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**Property Library for
Decamethylcyclopentasiloxane (D5)
 $C_{10}H_{30}O_5Si_5$**

**FluidDYM
with LibD5
for DYMOLA[®]**

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Property Software for Decamethylcyclopentasiloxane $\text{C}_{10}\text{H}_{30}\text{O}_5\text{Si}_5$ (LibD5)

FluidDYM for DYMOLA®

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0. Package Contents

Zip-file "CD_FluidDYM_LibD5_Eng.zip" for DYMOLA®

Including the following files:

FluidDYM_LibD5_Setup.exe	Installation Program for the FluidDYM Add-In for use in DYMOLA®
LibD5.dll	Dynamic Link Library for Decamethylcyclopentasiloxane D5 for use in Dymola®
FluidDYM_LibD5_Docu_Eng.pdf	User's Guide
Folder "Users_Guide"	Includes the complete User's Guide

1. Property Functions

1.1 Calculation Programs

“D5” means Decamethylcyclopentasiloxane ($C_{10}H_{30}O_5Si_5$)

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibD5 as parameter	Property or Function	Unit of the result
$c_p = f(p, t, x)$	cp_ptx_D5	CPPTXD5(P,T,X)	C_CPPTXD5(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p, t, x)$	cv_ptx_D5	CVPTXD5(P,T,X)	C_CVPTXD5(CV,P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\left(\frac{\partial p}{\partial T}\right)_v = f(p, t, x)$	dptdv_ptx_D5	DPDVTXD5(P,T,X)	C_DPDVTXD5(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_D5	DPDVTXD5(P,T,X)	C_DPDVTXD5(DPDV,P,T,X)	Derivative of pressure with respect to specific volume (at constant temperature)	kPa/(m³/kg)
$h = f(p, t, x)$	h_ptx_D5	HPTXD5(P,T,X)	C_HPTXD5(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p, t, x)$	kappa_ptx_D5	KAPPAPTXD5(P,T,X)	C_KAPPAPTXD5(KAPPA,P,T,X)	Isentropic exponent	-
$p_s = f(t)$	ps_t_D5	PSTD5(T)	C_PSTD5(PS,T)	Vapor pressure from temperature	bar
$\rho = f(p, t, x)$	rho_ptx_D5	RHOPTXD5(P,T,X)	C_RHOPTXD5(RHO,P,T,X)	Density	kg/m³
$s = f(p, t, x)$	s_ptx_D5	SPTXD5(P,T,X)	C_SPTXD5(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p, h)$	t_ph_D5	TPHD5(P,H)	C_TPHD5(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p, s)$	t_ps_D5	TPSD5(P,S)	C_TPSD5(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_D5	TSPD5(P)	C_TSPD5(TS,P)	Saturation temperature from pressure	°C
$u = f(p, t, x)$	u_ptx_D5	UPTXD5(P,T,X)	C_UPTXD5(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p, t, x)$	v_ptx_D5	VPTXD5(P,T,X)	C_VPTXD5(V,P,T,X)	Specific volume	m³/kg
$w = f(p, t, x)$	w_ptx_D5	WPTXD5(P,T,X)	C_WPTXD5(W,P,T,X)	Isentropic speed of sound	m/s
$x = f(p, h)$	x_ph_D5	XPHD5(P,H)	C_XPHD5(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibD5 as parameter	Property or Function	Unit of the result
$x = f(p,s)$	x_ps_D5	XPSD5(P,S)	C_XPSD5(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
$Z = f(p,t,x)$	Z_ptx_D5	ZPTXD5(P,T,X)	C_ZPTXD5(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 $t = 26.85^\circ\text{C}$ to 399.85°C
Pressure range: from $p = 0.00001$ bar to 300 bar

Reference state

$h = 0$ kJ/kg and $s = 0$ kJ/(kg K) at $t_B = 210.9^\circ\text{C}$ on the boiling curve ($x = 0$; $p_s = p_N = 1.01325$ bar)

Details on the vapor fraction x

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

Single-phase region

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

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

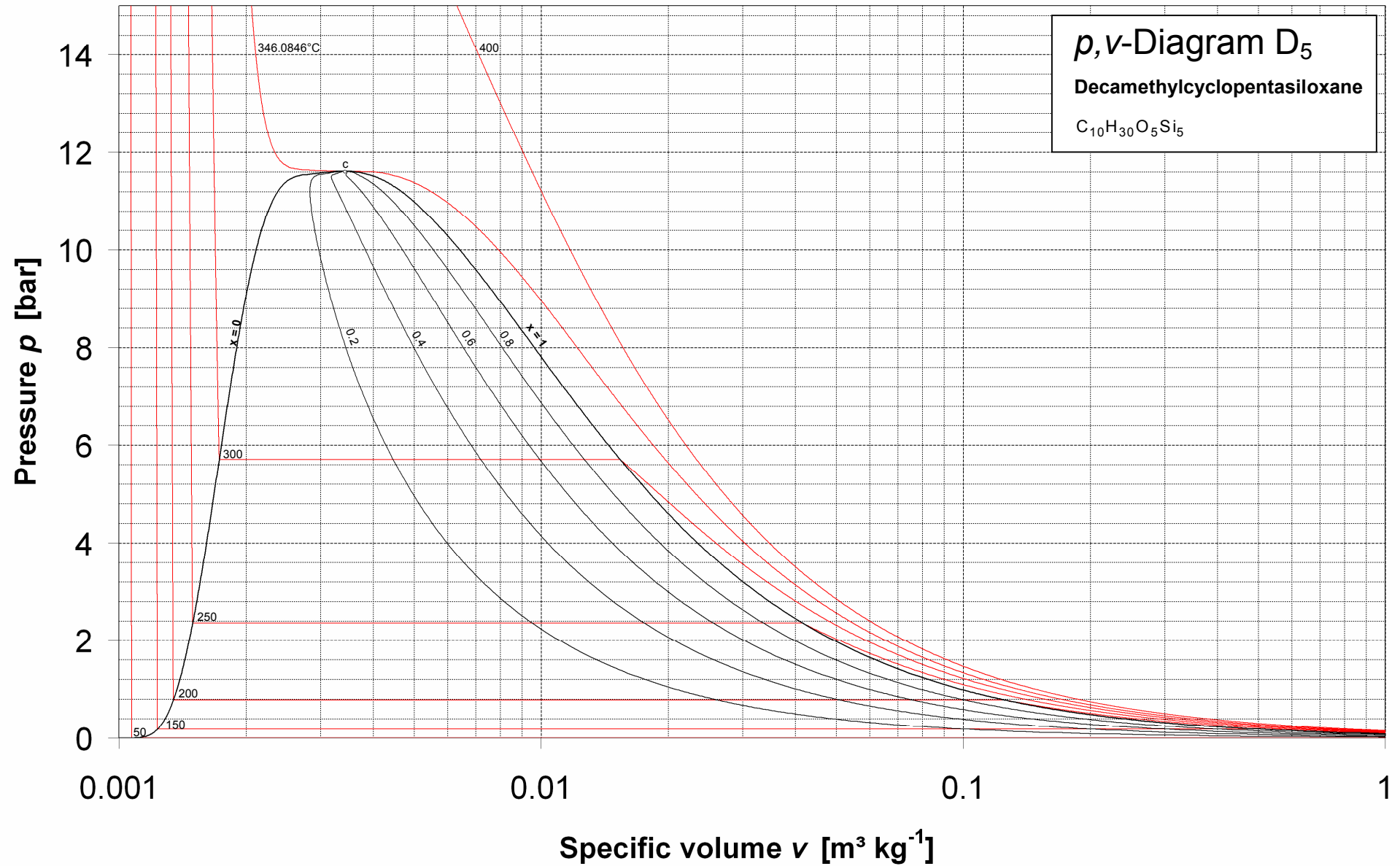
Wet steam region: Temperature range from $t = 26.85\text{ °C}$ to $t_c = 346.085\text{ °C}$

Pressure range from $p_s(26.85\text{ °C}) = 0.001477917\text{ bar}$ to $p_c = 11.6146\text{ bar}$

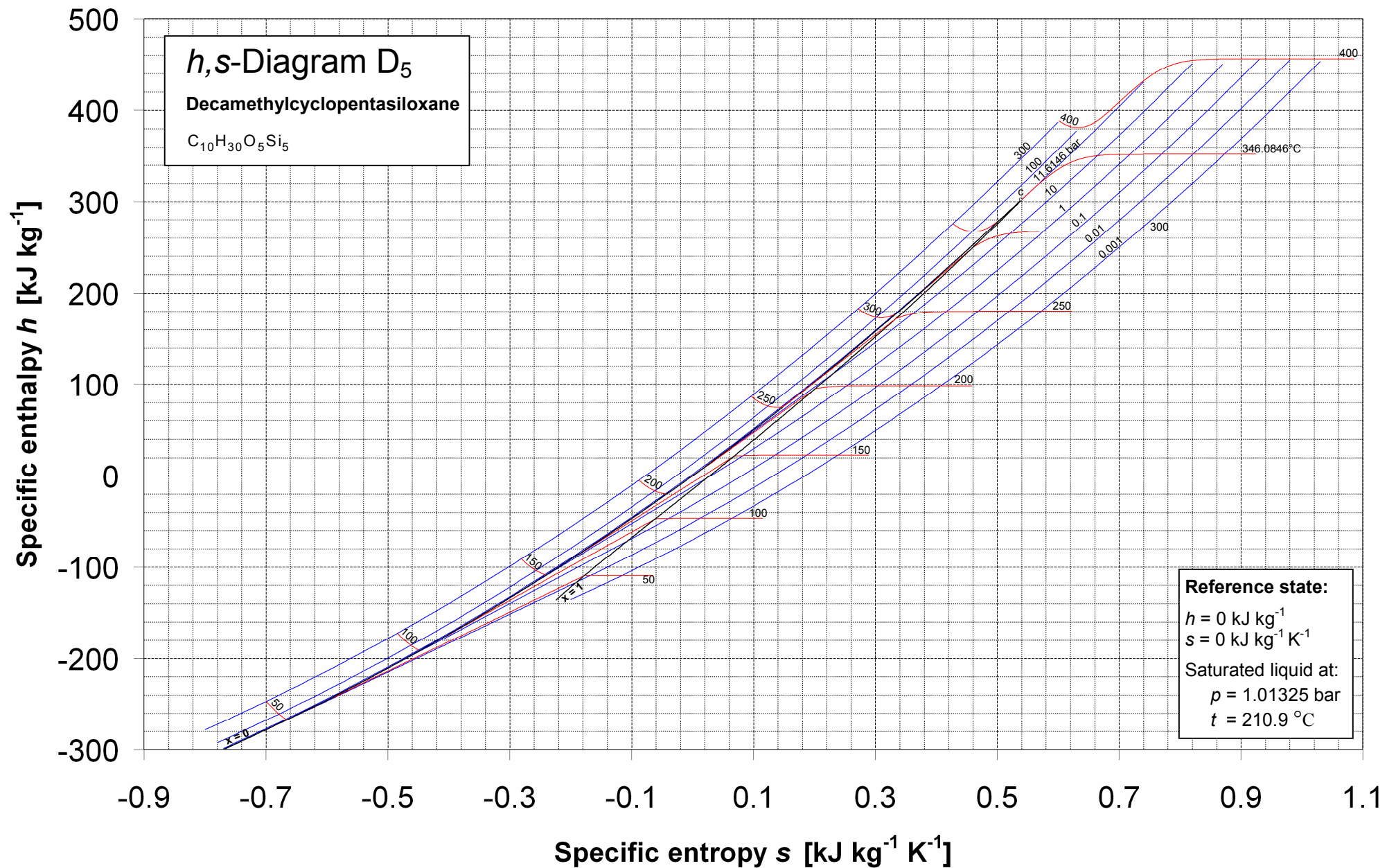
Hint.

If the calculation results in -1000 (except for x), the entered values represent a state point beyond the range of validity of LibD5. 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.

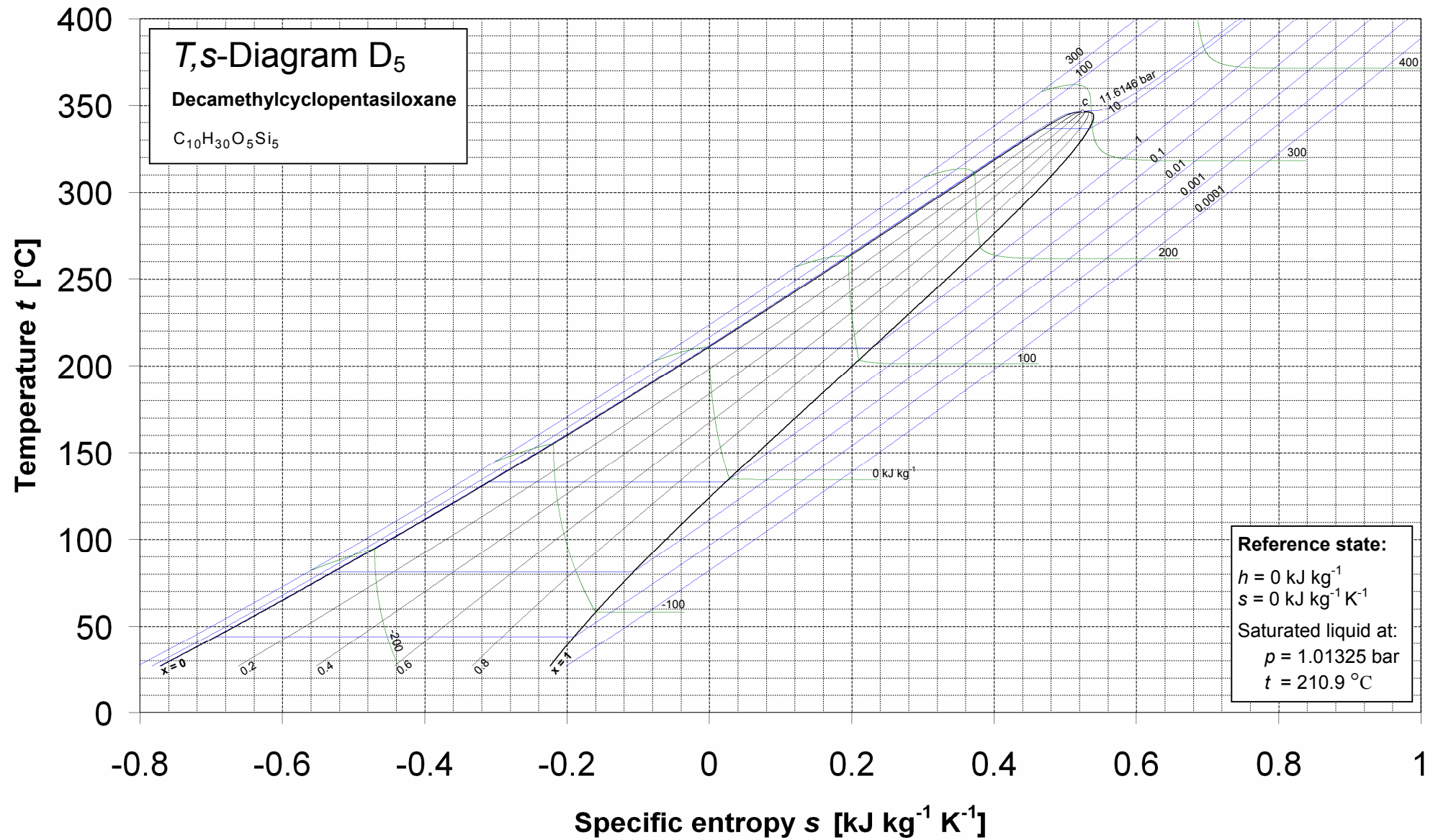
1.2 p,v -Diagram



1.3 h,s -Diagram



1.4 T,s-Diagram



2. Application of FluidDYM in Dymola®

The FluidDYM Add-In has been developed to calculate thermodynamic properties in Dymola® more conveniently. Within Dymola® it enables the direct call of functions relating to Decamethylcyclopentasiloxane from the LibD5 property library.

2.1 Installing FluidDYM

FluidDYM will be installed by means of a self-extracting setup file. 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_FluidDYM_LibD5_Eng.zip", you will see the folder

CD_FluidDYM_LibD5_Eng

in your Windows Explorer®, Norton Commander® etc.

Now, open this folder by double-clicking on it.

Within this folder you will see the following files:

FluidDYM_LibD5_Docu_Eng.pdf

FluidDYM_LibD5_Setup.exe.

In order to run the installation of FluidDYM including the LibD5 property library double-click the file

FluidDYM_LibD5_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 "Continue" button.

In the following dialog box, "Choose Destination Location", the default path offered automatically for the installation of FluidDYM is "C:\Program Files\FluidDYM\LibD5" (see Figure 2.1).

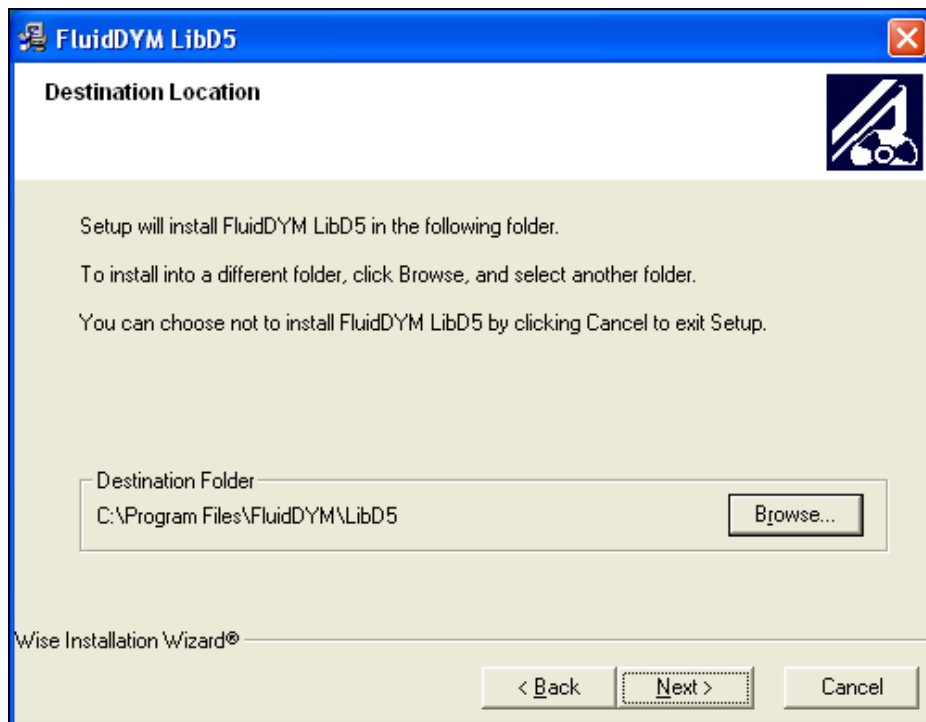


Figure 2.1: Dialog window "Destination Location"

By clicking the "Browse..." button, you can change the installation directory before installation. If you wish to change directory, click the "Browse..." button and select your desired directory. The instructions in this user's guide 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 the installation. The FluidDYM files are now being copied onto your hard disk drive into the created directory. Click the "Finish>" button in the following window to finish installation.

The installation program has copied the following files into the directory "C:\Program Files\FuildDYM\LibD5":

- Dynamic link library "LibD5.dll".
- Link up Dynamic link library "LibD5_Dym.dll" and other necessary system DLL files.
- Library File "LibD5_DYM.lib"
- Header File "LibD5_DYM.h" and other necessary system DLL files.
- Modelica File "FluidDYM_LibD5.mo", includes the following property functions:

cp_ptx_D5	t_ph_D5
cv_ptx_D5	t_ps_D5
dptvt_ptx_D5	ts_p_D5
dpdvt_ptx_D5	u_ptx_D5
h_ptx_D5	v_ptx_D5
kappa_ptx_D5	w_ptx_D5
ps_t_D5	x_ph_D5
rho_ptx_D5	x_ps_D5
s_ptx_D5	Z_ptx_D5

Now, you have to overwrite the file "LibD5.dll" in your LibD5 directory with the file of the same name provided in your CD folder with FluidDYM.

To do this, open the CD folder "CD_FluidDYM_LibD5_Eng" in "My Computer" and click on the file "LibD5.dll" in order to highlight it.

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

Now, open your LibD5 directory (the standard being

C:\Program Files\FluidDYM\LibD5)

and insert the file "LibD5.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 "LibD5.dll" successfully.

In the next step, copy the folder "Users_Guide" into your Dymola LibD5 directory with the file of the same name provided in your CD folder of FluidDYM.

To do this, open the CD folder "CD_FluidDYM_LibD5_Eng" in "My Computer" and click on the folder "Users_Guide" to highlight it. Then click on the "Edit" menu in your Explorer and select "Copy".

Now, open your Dymola LibD5 directory (the standard being:

C:\Program Files\FluidDYM\LibD5)

and insert the folder "Users_Guide" by clicking the "Edit" menu in your Explorer and then selecting "Paste". Now, the folder "Users_Guide" has been successfully placed in your installation directory.

Licensing the LibD5 Property Library

The licensing procedure has to be carried out when DYMOLA[®] is running and a model simulation starts. In this case, you will see the "License Information" window (see figure below).

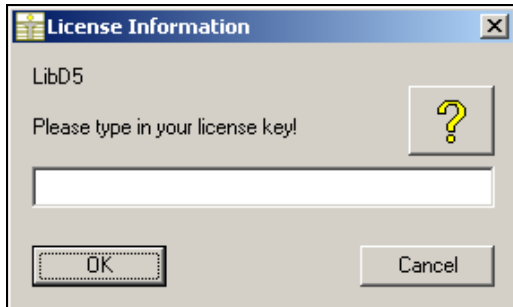


Figure 2.2: "License Information" window

Here you will have to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. You can find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:



Figure 2.3: "Help" window

If you do not enter a valid license it is still possible to use DYMOLA[®] by clicking "Cancel". In this case, the LibD5 property library will display the result "-11111111" for every calculation. The "License Information" window will appear every time you start DYMOLA unless you uninstall FluidDYM_LibD5 according to the description in section 2.3 of this User's Guide. Should you not wish to license the LibD5 property library, you have to delete the files

LibD5.dll
LibD5_DYM.dll
LibD5_DYM.lib
LibD5_DYM.h
LibD5_DYM.mo

in the installation folder of Dymola[®] (the standard being

C:\Program Files\FluidDYM)

using an appropriate program such as Explorer[®] or Norton Commander.

2.2 Example: Calculation of the Specific Enthalpy $h = f(p, t, x)$ of Decamethylcyclopentasiloxane

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

Please carry out the following instructions:

- Start Windows Explorer®, Total Commander®, My Computer or another file manager program.
The description here refers to Windows Explorer.
- Your Windows Explorer should be set to Details for a better view. Click the "View" (Ansicht) button and select "Details".
- Switch into the program directory of FluidDYM in which you will find the folder "\LibD5"; the standard location is: "C:\Program Files\FluidDYM\LibD5"
- Create the folder "\LibD5_Example" by clicking on "File" in the Explorer menu, then "New" in the menu which appears, and then selecting "Folder". Name the new folder "\LibD5_Example".
- You will see the following window:

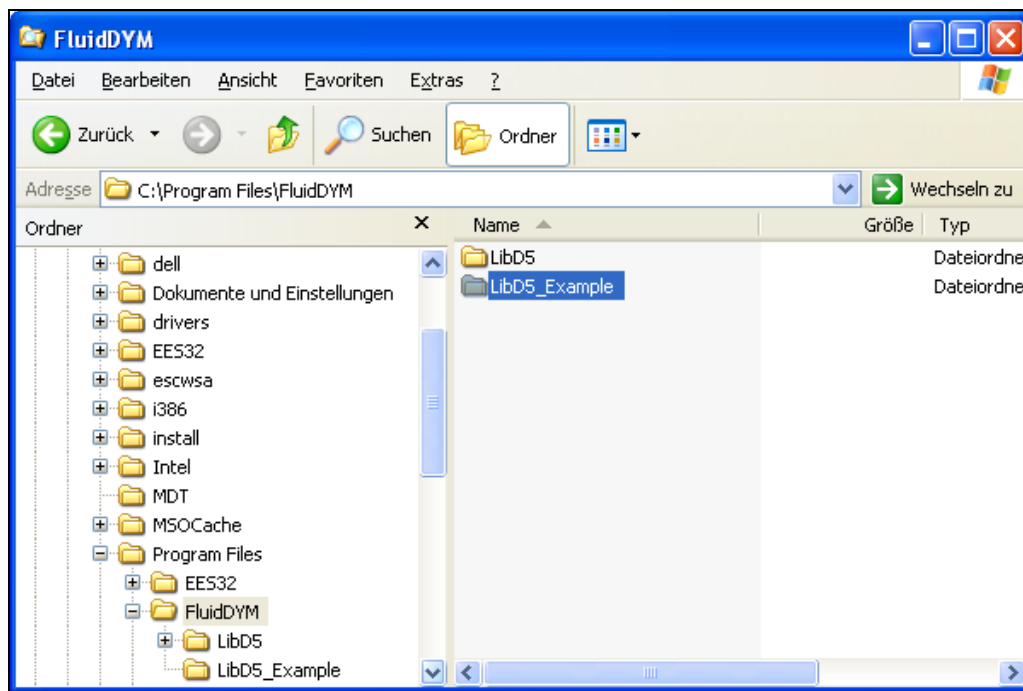


Figure 2.4: Highlighted *LibD5_Example* directory in FluidDYM

- Switch into the directory "\LibD5" within "\FluidDYM", the standard being: "C:\Program Files\FluidDYM\LibD5".

- You will see the following window:

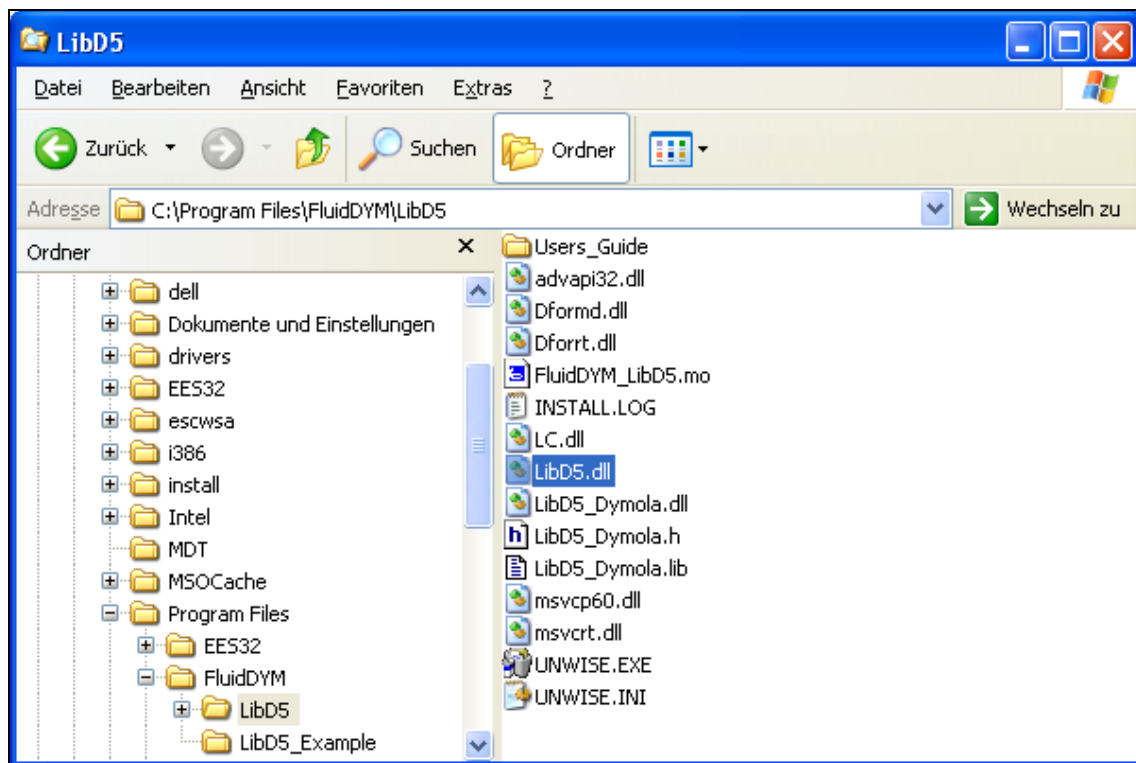


Figure 2.5: *LibD5* directory including installed files

In order to calculate the function $h = f(p, t, x)$, the following files are necessary. Copy them into the directory "C:\Program Files\FluidDYM\LibD5_Example":

- "advapi32.dll"
 - "Dformd.dll"
 - "Dforrt.dll"
 - "FluidDYM_LibD5.mo"
 - "LC.dll"
 - "LibD5.dll"
 - "LibD5_Dymola.dll"
 - "LibD5_Dymola.h"
 - "LibD5_Dymola.lib"
 - "msvc60.dll"
 - "Msvcrt.dll"
 - the folder "Users_Guide"
- Mark up these files, then click "Edit" in the upper menu bar and select "Copy".
 - Switch into the directory "C:\Program Files\FluidDYM\LibD5_Example", click "Edit" and then "Paste".

- You will see the following window:

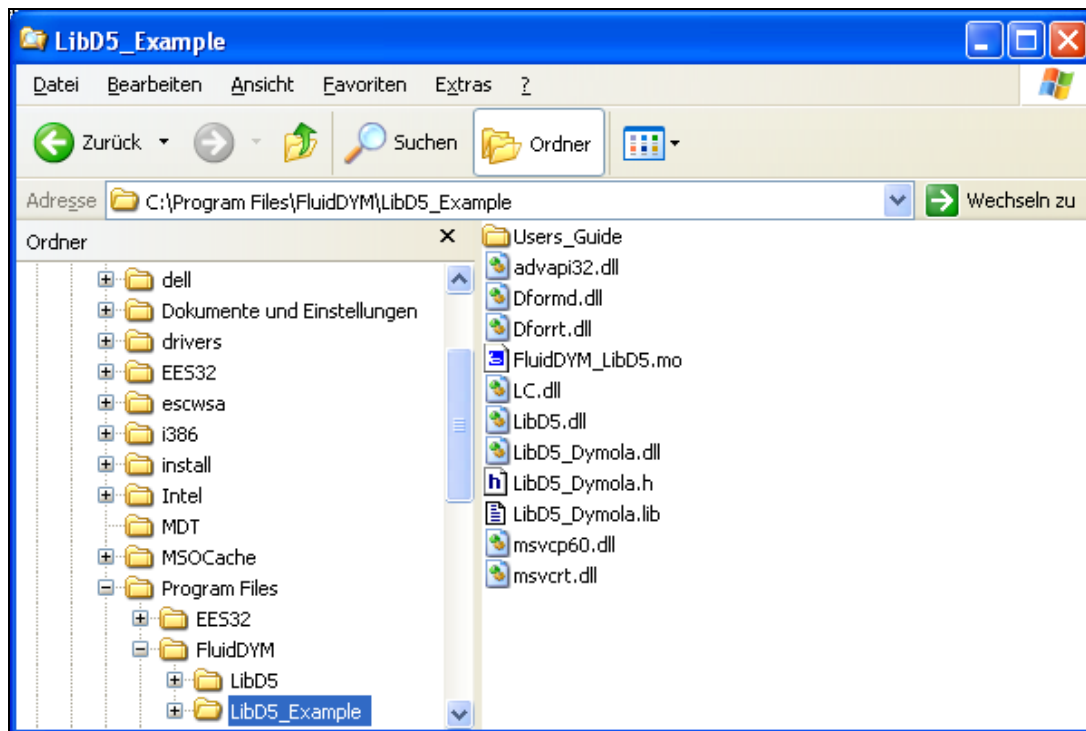


Figure 2.6: *LibD5_Example* directory including the newly-copied files

- Start Dymola®.
- Now click on "File" in the Dymola® menu bar and select "Open" (see Figure 2.7).

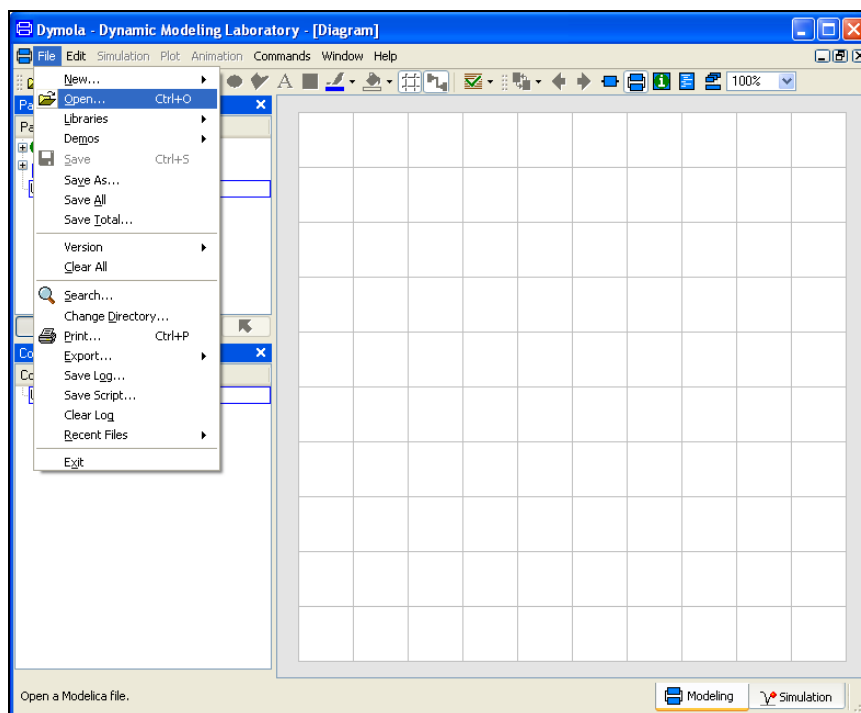


Figure 2.7: Selecting the menu entry "Open"

- Search and click on the directory "C:\Program Files\FluidDYM\LibD5_Example" in the pop-up menu.

- Select the "FluidDYM_LibD5.mo" file and click on the "Open" button (see Figure 2.8).

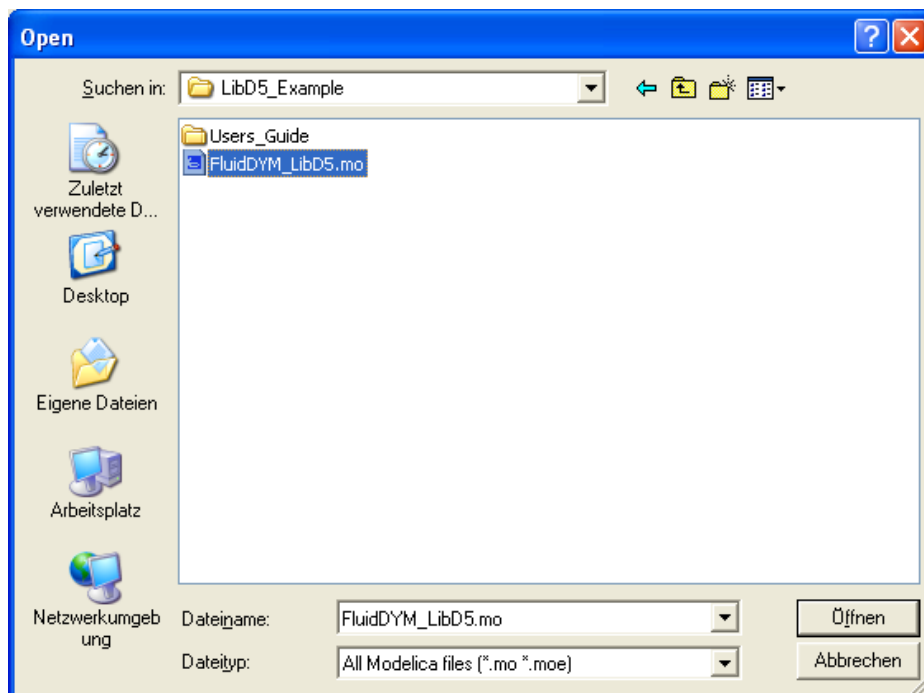


Figure 2.8: Selecting the *FluidDYM_LibD5.mo* file

- The library will be loaded by Dymola which may take a few seconds.
- After Dymola has finished loading the LibD5 library, you will see the window shown in Figure 2.9.

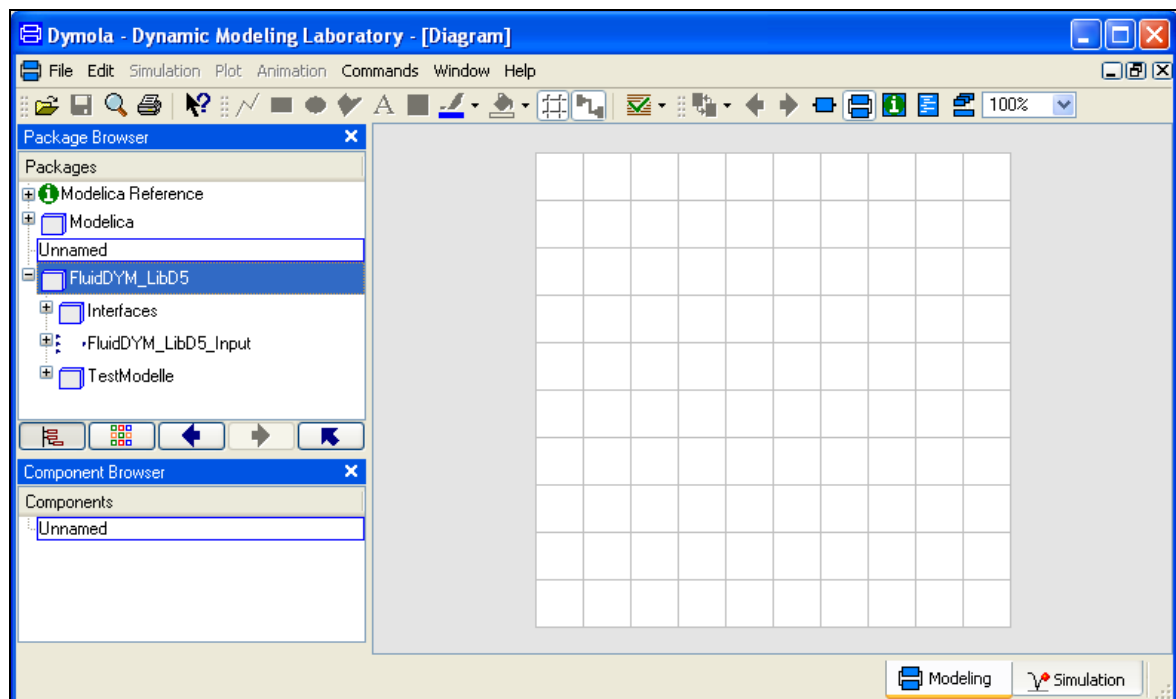


Figure 2.9: Dymola window after loading the *LibD5* library

- Now, click on "File" in the Dymola menu bar and select "Change Directory..." in order to open the folder "LibD5_Example" (see Figure 2.10).

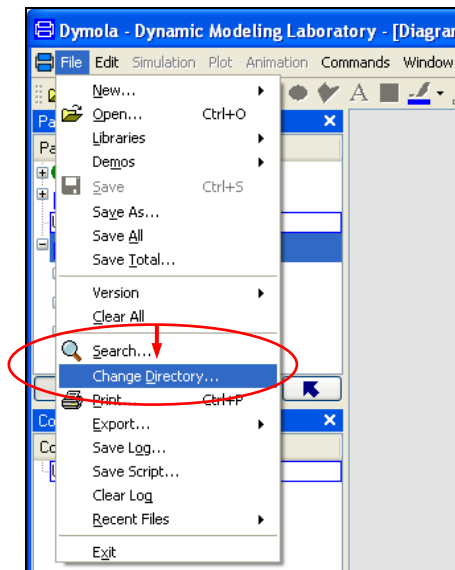


Figure 2.10: Selecting the menu entry "Change Directory..."

- Search and click on the directory "C:\Program Files\FluidDYM\LibD5_Example" in the pop-up menu (see Figure 2.11).



Figure 2.11: Selecting the *LibD5_Example* directory

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

As indicated in the table of property functions in Chapter 1, you have to call up the function "h_ptx_D5" as follows for calculating $h = f(p, t, x)$.

- Click on the Dymola-Block "Testmodelle," which can be found in the FluidDYM_LibD5 package in the "Package Browser" on the left hand side of the Dymola window. Here choose Example1 by double-clicking on it.
- Now click on the  button in the Dymola menu bar in order to switch to the Diagram Mode. You will see the following window:

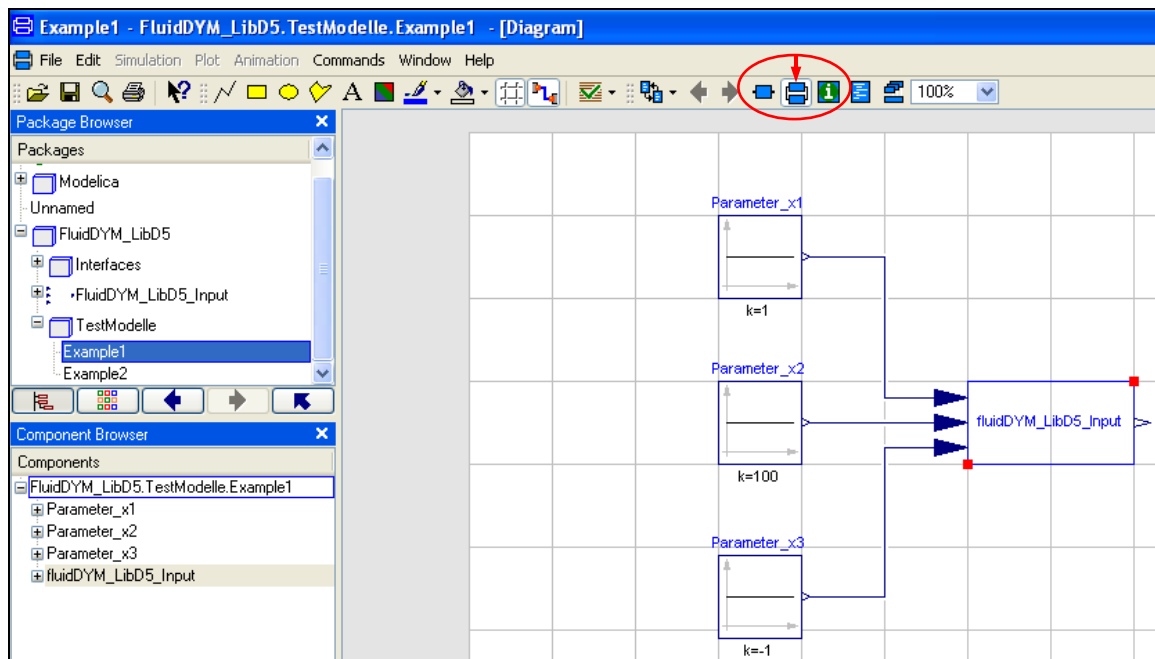


Figure 2.12: Dymola in Diagram Mode

- Now double-click on the "fluidDYM_LibD5_Input" block on the right hand side of the Dymola window.
- Search and click the "h_ptx_D5" function next to "Function Number" in the pop-up menu (see Figure 2.13).

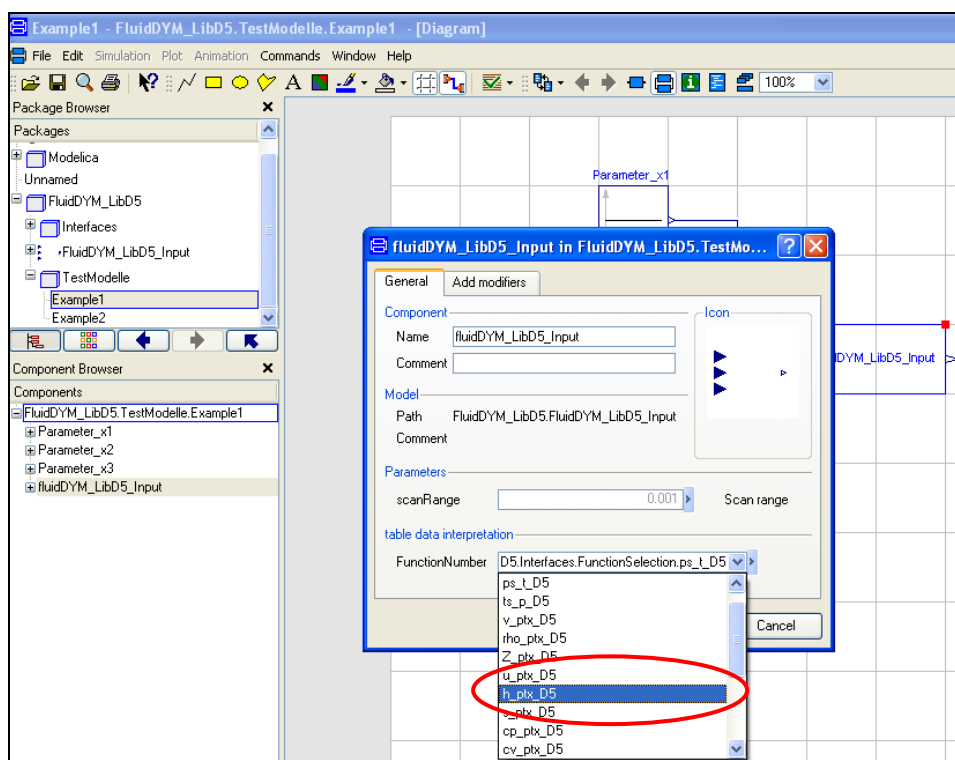


Figure 2.13: Choosing the function h_{ptx_D5}

- You can set the scan range (how many times the property will be calculated per second) next to "scanRange". The preset value 0.001 means that the property will be calculated 1000 times per second. E.g. if you enter the value 1, the property will be calculated once per second. Do not change the preset value of 0.001 for our example calculation.

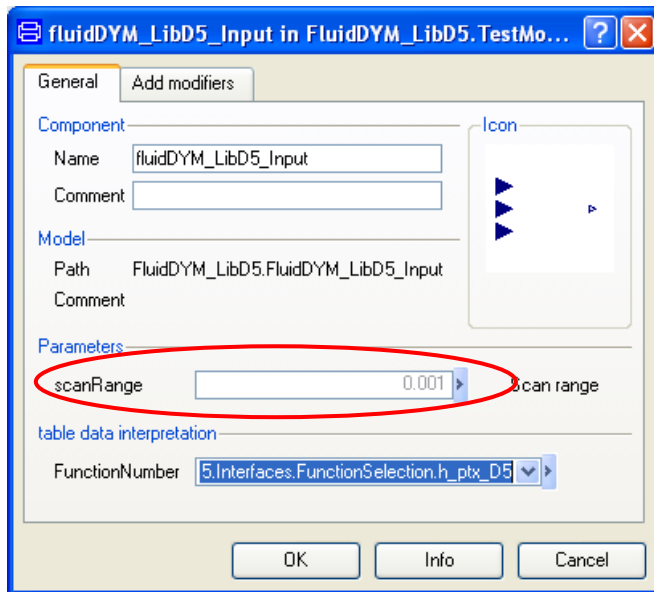


Figure 2.14: Setting the scan range

- Now we will configure the input parameters x_1 to x_3 , where x_1 represents the pressure p , x_2 represents the temperature t , and x_3 represents the vapor fraction x . When calculating a function with only two input parameters, the third input parameter x_3 will not be defined.
- First, double click on the "Parameter_x1" block which represents the first input parameter, here the pressure p in bar.

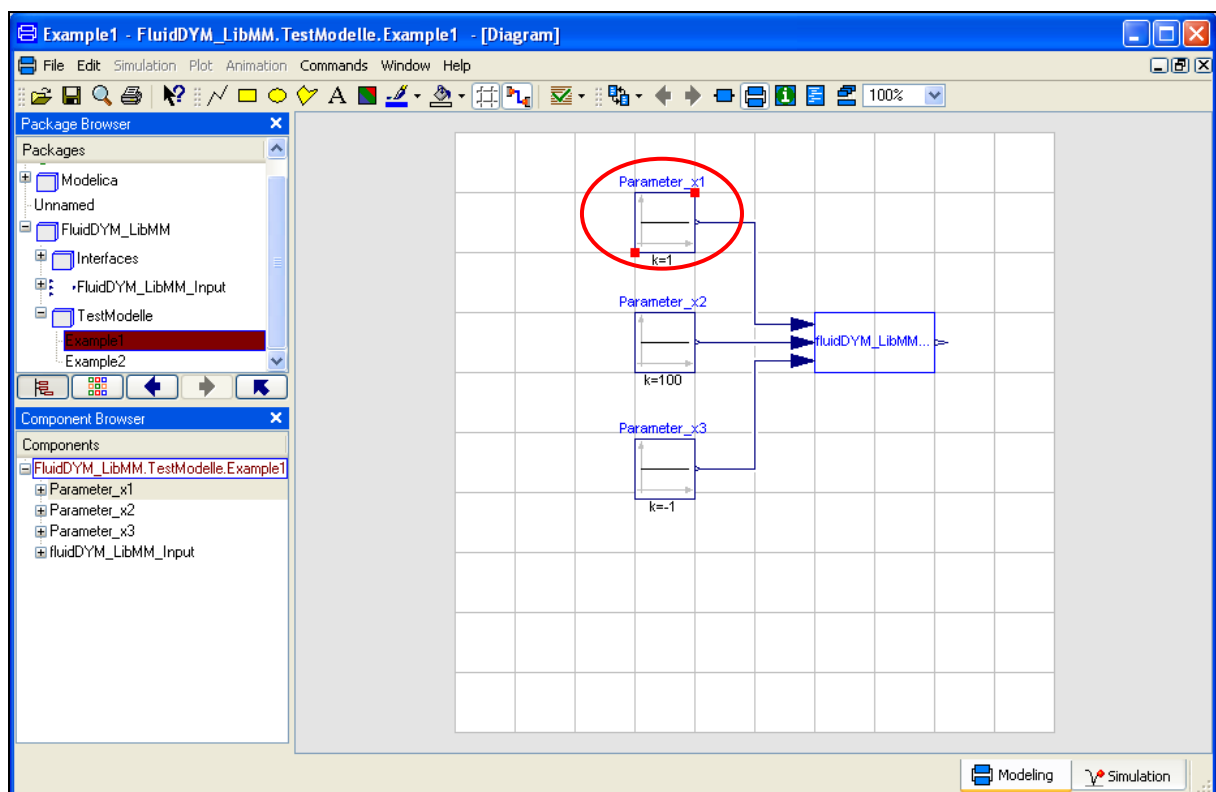


Figure 2.15: "Parameter_x1" block in Dymola

- Enter the value 10 on the line next to "k" in the dialog window which appears and then click the "OK" button (see Figure 2.16).

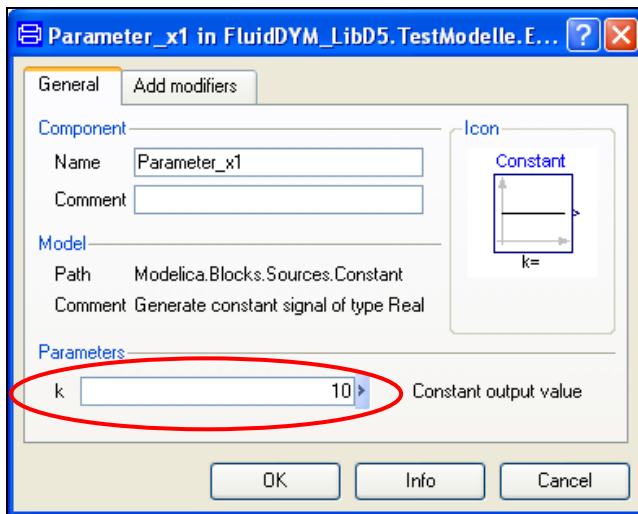


Figure 2.16: Entering the value for the pressure p

- Now, double click on the "Parameter_x2" block which represents the second input parameter, here the temperature t in °C.
- Enter the value 300 on the line next to "k" in the dialog window which appears and then click the "OK" button (see Figure 2.17).

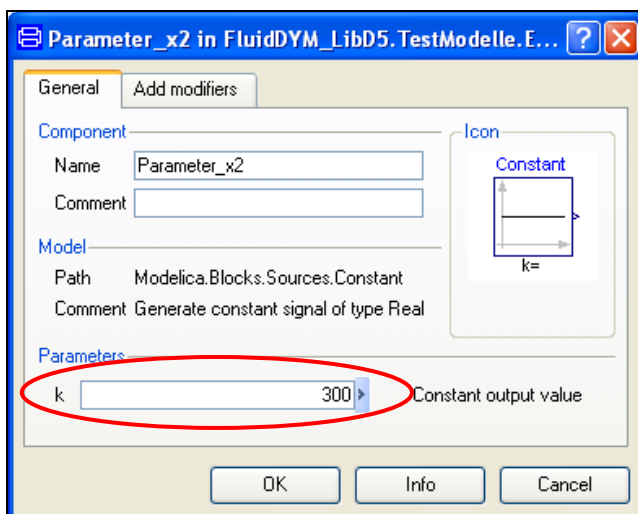


Figure 2.17: Entering the value for the temperature t

- Now, double click on the "Parameter_x3" block which represents the third input parameter, here the vapor fraction x in 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.

If 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 $p = -1$, or the given value for p and $t = -1$, 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.

(D5 Saturation pressure curve:

$$t = 26.85 \text{ °C to } t_c = 346.085 \text{ °C}$$

$$p_s(26.85 \text{ °C}) = 0.001477917 \text{ bar to } p_c = 11.6146 \text{ bar}$$

- Enter the value -1 on the line next to "k" in the dialog window which appears and then click the "OK" button (see Figure 2.18).

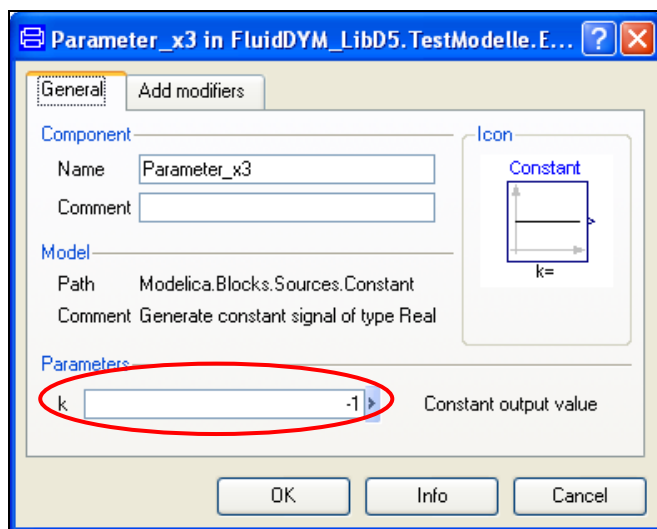
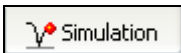


Figure 2.18: Entering the value for the vapor fraction x

All parameters have now been defined.

- Click on the  button in the lower right area of Dymola in order to switch into the "Simulation Mode".

In Figure 2.19 you can see how the Dymola "Simulation Mode" looks like.

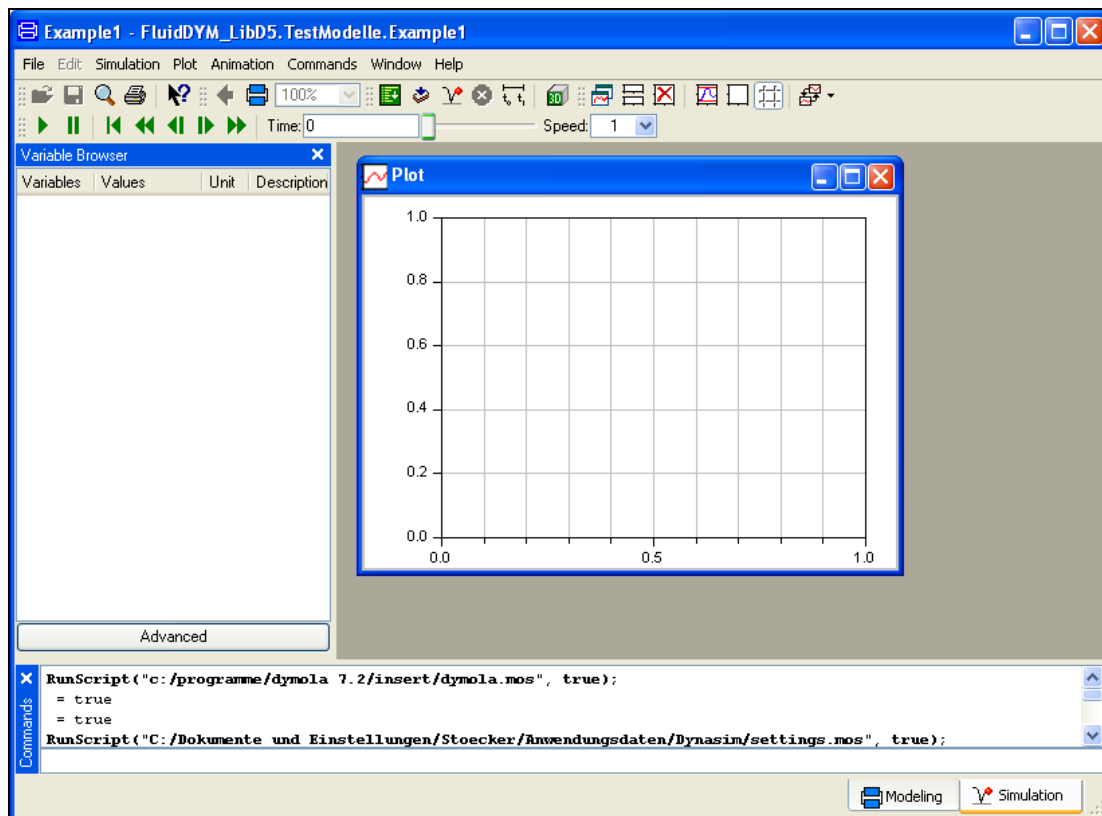


Figure 2.19: "Simulation Mode" window

- Click on the "Simulate" Button  in the Dymola menu bar to start the calculation. Now the model will be compiled and the simulation started.
- Afterwards you will see the following entries within the "Variable Browser" window in Dymola (see Figure 2.20):

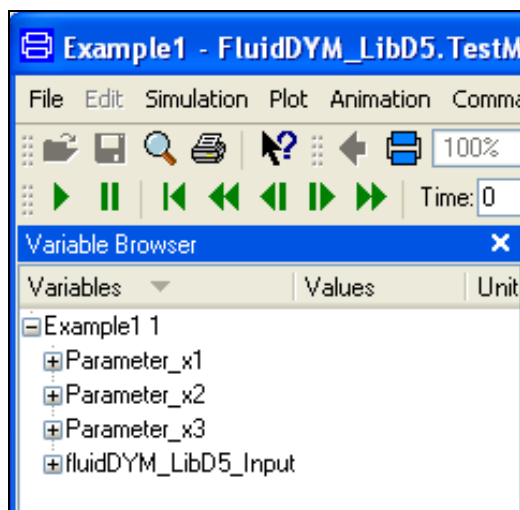


Figure 2.20: "Variable Browser" with new entries

- By clicking on the "New Plot Window" button , a new diagram window will be opened.
- Click on "fluidDYM_LibD5_Input" within the "Variable Browser"; then you will see the input and output parameters "scanRange", "FunctionNumber", "z", "x1", "x2" and "x3" (see Figure 2.21).

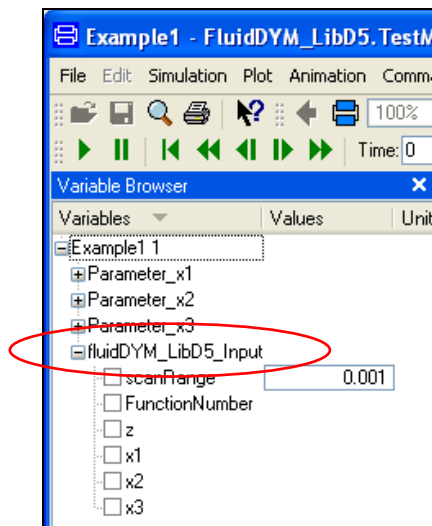


Figure 2.21: Parameters of *fluidDYM_LibD5_Input*

- After clicking on the output parameter "z", the calculated property will be represented graphically in the "PlotWindow".
- Move the mouse over the curve to see the result of the simulation at a specific point in time (see Figure 2.22).

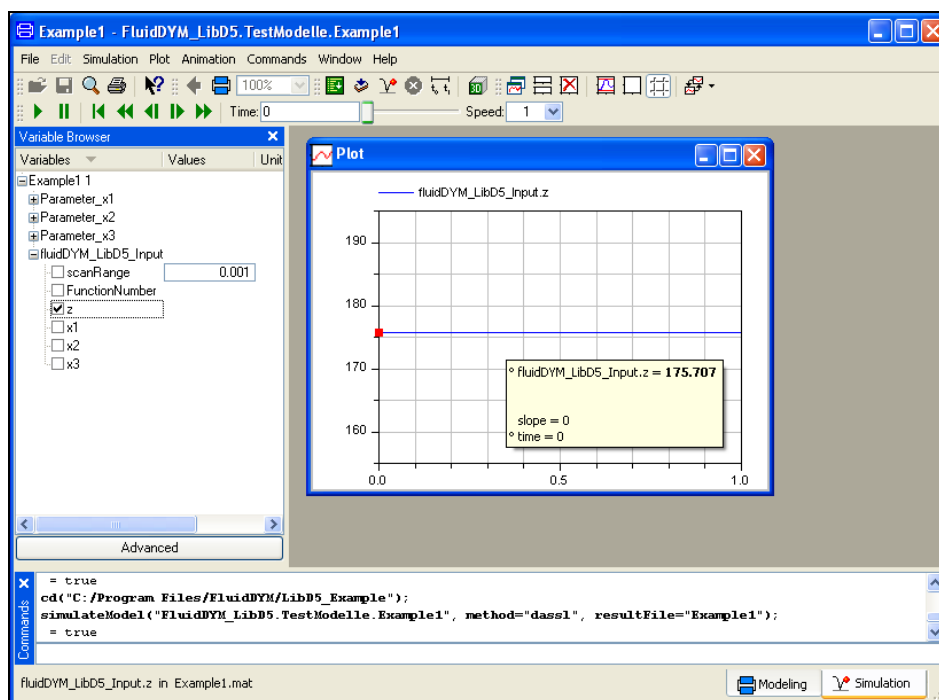


Figure 2.22: "DiagramWindow" showing the result

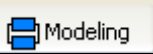
The result for h appears in the "DiagramWindow"

⇒ The result in our sample calculation here is: " $h = 175.707$ ". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

- Now click on the Modeling button  in the lower right area of Dymola in order to switch into the "Modeling Mode". Here you can arbitrarily change the values for p , t , or x in the appropriate blocks.

Help Systems in Dymola®

Dymola® provides detailed help functions. You can choose to read the program documentation or the help page of a specific property function, as desired.

Within the "Modeling-Mode"  the help may be accessed via two different steps.

First we will show you how to access the program documentation of the property library.

- Make sure Dymola is set to the "Modeling-Mode".
- Now click the  button in the Dymola menu bar to choose the "Documentation Mode".
- Double-click on the "FluidDYM_LibD5" Block at the left and then click on "Users_Guide" (see Figure 2.23).

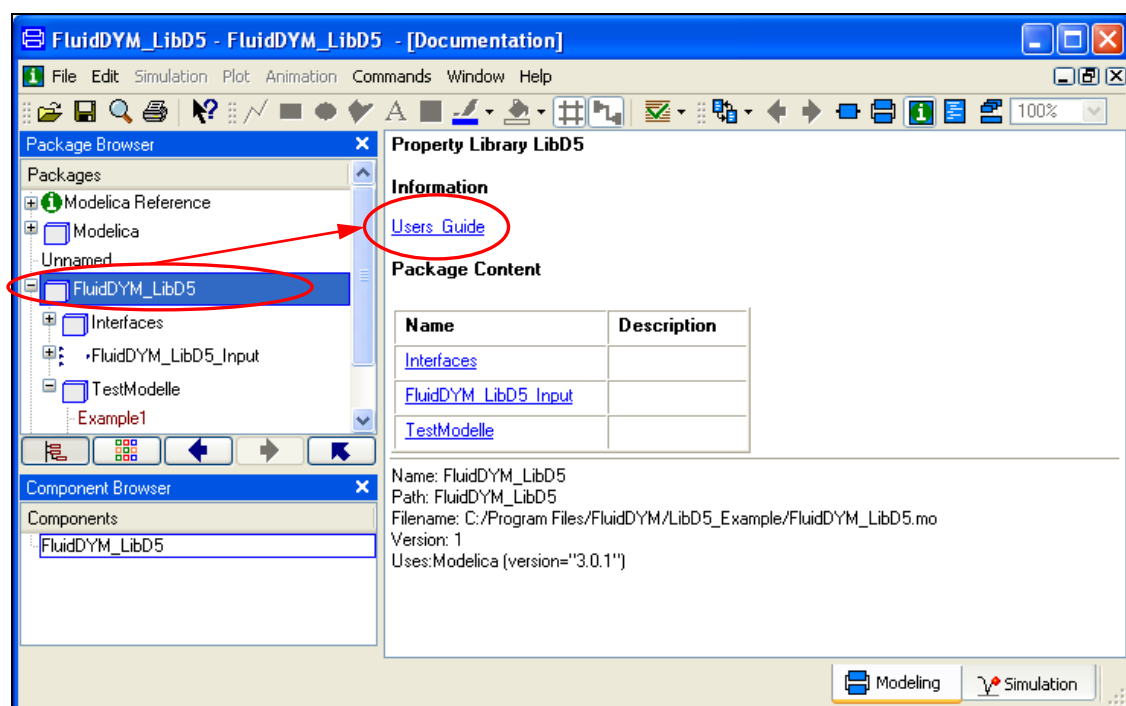


Figure 2.23: Selecting the "Users_Guide"

- The program documentation will be displayed within your default web browser.

Now, we will show you how to access the help page of a specific property function.

- Make sure Dymola is set to the "Modeling-Mode".
- Now click the  button in the Dymola menu bar to choose the "Documentation Mode".
- Double-click on the "FluidDYM_LibD5_Input" block on the left (see Figure 2.24).

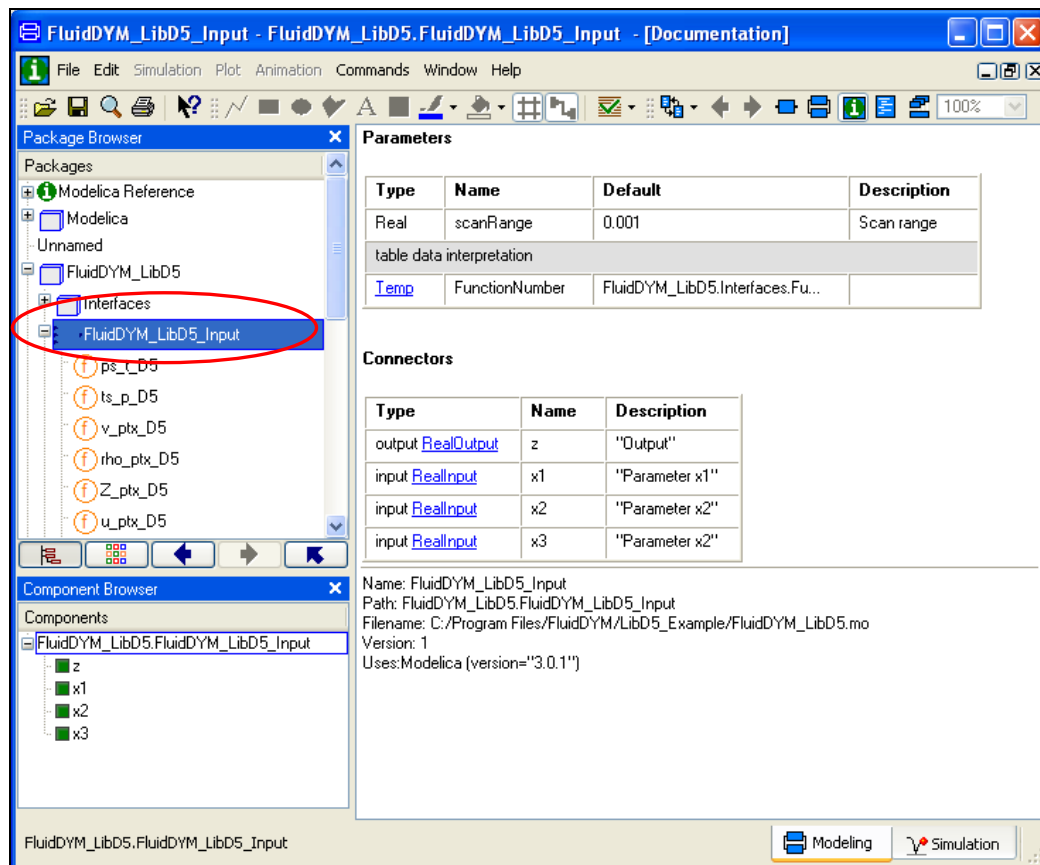


Figure 2.24: Selected "FluidDYM_LibD5_Input" Block

- Below "FluidDYM_LibD5_Input" you will see all functions of the LibD5 property function (see Figure 2.24).
- Now select a function, e.g. "h_ptx_D5", and then click on "Users_Guide" (see Figure 2.25).

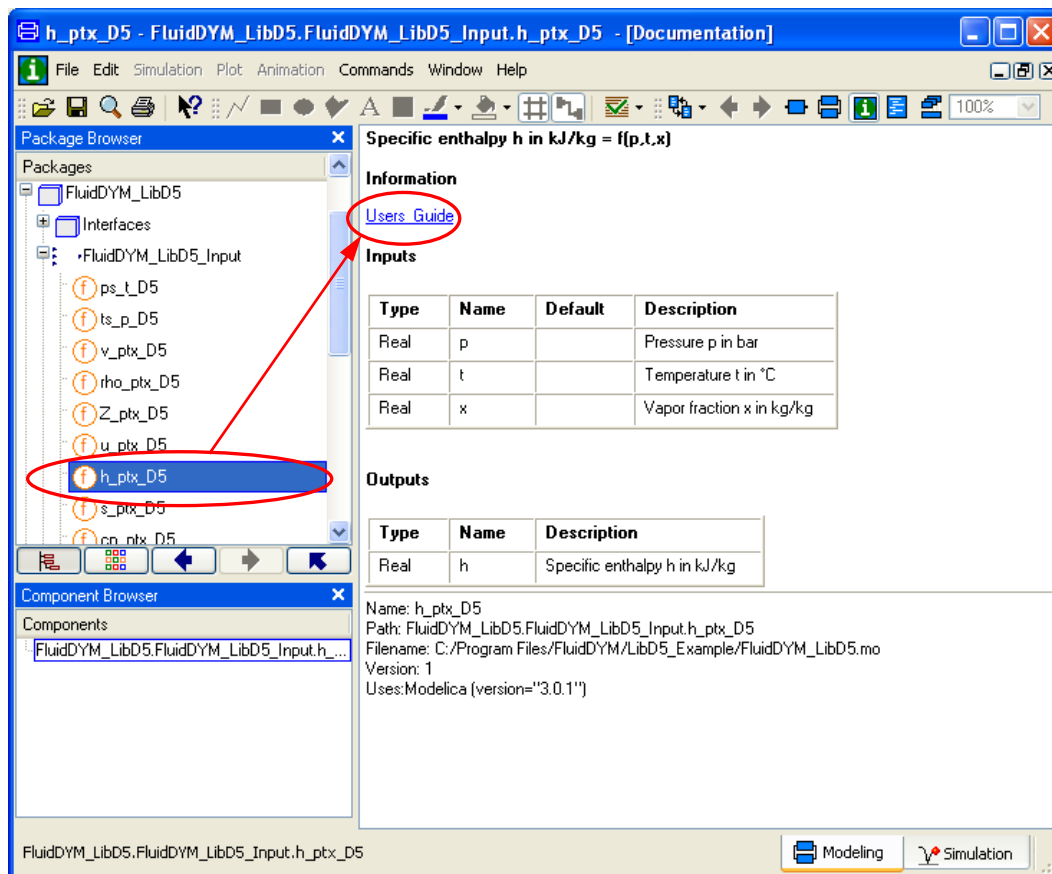


Figure 2.25: Marking the "h_ptx_D5" function and selecting the "Users_Guide"

- You will now see the help page of the selected function, here "h_ptx_D5", in your default web browser (see Figure 2.26).

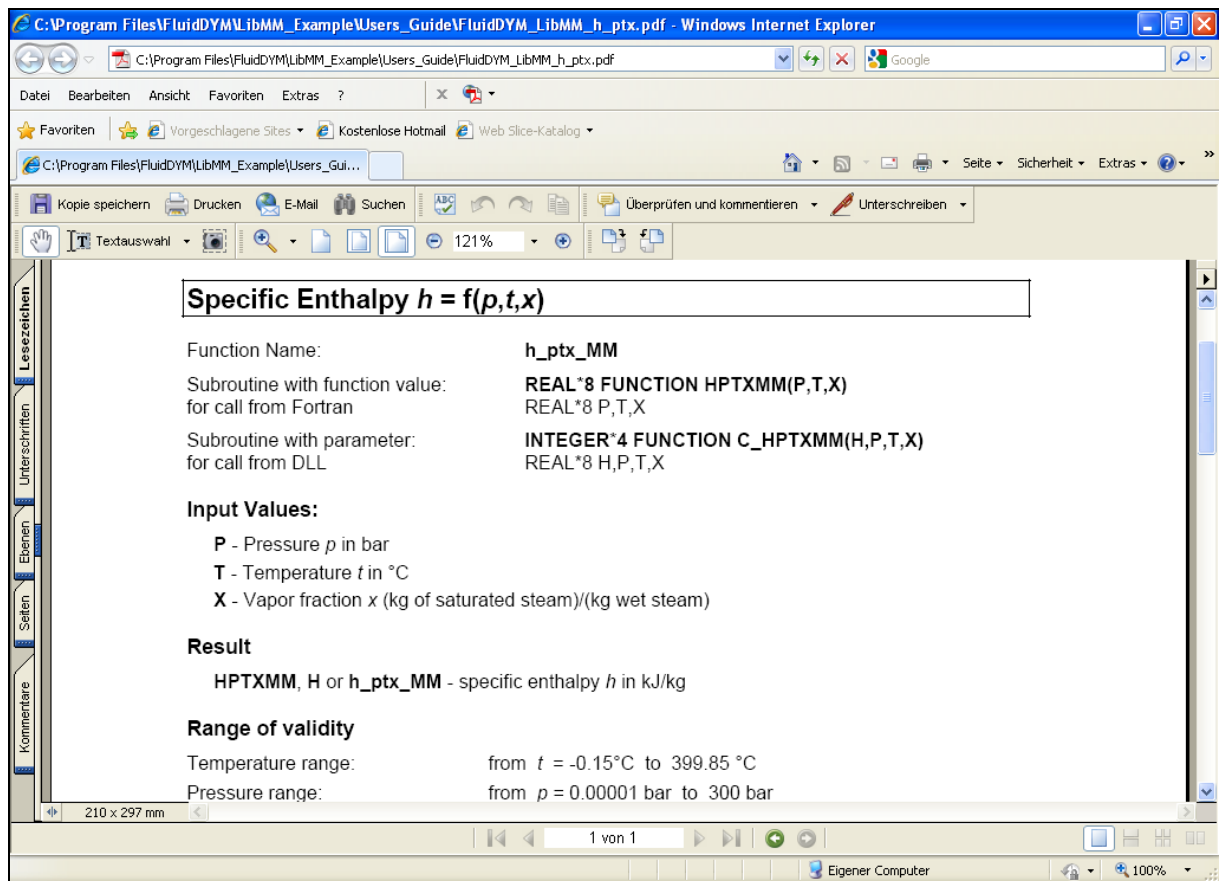


Figure 2.26: Help page of the function "h_ptx_D5" in the web browser

2.3 Removing LibD5 in Dymola

In order to remove the property library LibD5 from your hard drive in Windows®, click "Start" in the lower task bar, then "Settings" and "Control Panel".

Afterwards double-click on "Add or Remove Programs".

In the list box of the "Add or Remove Programs" menu which appears, select "FluidDYM LibD5" by clicking on it and then clicking the "Change/Remove" button.

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

Confirm the "Perform Uninstall" menu which appears by clicking the "Finish" button.

Finally, close the "Add or Remove Programs" and "Control Panel" windows.

"FluidDYM LibD5" has now been removed.

If LibD5 is the only library installed, the directory "FluidDYM" will be removed as well.

3. Program Documentation

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

Function Name: **cp_ptx_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION CPPTXD5(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_CPPTXD5(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

CPPTXD5, CP or cp_ptx_D5 - specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Wet steam region: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **CPPTXD5 = -1000, CP = -1000 or cp_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **cv_ptx_D5**

Subroutine with function value: **REAL*8 FUNCTION CVPTXD5(P,T,X)**
for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_CVPTXD5(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

CVPTXD5, CV or **cv_ptx_D5** - specific isochoric heat capacity c_v in kJ/(kg K)

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Wet steam region: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **CVPTXD5 = -1000, CV = -1000** or **cv_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

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: **dpdptv_ptx_D5**
 Subroutine with function value: **REAL*8 FUNCTION DPDTVPTXD5(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_DPDPTVPTXD5(DPDPTV,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

DPDTVPTXD5, DPDTV or dpdptv_ptx_D5 - Derivative of pressure with respect to temperature (at constant specific volume) dpdptv in kPa/K

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Boiling and dew curve: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **DPDTVPTXD5 = -1000, DPDTV = -1000 or dpdptv_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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_D5**
 Subroutine with function value: **REAL*8 FUNCTION DPDVTPTXD5(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_DPDVTPTXD5(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

DPDVTPTXD4, DPDVT or dpdvt_ptx_D4 - Derivative of pressure with respect to temperature (at constant specific volume) dpdvt in kPa/(m³/kg)

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Wet steam region: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **DPDVTPTXD5 = -1000, DPDVT = -1000 or dpdvt_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **h_ptx_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION HPTXD5(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_HPTXD5(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

HPTXD5, H or **h_ptx_D5** - specific enthalpy h in kJ/kg

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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 $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **HPTXD5 = -1000, H = -1000** or **h_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **kappa_ptx_D5**
 Subroutine with function value: **REAL*8 FUNCTION KAPPAPTXD5(P,T,X)**
 for call from Fortran **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_KAPPAPTXD5(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

KAPPAPTXD5, KAPPA or kappa_ptx_D5 - Isentropic exponent $\kappa = \frac{w^2}{p \cdot v}$

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Boiling and dew curve: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **KAPPAPTXD5, KAPPA = -1000** or **kappa_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

Vapor Pressure $p_s = f(t)$

Function Name:	ps_t_D5
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION PSTD5(T) REAL*8 T
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_PSTD5(PS,T) REAL*8 PS,T

Input Values:

T - Temperature t in °C

Result

PSTD5, PS or ps_t_D5 - Vapor pressure p_s in bar

Range of validity

Temperature range: from $t = 26.85$ °C to $t_c = 346.0846$ °C

Results for wrong input values

Result **PSTD5 = -1000, PS = -1000 or ps_t_D5 = -1000** for input values:

$t = 26.85$ °C to $t_c = 346.0846$ °C

References: [1]

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

Function Name: **rho_ptx_D5**

Subroutine with function value: **REAL*8 FUNCTION RHOPTXD5(P,T,X)**
for call from Fortran **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_RHOPTXD5(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

RHO_PTX_D5, RHO or **rho_ptx_D5** - Density ρ in kg/m³

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Wet steam region: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **RHOPTXD5 = -1000, RHO = -1000** or **rho_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **s_ptx_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION SPTXD5(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_SPTXD5(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

SPTXD5, S or s_ptx_D5 - Specific entropy s in kJ/kg K

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Wet steam region: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **SPTXD5 = -1000, S = -1000 or s_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **t_ph_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION TPHD5(P,H)**
REAL*8 P,H

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_TPHD5(T,P,H)**
REAL*8 T,P,H

Input Values:

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

Result

TPHD5, T or **t_ph_D5** - Temperature t in °C

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. 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 $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **T_PH_D5, T = -1000** or **t_ph_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 ($x = -1$) at result $t > 399.85^\circ\text{C}$, $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 at result $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **t_ps_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION TPSD5(P,S)**
REAL*8 P,S

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_TPSD5(T,P,S)**
REAL*8 T,P,S

Input Values:

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

Result

TPSD5, T or t_ps_D5 - Temperature t in °C

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. 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 $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **T_PS_D5, T = -1000** or **t_ps_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 (x = -1) at result $t > 399.85^\circ\text{C}$, $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 at result $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

Saturation Temperature $t_s = f(p)$

Function Name:	ts_p_D5
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION TSPD5(P) REAL*8 P
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_TSPD5(TS,P) REAL*8 TS,P

Input Values:

P - Pressure p in bar

Result

TSPD5, TS or ts_p_D5 - Saturation temperature t_s in °C

Range of validity

Pressure ranges: from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **TSPD5 = -1000, TS = -1000 or ts_p_D5 = -1000** for input values:

$p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or $p > p_c = 11.6146$ bar

References: [1]

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

Function Name: **u_ptx_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION UPTXD5(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_UPTXD5(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

UPTXD5, U or u_ptx_D5 - Specific internal energy u in kJ/kg

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Wet steam region: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **UPTXD5 = -1000, U = -1000 or u_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **v_ptx_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION VPTXD5(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_VPTXD5(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

VPTXD5, V or v_ptx_D5 - Specific volume v in m^3/kg

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 p and t 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 property of the chosen function to be calculated results in -1000 .

Wet steam region: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **VPTXD5 = -1000, V = -1000 or v_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Wet steam region: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name: **w_ptx_D5**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION WPTXD5(P,T,X)**
REAL*8 P,T,X

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_WPTXD5(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

WPTXD5, W or **w_ptx_D5** - Speed of sound w in m/s

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Boiling and dew curve: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **WPTXD5 = -1000, W = -1000** or **w_ptx_D5 = -1000** for input values:

Single phase region:
 ($x = -1$) $p > 300$ bar or $p < 0.00001$ bar or
 $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve:
 at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]

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

Function Name:	x_ph_D5
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION XPHD5(P,H) REAL*8 P,H
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_XPHD5(X,P,H) REAL*8 X,P,H

Input Values:

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

Result

XPHD5, X or x_ph_D5 - Vapor fraction x in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure range: from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. 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 $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **X_PH_D5 = -1, X = -1 or x_ph_D5 = -1** for input values:

If the state point is located in the single phase region:
 $p > p_c = 11.6146$ bar or $p < 0.001477917$ bar

References: [1]

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

Function Name:	x_ps_D5
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION XPSD5(P,S) REAL*8 P,S
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_XPSD5(X,P,S) REAL*8 X,P,S

Input Values:

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

Result

XPSD5, X or x_ps_D5 - Vapor fraction x in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure range: from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. 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 $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **X_PS_D5, X = -1** or **x_ps_D5 = -1** for input values:

If the state point is located in the single phase region:
 $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar

References: [1]

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

Function Name:	Z_ptx_D5
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION ZPTXD5(P,T,X) REAL*8 P,T,X
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_ZPTXD5(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

ZPTXD5, Z or Z_ptx_D5 - Speed of sound w in m/s

Range of validity

Temperature range: from $t = 26.85^\circ\text{C}$ to 399.85°C
 Pressure range: from $p = 0.00001$ 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:

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. Here the backward functions will also result in $x = -1$.

Wet-steam region

When calculating wet steam, a value 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 . 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 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 property of the chosen function to be calculated results in -1000 .

Boiling and dew curve: Temperature ranges from $t = 26.85^\circ\text{C}$ to $t_c = 346.0846^\circ\text{C}$
 Pressure ranges from $p_s(26.85^\circ\text{C}) = 0.001477917$ bar to $p_c = 11.6146$ bar

Results for wrong input values

Result **ZPTXD5 = -1000, Z = -1000 or Z_ptx_D5 = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
 ($x = -1$) $t > 399.85^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$
 at $t = -1000$ and $p > p_c = 11.6146$ bar
 or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar or
 at $p > p_c = 11.6146$ bar or $p < p_s(26.85^\circ\text{C}) = 0.001477917$ bar and
 $t > t_c = 346.0846^\circ\text{C}$ or $t < 26.85^\circ\text{C}$

References: [1]



4. 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:
- CO₂ - Span and Wagner O₂ - Schmidt and Wagner
H₂O - IAPWS-95 Ar - Tegeler et al.
N₂ - Span et al.
- and of the ideal gases:
- SO₂, CO, Ne (Scientific Formulation of Bucker 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 Formulation 2008 of Feistel and IAPWS-IF97

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 ₂ O | F ₂ | Propane |
| N ₂ | SO ₂ | NH ₃ | Iso-Butane |
| O ₂ | H ₂ | Methane | n-Butane |
| CO | H ₂ S | 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 Bucker et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bucker 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 ₂ H ₆ O ₂	Ethylene glycol
C ₃ H ₈ O ₂	Propylene glycol
C ₂ H ₅ OH	Ethyl alcohol
CH ₃ OH	Methyl alcohol
C ₃ H ₈ O ₃	Glycerol
K ₂ CO ₃	Potassium carbonate
CaCl ₂	Calcium chloride
MgCl ₂	Magnesium chloride
NaCl	Sodium chloride
C ₂ H ₃ KO ₂	Potassium acetate

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $\text{C}_8\text{H}_{24}\text{O}_4\text{Si}_4$ **Library LibD4**

Decamethylcyclopentasiloxane $\text{C}_{10}\text{H}_{30}\text{O}_5\text{Si}_5$ **Library LibD5**

Tetradecamethylhexasiloxane $\text{C}_{14}\text{H}_{42}\text{O}_6\text{Si}_6$ **Library LibMD4M**

Hexamethyldisiloxane $\text{C}_6\text{H}_{18}\text{OSi}_2$ **Library LibMM**

Formulation of Colonna et al. (2006)

Dodecamethylcyclohexasiloxane $\text{C}_{12}\text{H}_{36}\text{O}_6\text{Si}_6$ **Library LibD6**

Decamethyltetrasiloxane $\text{C}_{10}\text{H}_{30}\text{O}_3\text{Si}_4$ **Library LibMD2M**

Dodecamethylpentasiloxane $\text{C}_{12}\text{H}_{36}\text{O}_4\text{Si}_5$ **Library LibMD3M**

Octamethyltrisiloxane $\text{C}_8\text{H}_{24}\text{O}_2\text{Si}_3$ **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 $\text{C}_{10}\text{H}_{22}$ **Library LibC10H22**

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC5H14**

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**

Dinitrogen monoxide **N₂O** **Library LibN2O**

Sulfur dioxide **SO₂** **Library LibSO2**

Acetone **C₃H₆O** **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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Dr. Ines Stoecker

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Fax.: +49-3583-61-1846

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[®]

SUM	A	B	C	D	E	F
1	Calculating an isentropic expansion					
2						
3	p	t	x	s	h	v
4	bar	°C	kg/kg	kJ/kgK	kJ/kg	m³/kg
5	20	400	-1		A5:B5:C5	
6	10					
7	5					
8	1					
9	0,5					
10	0,1					
11						
12						
13						
14						
15						
16						
17						

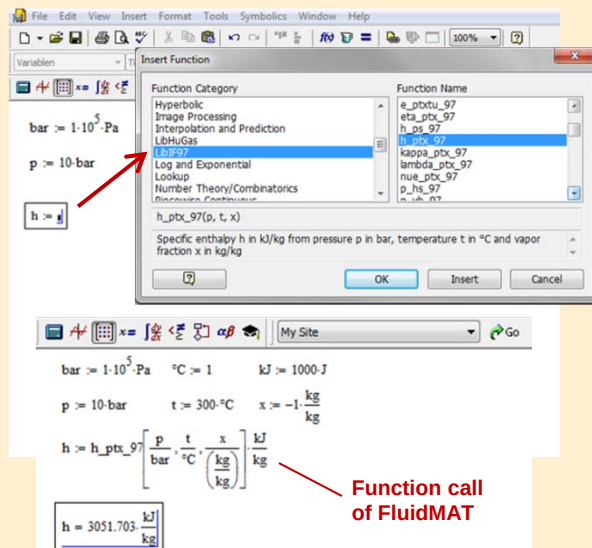
Choosing a property library and a function

Displaying the calculated values in diagrams

Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

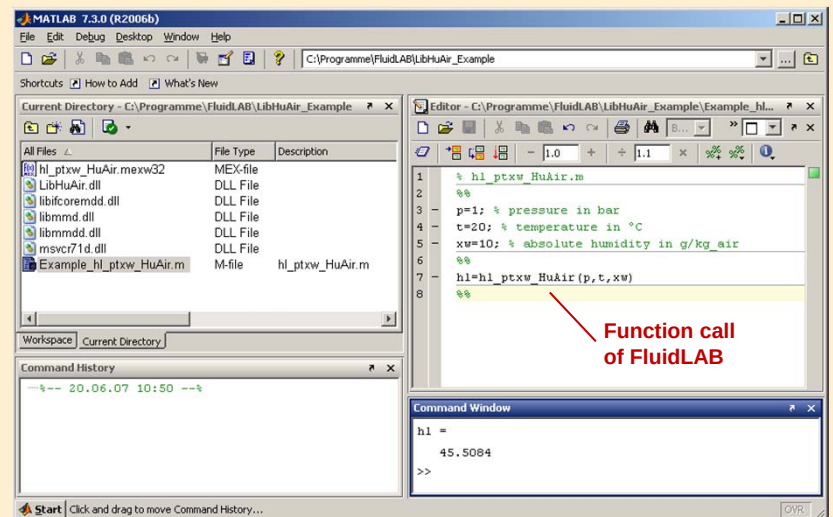
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

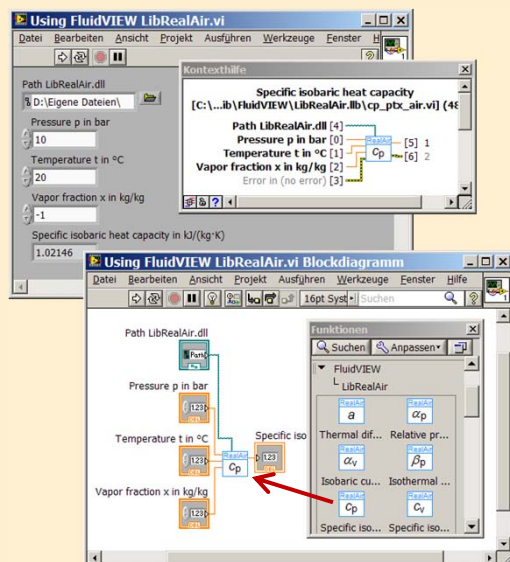
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

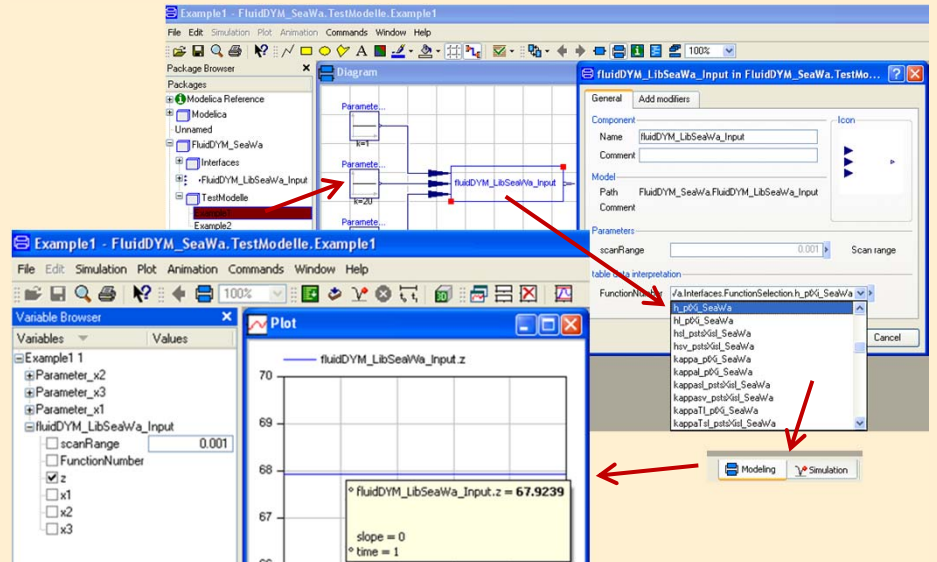
Add-On FluidVIEW for LabVIEW[®]

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

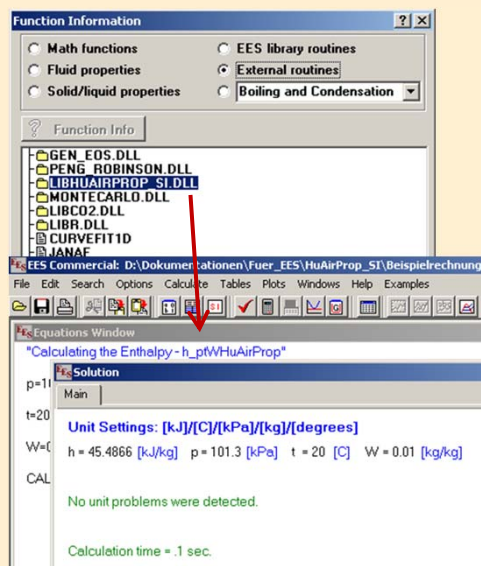


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

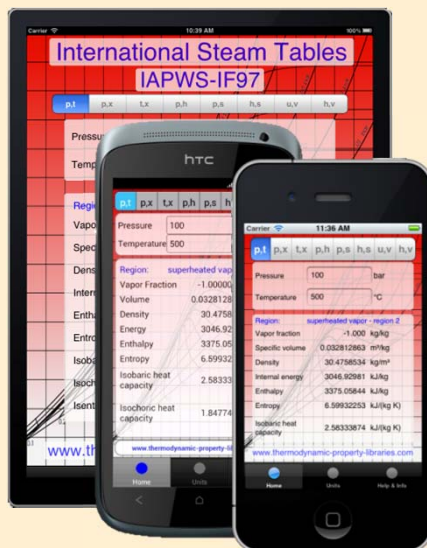
The property functions can be called in DYMOLA[®] and SimulationX[®].



Add-In FluidEES for Engineering Equation Solver®



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



Online Property Calculator at www.thermodynamics-zittau.de

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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www.thermodynamics-zittau.de
www.thermodynamic-property-libraries.com
www.international-steam-tables.com
www.thermodynamic-formelsammlung.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 83 TI Voyage 200 TI 92

For more information please contact:

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

Thermodynamic Properties

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

Transport Properties

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

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

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, A.; Lemmon, E. W.
Multiparameter equations of state for selected siloxanes
Fluid Phase Equilibria, 244, (2006) S. 193-211

6. Satisfied Customers

Date: 10/2011

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)
- FluidVIEW for LabVIEW[®]:

2011

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SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
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RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011, 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
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Technical University of Dresden	01/2011, 05/2011, 06/2011, 08/2011

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2003

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Emden University of Applied Sciences, Department of Technology	05/2003
Pettersson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
Ingenieurbuero Ostendorf, Gummersbach	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
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LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
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Mainova, Frankfurt	12/2003
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2002

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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
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
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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ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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SOFBID, Zwingenberg (general EBSILON program license)	01/2000
AG KKK - PGW Turbo, Leipzig	01/2000

PREUSSAG NOELL, Wuerzburg	01/2000
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KRUPP-UHDE, Dortmund (company license)	03/2000
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VEAG, Berlin (group license)	03/2000
Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
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
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
Steinhaus Informationssysteme, Datteln (general license for process data software)	12/2000

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Bayernwerk, Munich	01/1999
DREWAG, Dresden (company license)	02/1999
KEMA IEV, Dresden	03/1999
Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
Technical University of Cottbus, Chair in Power Plant Engineering	07/1999
Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
M&M Turbine Technology Bielefeld	06/1998
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