Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

Faculty of
MECHANICAL ENGINEERING

Department of
TECHNICAL THERMODYNAMICS

Property Library for Dodecamethyl-cyclohexasiloxane (D6) $C_{12}H_{36}Si_6O_6$

FluidDYM
with LibD6
for DYMOLA®

Prof. Hans-Joachim Kretzschmar
Dr. Ines Stoecker
Matthias Kunick
Frank Elschner

Property Software for Dodecamethylcyclohexasiloxane

$C_{12}H_{36}Si_6O_6$ (LibD6)

FluidDYM

for DYMOLA®

Contents

0. Package Contents

1. Property Functions

   1.1 Calculation Programs
   1.2 p,v Diagram
   1.3 h,s Diagram
   1.4 T,s Diagram

2. Application of FluidDYM in DYMOLA®

   2.1 Installing FluidDYM
   2.2 Example: Calculation of the Specific Enthalpy $h = f(p,t,x)$ of Dodecamethylcyclohexasiloxane
   2.3 Removing FluidDYM

3. Program Documentation

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

5. References

6. Satisfied Customers

© Zittau/Goerlitz University of Applied Sciences, Germany
Faculty of Mechanical Engineering
Department of Technical Thermodynamics
Prof. Hans-Joachim Kretzschmar
Dr. Ines Stoecker
Phone: +49-3583-61-1846 or -1881
Fax: +49-3583-61-1846
E-mail: hj.kretzschmar@hs-zigr.de
Internet: www.thermodynamics-zittau.de

0. Package Contents

Zip-file "CD_FluidDYM_LibD6_Eng.zip" for DYMOLA®

Including the following files:

FluidDYM_LibD6_Setup.exe	Installation Program for the FluidDYM Add-In for use in DYMOLA®
LibD6.dll	Dynamic Link Library for Dodecamethylcyclohexasiloxane D6 for use in DYMOLA®
FluidDYM_LibD6_Docu_Eng.pdf	User's Guide
Folder "Users_Guide"	Includes the complete User's Guide

1. Property Functions

1.1 Calculation Programs

"D6" means Dodecamethylcyclohexasiloxane **($C_{12}H_{36}Si_6O_6$)**

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibD6 as parameter	Property or Function	Unit of the result
$c_p = f(p,t,x)$	cp_ptx_D6	CPPTXD6(P,T,X)	C_CPPTXD6(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_D6	CVPTXD6(P,T,X)	C_CVPTXD6(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_D6	DPDTVD6(P,T,X)	C_DPDTVD6(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_D6	DPDVTD6(P,T,X)	C_DPDVTD6(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_D6	HPTXD6(P,T,X)	C_HPTXD6(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_D6	KAPPAPTXD6(P,T,X)	C_KAPPAPTXD6(KAPPA,P,T,X)	Isentropic exponent	-
$p_s = f(t)$	ps_t_D6	PSTD6(T)	C_PSTD6(PS,T)	Vapor pressure from temperature	bar
$\rho = f(p,t,x)$	rho_ptx_D6	RHOPTXD6(P,T,X)	C_RHOPTXD6(RHO,P,T,X)	Density	kg/m³
$s = f(p,t,x)$	s_ptx_D6	SPTXD6(P,T,X)	C_SPTXD6(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_D6	TPHD6(P,H)	C_TPHD6(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_D6	TPSD6(P,S)	C_TPSD6(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_D6	TSPD6(P)	C_TSPD6(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_D6	UPTXD6(P,T,X)	C_UPTXD6(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_D6	VPTXD6(P,T,X)	C_VPTXD6(V,P,T,X)	Specific volume	m³/kg
$w = f(p,t,x)$	w_ptx_D6	WPTXD6(P,T,X)	C_WPTXD6(W,P,T,X)	Isentropic speed of sound	m/s
$x = f(p,h)$	x_ph_D6	XPHD6(P,H)	C_XPHD6(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibD6 as parameter	Property or Function	Unit of the result
x = f(p,s)	x_ps_D6	XPSD6(P,S)	C_XPSD6(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
Z = f(p,t,x)	Z_ptx_D6	ZPTXD6(P,T,X)	C_ZPTXD6(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 = 0.0000022823 bar to 300 bar

Reference state

h = 0 kJ/kg and s = 0 kJ/(kg K) at t_B = 244.99 °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. Here the backward functions will also result in x = –1.

Wet-steam region

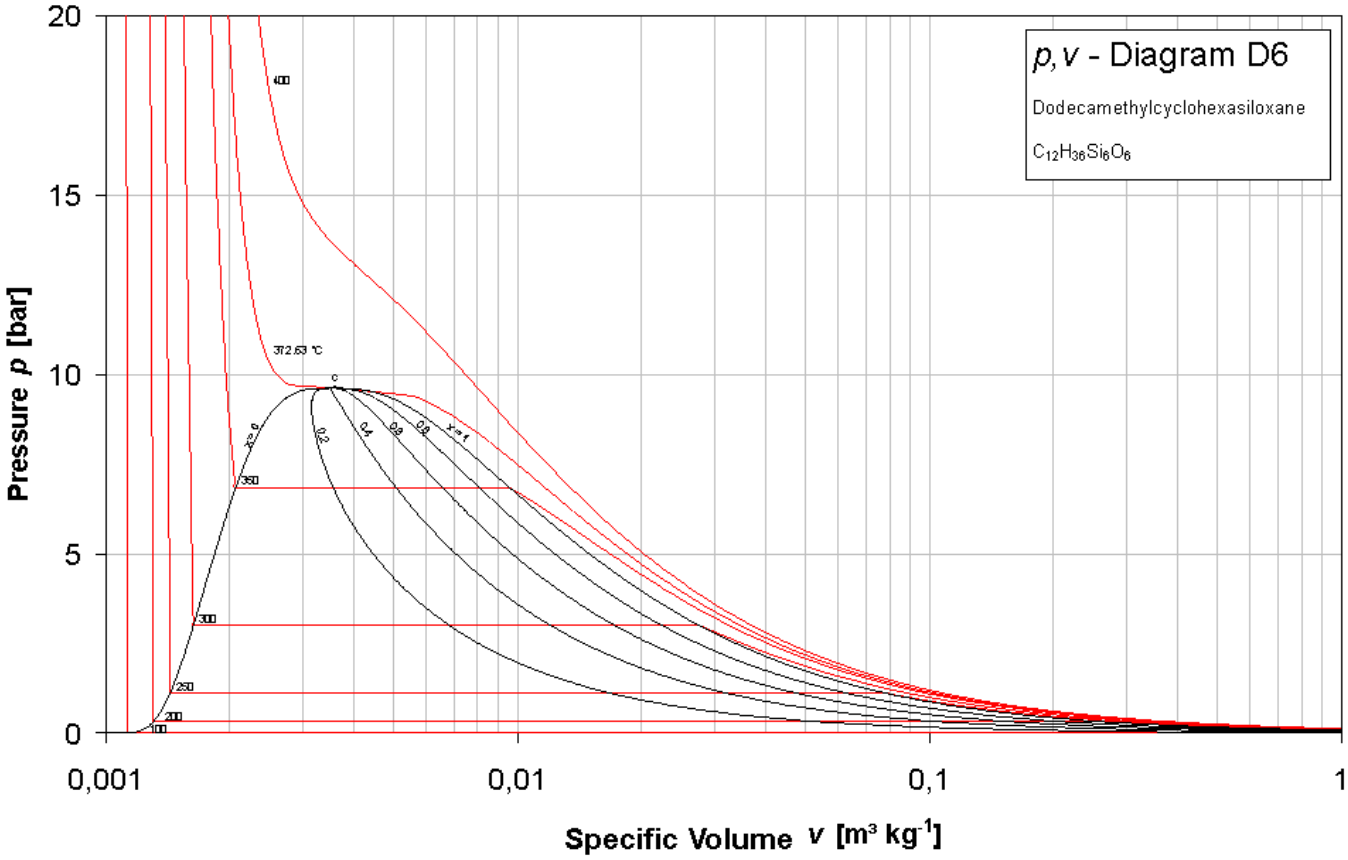
When calculating wet steam, a value between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for *x*. It is adequate to enter either the given value for *t* and p = –1000, or the given 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 = 0 °C to t_c = 372.63 °C
Pressure ranges from p_s (0 °C) = 0.00078994 bar to p_c = 9.61 bar

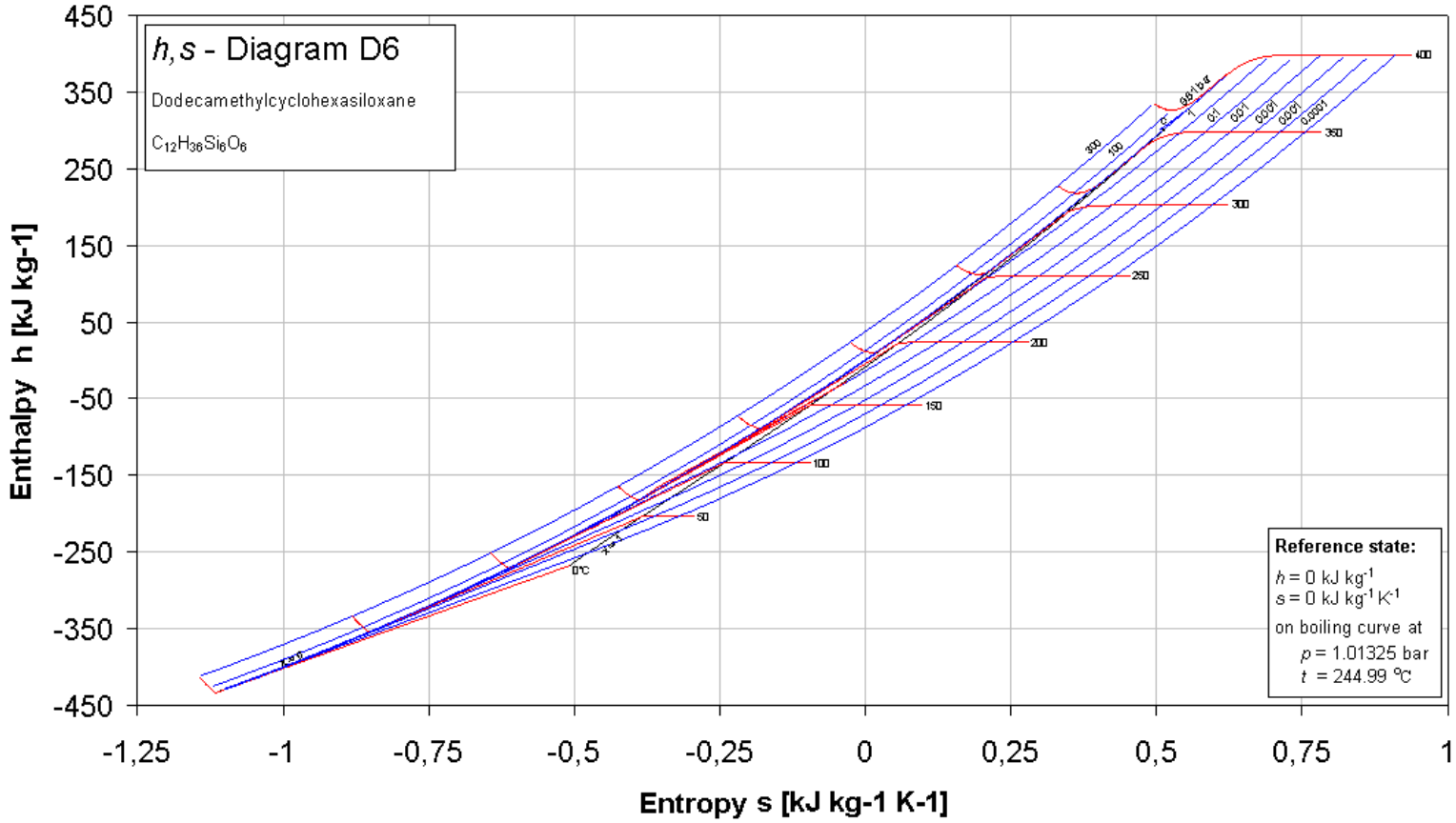
Note.

If the calculation results in –1000 (except for x), the values entered represent a state point beyond the range of validity of D6. 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.

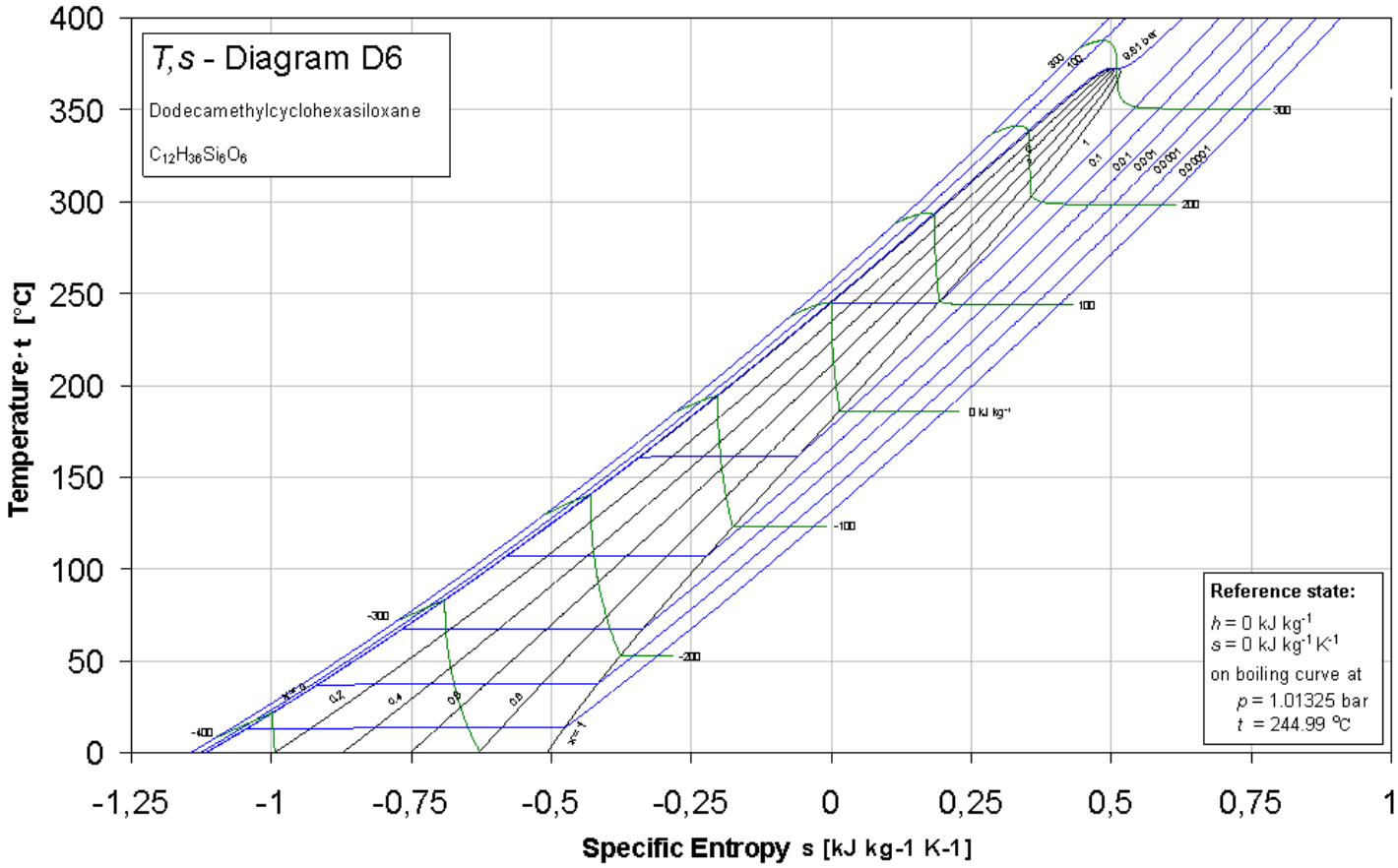
1.2 p,v-Diagram



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 Dodecamethylcyclohexasiloxane from the LibD6 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_LibD6_Eng.zip", you will see the folder

CD_FluidDYM_LibD6_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_LibD6_Docu_Eng.pdf
FluidDYM_LibD6_Setup.exe.

In order to run the installation of FluidDYM including the LibD6 property library double-click the file

FluidDYM_LibD6_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\LibD6" (see Figure 2.1).

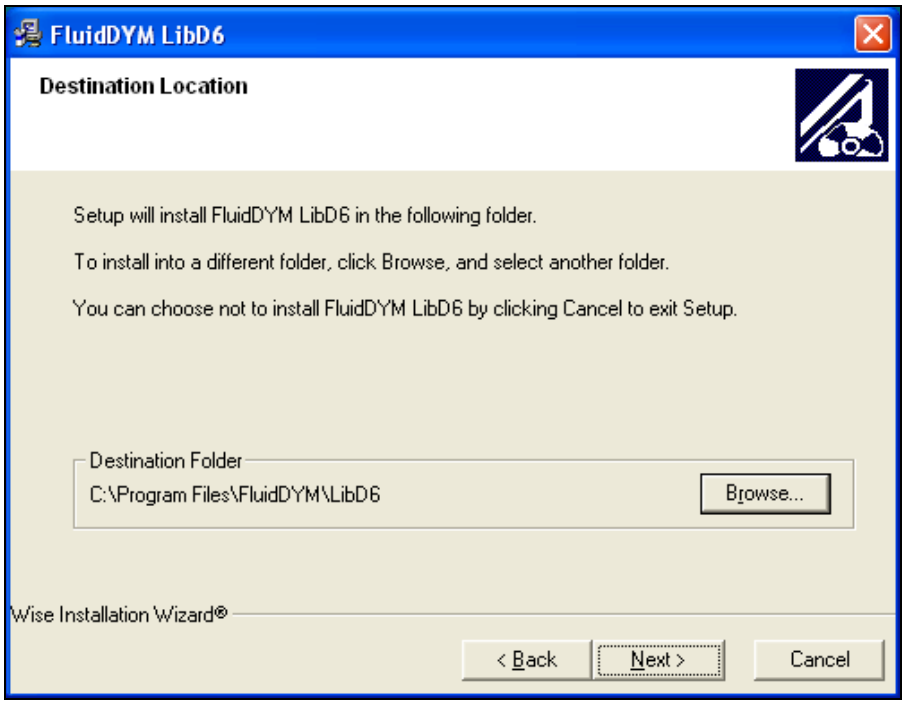


Figure 2.1: Dialog window "Destination Location"

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\FluidDYM\LibD6":

- Dynamic link library "LibD6.dll".

- Link up Dynamic link library "LibD6_Dym.dll" and other necessary system DLL files.

- Library File "LibD6_DYM.lib"

- Header File "LibD6_DYM.h" and other necessary system DLL files.

- Modelica File "FluidDYM_LibD6.mo", includes the following property functions:

cp_ptx_D6	t_ph_D6
cv_ptx_D6	t_ps_D6
dpdtv_ptx_D6	ts_p_D6
dpdvt_ptx_D6	u_ptx_D6
h_ptx_D6	v_ptx_D6
kappa_ptx_D6	w_ptx_D6
ps_t_D6	x_ph_D6
rho_ptx_D6	x_ps_D6
s_ptx_D6	Z_ptx_D6

Now, you have to overwrite the file "LibD6.dll" in your LibD6 directory with the file of the same name provided in your CD folder with FluidDYM.
To do this, open the CD folder "CD_FluidDYM_LibD6_Eng" in "My Computer" and click on the file "LibD6.dll" in order to highlight it.

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

Now, open your LibD6 directory (the standard being

C:\Program Files\FluidDYM\LibD6)

and insert the file "LibD6.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 "LibD6.dll" successfully.

In the next step, copy the folder "Users_Guide" into your Dymola LibD6 directory with the file of the same name provided in your CD folder of FluidDYM.
To do this, open the CD folder "CD_FluidDYM_LibD6_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 LibD6 directory (the standard being:

C:\Program Files\FluidDYM\LibD6)

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 LibD6 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).

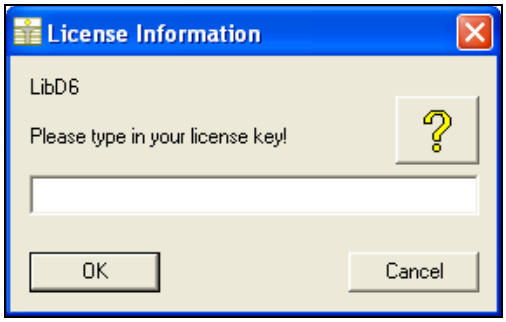


Figure 2.2: "License Information" window

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:

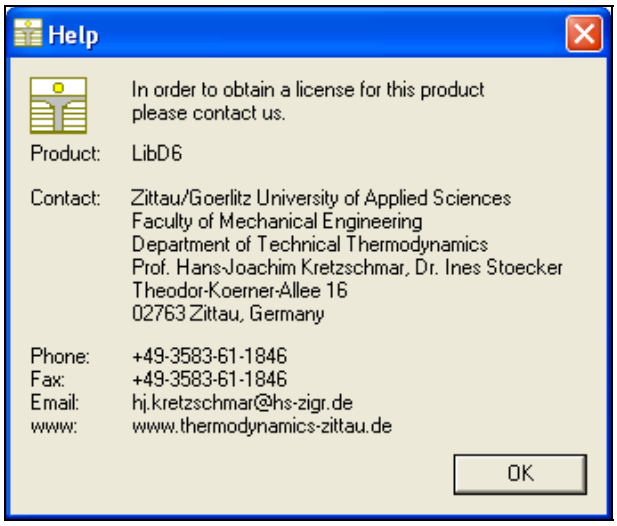


Figure 2.3: "Help" window

If you do not enter a valid license it is still possible to use DYMOLA® by clicking "Cancel". In this case, the LibD6 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_LibD6 according to the description in section 2.3 of this User's Guide. Should you not wish to license the LibD6 property library, you have to delete the files

LibD6.dll
LibD6_DYM.dll
LibD6_DYM.lib
LibD6_DYM.h
LibD6_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 Dodecamethylcyclohexasiloxane

Now we will calculate, step by step, the specific enthalpy *h* of Dodecamethylcyclohexasiloxane 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 "\LibD6"; the standard location is: "C:\Program Files\FluidDYM\LibD6"
- Create the folder "\LibD6_Example" by clicking on "File" in the Explorer menu, then "New" in the menu which appears, and then selecting "Folder". Name the new folder "\LibD6_Example".
- You will see the following window:

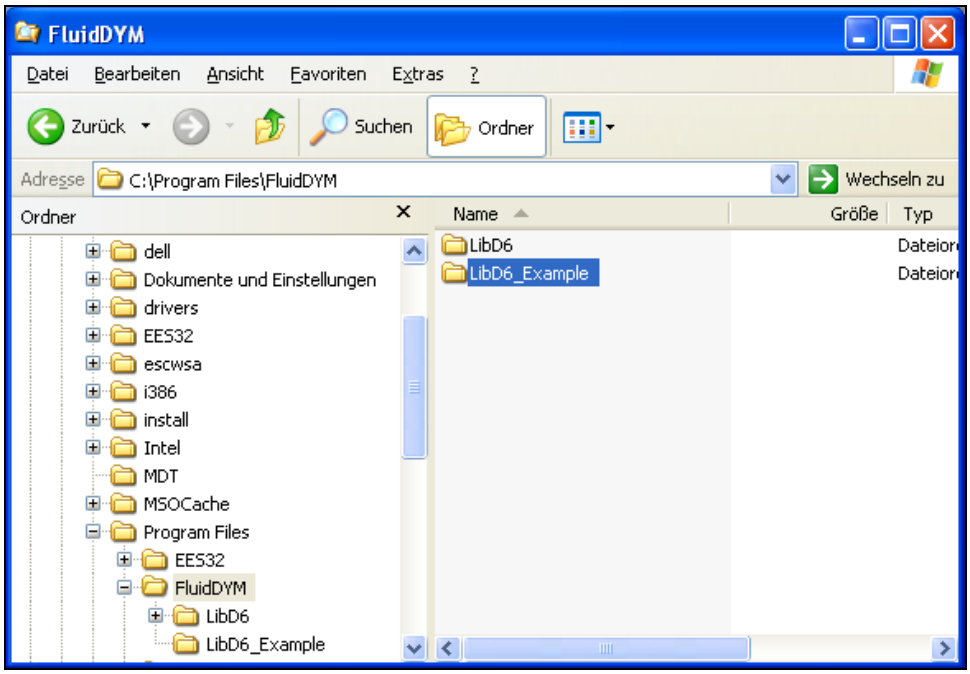


Figure 2.4: Highlighted *LibD6_Example* directory in FluidDYM

- Switch into the directory "\LibD6" within "\FluidDYM", the standard being: "C:\Program Files\FluidDYM\LibD6".

- You will see the following window:

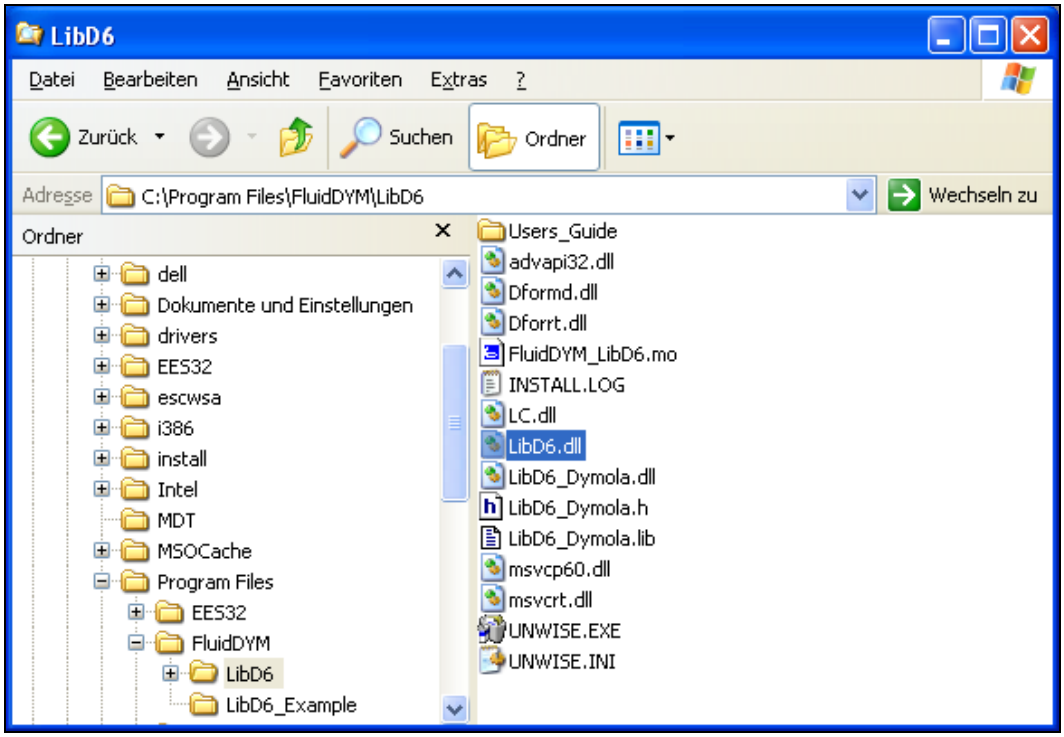


Figure 2.5: *LibD6* directory including installed files

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\LibD6_Example":

- "advapi32.dll"
- "Dformd.dll"
- "Dforrt.dll"
- "FluidDYM_LibD6.mo"
- "LC.dll"
- "LibD6.dll"
- "LibD6_Dymola.dll"
- "LibD6_Dymola.h"
- "LibD6_Dymola.lib"
- "msvcp60.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\LibD6_Example", click "Edit" and then "Paste".

- You will see the following window:

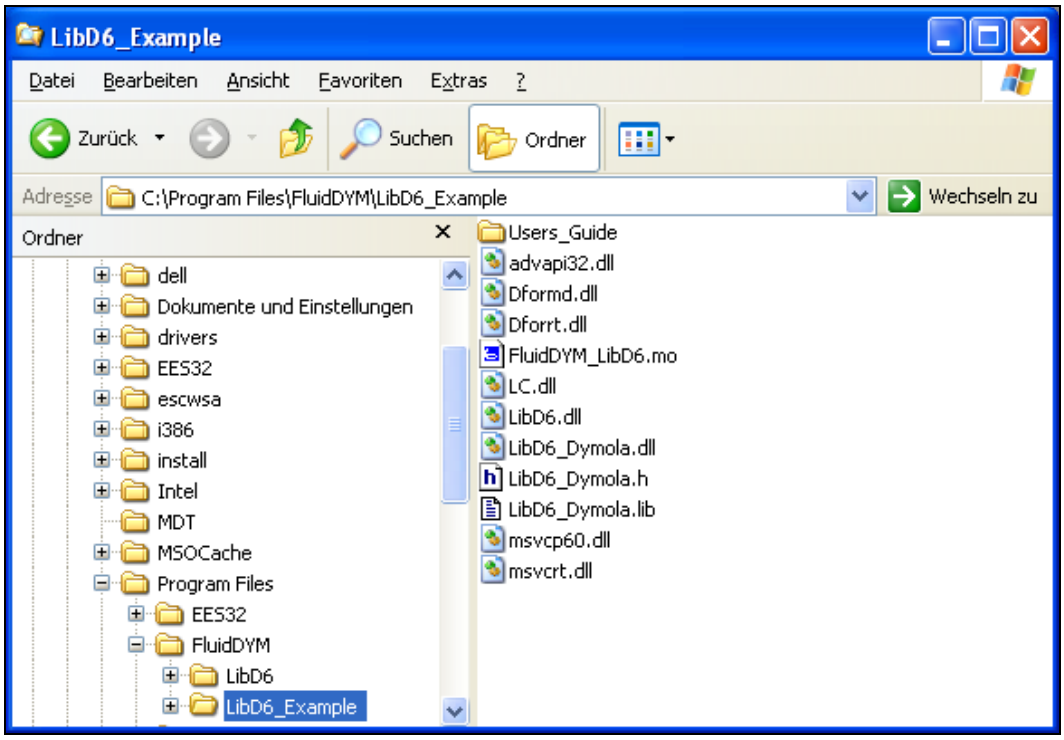


Figure 2.6: *LibD6_Example* directory including the newly-copied files

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

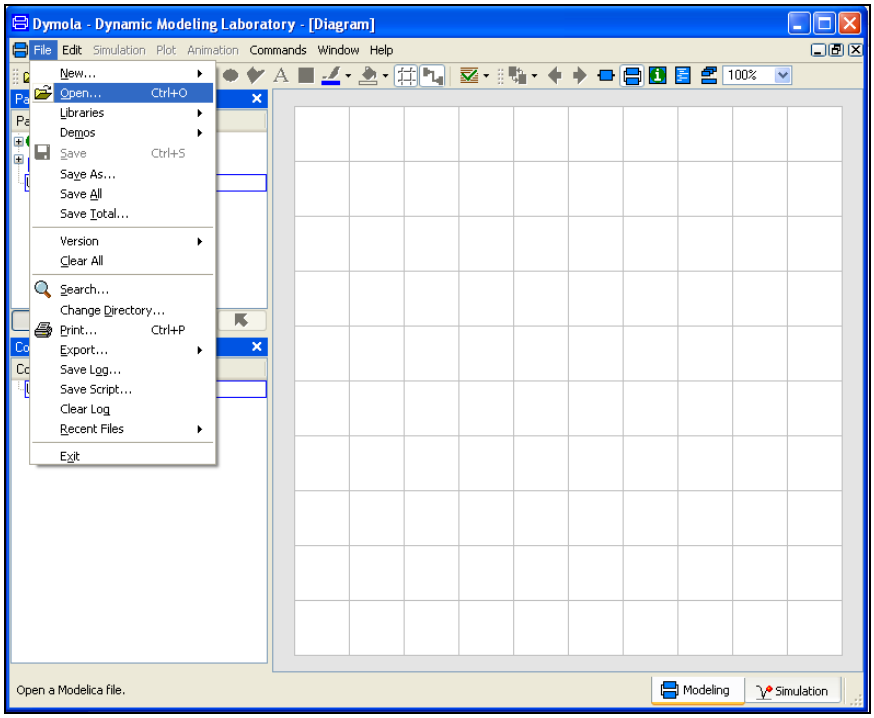


Figure 2.7: Selecting the menu entry "Open"

- Search and click on the directory "C:\Program Files\FluidDYM\LibD6_Example" in the pop-up menu.

- Select the "FluidDYM_LibD6.mo" file and click on the "Open" button (see Figure 2.8).

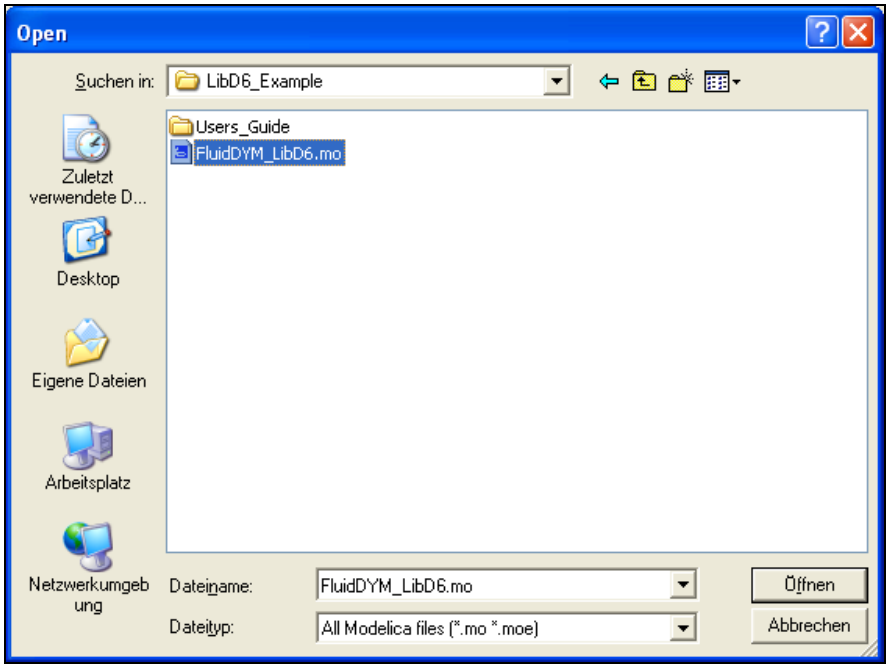


Figure 2.8: Selecting the *FluidDYM_LibD6.mo* file

- The library will be loaded by Dymola which may take a few seconds.
- After Dymola has finished loading the LibD6 library, you will see the window shown in Figure 2.9.

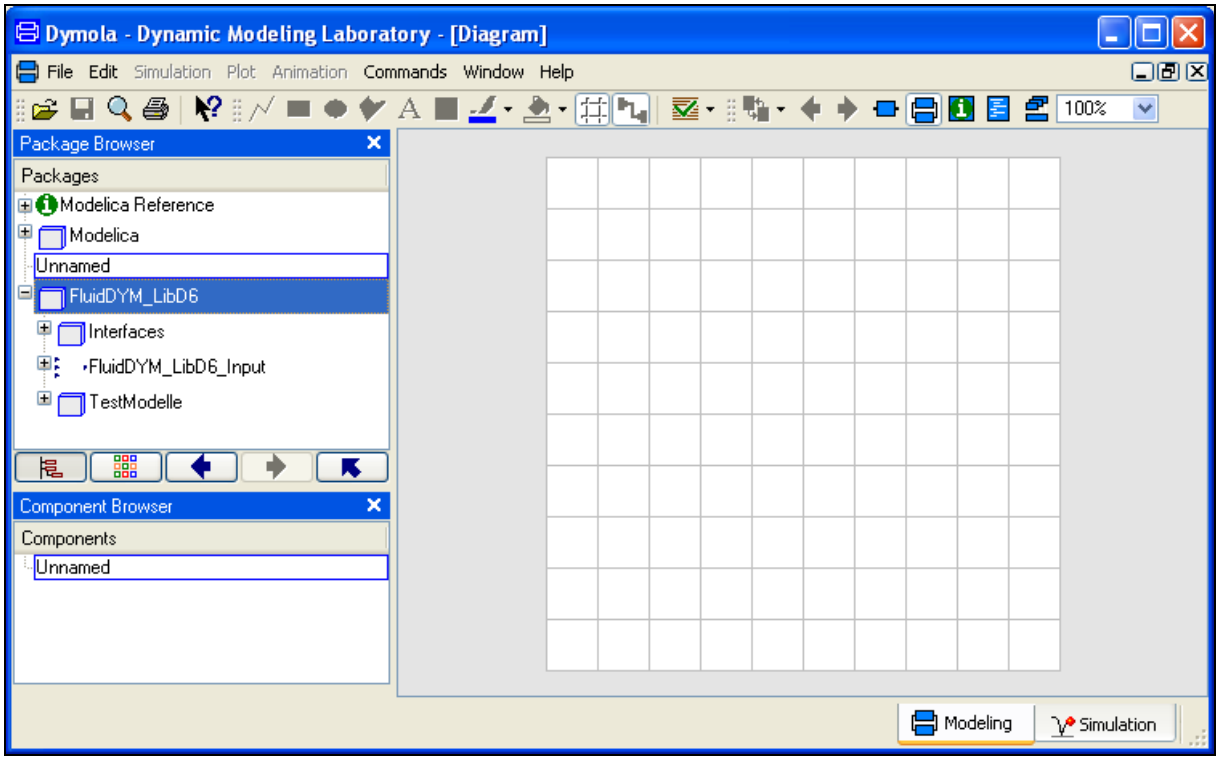


Figure 2.9: Dymola window after loading the *LibD6* library

- Now, click on "File" in the Dymola menu bar and select "Change Directory…" in order to open the folder "\LibD6_Example" (see Figure 2.10).

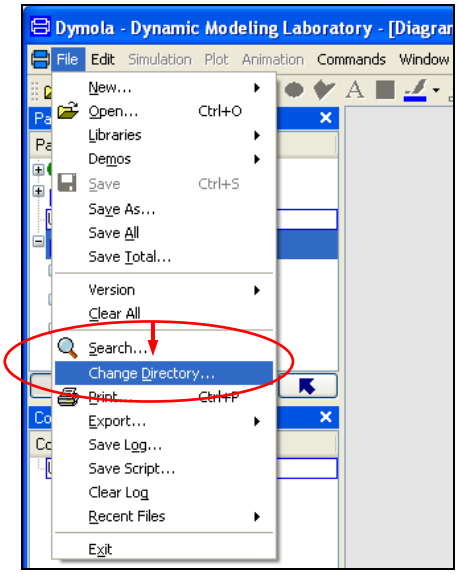


Figure 2.10: Selecting the menu entry "Change Directory…"

- Search and click on the directory "C:\Program Files\FluidDYM\LibD6_Example" in the pop-up menu (see Figure 2.11).

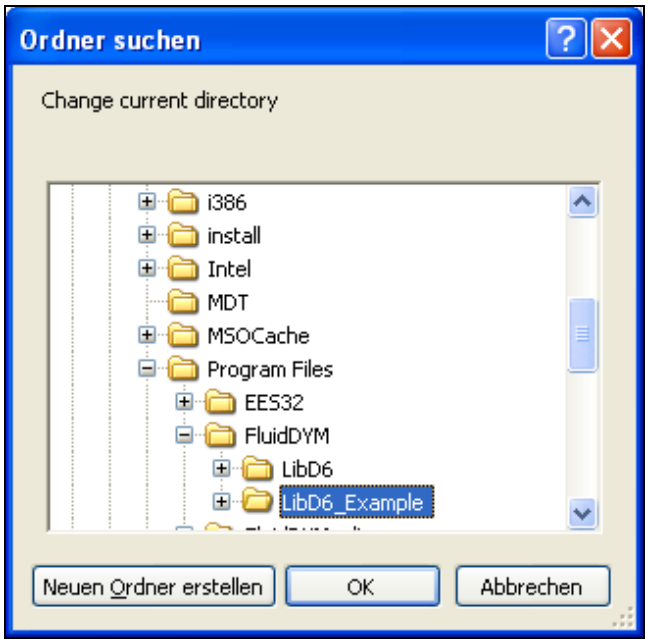


Figure 2.11: Selecting the *LibD6_Example* directory

- 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_D6" as follows for calculating $h = f(p,t,x)$.

- Click on the Dymola-Block "Testmodelle," which can be found in the FluidDYM_LibD6 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:

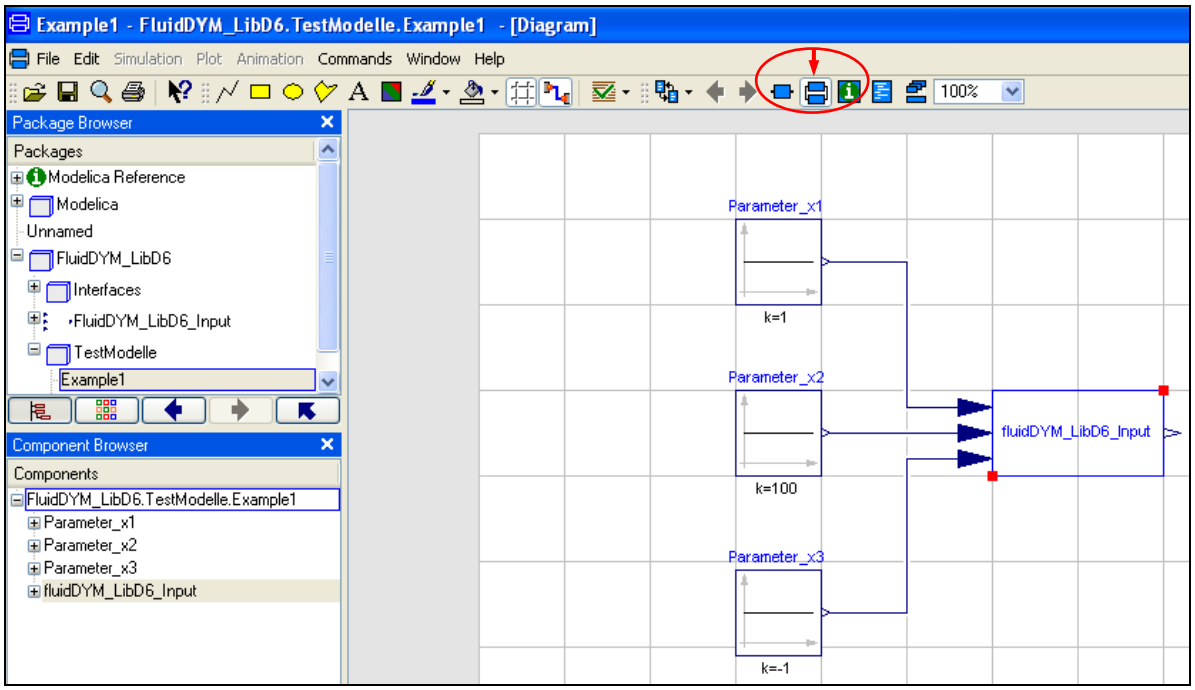


Figure 2.12: Dymola in Diagram Mode

- Now double-click on the "fluidDYM_LibD6_Input" block on the right hand side of the Dymola window.
- Search and click the "h_ptx_D6" function next to "Function Number" in the pop-up menu (see Figure 2.13).

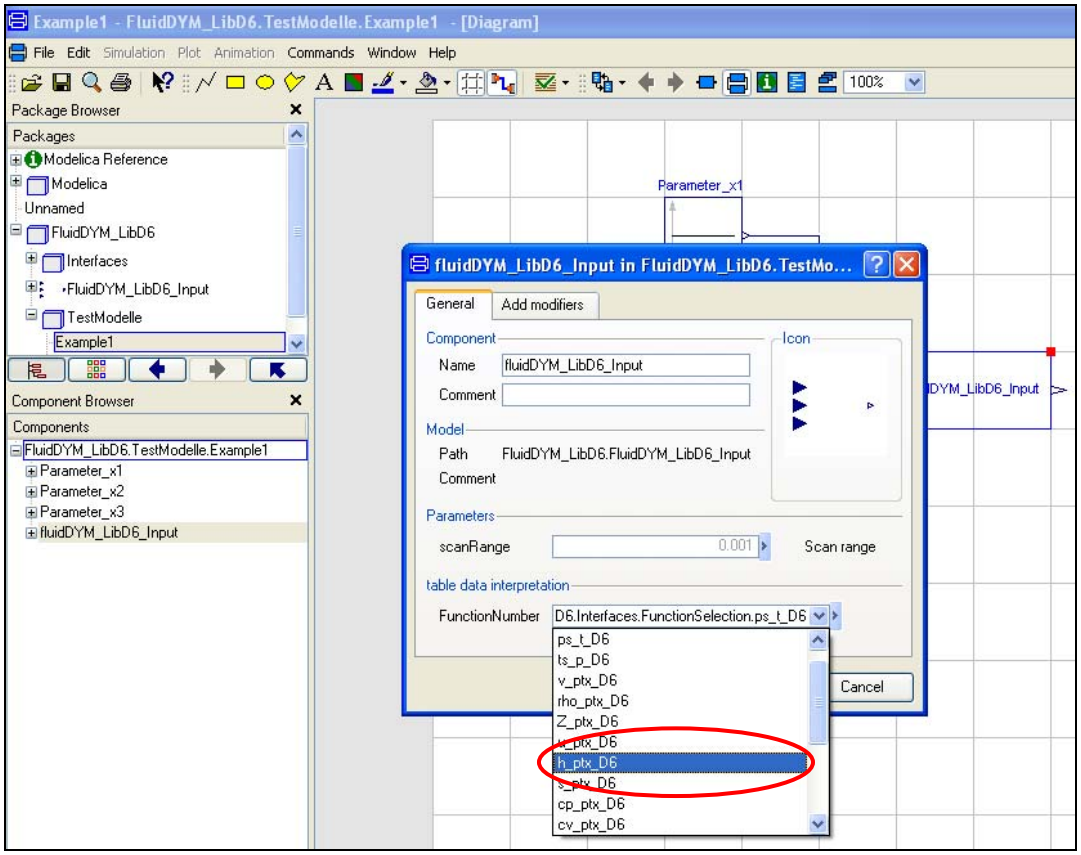


Figure 2.13: Choosing the function *h_ptx_D6*

- 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.

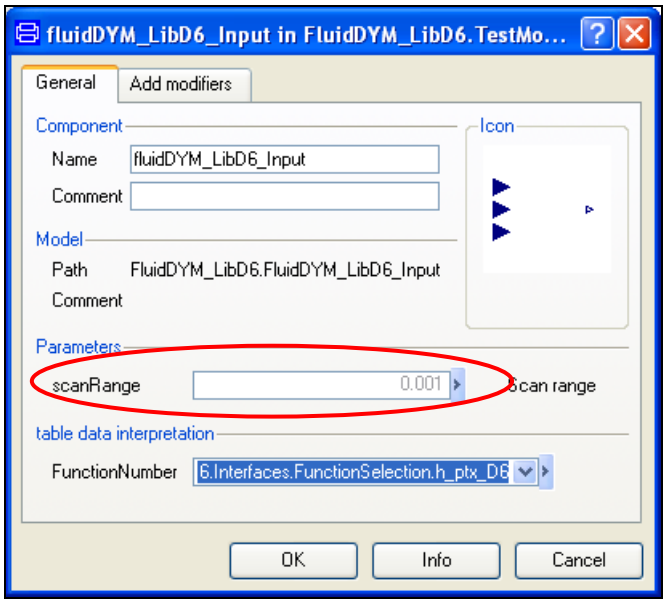


Figure 2.14: Setting the scan range

- Now we will configure the input parameters x1 to x3, where x1 represents the pressure *p*, x2 represents the temperature *t,* and x3 represents the vapor fraction *x*. When calculating a function with only two input parameters, the third input parameter x3 will not be defined.
- First, double click on the "Parameter_x1" block which represents the first input parameter, here the pressure *p* in bar.

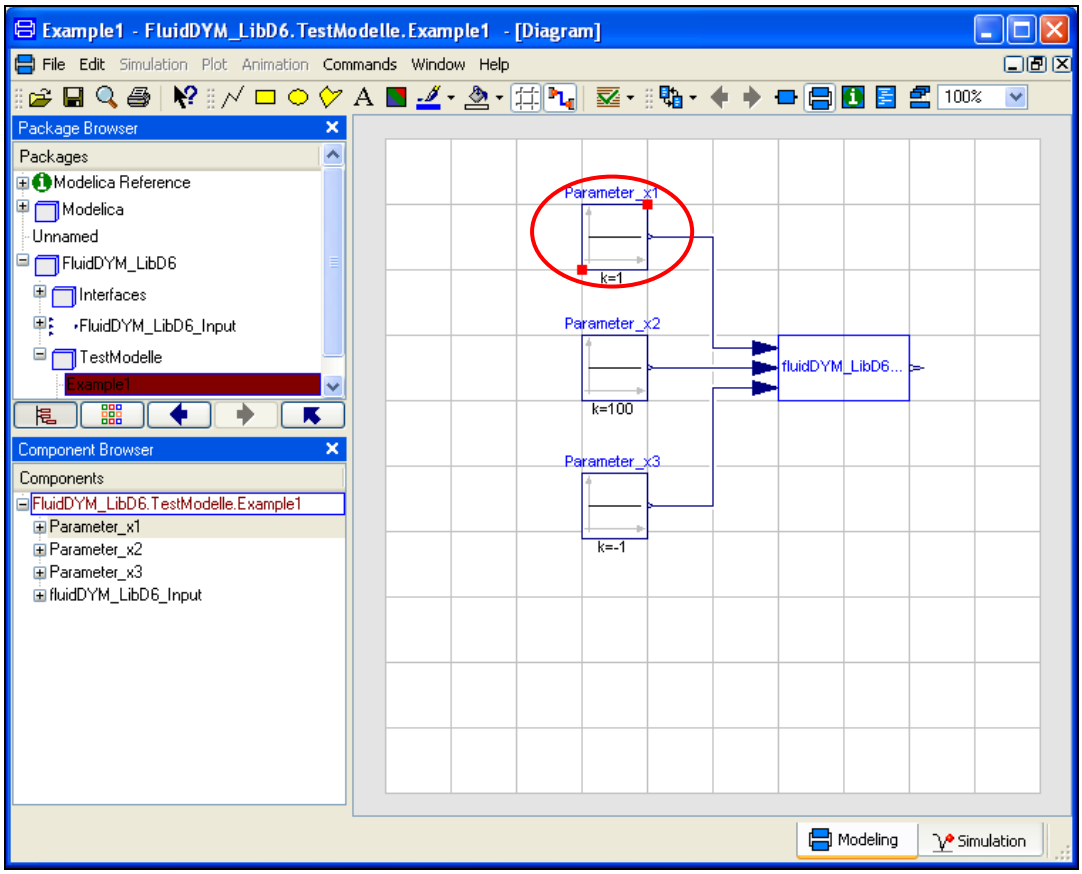


Figure 2.15: "Parameter_x1" block in Dymola

- 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).

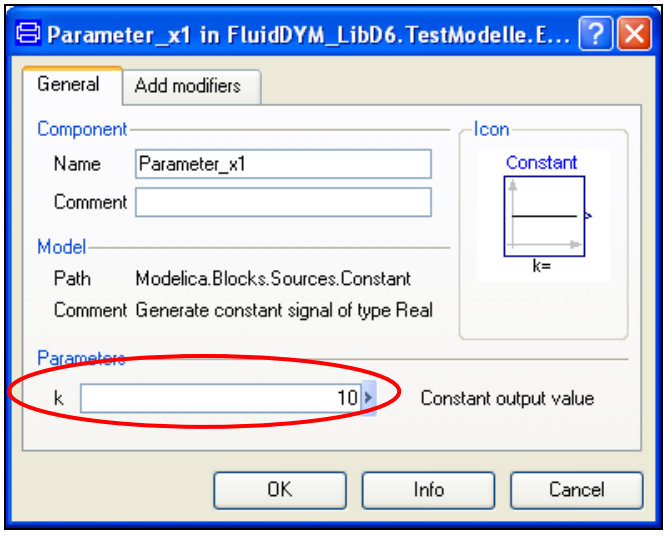


Figure 2.16: Entering the value for the pressure *p*

- 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).

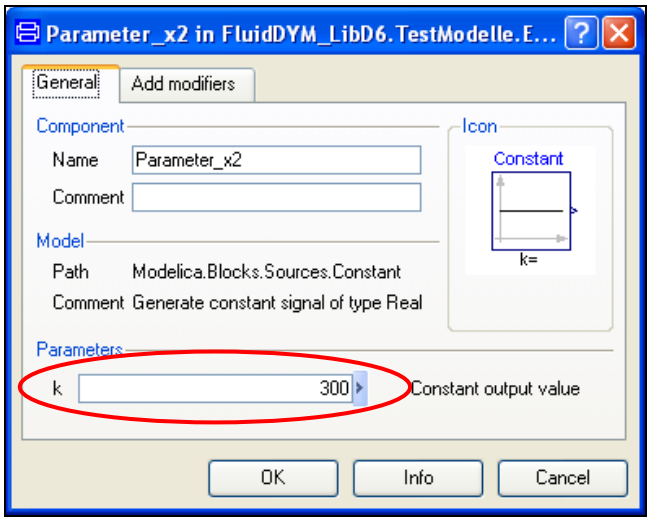


Figure 2.17: Entering the value for the temperature *t*

- 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* <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.

  (D6 Saturation pressure curve:

  $t = 0\ °C$ to $t_c = 290.94\ °C$

  $p_S(0\ °C) = 0.00078994$ bar to $p_C = 14.15055$ 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).

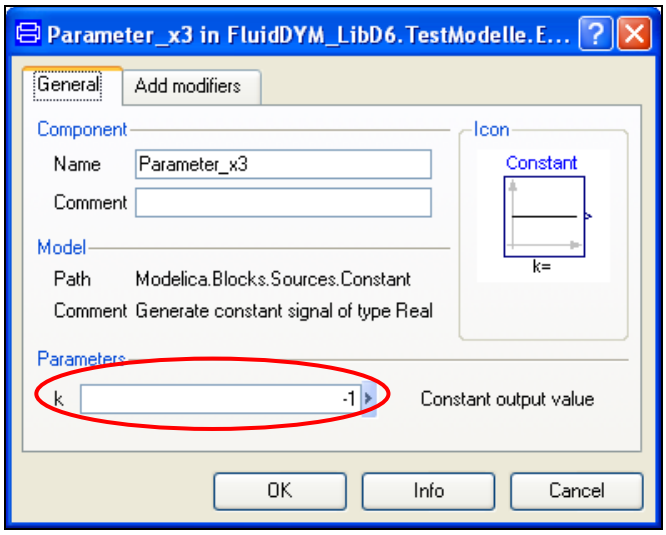


Figure 2.18: Entering the value for the vapor fraction *x*

All parameters have now been defined.

- Click on the Simulation 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.

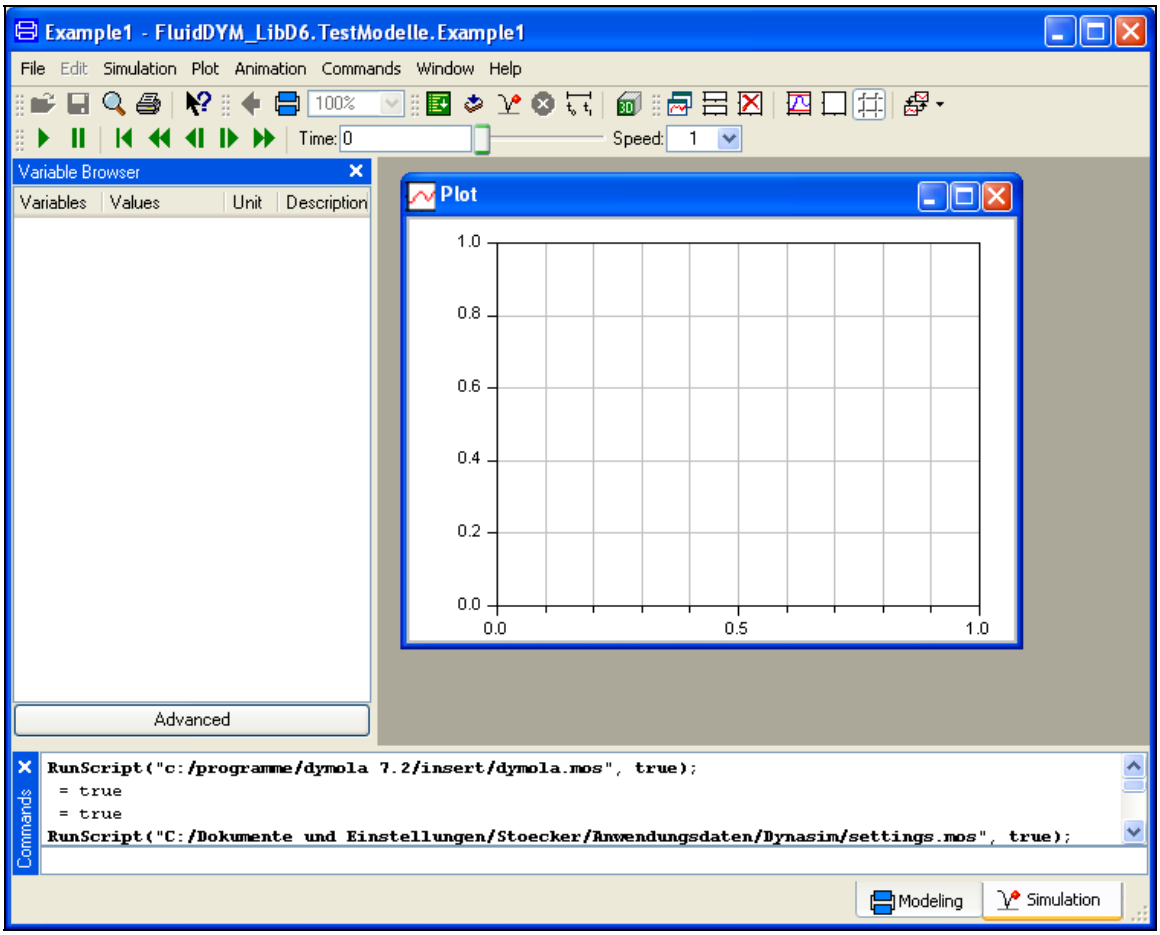


Figure 2.19: "Simulation Mode" window

- 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):

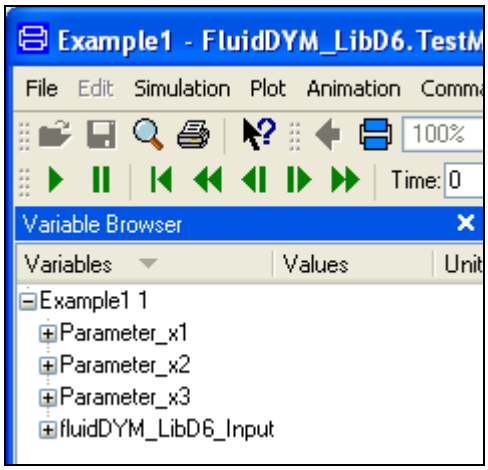


Figure 2.20: "Variable Browser" with new entries

- By clicking on the "New Plot Window" button , a new diagram window will be opened.
- Click on "fluidDYM_LibD6_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).

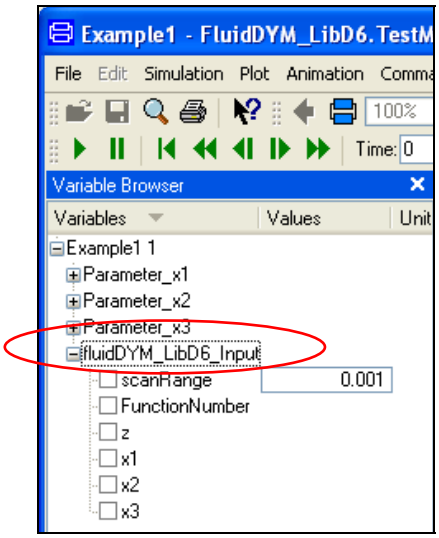


Figure 2.21: Parameters of *fluidDYM_LibD6_Input*

- 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).

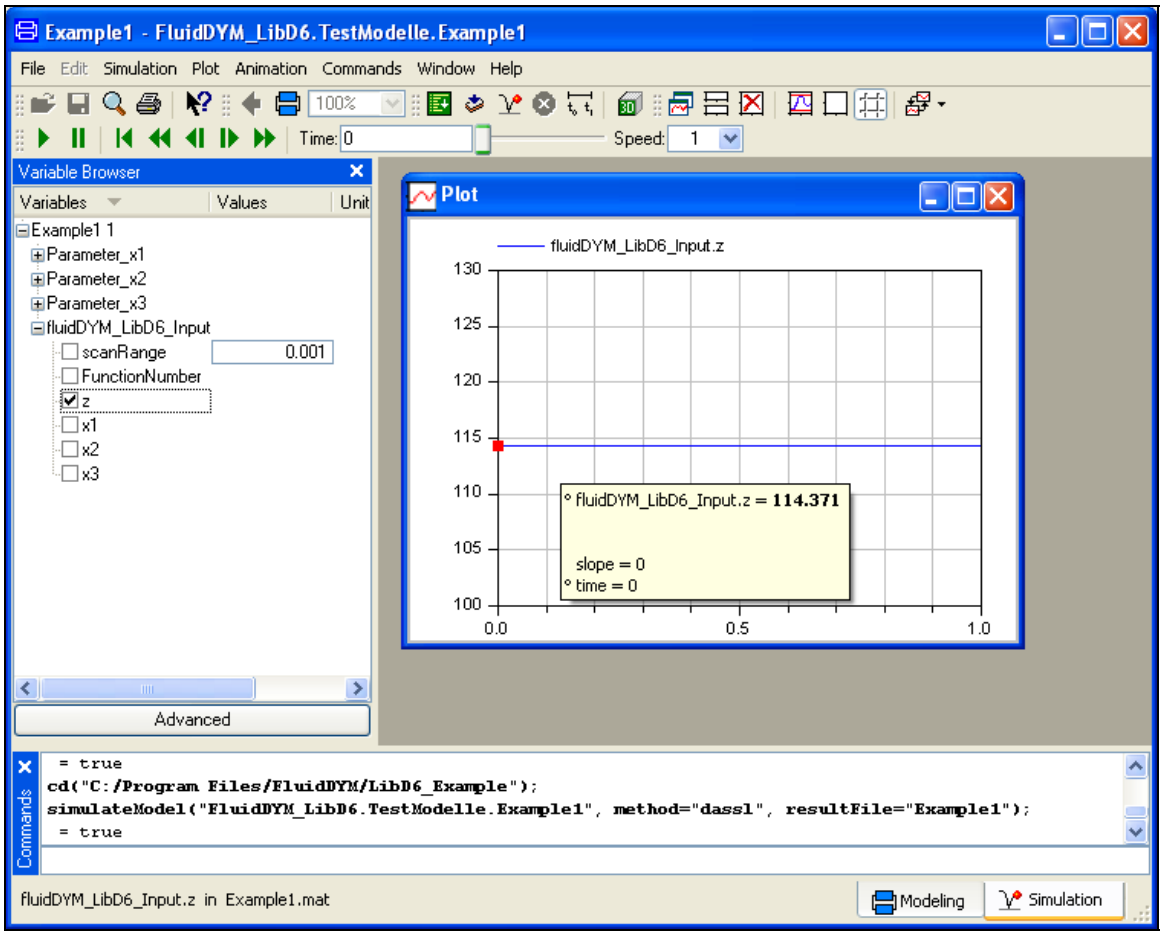


Figure 2.22: "DiagramWindow" showing the result

The result for *h* appears in the "DiagramWindow"

⇒ The result in our sample calculation here is: "h = 114.371". 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_LibD6" Block at the left and then click on "Users_Guide" (see Figure 2.23).

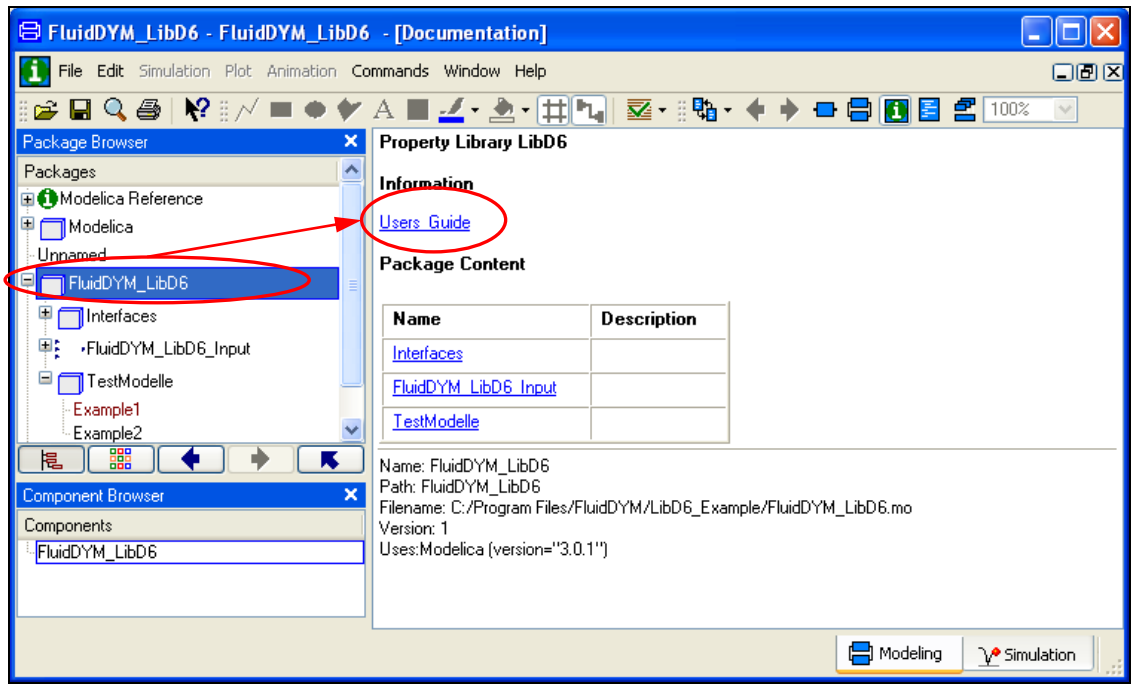


Figure 2.23: Selecting the "Users_Guide"

- 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_LibD6_Input" block on the left (see Figure 2.24).

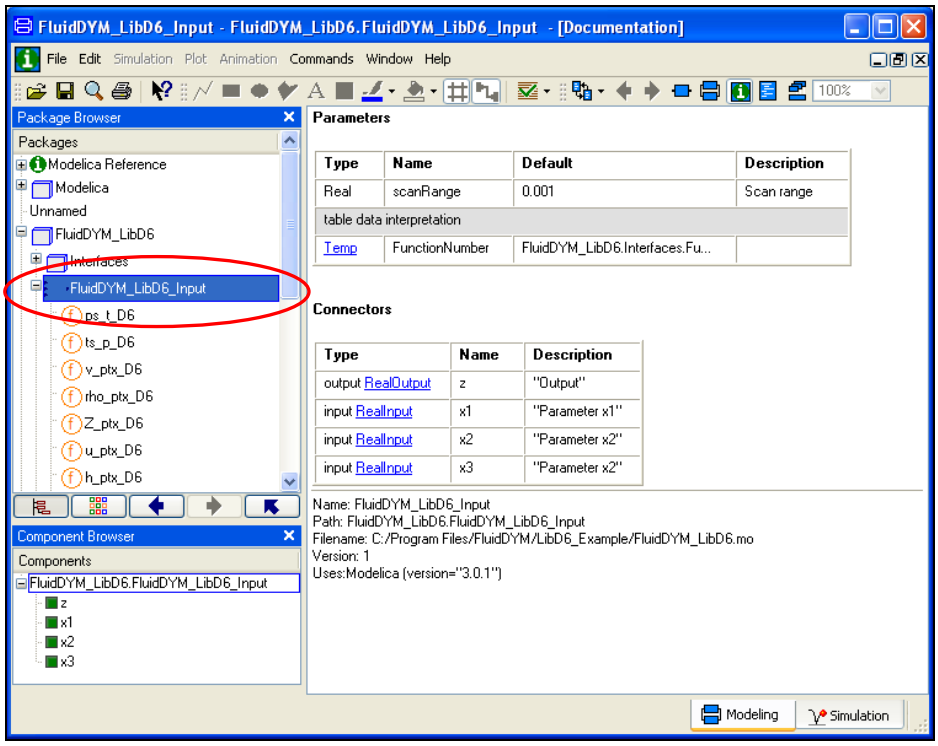


Figure 2.24: Selected "FluidDYM_LibD6_Input" Block

- Below "FluidDYM_LibD6_Input" you will see all functions of the LibD6 property function (see Figure 2.24).
- Now select a function, e.g. "h_ptx_D6", and then click on "Users_Guide" (see Figure 2.25).

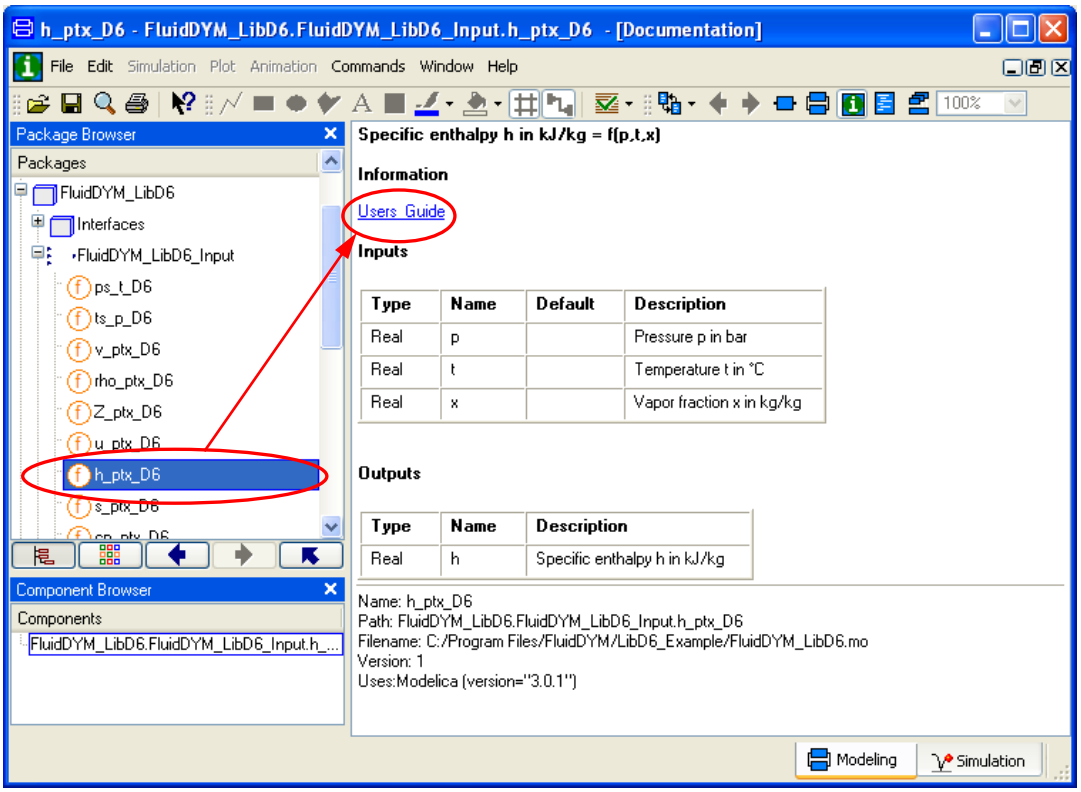


Figure 2.25: Marking the "h_ptx_D6" function and selecting the "Users_Guide"

- You will now see the help page of the selected function, here "h_ptx_D6", in your default web browser (see Figure 2.26).

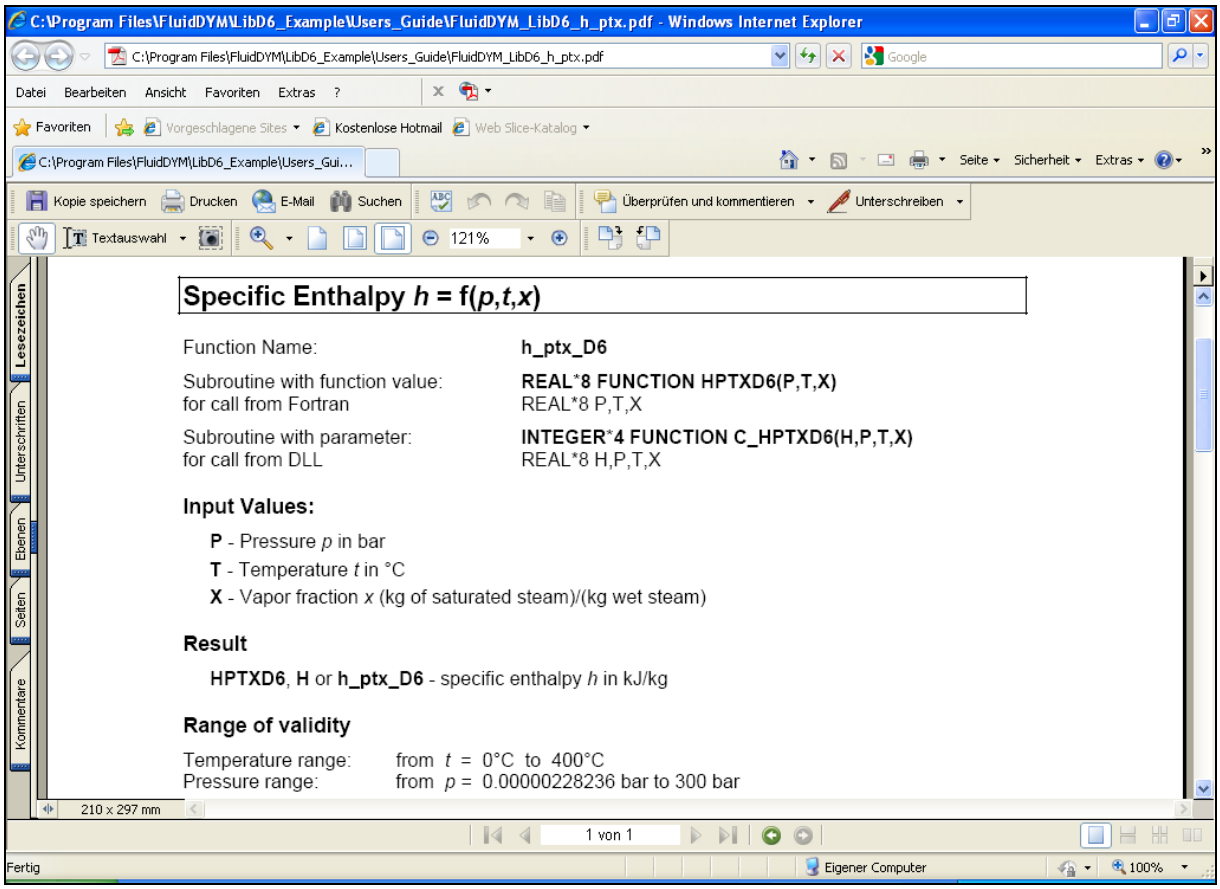


Figure 2.26: Help page of the function "h_ptx_D6" in the web browser

2.3 Removing LibD6 in Dymola

In order to remove the property library LibD6 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 LibD6" 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 LibD6" has now been removed.

If LibD6 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_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION CPPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CPPTXD6(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

CPPTXD6, CP or **cp_ptx_D6** – 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 = 0.00000228236 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 $t = 0°C$ to $t_c = 372.63$ °C

Pressure ranges from $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **CPPTXD6 = -1000**, **CP = -1000** or **cp_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)	p > 300 bar or p < 0.0000022823 bar or t > 400 °C or t < 0°C
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 372.63°C$ to $t < 0°C$ at $t = -1000$ and $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar or or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and $t > t_c = 372.63°C$ or $t < 0°C$

References: [1], [2]

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

Function Name:	**cv_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION CVPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CVPTXD6(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

CVPTXD6, CV or **cv_ptx_D6** – 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 = 0.00000228236 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 $t = 0°C$ to $t_c = 372.63°C$
Pressure ranges from $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **CVPTXD6 = -1000**, **CV = -1000** or **cv_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 372.63°C$ to $t < 0°C$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and
$t > t_c = 372.63°C$ or $t < 0°C$

References: [1], [2]

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

Function Name: **dpdtv_ptx_D6**

Subroutine with function value: **REAL*8 FUNCTION DPDTVPTXD6(P,T,X)**
for call from Fortran REAL*8 P,T,X

Subroutine with parameter: **INTEGER*4 FUNCTION C_DPDTVPTXD6(DPDTV,P,T,X)**
for call from DLL REAL*8 DPDTV,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Result

DPDTVPTXD6, **DPDTV** or **dpdtv_ptx_D6** - 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 = 0.00000228236 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 $t = 0°C$ to $t_c = 372.63°C$
Pressure ranges from $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **DPDTVPTXD6 = -1000**, **DPDTV = -1000** or **dpdtvo_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 372.63°C$ to $t < 0°C$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and
$t > t_c = 372.63°C$ 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_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION DPDVTPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_DPDVTPTXD6(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

DPDVTPTXD6, **DPDVT** or **dpdvt_ptx_D6** - 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 = 0.00000228236 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 $t = 0°C$ to $t_c = 372.63°C$
Pressure ranges from $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **DPDVTPTXD6 = -1000**, **DPDVT = -1000** or **dpdvt_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 372.63°C$ to $t < 0°C$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and
$t > t_c = 372.63°C$ or $t < 0°C$

References: [1], [2]

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

Function Name:	**h_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION HPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_HPTXD6(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

HPTXD6, **H** or **h_ptx_D6** - specific enthalpy *h* in kJ/kg

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00000228236 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 $t = 0°\text{C}$ to $t_c = 372.63°\text{C}$
Pressure ranges from $p_s(0°\text{C}) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **HPTXD6 = -1000**, **H = -1000** or **h_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_c = 372.63°\text{C}$ to $t < 0°\text{C}$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°\text{C}) = 0.0000022823$ bar and
$t > t_c = 372.63°C$ or $t < 0°\text{C}$

References: [1], [2]

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

Function Name:	**kappa_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION KAPPAPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_KAPPAPTXD6(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

KAPPAPTXD6, **KAPPA** or **kappa_ptx_D6** – 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 = 0.00000228236 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 $t = 0°C$ to $t_c = 372.63°C$
Pressure ranges from $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **KAPPAPTXD6**, **KAPPA = -1000** or **kappa_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 372.63°C$ to $t < 0°C$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and
$t > t_c = 372.63°C$ or $t < 0°C$

References: [1], [2]

Vapor Pressure $p_s = f(t)$

Function Name:	**ps_t_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION PSTD6(T)** REAL*8 T
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PSTD6(PS,T)** REAL*8 PS,T

Input Values:

T - Temperature t in °C

Result

PSTD6 or **ps_t_D6** – Vapourpressure p_s in bar

Range of validity

Temperature ranges from $t = 0°C$ to $t_c = 372.63°C$

Results for wrong input values

Result **PSTD6 = -1000**, **PS = -1000** or **ps_t_D6 = -1000** for input values:

$t < 0°C$ or $t > t_c = 372.63°C$

References: [1], [2]

Density ρ = f(p,t,x)

Function Name:	**rho_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION RHOPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_RHOPTXD6(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

RHOPTXD6, **RHO** or **rho_ptx_D6** – Density ρ in kg/ m^3

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00000228236 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:

<u>Single-phase region</u>

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.

<u>Wet-steam region</u>

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 <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 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 property of the chosen function to be calculated results in –1000.

Wet steam region: Temperature ranges from $t = 0°\mathrm{C}$ to $t_c = 372.63°\mathrm{C}$
Pressure ranges from $p_s(0°\mathrm{C}) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **RHOPTXD6 = -1000**, **RHO = -1000** or **rho_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_c = 372.63°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and
$t > t_c = 372.63°\mathrm{C}$ or $t < 0°\mathrm{C}$

References: [1], [2]

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

Function Name:	**s_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION SPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_SPTXD6(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

SPTXD6, **S** or **s_ptx_D6** - Specific entropy *s* in kJ/kg K

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00000228236 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 $t = 0°\mathrm{C}$ to $t_c = 372.63°\mathrm{C}$
Pressure ranges from $p_s(0°\mathrm{C}) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **SPTXD6 = -1000**, **S = -1000** or **s_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_c = 372.63°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°\mathrm{C}) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°\mathrm{C}) = 0.0000022823$ bar and
$t > t_c = 372.63°\mathrm{C}$ or $t < 0°\mathrm{C}$

References: [1], [2]

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

Function Name:	**t_ph_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TPHD6(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TPHD6(T,P,H)** REAL*8 T,P,H

Input Values:

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

TPHD6, **T** or **t_ph_D6 -** Temperature *t* in °C

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00000228236 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 $p_s(0°C) = 0.0000022832$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **T_PH_D6**, **T = -1000** or **t_ph_D6 = -1000** for input values:

Single phase region: (x = -1)	p > 300 bar or p < 0.0000022832 bar or at result t > 400 °C or t < 0°C
Boiling or dew curve:	or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022832$ bar and at result $t > t_c = 372.63°C$ or $t < 0°C$

References: [1], [2]

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

Function Name:	**t_ps_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TPSD6(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TPSD6(T,P,S)** REAL*8 T,P,S

Input Values:

P - Pressure *p* in bar

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

Result

TPSD6, **T** or **t_ps_D6 -** Temperature *t* in °C

Range of validity

Temperature range:	from t = 0°C to 400°C
Pressure range:	from p = 0.00000228236 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 $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **T_PS_D6**, **T = -1000** or **t_ps_D6 = -1000** for input values:

Single phase region: (x = -1)	p > 300 bar or p < 0.0000022823 bar or at result t > 400 °C or t < 0°C
Boiling or dew curve:	or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and at result $t > t_c = 372.63°C$ or $t < 0°C$

References: [1], [2]

Saturation Temperature t_s = f(p)

Function Name:	**ts_p_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TSPD6(P)** REAL*8 P
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TSPD6(TS,P)** REAL*8 TS,P

Input Values:

P - Pressure p in bar

Result

TSPD6, **TS** or **ts_p_D6** – Saturation Temperature t_s in °C

Range of validity

Pressure ranges from $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **TSPD6 = -1000**, **TS = -1000** or **ts_p_D6 = -1000** for input values:

$p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar

References: [1], [2]

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

Function Name:	**u_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION UPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_UPTXD6(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

UPTXD6, **U** or **u_ptx_D6** - Specific internal energy *u* in kJ/kg

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00000228236 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 $t = 0°\mathrm{C}$ to $t_c = 372.63°\mathrm{C}$
Pressure ranges from $p_s(0°\mathrm{C}) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **UPTXD6 = -1000**, **U = -1000** or **u_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Wet steam region:
at $p = -1000$ and $t > t_c = 372.63°\mathrm{C}$ to $t < 0°\mathrm{C}$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°\mathrm{C}) = 0.0000022823$ bar and
$t > t_c = 372.63°\mathrm{C}$ or $t < 0°\mathrm{C}$

References: [1], [2]

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

Function Name:	**v_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION VPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_VPTXD6(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

VPTXD6, V *or* **v_ptx_D6** – Specific volume *v* in m^3/kg

Range of validity

Temperature range: from *t* = 0°C to 400°C
Pressure range: from *p* = 0.00000228236 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 $t = 0°C$ to $t_c = 372.63°C$
Pressure ranges from $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **VPTXD6 = -1000**, **V = -1000** or **v_ptx_D6 = -1000** for input values:

Single phase region: *p* > 300 bar or *p* < 0.0000022823 bar or
(*x* = -1) *t* > 400 °C or *t* < 0°C

Wet steam region: at $p = -1000$ and $t > t_c = 372.63°C$ to $t < 0°C$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°C) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.0000022823$ bar and
$t > t_c = 372.63°C$ or $t < 0°C$

References: [1], [2]

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

Function Name:	**w_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION WPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_WPTXD6(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

WPTXD6, **W** or **w_ptx_D6 -** Speed of sound *w* in m/s

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00000228236 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 $t = 0°\text{C}$ to $t_c = 372.63°\text{C}$
Pressure ranges from $p_s(0°\text{C}) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **WPTXD6 = -1000, W = -1000** or **w_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 372.63°\text{C}$ to $t < 0°\text{C}$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°\text{C}) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°\text{C}) = 0.0000022823$ bar and
$t > t_c = 372.63°\text{C}$ or $t < 0°\text{C}$

References: [1], [2]

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

Function Name:	**x_ph_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION XPHD6(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_XPHD6(X,P,H)** REAL*8 X,P,H

Input Values:

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

XPHD6, **X** or **x_ph_D6 -** 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 = 0.00000228236 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 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 $p_s(0°C) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **X_PH_D6**, **X =** -1 or **x_ph_D6 =** -1 for input values:

If the state point is located in the single phase region:

$p > p_c = 9.613975$ bar or $p < p_s(0°C) = 0.00000228236$ bar

References: [1], [2]

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

Function Name:	**x_ps_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION XPSD6(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_XPSD6(X,P,S)** REAL*8 X,P,S

Input Values:

P - Pressure *p* in bar

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

Result

XPSD6, **X** or **x_ps_D6 -** 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 = 0.00000228236 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 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 $p_s(0°\mathrm{C}) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **X_PS_D6**, **X = -1** or **x_ps_D6 = -1** for input values:

If the state point is located in the single phase region:

$p > p_c = 9.613975$ bar or $p < p_s(0°\mathrm{C}) = 0.00000228236$ bar

References: [1], [2]

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

Function Name:	**Z_ptx_D6**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION ZPTXD6(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ZPTXD6(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

ZPTXD6, **Z** or **Z_ptx_D6 -** Compression Factor

Range of validity

Temperature range: from t = 0°C to 400°C
Pressure range: from p = 0.00000228236 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 $t = 0°\text{C}$ to $t_c = 372.63°\text{C}$
Pressure ranges from $p_s(0°\text{C}) = 0.0000022823$ bar to $p_c = 9.613975$ bar

Results for wrong input values

Result **ZPTXD6 = -1000, Z = -1000** or **Z_ptx_D6 = -1000** for input values:

Single phase region: (x = -1)
p > 300 bar or p < 0.0000022823 bar or
t > 400 °C or t < 0°C

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 372.63°\text{C}$ to $t < 0°\text{C}$
at $t = -1000$ and $p > p_c = 9.613975$ bar
or $p < p_s(0°\text{C}) = 0.0000022823$ bar or
or $p > p_c = 9.613975$ bar or $p < p_s(0°\text{C}) = 0.0000022823$ bar and
$t > t_c = 372.63°\text{C}$ or $t < 0°\text{C}$

References: [1], [2]

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

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:

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 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_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_5H_{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 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)

For more information please contact:

Zittau/Goerlitz University of Applied Sciences
Department of Technical Thermodynamics
Professor Hans-Joachim Kretzschmar
Dr. Ines Stoecker

Theodor-Koerner-Allee 16
02763 Zittau, Germany

Internet: www.thermodynamics-zittau.de
E-mail: hj.kretzschmar@hs-zigr.de
Phone: +49-3583-61-1846
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.

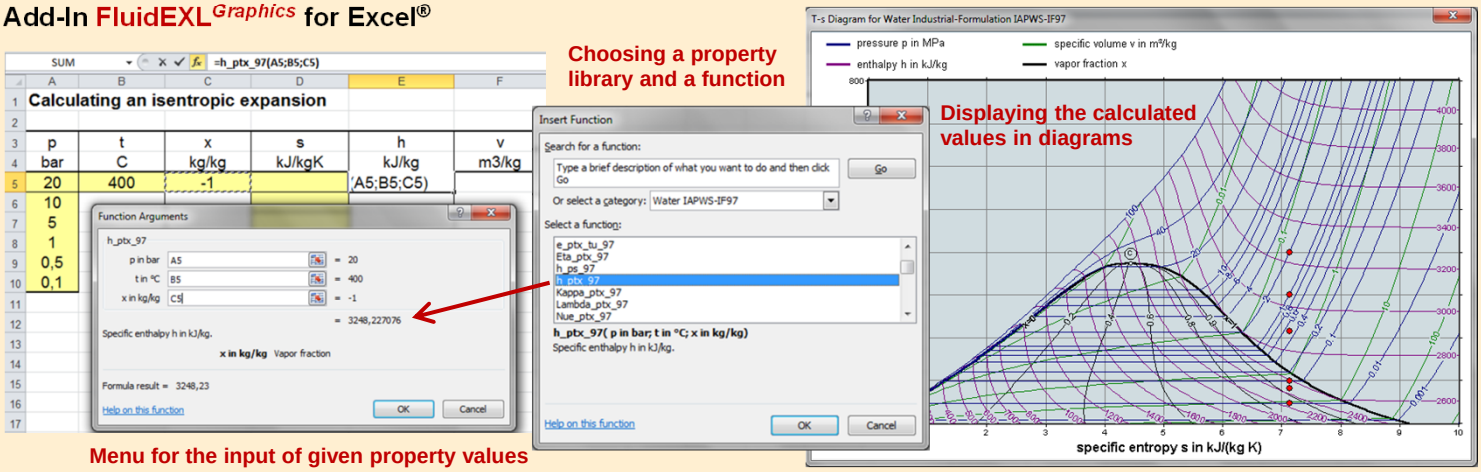
[a] Not all of these property functions are available in all property libraries.

www.thermodynamic-property-libraries.com

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

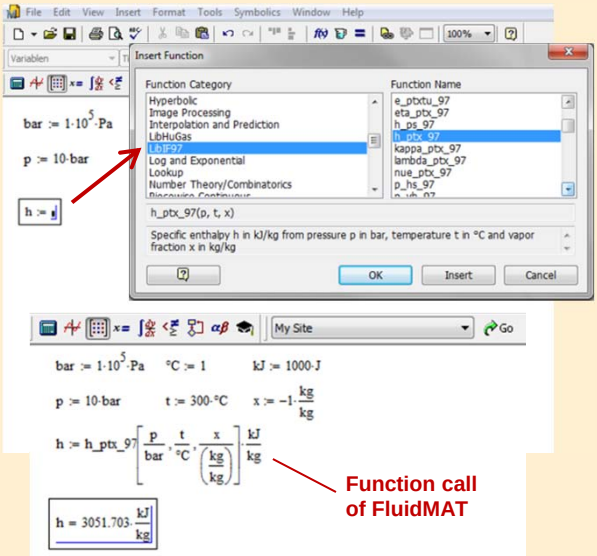
Property Software for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



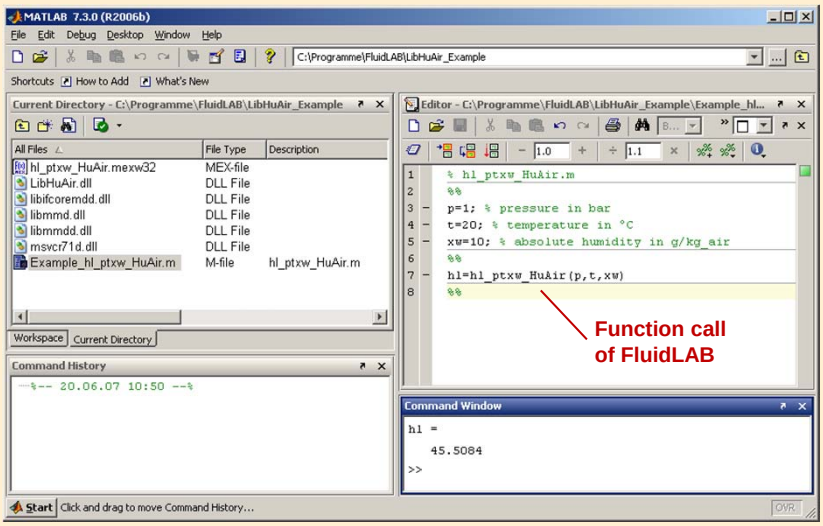
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



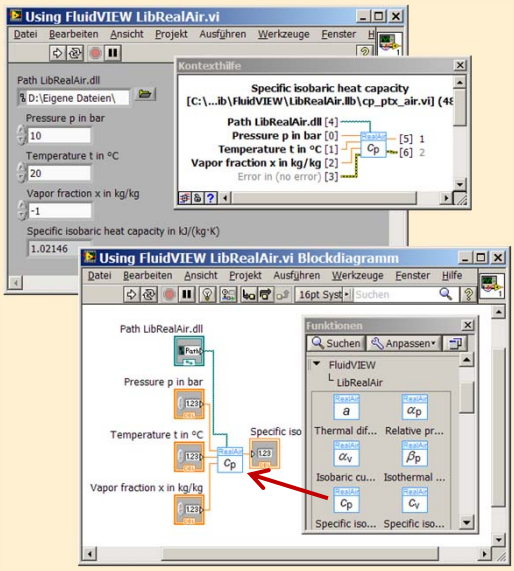
Add-In FluidLAB for MATLAB®

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



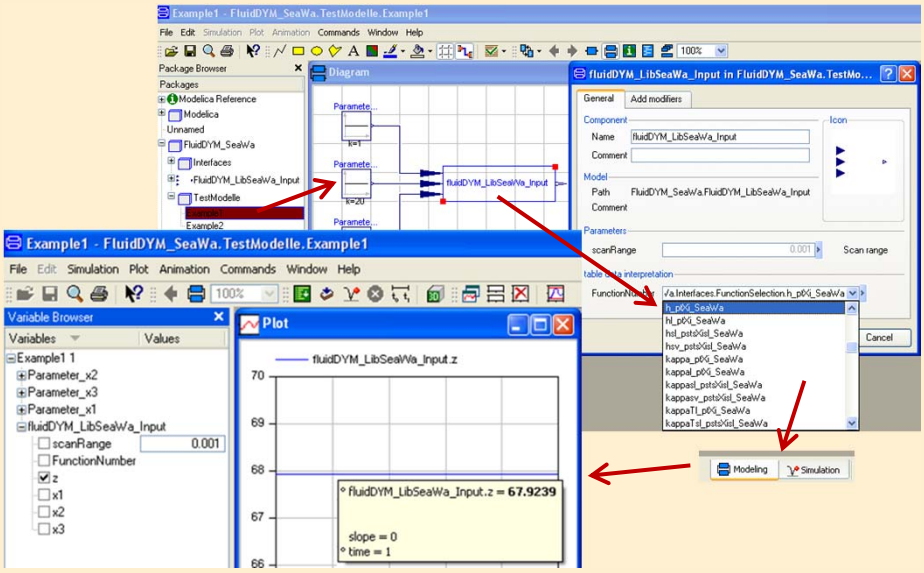
Add-On FluidVIEW for LabVIEW®

The property functions can be calculated in LabVIEW®.

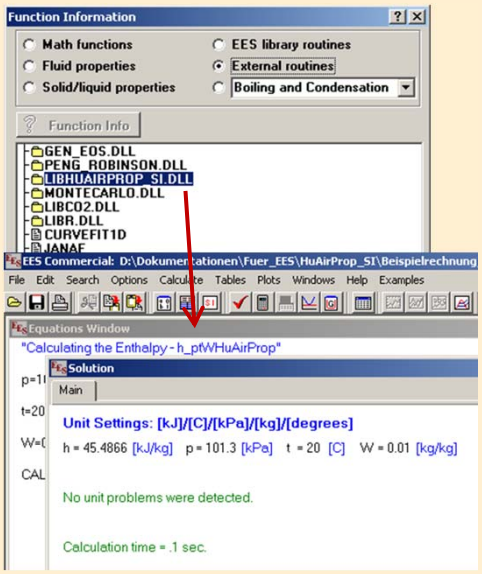


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

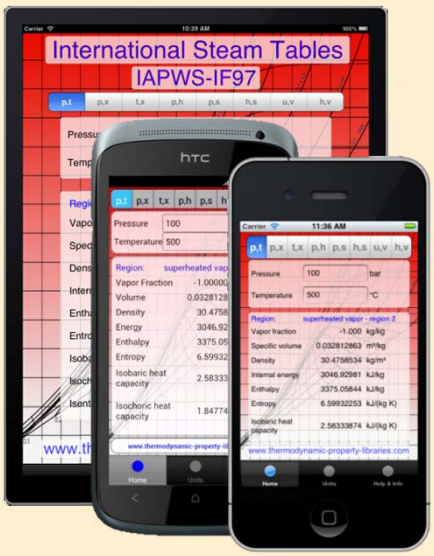
The property functions can be called in DYMOLA® and SimulationX®



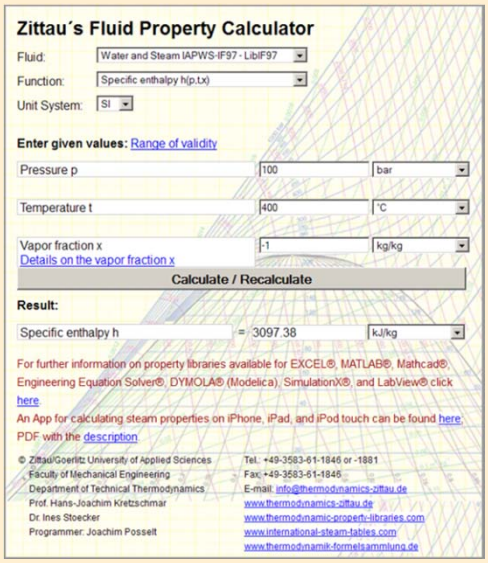
Add-In FluidEES for Engineering Equation Solver®



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 83, TI 84, TI 89 | TI Voyage 200 | TI 92

For more information please contact:

Zittau/Goerlitz University of Applied Sciences
Department of Technical Thermodynamics
Professor Hans-Joachim Kretzschmar
Dr. Ines Stoecker
Theodor-Koerner-Allee 16
02763 Zittau, Germany

E-mail: hj.kretzschmar@hs-zigr.de
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

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

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

6. Satisfied Customers

Date: 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

Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011
Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011, 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
Voith, Zschopau	07/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011

Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011, 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010
University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010

Vaillant, Remscheid	10/2010
PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
Saacke, Bremen	09/2010
WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	08/2010
ERGION, Mannheim	07/2010
Fichtner IT Consulting, Stuttgart	07/2010
TF Design, Matieland, South Africa	07/2010
MCE, Berlin	07/2010, 12/2010
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	06/2010
RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010
Universitaet der Bundeswehr, Munich	04/2010
Technical University of Hamburg-Harburg	04/2010
Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
VER, Dresden	04/2010
CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
Technical University of Dresden	02/2010
Siemens Energy, Nuremberg	02/2010

Augsburg University of Applied Sciences	02/2010
ALSTOM Power, Baden, Switzerland	02/2010, 05/2010
MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	01/2010, 12/2010
Technical University of Freiberg	01/2010
ILK, Dresden	01/2010, 12/2010
Fischer-Uhrig Consulting Engineers, Berlin	01/2010

2009

ALSTOM Power, Baden, Schweiz	01/2009, 03/2009, 05/2009
Nordostschweizerische Kraftwerke AG, Doettingen, Switzerland	02/2009
RWE, Neurath	02/2009
Brandenburg University of Technology, Cottbus	02/2009
Hamburg University of Applied Sciences	02/2009
Kehrein, Moers	03/2009
EPP Software, Marburg	03/2009
Bernd Münstermann, Telgte	03/2009
Suedzucker, Zeitz	03/2009
CPP, Marburg	03/2009
Gelsenkirchen University of Applied Sciences	04/2009
Regensburg University of Applied Sciences	05/2009
Gatley & Associates, Atlanta, USA	05/2009
BOSCH, Stuttgart	06/2009, 07/2009
Dr. Nickolay, Consulting Engineers, Gommersheim	06/2009
Ferrostal Power, Saarlouis	06/2009
BHR Bilfinger, Essen	06/2009
Intraserv, Wiesbaden	06/2009
Lausitz University of Applied Sciences, Senftenberg	06/2009
Nuernberg University of Applied Sciences	06/2009
Technical University of Berlin	06/2009
Fraunhofer Institut UMSICHT, Oberhausen	07/2009
Bischoff, Aurich	07/2009
Fichtner IT Consulting, Stuttgart	07/2009
Techsoft, Linz, Austria	08/2009

DLR, Stuttgart	08/2009
Wienstrom, Vienna, Austria	08/2009
RWTH Aachen University	09/2009
Vattenfall, Hamburg	10/2009
AIC, Chemnitz	10/2009
Midiplan, Bietigheim-Bissingen	11/2009
Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
FZD, Rossendorf	11/2009
Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
EC, Heidelberg	11/2009
MCI, Innsbruck, Austria	12/2009
Saacke, Bremen	12/2009
ENERKO, Aldenhoven	12/2009

2008

Pink, Langenwang	01/2008
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
WEBASTO, Neubrandenburg	04/2008
CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008
Technip Benelux BV, Zoetermeer, Netherlands	08/2008

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

2007

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

National Energy Technology Laboratory, Pittsburg, USA	10/2007
Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007
Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

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

Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	05/2006
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
Suedzucker, Ochsenfurt	06/2006
M&M Turbine Technology, Bielefeld	06/2006
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006
Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005, 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden Professorship of Thermic Energy Machines and Plants	04/2005
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005

Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
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

2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	01/2004
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

2003

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

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
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
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
ALSTOM Power Baden, Switzerland (group licenses)	05/2002
InfraServ, Gendorf	05/2002
SoftSolutions, Muehlhausen (company license)	05/2002
DREWAG, Dresden (company license)	05/2002
SOFBID, Zwingenberg (general EBSILON program license)	06/2002
Kleemann Engineering, Dresden	06/2002
Caliqua, Basel, Switzerland (company license)	07/2002
PCK Raffinerie, Schwedt (group license)	07/2002
Fischer-Uhrig Engineering, Berlin	08/2002

Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	08/2002
Stadtwerke Duisburg	08/2002
Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

2001

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
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
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

2000

SOFBID, Zwingenberg (general EBSILON program license)	01/2000
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
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
UMAG W. UDE, Husum	03/2000
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

1999

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

1997

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