

**Property Library for
Dodecamethyl-
pentasiloxane (MD3M)
 $\text{C}_{12}\text{H}_{36}\text{Si}_5\text{O}_4$**

**FluidLAB
with LibMD3M
for MATLAB®**

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**Property Library for the Calculation
of Dodecamethylpentasiloxane (MD3M)
FluidLAB for MATLAB®
LibMD3M**

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0. Package Contents

Zip-file "CD_FluidLAB_LibMD3M.zip" including the following files:

- | | |
|----------------------------|--|
| FluidLAB_LibMD3M_Setup.exe | - Installation program for the FluidLAB Add-On
for use in MATLAB® |
| LibMD3M.dll | - DLL with functions of the LibMD3M library |

Documentation

- | | |
|-------------------------------|----------------|
| FluidLAB_LibMD3M_Docu_Eng.pdf | - User's Guide |
|-------------------------------|----------------|

1. Property Functions

1.1 Calculation Programs

"MD3M" means Dodecamethylpentasiloxane ($\text{C}_{12}\text{H}_{36}\text{Si}_5\text{O}_4$)

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibMD3M as parameter	Property or Function	Unit of the result
$c_p = f(p, t, x)$	cp_ptx_MD3M	CPPTXMD3M(P,T,X)	C_CPPTXMD3M(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p, t, x)$	cv_ptx_MD3M	CVPTXMD3M(P,T,X)	C_CVPTXMD3M(CV,P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\left(\frac{\partial p}{\partial T}\right)_v = f(p, t, x)$	dpdvt_ptx_MD3M	DPDTVMD3M(P,T,X)	C_DPDTVMD3M(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_MD3M	DPDVTMD3M(P,T,X)	C_DPDVTMD3M(DPDV,P,T,X)	Derivative of pressure with respect to specific volume (at constant temperature)	kPa/(m ³ /kg)
$h = f(p, t, x)$	h_ptx_MD3M	HPTXMD3M(P,T,X)	C_HPTXMD3M(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p, t, x)$	kappa_ptx_MD3M	KAPPAPTMD3M(P,T,X)	C_KAPPAPTMD3M(KAPPA,P,T,X)	Isentropic exponent	-
$p_s = f(t)$	ps_t_MD3M	PSTMD3M(T)	C_PSTMD3M(PS,T)	Vapor pressure from temperature	bar
$\rho = f(p, t, x)$	rho_ptx_MD3M	RHOPTXMD3M(P,T,X)	C_RHOPTXMD3M(RHO,P,T,X)	Density	kg/m ³
$s = f(p, t, x)$	s_ptx_MD3M	SPTXMD3M(P,T,X)	C_SPTXMD3M(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p, h)$	t_ph_MD3M	TPHMD3M(P,H)	C_TPHMD3M(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p, s)$	t_ps_MD3M	TPSMD3M(P,S)	C_TPSMD3M(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_MD3M	TSPMD3M(P)	C_TSPMD3M(TS,P)	Saturation temperature from pressure	°C
$u = f(p, t, x)$	u_ptx_MD3M	UPTXMD3M(P,T,X)	C_UPTXMD3M(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p, t, x)$	v_ptx_MD3M	VPTXMD3M(P,T,X)	C_VPTXMD3M(V,P,T,X)	Specific volume	m ³ /kg
$w = f(p, t, x)$	w_ptx_MD3M	WPTXMD3M(P,T,X)	C_WPTXMD3M(W,P,T,X)	Isentropic speed of sound	m/s
$x = f(p, h)$	x_ph_MD3M	XPMD3M(P,H)	C_XPHMD3M(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibMD3M as parameter	Property or Function	Unit of the result
$x = f(p, s)$	x_ps_MD3M	XPSMD3M(P,S)	C_XPSMD3M(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
$Z = f(p, t, x)$	Z_ptx_MD3M	ZPTXMD3M(P,T,X)	C_ZPTXMD3M(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 $t = 0^\circ\text{C}$ to 400°C Pressure range: from $p = 0.0000048971$ bar to 300 bar**Reference state** $h = 0$ kJ/kg and $s = 0$ kJ/(kg K) at $t_B = 229.88^\circ\text{C}$ 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.

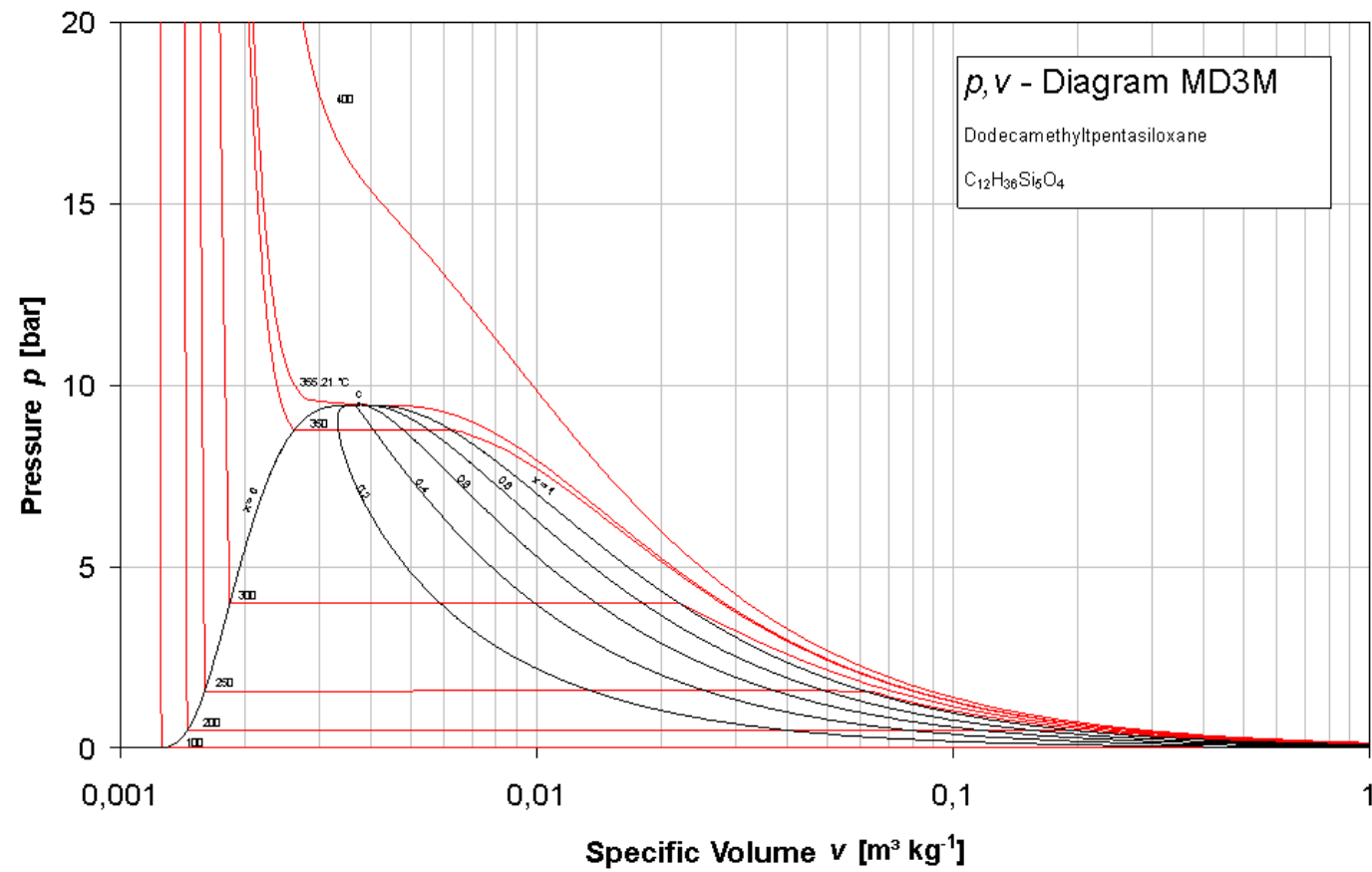
If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in -1000 .

Wet steam region: Temperature range from $t = 0\text{ °C}$ to $t_c = 355.21\text{ °C}$
 Pressure range from $p_s (0\text{ °C}) = 0.00078994\text{ bar}$ to $p_c = 9.45229\text{ bar}$

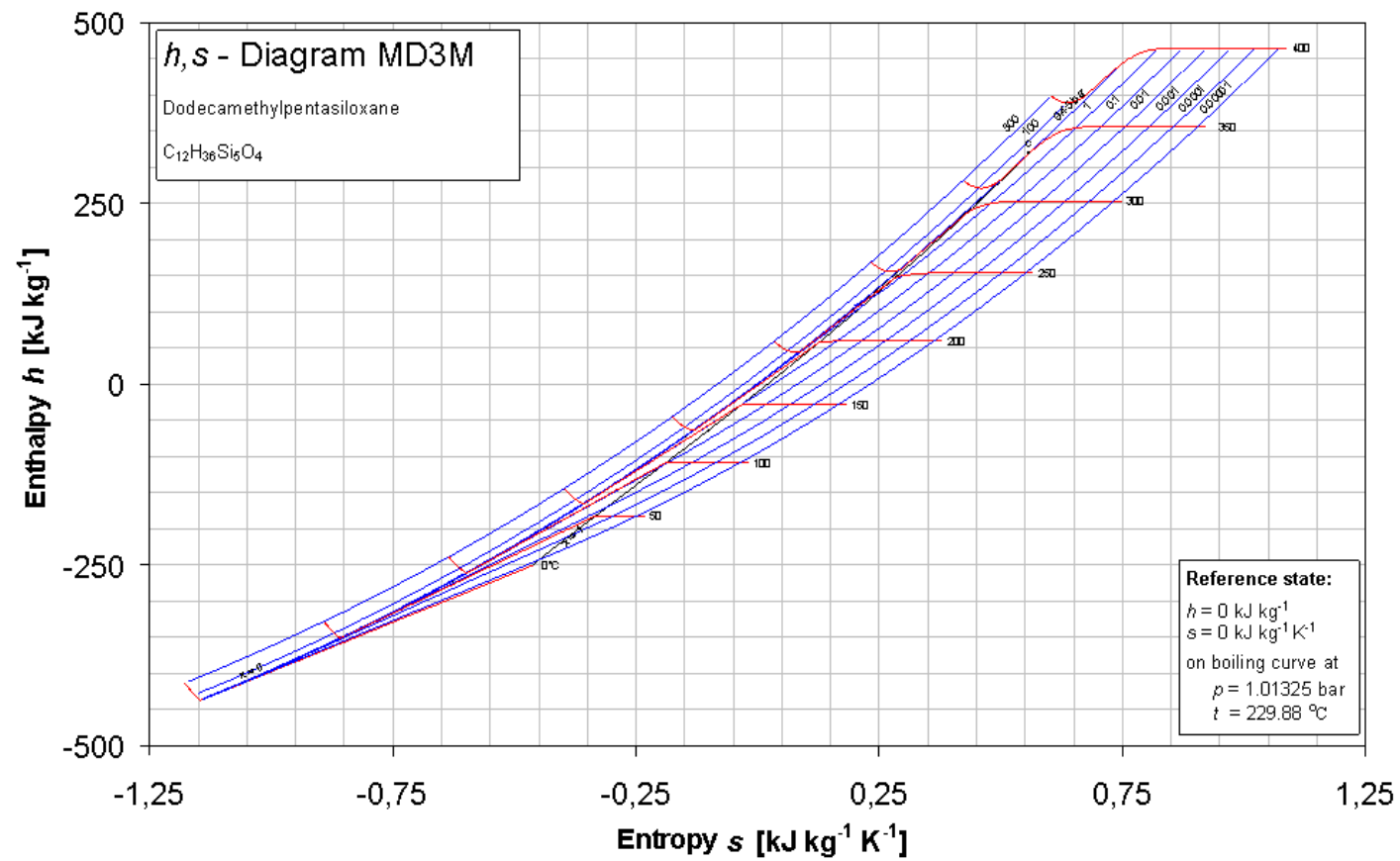
Note.

If the calculation results in -1000 , the values entered represent a state point beyond the range of validity of MD3M. 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.

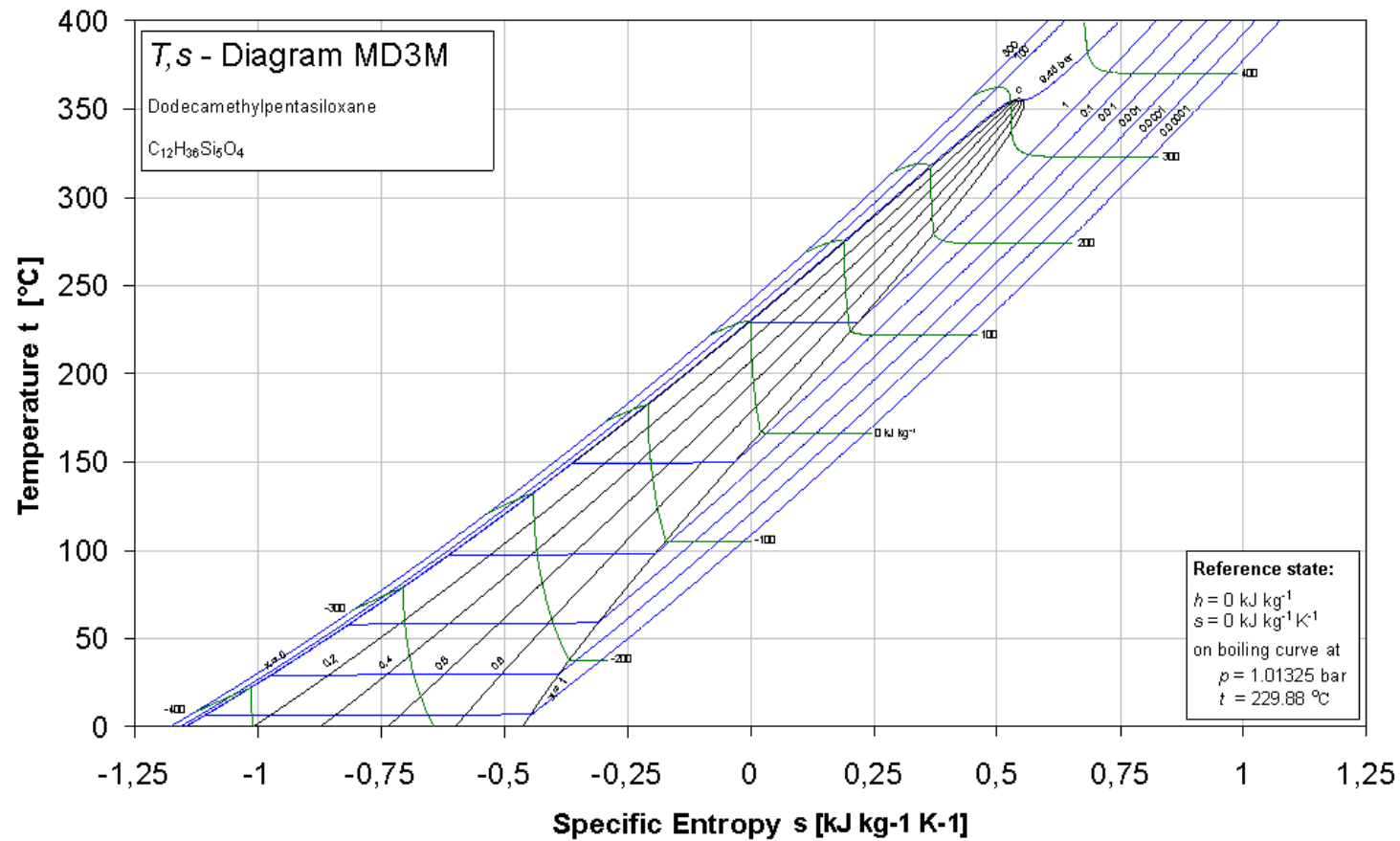
1.2 p,v-Diagram



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 Dodecamethylpentasiloxane from the LibMD3M property library.

2.1 Installing FluidLAB including LibMD3M

This section describes the installation of FluidLAB including the LibMD3M 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_LibMD3M.zip", you will see the folder

CD_FluidLAB_LibMD3M

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_LibMD3M_Docu_Eng.pdf

FluidLAB_LibMD3M_Setup.exe

LibMD3M.dll.

In order to run the installation of FluidLAB including the LibMD3M property library, double-click on the file

FluidLAB_LibMD3M_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\LibMD3M

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

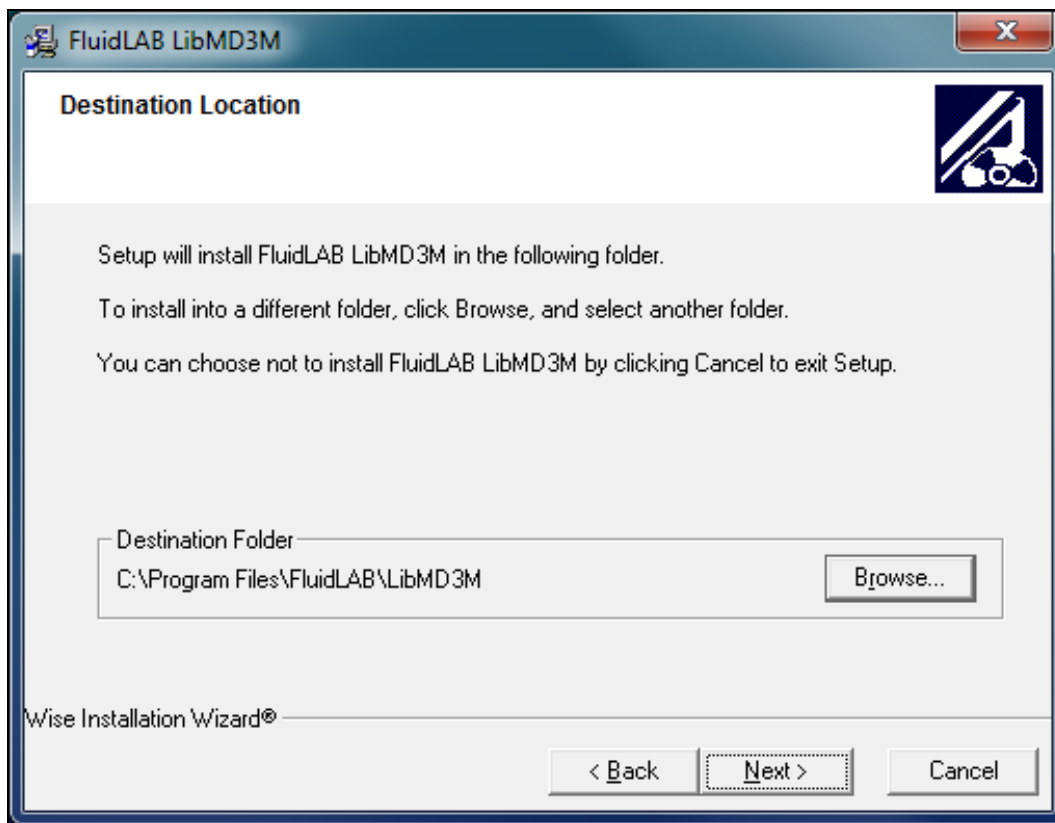


Figure 2.1: "Destination Location"

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 LibMD3M into the directory "C:\Program Files\FuildLAB\LibMD3M":

advapi32.dll	LibMD3M.dll
Dformd.dll	msvc60.dll
Dforrt.dll	msvcrt.dll
INSTALL.LOG	Unwise.exe
LC.dll	Unwise.ini

- MATLAB®-Interface-Program for calculable functions

cp_ptx_MD3M	t_ph_MD3M
cv_ptx_MD3M	t_ps_MD3M
dpdtv_ptx_MD3M	ts_p_MD3M
dpdvt_ptx_MD3M	u_ptx_MD3M
h_ptx_MD3M	v_ptx_MD3M
Kappa_ptx_MD3M	w_ptx_MD3M
ps_t_MD3M	x_ph_MD3M
rho_ptx_MD3M	x_ps_MD3M
s_ptx_MD3M	Z_ptx_MD3M

Now, you have to overwrite the file "LibMD3M.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 "LibMD3M.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\FuildLAB\LibMD3M) and insert the file "LibMD3M.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 "LibMD3M.dll" successfully and the property functions are available in MATLAB®.

Licensing the LibMD3M 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 LibMD3M (see figure below).

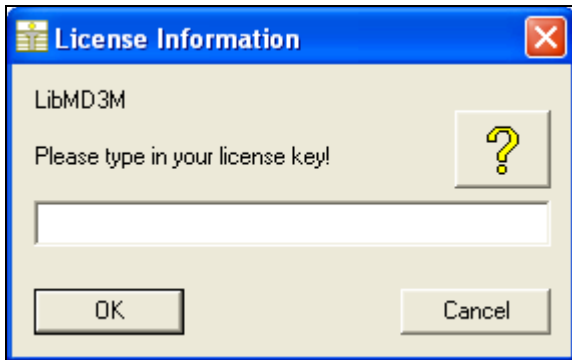


Figure 2.2: "License Information" window

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:

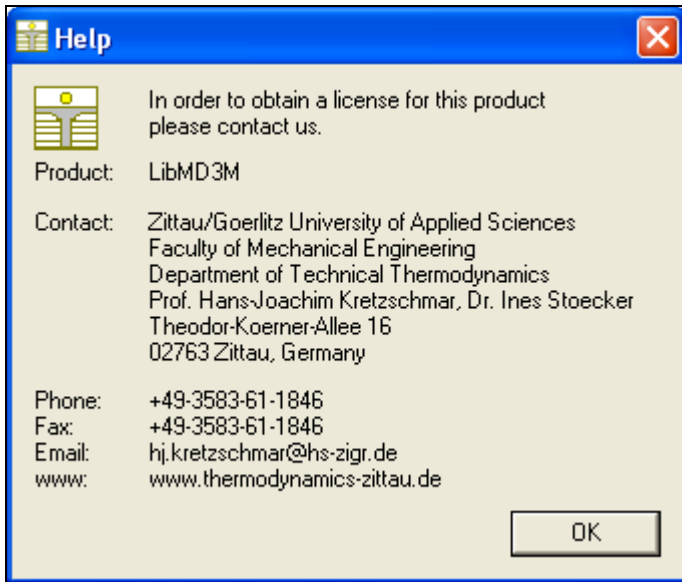


Figure 2.3: "Help" window

If you do not enter a valid license it is still possible to use MATLAB® by clicking "Cancel". In this case, the LibMD3M property library will display the result "-11111111" for every calculation.

The "License Information" window will appear every time you use FluidLAB LibMD3M until you enter a license code to complete registration. If you decide not to use FluidLAB LibMD3M, 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 "\LibMD3M"; it is generally saved under: "C:\Program Files\FluidLAB"
- Create the folder "\LibMD3M_Example" by clicking on "File" in the Explorer® menu, then "New" in the menu which appears and afterwards selecting "Folder". Name the new folder "\LibMD3M_Example."
- You will now see the following window:

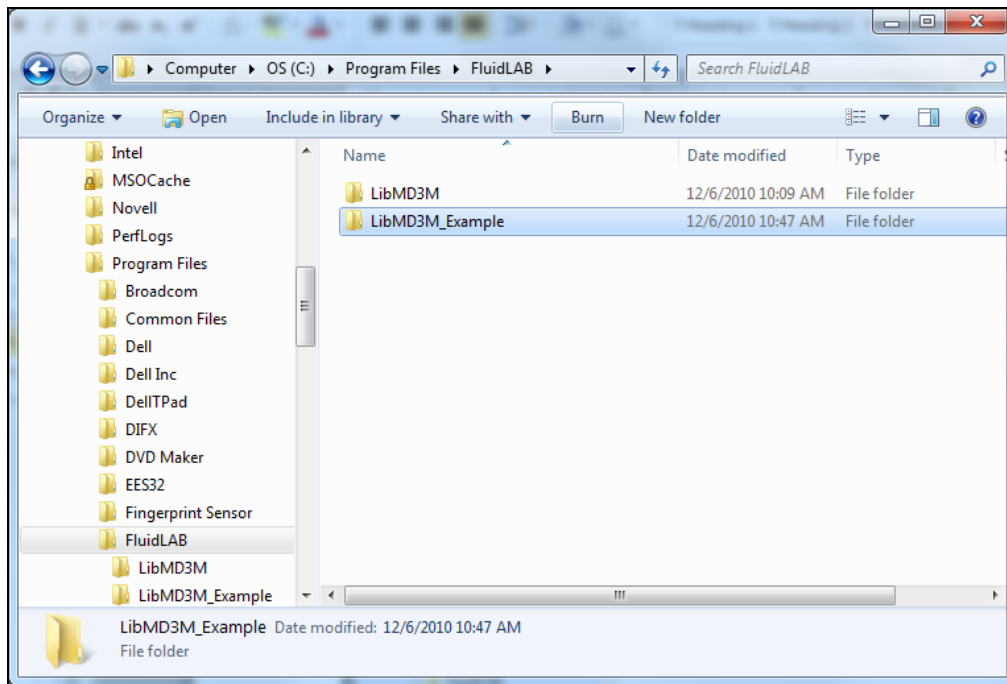


Figure 2.4: Folders "LibMD3M" and "LibMD3M_Example"

- Switch into the directory "\LibMD3M" within "\FluidLAB", the standard being "C:\Program Files\FluidLAB\LibMD3M."

- You will see the following window:

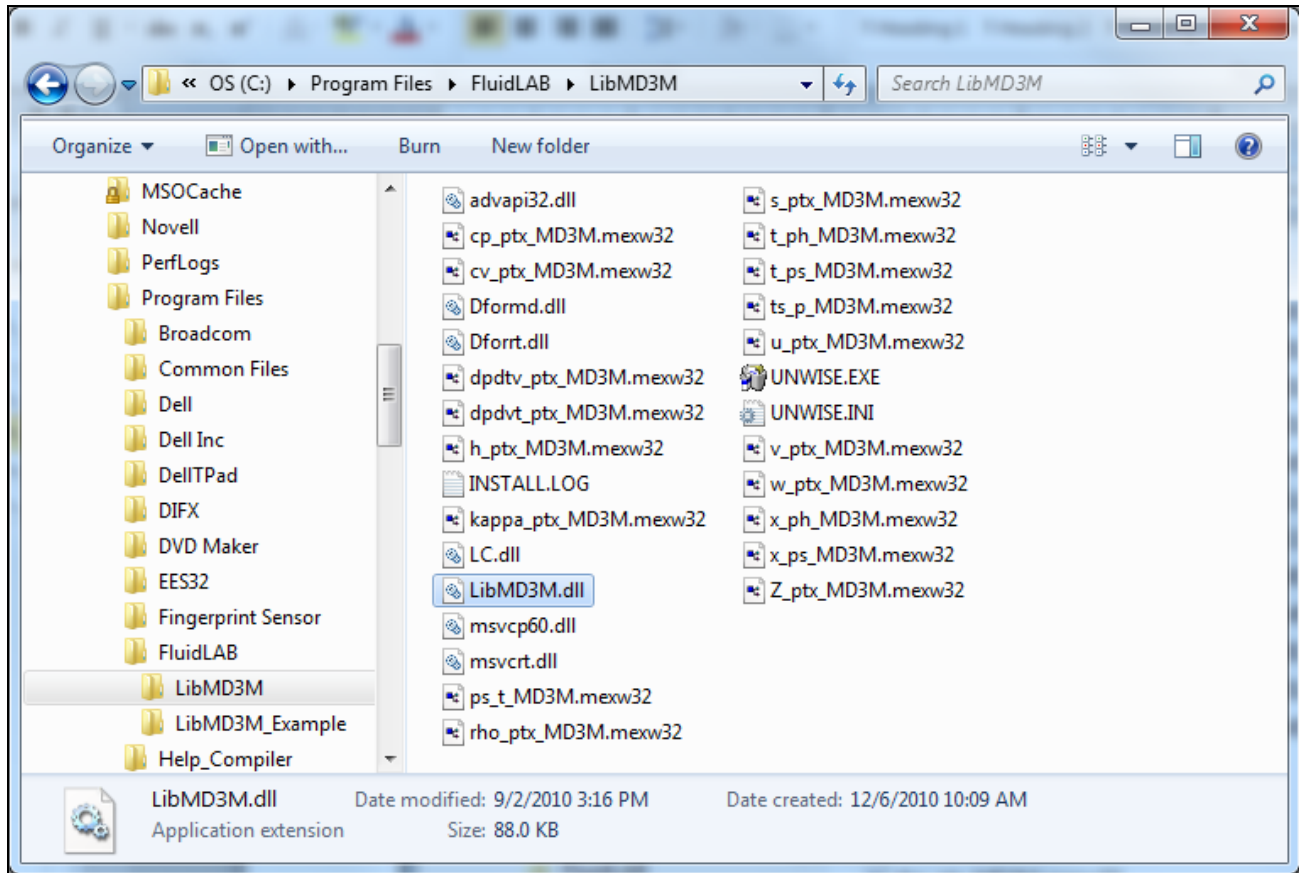


Figure 2.5: Contents of the folder "LibMD3M"

You will now have to copy the following files into the directory "C:\Program Files\FluidLAB\LibMD3M_Example" in order to calculate the function $h = f(p, t, x)$.

- The following eight files are needed:
 - "advapi32.dll"
 - "Dformd.dll"
 - "Dforrt.dll"
 - "h_ptx_MD3M.mexw32"
 - "LC.dll"
 - "LibMD3M.dll"
 - "msvc60.dll"
 - "msvcrt.dll."
- Click the file "h_ptx_MD3M.mexw32", then click "Edit" in the upper menu bar and select "Copy".
- Switch into the directory "C:\Program Files\FluidLAB\LibMD3M_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:

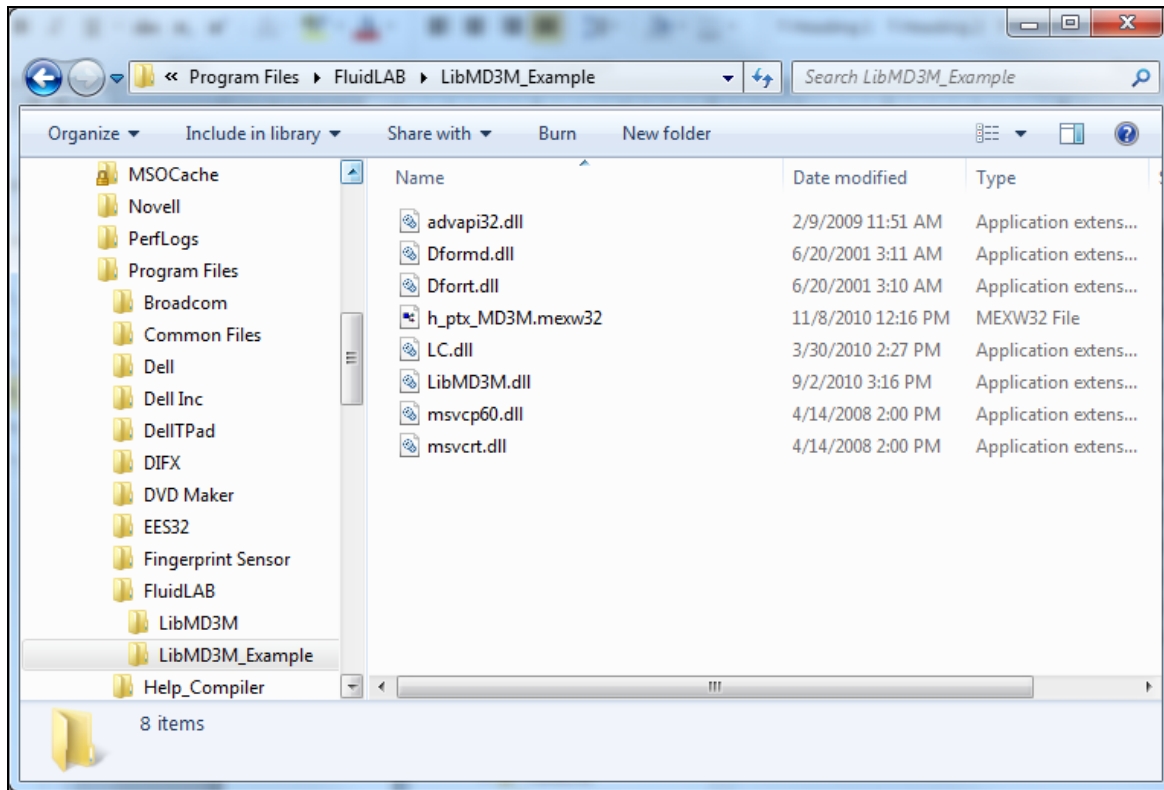


Figure 2.6: Contents of the folder "LibMD3M_Example"

- Start MATLAB® (if you have not started it before).
- Click the button marked in the next figure in order to open the folder "LibMD3M_Example" in the "Current Folder" window.

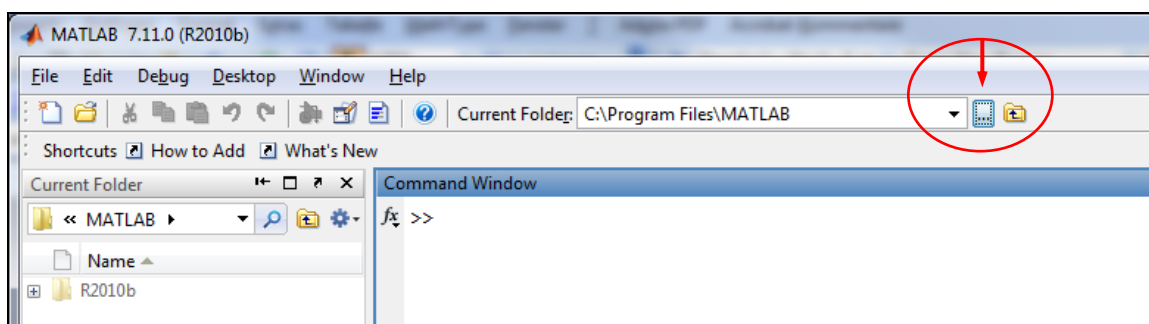


Figure 2.7: Selection of the working directory

- Find and select the directory "C:\Program Files\FluidLAB\LibMD3M_Example" in the pop-up menu (see the following image).

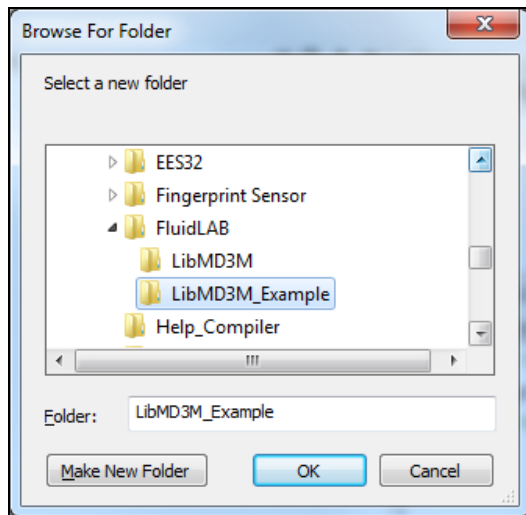


Figure 2.8: Choosing the "LibMD3M_Example" folder

- 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.

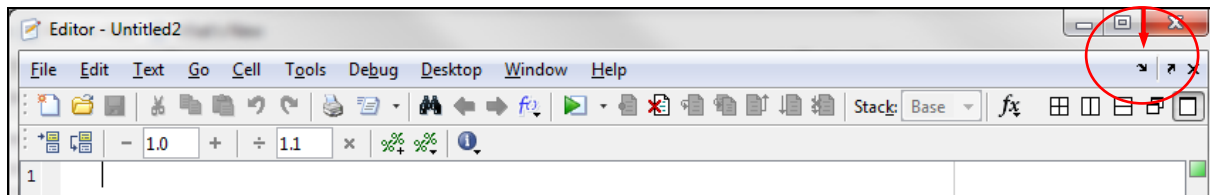


Figure 2.9: Embedding the "Editor" window

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

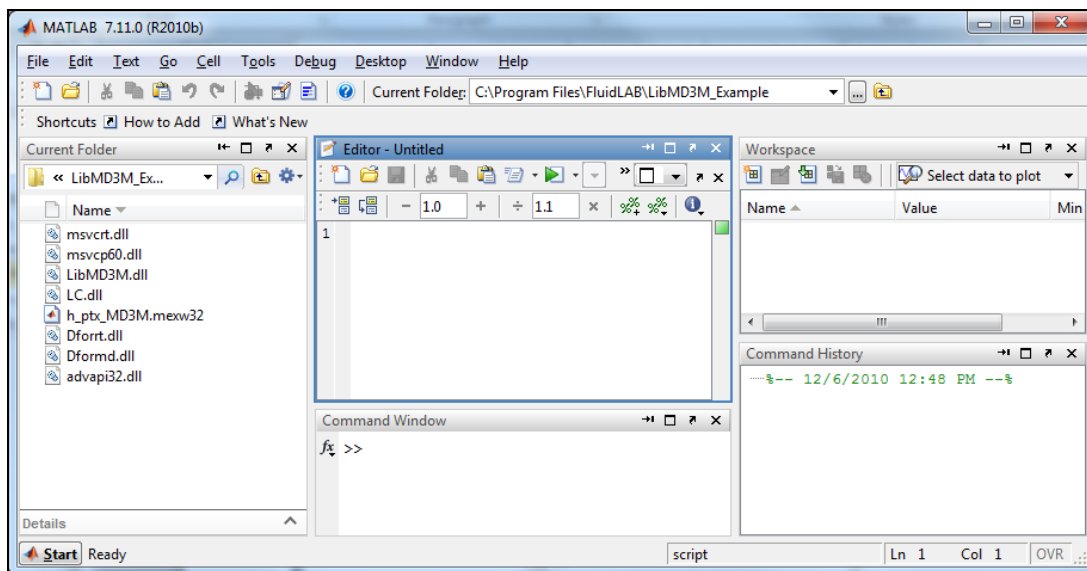


Figure 2.10: Embedded "Editor" window

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

Text to be written:	Explanation:
<code>% h_ptx_MD3M.m</code>	file name as comment
<code>%%</code>	paragraph separation
<code>p=10; % pressure in bar</code>	declaration of the
<code>t=300; % temperature in °C</code>	variables pressure,
<code>x=-1; % vapor fraction in kg/kg</code>	temperature, art and
<code>%%</code>	composition of mixture
<code>h=h_ptx_MD3M(p,t,x)</code>	paragraph separation
<code>%%</code>	function call
<code>%%</code>	paragraph separation

- Remarks:

- The program interprets the first line, starting with "%," to be a data description in "Current Directory."
- Paragraph separations which are mandatory are marked with "%%". This also serves to separate the declaration of variables and calculation instructions.
- The words which are printed in green, start with "%" and come after the variables are comments. They are not in fact absolutely necessary, but they are very helpful for your overview and to make the process more easily understood.
- Omit the semicolons after the numerical values if you wish to see the result for h and the input parameters.

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

- First operand: Value for $p = 10$
(Range of validity: $p = 0.00001 \text{ bar}$ to 300 bar)
- Second operand: Value for $t = 300 \text{ °C}$
(Range of validity: $t = 26.85 \text{ °C}$ to 399.85 °C)
- Third operand: Value for $x = -1 \text{ kg/kg}$

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

Single-phase region

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

Wet-steam region

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

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

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

(MD3M Saturation pressure curve:

$$t = 0\text{ }^{\circ}\text{C} \text{ to } t_c = 355.21\text{ }^{\circ}\text{C}$$

$$p_s(0\text{ }^{\circ}\text{C}) = 0.00078994\text{ bar to } p_c = 9.45229\text{ bar})$$

- 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 "LibMD3M_Example" must be displayed in the "Save in:" field.
- Next to "File name" you have to type "Example_h_ptx_MD3M.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_MD3M.m" in this case. Otherwise an error message will appear during the calculation.

- You will now see the following window:

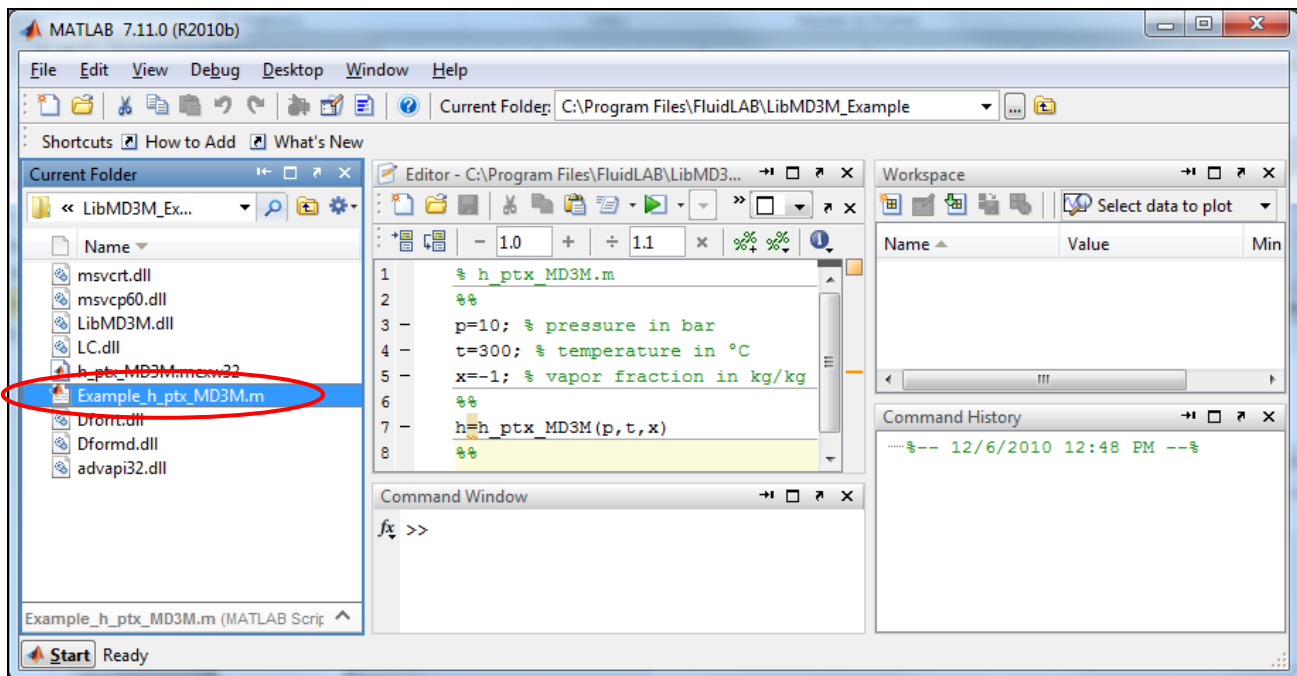


Figure 2.11: "Example_h_ptx_MD3M.m" M-file

- Within the "Current Folder" window, the file "Example_h_ptx_MD3M.m" appears.
- Right-click on this file and select "Run" in the menu which appears (see next image).

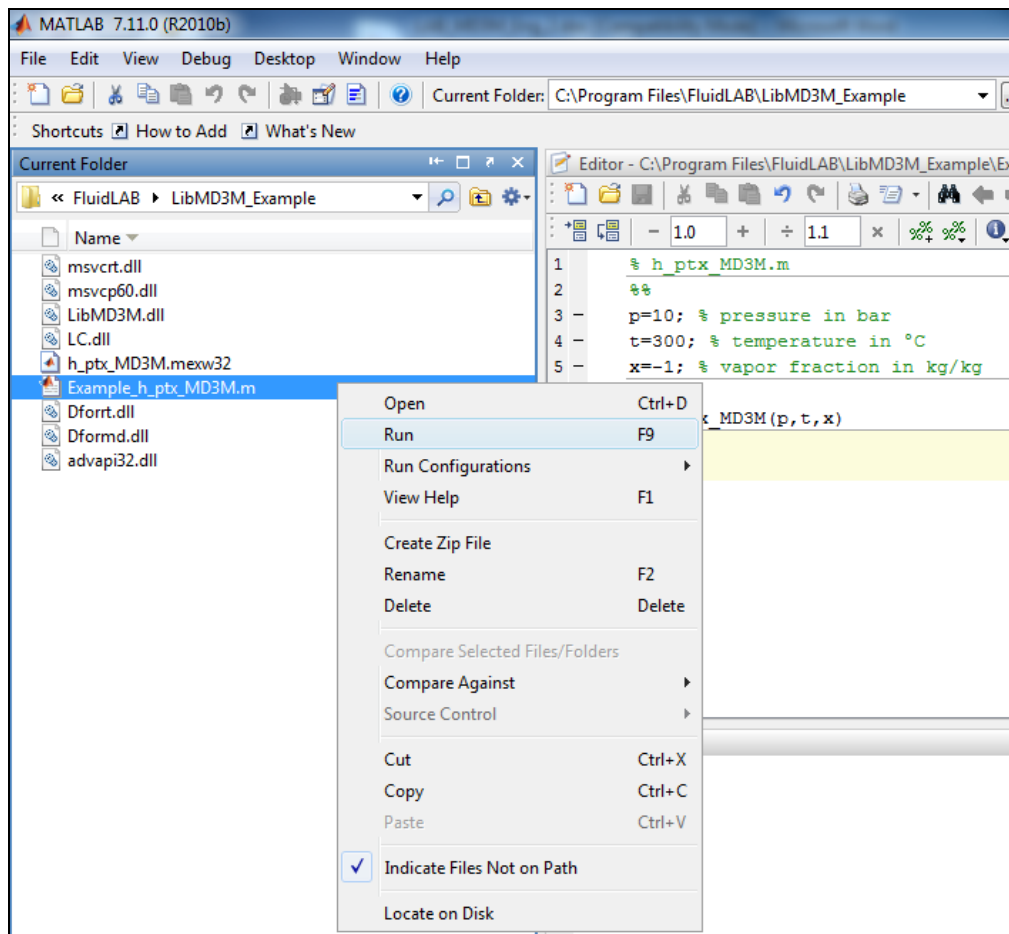


Figure 2.12: Running the "Example_h_ptx_MD3M.m" M-file

- You will see the following window:

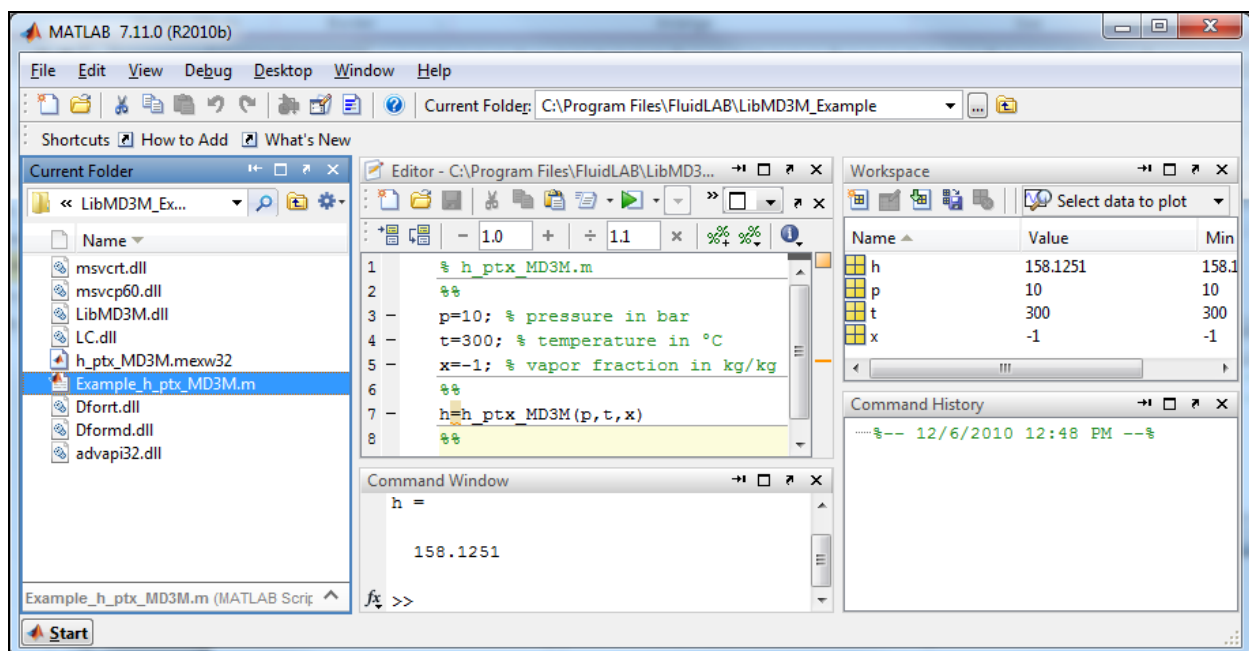


Figure 2.13: MATLAB® with calculated result

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

⇒ The result in our sample calculation here is: " $h = 158.1251$ ". 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\LibMD3M_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 "\LibMD3M_Example" in the window "Current Folder."

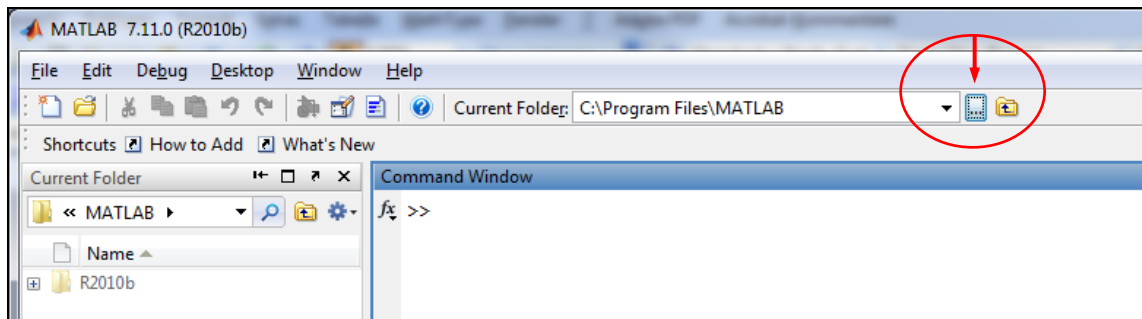


Figure 2.14: Selection of the working directory

- Find and select the directory "C:\Program Files\FluidLAB\LibMD3M_Example" in the pop-up menu (see the following image).

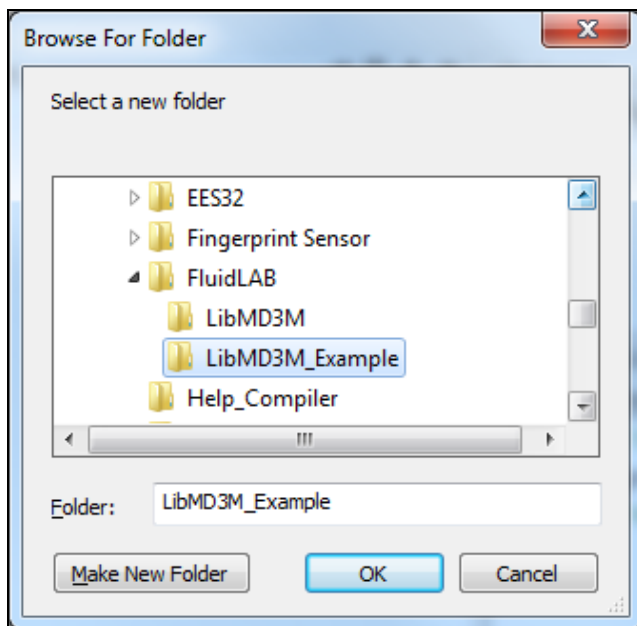


Figure 2.15: Choosing the "LibMD3M_Example" folder

- Confirm your selection by clicking the "OK" button.

- You will see the following window:

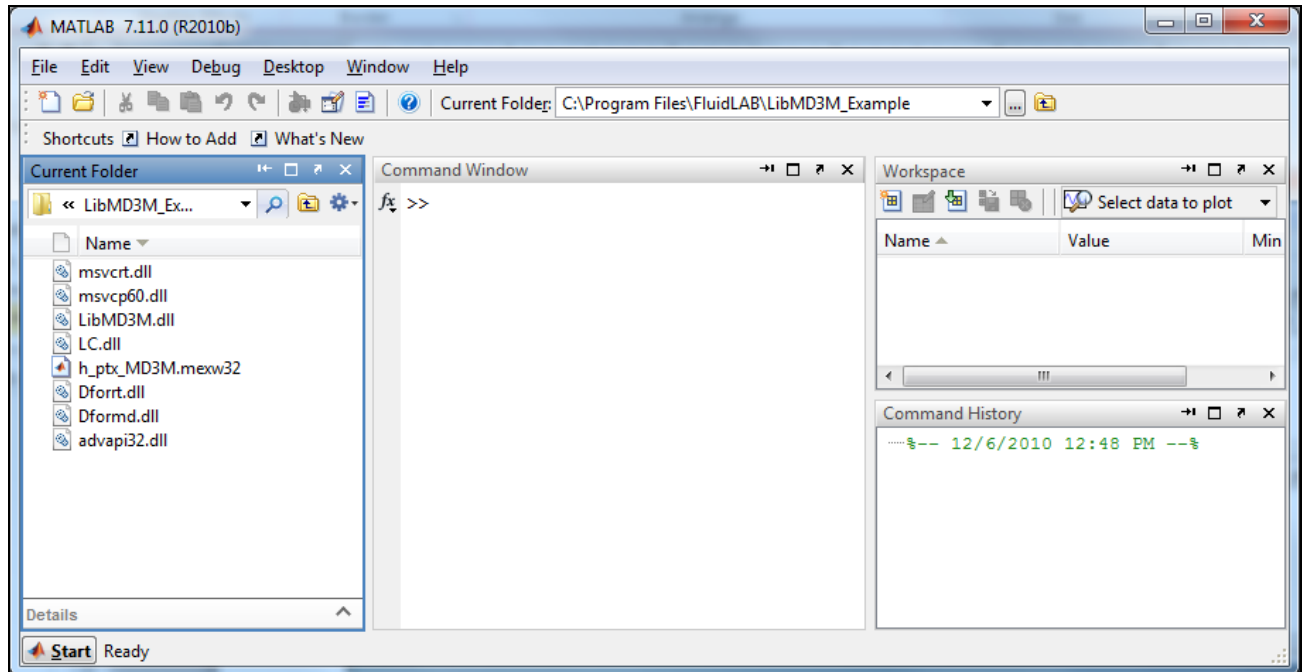


Figure 2.16: MATLAB® with necessary files

Corresponding to the table of the property functions in Chapter 1 you have to call up the function "**h_ptx_MD3M**" as follows for calculating $h = f(p, t, x)$.

Write "**h=h_ptx_MD3M(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: $p = 0.00001$ bar to 300 bar)
- **Second operand: Value for $t = 300$ °C**
(Range of validity: $t = 26.85$ °C to 399.85 °C)
- **Third operand: Value for $x = -1$**

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

Single-phase region

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

Wet-steam region

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

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

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

(MD3M Saturation pressure curve:

$$t = 0\text{ °C to } t_c = 355.21\text{ °C}$$

$$p_s(0\text{ °C}) = 0.00078994\text{ bar to } p_c = 9.45229\text{ bar})$$

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

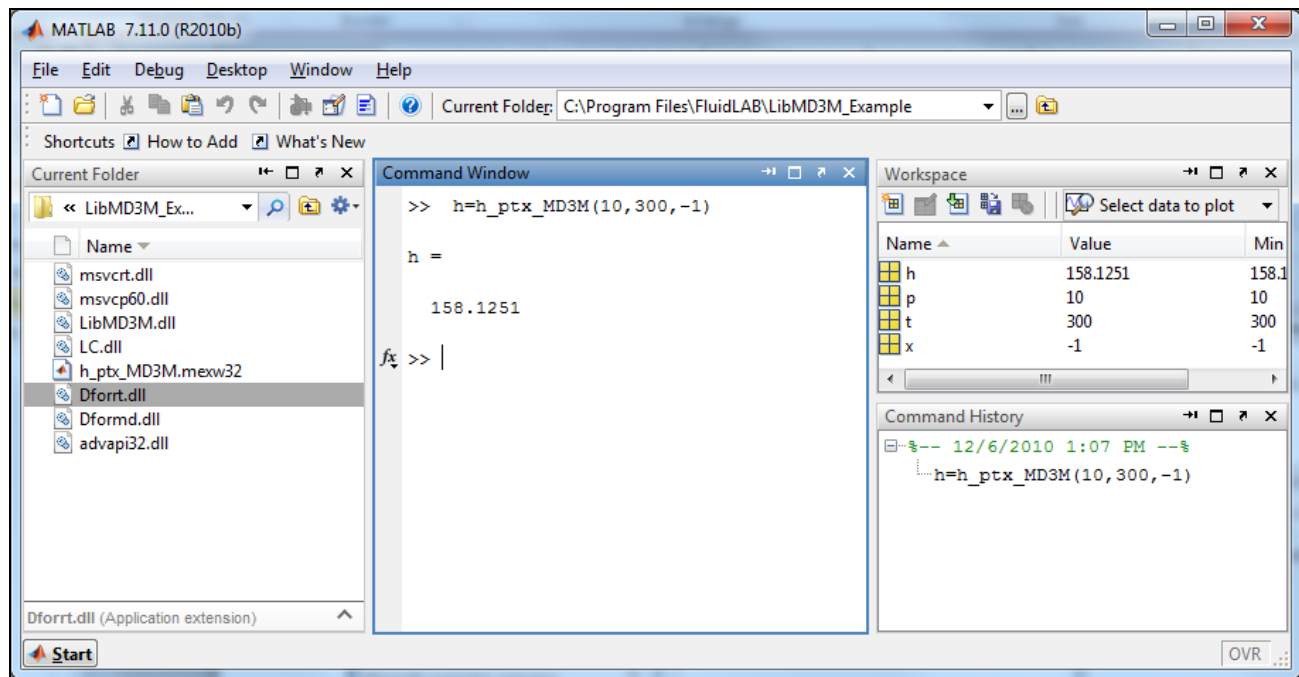


Figure 2.17: MATLAB® with calculated result

⇒ In the "Command Window" you will see the result " $h = 158.1251$ ". 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.

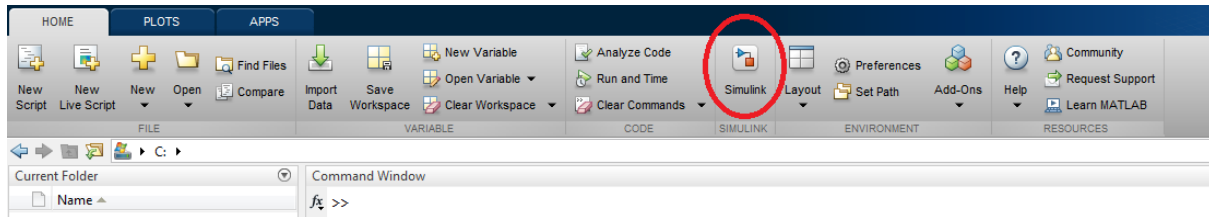


Figure 2.18: Starting Simulink

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.

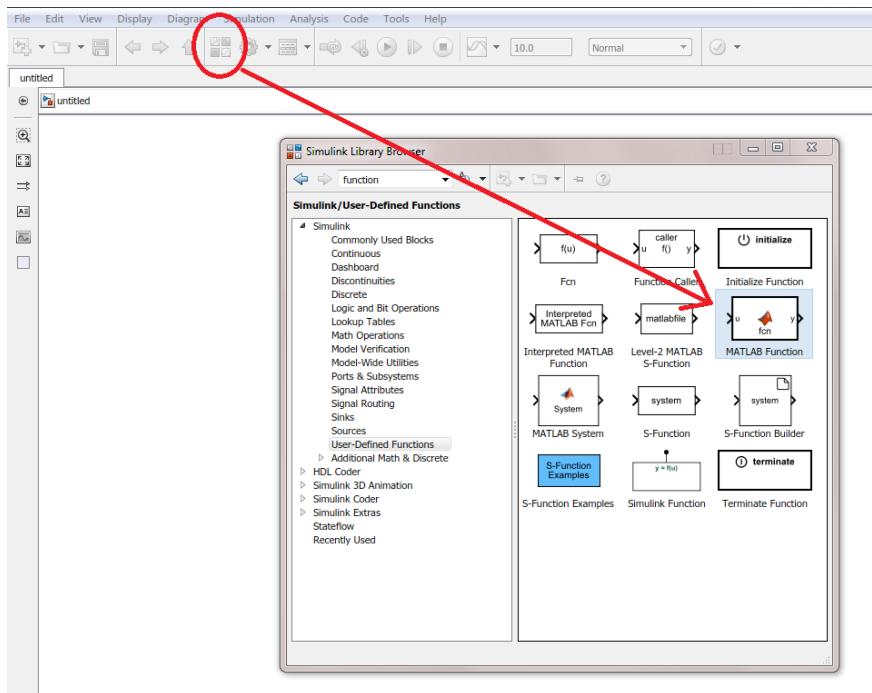


Figure 2.19: Simulink library browser and choosing a MATLAB Function

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.

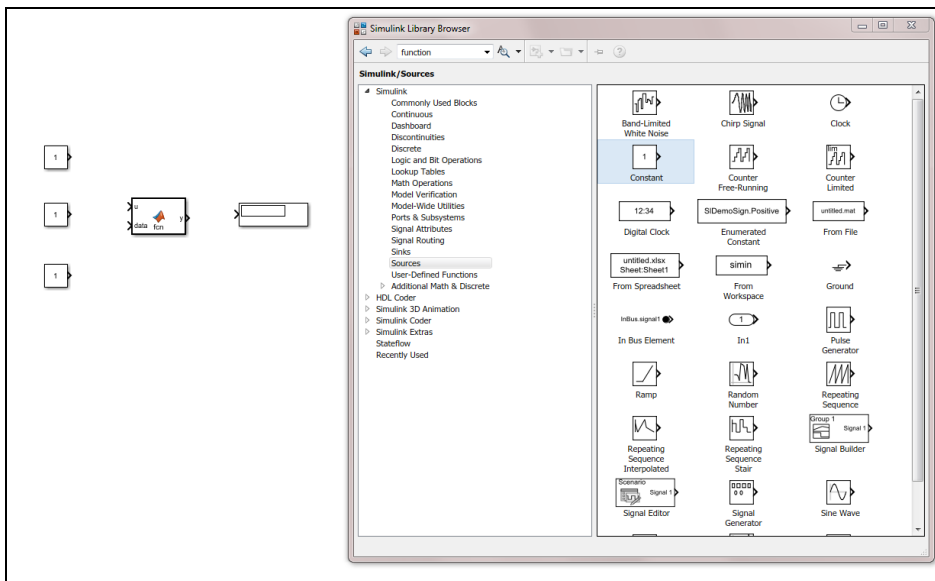


Figure 2.20: Inputs and outputs of the example

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.

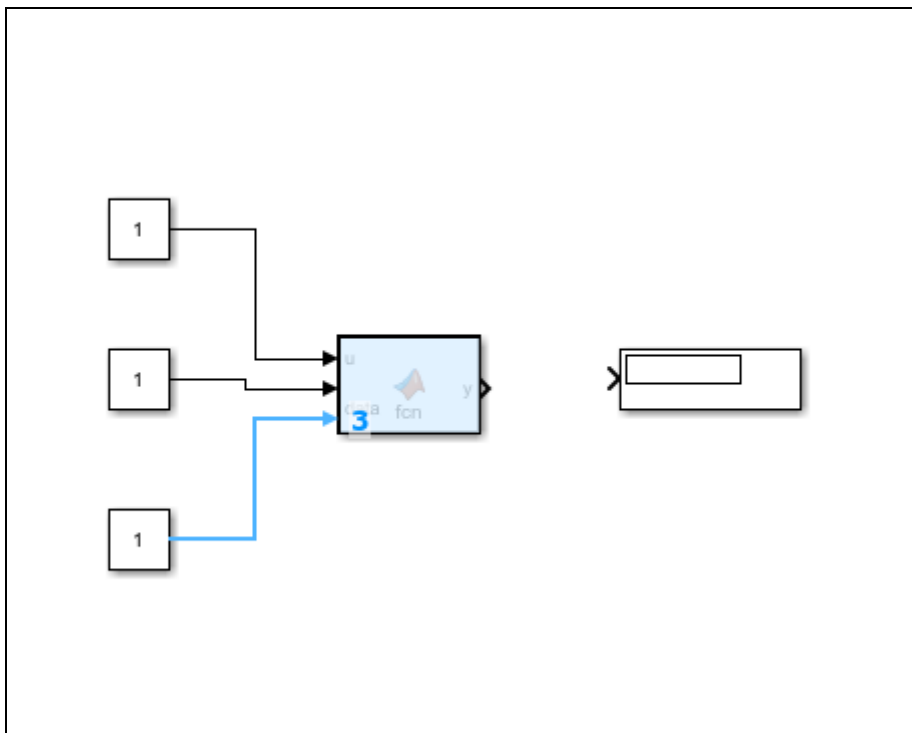


Figure 2.21: Linking blocks in Simulink

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_MD3M');
addpath('C:\Program Files\FluidLAB\LibMD3M');
h = h_ptx_MD3M(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_MD3M');	Choose the function name of the FluidLAB function
addpath('C:\Program Files\FluidLAB\LibMD3M');	Add the installation path of FluidLAB
h = h_ptx_MD3M(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.

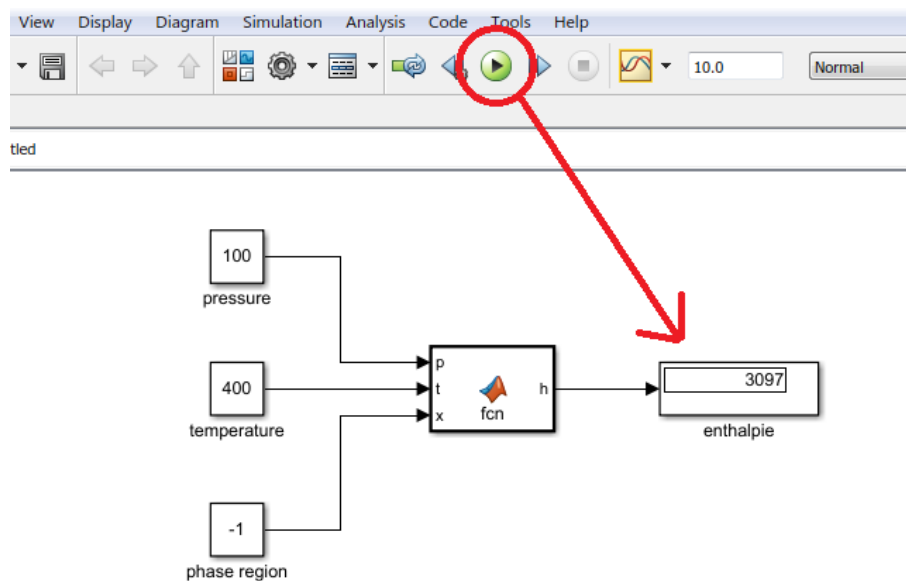


Figure 2.22: Starting the simulation and result of the calculation

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 LibMD3M

To remove the property library LibMD3M 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 LibMD3M" 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 LibMD3M installed, the directory "FluidLAB" will be removed as well.

3. Program Documentation

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

Function Name: **cp_ptx_MD3M**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION CPPTXMD3M(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_CPPTXMD3M(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

CPPTXMD3M, CP or **cp_ptx_MD3M** – specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ 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 are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve.

Saturated liquid and Temperature ranges from $t = 0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 saturated vapor line: Pressure ranges from $p_s(0^\circ\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **CPPTXMD3M = -1000, CP = -1000** or **cp_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Saturation lines: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

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

Function Name: **cv_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION CVPTXMD3M(P,T,X)**
for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_CVPTXMD3M(CV,P,T,X)**
for call from DLL **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

CVPTXMD3M, CV or **cv_ptx_MD3M** – specific isochoric heat capacity c_v in kJ/(kg K)

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

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

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

If the state point to be calculated is located on the 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.

Saturated liquid and Temperature ranges from $t = 0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 saturated vapor line: Pressure ranges from $p_s(0^\circ\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **CVPTXMD3M = -1000, CV = -1000** or **cv_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Saturation lines: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

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

Function Name: **dpdtv_ptx_MD3M**
 Subroutine with function value: **REAL*8 FUNCTION DPDTVPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_DPDTVPTXMD3M(DPDTV,P,T,X)**
 for call from DLL **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

DPDTVPTXMD3M, DPDTV or dpdtv_ptx_MD3M - Derivative of pressure with respect to temperature (at constant specific volume) dpdtv in kPa/K

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

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

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

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and Temperature ranges from $t = 0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 saturated vapor line: Pressure ranges from $p_s(0^\circ\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **DPDTVPTXMD3M = -1000, DPDTV = -1000 or dpdtvo_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

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

Function Name: **dpdvt_ptx_MD3M**
 Subroutine with function value: **REAL*8 FUNCTION DPDVTPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_DPDVTPTXMD3M(DPDVT,P,T,X)**
 for call from DLL **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

DPDVTPTXMD3M, DPDVT or dpdvt_ptx_MD3M - Derivative of pressure with respect to temperature (at constant specific volume) dpdvt in kPa/K

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

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

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

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
 The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and Temperature ranges from $t = 0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 saturated vapor line: Pressure ranges from $p_s(0^\circ\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **DPDVTPTXMD3M = -1000, DPDVT = -1000 or dpdvt_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

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

Function Name: **h_ptx_MD3M**
 Subroutine with function value: **REAL*8 FUNCTION HPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_HPTXMD3M(H,P,T,X)**
 for call from DLL **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

HPTXMD3M, H or h_ptx_MD3M - Specific enthalpy h in kJ/kg

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

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

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

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

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

When calculating wet steam either the given value for t 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 are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

Wet steam region: Temperature ranges from $t = 0^{\circ}\text{C}$ to $t_c = 355.21^{\circ}\text{C}$
 Pressure ranges from $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **HPTXMD3M = -1000, H = -1000 or h_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 355.21^{\circ}\text{C}$ to $t < 0^{\circ}\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

References: [1], [2]

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

Function Name: **kappa_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION KAPPAPTXMD3M(P,T,X)**
for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_KAPPAPTXMD3M(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

KAPPAPTXMD3M, KAPPA or **kappa_ptx_MD3M** – Isentropic exponent $\kappa = \frac{w^2}{p \cdot v}$

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

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

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

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.

The calculation for x -values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and Temperature ranges from $t = 0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 saturated vapor line: Pressure ranges from $p_s(0^\circ\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **KAPPAPTXMD3M, KAPPA = -1000** or **kappa_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

Vapor Pressure $p_s = f(t)$

Function Name:	ps_t_MD3M
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION PSTMD3M(T) REAL*8 T
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_PSTMD3M(PS,T) REAL*8 PS,T

Input Values:

T - Temperature t in °C

Result

PSTMD3M, ps or ps_t_MD3M – Vapor pressure p_s in bar

Range of validity

Temperature ranges from $t=0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$

Results for wrong input values

Result **PSTMD3M = -1000, PS = -1000 or ps_t_MD3M = -1000** for input values:

$t < 0^\circ\text{C}$ or $t > t_c = 355.21^\circ\text{C}$

References: [1], [2]

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

Function Name: **rho_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION RHOPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_RHOPTXMD3M(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

RHOPTXMD3M, RHO or rho_ptx_MD3M – Density ρ in kg/m³

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

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

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

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

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

When calculating wet steam either the given value for t 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.

Wet steam region: Temperature ranges from $t = 0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 Pressure ranges from $p_s(0^\circ\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **RHOPTXMD3M = -1000, RHO = -1000 or rho_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

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

Function Name: **s_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION SPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_SPTXMD3M(S,P,T,X)**
 for call from DLL **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

SPTXMD3M, S or **s_ptx_MD3M** - Specific entropy s in kJ/kg K

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

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

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

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

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

When calculating wet steam either the given value for t 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.

Wet steam region: Temperature ranges from $t = 0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 Pressure ranges from $p_s(0^\circ\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **SPTXMD3M = -1000, S = -1000** or **s_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

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

Function Name: **t_ph_MD3M**

Subroutine with function value: **REAL*8 FUNCTION TPHMD3M(P,H)**
 for call from Fortran **REAL*8 P,H**

Subroutine with parameter: **INTEGER*4 FUNCTION C_TPHMD3M(T,P,H)**
 for call from DLL **REAL*8 T,P,H**

Input Values:

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

TPHMD3M, T or **t_ph_MD3M** - Temperature t in °C

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **T_PH_MD3M, T = -1000** or **t_ph_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) at result $t > 400^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

Boiling or dew curve: or $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar and
 at result $t > t_c = 355.21^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

References: [1], [2]

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

Function Name: **t_ps_MD3M**

Subroutine with function value: **REAL*8 FUNCTION TPSMD3M(P,S)**
 for call from Fortran **REAL*8 P,S**

Subroutine with parameter: **INTEGER*4 FUNCTION C_TPSMD3M(T,P,S)**
 for call from DLL **REAL*8 T,P,S**

Input Values:

P - Pressure p in bar
S - Specific entropy s in kJ/(kg K)

Result

TPSMD3M, T or t_ps_MD3M - Temperature t in °C

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ bar to 300 bar

Details on the calculation of wet steam

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

Wet steam region: Pressure ranges from $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **T_PS_MD3M, T = -1000** or **t_ps_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) at result $t > 400^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

Boiling or dew curve: or $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar and
 at result $t > t_c = 326.25^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

References: [1], [2]

Saturation Temperature $t_s = f(p)$

Function Name:	ts_p_MD3M
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION TSPMD3M(P) REAL*8 P
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_TSPMD3M(TS,P) REAL*8 TS,P

Input Values:

P - Pressure p in bar

Result

TSPMD3M, TS or **ts_p_MD3M** – Saturation Temperature t_s in °C

Range of validity

Pressure ranges from $p_s(0^\circ\text{C}) = 0.000004897 \text{ bar}$ to $p_c = 9.45229 \text{ bar}$

Results for wrong input values

Result **TSPMD3M = -1000**, **TS = -1000** or **ts_p_MD3M = -1000** for input values:

$p > p_c = 9.45229 \text{ bar}$ or $p < p_s(0^\circ\text{C}) = 0.0000048971 \text{ bar}$

References: [1], [2]

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

Function Name: **u_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION UPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_UPTXMD3M(U,P,T,X)**
 for call from DLL **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

UPTXMD3M, U or **u_ptx_MD3M** - Specific internal energy u in kJ/kg

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ 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 $t = 0^{\circ}\text{C}$ to $t_c = 355.21^{\circ}\text{C}$
 Pressure ranges from $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **UPTXMD3M = -1000, U = -1000** or **u_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 355.21^{\circ}\text{C}$ to $t < 0^{\circ}\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

References: [1], [2]

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

Function Name: **v_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION VPTXMD3M(P,T,X)**
for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_VPTXMD3M(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

VPTXMD2M, V or **v_ptx_MD2M** – Specific volume v in m^3/kg

Range of validity

Temperature range: from $t = 0^\circ\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ 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 $t=0^\circ\text{C}$ to $t_c = 355.21^\circ\text{C}$
 Pressure ranges from $p_s(0^\circ\text{C})=0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **VPTXMD3M = -1000, V = -1000** or **v_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^\circ\text{C}$ or $t < 0^\circ\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 355.21^\circ\text{C}$ to $t < 0^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^\circ\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^\circ\text{C}$ or $t < 0^\circ\text{C}$

References: [1], [2]

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

Function Name: **w_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION WPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_WPTXMD3M(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

WPTXMD3M, W or w_ptx_MD3M - Speed of sound w in m/s

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ 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 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 $t = 0^{\circ}\text{C}$ to $t_c = 355.21^{\circ}\text{C}$
 Pressure ranges from $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **WPTXMD3M = -1000, W = -1000 or w_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 355.21^{\circ}\text{C}$ to $t < 0^{\circ}\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

References: [1], [2]

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

Function Name:	x_ph_MD3M
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION XPHMD3M(P,H) REAL*8 P,H
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_XPHMD3M(X,P,H) REAL*8 X,P,H

Input Values:

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

XPHMD3M, X or x_ph_MD3M - Vapor fraction x in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ 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 $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **X_PH_MD3M, X = -1** or **x_ph_MD3M = -1** for input values:

If the state point is located in the single phase region:
 $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar

References: [1], [2]

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

Function Name: **x_ps_MD3M**

Subroutine with function value: **REAL*8 FUNCTION XPSMD3M(P,S)**
 for call from Fortran **REAL*8 P,S**

Subroutine with parameter: **INTEGER*4 FUNCTION C_XPSMD3M(X,P,S)**
 for call from DLL **REAL*8 X,P,S**

Input Values:

P - Pressure p in bar
S - Specific entropy s in kJ/(kg K)

Result

XPSMD3M, X or x_ps_MD3M - Vapor fraction x in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ 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 $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **X_PS_MD3M, X = -1** or **x_ps_MD3M = -1** for input values:

If the state point is located in the single phase region:
 $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar

References: [1], [2]

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

Function Name: **Z_ptx_MD3M**

Subroutine with function value: **REAL*8 FUNCTION ZPTXMD3M(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_ZPTXMD3M(Z,P,T,X)**
 for call from DLL **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

ZPTXMD3M, Z or Z_ptx_MD3M - Compression Factor

Range of validity

Temperature range: from $t = 0^{\circ}\text{C}$ to 400°C
 Pressure range: from $p = 0.0000048971$ 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 $t = 0^{\circ}\text{C}$ to $t_c = 355.21^{\circ}\text{C}$
 Pressure ranges from $p_s(0^{\circ}\text{C}) = 0.0000048971$ bar to $p_c = 9.45229$ bar

Results for wrong input values

Result **ZPTXMD3M = -1000, Z = -1000 or Z_ptx_MD3M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.0000048971$ bar or
 ($x = -1$) $t > 400^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 355.21^{\circ}\text{C}$ to $t < 0^{\circ}\text{C}$
 at $t = -1000$ and $p > p_c = 9.451229$ bar
 or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar or
 or $p > p_c = 9.45229$ bar or $p < p_s(0^{\circ}\text{C}) = 0.0000048971$ bar and
 $t > t_c = 355.21^{\circ}\text{C}$ or $t < 0^{\circ}\text{C}$

References: [1], [2]

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 Bucker 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 Bucker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bucker 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

$\text{C}_2\text{H}_6\text{O}_2$	Ethylene glycol
$\text{C}_3\text{H}_8\text{O}_2$	Propylene glycol
$\text{C}_2\text{H}_5\text{OH}$	Ethanol
CH_3OH	Methanol
$\text{C}_3\text{H}_8\text{O}_3$	Glycerol
K_2CO_3	Potassium carbonate
CaCl_2	Calcium chloride
MgCl_2	Magnesium chloride
NaCl	Sodium chloride
$\text{C}_2\text{H}_3\text{KO}_2$	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 $C_{14}H_{42}O_6Si_6$ **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 **H₂S** **Library LibH2S**

Nitrous oxide **N₂O** **Library LibN2O**

Sulfur dioxide **SO₂** **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 Kretschmar

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

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

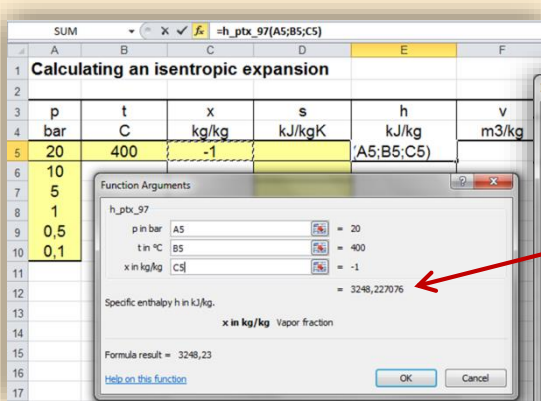
Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

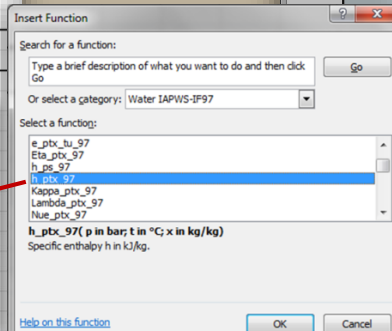
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL^{Graphics} for Excel[®]

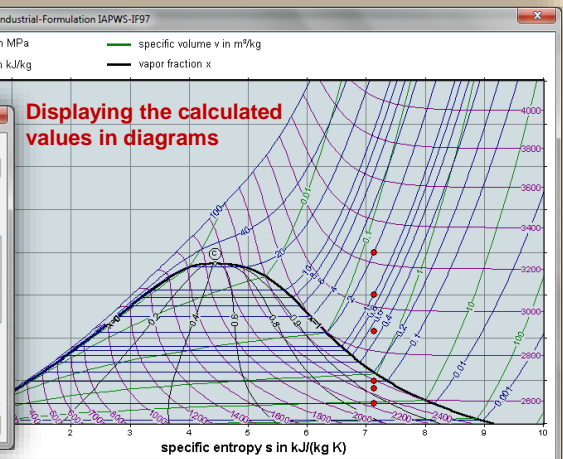


Menu for the input of given property values

Choosing a property library and a function

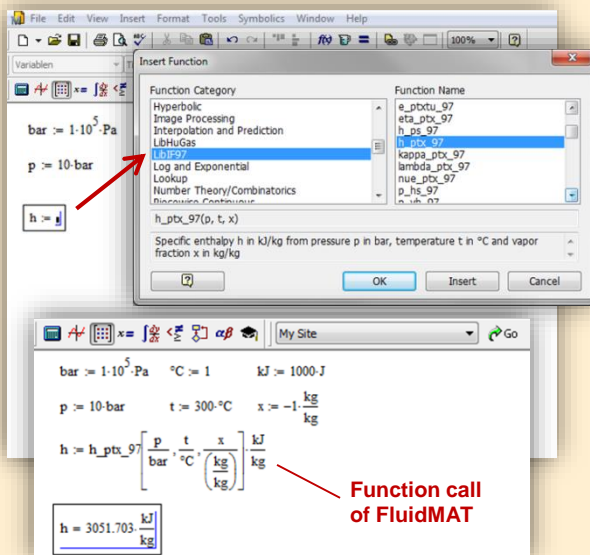


Displaying the calculated values in diagrams



Add-In FluidMAT for Mathcad[®]

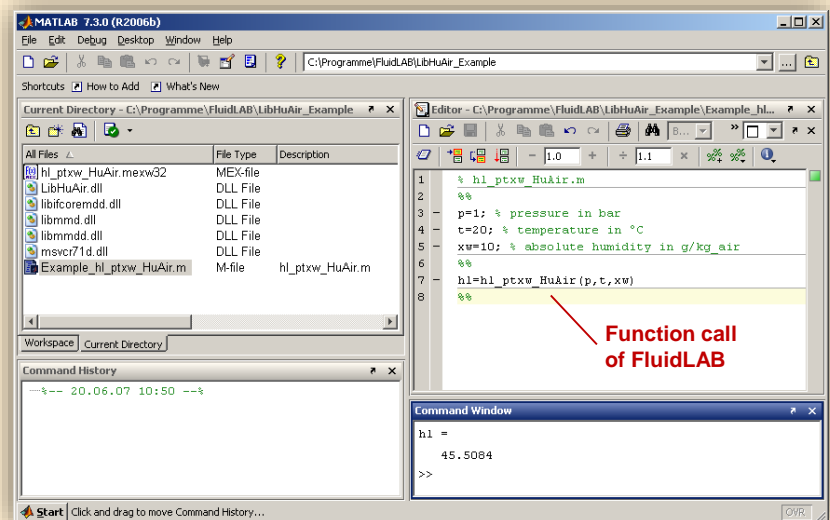
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

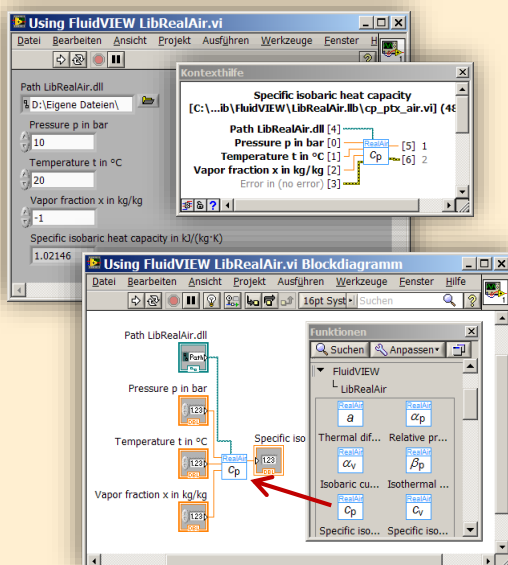
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

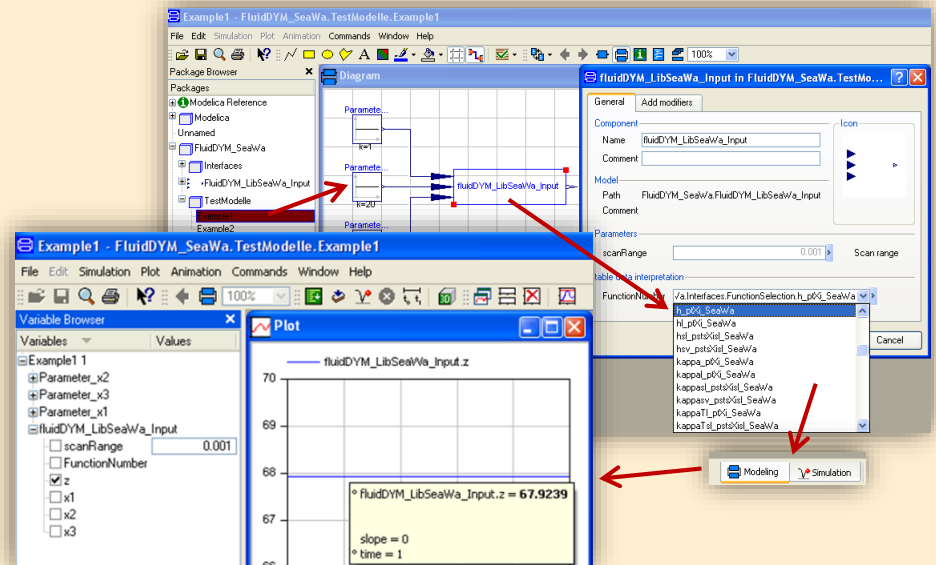
Add-On FluidVIEW for LabVIEW[™]

The property functions can be calculated in LabVIEW[™].

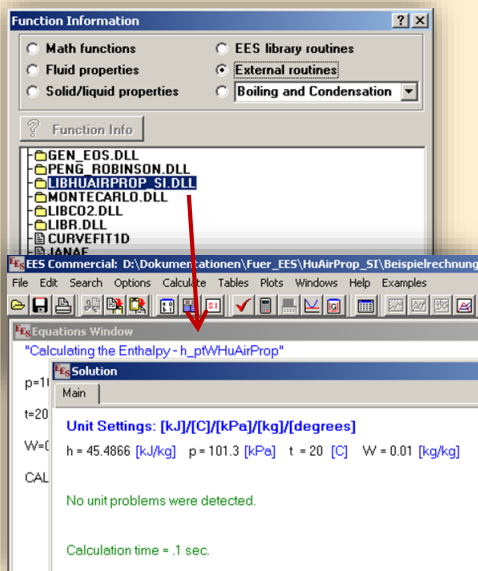


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

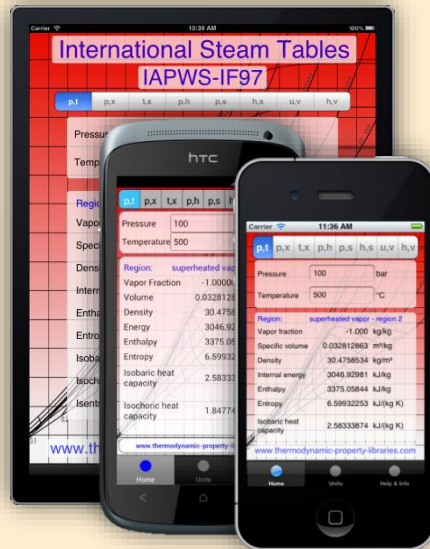
The property functions can be called in DYMOLA[®] and SimulationX[®].



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

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

Enter given values: [Range of validity](#)

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = 3097.38 kJ/kg

For further information on property libraries available for EXCEL®, MATLAB®, Mathcad®, Engineering Equation Solver®, DYMOLA® (Modelica), SimulationX®, and LabView® click [here](#).

An App for calculating steam properties on iPhone, iPad, and iPod touch can be found [here](#) PDF with the [description](#).

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Dr. Ines Stöcker
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www.thermofluidprop.com
www.thermofluidprop.com
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 83 TI 84 TI 89 TI 92

For more information please contact:

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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.

5. References

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

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

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, Sønderød, 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, Bellevue (USA)	11/2016
DREWAG Dresden, Dresden	10/2016
AGO AG Energie+Anlagen, Kulmbach	10/2016
Universität Stuttgart, ITW, Stuttgart	09/2016
Pöry 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
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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
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COMPAREX, Leipzig	08/2013, 11/2013
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Siemens, Frankenthal	08/2013, 10/2013
	11/2013
VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
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IGUS GmbH, Dresden	06/2013
BHR Bilfinger, Essen	06/2013
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frischli Milchwerke, Rehburg-Loccum	01/2013

2012

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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
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TERA Ingegneria, Trento, Italy	04/2012
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Sennheiser, Wedemark	03/2012
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2011

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Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011 10/2011
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RWTH Aachen University	07/2011, 08/2011
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Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
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Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
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

Technical University of Berlin	06/2009
Fraunhofer Institut UMSICHT, Oberhausen	07/2009
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Fichtner IT Consulting, Stuttgart	07/2009
Techsoft, Linz, Austria	08/2009
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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
MAAG, Kuesnacht, Switzerland	02/2008
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Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008
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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,	07/2008
Professorship of Building Services	
Technical University of Cottbus,	07/2008, 10/2008
Chair in Power Plant Engineering	
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

2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
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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

2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart,	02/2006
Department of Thermal Fluid Flow Engines	
Technical University of Munich,	02/2006
Chair in Apparatus and Plant Engineering	
Energietechnik Leipzig (company license),	02/2006
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RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig,	04/2006
Department of Thermodynamics	
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg,	05/2006
Department of USET Merseburg incorporated society	
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Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
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M&M Turbine Technology, Bielefeld	06/2006
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ThyssenKrupp Marine Systems, Kiel	07/2006

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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	04/2005
Professorship of Thermic Energy Machines and Plants	
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences, 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

Midiplan, Bietigheim-Bissingen	11/2005
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
Rerum Cognitio, Zwickau	04/2004
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
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
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Freudenberg Service, Weinheim	12/2004

2003

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

Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	05/2003
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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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2002

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Siemens, Karlsruhe (general license for the WinIS information system)	02/2002

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VEAG, Berlin (group license)	12/2002

2001

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Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart	04/2001
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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
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
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Bayernwerk, Munich	01/1999
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Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart	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
Alfa Engineering, Switzerland	09/1998
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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
Siemens Power Generation, Goerlitz	07/1997