

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

**FluidEES  
with LibldGas  
for Engineering Equation Solver<sup>®</sup>**

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# **Software for the Calculation of the Properties of Combustion Gas Mixtures calculated from VDI-Guideline 4670**

**FluidEES  
LibIdGas**

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## **0 Package Contents**

**Zip-file "CD\_FluidEES\_LibIdGas.zip" includes the following files:**

FluidEES_LibIdGas_Setup.exe	- Self-extracting and self-installing program
LibIdGas.dll	- DLL with functions of the LibIdGas library
FluidEES_LibIdGas_Docu.pdf	- User's Guide
LibIDGAS.chm	- Help file for the LibIdGas property 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 <sub>2</sub>
4	Oxygen	O <sub>2</sub>
5	Carbon monoxide	CO
6	Carbon dioxide	CO <sub>2</sub>
7	Steam	H <sub>2</sub> O
8	Sulfur dioxide	SO <sub>2</sub>
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 <sup>2</sup> /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	kJ/(kg · 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	kJ/(kg · 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	Pa·s = kg/(m·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	W/(m · 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 <sup>2</sup> /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	kJ/(kg · 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 <sup>3</sup>	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	m³/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 <sub>2</sub>
4	Oxygen	O <sub>2</sub>
5	Carbon monoxide	CO
6	Carbon dioxide	CO <sub>2</sub>
7	Steam	H <sub>2</sub> O
8	Sulfur dioxide	SO <sub>2</sub>
9	Air (dry) from VDI4670 [21]	Composition in mole fractions: 78.1109 % N <sub>2</sub> 20.9548 % O <sub>2</sub> 0.9343 % Ar Composition in mass fractions: 75.5577 % N <sub>2</sub> 23.1535 % O <sub>2</sub> , 1.2888 % Ar
10	Air nitrogen from Brandt [15]	Composition in mole fractions: 98.8180 % N <sub>2</sub> 1.1820 % Ar Composition in mass fractions: 98.3229 % N <sub>2</sub> 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. Add-In FluidEES for Engineering Equation Solver®**

The FluidEES Add-In has been developed to conveniently calculate thermodynamic properties in the Engineering Equation Solver® (EES). Within EES®, it enables the direct call of functions relating to ideal gases and gas mixtures from the LibIDGAS property library.

### **2.1 Installing FluidEES including LibIDGAS**

In this section, the installation of FluidEES LibIDGAS is described.

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

After you have downloaded and extracted the zip-file "CD\_FluidEES\_LibIDGAS.zip", you will see the folder

CD\_FluidEES\_LibIDGAS

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

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

Within this folder you will see the following three files:

FluidEES\_LibIDGAS\_Docu\_Eng.pdf

FluidEES\_LibIDGAS\_Setup.exe

LibIDGAS.ctx

LibIDGAS.dll.

LibIDGAS.chm

In order to run the installation of FluidEES including the LibIDGAS property library, first double-click the file

FluidEES\_LibIDGAS\_Setup.exe.

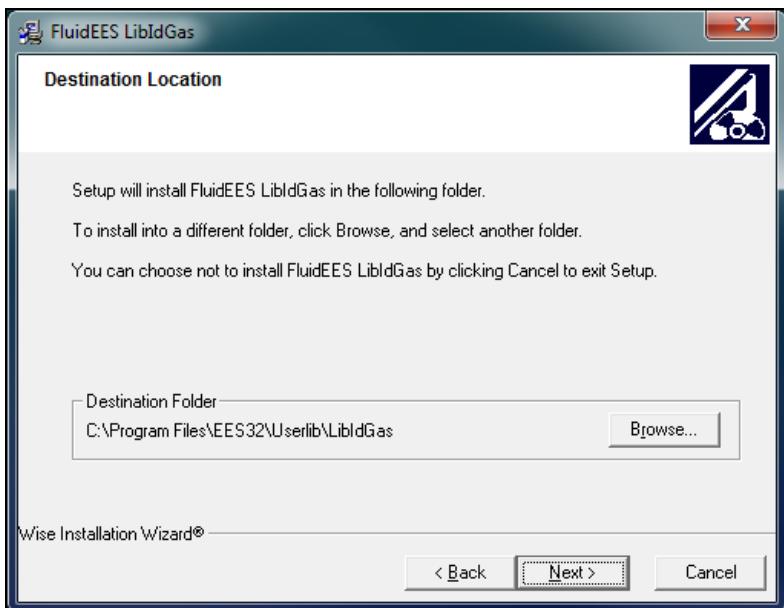
Installation may start with a window noting that all Windows® programs should be closed.

When this is the case, the installation can be continued. Click the "Next >" button.

In the following dialog box, "Destination Location" (see figure below), the default path where Engineering Equation Solver has been installed will be shown (the standard location is:

C:\Program Files\EES32\Userlib\LibIDGAS      (for English version of Windows)

C:\Programme\EES32\Userlib\LibIDGAS      (for German version of Windows)).



**Figure 2.1:** "Destination Location"

Click on "Next >" in the window "Destination Location."

Click on the "Next >" button in the "Start Installation" window.

The FluidEES files are now being copied into the "\LibIDGAS" folder on your hard drive.

Click the "Finish >" button in the next window to complete installation.

The installation program has copied the following files into the directory

"C:\Program Files\EES32\Userlib\LibIDGAS" (for English version of Windows)  
"C:\Programme\EES32\Userlib\LibIDGAS" (for German version of Windows):

advapi32.dll	- Dynamic link library for use in Windows® programs
Dformd.dll	- Dynamic link library for use in Windows® programs
Dforrt.dll	- Dynamic link library for use in Windows® programs
INSTALL.LOG	- Log file
LC.dll	- Dynamic link library for use in Windows® programs
LibIDGAS.ctx	- Interface including property functions of LibIDGAS for EES®
LibIDGAS.dll	- Dynamic link library with property functions of LibIDGAS
LibIDGAS.chm	- Help file of the LibIDGAS property library
msvcp60.dll	- Dynamic link library for use in Windows® programs
msvcrt.dll	- Dynamic link library for use in Windows® programs
UNWISE.EXE	- File to remove the LibIDGAS library
UNWISE.INI	- File to remove the LibIDGAS library

Now, you have to overwrite the files

LibIDGAS.ctx

LibIDGAS.dll

LibIDGAS.chm

in your Engineering Equation Solver directory with the files of the same name provided in your CD folder with FluidEES LibIDGAS.

To do this, open the CD folder in "My Computer" and hold the Ctrl key and click on the files

LibIDGAS.ctx

LibIDGAS.dll.

LibIDGAS.chm

in order to highlight them.

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

Now, open your EES directory (the standard being

"C:\Program Files\EES32\Userlib\LibIDGAS" (for English version of Windows)

"C:\Programme\EES32\Userlib\LibIDGAS" (for German version of Windows):

and insert the files 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 successfully overwritten the files

LibIDGAS.ctx

LibIDGAS.dll.

LibIDGAS.chm.

You can now select the LibIDGAS property functions from within Engineering Equation Solver®.

## 2.2 The FluidEES Help System

As mentioned earlier, FluidEES also provides detailed online help functions.

Information on individual property functions may be accessed via the following steps:

- Click "Options" in the EES menu bar and select "Function Info".
- The "Function Information" window will appear. Select "External routines" and double-click on the entry "LIBIDGAS.DLL".
- A list with calculable functions of the "LibIDGAS" library appears.
- Find and select the desired function, e.g. "h\_pt\_ID\_EES" and click the  button above.

If the "LibIDGAS.chm" function help cannot be found, confirm the question whether you want to look for it yourself with "Yes." Select the "LibIDGAS.chm" file in the installation menu of FluidEES in the window which is opened, the standard being

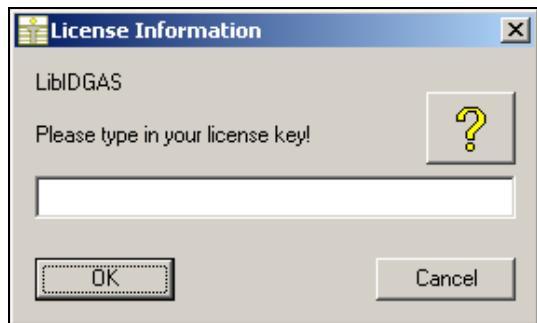
"C:\Program Files\EES32\Userlib\LibIDGAS" (for English version of Windows)

"C:\Programme\EES32\Userlib\LibIDGAS" (for German version of Windows)

and click "Yes" in order to complete the search.

## Licensing the LibIDGAS Property Library

The licensing procedure must be carried out when Engineering Equation Solver® starts up and a FluidEES prompt message appears. In this case, you will see the "License Information" window for LibIDGAS (see figure below).



**Figure 2.11:** "License Information" window

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



**Figure 2.12:** "Help" window

If you do not enter a valid license it is still possible to start EES® 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 use FluidEES LibIDGAS until you enter a license code to complete registration. If you decide not to use FluidEES LibIDGAS, you can uninstall the program following the instructions given in section 2.6 of this User's Guide.

With this procedure the LibIDGAS property library has been licensed.

## 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 pressure of  $p = 1$  bar and a temperature of  $t = 100$  °C for a given mixture composed of the following mass fractions using FluidEES with LibIDGAS in the Engineering Equation Solver®:

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

From the gas classification in the program library (table: mixture gases) in chapter 1.2 follows:

Gas	Number	Mass fraction
Carbon dioxide	6	$\xi_6 = 13\%$
Steam	7	$\xi_7 = 11\%$
Air nitrogen	10	$\xi_{10} = 76\%$

How to perform a calculation with FluidEES:

- Start Engineering Equation Solver® (EES).
- The LibIDGAS library, if installed, is loaded by the program automatically.
- We recommend preparing an EES® sheet, as shown in Figure 2.13.

Note: the units of  $p$ ,  $t$ , type, and comp must correspond to those in Chapter 1.

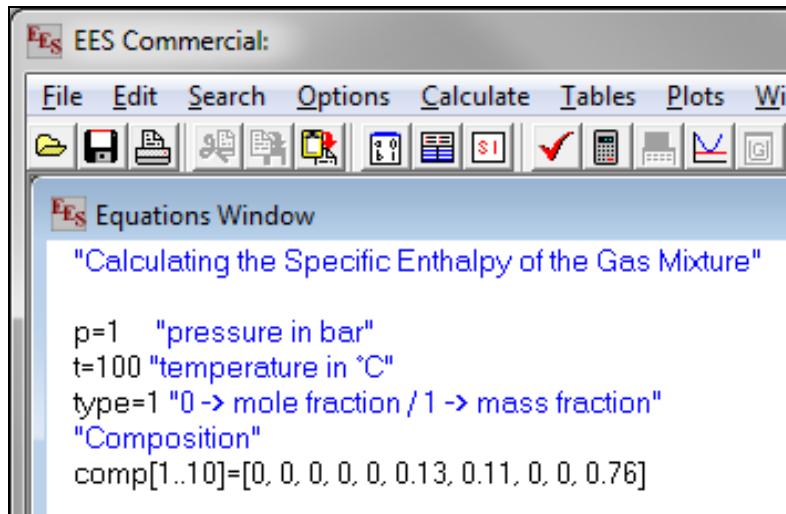


Figure 2.13: Preparing an EES® sheet for the calculation

- The function parameters values stand for:
  - First operand: Total pressure  $p = 1$  bar  
(Range of validity:  $p = 0.01$  mbar up to 50 bar)
  - Second operand: Temperature  $t = 100$  °C  
(Range of validity:  $t = -73.15$  °C ... 3026.85 °C)
  - Third operand: type = 1  
type = 1 for mass fractions  $\xi_1 \dots \xi_{10}$  as input value.  
type = 0 for mole fractions, i.e., volume fractions  $\psi_1 \dots \psi_{10}$  as input value

- Fourth operand: Vector for the composition

Enter: "comp[1..10]=[0, 0, 0, 0, 0, 0.13, 0.11, 0, 0, 0.76]"

The values stand for the appropriate gases:

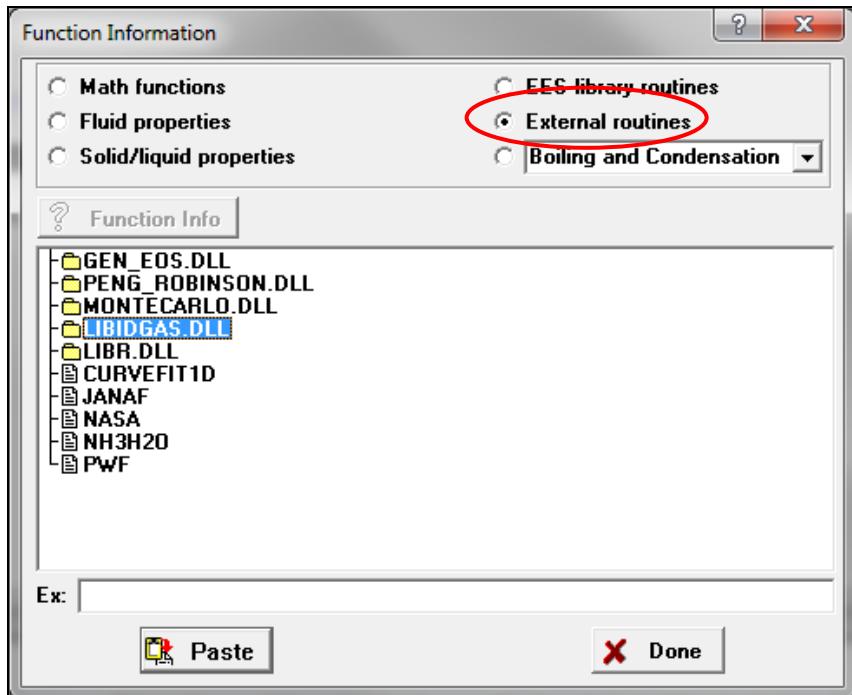
$\xi_1$ for argon	Ar	$\Rightarrow$ e. g.: Enter the value 0
$\xi_2$ for neon	Ne	$\Rightarrow$ e. g.: Enter the value 0
$\xi_3$ for nitrogen	N <sub>2</sub>	$\Rightarrow$ e. g.: Enter the value 0
$\xi_4$ for oxygen	O <sub>2</sub>	$\Rightarrow$ e. g.: Enter the value 0
$\xi_5$ for carbon monoxide	CO	$\Rightarrow$ e. g.: Enter the value 0
$\xi_6$ for carbon dioxide	CO <sub>2</sub>	$\Rightarrow$ e. g.: Enter the value 0.13
$\xi_7$ for steam	H <sub>2</sub> O	$\Rightarrow$ e. g.: Enter the value 0.11
$\xi_8$ for sulfur dioxide	SO <sub>2</sub>	$\Rightarrow$ e. g.: Enter the value 0
$\xi_9$ for air nitrogen (dry)		$\Rightarrow$ e. g.: Enter the value 0
$\xi_{10}$ for air nitrogen		$\Rightarrow$ e. g.: Enter the value 0.76

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

**Note:**

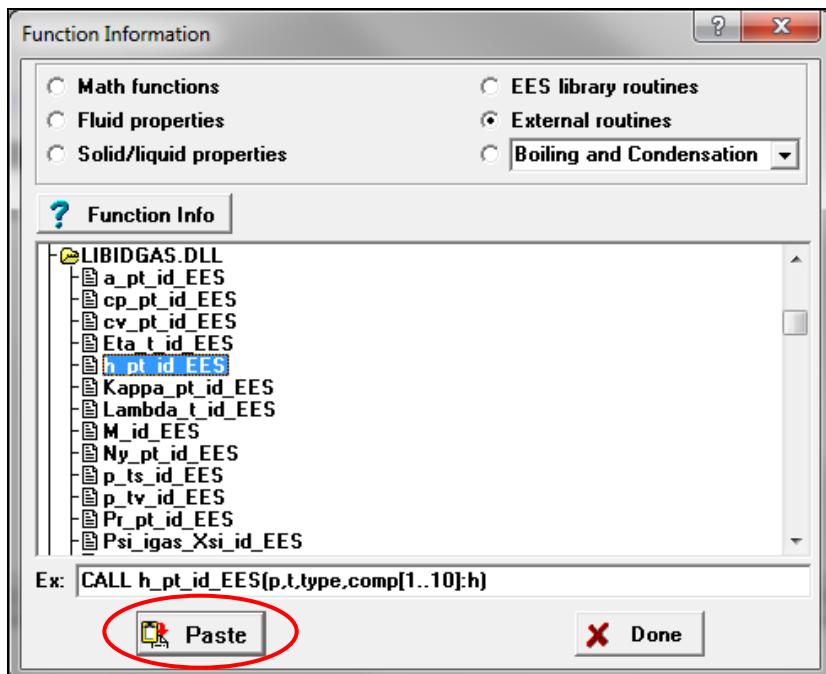
EES® adapts to the language that is set in the "Regional and Language Options," which can be found in the "Control Panel." If you run Engineering Equation Solver® on an English version of Windows®, the standard decimal separator will be a dot (as shown in Fig. 2.4.4 and in the following sample calculation). If your computer is set to German, for example, the expected decimal separator will be a comma. In this case enter a comma in the values above instead of a dot. To separate the input values of the different gases in the vector use a semicolon. You can find additional information on this issue by clicking on "Help" in the EES® menu bar and then select "Help Index". Click on "Search" in the window which appears, type "decimal separator" and press the "ENTER" key.

- For calculating  $h = f(p,t,comp)$ , call up the function "h\_pt\_id\_EES" of the property library LibIDGAS as follows:
- Click on "Options" in the EES® menu bar and select "Function Info".
- The "Function Information" window will appear. Select "External routines" and you will see the screen shown here in Figure 2.14.



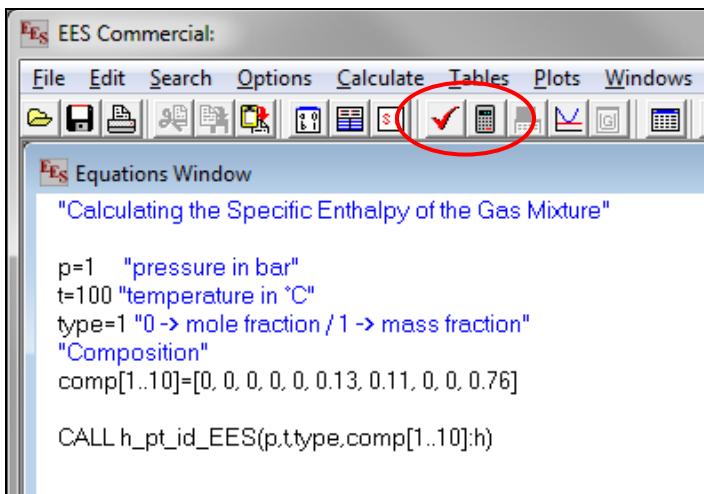
**Figure 2.14:** "Function Information" window offering different libraries (routines)

- Double-click on the entry "LIBIDGAS.DLL".
- A list with calculable functions of the "LibIDGAS" library appears.
- Find and select the desired function, here "h\_pt\_id\_EES" (see Figure 2.15), and click the "Paste" button below.



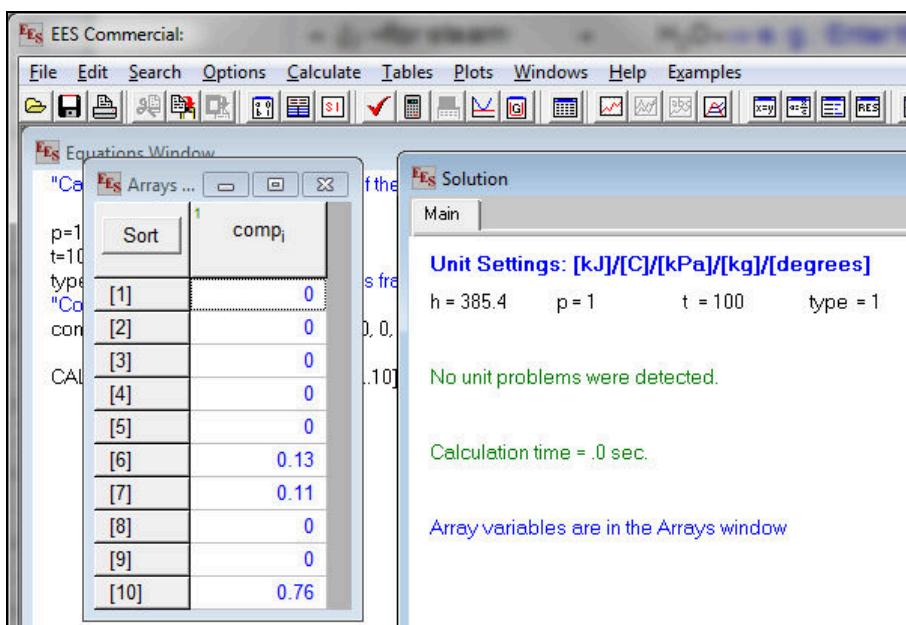
**Figure 2.15:** Selecting the "h\_pt\_id\_EES" function

- The selected function will be copied and appears in the "Equations Window" (see Fig. 2.16).



**Figure 2.16:** "Equations Window" with the call of the property function

- Now, you can check the syntax of the instructions in the "Equations Window" by clicking the  symbol in the upper menu bar of EES®. The program tests whether or not the syntax is correct (e.g. dots as decimal separators versus commas). Confirm the "Information" window which appears by clicking the "OK" button.
- Then click the  symbol in the upper menu bar of EES® to start the calculation.
- Soon you will see the "Calculations Completed" window. Leave this window by clicking the "Continue" button.
- The result for the specific enthalpy  $h$  appears in the "Solution" window (see Figure 2.17).



**Figure 2.17:** "Solution" window showing the result

The calculation of  $h = f(p,t,comp)$  has thus been carried out.

⇒ The result in our sample calculation here is: " $h = 385.4$ ". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

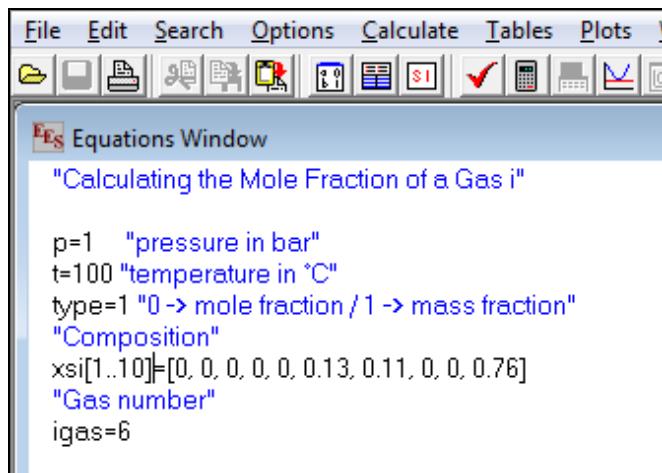
## Example: Calculation of the Mole Fraction $\psi_i = f(i, \xi_1 \dots \xi_{10})$ of a Gas $i$ in the Mixture

Resuming the example in part 2.4, we will now calculate the mole fraction of carbon dioxide ( $\text{CO}_2$ ). The values for the mass fractions  $\xi_1 \dots \xi_{10}$  have already been typed in the vector.

The following steps have to be carried out:

- Rename "comp" to "xsi" in front of the vector.
- Add a fifth operand with the gas number of the gas which is to be calculated below the four other operands in the "Equations Window".
  - Fifth operand:  $\text{igas} = 16$

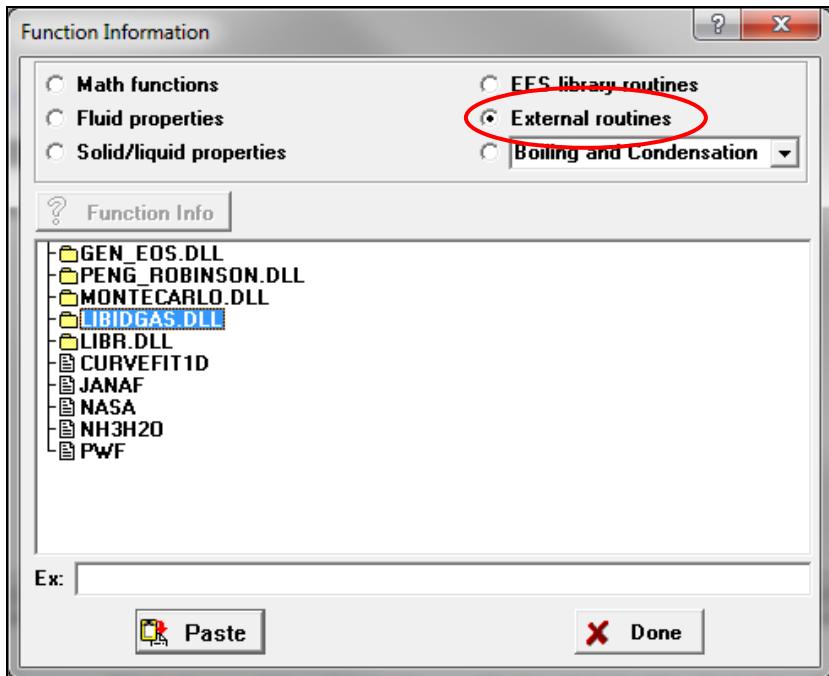
Your EES "Equations Window" should now look like this example:



```
File Edit Search Options Calculate Tables Plots 
EES Equations Window
"Calculating the Mole Fraction of a Gas i"
p=1 "pressure in bar"
t=100 "temperature in °C"
type=1 "0 -> mole fraction / 1 -> mass fraction"
"Composition"
xsi[1..10]=[0, 0, 0, 0, 0, 0.13, 0.11, 0, 0, 0.76]
"Gas number"
igas=6
```

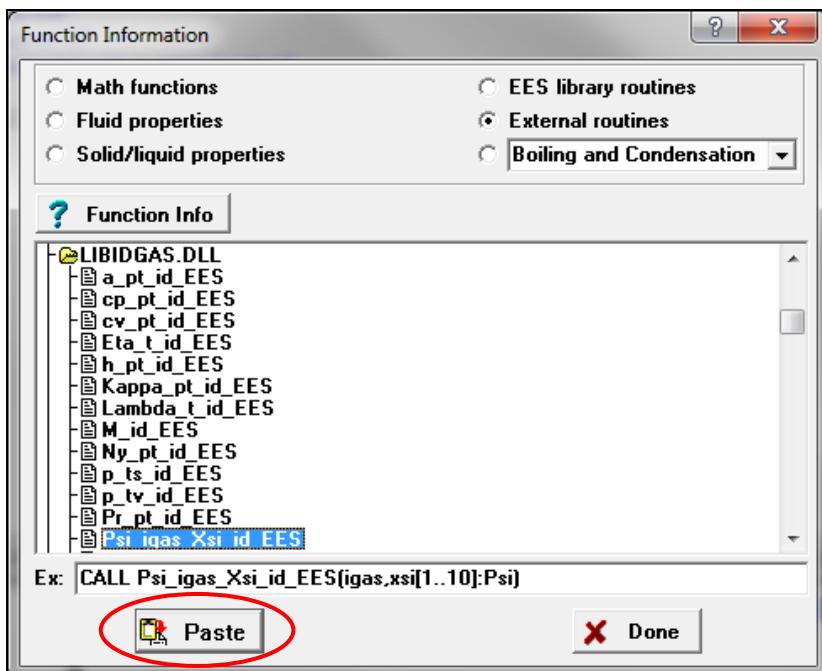
Figure 2.18: "Equations Window" including the fifth operand "Gas number"

- For calculating  $\psi_i = f(i, \text{comp})$ , call up the function "Psi\_igas\_Xsi\_id\_EES" of the property library LibIDGAS as follows:
- Click on "Options" in the EES® menu bar and select "Function Info".
- The "Function Information" window will appear. Select "External routines" and you will see the screen shown here in Figure 2.19.



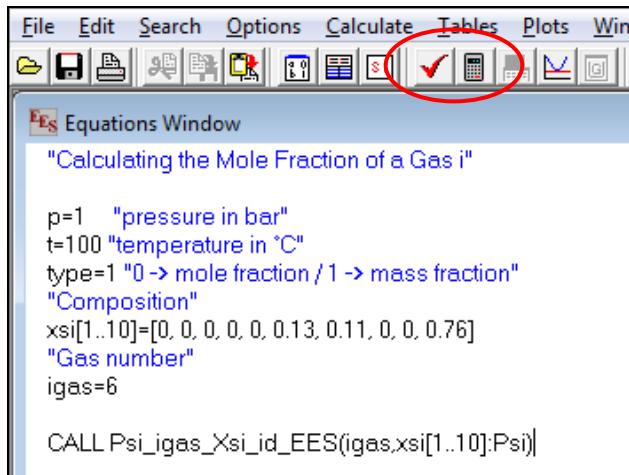
**Figure 2.19:** "Function Information" window offering different libraries (routines)

- Double-click on the entry "LIBIDGAS.DLL".
- A list with calculable functions of the "LibIDGAS" library appears.
- Find and select the desired function, here "Psi\_igas\_Xsi\_id\_EES" (see Figure 2.20), and click the "Paste" button below.



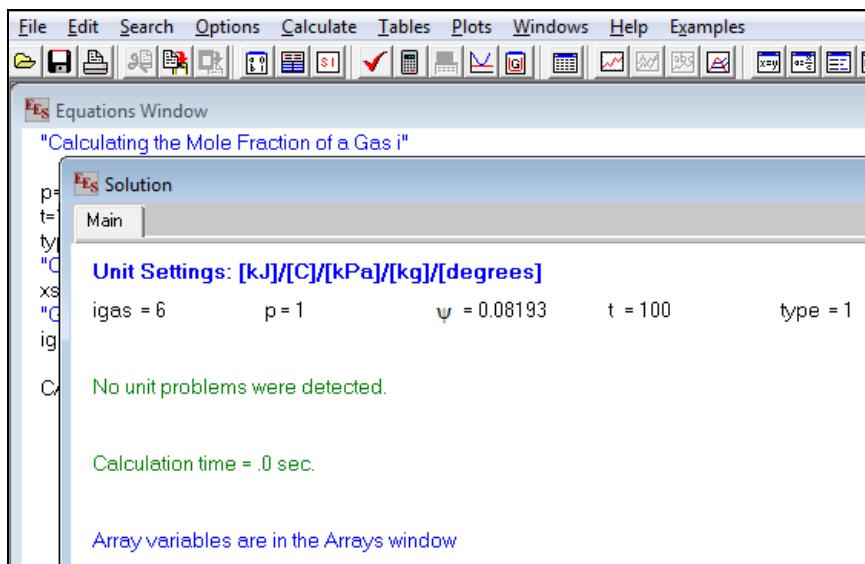
**Figure 2.20:** Selecting the "Psi\_igas\_Xsi\_id\_EES" function

- The selected function will be copied and now appears in the "Equations Window" (see Fig. 2.21).



**Figure 2.21:** "Equations Window" with the call of the property function

- Now, you can check the syntax of the instructions in the "Equations Window" by clicking the  symbol in the upper menu bar of EES®. The program tests whether or not the syntax is correct (e.g. dots as decimal separators versus commas). Confirm the "Information" window which appears by clicking the "OK" button.
- Then click the  symbol in the upper menu bar of EES® to start the calculation.
- Soon you will see the "Calculations Completed" window. Leave this window by clicking the "Continue" button.
- The result for the mole fraction  $\psi_i$  of carbon dioxide appears in the "Solution" window (see Fig. 2.22).



**Figure 2.22:** "Solution" window showing the result

The calculation of  $\psi_i = f(i, \text{comp})$  has thus been carried out.

⇒ The result in our sample calculation here is: " $\psi_i = 0.08193$ ". The corresponding unit is kmol/kmol (see table of the property functions in Chapter 1).

For further property functions calculable in FluidEES see the function table in Chapter 1.

## **2.4 Removing FluidEES including LibIDGAS**

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 "FluidEES LibIDGAS" by clicking on it and click the "Change/Remove" button.

In the following dialog box select "Automatic" and then click the "Next >" button.

Then confirm the menu "Perform Uninstall" by clicking the "Finish" button.

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

"FluidEES LibIDGAS" has now been removed.

### 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:

**REAL\*8 FUNCTION A\_PT\_ID(P,T,ART, ZU)**

for the call out of Fortran

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

**INTEGER\*4 ART**

Subprogram with parameter:

**INTEGER\*4 FUNCTION C\_A\_PT\_ID(A,P,T,ART, ZU)**

for the call out of the DLL

**REAL\*8 A, P, T, ZU(0:10)**

**INTEGER\*4 ART**

#### Input Values:

p - Mixture pressure  $p$  in bar

t - Temperature  $t$  in °C

type = 1 for composition in mass fractions  $\xi$

= 0 for composition in mole fractions  $\psi$

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  $\text{m}^2/\text{s}$

#### 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:

$\lambda$  corresponding to Brandt [15]

$c_p$  corresponding to VDI 4670 [18]

$\rho$  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:  
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 ART
```

### Input Values:

p	- Mixture pressure $p$ in bar
t	- Temperature $t$ in °C
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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  $\psi_{H_2O} \geq 0.1$

### 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 ART**

### Input Values:

p                    - Mixture pressure  $p$  in bar  
 t                    - Temperature  $t$  in °C  
 type                =1 for composition in mass fractions  $\xi$   
                      =0 for composition in mole fractions  $\psi$   
 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:  
 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 ART

### Input Values:

t                                    - Temperature  $t$  in °C  
 type                                =1 for composition in mass fractions  $\xi$   
                                       =0 for composition in mole fractions  $\psi$   
 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 according to *Brandt*

### Results for wrong input values:

Eta\_t\_id, Eta = -1

### References:

Unsaturated and saturated humid air:

$\eta$  corresponding to *Brandt* [15]

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

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 ART

### Input Values:

p	- Mixture pressure $p$ in bar
t	- Temperature $t$ in °C
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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  $\psi_{H_2O} \geq 0.1$

### 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:  
 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 ART**

### Input Values:

- p - Mixture pressure  $p$  in bar
- t - Temperature  $t$  in °C
- type
  - =1 for composition in mass fractions  $\xi$
  - =0 for composition in mole fractions  $\psi$
- 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 ART

### Input Values:

- t                   - Temperature  $t$  in °C
- type               =1 for composition in mass fractions  $\xi$   
                      =0 for composition in mole fractions  $\psi$
- 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 according *Brandt*

### Results for wrong input values:

Lambda\_t\_id, Lambda = -1

### References:

Unsaturated and saturated humid air:

$\lambda$  corresponding to *Brandt* [15]

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

Function Name:	<b>M_id</b>
Subprogram with value of the function: for the call out of Fortran	<b>REAL*8 FUNCTION M_ID(ART, COMP)</b> REAL*8 COMP(0:10) INTEGER*4 ART
Subprogram with parameter: for the call out of the DLL	<b>INTEGER*4 FUNCTION C_M_ID(M,ART, COMP)</b> REAL*8 M, COMP(0:10) INTEGER*4 ART

### Input Values:

type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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:  
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 ART
```

### Input Values:

- p - Mixture pressure  $p$  in bar
- t - Temperature  $t$  in °C
- type  
=1 for composition in mass fractions  $\xi$   
=0 for composition in mole fractions  $\psi$
- 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  $\text{m}^2/\text{s}$

### 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:

$\eta$  corresponding to Brandt [15]

$\rho$  for ideal gas mixture

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

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 ART

### Input Values:

t	- Temperature $t$ in °C
s	- Specific Entropy in kJ/(kg K)
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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:

- Calculation according to *Brandt* considering 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:  
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 ART

### **Input Values:**

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

### **Result:**

**p\_tv\_id**, v - Mixture pressure in bar

### **Range of Validity:**

Temperature  $t$ : from – 73.15  $^\circ\text{C}$  to 3026.85  $^\circ\text{C}$

Specific volume  $v$ : from 5.1  $\text{m}^3/\text{kg}$  to 2.9 109  $\text{m}^3/\text{kg}$

### **Comments:**

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

### **Results for wrong input values:**

**p\_tv\_id**, p = -1

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

Function Name:

**Pr\_pt\_id**

Subprogram with value of the function:  
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 ART

### Input Values:

p	- Mixture pressure $p$ in bar
t	- Temperature $t$ in °C
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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:

$\lambda$  corresponding to Brandt [15]

$\eta$  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 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:  $\psi_i = \frac{R_i}{\sum(\xi_j \cdot R_j)} \cdot \xi_i$

### 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:  
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 ART
```

### Input Values:

type                   =1 for composition in mass fractions  $\xi$   
                        =0 for composition in mole fractions  $\psi$

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:

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

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

### Results for wrong input values:

R\_id, R = -1

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

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 ART

### **Input Values:**

- p                   - Mixture pressure  $p$  in bar
- t                   - Temperature  $t$  in °C
- type               =1 for composition in mass fractions  $\xi$   
                      =0 for composition in mole fractions  $\psi$
- 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/m<sup>3</sup>

### **Range of Validity:**

Mixture pressure  $p$ : from 0.01 mbar to 50 bar

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

### **Comments:**

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

### **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 ART**

### Input Values:

- p - Mixture pressure  $p$  in bar
- t - Temperature  $t$  in °C
- type =1 for composition in mass fractions  $\xi$   
=0 for composition in mole fractions  $\psi$
- 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  $\psi_{H_2O} \geq 0.1$

### Results for wrong input values:

**s\_pt\_id, s = -1**

### References:

s corresponding to VDI 4670 [18]

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

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 ART

### Input Values:

p	- Mixture pressure $p$ in bar
h	- Enthalpy $h$ in kJ/kg
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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:  
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 ART

### Input Values:

p	- Mixture pressure $p$ in bar
s	- Entropy $s$ in kJ/(kg K)
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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:  
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 ART**

### Input Values:

p                    - Mixture pressure  $p$  in bar  
v                    - Specific volume  $v$  in  $\text{m}^3/\text{kg}$   
type                =1 for composition in mass fractions  $\xi$   
                      =0 for composition in mole fractions  $\psi$   
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  $2.9 \text{ 109 m}^3/\text{kg}$

### Comments:

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

### Results for wrong input values:

**t\_pv\_id, t = -1**

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

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 ART**

### Input Values:

p	- Mixture pressure $p$ in bar
t	- Temperature $t$ in °C
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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:  
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 ART**

### Input Values:

p                    - Mixture pressure  $p$  in bar  
t                    - Temperature  $t$  in °C  
type                =1 for composition in mass fractions  $\xi$   
                      =0 for composition in mole fractions  $\psi$   
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  $\text{m}^3/\text{kg}$

### Range of Validity:

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

### Comments:

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

### 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 ART

### Input Values:

p	- Mixture pressure $p$ in bar
t	- Temperature $t$ in °C
type	=1 for composition in mass fractions $\xi$ =0 for composition in mole fractions $\psi$
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:  
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 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:

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

### Results for wrong input values:

Xsi\_igas\_Psi\_id, Xsi = -1

## 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 Thermo-dynamic 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:  
 $\text{CO}_2$  - Span, Wagner     $\text{H}_2\text{O}$  - IAPWS-95  
 $\text{O}_2$  - Schmidt, Wagner     $\text{N}_2$  - Span et al.  
 Ar - Tegeler et al.

and of the ideal gases:

$\text{SO}_2$ ,  $\text{CO}$ ,  $\text{Ne}$   
 (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	$\text{H}_2\text{O}$	$\text{F}_2$	Propane
$\text{N}_2$	$\text{SO}_2$	$\text{NH}_3$	Iso-Butane
$\text{O}_2$	$\text{H}_2$	Methane	n-Butane
CO	$\text{H}_2\text{S}$	Ethane	Benzene
$\text{CO}_2$	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](http://www.ashrae.org/bookstore)

### 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

$\text{C}_2\text{H}_6\text{O}_2$	Ethylene glycol
$\text{C}_3\text{H}_8\text{O}_2$	Propylene glycol
$\text{C}_2\text{H}_5\text{OH}$	Ethanol
$\text{CH}_3\text{OH}$	Methanol
$\text{C}_3\text{H}_8\text{O}_3$	Glycerol
$\text{K}_2\text{CO}_3$	Potassium carbonate
$\text{CaCl}_2$	Calcium chloride
$\text{MgCl}_2$	Magnesium chloride
$\text{NaCl}$	Sodium chloride
$\text{C}_2\text{H}_3\text{KO}_2$	Potassium acetate
$\text{CHKO}_2$	Potassium formate
$\text{LiCl}$	Lithium chloride
$\text{NH}_3$	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

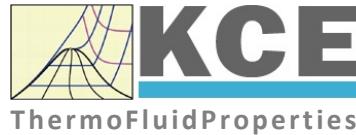
Hydrogen sulfide  $H_2S$  Library LibH2S

Nitrous oxide  $N_2O$  Library LibN2O

Sulfur dioxide  $SO_2$  Library LibSO2

Acetone  $C_3H_6O$  Library LibC3H6O

Formulation of Lemmon and Span (2006)



## For more information please contact:

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## The following thermodynamic and transport properties can be calculated<sup>a</sup>:

### Thermodynamic Properties

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

### Transport Properties

- Dynamic viscosity  $\eta$
- Kinematic viscosity  $\nu$
- Thermal conductivity  $\lambda$
- Prandtl number  $Pr$
- Thermal diffusivity  $a$

### Backward Functions

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

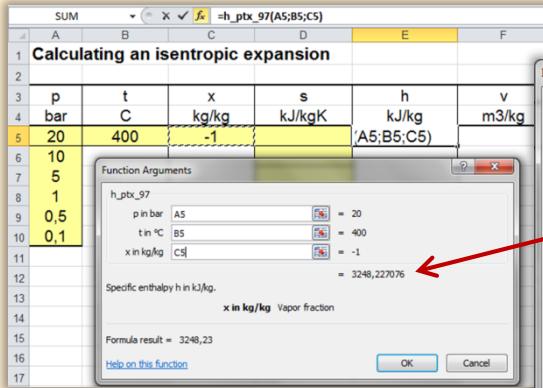
### Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

<sup>a</sup> Not all of these property functions are available in all property libraries.

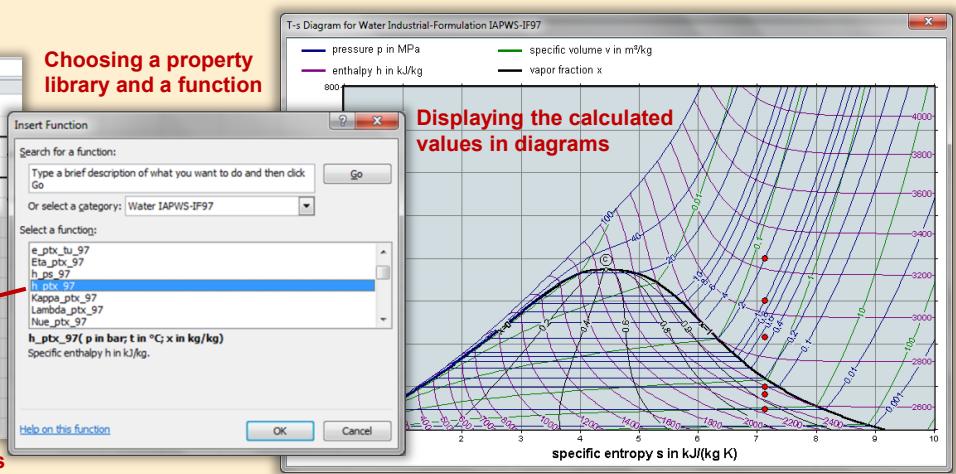
## Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

### Add-In FluidEXL Graphics for Excel®



Menu for the input of given property values

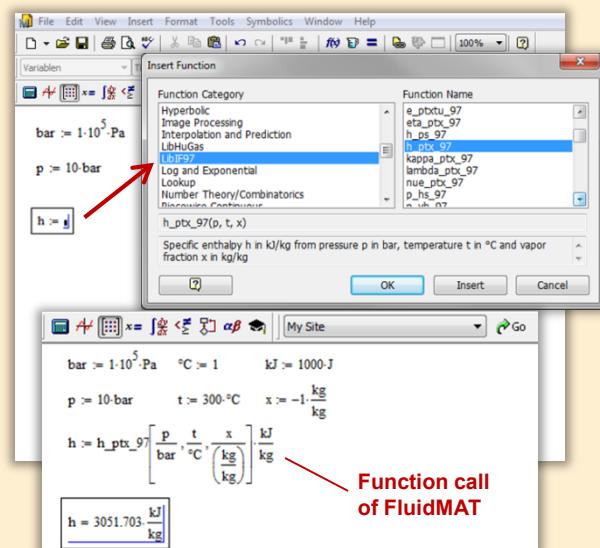
Choosing a property library and a function



### Add-On FluidMAT for Mathcad®

### Add-On FluidPRIME for Mathcad Prime®

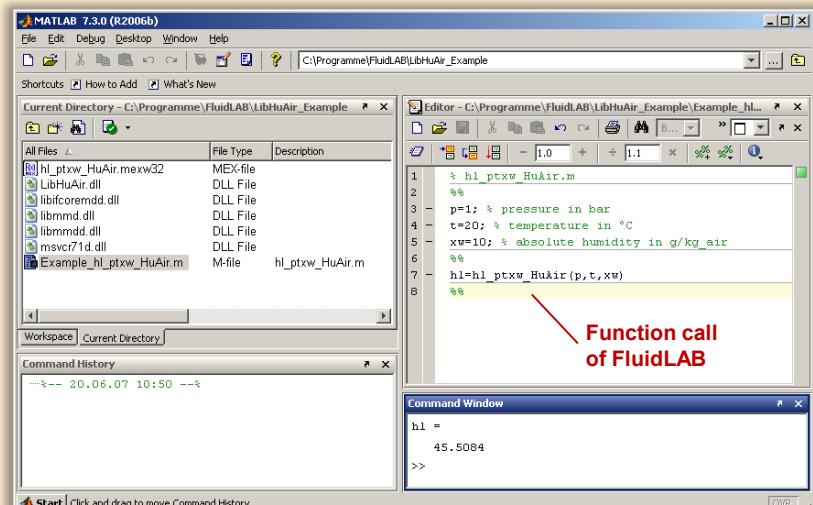
The property libraries can be used in Mathcad® and Mathcad Prime®.



Function call of FluidMAT

### Add-On FluidLAB for MATLAB® and SIMULINK®

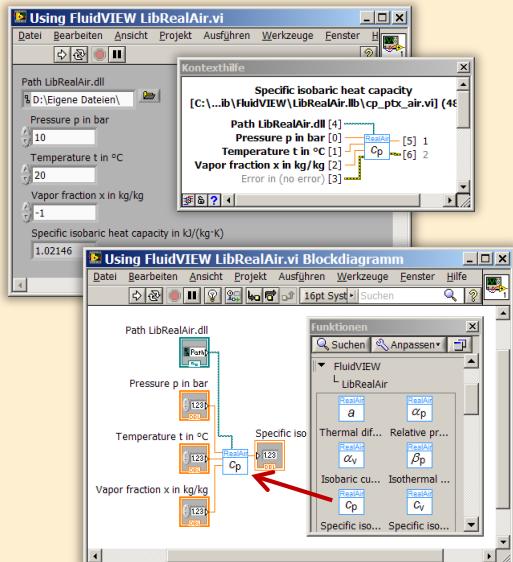
Using the Add-In FluidLAB the property functions can be called in MATLAB® and SIMULINK®.



Function call of FluidLAB

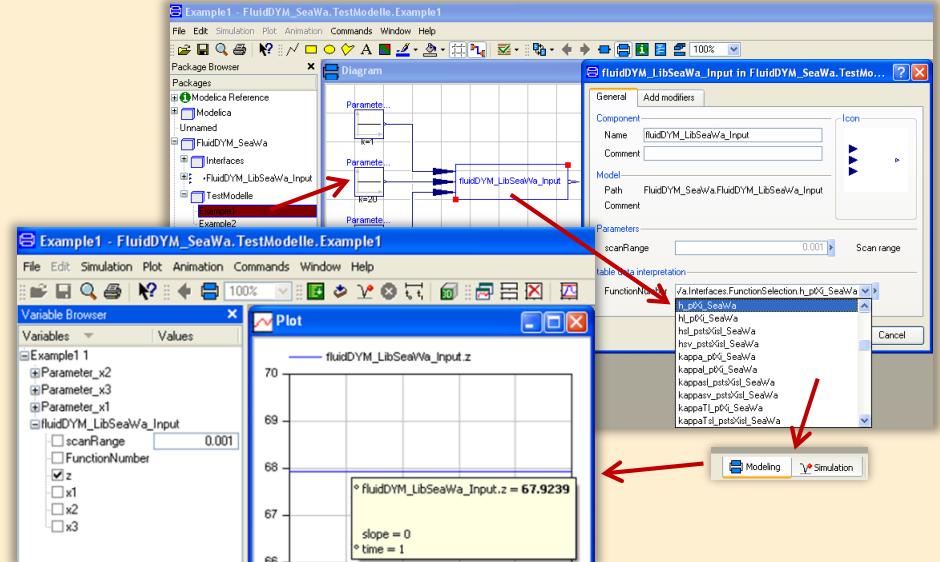
### Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

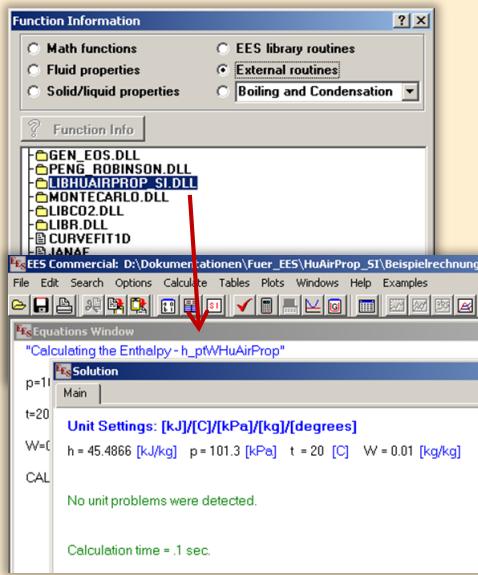


### Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

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



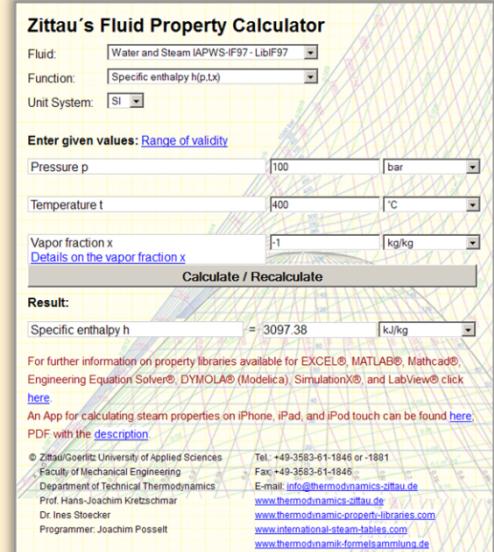
## Add-On FluidEES for Engineering Equation Solver®



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



## Online Property Calculator at [www.thermofluidprop.com](http://www.thermofluidprop.com)

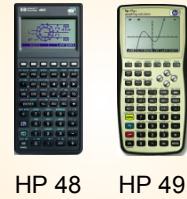


## Property Software for Pocket Calculators

### FluidCasio



### FluidHP



### FluidTI



## For more information please contact:



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Fax: +49-3222-1095810

The following thermodynamic and transport properties<sup>a</sup> 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  $\rho$
- Specific volume  $v$
- Enthalpy  $h$
- Internal energy  $u$
- Entropy  $s$
- Exergy  $e$
- Isobaric heat capacity  $c_p$
- Isochoric heat capacity  $c_v$
- Isentropic exponent  $\kappa$
- Speed of sound  $w$
- Surface tension  $\sigma$

### Transport Properties

- Dynamic viscosity  $\eta$
- Kinematic viscosity  $\nu$
- Thermal conductivity  $\lambda$
- 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.

<sup>a</sup> Not all of these property functions are available in all property libraries.

## 5. References

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## 6. Satisfied Customers

Date: 07/2019

The following companies and institutions use the property libraries:

- FluidEXL<sup>Graphics</sup> for Excel®
- 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™
- DLLs for Windows™
- Shared Objects for Linux®.

### 2019

WARNICA, Waterloo, Canada	07/2019
MIBRAG, Zeitz	06/2019
Pöry, Zürich, Switzerland	06/2019
RWTH Aachen, Inst. Strahlantriebe und Turbomaschinen	06/2019
Midiplan, Bietigheim-Bissingen	06/2019
GKS Schweinfurt	06/2019
HS Zittau/Görlitz, Wirtschaftswissenschaften und Wirtschaftsingenieurwesen	06/2019
ILK Dresden	06/2019
HZDR Helmholtz Zentrum Dresden-Rossendorf	06/2019
TH Köln, TGA	05/2019
IB Knittel, Braunschweig	05/2019
Norsk Energi, Oslo, Norway	05/2019
STEAG Essen	05/2019
Stora Enso, Eilenburg	05/2019
IB Lücke, Paderborn	05/2019
Haarslev, Sonderso, Denmark	05/2019
MAN Augsburg	05/2019
Wieland Werke, Ulm	04/2019
Fels-Werke, Elbingerode	04/2019
Univ. Luxembourg Luxembourg	04/2019
BTU Cottbus, Power Engineering	03/2009
Eins-Energie Sachsen, Schwarzenberg	03/2019
TU Dresden, Kälte- und Kryotechnik	03/2019
ITER, St. Paul Lez Durance Cedex, France	03/2019
Fraunhofer UMSICHT, Oberhausen	03/2019
Comparex Leipzig for Spedition Thiele HEMMERSBACH	03/2019
Rückert NaturGas, Lauf/Pegnitz	03/2019
BASF, Basel, Switzerland	02/2019
Stadtwerke Leipzig	02/2019

Maerz Ofenbau Zürich, Switzerland	02/2019
Hanon Systems Germany, Kerpen	02/2019
Thermofin, Heinsdorfergrund	01/2019
BSH Berlin	01/2019

## 2018

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

## 2017

Compact Kältetechnik, Dresden	12/2017
Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	12/2017
TH Mittelhessen, Gießen	11/2017
Haarslev Industries, Søndersø, Denmark	11/2017
Hochschule Zittau/Görlitz, Fachgebiet Energiesystemtechnik	11/2017
ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	10/2017
Fels-Werke GmbH, Elbingerode	10/2017

KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik	09/2017
Air-Consult, Jena	09/2017
Papierfabrik Koehler, Oberkirch	09/2017
ZWILAG, Würenlingen, Switzerland	09/2017
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017
Fichtner IT Consulting AG, Stuttgart	07/2017
Hochschule Ansbach, Ansbach	06/2017
RONAL, Härkingen, Switzerland	06/2017
BORSIG Service, Berlin	06/2017
BOGE Kompressoren, Bielefeld	06/2017
STEAG Energy Services, Zwingenberg	06/2017
CES clean energy solutions, Wien, Austria	04/2017
Princeton University, Princeton, USA	04/2017
B2P Bio-to-Power, Wadersloh	04/2017
TU Dresden, Institute for Energy Engineering, Dresden	04/2017
SAINT-GOBAIN, Vaujours, France	03/2017
TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
SCHMIDT + PARTNER, Therwil, Switzerland	03/2017
KAESER Kompressoren, Gera	03/2017
F&R, Praha, Czech Republic	03/2017
ULT Umwelt-Lufttechnik, Löbau	02/2017
JS Energie & Beratung, Erding	02/2017
Kelvion Brazed PHE, Nobitz-Wilchwitz	02/2017
MTU Aero Engines, München	02/2017
Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	01/2017
SHELL Deutschland Oil, Wesseling	01/2017
MARTEC Education Center, Frederikshaven, Denmark	01/2017
SynErgy Thermal Management, Krefeld	01/2017

## 2016

BOGE Druckluftsysteme, Bielefeld	12/2016
BFT Planung, Aachen	11/2016
Midiplan, Bietigheim-Bissingen	11/2016
BBE Barnich IB	11/2016
Wenisch IB,	11/2016
INL, Idaho Falls	11/2016
TU Kältetechnik, Dresden	11/2016
Kopf SynGas, Sulz	11/2016
INTVEN, Bellevue (USA)	11/2016
DREWAG Dresden, Dresden	10/2016
AGO AG Energie+Anlagen, Kulmbach	10/2016
Universität Stuttgart, ITW, Stuttgart	09/2016
Pöry Deutschland GmbH, Dresden	09/2016
Siemens AG, Erlangen	09/2016
BASF über Fichtner IT Consulting AG	09/2016
B+B Engineering GmbH, Magdeburg	09/2016
Wilhelm Büchner Hochschule, Pfungstadt	08/2016

Webasto Thermo & Comfort SE, Gliching	08/2016
TU Dresden, Dresden	08/2016
Endress+Hauser Messtechnik GmbH+Co. KG, Hannover	08/2016
D + B Kältetechnik, Althausen	07/2016
Fichtner IT Consulting AG, Stuttgart	07/2016
AB Electrolux, Krakow, Poland	07/2016
ENEXIO Germany GmbH, Herne	07/2016
VPC GmbH, Vetschau/Spreewald	07/2016
INWAT, Lodz, Poland	07/2016
E.ON SE, Düsseldorf	07/2016
Planungsbüro Waidhas GmbH, Chemnitz	07/2016
EEB Enerko, Aldershoven	07/2016
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	07/2016
SSP Kälteplaner AG, Wolfertschwenden	07/2016
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	07/2016
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
Universidad Carlos III de Madrid, Madrid, Spain	04/2016
INWAT, Lodz, Poland	04/2016
Planungsbüro WAIDHAS GmbH, Chemnitz	04/2016
STEAG Energy Services GmbH, Laszlo Küppers, Zwingenberg	03/2016
WULFF & UMAG Energy Solutions GmbH, Husum	03/2016
FH Bielefeld, Bielefeld	03/2016
EWT Eckert Wassertechnik GmbH, Celle	03/2016
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016, 06/2016
IEV KEMA - DNV GV – Energie, Dresden	02/2016
Allborg University, Department of Energie, Aalborg, Denmark	02/2016
G.A.M. Heat GmbH, Gräfenhainichen	02/2016
Institut für Luft- und Kältetechnik, Dresden	02/2016, 05/2016, 06/2016
Bosch, Stuttgart	02/2016
INL Idaho National Laboratory, Idaho, USA	11/2016, 01/2016
Friedl ID, Wien, Austria	01/2016
Technical University of Dresden, Dresden	01/2016

## 2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	12/2015
Allborg University, Department of Energie, Aalborg, Denmark	12/2015
University of Lyubljana, Slovenia	12/2015
Steinbrecht IB, Berlin	11/2015
Universidad Carlos III de Madrid, Madrid, Spain	11/2015
STEAK, Essen	11/2015
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	07/2015
ILK, Dresden	07/2015
Schniewindt GmbH & Co. KG, Neuenwalde	08/2015

## 2014

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

## 2013

TRANTER-GmbH, Artern	12/2013
SATAKE, Shanghai, China	12/2013
VOITH, Kunshan, China	12/2013
ULT, Löbau	12/2013
MAN, Copenhagen, Dänemark	11/2013
DREWAG, Dresden	11/2013
Haarslev Industries, Herlev, Dänemark	11/2013
STEAG, Herne	11/2013, 12/2013
Ingersoll-Rand, Oberhausen	11/2013
Wilhelm-Büchner HS, Darmstadt	10/2013
IAV, Chemnitz	10/2013
Technical University of Regensburg	10/2013
PD-Energy, Bitterfeld	09/2013
Thermofin, Heinsdorfergrund	09/2013
SHI, New Jersey, USA	09/2013
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	08/2013
TIG-Group, Husum	08/2013
COMPAREX, Leipzig for RWE Essen	08/2013, 11/2013 12/2013
University of Budapest, Hungary	08/2013
Siemens, Frankenthal	08/2013, 10/2013

		11/2013
VGB, Essen		07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland		07/2013
Technical University of Deggendorf		07/2013
University of Maryland, USA		07/2013, 08/2013
University of Princeton, USA		07/2013
NIST, Boulder, USA		06/2013
IGUS GmbH, Dresden		06/2013
BHR Bilfinger, Essen		06/2013
SÜDSALZ, Bad Friedrichshall		06/2013, 12/2013
Technician School of Berlin		05/2013
KIER, Gajeong-ro, Südkorea		05/2013
Schwing/Stetter GmbH, Memmingen		05/2013
Vattenfall, Berlin		05/2013
AUTARK, Kleinmachnow		05/2013
STEAG, Zwingenberg		05/2013
Hochtief, Düsseldorf		05/2013
University of Stuttgart		04/2013
Technical University -Bundeswehr, Munich		04/2013
Rerum Cognitio Forschungszentrum, Frankfurt		04/2013
Kältetechnik Dresen + Bremen, Alfhausen		04/2013
University Auckland, New Zealand		04/2013
MASDAR Institut, Abu Dhabi, United Arab Emirates		03/2013
Simpelkamp, Dresden		02/2013
VEO, Eisenhüttenstadt		02/2013
ENTEC, Auerbach		02/2013
Caterpillar, Kiel		02/2013
Technical University of Wismar		02/2013
Technical University of Dusseldorf		02/2013
ILK, Dresden		01/2013, 08/2013
Fichtner IT, Stuttgart		01/2013, 11/2013
Schnepf Ingenierbüro, Nagold		01/2013
Schütz Engineering, Wadgassen		01/2013
Endress & Hauser, Reinach, Switzerland		01/2013
Oschatz GmbH, Essen		01/2013
frischli Milchwerke, Rehburg-Loccum		01/2013

## 2012

Voith, Bayreuth	12/2012
Technical University of Munich	12/2012
Dillinger Huette	12/2012
University of Stuttgart	11/2012
Siemens, Muehlheim	11/2012
Sennheiser, Hannover	11/2012
Oschatz GmbH, Essen	10/2012
Fichtner IT, Stuttgart	10/2012, 11/2012
Helbling Technik AG, Zurich, Switzerland	10/2012
University of Duisburg	10/2012

Rerum Cognitio Forschungszentrum, Frankfurt	09/2012
Pöyry Deutschland GmbH, Dresden	08/2012
Extracciones, Guatemala	08/2012
RWE, Essen	08/2012
Weghaus Consulting Engineers, Wuerzburg	08/2012
GKS, Schweinfurt	07/2012
COMPAREX, Leipzig for RWE Essen	07/2012
GEA, Nobitz	07/2012
Meyer Werft, Papenburg	07/2012
STEAG, Herne	07/2012
GRS, Cologne	06/2012
Fichtner IT Consult, Chennai, India	06/2012
Siemens, Freiburg	06/2012
Nikon Research of America, Belmont, USA	06/2012
Niederrhein University of Applied Sciences, Krefeld	06/2012
STEAG, Zwingenberg	06/2012
Mainova, Frankfurt on Main via Fichtner IT Consult	05/2012
Endress & Hauser	05/2012
PEU, Espenheim	05/2012
Luzern University of Applied Sciences, Switzerland	05/2012
BASF, Ludwigshafen (general license) via Fichtner IT Consult	05/2012
SPX Balcke-Dürr, Ratingen	05/2012, 07/2012
Gruber-Schmidt, Wien, Austria	04/2012
Vattenfall, Berlin	04/2012
ALSTOM, Baden	04/2012
SKW, Piesteritz	04/2012
TERA Ingegneria, Trento, Italy	04/2012
Siemens, Erlangen	04/2012, 05/2012
LAWI Power, Dresden	04/2012
Stadtwerke Leipzig	04/2012
SEITZ, Wetzikon, Switzerland	03/2012, 07/2012
M & M, Bielefeld	03/2012
Sennheiser, Wedemark	03/2012
SPG, Montreuil Cedex, France	02/2012
German Destilation, Sprendlingen	02/2012
Lopez, Munguia, Spain	02/2012
Endress & Hauser, Hannover	02/2012
Palo Alto Research Center, USA	02/2012
WIPAK, Walsrode	02/2012
Freudenberg, Weinheim	01/2012
Fichtner, Stuttgart	01/2012
airinotec, Bayreuth	01/2012, 07/2012
University Auckland, New Zealand	01/2012
VPC, Vetschau	01/2012
Franken Guss, Kitzingen	01/2012

## 2011

XRG-Simulation, Hamburg	12/2011
Smurfit Kappa PPT, AX Roermond, Netherlands	12/2011
AWTEC, Zurich, Switzerland	12/2011
eins-energie, Bad Elster	12/2011
BeNow, Rodenbach	11/2011
Luzern University of Applied Sciences, Switzerland	11/2011
GMVA, Oberhausen	11/2011
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	10/2011
PLANAIR, La Sagne, Switzerland	10/2011
LAWI, Dresden	10/2011
Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011
Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011
	10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
	05/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011

ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011
	06/2011, 08/2011

## 2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010
University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010
Vaillant, Remscheid	10/2010
PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
Saacke, Bremen	09/2010
WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	08/2010
ERGION, Mannheim	07/2010
Fichtner IT Consulting, Stuttgart	07/2010
TF Design, Matieland, South Africa	07/2010
MCE, Berlin	07/2010, 12/2010
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	06/2010
RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010

Universitaet der Bundeswehr, Munich	04/2010
Technical University of Hamburg-Harburg	04/2010
Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
VER, Dresden	04/2010
CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
Technical University of Dresden	02/2010
Siemens Energy, Nuremberg	02/2010
Augsburg University of Applied Sciences	02/2010
ALSTOM Power, Baden, Switzerland	02/2010, 05/2010
MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	01/2010, 12/2010
Technical University of Freiberg	01/2010
ILK, Dresden	01/2010, 12/2010
Fischer-Uhrig Consulting Engineers, Berlin	01/2010

## 2009

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

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

## 2008

Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	01/2008
University of Karlsruhe	01/2008
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	02/2008
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008
WEBASTO, Neubrandenburg	04/2008
CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008
Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008
Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Popty, Dresden	09/2008
WINGAS, Kassel	09/2008
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

## 2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
VER, Dresden	02/2007
Technical University of Dresden, Chair in Jet Propulsion Systems	02/2007
Redacom, Nidau, Switzerland	02/2007
Universität der Bundeswehr, Munich	02/2007
Maxxtec, Sinsheim	03/2007
University of Rostock, Chair in Technical Thermodynamics	03/2007
AGO, Kulmbach	03/2007
University of Stuttgart, Chair in Aviation Propulsions	03/2007
Siemens Power Generation, Duisburg	03/2007
ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
Technical University of Cottbus, Chair in Power Plant Engineering	06/2007
Voith Paper Air Systems, Bayreuth	06/2007
Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
National Energy Technology Laboratory, Pittsburg, USA	10/2007
Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007
Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

## 2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart,	02/2006

Department of Thermal Fluid Flow Engines	
Technical University of Munich,	02/2006
Chair in Apparatus and Plant Engineering	
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig,	04/2006
Department of Thermodynamics	
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg,	05/2006
Department of USET Merseburg incorporated society	
Technical University of Dresden,	05/2006
Professorship of Thermic Energy Machines and Plants	
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
Suedzucker, Ochsenfurt	06/2006
M&M Turbine Technology, Bielefeld	06/2006
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006
Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzeide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

## 2005

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

Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences,	05/2005
Department of Mechanical Engineering and Process Engineering	
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences,	10/2005
Department of Mechanical Engineering, Switzerland	
Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

## 2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	01/2004
University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden,	
Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004

Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

## 2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003
Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Pettersson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
Ingenieurbuero Ostendorf, Gummersbach	05/2003
TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	06/2003
University of Cali, Colombia	07/2003
Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003
Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

## 2002

Hamilton Medical AG, Rhaeuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002

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

## 2001

ALSTOM Power, Baden, Switzerland	01/2001, 06/2001 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart	04/2001
(company licenses and distribution)	
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe	08/2001
(general license for the WinIS information system)	
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001

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

## 2000

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

## 1999

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

## 1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart	05/1998
(general KPRO program license)	
M&M Turbine Technology Bielefeld	06/1998
B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998

SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

## 1997

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