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Property Library for Humid Gas Mixtures

**FluidVIEW
with LibHuGas
for LabVIEW™**

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Software for the Calculation of the Properties of Humid Gas Mixtures

Including DLL and Add-on for LabVIEW™

FluidVIEW LibHuGas

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0. Package Contents

0.1 Zip files for 32-bit LabVIEW®

In order to install FluidVIEW on a computer running a 32-bit version of LabVIEW® the zip file **CD_FluidVIEW_LibHuGas.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™. All contained files, their paths and the structure of the archive are shown in the screenshot of the WinRAR file archiver and compression tool illustrated in Figure 0.1.

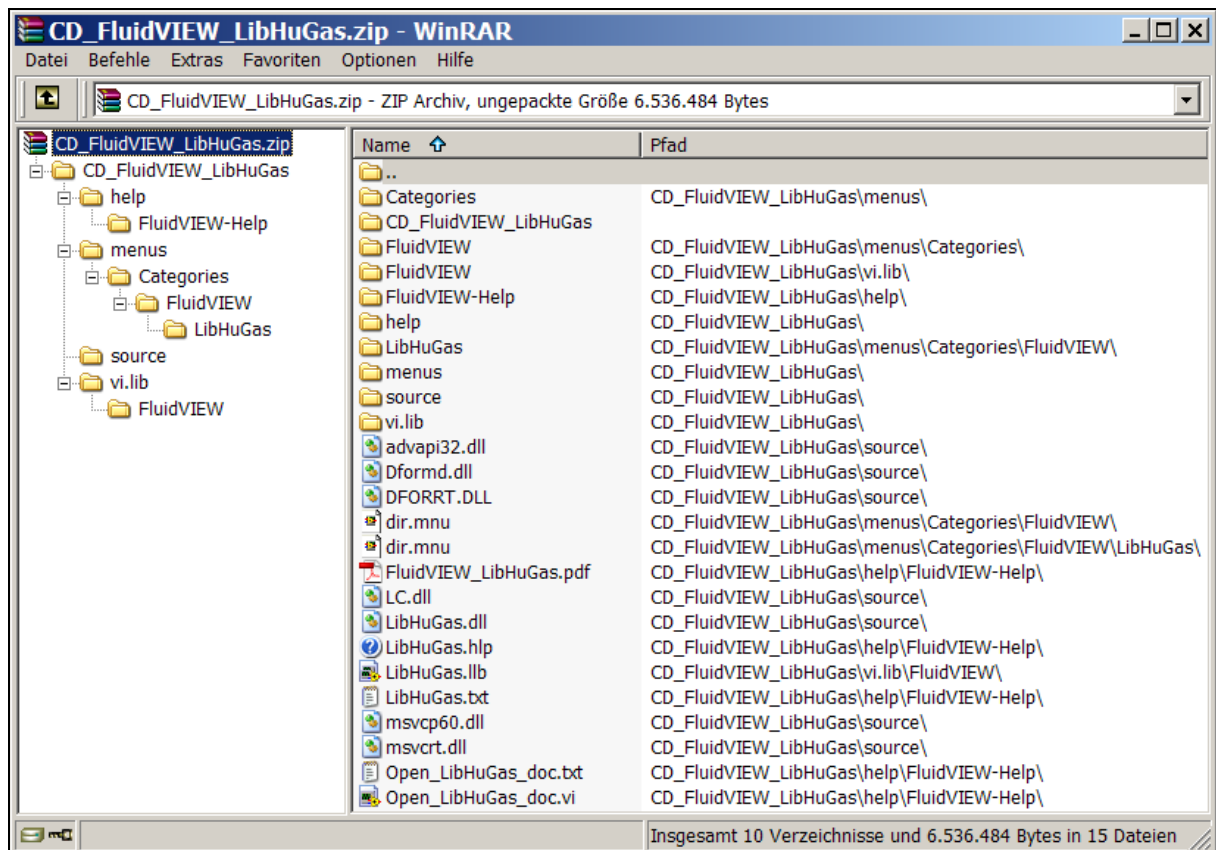


Figure 0.1 Screenshot of WinRAR showing the **CD_FluidVIEW_LibHuGas.zip** archive.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.1, 0.2, 0.3 and 0.4.

Table 0.1 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas\vi.lib\FluidVIEW\LibHuGas**

Filename	Effects
LibHuGas.llb	LabVIEW™ library file, containing every function of the LibHuGas property library in the form of subprograms (SubVIs)

Table 0.2 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas\menus\Categories\FluidVIEW**

Filename	Effects
dir.mnu	The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items)

Table 0.3 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas\source**

Filename	Effects
LibHuGas.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of humid gas mixtures
advapi32.dll	Runtime library
Dformd.dll	Runtime library for the Fortran DLL
Dfortrt.dll	Runtime library for the Fortran DLL
LC.dll	Auxiliary library
msvc60.dll	Runtime library
msvcrt.dll	Runtime library

Table 0.4 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas\help\FluidVIEW-help**

Filename	Effects
FluidVIEW_LibHuGas.pdf	User's guide of the property library LibHuGas for the LabVIEW™ Add-On FluidVIEW
LibHuGas.hlp	Help file with descriptions for each function
OpenLibHuGas_doc.vi	LabVIEW™ instrument to open the user's guide via the help menu
LibHuGas.txt	Text file to change the name of the menu item of the help file
OpenLibHuGas_doc.txt	Text file to change the name of the menu item of the file OpenLibHuGas_doc.vi

0.2 Zip files for 64-bit LabVIEW®

In order to install FluidVIEW on a computer running a 64-bit version of LabVIEW® the zip file **CD_FluidVIEW_LibHuGas_x64.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™. All contained files, their paths and the structure of the archive are shown in the screenshot of the WinRAR file archiver and compression tool illustrated in Figure 0.2.

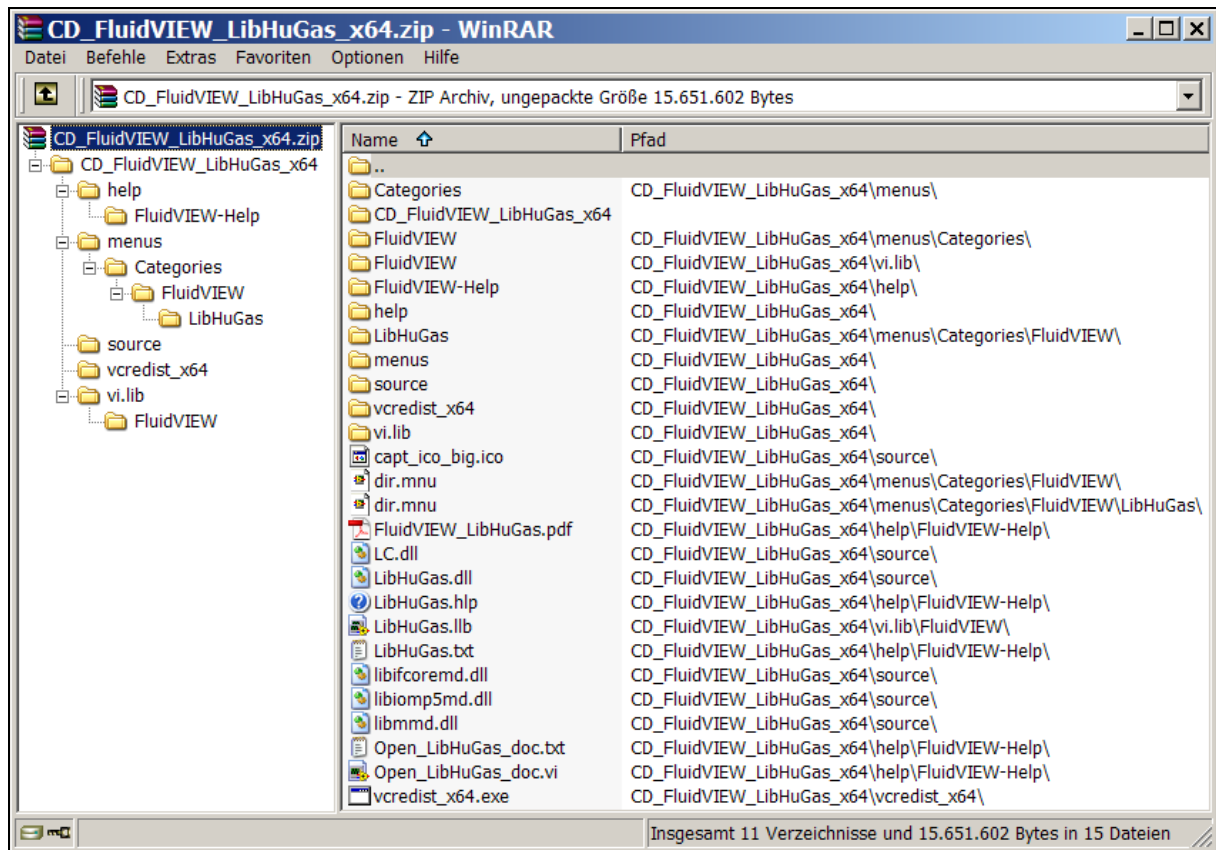


Figure 0.2 Screenshot of WinRAR showing the **CD_FluidVIEW_LibHuGas_x64.zip** archive.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.5, 0.6, 0.7 and 0.8.

Table 0.5 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas_x64\vi.lib\FluidVIEW\LibHuGas**

Filename	Effects
LibHuGas.llb	LabVIEW™ library file, containing every function of the LibHuGas property library in the form of subprograms (SubVIs)

Table 0.6 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas_x64\menus\Categories\FluidVIEW**

Filename	Effects
dir.mnu	The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items)

Table 0.7 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas_x64\source**

Filename	Effects
LibHuGas.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of humid gas mixtures
Capt_ico_big.ico	Icon file
Libmmd.dll	Runtime library
Libifcoremd.dll	Runtime library
LC.dll	Auxiliary library
Libiomp5md.dll	Runtime library

Table 0.8 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas_x64\help\FluidVIEW-help**

Filename	Effects
FluidVIEW_LibHuGas.pdf	User's guide of the LibHuGas property library for the LabVIEW™ Add-On FluidVIEW
LibHuGas.hlp	Help file with descriptions for each function
OpenLibHuGas_doc.vi	LabVIEW™ instrument to open the user's guide via the help menu
LibHuGas.txt	Text file to change the name of the menu item of the help file
OpenLibHuGas_doc.txt	Text file to change the name of the menu item of the file OpenLibHuGas_doc.vi

Table 0.9 Effects of the files located in the archive directory **CD_FluidVIEW_LibHuGas_x64\vc redistrib_x64**

Filename	Effects
vc redistrib_x64.exe	Executable file to install the Microsoft Visual C++ 2008 Redistributable Package (x64). Within runtime components of Visual C++ Libraries required to run 64-bit applications developed with Visual C++ on a computer that does not have Visual C++ 2010 installed.

1. Property Functions

Function	Function Name	Call of Fortran Program	Property or Function	Unit
$a = f(p, t)$	a_ptcomp_HuGas	= a_pTcomp_HuGas(p, T, type, comp)	Thermal diffusivity	m^2/s
$c_p = f(h, s)$	cp_hscomp_HuGas	= cp_hscomp_HuGas(h, s, type, comp)	Backward function: Specific isobaric heat capacity from enthalpy and entropy	$\text{kJ}/(\text{kg} \cdot \text{K})$
$c_p = f(p, h)$	cp_phcomp_HuGas	= cp_phcomp_HuGas(p, h, type, comp)	Backward function: Specific isobaric heat capacity from pressure and enthalpy	$\text{kJ}/(\text{kg} \cdot \text{K})$
$c_p = f(p, s)$	cp_pscomp_HuGas	= cp_pscomp_HuGas(p, s, type, comp)	Backward function: Specific isobaric heat capacity from pressure and entropy	$\text{kJ}/(\text{kg} \cdot \text{K})$
$c_p = f(p, t)$	cp_ptcomp_HuGas	= cp_pTcomp_HuGas(p, T, type, comp)	Specific isobaric heat capacity	$\text{kJ}/(\text{kg} \cdot \text{K})$
$c_p = f(t, s)$	cp_tscomp_HuGas	= cp_Tscomp_HuGas(T, s, type, comp)	Backward function: Specific isobaric heat capacity from temperature and entropy	$\text{kJ}/(\text{kg} \cdot \text{K})$
$c_v = f(p, t)$	cv_ptcomp_HuGas	= cv_pTcomp_HuGas(p, T, type, comp)	Specific isochoric heat capacity	$\text{kJ}/(\text{kg} \cdot \text{K})$
$\eta = f(p, t)$	Eta_ptcomp_HuGas	= eta_pTcomp_HuGas(p, T, type, comp)	Dynamic viscosity	$\text{Pa} \cdot \text{s}$
$h = f(p, s)$	h_pscomp_HuGas	= h_pscomp_HuGas(p, s, type, comp)	Backward function: Specific enthalpy from pressure and entropy	kJ/kg
$h = f(p, t)$	h_ptcomp_HuGas	= h_pTcomp_HuGas(p, T, type, comp)	Specific Enthalpy	kJ/kg
$h = f(t, s)$	h_tscomp_HuGas	= h_Tscomp_HuGas(T, s, type, comp)	Backward function: Specific enthalpy from temperature and entropy	kJ/kg
$\kappa = f(p, s)$	Kappa_pscomp_HuGas	= kappa_pscomp_HuGas(p, s, type, comp)	Backward function: Isentropic exponent from pressure and entropy	-

Function	Function Name	Call of Fortran Program	Property or Function	Unit
$\kappa = f(p, t)$	Kappa_ptcomp_HuGas	= kappa_pTcomp_HuGas(p, T, type, comp)	Isentropic exponent	-
$\lambda = f(p, t)$	Lambda_ptcomp_HuGas	= lambda_pTcomp_HuGas(p, T, type, comp)	Thermal conductivity	W/(m · K)
M	M_comp_HuGas	= M_comp_HuGas(type, comp)	Molar mass	kg/kmol
$\nu = f(p, t)$	Ny_ptcomp_HuGas	= ny_pTcomp_HuGas(p, T, type, comp)	Kinematic viscosity	m ² /s
$p = f(h, s)$	p_hscomp_HuGas	= p_hscomp_HuGas(h, s, type, comp)	Backward function: Pressure from enthalpy and entropy	bar
$p = f(t, s)$	p_tscomp_HuGas	= p_Tscomp_HuGas(T, s, type, comp)	Backward function: Pressure from temperature and entropy	bar
$p_{\text{dsat}} = f(p, t)$	pdsat_pt_HuGas	= pdsat_pT_HuGas(p, T)	Saturation pressure of water in mixture	bar
$\varphi = f(p, t)$	Phi_ptcomp_HuGas	= phi_pTcomp_HuGas(p, T, type, comp)	Relative humidity	%
$Pr = f(p, t)$	Pr_ptcomp_HuGas	= Pr_pTcomp_HuGas(p, T, type, comp)	Prandtl number	-
$\psi_{\text{wl}} = f(p, t)$	Psiwl_ptcomp_HuGas	= psiwl_pTcomp_HuGas(p, T, type, comp)	Mole fraction of water (liquid)	kmol/kmol
$\psi_{\text{wsat}} = f(p, t)$	Psiwsat_ptcomp_HuGas	= psiwsat_pTcomp_HuGas(p, T, type, comp)	Mole fraction of water of the saturated gas	kmol/kmol
R	R_comp_HuGas	= R_comp_HuGas(type, comp)	Gas constant	KJ/(kg · K)
$Region = f(h, s)$	Region_hscomp_HuGas	= Region_hscomp_HuGas(h, s, type, comp)	Region from given enthalpy and entropy	-
$Region = f(p, h)$	Region_phcomp_HuGas	= Region_phcomp_HuGas(p, h, type, comp)	Region from given pressure and enthalpy	-
$Region = f(p, s)$	Region_pscomp_HuGas	= Region_pscomp_HuGas(p, s, type, comp)	Region from given pressure and entropy	-

Function	Function Name	Call of Fortran Program	Property or Function	Unit
$Region = f(p, t)$	Region_ptcomp_HuGas	= Region_pTcomp_HuGas(p, T, type, comp)	Region from given pressure and temperature	-
$Region = f(t, s)$	Region_tscomp_HuGas	= Region_Tscomp_HuGas(T, s, type, comp)	Region from given temperature and entropy	-
$\rho = f(p, t)$	Rho_ptcomp_HuGas	= rho_pTcomp_HuGas(p, T, type, comp)	Density	kg/m ³
$s = f(p, h)$	s_phcomp_HuGas	= s_phcomp_HuGas(p, h, type, comp)	Backward function: Specific entropy from pressure and specific enthalpy	kJ/(kg · K)
$s = f(p, t)$	s_ptcomp_HuGas	= s_pTcomp_HuGas(p, T, type, comp)	Entropy	kJ/(kg · K)
$\sigma_w = f(t)$	Sigmaw_t_HuGas	= sigmaw_T_HuGas(T)	Surface tension of water	N/m
$t = f(h, s)$	t_hscomp_HuGas	= T_hscomp_HuGas(h, s, type, comp)	Backward function: Temperature from enthalpy and entropy	°C
$t = f(p, h)$	t_phcomp_HuGas	= T_phcomp_HuGas(p, h, type, comp)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p, s)$	t_pscomp_HuGas	= T_pscomp_HuGas(p, s, type, comp)	Backward function: Temperature from pressure and entropy	°C
$t_{w,dew} = f(p)$	twdew_pcomp_HuGas	= Twdew_pcomp_HuGas(p, type, comp)	Dew point temperature of water	°C
$u = f(p, t)$	u_ptcomp_HuGas	= u_pTcomp_HuGas(p, T, type, comp)	Specific internal energy	kJ/kg
$v = f(h, s)$	v_hscomp_HuGas	= v_hscomp_HuGas(h, s, type, comp)	Backward function: Specific volume from enthalpy and entropy	m ³ /kg

Function	Function Name	Call of Fortran Program	Property or Function	Unit
$v = f(p, h)$	v_phcomp_HuGas	= v_phcomp_HuGas(p, h, type, comp)	Backward function: Specific volume from pressure and enthalpy	m ³ /kg
$v = f(p, s)$	v_pscomp_HuGas	= v_pscomp_HuGas(p, s, type, comp)	Backward function: Specific volume from pressure and entropy	m ³ /kg
$v = f(p, t)$	v_ptcomp_HuGas	= v_pTcomp_HuGas(p, T, type, comp)	Specific volume	m ³ /kg
$v = f(t, s)$	v_tscomp_HuGas	= v_Tscomp_HuGas(T, s, type, comp)	Backward function: Specific volume from temperature and entropy	m ³ /kg
$w = f(p, t)$	w_ptcomp_HuGas	= w_pTcomp_HuGas(p, T, type, comp)	Isentropic speed of sound	m/s
x_w	xw_comp_HuGas	= xw_comp_HuGas(type, comp)	Humidity ratio (Absolute humidity)	g/kg _{Gas}

Parameter

- p - Pressure p of mixture in bar
 t - Temperature t in °C
 $type$ - Type of composition:
 $type = 0$ for composition in mole fractions
 $type = 1$ for composition in mass fractions
 $comp(1:8)$ - Mole or mass fractions of components

Parameter for using Fortran Functions of LibHuGas

- p - Pressure p of mixture in bar
 T - Temperature t in °C

For input of composition in mass fractions use the function `set_comp_mass_HuGas` or

For input of composition in mole fractions use the function `set_comp_mol_HuGas`.

This composition will be stored in a Common Block and will be used for all calculations after that.

This will continue to occur unless the composition is changed by calling `set_comp_mol_HuGas` or `set_comp_mass_HuGas` again.

In order to know what composition is stored, it can be called by using `get_comp_mass_HuGas` or `get_comp_mol_HuGas`.

Range of Validity

- Temperature: $t = -70\text{ °C} \dots 3026.15\text{ °C}$
 Pressure of mixture: $p = 0.01\text{ bar} \dots 1000\text{ bar}$

Mixture Components

Nr.	Symbol	Name of mixture component
0	Dummy	
1	Ar	Argon
2	Ne	Neon
3	N ₂	Nitrogen
4	O ₂	Oxygen
5	CO	Carbon Monoxide
6	CO ₂	Carbon Dioxide
7	H ₂ O	Water
8	SO ₂	Sulfur dioxide

Values of the Region Functions

Region	Description
0	Out of range of validity
1	Dry gas mixture
2	Unsaturated humid gas mixture
3	Liquid fog
4	Ice fog
5	Liquid-ice fog at 0.01 °C exactly
6	Pure liquid water
7	Pure water-wet steam
8	Pure steam
10	The CO ₂ in the gas mixture would be partly liquid. Calculation is terminated.
11	The SO ₂ in the gas mixture would be partly liquid. Calculation is terminated.

Reference States of LibHuGas

Fluid	t_0 [°C]	p_0 [bar]	h_0 [kJ/kg]	s_0 [kJ/(kg K)]	u_0 [kJ/kg]
Argon	0	1.01325	0	0	-56.79766
Neon	0	1.01325	0	0	-112.5436
Nitrogen	0	1.01325	0	0	-81.03459
Oxygen	0	1.01325	0	0	-70.90573
Carbon monoxide	0	1.01325	0	0	-81.08139
Carbon dioxide	0	1.01325	0	0	-51.25686
Water	0.01	0.00611657	$0.611872 \cdot 10^{-3}$	0	0
Sulfur dioxide	0	1.01325	0	0	-35.45001

Conversion to the Reference State of Water to $t_0 = 0$ °C

$$h = h_{\text{HuGas}} - \xi_{\text{H}_2\text{O}} \cdot 2500.914579 \text{ kJ/kg}$$

$$u = u_{\text{HuGas}} - \xi_{\text{H}_2\text{O}} \cdot 2500.914579 \text{ kJ/kg}$$

$$s = s_{\text{HuGas}} - \xi_{\text{H}_2\text{O}} \cdot 9.155493408 \text{ (kJ/kg K)}$$

Conversion to the Reference States of the Publications

$$Z_{\text{Publication}} = Z_{\text{LibHuGas}} + \Delta Z \quad \text{where } z \equiv h, s, u$$

Fluid	t_0 [°C]	p_0 [bar]	Δh [kJ/kg]	Δs [kJ/(kg K)]	Δu [kJ/kg]	Reference
Argon	25	1.01325	-13.23564	$-4.6203961 \cdot 10^{-2}$	-13.23564	[27]
Neon	0	1.01325	0	0	0	-
Nitrogen	25	1.01325	283.2331	6.744095	283.2331	[28]
Oxygen	25	1	-23.20175	$-8.448914 \cdot 10^{-2}$	-23.20175	[29]
Carbon monoxide	0	1.01325	0	0	0	-
Carbon dioxide	25	1.01325	-21.90979	$-7.564382 \cdot 10^{-2}$	-21.90979	[30]
Water	0.01	0.00611657	0	0	0	[31]
Sulfur dioxide	0	1.01325	0	0	0	-

2 Application of FluidVIEW in LabVIEW™

The FluidVIEW Add-on has been developed to calculate thermodynamic properties in LabVIEW™ (version 10.0 or higher) more conveniently. Within LabVIEW™, it enables the direct call of functions relating to humid gas mixtures from the LibHuGas property library.

2.1 Installing FluidVIEW

If a FluidVIEW property library has not yet been installed, please complete the initial installation procedure described below.

If a FluidVIEW property library has already been installed, you only need to copy several files which belong to the LibHuGas library. In this case, follow the subsection "Adding the LibHuGas Library" on page 2/3.

In both cases folders and files from the zip archive

CD_FluidVIEW_LibHuGas.zip	(for 32-bit version of Windows®)
CD_FluidVIEW_LibHuGas_x64.zip	(for 64-bit version of Windows®)

have to be copied into the default directory of the LabVIEW™ development environment. In the following text these zipped directories for the 32-bit or 64-bit operating system will be symbolised with the term **<CD>**.

You can see the current default directory of LabVIEW™ in the paths page (options dialog box). To display this page please select *Tools* and click on *Options* to open the options dialog box and then select *Paths* from the category list.

By choosing *Default Directory* from the drop-down list the absolute pathname to the default directory, where LabVIEW™ automatically stores information, is displayed. In the following sections the pathname of the default directory will be symbolised by the term **<LV>**.

Additional Requirement When Using the 64-bit Operating System

If you want to use FluidVIEW on a 64-bit computer that does not have Visual C++ installed, please make sure the Microsoft Visual C++ 2010 x64 Redistributable Package is installed.

If it is not the case, please install it by double clicking the file

vcredist_x64.exe

which you find in the folder **lvcredist_x64** in the **64-bit** CD folder

"CD_FluidVIEW_LibHuGas_x64."

In the following window you are required to accept the Microsoft® license terms to install the Microsoft Visual C++ 2010 runtime libraries by ticking the box next to "I have read and accept the license terms" (see Figure 2.1).

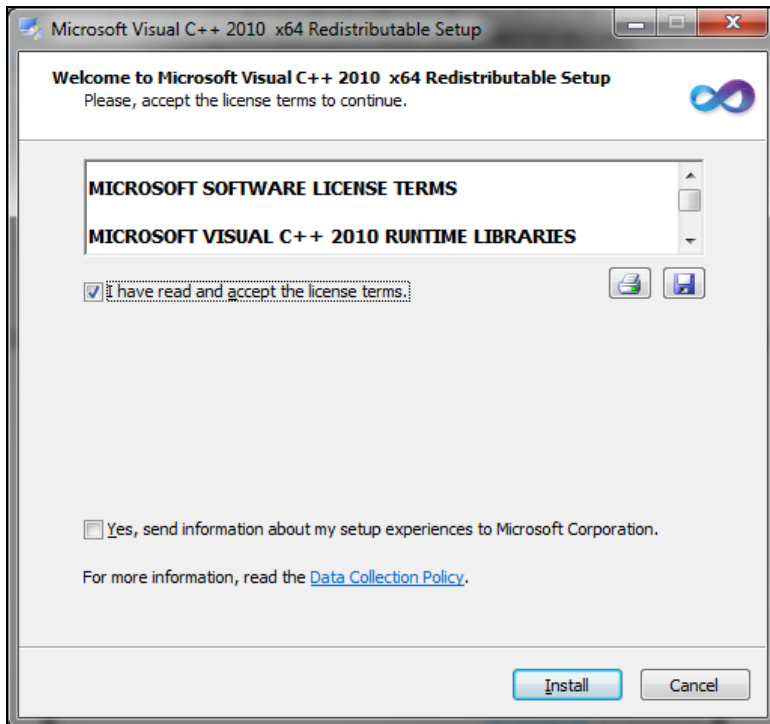


Figure 2.1 Accepting the license terms to install the Microsoft Visual C++ 2010 x64 Redistributable Package

Now click on "Install" to continue installation.

After the "Microsoft Visual C++ 2010 x64 Redistributable Pack" has been installed, you will see the sentence "Microsoft Visual C++ 2010 x64 Redistributable has been installed." Confirm this by clicking "Finish."

Now you can use the FluidVIEW Add-On on your 64-bit operating system. Please follow the instructions below to install FluidVIEW.

Initial Installation of FluidVIEW

The initial installation of FluidVIEW is carried out by copying three directories with its contents from the zip archive to the standard directory of LabVIEW™. The directories that have to be copied, their paths in the zip archive and their target paths are listed in Table 2.1.

The installation is complete after copying the files and restarting LabVIEW™.

Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory **<CD>source** can be stored in a random directory. The pathname has to be indicated in order to calculate the property functions.

All source files have to be stored in the same directory to make the property functions of the LibHuGas library work. These files are for the

- **32-bit system:** LibHuGas.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcr7.dll

and for the

- **64-bit system:** LibHuGas.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll.

Table 2.1 Directories which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for the initial installation of FluidVIEW

Name of the directory	Pathname in the zip archive	Target path in the default directory of LabVIEW (<LV>)
FluidVIEW	<CD>\vi.lib	<LV>\vi.lib
FluidVIEW	<CD>\menus\Categories	<LV>\menus\Categories
FluidVIEW-Help	<CD>\help	<LV>\help

Adding the LibHuGas Library

In order to add the LibHuGas property library to an existing FluidVIEW installation, one folder with its contents and five files have to be copied from the zip archive to the standard directory of LabVIEW™. This directory, the files plus their pathnames in the zip archive and their target paths are listed in Table 2.2.

The installation is complete after copying the files and restarting LabVIEW™. Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory <CD>\source can be stored in a random directory. The pathname has to be indicated in order to calculate the property functions. All source files have to be stored in the same directory to make the property functions of the LibHuGas library work. These files are for the

- **32-bit system:** LibHuGas.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system:** LibHuGas.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll

Table 2.2 Data which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for adding the LibHuGas property library to an existing installation of FluidVIEW

File name with file extension or name of the directory	Pathname in the zip archive	Target path in the default directory of LabVIEW (<LV>)
LibHuGas.llb	<CD>\vi.lib\FluidVIEW	<LV>\vi.lib\FluidVIEW
LibHuGas	<CD>\menus\Categories\FluidVIEW	<LV>\menus\Categories\FluidVIEW
LibHuGas.hlp	<CD>\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
LibHuGas.txt	<CD>\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
FluidVIEW_LibHuGas.pdf	<CD>\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
Open_LibHuGas_doc.vi	<CD>\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help
Open_LibHuGas_doc.txt	<CD>\help\FluidVIEW-Help	<LV>\help\FluidVIEW-Help

After you have restarted LabVIEW™ you will find the functions of the LibHuGas property library in the functions palette under the sub palette FluidVIEW. An example calculation of the specific enthalpy h and the specific entropy s is shown in section 2.4.

2.2 The FluidVIEW Help System

FluidVIEW provides detailed online help functions. If you are running Windows Vista or Windows 7, please note the paragraph

"Using the FluidVIEW Online-Help in Windows Vista or Windows 7."

General Information

The FluidVIEW Help System consists of the Microsoft WinHelp file **LibHuGas.hlp** and this user's guide as PDF document **FluidVIEW_LibHuGas.pdf**. Both files can be opened via the help menu. To do this please click *Help* in the menu bar. In the submenu *FluidVIEW-Help* you will find the commands *LibHuGas Help File* and *LibHuGas User's Guide* to open an appropriate file.

Context-Sensitive Help

If you have activated the context help function in LabVIEW™ (Ctrl-H) and move the cursor over a FluidVIEW object basic information is displayed in the context help window. The in- and output parameters plus a short information text are displayed for a property function. By clicking the **Detailed help** button in the **Context help** window the online help will be opened. The context help window of the function `v_ptcomp_HuGas.vi` is shown in Figure 2.2.

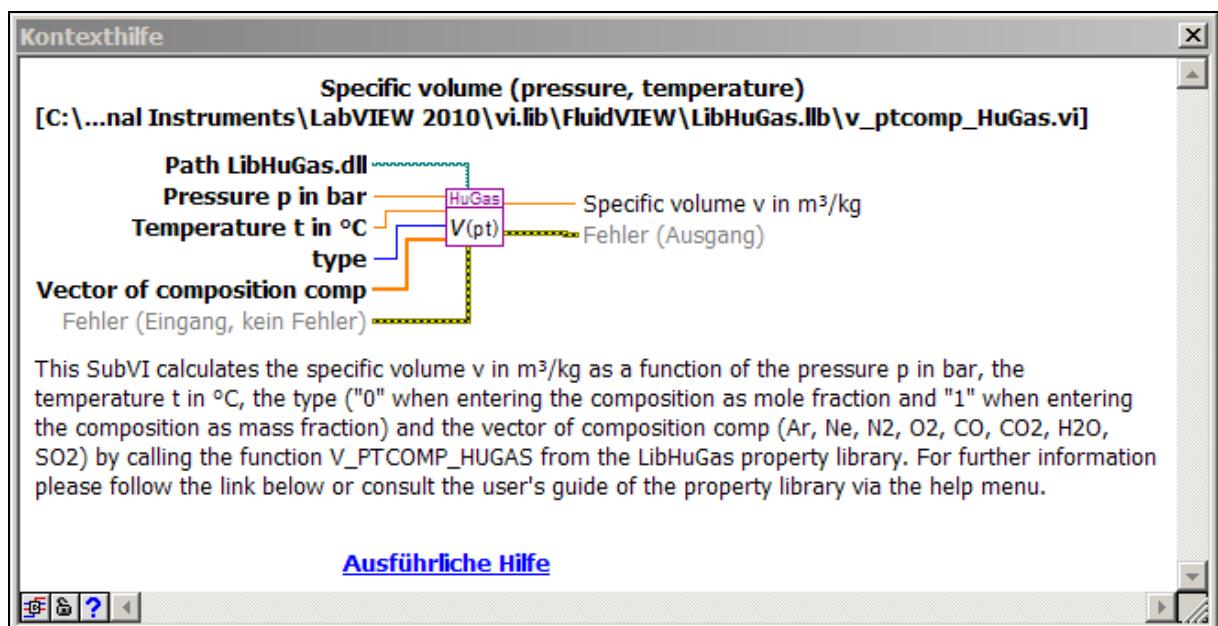


Figure 2.2 Context help window of the function `v_ptcomp_HuGas.vi`

Using the FluidVIEW Online-Help in Windows Vista or Windows 7

If you are running Windows Vista or Windows 7 on your computer, you might not be able to open Help files. To view these files you have to install the Microsoft® Windows Help program which is provided by Microsoft®. Please carry out the following steps in order to download and install the Windows Help program. The description relates to Windows® 7. The procedure is analogous for Windows® Vista.

Open Microsoft Internet Explorer® and go to <http://support.microsoft.com/kb/917607>. Scroll down until you see the headline "Resolution". Under the first Point you'll find the links to download the Windows Help program. Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.3)

RESOLUTION

To resolve this issue, obtain the Windows Help program (WinHlp32.exe) for the versions of Windows that support it. To obtain the correct version for your operating system, you must know whether you have a Windows 32-bit or Windows 64-bit system. If you are not sure which version of Windows you are running, follow the steps under "If you are not sure which Windows version is installed."

Note To determine which version of Windows you are running, you must be logged on as an administrator. To verify that you are logged on as an administrator, follow the steps under "To verify that you are logged on as an administrator."

[↑ Back to the top](#)

If you are not sure which Windows version is installed

If you are not sure which version of Windows is installed on your computer, follow the steps in the following wizard.

[Click here to view or hide step-by-step instructions with pictures](#)

[↑ Back to the top](#)

To verify that you are logged on as an administrator

To verify that you are logged on as an administrator, follow the steps in the following wizard.

[Click here to view or hide step-by-step instructions with pictures](#) **How to obtain the correct version of the Windows Help program (WinHlp32.exe)**

1. Click one of the following "Windows Help program" links, depending on the operating system that you are running:

-  [Windows Help program \(WinHlp32.exe\) for Windows Vista](#)
-  [Windows Help program \(WinHlp32.exe\) for Windows 7](#)
-  [Windows Help program \(winHlp32.exe\) for Windows Server 2008](#)
-  [Windows Help program \(WinHlp32.exe\) for Windows Server 2008 R2](#)

Note The Windows Help program is not supported for Windows 8 Server Beta, and no download will be provided for this Windows version. The Windows Help program is supported for the x64 and x86 editions of the Windows 8 client, and a download package for these editions will be made available in this article at a later date.

2. Click **Continue** to run Genuine Windows Validation. For more information about how to install Genuine Windows Validation Component, visit the following Microsoft website:
<http://www.microsoft.com/download/en/genuine-validation.aspx?id=5143>
3. Download and install **Windows6.*-KB917607-x64.msu** or **Windows6.*-KB917607-x86.msu**, depending on the edition of the operating system that you are running.

Figure 2.3 Selecting your Windows® Version

You will be forwarded to the Microsoft Download Center where you can download the Microsoft Windows Help program. First, a validation of your Windows License is required. To do this click on the "Continue" button (see Figure 2.4).

Validation Required

For more information about the validation process, [click here](#).

Quick details

Version:	1.0	Date published:	10/14/2009
Change language:	English		

KB articles:	KB917607
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Files in this download

The links in this section correspond to files available for this download. Download the files appropriate for you.

File name	Size
Windows6.1-KB917607-x64.msu	702 KB
Windows6.1-KB917607-x86.msu	688 KB

CONTINUE

Figure 2.4 Microsoft® Download Center

Afterwards a web page with instructions on how to install the Genuine Windows Validation Component opens. At the top of your Windows Internet Explorer you will see a yellow information bar. It reads

"This website wants to install the following add-on: 'Windows Genuine Advantage' from 'Microsoft Corporation'. If you trust this website and the add-on and want to install it, click here."

Right-click this bar and select "Install ActiveX Control" in the context menu. A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue. After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.5).

To download and install the correct file you need to know which Windows version (32-bit or 64-bit) you are running on your computer.

If you are running a 64-bit operating system, please download the file

Windows6.1-KB917607-x64.msu.

If you are running a 32-bit operating system, please download the file

Windows6.1-KB917607-x86.msu.

Genuine Microsoft Software

Please click **Download** to download the software.

Quick details

Version: 1.0

Date published: 10/14/2009

Change language: English

KB articles: [KB917607](#)

Files in this download

The links in this section correspond to files available for this download. Download the files appropriate for you.

File name	Size	
Windows6.1-KB917607-x64.msu	702 KB	DOWNLOAD
Windows6.1-KB917607-x86.msu	688 KB	DOWNLOAD

Figure 2.5 Downloading the Windows Help Program

In order to run the installation of the Windows Help program double-click the file you have just downloaded on your computer.

Installation starts with a window searching for updates on your computer.

After the program has finished searching you may be asked, if you want to install the "Update for Windows (KB917607)."

(If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.")

The installation can be continued by clicking the "Yes" button.

In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept".

After the Windows Help program has been installed, the notification "Installation complete" will appear. Confirm this by clicking the "Close" button.

The installation of the Windows Help program has been completed and you will now be able to open the Help files.

2.3 Licensing the LibHuGas Property Library

The licensing procedure has to be carried out when calculating a LibHuGas function and a FluidVIEW prompt message appears. In this case, you will see the "License Information" window (see figure below).

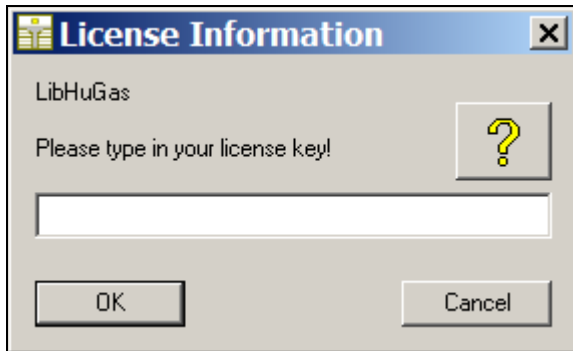


Figure 2.6 "License Information" window

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

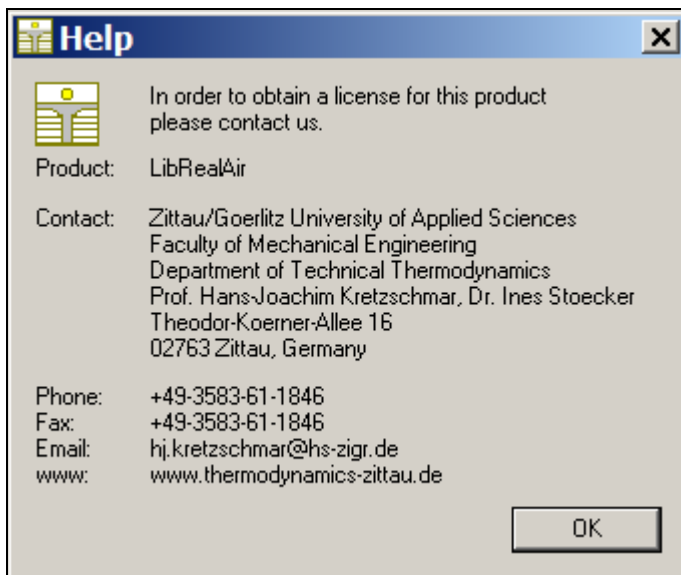


Figure 2.7 "Help" window

If you do not enter a valid license it is still possible to run your VI by clicking "Cancel". In this case, the LibHuGas property library will display the result "-1.11111E+7" for every calculation.

The "License Information" window will appear every time you reopen your Virtual Instrument (VI) or reload the path of the LibHuGas.dll. Should you not wish to license the LibHuGas property library, you have to uninstall FluidVIEW according to the description in section 2.5 of this User's Guide.

2.4 Example: Calculation of $h = f(p, t, \text{type}, \text{comp}(1:8))$

After the delivered files have been copied in the appropriate folders of the default directory LabVIEW™ (described in section 2.1), the LibHuGas property library is ready to use. The function nodes of the LibHuGas property library can be used by dragging them from the functions palette into the block diagram and connecting them with the wires representing the required input parameters.

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p , temperature t , type (composition as mole or mass fraction) and composition vector, using FluidVIEW.

- Start LabVIEW™ and wait for the *Getting Started* window to be displayed. Then select *Blank VI*. The *Blank VI* will be displayed in two windows, the front panel and the block diagram.
- Open the functions palette in the block diagram via **view / Functions Palette** (or by clicking the right mouse button anywhere in the free area of the block diagram) if not yet displayed.
- In addition to the default LabVIEW™ palettes the functions palette contains the sub palette *FluidVIEW* (see Figure 2.8) with the sub palette *LibHuGas* (see Figure 2.9).

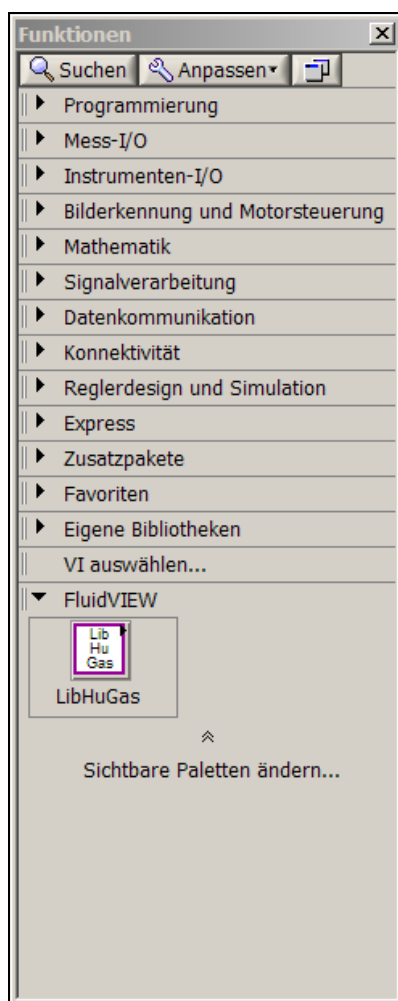


Figure 2.8
Functions palette with the sub palettes FluidVIEW and LibHuGas

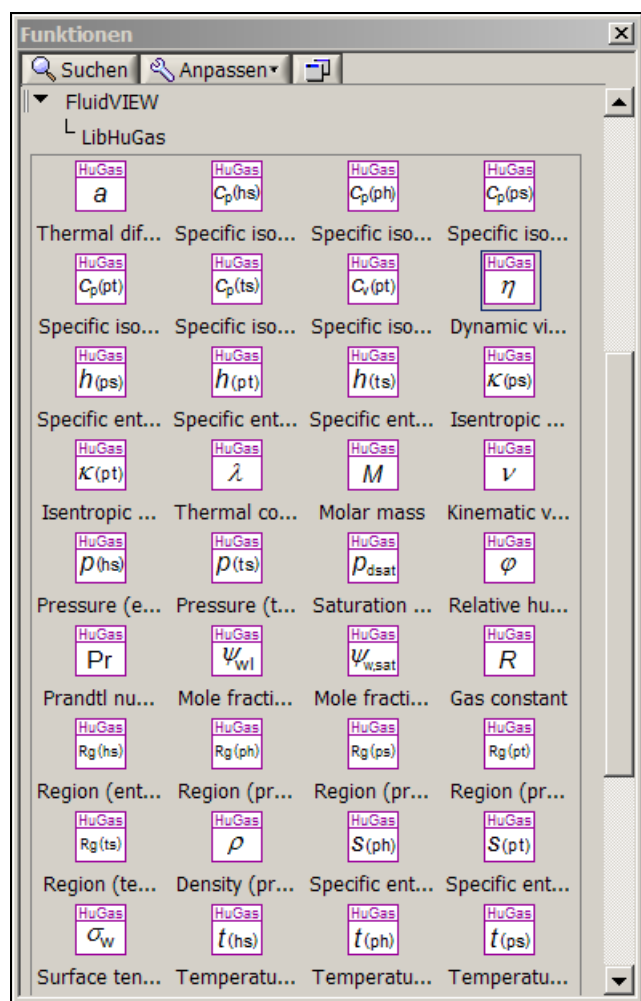


Figure 2.9
Functions palette with the property functions of the LibHuGas library

In order to calculate the specific enthalpy h , drag the function (SubVI) whose symbol shows $h_{(pt)}$ from the functions palette into the block diagram.

While the short names of the SubVIs behind the symbols will be shown in the control tip, the full names and brief descriptions of the property functions are displayed in the *Context Help* window (see Figure 2.2). To use the context help press <Ctrl>+<H> on your keyboard.

- After placing the node of the SubVI **h_ptcomp_HuGas.vi** on your block diagram the required input parameters have to be defined.
The input parameters which are set as required appear in bold type in the Context Help window. In this case these input parameters are **Path LibHuGas.dll** (LabVIEW™ data type: Path), **Pressure p in bar** (LabVIEW™ data type: Double precision, floating-point), **Temperature t in °C** (LabVIEW™ data type: Double precision, floating-point), **type** (LabVIEW™ data type: Long signed integer) and **Vector of composition comp** (1-D Array, LabVIEW™ data type: Double precision, floating-point).
- To define these variables wire their input terminals with input elements on the front panel. You can accomplish this in one step by choosing **Create / Control** in the context menu of all required input terminals. In order to wire the output terminal of the function node with an output element on the front panel, choose **Create / Indicator** in the context menu of the output terminal **Specific enthalpy h in kJ/kg** (LabVIEW™ data type: Double precision, floating-point). After cleaning up the block diagram by pressing <Ctrl>+<U> it has the appearance illustrated in Figure 2.10. The same input and output elements are available on the appropriate front panel (see Figure 2.11).

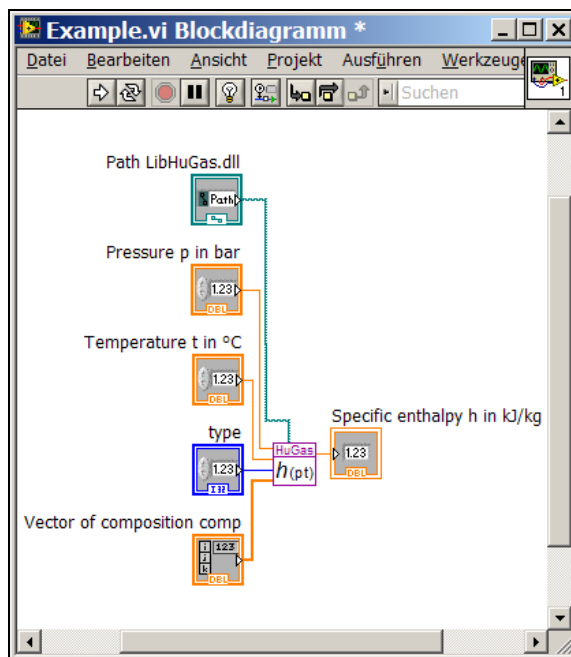


Figure 2.10
Block diagram of the example calculation

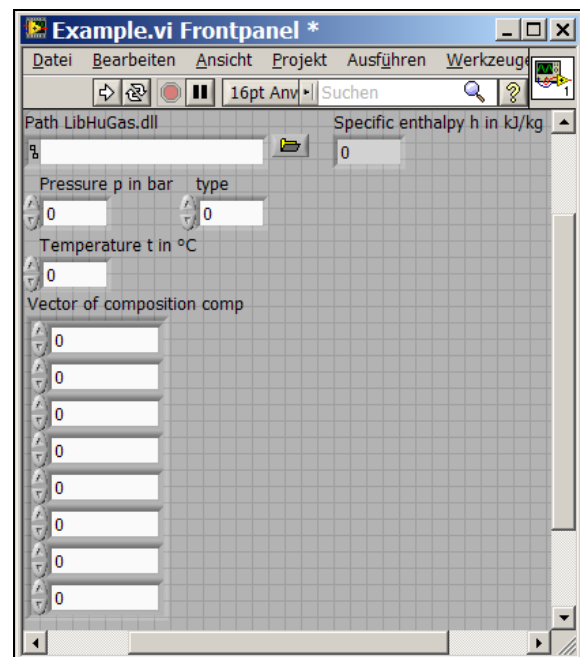


Figure 2.11
Front panel of the example calculation

- Enter a value in the input element *Pressure p in bar* on the front panel (Range of validity of LibHuGas: $p = 0.01 \dots 1000$ bar)
⇒ e. g.: Enter the value 10

- Enter a value in the input element *Temperature t in °C* on the front panel
(Range of validity of LibHuGas: $t = -70 \dots 3026.15$ °C)
⇒ e. g.: Enter the value 500
- Enter the value for type into the input element *type* on the front panel
("0" when entering the composition as mole fractions, "1" when entering the composition as mass fractions)
⇒ e. g.: Enter the value 0
- Enter the composition vector into the input element *Vector of composition comp* on the frontpanel. Use the following order to define the vector elements.

Mole fraction for Argon (Ar)	⇒ e. g.: Enter the value 0.0088
Mole fraction for Neon (Ne)	⇒ e. g.: Enter the value 0
Mole fraction for Nitrogen (N ₂)	⇒ e. g.: Enter the value 0.7480
Mole fraction for Oxygen (O ₂)	⇒ e. g.: Enter the value 0.1352
Mole fraction for Carbon monoxide (CO)	⇒ e. g.: Enter the value 0
Mole fraction for Carbon dioxide (CO ₂)	⇒ e. g.: Enter the value 0.0330
Mole fraction for Water (H ₂ O)	⇒ e. g.: Enter the value 0.0750
Mole fraction for Sulfur dioxide (SO ₂)	⇒ e. g.: Enter the value 0
- Enter the path of the LibHuGas.dll in the input element *Path LibHuGas.dll* on the front panel (as explained in section 2.1 the LibHuGas.dll and the other library files from the directory **<CD>source** have to be stored in the same directory which is arbitrary). To do this you can use the *File Open Dialog* which appears by clicking the yellow folder symbol on the right of the input element.
- To run the calculation of the specific enthalpy click on the *Run* button or press <Ctrl>+<R>. The result for h in kJ/kg appears in the output element (see Figure 2.12).
⇒ The result for h in our sample calculation is 662.8039107 in kJ/kg.

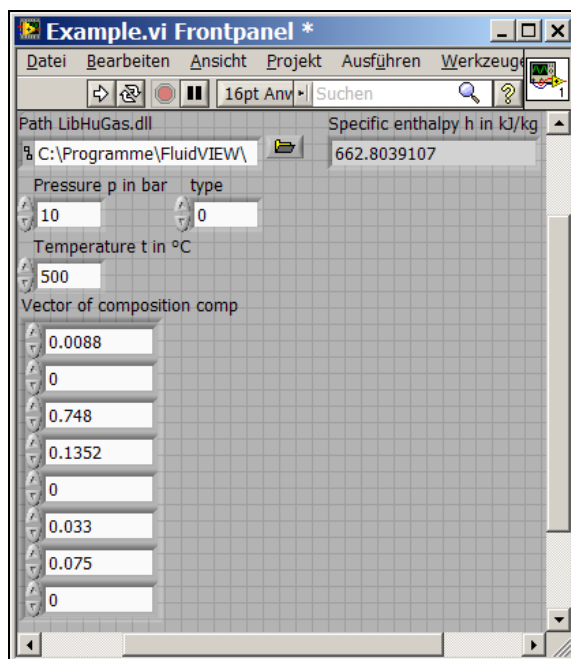


Figure 2.12
Result of the example calculation of h

The calculation of $h = f(p, t, \text{type}, \text{comp}(1:8))$ has thus been completed.

2.5 Removing FluidVIEW

Should you wish to remove the LibHuGas library or the complete FluidVIEW Add-on you merely have to delete the files that have been copied in the default directory of the LabVIEW™ development environment <LV>.

Removing the FluidVIEW Add-on

To remove the FluidVIEW Add-on please delete the folders listed in Table 2.3 from the default directory of LabVIEW™.

Table 2.3 Directories that have to be deleted from the default directory of LabVIEW™ to remove the FluidVIEW Add-on

Name of the directory	Path in the default directory of LabVIEW™ (<LV>)
FluidVIEW	<LV>\vi.lib
FluidVIEW	<LV>\menus\Categories
FluidVIEW-Help	<LV>\help

Removing only the LibHuGas library

To remove only the LibHuGas library please delete the folders or files listed in Table 2.4 from the default directory of LabVIEW™.

Table 2.4 Data that have to be deleted from the default directory of LabVIEW™ (<LV>) to remove only the LibHuGas library.

File name with file extension or name of the directory	Path in the default directory of LabVIEW (<LV>)
LibHuGas.llb	<LV>\vi.lib\FluidVIEW
LibHuGas	<LV>\menus\Categories\FluidVIEW
LibHuGas.hlp	<LV>\help\FluidVIEW-Help
LibHuGas.txt	<LV>\help\FluidVIEW-Help
FluidVIEW_LibHuGas.pdf	<LV>\help\FluidVIEW-Help
Open_LibHuGas_doc.vi	<LV>\help\FluidVIEW-Help
Open_LibHuGas_doc.txt	<LV>\help\FluidVIEW-Help

The changes will take effect after restarting LabVIEW™.

3. Program Documentation

Thermal Diffusivity $a = f(p, t, \text{type}, \text{comp}(1:8))$

Function Name:

a_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 type = 0 → composition as mole fraction
 = 1 → composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

a_ptcomp_HuGas - Thermal diffusivity in m²/s

Range of validity:

Temperature t : - 70 °C ≤ t ≤ 3026.85 °C
 Pressure p : 0.01 bar ≤ p ≤ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

- Thermal diffusivity $a = \frac{\lambda}{\rho \cdot c_p}$, model of ideal mixture of real fluids
 - Valid only for unsaturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$)

Result for incorrect input values:

a_ptcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	ρ, c_p - ideal part	ρ, c_p - real part	λ
Ar	[26]	[27]	[33]
Ne	[26]	-	[34],[35],[40],[41]
N ₂	[26]	[28]	[42]
O ₂	[26]	[29]	[37]
CO	[26]	-	[38]
CO ₂	[26]	[30]	[43]
H ₂ O	[26]	[31]	[16]
SO ₂	[26]	-	[34],[35],[40]

Specific Isobaric Heat Capacity $c_p = f(h,s,type,comp(1:8))$
Function Name:

cp_hscomp_HuGas

Input values:

h - Specific enthalpy h in kJ/kg
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

cp_hscomp_HuGas - specific isobaric heat capacity in kJ/(kg K)

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of p and t from $h(p,t,comp)$ and $s(p,t,comp)$ and calculation of c_p from $c_p(p,t,comp)$

Calculation:

- Valid only for unsaturated humid gas ($\psi_w \leq \psi_{w,sat}$)
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

cp_hscomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	c_p, h, s - ideal part	c_p, h, s - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Isobaric Heat Capacity $c_p = f(p, h, \text{type}, \text{comp}(1:8))$
Function Name:

cp_phcomp_HuGas

Input values:

p - Pressure p in bar
 h - Specific enthalpy h in kJ/kg
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

cp_phcomp_HuGas - specific isobaric heat capacity in kJ/(kg K)

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t from $h(p, t, \text{comp})$ and calculation of c_p from $c_p(p, t, \text{comp})$

Calculation:

- Valid only for unsaturated humid gas ($\psi_w \leq \psi_{w, \text{sat}}$)
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

cp_phcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	c_p, h - ideal part	c_p, h - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Isobaric Heat Capacity $c_p = f(p,s,type,comp(1:8))$
Function Name:

cp_pscomp_HuGas

Input values:

p - Pressure p in bar
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

cp_pscomp_HuGas - specific isobaric heat capacity in kJ/(kg K)

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:Iteration of t from $s(p,t,comp)$ and calculation of c_p from $c_p(p,t,comp)$

Calculation:

- Valid only for unsaturated humid gas ($\psi_w \leq \psi_{w,sat}$)
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:cp_pscomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	$c_{p,s}$ - ideal part	$c_{p,s}$ - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Isobaric Heat Capacity $c_p = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

cp_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

cp_ptcomp_HuGas - specific isobaric heat capacity in kJ/(kg K)

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- Valid only for unsaturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$)
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

cp_ptcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	c_p - ideal part	c_p - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Isobaric Heat Capacity $c_p = f(t,s,type,comp(1:8))$
Function Name:

cp_tscomp_HuGas

Input values:

t - Temperature t in °C
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

cp_tscomp_HuGas - specific isobaric heat capacity in kJ/(kg K)

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:Iteration of p from $s(p,t,comp)$ and calculation of c_p from $c_p(p,t,comp)$

Calculation:

- Valid only for unsaturated humid gas ($\psi_w \leq \psi_{w,sat}$)
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:cp_tscomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	$c_{p,s}$ - ideal part	$c_{p,s}$ - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Isochoric Heat Capacity $c_v = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

cv_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

cv_ptcomp_HuGas - Specific isochoric heat capacity in kJ/(kg K)

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:
 - Valid only for unsaturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$)
 - Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

cv_ptcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	c_v - ideal part	c_v - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Dynamic Viscosity $\eta = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

Eta_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Eta_ptcomp_HuGas - Dynamic viscosity in Pa s

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for liquid fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water
- for ice fog ($\psi_w > \psi_{w,\text{sat}}$, $t < 0.01\text{ °C}$) as saturated humid gas mixture

Result for incorrect input values:Eta_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	η
Ar	[33]
Ne	[34]
N ₂	[36]
O ₂	[37]
CO	[38]
CO ₂	[39]
H ₂ O	[17]
SO ₂	[34]

Specific Enthalpy $h = f(p,s,type,comp(1:8))$
Function Name:

`h_pscomp_HuGas`

Input values:

p - Pressure p in bar
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

`h_pscomp_HuGas` - specific enthalpy in kJ/kg

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t from $s(p,t,comp)$ and calculation of h from $h(p,t,comp)$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

`h_pscomp_HuGas` = $-1 \cdot 10^{100}$

Reference:

Gas	h,s - ideal part	h,s - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Specific Enthalpy $h = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

h_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

h_ptcomp_HuGas - Specific enthalpy in kJ/kg

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:h_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	h - ideal part	h - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Specific Enthalpy $h = f(t,s,type,comp(1:8))$
Function Name:

`h_tscomp_HuGas`

Input values:

t - Temperature t in °C
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

`h_tscomp_HuGas` - Specific enthalpy in kJ/kg

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of p from $s(p,t,comp)$ and calculation h from $h(p,t,comp)$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real gases (dry gas and steam)
- for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water or water ice, calculation is not possible for liquid-ice fog at 0.01 °C
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

`h_tscomp_HuGas` = $-1 \cdot 10^{100}$

Reference:

Gas	h,s ideal part	h,s real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Isentropic Exponent $\kappa = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

Kappa_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Kappa_ptcomp_HuGas - Isentropic exponent

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$):

$$\kappa = -\frac{v}{p} \cdot \left(\frac{\partial p}{\partial v} \right)_T \cdot \frac{c_p}{c_v}$$

- for liquid fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water- for ice fog ($\psi_w > \psi_{w,\text{sat}}$, $t < 0.01\text{ °C}$) as saturated humid gas mixture**Result for incorrect input values:**kappa_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	v, c_p, c_v - ideal part	v, c_p, c_v - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Isentropic Exponent $\kappa = f(p,s,type,comp(1:8))$
Function Name:

Kappa_pscomp_HuGas

Input values:

p - Pressure p in bar
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $= 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Kappa_pscomp_HuGas - Isentropic exponent

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t from $s(p,t,comp)$ and calculation of κ from $kappa(p,t,comp)$:

- for unsaturated and saturated humidity gas ($\psi_w \leq \psi_{w,sat}$)

$$\kappa = -\frac{v}{p} \cdot \left(\frac{\partial p}{\partial v} \right)_T \cdot \frac{c_p}{c_v}$$

- for liquid fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water

- for ice fog ($\psi_w > \psi_{w,sat}$, $t < 0.01\text{ °C}$) as saturated humid gas mixture

Result for incorrect input values:

$kappa_pscomp_HuGas = -1 \cdot 10^{100}$

Reference:

Gas	v, c_p, c_v - ideal part	v, c_p, c_v - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Thermal Conductivity $\lambda = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

Lambda_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Lambda_ptcomp_HuGas - Thermal conductivity in W/(m K)

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for liquid fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water
- for ice fog ($\psi_w > \psi_{w,\text{sat}}$, $t < 0.01$ °C) as saturated humid gas mixture

Result for incorrect input values:

lambda_ptcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	λ
Ar	[33]
Ne	[34],[35],[40],[41]
N ₂	[42]
O ₂	[37]
CO	[38]
CO ₂	[43]
H ₂ O	[16]
SO ₂	[34],[35],[40]

Molar Mass $M = f(\text{type}, \text{comp}(1:8))$ **Function Name:**

M_comp_HuGas

Input values:

type = 0 → composition as mole fraction

= 1 → composition as mass fraction

comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

M_comp_HuGas - Molar mass in kg/kmol

Result for incorrect input values:

M_comp_HuGas = $-1 \cdot 10^{100}$

Kinematic Viscosity $\nu = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

Ny_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:Ny_ptcomp_HuGas - Kinematic viscosity in m²/s**Range of validity:**

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

- Kinematic viscosity $\nu = \frac{\eta}{\rho} = \eta \cdot \nu$
- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for liquid fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water
- for ice fog ($\psi_w > \psi_{w,\text{sat}}$, $t < 0.01$ °C) as saturated humid gas mixture

Result for incorrect input values:Ny_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	ν - ideal part	ν - real part	λ
Ar	[26]	[27]	[33]
Ne	[26]	-	[34],[35],[40],[41]
N ₂	[26]	[28]	[42]
O ₂	[26]	[29]	[37]
CO	[26]	-	[38]
CO ₂	[26]	[30]	[43]
H ₂ O	[26]	[31]	[16]
SO ₂	[26]	-	[34],[35],[40]

Pressure $p = f(h, s, \text{type}, \text{comp}(1:8))$
Function Name:

p_hscomp_HuGas

Input values:

h - Specific enthalpy h in kJ/kg
 s - Specific entropy s in kJ/(kg K)
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

p_hscomp_HuGas - Pressure in bar

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t and p from $h(p, t, \text{comp})$ and $s(p, t, \text{comp})$ and calculation:
 - for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w, \text{sat}}$) as ideal mixture of real gases (dry gas and steam)
 - for fog ($\psi_w > \psi_{w, \text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice, calculation is not possible for liquid-ice fog at 0.01 °C
 - Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

p_hscomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	h, s - ideal part	h, s - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Pressure $p = f(t,s,type,comp(1:8))$
Function Name:

p_tscomp_HuGas

Input values:t - Temperature t in °Cs - Specific entropy s in kJ/(kg K)

type = 0 → composition as mole fraction

= 1 → composition as mass fraction

comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)**Result:**

p_tscomp_HuGas - Pressure in bar

Range of validity:Temperature t : - 70 °C ≤ t ≤ 3026.85 °CPressure p : 0.01 bar ≤ p ≤ 1000 barPartial pressures of CO₂ and SO₂ less than saturation pressures**Comments:**Iteration of p from $s(p,t,comp)$ and calculation:- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real gases

(dry gas and steam)

- for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and

liquid water or water ice, calculation is not possible for liquid-ice fog at 0.01 °C

- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:p_tscomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	s - ideal part	s - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Saturation Pressure of Water $p_{\text{dsat}} = f(p, t)$
Function Name:

pdsat_pt_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C

Result:

pdsat_pt_HuGas - Saturation pressure of water in bar

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar

Comments:

$p_{\text{dsat}}(p, t)$ for $t \geq 0.01$ °C – Vapour pressure of water in gas mixtures
 for $t < 0.01$ °C – Sublimation pressure of water in gas mixtures

Result for incorrect input values:pdsat_pt_HuGas = $-1 \cdot 10^{100}$ **Reference:**

$p_{\text{dsat}}(p, t)$ for $t \geq 0.01$ °C from IAPWS-IF97 [1], [2], [3], [4]
 $p_{\text{dsat}}(p, t)$ for $t < 0.01$ °C from IAPWS-92 [24]

Relative Humidity $\varphi = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

Phi_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Phi_ptcomp_HuGas - Relative humidity in %

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

$$\text{Relative humidity } \varphi = \frac{\frac{X_w}{\frac{R_l}{R_w} + X_w}}{\frac{p}{p_{\text{dsat}}(p, t)}} \cdot 100\%$$

with $p_{\text{dsat}}(p, t)$ for $t \geq 0.01$ °C - Vapour pressure of water in gas mixtures
 for $t < 0.01$ °C - Sublimation pressures of water in gas mixtures

Result for incorrect input values:Phi_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

$p_{\text{dsat}}(p, t)$ for $t \geq 0.01$ °C from IAPWS-IF97 [1], [2], [3], [4]
 $p_{\text{dsat}}(p, t)$ for $t < 0.01$ °C from IAPWS-92 [24]

Prandtl Number $Pr = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

Pr_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Pr_ptcomp_HuGas - Prandtl-number

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

- Prandtl-number $Pr = \frac{\nu}{a} = \frac{\eta \cdot c_p}{\lambda}$
- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for liquid fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water
- for ice fog ($\psi_w > \psi_{w,\text{sat}}$, $t < 0.01$ °C) as saturated humid gas mixture

Result for incorrect input values:

Pr_ptcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	c_p - ideal part	c_p - real part	η	λ
Ar	[26]	[27]	[33]	[33]
Ne	[26]	-	[34]	[34],[35],[40],[41]
N ₂	[26]	[28]	[36]	[42]
O ₂	[26]	[29]	[37]	[37]
CO	[26]	-	[38]	[38]
CO ₂	[26]	[30]	[39]	[43]
H ₂ O	[26]	[31]	[17]	[16]
SO ₂	[26]	-	[34]	[34],[35],[40]

Gas Constant $R = f(\text{type}, \text{comp}(1:8))$ **Function Name:**

R_comp_HuGas

Input values:

type = 0 → composition as mole fraction

= 1 → composition as mass fraction

comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

R_comp_HuGas - Gas constant in kJ/(kg K)

Result for incorrect input values:

R_comp_HuGas = $-1 \cdot 10^{100}$

Reference: [32]

$Region = f(h,s,type,comp(1:8))$

Function Name:

Region_hscomp_HuGas

Input values:

h - Specific enthalpy h in kJ/kg
 s - Specific entropy s in kJ/(kg K)
 $type$ = 0 → composition as mole fraction
 = 1 → composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Region_hscomp_HuGas - State point of humid gas mixture

= 0 → Out of range of validity	= 6 → Pure liquid water
= 1 → Dry gas mixture	= 7 → Pure water-wet steam
= 2 → Unsaturated Gas mixture	= 8 → Pure steam
= 3 → Liquid fog	= 10 → The CO ₂ in the gas mixture would be partly liquid. Calculation is terminated.
= 4 → Ice fog	
= 5 → Liquid-ice fog at 0.01 °C exactly	= 11 → The SO ₂ in the gas mixture would be partly liquid. Calculation is terminated.

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of p and t from $s(p,t,comp)$ and $h(p,t,comp)$ and calculation of $Region$ from $Region(p,t,comp)$

Result for incorrect input values:

Region_hscomp_HuGas = 0

Reference:

Gas	h, s - ideal part	h, s - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

$Region = f(p, h, type, comp(1:8))$
Function Name:

Region_phcomp_HuGas

Input values:

p - Pressure p in bar
 h - Specific enthalpy h in kJ/kg
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Region_phcomp_HuGas - State point of humid gas mixture

= 0 $\rightarrow$ Out of range of validity	= 6 $\rightarrow$ Pure liquid water
= 1 $\rightarrow$ Dry gas mixture	= 7 $\rightarrow$ Pure water-wet steam
= 2 $\rightarrow$ Unsaturated Gas mixture	= 8 $\rightarrow$ Pure steam
= 3 $\rightarrow$ Liquid fog	= 10 $\rightarrow$ The CO ₂ in the gas mixture would be partly liquid. Calculation is terminated.
= 4 $\rightarrow$ Ice fog	
= 5 $\rightarrow$ Liquid-ice fog at 0.01 °C exactly	= 11 $\rightarrow$ The SO ₂ in the gas mixture would be partly liquid. Calculation is terminated.

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

 Iteration of t from $h(p, t, comp)$ and calculation of $Region$ from $Region(p, t, comp)$
Result for incorrect input values:

Region_phcomp_HuGas = 0

Reference:

Gas	h - ideal part	h - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

***Region* = f(*p,s,type,comp*(1:8))**

Function Name:

Region_pscomp_HuGas

Input values:

p - Pressure *p* in bar
s - Specific entropy *s* in kJ/(kg K)
type = 0 → composition as mole fraction
 = 1 → composition as mass fraction
comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Region_pscomp_HuGas - State point of humid gas mixture

= 0 → Out of range of validity	= 6 → Pure liquid water
= 1 → Dry gas mixture	= 7 → Pure water-wet steam
= 2 → Unsaturated Gas mixture	= 8 → Pure steam
= 3 → Liquid fog	= 10 → The CO ₂ in the gas mixture would be partly liquid. Calculation is terminated.
= 4 → Ice fog	
= 5 → Liquid-ice fog at 0.01 °C exactly	= 11 → The SO ₂ in the gas mixture would be partly liquid. Calculation is terminated.

Range of validity:

Temperature *t* : - 70 °C ≤ *t* ≤ 3026.85 °C
 Pressure *p*: 0.01 bar ≤ *p* ≤ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of *t* from *s*(*p,t,comp*) and calculation of *Region* from *Region*(*p,t,comp*)

Result for incorrect input values:

Region_pscomp_HuGas = 0

Reference:

Gas	<i>s</i> - ideal part	<i>s</i> - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

$Region = f(p, t, type, comp(1:8))$
Function Name:

Region_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Region_ptcomp_HuGas - State point of humid gas mixture

= 0 $\rightarrow$ Out of range of validity	= 6 $\rightarrow$ Pure liquid water
= 1 $\rightarrow$ Dry gas mixture	= 7 $\rightarrow$ Pure water-wet steam
= 2 $\rightarrow$ Unsaturated Gas mixture	= 8 $\rightarrow$ Pure steam
= 3 $\rightarrow$ Liquid fog	= 10 $\rightarrow$ The CO ₂ in the gas mixture would be partly liquid. Calculation is terminated.
= 4 $\rightarrow$ Ice fog	
= 5 $\rightarrow$ Liquid-ice fog at 0.01 °C exactly	= 11 $\rightarrow$ The SO ₂ in the gas mixture would be partly liquid. Calculation is terminated.

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water or water ice

Result for incorrect input values:

Region_ptcomp_HuGas = 0

***Region* = f(*t,s,type,comp*(1:8))**

Function Name:

Region_tscomp_HuGas

Input values:

t - Temperature *t* in °C
s - Specific entropy *s* in kJ/(kg K)
type = 0 → composition as mole fraction
 = 1 → composition as mass fraction
comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Region_tscomp_HuGas - State point of humid gas mixture

= 0 → Out of range of validity	= 6 → Pure liquid water
= 1 → Dry gas mixture	= 7 → Pure water-wet steam
= 2 → Unsaturated Gas mixture	= 8 → Pure steam
= 3 → Liquid fog	= 10 → The CO ₂ in the gas mixture would be partly liquid. Calculation is terminated.
= 4 → Ice fog	
= 5 → Liquid-ice fog at 0.01 °C exactly	= 11 → The SO ₂ in the gas mixture would be partly liquid. Calculation is terminated.

Range of validity:

Temperature *t* : - 70 °C ≤ *t* ≤ 3026.85 °C
 Pressure *p*: 0.01 bar ≤ *p* ≤ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of *p* from *s*(*p,t,comp*) and calculation of *Region* from *Region*(*p,t,comp*)

Result for incorrect input values:

Region_tscomp_HuGas = 0

Reference:

Gas	<i>s</i> - ideal part	<i>s</i> - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Density $\rho = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

rho_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:rho_ptcomp_HuGas - Density in kg/m³**Range of validity:**

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice

Result for incorrect input values:rho_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	ρ - ideal part	ρ - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Specific Entropy $s = f(p, h, \text{type}, \text{comp}(1:8))$
Function Name:

s_phcomp_HuGas

Input values:

p - Pressure p in bar
 h - Specific enthalpy h in kJ/kg
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

s_phcomp_HuGas - Specific entropy in kJ/(kg K)

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t from $h(p, t, \text{comp})$ and calculation of s from $s(p, t, \text{comp})$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

s_phcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	h, s - ideal part	h, s - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Specific Entropy $s = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

s_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

s_ptcomp_HuGas - Specific entropy in kJ/(kg K)

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:s_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	s - ideal part	s - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Surface Tension of Water $\sigma_w = f(t)$
Function Name:

Sigmaw_t_HuGas

Input values:

t - Temperature t in °C

Result:

Sigmaw_t_HuGas - Surface tension of water σ_w in N/m

Range of validity:

Temperature t : $0\text{ °C} \leq t \leq 373.946\text{ °C}$

Comments:

Calculation for pure water from IAPWS-IF97

Result for incorrect input values:

sigmaw_t_HuGas = $-1 \cdot 10^{100}$

References: [8]

Temperature $t = f(h,s,type,comp(1:8))$
Function Name:

t_hscomp_HuGas

Input values:

- h - Specific enthalpy h in kJ/kg
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

t_hscomp_HuGas - Temperature t in °C

Range of validity:

- Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of p and t from $h(p,t,comp)$ and $s(p,t,comp)$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

t_hscomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	h,s - ideal part	h,s - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Temperature $t = f(p, h, \text{type}, \text{comp}(1:8))$
Function Name:

t_phcomp_HuGas

Input values:

p - Pressure p in bar
 h - Specific enthalpy h in kJ/kg
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

t_phcomp_HuGas - Temperature in °C

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t from $h(p, t, \text{comp})$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:

t_phcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	h - ideal part	h - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Temperature $t = f(p, s, \text{type}, \text{comp}(1:8))$
Function Name:

t_pscomp_HuGas

Input values:

p - Pressure p in bar
 s - Specific entropy s in kJ/(kg K)
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:t_pscomp_HuGas - Temperature t in °C**Range of validity:**

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:Iteration of t from $s(p, t, \text{comp})$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:t_pscomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	h, s - ideal part	h, s - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Dew Point Temperature of Water $t_{w,dew} = f(p, type, comp(1:8))$
Function Name:

twdew_pcomp_HuGas

Input values:

p - Pressure p in bar
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

twdew_pcomp_HuGas - Dew point temperature of water $t_{w,dew}$ in °C

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Dew point temperature of water $t_{w,dew} = t_s(p, p_d)$ for $t \geq 0.01\text{ °C}$
 (t_s – Saturation temperature of water in gas mixtures)
 $t_{w,dew} = t_{sub}(p, p_d)$ for $t < 0.01\text{ °C}$
 (t_{sub} – Sublimation temperature of water in gas mixtures)

Result for incorrect input values:

twdew_pcomp_HuGas = $-1 \cdot 10^{100}$

References:

$t_s(p, p_d)$ for $t \geq 0.01\text{ °C}$ from IAPWS-IF97 [1], [2], [3], [4]
 $t_{sub}(p, p_d)$ for $t < 0.01\text{ °C}$ from IAPWS-92 [24]

Internal Energy $u = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

u_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

u_ptcomp_HuGas - Internal energy in kJ/kg

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice
- Effects of dissociation are considered for temperatures greater than 500 °C

Result for incorrect input values:u_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	u - ideal part	u - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Specific Volume $v = f(h,s,type,comp(1:8))$
Function Name:

`v_hscomp_HuGas`

Input values:

h - Specific enthalpy h in kJ/kg
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

`v_hscomp_HuGas` - Specific volume in m³/kg

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of p and t from $h(p,t,comp)$ and $s(p,t,comp)$ and calculation of v from $v(p,t,comp)$
 Calculation:
 - for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real fluids
 - for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water or water ice

Result for incorrect input values:

`v_hscomp_HuGas` = $-1 \cdot 10^{100}$

Reference:

Gas	v,h,s - ideal part	v,h,s - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Volume $v = f(p, h, \text{type}, \text{comp}(1:8))$
Function Name:

`v_phcomp_HuGas`

Input values:

p - Pressure p in bar
 h - Specific enthalpy h in kJ/kg
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

`v_phcomp_HuGas` - Specific volume in m³/kg

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t from $h(p, t, \text{comp})$ and calculation of v from $v(p, t, \text{comp})$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice

Result for incorrect input values:

`v_phcomp_HuGas` = $-1 \cdot 10^{100}$

Reference:

Gas	v, h - ideal part	v, h - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Volume $v = f(p,s,type,comp(1:8))$
Function Name:

v_pscomp_HuGas

Input values:

p - Pressure p in bar
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

v_pscomp_HuGas - Specific volume in m³/kg

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq 3026.85\text{ °C}$
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of t from $s(p,t,comp)$ and calculation of v from $v(p,t,comp)$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water or water ice

Result for incorrect input values:

v_pscomp_HuGas = $-1 \cdot 10^{100}$

Reference:

Gas	v,s - ideal part	v,s - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Specific Volume $v = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

v_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:v_ptcomp_HuGas - Specific volume in m³/kg**Range of validity:**

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$) as ideal mixture of real fluids
- for fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water or water ice

Result for incorrect input values:v_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	v - ideal part	v - real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Specific Volume $v = f(t,s,type,comp(1:8))$
Function Name:

`v_tscomp_HuGas`

Input values:

t - Temperature t in °C
 s - Specific entropy s in kJ/(kg K)
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

`v_tscomp_HuGas` - Specific volume in m³/kg

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Iteration of p from $s(p,t,comp)$ and calculation v from $v(p,t,comp)$

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,sat}$) as ideal mixture of real gases (dry gas and steam)
- for fog ($\psi_w > \psi_{w,sat}$) as ideal mixture of saturated humid gas and liquid water or water ice, calculation is not possible for liquid-ice fog at 0.01 °C

Result for incorrect input values:

`v_tscomp_HuGas` = $-1 \cdot 10^{100}$

Reference:

Gas	v,h,s ideal part	v,h,s real part	ice
Ar	[26]	[27]	-
Ne	[26]	-	-
N ₂	[26]	[28]	-
O ₂	[26]	[29]	-
CO	[26]	-	-
CO ₂	[26]	[30]	-
H ₂ O	[26]	[31]	[25]
SO ₂	[26]	-	-

Isentropic Speed of Sound $w = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

w_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

w_ptcomp_HuGas - Isentropic speed of sound in m/s

Range of validity:

Temperature t : - 70 °C $\leq t \leq$ 3026.85 °C
 Pressure p : 0.01 bar $\leq p \leq$ 1000 bar
 Partial pressures of CO₂ and SO₂ less than saturation pressures

Comments:

Calculation:

- for unsaturated and saturated humid gas ($\psi_w \leq \psi_{w,\text{sat}}$)

$$w = \sqrt{-v^2 \cdot \left(\frac{\partial p}{\partial v} \right)_T \cdot \frac{c_p}{c_v}}$$

- for liquid fog ($\psi_w > \psi_{w,\text{sat}}$) as ideal mixture of saturated humid gas and liquid water- for ice fog ($\psi_w > \psi_{w,\text{sat}}$, $t < 0.01$ °C) as saturated humid gas mixture**Result for incorrect input values:**w_ptcomp_HuGas = $-1 \cdot 10^{100}$ **Reference:**

Gas	v, c_p, c_v - ideal part	v, c_p, c_v - real part
Ar	[26]	[27]
Ne	[26]	-
N ₂	[26]	[28]
O ₂	[26]	[29]
CO	[26]	-
CO ₂	[26]	[30]
H ₂ O	[26]	[31]
SO ₂	[26]	-

Humidity Ratio (Absolute Humidity) $x_w = f(\text{type}, \text{comp}(1:8))$
Function Name:

xw_comp_HuGas

Input values:

type = 0 → composition as mole fraction

= 1 → composition as mass fraction

comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

xw_comp_HuGas - Humidity ratio in g_{Water}/kg_{Gas}

Comments:

$$\text{Humidity ratio of water } x_w = \frac{\psi_w}{\frac{R_w}{R_{\text{mix}}} - \psi_w}$$

Result for incorrect input values:

$$\text{xw_comp_HuGas} = -1 \cdot 10^{100}$$

Mole Fraction of Liquid Water $\psi_{wl} = f(p, t, \text{type}, \text{comp}(1:8))$
Function Name:

Psiwl_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $\text{type} = 0 \rightarrow$ composition as mole fraction
 $\text{type} = 1 \rightarrow$ composition as mass fraction
 comp - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Psiwl_ptcomp_HuGas - Mole fraction of water in kmol/kmol

Range of validity:

Temperature t : $t_t(p, \text{comp}) \leq t \leq t_s(p, p_d)$
 (t_s – Saturation temperature of water in gas mixtures)
 Pressure p : $0.01 \text{ bar} \leq p \leq 1000 \text{ bar}$

Comments:

Mole fraction of liquid water: $\psi_{wl} = \psi_w - \psi_{wsat}$

$$\text{with } \psi_{wsat} = \frac{p_{dsat}(p, t)}{p}$$

with $p_{dsat}(p, t)$ for $t \geq 0.01 \text{ °C}$ – Vapour pressure of water in gas mixtures
 for $t < 0.01 \text{ °C}$ – Sublimation pressure of water in gas mixtures

Result for incorrect input values:

Psiwl_ptcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

$p_{dsat}(p, t)$ for $t \geq 0.01 \text{ °C}$ from IAPWS-IF97 [1], [2], [3], [4]
 $p_{dsat}(p, t)$ for $t < 0.01 \text{ °C}$ from IAPWS-92 [24]

Mole Fraction of Water of Saturated Gas

$$\psi_{w,sat} = f(p, t, type, comp(1:8))$$

Function Name:

Psiwsat_ptcomp_HuGas

Input values:

p - Pressure p in bar
 t - Temperature t in °C
 $type = 0 \rightarrow$ composition as mole fraction
 $type = 1 \rightarrow$ composition as mass fraction
 $comp$ - Vector of composition (Ar, Ne, N₂, O₂, CO, CO₂, H₂O, SO₂)

Result:

Psiwsat_ptcomp_HuGas – Mole fraction of water of saturated gas $\psi_{w,sat}$ in kmol/ kmol

Range of validity:

Temperature t : $-70\text{ °C} \leq t \leq t_s(p, p_d)$
 (t_s – Saturation temperature of water in gas mixtures)
 Pressure p : $0.01\text{ bar} \leq p \leq 1000\text{ bar}$

Comments:

Mole fraction of liquid water: $\psi_{wsat} = \frac{p_{dsat}(p, t)}{p}$

with $p_{dsat}(p, t)$ for $t \geq 0.01\text{ °C}$ – Vapour pressure of water in gas mixtures
 for $t < 0.01\text{ °C}$ – Sublimation pressure of water in gas mixtures

Result for incorrect input values:

Psiwsat_ptcomp_HuGas = $-1 \cdot 10^{100}$

Reference:

$p_{dsat}(p, t)$ for $t \geq 0.01\text{ °C}$ from IAPWS-IF97 [1], [2], [3], [4]
 $p_{dsat}(p, t)$ for $t < 0.01\text{ °C}$ from IAPWS-92 [24]



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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

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

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:
Ar NO He Propylene
Ne H₂O F₂ Propane
N₂ SO₂ NH₃ Iso-Butane
O₂ H₂ Methane n-Butane
CO H₂S Ethane Benzene
CO₂ OH Ethylene Methanol
Air

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bückner et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bückner et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

IAPWS Guideline 2001 of Tillner-Roth and Friend (1998)
Helmholtz energy equation for the mixing term (also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)
Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with
C₂H₆O₂ Ethylene glycol
C₃H₈O₂ Propylene glycol
C₂H₅OH Ethyl alcohol
CH₃OH Methyl alcohol
C₃H₈O₃ Glycerol
K₂CO₃ Potassium carbonate
CaCl₂ Calcium chloride
MgCl₂ Magnesium chloride
NaCl Sodium chloride
C₂H₃KO₂ Potassium acetate
Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

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

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

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

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide CO **Library LibCO**

Carbonyl sulfide COS **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monoxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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Fax.: +49-3583-61-1846

The following thermodynamic and transport properties can be calculated^a:

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

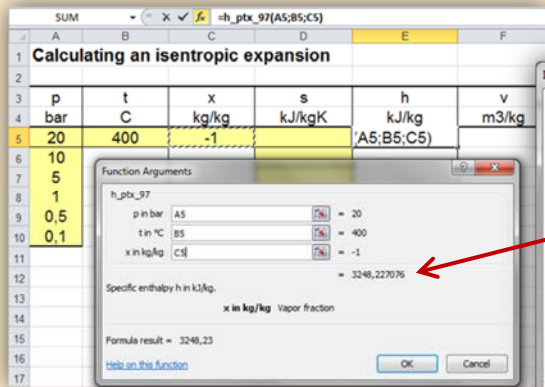
- Partial derivatives can be calculated.

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

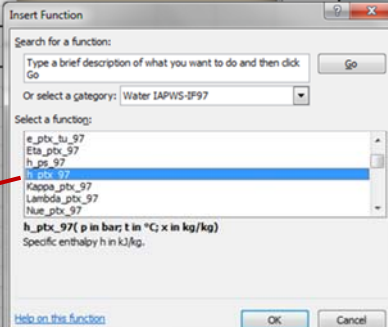


Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

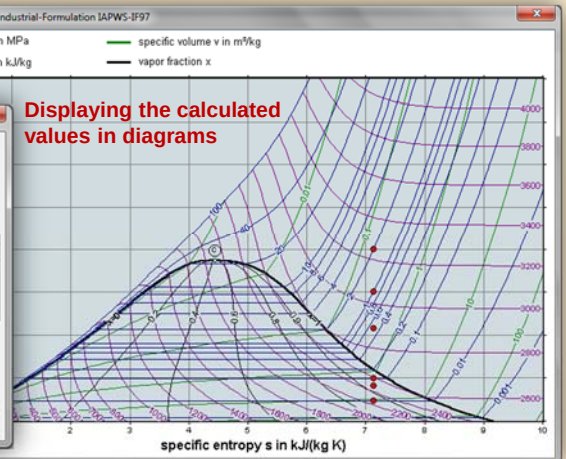
Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function



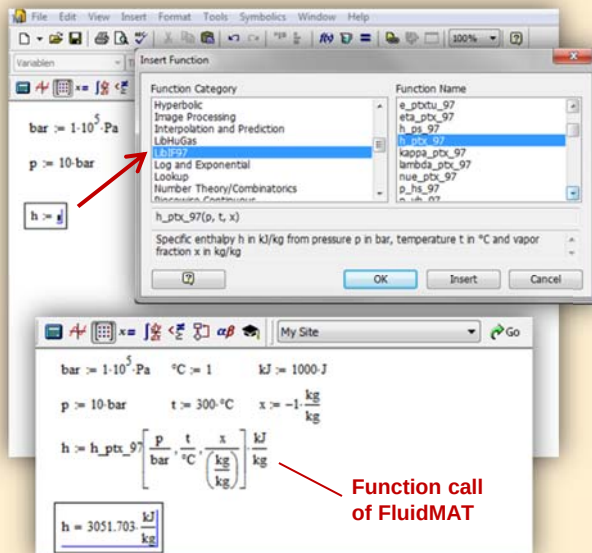
Displaying the calculated values in diagrams



Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

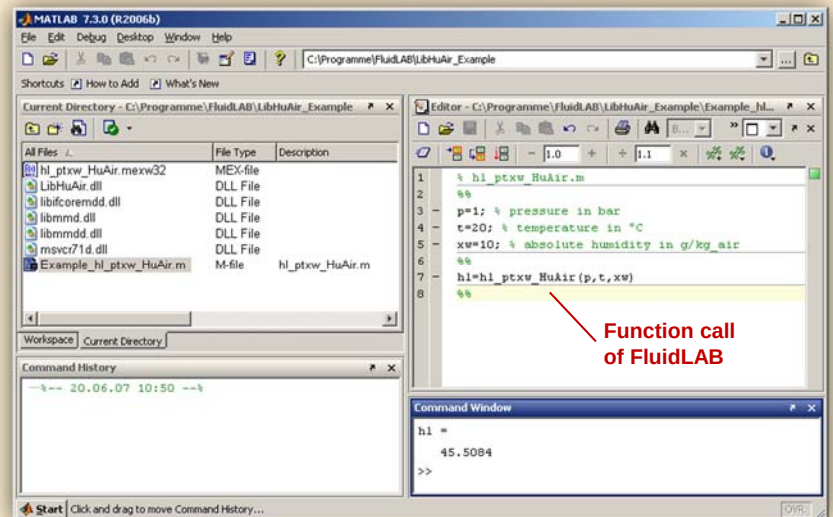
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

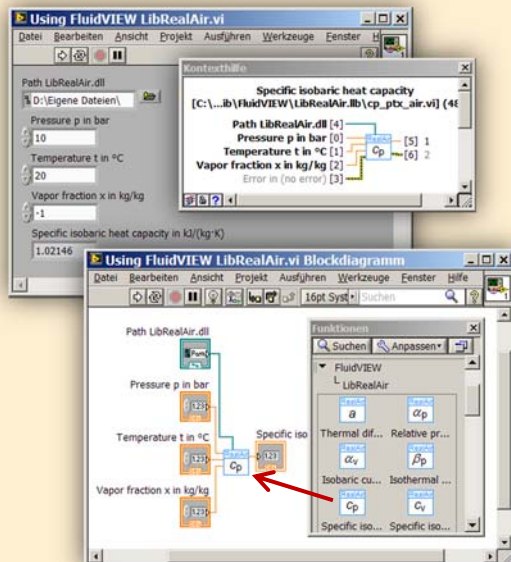
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

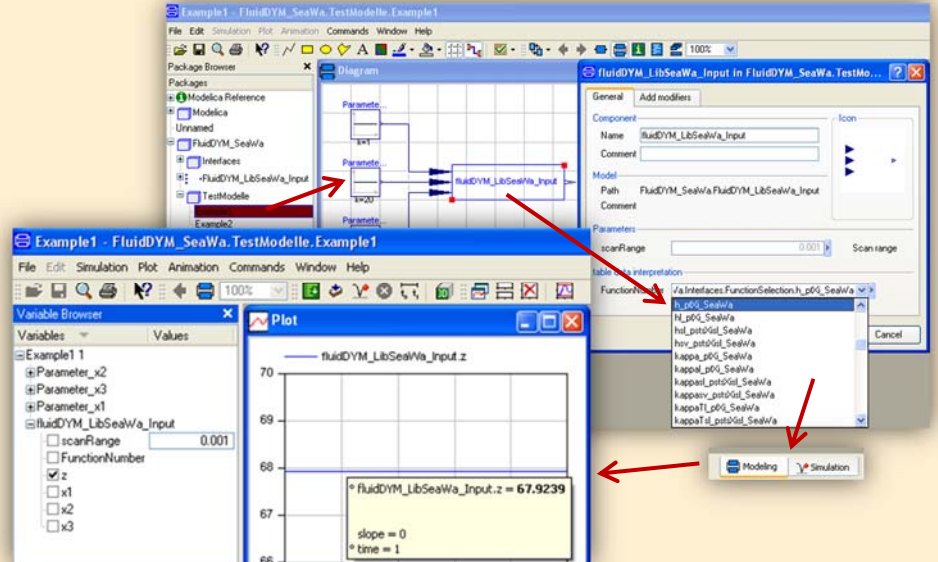
Add-On FluidVIEW for LabVIEW[®]

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

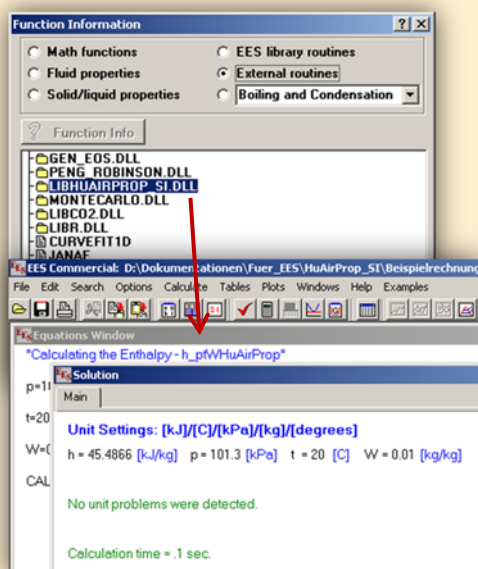


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

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



Add-In FluidEES for Engineering Equation Solver®



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



Online Property Calculator at www.thermodynamics-zittau.de

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

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

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = 3097.38 kJ/kg

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

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

PDF with the description

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Department of Technical Thermodynamics
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Programmer: Joachim Posselt

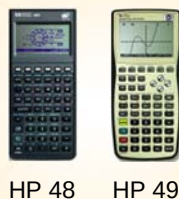
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www.thermodynamic-formelsammlung.de

Property Software for Pocket Calculators

FluidCasio



FluidHP



FluidTI



For more information please contact:

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

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6. Satisfied Customers

Date: 04/2014

The following companies and institutions use the property libraries

- FluidEXL *Graphics* for Excel®
- FluidLAB for MATLAB®
- FluidMAT for Mathcad®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica) and SimulationX®
- FluidVIEW for LabVIEW®:

2014

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Technical University of Vienna, Austria	04/2014
MTU Aero Engines AG, Munich	04/2014
GKS, Schweinfurt	03/2014
Technical University of Nurnberg	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, Nürnberg	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
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Technical University of Regensburg	10/2013
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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
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Technical University of Deggendorf	07/2013
University of Maryland, USA	07/2013, 08/2013
University of Princeton, USA	07/2013
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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
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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 Dresden + Bremen, Alfhausen	04/2013
University Auckland, New Zealand	04/2013
MASDAR Institut, Abu Dhabi, United Arab Emirates	03/2013
Simpelkamp, Dresden	02/2013
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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 Ingenieurbüro, 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

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Technical University of Munich	12/2012
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University of Stuttgart	11/2012
Siemens, Muehlheim	11/2012
Sennheiser, Hannover	11/2012
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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
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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
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010
University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010

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

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

2009

ALSTOM Power, Baden, Schweiz	01/2009, 03/2009 05/2009
Nordostschweizerische Kraftwerke AG, Doettingen, Switzerland	02/2009
RWE, Neurath	02/2009
Brandenburg University of Technology, Cottbus	02/2009
Hamburg University of Applied Sciences	02/2009
Kehrein, Moers	03/2009
EPP Software, Marburg	03/2009
Bernd Münstermann, Telgte	03/2009
Suedzucker, Zeitz	03/2009
CPP, Marburg	03/2009
Gelsenkirchen University of Applied Sciences	04/2009
Regensburg University of Applied Sciences	05/2009
Gatley & Associates, Atlanta, USA	05/2009

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

2008

Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	01/2008
University of Karlsruhe	01/2008
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	02/2008
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008

WEBASTO, Neubrandenburg	04/2008
CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008
Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008
Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
VER, Dresden	02/2007
Technical University of Dresden, Chair in Jet Propulsion Systems	02/2007
Redacom, Nidau, Switzerland	02/2007
Universität der Bundeswehr, Munich	02/2007
Maxxtec, Sinsheim	03/2007
University of Rostock, Chair in Technical Thermodynamics	03/2007
AGO, Kulmbach	03/2007
University of Stuttgart, Chair in Aviation Propulsions	03/2007
Siemens Power Generation, Duisburg	03/2007

ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
Technical University of Cottbus, Chair in Power Plant Engineering	06/2007
Voith Paper Air Systems, Bayreuth	06/2007
Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
National Energy Technology Laboratory, Pittsburg, USA	10/2007
Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007
Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

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

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

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005

FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden	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, Department of Mechanical Engineering and Process Engineering	05/2005
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005
Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	01/2004
University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004

Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003
Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003

Emden University of Applied Sciences, Department of Technology	05/2003
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, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
FZR Forschungszentrum, Rossendorf/Dresden	03/2002

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

2001

ALSTOM Power, Baden, Switzerland	01/2001, 06/2001 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001

Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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

1999

Bayernwerk, Munich	01/1999
DREWAG, Dresden (company license)	02/1999
KEMA IEV, Dresden	03/1999

Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
Technical University of Cottbus, Chair in Power Plant Engineering	07/1999
Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
M&M Turbine Technology Bielefeld	06/1998
B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998
SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

1997

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