Property Library for R134a

FluidLAB with LibR134a for MATLAB®

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Property Library for the Calculation

of R134a

FluidLAB for MATLAB®

LibR134a

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0. Package Contents

0.1 Zip file for 32-bit MATLAB®

The following zip file is delivered for your computer running a 32-bit version of MATLAB®.

"CD_FluidLAB_LibR134a.zip"

Including the following files:

FluidLAB_LibR134a_Setup.exe	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibR134a.dll	- Dynamic Link Library for R134a for use in MATLAB®
FluidLAB_LibR134a_Docu_Eng.pdf	- User's Guide

0.2 Zip file for 64-bit MATLAB®

The following zip file is delivered for your computer running a 64-bit version of MATLAB®.

"CD_FluidLAB_LibR134a_x64.zip"

Including the following files and folders:

Files:

Setup.exe	- Self-extracting and self-installing program for FluidLAB
FluidLAB_LibR134a_64_Setup.msi	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibR134a.dll	- Dynamic Link Library for R134a for use in MATLAB®
FluidLAB_LibR134a_Docu_Eng.pdf	- User's Guide

Folders:

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

1. Property Functions

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibR134a as parameter	Property or Function	Unit of the result
$a = f(p,t,x)$	a_ptx_R134a	A_PTX_R134A(P,T,X)	C_A_PTX_R134A(A,P,T,X)	Thermal diffusivity	m^2/s
$c_p = f(p,t,x)$	cp_ptx_R134a	CP_PTX_R134A(P,T,X)	C_CP_PTX_R134A(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_R134a	CV_PTX_R134A(P,T,X)	C_CV_PTX_R134A(CV,P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\eta = f(p,t,x)$	eta_ptx_R134a	ETA_PTX_R134A(P,T,X)	C_ETA_PTX_R134A(ETA,P,T,X)	Dynamic viscosity	Pa s
$h = f(p,t,x)$	h_ptx_R134a	H_PTX_R134A(P,T,X)	C_H_PTX_R134A(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_R134a	KAP_PTX_R134A(P,T,X)	C_KAP_PTX_R134A(KAP,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lambda_ptx_R134a	LAM_PTX_R134A(P,T,X)	C_LAM_PTX_R134A(LAM,P,T,X)	Thermal conductivity	W/m K
$\nu = f(p,t,x)$	ny_ptx_R134a	NY_PTX_R134A(P,T,X)	C_NY_PTX_R134A(NY,P,T,X)	Kinematic viscosity	m^2/s
$p_s = f(t)$	ps_t_R134a	PS_T_R134A(T)	C_PS_T_R134A(PS,T)	Vapor pressure from temperature	Bar
$Pr = f(p,t,x)$	Pr_ptx_R134a	PR_PTX_R134A(P,T,X)	C_PR_PTX_R134A(PR,P,T,X)	*Prandtl*-Number	-
$\rho = f(p,t,x)$	rho_ptx_R134a	RHO_PTX_R134A(P,T,X)	C_RHO_PTX_R134A(RHO,P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_R134a	S_PTX_R134A(P,T,X)	C_S_PTX_R134A(S,P,T,X)	Specific entropy	kJ/(kg K)
$\sigma = f(t)$	sigma_t_R134a	SIGMA_T_R134A(T)	C_SIGMA_T_R134A(SIGMA,T)	Surface tension	N/m
$t = f(p,h)$	t_ph_R134a	T_PH_R134A(P,H)	C_T_PH_R134A(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_R134a	T_PS_R134A(P,S)	C_T_PS_R134A(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_R134a	TS_P_R134A(P)	C_TS_P_R134A(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_R134a	U_PTX_R134A(P,T,X)	C_U_PTX_R134A(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_R134a	V_PTX_R134A(P,T,X)	C_V_PTX_R134A(V,P,T,X)	Specific volume	m^3/kg
$w = f(p,t,x)$	w_ptx_R134a	W_PTX_R134A(P,T,X)	C_W_PTX_R134A(W,P,T,X)	Isentropic speed of sound	m/s^2
$x = f(p,h)$	x_ph_R134a	X_PH_R134A(P,H)	C_X_PH_R134A(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	x_ps_R134a	X_PS_R134A(P,S)	C_X_PS_R134A(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg

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

Range of validity

Temperature range: from $t(p, \rho_{max})$ to 181.85 °C

Pressure range: from p_t = 0.000389564 bar to 700 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 –1000.

Wet steam region: Temperature ranges from t_t = –103.30 °C to t_c = 101.03 °C

Pressure ranges from p_t = 0. 000389564 bar to p_c = 40.566 bar

Hint:

If the calculation results in –1000, the values entered represent a state point beyond the range of validity of LibR134a. For further information on each function and its range of validity see Chapter 3. The same information may also be accessed via the online help pages.

2 Application of FluidLAB in MATLAB®

The FluidLAB Add-In has been developed to calculate thermodynamic properties in MATLAB® more conveniently. Within MATLAB® it enables the direct call of functions relating to R134a from the LibR134a property library.

2.1 Installing FluidLAB

Installing FluidLAB including LibR134a for 32-bit MATLAB®

This section describes the installation of FluidLAB LibR134a for a 32-bit version of MATLAB®.

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

After you have downloaded and extracted the zip-file "CD_FluidLAB_LibR134a.zip", you will see the folder

CD_FluidLAB_LibR134a

in your Windows Explorer®, Norton Commander® or another similar program you are using.

Open this folder by double-clicking on it.

In this folder you will see the following files:

FluidLAB_LibR134a_Docu_Eng.pdf
FluidLAB_LibR134a_Setup.exe
LibR134a.dll.

In order to run the installation of FluidLAB including, the LibR134a property library, double-click on the file

FluidLAB_LibR134a_Setup.exe.

Installation may start with a window noting that all Windows® programs should be closed. When this is the case, the installation can be continued. Click the "Next >" button.

In the following dialog box, "Destination Location", the default path offered automatically for the installation of FluidLAB is

C:\Program Files\FluidLAB\LibR134a (for English version of Windows)
C:\Programme\FluidLAB\LibR134a (for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.1).

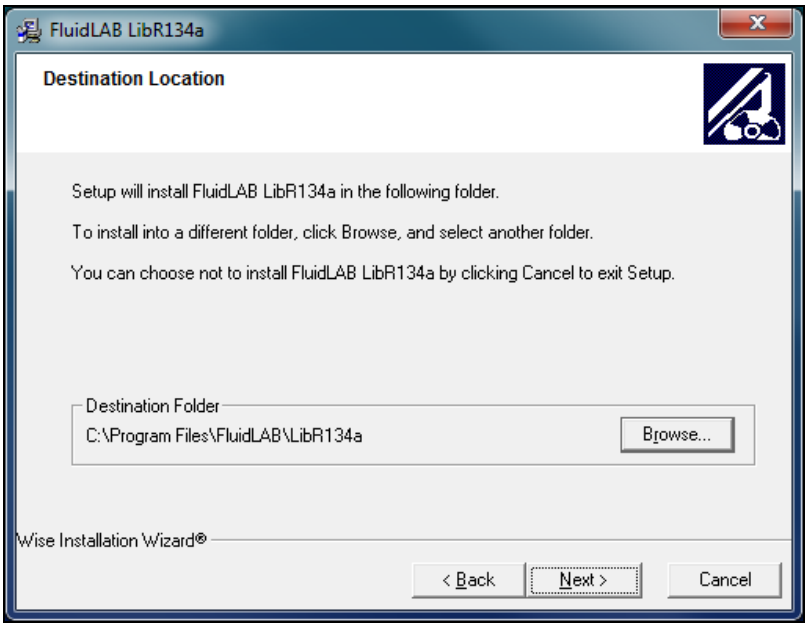

Figure 2.1: "Destination Location"

If you wish to change directories, click the "Browse…" button and select your desired directory. The instructions in this documentation refer to the stated default directory. Leave this window by clicking the "Next >" button.

The dialog window "Start Installation" pops up. Click the "Next >" button to continue installation. The FluidLAB files are now being copied into the created directory on your hard drive. Click the "Finish >" button in the following window to complete installation.

The installation program has copied the following files for LibR134a into the directory:

C:\Program Files\FluidLAB\LibR134a (for English version of Windows)
C:\Programme\FluidLAB\LibR134a (for German version of Windows)):

advapi32.dll	LC.dll
Dformd.dll	msvcp60.dll
Dforrt.dll	msvcrt.dll
INSTALL.LOG	Unwise.exe
LibR134a.dll	Unwise.ini

Now, you have to overwrite the file "LibR134a.dll" in your FluidLAB directory with the file of the same name provided on your CD with FluidLAB.

To do this, open the CD in "My Computer" and click on the file "LibR134a.dll" in order to highlight it.

Then click on the "Edit" menu in your Explorer and select "Copy".

Now, open your FluidLAB directory (the standard being

C:\Program Files\FluidLAB\LibR134a (for English version of Windows)
C:\Programme\FluidLAB\LibR134a (for German version of Windows))

and insert the file "LibR134a.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button. Now, you have overwritten the file "LibR134a.dll" successfully and the property functions are available in MATLAB.

Installing FluidLAB including LibR134a for 64-bit MATLAB®

This section describes the installation of FluidLAB LibR134a.

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

After you have downloaded and extracted the zip-file "CD_FluidLAB_LibR134a_x64.zip", you will see the folder

CD_FluidLAB_LibR134a

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

Open this folder by double-clicking on it.

In this folder you will see the following files

FluidLAB_LibR134a_Docu_Eng.pdf
FluidLAB_LibR134a_64_Setup.msi
LibR134a.dll
Setup.exe

and folders

/vcredist_x64
/WindowsInstaller3_1.

In order to run the installation of FluidLAB including, the LibR134a property library, double-click on the file

Setup.exe.

Installation of FluidLAB LibR134a starts with a window noting that the installer will guide you through the installation process. Click the "Next >" button to continue.

In the following dialog box, "Destination Location", the default path offered automatically for the installation of FluidLAB is

C:\Program Files\FluidLAB\LibR134a (for English version of Windows)
C:\Programme\FluidLAB\LibR134a (for German version of Windows)

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.2).

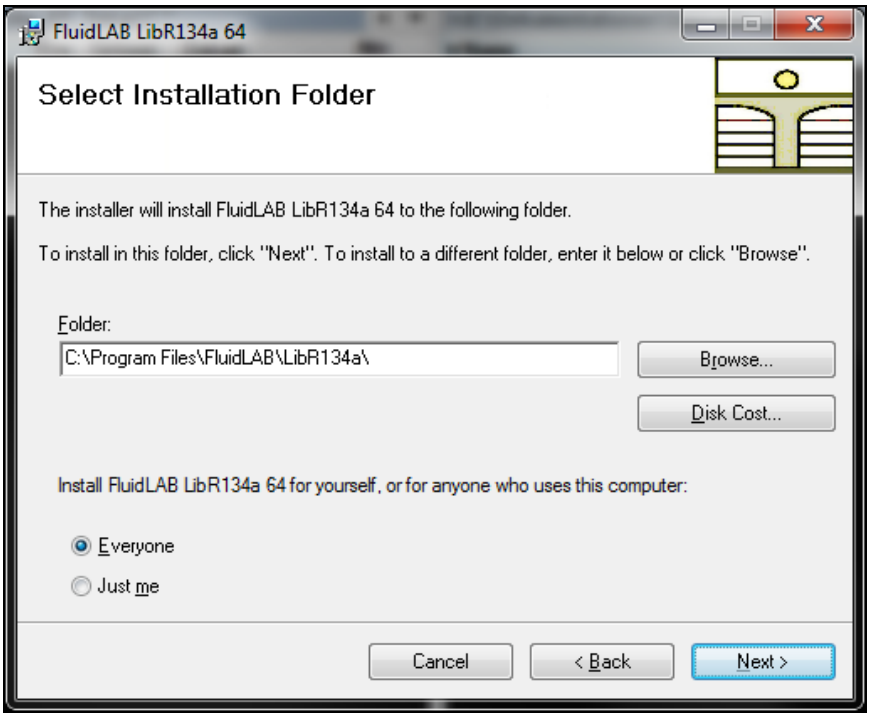

Figure 2.2: "Select Installation Folder"

Finally, click on "Next >" to continue installation; click "Next >" again in the "Confirm Installation" window which follows in order to start the installation of FluidLAB.

After FluidLAB has been installed, you will see the sentence "FluidLAB LibR134a 64 has been successfully installed." Confirm this by clicking the "Close" button.

The installation program has copied the following files for LibR134a into the directory

"C:\Program Files\FluidLAB\LibR134a" (for English version of Windows)
"C:\Programme\FluidLAB\LibR134a" (for German version of Windows):

capt_ico_big.ico	libifcoremd.dll
LC.dll	libiomp5md.dll
LibR134a.dll	libmmd.dll

Now, you have to overwrite the file "LibR134a.dll" in your FluidLAB directory with the file of the same name provided on your CD with FluidLAB.
To do this, open the CD in "My Computer" and click on the file "LibR134a.dll" in order to highlight it. Then click on the "Edit" menu in your Explorer and select "Copy".
Now, open your FluidLAB directory (the standard being

"C:\Program Files\FluidLAB\LibR134a" (for English version of Windows)
"C:\Programme\FluidLAB\LibR134a" (for German version of Windows))

and insert the file "LibR134a.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button.
Now, you have overwritten the file "LibR134a.dll" successfully and the property functions are available in MATLAB.

The installation programs for both the 32-bit and the 64-bit Windows version have copied the following function files for LibR134a into the directory

"C:\Program Files\FluidLAB\LibR134a" (for English version of Windows)
"C:\Programme\FluidLAB\LibR134a" (for German version of Windows):

- Dynamic Link Library "LibR134a.dll" and other necessary system DLL files.

- MATLAB®-Interface-Program for calculable functions

a_ptx_R134a	rho_ptx_R134a
cp_ptx_R134a	s_ptx_R134a
cv_ptx_R134a	t_ph_R134a
eta_ptx_R134a	t_ps_R134a
h_ptx_R134a	ts_p_R134a
kappa_ptx_R134a	u_ptx_R134a
lambda_ptx_R134a	v_ptx_R134a
ny_ptx_R134a	w_ptx_R134a
Pr_ptx_R134a	x_ph_R134a
ps_t_R134a	x_ps_R134a

Please note that there is a difference in the file extension of the function files.

The 32-bit installation program has copied function files with the file extension

.mexw32

and the 64-bit installation program has copied function files with the file extension

.mexw64

into your LibR134a directory (the standard being

"C:\Program Files\FluidLAB\LibR134a" (for English version of Windows)
"C:\Programme\FluidLAB\LibR134a" (for German version of Windows)).

2.2 Licensing the LibR134a Property Library

The licensing procedure must be carried out when the prompt message appears. In this case, you will see the "License Information" window for LibR134a (see figure below).

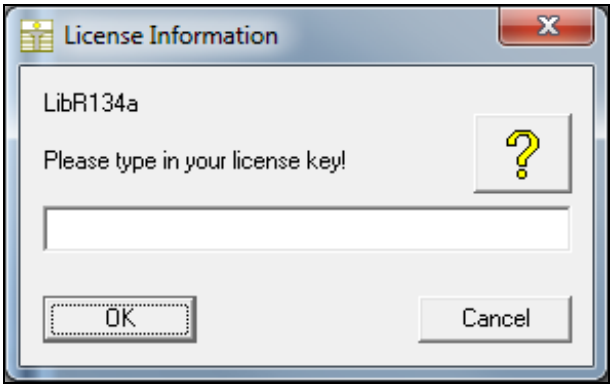

Figure 2.3: "License Information" window

Here you are asked to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. If you do not have this, or have any questions, you will 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:

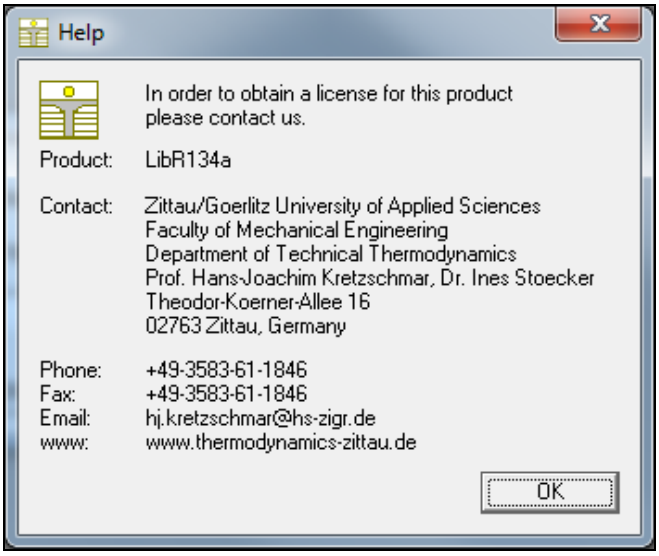

Figure 2.4: "Help" window

If you do not enter a valid license it is still possible to use MATLAB® by clicking "Cancel". In this case, the LibR134a property library will display the result "–11111111" for every calculation.

The "License Information" window will appear every time you use FluidLAB LibR134a until you enter a license code to complete registration. If you decide not to use FluidLAB LibR134a, you can uninstall the program following the instructions given in section 2.5 of this User's Guide.

2.3 Example: Calculation of *h* = f(*p*,*t*,*x*) in an M-File

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

Please carry out the following instructions:

- Start Windows Explorer®, Total Commander®, My Computer or another file manager program. The following description refers to Windows Explorer®.
- Your Windows Explorer® should be set to "Details" for easier viewing. Click the "Views" button and select "Details."
- Switch into the program directory of FluidLAB, in which you will find the folder "\LibR134a"; it is generally saved under: "C:\Program Files\FluidLAB"
- Create the folder "\LibR134a_Example" by clicking on "File" in the Explorer® menu, then "New" in the menu which appears and afterwards selecting "Folder". Name the new folder "\LibR134a_Example."
- You will now see the following window:

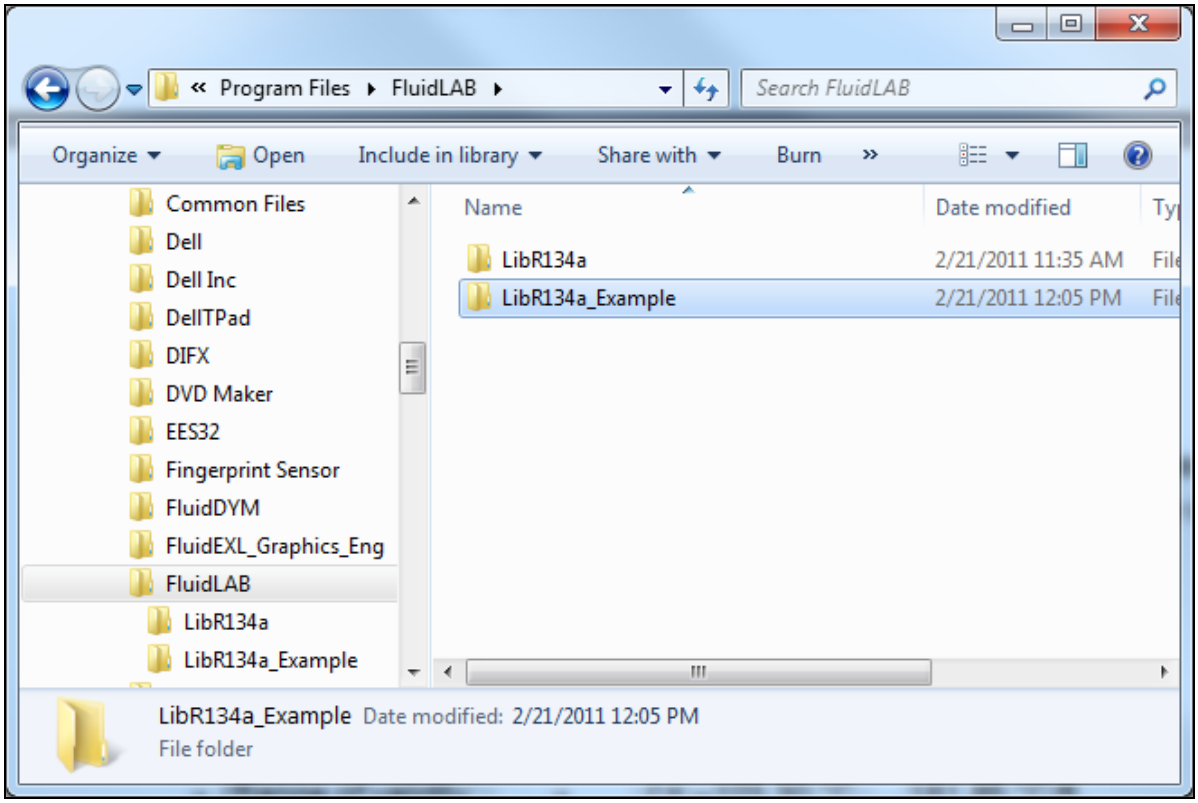

Figure 2.5: Folders "LibR134a" and "LibR134a_Example"

- Switch into the directory "\LibR134a" within "\FluidLAB", the standard being

  "C:\Program Files\FluidLAB\LibR134a" (for English version of Windows)
  "C:\Programme\FluidLAB\LibR134a" (for German version of Windows))."

- You will see the following window:

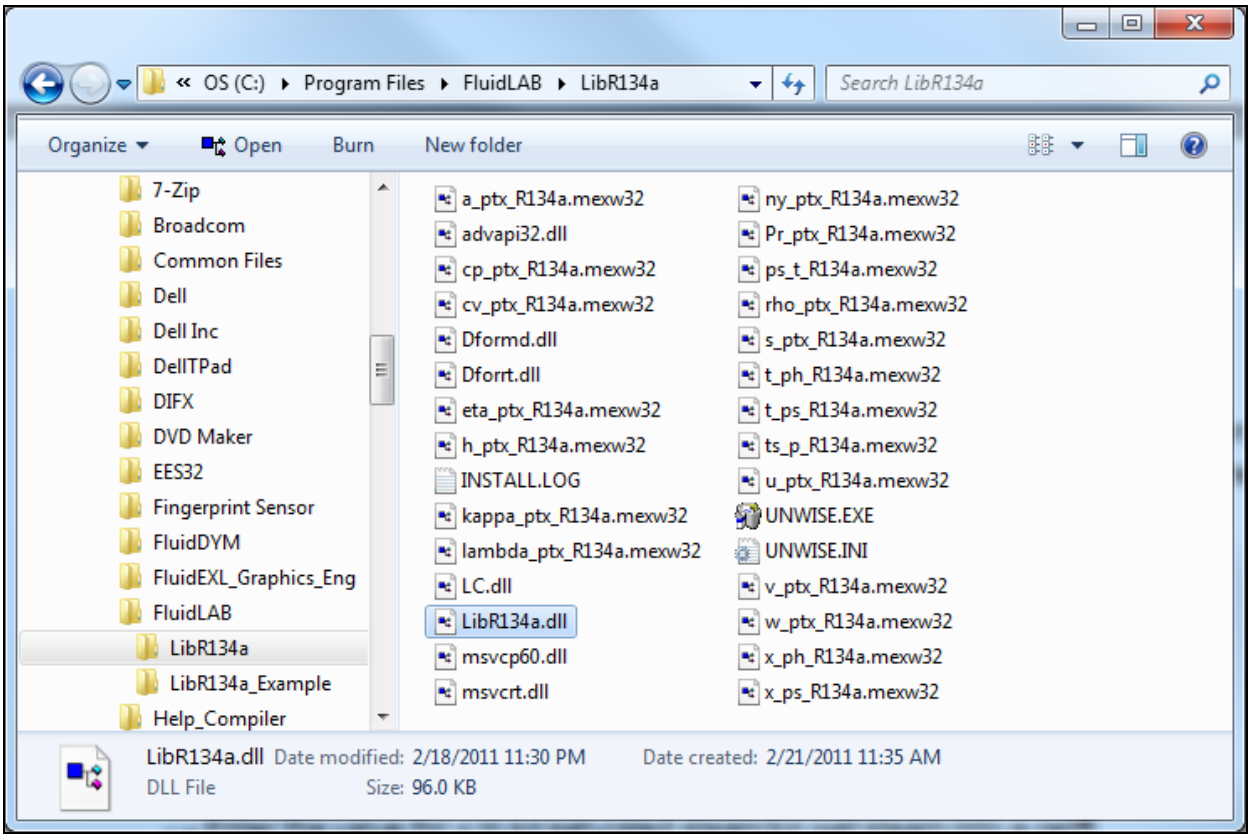

Figure 2.6: Contents of the folder "LibR134a"

If you have installed the 32-bit version of LibR134a you will now have to copy the following files into the directory

"C:\Program Files\FluidLAB\LibR134a_Example" (for English version of Windows)
"C:\Programme\FluidLAB\LibR134a_Example" (for German version of Windows)

in order to calculate the function $h = f(p,t,x)$.

- The following files are needed:
  - "h_ptx_R134a.mexw32"
  - "LibR134a.dll"
  - "libifcoremdd.dll"
  - "libmmd.dll"
  - "libmmdd.dll"
  - "msvcr71d.dll"
  - "dforrt.dll.dll"
  - "msvcrt.dll"
- Click the file "h_ptx_R134a.mexw32", then click "Edit" in the upper menu bar and select "Copy".
- Switch into the directory

  "C:\Program Files\FluidLAB\LibR134a_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibR134a_Example" (for German version of Windows),

click "Edit" and select "Paste".

- Repeat these steps in order to copy the other files listed above.

You may also select all the above-named files and then copy them as a group (press the Control button to enable multiple markings).

- You will see the following window:

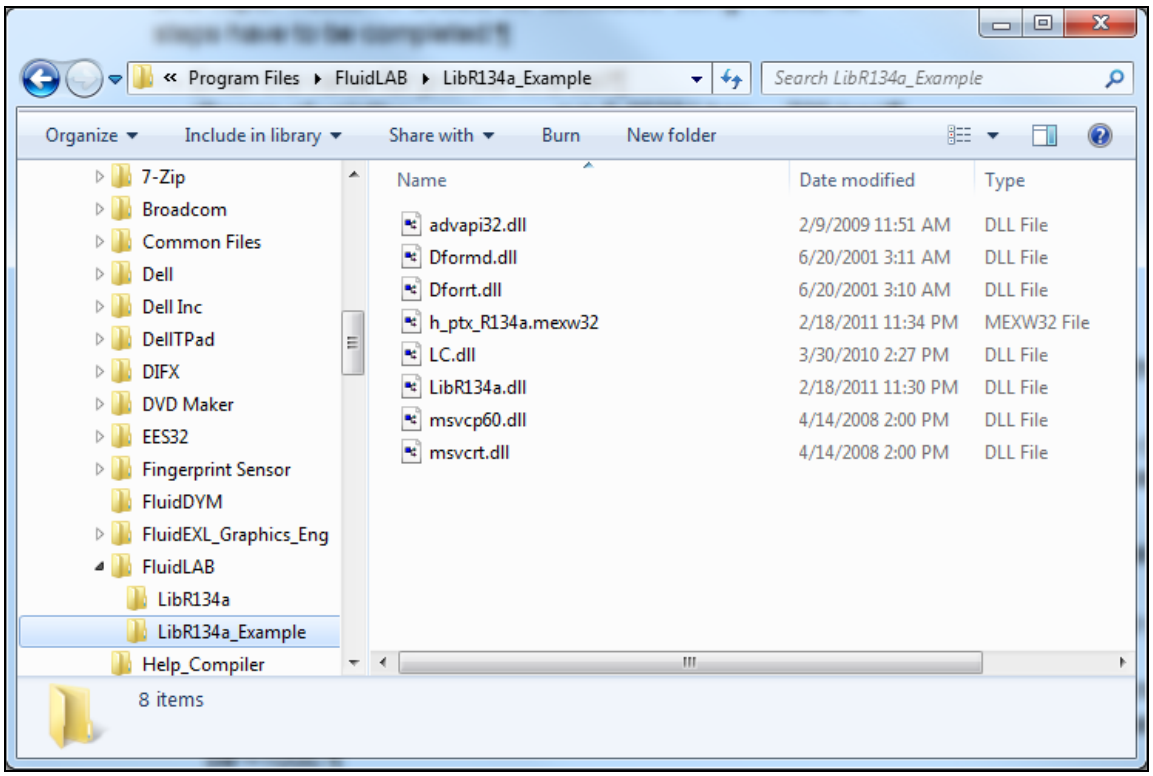

Figure 2.7: Contents of the folder "LibR134a_Example"

If you have installed the 64-bit version of LibR134a you will now have to copy the following files into the directory

"C:\Program Files\FluidLAB\LibR134a_Example" (for English version of Windows)

"C:\Programme\FluidLAB\LibR134a_Example" (for German version of Windows)

in order to calculate the function $h = f(p,t,x)$.

- The following six files are needed:
  - "h_ptx_R134a.mexw64"
  - "LC.dll"
  - "LibR134a.dll"
  - "libifcoremd.dll"
  - "libiomp5.dll"
  - "libmmd.dll."
- Click the file "h_ptx_R134a.mexw64", then click "Edit" in the upper menu bar and select "Copy."
- Switch into the directory

"C:\Program Files\FluidLAB\LibR134a_Example" (for English version of Windows)
"C:\Programme\FluidLAB\LibR134a_Example" (for German version of Windows),

click "Edit" and then "Paste."

- Repeat these steps in order to copy the other files listed above. You may also select all the above-named files and then copy them as a group (press the Control button to enable multiple markings).
- Now, start MATLAB (if you have not started it before).
- Click the button marked in the next figure in order to open the folder "\LibR134a_Example" in the "Current Folder" window.

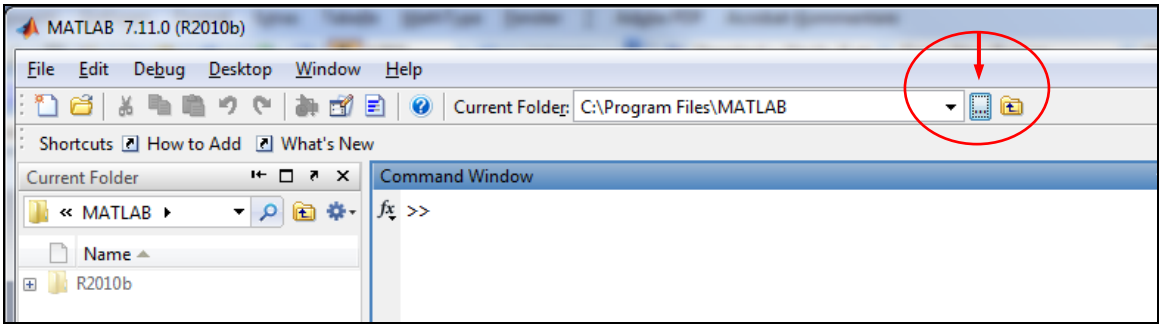

Figure 2.8: Selection of the working directory

- Find and select the directory "C:\Program Files\FluidLAB\LibR134a_Example" in the pop-up menu (see the following figure).

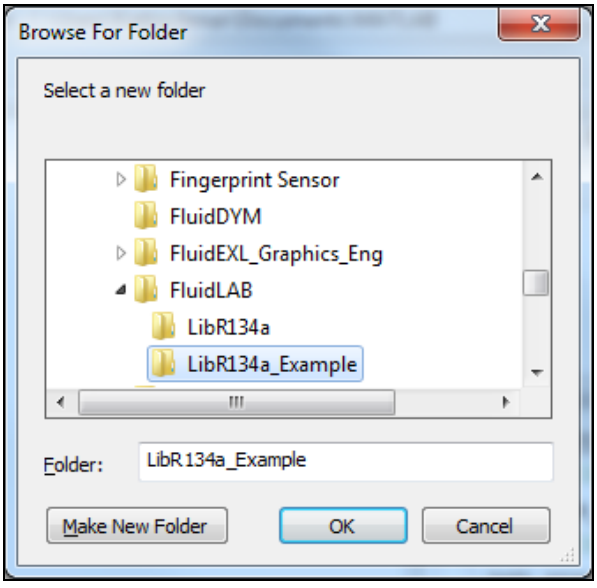

Figure 2.9: Choosing the "LibR134a_Example" folder

- Confirm your selection by clicking the "OK" button.
- First of all you need to create an M–File in MATLAB®. Within MATLAB® click "Desktop", then select "Editor". Now click on the "New Script" button in the Editor Window.
- If the "Editor" window appears as a separate window, you can embed it into MATLAB® by clicking the insertion arrow (see next figure) in order to obtain a better view.

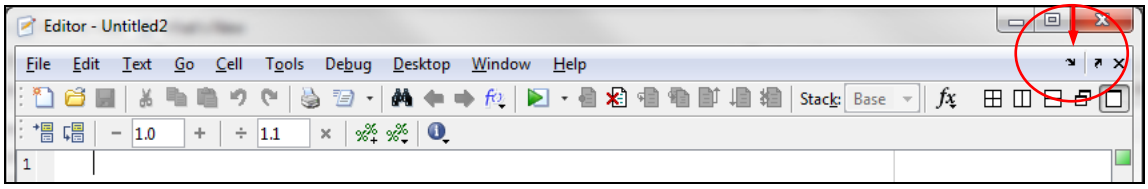

Figure 2.10: Embedding the "Editor" window

- In the following figure you will see the "Editor – Untitled" window.

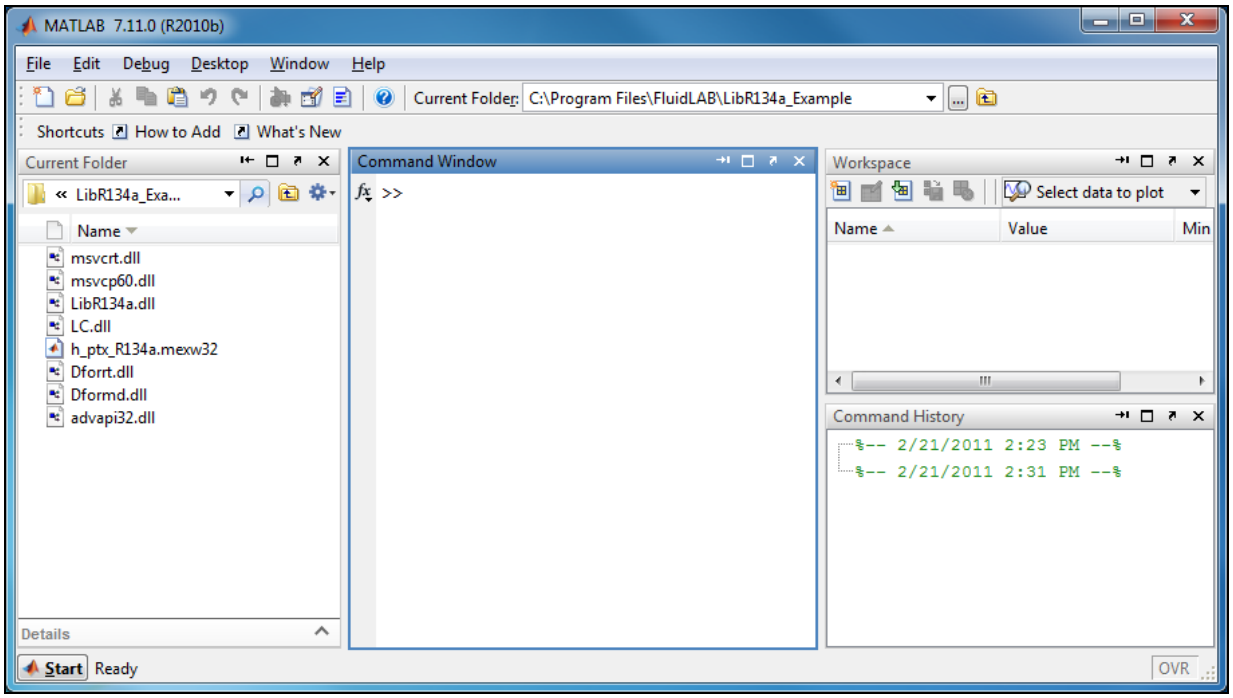

Figure 2.11: Embedded "Editor" window

- Now type the following lines in the "Editor - Untitled" window:

Text to be written:	Explanation:
`% h_ptx_R134a.m`	file name as comment
`%%`	paragraph separation
`p=10; % pressure in bar`	declaration of the variables pressure, temperature, art and composition of mixture
`t=25; % temperature in °C`	
`x=-1; % vapor fraction in kg/kg`	
`%%`	paragraph separation
`h=h_ptx_R134a(p,t,x)`	function call
`%%`	paragraph separation

- Remarks:

  - The program interprets the first line, starting with "%," to be a data description in "Current Directory."
  - Paragraph separations which are mandatory are marked with "%%". This also serves to separate the declaration of variables and calculation instructions.

- The words which are printed in green, start with "%" and come after the variables are comments. They are not in fact absolutely necessary, but they are very helpful for your overview and to make the process more easily understood.
- Omit the semicolons after the numerical values if you wish to see the result for *h* and the input parameters.

The values of the function parameters in their corresponding units stand for:

- First operand: Value for p = 10
  (Range of validity: p = 0.00391 bar ... 700 bar)
- Second operand: Value for t = 25 °C
  (Range of validity: t = –103.30 °C ... 181.85 °C)
- Third operand: Value for x = -1 kg/kg

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:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam), e. g., pressure *p* and temperature *t* are given, x = –1 must be entered as a pro-forma value.

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

When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000, plus 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 enthalpy calculated later will result in -1000.

(Vapor pressure curve of R134a: $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ ... t_c = 101.03 °C
p_t = 0.00389564 bar ... p_c = 40.566 bar)

- Save the "M-File" by clicking the "File" button and then click "Save As...".
- The menu "Save file as:" appears; In this menu, the folder name "LibR134a_Example" must be displayed in the "Save in:" field.
- Next to "File name" you have to type "Example_h_ptx_R134a.m" and afterwards click the "Save" button.

Note.
The name of the example file has to be different in comparison to the name of the used function. For example, the file could not be named "h_ptx_R134a.m" in this case. Otherwise an error message will appear during the calculation.

- You will now see the following window:

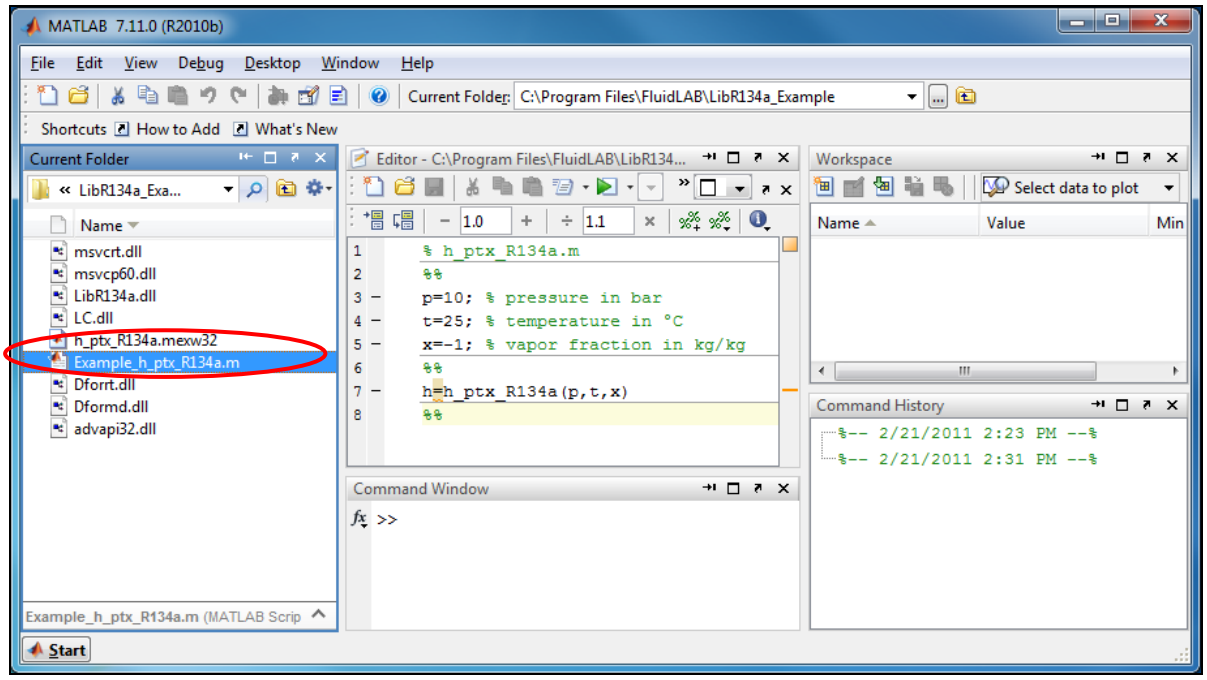

Figure 2.12: "Example_h_ptx_R134a.m" M-file

- Within the "Current Folder" window, the file "Example_h_ptx_R134a.m" appears.
- Right-click on this file and select "Run" in the menu which appears (see next figure).

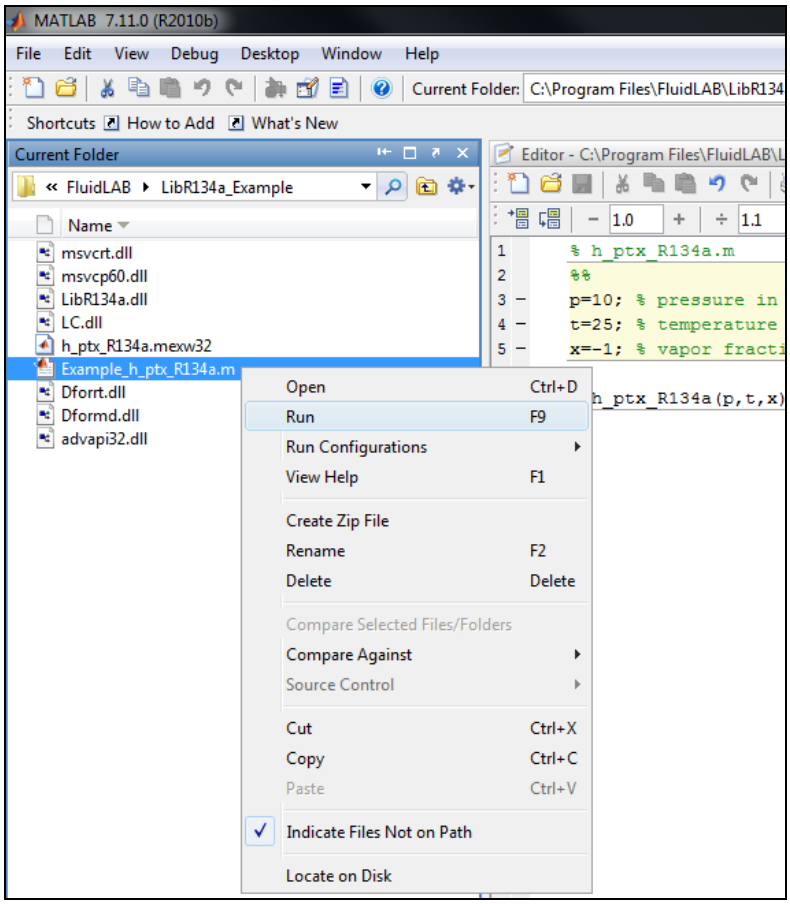

Figure 2.13: Running the "Example_h_ptx_R134a.m" M-file

- You will see the following window:

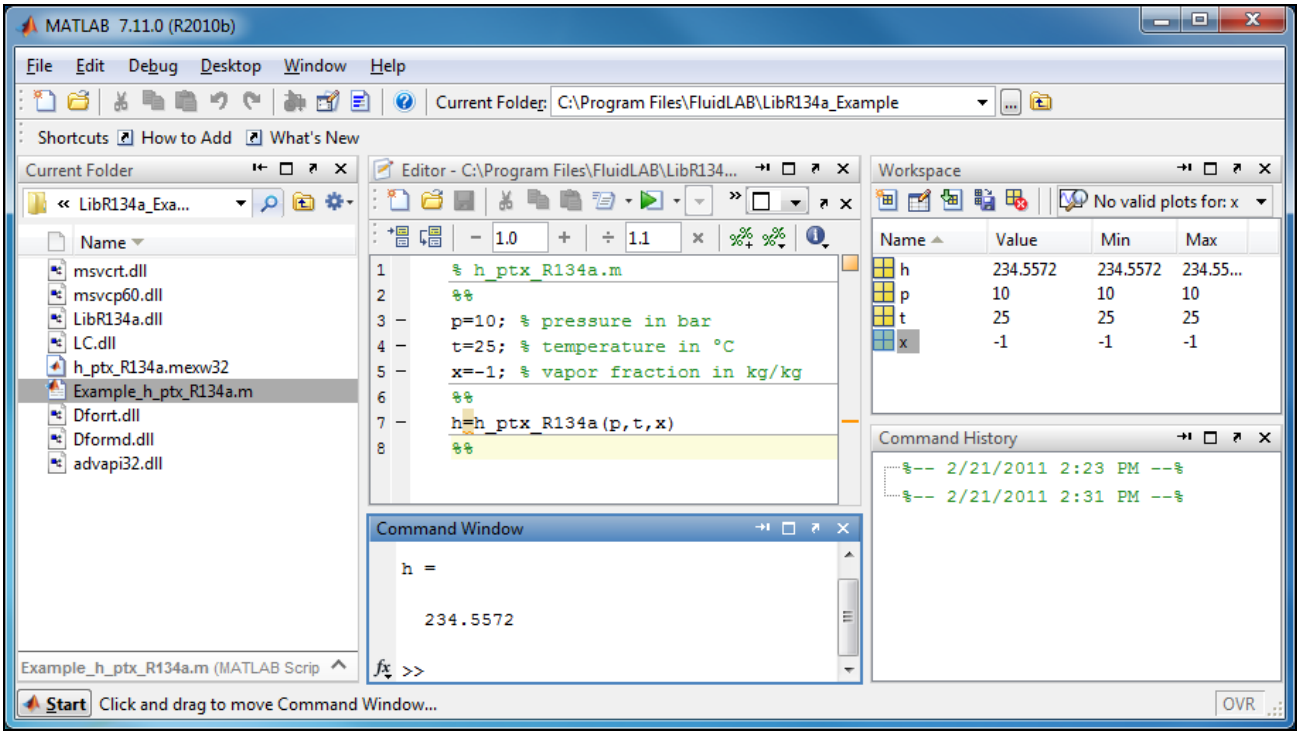

Figure 2.14: MATLAB® with calculated result

The result for *h* appears in the "Command Window".

⇒ The result in our sample calculation here is: "h = 234.5572". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

To be able to calculate other values, you have to copy the associated mexw32 files as well because MATLAB® can only access functions that are located in the "Current Directory" window. The example calculated can be found in the directory C:\Program Files\FluidLAB\LibR134a_Example," and you may use it as a basis for further calculations using FluidLAB.

2.4 Example: Calculation of *h* = f(*p*,*t*,*x*) in the Command Window

- Start MATLAB® (if you have not started it already).
- Click the button marked in the following image in order to open the folder "\LibR134a_Example" in the window "Current Folder."

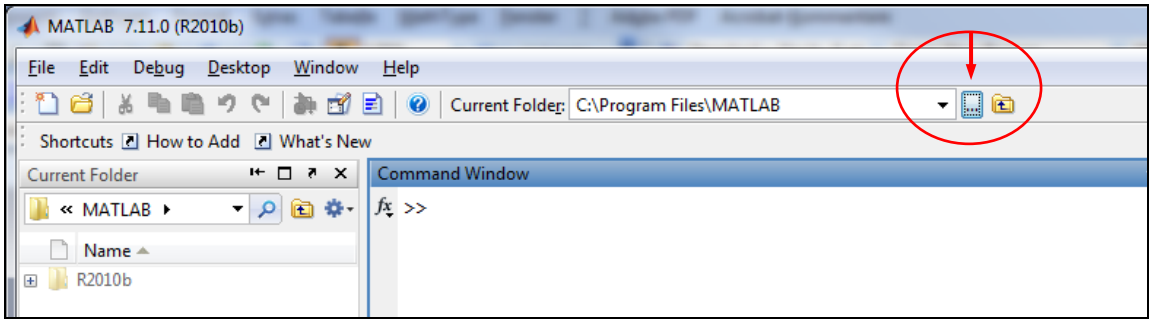

Figure 2.15: Selection of the working directory

- Find and select the directory
  "C:\Program Files\FluidLAB\LibR134a_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibR134a_Example" (for German version of Windows)
  in the menu which appears (see the following figure).

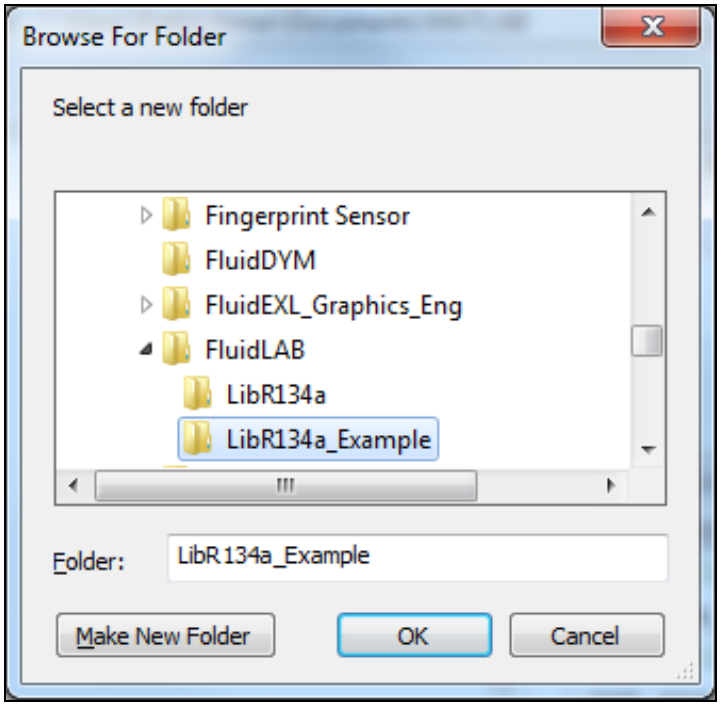

Figure 2.16: Choosing the "LibR134a_Example" folder

- Confirm your selection by clicking the "OK" button.
- You will see the following window:

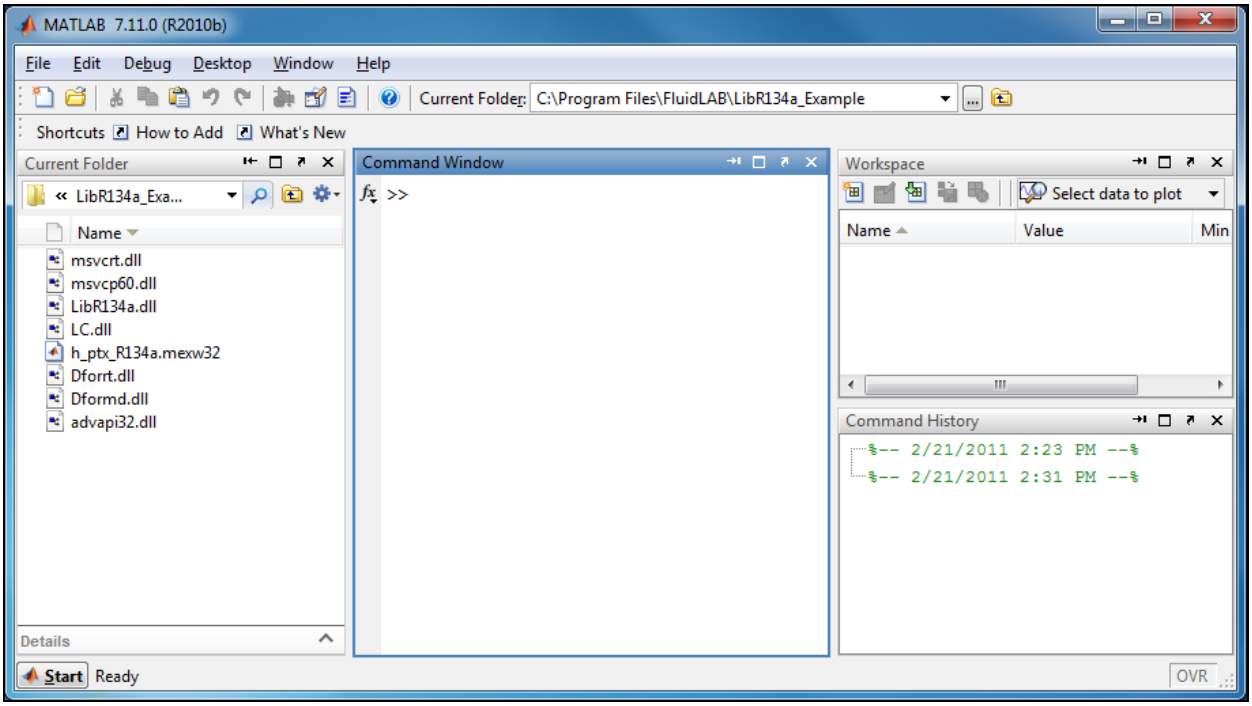

Figure 2.17: MATLAB® with necessary files

Corresponding to the table of the property functions in Chapter 1 you have to call up the function "**h_ptx_R134a**" as follows for calculating $h = f(p,t,x)$.

Write "**h=h_ptx_R134a(10,25,-1)**" within the "Command Window"

The values of the function parameters in their corresponding units stand for:

- First operand: Value for p = 10 bar
  (Range of validity: p = 0.00391 bar ... 700 bar)
- Second operand: Value for t = 25 °C
  (Range of validity: t = –103.30 °C ... 181.85 °C)
- Third operand: Value for x = -1

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:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam), e. g., pressure p and temperature t are given, x = –1 must be entered as a pro-forma value.

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

When calculating wet steam either the given value for t and p = -1000 or the given value for p and t = -1000, plus 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 enthalpy calculated later will result in -1000.

(Vapor pressure curve of R134a: $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ ... t_c = 101.03 °C
p_t = 0.00389564 bar ... p_c = 40.566 bar)

- Confirm your entry by pressing the "ENTER" button.
- You will see the following window:

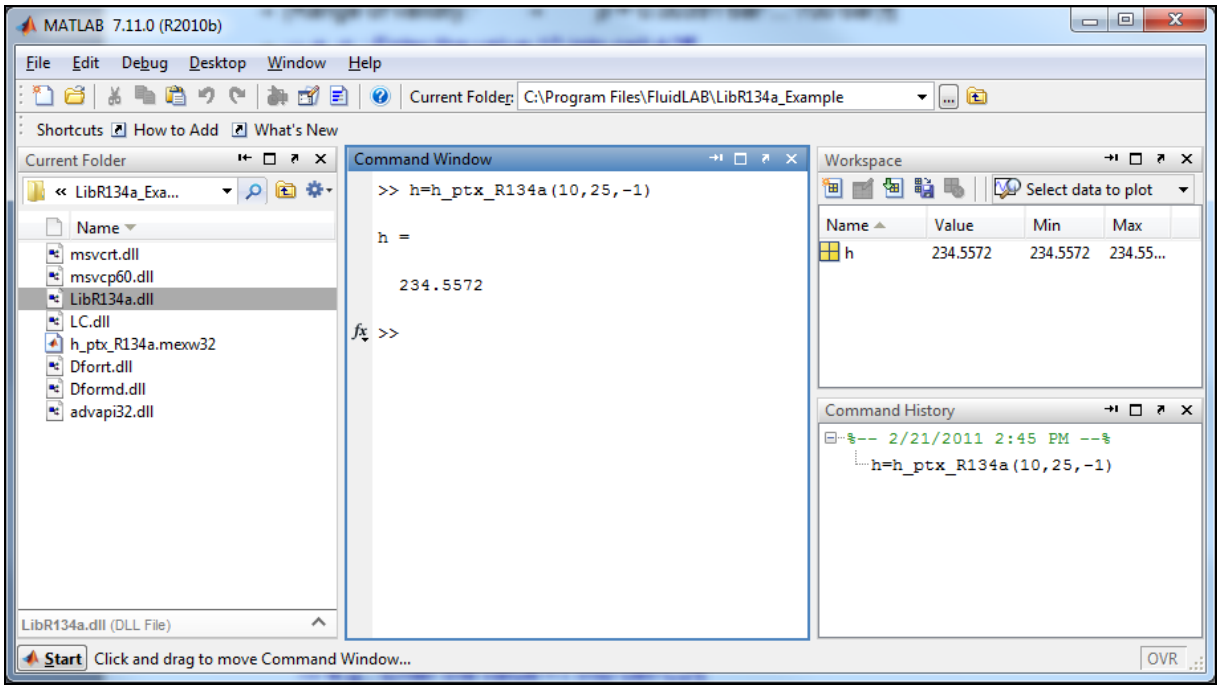

Figure 2.18: MATLAB® with calculated result

⇒ In the "Command Window" you will see the result "h = 234.5572". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

To be able to calculate other values, you will have to copy the respective mexw32 or mexw64 files into the working directory as well because MATLAB® can only access functions that are located in the "Current Directory" window.

2.4 Using FluidLAB with SIMULINK

To use the functions of FluidLAB with the simulation program SIMULINK you have to start SIMULINK in MATLAB® by clicking on Simulink in the upper menu bar shown in Figure 2.19.

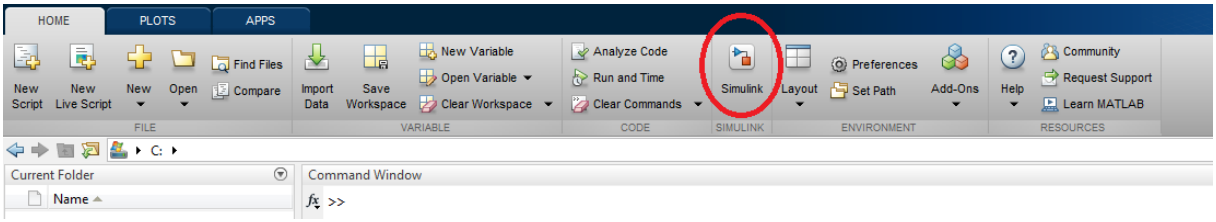

Figure 2.19: Starting Simulink

Then choose a blank model or a simulation in which you would like to use FluidLAB. Now you need to add a MATLAB function block that you can find in the library browser shown in Figure 2.20.

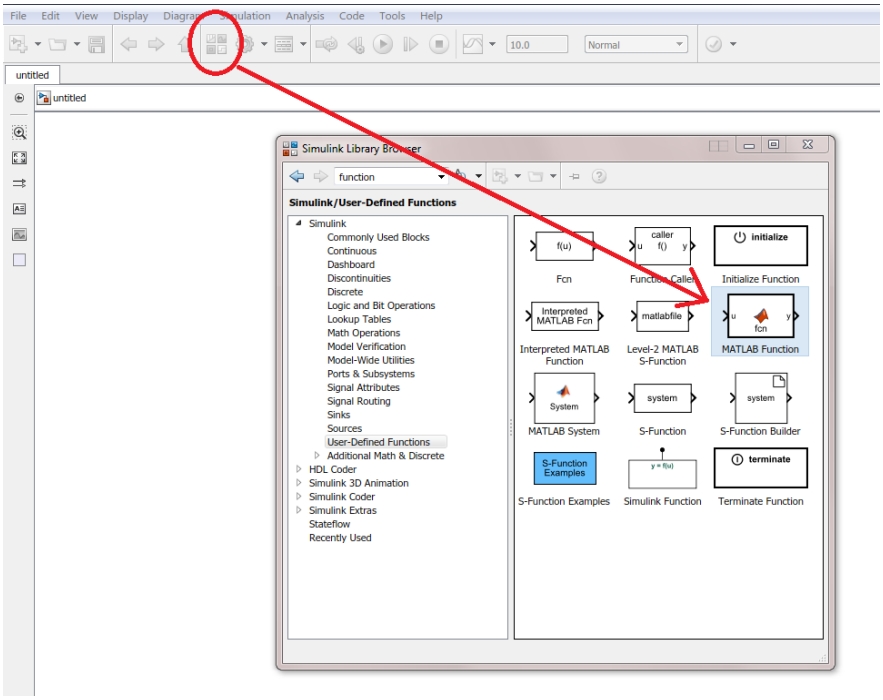

Figure 2.20: Simulink library browser and choosing a MATLAB Function

By dragging and dropping you can drag a Simulink block in your model. The function needs inputs and output that you can find in the Simulink library browser under sources and sinks. For this example constants were taken for the inputs and a display block were taken for outputting.

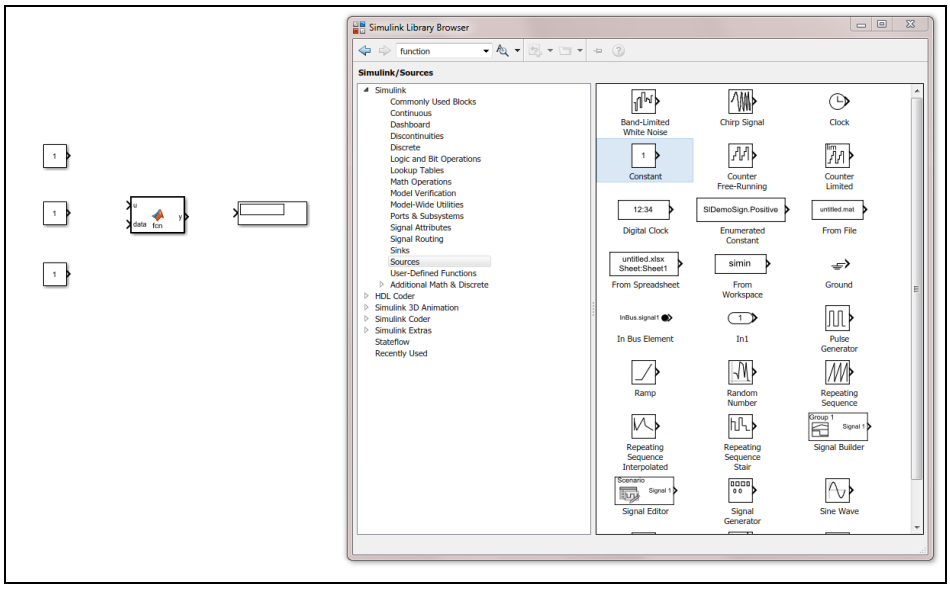

Figure 2.21: Inputs and outputs of the example

Now you have to link inputs and outputs to the MATLAB function block. By pressing and holding the left mouse button on the arrow of a block, you can draw a line and drag it to the MATLAB function block. With this method you can link all blocks together.

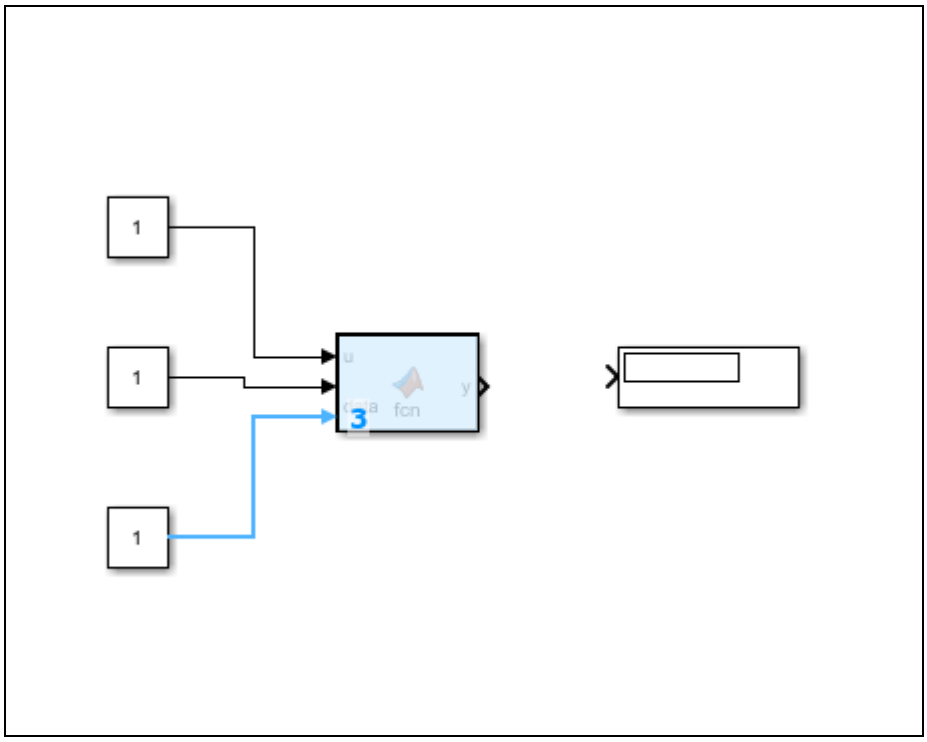

Figure 2.22: Linking blocks in Simulink

You can define the value of a constant block by double-click on them. If you want to calculate the example use the values you can find in section 2.2 and 2.3. With a double-click on the MATLAB function block you can define the function in MATLAB®. The following source code is for the example calculation and the table below describes the source code closer. You can adapt these few lines to call all other function of FluidLAB.

```
function h = fcn(p, t, x)
coder.extrinsic('addpath');
coder.extrinsic('h_ptx_R134a');
addpath('C:\Program Files\FluidLAB\LibR134A');
h = h_ptx_R134a(p,t,x);
```

Matlab source code	Explanation
`function h = fcn(p, t, x)`	function header, you can define the function name and the inputs like p, t and x of the example
`coder.extrinsic('addpath');`	necessary to add a path
`coder.extrinsic('h_ptx_R134a');`	Choose the function name of the FluidLAB function
`addpath('C:\Program Files\FluidLAB\LibR134A');`	Add the installation path of FluidLAB
`h = h_ptx_R134a(p,t,x);`	Linking the FluidLAB function to the MATLAB function block

You can copy and paste the sourcecode in MATLAB® or write it into the MATLAB® editor. The simulation will start by clicking the run button in Matlab or Simulink and you can see the example in the display block of the simulation which is shown in figure 2.23.

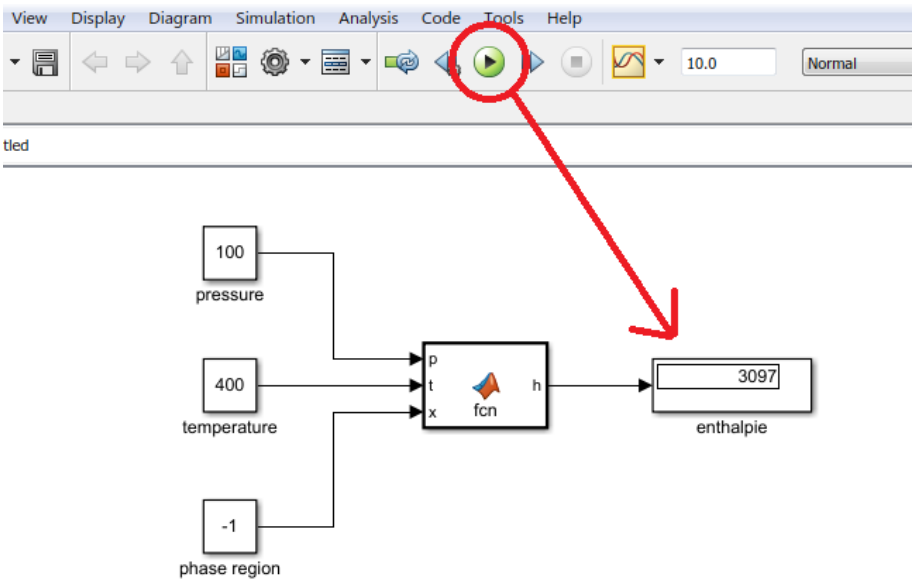

Figure 2.23: Starting the simulation and result of the calculation

Your result is may an other than shown in figure 2.23. If you want to calculate the example please use the values from section 2.2 and 2.3.

2.5 Removing FluidLAB including LibR134a

To remove the property library LibR134a from your hard disk drive in Windows®, click "Start" in the Windows® task bar, select "Settings" and click "Control Panel".

Now double-click on "Add or Remove Programs". In the list box of the "Add or Remove Programs" window that appears select "FluidLAB LibR134a" by clicking on it and click the "Change/Remove" button.

In the following dialog box click "Automatic" and then click the "Next >" button.

Confirm the following menu "Perform Uninstall" by clicking the "Finish" button.

Finally, close the "Add or Remove Programs" and "Control Panel" windows. Now, FluidLAB has been removed.

If there is no library other than LibR134a installed, the directory "FluidLAB" will be removed as well.

3. Program Documentation

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

Function Name:	**a_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION A_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_A_PTX_R134A(A,P,T,X)** REAL*8 A,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

A_PTX_R134A, A or **a_ptx_R134a** – Thermal diffusivity $a = \frac{\lambda * v}{c_p}$ in m² / s

Range of validity

Temperature range:	from - 73.15 °C to 176.85 °C
Pressure range:	from 0.00389564 bar to 700 bar
Density range:	from 0.00105455 kg /m^3 to 1550 kg / m^3

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* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *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 range	from $t = -73.15$ °C to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **A_PTX_R134A, A = -1000** or **a_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < -103.3$ °C or $\rho > 1550$ m^3 / kg
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < 73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < -103.3$ °C

References: [16], [23]

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

Function Name:	**cp_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION CP_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_CP_PTX_R134A(CP,P,T,X)** REAL*8 CP,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

CP_PTX_R134A, **CP** or **cp_ptx_R134a** – Specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 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 and p = -1000, or the given value for p and t = -1000, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **CP_PTX_R134A, CP = -1000**, or **cp_ptx_R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ kg/m^3$
Saturation lines:	at p = -1000 and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$
	at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and
	t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**cv_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION CV_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_CV_PTX_R134A(CV,P,T,X)** REAL*8 CV,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

CV_PTX_R134A, **CV** or **cv_ptx_R134a** – Specific isochoric heat capacity c_v in $kJ/(kg\,K)$

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 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* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to $t_c =$ 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **CV_PTX_R134A, CV = -1000** or **cv_ptx_R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564 bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$
	at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and
	t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

Dynamic Viscosity $\eta = f(p,t,x)$

Function Name:	**eta_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION ETA_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_ETA_PTX_R134A(ETA,P,T,X)** REAL*8 ETA,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

ETA_PTX_R134A, **ETA** or **eta_ptx_R134a** – Dynamic viscosity η in Pa s

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 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* and p = -1, or the given value for *p* and t = -1, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **ETA_PTX_R134A, ETA = -1000** or **eta_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 18185$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$
	at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and
	$t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16], [22]

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

Function Name:	**h_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION H_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_H_PTX_R134A(H,P,T,X)** REAL*8 H,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

H_PTX_R134A, **H** or **h_ptx_R134a** - Specific enthalpy *h* in kJ/kg

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

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

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

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

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

When calculating wet steam either the given value for *t* 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 it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **H_PTX_R134A, H = -1000** or **eta_ptx_R134a = -1000** for input values:

Single phase region: $(x = -1)$	p > 700 bar or p < 0.00389564 bar or $t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**kappa_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION KAP_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_KAP_PTX_R134A(KAP,P,T,X)** REAL*8 KAP,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

KAP_PTX_R134A, **KAP** or **kappa_ptx_R134a** – Isentropic exponent $\kappa = \frac{w^2}{p^*v}$

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 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* and p = -1000, or the given value for *p* and t = -1000, plus the value for x (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **KAP_PTX_R134A**, **KAP = -1000** or **kappa_ptx_R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564 bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$
	at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and
	t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

Thermal Conductivity $\lambda = f(p,t,x)$

Function Name:	**lambda_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION LAM_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_LAM_PTX_R134A(LAM,P,T,X)** REAL*8 LAM,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

LAM_PTX_R134A, **LAM** or **lambda_ptx_R134a** – Thermal conductivity λ in W / m K

Range of validity

Temperature range:	from - 73.15 °C to 176.85 °C
Pressure range:	from 0.00389564 bar to 700 bar
Density range:	from 0.00105455 kg /m^3 to 1550 kg / m^3

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* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t = -103.30$ °C to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **LAM_PTX_R134A, LAM = - 1000** or **lambda_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < -103.3$ °C or $\rho > 1550$ m^3 / kg
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < 73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < -103.30$ °C

References: [16], [23]

Kinematic Viscosity $\nu = f(p,t,x)$

Function Name:	**ny_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION NY_PTX_ R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_NY _PTX_ R134A(NY,P,T,X)** REAL*8 NY,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

NY_PTX_ R134A, **NY** or **ny_ptx_ R134a** – Kinematic viscosity $\nu = \eta * v$ in m² / s

Range of validity

Temperature range:	from - 73.15 °C to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar
Density range:	from 0.00105455 m^3 / kg to 1550 m^3 / kg

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* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t = -103.30$ °C to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **NY_PTX_ R134A, NY= -1000** or **ny_ptx_ R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < -103.3$ °C or $\rho > 1550$ m^3 / kg
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < 73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < -103.30$ °C

References: [16], [22]

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

Function Name:	**Pr_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION PR_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_PR _PTX_R134A(PR,P,T,X)** REAL*8 PR,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

PR_PTX_R134A, **PR** or **Pr_ptx_R134a** – Prandtl-Number $\mathrm{Pr} = \frac{\eta * c_p}{\lambda}$

Range of validity

Temperature range:	from - 73.15 °C to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar
Density range:	from 0.00105455 m^3 / kg to 1550 m^3 / kg

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* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from t = – 103.30 °C to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **PR_PTX_ R134A, PR= -1000** or **Pr_ptx_ R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564 bar or
$(x = -1)$	t > 181.85°C or t < –103.3 °C or ρ > 1550 m^3 / kg
Saturation lines:	at p = -1000 and t > 101.03 °C or t < -73.15°C at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or t < -103.30 °C

References: [16], [22], [23]

Vapor Pressure $p_s = f(t)$

Function Name:	**ps_t_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION PS_T_ R134A(T)** REAL*8 T
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_PS_T_ R134A(PS,T)** REAL*8 PS,T

Input Values:

T - Temperature *t* in °C

Result

PS_T_ R134A, **PS** or **ps_t_ R134a** – Vapor pressure p_S in bar

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 101.03 °C

Results for wrong input values

Result **PS_T_ R134A, PS = -1000** or **ps_t_ R134a = -1000** for input values:

t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**rho_ptx_ R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION RHO_PTX_ R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_RHO_PTX_ R134A(RHO,P,T,X)** REAL*8 RHO,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

RHO_PTX_R134A, **RHO** or **rho_ptx_R134a** – Density ρ in kg / m^3

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

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

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

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

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

When calculating wet steam either the given value for *t* 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 it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to $t_c =$ 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **RHO_PTX_R134a, RHO= -1000** or **rho_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < -73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

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

Function Name:	**s_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION S_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_S_PTX_R134A(S,P,T,X)** REAL*8 S,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

S_PTX_R134A, **S** or **s_ptx_R134a** - Specific entropy *s* in kJ/kg K

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar

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

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

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

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

When calculating wet steam either the given value for *t* 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 it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **S_PTX_R134A, S = -1000** or **s_ptx_R134a = -1000** for input values:

Single phase region:	*p* > 700 bar or *p* < 0.00389564 bar or
$(x = -1)$	*t* > 181.85°C or *t* < –73.15 °C or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at *p* = -1000 and *t* > 101.03 °C or *t* < -73.15°C at *t* = -1000 and *p* > 40.566 bar or *p* < 0.00389564 bar or at *p* > 40.566 bar or *p* < 0.00389564 bar and *t* > 101.03 °C or *t* < $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

Surface Tension $\sigma = f(t)$

Function Name:	**sigma_t_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION SIGMA_T_R134A(T)** REAL*8 T
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_SIGMA_T_R134A(SIGMA,T)** REAL*8 SIGMA,T

Input Values:

T - Temperature *t* in °C

Result

SIGMA_T_R134A, **SIGMA** or **sigma_t_R134a** – Surface tension σ in N/m

Range of validity

Temperature range: from - 103.30 °C to 181.85 °C

Results for wrong input values

Result **SIGMA_T_R134A, SIGMA= -1000** or **sigma_t_R134a = -1000** for input values:

References: [16], [22]

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

Function Name:	**t_ph_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION T_PH_R134A(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_T _PH_R134A(T,P,H)** REAL*8 T,P,H

Input Values:

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

T_PH_R134A, **T** or **t_ph_R134a** - Temperature *t* in °C

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **T_PH_R134A**, **T = -1000** or **t_ph_R134a = -1000** for input values:

Single phase region:	*p* > 700 bar or *p* < 0.00389564 bar or
$(x = -1)$	$t > 18185$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at *p* > 70.54 bar or *p* < 0.00389564 bar or
	t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

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

Function Name:	**t_ps_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION T_PS_R134A(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_T_PS_R134A(T,P,S)** REAL*8 T,P,S

Input Values:

P - Pressure *p* in bar

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

Result

T_PS_R134A, **T** or **t_ps_R134a** - Temperature *t* in °C

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **T_PS_R134A**, **T = -1000** or **t_ps_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 18185$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at $p > 70.54$ bar or $p < 0.00389564$ bar or
	$t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

Saturation Temperature $t_s = f(p)$

Function Name:	**ts_p_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION TS_P_R134A(P)** REAL*8 P
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_TS_P_R134A(TS,P)** REAL*8 TS,P

Input Values:

P - Pressure *p* in bar

Result

TS_P_R134A, **TS** or **ts_p_R134a** – Saturation temperature t_s in °C

Range of validity

Pressure range: from 0.00389564 bar to 40.566 bar

Results for wrong input values

Result **TS_P_R134A**, **TS = -1000** or **ts_p_R134a = -1000** for input values:

$p < 0.00389564$ bar or $p > 40.566$ bar

References: [16]

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

Function Name:	**u_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION U_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_U_PTX_R134A(U,P,T,X)** REAL*8 U,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

U_PTX_R134A, **U** or **u_ptx_R134a** - Specific internal energy *u* in kJ/kg

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar

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

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

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

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

When calculating wet steam either the given value for *t* 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 it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **U_PTX_R134A, U = -1000** or **u_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at *p* = -1000 and *t* > 101.03 °C or *t* < -73.15°C at *t* = -1000 and *p* > 40.566 bar or *p* < 0.00389564 bar or at *p* > 40.566 bar or *p* < 0.00389564 bar and *t* > 101.03 °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

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

Function Name:	**v_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION V_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_V_PTX_R134A(V,P,T,X)** REAL*8 V,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

V_PTX_R134A, **V** or **v_ptx_R134a** – Specific volume v in m^3 / kg

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar

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

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

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

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

When calculating wet steam either the given value for t 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 it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **V_PTX_R134A, V = -1000** or **v_ptx_R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564 bar or
$(x = -1)$	t > 181.85°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or ρ > 1550 m^3 / kg
Saturation lines:	at p = -1000 and t > 101.03 °C or t < -73.15°C at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**w_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION W_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_W_PTX_R134A(W,P,T,X)** REAL*8 W,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

W_PTX_R134A, **W** or **w_ptx_R134a** - Speed of sound *w* in m/s

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 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* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *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 range	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **W_PTX_R134A, W = -1000** or **w_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < -73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

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

Function Name:	**x_ph_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION X_PH_R134A(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_X_PH_R134A(T,P,H)** REAL*8 X,P,H

Input Values:

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

X_PH_R134A, **X** or **x_ph_R134a** - Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **X_PH_R134A**, **X = -1** or **x_ph_R134a = -1** for input values:

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

$p <$ 40.566 bar or $p >$ 0.00389564 bar

References: [16]

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

Function Name:	**x_ps_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION X_PS_R134A(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_X_PS_R134A(X,P,S)** REAL*8 X,P,S

Input Values:

P - Pressure *p* in bar

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

Result

X_PS_R134A, **X** or **x_ps_R134a** - Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 101.03 °C
Pressure range:	from 0.00389564 bar to 700 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 $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **X_PS_R134A**, **X = -1** or **x_ps_R134a = -1** for input values:

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

$p <$ 40.566 bar or $p >$ 0.00389564 bar

References: [16]

KCE

KCE-ThermoFluidProperties
www.thermofluidprop.com

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

Water and Steam

Library LibIF97

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

Library LibSBTL_IF97
Library LibSBTL_95

Extremely fast property calculations according to the IAPWS Guideline 2015
Spline-based Table Look-up Method (SBTL)
applied to the Industrial Formulation IAPWS-IF97 and to the Scientific Formulation IAPWS-95
for Computational Fluid Dynamics and simulating non-stationary processes

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

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 (2012)

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)

For more information please contact:

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Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-4262250

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

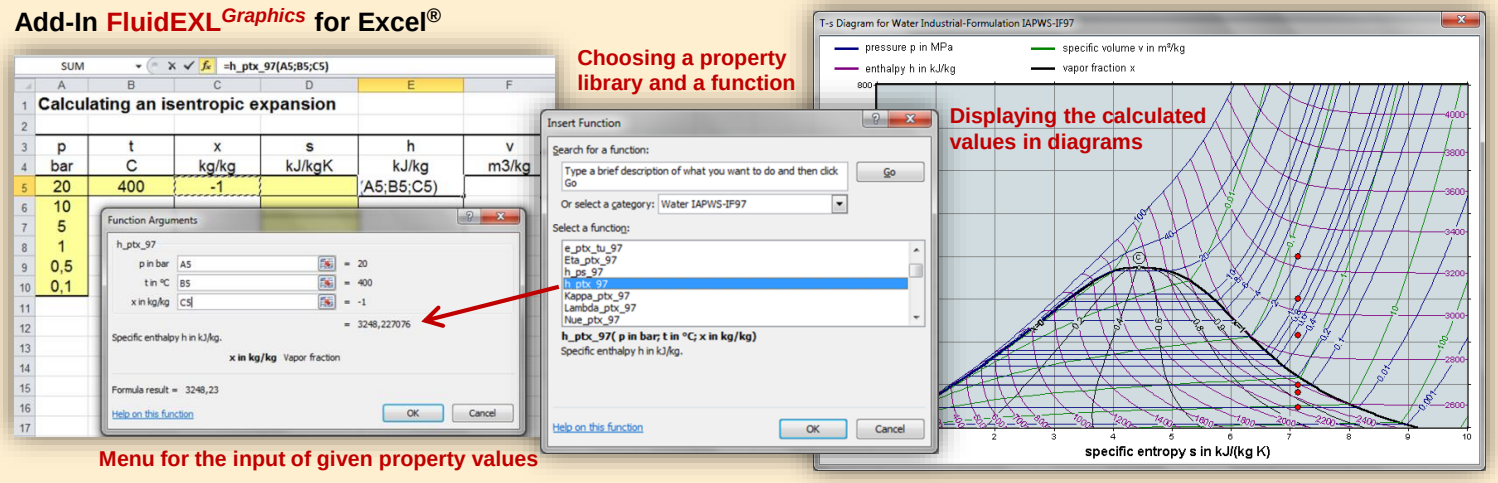
[a] Not all of these property functions are available in all property libraries.

KCE

KCE-ThermoFluidProperties
www.thermofluidprop.com

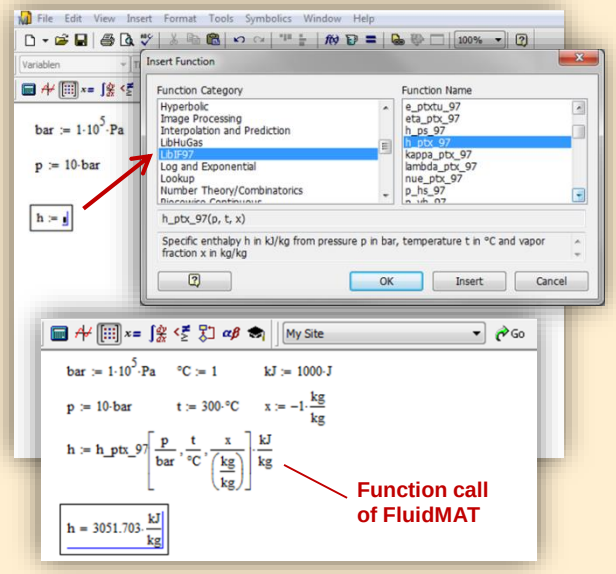
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



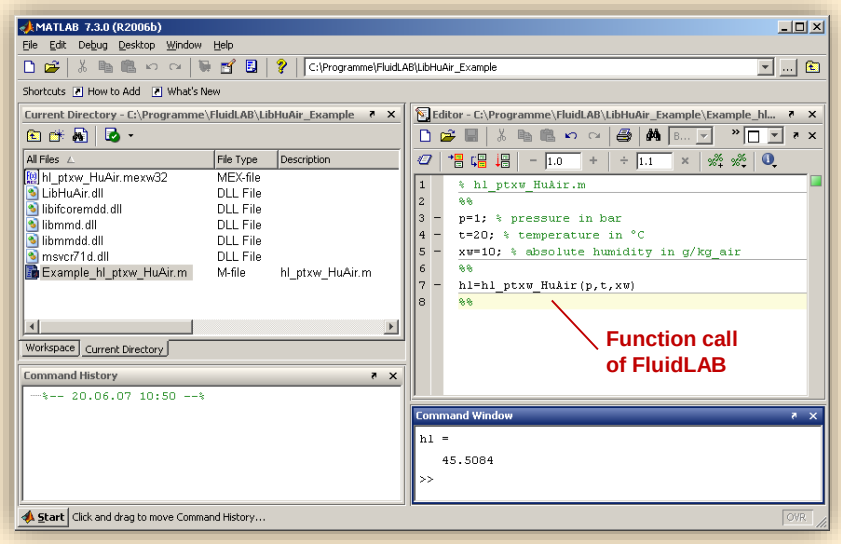
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



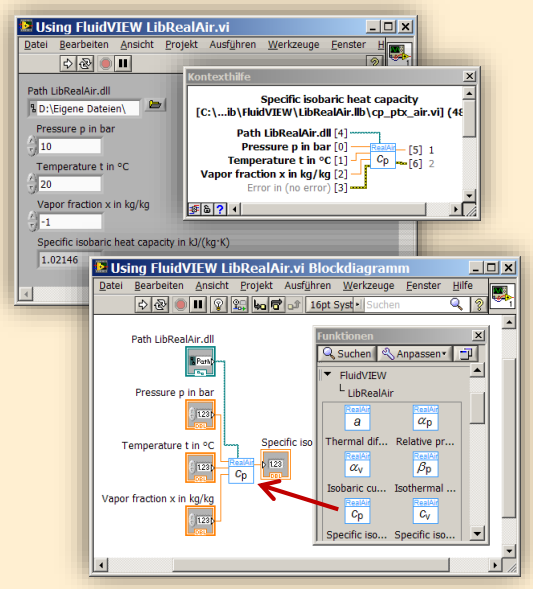
Add-In FluidLAB for MATLAB®

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



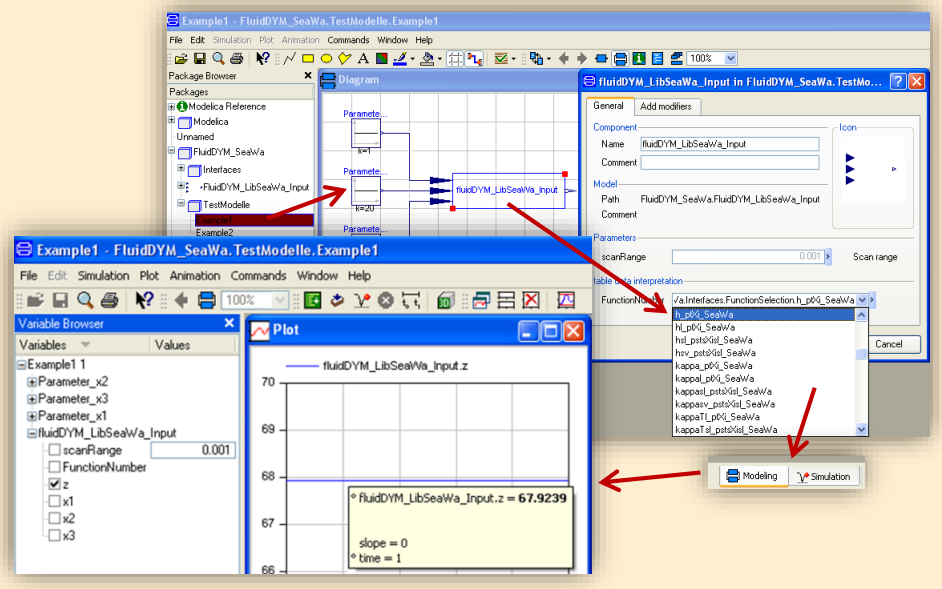
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

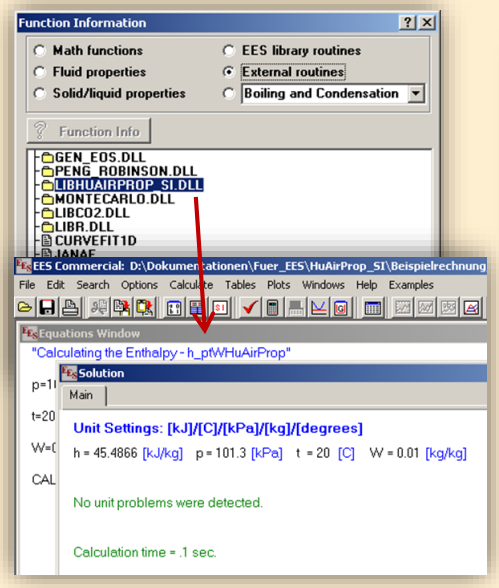


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

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

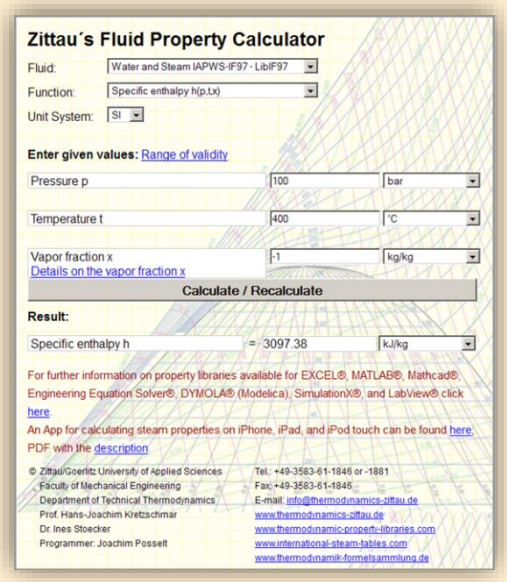


Add-In FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android 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:

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

www.thermofluidprop.com

5. References

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IAPWS Sekretariat, Dooley, B, EPRI, Palo Alto CA (1997)

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in: Steam, Water and Hydrothermal Systems: Physics and Chemistry Meeting the Needs of Industry, Proceedings of the 13th International Conference on the Properties of Water and Steam, Eds. P.G. Hill et al., NRC Press, Ottawa, 2000

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Springer-Verlag, Berlin (1998)

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6. Satisfied Customers

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AIXPROCESS, Aachen	02/2018
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TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
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Fraunhofer Institut UMSICHT, Oberhausen	07/2009
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FZD, Rossendorf	11/2009
Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
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MCI, Innsbruck, Austria	12/2009
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ENERKO, Aldenhoven	12/2009

2008

Pink, Langenwang	01/2008
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MAAG, Kuesnacht, Switzerland	02/2008
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Evonik, Zwingenberg (general EBSILON program license)	04/2008
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CFC Solutions, Munich	04/2008
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AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008

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AWTEC, Zurich, Switzerland	11/2008
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2006

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Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

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TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden Professorship of Thermic Energy Machines and Plants	04/2005
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
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Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
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Stadtwerke Leipzig	07/2005
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Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

Midiplan, Bietigheim-Bissingen	11/2005
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Visteon, Kerpen	03/2004, 10/2004
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Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
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Freudenberg Service, Weinheim	12/2004

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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
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ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
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exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
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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
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Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
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PREUSSAG NOELL, Wuerzburg	03/2001
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Neusiedler AG, Ulmerfeld, Austria	09/2001

h s energieanlagen, Freising	09/2001
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M&M Turbine Technology, Bielefeld	01/2000
IBR Engineering Reis, Nittendorf-Undorf	02/2000
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DVO Data Processing Service, Oberhausen	05/2000
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VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
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Steinhaus Informationssysteme, Datteln (general license for process data software)	12/2000

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Bayernwerk, Munich	01/1999
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KEMA IEV, Dresden	03/1999
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Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
Technical University of Cottbus, Chair in Power Plant Engineering	07/1999
Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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B+H Software Engineering Stuttgart	08/1998
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SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
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Energieversorgung, Offenbach	11/1998

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Siemens Power Generation, Goerlitz	07/1997