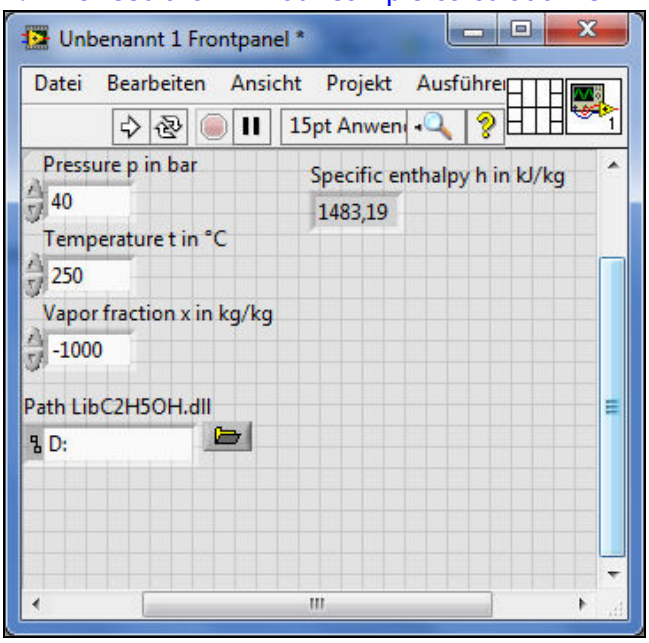


Figure 2.9 Result of the example calculation of *h*

The calculation of *h* = f(*p*,*t*,*x*) has thus been completed. You can now arbitrarily change the values for *p*, *t*, or *x* in the appropriate input elements.

Note:
If the calculation results in –1000, this indicates that the values entered are located outside the range of validity. More detailed information on each function and its range of validity is available in chapter 3. For further property functions calculable with FluidVIEW, see the function table in chapter 1.

2.5 Removing FluidVIEW

Should you wish to remove the LibC2H5OH library or the complete FluidVIEW Add-on you have to delete the files that have been copied in the default directory of the LabVIEW™ development environment **<LV>**.

Removing the FluidVIEW Add-on

To remove the FluidVIEW Add-on please delete the folders listed in Table 2.3 from the default directory of LabVIEW™.

Table 2.3 Directories that have to be deleted from the default directory of LabVIEW™ to remove the FluidVIEW Add-on

Name of the directory	Parent directory in the default directory of LabVIEW™ (<LV>)
FluidVIEW	<LV>\vi.lib
FluidVIEW	<LV>\menus\Categories
FluidVIEW-Help	<LV>\help

Removing only the LibC2H5OH library

To remove only the LibC2H5OH library please delete the folders or files listed in Table 2.4 from the default directory of LabVIEW™.

Table 2.4 Data that have to be deleted from the default directory of LabVIEW™ (<LV>) to remove only the LibC2H5OH library.

File name with file extension or name of the directory	Parent directory in the default directory of LabVIEW (<LV>)
LibC2H5OH.llb	<LV>\vi.lib\FluidVIEW
LibC2H5OH	<LV>\menus\Categories\FluidVIEW
LibC2H5OH.hlp	<LV>\help\FluidVIEW-Help
LibC2H5OH.txt	<LV>\help\FluidVIEW-Help
FluidVIEW_LibC2H5OH.pdf	<LV>\help\FluidVIEW-Help
Open_LibC2H5OH_doc.vi	<LV>\help\FluidVIEW-Help
Open_LibC2H5OH_doc.txt	<LV>\help\FluidVIEW-Help

The changes will take effect after restarting LabVIEW™.

3. Program Documentation

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

Function Name:	**a_ptx_C2H5OH**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION A_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_APTX_C2H5OH(A,P,T,X)** REAL*8 A,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

A_PTX_C2H5OH, **A** or **a_ptx_C2H5OH** - Thermal diffusivity a = in m^2/s

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 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_{min} = – 114.15 °C to t_c = 241.56 °C

Pressure ranges from p_{min} = 7.2 x 10^{-9} bar to 61.48 bar)

Results for wrong input values

Result **A_PTX_C2H5OH = –1000**, **A = –1000 or a_ptx_C2H5OH = –1000** for input values:

Single-phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
(x = –1)	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at p = –1000 and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at t = –1000 and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2], [4]

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

Function name:	**cp_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION CP_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_CPPTX_C2H5OH(CP,P,T,X)** REAL*8 CP,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Output value

CP_PTX_C2H5OH, **CP** or **cp_ptx_C2H5OH** - Specific isobaric heat capacity c_p in kJ / (kg K)

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Details on the vapor fraction *x* and on calculating 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_{min} = – 114.15 °C to t_c = 241.56 °C
Pressure ranges	from p_{min} = 7.2 x 10^{-9} bar to 2800 bar

Results for wrong input values

Result **CP_PTX_C2H5OH = -1000**, **CP = -1000** or **cp_ptx_C2H5OH = -1000** for input values:

Single – phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
(x = –1)	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at p = –1000 and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at t = –1000 and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2]

Dynamic Viscosity η = f(p,t,x)

Function Name:	**Eta_ptx_C2H5OH**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION ETA_PTX_C2H5OH (P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ETAPTX_C2H5OH (ETA,P,T,X)** REAL*8 ETA,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ETAPTXC2H5OH, **ETA** or **eta_ptx_C2H5OH** - Dynamic viscosity η in Pa s

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 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_{min} = – 114.15 °C to t_c = 241.56 °C

Pressure ranges from p_{min} = 7.2 x 10^{-9} bar to 61.48 bar)

Results for wrong input values

Result **ETA_PTX_C2H5OH = –1000**, **ETA = –1000** bzw. **eta_ptx_C2H5OH = –1000** for input values:

Single – phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
$(x = -1)$	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at $p = -1000$ and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at $t = -1000$ and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [3]

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

Function name:	**h_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION H_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_HPTX_C2H5OH(H,P,T,X)** REAL*8 H,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Output value

H_PTX_C2H5OH, **H or h_ptx_C2H5OH** - Specific enthalpy *h* in kJ/kg

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Details on the vapor fraction *x* and on calculating wet steam

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

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

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

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

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

Saturated liquid and saturated vapor line:

Temperature ranges	from t_{min} = – 114.15 °C to t_c = 241.56 °C
Pressure ranges	from p_{min} = 7.2 x 10^{-9} bar to p_c = 62.68 bar

Results for wrong input values

Result **H_PTX_C2H5OH = –1000**, **H = –1000** or **h_ptx_C2H5OH = –1000** for input values:

Single-phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
$(x = -1)$	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at $p = -1000$ and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at $t = -1000$ and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2]

Isentropic Exponent κ = f(p,t,x)

Function name:	**ka_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION KA_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_KAPTX_C2H5OH(KAP,P,T,X)** REAL*8 KAP,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg Wet steam)

Output value

KA_PTX_C2H5OH, **KAP** or **ka_ptx_C2H5OH** - Isentropic exponent $\kappa = \dfrac{w^2}{p * v}$

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Details on the vapor fraction *x* and on calculating 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_{min} = – 114.15 °C to t_c = 241.56 °C
Pressure ranges	from p_{min} = 7.2 x 10^{-9} bar to 2800 bar

Results for wrong input values

Result **KA_PTX_C2H5OH**, **KAP = –1000** or **ka_ptx_C2H5OH = –1000** for input values:

Single – phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
$(x = -1)$	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at $p = -1000$ and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at $t = -1000$ and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2]

Thermal Conductivity λ = f(p,t,x)

Function Name:	**Lam_ptx_C2H5OH**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION LAM_PTX_C2H5OH (P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_LAMPTX_C2H5OH (LAM,P,T,X)** REAL*8 LAM,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

LAM_PTX_C2H5OH, **LAM** or **lambda_ptx_C2H5OH** - Thermal conductivity λ in W/m·K

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 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_{min} = – 114.15 °C to t_c = 241.56 °C

Pressure ranges from p_{min} = 7.2 x 10^{-9} bar to 61.48 bar)

Results for wrong input values

Result **LAM_PTX_C2H5OH**, **LAM = –1000** bzw. **lam_ptx_C2H5OH = –1000** for input values:

Single-phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
(x = –1)	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at p = –1000 and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at t = –1000 and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [4]

Kinematic Viscosity ν = f(p,t,x)

Function Name:	**Ny_ptx_C2H5OH**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION NY_PTX_C2H5OH (P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_NYPTX_C2H5OH (NY,P,T,X)** REAL*8 NUE,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

NYPTXC2H5OH, **NY** or **ny_ptx_C2H5OH** - Kinematic viscosity ν in m^2 / s

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 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_{min} = – 114.15 °C to t_c = 241.56 °C

Pressure ranges from p_{min} = 7.2 x 10^{-9} bar to 61.48 bar)

Results for wrong input values

Result **NY_PTX_C2H5OH**, **NY = –1000** bzw. **ny_ptx_C2H5OH = –1000** for input values:

Single-phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
(x = –1)	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at p = –1000 and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at t = –1000 and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2], [3]

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

Function Name:	**Pr_ptx_C2H5OH**
Sub-program with function value: for call from Fortran	**REAL*8 FUNCTION PR_PTX_C2H5OH (P,T,X)** REAL*8 P,T,X
Sub-program with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PRPTX_C2H5OH (PR,P,T,X)** REAL*8 PR,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

PRPTXC2H5OH, **Pr** or **Pr_ptx_C2H5OH** - Prandtl-number *Pr*

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 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_{min} = – 114.15 °C to t_c = 241.56 °C

Pressure ranges from p_{min} = 7.2 x 10^{-9} bar to 61.48 bar)

Results for wrong input values

Result **PR_PTX_C2H5OH**, **PR = –1000** bzw. **pr_ptx_C2H5OH = –1000** for input values:

Single-phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
(x = –1)	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at p = –1000 and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at t = –1000 and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2], [3], [4]

Vapor Pressure p_s = f(t)

Function name:	**ps_t_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION PST_C2H5OH(T)** REAL*8 T
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_PST_C2H5OH(PS,T)** REAL*8 PS,T

Input values

T - Temperature t in °C

Output value

PS_T_C2H5OH, **PS** or **ps_t_C2H5OH** - Vapor pressure p_s in bar

Range of validity

Temperature range: from $t_{min} = -114.15$ °C to $t_c = 241.56$ °C

Results for wrong input values

Result **PST_C2H5OH = –1000**, **PS = –1000 or ps_t_C2H5OH = –1000** for input values:

$t < t_{min} = -114.15$ °C or $t > t_c = 241.56$ °C

References: [2]

Density ρ = f(p,t,x)

Function name:	**rho_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION RHO_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_RHOPTX_C2H5OH(RHO,P,T,X)** REAL*8 RHO,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Output value

RHO_PTX_C2H5OH, **RHO** or **rho_ptx_C2H5OH** - Density ρ in kg / m^3

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Details on the vapor fraction *x* and on calculating wet steam

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

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

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

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

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

Saturated liquid and saturated vapor line:

Temperature ranges	from t_{min} = – 114.15 °C to t_c = 241.56 °C
Pressure ranges	from p_{min} = 7.2 x 10^{-9} bar to 2800 bar

Results for wrong input values

Result **RHO_PTX_C2H5OH = –1000**, **RHO = –1000** or **rho_ptx_C2H5OH = –1000** for input values:

Single – phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
$(x = -1)$	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at $p = -1000$ and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at $t = -1000$ and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2]

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

Function name:	**s_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION S_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_SPTX_C2H5OH(S,P,T,X)** REAL*8 S,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Output value

S_PTX_C2H5OH, **S** or **s_ptx_C2H5OH** - Specific entropy *s* in kJ/kg K

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from $p_t = 7.2 \times 10^{-9}$ bar to 2800 bar

Details on the vapor fraction *x* and on calculating wet steam

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

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

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

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

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

Saturated liquid and saturated vapor line:

Temperature ranges	from $t_{min} = -114.15$ °C to $t_c = 241.56$ °C
Pressure ranges	from $p_{min} = 7.2 \times 10^{-9}$ bar to 2800 bar

Results for wrong input values

Result **S_PTX_C2H5OH = –1000**, **S = –1000** or **s_ptx_C2H5OH = –1000** for input values:

Single-phase region:	$p > 2800$ bar or $p < p_t = 7.2 \times 10^{-9}$ bar or
$(x = -1)$	$t > 376.85$ °C or $t < t_{min} = -114.15$ °C
Saturated liquid or	at $p = -1000$ and $t > t_c = 241.56$ °C or $t < t_{min} = -114.15$ °C
saturated vapor	at $t = -1000$ and $p > p_c = 61.48$ bar or $p < p_{min} = 7.2 \times 10^{-9}$ bar or
line	at $p > p_c = 61.48$ bar or $p < p_{min} = 7.2 \times 10^{-9}$ bar and $t > t_c = 241.56$ °C or $t < t_{min} = -114.15$°C

References: [2]

Surface Tension σ = f(t)

Function name:	**sigma_t_C2H5OH**
Subrprogram with function value: For the call out of Fortran	**REAL*8 FUNCTION SIGMA_T_C2H5OH(T)** REAL*8 T
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_SIGMAT_C2H5OH(SIG,T)** REAL*8 SIG,T

Input value

T - Temperature t in °C

Outpu value

SIGMA_T_C2H5OH, **SIG** bzw. **sigma_t_C2H5OH** – Surface tension σ in N/m

Range of validity

Temperature range: from - 114.15 °C to t_C = 241.56 °C

Results for wrong input values

Result **SIGMA_T_C2H5OH = –1000**, **SIG = –1000** or **sigma_t_C2H5OH = –1000** for

$t < t_{min} = -114.15$ °C or $t > t_c = 241.56$°C

References: [2]

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

Function name:	**t_ph_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION T_PH_C2H5OH(P,H)** REAL*8 P,H
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_TPH_C2H5OH(T,P,H)** REAL*8 T,P,H

Input values

P - Pressure p in bar

H - Specific enthalpy h in kJ/kg

Output value

T_PH_C2H5OH, **T** or **t_ph_C2H5OH** - Temperature t in °C

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from $p_t = 7.2 \times 10^{-9}$ bar to 2800 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 $p_{min} = 7.2 \times 10^{-9}$ bar to $p_c = 61.48$ bar

Results for wrong input values

Result **T_PH_C2H5OH**, **T = –1000 or t_ph_C2H5OH = –1000** for input values:

Single-phase region: $(x = -1)$	$p >$ 2800 bar or $p < p_t = 7.2 \times 10^{-9}$ bar or at calculation result $t >$ 376.85 °C , $t < t_{min} = -114.15$ °C
Saturated liquid or saturated vapor line	at $p > p_c =$ 61.48 bar or $p < p_t = 7.2 \times 10^{-9}$ bar or at calculation result $t > t_c =$ 241.56 °C or $t < t_{min} = -114.15$ °C

References: [2]

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

Function name:	**t_ps_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION T_PS_C2H5OH(P,S)** REAL*8 P,S
Subprogram with Parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_TPS_C2H5OH(T,P,S)** REAL*8 T,P,S

Input values

P - Pressure *p* in bar

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

Output value

T_PS_C2H5OH, **T or t_ps_C2H5OH** - Temperature *t* in °C

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from $p_t = 7.2 \times 10^{-9}$ bar to 2800 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 $p_{min} = 7.2 \times 10^{-9}$ bar to $p_c = 61.48$ bar

Results for wrong input values

Result **T_PS_C2H5OH**, **T = –1000 or t_ps_C2H5OH = –1000** for input values:

Single-phase region: $(x = -1)$	$p >$ 2800 bar or $p < p_t = 7.2 \times 10^{-9}$ bar or at calculation result $t >$ 376.85 °C , $t < t_{min} = -114.15$ °C
Saturated liquid or saturated vapor line	at $p > p_c =$ 61.48 bar or $p < p_t = 7.2 \times 10^{-9}$ bar or at calculation result $t > t_c =$ 241.56 °C or $t < t_{min} = -114.15$ °C

References: [2]

Saturation Temperature t_s = f(p)

Function name:	**ts_p_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION TSP_C2H5OH(P)** REAL*8 P
Subprogram with Parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_TSP_C2H5OH(TS,P)** REAL*8 TS,P

Input values

P - Pressure p in bar

Output value

TS_P_C2H5OH, **TS** or **ts_p_C2H5OH** - Saturation temperature t_s in °C

Range of validity

Pressure range: from $p_t = 7.2 \times 10^{-9}$ bar to $p_c = 61.48$ bar

Results for wrong input values

Result **TSP_C2H5OH = –1000**, **TS = –1000 or ts_p_C2H5OH = –1000** for input values:

$p > p_c = 61.48$ bar or $p < p_t = 7.2 \times 10^{-9}$ bar

References: [2]

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

Function name:	**u_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION U_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_UPTX_C2H5OH(H,P,T,X)** REAL*8 H,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Output value

U_PTX_C2H5OH, **U or u_ptx_C2H5OH** - Specific internal energy *u* in kJ/kg

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Details on the vapor fraction *x* and on calculating wet steam

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

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

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

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

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

Saturated liquid and saturated vapor line:

Temperature ranges	from t_{min} = – 114.15 °C to t_c = 241.56 °C
Pressure ranges	from p_{min} = 7.2 x 10^{-9} bar to 2800 bar

Results for wrong input values

Result **U_PTX_C2H5OH = –1000**, **U = –1000 or u_ptx_C2H5OH = –1000** for input values:

Single – phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
$(x = -1)$	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at $p = -1000$ and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at $t = -1000$ and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2]

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

Function name:	**v_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION V_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_VPTX_C2H5OH(V,P,T,X)** REAL*8 V,P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Output value

V_PTX_C2H5OH, **V** or **v_ptx_C2H5OH** - Specific volume v in m^3 / kg

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Details on the vapor fraction *x* and on calculating wet steam

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

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

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

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

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

Saturated liquid and saturated vapor line:

Temperature ranges	from t_{min} = – 114.15 °C to t_c = 241.56 °C
Pressure ranges	from p_{min} = 7.2 x 10^{-9} bar to 2800 bar

Results for wrong input values

Result **V_PTX_C2H5OH = –1000**, **V = –1000** or **v_ptx_C2H5OH = –1000** for input values:

Single – phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
$(x = -1)$	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at $p = -1000$ and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at $t = -1000$ and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2]

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

Function name:	**w_ptx_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION W_PTX_C2H5OH(P,T,X)** REAL*8 P,T,X
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_WPTX_C2H5OH(W,P,T,X)** REAL*8 W,P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Output value

WPTXC2H5OH, **W** or **w_ptx_C2H5OH** - Isentropic speed of sound *w* in m/s

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from p_t = 7.2 x 10^{-9} bar to 2800 bar

Details on the vapor fraction *x* and on calculating boiling 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_{min} = – 114.15 °C to t_c = 241.56 °C
Pressure ranges	from p_{min} = 7.2 x 10^{-9} bar to 2800 bar

Results for wrong input values

Result **W_PTX_C2H5OH = –1000**, **W = –1000 or w_ptx_C2H5OH = –1000** for input values:

Single – phase region:	$p >$ 2800 bar or $p < p_t$ = 7.2 x 10^{-9} bar or
$(x = -1)$	$t >$ 376.85 °C or $t < t_{min}$ = – 114.15 °C
Saturated liquid or	at $p = -1000$ and $t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15 °C
saturated vapor	at $t = -1000$ and $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar or
line	at $p > p_c$ = 61.48 bar or $p < p_{min}$ = 7.2 x 10^{-9} bar and
	$t > t_c$ = 241.56 °C or $t < t_{min}$ = – 114.15°C

References: [2]

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

Function name:	**x_ph_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION X_PH_C2H5OH(P,H)** REAL*8 P,H
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_XPH_C2H5OH(T,P,H)** REAL*8 X,P,H

Input values

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Output value

X_PH_C2H5OH, **X** or **x_ph_C2H5OH** - Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from $p_{min} = 7.2 \times 10^{-9}$ bar to 2800 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 $p_{min} = 7.2 \times 10^{-9}$ bar to 2800 bar

Results for wrong input values

Result **X_PH_C2H5OH = –1** , **X = –1** or **x_ph_C2H5OH = –1** for input values:

If the state point to be calculated is located in the single-phase region

$p > p_c = 61.48$ bar or $p < p_t = 7.2 \times 10^{-9}$ bar

References: [2]

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

Function name:	**x_ps_C2H5OH**
Subprogram with function value: for the call out of Fortran	**REAL*8 FUNCTION X_PS_C2H5OH(P,S)** REAL*8 P,S
Subprogram with parameter: for the call out of DLL	**INTEGER*4 FUNCTION C_XPS_C2H5OH(X,P,S)** REAL*8 X,P,S

Input values

P - Pressure *p* in bar

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

Output value

X_PS_C2H5OH, **X or x_ps_C2H5OH** - Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from - 114.15 °C to 376.85 °C

Pressure range: from $p_{min} = 7.2 \times 10^{-9}$ bar to 2800 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 $p_{min} = 7.2 \times 10^{-9}$ bar to 2800 bar

Results for wrong input values

Result **X_PS_C2H5OH = –1**, **X = –1** or **x_ps_C2H5OH = –1** for input values:

If the state point to be calculated is located in the single-phase region

$p > p_c = 61.48$ bar or $p < p_t = 7.2 \times 10^{-9}$ bar

References: [2]

KCE ThermoFluidProperties

KCE-ThermoFluidProperties
www.thermofluidprop.com

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

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, -S03rev, -S04, and -S05
- IAPWS Revised Advisory Note No. 3 on Thermo-dynamic Derivatives (2008)

Library LibIF97_META

- Industrial Formulation IAPWS-IF97 (Revision 2007) for metastable steam

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

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

and of the ideal gases:
SO_2, CO, Ne
(Scientific Formulation of Bücker et al.)

Consideration of:

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

Extremely Fast Property Calculations

Spline-Based Table Look-up Method (SBTL)

Library LibSBTL_IF97
Library LibSBTL_95
Library LibSBTL_HuAir

For steam, water, humid air, carbon dioxide and other fluids and mixtures according IAPWS Guideline 2015 for Computational Fluid Dynamics (CFD), real-time and non-stationary simulations

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

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

Humid Air

Library ASHRAE LibHuAirProp

Model: Virial equation from ASHRAE Report RP-1485 for real mixture of the real fluids:
- Dry air
- Steam

Consideration of:

- Enhancement of the partial saturation pressure of water vapor at elevated total pressures

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bücker and Wagner (2006)

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 the 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	Ethanol
CH_3OH	Methanol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate
$CHKO_2$	Potassium formate
LiCl	Lithium chloride
NH_3	Ammonia

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol

Library LibC2H5OH

Formulation of
Schroeder et al. (2014)

Methanol

Library LibCH3OH

Formulation of
de Reuck and Craven (1993)

Propane

Library LibPropane

Formulation of
Lemmon et al. (2009)

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)

Nitrogen and Oxygen

Libraries LibN2 and LibO2

Formulations of Span et al. (2000)
and Schmidt and Wagner (1985)

Hydrogen

Library LibH2

Formulation of
Leachman et al. (2009)

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_6H_{14} **Library LibC6H14**

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**

Nitrous oxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

KCE ThermoFluidProperties

For more information please contact:

KCE-ThermoFluidProperties UG & Co. KG
Prof. Dr. Hans-Joachim Kretzschmar
Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

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

Thermodynamic Properties

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

Transport Properties

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

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 used in process modeling can be calculated.

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

www.thermofluidprop.com

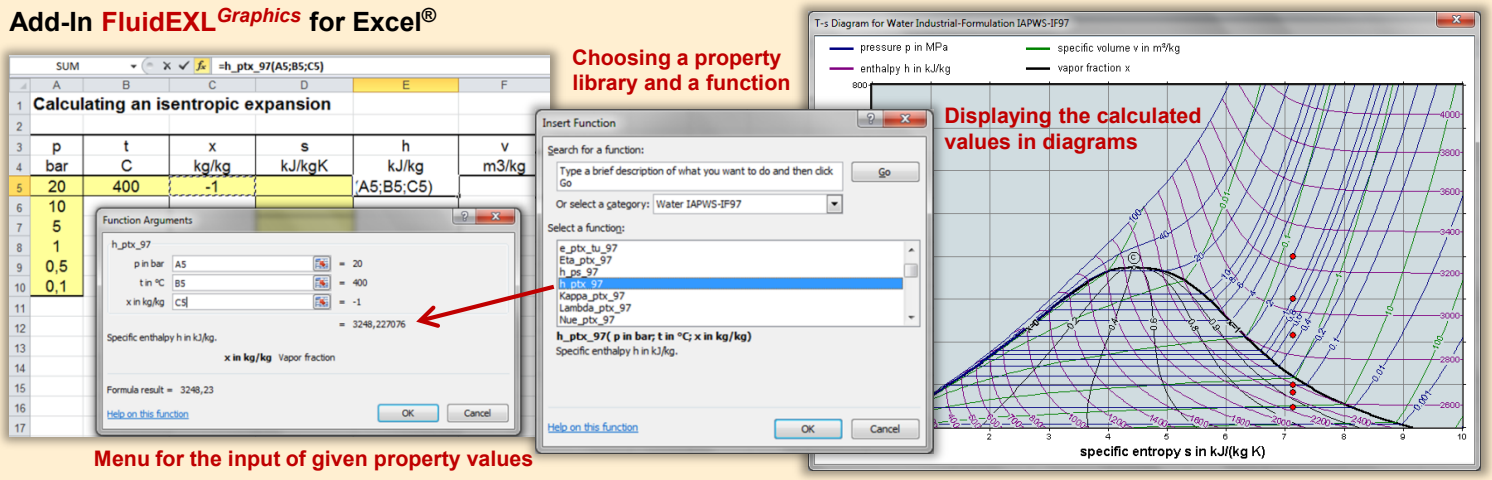
KCE-ThermoFluidProperties
www.thermofluidprop.com

KCE ThermoFluidProperties

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

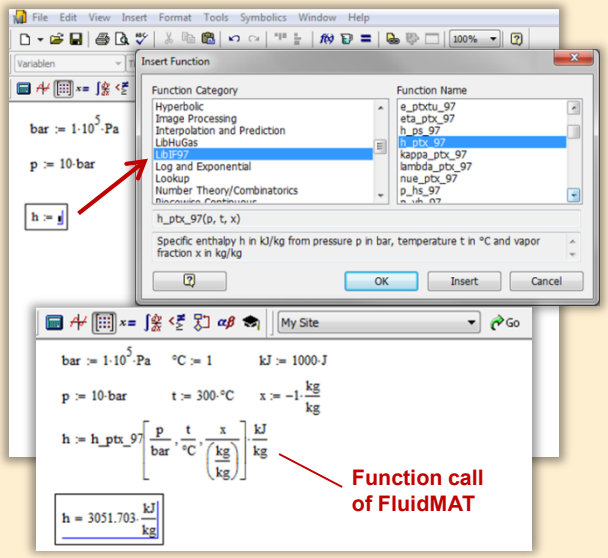
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



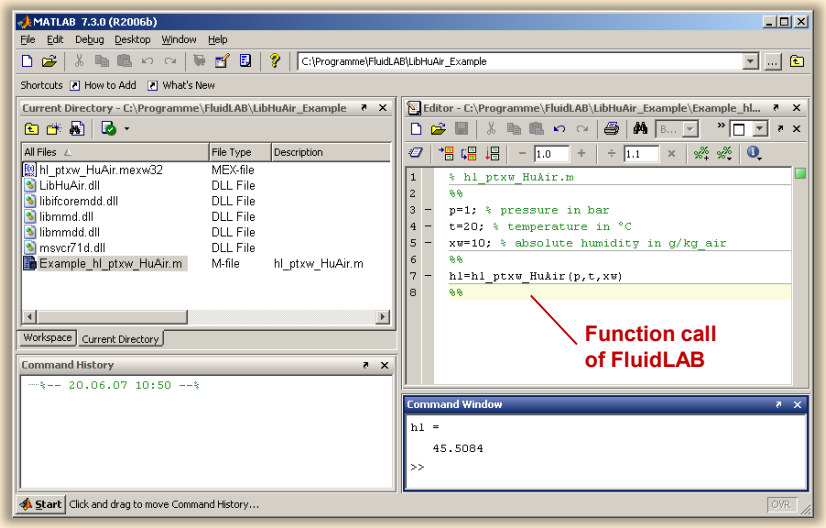
Add-On FluidMAT for Mathcad®
Add-On FluidPRIME for Mathcad Prime®

The property libraries can be used in Mathcad® and Mathcad Prime®.



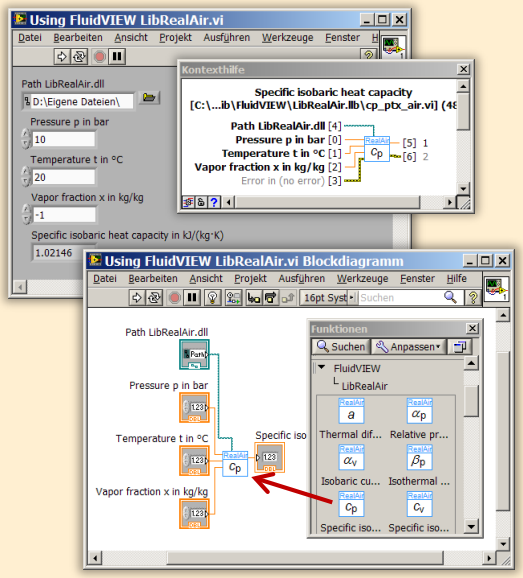
Add-On FluidLAB for MATLAB® and SIMULINK®

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



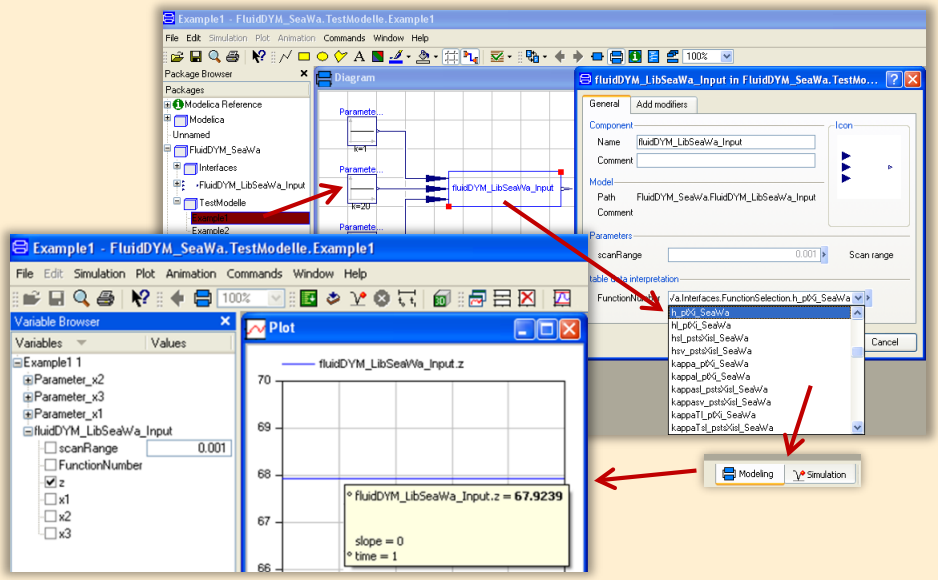
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

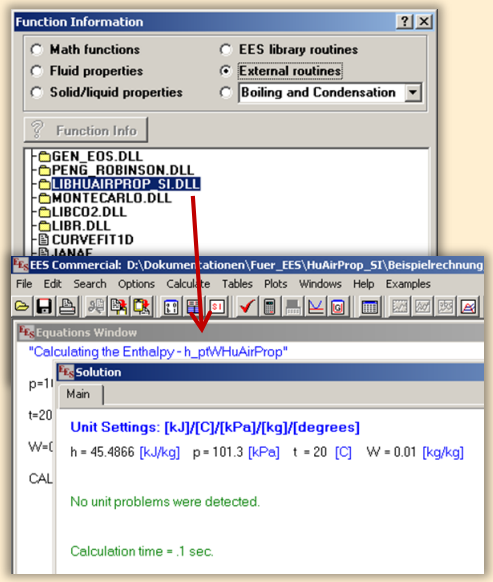


Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

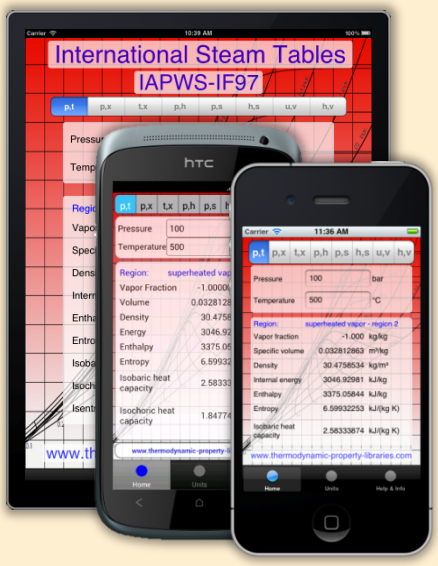
The property functions can be called in DYMOLA® and SimulationX®.



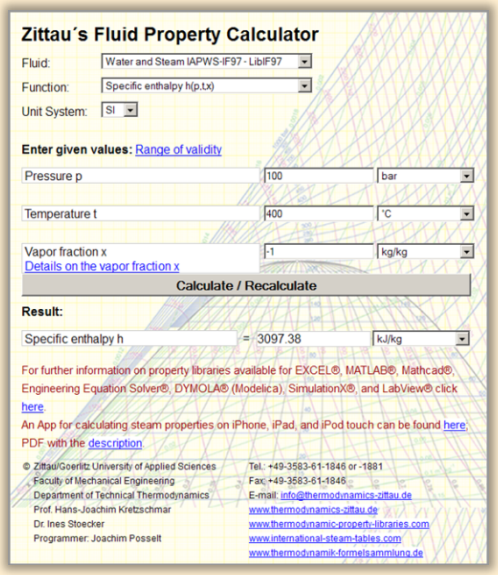
Add-On FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android Smartphones and Tablets



Online Property Calculator at www.thermofluidprop.com



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 Nspire CX CAS
TI Nspire CAS

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

For more information please contact:

KCE ThermoFluidProperties

KCE-ThermoFluidProperties UG & Co. KG
Prof. Dr. Hans-Joachim Kretzschmar
Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

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

Thermodynamic Properties

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

Transport Properties

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

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 used in process modeling can be calculated.

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

www.thermofluidprop.com

5. References

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

[2] Schroeder, J.A.:
A new Fundamental Equation for Ethanol
Master Thesis, University of Idaho, (2012)

[3] Kiselev, S. B., Ely, J. F., Abdulagatov, I. M., Huber, M. L.:
Generalized SAFT-DFT/DMT Model for the Thermodynamic, Interfacial, and Transport Properties of Associating Fluids: Application for n-Alkanols
Ind. Eng. Chem. Res., 2005, 44, 6916-6927.

[4] Marsh, K., Perkins, R., and Ramires, M.L.V.:
Measurement and Correlation of the Thermal Conductivity of Propane from 86 to 600 K at Pressures to 70 MPa
J. Chem. Eng. Data, 47(4):932-940, 2002.

6. Satisfied Customers

Date: 07/2019

The following companies and institutions use the property libraries:

- FluidEXL*Graphics* for Excel®
- FluidLAB for MATLAB® and Simulink
- FluidMAT for Mathcad®
- FluidPRIME for Mathcad Prime®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica) and SimulationX®
- FluidVIEW for LabVIEW™
- DLLs for Windows™
- Shared Objects for Linux®.

2019

WARNICA, Waterloo, Canada	07/2019
MIBRAG, Zeitz	06/2019
Pöyry, Zürich, Switzerland	06/2019
RWTH Aachen, Inst. Strahlantriebe und Turbomaschinen	06/2019
Midiplan, Bietigheim-Bissingen	06/2019
GKS Schweinfurt	06/2019
HS Zittau/Görlitz, Wirtschaftswissenschaften und Wirtschaftsingenieurwesen	06/2019
ILK Dresden	06/2019
HZDR Helmholtz Zentrum Dresden-Rossendorf	06/2019
TH Köln, TGA	05/2019
IB Knittel, Braunschweig	05/2019
Norsk Energi, Oslo, Norway	05/2019
STEAG Essen	05/2019
Stora Enso, Eilenburg	05/2019
IB Lücke, Paderborn	05/2019
Haarslev, Sonderso, Denmark	05/2019
MAN Augsburg	05/2019
Wieland Werke, Ulm	04/2019
Fels-Werke, Elbingerode	04/2019
Univ. Luxembourg Luxembourg	04/2019
BTU Cottbus, Power Engineering	03/2009
Eins-Energie Sachsen, Schwarzenberg	03/2019
TU Dresden, Kälte- und Kryotechnik	03/2019
ITER, St. Paul Lez Durance Cedex, France	03/2019
Fraunhofer UMSICHT, Oberhausen	03/2019
Comparex Leipzig for Spedition Thiele HEMMERSBACH	03/2019
Rückert NaturGas, Lauf/Pegnitz	03/2019
BASF, Basel, Switzerland	02/2019
Stadtwerke Leipzig	02/2019

Maerz Ofenbau Zürich, Switzerland	02/2019
Hanon Systems Germany, Kerpen	02/2019
Thermofin, Heinsdorfergrund	01/2019
BSH Berlin	01/2019

2018

Jaguar Energy, Guatemala	12/2018
WEBASTO, Gilching	12/2018
Smurfit Kappa, Oosterhout, Netherlands	12/2018
Univ. BW München	12/2018
RAIV, Liberec for VALEO, Prague, Czech Republic	11/2018
VPC Group Vetschau	11/2018
SEITZ, Wetzikon, Switzerland	11/2018
MVV, Mannheim	10/2018
IB Troche	10/2018
KANIS Turbinen, Nürnberg	10/2018
TH Ingolstadt, Institut für neue Energiesysteme	10/2018
IB Kristl & Seibt, Graz, Austria	09/2018
INEOS, Köln	09/2018
IB Lücke, Paderborn	09/2018
Südzucker, Ochsenfurt	08/2018
K&K Turbinenservice, Bielefeld	07/2018
OTH Regensburg, Elektrotechnik	07/2018
Comparex Leipzig for LEAG, Berlin	06/2018
Münstermann, Telgte	05/2018
TH Nürnberg, Verfahrenstechnik	05/2018
Universität Madrid, Madrid, Spanien	05/2018
HS Zittau/Görlitz, Wirtschaftswissenschaften und Wirtschaftsingenieurwesen	05/2018
HS Niederrhein, Krefeld	05/2018
Wilhelm-Büchner HS, Pfungstadt	03/2018
GRS, Köln	03/2018
WIB, Dennheritz	03/2018
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	02/2018
AIXPROCESS, Aachen	02/2018
KRONES, Neutraubling	02/2018
Doosan Lentjes, Ratingen	01/2018

2017

Compact Kältetechnik, Dresden	12/2017
Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	12/2017
TH Mittelhessen, Gießen	11/2017
Haarslev Industries, Søndersø, Denmark	11/2017
Hochschule Zittau/Görlitz, Fachgebiet Energiesystemtechnik	11/2017
ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	10/2017
Fels-Werke GmbH, Elbingerode	10/2017

KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik	09/2017
Air-Consult, Jena	09/2017
Papierfabrik Koehler, Oberkirch	09/2017
ZWILAG, Würenlingen, Switzerland	09/2017
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017
Fichtner IT Consulting AG, Stuttgart	07/2017
Hochschule Ansbach, Ansbach	06/2017
RONAL, Härkingen, Switzerland	06/2017
BORSIG Service, Berlin	06/2017
BOGE Kompressoren, Bielefeld	06/2017
STEAG Energy Services, Zwingenberg	06/2017
CES clean energy solutions, Wien, Austria	04/2017
Princeton University, Princeton, USA	04/2017
B2P Bio-to-Power, Wadersloh	04/2017
TU Dresden, Institute for Energy Engineering, Dresden	04/2017
SAINT-GOBAIN, Vaujours, France	03/2017
TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
SCHMIDT + PARTNER, Therwil, Switzerland	03/2017
KAESER Kompressoren, Gera	03/2017
F&R, Praha, Czech Republic	03/2017
ULT Umwelt-Lufttechnik, Löbau	02/2017
JS Energie & Beratung, Erding	02/2017
Kelvion Brazed PHE, Nobitz-Wilchwitz	02/2017
MTU Aero Engines, München	02/2017
Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	01/2017
SHELL Deutschland Oil, Wesseling	01/2017
MARTEC Education Center, Frederikshaven, Denmark	01/2017
SynErgy Thermal Management, Krefeld	01/2017

2016

BOGE Druckluftsysteme, Bielefeld	12/2016
BFT Planung, Aachen	11/2016
Midiplan, Bietigheim-Bissingen	11/2016
BBE Barnich IB	11/2016
Wenisch IB,	11/2016
INL, Idaho Falls	11/2016
TU Kältetechnik, Dresden	11/2016
Kopf SynGas, Sulz	11/2016
INTVEN, Bellevne (USA)	11/2016
DREWAG Dresden, Dresden	10/2016
AGO AG Energie+Anlagen, Kulmbach	10/2016
Universität Stuttgart, ITW, Stuttgart	09/2016
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B+B Engineering GmbH, Magdeburg	09/2016
Wilhelm Büchner Hochschule, Pfungstadt	08/2016

Webasto Thermo & Comfort SE, Gliching	08/2016
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Endress+Hauser Messtechnik GmbH+Co. KG, Hannover	08/2016
D + B Kältetechnik, Althausen	07/2016
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Planungsbüro Waidhas GmbH, Chemnitz	07/2016
EEB Enerko, Aldershoven	07/2016
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	07/2016
SSP Kälteplaner AG, Wolfertschwenden	07/2016
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	07/2016
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
Universidad Carlos III de Madrid, Madrid, Spain	04/2016
INWAT, Lodzi, Poland	04/2016
Planungsbüro WAIDHAS GmbH, Chemnitz	04/2016
STEAG Energy Services GmbH, Laszlo Küppers, Zwingenberg	03/2016
WULFF & UMAG Energy Solutions GmbH, Husum	03/2016
FH Bielefeld, Bielefeld	03/2016
EWT Eckert Wassertechnik GmbH, Celle	03/2016
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016, 06/2016
IEV KEMA - DNV GV – Energie, Dresden	02/2016
Allborg University, Department of Energie, Aalborg, Denmark	02/2016
G.A.M. Heat GmbH, Gräfenhainichen	02/2016
Institut für Luft- und Kältetechnik, Dresden	02/2016, 05/2016, 06/2016
Bosch, Stuttgart	02/2016
INL Idaho National Laboratory, Idaho, USA	11/2016, 01/2016
Friedl ID, Wien, Austria	01/2016
Technical University of Dresden, Dresden	01/2016

2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	12/2015
Allborg University, Department of Energie, Aalborg, Denmark	12/2015
University of Lyubljana, Slovenia	12/2015
Steinbrecht IB, Berlin	11/2015
Universidad Carlos III de Madrid, Madrid, Spain	11/2015
STEAK, Essen	11/2015
Bosch, Lohmar	10/2015
Team Turbo Machines, Rouen, France	09/2015
BTC – Business Technology Consulting AG, Oldenburg	07/2015
KIT Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen	07/2015
ILK, Dresden	07/2015
Schniewindt GmbH & Co. KG, Neuenwalde	08/2015

2014

PROJEKTPLAN, Dohna	04/2014
Technical University of Vienna, Austria	04/2014
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GKS, Schweinfurt	03/2014
Technical University of Nuremberg	03/2014
EP-E, Niederstetten	03/2014
Rückert NatUrgas GmbH, Lauf	03/2014
YESS-World, South Korea	03/2014
ZAB, Dessau	02/2014
KIT-TVT, Karlsruhe	02/2014
Stadtwerke Neuburg	02/2014
COMPAREX, Leipzig for RWE Essen	02/2014
Technical University of Prague, Czech Republic	02/2014
HS Augsburg	02/2014
Envi-con, Nuremberg	01/2014
DLR, Stuttgart	01/2014
Doosan Lentjes, Ratingen	01/2014
Technical University of Berlin	01/2014
Technical University of Munich	01/2014
Technical University of Braunschweig	01/2014
M&M Turbinentechnik, Bielefeld	01/2014

2013

TRANTER-GmbH, Artern	12/2013
SATAKE, Shanghai, China	12/2013
VOITH, Kunshan, China	12/2013
ULT, Löbau	12/2013
MAN, Copenhagen, Dänemark	11/2013
DREWAG, Dresden	11/2013
Haarslev Industries, Herlev, Dänemark	11/2013
STEAG, Herne	11/2013, 12/2013
Ingersoll-Rand, Oberhausen	11/2013
Wilhelm-Büchner HS, Darmstadt	10/2013
IAV, Chemnitz	10/2013
Technical University of Regensburg	10/2013
PD-Energy, Bitterfeld	09/2013
Thermofin, Heinsdorfergrund	09/2013
SHI, New Jersey, USA	09/2013
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	08/2013
TIG-Group, Husum	08/2013
COMPAREX, Leipzig for RWE Essen	08/2013, 11/2013 12/2013
University of Budapest, Hungary	08/2013
Siemens, Frankenthal	08/2013, 10/2013

	11/2013
VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
Technical University of Deggendorf	07/2013
University of Maryland, USA	07/2013, 08/2013
University of Princeton, USA	07/2013
NIST, Boulder, USA	06/2013
IGUS GmbH, Dresden	06/2013
BHR Bilfinger, Essen	06/2013
SÜDSALZ, Bad Friedrichshall	06/2013, 12/2013
Technician School of Berlin	05/2013
KIER, Gajeong-ro, Südkorea	05/2013
Schwing/Stetter GmbH, Memmingen	05/2013
Vattenfall, Berlin	05/2013
AUTARK, Kleinmachnow	05/2013
STEAG, Zwingenberg	05/2013
Hochtief, Düsseldorf	05/2013
University of Stuttgart	04/2013
Technical University -Bundeswehr, Munich	04/2013
Rerum Cognitio Forschungszentrum, Frankfurt	04/2013
Kältetechnik Dresen + Bremen, Alfhausen	04/2013
University Auckland, New Zealand	04/2013
MASDAR Institut, Abu Dhabi, United Arab Emirates	03/2013
Simpelkamp, Dresden	02/2013
VEO, Eisenhüttenstadt	02/2013
ENTEC, Auerbach	02/2013
Caterpillar, Kiel	02/2013
Technical University of Wismar	02/2013
Technical University of Dusseldorf	02/2013
ILK, Dresden	01/2013, 08/2013
Fichtner IT, Stuttgart	01/2013, 11/2013
Schnepf Ingeniuerbüro, Nagold	01/2013
Schütz Engineering, Wadgassen	01/2013
Endress & Hauser, Reinach, Switzerland	01/2013
Oschatz GmbH, Essen	01/2013
frischli Milchwerke, Rehburg-Loccum	01/2013

2012

Voith, Bayreuth	12/2012
Technical University of Munich	12/2012
Dillinger Huette	12/2012
University of Stuttgart	11/2012
Siemens, Muehlheim	11/2012
Sennheiser, Hannover	11/2012
Oschatz GmbH, Essen	10/2012
Fichtner IT, Stuttgart	10/2012, 11/2012
Helbling Technik AG, Zurich, Switzerland	10/2012
University of Duisburg	10/2012

Rerum Cognitio Forschungszentrum, Frankfurt	09/2012
Pöyry Deutschland GmbH, Dresden	08/2012
Extracciones, Guatemala	08/2012
RWE, Essen	08/2012
Weghaus Consulting Engineers, Wuerzburg	08/2012
GKS, Schweinfurt	07/2012
COMPAREX, Leipzig for RWE Essen	07/2012
GEA, Nobitz	07/2012
Meyer Werft, Papenburg	07/2012
STEAG, Herne	07/2012
GRS, Cologne	06/2012
Fichtner IT Consult, Chennai, India	06/2012
Siemens, Freiburg	06/2012
Nikon Research of America, Belmont, USA	06/2012
Niederrhein University of Applied Sciences, Krefeld	06/2012
STEAG, Zwingenberg	06/2012
Mainova, Frankfurt on Main via Fichtner IT Consult	05/2012
Endress & Hauser	05/2012
PEU, Espenheim	05/2012
Luzern University of Applied Sciences, Switzerland	05/2012
BASF, Ludwigshafen (general license) via Fichtner IT Consult	05/2012
SPX Balcke-Dürr, Ratingen	05/2012, 07/2012
Gruber-Schmidt, Wien, Austria	04/2012
Vattenfall, Berlin	04/2012
ALSTOM, Baden	04/2012
SKW, Piesteritz	04/2012
TERA Ingegneria, Trento, Italy	04/2012
Siemens, Erlangen	04/2012, 05/2012
LAWI Power, Dresden	04/2012
Stadtwerke Leipzig	04/2012
SEITZ, Wetzikon, Switzerland	03/2012, 07/2012
M & M, Bielefeld	03/2012
Sennheiser, Wedemark	03/2012
SPG, Montreuil Cedex, France	02/2012
German Destilation, Sprendlingen	02/2012
Lopez, Munguia, Spain	02/2012
Endress & Hauser, Hannover	02/2012
Palo Alto Research Center, USA	02/2012
WIPAK, Walsrode	02/2012
Freudenberg, Weinheim	01/2012
Fichtner, Stuttgart	01/2012
airinotec, Bayreuth	01/2012, 07/2012
University Auckland, New Zealand	01/2012
VPC, Vetschau	01/2012
Franken Guss, Kitzingen	01/2012

2011

XRG-Simulation, Hamburg	12/2011
Smurfit Kappa PPT, AX Roermond, Netherlands	12/2011
AWTEC, Zurich, Switzerland	12/2011
eins-energie, Bad Elster	12/2011
BeNow, Rodenbach	11/2011
Luzern University of Applied Sciences, Switzerland	11/2011
GMVA, Oberhausen	11/2011
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	10/2011
PLANAIR, La Sagne, Switzerland	10/2011
LAWI, Dresden	10/2011
Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011
Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011

ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010
University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010
Vaillant, Remscheid	10/2010
PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
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IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
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Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
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HUBER Consulting Engineers, Berching	04/2010
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MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
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Fischer-Uhrig Consulting Engineers, Berlin	01/2010

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Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
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Techgroup, Ratingen	11/2009
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MCI, Innsbruck, Austria	12/2009
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ENERKO, Aldenhoven	12/2009

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Pink, Langenwang	01/2008
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Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
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Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008
Technip Benelux BV, Zoetermeer, Netherlands	08/2008
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PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
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Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
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Maxxtec, Sinsheim	03/2007
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University of Stuttgart, Chair in Aviation Propulsions	03/2007
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ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
Technical University of Cottbus, Chair in Power Plant Engineering	06/2007
Voith Paper Air Systems, Bayreuth	06/2007
Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
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National Energy Technology Laboratory, Pittsburg, USA	10/2007
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Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
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University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

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Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart,	02/2006

Department of Thermal Fluid Flow Engines	
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Chair in Apparatus and Plant Engineering	
Energietechnik Leipzig (company license),	02/2006
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RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
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Department of Thermodynamics	
EnviCon & Plant Engineering, Nuremberg	04/2006
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Department of USET Merseburg incorporated society	
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Siemens Power Generation, Berlin	11/2006
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BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

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J.H.K Plant Engineering and Service, Bremerhaven	01/2005
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FCIT, Stuttgart	01/2005
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eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden	04/2005
Professorship of Thermic Energy Machines and Plants	
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005

Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences,	05/2005
Department of Mechanical Engineering and Process Engineering	
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
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Technical University of Berlin	10/2005
Basel University of Applied Sciences,	10/2005
Department of Mechanical Engineering, Switzerland	
Midiplan, Bietigheim-Bissingen	11/2005
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STORA ENSO Sachsen, Eilenburg	12/2005
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MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
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Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden,	
Professorship of Thermic Energy Machines and Plants	04/2004
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University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
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HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004

Enertech EUT, Radebeul (company license)	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003
Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
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University of Cali, Colombia	07/2003
Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003
Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002

SAAS, Possendorf/Dresden	02/2002
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Siemens Power Generation, Goerlitz	10/2002
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2001

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Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of	02/2001
Power Machinery and Plants	
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart	04/2001
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SaarEnergie, Saarbruecken	05/2001
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Neusiedler AG, Ulmerfeld, Austria	09/2001
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GK, Hannover	03/2000
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Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
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VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
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Compania Electrica, Bogota, Colombia	10/2000
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Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

1998

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Fichtner Consulting & IT (CADIS information systems) Stuttgart	05/1998
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