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

FluidLAB
with LibMDM
for MATLAB®

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Property Library for the Calculation of Octamethyltrisiloxane (MDM)

FluidLAB for MATLAB®
LibMDM

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0. Package Contents

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

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

Documentation

FluidLAB_LibMDM_Docu_Eng.pdf - User's Guide

1. Property Functions

1.1 Calculation Programs

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

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibMDM as parameter	Property or Function	Unit of the result
$a = f(p,t,x)$	a_ptx_MDM	APTXMDM(P,T,X)	C_APTXMDM(PR,P,T,X)	Thermal diffusivity	m^2/s
$c_p = f(p,t,x)$	cp_ptx_MDM	CPPTXMDM(P,T,X)	C_CPPTXMDM(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_MDM	CVPTXMDM(P,T,X)	C_CVPTXMDM(CV,P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\left(\frac{\partial p}{\partial T}\right)_v = f(p,t,x)$	dpdtv_ptx_MDM	DPDTVPTXMDM(P,T,X)	C_DPDTVMDM(DPDT,P,T,X)	Derivative of pressure with respect to temperature (at constant specific volume)	kPa/K
$\left(\frac{\partial p}{\partial v}\right)_T = f(p,t,x)$	dpdvt_ptx_MDM	DPDVTPTXMDM(P,T,X)	C_DPDVTMDM(DPDV,P,T,X)	Derivative of pressure with respect to specific volume (at constant temperature)	kPa/(m³/kg)
$\eta = f(p,t,x)$	eta_ptx_MDM	ETAPTXMDM(P,T,X)	C_ETAPTXMDM(ETA,P,T,X)	Dynamic viscosity	Pa·s
$h = f(p,t,x)$	h_ptx_MDM	HPTXMDM(P,T,X)	C_HPTXMDM(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_MDM	KAPPAPTXMDM(P,T,X)	C_KAPPAPTXMDM(KAPPA,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lamda_ptx_MDM	LAMPTXMDM(P,T,X)	C_LAMPTXMDM(LAM,P,T,X)	Thermal conductivity	W/(m·K)
$\nu = f(p,t,x)$	nu_ptx_MDM	NUPTXMDM(P,T,X)	C_NUPTXMDM(NUE,P,T,X)	Kinematic viscosity	m^2/s
$Pr = f(p,t,x)$	Pr_ptx_MDM	PRPTXMDM(P,T,X)	C_PRPTXMDM(PR,P,T,X)	*Prandtl* number	-
$p_s = f(t)$	ps_t_MDM	PSTMDM(T)	C_PSTMDM(PS,T)	Vapor pressure from temperature	bar
$\rho = f(p,t,x)$	rho_ptx_MDM	RHOPTXMDM(P,T,X)	C_RHOPTXMDM(RHO,P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_MDM	SPTXMDM(P,T,X)	C_SPTXMDM(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_MDM	TPHMDM(P,H)	C_TPHMDM(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_MDM	TPSMDM(P,S)	C_TPSMDM(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_MDM	TSPMDM(P)	C_TSPMDM(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_MDM	UPTXMDM(P,T,X)	C_UPTXMDM(U,P,T,X)	Specific internal energy	kJ/kg

Functional Dependence	**Function Name**	**Call from Fortran program**	**Call in DLL LibMDM as parameter**	**Property or Function**	**Unit of the result**
$v = f(p,t,x)$	v_ptx_MDM	VPTXMDM(P,T,X)	C_VPTXMDM(V,P,T,X)	Specific volume	m^3/kg
$w = f(p,t,x)$	w_ptx_MDM	WPTXMDM(P,T,X)	C_WPTXMDM(W,P,T,X)	Isentropic speed of sound	m/s
$x = f(p,h)$	x_ph_MDM	XPHMDM(P,H)	C_XPHMDM(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	x_ps_MDM	XPSMDM(P,S)	C_XPSMDM(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
$Z = f(p,t,x)$	Z_ptx_MDM	ZPTXMDM(P,T,X)	C_ZPTXMDM(W,P,T,X)	Compression factor	-

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

Range of validity

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

Reference state

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

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

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

Single-phase region

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

Wet-steam region

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

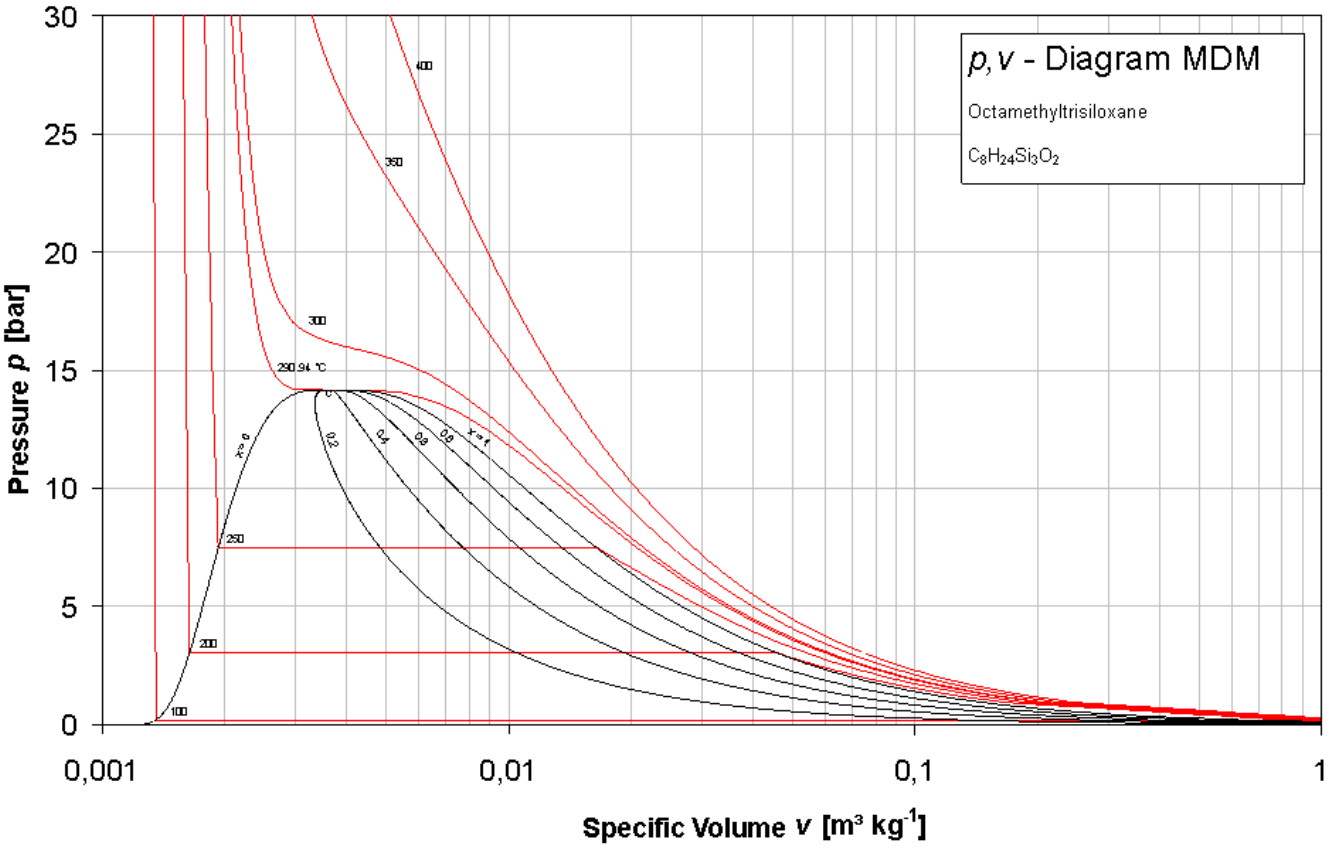
If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in –1000.

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

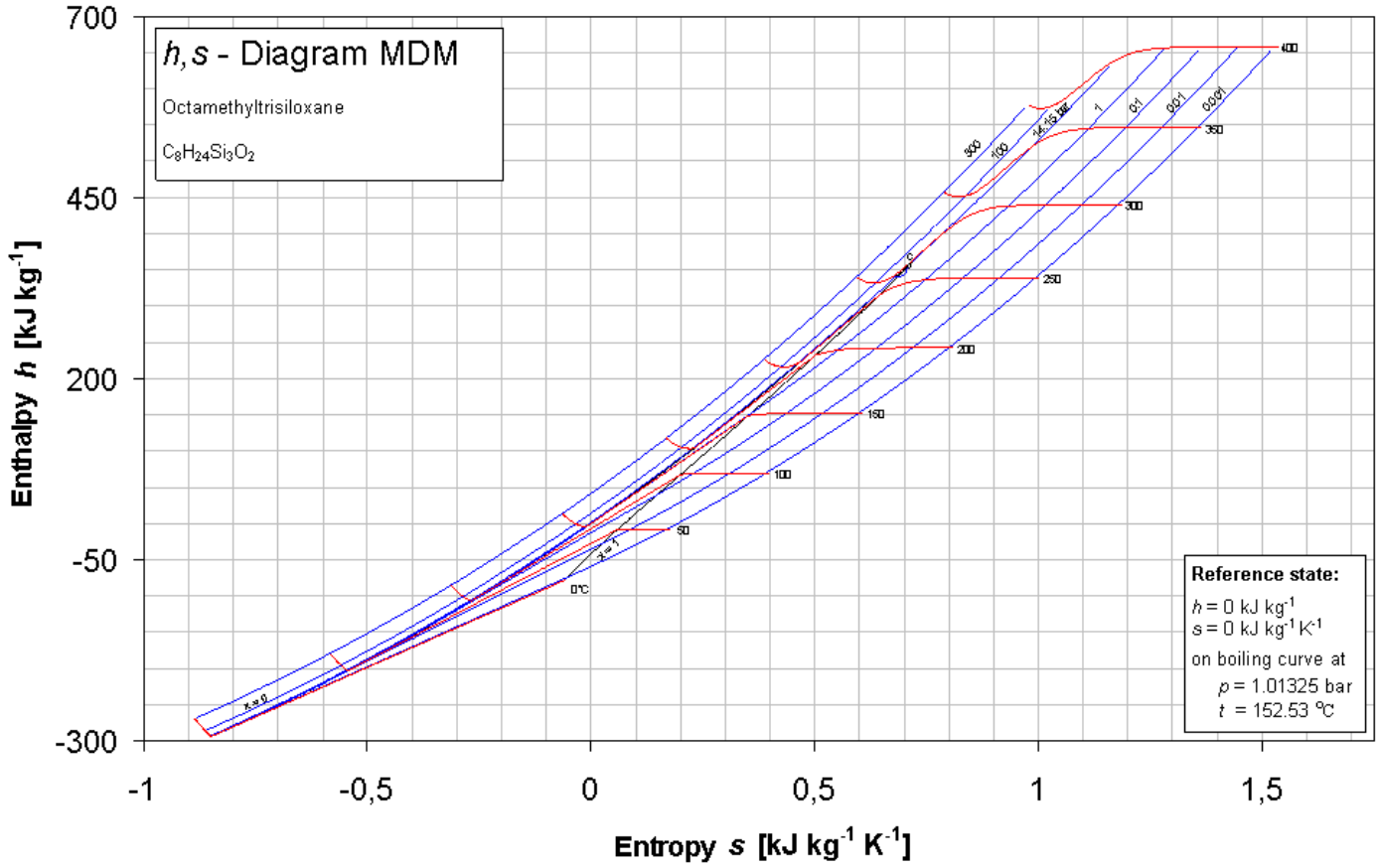
Note:

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

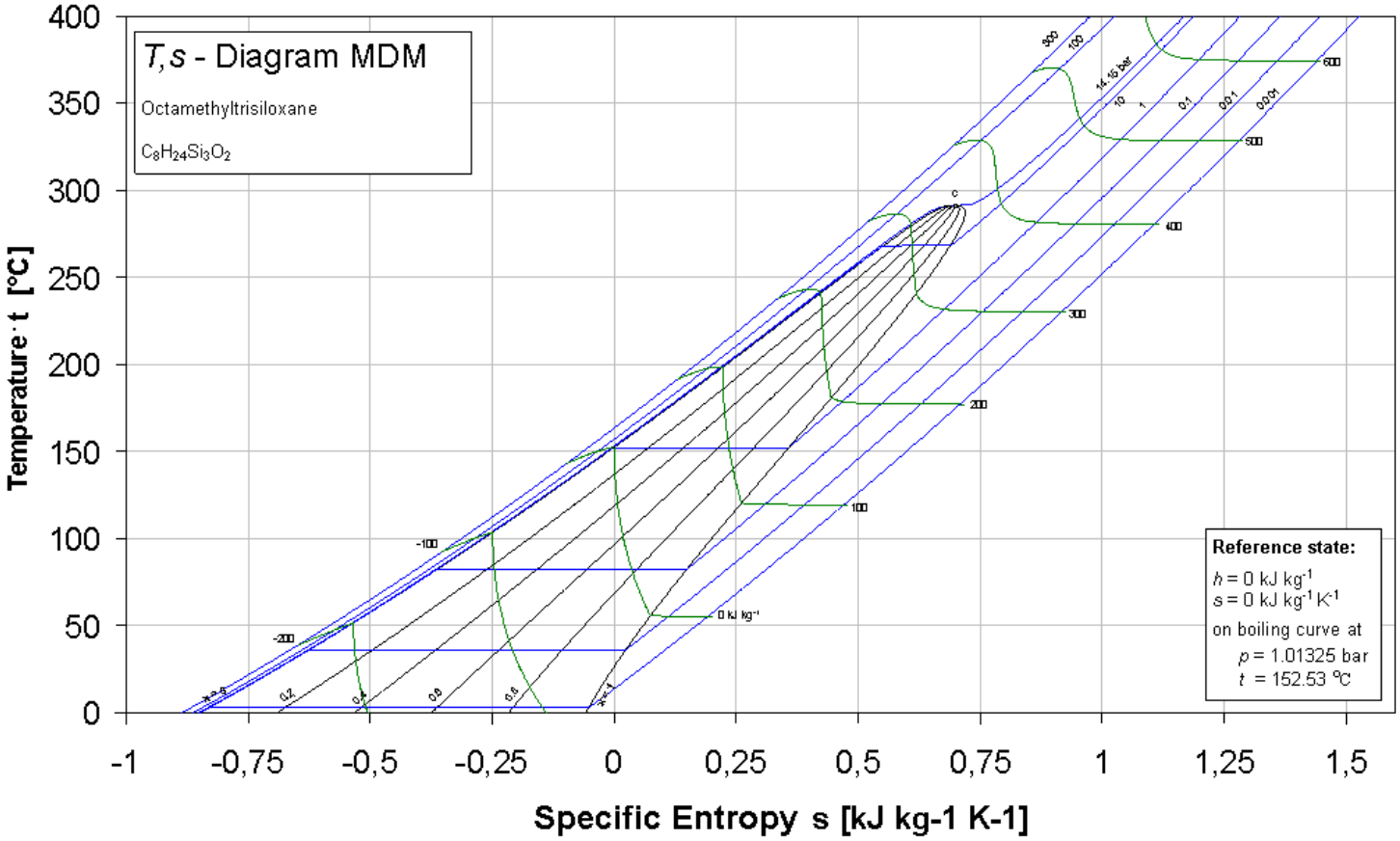
1.2 p,v-Diagram



1.3 h,s-Diagram



1.4 T,s-Diagram



2 Application of FluidLAB in MATLAB®

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

2.1 Installing FluidLAB including LibMDM

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

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

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

CD_FluidLAB_LibMDM

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

Open this folder by double-clicking on it.

In this folder you will see the following three files:

FluidLAB_LibMDM_Docu_Eng.pdf
FluidLAB_LibMDM_Setup.exe
LibMDM.dll.

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

FluidLAB_LibMDM_Setup.exe.

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

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

C:\Program Files\FluidLAB\LibMDM

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

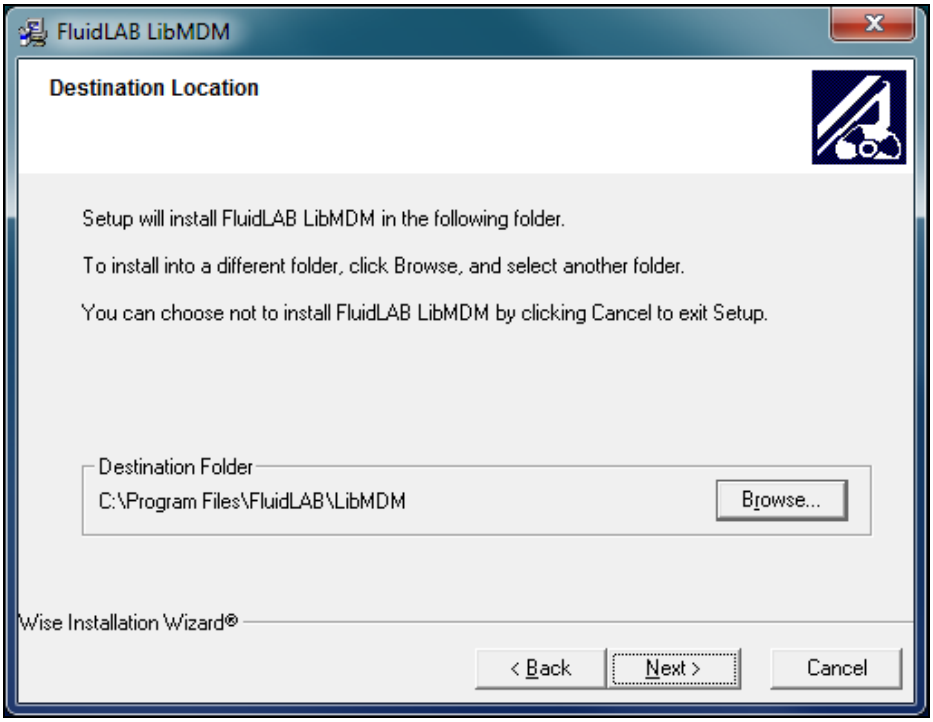


Figure 2.1: "Destination Location"

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

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

The installation program has copied the following files for LibMDM into the directory "C:\Program Files\FluidLAB\LibMDM":

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

- MATLAB®-Interface-Program for calculable functions

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

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

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

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

Now, open your FluidLAB directory (the standard being C:\Program Files\FluidLAB\LibMDM) and insert the file "LibMDM.dll" by clicking the "Edit" menu in your Explorer and then select "Paste".

Answer the question whether you want to replace the file by clicking the "Yes" button. Now, you have overwritten the file "LibMDM.dll" successfully and the property functions are available in MATLAB®.

Licensing the LibMDM Property Library

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

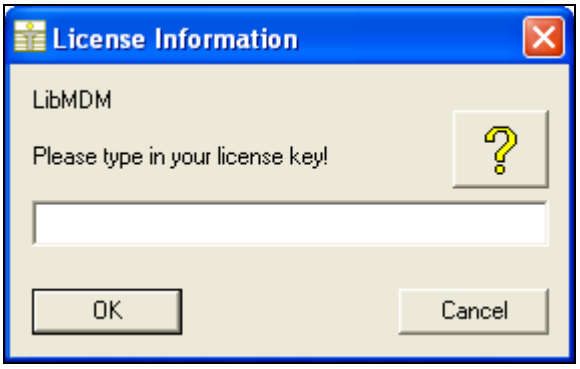


Figure 2.2: "License Information" window

Here you are asked to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. If you do not have this, or have any questions, you will find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:

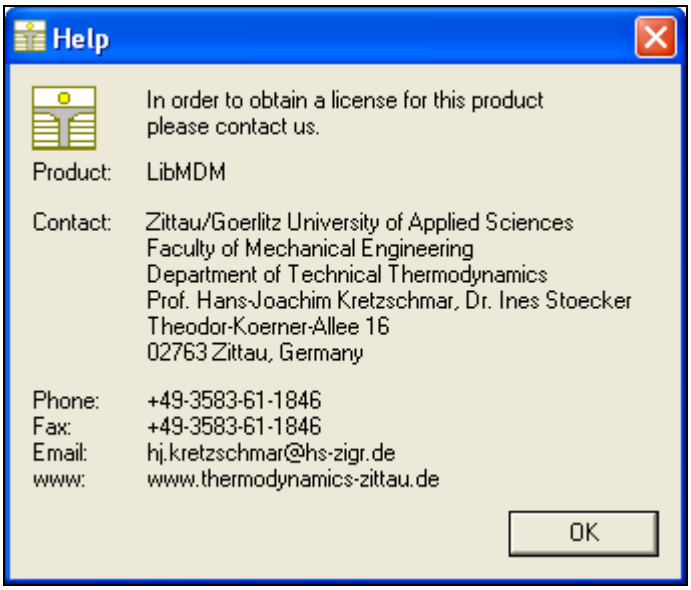


Figure 2.3: "Help" window

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

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

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

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

Please carry out the following instructions:

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

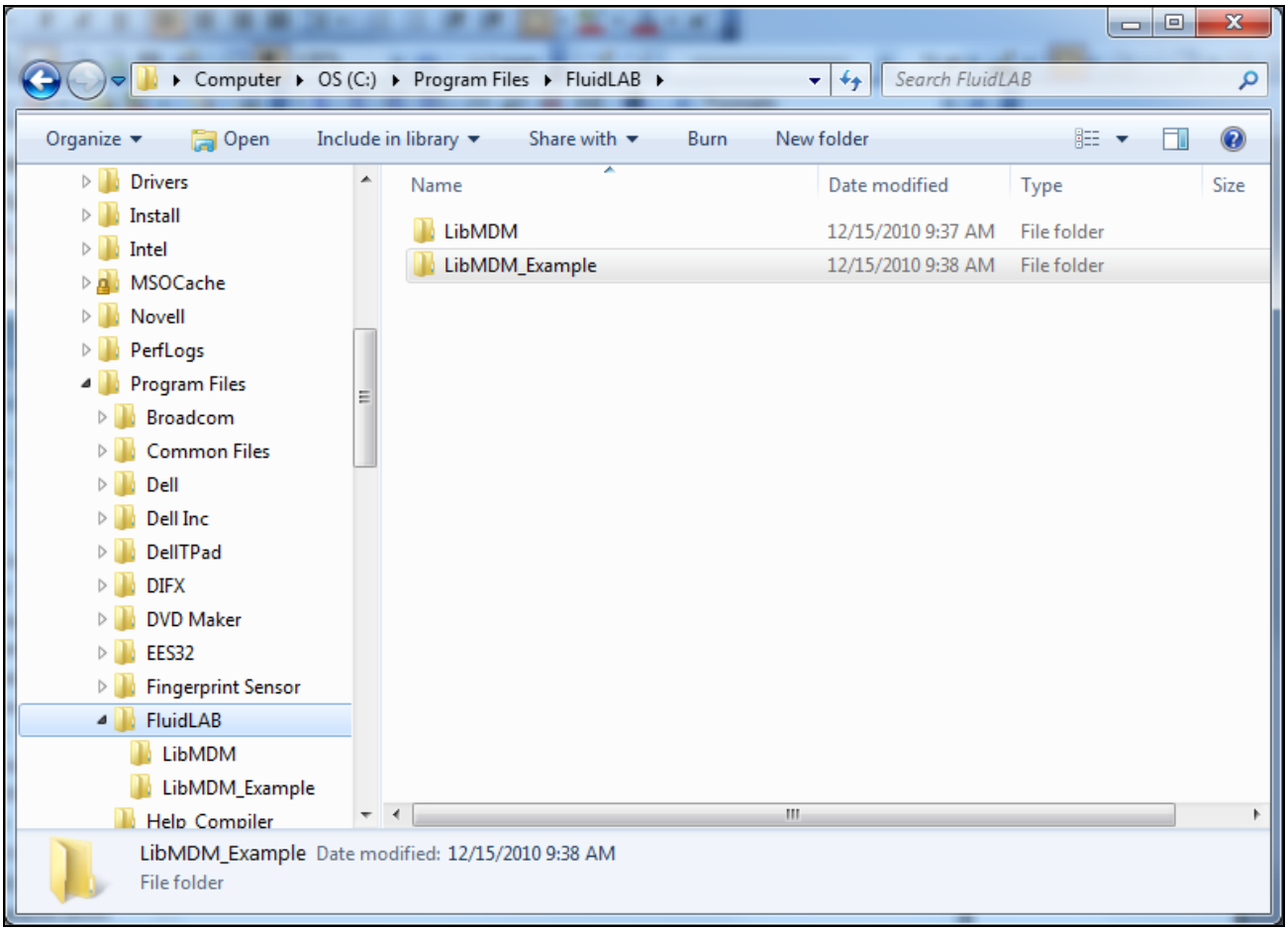


Figure 2.4: Folders "LibMDM" and "LibMDM_Example"

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

- You will see the following window:

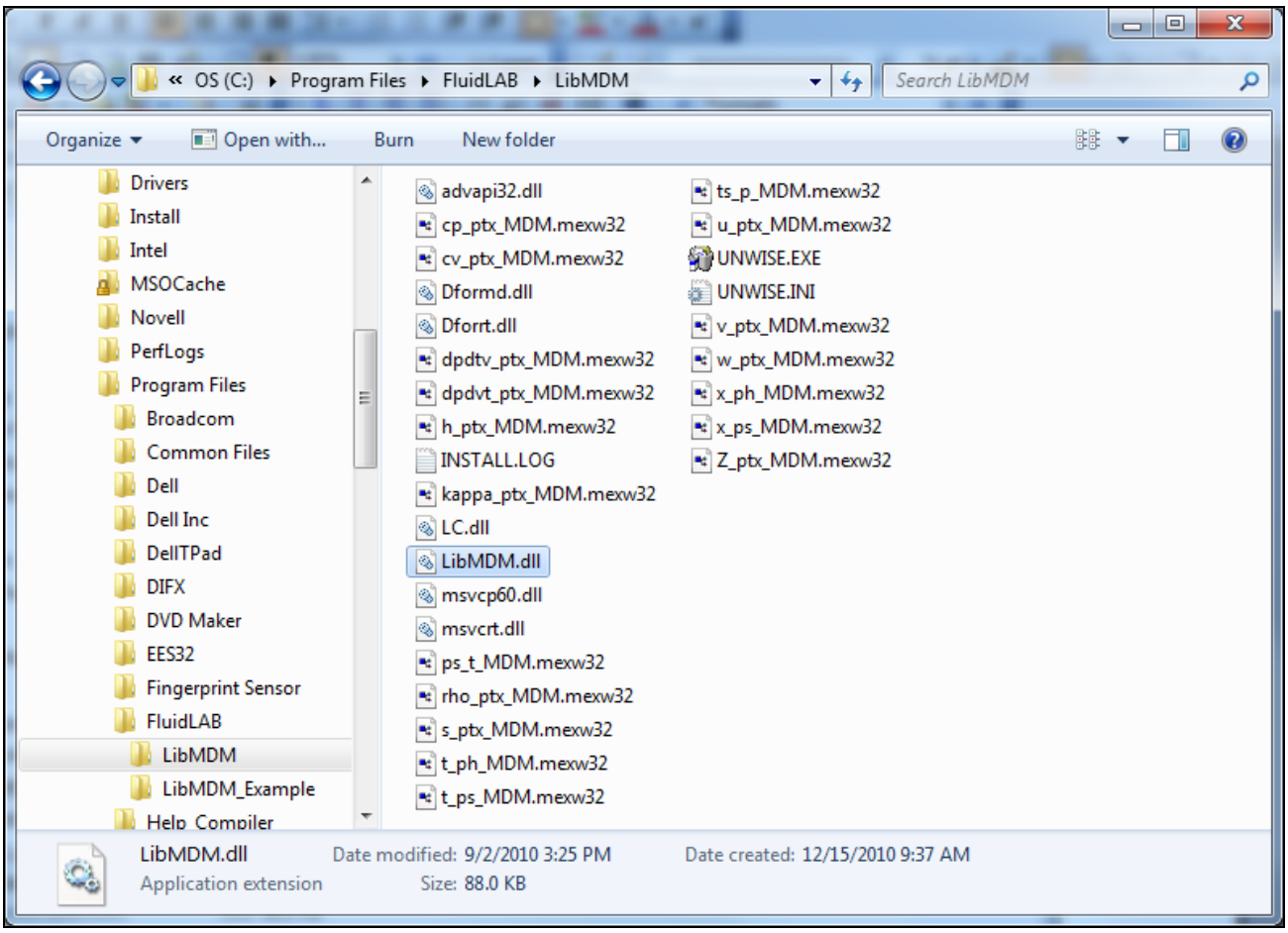


Figure 2.5: Contents of the folder "LibMDM"

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

- The following eight files are needed:
    - "advapi32.dll"
    - "Dformd.dll"
    - "Dforrt.dll"
    - "h_ptx_MDM.mexw32"
    - "LC.dll"
    - "LibMDM.dll"
    - "msvcp60.dll"
    - "msvcrt.dll."
- Click the file "h_ptx_MDM.mexw32", then click "Edit" in the upper menu bar and select "Copy".
- Switch into the directory "C:\Program Files\FluidLAB\LibMDM_Example", click "Edit" and then "Paste".
- Repeat these steps in order to copy the other files listed above. You may also select all the above-named files and then copy them as a group (press the Control button to enable

multiple markings).

- You will see the following window:

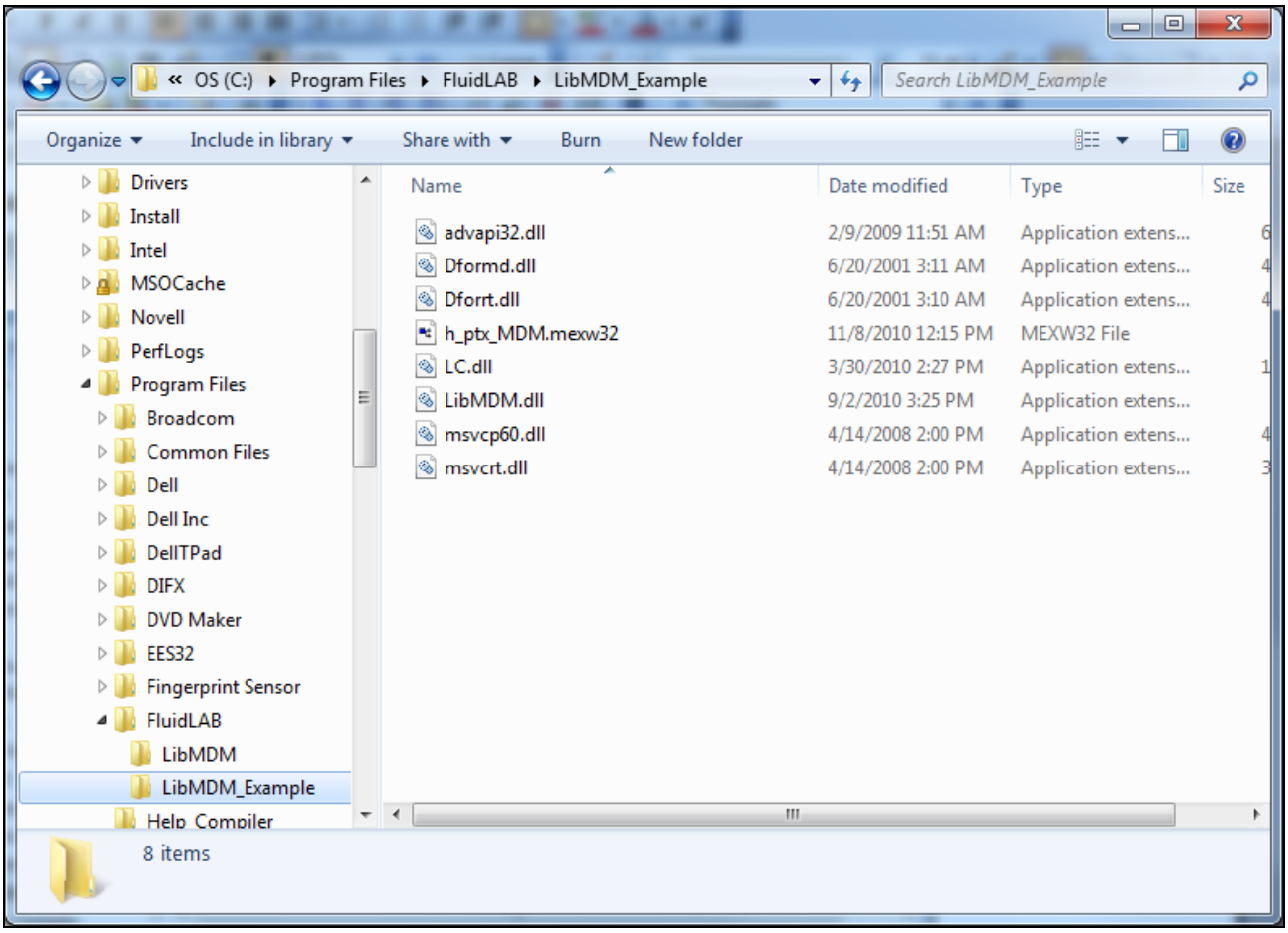


Figure 2.6: Contents of the folder "LibMDM_Example"

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

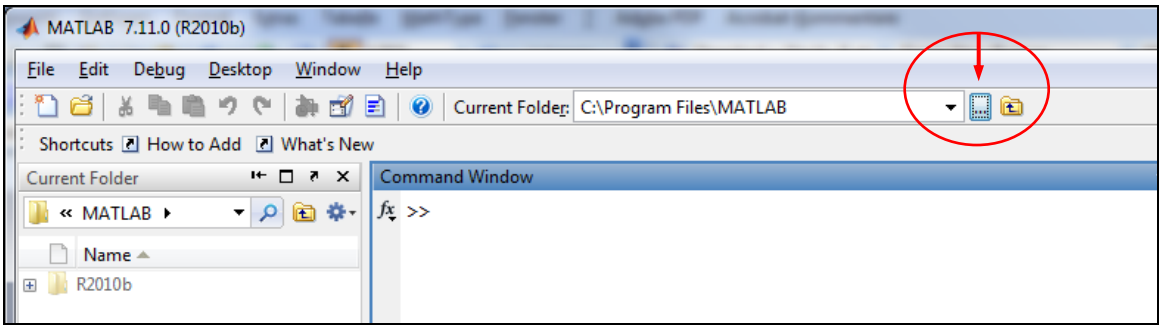


Figure 2.7: Selection of the working directory

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

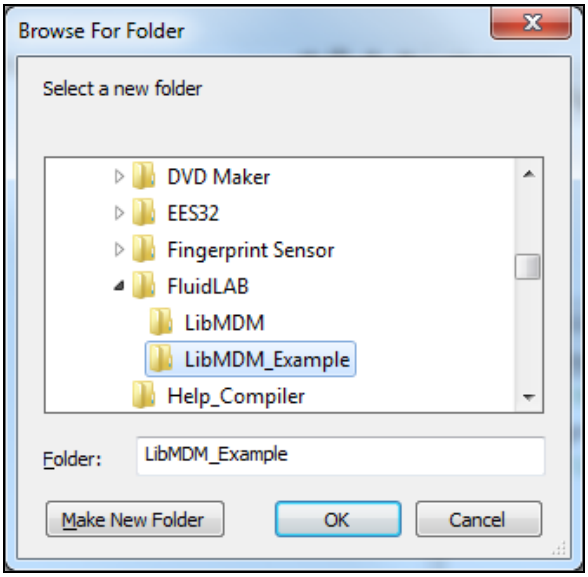


Figure 2.8: Choosing the "LibMDM_Example" folder

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

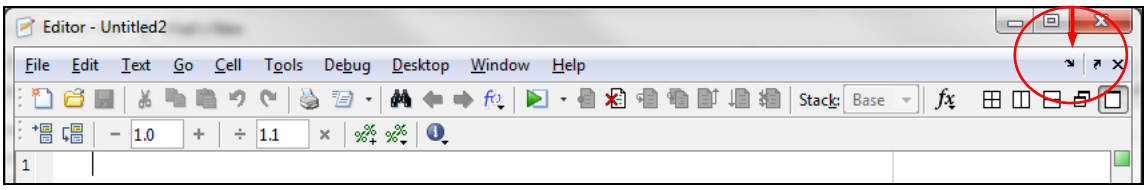


Figure 2.9: Embedding the "Editor" window

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

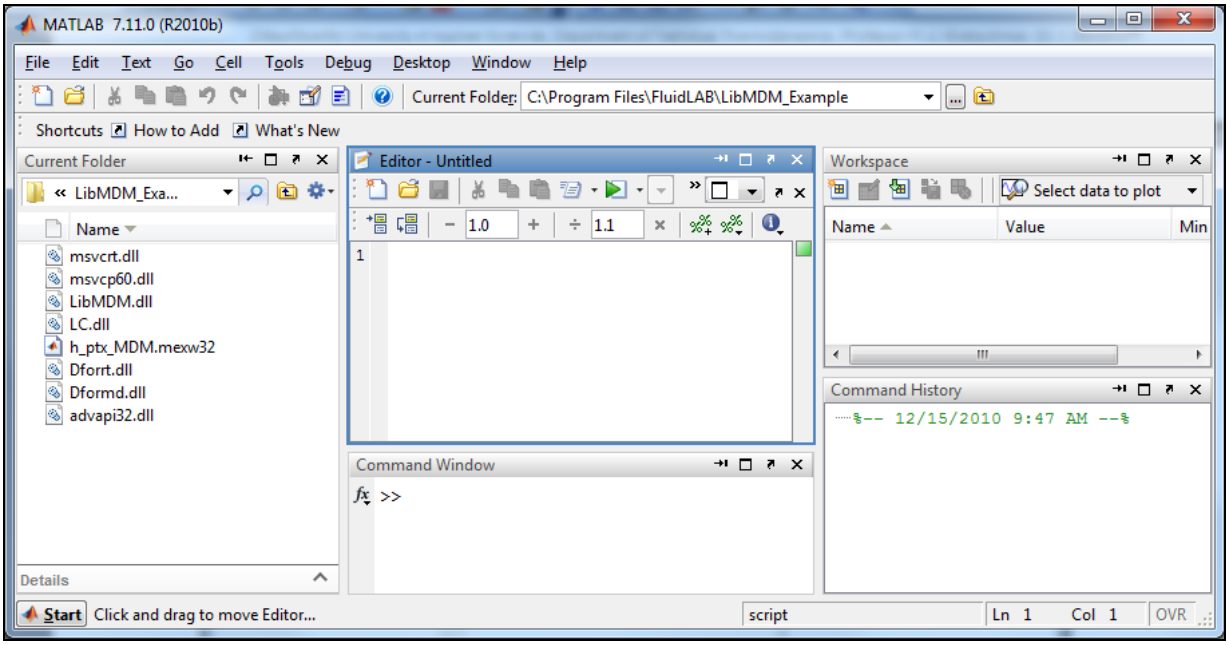


Figure 2.10: Embedded "Editor" window

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

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

- Remarks:

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

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

  - First operand: Value for p = 10
    (Range of validity: p = 00078994 bar to 300 bar)
  - Second operand: Value for t = 300 °C
    (Range of validity: t = 0°C to 400 °C)
  - Third operand: Value for x = -1 kg/kg

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

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

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

  (MDM Saturation pressure curve:

  t = 0 °C to t_C = 290.94 °C

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

- Save the "M-File" by clicking the "File" button and then click "Save As...".

- The menu "Save file as:" appears; In this menu, the folder name "LibMDM_Example" must be displayed in the "Save in:" field.

- Next to "File name" you have to type "Example_h_ptx_MDM.m" and afterwards click the

"Save" button.

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

- You will now see the following window:

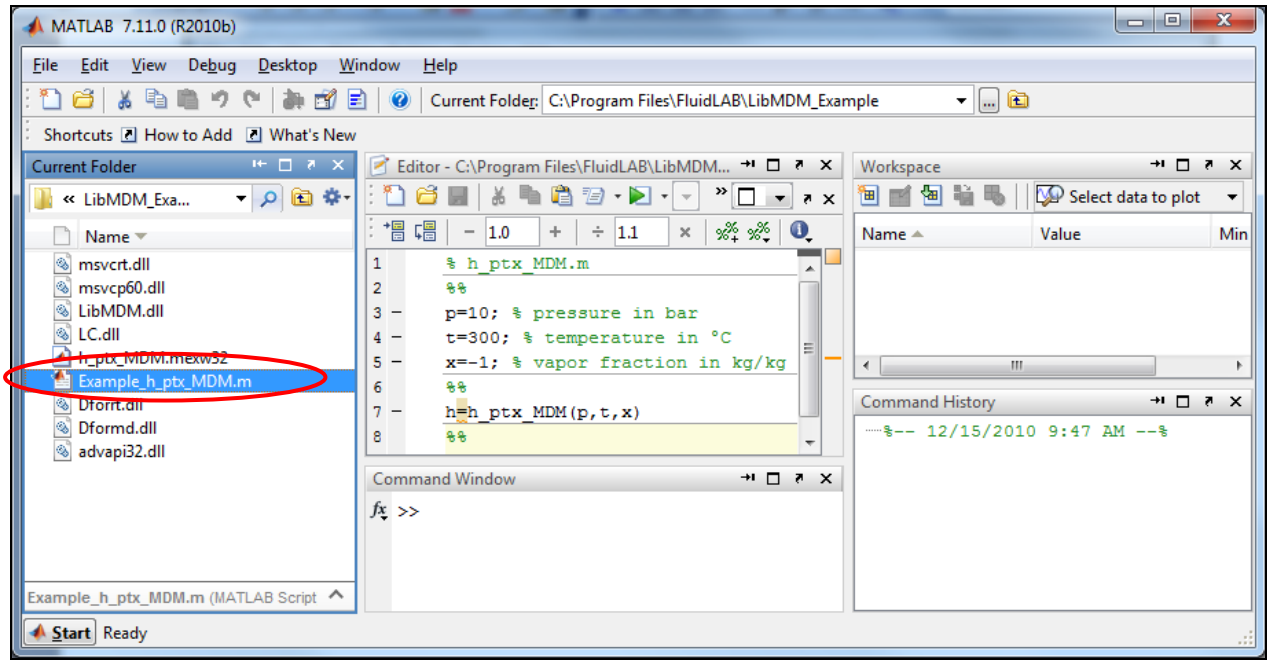


Figure 2.11: "Example_h_ptx_MDM.m" M-file

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

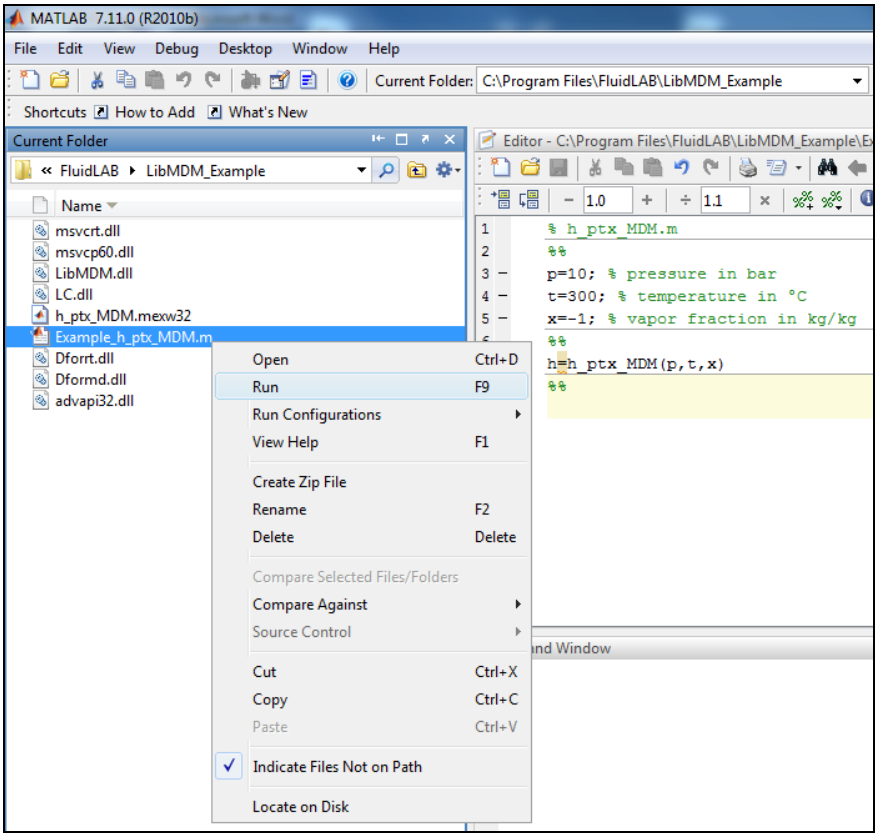


Figure 2.12: Running the "Example_h_ptx_MDM.m" M-file

- You will see the following window:

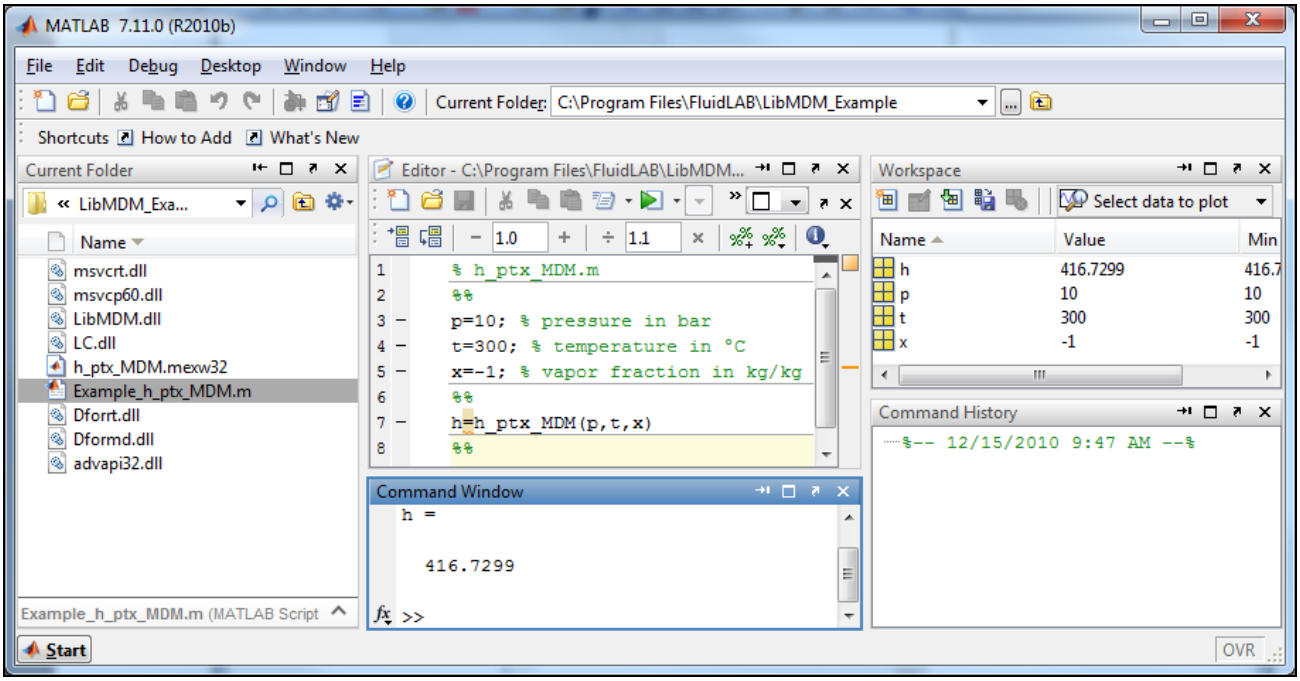


Figure 2.13: MATLAB® with calculated result

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

⇒ The result in our sample calculation here is: "h = 416.7299". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

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

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

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

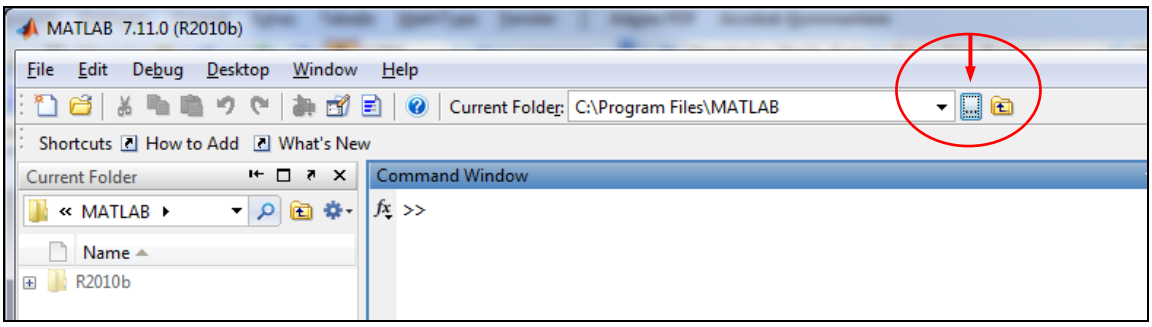


Figure 2.14: Selection of the working directory

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

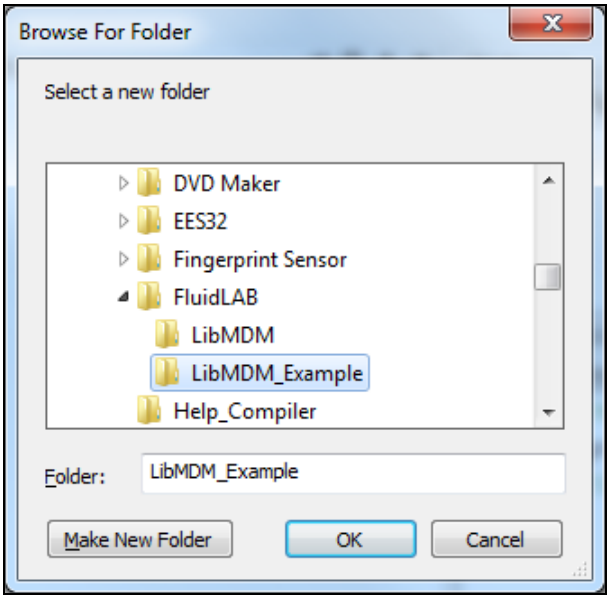


Figure 2.15: Choosing the "LibMDM_Example" folder

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

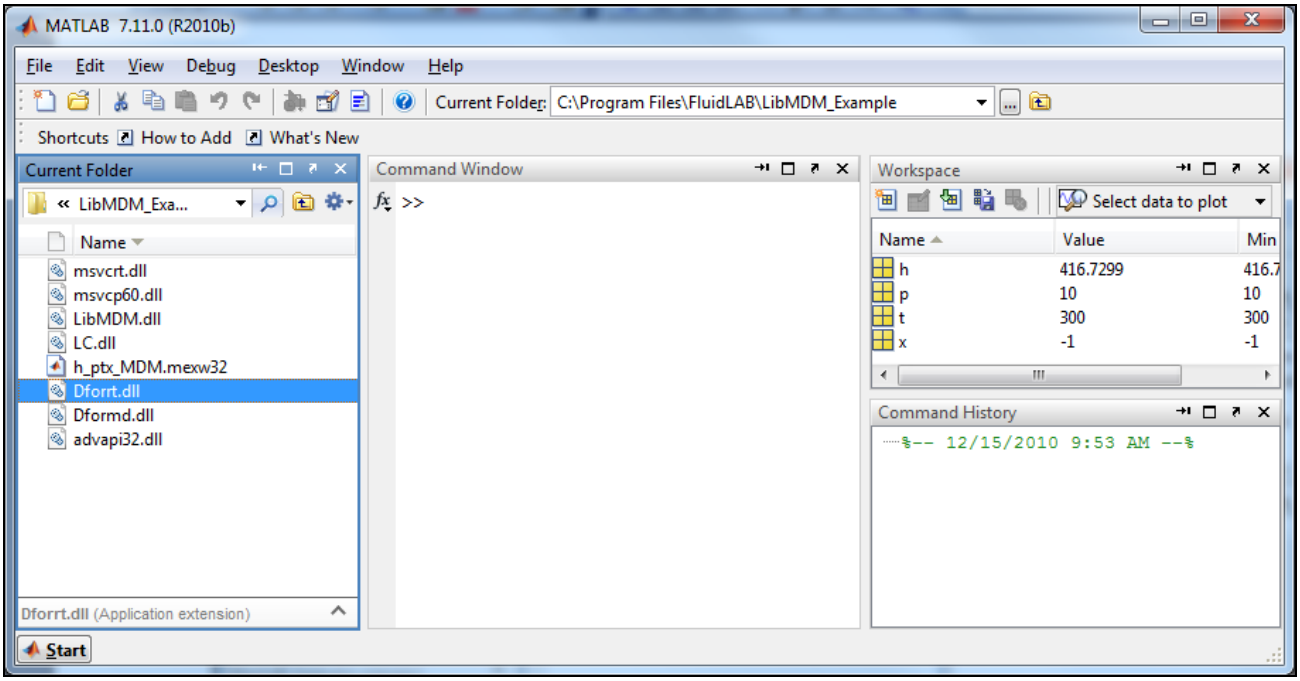


Figure 2.16: MATLAB® with necessary files

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

Write "**h=h_ptx_MDM(10,300,-1)**" within the "Command Window"

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

- First operand: Value for p = 10 bar
  (Range of validity: p = 0.00078994 bar to 300 bar)
- Second operand: Value for t = 300 °C
  (Range of validity: t = 0°C to 400 °C)
- Third operand: Value for x = -1

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

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

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

(MDM Saturation pressure curve:

$$t = 0\ °C \text{ to } t_C = 290.94\ °C$$

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

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

- You will see the following window:

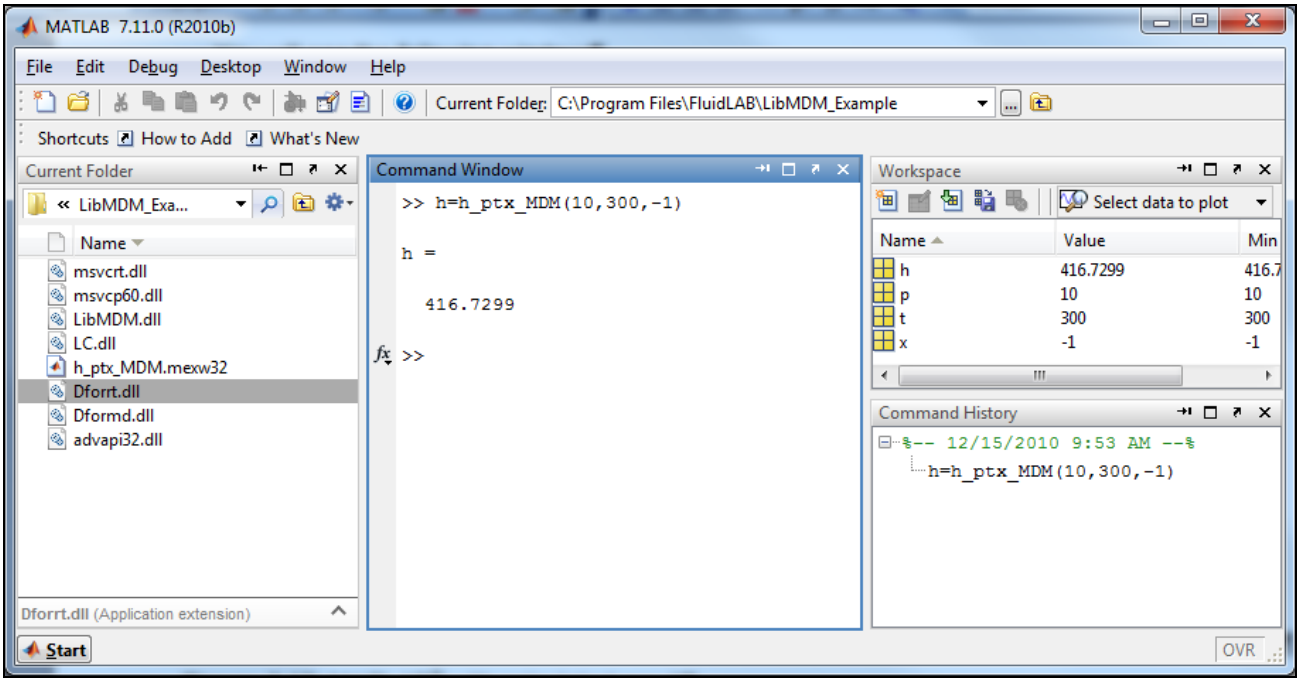


Figure 2.17: MATLAB® with calculated result

⇒ In the "Command Window" you will see the result "h = 416.7299". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

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

2.2.4 Removing FluidLAB including LibMDM

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

Now double-click on "Add or Remove Programs". In the list box of the "Add or Remove Programs" window that appears select "FluidLAB LibMDM" by clicking on it and click the "Change/Remove" button.
In the following dialog box click "Automatic" and then click the "Next >" button.
Confirm the following menu "Perform Uninstall" by clicking the "Finish" button.
Finally, close the "Add or Remove Programs" and "Control Panel" windows. Now, FluidLAB has been removed.

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

3. Program Documentation

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

Wet steam region: Temperature ranges from $t = 0°C$ to $t_c = 290.94°C$

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

Results for wrong input values

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

Single phase region: (x = -1)	p > 300 bar or p < 0,00078993 bar or t > 400 °C or t < 0°C
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 290.94°C$ to $t < 0°C$ at $t = -1000$ and $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar or or $p > p_c = 14.151055$ bar or $p < p_s(0°C) = 0.00078993$ bar and $t > t_c = 290.94°C$ or $t < 0°C$

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1]

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

Boiling and dew curve: Temperature ranges from $t = 0°C$ to $t_c = 290.94°C$

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

Results for wrong input values

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

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

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1], [2]

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

Function Name:	**kappa_ptx_MDM**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION KAPPAPTXMDM(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_KAPPAPTXMDM(KAPPA, P,T,X)** REAL*8 KAPPA,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1]

Vapor Pressure p_s = f(t)

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

Input Values:

T - Temperature t in °C

Result

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

Range of validity

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

Results for wrong input values

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

$t < 0°C$ or $t > t_c = 290.94°C$

References: [1], [2]

Density ρ = f(p,t,x)

Function Name:	**rho_ptx_MDM**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION RHOPTXMDM(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_RHOPTXMDM(RHO,P,T,X)** REAL*8 RHO,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

RHOPTXMDM, **RHO** or **rho_ptx_MDM** – Density ρ in kg/ m^3

Range of validity

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

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

Range of validity

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

Details on the calculation of wet steam

The wet steam region is calculated automatically. That means the given values of *p* and *h* are taken as a basis and the subprogram will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of the appropriate state region will be carried out.

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

Results for wrong input values

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

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

Result

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

Range of validity

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

Details on the calculation of wet steam

The wet steam region is calculated automatically. That means the given values of *p* and *s* are taken as a basis and the subprogram will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of the appropriate state region will be carried out.

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

Results for wrong input values

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

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

References: [1], [2]

Saturation Temperature t_s = f(p)

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

Input Values:

P - Pressure p in bar

Result

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

Range of validity

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

Results for wrong input values

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

Boiling and dew curve: Temperature ranges from $t = 0°C$ to $t_c = 290.94°C$

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

Results for wrong input values

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

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

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

Range of validity

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

Details on the calculation of wet steam

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

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

Results for wrong input values

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

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

References: [1], [2]

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

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

Input Values:

P - Pressure *p* in bar

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

Result

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

Range of validity

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

Details on the calculation of wet steam

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

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

Results for wrong input values

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

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

References: [1], [2]

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

Function Name:	**Z_ptx_MDM**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION ZPTXMDM(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ZPTXMDM(Z,P,T,X)** REAL*8 Z,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

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

Range of validity

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

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

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

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

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

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

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

Results for wrong input values

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

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

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

References: [1], [2]

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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

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

and of the ideal gases:

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

Consideration of:

Dissociation from VDI 4670 and Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS 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

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bücker et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term

(also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

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

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

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

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

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

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

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monooxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

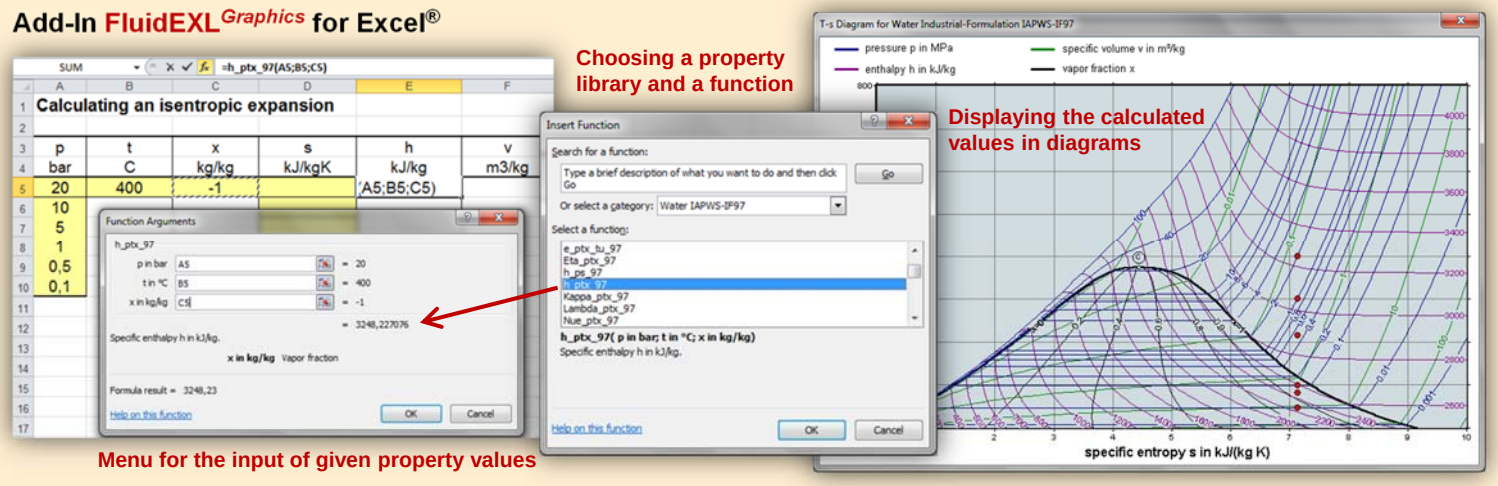
[a] Not all of these property functions are available in all property libraries.

www.thermodynamic-property-libraries.com

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

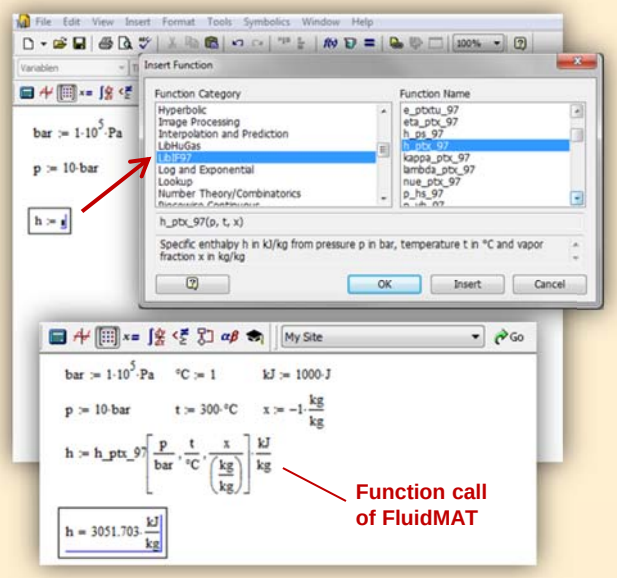
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



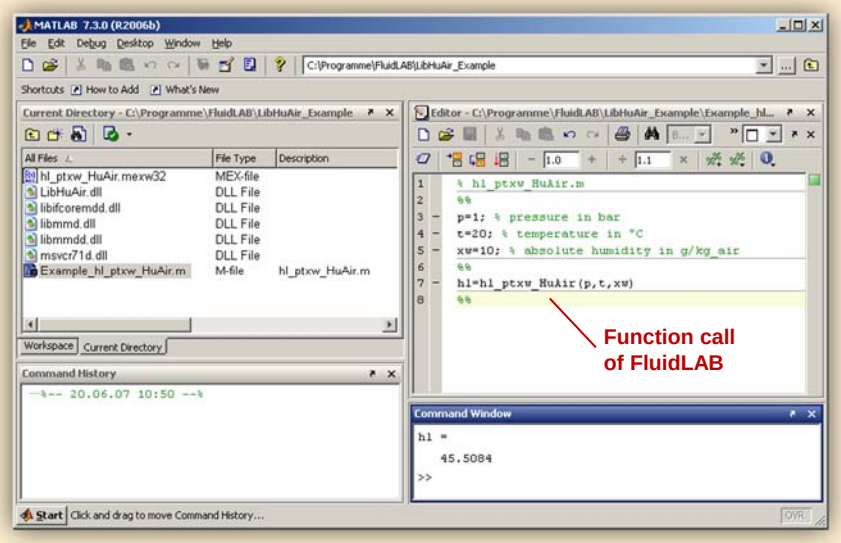
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



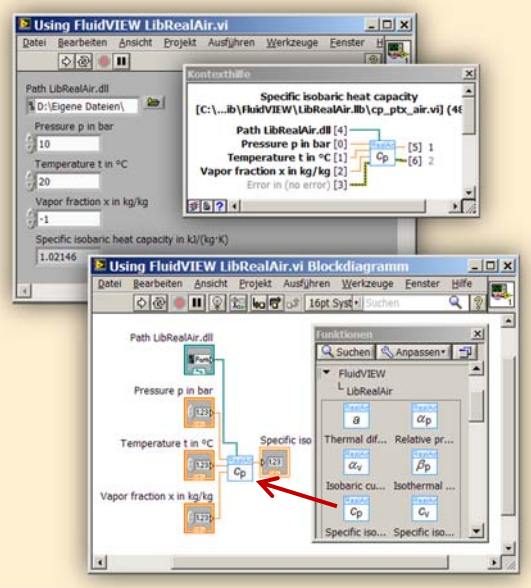
Add-In FluidLAB for MATLAB®

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



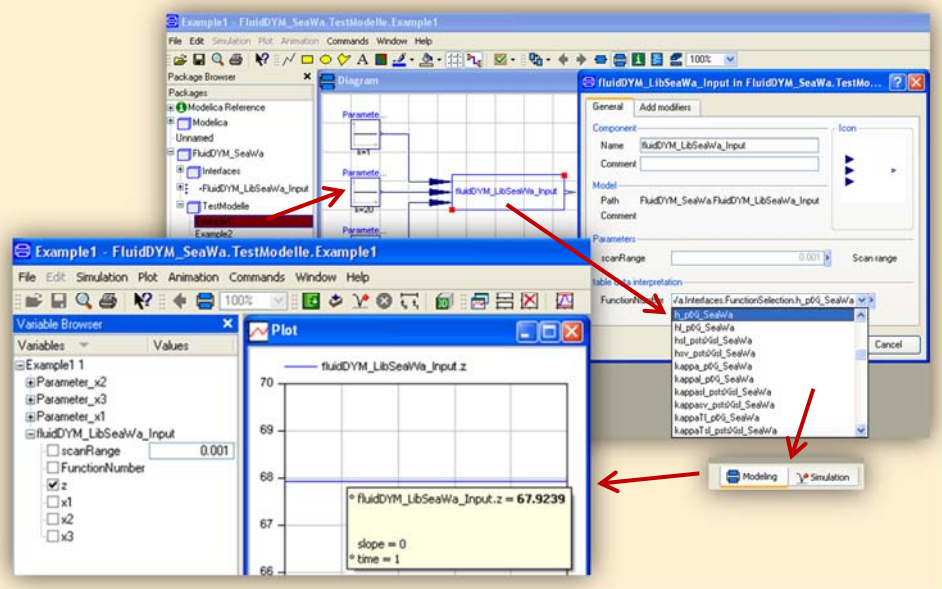
Add-On FluidVIEW for LabVIEW®

The property functions can be calculated in LabVIEW®.

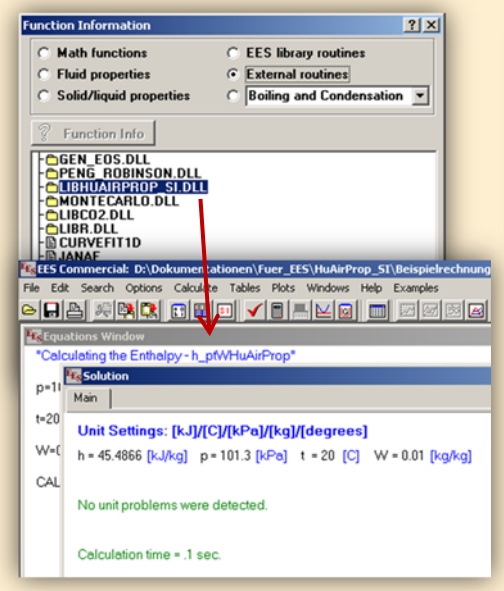


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

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



Add-In FluidEES for Engineering Equation Solver®



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

Online Property Calculator at www.thermodynamics-zittau.de

Property Software for Pocket Calculators

FluidCasio

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

FluidHP

HP 48 | HP 49

FluidTI

TI Nspire CX CAS
TI Nspire CAS

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

For more information please contact:

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

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

www.thermodynamic-property-libraries.com

5. References

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Fluid Phase Equilibria, 263, (2008) pp. 115-130

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Multiparameter Equations of State;
An Accurate Source of Thermodynamic Property Data
Springer Verlag 2000

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Generalized multiparameter correlation for nonpolar and polar fluid transport properties
Industrial & Engineering Chemistry Research, 27, (1988) pp. 671-679

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McGraw-Hill, New York, 5th Edition, 2001, Chapter 9.40, 10.23

[5] Olchowy, G. A.; Sengers, J. V.
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International Journal of Thermophysics, 10, (1989) pp. 417-426

6. Satisfied Customers

Date: 04/2014

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®:

2014

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

2013

TRANTER-GmbH, Artern	12/2013
SATAKE, Shanghai, China	12/2013
VOITH, Kunshan, China	12/2013
ULT, Löbau	12/2013
MAN, Copenhagen, Dänemark	11/2013
DREWAG, Dresden	11/2013
Haarslev Industries, Herlev, Dänemark	11/2013
STEAG, Herne	11/2013, 12/2013
Ingersoll-Rand, Oberhausen	11/2013
Wilhelm-Büchner HS, Darmstadt	10/2013
IAV, Chemnitz	10/2013
Technical University of Regensburg	10/2013
PD-Energy, Bitterfeld	09/2013
Thermofin, Heinsdorfergrund	09/2013
SHI, New Jersey, USA	09/2013
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	08/2013
TIG-Group, Husum	08/2013
COMPAREX, Leipzig for RWE Essen	08/2013, 11/2013 12/2013
University of Budapest, Hungary	08/2013
Siemens, Frankenthal	08/2013, 10/2013 11/2013
VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
Technical University of Deggendorf	07/2013
University of Maryland, USA	07/2013, 08/2013
University of Princeton, USA	07/2013
NIST, Boulder, USA	06/2013
IGUS GmbH, Dresden	06/2013
BHR Bilfinger, Essen	06/2013
SÜDSALZ, Bad Friedrichshall	06/2013, 12/2013
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Hochtief, Düsseldorf	05/2013
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Technical University -Bundeswehr, Munich	04/2013
Rerum Cognitio Forschungszentrum, Frankfurt	04/2013
Kältetechnik Dresen + Bremen, Alfhausen	04/2013
University Auckland, New Zealand	04/2013
MASDAR Institut, Abu Dhabi, United Arab Emirates	03/2013
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frischli Milchwerke, Rehburg-Loccum	01/2013

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Fischer-Uhrig, Berlin	01/2008
University of Karlsruhe	01/2008
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	02/2008
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008

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RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
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Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
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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
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2007

Audi, Ingolstadt	02/2007
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VER, Dresden	02/2007
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Redacom, Nidau, Switzerland	02/2007
Universität der Bundeswehr, Munich	02/2007
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ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
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Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
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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
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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
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Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006

Technical University of Munich, Chair in Apparatus and Plant Engineering	02/2006
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
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WAETAS, Pobershau	04/2006
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Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
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BASF, Schwarzheide	12/2006
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2005

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J.H.K Plant Engineering and Service, Bremerhaven	01/2005
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SaarEnergie, Saarbruecken	07/2005
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Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005
Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

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Vattenfall Europe (group license)	01/2004
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University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004

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
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

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Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003
Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003

Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
Ingenieurbuero Ostendorf, Gummersbach	05/2003
TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	06/2003
University of Cali, Colombia	07/2003
Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003
Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

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Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
FZR Forschungszentrum, Rossendorf/Dresden	03/2002

CompAir, Simmern	03/2002
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G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

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ALSTOM Power, Baden, Switzerland	01/2001, 06/2001 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
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
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Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001

Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
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VEAG, Berlin (group license)	12/2001

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AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000
IBR Engineering Reis, Nittendorf-Undorf	02/2000
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Thinius Engineering, Erkrath	04/2000
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DVO Data Processing Service, Oberhausen	05/2000
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
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Steinhaus Informationssysteme, Datteln (general license for process data software)	12/2000

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Bayernwerk, Munich	01/1999
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KEMA IEV, Dresden	03/1999

Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
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Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998
SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

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