



Hochschule
Zittau/Görlitz

UNIVERSITY OF APPLIED SCIENCES

Faculty of
MECHANICAL ENGINEERING
Department of
TECHNICAL THERMODYNAMICS

Property Library for Combustion Gas Mixtures calculated from VDI-Guideline 4670

FluidDYM
with **LibIDGAS**
for DYMOLA®

Prof. Hans-Joachim Kretzschmar

Dr. Ines Stoecker

Matthias Kunick

K. Knobloch

J. Karich

Property Software for Combustion Gas Mixtures calculated from VDI-Guideline 4670

Including DLL and Add-In for DYMOLA[®]

FluidDYM LibIDGAS

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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_LibIDGAS_Eng.zip" for Dymola®

Including the following files:

FluidDYM_LibIDGAS_Setup.exe	Installation Program for the FluidDYM Add-In for use in Dymola®
LibIDGAS.dll	Dynamic Link Library for ideal gas mixtures for use in Dymola®
Docu_FluidDYM_LibIDGAS_Eng.pdf	User's Guide
Folder "Users_Guide"	Includes the complete User's Guide

1. Property Functions

1.1 Range of Validity and Structure of the Program Library

The thermodynamic properties of combustion gas mixtures in the ideal gas state are calculated corresponding to the

VDI Guideline 4670 [21].

The transport properties are calculated corresponding to

Brandt [15] and VDI-Wärmeatlas [19].

Important property constants were taken from the compendium from *Blanke* [20].

The mixture can contain the following components:

Number	Component	
1	Argon	Ar
2	Neon	Ne
3	Nitrogen	N ₂
4	Oxygen	O ₂
5	Carbon monoxide	CO
6	Carbon dioxide	CO ₂
7	Steam	H ₂ O
8	Sulfur dioxide	SO ₂
9	Air (dry)	
10	Air nitrogen	

Range of validity:

Temperature t : from -73.15 °C to 3026.85 °C

Mixture pressure p : from >0 bar to 10 (30), max 50 bar

The pressure range is limited for gases and mixtures in the ideal gas state.

For temperatures higher than 700 °C the influence of dissociation is taken into consideration.

1.2 Property Functions for Ideal Gas Mixtures

Functional Dependence	Function Name	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$a = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	a_pt_id	a_pt_id(p,t,type,zu(1:10))	Thermal diffusivity	m^2/s	[15], [18]	3/1
$c_p = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	cp_pt_id	cp_pt_id(p,t,type,zu(1:10))	Specific isobaric heat capacity	$\text{kJ}/(\text{kg} \cdot \text{K})$	[18]	3/2
$c_v = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	cv_pt_id	cv_pt_id(p,t,type,zu(1:10))	Specific isochoric heat capacity	$\text{kJ}/(\text{kg} \cdot \text{K})$	[18]	3/3
$\eta = f(t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	Eta_t_id	Eta_t_id(t,type,zu(1:10))	Dynamic viscosity	$\text{Pa} \cdot \text{s} = \text{kg}/(\text{m} \cdot \text{s})$	[15], [18]	3/4
$h = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	h_pt_id	h_pt_id(p,t,type,zu(1:10))	Specific enthalpy	kJ/kg	[18]	3/5
$\kappa = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	Kappa_pt_id	Kappa_pt_id(p,t,type,zu(1:10))	Isentropic exponent		[18]	3/6
$\lambda = f(t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	Lambda_t_id	Lambda_t_id(t,type,zu(1:10))	Thermal conductivity	$\text{W}/(\text{m} \cdot \text{K})$	[15]	3/7
$M = f(\xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	M_id	M_id(type,zu(1:10))	Molar mass of the mixture	kg/kmol	[17]	3/8
$\nu = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	Ny_pt_id	Ny_pt_id(p,t,type,zu(1:10))	Kinematic Viscosity	m^2/s	[15], [16]	3/9
$p = f(t, s, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	p_ts_id	p_ts_id(t,s,type,zu(1:10))	Backward Function: Mixture pressure from temperature and entropy of the mixture	bar	[18]	3/10
$p = f(t, v, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	p_tv_id	p_tv_id(t,v,type,zu(1:10))	Backward Function Mixture pressure from temperature and specific volume	bar	Ideal gas equation	3/11
$Pr = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	Pr_pt_id	Pr_pt_id(p,t,type,zu(1:10))	Prandtl-number		[15], [16]	3/12
$\psi_i = f(i, \xi_1 \dots \xi_{10})$	Psi_igas_Xsi_id	Psi_igas_Xsi_id(i,Xsi(1:10))	Mole fraction of the mixture gas i from the mass fractions of all mixture gases	kmol/kmol	Mixture calculation	3/13
$R = f(\xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	R_id	R_id(type,zu(1:10))	Specific gas constant	$\text{kJ}/(\text{kg} \cdot \text{K})$	[17]	3/14
$\rho = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	Rho_pt_id	Rho_pt_id(p,t,type,zu(1:10))	Density	kg/m^3	Ideal gas equation	3/15

Functional Dependence	Function Name	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$s = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	s_pt_id	s_pt_id(p,t,type,zu(1:10))	Specific entropy of the mixture	kJ/(kg · K)	[18]	3/16
$T = f(p, h, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	t_ph_id	t_ph_id(p,h,type,zu(1:10))	Backward Function: Temperature from pressure and enthalpy of the mixture	°C	[18]	3/17
$t = f(p, s, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	t_ps_id	t_ps_id(p,s,type,zu(1:10))	Backward Function: Temperature from pressure and entropy of the mixture	°C	[18]	3/18
$t = f(p, v, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	t_pv_id	t_pv_id(p,v,type,zu(1:10))	Backward Function: Temperature from pressure and specific volume of the mixture	°C	[18]	3/19
$u = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	u_pt_id	u_pt_id(p,t,type,zu(1:10))	Specific internal energy	kJ/kg		3/20
$v = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	v_pt_id	v_pt_id(p,t,type,zu(1:10))	Specific volume	m ³ /kg	Ideal gas equation	3/21
$w = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$	w_pt_id	w_pt_id(p,t,type,zu(1:10))	Isentropic speed of sound of the mixture	m/s	[18]	3/22
$\xi_i = f(i, \psi_1 \dots \psi_{10})$	Xsi_igas_Psi_id	Xsi_igas_Psi_id(i,Psi(1:10))	Mass fraction of the mixture gas i from the mole fractions of all mixture gases	kg/kg	Mixture calculation	3/23

Units:

Symbol	Name	Unit
t	Temperature	°C
p	Mixture pressure	bar
$\xi_1 \dots \xi_{10}$	Mass fractions of the components	kg/kg
$\psi_1 \dots \psi_{10}$	Mole fractions, volume fractions of the components	kmol/kmol
type	Input: type = 1 for mass fractions $\xi_1, \dots, \xi_{10}$ type = 0 for mole fractions $\psi_1, \dots, \psi_{10}$	
comp(1:10) for type =1	Mass fractions $\xi_1, \dots, \xi_{10}$	kg/kg
comp(1:10) for type =0	Mole fractions $\psi_1, \dots, \psi_{10}$	kmol/kmol

Mixture Gases:

Gas	Mixture gas	
1	Argon	Ar
2	Neon	Ne
3	Nitrogen	N ₂
4	Oxygen	O ₂
5	Carbon monoxide	CO
6	Carbon dioxide	CO ₂
7	Steam	H ₂ O
8	Sulfur dioxide	SO ₂
9	Air (dry) from VDI4670 [21]	Composition in mole fractions: 78.1109 % N ₂ 20.9548 % O ₂ 0.9343 % Ar Composition in mass fractions: 75.5577 % N ₂ 23.1535 % O ₂ , 1.2888 % Ar
10	Air nitrogen from <i>Brandt</i> [15]	Composition in mole fractions: 98.8180 % N ₂ 1.1820 % Ar Composition in mass fractions: 98.3229 % N ₂ 1.6771 % Ar

Range of Validity:

Temperature:	t = -73.15 °C ... 3026.85 °C
Pressure:	p = 0.01 mbar ... 50 bar

Reference States:

Property	Gases (except steam)	Steam
Pressure	1.01325 bar	0.006112127 bar
Temperature	0.0 °C	0 °C
Enthalpy	0 kJ/kg	2500.9342 kJ/kg
Entropy	0 kJ/kg K	9.15591 kJ/(kg K)

Variable Types for Function Call:

All functions:	Double
Variable p, t, v, h, s :	Double
Variable to [1..10] :	Array of Double
Variable type, i :	Integer

Note:

If the input values are located outside the range of validity or if they do not fit together, the chosen function to be calculated results in -1.

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 ideal gases and gas mixtures from the LibIDGAS 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_LibIDGAS.zip", you will see the folder

CD_FluidDYM_LibIDGAS

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_LibIDGAS_Docu_Eng.pdf

FluidDYM_LibIDGAS_Setup.exe

LibIDGAS.dll

Folder "Users_Guide."

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

FluidDYM_LibIDGAS_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 (see Figure 2.1), "Choose Destination Location", the default path offered automatically for the installation of FluidDYM is

C:\Program Files\FluidDYM\LibIDGAS (for English version of Windows)

C:\Programme\FluidDYM\LibIDGAS (for German version of Windows)).

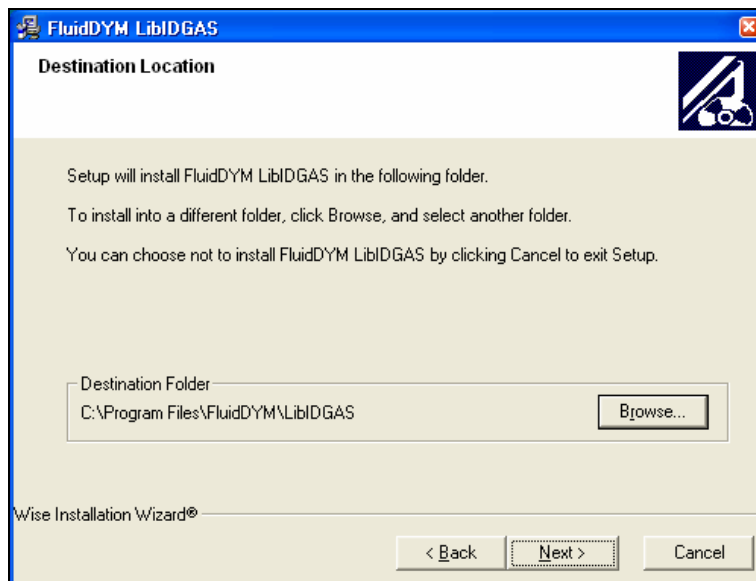


Figure 2.1: Dialog window "Destination Location"

By clicking the "Browse..." button, you can change the installation directory before installation. If you wish to change directory, click the "Browse..." button and select your desired directory. The instructions in this user's guide refer to the stated default directory. Leave this window by clicking the "Next>" button.

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

The installation program has copied the following files into the directory

C:\Program Files\FuildDYM\LibIDGAS (for English version of Windows)
 C:\Programme\FuildDYM\LibIDGAS (for German version of Windows):

- Dynamic link library "LibIDGAS.dll"
- Folder "Users_Guide"
- Link up Dynamic link library "LibIDGAS_Dymola.dll" and other necessary system DLL files
- Library File "LibIDGAS_Dymola.lib"
- Header File "LibIDGAS_Dymola.h" and other necessary system DLL files
- Modelica File "FluidDYM_LibIDGAS.mo", includes the following property functions:

a_pt_id	Psi_igas_Xsi_id
cp_pt_id	R_id
cv_pt_id	rho_pt_id
eta_pt_id	s_pt_id
h_pt_id	t_ph_id
kappa_pt_id	t_ps_id
lambda_pt_id	t_pv_id
M_id	u_pt_id
ny_pt_id	v_pt_id

p_ts_id
p_tv_id
Pr_pt_id

w_pt_id
Xsi_igas_Psi_id

Now, you have to overwrite the file "LibIDGAS.dll" and the folder "Users_Guide" in your LibIDGAS directory with the files of the same names provided in your CD folder with FluidDYM.

To do this, open the CD folder "CD_FluidDYM_LibIDGAS" in "My Computer" and click on the file "LibIDGAS.dll" in order to highlight it. Hold Ctrl and click on the folder "Users_Guide" to mark it as well.

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

Now, open your LibIDGAS directory (the standard being

C:\Program Files\FluidDYM\LibIDGAS (for English version of Windows)
C:\Programme\FluidDYM\LibIDGAS (for German version of Windows))

and insert the "LibIDGAS.dll" and the "Users_Guide" folder by clicking the "Edit" menu in your Explorer and then select "Paste".

Answer the question whether you want to replace the files by clicking the "Yes" button. Now, you have overwritten the file "LibIDGAS.dll" and the folder "Users_Guide" successfully.

2.2 Licensing the LibIDGAS 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 2.2).

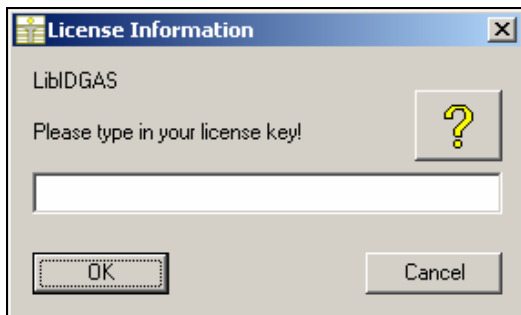


Figure 2.2: "License Information" window

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 LibIDGAS property library will display the result "-11111111" for every calculation.

The "License Information" window will appear every time you start Dymola.

Should you not wish to license the LibIDGAS property library, you have to uninstall the FluidDYM LibIDGAS property library following the description in section 2.4 of this User's Guide.

2.3 Example: Calculation of the Enthalpy $h = f(p, t, \xi_1 \dots \xi_{10})$ of a Gas Mixture

Now we will calculate, step by step, the specific enthalpy h as a function of mixture pressure $p=1$, temperature $t=100^\circ\text{C}$ for a given mixture composed of the mass fractions

13 % carbon dioxide, 11 % steam, 76 % air nitrogen,

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" button and select "Details".
- Switch into the program directory of FluidDYM in which you will find the folder "LibIDGAS"; the standard location is:

C:\Program Files\FluidDYM\LibIDGAS	(for English version of Windows)
C:\Programme\FluidDYM\LibIDGAS	(for German version of Windows))
- Create the folder "LibIDGAS_Example" by clicking on "File" in the Explorer menu, then "New" in the menu which appears, and then selecting "Folder". Name the new folder "LibIDGAS_Example".
- You will see the following window:

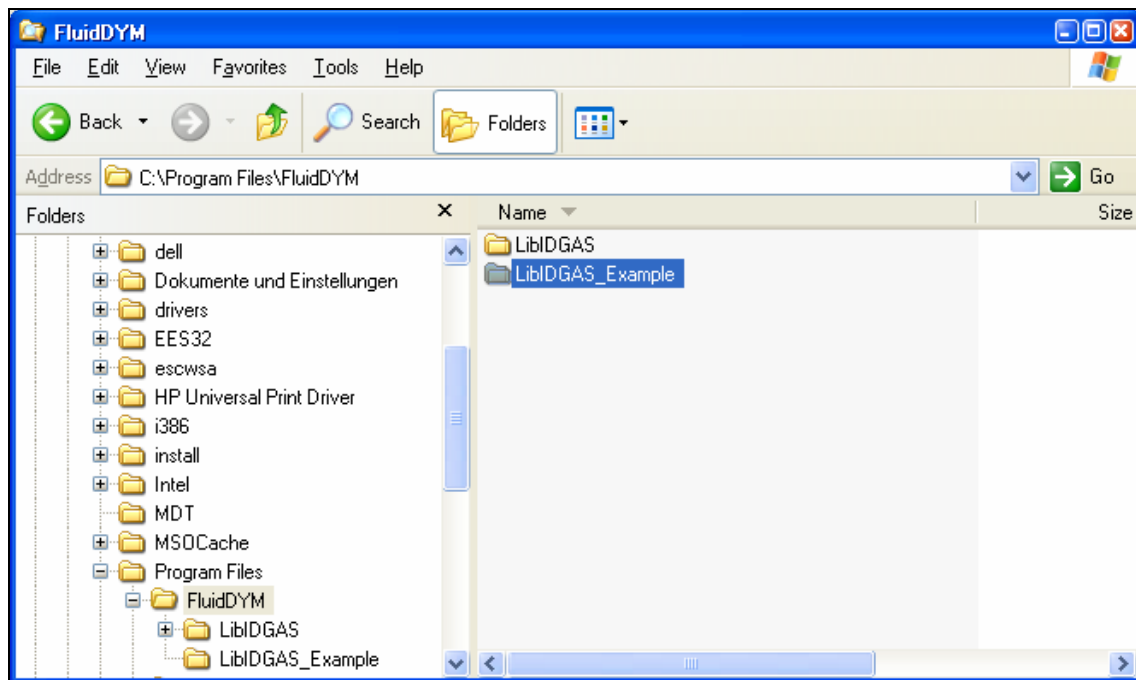


Figure 2.4: "LibIDGAS_Example" and "LibIDGAS" directory in FluidDYM

- Switch into the directory "LibIDGAS" within "FluidDYM", the standard being:

C:\Program Files\FluidDYM\LibIDGAS	(for English version of Windows)
C:\Programme\FluidDYM\LibIDGAS	(for German version of Windows)).

- You will see the following window:

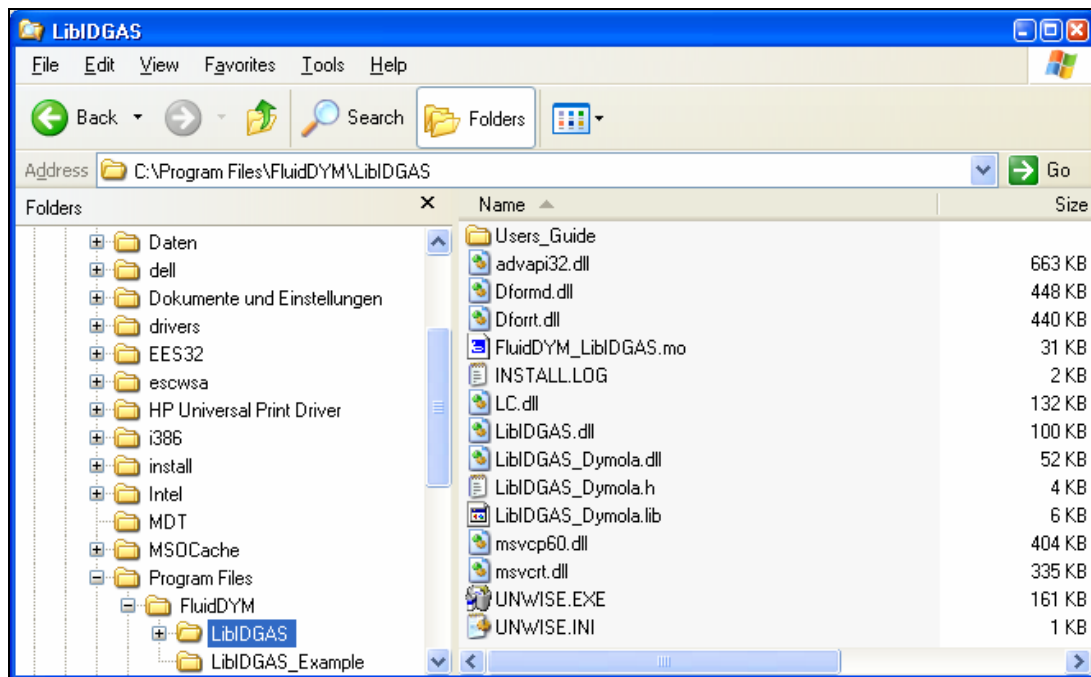


Figure 2.5: "LibIDGAS" directory including installed files

In order to calculate the function $h = f(p, t, \xi_1 \dots \xi_{10})$, the following files are necessary. Copy them into the directory

C:\Program Files\FluidDYM\LibIDGAS (for English version of Windows)
 C:\Programme\FluidDYM\LibIDGAS (for German version of Windows):

- "advapi32.dll"
- "Dformd.dll"
- "Dfortt.dll"
- "FluidDYM_LibIDGAS.mo"
- "LC.dll"
- "LibIDGAS.dll"
- "LibIDGAS_Dymola.dll"
- "LibIDGAS_Dymola.h"
- "LibIDGAS_Dymola.lib"
- "msvc60.dll"
- "Msvcrt.dll"
- the folder "Users_Guide"

- Mark up these files, then click "Edit" in the upper menu bar and select "Copy".
- Switch into the directory

C:\Program Files\FluidDYM\LibIDGAS_Example (for English version of Windows)
 C:\Programme\FluidDYM\LibIDGAS_Example (for German version of Windows)),

click "Edit" and then "Paste".

- You will see the following window:

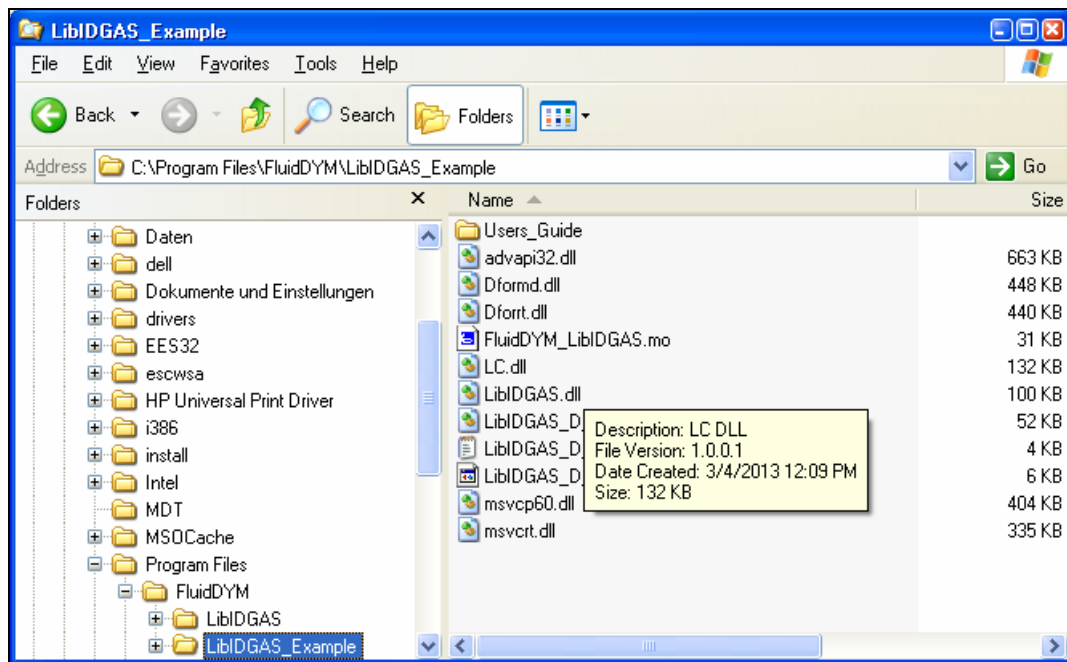


Figure 2.6: "LibIDGAS_Example" directory including the newly-copied files

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

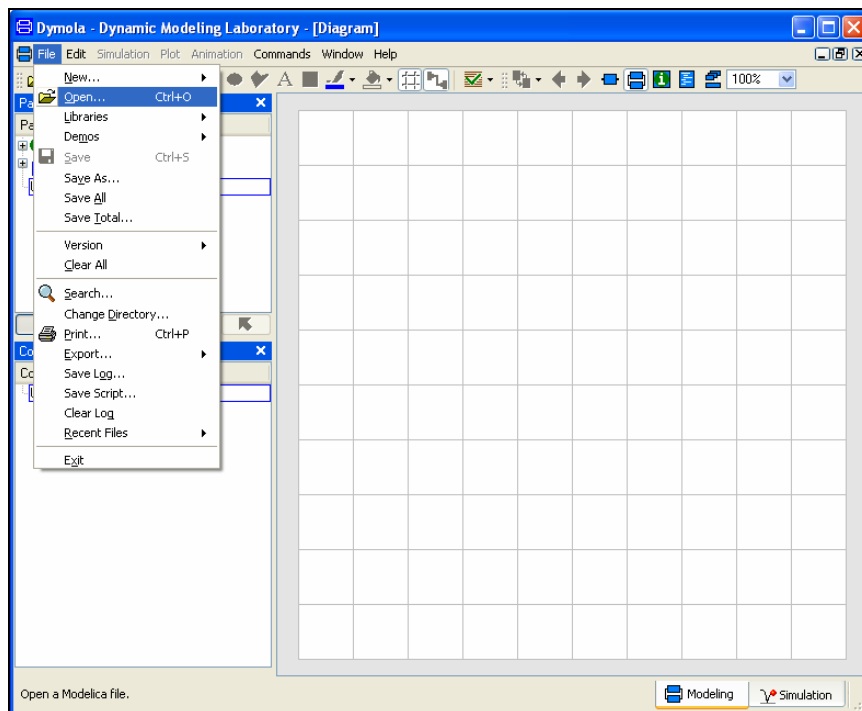


Figure 2.7: Selecting the menu entry "Open"

- Search and click on the directory
 "C:\Program Files\FluidDYM\LibIDGAS_Example" (for English version of Windows)
 "C:\Programme\FluidDYM\LibIDGAS_Example" (for German version of Windows)
 in the appearing menu.

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

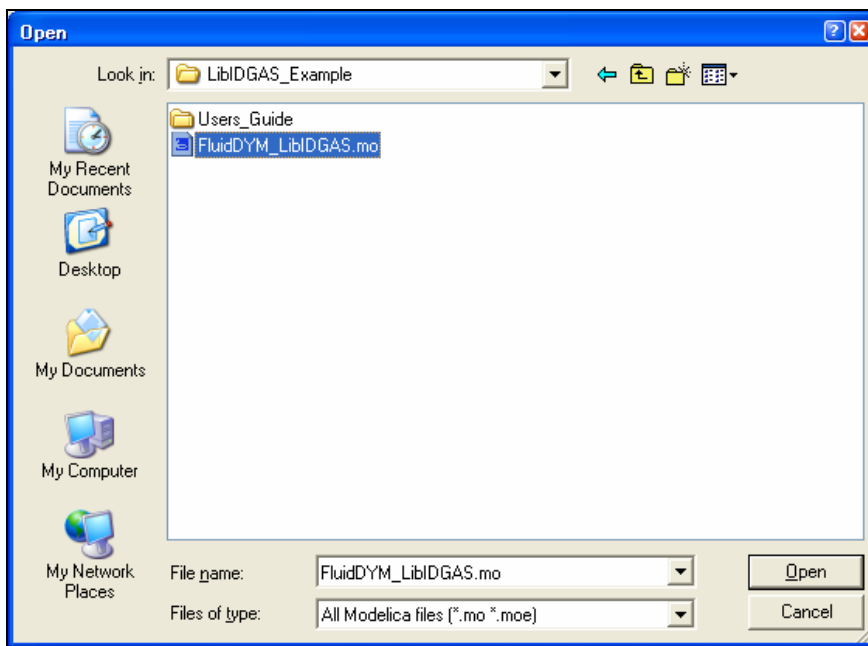


Figure 2.8: Selecting the "FluidDYM_LibIDGAS.mo" file

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

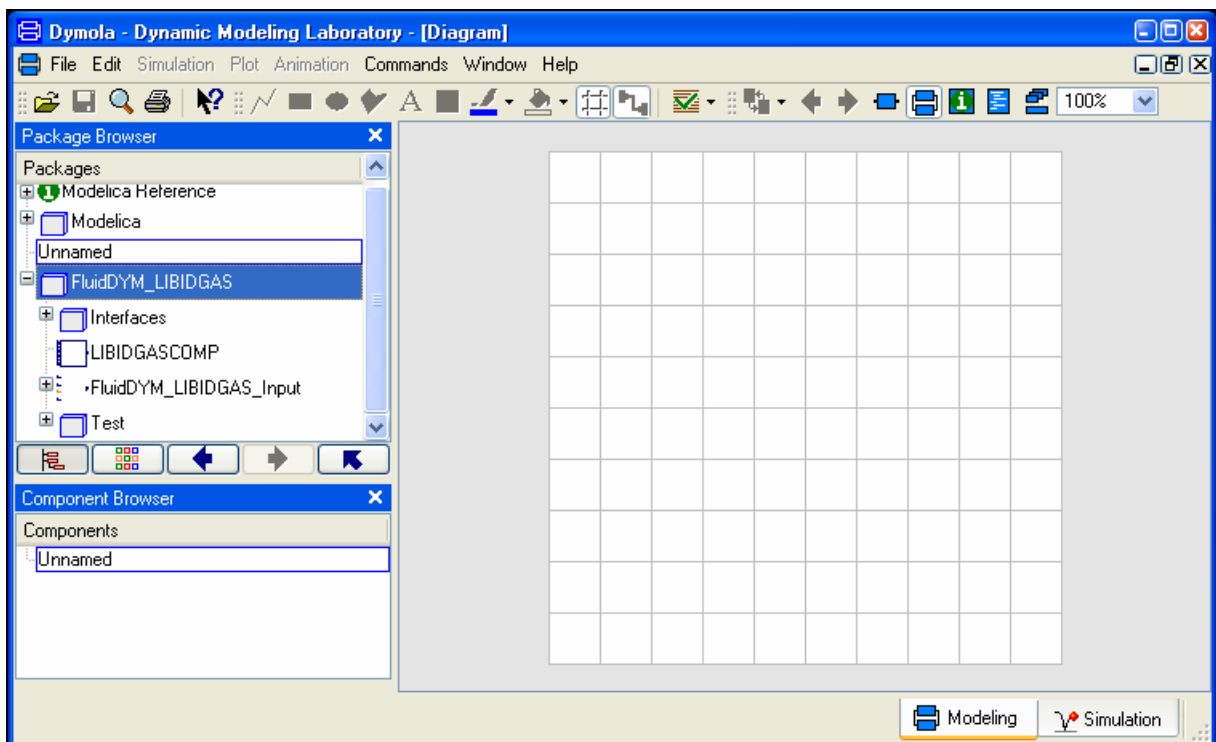


Figure 2.9: Dymola window after loading the "LibIDGAS" library

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

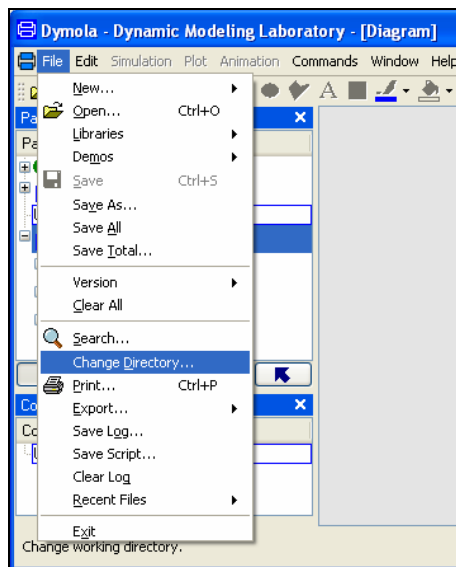


Figure 2.10: Selecting the menu entry "Change Directory..."

- Search and click on the directory
 - "C:\Program Files\FluidDYM\LibIDGAS_Example" (for English version of Windows)
 - "C:\Programme\FluidDYM\LibIDGAS_Example" (for German version of Windows)
 in the menu that appears (see Figure 2.11).

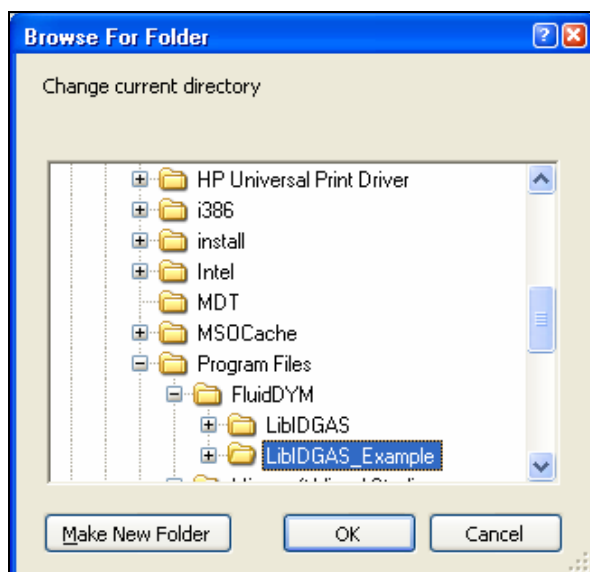


Figure 2.11: Selecting the "LibIDGAS_Example" directory

- 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_pt_id" as follows for calculating $h = f(p, t, \xi_1 \dots \xi_{10})$.

- Click on the Dymola-Block "Test," which can be found in the FluidDYM_LibIDGAS package in the "Package Browser" on the left hand side of the Dymola window. Here choose Example 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:

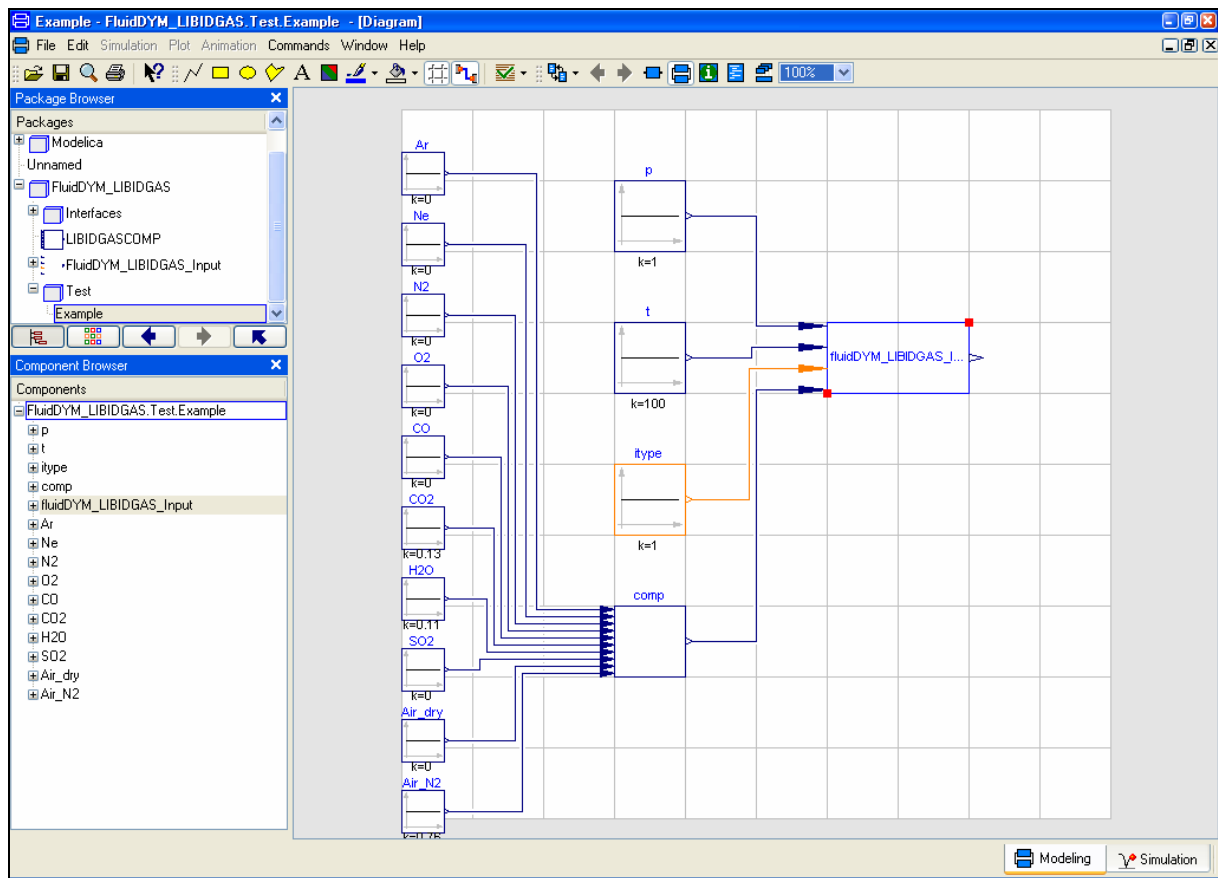


Figure 2.12: Dymola in Diagram Mode

- Now double-click on the "fluidDYM_LibIDGAS_Input" block on the right hand side of the Dymola window.
- Search and click the "h_pt_id" function next to "Function Number" in the menu that appears (see Figure 2.13).

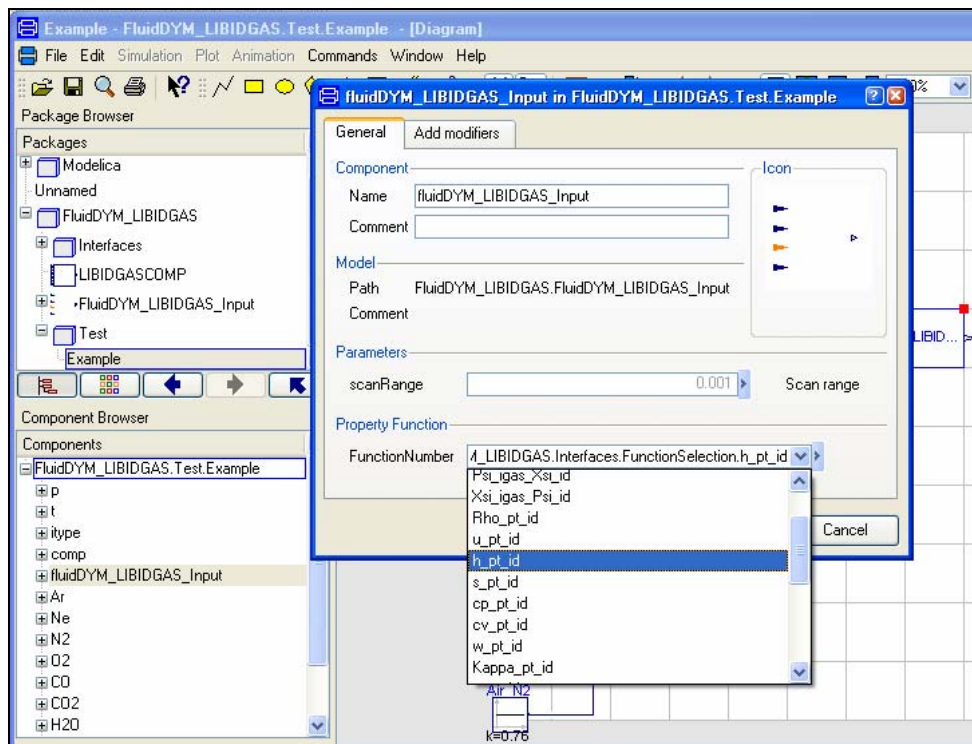


Figure 2.13: Choosing the function "h_pt_id"

- 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.

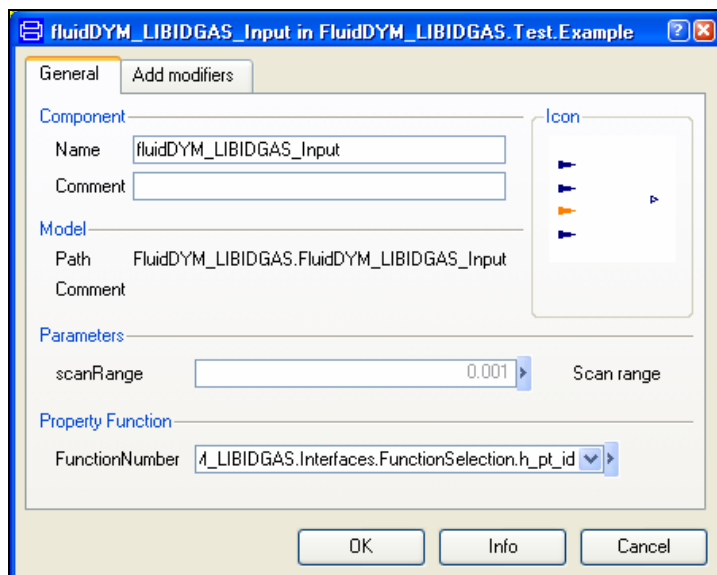


Figure 2.14: Setting the scan range

- Now we will configure the input parameters x1 to x4, whereas x1 represents the pressure p , x2 represents the temperature t , x3 represents $itype$, and x4 represents $comp$. When calculating a function with only one or two input parameters, the other input parameter(s) will not be defined.
- First, double click on the "p" block which represents the first input parameter, here the pressure p in bar.

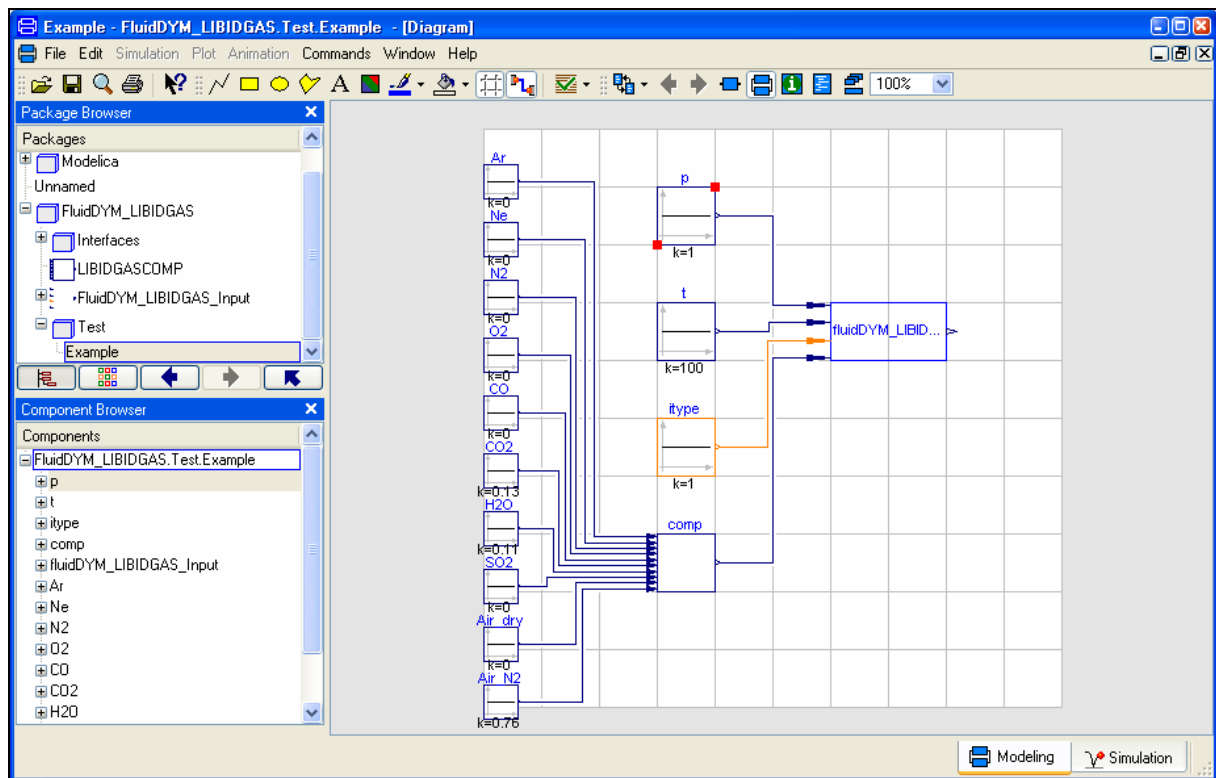


Figure 2.15: "p" block in Dymola

- Enter the value 1 on the line next to "k" in the dialog window which appears
(Range of validity of LibIDGAS: $p = 0.01 \text{ mbar} \dots 50 \text{ bar}$)
- Then click the "OK" button (see Figure 2.16).

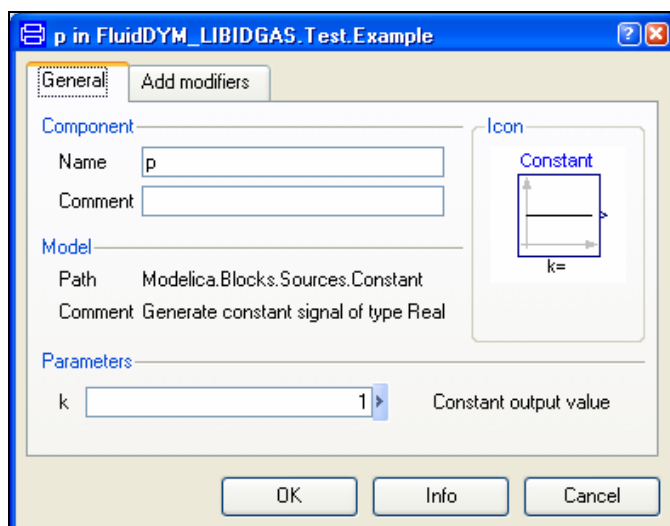


Figure 2.16: Entering the value for the pressure p

- Now, double click on the "t" block which represents the second input parameter, here the temperature t in $^{\circ}\text{C}$.
- Enter the value 1 on the line next to "k" in the dialog window which appears
(Range of validity of LibIDGAS: $t = -73.15 \text{ }^{\circ}\text{C} \dots 3026.85 \text{ }^{\circ}\text{C}$)
- Then click the "OK" button (see Figure 2.17).

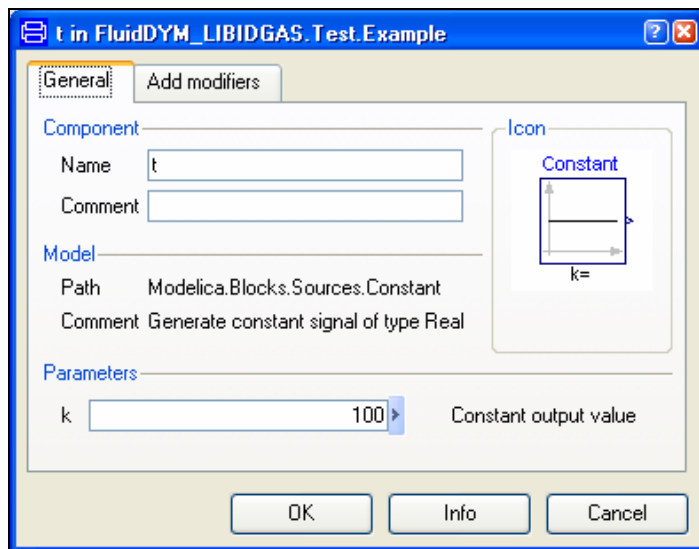


Figure 2.17: Entering the value for the temperature t

- Now, double click on the "itype" block which represents the third input parameter, here the identification of mole fraction or mass fraction:
 type = 1 for mass fraction as input value
 type = 0 for mole fraction as input value
- Enter the value 100 on the line next to "k" in the dialog window which appears
- Then click the "OK" button (see Figure 2.18)

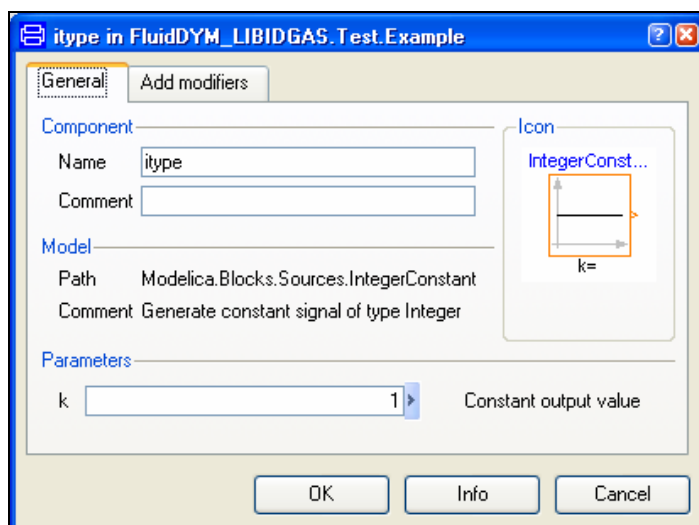


Figure 2.18: Entering the value for type

- Now, double click on the appropriate blocks on the left to enter the mass fractions $\xi_1 \dots \xi_{10}$ of the mixture gases" as described above.
- | | | | |
|---------|---------------------|----------------|----------------------------|
| ξ_1 | for argon | Ar | ⇒ e. g.: Enter the value 0 |
| ξ_2 | for neon | Ne | ⇒ e. g.: Enter the value 0 |
| ξ_3 | for nitrogen | N ₂ | ⇒ e. g.: Enter the value 0 |
| ξ_4 | for oxygen | O ₂ | ⇒ e. g.: Enter the value 0 |
| ξ_5 | for carbon monoxide | CO | ⇒ e. g.: Enter the value 0 |

- ξ_6 for carbon dioxide $\text{CO}_2 \Rightarrow$ e. g.: Enter the value 0.13
 ξ_7 for steam $\text{H}_2\text{O} \Rightarrow$ e. g.: Enter the value 0.11
 ξ_8 for sulfur dioxide $\text{SO}_2 \Rightarrow$ e. g.: Enter the value 0
 ξ_9 for air nitrogen (dry) $\Rightarrow$ e. g.: Enter the value 0
 ξ_{10} for air nitrogen $\Rightarrow$ e. g.: Enter the value 0.76

All parameters have now been defined.

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

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

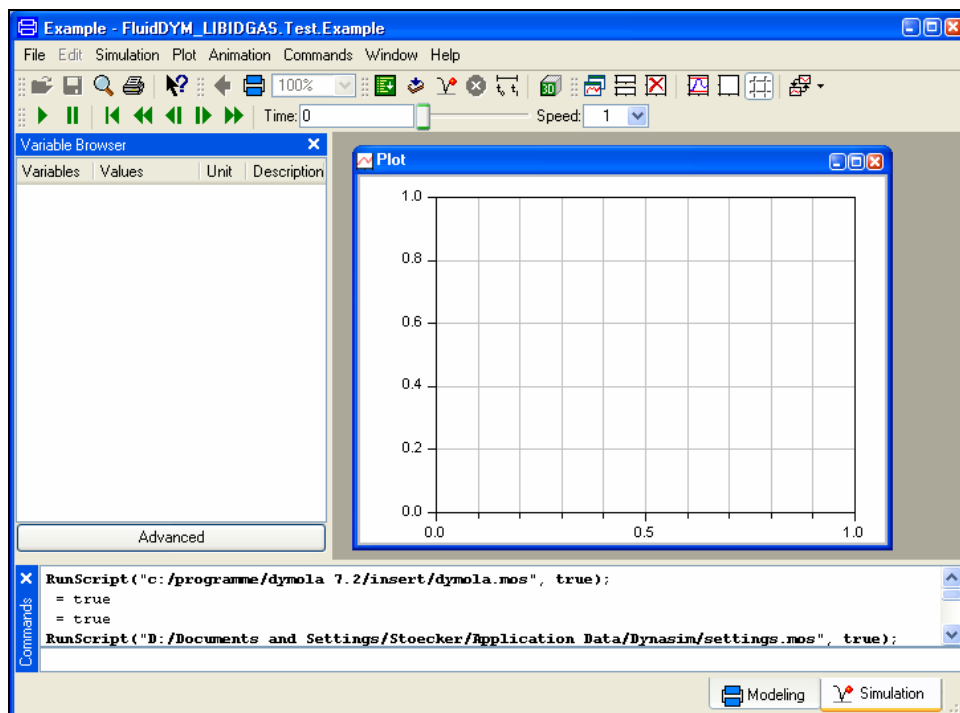


Figure 2.19: "Simulation Mode" window

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

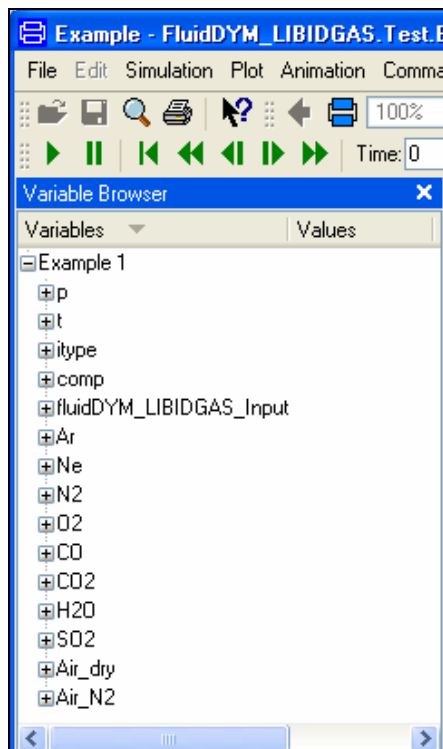


Figure 2.20: "Variable Browser" with new entries

- By clicking on the "New Plot Window" button , a new diagram window will be opened.
- Click on "fluidDYM_LibIDGAS_Input" within the "Variable Browser"; then you will see the input and output parameters "scanRange", "FunctionNumber", "z", "x1", "x2", "x3", x4[1] ... x4[10] (see Figure 2.21).

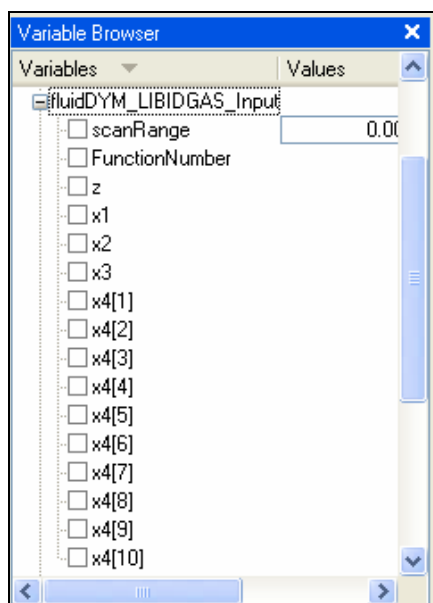


Figure 2.21: Parameters of "fluidDYM_LibIDGAS_Input"

- 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).

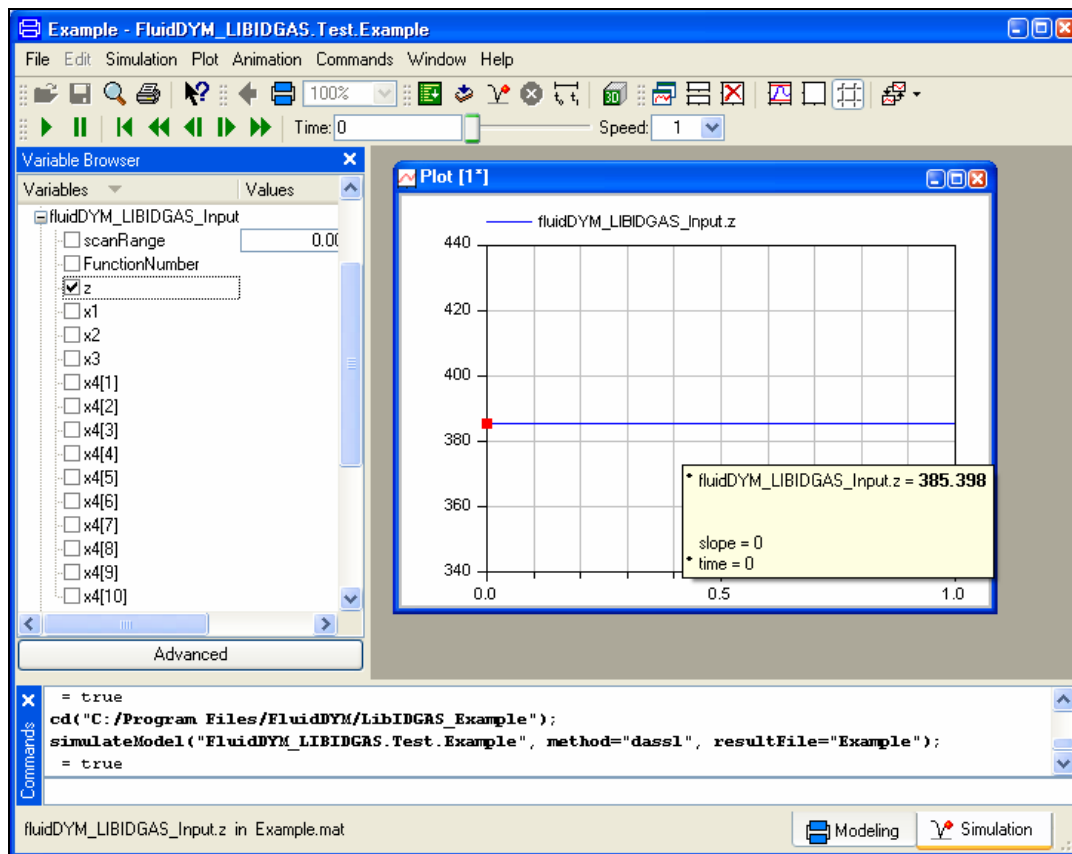


Figure 2.22: "DiagramWindow" showing the result

The result for h appears in the "DiagramWindow"

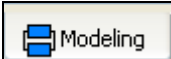
⇒ The result in our sample calculation here is: " $h = 385.398$ ".

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 , type, and comp 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_LibIDGAS" Block at the left and then click on "Users_Guide" (see Figure 2.23).

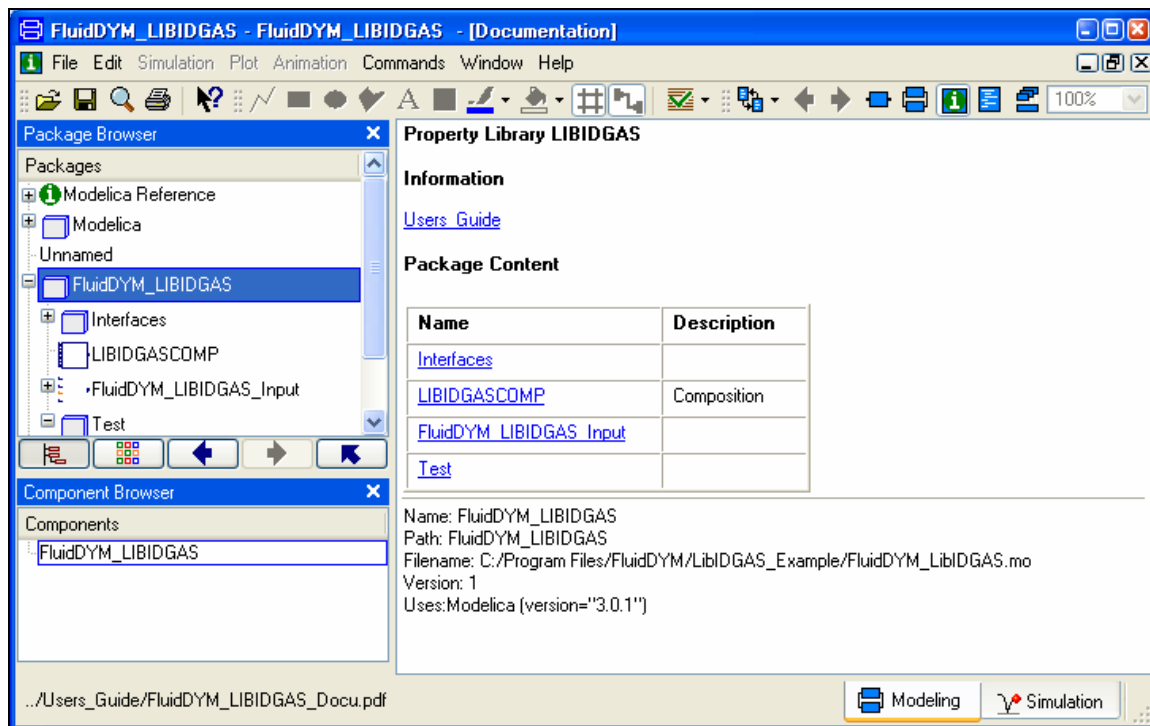


Figure 2.23: Selecting the "Users_Guide"

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

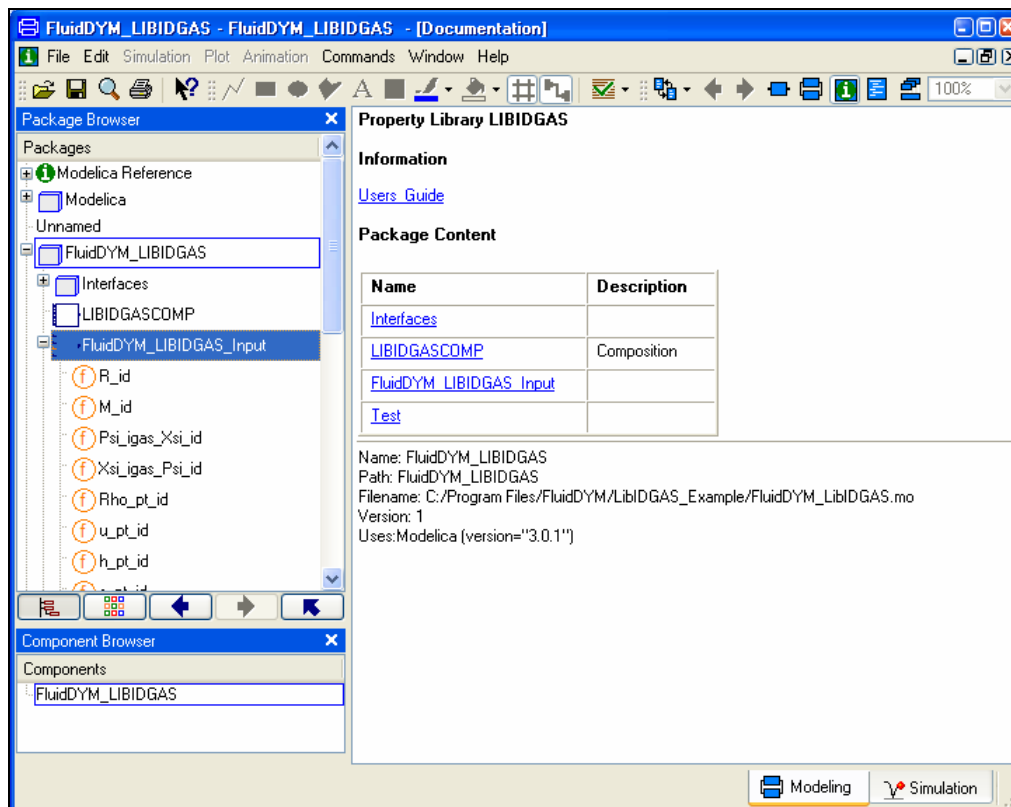


Figure 2.24: Selected "FluidDYM_LibIDGAS_Input" Block

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

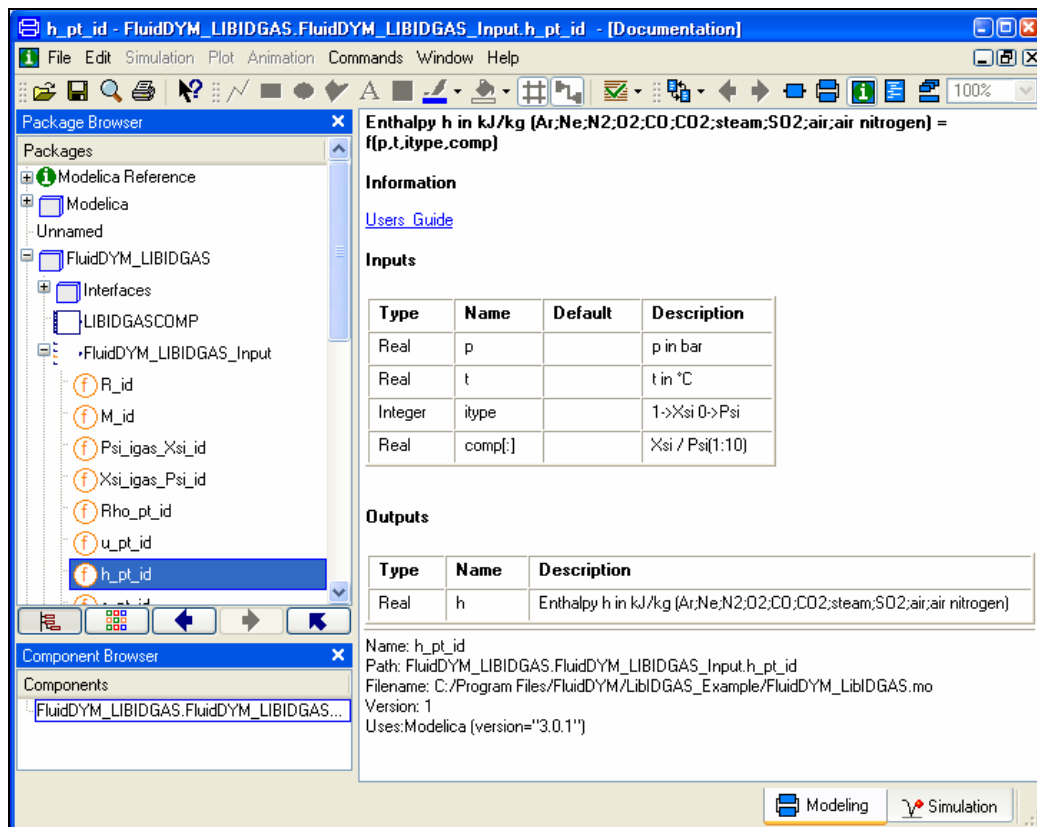


Figure 2.25: Marking the "h_pt_id" function and selecting the "Users_Guide"

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

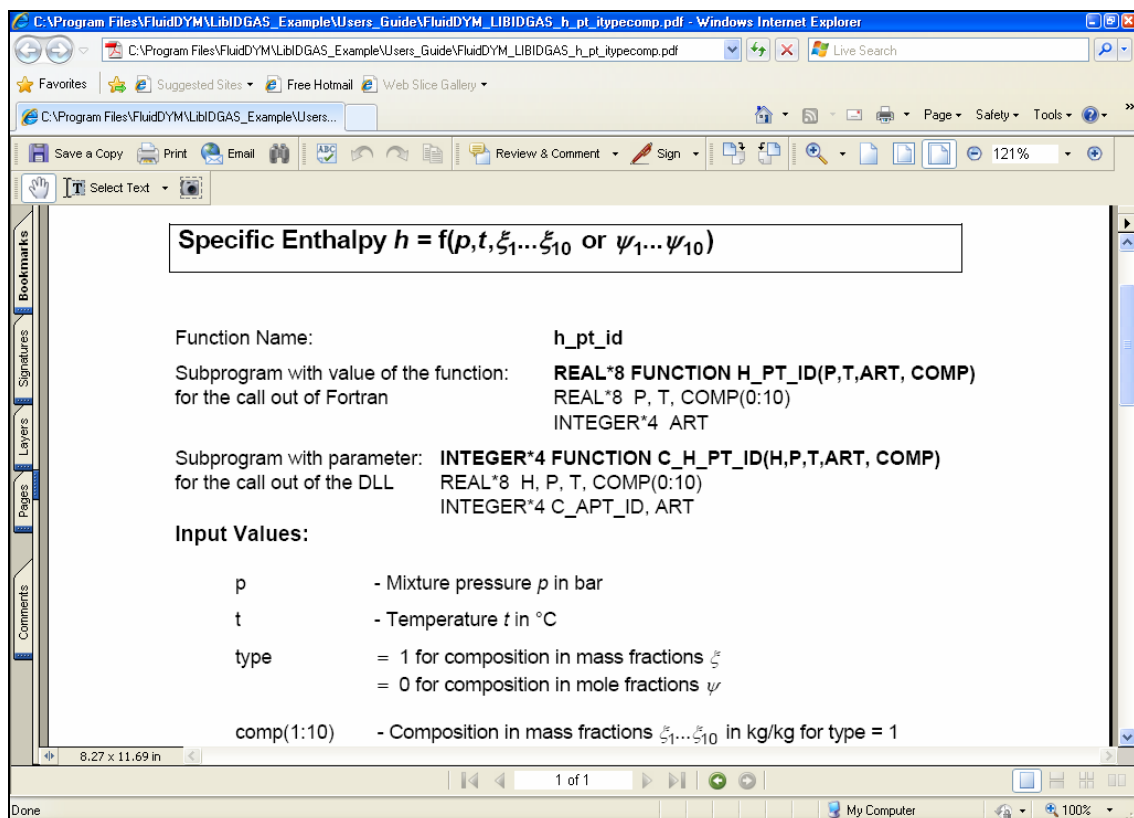


Figure 2.26: Help page of the function "h_pt_id" in the web browser

2.4 Removing FluidDYM

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

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

3. Program Documentation

Thermal Diffusivity $a = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **a_pt_id**

Subprogram with value of the function:
for the call out of Fortran **REAL*8 FUNCTION A_PT_ID(P,T,ART, ZU)**
REAL*8 P, T, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter:
for the call out of the DLL **INTEGER*4 FUNCTION C_A_PT_ID(A,P,T,ART, ZU)**
REAL*8 A, P, T, ZU(0:10)
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar

t - Temperature t in °C

type = 1 for composition in mass fractions ξ
= 0 for composition in mole fractions ψ

comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

a_pt_id, a - Thermal diffusivity a in m^2/s

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar

Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

$$\text{Thermal diffusivity } a = \frac{\lambda}{\rho \cdot c_p}$$

Results for wrong input values:

a_pt_id, a = -1

References:

Unsaturated and saturated humid air:

λ corresponding to *Brandt* [15]

c_p corresponding to VDI 4670 [18]

ρ for ideal gas mixture

Specific Isobaric Heat Capacity $c_p = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **cp_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION CP_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_CP_PT_ID(CP,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 CP, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
t - Temperature t in °C
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

cp_pt_id, cp - Specific isobaric heat capacity in kJ/(kg K)

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

Model of ideal mixture in consideration of dissociation above 500°C and $\psi_{\text{H}_2\text{O}} \geq 0.1$

Results for wrong input values:

cp_pt_id, cp = -1

References:

c_p corresponding to VDI 4670 [18]

Specific Isochoric Heat Capacity $c_v = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **cv_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION CV_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_CV_PT_ID(CV,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 CV, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

- p - Mixture pressure p in bar
- t - Temperature t in °C
- type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
- comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

cv_pt_id, cv - Specific isobaric heat capacity in kJ/(kg K)

Range of Validity:

- Mixture pressure p : from 0.01 mbar to 50 bar
- Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

$$c_v = c_p - R$$

Results for wrong input values:

cv_pt_id, cv = -1

References:

- Unsaturated and saturated humid air:
- c_p corresponding to VDI 4670 [18]

Dynamic Viscosity $\eta = f(t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **Eta_t_id**

Subprogram with value of the function:
for the call out of Fortran **REAL*8 FUNCTION ETA_T_ID(P,T,ART, COMP)**
REAL*8 T, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_ETA_T_ID(ETA,T,ART, COMP)**
for the call out of the DLL REAL*8 ETA, T, COMP(0:10)
INTEGER*4 C_APT_ID, ART

Input Values:

t - Temperature t in °C

type = 1 for composition in mass fractions ξ
= 0 for composition in mole fractions ψ

comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

Eta_t_id, eta - Dynamic viscosity in Pa s

Range of Validity:

Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

Calculation from *Brandt* - Model of ideal mixture

Results for wrong input values:

Eta_t_id, Eta = -1

References:

Unsaturated and saturated humid air:
 η corresponding to *Brandt* [15]

Specific Enthalpy $h = f(p, t, \xi_1 \dots \xi_{10}$ or $\psi_1 \dots \psi_{10}$)

Function Name: **h_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION H_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_H_PT_ID(H,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 H, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
t - Temperature t in °C
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

h_pt_id, h - Specific enthalpy in kJ/kg

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

Model of ideal mixture in consideration of dissociation above 500 °C and $\psi_{\text{H}_2\text{O}} \geq 0.1$

Results for wrong input values:

h_pt_id, h = -1

References:

h corresponding to VDI 4670 [18]

Isentropic Exponent $\kappa = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **Kappa_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION KAPPA_PT_ID(P,T,ART, COMP)**

for the call out of Fortran

REAL*8 P, T, COMP(0:10)

INTEGER*4 ART

Subprogram with parameter:

INTEGER*4 FUNCTION

for the call out of the DLL

C_KAPPA_PT_ID(KAPPA,P,T,ART,COMP)

REAL*8 KAPPA, P, T, COMP(0:10)

INTEGER*4 C_APT_ID, ART

Input Values:

- | | |
|------------|--|
| p | - Mixture pressure p in bar |
| t | - Temperature t in °C |
| type | = 1 for composition in mass fractions ξ
= 0 for composition in mole fractions ψ |
| comp(1:10) | - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0 |

Result:

Kappa_pt_id, Kappa - Isentropic exponent

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar

Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

$$\text{Kappa } \kappa = \frac{c_p}{c_p - R}$$

Results for wrong input values:

Kappa_pt_id, Kappa = -1

References:

Unsaturated and saturated humid air:

c_p corresponding to VDI 4670 [18]

Thermal Conductivity $\lambda = f(t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **Lambda_t_id**

Subprogram with value of the function: **REAL*8 FUNCTION LAMBDA_T_ID(T,ART, COMP)**

for the call out of Fortran **REAL*8 T, COMP(0:10)**
 INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_LAMBDA_T_ID(LAMBDA,T,ART,ZU)**

for the call out of the DLL **REAL*8 LAMBDA, T, COMP(0:10)**
 INTEGER*4 C_APT_ID, ART

Input Values:

- | | |
|------------|--|
| t | - Temperature t in °C |
| type | = 1 for composition in mass fractions ξ
= 0 for composition in mole fractions ψ |
| comp(1:10) | - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0 |

Result:

Lambda_t_id, Lambda - Thermal conductivity in W/(m K)

Range of Validity:

Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

Calculation from *Brandt* - Model of ideal mixture

Results for wrong input values:

Lambda_t_id, Lambda = -1

References:

Unsaturated and saturated humid air:

λ corresponding to *Brandt* [15]

Molar Mass $M = f(\xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **M_id**

Subprogram with value of the function: **REAL*8 FUNCTION M_ID(ART, COMP)**
 for the call out of Fortran REAL*8 COMP(0:10)
 INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_M_ID(M, ART, COMP)**
 for the call out of the DLL REAL*8 M, COMP(0:10)
 INTEGER*4 C_APT_ID, ART

Input Values:

type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ

comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

M_id, M - Molar mass in kg/kmol

Comments:

Calculation from *Blanke*

Results for wrong input values:

M_id, M = -1

References:

M corresponding to *Blanke* [17]

Kinematic Viscosity $\nu = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **Ny_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION NY_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_NY_PT_ID(CV,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 NY, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
t - Temperature t in °C
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

Ny_pt_id, Nue - Kinematic viscosity in m²/s

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from – 73.15 °C to 3026.85 °C

Comments:

Kinematic viscosity

Results for wrong input values:

Ny_pt_id, Ny = -1

References:

Unsaturated and saturated humid air:

η corresponding to *Brandt* [15]

ρ for ideal gas mixture

Backward Function: Pressure $p = f(t, s, \xi_1 \dots \xi_{10}$ or $\psi_1 \dots \psi_{10}$)

Function Name: **p_ts_id**

Subprogram with value of the function: **REAL*8 FUNCTION P_TS_ID(T,S,ART, COMP)**
 for the call out of Fortran **REAL*8 T, S, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_P_TS_ID(P,T,S,ART, COMP)**
 for the call out of the DLL **REAL*8 P, T, S, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

t - Temperature t in °C
s - Specific Entropy in kJ/(kg K)
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

p_ts_id, p - Mixture pressure in bar

Range of Validity:

Temperature t : from – 73.15 °C to 3026.85 °C
 Entropy s : from – 2.3771 kJ/(kg K) to 9.7061 kJ/(kg K)

Comments:

- Model of ideal mixture in consideration of dissociation above 500 °C
- Iteration of p from $s = f(p, t, (1:10))$

Results for wrong input values:

p_ts_id, p = -1

References:

s corresponding to VDI 4670 [18]

Backward Function: Pressure $p = f(t, v, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **p_tv_id**

Subprogram with value of the function: **REAL*8 FUNCTION P_TV_ID(T,V,ART, COMP)**
 for the call out of Fortran **REAL*8 T, V, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_P_TV_ID(P,T,V,ART, COMP)**
 for the call out of the DLL **REAL*8 P, T, V, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

- v - Specific volume v in m^3/kg
- t - Temperature t in $^{\circ}\text{C}$
- type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
- comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

p_tv_id , v - Mixture pressure in bar

Range of Validity:

- Temperature t : from -73.15°C to 3026.85°C
- Specific volume v : from $5.1 \text{ m}^3/\text{kg}$ to $2.9 \cdot 10^9 \text{ m}^3/\text{kg}$

Comments:

$$p = \frac{R \cdot T}{v}$$

Results for wrong input values:

p_tv_id, p = -1

PRANDTL-Number $Pr = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **Pr_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION PR_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_PR_PT_ID(PR,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 PR, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

- p - Mixture pressure p in bar
- t - Temperature t in °C
- type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
- comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

Pr_pt_id, Pr - PRANDTL-Number

Range of Validity:

- Temperature t : from – 73.15 °C to 3026.85 °C
- Mixture pressure p : from 0.01 mbar to 50 bar

Comments:

PRANDTL-number

Results for wrong input values:

Pr_pt_id, Pr = -1

References:

- Unsaturated and saturated humid air:
- λ corresponding to *Brandt* [15]
- η corresponding to *Brandt* [15]
- c_p corresponding to VDI 4670 [18]

Mole Fraction $\psi_i = f(i, \xi_1 \dots \xi_{10})$

Function Name:

Psi_igas_Xsi_id

Subprogram with value of the function:
for the call out of Fortran

REAL*8 FUNCTION PSI_IGAS_ID(IGAS, COMP)
REAL*8 IGAS, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter:
for the call out of the DLL

INTEGER*4 FUNCTION C_PSI_IGAS_ID(PSI, IGAS, COMP)
REAL*8 PSI, IGAS, COMP(0:10)
INTEGER*4 C_APT_ID, ART

Input Values:

i - Gas number
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1

Result:

Psi_igas_Xsi_id, Psi - Mole fraction in kmol/kmol

Comments:

Calculation: $\psi_i = \frac{R_i}{\sum (\xi_i \cdot R_i)} \cdot \xi_i$

Results for wrong input values:

Psi_igas_Xsi_id, Psi = -1

Specific Gas Constant $R = f(\xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **R_id**

Subprogram with value of the function: **REAL*8 FUNCTION R_ID(ART, COMP)**
 for the call out of Fortran **REAL*8 COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_R_ID(R, ART, COMP)**
 for the call out of the DLL **REAL*8 R, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ

comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

R_id, R - Specific gas constant in kJ/(kg K)

Comments:

Calculation: $R = \sum_i (\xi_i \cdot R_i)$

$$R = \frac{1}{\sum_i \left(\frac{\psi_i}{R_i} \right)}$$

Results for wrong input values:

R_id, R = -1

Density $\rho = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **Rho_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION RHO_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_RHO_PT_ID(RHO,P,T,ART,COMP)**
 for the call out of the DLL **REAL*8 RHO, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
t - Temperature t in °C
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

Rho_pt_id, Rho - Density in kg/m³

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

Calculation: $\rho = \frac{p}{R \cdot T}$

Results for wrong input values:

Rho_pt_id, Rho = -1

Specific Entropy $s = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **s_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION S_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran REAL*8 P, T, COMP(0:10)
 INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_S_PT_ID(S,P,T,ART, COMP)**
 for the call out of the DLL REAL*8 S, P, T, COMP(0:10)
 INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
 t - Temperature t in °C
 type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
 comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

s_pt_id, s - Specific entropy in kJ/(kg K)

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from - 73.15 °C to 3026.85 °C

Comments:

Model of ideal mixture in consideration of dissociation above 500 °C and $\psi_{\text{H}_2\text{O}} \geq 0.1$

Results for wrong input values:

s_pt_id, s = -1

References:

s corresponding to VDI 4670 [18]

Backward Function: Temperature $t = f(p, h, \xi_1 \dots \xi_{10}$ or $\psi_1 \dots \psi_{10}$)

Function Name: **t_ph_id**

Subprogram with value of the function: **REAL*8 FUNCTION T_PH_ID(P,H,ART, COMP)**
 for the call out of Fortran **REAL*8 P, H, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_T_PH_ID(T,P,H,ART, COMP)**
 for the call out of the DLL **REAL*8 T, P, H, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
h - Enthalpy h in kJ/kg
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

t_ph_id, t - Temperature in °C

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Enthalpy h : from -135.6 kJ/kg to 4100 kJ/kg

Comments:

Iteration of t from $h = f(p, t, (1:10))$

Results for wrong input values:

t_ph_id, t = -1

References:

h corresponding to VDI 4670 [18]

Backward Function: Temperature $t = f(p, s, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **t_ps_id**

Subprogram with value of the function: **REAL*8 FUNCTION T_PS_ID(P,S,ART, COMP)**
 for the call out of Fortran **REAL*8 P, S, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_T_PS_ID(T,P,S,ART, COMP)**
 for the call out of the DLL **REAL*8 T, P, S, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
s - Entropy s in kJ/(kg K)
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

t_ps_id, t - Temperature in °C

Range of Validity:

Mixture pressure p : from 0.001 bar to 50 bar
 Enthalpy s : from -2.377 kJ/(kg K) to 9.706 kJ/(kg K)

Comments:

Iteration of t from $s = f(p, t, (1:10))$

Results for wrong input values:

t_ps_id, t = -1

References:

s corresponding to VDI 4670 [18]

Backward Function: Temperature $t = f(p, v, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **t_pv_id**

Subprogram with value of the function: **REAL*8 FUNCTION T_PV_ID(P,V,ART, COMP)**
 for the call out of Fortran **REAL*8 P, V, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_T_PV_ID(T,P,V,ART, COMP)**
 for the call out of the DLL **REAL*8 T, P, V, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
v - Specific volume v in m^3/kg
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

t_pv_id, t - Temperature in °C

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Specific volume v : from $5.1 \text{ m}^3/\text{kg}$ to $2.9 \cdot 10^9 \text{ m}^3/\text{kg}$

Comments:

Calculation: $T = \frac{p \cdot v}{R}$

Results for wrong input values:

t_pv_id, t = -1

Specific Internal Energy $u = f(p, t, \xi_1 \dots \xi_{10}$ or $\psi_1 \dots \psi_{10}$)

Function Name: **u_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION U_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_U_PT_ID(U,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 U, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
t - Temperature t in °C
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

u_pt_id, u - Specific internal energy in kJ/kg

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from -73.15 °C to 3026.85 °C

Comments:

Calculation: $u = h(p, t, (1:10)) - R \cdot T$

Results for wrong input values:

u_pt_id, u = -1

References:

h corresponding to VDI 4670 [18]

Specific Volume $v = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **v_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION V_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_V_PT_ID(V,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 V, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
t - Temperature t in °C
type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
comp(1:10) - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

v_pt_id, v - Specific volume in m³/kg

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from -73.15 °C to 3026.85 °C

Comments:

Calculation:
$$v = \frac{R_m \cdot T}{p}$$

Results for wrong input values:

v_pt_id, v = -1

Isentropic Speed of Sound $w = f(p, t, \xi_1 \dots \xi_{10} \text{ or } \psi_1 \dots \psi_{10})$

Function Name: **w_pt_id**

Subprogram with value of the function: **REAL*8 FUNCTION W_PT_ID(P,T,ART, COMP)**
 for the call out of Fortran **REAL*8 P, T, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_W_PT_ID(W,P,T,ART, COMP)**
 for the call out of the DLL **REAL*8 W, P, T, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

p - Mixture pressure p in bar
 t - Temperature t in °C
 type = 1 for composition in mass fractions ξ
 = 0 for composition in mole fractions ψ
 $\text{comp}(1:10)$ - Composition in mass fractions $\xi_1 \dots \xi_{10}$ in kg/kg for type = 1
 - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

w_pt_id, w - Isentropic speed of sound in m/s

Range of Validity:

Mixture pressure p : from 0.01 mbar to 50 bar
 Temperature t : from -73.15 °C to 3026.85 °C

Comments:

$$\text{Calculation: } w = \sqrt{\frac{R_m \cdot T \cdot c_p}{c_p - R_m}}$$

$$c_p = f(p, t, (1:10))$$

Results for wrong input values:

$w_pt_id, w = -1$

References:

c_p corresponding to VDI 4670 [18]

Mass Fraction $\xi_i = f(i, \psi_1 \dots \psi_{10})$

Function Name: **Xsi_igas_Psi_id**

Subprogram with value of the function: **REAL*8 FUNCTION XSI_IGAS_ID(IGAS, COMP)**
 for the call out of Fortran **REAL*8 IGAS, COMP(0:10)**
INTEGER*4 ART

Subprogram with parameter: **INTEGER*4 FUNCTION C_XSI_IGAS_ID(XSI, IGAS, COMP)**
 for the call out of the DLL **REAL*8 XSI, IGAS, COMP(0:10)**
INTEGER*4 C_APT_ID, ART

Input Values:

i - Gas number
 comp(1:10) - Composition in mole fractions $\psi_1 \dots \psi_{10}$ in kmol/kmol for type = 0

Result:

Xsi_igas_Psi_id, Xsi - Mass fraction in kg/kg

Comments:

Calculation: $\xi_i = \frac{M_i}{\sum (\psi_i \cdot M_i)} \cdot \psi_i$

Results for wrong input values:

Xsi_igas_Psi_id, Xsi = -1



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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

- Model: Ideal mixture of the real fluids:
- CO₂ - Span and Wagner O₂ - Schmidt and Wagner
H₂O - IAPWS-95 Ar - Tegeler et al.
N₂ - Span et al.
- and of the ideal gases:
- SO₂, CO, Ne (Scientific Formulation of Bückner et al.)
- Consideration of:
- Dissociation from VDI 4670 and Poynting effect

Humid Air

Library LibHuAir

- Model: Ideal mixture of the real fluids:
- Dry Air from Lemmon et al.
 - Steam, water and ice from IAPWS-IF97 and IAPWS-06
- Consideration of:
- Condensation and freezing of steam
 - Dissociation from the VDI 4670
 - Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

Ice from IAPWS-06, Melting and sublimation pressures from IAPWS-08, Water from IAPWS-IF97, Steam from IAPWS-95 and -IF97

Ideal Gas Mixtures

Library LibIdGasMix

- Model: Ideal mixture of the ideal gases:
- | | | | |
|-----------------|------------------|-----------------|------------|
| Ar | NO | He | Propylene |
| Ne | H ₂ O | F ₂ | Propane |
| N ₂ | SO ₂ | NH ₃ | Iso-Butane |
| O ₂ | H ₂ | Methane | n-Butane |
| CO | H ₂ S | Ethane | Benzene |
| CO ₂ | OH | Ethylene | Methanol |
| Air | | | |

- Consideration of:
- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

- Consideration of:
- Dissociation from the VDI Guideline 4670

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bückner et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bückner et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term (also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

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

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

Tetradecamethylhexasiloxane $C_{14}H_{42}O_6Si_6$ **Library LibMD4M**

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide CO **Library LibCO**

Carbonyl sulfide COS **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monoxide 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@hszg.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

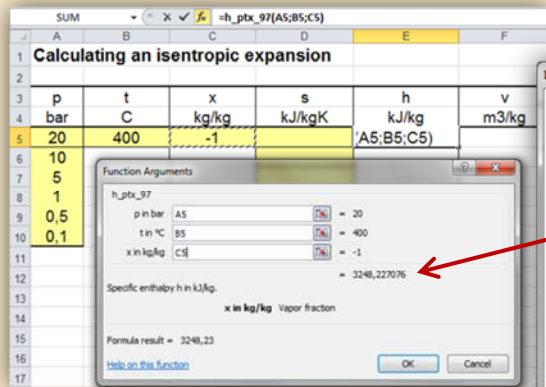
- Partial derivatives can be calculated.

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

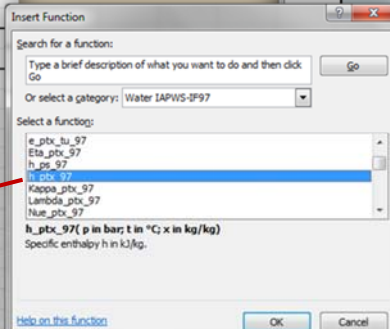


Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

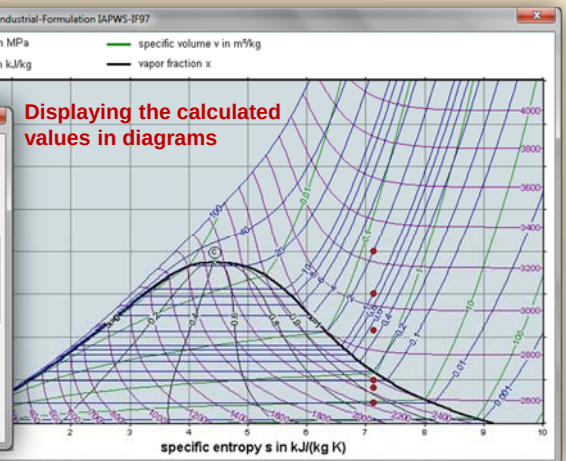
Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function



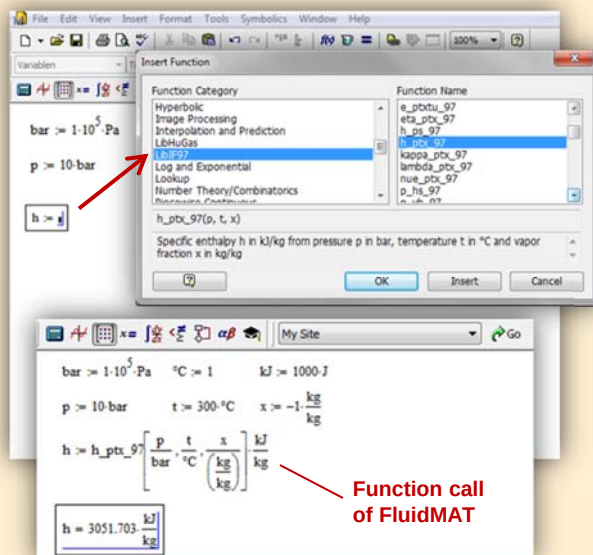
Displaying the calculated values in diagrams



Menu for the input of given property values

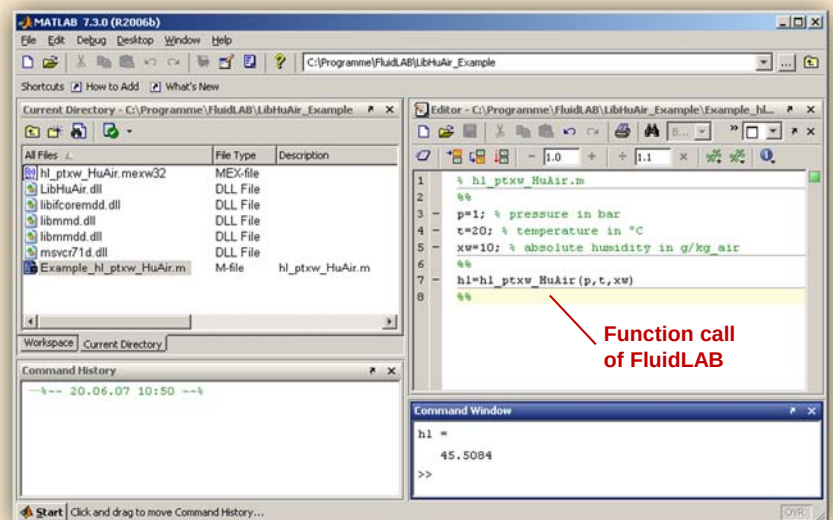
Add-In FluidMAT for Mathcad[®]

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



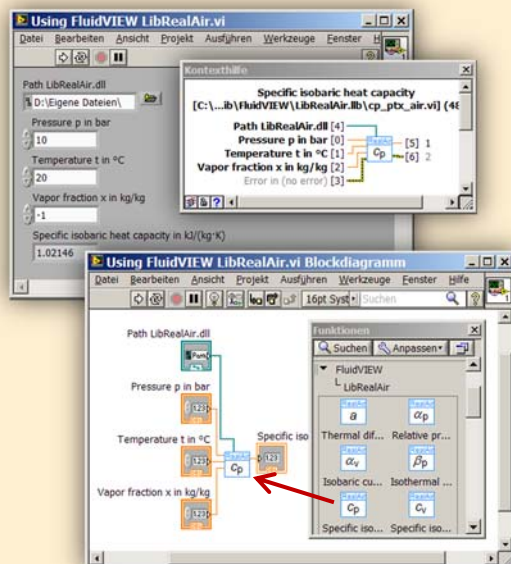
Add-In FluidLAB for MATLAB[®]

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



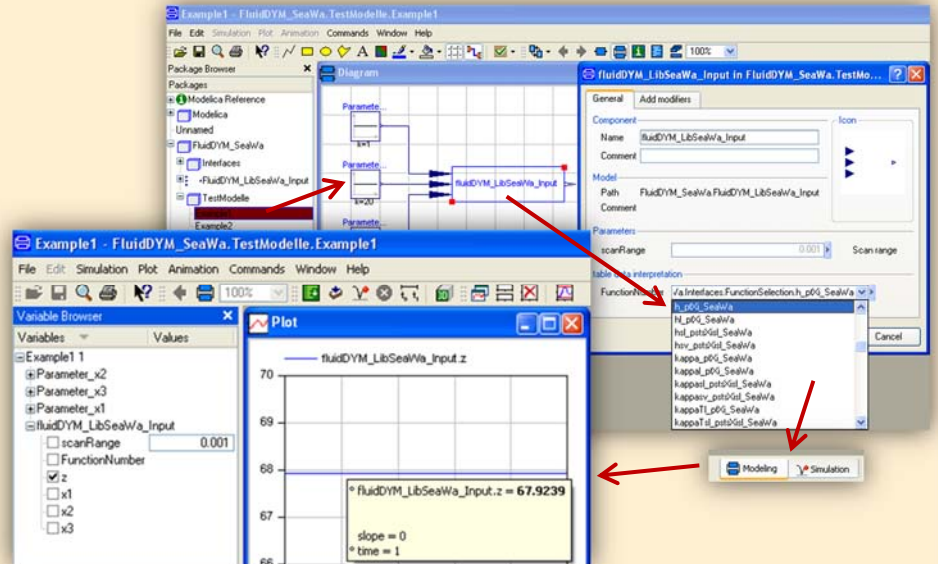
Add-On FluidVIEW for LabVIEW[®]

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

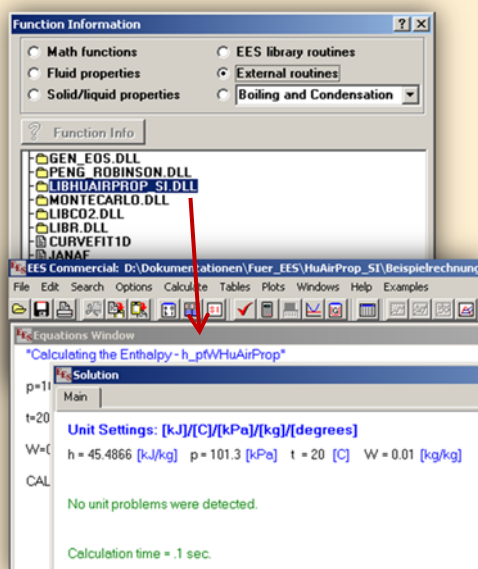


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

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

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

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

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = 3097.38 kJ/kg

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

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

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Faculty of Mechanical Engineering
Department of Technical Thermodynamics
Prof. Hans-Joachim Kretzschmar
Dr. Ines Stoecker
Programmer: Joachim Posselt

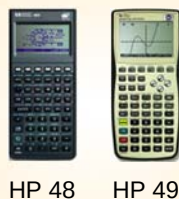
Tel.: +49-3583-61-1846 or -1881
Fax: +49-3583-61-1845
E-mail: info@thermodynamics-zittau.de
www.thermodynamics-zittau.de
www.thermodynamic-property-libraries.com
www.international-steam-tables.com
www.thermodynamic-formelsammlung.de

Property Software for Pocket Calculators

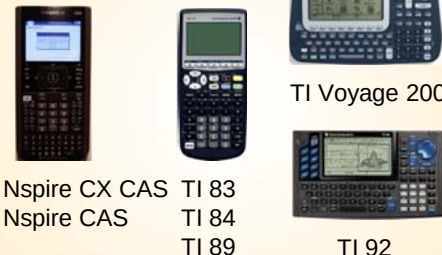
FluidCasio



FluidHP



FluidTI



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
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- Isobaric heat capacity c_p
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- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

5. References

- [1] Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam IAPWS-IF97.
Available at the IAPWS website <http://www.iapws.org>
- [2] Wagner, W.; Kretzschmar, H.-J.:
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Springer-Verlag, Berlin (2008)
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FZR Forschungszentrum, Rossendorf/Dresden	10/2003
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VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
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