Property Library for Octamethyltrisiloxane (MDM) $C_8H_{24}Si_3O_2$

FluidLAB

with LibMDM

for MATLAB®

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Property Library for the Calculation of Octamethyltrisiloxane (MDM)

FluidLAB for MATLAB®
LibMDM

Contents

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0. Package Contents

Zip-file "CD_FluidLAB_LibMDM.zip" including the following files:

FluidLAB_LibMDM_Setup.exe	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibMDM.dll	- DLL with functions of the LibMDM library

Documentation

FluidLAB_LibMDM_Docu_Eng.pdf - User's Guide

1. Property Functions

1.1 Calculation Programs

"MDM" means Octamethyltrisiloxane **($C_8H_{24}Si_3O_2$)**

Functional Dependence	**Function Name**	**Call from Fortran program**	**Call in DLL LibMDM as parameter**	**Property or Function**	**Unit of the result**
$a = f(p,t,x)$	a_ptx_MDM	APTXMDM(P,T,X)	C_APTXMDM(PR,P,T,X)	Thermal diffusivity	m^2/s
$c_p = f(p,t,x)$	cp_ptx_MDM	CPPTXMDM(P,T,X)	C_CPPTXMDM(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_MDM	CVPTXMDM(P,T,X)	C_CVPTXMDM(CV,P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\left(\frac{\partial p}{\partial T}\right)_v = f(p,t,x)$	dpdtv_ptx_MDM	DPDTVPTXMDM(P,T,X)	C_DPDTVMDM(DPDT,P,T,X)	Derivative of pressure with respect to temperature (at constant specific volume)	kPa/K
$\left(\frac{\partial p}{\partial v}\right)_T = f(p,t,x)$	dpdvt_ptx_MDM	DPDVTPTXMDM(P,T,X)	C_DPDVTMDM(DPDV,P,T,X)	Derivative of pressure with respect to specific volume (at constant temperature)	$kPa/(m^3/kg)$
$\eta = f(p,t,x)$	eta_ptx_MDM	ETAPTXMDM(P,T,X)	C_ETAPTXMDM(ETA,P,T,X)	Dynamic viscosity	Pa·s
$h = f(p,t,x)$	h_ptx_MDM	HPTXMDM(P,T,X)	C_HPTXMDM(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_MDM	KAPPAPTXMDM(P,T,X)	C_KAPPAPTXMDM(KAPPA,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lamda_ptx_MDM	LAMPTXMDM(P,T,X)	C_LAMPTXMDM(LAM,P,T,X)	Thermal conductivity	W/(m·K)
$\nu = f(p,t,x)$	nu_ptx_MDM	NUPTXMDM(P,T,X)	C_NUPTXMDM(NUE,P,T,X)	Kinematic viscosity	m^2/s
$Pr = f(p,t,x)$	Pr_ptx_MDM	PRPTXMDM(P,T,X)	C_PRPTXMDM(PR,P,T,X)	*Prandtl* number	-
$p_s = f(t)$	ps_t_MDM	PSTMDM(T)	C_PSTMDM(PS,T)	Vapor pressure from temperature	bar
$\rho = f(p,t,x)$	rho_ptx_MDM	RHOPTXMDM(P,T,X)	C_RHOPTXMDM(RHO,P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_MDM	SPTXMDM(P,T,X)	C_SPTXMDM(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_MDM	TPHMDM(P,H)	C_TPHMDM(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_MDM	TPSMDM(P,S)	C_TPSMDM(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_MDM	TSPMDM(P)	C_TSPMDM(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_MDM	UPTXMDM(P,T,X)	C_UPTXMDM(U,P,T,X)	Specific internal energy	kJ/kg

Functional Dependence	**Function Name**	**Call from Fortran program**	**Call in DLL LibMDM as parameter**	**Property or Function**	**Unit of the result**
v = f(p,t,x)	v_ptx_MDM	VPTXMDM(P,T,X)	C_VPTXMDM(V,P,T,X)	Specific volume	m³/kg
w = f(p,t,x)	w_ptx_MDM	WPTXMDM(P,T,X)	C_WPTXMDM(W,P,T,X)	Isentropic speed of sound	m/s
x = f(p,h)	x_ph_MDM	XPHMDM(P,H)	C_XPHMDM(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
x = f(p,s)	x_ps_MDM	XPSMDM(P,S)	C_XPSMDM(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
Z = f(p,t,x)	Z_ptx_MDM	ZPTXMDM(P,T,X)	C_ZPTXMDM(W,P,T,X)	Compression factor	-

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

Range of validity

Temperature range: from t = 0°C to 400 °C
Pressure range: from p = 0.00078994 bar to 300 bar

Reference state

h = 0 kJ/kg and s = 0 kJ/(kg K) at t_B = 152.53 °C on the boiling curve (x = 0; $p_s = p_N$ = 1.01325 bar)

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

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

Single-phase region

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

Wet-steam region

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

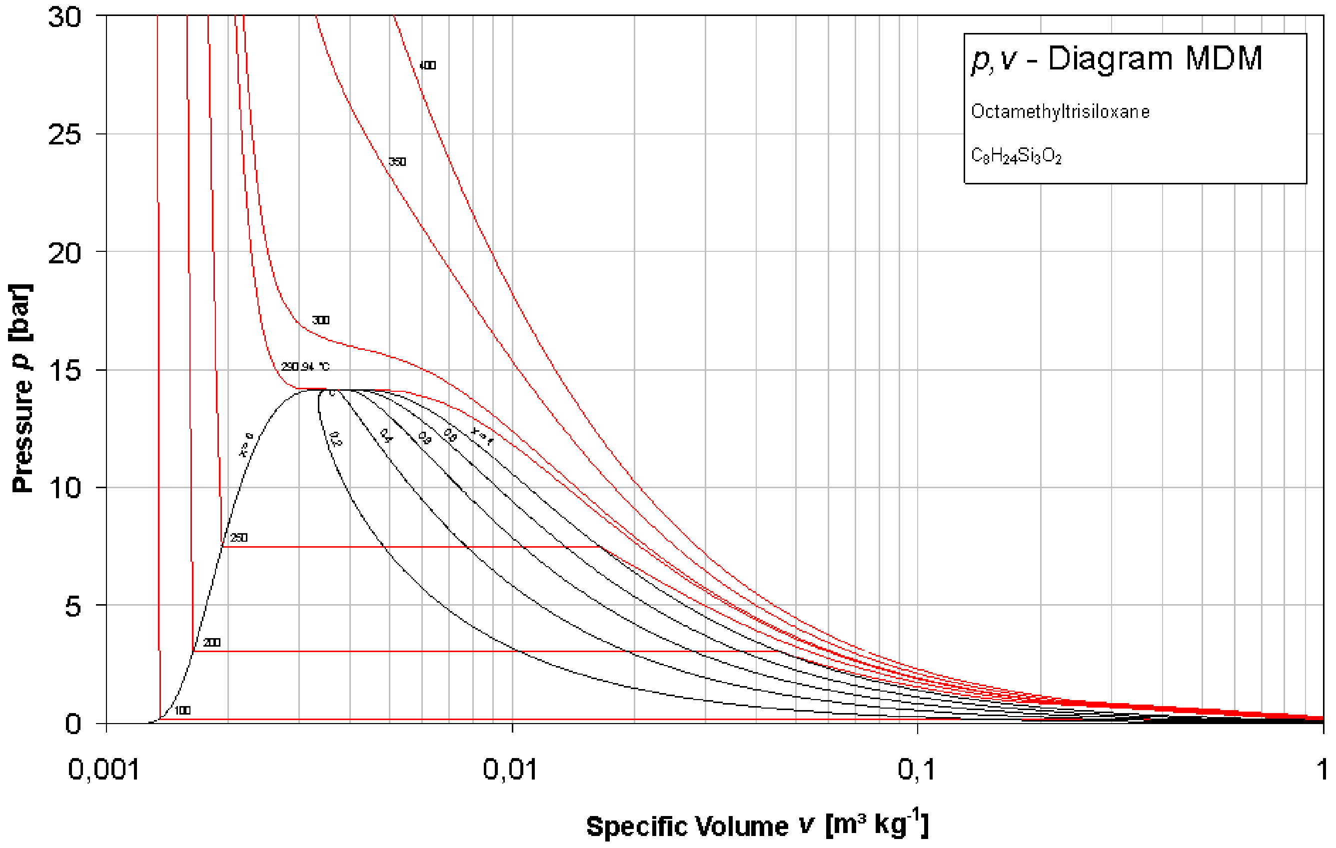
If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in –1000.

Wet steam region: Temperature range from t = 0 °C to t_c = 290.94 °C
Pressure range from p_s (0 °C) = 0.00078994 bar to p_c = 14.1510555 bar

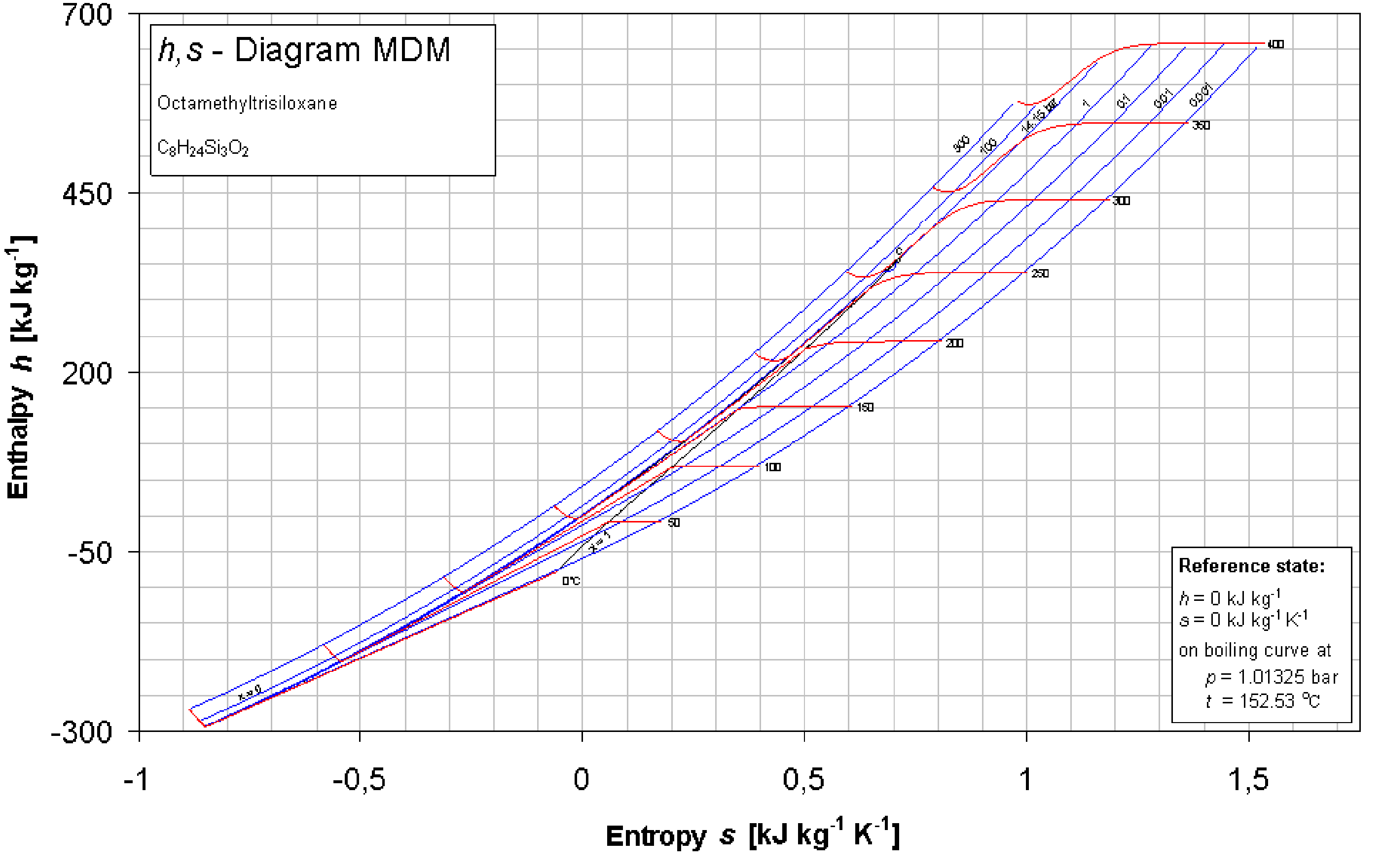
Note:

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

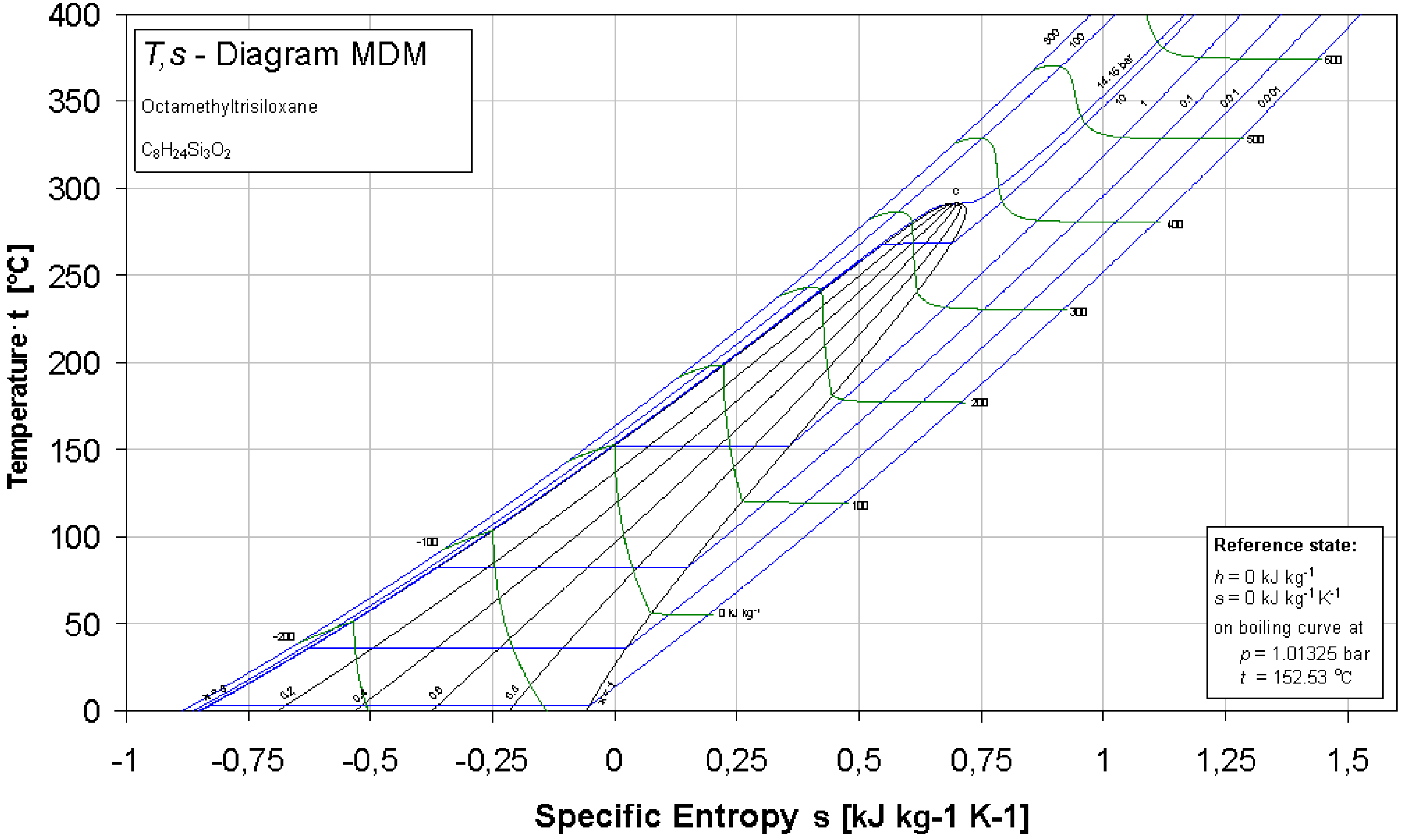
1.2 p,v-Diagram



1.3 h,s-Diagram



1.4 T,s-Diagram



2 Application of 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 Octamethyltrisiloxane from the LibMDM property library.

2.1 Installing FluidLAB including LibMDM

This section describes the installation of FluidLAB including the LibMDM property library.

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_LibMDM.zip", you will see the folder

CD_FluidLAB_LibMDM

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

Open this folder by double-clicking on it.

In this folder you will see the following three files:

FluidLAB_LibMDM_Docu_Eng.pdf
FluidLAB_LibMDM_Setup.exe
LibMDM.dll.

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

FluidLAB_LibMDM_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\LibMDM

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

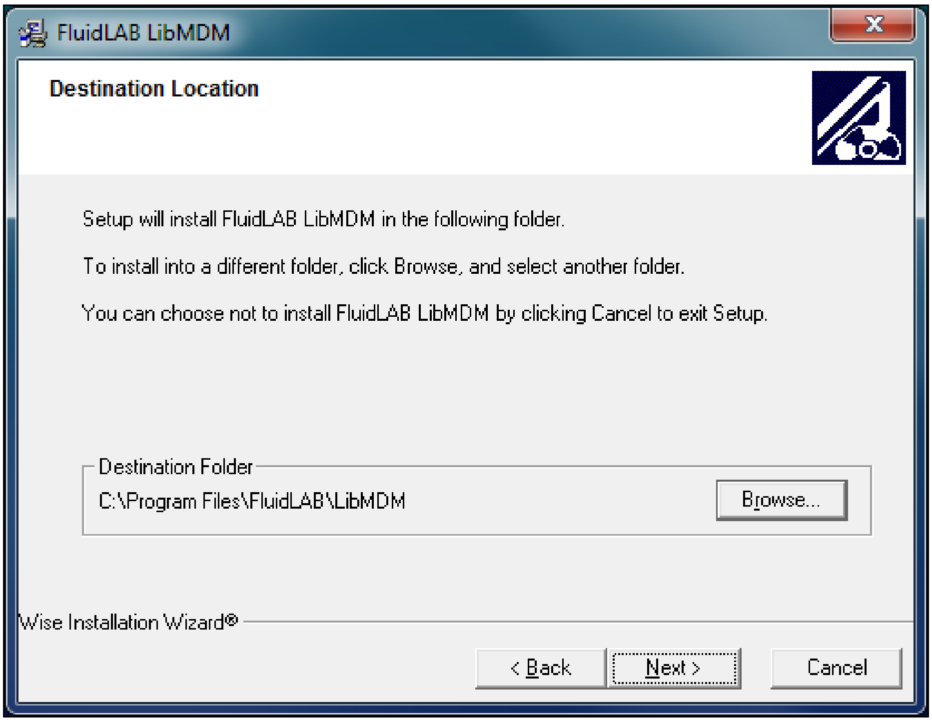


Figure 2.1: "Destination Location"

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 LibMDM into the directory "C:\Program Files\FluidLAB\LibMDM":

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

- MATLAB®-Interface-Program for calculable functions

cp_ptx_MDM	t_ph_MDM
cv_ptx_MDM	t_ps_MDM
dpdtv_ptx_MDM	ts_p_MDM
dpdvt_ptx_MDM	u_ptx_MDM
h_ptx_MDM	v_ptx_MDM
Kappa_ptx_MDM	w_ptx_MDM
ps_t_MDM	x_ph_MDM
rho_ptx_MDM	x_ps_MDM
s_ptx_MDM	Z_ptx_MDM

Now, you have to overwrite the file "LibMDM.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 "LibMDM.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\LibMDM) and insert the file "LibMDM.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 "LibMDM.dll" successfully and the property functions are available in MATLAB®.

Licensing the LibMDM 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 LibMDM (see figure below).

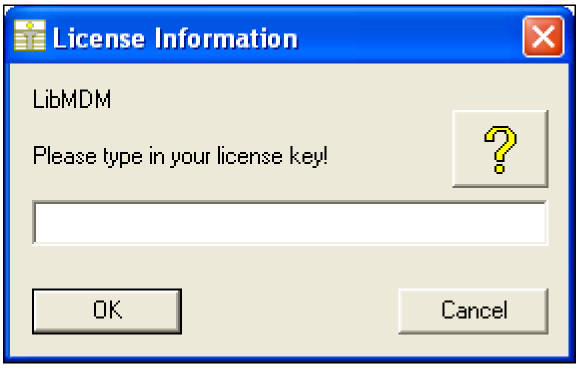


Figure 2.2: "License Information" window

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:

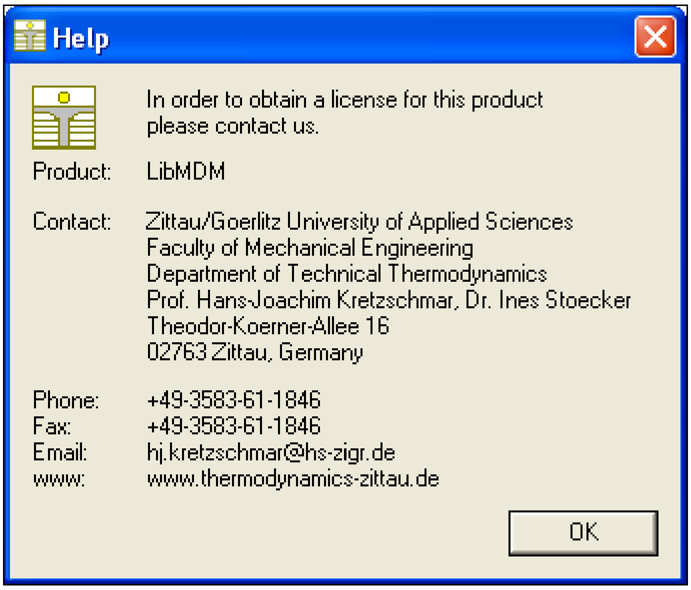


Figure 2.3: "Help" window

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

The "License Information" window will appear every time you use FluidLAB LibMDM until you enter a license code to complete registration. If you decide not to use FluidLAB LibMDM, you can uninstall the program following the instructions given in section 2.4 of this User's Guide.

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

Now we will calculate, step by step, the air-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 "\LibMDM"; it is generally saved under: "C:\Program Files\FluidLAB"
- Create the folder "\LibMDM_Example" by clicking on "File" in the Explorer® menu, then "New" in the menu which appears and afterwards selecting "Folder". Name the new folder "\LibMDM_Example."
- You will now see the following window:

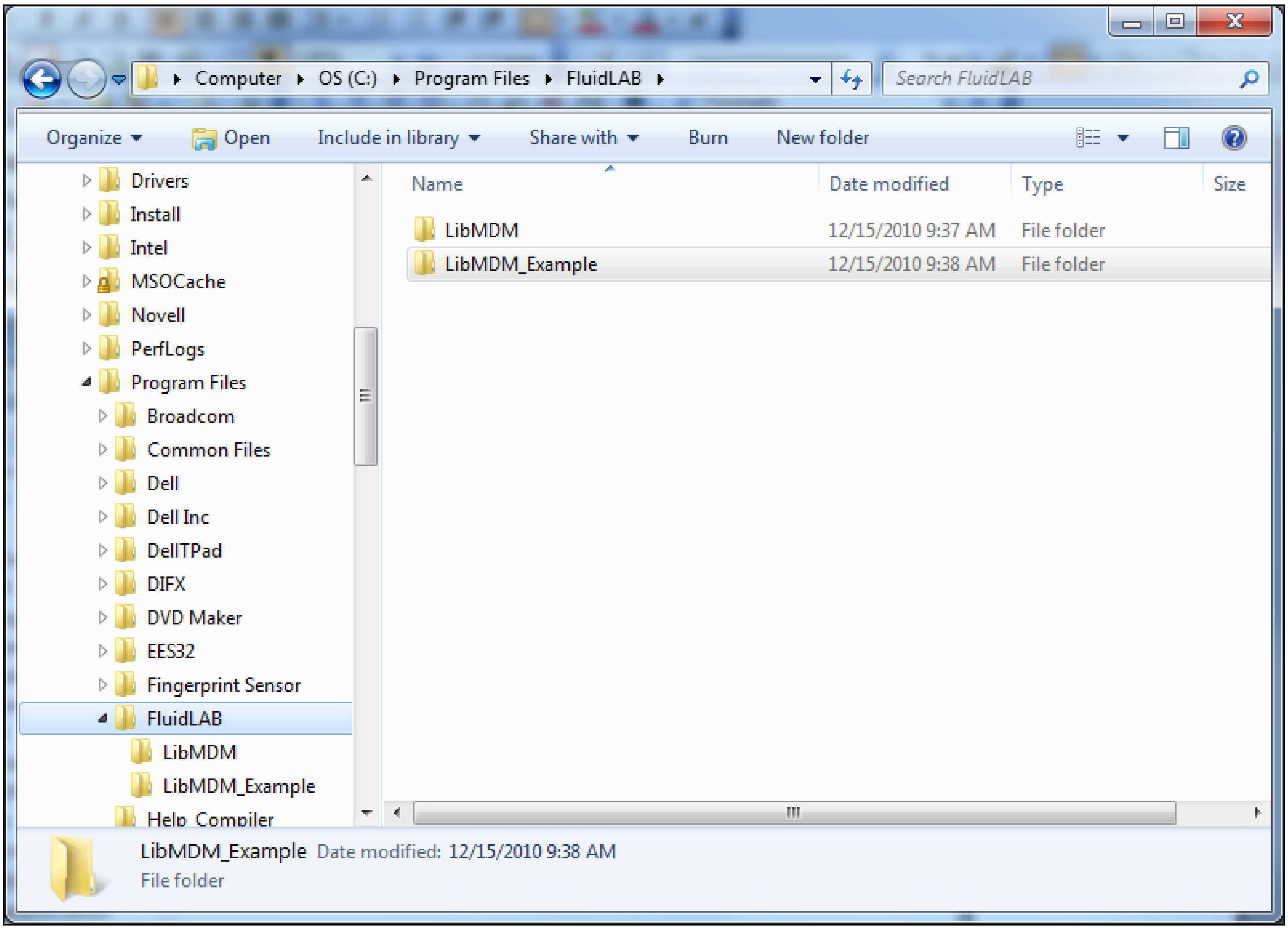


Figure 2.4: Folders "LibMDM" and "LibMDM_Example"

- Switch into the directory "\LibMDM" within "\FluidLAB", the standard being "C:\Program Files\FluidLAB\LibMDM."

- You will see the following window:

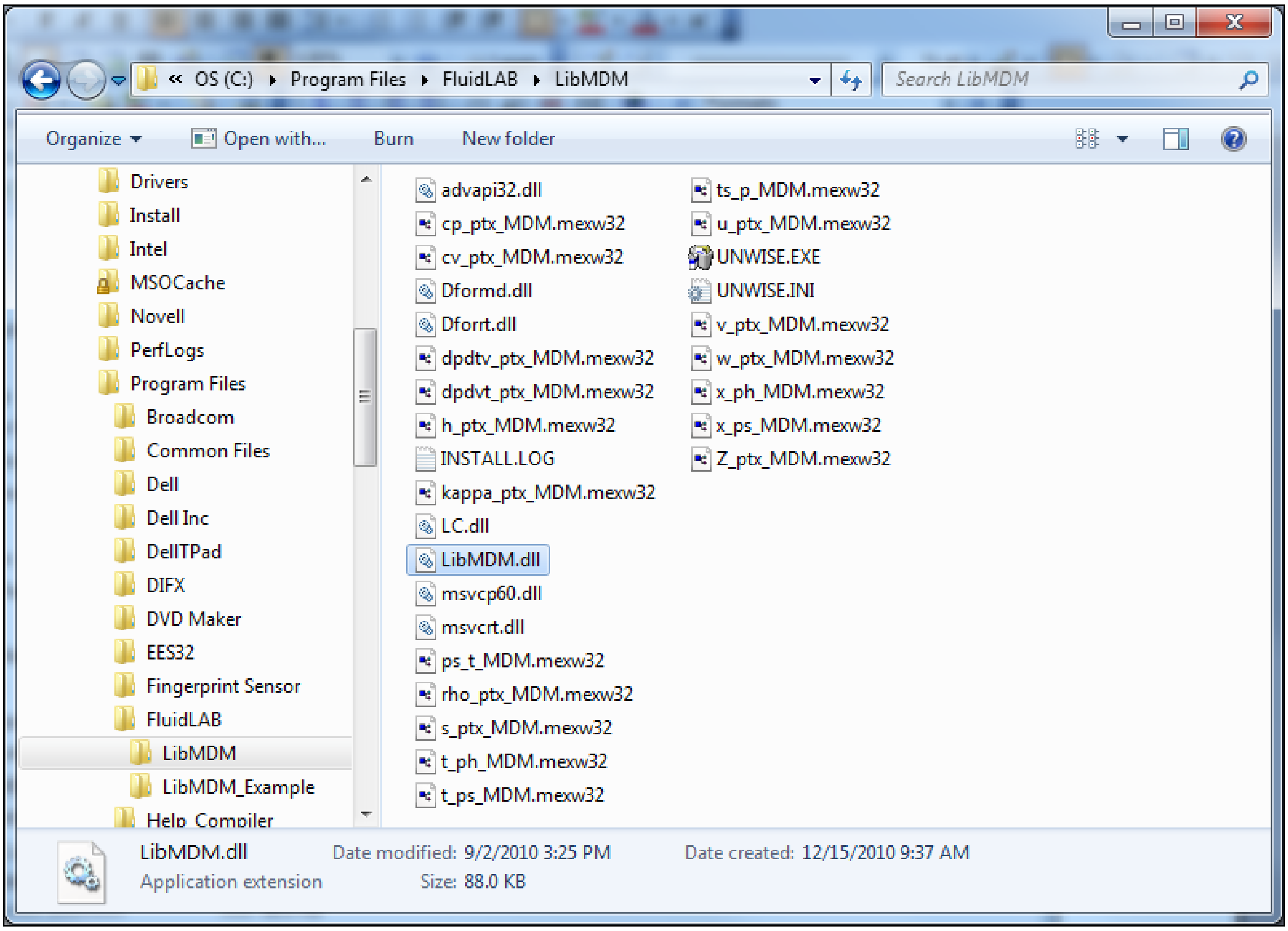


Figure 2.5: Contents of the folder "LibMDM"

You will now have to copy the following files into the directory "C:\Program Files\FluidLAB\LibMDM_Example" in order to calculate the function $h = \mathrm{f}(p,t,x)$.

- The following eight files are needed:
  - "advapi32.dll"
  - "Dformd.dll"
  - "Dforrt.dll"
  - "h_ptx_MDM.mexw32"
  - "LC.dll"
  - "LibMDM.dll"
  - "msvcp60.dll"
  - "msvcrt.dll."
- Click the file "h_ptx_MDM.mexw32", then click "Edit" in the upper menu bar and select "Copy".
- Switch into the directory "C:\Program Files\FluidLAB\LibMDM_Example", 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).

- You will see the following window:

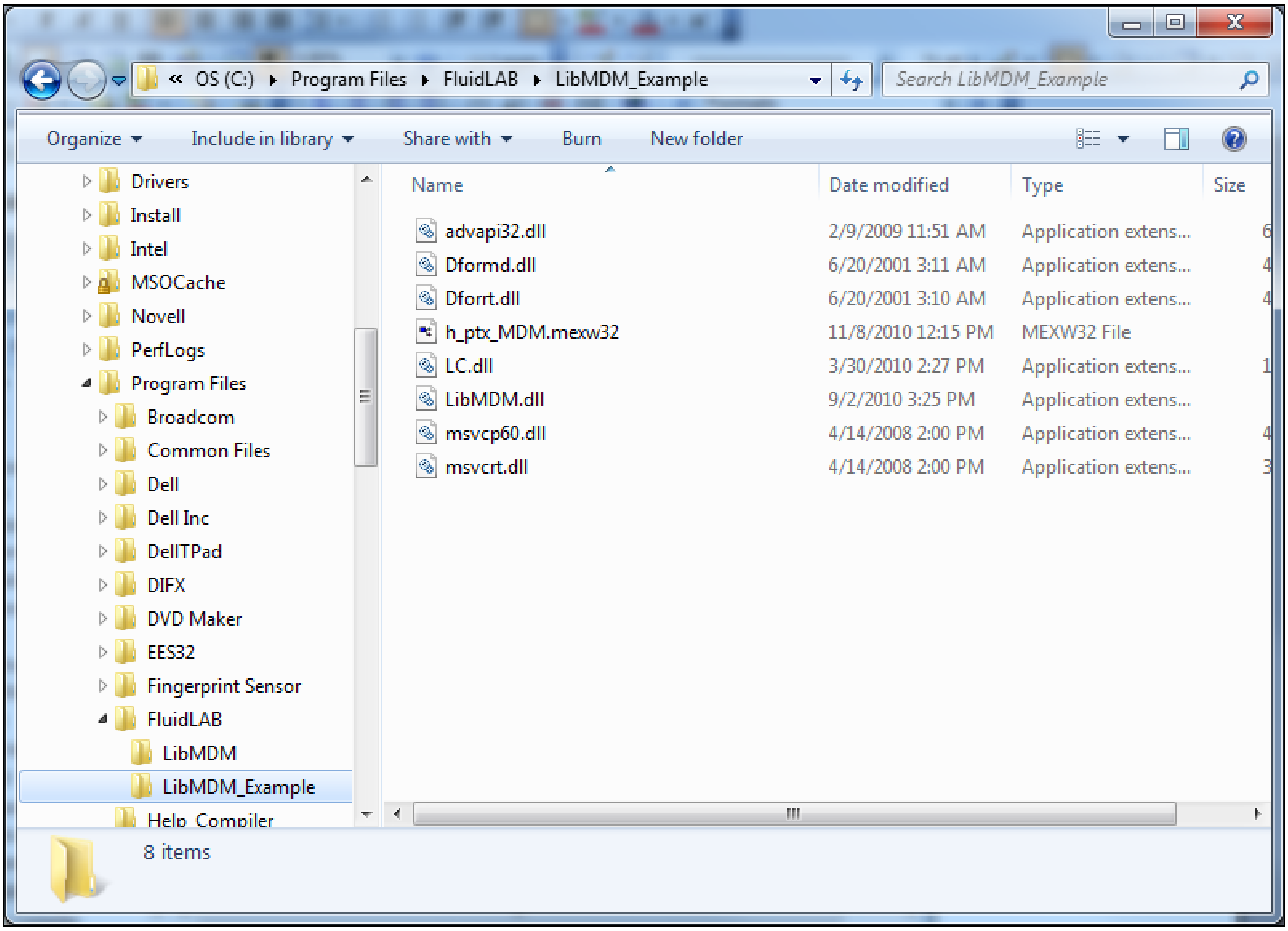


Figure 2.6: Contents of the folder "LibMDM_Example"

- Start MATLAB® (if you have not started it before).
- Click the button marked in the next figure in order to open the folder "\LibMDM_Example" in the "Current Folder" window.

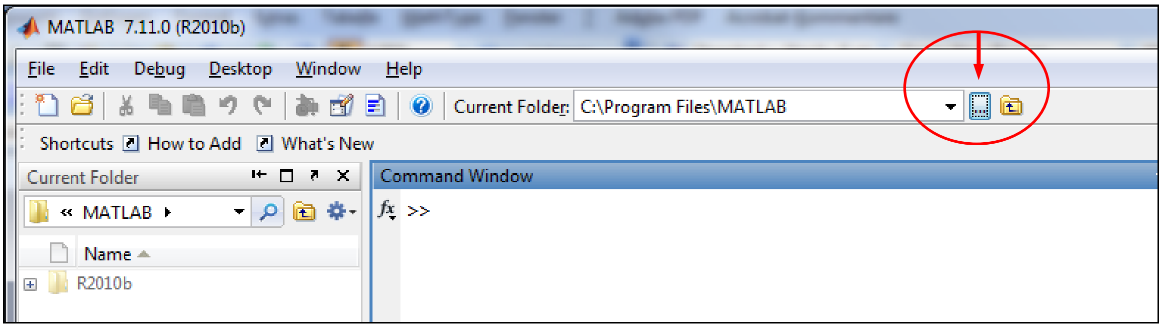


Figure 2.7: Selection of the working directory

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

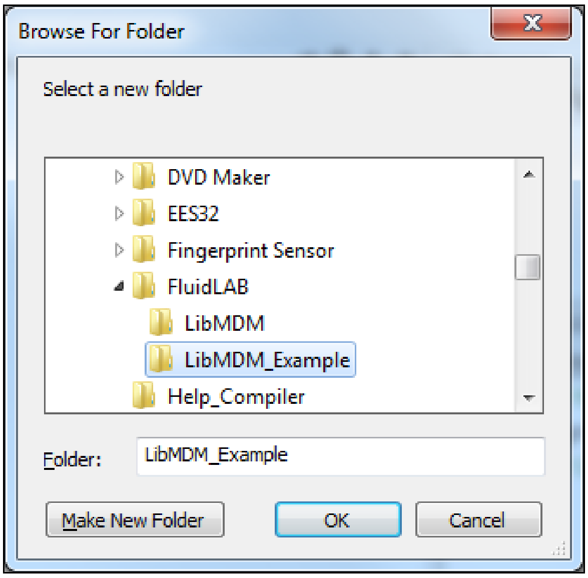


Figure 2.8: Choosing the "LibMDM_Example" folder

- 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.

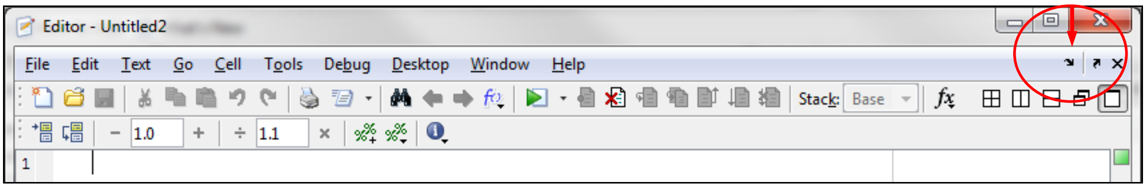


Figure 2.9: Embedding the "Editor" window

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

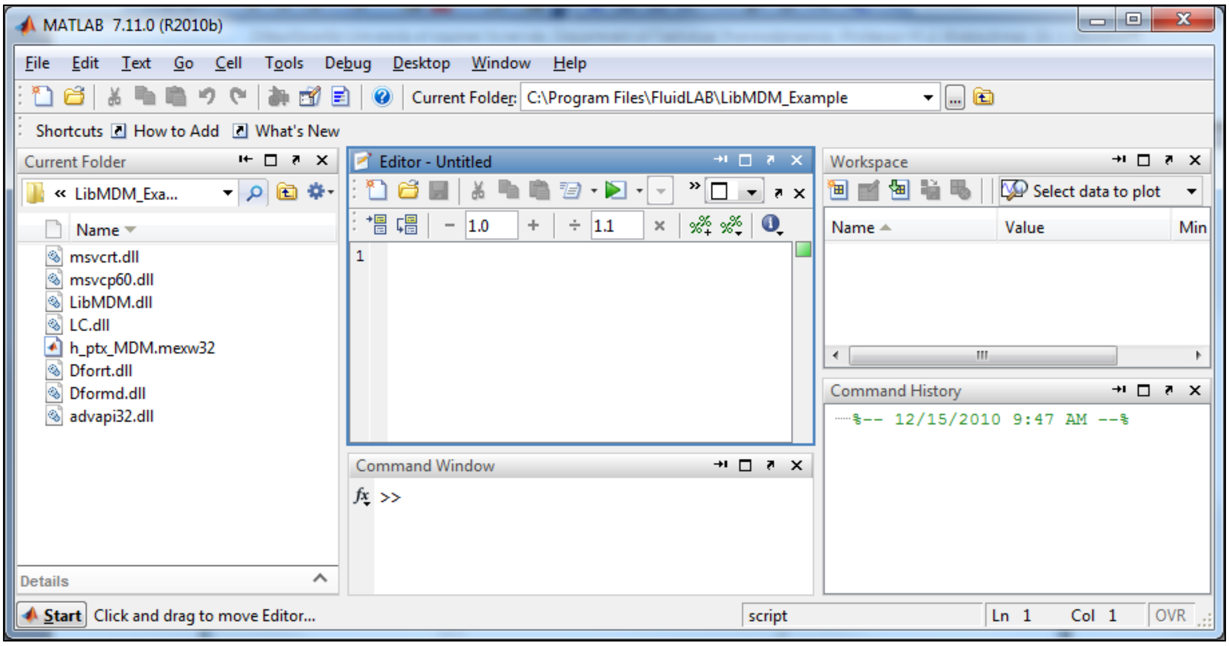


Figure 2.10: Embedded "Editor" window

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

Text to be written:	Explanation:
`% h_ptx_MDM.m`	file name as comment
`%%`	paragraph separation
`p=10; % pressure in bar`	declaration of the variables pressure, temperature, art and composition of mixture
`t=300; % temperature in °C`	
`x=-1; % vapor fraction in kg/kg`	
`%%`	paragraph separation
`h=h_ptx_MDM(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 = 00078994 bar to 300 bar)
  - Second operand: Value for t = 300 °C
    (Range of validity: t = 0°C to 400 °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:

  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, the value –1 must be entered into the x cell as a pro-forma value.

  In case, the state point to be calculated is located in the wet steam region, values between 0 and 1 have to be entered for x (the value 0 for boiling liquid, the value 1 for saturated steam).
  Here, it is adequate to enter either the value given for t <u>and</u> p = –1, or the given value for p <u>and</u> t = –1, plus the value for x between 0 and 1.
  However, if p <u>and</u> t <u>and</u> x are given when calculating wet steam, the program initially checks whether p and t meet the saturation-pressure curve. If this is not the case the enthalpy calculated later will result in -1000.

  (MDM Saturation pressure curve:

  t = 0 °C to t_c = 290.94 °C

  p_s(0 °C) = 0.00078994 bar to p_c = 14.1510555 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 "LibMDM_Example" must be displayed in the "Save in:" field.
- Next to "File name" you have to type "Example_h_ptx_MDM.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_MDM.m" in this case. Otherwise an error message will appear during the calculation.

- You will now see the following window:

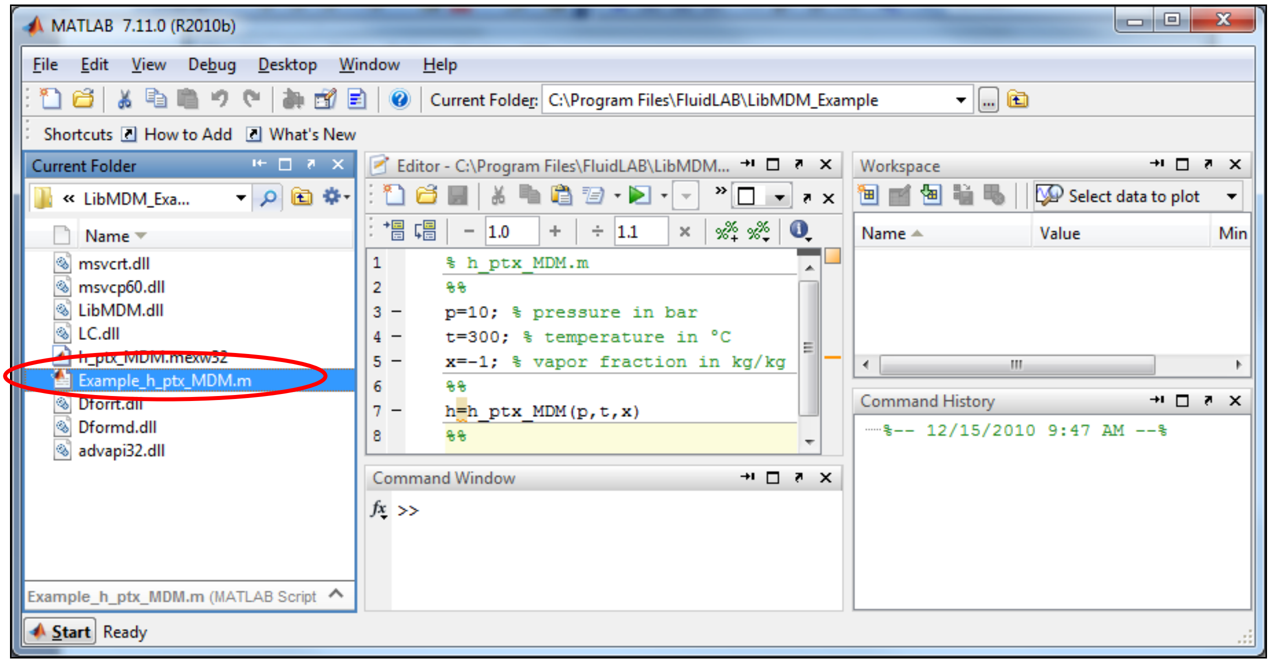


Figure 2.11: "Example_h_ptx_MDM.m" M-file

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

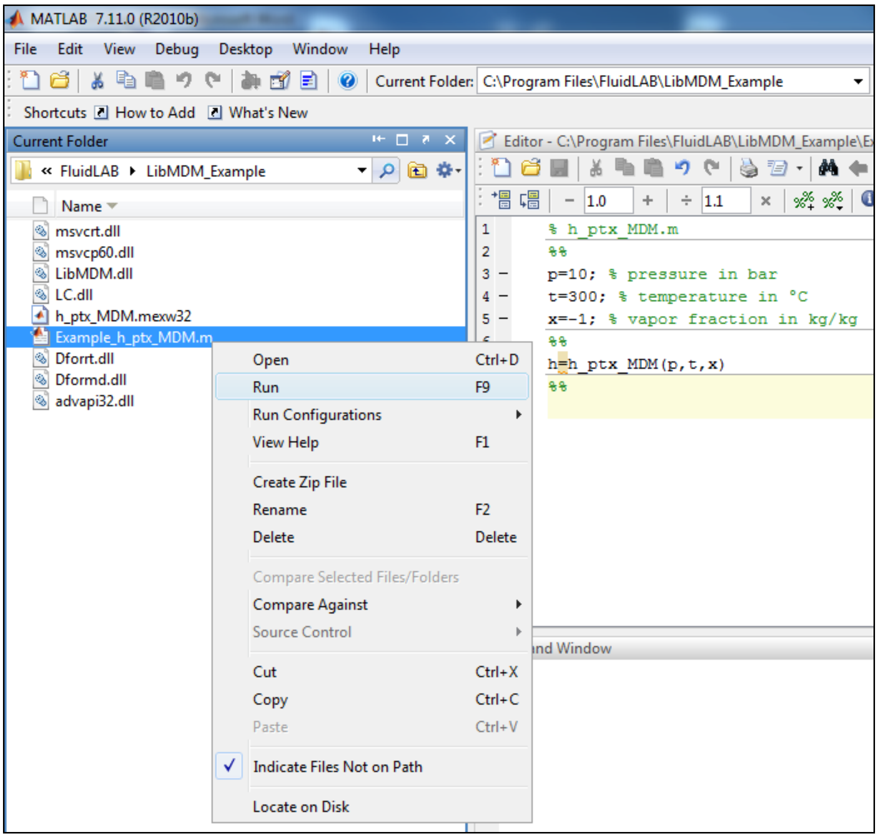


Figure 2.12: Running the "Example_h_ptx_MDM.m" M-file

- You will see the following window:

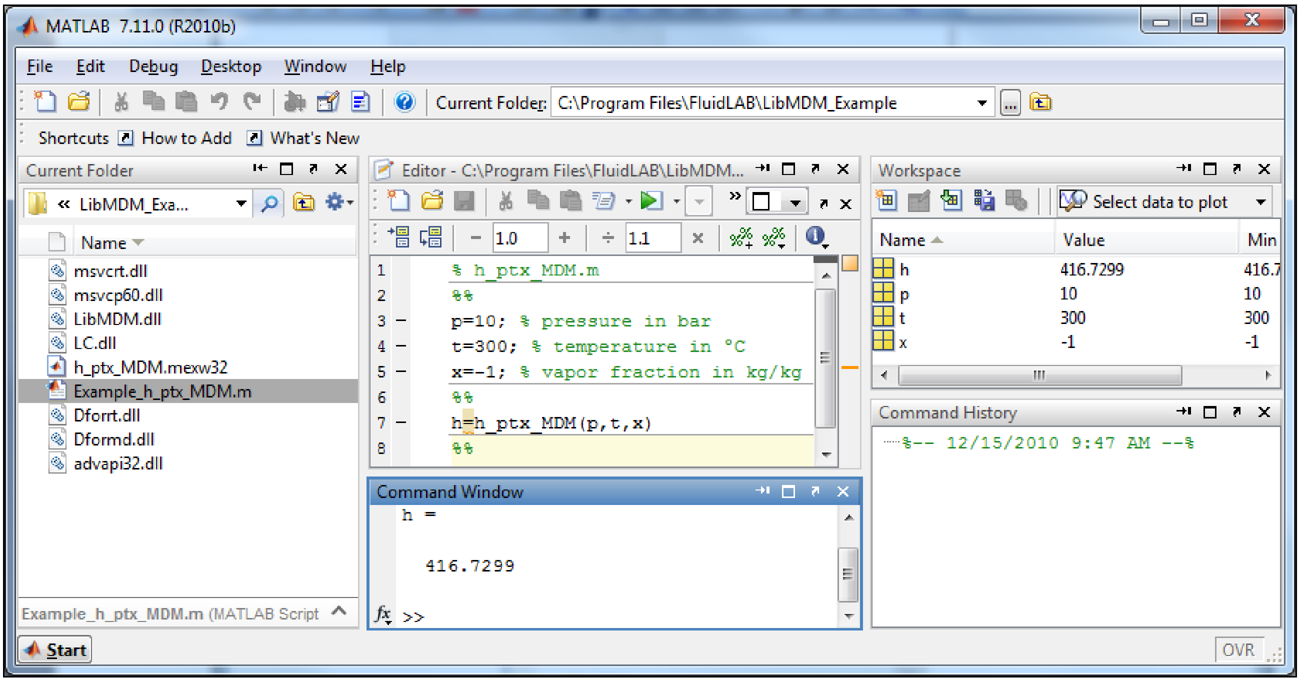


Figure 2.13: MATLAB® with calculated result

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

⇒ The result in our sample calculation here is: "h = 416.7299". 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\LibMDM_Example," and you may use it as a basis for further calculations using FluidLAB.

2.3 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 "\LibMDM_Example" in the window "Current Folder."

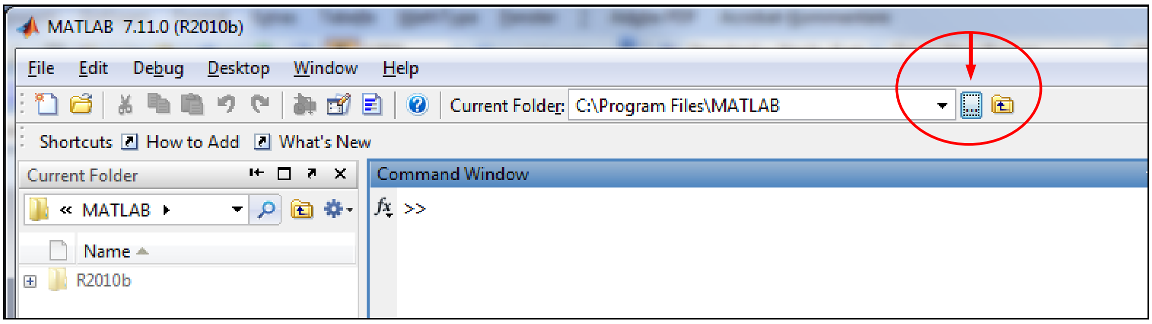


Figure 2.14: Selection of the working directory

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

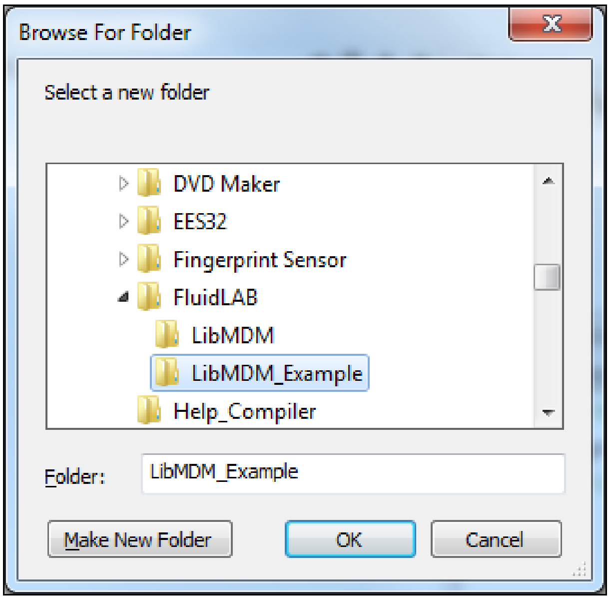


Figure 2.15: Choosing the "LibMDM_Example" folder

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

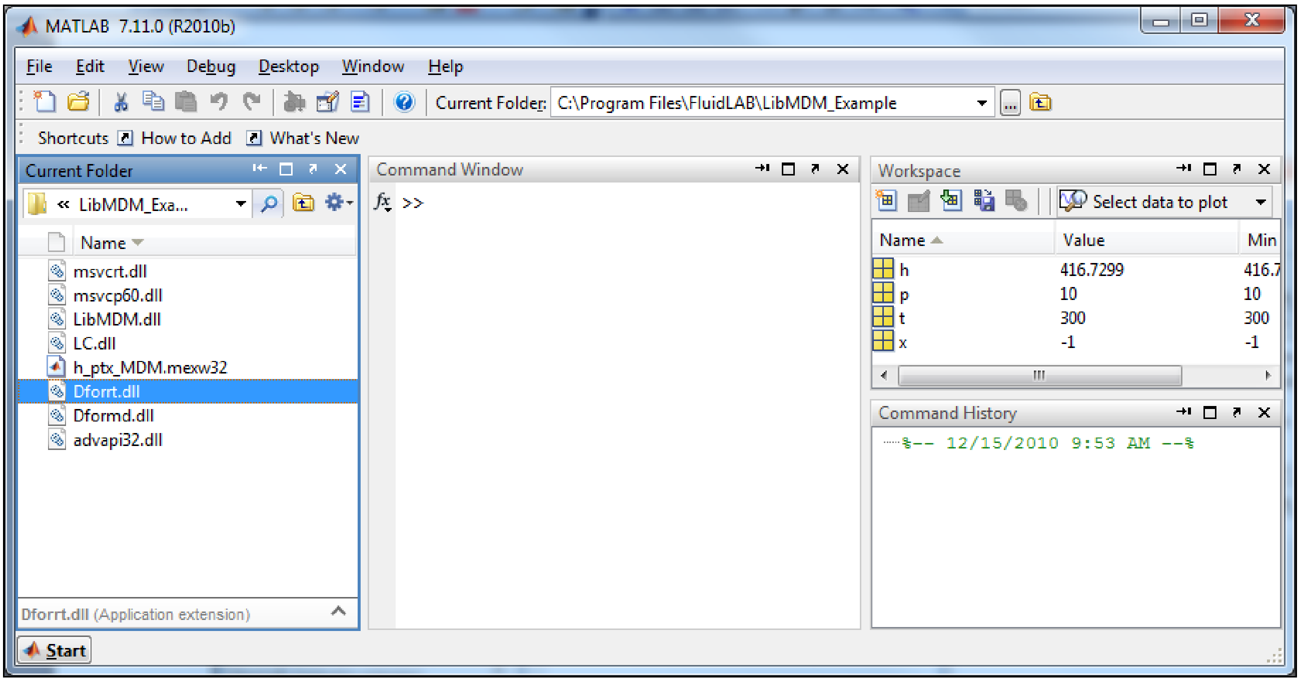


Figure 2.16: MATLAB® with necessary files

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

Write "**h=h_ptx_MDM(10,300,-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 = 0.00078994 bar to 300 bar)
- Second operand: Value for t = 300 °C
  (Range of validity: t = 0°C to 400 °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:

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, the value –1 must be entered into the *x* cell as a pro-forma value.

In case, the state point to be calculated is located in the wet steam region, values between 0 and 1 have to be entered for *x* (the value 0 for boiling liquid, the value 1 for saturated steam).
Here, it is adequate to enter either the value given for *t* <u>and</u> p = –1000, or the given value for *p* <u>and</u> t = –1000, plus the value for *x* between 0 and 1.
However, if *p* <u>and</u> *t* <u>and</u> *x* are given when calculating wet steam, the program initially checks whether *p* and *t* meet the saturation-pressure curve. If this is not the case the enthalpy calculated later will result in -1000.

(MDM Saturation pressure curve:

$t = 0$ °C to $t_C = 290.94$ °C

$p_S(0\ °C) = 0.00078994$ bar to $p_C = 14.1510555$ bar)

- Confirm your entry by pressing the "ENTER" button.

- You will see the following window:

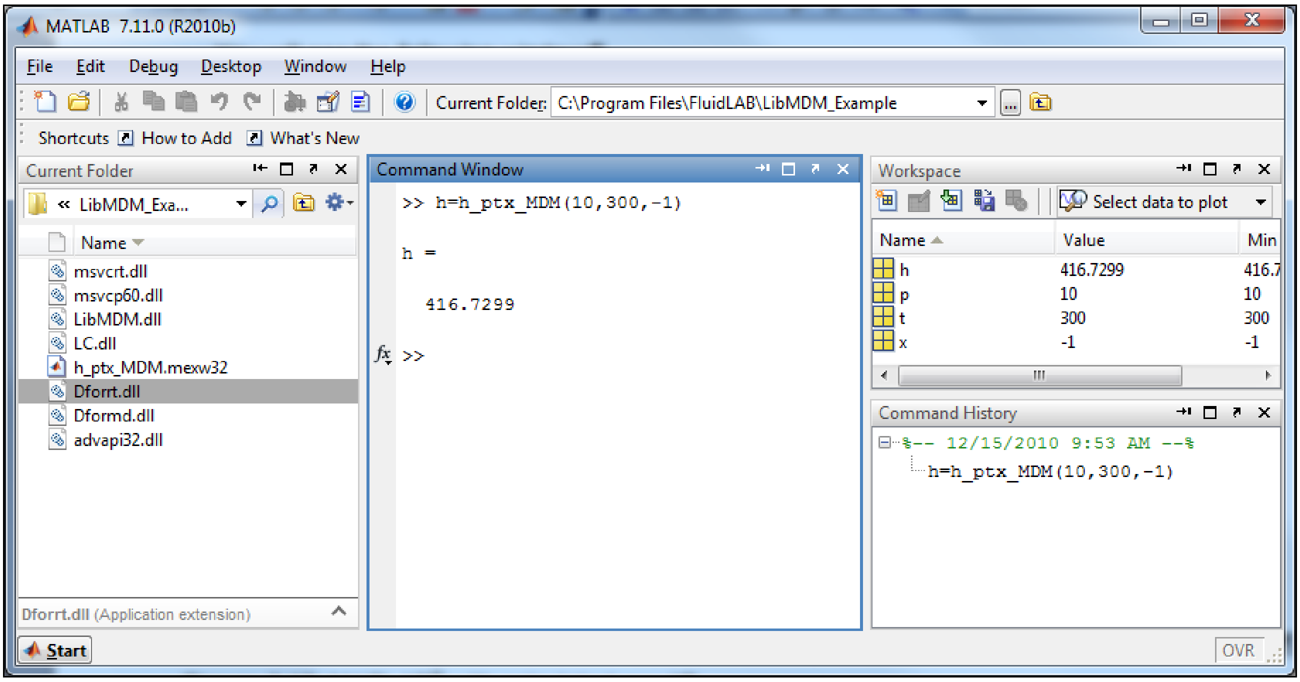


Figure 2.17: MATLAB® with calculated result

⇒ In the "Command Window" you will see the result "h = 416.7299". 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 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.

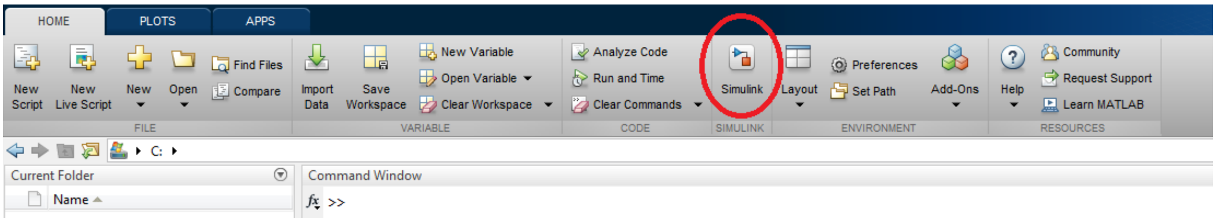


Figure 2.18: Starting Simulink

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 2.19.

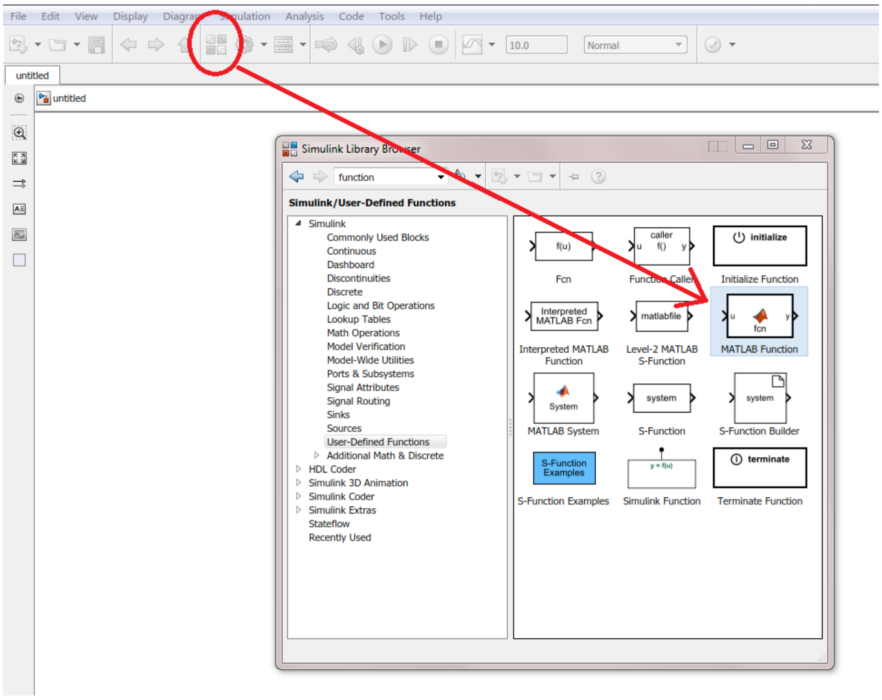


Figure 2.19: Simulink library browser and choosing a MATLAB Function

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.

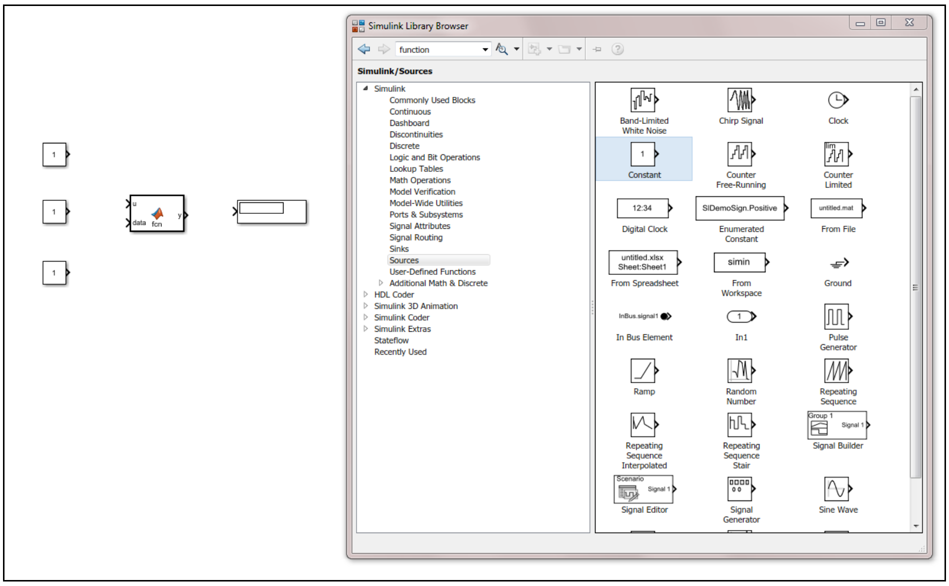


Figure 2.20: Inputs and outputs of the example

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.

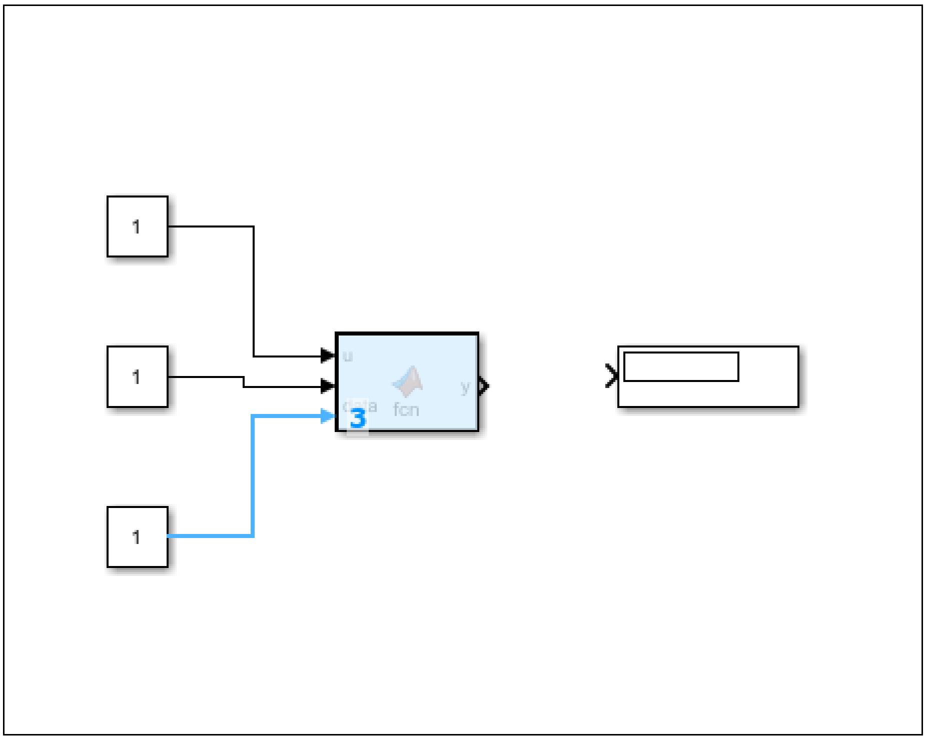


Figure 2.21: Linking blocks in Simulink

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_MDM');
addpath('C:\Program Files\FluidLAB\LibMDM');
```

```
h = h_ptx_MDM(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_MDM');`	Choose the function name of the FluidLAB function
`addpath('C:\Program Files\FluidLAB\LibMDM');`	Add the installation path of FluidLAB
`h = h_ptx_MDM(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.

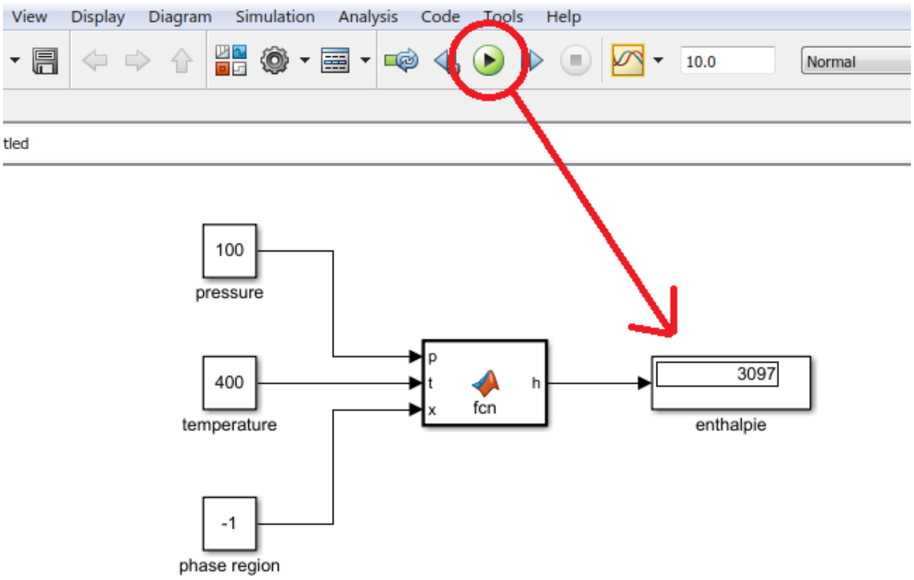


Figure 2.22: Starting the simulation and result of the calculation

Your result is may an other than shown in figure 2.22. If you want to calculate the example please use the values from section 2.2 and 2.3.

2.5 Removing FluidLAB including LibMDM

To remove the property library LibMDM 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 LibMDM" 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 LibMDM installed, the directory "FluidLAB" will be removed as well.

3. Program Documentation

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

Function Name:	**cp_ptx_MDM**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION CPPTXMDM(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CPPTXMDM(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

CPPTXMDM, CP or **cp_ptx_MDM** – specific isobaric heat capacity c_p in $\mathrm{kJ/(kg\,K)}$

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for x values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x between 0 and 1. When calculating wet steam and p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve.

Wet steam region: Temperature ranges from $t = 0\,°\mathrm{C}$ to $t_\mathrm{c} = 290.94\,°\mathrm{C}$
Pressure ranges from $p_\mathrm{s}(0\,°\mathrm{C}) = 0.00078993\,\mathrm{bar}$ to $p_\mathrm{c} = 14.151055\,\mathrm{bar}$

Results for wrong input values

Result **CPPTXMDM = -1000**, **CP = -1000** or **cp_ptx_MDM = -1000** for input values:

Single phase region: p > 300 bar or p < 0,00078993 bar or
(x = -1) t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_\mathrm{c} = 290.94\,°\mathrm{C}$ to $t < 0\,°\mathrm{C}$
at $t = -1000$ and $p > p_\mathrm{c} = 14.151055\,\mathrm{bar}$
or $p < p_\mathrm{s}(0°C) = 0.00078993\,\mathrm{bar}$ or
or $p > p_\mathrm{c} = 14.151055\,\mathrm{bar}$ or $p < p_\mathrm{s}(0°C) = 0.00078993\,\mathrm{bar}$ and
$t > t_\mathrm{c} = 290.94\,°\mathbf{C}$ or $t < 0\,°\mathrm{C}$

References: [1], [2]

Specific Isochoric Heat Capacity $c_v = \mathrm{f}(p,t,x)$

Function Name:	**cv_ptx_MDM**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION CVPTXMDM(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CVPTXMDM(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

CVPTXMDM, CV or **cv_ptx_MDM** – specific isochoric heat capacity c_v in kJ/(kg K)

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* between 0 and 1. When calculating wet steam and *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve.

Wet steam region: Temperature ranges from $t = 0°\mathrm{C}$ to $t_c = 290.94°\mathrm{C}$
Pressure ranges from $p_s(0°\mathrm{C}) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **CVPTXMDM = -1000**, **CV = -1000** or **cv_ptx_MDM = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0,00078993 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 290.94°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_c = 14.151055$ bar
or $p < p_s(0°C) = 0.00078993$ bar or
or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and
$t > t_c = 290.94°\mathbf{C}$ or $t < 0°\mathrm{C}$

References: [1]

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

Function Name: **dpdtv_ptx_MDM**

Subroutine with function value: for call from Fortran — **REAL*8 FUNCTION DPDTVPTXMDM(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter: for call from DLL — **INTEGER*4 FUNCTION C_DPDTVPTXMDM(DPDTV,P,T,X)**
REAL*8 DPDTV,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

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

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for x values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x between 0 and 1. When calculating wet steam and p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve.

Boiling and dew curve: Temperature ranges from $t = 0°\mathrm{C}$ to $t_\mathrm{c} = 290.94°\mathrm{C}$

Pressure ranges from $p_\mathrm{s}(0°\mathrm{C}) = 0.00078993$ bar to $p_\mathrm{c} = 14.151055$ bar

Results for wrong input values

Result **DPDTVPTXMDM = -1000**, **DPDTV = -1000** or **dpdtvo_ptx_MDM = -1000** for input values:

Single phase region: (x = -1) — p > 300 bar or p < 0,00078993 bar or t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_\mathrm{c} = 290.94°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_\mathrm{c} = 14.151055$ bar
or $p < p_\mathrm{s}(0°C) = 0.00078993$ bar or
or $p > p_\mathrm{c} = 14.151055$ bar or $p < p_\mathrm{s}(0°C) = 0.00078993$ bar and
$t > t_\mathrm{c} = 290.94°\mathbf{C}$ or $t < 0°\mathrm{C}$

References: [1], [2]

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

Function Name:	**dpdvt_ptx_MDM**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION DPDVTPTXMDM(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_DPDVTPTXMDM(DPDVT,P,T,X)** REAL*8 DPDVT,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* between 0 and 1. When calculating wet steam and *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve.

Wet steam region: Temperature ranges from $t = 0\,°\mathrm{C}$ to $t_\mathrm{c} = 290.94\,°\mathrm{C}$
Pressure ranges from $p_\mathrm{s}(0\,°\mathrm{C}) = 0.00078993$ bar to $p_\mathrm{c} = 14.151055$ bar

Results for wrong input values

Result **DPDVTPTXMDM = -1000**, **DPDVT = -1000** or **dpdvt_ptx_MDM = -1000** for input values:

Single phase region: (x = -1) p > 300 bar or p < 0,00078993 bar or t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_\mathrm{c} = 290.94\,°\mathrm{C}$ to $t < 0\,°\mathrm{C}$
at $t = -1000$ and $p > p_\mathrm{c} = 14.151055$ bar
or $p < p_\mathrm{s}(0\,°C) = 0.00078993$ bar or
or $p > p_\mathrm{c} = 14.151055$ bar or $p < p_\mathrm{s}(0\,°C) = 0.00078993$ bar and
$t > t_\mathrm{c} = 290.94\,°\mathbf{C}$ or $t < 0\,°\mathrm{C}$

References: [1], [2]

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

Function Name:	**h_ptx_MDM**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION HPTXMDM(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_HPTXMDM(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

HPTXMDM, **H** or **h_ptx_MDM** - specific enthalpy *h* in kJ/kg

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located in the two phase region (wet steam), either the value 0 or 1 has to be entered for *x* (x = 0 for boiling liquid, x = 1 for saturated steam). The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* between 0 and 1.

When calculating wet steam and *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Wet steam region: Temperature ranges from $t = 0°\mathrm{C}$ to $t_c = 290.94°\mathrm{C}$
Pressure ranges from $p_s(0°\mathrm{C}) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **HPTXMDM = -1000**, **H = -1000** or **h_ptx_MDM = -1000** for input values:

Single phase region: p > 300 bar or p < 0,00078993 bar or
(x = -1) t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_c = 290.94°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_c = 14.151055$ bar
or $p < p_s(0°C) = 0.00078993$ bar or
or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and
$t > t_c = 290.94°\mathbf{C}$ or $t < 0°\mathrm{C}$

References: [1], [2]

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

Function Name: **kappa_ptx_MDM**

Subroutine with function value: **REAL*8 FUNCTION KAPPAPTXMDM(P,T,X)**
for call from Fortran REAL*8 P,T,X

Subroutine with parameter: **INTEGER*4 FUNCTION C_KAPPAPTXMDM(KAPPA, P,T,X)**
for call from DLL REAL*8 KAPPA,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

KAPPAPTXMDM, **KAPPA** or **kappa_ptx_MDM** – Isentropic exponent $\kappa = \dfrac{w^2}{p \cdot v}$

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for x values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x between 0 and 1. When calculating wet steam and p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve.

Boiling and dew curve: Temperature ranges from $t = 0°\text{C}$ to $t_c = 290.94°\text{C}$
Pressure ranges from $p_s(0°\text{C}) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **KAPPAPTXMDM**, **KAPPA = -1000** or **kappa_ptx_MDM = -1000** for input values:

Single phase region: p > 300 bar or p < 0,00078993 bar or
(x = -1) t > 400 °C or t < 0°C

Boiling or dew curve: at $p = -1000$ and $t > t_c = 290.94°\text{C}$ to $t < 0°\text{C}$
at $t = -1000$ and $p > p_c = 14.151055$ bar
or $p < p_s(0°C) = 0.00078993$ bar or
or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and
$t > t_c = 290.94°\textbf{C}$ or $t < 0°\text{C}$

References: [1]

Vapor Pressure $p_s = f(t)$

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

Input Values:

T - Temperature t in °C

Result

PSTMDM, **PS** or **ps_t_MDM** – Vapor pressure p_s in bar

Range of validity

Temperature ranges from $t = 0°C$ to $t_c = 290.94°C$

Results for wrong input values

Result **PSTMDM = -1000**, **PS = -1000** or **ps_t_MDM = -1000** for input values:

$t < 0°C$ or $t > t_c = 290.94°C$

References: [1], [2]

Density ρ = f(p,t,x)

Function Name: **rho_ptx_MDM**

Subroutine with function value: **REAL*8 FUNCTION RHOPTXMDM(P,T,X)**
for call from Fortran REAL*8 P,T,X

Subroutine with parameter: **INTEGER*4 FUNCTION C_RHOPTXMDM(RHO,P,T,X)**
for call from DLL 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

RHOPTXMDM, **RHO** or **rho_ptx_MDM** – Density ρ in $\mathrm{kg/m^3}$

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for x values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x between 0 and 1. When calculating wet steam and p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve.

Wet steam region: Temperature ranges from $t = 0\,°\mathrm{C}$ to $t_\mathrm{c} = 290.94\,°\mathrm{C}$
Pressure ranges from $p_\mathrm{s}(0\,°\mathrm{C}) = 0.00078993$ bar to $p_\mathrm{c} = 14.151055$ bar

Results for wrong input values

Result **RHOPTXMDM = -1000**, **RHO = -1000** or **rho_ptx_MDM = -1000** for input values:

Single phase region: p > 300 bar or p < 0,00078993 bar or
(x = -1) t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_\mathrm{c} = 290.94\,°\mathrm{C}$ to $t < 0\,°\mathrm{C}$
at $t = -1000$ and $p > p_\mathrm{c} = 14.151055$ bar
or $p < p_\mathrm{s}(0\,°C) = 0.00078993$ bar or
or $p > p_\mathrm{c} = 14.151055$ bar or $p < p_\mathrm{s}(0\,°C) = 0.00078993$ bar and
$t > t_\mathrm{c} = 290.94\,°\mathrm{C}$ or $t < 0\,°\mathrm{C}$

References: [1], [2]

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

Function Name: **s_ptx_MDM**

Subroutine with function value: for call from Fortran — **REAL*8 FUNCTION SPTXMDM(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter: for call from DLL — **INTEGER*4 FUNCTION C_SPTXMDM(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

SPTXMDM, **S** or **s_ptx_MDM** - Specific entropy *s* in kJ/kg K

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located in the two phase region (wet steam), either the value 0 or 1 has to be entered for *x* (x = 0 for boiling liquid, x = 1 for saturated steam). The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* between 0 and 1.

When calculating wet steam and *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Wet steam region: Temperature ranges from $t = 0°\text{C}$ to $t_c = 290.94°\text{C}$
Pressure ranges from $p_s(0°\text{C}) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **SPTXMDM = -1000**, **S = -1000** or **s_ptx_MDM = -1000** for input values:

Single phase region: (x = -1) — p > 300 bar or p < 0.00078993 bar or t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_c = 290.94°\text{C}$ to $t < 0°\text{C}$
at $t = -1000$ and $p > p_c = 14.151055$ bar
or $p < p_s(0°C) = 0.00078993$ bar or
or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and
$t > t_c = 290.94°\mathbf{C}$ or $t < 0°\text{C}$

References: [1], [2]

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

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

Input Values:

P - Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

TPHMDM, **T** or **t_ph_MDM -** Temperature t in °C

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. That means the given values of p and h are taken as a basis and the subprogram 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 the appropriate state region will be carried out.

Wet steam region: Pressure ranges from $p_s(0°C) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **T_PH_MDM**, **T = -1000** or **t_ph_MDM = -1000** for input values:

Single phase region: (x = -1)	p > 300 bar or p < 0.00078993 bar or at result t > 400 °C or t < 0°C
Boiling or dew curve:	or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and at result $t > t_c = 290.94$°**C** or $t < 0°C$

References: [1], [2]

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

Function Name: **t_ps_MDM**

Subroutine with function value: for call from Fortran — **REAL*8 FUNCTION TPSMDM(P,S)**
REAL*8 P,S

Subroutine with parameter: for call from DLL — **INTEGER*4 FUNCTION C_TPSMDM(T,P,S)**
REAL*8 T,P,S

Input Values:

P - Pressure p in bar

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

Result

TPSMDM, **T** or **t_ps_MDM -** Temperature t in °C

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. That means the given values of p and s are taken as a basis and the subprogram 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 the appropriate state region will be carried out.

Wet steam region: Pressure ranges from $p_s(0°C) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **T_PS_MDM**, **T = -1000** or **t_ps_MDM = -1000** for input values:

Single phase region: (x = -1) — p > 300 bar or p < 0.00078993 bar or at result t > 400 °C or t < 0°C

Boiling or dew curve: or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and at result $t > t_c = 290.94$°**C** or $t < 0°C$

References: [1], [2]

Saturation Temperature t_s = f(p)

Function Name: **ts_p_MDM**

Subroutine with function value: for call from Fortran
REAL*8 FUNCTION TSPMDM(P)
REAL*8 P

Subroutine with parameter: for call from DLL
INTEGER*4 FUNCTION C_TSPMDM(TS,P)
REAL*8 TS,P

Input Values:

P - Pressure p in bar

Result

TSPMDM, TS or ts_p_MDM – Saturation temperature t_s in °C

Range of validity

Pressure ranges from $p_s(0°C) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **TSPMDM = -1000**, **TS = -1000** or **ts_p_MDM = -1000** for input values:

$p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar

References: [1], [2]

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

Function Name: **u_ptx_MDM**

Subroutine with function value: for call from Fortran
REAL*8 FUNCTION UPTXMDM(P,T,X)
REAL*8 P,T,X

Subroutine with parameter: for call from DLL
INTEGER*4 FUNCTION C_UPTXMDM(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

UPTXMDM, **U** or **u_ptx_MDM** - Specific internal energy *u* in kJ/kg

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located in the two phase region (wet steam), either the value 0 or 1 has to be entered for *x* (x = 0 for boiling liquid, x = 1 for saturated steam). The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* between 0 and 1.

When calculating wet steam and *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Wet steam region: Temperature ranges from $t = 0°\mathrm{C}$ to $t_c = 290.94°\mathrm{C}$
Pressure ranges from $p_s(0°\mathrm{C}) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **UPTXMDM = -1000**, **U = -1000** or **u_ptx_MDM = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0,00078993 bar or
t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_c = 290.94°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_c = 14.151055$ bar
or $p < p_s(0°C) = 0.00078993$ bar or
or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and

References: [1], [2]

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

Function Name: **v_ptx_MDM**

Subroutine with function value: **REAL*8 FUNCTION VPTXMDM(P,T,X)**
for call from Fortran REAL*8 P,T,X

Subroutine with parameter: **INTEGER*4 FUNCTION C_VPTXMDM(V,P,T,X)**
for call from DLL 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

VPTXMDM, **V** or **v_ptx_MDM** – Specific volume v in m^3/kg

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located in the two phase region (wet steam), either the value 0 or 1 has to be entered for *x* (x = 0 for boiling liquid, x = 1 for saturated steam). The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* between 0 and 1.

When calculating wet steam and *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Wet steam region: Temperature ranges from $t = 0°C$ to $t_c = 290.94°C$
Pressure ranges from $p_s(0°C) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **VPTXMDM = -1000**, **V = -1000** or **v_ptx_MDM = -1000** for input values:

Single phase region: p > 300 bar or p < 0,00078993 bar or
(x = -1) t > 400 °C or t < 0°C

Wet steam region: at $p = -1000$ and $t > t_c = 290.94°C$ to $t < 0°C$
at $t = -1000$ and $p > p_c = 14.151055$ bar
or $p < p_s(0°C) = 0.00078993$ bar or
or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and

References: [1], [2]

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

Function Name: **w_ptx_MDM**

Subroutine with function value: **REAL*8 FUNCTION WPTXMDM(P,T,X)**
for call from Fortran REAL*8 P,T,X

Subroutine with parameter: **INTEGER*4 FUNCTION C_WPTXMDM(W,P,T,X)**
for call from DLL 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

WPTXMDM, **W** or **w_ptx_MDM -** Speed of sound *w* in m/s

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* between 0 and 1. When calculating wet steam and *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve.

Boiling and dew curve: Temperature ranges from $t = 0\,°\mathrm{C}$ to $t_\mathrm{c} = 290.94\,°\mathrm{C}$

Pressure ranges from $p_\mathrm{s}(0\,°\mathrm{C}) = 0.00078993\,\mathrm{bar}$ to $p_\mathrm{c} = 14.151055\,\mathrm{bar}$

Results for wrong input values

Result **WPTXMDM = -1000, W = -1000** or **w_ptx_MDM = -1000** for input values:

Single phase region: p > 300 bar or p < 0,00078993 bar or
(x = -1) t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_\mathrm{c} = 290.94\,°\mathrm{C}$ to $t < 0\,°\mathrm{C}$
at $t = -1000$ and $p > p_\mathrm{c} = 14.151055\,\mathrm{bar}$
or $p < p_\mathrm{s}(0\,°C) = 0.00078993\,\mathrm{bar}$ or
or $p > p_\mathrm{c} = 14.151055\,\mathrm{bar}$ or $p < p_\mathrm{s}(0\,°C) = 0.00078993\,\mathrm{bar}$ and

References: [1], [2]

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

Function Name: **x_ph_MDM**

Subroutine with function value: for call from Fortran
REAL*8 FUNCTION XPHMDM(P,H)
REAL*8 P,H

Subroutine with parameter: for call from DLL
INTEGER*4 FUNCTION C_XPHMDM(X,P,H)
REAL*8 X,P,H

Input Values:

P - Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

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

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. That means the given values of p and h are taken as a basis and the subprogram will determine whether the state point to be calculated is located within the single-phase region (liquid or superheated steam) or the wet steam region. In case of wet steam, x will be calculated, otherwise the result is set to x = -1.

Wet steam region: Pressure ranges from $p_s(0°C) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **X_PH_MDM**, **X =** -1 or **x_ph_MDM =** -1 for input values:

If the state point is located in the single phase region:
$p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar

References: [1], [2]

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

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

Input Values:

P - Pressure p in bar

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

Result

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

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. That means the given values of p and h are taken as a basis and the subprogram will determine whether the state point to be calculated is located within the single-phase region (liquid or superheated steam) or the wet steam region. In case of wet steam, x will be calculated, otherwise the result is set to x = -1.

Wet steam region: Pressure ranges from $p_s(0°C) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **X_PS_MDM**, **X = -1** or **x_ps_MDM = -1** for input values:

If the state point is located in the single phase region:
$p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar

References: [1], [2]

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

Function Name: **Z_ptx_MDM**

Subroutine with function value: for call from Fortran
REAL*8 FUNCTION ZPTXMDM(P,T,X)
REAL*8 P,T,X

Subroutine with parameter: for call from DLL
INTEGER*4 FUNCTION C_ZPTXMDM(Z,P,T,X)
REAL*8 Z,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

ZPTXMDM, **Z** or **Z_ptx_MDM -** Compression Factor

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00078993 bar to 300 bar

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

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

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

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for x values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x between 0 and 1. When calculating wet steam and p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve.

Boiling and dew curve: Temperature ranges from $t = 0°\mathrm{C}$ to $t_c = 290.94°\mathrm{C}$
Pressure ranges from $p_s(0°\mathrm{C}) = 0.00078993$ bar to $p_c = 14.151055$ bar

Results for wrong input values

Result **ZPTXMDM = -1000, Z = -1000** or **Z_ptx_MDM = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0,00078993 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 290.94°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_c = 14.151055$ bar
or $p < p_s(0°C) = 0.00078993$ bar or
or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and

References: [1], [2]

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:

KCE-ThermoFluidProperties UG (limited liability) & Co. KG
Professor Hans-Joachim Kretzschmar

Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
E-mail: info@thermofluidprop.com
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

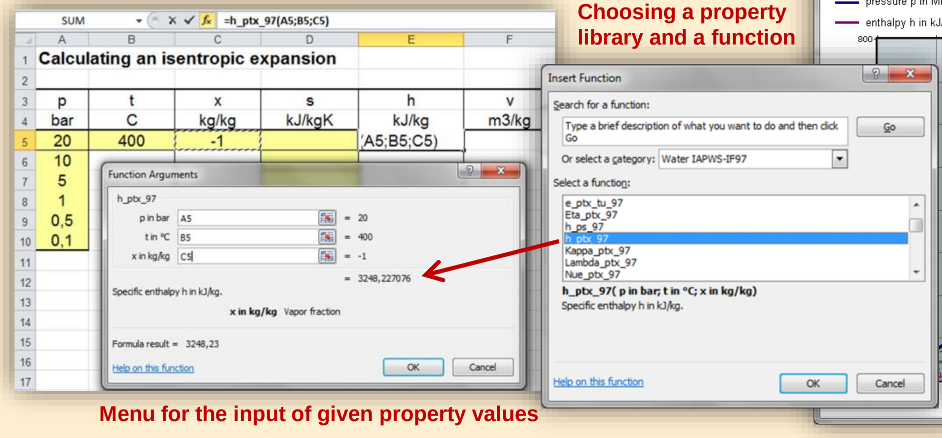
- Partial derivatives can be calculated.

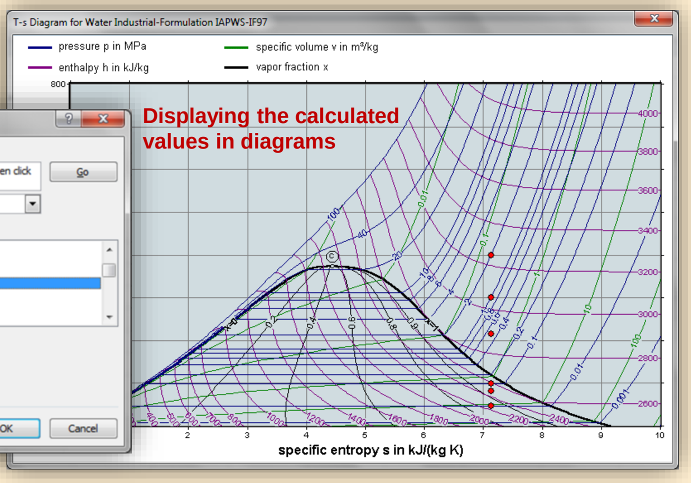
[a] Not all of these property functions are available in all property libraries.

KCE-ThermoFluidProperties
www.thermofluidprop.com

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

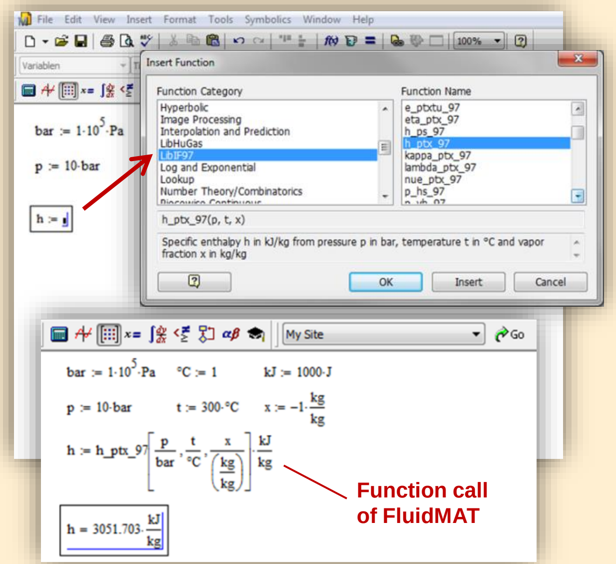
Add-In FluidEXL *Graphics* for Excel®





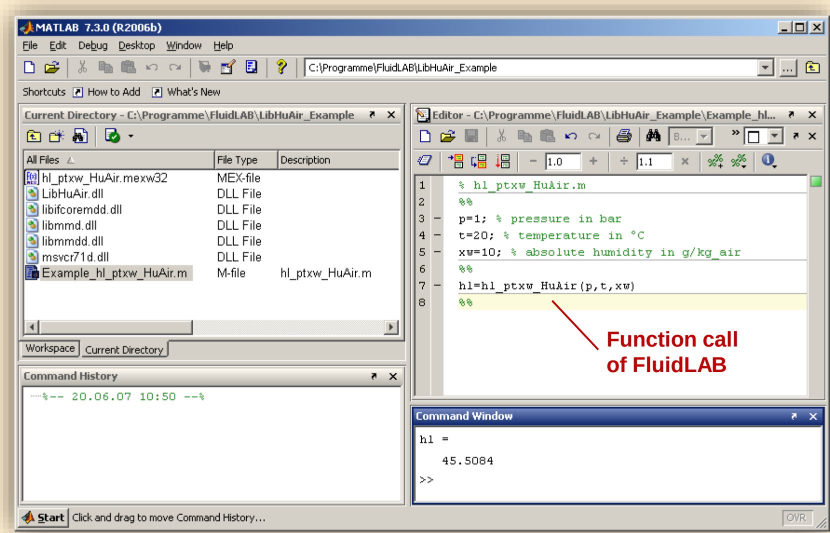
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



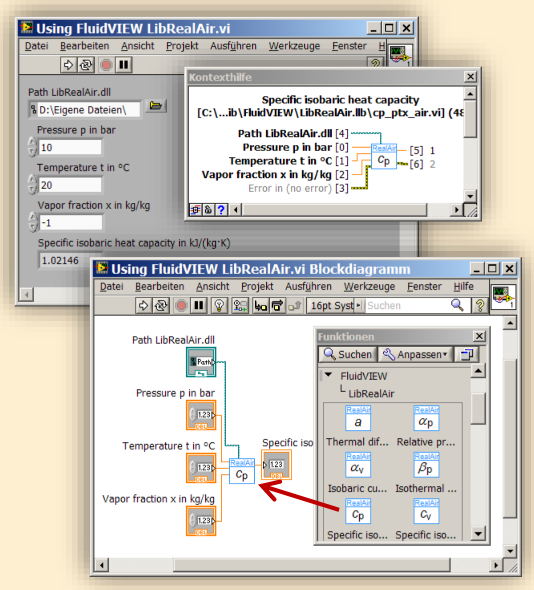
Add-In FluidLAB for MATLAB®

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



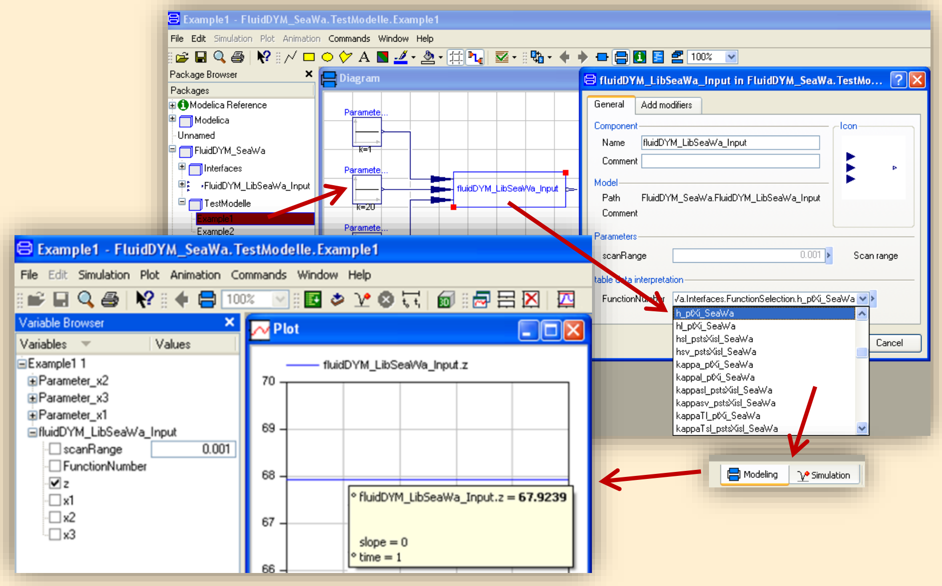
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

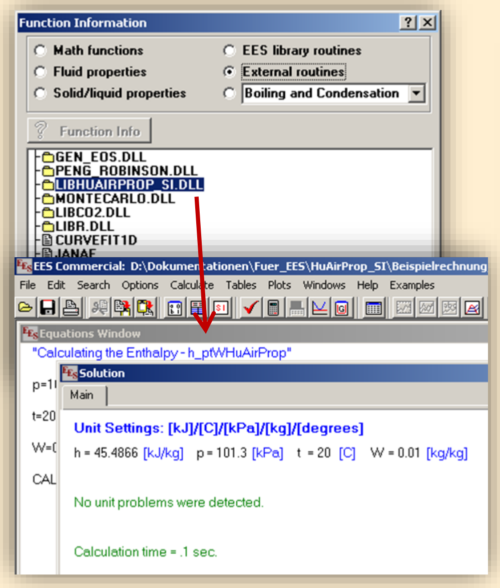


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

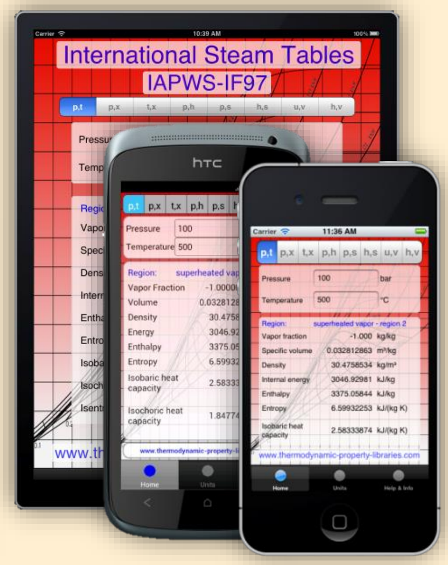
The property functions can be called in DYMOLA® and SimulationX®.



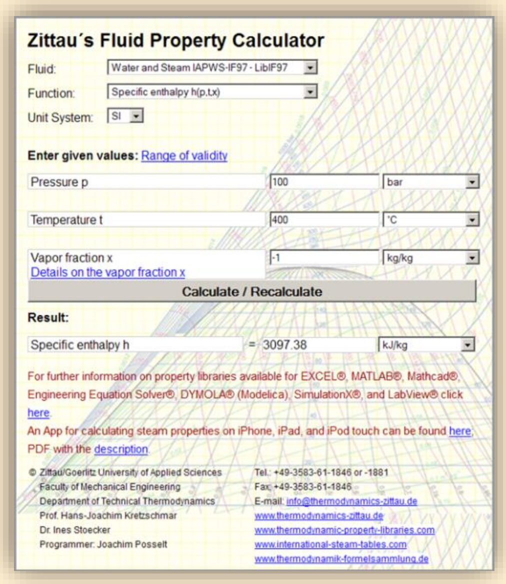
Add-In FluidEES for Engineering Equation Solver®



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:

KCE-ThermoFluidProperties UG (limited liability) & Co. KG
Professor Hans-Joachim Kretzschmar

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01307 Dresden, Germany

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E-mail: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-4262250

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

[1] Colonna, P.; Nannan, N. R.; Guardone
Multiparameter equations of state for selected siloxanes
Fluid Phase Equilibria, 263, (2008) pp. 115-130

[2] Span, R.
Multiparameter Equations of State;
An Accurate Source of Thermodynamic Property Data
Springer Verlag 2000

[3] Chung, T. H.; Ajlan, M.; Lee, L. L.; Starling, K. E.
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Industrial & Engineering Chemistry Research, 27, (1988) pp. 671-679

[4] Poling, B. E.; Prausnitz, J. M.; O'Connel, J. P.
The Properties of Gases and Liquids
McGraw-Hill, New York, 5th Edition, 2001, Chapter 9.40, 10.23

[5] Olchowy, G. A.; Sengers, J. V.
A simplified representation for the thermal conductivity of fluids in the critical region
International Journal of Thermophysics, 10, (1989) pp. 417-426

6. Satisfied Customers

Date: 05/2018

The following companies and institutions use the property libraries

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

2018

Universität Madrid, Madrid, Spanien	05/2018
HS Zittau/ Görlitz, Fakultät Wirtschaft, Zittau	05/2018
HS Niederrhein, Krefeld	05/2018
GRS, Köln	03/2018
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	02/2018
AIXPROCESS, Aachen	02/2018
KRONES, Neutraubling	02/2018
Doosan Lentjes, Ratingen	01/2018

2017

Compact Kältetechnik, Dresden	12/2017
Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	12/2017
TH Mittelhessen, Gießen	11/2017
Haarslev Industries, Søndersø, Denmark	11/2017
Hochschule Zittau/Görlitz, Fachgebiet Energiesystemtechnik	11/2017
ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	10/2017
Fels-Werke GmbH, Elbingerode	10/2017
KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik	09/2017
Air-Consult, Jena	09/2017
Papierfabrik Koehler, Oberkirch	09/2017
ZWILAG, Würenlingen, Switzerland	09/2017
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017
Fichtner IT Consulting AG, Stuttgart	07/2017
Hochschule Ansbach, Ansbach	06/2017
RONAL, Härkingen, Switzerland	06/2017
BORSIG Service, Berlin	06/2017

BOGE Kompressoren, Bielefeld	06/2017
STEAG Energy Services, Zwingenberg	06/2017
CES clean energy solutions, Wien, Austria	04/2017
Princeton University, Princeton, USA	04/2017
B2P Bio-to-Power, Wadersloh	04/2017
TU Dresden, Institute for Energy Engineering, Dresden	04/2017
SAINT-GOBAIN, Vaujours, France	03/2017
TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
SCHMIDT + PARTNER, Therwil, Switzerland	03/2017
KAESER Kompressoren, Gera	03/2017
F&R, Praha, Czech Republic	03/2017
ULT Umwelt-Lufttechnik, Löbau	02/2017
JS Energie & Beratung, Erding	02/2017
Kelvion Brazed PHE, Nobitz-Wilchwitz	02/2017
MTU Aero Engines, München	02/2017
Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	01/2017
SHELL Deutschland Oil, Wesseling	01/2017
MARTEC Education Center, Frederikshaven, Denmark	01/2017
SynErgy Thermal Management, Krefeld	01/2017

2016

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

Webasto Thermo & Comfort SE, Gliching	08/2016
TU Dresden, Dresden	08/2016
Endress+Hauser Messtechnik GmbH+Co. KG, Hannover	08/2016
D + B Kältetechnik, Althausen	07/2016
Fichtner IT Consulting AG, Stuttgart	07/2016
AB Electrolux, Krakow, Poland	07/2016
ENEXIO Germany GmbH, Herne	07/2016
VPC GmbH, Vetschau/Spreewald	07/2016
INWAT, Lodz, Poland	07/2016
E.ON SE, Düsseldorf	07/2016
Planungsbüro Waidhas GmbH, Chemnitz	07/2016
EEB Enerko, Aldershoven	07/2016
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	07/2016
SSP Kälteplaner AG, Wolfertschwenden	07/2016
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	07/2016
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
Universidad Carlos III de Madrid, Madrid, Spain	04/2016
INWAT, Lodzi, Poland	04/2016
Planungsbüro WAIDHAS GmbH, Chemnitz	04/2016
STEAG Energy Services GmbH, Laszlo Küppers, Zwingenberg	03/2016
WULFF & UMAG Energy Solutions GmbH, Husum	03/2016
FH Bielefeld, Bielefeld	03/2016
EWT Eckert Wassertechnik GmbH, Celle	03/2016
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016, 06/2016 (2x)
IEV KEMA - DNV GV – Energie, Dresden	02/2016
Allborg University, Department of Energie, Aalborg, Denmark	02/2016
G.A.M. Heat GmbH, Gräfenhainichen	02/2016
Institut für Luft- und Kältetechnik, Dresden	02/2016, 05/2016, 06/2016
Bosch, Stuttgart	02/2016
INL Idaho National Laboratory, Idaho, USA	11/2016, 01/2016
Friedl ID, Wien, Austria	01/2016
Technical University of Dresden, Dresden	01/2016

2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	12/2015
Allborg University, Department of Energie, Aalborg, Denmark	12/2015
University of Lyubljana, Slovenia	12/2015
Steinbrecht IB, Berlin	11/2015
Universidad Carlos III de Madrid, Madrid, Spain	11/2015
STEAK, Essen	11/2015

Bosch, Lohmar	10/2015
Team Turbo Machines, Rouen, France	09/2015
BTC – Business Technology Consulting AG, Oldenburg	07/2015
KIT Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen	07/2015
ILK, Dresden	07/2015
Schniewindt GmbH & Co. KG, Neuenwalde	08/2015

2014

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

2013

TRANTER-GmbH, Artern	12/2013
SATAKE, Shanghai, China	12/2013
VOITH, Kunshan, China	12/2013
ULT, Löbau	12/2013
MAN, Copenhagen, Dänemark	11/2013
DREWAG, Dresden	11/2013
Haarslev Industries, Herlev, Dänemark	11/2013
STEAG, Herne	11/2013, 12/2013
Ingersoll-Rand, Oberhausen	11/2013
Wilhelm-Büchner HS, Darmstadt	10/2013

IAV, Chemnitz	10/2013
Technical University of Regensburg	10/2013
PD-Energy, Bitterfeld	09/2013
Thermofin, Heinsdorfergrund	09/2013
SHI, New Jersey, USA	09/2013
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	08/2013
TIG-Group, Husum	08/2013
COMPAREX, Leipzig	08/2013, 11/2013
for RWE Essen	12/2013
University of Budapest, Hungary	08/2013
Siemens, Frankenthal	08/2013, 10/2013
	11/2013
VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
Technical University of Deggendorf	07/2013
University of Maryland, USA	07/2013, 08/2013
University of Princeton, USA	07/2013
NIST, Boulder, USA	06/2013
IGUS GmbH, Dresden	06/2013
BHR Bilfinger, Essen	06/2013
SÜDSALZ, Bad Friedrichshall	06/2013, 12/2013
Technician School of Berlin	05/2013
KIER, Gajeong-ro, Südkorea	05/2013
Schwing/Stetter GmbH, Memmingen	05/2013
Vattenfall, Berlin	05/2013
AUTARK, Kleinmachnow	05/2013
STEAG, Zwingenberg	05/2013
Hochtief, Düsseldorf	05/2013
University of Stuttgart	04/2013
Technical University -Bundeswehr, Munich	04/2013
Rerum Cognitio Forschungszentrum, Frankfurt	04/2013
Kältetechnik Dresen + Bremen, Alfhausen	04/2013
University Auckland, New Zealand	04/2013
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Technical University of Wismar	02/2013
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ILK, Dresden	01/2013, 08/2013
Fichtner IT, Stuttgart	01/2013, 11/2013
Schnepf Ingeniuerbüro, Nagold	01/2013
Schütz Engineering, Wadgassen	01/2013
Endress & Hauser, Reinach, Switzerland	01/2013
Oschatz GmbH, Essen	01/2013
frischli Milchwerke, Rehburg-Loccum	01/2013

2012

Voith, Bayreuth	12/2012
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University of Stuttgart	11/2012
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GKS, Schweinfurt	07/2012
COMPAREX, Leipzig for RWE Essen	07/2012
GEA, Nobitz	07/2012
Meyer Werft, Papenburg	07/2012
STEAG, Herne	07/2012
GRS, Cologne	06/2012
Fichtner IT Consult, Chennai, India	06/2012
Siemens, Freiburg	06/2012
Nikon Research of America, Belmont, USA	06/2012
Niederrhein University of Applied Sciences, Krefeld	06/2012
STEAG, Zwingenberg	06/2012
Mainova, Frankfurt on Main via Fichtner IT Consult	05/2012
Endress & Hauser	05/2012
PEU, Espenheim	05/2012
Luzern University of Applied Sciences, Switzerland	05/2012

BASF, Ludwigshafen (general license) via Fichtner IT Consult	05/2012
SPX Balcke-Dürr, Ratingen	05/2012, 07/2012
Gruber-Schmidt, Wien, Austria	04/2012
Vattenfall, Berlin	04/2012
ALSTOM, Baden	04/2012
SKW, Piesteritz	04/2012
TERA Ingegneria, Trento, Italy	04/2012
Siemens, Erlangen	04/2012, 05/2012
LAWI Power, Dresden	04/2012
Stadtwerke Leipzig	04/2012
SEITZ, Wetzikon, Switzerland	03/2012, 07/2012
M & M, Bielefeld	03/2012
Sennheiser, Wedemark	03/2012
SPG, Montreuil Cedex, France	02/2012
German Destilation, Sprendlingen	02/2012
Lopez, Munguia, Spain	02/2012
Endress & Hauser, Hannover	02/2012
Palo Alto Research Center, USA	02/2012
WIPAK, Walsrode	02/2012
Freudenberg, Weinheim	01/2012
Fichtner, Stuttgart	01/2012
airinotec, Bayreuth	01/2012, 07/2012
University Auckland, New Zealand	01/2012
VPC, Vetschau	01/2012
Franken Guss, Kitzingen	01/2012

2011

XRG-Simulation, Hamburg	12/2011
Smurfit Kappa PPT, AX Roermond, Netherlands	12/2011
AWTEC, Zurich, Switzerland	12/2011
eins-energie, Bad Elster	12/2011
BeNow, Rodenbach	11/2011
Luzern University of Applied Sciences, Switzerland	11/2011
GMVA, Oberhausen	11/2011
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	10/2011
PLANAIR, La Sagne, Switzerland	10/2011
LAWI, Dresden	10/2011
Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011

Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010

University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010
Vaillant, Remscheid	10/2010
PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
Saacke, Bremen	09/2010
WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	08/2010
ERGION, Mannheim	07/2010
Fichtner IT Consulting, Stuttgart	07/2010
TF Design, Matieland, South Africa	07/2010
MCE, Berlin	07/2010, 12/2010
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	06/2010
RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010
Universitaet der Bundeswehr, Munich	04/2010

Technical University of Hamburg-Harburg	04/2010
Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
VER, Dresden	04/2010
CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
Technical University of Dresden	02/2010
Siemens Energy, Nuremberg	02/2010
Augsburg University of Applied Sciences	02/2010
ALSTOM Power, Baden, Switzerland	02/2010, 05/2010
MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	01/2010, 12/2010
Technical University of Freiberg	01/2010
ILK, Dresden	01/2010, 12/2010
Fischer-Uhrig Consulting Engineers, Berlin	01/2010

2009

ALSTOM Power, Baden, Schweiz	01/2009, 03/2009
	05/2009
Nordostschweizerische Kraftwerke AG, Doettingen, Switzerland	02/2009
RWE, Neurath	02/2009
Brandenburg University of Technology, Cottbus	02/2009
Hamburg University of Applied Sciences	02/2009
Kehrein, Moers	03/2009
EPP Software, Marburg	03/2009
Bernd Münstermann, Telgte	03/2009
Suedzucker, Zeitz	03/2009
CPP, Marburg	03/2009
Gelsenkirchen University of Applied Sciences	04/2009
Regensburg University of Applied Sciences	05/2009
Gatley & Associates, Atlanta, USA	05/2009
BOSCH, Stuttgart	06/2009, 07/2009
Dr. Nickolay, Consulting Engineers, Gommersheim	06/2009
Ferrostal Power, Saarlouis	06/2009
BHR Bilfinger, Essen	06/2009
Intraserv, Wiesbaden	06/2009
Lausitz University of Applied Sciences, Senftenberg	06/2009
Nuernberg University of Applied Sciences	06/2009

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Fraunhofer Institut UMSICHT, Oberhausen	07/2009
Bischoff, Aurich	07/2009
Fichtner IT Consulting, Stuttgart	07/2009
Techsoft, Linz, Austria	08/2009
DLR, Stuttgart	08/2009
Wienstrom, Vienna, Austria	08/2009
RWTH Aachen University	09/2009
Vattenfall, Hamburg	10/2009
AIC, Chemnitz	10/2009
Midiplan, Bietigheim-Bissingen	11/2009
Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
FZD, Rossendorf	11/2009
Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
EC, Heidelberg	11/2009
MCI, Innsbruck, Austria	12/2009
Saacke, Bremen	12/2009
ENERKO, Aldenhoven	12/2009

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Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	01/2008
University of Karlsruhe	01/2008
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Lentjes, Ratingen	03/2008
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CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
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

Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008
Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

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Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
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Redacom, Nidau, Switzerland	02/2007
Universität der Bundeswehr, Munich	02/2007
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University of Rostock, Chair in Technical Thermodynamics	03/2007
AGO, Kulmbach	03/2007
University of Stuttgart, Chair in Aviation Propulsions	03/2007
Siemens Power Generation, Duisburg	03/2007
ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
Technical University of Cottbus, Chair in Power Plant Engineering	06/2007
Voith Paper Air Systems, Bayreuth	06/2007
Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
National Energy Technology Laboratory, Pittsburg, USA	10/2007
Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007

Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

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STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006
Technical University of Munich, Chair in Apparatus and Plant Engineering	02/2006
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Department of USET Merseburg incorporated society	05/2006
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Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
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ThyssenKrupp Marine Systems, Kiel	07/2006

Caliqua, Basel, Switzerland (company license)	09/2006
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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

2005

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
Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
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Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

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Technical University of Freiberg, Chair in Hydrogeology	11/2005
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Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
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University of Saarbruecken	04/2004
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HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
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Enertech EUT, Radebeul (company license)	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
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2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003

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

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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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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SaarEnergie, Saarbruecken	05/2001
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Neusiedler AG, Ulmerfeld, Austria	09/2001

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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
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Compania Electrica, Bogota, Colombia	10/2000
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Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
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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
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B+H Software Engineering Stuttgart	08/1998
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SCA Hygiene Products, Munich	10/1998
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Energieversorgung, Offenbach	11/1998

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Gerb, Dresden	06/1997
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