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Property Library for Ammonia-Water Mixtures

**FluidVIEW
with LibAmWa
for LabVIEW™**

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Property Library for Ammonia-Water Mixtures

Including DLL and Add-on for LabVIEW™

FluidVIEW

LibAmWa

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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_LibAmWa.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.

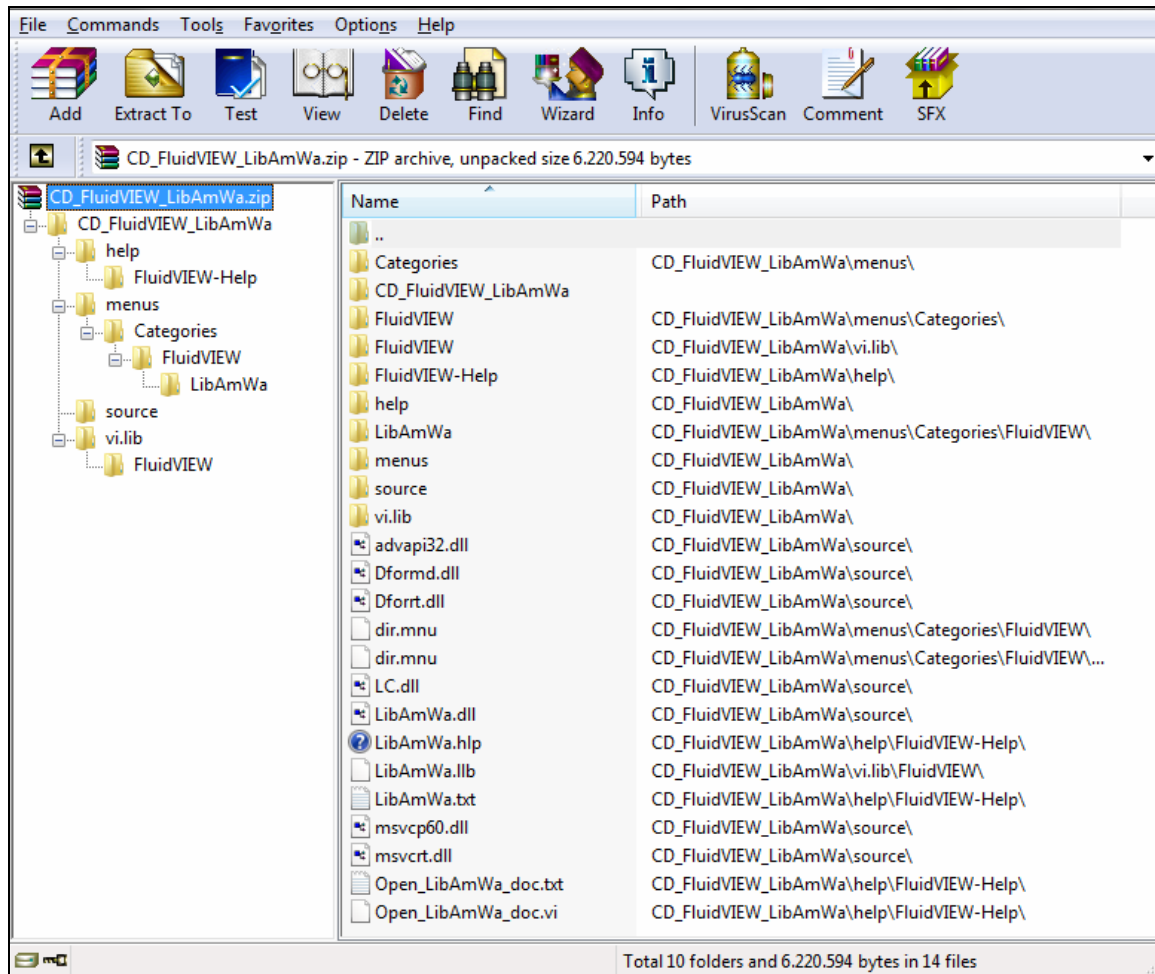


Figure 0.1 Screenshot of WinRAR showing the **CD_FluidVIEW_LibAmWa.zip** archive.

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_LibAmWa\vi.lib\FluidVIEW\LibAmWa**

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

Table 0.2 Effects of the files located in the archive directory **CD_FluidVIEW_LibAmWalmenus\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_LibAmWalsource**

Filename	Effects
LibAmWa.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of ammonia/water
advapi32.dll	Runtime library
Dformd.dll	Runtime library for the Fortran DLL
Dfortrt.dll	Runtime library for the Fortran DLL
LC.dll	Auxiliary library
msvcpx60.dll	Runtime library
msvcrt.dll	Runtime library

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

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

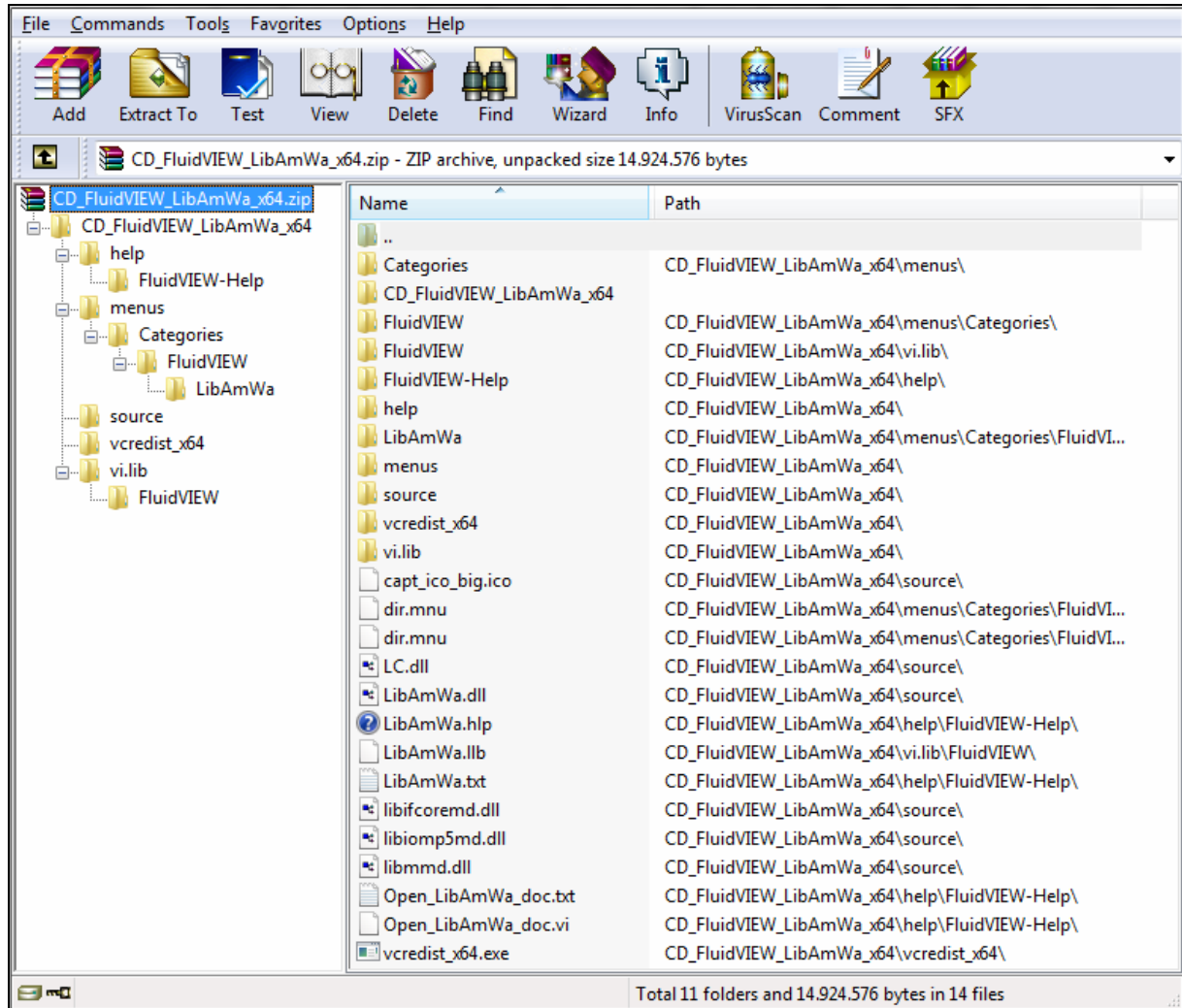


Figure 0.2 Screenshot of WinRAR showing the **CD_FluidVIEW_LibAmWa_x64.zip** archive.

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, 0.8 and 0.9.

Table 0.5 Effects of the files located in the archive directory **CD_FluidVIEW_LibAmWa_x64\vi.lib\FluidVIEW\LibAmWa**

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

Table 0.6 Effects of the files located in the archive directory **CD_FluidVIEW_LibAmWa_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_LibAmWa_x64\source**

Filename	Effects
LibAmWa.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of ammonia/water
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_LibAmWa_x64\help\FluidVIEW-help**

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

Table 0.9 Effects of the files located in the archive directory **CD_FluidVIEW_LibAmWa_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

Functional Dependence	Function Name	Call in Fortran	Property or Function	Unit
$a = f(p, t, \xi)$	a_ptxi_AmWa	APTxiAMWA(P,T,XI)	Thermal diffusivity	m^2/s
$a' = f(p, t, \xi')$	al_ptxil_AmWa	ALPTxiLAMWA(P,T,XIL)	Thermal diffusivity of saturated liquid	m^2/s
$a' = f(p, t, \xi'')$	al_ptxiv_AmWa	ALPTxiVAMWA(P,T,XIV)	Thermal diffusivity of saturated liquid	m^2/s
$a'' = f(p, t, \xi')$	av_ptxil_AmWa	AVPTxiLAMWA(P,T,XIL)	Thermal diffusivity of saturated vapor	m^2/s
$a'' = f(p, t, \xi'')$	av_ptxiv_AmWa	AVPTxiVAMWA(P,T,XIV)	Thermal diffusivity of saturated vapor	m^2/s
$c_p = f(p, t, \xi)$	cp_ptxi_AmWa	CPPTxiAMWA(P,T,XI)	Specific isobaric heat capacity	$\text{kJ}/(\text{kg K})$
$c'_p = f(p, t, \xi')$	cpl_ptxil_AmWa	CPLPTxiLAMWA(P,T,XIL)	Specific isobaric heat capacity of saturated liquid	$\text{kJ}/(\text{kg K})$
$c'_p = f(p, t, \xi'')$	cpl_ptxiv_AmWa	CPLPTxiVAMWA(P,T,XIV)	Specific isobaric heat capacity of saturated liquid	$\text{kJ}/(\text{kg K})$
$c''_p = f(p, t, \xi')$	cpv_ptxil_AmWa	CPVPTxiLAMWA(P,T,XIL)	Specific isobaric heat capacity of saturated vapor	$\text{kJ}/(\text{kg K})$
$c''_p = f(p, t, \xi'')$	cpv_ptxiv_AmWa	CPVPTxiVAMWA(P,T,XIV)	Specific isobaric heat capacity of saturated vapor	$\text{kJ}/(\text{kg K})$
$c_v = f(p, t, \xi)$	cv_ptxi_AmWa	CVPTxiAMWA(P,T,XI)	Specific isochoric heat capacity	$\text{kJ}/(\text{kg K})$
$c'_v = f(p, t, \xi')$	cvl_ptxil_AmWa	CVLPTxiLAMWA(P,T,XIL)	Specific isochoric heat capacity of saturated liquid	$\text{kJ}/(\text{kg K})$
$c'_v = f(p, t, \xi'')$	cvl_ptxiv_AmWa	CVLPTxiVAMWA(P,T,XIV)	Specific isochoric heat capacity of saturated liquid	$\text{kJ}/(\text{kg K})$
$c''_v = f(p, t, \xi')$	cvv_ptxil_AmWa	CVVPTxiLAMWA(P,T,XIL)	Specific isochoric heat capacity of saturated vapor	$\text{kJ}/(\text{kg K})$
$c''_v = f(p, t, \xi'')$	cvv_ptxiv_AmWa	CVVPTxiVAMWA(P,T,XIV)	Specific isochoric heat capacity of saturated vapor	$\text{kJ}/(\text{kg K})$
$D_g = f(p, t, \xi_v)$	Dg_ptxiv_AmWa	DGPTxiVAMWA(P,T,XIV)	Diffusion coefficient vapor mixture	m^2/s
$D_l = f(t, \xi_l)$	DI_txil_AmWa	DLTXiLAMWA(P,XIL)	Diffusion coefficient in liquid mixture	m^2/s
$h = f(p, t, \xi)$	h_ptxi_AmWa	HPTxiAMWA(P,T,XI)	Specific enthalpy	kJ/kg
$h' = f(p, t, \xi')$	hl_ptxil_AmWa	HLPTxiLAMWA(P,T,XIL)	Specific enthalpy of saturated liquid	kJ/kg

Functional Dependence	Function Name	Call in Fortran	Property or Function	Unit
$h' = f(p, t, \xi'')$	hl_ptxiv_AmWa	HLPTXIVAMWA(P,T,XIV)	Specific enthalpy of saturated liquid	kJ/kg
$h'' = f(p, t, \xi')$	hv_ptxil_AmWa	HVPTXILAMWA(P,T,XIL)	Specific enthalpy of saturated vapor	kJ/kg
$h'' = f(p, t, \xi'')$	hv_ptxiv_AmWa	HVPTXIVAMWA(P,T,XIV)	Specific enthalpy of saturated vapor	kJ/kg
$p = f(h, s, \xi)$	p_hsxi_AmWa	PHSXIAMWA(H,S,XI)	Backward function: Pressure from enthalpy, entropy, and NH ₃ mass fraction	kg/kg
$p = f(t, \xi, x_\delta)$	p_tixid_AmWa	PTXIXDAMWA(T,XI,XD)	Pressure from temperature, NH ₃ mass fraction, and vapor fraction	bar
$p_s = f(t, \xi')$	ps_txil_AmWa	PSTXILAMWA(T,XIL)	Vapor pressure	bar
$p_s = f(t, \xi'')$	ps_txiv_AmWa	PSTXIVAMWA(T,XIV)	Vapor pressure	bar
$Pr = f(p, t, \xi)$	Pr_ptxi_AmWa	PRPTXIAMWA(P,T,XI)	Prandtl-Number	-
$Pr' = f(p, t, \xi')$	PrI_ptxil_AmWa	PRLPTXILAMWA(P,T,XIL)	Prandtl-Number of saturated liquid	-
$Pr' = f(p, t, \xi'')$	PrI_ptxiv_AmWa	PRLPTXIVAMWA(P,T,XIV)	Prandtl-Number of saturated liquid	-
$Pr'' = f(p, t, \xi')$	Prv_ptxil_AmWa	PRVPTXILAMWA(P,T,XIL)	Prandtl-Number of saturated vapor	-
$Pr'' = f(p, t, \xi'')$	Prv_ptxiv_AmWa	PRVPTXIAMWA(P,T,XIV)	Prandtl-Number of saturated vapor	-
$\text{region} = f(p, h, \xi)$	region_phxi_AmWa	REGPHXIAMWA(P,H,XI)	Phase region from pressure, enthalpy, and NH ₃ mass fraction	-
$\text{region} = f(p, s, \xi)$	region_psexi_AmWa	REGPSXIAMWA(P,S,XI)	Phase region from pressure, entropy, and NH ₃ mass fraction	-
$\text{region} = f(p, t, \xi)$	region_ptxi_AmWa	REGPTXIAMWA(P,T,XI)	Phase region from pressure, temperature, and NH ₃ mass fraction	-
$\text{region} = f(h, s, \xi)$	region_hsxi_AmWa	REGHSXIAMWA(H,S,XI)	Phase region from enthalpy, entropy, and NH ₃ mass fraction	-
$s = f(p, t, \xi)$	s_ptxi_AmWa	SPTXIAMWA(P,T,XI)	Specific entropy	kJ/(kg K)
$s' = f(p, t, \xi')$	sl_ptxil_AmWa	SLPTXILAMWA(P,T,XIL)	Specific entropy of saturated liquid	kJ/(kg K)
$s' = f(p, t, \xi'')$	sl_ptxiv_AmWa	SLPTXIVAMWA(P,T,XIV)	Specific entropy of saturated liquid	kJ/(kg K)
$s'' = f(p, t, \xi')$	sv_ptxil_AmWa	SVPTXILAMWA(P,T,XIL)	Specific entropy of saturated vapor	kJ/(kg K)
$s'' = f(p, t, \xi'')$	sv_ptxiv_AmWa	SVPTXIVAMWA(P,T,XIV)	Specific entropy of saturated vapor	kJ/(kg K)
$\sigma_l = f(t, \xi')$	sigmaI_txil_AmWa	SIGMALTXILAMWA(T,XIL)	Surface tension of saturated liquid	mN/m

Functional Dependence	Function Name	Call in Fortran	Property or Function	Unit
$t = f(p, h, \xi)$	t_phxi_AmWa	TPHXIAMWA(P,H,XI)	Backward function: Temperature from pressure, enthalpy, and NH ₃ mass fraction	°C
$t = f(p, s, \xi)$	t_psxi_AmWa	TPSXIAMWA(P,S,XI)	Backward function: Temperature from pressure, entropy, and NH ₃ mass fraction	°C
$t = f(p, \xi, x_\delta)$	t_pxixd_AmWa	TPXIXDAMWA(P,XI,XD)	Temperature from pressure, NH ₃ mass fraction, and vapor fraction	°C
$t_s = f(p, \xi')$	ts_pxil_AmWa	TSPXILAMWA(P,XIL)	Saturation temperature	°C
$t_s = f(p, \xi'')$	ts_pxiv_AmWa	TSPXIVAMWA(P,XIV)	Saturation temperature	°C
$v = f(p, t, \xi)$	v_ptxi_AmWa	VPTXIAMWA(P,T,XI)	Specific volume	m ³ /kg
$v' = f(p, t, \xi')$	vl_ptxil_AmWa	VLPTXILAMWA(P,T,XIL)	Specific volume of saturated liquid	m ³ /kg
$v' = f(p, t, \xi'')$	vl_ptxiv_AmWa	VLPTXIVAMWA(P,T,XIV)	Specific volume of saturated liquid	m ³ /kg
$v'' = f(p, t, \xi')$	vv_ptxil_AmWa	VVPTXILAMWA(P,T,XIL)	Specific volume of saturated vapor	m ³ /kg
$v'' = f(p, t, \xi'')$	vv_ptxiv_AmWa	VVPTXIVAMWA(P,T,XIV)	Specific volume of saturated vapor	m ³ /kg
$w = f(p, t, \xi)$	w_ptxi_AmWa	WPTXIAMWA(P,T,XI)	Speed of sound	m/s
$w' = f(p, t, \xi')$	wl_ptxil_AmWa	WLPTXILAMWA(P,T,XIL)	Speed of sound of saturated liquid	m/s
$w' = f(p, t, \xi'')$	wl_ptxiv_AmWa	WLPTXIVAMWA(P,T,XIV)	Speed of sound of saturated liquid	m/s
$w'' = f(p, t, \xi')$	wv_ptxil_AmWa	WVPTXILAMWA(P,T,XIL)	Speed of sound of saturated vapor	m/s
$w'' = f(p, t, \xi'')$	wv_ptxiv_AmWa	WVPTXIVAMWA(P,T,XIV)	Speed of sound of saturated vapor	m/s
$\eta = f(p, t, \xi)$	eta_ptxi_AmWa	ETAPTXIAMWA(P,T,XI)	Dynamic viscosity	Pa s
$\eta' = f(p, t, \xi')$	etal_ptxil_AmWa	ETALPTXILAMWA(P,T,XIL)	Dynamic viscosity of saturated liquid	Pa s
$\eta' = f(p, t, \xi'')$	etal_ptxiv_AmWa	ETALPTXIVAMWA(P,T,XIV)	Dynamic viscosity of saturated liquid	Pa s
$\eta'' = f(p, t, \xi')$	etav_ptxil_AmWa	ETAVPTXILAMWA(P,T,XIL)	Dynamic viscosity of saturated vapor	Pa s
$\eta'' = f(p, t, \xi'')$	etav_ptxiv_AmWa	ETAVPTXIVAMWA(P,T,XIV)	Dynamic viscosity of saturated vapor	Pa s
$\lambda = f(p, t, \xi)$	lambda_ptxi_AmWa	LAMBDAPTXIAMWA(P,T,XI)	Therm. conductivity	W/(m K)

Functional Dependence	Function Name	Call in Fortran	Property or Function	Unit
$\lambda' = f(p, t, \xi')$	lambdal_ptxil_AmWa	LAMBDALPTXILAMWA(P,T,XIL)	Therm. conductivity of saturated liquid	W/(m K)
$\lambda' = f(p, t, \xi'')$	lambdal_ptxiv_AmWa	LAMBDALPTXIVAMWA(P,T,XIV)	Therm. conductivity of saturated liquid	W/(m K)
$\lambda'' = f(p, t, \xi')$	lambdav_ptxil_AmWa	LAMBDAPTXILAMWA(P,T,XIL)	Therm. conductivity of saturated vapor	W/(m K)
$\lambda'' = f(p, t, \xi'')$	lambdav_ptxiv_AmWa	LAMBDAPTXIVAMWA(P,T,XIV)	Therm. conductivity of saturated vapor	W/(m K)
$\nu = f(p, t, \xi)$	nue_ptxi_AmWa	NUEPTXIAMWA(P,T,XI)	Kinematic viscosity	m ² /s
$\nu' = f(p, t, \xi')$	nuel_ptxil_AmWa	NUELPTXILAMWA(P,T,XIL)	Kinematic viscosity of saturated liquid	m ² /s
$\nu' = f(p, t, \xi'')$	nuel_ptxiv_AmWa	NUELPTXIVAMWA(P,T,XIV)	Kinematic viscosity of saturated liquid	m ² /s
$\nu'' = f(p, t, \xi')$	nuev_ptxil_AmWa	NUEVPTXILAMWA(P,T,XIL)	Kinematic viscosity of saturated vapor	m ² /s
$\nu'' = f(p, t, \xi'')$	nuev_ptxiv_AmWa	NUEVPTXIVAMWA(P,T,XIV)	Kinematic viscosity of saturated vapor	m ² /s
$x_\delta = f(p, t, \xi)$	xd_ptxi_AmWa	XDPTXIAMWA(P,T,XI)	Vapor fraction from pressure, temperature and NH ₃ mass fraction	kg/kg
$x_\delta = f(h, s, \xi)$	xd_hsxi_AmWa	XDHSXIAMWA(H,S,XI)	Backward function: Vapor fraction from enthalpy, entropy, and NH ₃ mass fraction	kg/kg
$\xi' = f(p, t, \xi'')$	xil_ptxiv_AmWa	XILPTXIVAMWA(P,T,XIV)	NH ₃ mass fraction of saturated liquid	kg/kg
$\xi'' = f(p, t, \xi')$	xiv_ptxil_AmWa	XIVPTXILAMWA(P,T,XIL)	NH ₃ mass fraction of saturated vapor	kg/kg

Units:

- t in °C
- p in bar
- ξ in (kg NH₃)/(kg mixture)

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms which are valid in the entire range of validity.

For the functions of saturated liquid (...^l) and saturated vapor (...^v) it is adequate to enter two parameters:

- either p and t ,
- or t and ξ' resp. t and ξ'' ,
- or p and ξ' resp. p and ξ'' .

Enter -1000 for the value which is not given. If p , t , and ξ' or p , t , and ξ'' are entered the program considers the parameters to match, i.e., to represent the p - t saturation curve. If this is not true the function value to be calculated results in -1000.

Range of validity

Temperature ranges	from $t_{tr}(\xi)$ up to $2 \cdot t_c(\xi)$, with: $t_{tr,NH_3} = -77.655$ °C, $t_{tr,H_2O} = 0.01$ °C
Pressure ranges	from 0.1 bar up to 400 bar
Composition ranges	from 0.0 up to 1.0 (kg NH ₃)/(kg mixture)

Reference state

Water:	triple point for saturated liquid $h_{H_2O} = 0.000611783$ kJ/kg and $s_{H_2O} = 0.0$ kJ/(kg K) at $p_{tr} = 0.00611657$ bar and $t_{tr} = 0.01$ °C
Ammonia:	triple point for saturated liquid $h_{NH_3} = 2.333$ kJ/kg and $s_{NH_3} = 0.0$ kJ/(kg K) at $p_{tr} = 0.060912$ bar and $t_{tr} = -77.655$ °C

Note:

If the calculated function results in -1000, the values entered represent a state point beyond the range of validity of LibAmWa. For further information on each function and its range of validity see Chapter 3. The same information may also be accessed via the online help pages.

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 ammonia-water mixtures from the LibAmWa 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 LibAmWa library. In this case, follow the subsection "Adding the LibAmWa Library" on page 2/3.

In both cases folders and files from the zip archive

CD_FluidVIEW_LibAmWa.zip (for 32-bit version of Windows®)

CD_FluidVIEW_LibAmWa_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_LibAmWa_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).

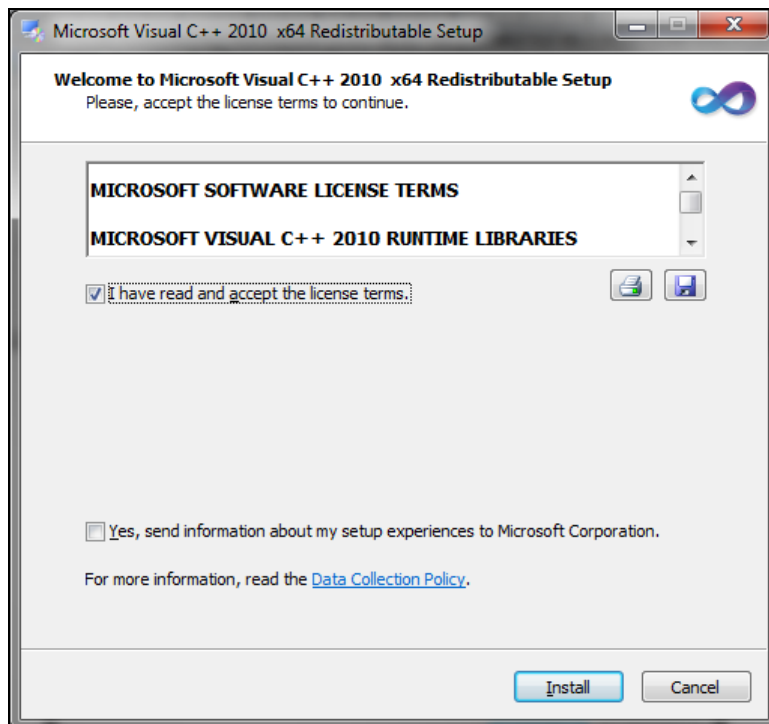


Figure 2.1 Accepting the license terms to install the Microsoft Visual C++ 2010 x64 Redistributable Package

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 on the harddisc. The pathname of LibHuAir.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9).

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

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

and for the

- **64-bit system:** LibAmWa.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	Parent directory 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 LibAmWa Library

In order to add the LibAmWa 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 on the harddisc. The pathname of LibHuAir.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9).

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

- **32-bit system:** LibAmWa.dll, advapi32.dll, Dformd.dll, Dfortrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system:** LibAmWa.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 LibAmWa property library to an existing installation of FluidVIEW

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

After you have restarted LabVIEW™ you will find the functions of the LibAmWa 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 **LibAmWa.hlp** and this user's guide as PDF document **FluidVIEW_LibAmWa_Docu_Eng.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 *LibAmWa Help File* and *LibAmWa 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 `h_ptxi_AmWa.vi` is shown in Figure 2.2.

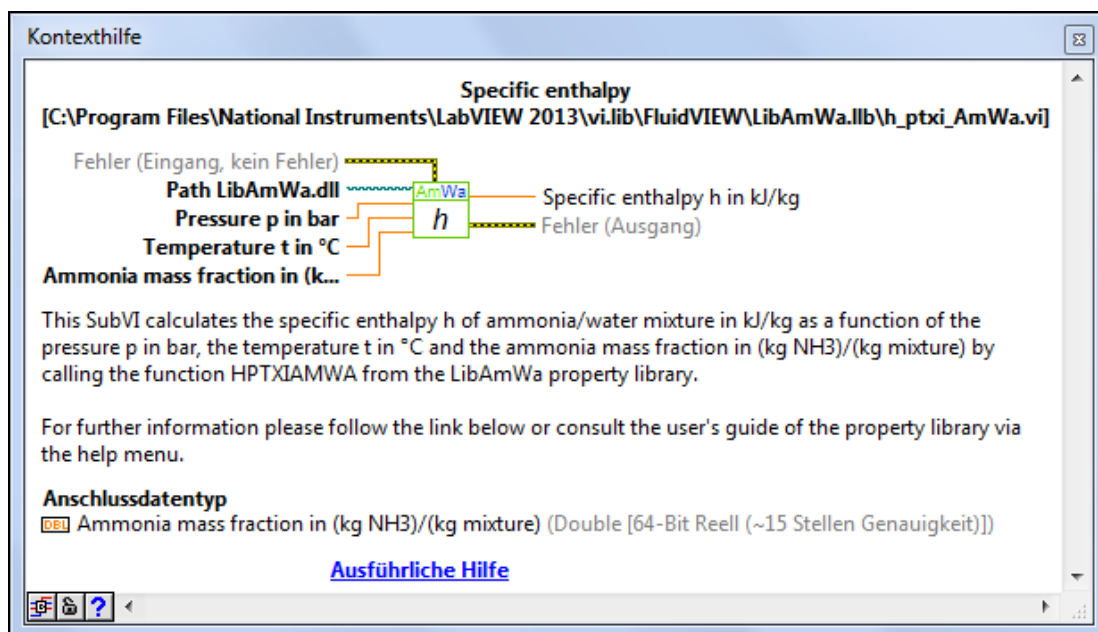


Figure 2.2 Context help window of the function `h_ptxi_AmWa.vi`

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)**

- 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.

- 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>
- 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](#)

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 are 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
Change language: English

Date published: 10/14/2009

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 LibAmWa Property Library

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

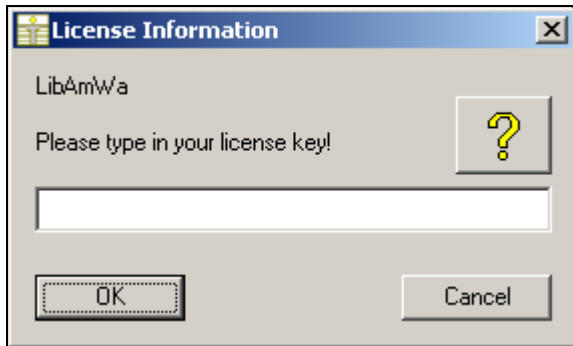


Figure 2.6 "License Information" window

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:

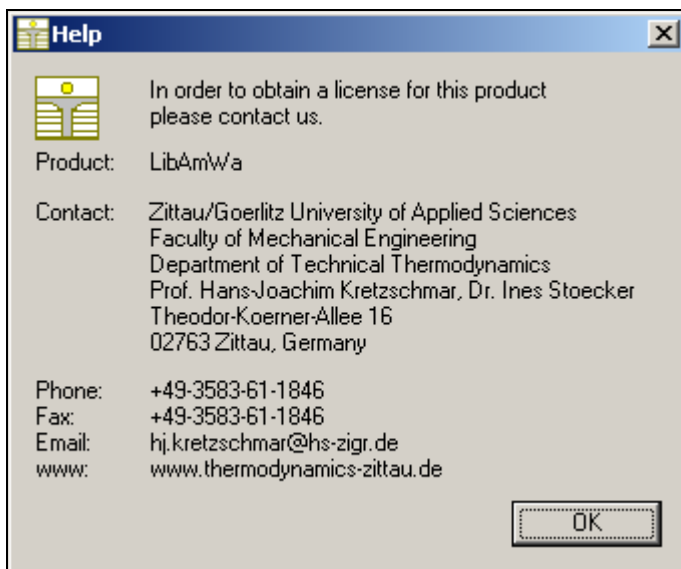


Figure 2.7 "Help" window

If you do not enter a valid license it is still possible to run your VI by clicking "Cancel". In this case, the LibAmWa 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 LibAmWa.dll. Should you not wish to license the LibAmWa 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 $h = f(p, t, \xi)$ and $s = f(p, t, \xi)$

After the delivered files have been copied in the appropriate folders of the default directory LabVIEW™ (described in section 2.1), the LibAmWa property library is ready to use. The function nodes of the LibAmWa 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 , and mass fraction ξ , 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 *LibAmWa* (see Figure 2.9).

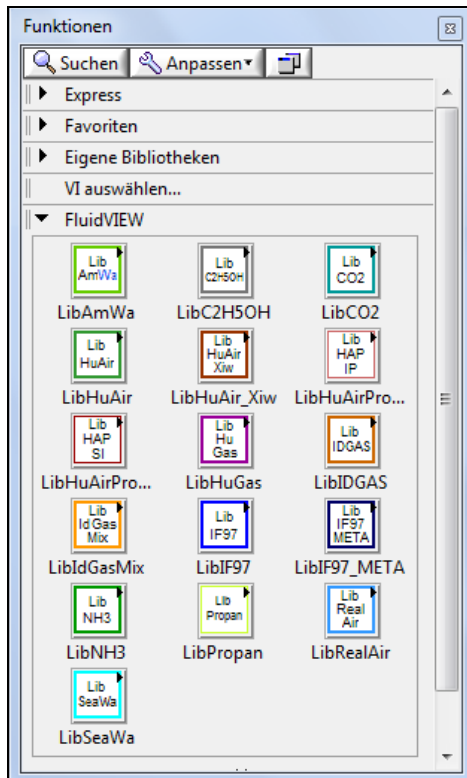


Figure 2.8

Functions palette with the sub palettes FluidVIEW and LibAmWa

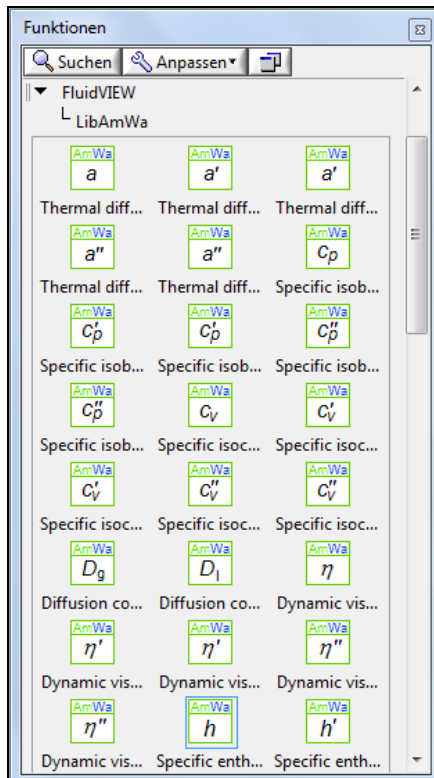


Figure 2.9

Functions palette with the property functions of the LibAmWa library

In order to calculate the specific enthalpy h , drag the function (SubVI) whose symbol shows the h 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_ptxi_AmWa.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 LibAmWa.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) and **Mass fraction ξ in kg/kg** (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).

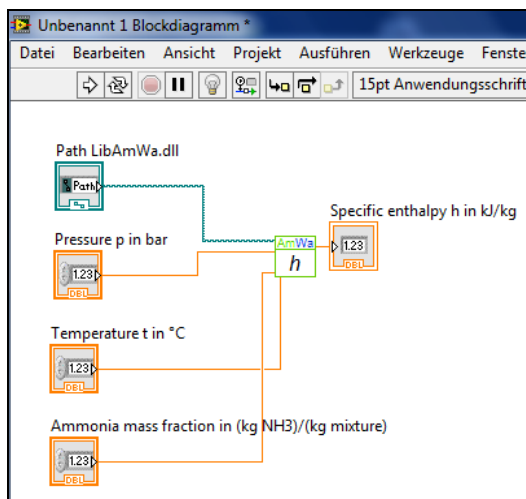


Figure 2.10

Block diagram of the example calculation

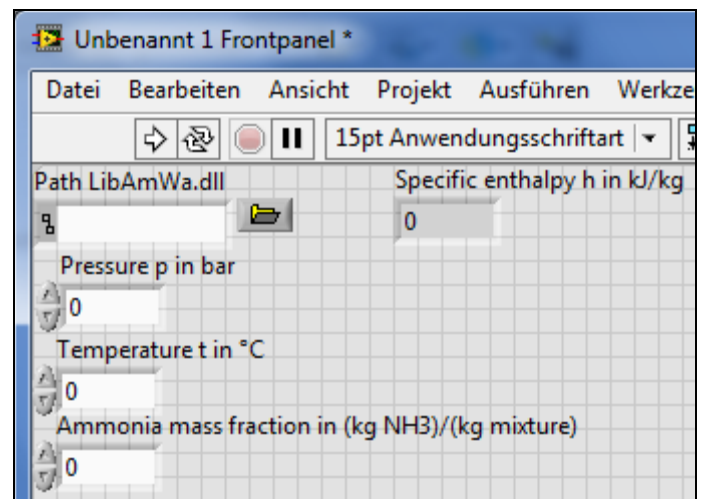


Figure 2.11

Front panel of the example calculation

- Enter a value in the input element *pressure p in bar* on the front panel
(Range of validity: from $p = 0.1 \text{ bar} \dots 400 \text{ bar}$)
⇒ e. g.: Enter the value 10.
- Enter a value in the input element *temperature t in °C* on the front panel
(Range of validity: $t = t_v(\xi) \dots 2 \cdot t_c(\xi)$)
⇒ e. g.: Enter the value 130.

Enter a value in the input element *mass fraction ξ in kg ammonia / kg mixture* on the front panel.

(Range of validity: $\xi = 0.0 \text{ kg NH}_3/\text{kg} \dots 1.0 \text{ kg NH}_3/\text{kg}$)

⇒ e. g.: Enter the value 0.5.

- Enter the path of the LibAmWa.dll in the input element *Path LibAmWa.dll* on the front panel (as explained in section 2.1 the LibAmWa.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 $h = 1373.097681$ kJ/kg.

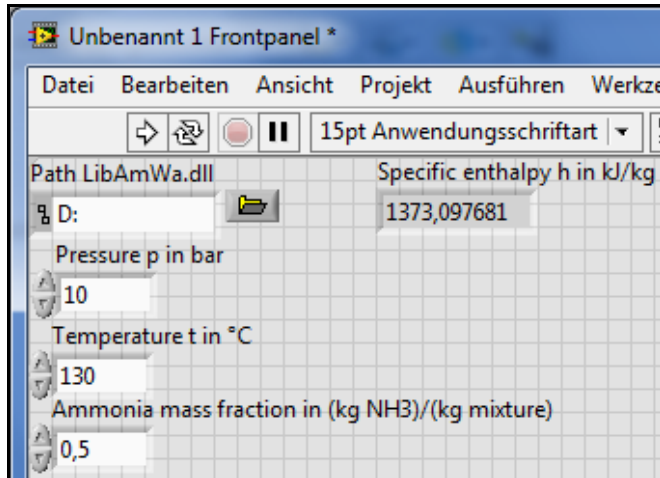


Figure 2.12

Result of the example calculation of h

The calculation of $h = f(p, t, \xi)$ has thus been completed.

Correspondingly, the specific enthalpy of saturated liquid $h' = f(p, t, \xi')$ can be calculated now. The following changes need to be implemented.

- Open the context menu of the function node *specific enthalpy* on the block diagram. Under **Replace / Palette LibAmWa** you will find the function **Specific enthalpy of saturated liquid** symbolized with h' . The node on the block diagram changes to **Specific enthalpy** by clicking on this symbol.
- Since the input parameter p is the same as before, its label need not be changed.
- The label of the input parameter t must be changed

It is adequate to determine only two parameters for the calculation of the specific enthalpy for the saturated liquid h' , i.e., either t and ξ' , or p and ξ' , or p and t . Enter the value -1000 for the missing parameter. If p , t , and ξ' are entered, the program considers all parameters to be appropriate, i.e., to meet the vapor-pressure curve. If this is not true the property calculated with the selected function results in -1000.

The following input varieties are possible:

$$h' = f(-1000, t, \xi')$$

$$h' = f(p, -1000, \xi')$$

$$h' = f(p, t, -1000)$$

$$h' = f(p, t, \xi')$$

⇒ In our example here the input variety $h' = f(p, -1000, \xi')$ has been chosen. The value -1000 has to be entered as the new value for t .

- The label of the input parameter ξ must be changed to ξ' and a new value must be entered.

Enter the value 0.5 for ξ' .

- The output parameter can be changed from *specific enthalpy h in kJ/kg* to *specific enthalpy for saturated liquid h_l in kJ/kg* by double clicking on it and typing the new name.
- On the front panel you can see that the new label for the output element *specific enthalpy for saturated liquid h_l in kJ/kg* was taken automatically. Since the values in the input elements have been changed before the calculation can be started now by pressing <Ctrl>+<R> or clicking the *Run* button. The result for h_l in kJ/kg·K appears in the output element.

⇒ The result for h_l in our sample calculation is 208.9192108 kJ/kg.

The calculation of $h' = f(p, t, \xi)$ has been carried out. You can now arbitrarily change the values for p , t , or ξ in the appropriate input elements.

Note:

If the calculation results in –1000, this indicates that the values entered are located outside the range of validity. More detailed information on each function and its range of validity is available in chapter 3. For further property functions calculable with FluidVIEW, see the function table in chapter 1.

2.5 Removing FluidVIEW

Should you wish to remove the LibAmWa library or the complete FluidVIEW Add-on you 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	Parent directory in the default directory of LabVIEW™ (<LV>)
FluidVIEW	<LV>\vi.lib
FluidVIEW	<LV>\menus\Categories
FluidVIEW-Help	<LV>\help

Removing only the LibAmWa library

To remove only the LibAmWa 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 LibAmWa library.

File name with file extension or name of the directory	Parent directory in the default directory of LabVIEW (<LV>)
LibAmWa.llb	<LV>\vi.lib\FuildVIEW
LibAmWa	<LV>\menus\Categories\FuildVIEW
LibAmWa.hlp	<LV>\help\FuildVIEW-Help
LibAmWa.txt	<LV>\help\FuildVIEW-Help
FluidVIEW_LibAmWa.pdf	<LV>\help\FuildVIEW-Help
Open_LibAmWa_doc.vi	<LV>\help\FuildVIEW-Help
Open_LibAmWa_doc.txt	<LV>\help\FuildVIEW-Help

The changes will take effect after restarting LabVIEW™.

3. Program Documentation

Thermal Diffusivity $a = f(p, t, \xi)$

Function Name: **a_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION APTXIAMWA(P,T,XI)**
 for the call out of Fortran **REAL*8 P,T,XI**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

APTXIAMWA or **a_ptxi_AmWa** - Thermal diffusivity a in m²/s

Range of validity

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH ₃ :	$t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O :	$t_{tr,H_2O} = 0.01^\circ\text{C}$
	$t_{c,NH_3} = 132.25^\circ\text{C}$		$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **APTXIAMWA = -1000** or **a_ptxi_AmWa = -1000** is valid for the following input values:

- $p > 400$ bar or $p < 0.1$ bar or
- $t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or
- $\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Thermal Diffusivity $a' = f(p, t, \xi'')$

Function Name: **al_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION ALPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

ALPTXIVAMWA or **al_ptxiv_AmWa** - Thermal diffusivity of saturated liquid a' in m² / s

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **ALPTXIVAMWA = -1000** or **al_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Thermal Diffusivity $a'' = f(p, t, \xi'')$

Function Name: **av_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION AVPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

AVPTXIVAMWA or **av_ptxiv_AmWa** - Thermal diffusivity of saturated vapor a'' in m²/s

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **AVPTXIVAMWA = -1000** or **av_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Specific Isobaric Heat Capacity $c_p = f(p, t, \xi)$

Function Name: **cp_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CPPTXIAMWA(P,T,XI)**
 for the call out of Fortran **REAL*8 P,T,XI**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

CPPTXIAMWA or **cp_ptxi_AmWa** - Specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range: $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH ₃ :	$t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O :	$t_{tr,H_2O} = 0.01^\circ\text{C}$
	$t_{c,NH_3} = 132.25^\circ\text{C}$		$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **CPPTXIAMWA = -1000** or **cp_ptxi_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or

$\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

State points in the wet steam region are located between saturated liquid and saturated vapor.

References: [1], [2], [3], [4]

Zittau/Goerlitz University of Applied Sciences, Department of Technical Thermodynamics, Professor H.-J. Kretzschmar, Dr. I. Stoecker

Specific Isobaric Heat Capacity of Saturated Liquid $c'_p = f(p, t, \xi'')$

Function Name: **cpl_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CPLPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

CPLPTXIVAMWA or **cpl_ptxiv_AmWa** - Specific isobaric heat capacity of saturated liquid c'_p in kJ/(kg K)

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on input types

For the calculation of the specific isobaric heat capacity of saturated liquid it is adequate to enter two parameters (either t and ξ'' , or p and ξ'' , or p and t). Enter -1000 for the missing value. If p , t , and ξ'' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Input types possible:

$$c'_p = f(-1000, t, \xi'')$$

$$c'_p = f(p, -1000, \xi'')$$

$$c'_p = f(p, t, -1000)$$

$$c'_p = f(p, t, \xi'')$$

Results for wrong input values

The result **CPLPTXIVAMWA = -1000** or **cpl_ptxiv_AmWa = -1000** is valid for values which range from:

$p > 400$ bar or $p < 0.1$ bar or

$t < t_{tr}(\xi'')$ or $t > t_c(\xi'')$

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4]

Specific Isobaric Heat Capacity of Saturated Vapor $c_p'' = f(p, t, \xi'')$

Function Name: **cpv_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CPVPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated liquid ξ'' in (kg NH₃)/(kg mixture)

Output value

CPVPTXIVAMWA or **cpv_ptxiv_AmWa** - Specific isobaric heat capacity of saturated vapor c_p'' in kJ/(kg K)

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on input types

For the calculation of the specific isobaric heat capacity of saturated vapor it is adequate to enter two parameters (either t and ξ'' , or p and ξ'' , or p and t). Enter -1000 for the missing value. If p , t , and ξ'' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Input types possible: $c_p'' = f(-1000, t, \xi'')$

$c_p'' = f(p, -1000, \xi'')$

$c_p'' = f(p, t, -1000)$

$c_p'' = f(p, t, \xi'')$

Results for wrong input values

The result **CPVPTXIVAMWA = -1000** or **cpv_ptxiv_AmWa = -1000** is valid for values which range from:

$p > 400$ bar or $p < 0.1$ bar or

$t < t_{tr}(\xi'')$ or $t > t_c(\xi'')$

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4]

Zittau/Goerlitz University of Applied Sciences, Department of Technical Thermodynamics, Professor H.-J. Kretzschmar, Dr. I. Stoecker

Subprogram with function value: **REAL*8 FUNCTION CVLPTXILAMWA(P,T,XIL)**
for the call out of Fortran **REAL*8 P,T,XIL**

Input values

P - Pressure p in bar
T - Temperature t in °C
XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃) / (kg mixture)

Output value

CVLPTXILAMWA or **cvl_ptxil_AmWa** - Specific isochoric heat capacity of saturated liquid c'_v in kJ / (kg K)

Range of validity

Temperature range: from $t = t_{\text{tr}}(\xi') \dots t_{\text{c}}(\xi')$

NH_3 :	$t_{\text{tr},\text{NH}_3} = -77.655^\circ\text{C}$	H_2O :	$t_{\text{tr},\text{H}_2\text{O}} = 0.01^\circ\text{C}$
	$t_{\text{c},\text{NH}_3} = 132.25^\circ\text{C}$		$t_{\text{c},\text{H}_2\text{O}} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on input types

For the calculation of the specific isochoric heat capacity of saturated liquid it is adequate to enter two parameters (either t and ξ' , or p and ξ' , or p and t). Enter -1000 for the missing value. If p , t , and ξ' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Input types possible:

- $c'_v = f(-1000, t, \xi')$
- $c'_v = f(p, -1000, \xi')$
- $c'_v = f(p, t, -1000)$
- $c'_v = f(p, t, \xi')$

Results for wrong input values

The result **CVLPTXILAMWA = -1000** or **cvl_ptxil_AmWa = -1000** is valid for values which range from:

$$p > 400 \text{ bar or } p < 0.1 \text{ bar or}$$
$$t < t_{\text{tr}}(\xi') \text{ or } t > t_{\text{c}}(\xi')$$
$$\xi' > 1.0 \text{ kg/kg or } \xi' < 0.0 \text{ kg/kg}$$

References: [1], [2], [3], [4]

Diffusion Coefficient in Gaseous Mixture $D_g = f(p, t, \xi_v)$

Function Name: **Dg_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION DGPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated steam ξ_v in (kg NH₃)/(kg mixture)

Output value

DGPTXIVAMWA or **Dg_ptxiv_AmWa** - Diffusion coefficient in gaseous mixture D_g in m² / s

Range of validity

Temperature range: from $t = t_{tr}(\xi_v) \dots t_c(\xi_v)$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$

H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Results for wrong input values

The result **DGPTXIVAMWA = -1000** or **Dg_ptxiv_AmWa = -1000** is valid for values which range from:

$p > 400$ bar or $p < 0.1$ bar or

$t < t_{tr}(\xi_v)$ or $t > t_c(\xi_v)$

$\xi_v > 1.0$ kg/kg or $\xi_v < 0.0$ kg/kg

References: [1], [2], [3], [4], [12]

Dynamic Viscosity $\eta' = f(p, t, \xi')$

Function Name: **etal_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION ETALPTXILAMWA(P,T,XIL)**
 for the call out of Fortran **REAL*8 P,T,XIL**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃) / (kg mixture)

Output value

ETALPTXILAMWA or **etal_ptxil_AmWa** - Dynamic viscosity of saturated liquid η' in Pa s

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃) / (kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **ETALPTXILAMWA = -1000** or **etal_ptxil_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi')$ or $t < t_{tr}(\xi')$ or

$\xi' > 1.0$ kg/kg or $\xi' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9]

Dynamic Viscosity $\eta' = f(p, t, \xi'')$

Function Name: **etal_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION ETALPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

ETALPTXIVAMWA or **etal_ptxiv_AmWa** - Dynamic viscosity of saturated liquid η' in Pa s

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **ETALPTXIVAMWA = -1000** or **etal_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9]

Dynamic Viscosity $\eta'' = f(p, t, \xi')$

Function Name: **etav_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION ETAVPTXILAMWA(P,T,XIL)**
 for the call out of Fortran **REAL*8 P,T,XIL**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XIL** - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

ETAVPTXILAMWA or **etav_ptxil_AmWa** - Dynamic viscosity of saturated vapor η'' in Pa s

Range of validity

- Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$
- | | | | |
|-------------------|---------------------------------------|--------------------|--------------------------------------|
| NH ₃ : | $t_{tr,NH_3} = -77.655^\circ\text{C}$ | H ₂ O : | $t_{tr,H_2O} = 0.01^\circ\text{C}$ |
| | $t_{c,NH_3} = 132.25^\circ\text{C}$ | | $t_{c,H_2O} = 373.946^\circ\text{C}$ |
- Pressure range: from 0.1 bar to 400 bar
- Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **ETAVPTXILAMWA = -1000** or **etav_ptxil_AmWa = -1000** is valid for the following input values:

- $p > 400$ bar or $p < 0.1$ bar or
- $t > t_c(\xi')$ or $t < t_{tr}(\xi')$ or
- $\xi' > 1.0$ kg/kg or $\xi' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9]

Dynamic Viscosity $\eta'' = f(p, t, \xi'')$

Function Name: **etav_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION ETAVPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

ETAVPTXIVAMWA or **etav_ptxiv_AmWa** - Dynamic viscosity of saturated vapor η'' in Pa s

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **ETAVPTXIVAMWA = -1000** or **etav_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9]

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Specific Enthalpy of Saturated Liquid $h' = f(p, t, \xi'')$

Function Name:	hl_ptxiv_AmWa
Subprogram with function value: for the call out of Fortran	REAL*8 FUNCTION HLPTXIVAMWA(P,T,XIV) REAL*8 P,T,XIV

Input values

P - Pressure p in bar
T - Temperature t in °C
XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

HLPTXIVAMWA or **hl_ptxiv_AmWa** - Specific enthalpy of saturated liquid h' in kJ/kg

Range of validity

Temperature range:	from $t = t_{tr}(\xi'') \dots t_c(\xi'')$	
	NH_3 : $t_{tr,\text{NH}_3} = -77.655^\circ\text{C}$ $t_{c,\text{NH}_3} = 132.25^\circ\text{C}$	H_2O : $t_{tr,\text{H}_2\text{O}} = 0.01^\circ\text{C}$ $t_{c,\text{H}_2\text{O}} = 373.946^\circ\text{C}$
Pressure range:	from 0.1 bar to 400 bar	
Composition range:	from 0.0 to 1.0 (kg NH_3)/(kg mixture)	

Details on input types

For the calculation of the specific enthalpy of saturated liquid it is adequate to enter two parameters (either t and ξ'' , or p and ξ'' , or p and t). Enter -1000 for the missing value. If p , t , and ξ'' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Possible input types:

- $h' = f(-1000, t, \xi'')$
- $h' = f(p, -1000, \xi'')$
- $h' = f(p, t, -1000)$
- $h' = f(p, t, \xi'')$

Results for wrong input values

The result **HLPTXIVAMWA = -1000** or **hl_ptxiv_AmWa = -1000** is valid for values which range from:

$$p > 400 \text{ bar or } p < 0.1 \text{ bar or}$$
$$t < t_{\text{tr}}(\xi'') \text{ or } t > t_{\text{c}}(\xi'')$$
$$\xi'' > 1.0 \text{ kg/kg or } \xi'' < 0.0 \text{ kg/kg}$$

References: [1], [2], [3], [4]

Function Name:	hv_ptxil_AmWa
Subprogram with function value: for the call out of Fortran	REAL*8 FUNCTION HVPTXILAMWA(P,T,XIL) REAL*8 P,T,XIL

Input values

P - Pressure p in bar
T - Temperature t in °C
XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

HVPTXILAMWA or hv_ptxil_AmWa - Specific enthalpy of saturated vapor h'' in kJ/kg

Range of validity

Temperature range:	from $t = t_{tr}(\xi') \dots t_c(\xi')$	
	$\text{NH}_3 : \quad t_{tr,\text{NH}_3} = -77.655^\circ\text{C}$	$\text{H}_2\text{O} : \quad t_{tr,\text{H}_2\text{O}} = 0.01^\circ\text{C}$
	$t_{c,\text{NH}_3} = 132.25^\circ\text{C}$	$t_{c,\text{H}_2\text{O}} = 373.946^\circ\text{C}$
Pressure range:	from 0.1 bar to 400 bar	
Composition range:	from 0.0 to 1.0 (kg NH_3)/(kg mixture)	

Details on input types

For the calculation of the specific enthalpy of saturated vapor it is adequate to enter two parameters (either t and ξ' , or p and ξ' , or p and t). Enter -1000 for the missing value. If p , t , and ξ' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Possible input types:

- $h'' = f(-1000, t, \xi')$
- $h'' = f(p, -1000, \xi')$
- $h'' = f(p, t, -1000)$
- $h'' = f(p, t, \xi')$

Results for wrong input values

The result **HVPTXILAMWA = -1000** or **hv_ptxil_AmWa = -1000** is valid for values which range from:

$$p > 400 \text{ bar or } p < 0.1 \text{ bar or}$$

$$t < t_{\text{tr}}(\xi') \text{ or } t > t_{\text{c}}(\xi')$$

$$\xi' > 1.0 \text{ kg/kg or } \xi' < 0.0 \text{ kg/kg}$$

References: [1], [2], [3], [4]

Thermal Conductivity $\lambda = f(p, t, \xi)$

Function Name: **lambda_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION LAMBDAPTXIAMWA(P,T,XI)**
 for the call out of Fortran **REAL*8 P,T,XI**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

LAMBDAPTXIAMWA or **lambda_ptxi_AmWa** - Thermal conductivity λ in W/(m K)

Range of validity

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH ₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O : $t_{tr,H_2O} = 0.01^\circ\text{C}$
$t_{c,NH_3} = 132.25^\circ\text{C}$	$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **LAMBDAPTXIAMWA = -1000** or **lambda_ptxi_AmWa = -1000** is valid for the following input values:

$p > 400 \text{ bar}$ or $p < 0.1 \text{ bar}$ or
 $t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4], [5], [6], [7], [8], [9]

Thermal Conductivity $\lambda' = f(p, t, \xi')$

Function Name: **lambdal_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION LAMBDALPTXILAMWA(P,T,XIL)**
 for the call out of Fortran **REAL*8 P,T,XIL**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

LAMBDALPTXILAMWA or **lambdal_ptxil_AmWa** - Thermal conductivity of saturated liquid λ' in W/(m K)

Range of validity

Temperature range: from $t = t_{tr}(\xi')$... $t_c(\xi')$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$

H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **LAMBDALPTXILAMWA = -1000** or **lambdal_ptxil_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi')$ or $t < t_{tr}(\xi')$ or

$\xi' > 1.0$ kg/kg or $\xi' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9]

Thermal Conductivity $\lambda' = f(p, t, \xi'')$

Function Name: **lambdal_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION LAMBDALPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

LAMBDALPTXIVAMWA or **lambdal_ptxiv_AmWa** - Thermal conductivity of saturated liquid λ' in W/(m K)

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$

H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **LAMBDALPTXIVAMWA = -1000** or **lambdal_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9]

Kinematic Viscosity $\nu = f(p, t, \xi)$

Function Name: **nue_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION NUEPTXIAMWA(P,T,XI)**
 for the call out of Fortran **REAL*8 P,T,XI**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

NUEPTXIAMWA or **nue_ptxi_AmWa** - Kinematic viscosity ν in m²/s

Range of validity

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **NUEPTXIAMWA = -1000** or **nue_ptxi_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or

$\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Kinematic Viscosity $\nu' = f(p, t, \xi')$

Function Name: **nuel_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION NUELPTXILAMWA(P,T,XIL)**
 for the call out of Fortran **REAL*8 P,T,XIL**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

NUELPTXILAMWA or **nuel_ptxil_AmWa** - Kinematic viscosity of saturated liquid ν' in m²/s

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **NUELPTXILAMWA = -1000** or **nuel_ptxil_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi')$ or $t < t_{tr}(\xi')$ or

$\xi' > 1.0$ kg/kg or $\xi' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Kinematic Viscosity $\nu' = f(p, t, \xi'')$

Function Name: **nuel_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION NUELPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated steam ξ'' in (kg NH₃)/(kg mixture)

Output value

NUELPTXIVAMWA or **nuel_ptxiv_AmWa** - Kinematic viscosity of saturated liquid ν' in m²/s

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **NUELPTXIVAMWA = -1000** or **nuel_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Kinematic Viscosity $\nu'' = f(p, t, \xi')$

Function Name: **nuev_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION NUEVPTXILAMWA(P,T,XIL)**
 for the call out of Fortran **REAL*8 P,T,XIL**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

NUEVPTXILAMWA or **nuev_ptxil_AmWa** - Kinematic viscosity of saturated vapor ν'' in m²/s

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **NUEVPTXILAMWA = -1000** or **nuev_ptxil_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi')$ or $t < t_{tr}(\xi')$ or

$\xi' > 1.0$ kg/kg or $\xi' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Kinematic Viscosity $\nu'' = f(p, t, \xi'')$

Function Name: **nuev_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION NUEVPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated steam ξ'' in (kg NH₃)/(kg mixture)

Output value

NUELPTXIVAMWA or **nuel_ptxiv_AmWa** - Kinematic viscosity of saturated vapor ν'' in m²/s

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **NUEVPTXIVAMWA = -1000** or **nuev_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

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Backward Function: Pressure $p = f(t, \xi, x_\delta)$

Function Name: **p_txixd_AmWa**

Subprogram with function value: **REAL*8 FUNCTION PTXIXDAMWA(T,XI,XD)**
 for the call out of Fortran **REAL*8 T,XI,XD**

Input values

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

XD- Vapor fraction x_δ in kg/kg

Output value

PTXIXDAMWA or **p_txixd_AmWa** - Pressure p in bar

Range of validity

Pressure range: $p_{tr}(\xi) \leq p \leq p_c(\xi)$

Temperature range: $t = t_{tr}(\xi) \leq t \leq t_c(\xi)$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Vapor fraction range: $0.0 \leq x_\delta \leq 1.0$ kg/kg

Details on wet steam

In the single-phase region the calculation results in -1.

Results for wrong input values

The result **PTXIXDAMWA = -1000** or **p_txixd_AmWa = -1000** is valid for the following input values:

$p > p_{tr}(\xi)$ or $p < p_c(\xi)$ or

$t > t(p, \xi'' = \xi)$ or $t < t(p, \xi' = \xi)$ or

$\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4]

Subprogram with function value: **REAL*8 FUNCTION PRPTXIAMWA(P,T,XI)**
for the call out of Fortran **REAL*8 P,T,XI**

Input values

P - Pressure p in bar
T - Temperature t in °C
XI - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

PRPTXIAMWA or **Pr_ptxi_AmWa** - Prandtl-Number Pr

Range of validity

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$ H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$ $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **PRPTXIAMWA = -1000** or **Pr_ptxi_AmWa = -1000** is valid for the following input values:

$$p > 400 \text{ bar} \text{ or } p < 0.1 \text{ bar} \text{ or}$$

$$t > 2 \cdot t_c(\xi) \text{ or } t < t_{tr}(\xi) \text{ or}$$

$$\xi > 1.0 \text{ kg/kg} \text{ or } \xi < 0.0 \text{ kg/kg}$$

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

PRANDTL-Number $Pr' = f(p, t, \xi')$

Function Name: **Prl_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION PRLPTXILAMWA(P,T,XIL)**
 for the call out of Fortran **REAL*8 P,T,XIL**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XIL** - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

PRLPTXILAMWA or **Prl_ptxil_AmWa** – Prandtl – Number Pr'' of saturated liquid

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH ₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$ $t_{c,NH_3} = 132.25^\circ\text{C}$	H ₂ O : $t_{tr,H_2O} = 0.01^\circ\text{C}$ $t_{c,H_2O} = 373.946^\circ\text{C}$
--	---

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **PRLPTXILAMWA = -1000** or **Prl_ptxil_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi')$ or $t < t_{tr}(\xi')$ or

$\xi' > 1.0$ kg/kg or $\xi' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

PRANDTL-Number $Pr' = f(p, t, \xi'')$

Function Name: **Prl_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION PRLPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

PRLPTXIVAMWA or **Prl_ptxiv_AmWa** – Prandtl – Number Pr' of saturated liquid

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **PRLPTXIVAMWA = -1000** or **Prl_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

PRANDTL-Number $Pr'' = f(p, t, \xi')$

Function Name: **Prv_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION PRVPTXILAMWA(P,T,XIL)**
 for the call out of Fortran **REAL*8 P,T,XIL**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XIL** - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

PRVPTXILAMWA or **Prv_ptxil_AmWa** – Prandtl – Number Pr'' of saturated vapor

Range of validity

- Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$
- | | | | |
|-------------------|---------------------------------------|--------------------|--------------------------------------|
| NH ₃ : | $t_{tr,NH_3} = -77.655^\circ\text{C}$ | H ₂ O : | $t_{tr,H_2O} = 0.01^\circ\text{C}$ |
| | $t_{c,NH_3} = 132.25^\circ\text{C}$ | | $t_{c,H_2O} = 373.946^\circ\text{C}$ |
- Pressure range: from 0.1 bar to 400 bar
- Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **PRVPTXILAMWA = -1000** or **Prv_ptxil_AmWa = -1000** is valid for the following input values:

- $p > 400$ bar or $p < 0.1$ bar or
- $t > t_c(\xi')$ or $t < t_{tr}(\xi')$ or
- $\xi' > 1.0$ kg/kg or $\xi' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

PRANDTL-Number $Pr'' = f(p, t, \xi'')$

Function Name: **Prv_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION PRVPTXIVAMWA(P,T,XIV)**
 for the call out of Fortran **REAL*8 P,T,XIV**

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

PRVPTXIVAMWA or **Prv_ptxiv_AmWa** – Prandtl – Number Pr'' of saturated vapor

Range of validity

Temperature range: from $t = t_{tr}(\xi'') \dots t_c(\xi'')$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000.

Results for wrong input values

The result **PRVPTXIVAMWA = -1000** or **Prv_ptxiv_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > t_c(\xi'')$ or $t < t_{tr}(\xi'')$ or

$\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

Phase Region Region = $f(p, t, \xi)$

Function Name: **region_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION REGPTXIAMWA(P,T,XI)**
 for the call out of Fortran **REAL*8 P,T,XI**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

REGPTXIAMWA or **region_ptxi_AmWa** - Phase region

Range of validity

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on the function

This function determines the phase region at hand. The output values are defined as follows:

- 1 - supercooled liquid
- 2 - two-phase region
- 3 - gas phase

If the value for the state point is located outside the range of validity the output value is -1000.

Results for wrong input values

The result **REGPTXIAMWA = -1000** or **region_ptxi_AmWa = -1000** is valid for the following input values:

- $p > 400 \text{ bar}$ or $p < 0.1 \text{ bar}$ or
- $t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or
- $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4]

Phase Region Region = $f(p, h, \xi)$

Function Name: **region_phxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION REGPHXIAMWA(P,H,XI)**
 for the call out of Fortran **REAL*8 P,H,XI**

Input values

- P** - Pressure p in bar
- H** - Enthalpy h in kJ/kg
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

REGPHXIAMWA or **region_phxi_AmWa** - Phase region

Range of validity

For the range of the enthalpy, see ranges of validity for temperature, pressure, and composition:

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH ₃ :	$t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O :	$t_{tr,H_2O} = 0.01^\circ\text{C}$
	$t_{c,NH_3} = 132.25^\circ\text{C}$		$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on the function

This function determines the phase region at hand. The output values are defined as follows:

- 1 - supercooled liquid
- 2 - two-phase region
- 3 - gas phase

If the value for the state point is located outside the range of validity the output value is -1000.

Results for wrong input values

The result **REGPHXIAMWA = -1000** or **region_phxi_AmWa = -1000** is valid for the following input values:

The enthalpy is located outside the range of validity if:

- $p > 400 \text{ bar}$ or $p < 0.1 \text{ bar}$ or
- $t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or
- $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4]

Phase Region Region = $f(p, s, \xi)$

Function Name: **region_psexi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION REGPSXIAMWA(P,S,XI)**
 for the call out of Fortran **REAL*8 P,S,XI**

Input values

- P** - Pressure p in bar
- S** - Entropy s in kJ/(kg K)
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

REGPSXIAMWA or **region_psexi_AmWa** - Phase region

Range of validity

For the range of the entropy, see ranges of validity for temperature, pressure, and composition:

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH_3 : $t_{tr,\text{NH}_3} = -77.655^\circ\text{C}$ $t_{c,\text{NH}_3} = 132.25^\circ\text{C}$	H_2O : $t_{tr,\text{H}_2\text{O}} = 0.01^\circ\text{C}$ $t_{c,\text{H}_2\text{O}} = 373.946^\circ\text{C}$
--	---

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on the function

This function determines the phase region at hand. The output values are defined as follows:

- 1 - supercooled liquid
- 2 - two-phase region
- 3 - gas phase

If the value for the state point is located outside the range of validity the output value is -1000.

Results for wrong input values

The result **REGPSXIAMWA = -1000** or **region_psexi_AmWa = -1000** is valid for the following input values:

The entropy is located outside the range of validity if:

- $p > 400$ bar or $p < 0.1$ bar or
- $t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or
- $\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4]

Phase Region Region = $f(h,s,\xi)$

Function Name: **region_hsxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION REGHSXIAMWA(H,S,XI)**
 for the call out of Fortran **REAL*8 H,S,XI**

Input values

- H** - Enthalpy h in kJ/kg
- S** - Entropy s in kJ/(kg K)
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

REGHSXIAMWA or **region_hsxi_AmWa** - Phase region

Range of validity

For the range of enthalpy and entropy, see the ranges of validity of temperature, pressure, and composition:

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH ₃ :	$t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O :	$t_{tr,H_2O} = 0.01^\circ\text{C}$
	$t_{c,NH_3} = 132.25^\circ\text{C}$		$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on the function

This function determines the phase region at hand. The output values are defined as follows:

- 1 - supercooled liquid
- 2 - two-phase region
- 3 - gas phase

If the value for the state point is located outside the range of validity the output value is -1000.

Results for wrong input values

The result **REGHSXIAMWA = -1000** or **region_hsxi_AmWa = -1000** is valid for the following input values:

Enthalpy, entropy, or composition are located outside the range of validity if:

$p > 400$ bar or $p < 0.1$ bar or

$t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or

$\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4]

Specific Entropy $s = f(p, t, \xi)$

Function Name: **s_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION SPTXIAMWA(P,T,XI)**
 for the call out of Fortran **REAL*8 P,T,XI**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

SPTXIAMWA or **s_ptxi_AmWa** - Specific entropy s in kJ/(kg K)

Range of validity

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

The wet steam region is calculated automatically by the sub-programs.

Results for wrong input values

The result **SPTXIAMWA = -1000** or **s_ptxi_AmWa = -1000** is valid for the following input values:

- $p > 400 \text{ bar}$ or $p < 0.1 \text{ bar}$ or
- $t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or
- $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4]

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Surface Tension of Saturated Liquid $\sigma_l = f(t, \xi')$

Function Name: **signal_txil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION SIGMALTXILAMWA(T,XIL)**
 for the call out of Fortran **REAL*8 T,XIL**

Input values

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

SIGMALTXILAMWA or **signal_ptxil_AmWa** - Surface tension of sat. liquid σ_l in mN/m

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$

H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$

$t_{c,NH_3} = 132.25^\circ\text{C}$

$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Results for wrong input values

The result **SIGMALTXILAMWA = -1000** or **signal_txil_AmWa = -1000** is valid for values which range from:

$t < t_{tr}(\xi')$ or $t > t_c(\xi')$

$\xi' > 1.0 \text{ kg/kg}$ or $\xi' < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4], [5]

Saturation Temperature $t_s = f(p, \xi')$

Function Name: **ts_pxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION TS_PXIL_AMWA(P,XIL)**
 for the call out of Fortran **REAL*8 P,XIL**

Input values

P - Pressure p in bar

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

TS_PXIL_AMWA or **ts_pxil_AmWa** - Saturation temperature t_s in °C

Range of validity

Pressure range: from 0.1 bar to $p_c(\xi')$
 NH₃ : $p_{c,NH_3} = 113.33\text{bar}$ H₂O : $p_{c,H_2O} = 220.64\text{ bar}$

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Results for wrong input values

The result **TS_PXIL_AMWA = -1000** or **ts_pxil_AmWa = -1000** is valid for values which range from:

$p > p_c(\xi')$ or $p < 0.1\text{ bar}$ or

$\xi' > 1.0\text{ kg/kg}$ or $\xi' < 0.0\text{ kg/kg}$

References: [1], [2], [3], [4]

Saturation Temperature $t_s = f(p, \xi'')$

Function Name: **ts_pxiv_AmWa**
 Subprogram with function value: **REAL*8 FUNCTION TS_PXIV_AMWA(P,XIV)**
 for the call out of Fortran **REAL*8 P,XIV**

Input values

P - Pressure p in bar
XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg NH₃)/(kg mixture)

Output value

TS_PXIV_AMWA or **ts_pxiv_AmWa** - Saturation temperature t_s in °C

Range of validity

Pressure range: from 0.1 bar to $p_c(\xi'')$
 NH₃ : $p_{c,NH_3} = 113.33 \text{ bar}$ H₂O : $p_{c,H_2O} = 220.64 \text{ bar}$

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Results for wrong input values

The result **TS_PXIV_AMWA = -1000** or **ts_pxiv_AmWa = -1000** is valid for values which range from:

$p > p_c(\xi'')$ or $p < 0.1 \text{ bar}$ or
 $\xi'' > 1.0 \text{ kg/kg}$ or $\xi'' < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4]

Backward Function: Temperature $t = f(p, h, \xi)$

Function Name: **t_phxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION TPHXIAMWA(P,H,XI)**
 for the call out of Fortran **REAL*8 P,H,XI**

Input values

- P** - Pressure p in bar
- H** - Enthalpy h in kJ/kg
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

TPHXIAMWA or **t_phxi_AmWa** - Temperature t in °C

Range of validity

For the range of the enthalpy, see ranges of validity for temperature, pressure, and composition:

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH ₃ :	$t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O :	$t_{tr,H_2O} = 0.01^\circ\text{C}$
	$t_{c,NH_3} = 132.25^\circ\text{C}$		$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

The wet steam region is calculated automatically by the sub-programs.

Results for wrong input values

The result **TPHXIAMWA = -1000** or **t_phxi_AmWa = -1000** is valid for the following input values:

The enthalpy is located outside the range of validity if:

$p > 400$ bar or $p < 0.1$ bar or

$t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or

$\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4]

Backward Function: Temperature $t = f(p, s, \xi)$

Function Name: **t_psgi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION TPSXIAMWA(P,S,XI)**
 for the call out of Fortran **REAL*8 P,S,XI**

Input values

- P** - Pressure p in bar
- S** - Entropy s in kJ/(kg K)
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

TPSXIAMWA or **t_psgi_AmWa** - Temperature t in °C

Range of validity

For the range of the entropy, see ranges of validity for temperature, pressure, and composition:

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH ₃ :	$t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O :	$t_{tr,H_2O} = 0.01^\circ\text{C}$
	$t_{c,NH_3} = 132.25^\circ\text{C}$		$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

The wet steam region is calculated automatically by the sub-programs.

Results for wrong input values

The result **TPSXIAMWA = -1000** or **t_psgi_AmWa = -1000** is valid for the following input values:

The entropy is located outside the range of validity if:

- $p > 400 \text{ bar}$ or $p < 0.1 \text{ bar}$ or
- $t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or
- $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4]

Backward Function: Temperature $t = f(p, \xi, x_\delta)$

Function Name: **t_pxixd_AmWa**
 Subprogram with function value: **REAL*8 FUNCTION TPXIXDAMWA(P,XI,XD)**
 for the call out of Fortran **REAL*8 P,XI,XD**

Input values

P - Pressure p in bar
XI - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)
XD - Vapor fraction x_δ in kg/kg

Output value

TPXIXDAMWA or **t_pxixd_AmWa** - Temperature t in °C

Range of validity

Temperature range: $t = t_{tr}(\xi) \leq t \leq t_c(\xi)$
 NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$ H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$ $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: $p_{tr}(\xi) \leq p \leq p_c(\xi)$
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)
 Vapor fraction range: $0.0 \leq x_\delta \leq 1.0$ kg/kg

Details on wet steam

In the single-phase region the calculation results in -1.

Results for wrong input values

The result **TPXIXDAMWA = -1000** or **t_pxixd_AmWa = -1000** is valid for the following input values:

$p > p_{tr}(\xi)$ or $p < p_c(\xi)$ or
 $t > t(p, \xi'' = \xi)$ or $t < t(p, \xi' = \xi)$ or
 $\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4]

Function Name:	vl_ptxil_AmWa
Subprogram with function value: for the call out of Fortran	REAL*8 FUNCTION VLPTXILAMWA(P,T,XIL) REAL*8 P,T,XIL

Input values

P - Pressure p in bar
T - Temperature t in °C
XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

VLPTXILAMWA or **vl_ptxil_AmWa** - Specific volume of saturated liquid v' in m^3/kg

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$ H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$ $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on input types

For the calculation of the specific volume of saturated liquid it is adequate to enter two parameters (either t and ξ' , or p and ξ' , or p and t). Enter -1000 for the missing value. If p , t , and ξ' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Input types possible:

- $v' = f(-1000, t, \xi')$
- $v' = f(p, -1000, \xi')$
- $v' = f(p, t, -1000)$
- $v' = f(p, t, \xi')$

Results for wrong input values

The result **VLPTXILAMWA = -1000** or **vl_ptxil_AmWa = -1000** is valid for values which range from:

$$p > 400 \text{ bar} \text{ or } p < 0.1 \text{ bar or}$$
$$t < t_{\text{tr}}(\xi') \text{ or } t > t_{\text{c}}(\xi')$$
$$\xi' > 1.0 \text{ kg/kg or } \xi' < 0.0 \text{ kg/kg}$$

References: [1], [2], [3], [4]

Zittau/Goerlitz University of Applied Sciences, Department of Technical Thermodynamics, Professor H.-J. Kretzschmar, Dr. I. Stoecker

Function Name:	vv_ptxil_AmWa
Subprogram with function value: for the call out of Fortran	REAL*8 FUNCTION VVPTXILAMWA(P,T,XIL) REAL*8 P,T,XIL

Input values

P - Pressure p in bar
T - Temperature t in °C
XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

VVPTXILAMWA or **vv_ptxil_AmWa** - Specific volume of saturated vapor v'' in m^3/kg

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$ H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$ $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on input types

For the calculation of the specific volume of saturated vapor it is adequate to enter two parameters (either t and ξ' , or p and ξ' , or p and t). Enter -1000 for the missing value. If p , t , and ξ' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Input types possible:

- $v'' = f(-1000, t, \xi')$
- $v'' = f(p, -1000, \xi')$
- $v'' = f(p, t, -1000)$
- $v'' = f(p, t, \xi')$

Results for wrong input values

The result **VVPTXILAMWA = -1000** or **vv_ptxil_AmWa = -1000** is valid for values which range from:

 $p > 400 \text{ bar}$ or $p < 0.1 \text{ bar}$ or
$$t < t_{\text{tr}}(\xi') \text{ or } t > t_{\text{c}}(\xi')$$
 $\xi' > 1.0 \text{ kg/kg}$ or $\xi' < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4]

Zittau/Goerlitz University of Applied Sciences, Department of Technical Thermodynamics, Professor H.-J. Kretzschmar, Dr. I. Stoecker

Speed of Sound $w = f(p, t, \xi)$

Function Name: **w_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION WPTXIAMWA(P,T,XI)**
 for the call out of Fortran **REAL*8 P,T,XI**

Input values

- P** - Pressure p in bar
- T** - Temperature t in °C
- XI** - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

WPTXIAMWA or **w_ptxi_AmWa** - Speed of sound w in m/s

Range of validity

Temperature range: from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$

H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

Only saturated liquid and saturated vapor are calculated in the wet steam region. For the wet steam region in-between the calculation results in -1000

Results for wrong input values

The result **WPTXIAMWA = -1000** or **w_ptxi_AmWa = -1000** is valid for the following input values:

$p > 400$ bar or $p < 0.1$ bar or

$t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or

$\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

References: [1], [2], [3], [4]

Zittau/Goerlitz University of Applied Sciences, Department of Technical Thermodynamics, Professor H.-J. Kretzschmar, Dr. I. Stoecker

Function Name:	wv_ptxil_AmWa
Subprogram with function value: for the call out of Fortran	REAL*8 FUNCTION WVPTXILAMWA(P,T,XIL) REAL*8 P,T,XIL

Input values

- P** - Pressure p in bar
T - Temperature t in °C
XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH₃)/(kg mixture)

Output value

WVPTXILAMWA or **wv_ptxil_AmWa** - Speed of sound of saturated vapor w'' in m/s

Range of validity

Temperature range: from $t = t_{tr}(\xi') \dots t_c(\xi')$

NH_3 : $t_{tr,\text{NH}_3} = -77.655^\circ\text{C}$ H_2O : $t_{tr,\text{H}_2\text{O}} = 0.01^\circ\text{C}$
 $t_{c,\text{NH}_3} = 132.25^\circ\text{C}$ $t_{c,\text{H}_2\text{O}} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH_3)/(kg mixture)

Details on input types

For the calculation of the speed of sound of saturated vapor it is adequate to enter two parameters (either t and ξ' , or p and ξ' , or p and t). Enter -1000 for the missing value. If p , t , and ξ' are entered, the program considers all parameters to match, i.e., to represent the vapor-pressure curve. If this is not true, the property to be calculated of the selected function results in -1000.

Input types possible:

- $w'' = f(-1000, t, \xi')$
- $w'' = f(p, -1000, \xi')$
- $w'' = f(p, t, -1000)$
- $w'' = f(p, t, \xi')$

Results for wrong input values

The result **WVPTXILAMWA = -1000** or **wv_ptxil_AmWa = -1000** is valid for values which range from:

$$p > 400 \text{ bar or } p < 0.1 \text{ bar or}$$

$$t < t_{\text{tr}}(\xi') \text{ or } t > t_{\text{c}}(\xi')$$

$$\xi' > 1.0 \text{ kg/kg or } \xi' < 0.0 \text{ kg/kg}$$

References: [1], [2], [3], [4]

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Zittau/Goerlitz University of Applied Sciences, Department of Technical Thermodynamics, Professor H.-J. Kretzschmar, Dr. I. Stoecker

Backward Function: Vapor Fraction $x_\delta = f(h, s, \xi)$

Function Name: **xd_hsxi_AmWa**
 Subprogram with function value: **REAL*8 FUNCTION XDHSXIAMWA(H,S,XI)**
 for the call out of Fortran **REAL*8 H,S,XI**

Input values

H - Enthalpy h in kJ/kg
S - Entropy s in kJ/(kg K)
XI - Ammonia mass fraction ξ in (kg NH₃)/(kg mixture)

Output value

XDHSXIAMWA or **xd_hsxi_AmWa** - Vapor fraction x_δ in kg/kg

Range of validity

For the range of the enthalpy and entropy, see ranges of validity for temperature, pressure, and composition:

Temperature range:	from $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$	
	NH ₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O : $t_{tr,H_2O} = 0.01^\circ\text{C}$
	$t_{c,NH_3} = 132.25^\circ\text{C}$	$t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on the single-phase region

In the single-phase region the calculation results in -1.

Results for wrong input values

The result **XDHSXIAMWA = -1000** or **xd_hsxi_AmWa = -1000** is valid for the following input values:

Values of the enthalpy, entropy or composition are located outside the range of validity if:

$p > 400 \text{ bar}$ or $p < 0.1 \text{ bar}$ or

$t > 2 \cdot t_c(\xi)$ or $t < t_{tr}(\xi)$ or

$\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.0 \text{ kg/kg}$

References: [1], [2], [3], [4]

Ammonia Mass Fraction $\xi = f(p, t, x_\delta)$

Function Name: **xi_ptxd_AmWa**
 Subprogram with function value: **REAL*8 FUNCTION XIPTXDAMWA(P,T,XD)**
 for the call out of Fortran **REAL*8 P,T,XD**

Input values

P - Pressure p in bar
T - Temperature t in °C
XD - Vapor fraction x_δ in kg/kg

Output value

XIPTXDAMWA or **xi_ptxd_AmWa** - Ammonia mass fraction ξ in (kg NH₃)/kg

Range of validity

Pressure range: $p_{tr}(\xi) \leq p \leq p_c(\xi)$
 Temperature range: $t = t_{tr}(\xi) \leq t \leq t_c(\xi)$
 NH₃: $t_{tr,NH_3} = -77.655^\circ\text{C}$ H₂O: $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$ $t_{c,H_2O} = 373.946^\circ\text{C}$
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)
 Vapor fraction range: $0.0 \leq x_\delta \leq 1.0$ kg/kg

Details on input types

In the single-phase region the calculation results in -1.

Results for wrong input values

The result **XIPTXDAMWA = -1000** or **xi_ptxd_AmWa = -1000** is valid for values which range from:

$p > p_{tr}(\xi)$ or $p < p_c(\xi)$
 $t > t(p, \xi'' = \xi)$ or $t < t(p, \xi' = \xi)$
 $\xi'' > 1.0$ kg/kg or $\xi'' < 0.0$ kg/kg

References: [1], [2], [3], [4]

Zittau/Goerlitz University of Applied Sciences, Department of Technical Thermodynamics, Professor H.-J. Kretzschmar, Dr. I. Stoecker



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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:
 CO_2 - Span and Wagner O_2 - Schmidt and Wagner
 H_2O - IAPWS-95 Ar - Tegeler et al.
 N_2 - Span et al.
 and of the ideal gases:
 SO_2 , CO, Ne (Scientific Formulation of 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 (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

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

 Air

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

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

Consideration of:

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

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bückner and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bückner and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Water/Lithium Bromide Mixtures

Library LibWaLi

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

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

$\text{C}_2\text{H}_6\text{O}_2$	Ethylene glycol
$\text{C}_3\text{H}_8\text{O}_2$	Propylene glycol
$\text{C}_2\text{H}_5\text{OH}$	Ethyl alcohol
CH_3OH	Methyl alcohol
$\text{C}_3\text{H}_8\text{O}_3$	Glycerol
K_2CO_3	Potassium carbonate
CaCl_2	Calcium chloride
MgCl_2	Magnesium chloride
NaCl	Sodium chloride
$\text{C}_2\text{H}_3\text{KO}_2$	Potassium acetate

 Formulation of the International Institute of Refrigeration (1997)

Ethanol**Library LibC2H5OH**

Formulation of Schroeder
(2012)

Methanol**Library LibCH3OH**

Formulation of
de Reuck and Craven (1993)

Propane**Library LibPropane**

Formulation of
Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

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

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

Tetradecamethylhexasiloxane $C_{14}H_{42}O_6Si_6$ **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)

Nitrogen**Library LibN2**

Formulation of
Span et al. (2000)

Hydrogen**Library LibH2**

Formulation of
Leachman et al. (2009)

Helium**Library LibHe**

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**

Carbonyl sulfide **COS** **Library LibCOS**

Hydrogen sulfide **H₂S** **Library LibH2S**

Dinitrogen monoxide **N₂O** **Library LibN2O**

Sulfur dioxide **SO₂** **Library LibSO2**

Acetone **C₃H₆O** **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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The following thermodynamic and transport properties can be calculated^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

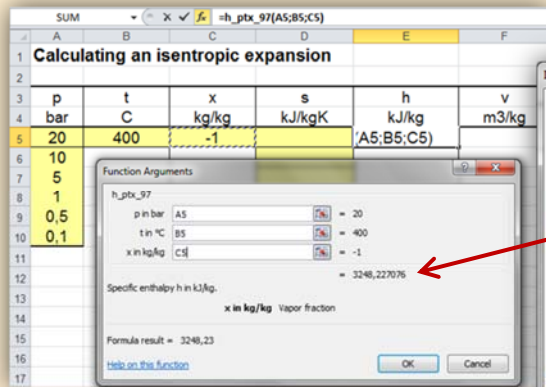
- Partial derivatives can be calculated.

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

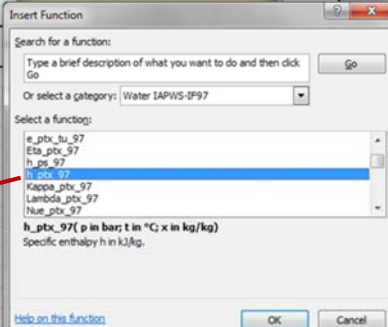


Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

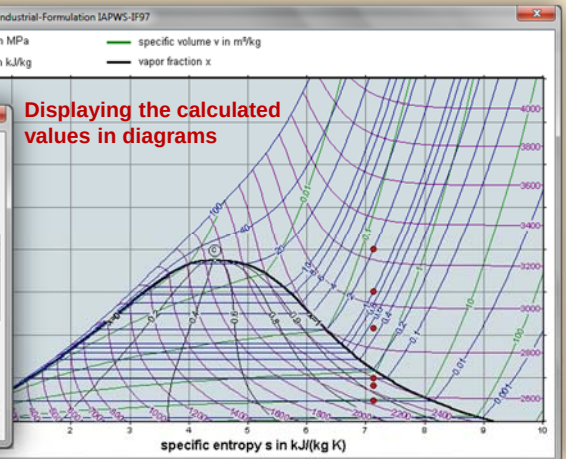
Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function



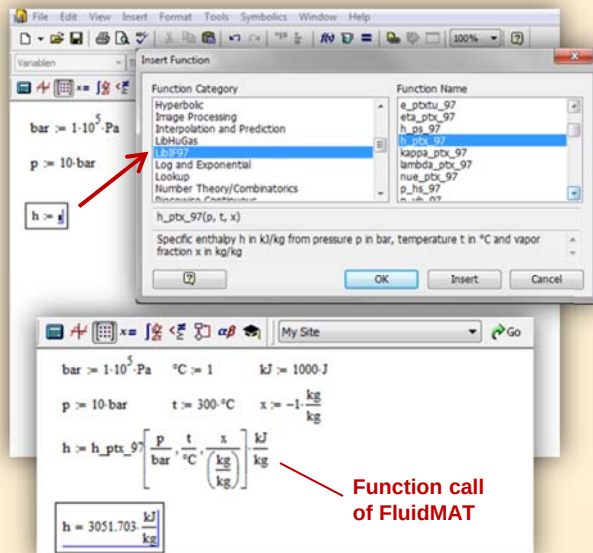
Displaying the calculated values in diagrams



Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

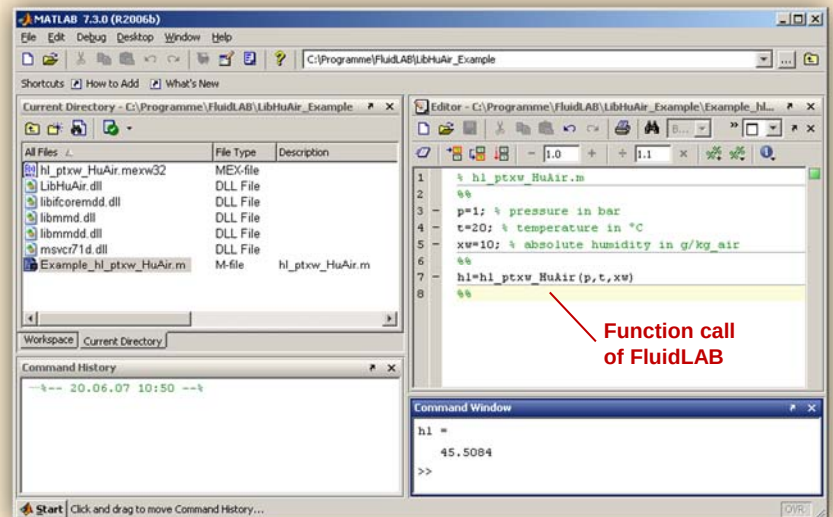
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

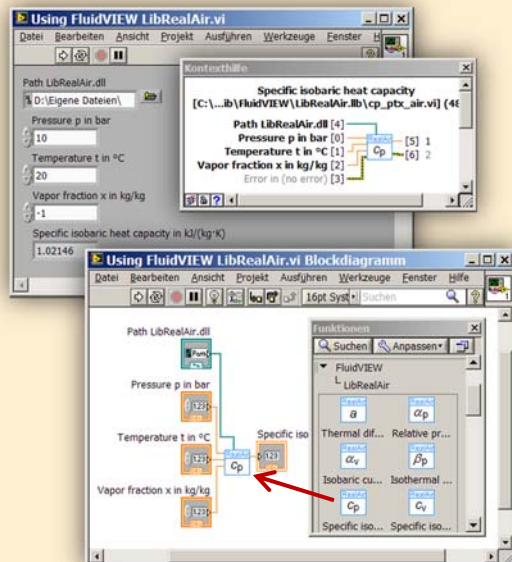
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

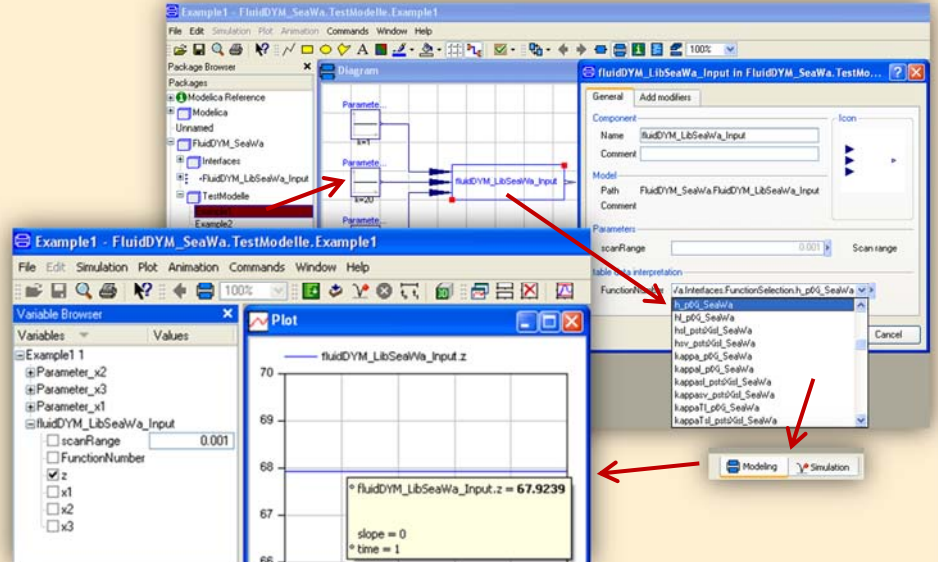
Add-On FluidVIEW for LabVIEW[®]

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

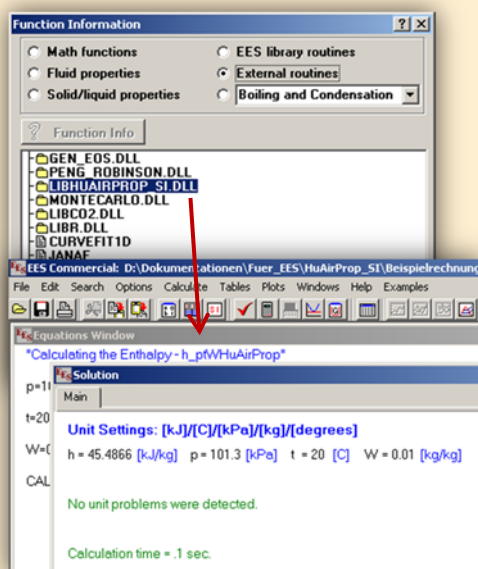


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

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

Property Software for Pocket Calculators

FluidCasio



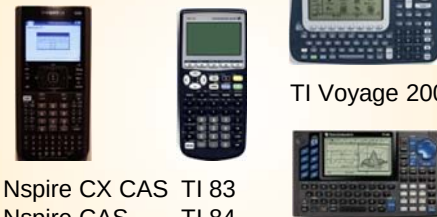
fx 9750 G II CFX 9850 fx-GG20 CFX 9860 G Graph 85 ALGEBRA FX 2.0

FluidHP



HP 48 HP 49

FluidTI



TI Nspire CX CAS TI 83 TI 84 TI 89 TI Voyage 200

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.

5. References

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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

PROJEKTPLAN, Dohna	04/2014
Technical University of Vienna, Austria	04/2014
MTU Aero Engines AG, Munich	04/2014
GKS, Schweinfurt	03/2014
Technical University of 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
Wilhelm-Büchner HS, Darmstadt	10/2013
IAV, Chemnitz	10/2013
Technical University of Regensburg	10/2013
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Thermofin, Heinsdorfergrund	09/2013
SHI, New Jersey, USA	09/2013
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	08/2013
TIG-Group, Husum	08/2013
COMPAREX, Leipzig for RWE Essen	08/2013, 11/2013 12/2013
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VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
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University of Stuttgart	04/2013
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frischli Milchwerke, Rehburg-Loccum	01/2013

2012

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2010

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MCI, Innsbruck, Austria	12/2009
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2008	
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Evonik, Zwingenberg (general EBSILON program license)	04/2008

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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
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Technip Benelux BV, Zoetermeer, Netherlands	08/2008
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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
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Technical University of Dresden, Chair in Jet Propulsion Systems	02/2007
Redacom, Nidau, Switzerland	02/2007
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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
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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
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Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006

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WAETAS, Poberschau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig, Department of Thermodynamics	04/2006
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Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Department of USET Merseburg incorporated society	05/2006
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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

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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
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Technical University of Dresden	04/2005
Professorship of Thermic Energy Machines and Plants	
Grenzebach BSH, Bad Hersfeld	04/2005
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Dumas Verfahrenstechnik, Hofheim	06/2005
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Stadtwerke Leipzig	07/2005
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Vattenfall Europe, Berlin (group license)	08/2005
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Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005
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Technical University of Freiberg, Chair in Hydrogeology	11/2005
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Visteon, Kerpen	03/2004, 10/2004
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HEW-Kraftwerk, Tiefstack	06/2004
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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
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energeticals (e-concept), Munich	11/2004
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Enertech EUT, Radebeul (company license)	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
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Paper Factory, Utzenstorf, Switzerland	01/2003
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ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
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Electrowatt-EKONO, Zurich, Switzerland	09/2003
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FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
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VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
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Fraunhofer-Gesellschaft, Munich	12/2003
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Eco Design, Saitamaken, Japan	01/2001
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MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
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SaarEnergie, Saarbruecken	05/2001

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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
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VEAG, Berlin (group license)	12/2001

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PREUSSAG NOELL, Wuerzburg	01/2000
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IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
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DVO Data Processing Service, Oberhausen	05/2000
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VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
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Bayernwerk, Munich	01/1999
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Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
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Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
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SCA Hygiene Products, Munich	10/1998
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Wilhelmshaven University of Applied Sciences	10/1998
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