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

FluidPRIME with LibIDGAS for Mathcad Prime®

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LibIDGAS

FluidPRIME

for Mathcad Prime®

Contents

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0. Package Contents

Zip file "CD_FluidPRIME_LibIDGAS.zip" includes the following files:

FluidPRIME_LibIDGAS_Docu.pdf	- User's Guide
Functions_LibIDGAS.mcdx	- Mathcad Prime® worksheet with all functions
LibIDGAS.msi	- MSI installer
setup.exe	- Setup installer
LibIDGAS.dll	- DLL with functions of the LibIDGAS library

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_2O
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 above 1000 °C and mole fractions of oxygen of more than 1 % ($\psi_{O_2} \geq 0.01$) the dissociation based on the VDI 4670 for the gases nitrogen, oxygen, carbon dioxide, steam, and sulfur dioxide are considered. For programming reasons, the calculation of the correction for the dissociation is already carried out from 500 °C.

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,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{10})	cp_pt_id	cp_pt_id(p,t,type,zu(1:10))	Specific isobaric heat capacity	kJ/(kg · K)	[18]	3/2
c_v = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{10})	cv_pt_id	cv_pt_id(p,t,type,zu(1:10))	Specific isochoric heat capacity	kJ/(kg · K)	[18]	3/3
η = f(t,ξ_1...ξ_{10} or ψ_1...ψ_{10})	Eta_t_id	Eta_t_id(t,type,zu(1:10))	Dynamic viscosity	Pa·s = kg/(m·s)	[15], [18]	3/4
h = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{10})	h_pt_id	h_pt_id(p,t,type,zu(1:10))	Specific enthalpy	kJ/kg	[18]	3/5
κ = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{10})	Kappa_pt_id	Kappa_pt_id(p,t,type,zu(1:10))	Isentropic exponent		[18]	3/6
λ = f(t,ξ_1...ξ_{10} or ψ_1...ψ_{10})	Lambda_t_id	Lambda_t_id(t,type,zu(1:10))	Thermal conductivity	W/(m · K)	[15]	3/7
M = f(ξ_1...ξ_{10} or ψ_1...ψ_{10})	M_id	M_id(type,zu(1:10))	Molar mass of the mixture	kg/kmol	[17]	3/8
ν = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{10})	Pr_pt_id	Pr_pt_id(p,t,type,zu(1:10))	*Prandtl*-number		[15], [16]	3/12
ψ_i = f(i,ξ_1...ξ_{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(ξ_1...ξ_{10} or ψ_1...ψ_{10})	R_id	R_id(type,zu(1:10))	Specific gas constant	kJ/(kg · K)	[17]	3/14
ρ = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{10})	u_pt_id	u_pt_id(p,t,type,zu(1:10))	Specific internal energy	kJ/kg		3/20
v = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{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,ξ_1...ξ_{10} or ψ_1...ψ_{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
ξ_i = f(i,ψ_1...ψ_{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
ξ_1 ... ξ_{10}	Mass fractions of the components	kg/kg
ψ_1... ψ_{10}	Mole fractions, volume fractions of the components	kmol/kmol
type	Input: type = 1 for mass fractions ξ_1, ... ξ_{10} type = 0 for mole fractions ψ_1, ... ψ_{10}	
comp(1:10) for type =1	Mass fractions ξ_1, ... ξ_{10}	kg/kg
comp(1:10) for type =0	Mole fractions ψ_1, ... ψ_{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_2O
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 *Brandt* [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 FluidPRIME in Mathcad Prime®

FluidPRIME has been developed to calculate thermodynamic properties in Mathcad Prime® more conveniently. Within Mathcad Prime, it enables the direct call of functions relating to humid air from the LibIdGas property library.

2.1 Installing FluidPRIME

In this section, the installation of FluidPRIME LibIdGas is described.
After you have downloaded and extracted the zip-file "CD_FluidPRIME_LibIdGas.zip", you will see the folder

CD_FluidPRIME_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 and a folders:

FluidPRIME_LibIdGas_Docu.pdf
Functions_LibIdGas.mcdx
LibIdGas.msi
setup.exe
LibIdGas.dll

In order to run the installation of FluidPRIME double-click the file

setup.exe.

Note: If you get an error message during the installation, please try the LibIdGas.msi instead of the setup.exe for the installation. The steps trough the install assistent are similiary on both the .exe and the .msi file.

After opening the installer-file you get the start window of the setup wizard (Figure 1.1). Please confirm with "Next".

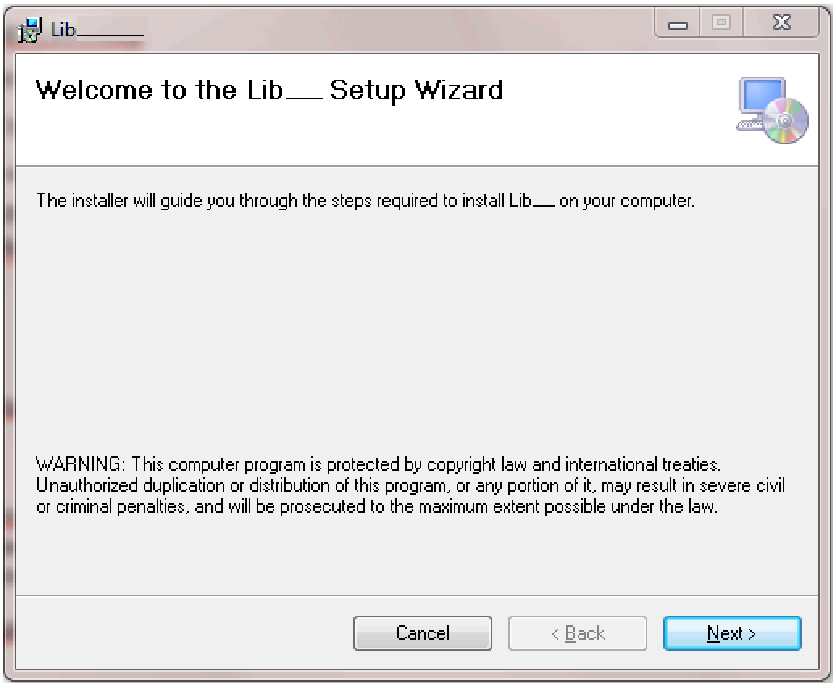


Figure 2.1: Setup Wizard

In Figure 2.2 you can see a note window that will inform you additionally to the next steps.

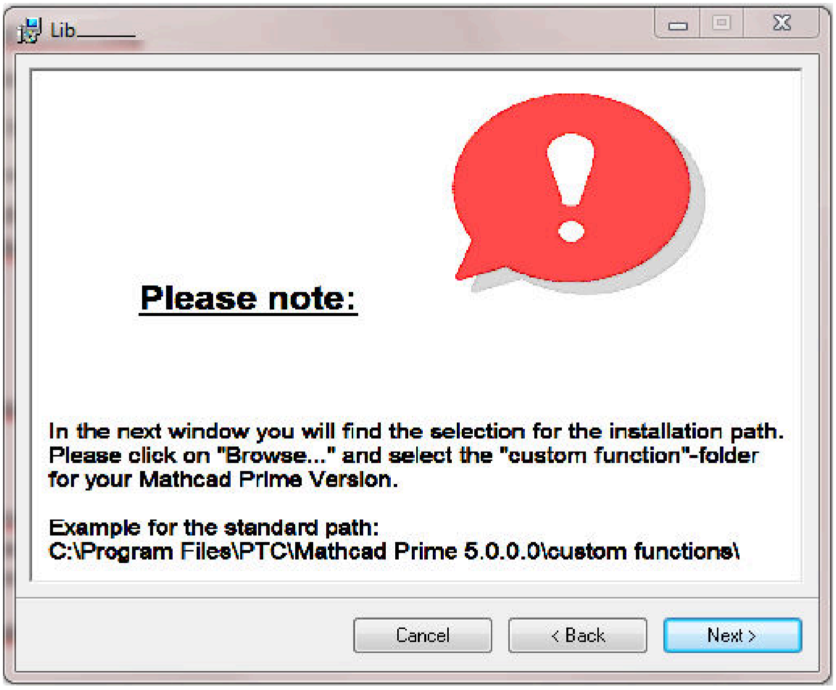


Figure 2.2: Note Window

Click on the "Next" button to get the "Select Installation Folder"-window (Figure 2.3).

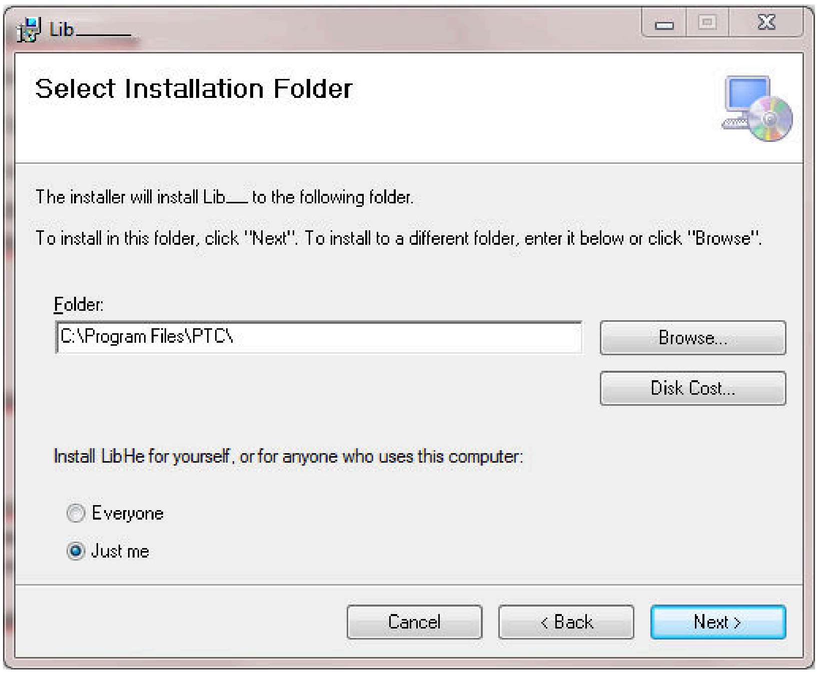


Figure 2.3: Select Installation Folder

Please click on "Browse…" to get another window where you can select the installation path.

You will get the standard path:

C:\Program Files\PTC\

Now select your Mathcad Prime® version folder. For example

C:\Program Files\PTC\Mathcad Prime 5.0.0.0 (Version 5.0.0.0).

On the next step you have to choose the "Custom Functions" folder, so that your final installation path looks like

C:\Program Files\PTC\Mathcad Prime 5.0.0.0\Custom Functions\

that you can also see in Figure 2.4.

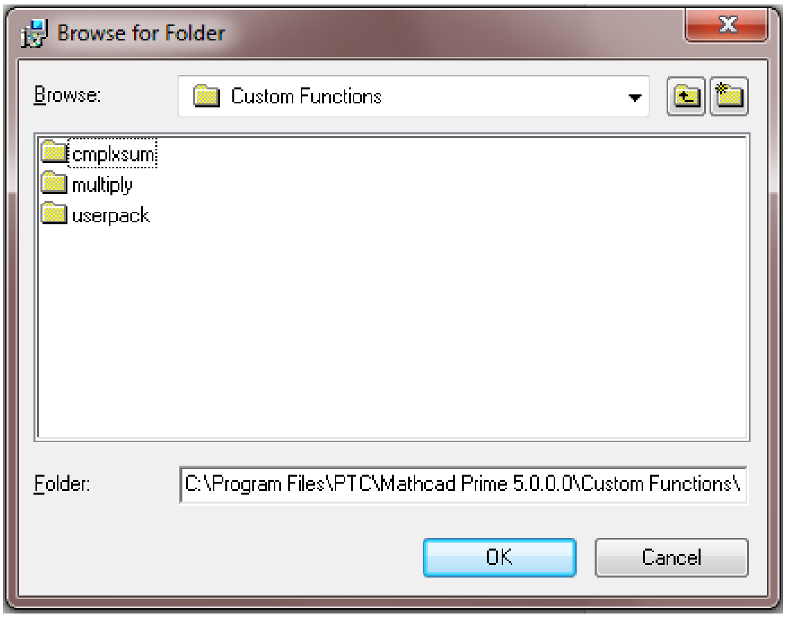


Figure 2.4: "Browse for Folder"-window with the full installation path

Please confirm with "OK" and continue in the further window (Figure 2.5) with "Next".

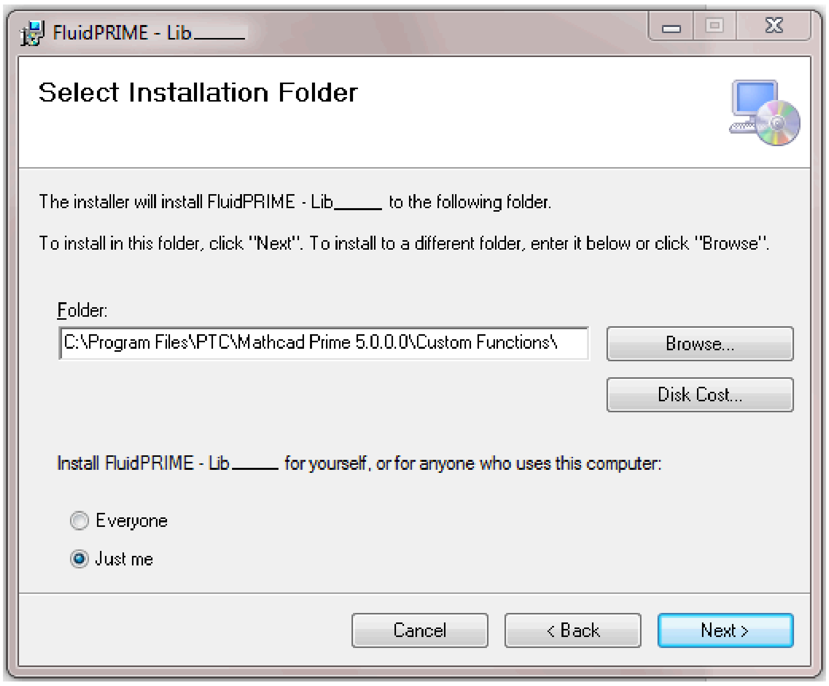


Figure 2.5: "Select Installation Folder"-window

To start the installation you have to click again on "Next".

After a few moments, you gets a message that the installation was successful and you can exit the setup with "Close".

The installation of FluidPRIME with the library LibIdGas is finished.

Finally, please copy or overwrite the LibIdGas.dll-file in the installation folder that is described before, with the file in the zip-file.

During the installation process the following files will have been copied into the destination folder chosen, the standard being

"C:\Program Files\PTC\Mathcad Prime 5.0.0.0\Custom Functions\":

LC.dll	LibIdGas.dll	PRIME_LibIdGas.dll
libifcoremd.dll	libiomp5.dll	libmmd.dll.

Note:

The shown default installation path for Mathcad Prime® may be different depending on the installation on your machine. In addition, the Mathcad Prime® version can be another than 5.0.0.0 that is used in this manual.

The underscore after "Lib" in the figures before, is representative of the library name of the library to be installed.

2.2 Licensing the LibIdGas Property Library

Within the installation that was shown in chapter 2.1 the licensing key will be registered on your computer automatically.

2.3 Example: Calculation the Enthalpy *h* = f(*p*, *t*, ξ_1 ... ξ_{10}) of the Gas Mixture

We will now calculate, step by step, the specific enthalpy *h* of a combustion gas as a function of pressure p = 1 bar, temperature t = 100 °C, and a mixture composed of the following mass fractions using FluidPRIME:

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

According to the "Mixture gases" table in Chapter 1.2, carbon dioxide represents in the LibIDGAS program library the gas no. 6, steam the gas no. 7 and air nitrogen the gas no. 10. Thus the mass fractions are

$\xi_6 = 13\,\%$, $\xi_7 = 11\,\%$, $\xi_{10} = 76\,\%$.

- Start Mathcad Prime.
- Type "p:" and enter the value for the pressure *p* in bar.
  (Range of validity: p = 0.01 bar ... 50 bar)
  e. g.: Enter "p:1 bar" for the first operand
- Type "t:" and enter the value for the temperature *t* in °C.
  (Range of validity: *t* = - 73.15 °C ... 3,026.85 °C)
  e. g.: Enter "t:100 °C" for the second operand
- Enter the code "type" to identify if the composition of the mixture is entered in mass fractions or mole fractions, i. e. volume fractions

  type = 1 for input of composition in mass fractions ξ_1, ... ξ_{10}

  type = 0 for input of composition in mass fractions ψ_1, ... ψ_{10}

  e. g.: Enter the value 1 for the third operand
- Situate the cursor on the fourth operand and type "zu:".
  Insert a matrix with ten rows and one column by clicking on the "Matrix/Tables"-toolbar.
  Then click the "Matrix insert" button and choose a 10x1-matrix.
  - Enter the values for the mass fractions ξ_1 ... ξ_{10} of the mixture gases into the vector

ξ_1	for argon	Ar	⇒ e. g.: Enter the value 0	into the 1st row
ξ_2	for neon	Ne	⇒ e. g.: Enter the value 0	into the 2nd row
ξ_3	for nitrogen	O_2	⇒ e. g.: Enter the value 0	into the 3rd row
ξ_4	for oxygen	N_2	⇒ e. g.: Enter the value 0	into the 4th row
ξ_5	for carbon monoxide	CO	⇒ e. g.: Enter the value 0	into the 5th row
ξ_6	for carbon dioxide	CO_2	⇒ e. g.: Enter the value 0.13	into the 6th row
ξ_7	for steam	H_2O	⇒ e. g.: Enter the value 0.11	into the 7th row
ξ_8	for sulfur dioxide	SO_2	⇒ e. g.: Enter the value 0	into the 8th row
ξ_9	for air - dry		⇒ e. g.: Enter the value 0	into the 9th row
ξ_{10}	for air nitrogen		⇒ e. g.: Enter the value 0.76	into the 10th row

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

- To insert units you can type it directly behind the value or you can use the units menu to search for the desired units (see Figure 2.6, marked red).

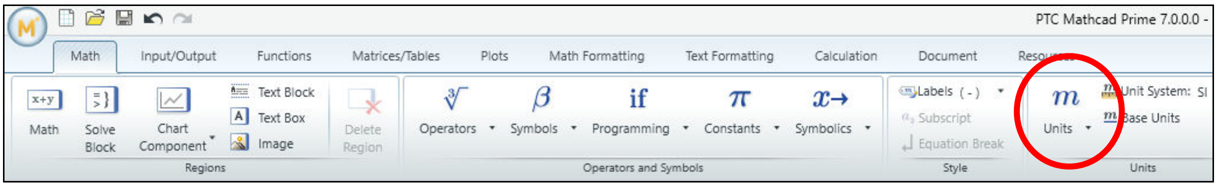


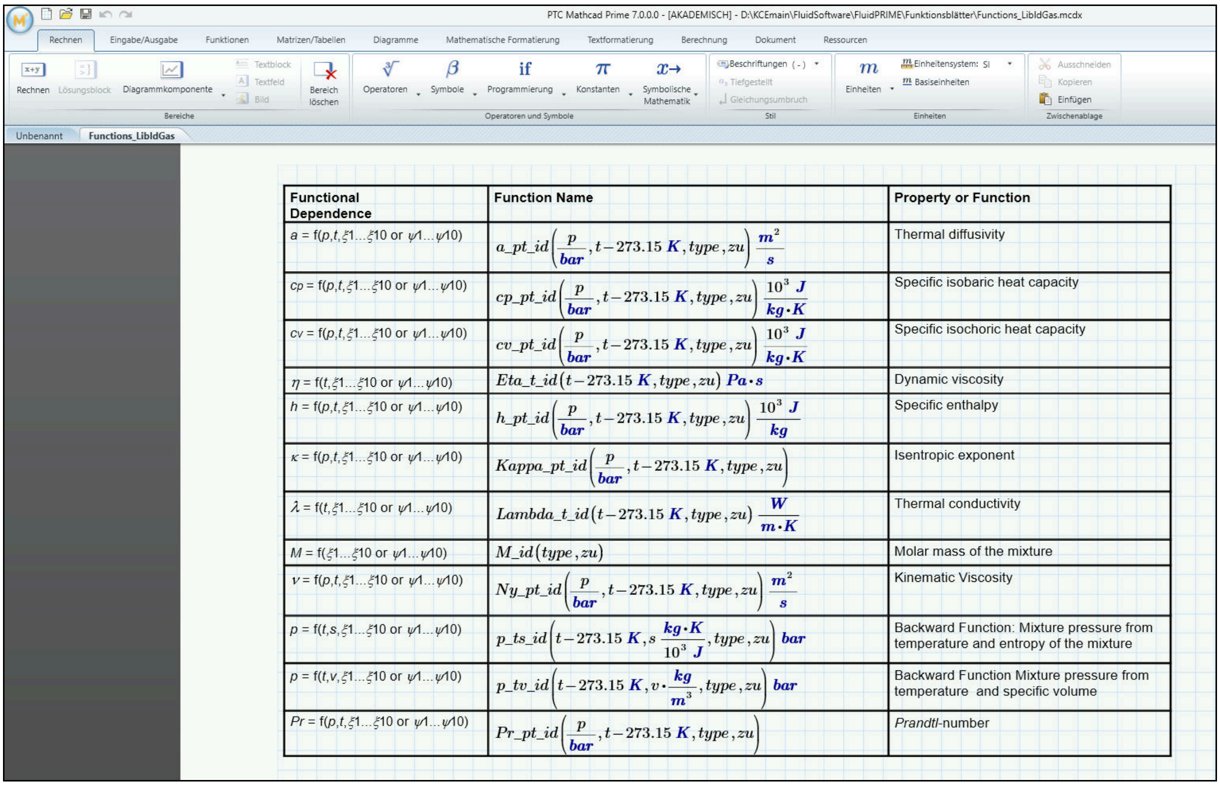
Figure 2.6: Mathcad Prime® menu bar with the units function

- Your Mathcad Prime calculation window should look like Figure 2.7:

$$p := 1\ \mathbf{bar}$$
$$t := 100\ \mathbf{°C}$$
$$type := 1$$
$$zu := \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0.13 \\ 0.11 \\ 0 \\ 0 \\ 0.76 \end{bmatrix}$$

Figure 2.7: Example Mathcad Prime® sheet after input of the given parameters

- Now, type open the file Functions_LibIDGAS.mcdx. In this Mathcad Prime® worksheet you can find all the functions of the library (see Figure 2.8)



Functional Dependence	Function Name	Property or Function
a = f(p,t,ξ1…ξ10 or ψ1…ψ10)	$a\_pt\_id\left(\frac{p}{bar}, t-273.15\ K, type, zu\right)\ \frac{m^2}{s}$	Thermal diffusivity
cp = f(p,t,ξ1…ξ10 or ψ1…ψ10)	$cp\_pt\_id\left(\frac{p}{bar}, t-273.15\ K, type, zu\right)\ \frac{10^3\ J}{kg \cdot K}$	Specific isobaric heat capacity
cv = f(p,t,ξ1…ξ10 or ψ1…ψ10)	$cv\_pt\_id\left(\frac{p}{bar}, t-273.15\ K, type, zu\right)\ \frac{10^3\ J}{kg \cdot K}$	Specific isochoric heat capacity
η = f(t,ξ1…ξ10 or ψ1…ψ10)	$Eta\_t\_id(t-273.15\ K, type, zu)\ Pa \cdot s$	Dynamic viscosity
h = f(p,t,ξ1…ξ10 or ψ1…ψ10)	$h\_pt\_id\left(\frac{p}{bar}, t-273.15\ K, type, zu\right)\ \frac{10^3\ J}{kg}$	Specific enthalpy
κ = f(p,t,ξ1…ξ10 or ψ1…ψ10)	$Kappa\_pt\_id\left(\frac{p}{bar}, t-273.15\ K, type, zu\right)$	Isentropic exponent
λ = f(t,ξ1…ξ10 or ψ1…ψ10)	$Lambda\_t\_id(t-273.15\ K, type, zu)\ \frac{W}{m \cdot K}$	Thermal conductivity
M = f(ξ1…ξ10 or ψ1…ψ10)	$M\_id(type, zu)$	Molar mass of the mixture
ν = f(p,t,ξ1…ξ10 or ψ1…ψ10)	$Ny\_pt\_id\left(\frac{p}{bar}, t-273.15\ K, type, zu\right)\ \frac{m^2}{s}$	Kinematic Viscosity
p = f(t,s,ξ1…ξ10 or ψ1…ψ10)	$p\_ts\_id\left(t-273.15\ K, s\ \frac{kg \cdot K}{10^3\ J}, type, zu\right)\ bar$	Backward Function: Mixture pressure from temperature and entropy of the mixture
p = f(t,v,ξ1…ξ10 or ψ1…ψ10)	$p\_tv\_id\left(t-273.15\ K, v \cdot \frac{kg}{m^3}, type, zu\right)\ bar$	Backward Function Mixture pressure from temperature and specific volume
Pr = f(p,t,ξ1…ξ10 or ψ1…ψ10)	$Pr\_pt\_id\left(\frac{p}{bar}, t-273.15\ K, type, zu\right)$	*Prandtl*-number

Figure 2.8: Mathcad Prime® worksheet for the LibIF97-Functions

- Search the function h_pt_id and mark it by drag a selection rectangle around it.
- Copy the marked function and paste it into your example worksheet
- Click it the function and type "h:" in front of it.
- Your Mathcad Prime calculation window should look like Figure 2.9:

$$p := 1\ \mathbf{bar}$$
$$t := 100\ \mathbf{°C}$$
$$type := 1$$
$$zu := \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0.13 \\ 0.11 \\ 0 \\ 0 \\ 0.76 \end{bmatrix}$$
$$h := \mathrm{h\_pt\_id}\left(\frac{p}{\mathbf{bar}}, t - 273.15\ \mathbf{K}, type, zu\right) \frac{10^3\ \mathbf{J}}{\mathbf{kg}}$$

Figure 2.9: Example Mathcad Prime® sheet i

- Now click in the first operand in the brackets of the function. . You can now enter the value for *p* either by entering the value directly or by entering the name of the variable where the value was saved.

  ⇒ e.g.: Enter "p".
- Situate the cursor on the next placeholder and set all the variables we set above.
- Close the input formula by pressing the "Enter"-Key.
- You can now go on working with the variable *h* which we have just calculated.
- If you wish to see the result, you have to type the following command on the next line in the Mathcad Prime window:
  "h =".

  You will now see the result h=1.103•10^5. m^2/s^{-1}. The corresponding unit is kJ/kg (see table of the property functions in Chapter 1). In Mathcad Prime® the final unit (given behind the function call) changed to base units. To display the result in the unit you have chosen, you can change the unit after the result value.

In the next figure you can the calculated value.

$$p := 1\ \mathbf{bar}$$

$$t := 100\ \mathbf{°C}$$

$$type := 1$$

$$zu := \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0.13 \\ 0.11 \\ 0 \\ 0 \\ 0.76 \end{bmatrix}$$

$$h := \mathrm{h\_pt\_id}\left(\frac{p}{\mathbf{bar}}, t - 273.15\ \mathbf{K}, type, zu\right) \frac{10^3\ \mathbf{J}}{\mathbf{kg}}$$

$$h = \left(1.103 \cdot 10^5\right) \frac{\mathbf{m}^2}{\mathbf{s}^2}$$

Figure 2.10: Example Mathcad Prime® sheet with finished calculation

2.4 Removing FluidPRIME

To remove FluidPRIME with the library LibIDGAS from your hard drive, carry out the following steps:

- Click "Start" in the lower task bar of your desktop, then "Settings" and then "Control Panel".
- Now, double click on "Add or Remove Programs".
- In the list box of the "Add or Remove Programs" window that appears select "FluidPRIME - LibIDGAS" by clicking on it and click the "Add/Remove…" button.
- In the following dialog box click "Yes" and wait until the windows is closing.
- Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidPRIME with the library LibIDGAS has been removed.

3. Program Documentation

Thermal Diffusivity a = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{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 ξ_1...ξ_{10} in kg/kg for type = 1
- Composition in mole fractions ψ_1... ψ_{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:

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

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 $c_p = f(p, t, \xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10})$

Function Name: **cp_pt_id**

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

```
REAL*8 FUNCTION CP_PT_ID(P,T,ART, COMP)
REAL*8  P, T, COMP(0:10)
INTEGER*4  ART
```

Subprogram with parameter: for the call out of the DLL

```
INTEGER*4 FUNCTION C_CP_PT_ID(CP,P,T,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ 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 $\psi_{O_2} \geq 0.01$

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,$\xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10}$)

Function Name:	**cv_pt_id**
Subprogram with value of the function: for the call out of Fortran	**REAL*8 FUNCTION CV_PT_ID(P,T,ART, COMP)** REAL*8 P, T, COMP(0:10) INTEGER*4 ART
Subprogram with parameter: for the call out of the DLL	**INTEGER*4 FUNCTION C_CV_PT_ID(CV,P,T,ART, COMP)** 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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1 - Composition in mole fractions $\psi_1 ... \psi_{10}$ 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:

- $c_v = c_p - R$
- Model of ideal mixture in consideration of dissociation above 500°C and $\psi_{O_2} \geq 0.01$

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 η = f(t,ξ_1...ξ_{10} or ψ_1...ψ_{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: for the call out of the DLL

INTEGER*4 FUNCTION C_ETA_T_ID(ETA,T,ART, COMP)
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 ξ_1...ξ_{10} in kg/kg for type = 1
- Composition in mole fractions ψ_1... ψ_{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,$\xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10}$)

Function Name: **h_pt_id**

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

REAL*8 FUNCTION H_PT_ID(P,T,ART, COMP)
REAL*8 P, T, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_H_PT_ID(H,P,T,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ 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 $\psi_{O_2} \geq 0.01$

Results for wrong input values:

h_pt_id, h = -1

References:

h corresponding to VDI 4670 [18]

Isentropic Exponent κ = f(p,t,ξ_1...ξ_{10} or ψ_1...ψ_{10})

Function Name: **Kappa_pt_id**

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

```
REAL*8 FUNCTION KAPPA_PT_ID(P,T,ART, COMP)
REAL*8  P, T, COMP(0:10)
INTEGER*4  ART
```

Subprogram with parameter: for the call out of the DLL

```
INTEGER*4 FUNCTION
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 ξ_1...ξ_{10} in kg/kg for type = 1 - Composition in mole fractions ψ_1... ψ_{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:

- Kappa $\kappa = \dfrac{c_p}{c_p - R}$
- Model of ideal mixture in consideration of dissociation above 500°C and $\psi_{O_2} \geq 0.01$

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 λ = f(t,ξ_1...ξ_{10} or ψ_1...ψ_{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 ξ_1...ξ_{10} in kg/kg for type = 1
- Composition in mole fractions ψ_1... ψ_{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($\xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10}$)

Function Name: **M_id**

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

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

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_M_ID(M,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ 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 $\nu = f(p,t,\xi_1...\xi_{10}$ or $\psi_1...\psi_{10})$

Function Name: **Ny_pt_id**

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

REAL*8 FUNCTION NY_PT_ID(P,T,ART, COMP)
REAL*8 P, T, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_NY_PT_ID(CV,P,T,ART, COMP)
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 $\xi_1...\xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1...\ \psi_{10}$ in kmol/kmol for type = 0

Result:

Ny_pt_id, Nue - Kinematic viscosity 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:

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 $p = f(t, s, \xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10})$

Function Name: **p_ts_id**

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

REAL*8 FUNCTION P_TS_ID(T,S,ART, COMP)
REAL*8 T, S, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_P_TS_ID(P,T,S,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1 - Composition in mole fractions $\psi_1 ... \psi_{10}$ 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 and $\psi_{O_2} \geq 0.01$
- 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 $p = f(t, v, \xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10})$

Function Name: **p_tv_id**

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

REAL*8 FUNCTION P_TV_ID(T,V,ART, COMP)
REAL*8 T, V, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_P_TV_ID(P,T,V,ART, COMP)
REAL*8 P, T, V, COMP(0:10)
INTEGER*4 C_APT_ID, ART

Input Values:

v - Specific volume v in m³/kg

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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ 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 m^3/kg to 2.9 109 m^3/kg

Comments:

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

Results for wrong input values:

p_tv_id, p = -1

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

Function Name: **Pr_pt_id**

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

REAL*8 FUNCTION PR_PT_ID(P,T,ART, COMP)
REAL*8 P, T, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_PR_PT_ID(PR,P,T,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ 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 ψ_i = f(i, $\xi_1 ... \xi_{10}$)

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 $\xi_1 ... \xi_{10}$ 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($\xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10}$)

Function Name: **R_id**

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

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

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_R_ID(R,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ in kmol/kmol for type = 0

Result:

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

Comments:

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

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

Results for wrong input values:

R_id, R = -1

Density ρ = f(p,t,$\xi_1 ... \xi_{10}$ or $\psi_1 ... \psi_{10}$)

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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ in kmol/kmol for type = 0

Result:

Rho_pt_id, Rho - Density in kg/m^3

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 : $\rho = \dfrac{p}{R \cdot T}$

Results for wrong input values:

Rho_pt_id, Rho = -1

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

Function Name:	**s_pt_id**
Subprogram with value of the function: for the call out of Fortran	**REAL*8 FUNCTION S_PT_ID(P,T,ART, COMP)** REAL*8 P, T, COMP(0:10) INTEGER*4 ART
Subprogram with parameter: for the call out of the DLL	**INTEGER*4 FUNCTION C_S_PT_ID(S,P,T,ART, COMP)** 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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1 - Composition in mole fractions $\psi_1 ... \psi_{10}$ 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 $\psi_{O_2} \geq 0.01$

Results for wrong input values:

s_pt_id, s = -1

References:

s corresponding to VDI 4670 [18]

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

Function Name: **t_ph_id**

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

REAL*8 FUNCTION T_PH_ID(P,H,ART, COMP)
REAL*8 P, H, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_T_PH_ID(T,P,H,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ 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))
- Model of ideal mixture in consideration of dissociation above 500°C and $\psi_{O_2} \geq 0.01$

Results for wrong input values:

t_ph_id, t = -1

References:

h corresponding to VDI 4670 [18]

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

Function Name: **t_ps_id**

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

REAL*8 FUNCTION T_PS_ID(P,S,ART, COMP)
REAL*8 P, S, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_T_PS_ID(T,P,S,ART, COMP)
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 $\xi_1...\xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1... \psi_{10}$ 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))
- Model of ideal mixture in consideration of dissociation above 500°C and $\psi_{O_2} \geq 0.01$

Results for wrong input values:

t_ps_id, t = -1

References:

s corresponding to VDI 4670 [18]

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

Function Name: **t_pv_id**

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

REAL*8 FUNCTION T_PV_ID(P,V,ART, COMP)
REAL*8 P, V, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_T_PV_ID(T,P,V,ART, COMP)
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 $\xi_1...\xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1...\psi_{10}$ 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 m^3/kg to 2.9 109 m^3/kg

Comments:

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

Results for wrong input values:

t_pv_id, t = -1

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

Function Name: **u_pt_id**

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

REAL*8 FUNCTION U_PT_ID(P,T,ART, COMP)
REAL*8 P, T, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_U_PT_ID(U,P,T,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1 - Composition in mole fractions $\psi_1 ... \psi_{10}$ 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: $u = h(p, t, (1:10)) - R \cdot T$
- Model of ideal mixture in consideration of dissociation above 500°C and $\psi_{O_2} \geq 0.01$

Results for wrong input values:

u_pt_id, u = -1

References:

h corresponding to VDI 4670 [18]

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

Function Name: **v_pt_id**

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

REAL*8 FUNCTION V_PT_ID(P,T,ART, COMP)
REAL*8 P, T, COMP(0:10)
INTEGER*4 ART

Subprogram with parameter: for the call out of the DLL

INTEGER*4 FUNCTION C_V_PT_ID(V,P,T,ART, COMP)
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 $\xi_1 ... \xi_{10}$ in kg/kg for type = 1
- Composition in mole fractions $\psi_1 ... \psi_{10}$ in kmol/kmol for type = 0

Result:

v_pt_id, v - Specific volume in m^3/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 : $v = \dfrac{R_m \cdot T}{p}$

Results for wrong input values:

v_pt_id, v = -1

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

Function Name:	**w_pt_id**
Subprogram with value of the function: for the call out of Fortran	**REAL*8 FUNCTION W_PT_ID(P,T,ART, COMP)** REAL*8 P, T, COMP(0:10) INTEGER*4 ART
Subprogram with parameter: for the call out of the DLL	**INTEGER*4 FUNCTION C_W_PT_ID(W,P,T,ART, COMP)** 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
comp(1:10)	- Composition in mass fractions $\xi_1 ... \xi_{10}$ in kg/kg for type = 1 - Composition in mole fractions $\psi_1 ... \psi_{10}$ 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:

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 ξ_i = f($i, \psi_1 ... \psi_{10}$)

Function Name:	**Xsi_igas_Psi_id**
Subprogram with value of the function: for the call out of Fortran	**REAL*8 FUNCTION XSI_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_XSI_IGAS_ID(XSI,IGAS, COMP)** 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 $\psi_1 ... \psi_{10}$ in kmol/kmol for type = 0

Result:

Xsi_igas_Psi_id, Xsi - Mass fraction in kg/kg

Comments:

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

Results for wrong input values:

Xsi_igas_Psi_id, Xsi = -1

KCE-ThermoFluidProperties
www.thermofluidprop.com

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

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, -S03rev, -S04, and -S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)

Library LibIF97_META

- Industrial Formulation IAPWS-IF97 (Revision 2007) for metastable steam

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

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

and of the ideal gases:
SO_2, CO, Ne
(Scientific Formulation of Bücker et al.)

Consideration of:

- Dissociation from VDI 4670
- Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

Extremely Fast Property Calculations

Spline-Based Table Look-up Method (SBTL)

Library LibSBTL_IF97
Library LibSBTL_95
Library LibSBTL_HuAir

For steam, water, humid air, carbon dioxide and other fluids and mixtures according IAPWS Guideline 2015 for Computational Fluid Dynamics (CFD), real-time and non-stationary simulations

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

Ar	NO	He	Propylene
Ne	H_2O	F_2	Propane
N_2	SO_2	NH_3	Iso-Butane
O_2	H_2	Methane	n-Butane
CO	H_2S	Ethane	Benzene
CO_2	OH	Ethylene	Methanol
Air			

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

Model: Virial equation from ASHRAE Report RP-1485 for real mixture of the real fluids:
- Dry air
- Steam

Consideration of:

- Enhancement of the partial saturation pressure of water vapor at elevated total pressures

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bücker and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term

(also useable for calculating the Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

$C_2H_6O_2$	Ethylene glycol
$C_3H_8O_2$	Propylene glycol
C_2H_5OH	Ethanol
CH_3OH	Methanol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate
$CHKO_2$	Potassium formate
LiCl	Lithium chloride
NH_3	Ammonia

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol

Library LibC2H5OH

Formulation of
Schroeder et al. (2014)

Methanol

Library LibCH3OH

Formulation of
de Reuck and Craven (1993)

Propane

Library LibPropane

Formulation of
Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

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

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

Tetradecamethylhexasiloxane $C_{14}H_{42}O_5Si_6$ **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)

Nitrogen and Oxygen

Libraries
LibN2 and LibO2

Formulations of Span et al. (2000)
and Schmidt and Wagner (1985)

Hydrogen

Library LibH2

Formulation of
Leachman et al. (2009)

Helium

Library LibHe

Formulation of
Arp et al. (1998)

Hydrocarbons

Decane $C_{10}H_{22}$ **Library LibC10H22**
Isopentane C_5H_{12} **Library LibC5H12_Iso**
Neopentane C_5H_{12} **Library LibC5H12_Neo**
Isohexane C_6H_{14} **Library LibC6H14**
Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide CO **Library LibCO**
Carbonyl sulfide COS **Library LibCOS**
Hydrogen sulfide H_2S **Library LibH2S**
Nitrous oxide N_2O **Library LibN2O**
Sulfur dioxide SO_2 **Library LibSO2**
Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

KCE
ThermoFluidProperties

For more information please contact:

KCE-ThermoFluidProperties UG & Co. KG
Prof. Dr. Hans-Joachim Kretzschmar
Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

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
- Thermal diffusivity a

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 used in process modeling can be calculated.

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

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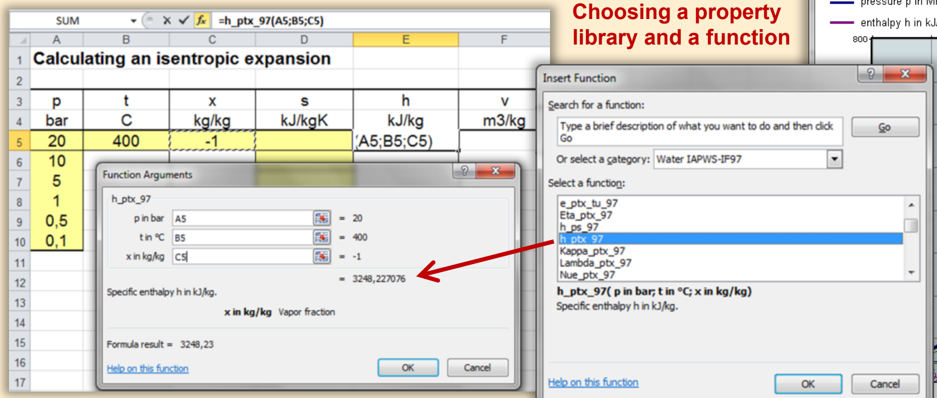
KCE ThermoFluidProperties

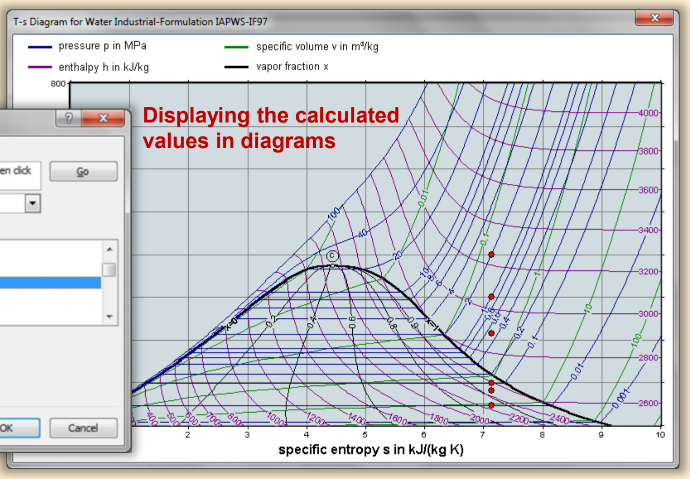
Hochschule Zittau/Görlitz UNIVERSITY OF APPLIED SCIENCES

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

Add-In FluidEXL *Graphics* for Excel®

Choosing a property library and a function

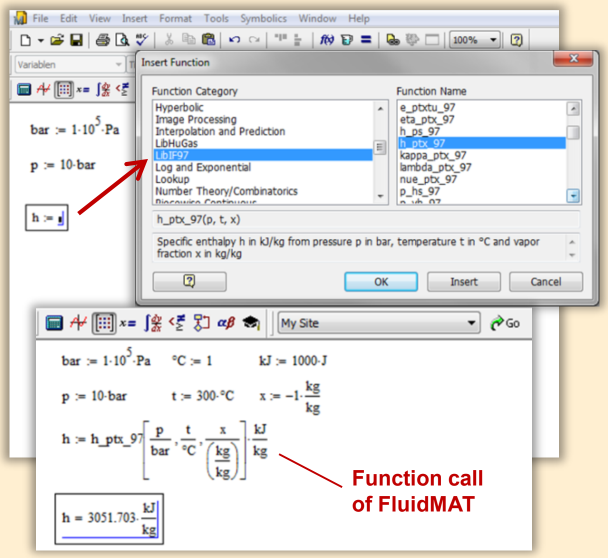




Menu for the input of given property values

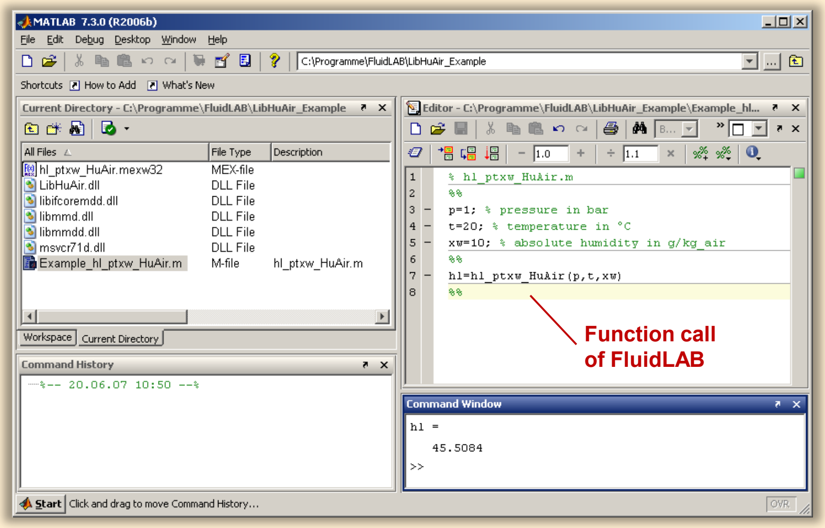
Add-On FluidMAT for Mathcad®
Add-On FluidPRIME for Mathcad Prime®

The property libraries can be used in Mathcad® and Mathcad Prime®.



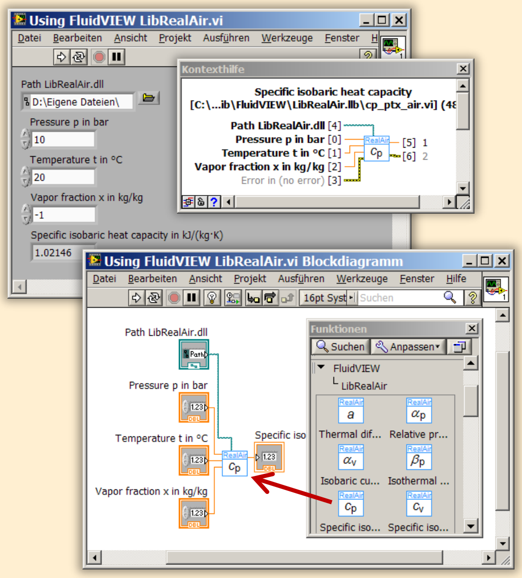
Add-On FluidLAB for MATLAB® and SIMULINK®

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



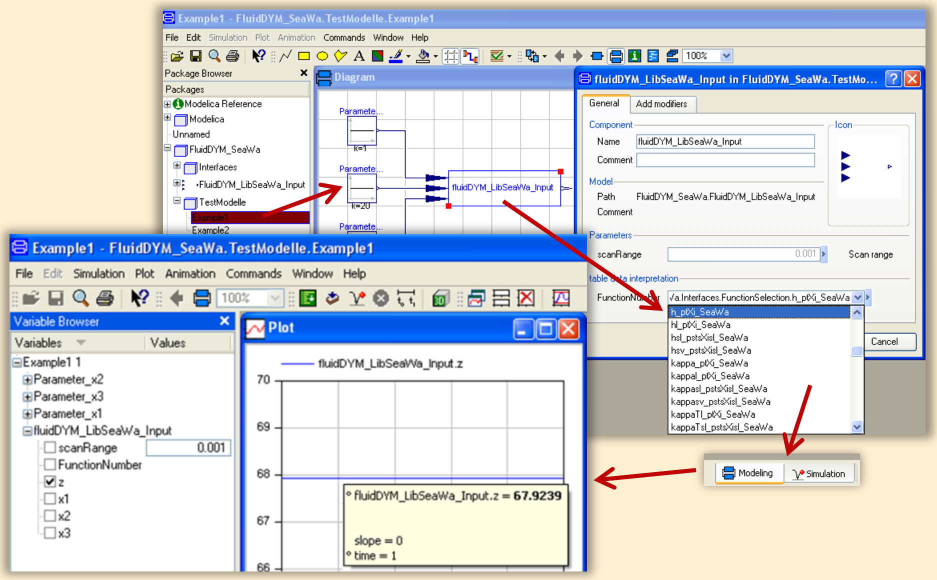
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

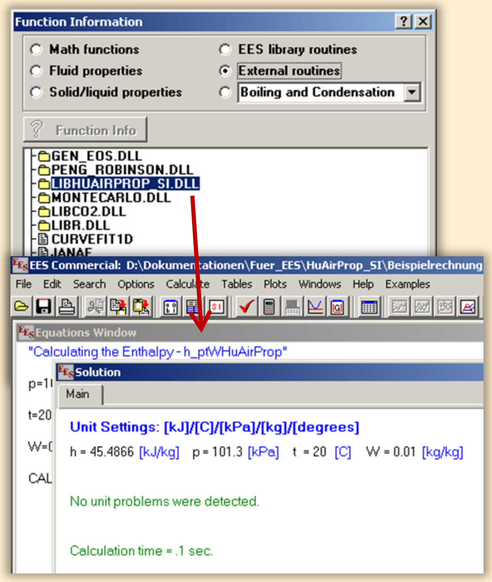


Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

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

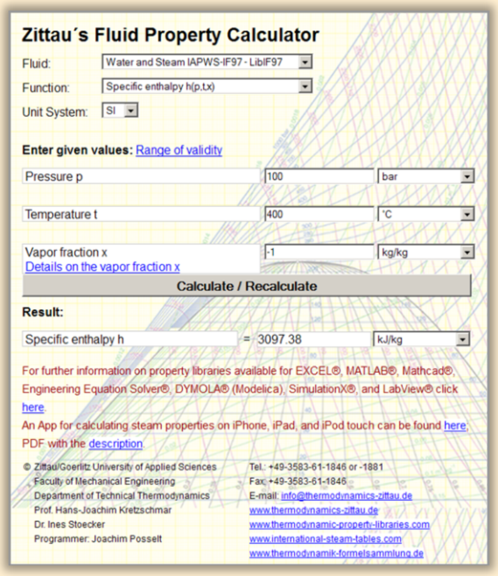


Add-On FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android Smartphones and Tablets

Online Property Calculator at www.thermofluidprop.com



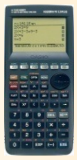
Property Software for Pocket Calculators

FluidCasio


fx 9750 G II


CFX 9850
fx-GG20


CFX 9860 G
Graph 85


ALGEBRA
FX 2.0

FluidHP

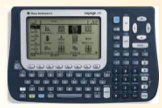

HP 48

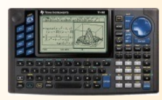

HP 49

FluidTI


TI Nspire CX CAS
TI Nspire CAS


TI 83
TI 84
TI 89


TI Voyage 200


TI 92

For more information please contact:

KCE ThermoFluidProperties

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Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

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
- Thermal diffusivity a

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 used in process modeling can be calculated.

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

www.thermofluidprop.com

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

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[8] Release on Surface Tension of Ordinary Water Substance 1994.
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[10] Supplementary Release on Backward Equations p(h,s) for Region 3, Equations as a Function of h and s for the Region Boundaries, and an Equation $T_{sat}(h,s)$ for Region 4 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam 2004. Available at the IAPWS website http://www.iapws.org

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[17] Blanke, W.:
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Thermodynamische Stoffwerte von feuchter Luft und Verbrennungsgasen.
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J. Phys. Chem. Ref. Data 29 (2000) No 2, pp. 331-385

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[21] Revised Supplementary Release on Saturation Properties of Ordinary Water Substance 1992. Available at the IAPWS website http://www.iapws.org

[22] Hyland, R. W.; Wexler, A.:
Formulations for the Thermodynamic Properties of Saturated Phases of H_2O from 173.15 K to 473.15 K.
Report No. 2793 (RP-216), National Bureau of Standards, Washington, D.C. (1983)

6. Satisfied Customers

Date: 12/2020

The following companies and institutions use the property libraries:

- FluidEXL*Graphics* for Excel® incl. VBA
- FluidLAB for MATLAB® and Simulink
- FluidMAT for Mathcad®
- FluidPRIME for Mathcad Prime®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica) and SimulationX®
- FluidVIEW for LabVIEW™
- FluidPYT for Python
- DLLs for Windows™ Applications
- Shared Objects for Linux®.

2020

Drill Cool, Bakersfield CA,USA	12/2020
Manders, The Netherlands	
RWE Essen	
NEOWAT Lodz, Poland	
University of Duisburg-Essen, Duisburg	11/2020
Stellenbosch University, South Africa	
University De France-COMTe, France	
RWE Essen	
STEAG, Herne	
Isenmann Ingenierbüro	
University of Stuttgart, ITLR, Stuttgart	
Norsk Energi, Norway	
TGM Kanis, Nürnberg	
Stadtwerke Neuburg	10/2020
Smurfit Kappa, Roermond, The Netherlands	
RWE Essen	
Hochschule Zittau/Görlitz, Wirtschaftsingenieurwesen	
Stadtwerke Neuburg	
ILK, Dresden	
ATESTEO, Alsdorf	
Hochschule Zittau/Görlitz, Maschinenwesen	
TH Nürnberg, Verfahrenstechnik	
Drill Cool, Bakersfield CA,USA	09/2020
RWE Essen	
2Meyers Ingenieurbüro, Nürnberg	
FELUWA, Mürlenbach	
Stadtwerke Neuburg	
Caverion, Wien, Austria	

GMVA Niederrhein, Oberhausen	
INWAT Lodz, Poland	
Troche Ingenieurbüro, Hayingen	08/2020
CEA Saclay, France	
VPC, Vetschau	07/2020
FSK System-Kälte-Klima, Dortmund	
Exergie Etudes, Sarl, Switzerland	
AWG Wuppertal	
STEAG Energy Services, Zwingenberg	
Hochschule Braunschweig	06/2020
DBI, Leipzig	
GOHL-KTK, Dumersheim	
TU Dresden, Energieverfahrenstechnik	
BASF SE, ESI/EE, Ludwigshafen	
Wärme Hamburg	
Ruchti Ingenieurbüro, Uster, Switzerland	
IWB, Basel, Switzerland	
Midiplan, Bietingen-Bissingen	05/2020
Knieschke, Ingenieurbüro	
RWE, Essen	
Leser, Hamburg	
AGRANA, Gmünd, Austria	
EWT Wassertechnik, Celle	
Hochschule Darmstadt	04/2020
MTU München CCP	
HAW Hamburg	03/2020
Hanon, Novi Jicin, Czech Republic	
TU Dresden, Kältetechnik	
MAN, Copenhagen, Denmark	
EnerTech, Radebeul	02/2020
LEAG, Cottbus	
B+B Enginering Magdeburg	
Hochschule Offenburg	
WIB, Dennheritz	01/2020
Universität Duisburg-Essen, Strömungsmaschinen	
Kältetechnik Dresen-Bremen	
TH Ingolstadt	
Vattenfall AB, Jokkmokk, Sweden	
Fraunhofer UMSICHT	

2019

PEU Leipzig, Rötha	12/2019
MB-Holding, Vestenbergsgreuth	
RWE, Essen	
Georg-Büchner-Hochschule, Darmstadt	11/2019
EEB ENERKO, Aldenhoven	
Robert Benoufa Energietechnik, Wiesloch	

Kehrein & Kubanek Klimatechnik, Moers	10/2019
Hanon Systems Autopal Services, Hluk, Czech Republic	
CEA Saclay, Gif Sur Yvette cedex, France	
Saudi Energy Efficiency Center SEEC, Riyadh, Saudi Arabia	
VPC, Vetschau	09/2019
jGanser PM + Engineering, Forchheim	
Endress+Hauser Flowtec AG, Reinach, Switzerland	
Ruchti IB, Uster, Switzerland	
ZWILAG Zwischenlager Würenlingen, Switzerland	08/2019
Hochschule Zittau/Görlitz, Faculty Maschinenwesen	
Stadtwerke Neubrandenburg	
Physikalisch Technische Bundesanstalt PTB, Braunschweig	
GMVA Oberhausen	07/2019
Endress+Hauser Flowtec AG, Reinach, Switzerland	
WARNICA, Waterloo, Canada	
MIBRAG, Zeitz	06/2019
Pöyry, Zürich, Switzerland	
RWTH Aachen, Institut für Strahlantriebe und Turbomaschinen	
Midiplan, Bietigheim-Bissingen	
GKS Schweinfurt	
HS Zittau/Görlitz, Wirtschaftswissenschaften und Wirtschaftsingenieurwesen	
ILK Dresden	
HZDR Helmholtz Zentrum Dresden-Rossendorf	
TH Köln, Technische Gebäudeausrüstung	05/2019
IB Knittel, Braunschweig	
Norsk Energi, Oslo, Norway	
STEAG, Essen	
Stora Enso, Eilenburg	
IB Lücke, Paderborn	
Haarslev, Sonderso, Denmark	
MAN Augsburg	
Wieland Werke, Ulm	04/2019
Fels-Werke, Elbingerode	
Univ. Luxembourg, Luxembourg	
BTU Cottbus, Power Engineering	03/2009
Eins-Energie Sachsen, Schwarzenberg	
TU Dresden, Kälte- und Kryotechnik	
ITER, St. Paul Lez Durance Cedex, France	
Fraunhofer UMSICHT, Oberhausen	
Comparex Leipzig for Spedition Thiele HEMMERSBACH	
Rückert NaturGas, Lauf/Pegnitz	
BASF, Basel, Switzerland	02/2019
Stadtwerke Leipzig	
Maerz Ofenbau Zürich, Switzerland	
Hanon Systems Germany, Kerpen	
Thermofin, Heinsdorfergrund	01/2019
BSH Berlin	

2018

Jaguar Energy, Guatemala	12/2018
WEBASTO, Gilching	
Smurfit Kappa, Oosterhout, Netherlands	
Univ. BW München	
RAIV, Liberec for VALEO, Prague, Czech Republic	11/2018
VPC Group Vetschau	
SEITZ, Wetzikon, Switzerland	
MVV, Mannheim	10/2018
IB Troche	
KANIS Turbinen, Nürnberg	
TH Ingolstadt, Institut für neue Energiesysteme	
IB Kristl & Seibt, Graz, Austria	09/2018
INEOS, Köln	
IB Lücke, Paderborn	
Südzucker, Ochsenfurt	08/2018
K&K Turbinenservice, Bielefeld	07/2018
OTH Regensburg, Elektrotechnik	
Comparex Leipzig for LEAG, Berlin	06/2018
Münstermann, Telgte	05/2018
TH Nürnberg, Verfahrenstechnik	
Universität Madrid, Madrid, Spanien	
HS Zittau/Görlitz, Wirtschaftsingenieurwesen	
HS Niederrhein, Krefeld	
Wilhelm-Büchner HS, Pfungstadt	03/2018
GRS, Köln	
WIB, Dennheritz	
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	
AIXPROCESS, Aachen	
KRONES, Neutraubling	
Doosan Lentjes, Ratingen	01/2018

2017

Compact Kältetechnik, Dresden	12/2017
Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	
TH Mittelhessen, Gießen	11/2017
Haarslev Industries, Søndersø, Denmark	
Hochschule Zittau/Görlitz, Fachgebiet Energiesystemtechnik	
ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	
Fels-Werke GmbH, Elbingerode	
KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik	09/2017
Air-Consult, Jena	
Papierfabrik Koehler, Oberkirch	
ZWILAG, Würenlingen, Switzerland	
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017

Fichtner IT Consulting AG, Stuttgart	07/2017
Hochschule Ansbach, Ansbach	06/2017
RONAL, Härkingen, Switzerland	
BORSIG Service, Berlin	
BOGE Kompressoren, Bielefeld	
STEAG Energy Services, Zwingenberg	
CES clean energy solutions, Wien, Austria	04/2017
Princeton University, Princeton, USA	
B2P Bio-to-Power, Wadersloh	
TU Dresden, Institute for Energy Engineering, Dresden	
SAINT-GOBAIN, Vaujours, France	03/2017
TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	
SCHMIDT + PARTNER, Therwil, Switzerland	
KAESER Kompressoren, Gera	
F&R, Praha, Czech Republic	
ULT Umwelt-Lufttechnik, Löbau	02/2017
JS Energie & Beratung, Erding	
Kelvion Brazed PHE, Nobitz-Wilchwitz	
MTU Aero Engines, München	
Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	
SHELL Deutschland Oil, Wesseling	
MARTEC Education Center, Frederikshaven, Denmark	
SynErgy Thermal Management, Krefeld	

2016

BOGE Druckluftsysteme, Bielefeld	12/2016
BFT Planung, Aachen	11/2016
Midiplan, Bietigheim-Bissingen	
BBE Barnich IB	
Wenisch IB,	
INL, Idaho Falls	
TU Kältetechnik, Dresden	
Kopf SynGas, Sulz	
I INL Idaho National Laboratory, Idaho, USA	
NTVEN, Bellevne (USA)	
DREWAG Dresden, Dresden	10/2016
AGO AG Energie+Anlagen, Kulmbach	
Universität Stuttgart, ITW, Stuttgart	09/2016
Pöyry Deutschland GmbH, Dresden	
Siemens AG, Erlangen	
BASF über Fichtner IT Consulting AG	
B+B Engineering GmbH, Magdeburg	
Wilhelm Büchner Hochschule, Pfungstadt	08/2016
Webasto Thermo & Comfort SE, Gliching	
TU Dresden, Dresden	
Endress+Hauser Messtechnik GmbH+Co. KG, Hannover	
D + B Kältetechnik, Althausen	07/2016

Fichtner IT Consulting AG, Stuttgart	
AB Electrolux, Krakow, Poland	
ENEXIO Germany GmbH, Herne	
VPC GmbH, Vetschau/Spreewald	
INWAT, Lodz, Poland	
E.ON SE, Düsseldorf	
Planungsbüro Waidhas GmbH, Chemnitz	
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	
EEB Enerko, Aldershoven	
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	
SSP Kälteplaner AG, Wolfertschwenden	
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
Institut für Luft- und Kältetechnik, Dresden	
Universidad Carlos III de Madrid, Madrid, Spain	04/2016
INWAT, Lodzi, Poland	
Planungsbüro WAIDHAS GmbH, Chemnitz	
STEAG Energy Services GmbH, Laszlo Küppers, Zwingenberg	03/2016
WULFF & UMAG Energy Solutions GmbH, Husum	
FH Bielefeld, Bielefeld	
EWT Eckert Wassertechnik GmbH, Celle	
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016
IEV KEMA - DNV GV – Energie, Dresden	
Allborg University, Department of Energie, Aalborg, Denmark	
G.A.M. Heat GmbH, Gräfenhainichen	
Institut für Luft- und Kältetechnik, Dresden	
Bosch, Stuttgart	
INL Idaho National Laboratory, Idaho, USA	01/2016
Friedl ID, Wien, Austria	
Technical University of Dresden, Dresden	

2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	
Allborg University, Department of Energie, Aalborg, Denmark	
University of Lyubljana, Slovenia	
Steinbrecht IB, Berlin	11/2015
Universidad Carlos III de Madrid, Madrid, Spain	
STEAK, Essen	
Bosch, Lohmar	10/2015
Team Turbo Machines, Rouen, France	09/2015
BTC – Business Technology Consulting AG, Oldenburg	07/2015
KIT Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen	
ILK, Dresden	
Schniewindt GmbH & Co. KG, Neuenwalde	08/2015

2014

PROJEKTPLAN, Dohna	04/2014

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

2013

TRANTER-GmbH, Artern	12/2013
SATAKE, Shanghai, China	
STEAG, Herne	
SÜDSALZ, Bad Friedrichshall	
RWE, Essen	
OITH, Kunshan, China	
ULT, Löbau	
MAN, Copenhagen, Dänemark	11/2013
DREWAG, Dresden	
Siemens, Frankenthal	
VGB, Essen	
Haarslev Industries, Herlev, Dänemark	
Fichtner IT, Stuttgart	
RWE, Essen	
STEAG, Herne	
Ingersoll-Rand, Oberhausen	
Wilhelm-Büchner HS, Darmstadt	10/2013
IAV, Chemnitz	
T Siemens, Frankenthal	
echnical University of Regensburg	
PD-Energy, Bitterfeld	09/2013
Thermofin, Heinsdorfergrund	
SHI, New Jersey, USA	
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	
ILK, Dresden	

University of Maryland, USA	
TIG-Group, Husum	
RWE, Essen	
University of Budapest, Hungary	
Siemens, Frankenthal	
VGB, Essen	07/2013
Brunner Energieberatung, Zurich, Switzerland	
Technical University of Deggendorf	
University of Maryland, USA	
University of Princeton, USA	
NIST, Boulder, USA	06/2013
IGUS GmbH, Dresden	
BHR Bilfinger, Essen	
SÜDSALZ, Bad Friedrichshall	
Technician School of Berlin	05/2013
KIER, Gajeong-ro, Südkorea	
Schwing/Stetter GmbH, Memmingen	
Vattenfall, Berlin	
AUTARK, Kleinmachnow	
STEAG, Zwingenberg	
Hochtief, Düsseldorf	
University of Stuttgart	04/2013
Technical University -Bundeswehr, Munich	
Rerum Cognitio Forschungszentrum, Frankfurt	
Kältetechnik Dresen + Bremen, Alfhausen	
University Auckland, New Zealand	
MASDAR Institut, Abu Dhabi, United Arab Emirates	03/2013
Simpelkamp, Dresden	02/2013
VEO, Eisenhüttenstadt	
ENTEC, Auerbach	
Caterpillar, Kiel	
Technical University of Wismar	
Technical University of Dusseldorf	
ILK, Dresden	01/2013
Fichtner IT, Stuttgart	
Schnepf Ingeniuerbüro, Nagold	
Schütz Engineering, Wadgassen	
Endress & Hauser, Reinach, Switzerland	
Oschatz GmbH, Essen	
frischli Milchwerke, Rehburg-Loccum	

2012

Voith, Bayreuth	12/2012
Technical University of Munich	
Dillinger Huette	
University of Stuttgart	11/2012
Siemens, Muehlheim	
Fichtner IT, Stuttgart	

Sennheiser, Hannover	
Oschatz GmbH, Essen	10/2012
Fichtner IT, Stuttgart	
Helbling Technik AG, Zurich, Switzerland	
University of Duisburg	
Rerum Cognitio Forschungszentrum, Frankfurt	09/2012
Pöyry Deutschland GmbH, Dresden	08/2012
Extracciones, Guatemala	
RWE, Essen	
Weghaus Consulting Engineers, Wuerzburg	
GKS, Schweinfurt	07/2012
RWE Essen	
SEITZ, Wetzikon, Switzerland	
SPX Balcke-Dürr, Ratingen	
airinotec, Bayreuth	
GEA, Nobitz	
Meyer Werft, Papenburg	
STEAG, Herne	
GRS, Cologne	06/2012
Fichtner IT Consult, Chennai, India	
Siemens, Freiburg	
Nikon Research of America, Belmont, USA	
Niederrhein University of Applied Sciences, Krefeld	
STEAG, Zwingenberg	
Mainova, Frankfurt on Main	05/2012
Endress & Hauser	
Siemens, Erlangen	
PEU, Espenheim	
Luzern University of Applied Sciences, Switzerland	
BASF, Ludwigshafen (general license)	
SPX Balcke-Dürr, Ratingen	
Gruber-Schmidt, Wien, Austria	04/2012
Vattenfall, Berlin	
ALSTOM, Baden	
SKW, Piesteritz	
TERA Ingegneria, Trento, Italy	
Siemens, Erlangen	
LAWI Power, Dresden	
Stadtwerke Leipzig	
SEITZ, Wetzikon, Switzerland	03/2012
M & M, Bielefeld	
Sennheiser, Wedemark	
SPG, Montreuil Cedex, France	02/2012
German Destilation, Sprendlingen	
Lopez, Munguia, Spain	
Endress & Hauser, Hannover	
Palo Alto Research Center, USA	
WIPAK, Walsrode	

Freudenberg, Weinheim	01/2012
Fichtner, Stuttgart	
airinotec, Bayreuth	
University Auckland, New Zealand	
VPC, Vetschau	
Franken Guss, Kitzingen	

2011

XRG-Simulation, Hamburg	12/2011
Smurfit Kappa PPT, AX Roermond, Netherlands	
AWTEC, Zurich, Switzerland	
eins-energie, Bad Elster	
BeNow, Rodenbach	11/2011
Luzern University of Applied Sciences, Switzerland	
GMVA, Oberhausen	
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	
PLANAIR, La Sagne, Switzerland	
Weihenstephan University of Applied Sciences	
LAWI, Dresden	
Lopez, Munguia, Spain	
University of KwaZulu-Natal, Westville, South Africa	
Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	
Weihenstephan University of Applied Sciences	
SPG TECH, Montreuil Cedex, France	
Voith, Heidenheim-Mergelstetten	
MTU Aero Engines, Munich	08/2011
RWTH Aachen University	
F Technical University of Dresden	
ichtner IT Consulting, Stuttgart	,
MIBRAG, Zeitz	
RWE, Essen	07/2011
Fels, Elingerode	
Weihenstephan University of Applied Sciences	
Forschungszentrum Juelich	
RWTH Aachen University	
INNEO Solutions, Ellwangen	06/2011
Fichtner IT Consulting, Stuttgart	
University of Duisburg	
Technical University of Dresden	
Caliqua, Basel, Switzerland	
Technical University of Freiberg	
Fichtner IT Consulting, Stuttgart	05/2011
Technical University of Dresden	
Salzgitter Flachstahl, Salzgitter	
Helbling Beratung & Bauplanung, Zurich, Switzerland	
INEOS, Cologne	04/2011

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

2010

Umweltinstitut Neumarkt 12/2010
YIT Austria, Vienna, Austria
MCI Innsbruck, Austria
University of Stuttgart
HS Cooler, Wittenburg
MCE, Berlin
S ILK, Dresden
iemens Energy, Goerlitz
Visteon, Novi Jicin, Czech Republic
CompuWave, Brunntal
Stadtwerke Leipzig
MCI Innsbruck, Austria
EVONIK Energy Services, Zwingenberg
Caliqua, Basel, Switzerland 11/2010
Shanghai New Energy Resources Science & Technology, China
Energieversorgung Halle
Hochschule für Technik Stuttgart, University of Applied Sciences
Steinmueller, Berlin
Amberg-Weiden University of Applied Sciences
AREVA NP, Erlangen 10/2010
MAN Diesel, Augsburg
KRONES, Neutraubling
Glen Dimplex, Kulmbach
Vaillant, Remscheid
PC Ware, Leipzig
Schubert Consulting Engineers, Weißenberg
Fraunhofer Institut UMSICHT, Oberhausen
Behringer Consulting Engineers, Tagmersheim 09/2010
Saacke, Bremen
WEBASTO, Neubrandenburg
Concordia University, Montreal, Canada

Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	
ERGION, Mannheim	07/2010
Glen Dimplex, Kulmbach	
Fichtner IT Consulting, Stuttgart	
TF Design, Matieland, South Africa	
MCE, Berlin	
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	
RWE IT, Essen	
Glen Dimplex, Kulmbach	05/2010
Hot Rock, Karlsruhe	
D ALSTOM Power, Baden, Switzerland	
armstadt University of Applied Sciences	
Voith, Heidenheim	04/2010
CombTec, Zittau	
University of Glasgow, Great Britain	
Universitaet der Bundeswehr, Munich	
Technical University of Hamburg-Harburg	
Vattenfall Europe, Berlin	
HUBER Consulting Engineers, Berching	
VER, Dresden	
CCP, Marburg	03/2010
Offenburg University of Applied Sciences	
Technical University of Berlin	
NIST Boulder CO, USA	
Technical University of Dresden	02/2010
Siemens Energy, Nuremberg	
Augsburg University of Applied Sciences	
ALSTOM Power, Baden, Switzerland	
MIT Massachusetts Institute of Technology Cambridge MA, USA	
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	
Technical University of Freiberg	
ILK, Dresden	
Fischer-Uhrig Consulting Engineers, Berlin	

2009

ALSTOM Power, Baden, Schweiz	01/2009
Nordostschweizerische Kraftwerke AG, Doettingen, Switzerland	02/2009
RWE, Neurath	
Brandenburg University of Technology, Cottbus	
Hamburg University of Applied Sciences	
Kehrein, Moers	03/2009
EPP Software, Marburg	
ALSTOM Power, Baden, Schweiz	
Bernd Münstermann, Telgte	
Suedzucker, Zeitz	

CPP, Marburg	
Gelsenkirchen University of Applied Sciences	04/2009
Regensburg University of Applied Sciences	05/2009
ALSTOM Power, Baden, Schweiz	
Gatley & Associates, Atlanta, USA	
BOSCH, Stuttgart	06/2009
Dr. Nickolay, Consulting Engineers, Gommersheim	
Ferrostal Power, Saarlouis	
BHR Bilfinger, Essen	
Intraserv, Wiesbaden	
Lausitz University of Applied Sciences, Senftenberg	
Nuernberg University of Applied Sciences	
Technical University of Berlin	
Fraunhofer Institut UMSICHT, Oberhausen	07/2009
BOSCH, Stuttgart	
Bischoff, Aurich	
Fichtner IT Consulting, Stuttgart	
Techsoft, Linz, Austria	08/2009
DLR, Stuttgart	
Wienstrom, Vienna, Austria	
RWTH Aachen University	09/2009
Vattenfall, Hamburg	10/2009
AIC, Chemnitz	
Midiplan, Bietigheim-Bissingen	11/2009
Institute of Air Handling and Refrigeration ILK, Dresden	
FZD, Rossendorf	
Techgroup, Ratingen	
Robert Sack, Heidelberg	
EC, Heidelberg	
MCI, Innsbruck, Austria	12/2009
Saacke, Bremen	12/2009
ENERKO, Aldenhoven	12/2009

2008

Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	
University of Karlsruhe	
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	
WEBASTO, Neubrandenburg	
CFC Solutions, Munich	
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	
ARUP, Berlin	05/2008
Rerum Cognitio, Zwickau	

Research Center, Karlsruhe	07/2008
AWECO, Neukirch	
Technical University of Dresden,	
Professorship of Building Services	
Technical University of Cottbus,	
Ingersoll-Rand, Unicov, Czech Republic	08/2008
Technip Benelux BV, Zoetermeer, Netherlands	
Fennovoima Oy, Helsinki, Finland	
Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	
Poyry, Dresden	
WINGAS, Kassel	
TUEV Sued, Dresden	10/2008
Technical University of Cottbus,	
Technical University of Dresden,	
AWTEC, Zurich, Switzerland	11/2008
Technical University of Dresden,	
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	
TUEV NORD SysTec, Hamburg	
VER, Dresden	
Technical University of Dresden, Chair in Jet Propulsion Systems	
Redacom, Nidau, Switzerland	
Universität der Bundeswehr, Munich	
Maxxtec, Sinsheim	03/2007
University of Rostock, Chair in Technical Thermodynamics	
AGO, Kulmbach	
University of Stuttgart, Chair in Aviation Propulsions	
Siemens Power Generation, Duisburg	
ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	
Technical University of Cottbus,	
Voith Paper Air Systems, Bayreuth	
Egger Holzwerkstoffe, Wismar	
Tissue Europe Technologie, Mannheim	
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
National Energy Technology Laboratory, Pittsburg, USA	10/2007
Energieversorgung Halle	
AL-KO, Jettingen	
Grenzebach BSH, Bad Hersfeld	

Wiesbaden University of Applied Sciences, Endress+Hauser Messtechnik, Hannover	11/2007
University of Rostock, Chair in Technical Thermodynamics	
Siemens Power Generation, Erlangen	
Munich University of Applied Sciences, Rerum Cognitio, Zwickau	12/2007
University of Rostock, Chair in Technical Thermodynamics	

2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	
NUTEC Engineering, Bisikon, Switzerland	
Conwel eco, Bochov, Czech Republic	
Offenburg University of Applied Sciences	
KOCH Transporttechnik, Wadgassen	
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, University of Stuttgart,	
Siemens Power Generation, Erlangen	
Technical University of Munich,	
Chair in Apparatus and Plant Engineering	
Energietechnik Leipzig (company license),	
Siemens Power Generation, Erlangen	03/2006
RWE Power, Essen	
WAETAS, Pobershau	04/2006
NUTEC Engineering, Bisikon, Switzerland	
Siemens Power Generation, Goerlitz	
Technical University of Braunschweig,	
EnviCon & Plant Engineering, Nuremberg	
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Technical University of Dresden,	
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	
Suedzucker, Ochsenfurt	06/2006
M&M Turbine Technology, Bielefeld	
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	
Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	
Konstanz University of Applied Sciences, Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	
Wismar University of Applied Sciences, Seafaring Department	
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	
Electrowatt-EKONO, Zurich, Switzerland	
FCIT, Stuttgart	
Energietechnik Leipzig (company license)	
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	
Technical University of Dresden	
Energietechnik Leipzig (company license)	
Grenzebach BSH, Bad Hersfeld	
TUEV Nord, Hamburg	
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	
Duesseldorf University of Applied Sciences,	
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	
Alensys Engineering, Erkner	07/2005
Energietechnik Leipzig (company license)	
Stadtwerke Leipzig	
SaarEnergie, Saarbruecken	
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	
Vattenfall Europe, Berlin (group license)	
Technical University of Berlin	10/2005
Basel University of Applied Sciences,	
Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	
KEMA IEV, Dresden	

2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	
University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	
Siemens AG Power Generation, Erlangen	
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	
Technical University of Dresden,	
Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	
University of Saarbruecken	4
Grenzebach BSH, Bad Hersfeld	
SOFBID Zwingenberg (general EBSILON program license)	
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	
Mainova Frankfurt	
Rietschle Energieplaner, Winterthur, Switzerland	
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	
University of Weimar	
Visteon, Kerpen	
energeticals (e-concept), Munich	11/2004
SorTech, Halle	
Enertech EUT, Radebeul (company license)	
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	
Technical University of Cottbus, Chair in Power Plant Engineering	
STEAG Kraftwerk, Herne	
Freudenberg Service, Weinheim	

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	
Wulff Energy Systems, Husum	
Technip Benelux BV, Zoetermeer, Netherlands	
ALSTOM Power, Baden, Switzerland	
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	
SOFBID ,Zwingenberg (general EBSILON program license)	
Ingenieurbuero Ostendorf, Gummersbach	
TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	
University of Cali, Colombia	07/2003
ALSTOM Power, Baden, Switzerland	
Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	
STEAG RKB, Leuna	
eta Energieberatung, Pfaffenhofen	
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	
Energie, Timelkam, Austria	
Electrowatt-EKONO, Zurich, Switzerland	
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	
EnviCon & Plant Engineering, Nuremberg	11/2003

Visteon, Kerpen	
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	
Stadtwerke Hannover	
SaarEnergie, Saarbruecken	
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences,	
SorTech, Freiburg	
Mainova, Frankfurt	
Energieversorgung Halle	

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Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences,	
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe	
FZR Forschungszentrum, Rossendorf/Dresden	03/2002
CompAir, Simmern	
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
ALSTOM Power Baden, Switzerland (group licenses)	05/2002
InfraServ, Gendorf	
SoftSolutions, Muehlhausen (company license)	
DREWAG, Dresden (company license)	
SOFBID, Zwingenberg (general EBSILON program license)	06/2002
Kleemann Engineering, Dresden	
Caliqua, Basel, Switzerland (company license)	07/2002
PCK Raffinerie, Schwedt (group license)	
Fischer-Uhrig Engineering, Berlin	08/2002
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	
Stadtwerke Duisburg	
Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin	

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ALSTOM Power, Baden, Switzerland	01/2001
KW2 B. V., Amersfoot, Netherlands	
Eco Design, Saitamaken, Japan	
M&M Turbine Technology, Bielefeld	
MVV Energie, Mannheim	02/2001
Technical University of Dresden	
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	

ALSTOM Power, Baden, Switzerland	06/2001
Siemens, Karlsruhegeneral license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	
M&M Turbine Technology, Bielefeld	
Electrowatt-EKONO, Zurich, Switzerland	
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
KW2 B. V., Amersfoot, Netherlands	
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	

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SOFBID, Zwingenberg (general EBSILON program license)	01/2000
AG KKK - PGW Turbo, Leipzig	
PREUSSAG NOELL, Wuerzburg	
M&M Turbine Technology, Bielefeld	
IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	
UMAG W. UDE, Husum	
VEAG, Berlin (group license)	
Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000
DVO Data Processing Service, Oberhausen	
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
SaarEnergie, Saarbruecken	
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
Steinhaus Informationssysteme, Dattelngeneral license for process data software)	12/2000

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

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

B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin	
NUTEC Engineering, Bisikon, Switzerland	10/1998
SCA Hygiene Products, Munich	
RWE Energie, Neurath	
Wilhelmshaven University of Applied Sciences	
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	

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