Hochschule Zittau/Görlitz
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Faculty of
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TECHNICAL THERMODYNAMICS

Property Library for Ammonia-Water Mixtures

FluidEXL *Graphics*
with LibAmWa
for Excel®

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Property Program Library for Ammonia-Water Mixtures

FluidEXL*Graphics*

LibAmWa

Content

For steam tables and further property libraries for Excel®, MATLAB®, EES®, DYMOLA®, LabVIEW®, and Mathcad® see the following link:

www.thermodynamic-property-libraries.com

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0. Package Contents

0.1 Zip files for 32-bit Office®

The following zip files are delivered for your computer running a 32-bit Office® version.

English zip file "CD_FluidEXL_Graphics_LibAmWa_Eng.zip" including the following files:

FluidEXL_Graphics_Eng_Setup.exe	- Self-extracting and self-installing program for FluidEXL*Graphics*
FluidEXL_Graphics_Eng.xla	- FluidEXL*Graphics* Add-In
LibAmWa.hlp	- Help file for the LibAmWa property library
LibAmWa.dll	- Dynamic link library with functions for ammonia-water mixtures
FluidEXL_Graphics_LibAmWa_Docu_Eng.pdf	- User's Guide

German zip file "CD_FluidEXL_Graphics_LibAmWa.zip" including the following files:

FluidEXL_Graphics_Setup.exe	- German installation program for the Add-In FluidEXL*Graphics* for application in Excel®.
FluidEXL_Graphics.xla	- German Add-In for FluidEXL*Graphics*
LibAmWa.hlp	- Help file for the LibAmWa property library
LibAmWa.dll	- Dynamic link library with functions for ammonia-water mixtures
FluidEXL_Graphics_LibAmWa_Docu_Eng.pdf	- User's Guide

0.2 Zip files for 64-bit Office®

The following zip files are delivered for your computer running a 64-bit Office® version.

English zip file "CD_FluidEXL_Graphics_LibAmWa_x64_Eng.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibAmWa_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics_Eng.xla	- FluidEXL*Graphics* Add-In
FluidEXL_Graphics_Eng_64_Setup.msi	- Self-extracting and self-installing program
LibAmWa.dll	- Dynamic link library with functions for ammonia-water mixtures
LibAmWa.hlp	- Help file for the LibAmWa property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL*Graphics*

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

German zip file "CD_FluidEXL_Graphics_LibAmWa_x64.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibAmWa_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics.xla	- German FluidEXL*Graphics* Add-In
FluidEXL_Graphics_64_Setup.msi	- Self-extracting and self-installing program
LibAmWa.dll	- Dynamic link library with functions for ammonia-water mixtures
LibAmWa.hlp	- Help file for the LibAmWa property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL*Graphics*

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

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	kJ/(kg K)
$c'_p = f(p,t,\xi')$	cpl_ptxil_AmWa	CPLPTXILAMWA(P,T,XIL)	Specific isobaric heat capacity of saturated liquid	kJ/(kg K)
$c'_p = f(p,t,\xi'')$	cpl_ptxiv_AmWa	CPLPTXIVAMWA(P,T,XIV)	Specific isobaric heat capacity of saturated liquid	kJ/(kg K)
$c''_p = f(p,t,\xi')$	cpv_ptxil_AmWa	CPVPTXILAMWA(P,T,XIL)	Specific isobaric heat capacity of saturated vapor	kJ/(kg K)
$c''_p = f(p,t,\xi'')$	cpv_ptxiv_AmWa	CPVPTXIVAMWA(P,T,XIV)	Specific isobaric heat capacity of saturated vapor	kJ/(kg K)
$c_v = f(p,t,\xi)$	cv_ptxi_AmWa	CVPTXIAMWA(P,T,XI)	Specific isochoric heat capacity	kJ/(kg K)
$c'_v = f(p,t,\xi')$	cvl_ptxil_AmWa	CVLPTXILAMWA(P,T,XIL)	Specific isochoric heat capacity of saturated liquid	kJ/(kg K)
$c'_v = f(p,t,\xi'')$	cvl_ptxiv_AmWa	CVLPTXIVAMWA(P,T,XIV)	Specific isochoric heat capacity of saturated liquid	kJ/(kg K)
$c''_v = f(p,t,\xi')$	cvv_ptxil_AmWa	CVVPTXILAMWA(P,T,XIL)	Specific isochoric heat capacity of saturated vapor	kJ/(kg K)
$c''_v = f(p,t,\xi'')$	cvv_ptxiv_AmWa	CVVPTXIVAMWA(P,T,XIV)	Specific isochoric heat capacity of saturated vapor	kJ/(kg K)
$D_g = f(p,t,\xi_v)$	Dg_ptxiv_AmWa	DGPTXIVAMWA(P,T,XIV)	Diffusion coefficient vapor mixture	m^2/s
$D_l = f(t,\xi_l)$	Dl_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_txixd_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	-
$Pr' = f(p,t,\xi')$	Prl_ptxil_AmWa	PRLPTXILAMWA(P,T,XIL)	Prandtl-Number of saturated liquid	-
$Pr' = f(p,t,\xi'')$	Prl_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	-
$region = f(p,h,\xi)$	region_phxi_AmWa	REGPHXIAMWA(P,H,XI)	Phase region from pressure, enthalpy, and NH_3 mass fraction	-
$region = f(p,s,\xi)$	region_psxi_AmWa	REGPSXIAMWA(P,S,XI)	Phase region from pressure, entropy, and NH_3 mass fraction	-
$region = f(p,t,\xi)$	region_ptxi_AmWa	REGPTXIAMWA(P,T,XI)	Phase region from pressure, temperature, and NH_3 mass fraction	-
$region = f(h,s,\xi)$	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)
$\sigma_l = f(t,\xi')$	sigmal_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	LAMBDAVPTXILAMWA(P,T,XIL)	Therm. conductivity of saturated vapor	W/(m K)
$\lambda'' = f(p,t,\xi'')$	lambdav_ptxiv_AmWa	LAMBDAVPTXIVAMWA(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_3mass 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 NH_3)/(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 ($\ldots'$) and saturated vapor ($\ldots''$) 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_{H2O} = 0.000611783 kJ/kg and
	s_{H2O} = 0.0 kJ/(kg K)
	at p_{tr} = 0.00611657 bar and t_{tr} = 0.01 °C
Ammonia:	triple point for saturated liquid
	h_{NH3} = 2.333 kJ/kg and
	s_{NH3} = 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 FluidEXL*Graphics* in Excel®

The FluidEXL*Graphics* Add-In has been developed to calculate thermodynamic properties in Excel more conveniently. Within Excel®, it enables the direct call of functions relating to ammonia-water mixtures from the LibAmWa property library.

2.1 Installing FluidEXL*Graphics*

If FluidEXL*Graphics* has not yet been installed or if there is a version installed which has been delivered before April 2010, please complete the initial installation procedure described below.

If FluidEXL*Graphics* has already been installed in a version which has been delivered after April 2010, you simply need to copy the files which belong to the LibAmWa library. In this case, follow the subsection "Adding the LibAmWa Library" on page 2/10.

Installing FluidEXL*Graphics* for 32-bit Office®

Complete the following steps for initial installation of FluidEXL*Graphics*.
Before you begin, it is best to uninstall any trial version or full version of FluidEXL*Graphics* delivered before June 2010.
After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibAmWa_Eng.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibAmWa.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibAmWa_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibAmWa (for German version of Windows)

in your Windows Explorer, Norton Commander etc.

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

Within this folder you will see the following files:

FluidEXL_Graphics_Eng_Setup.exe (for English version of Windows)
FluidEXL_Graphics_Setup.exe (for German version of Windows)
FluidEXL_Graphics_Eng.xla (for English version of Windows)
FluidEXL_Graphics.xla (for German version of Windows)
FluidEXL_Graphics_LibAmWa_Docu_Eng.pdf
LibAmWa.dll
LibAmWa.hlp.

In order to run the installation of FluidEXL*Graphics* double-click the file

FluidEXL_Graphics_Eng_Setup.exe (for English version of Windows)
FluidEXL_Graphics_Setup.exe (for German version of Windows).

Installation may start with a window noting that all Windows programs should be closed. When this is the case, the installation can be continued. Click the "Continue" button.

In the following dialog box, "Choose Destination Location", the default path offered automatically for the installation of FluidEXL*Graphics* is

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation (see figure below).

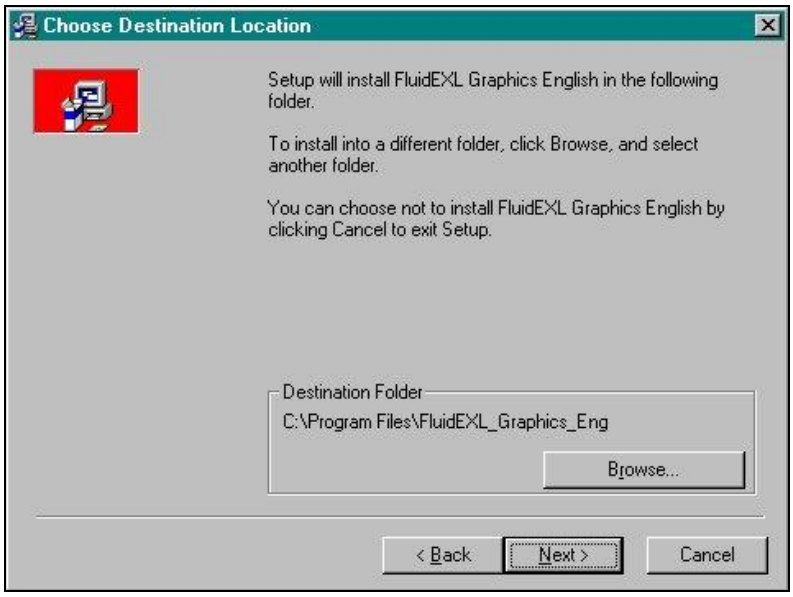

Figure 2.1: Choose Destination Location

Finally, click on "Next" to continue installation; click "Next" again in the "Start Installation" window which follows in order to start the installation of FluidEXL*Graphics*.

After FluidEXL*Graphics* has been installed, the sentence "FluidEXL Graphics English has been successfully installed." will be shown. Confirm this by clicking the "Finish" button.

During the installation process the following files

Advapi32.dll	LC.dll
DFORMD.dll	Msvcp60.dll
Dforrt.dll	Msvcrt.dll
FluidEXL_Graphics_Eng.xla	UNWISE.EXE
INSTALL_EXL.LOG	UNWISE.INI

have been copied into the chosen destination folder, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

In addition, the two subdirectories \FORMULATION97 and \FLuft have been compiled in the destination folder.

In the next step, the following files from the extracted folder

CD_FluidEXL_Graphics_LibAmWa_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibAmWa	(for German version of Windows)

must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

using an appropriate program such as Explorer or Norton Commander:

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibAmWa.dll	
LibAmWa.hlp.	

Installing FluidEXL*Graphics* for 64-bit Office®

Complete the following steps for initial installation of FluidEXL*Graphics*.
Before you begin, it is best to uninstall any trial version or full version of FluidEXL*Graphics* delivered before June 2010.
After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibAmWa_Eng_x64.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibAmWa_x64.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibAmWa_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibAmWa (for German version of Windows)

in your Windows Explorer, Norton Commander etc.

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

Within this folder you will see the following files

FluidEXL_Graphics_LibAmWa_Docu_Eng
FluidEXL_Graphics_Eng.xla (for English version of Windows)
FluidEXL_Graphics.xla (for German version of Windows)
FluidEXL_Graphics_Eng_Setup_64.msi (for English version of Windows)
FluidEXL_Graphics_Setup_64.msi (for German version of Windows)
LibAmWa.dll
LibAmWa.hlp
Setup.exe

and the folders

vcredist_x64
WindowsInstaller3_1.

In order to run the installation of FluidEXL*Graphics* double-click the file

Setup.exe.

If the "Microsoft Visual C++ 2010 x64 Redistributable Pack" is not running on your computer yet, installation will start with a window noting that the "Visual C++ 2010 runtime library (x64)" will be installed on your machine (see figure below).

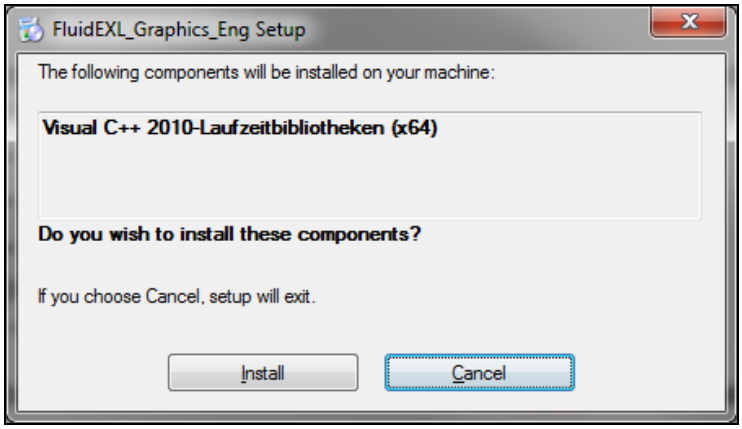

Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

Click on "Install" to continue.

In the following window you are required to accept the Microsoft® license terms to install the "Microsoft Visual C++ 2010 x64 Redistributable Pack" by ticking the box next to "I have read and accept the license terms" (see figure below).

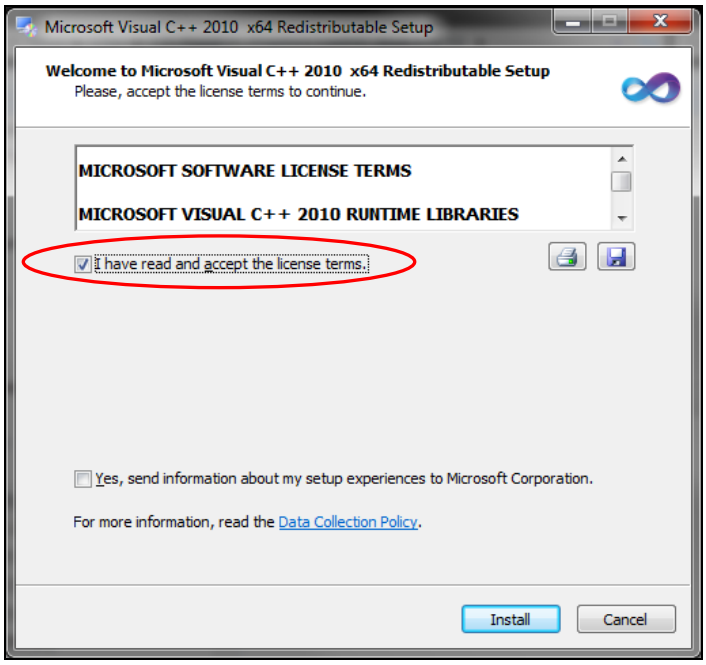

Figure 2.3: Accepting the license terms

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 the installation of FluidEXL_Graphics_Eng_64 starts with a window noting that the installer will guide you through the installation. Click the "Next >" button to continue.

In the following dialog box, "Select Installation Folder," the default path offered automatically for the installation of FluidEXL*Graphics* is

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

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

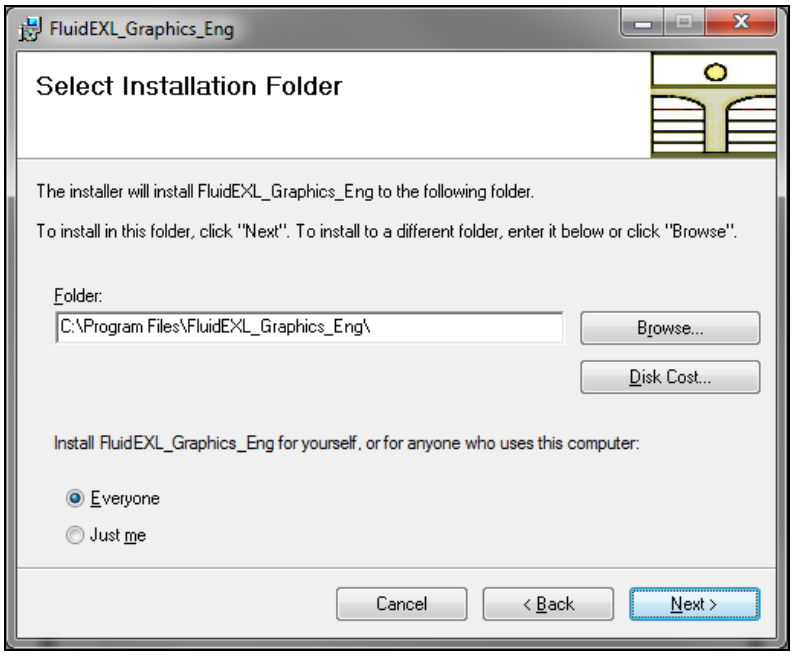

Figure 2.4: Choosing the Installation Folder of FluidEXL*Graphics*

Finally, click on "Next >" to continue installation; click "Next >" again in the "Confirm Installation" window which follows in order to start the installation of FluidEXL*Graphics*.

After FluidEXL*Graphics* has been installed, you will see the sentence "FluidEXL_Graphics_Eng has been successfully installed." Confirm this by clicking the "Close" button.

During the installation process the following files

capt_ico_big.ico	libmmd.dll
libifcoremd.dll	LC.dll
libiomp5md.dll	

will have been copied into the destination folder chosen, the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

In addition, the two subdirectories \FORMULATION97 and \FLuft were created in the destination folder.

In the next step, the files below, found on your CD, must be copied into the chosen destination folder (the standard being C:\Program Files\FluidEXL_Graphics_Eng) using an appropriate program such as Explorer or Norton Commander:

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibAmWa.dll	
LibAmWa.hlp.	

2.2 Registering FluidEXL*Graphics* as Add-In in Excel®

Registering FluidEXL*Graphics* as Add-In in Excel®, versions 2003 or earlier

After the installation of FluidEXL*Graphics*, the program must be registered as an Add-In in Excel®. In order to do so, start Excel® and carry out the following steps:

- Click "Tools" in the upper menu bar of Excel®.
- Here, click the "Add-Ins..." menu item.
  After a short delay the "Add-Ins" dialog box will appear.
- Click "Browse...."
- In the following dialog box, choose your destination folder (the standard being
  C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
  C:\Programme\FluidEXL_Graphics (for German version of Windows)),
  here select
  "FluidEXL_Graphics_Eng.xla" (for English version of Windows)
  "FluidEXL_Graphics.xla" (for German version of Windows)

  and afterwards click "OK."
- Now, the entry
  "FluidEXL Graphics Eng" (for English version of Windows)
  "FluidEXL Graphics" (for German version of Windows)

  will appear in the Add-Ins list.

Note:

As long as the check box next to the file name "FluidEXL Graphics Eng" is checked, this Add-In will be loaded automatically every time you start Excel® until you unmark the box by clicking on it again.

In order to register "FluidEXL Graphics Eng" as an Add-In, click "OK" in the "Add-Ins" dialog box. Now, the new FluidEXL*Graphics* menu bar will appear in the upper menu area of your Excel® screen, marked with a red circle in Figure 2.5.

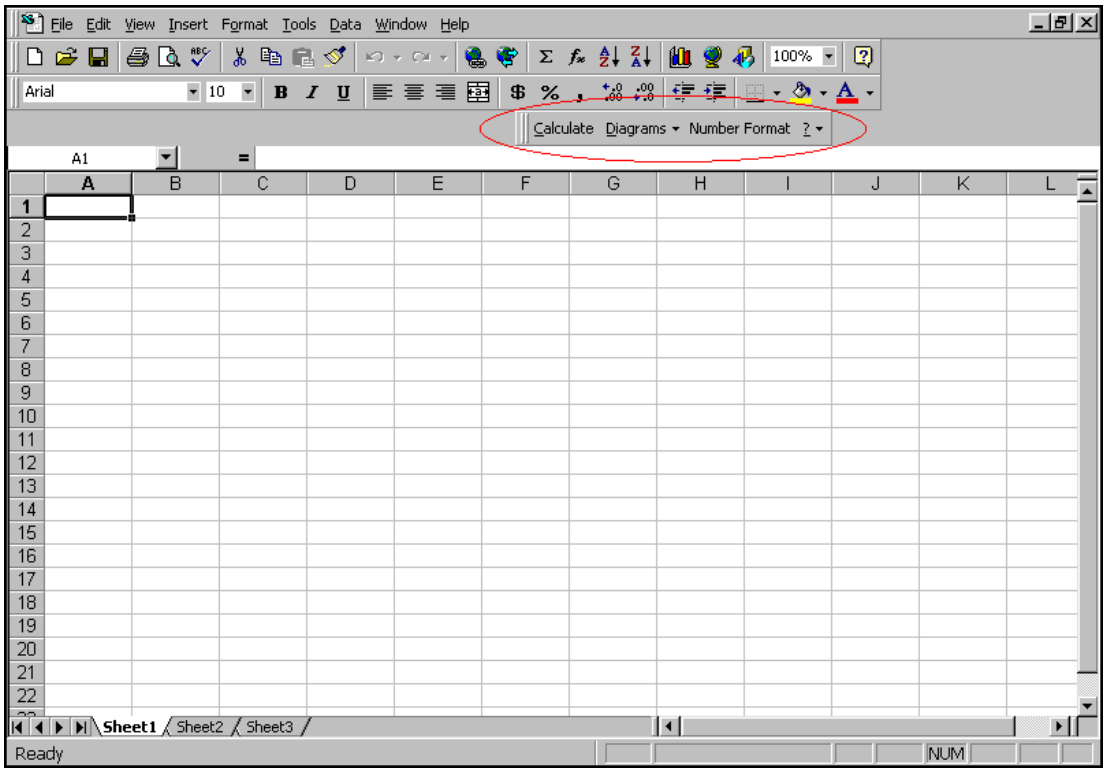

Figure 2.5: Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "NH3-H2O LibAmWa" DLL library property functions via this menu bar (see part 2.5 on page 2/19).

Registering FluidEXL*Graphics* as Add-In in Excel® 2007 (or later versions)

After installation in Windows®, FluidEXL*Graphics* must be registered in Excel® versions 2007 and later as an Add-In. To do this, start Excel® and carry out the following steps:

- Click the Windows Office® button in the upper left hand corner of Excel®
- Click on the "Excel Options" button in the menu which appears (see Figure 2.6)

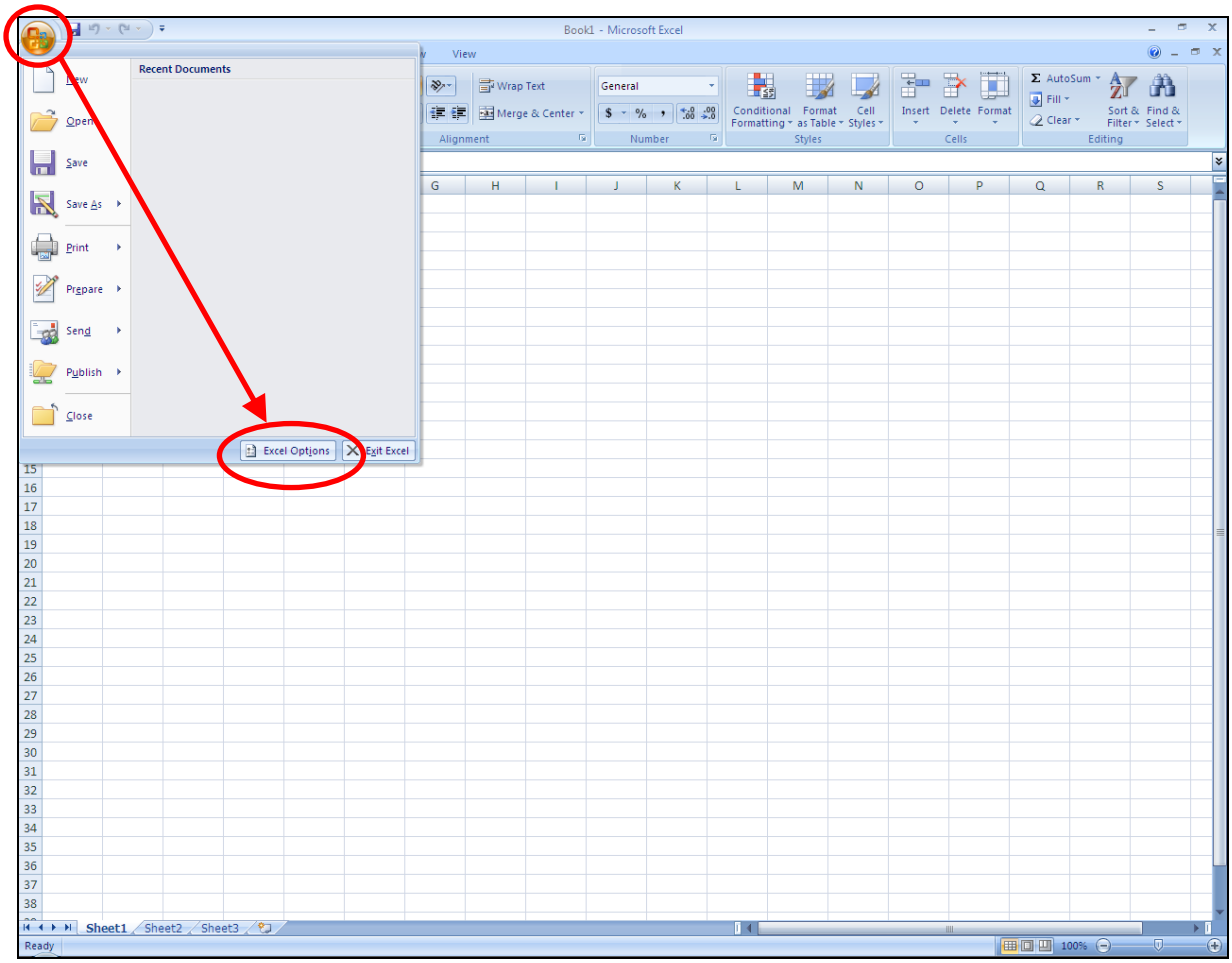

Figure 2.6: Registering FluidEXL*Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

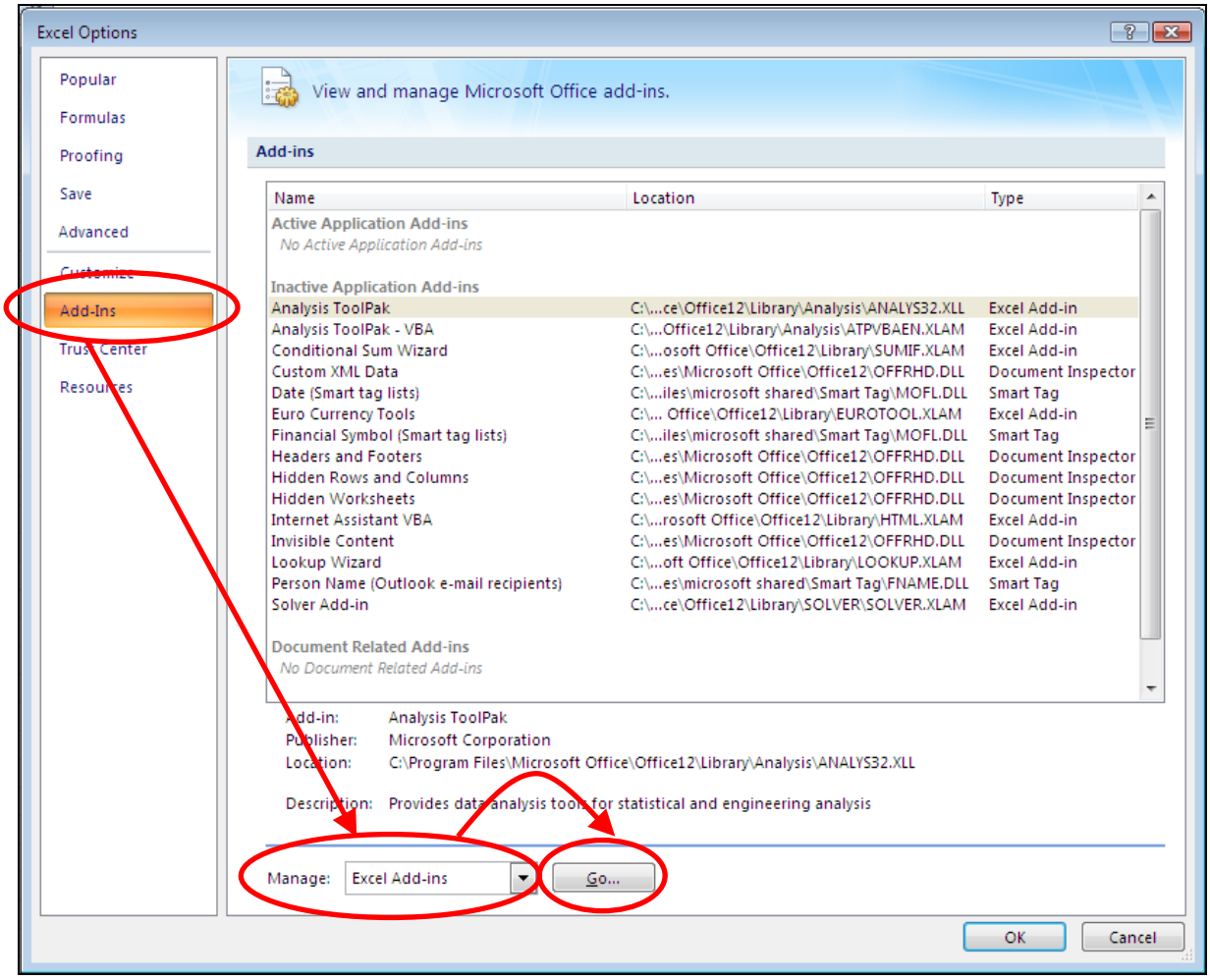

Figure 2.7: Dialog window "Excel Options"

- Should it not be shown in the list automatically, select "Excel Add-ins" (found next to "Manage:" in the lower area of the menu)
- Then click the "Go…" button
- Click "Browse" in the following window and locate the destination folder, the standard being

  C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
  C:\Programme\FluidEXL_Graphics (for German version of Windows);

  within that folder click on the file named

  "FluidEXL_Graphics_Eng.xla" (for English version of Windows)
  "FluidEXL_Graphics.xla" (for German version of Windows)

  and then hit "OK."

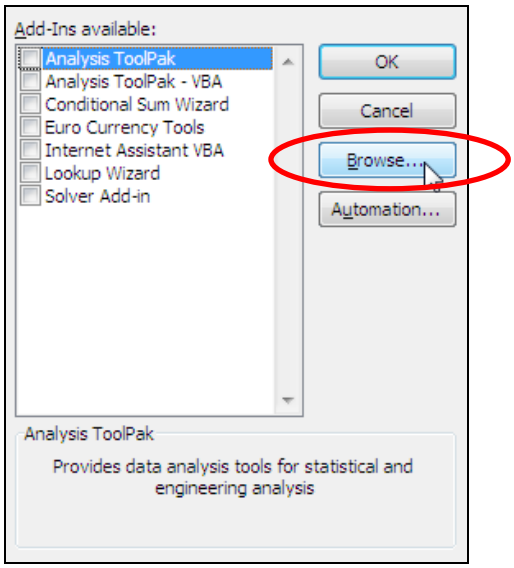

Figure 2.8: Dialog window "Add-Ins available"

- Now, "FluidEXL Graphics Eng" will be shown in your list of Add-Ins.
  (If a check-mark is situated in the box next to the name "FluidEXL Graphics Eng," this Add-In will automatically be loaded whenever Excel® starts. This will continue to occur unless the check-mark is removed from the box by clicking on it.)

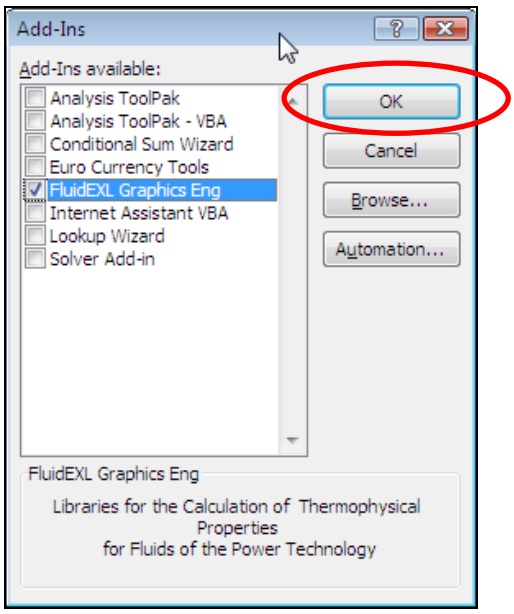

Figure 2.9: Dialog window "Add-Ins"

- In order to register the Add-In click the "OK" button in the "Add-Ins" window.

In order to use FluidEXL*Graphics* in the following example, click on the menu item "Add-Ins" shown in Figure 2.10.

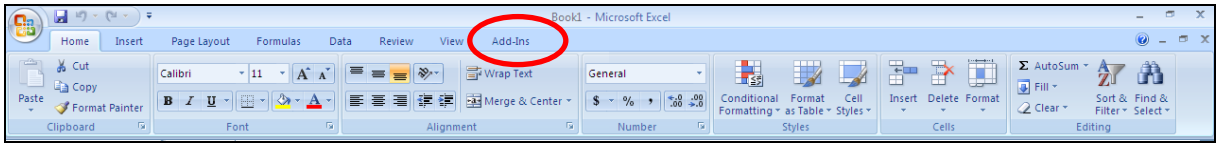

Figure 2.10: Menu item "Add-Ins"

In the upper menu region of Excel, the FluidEXL*Graphics* menu bar will appear as marked with the red circle in the next figure.

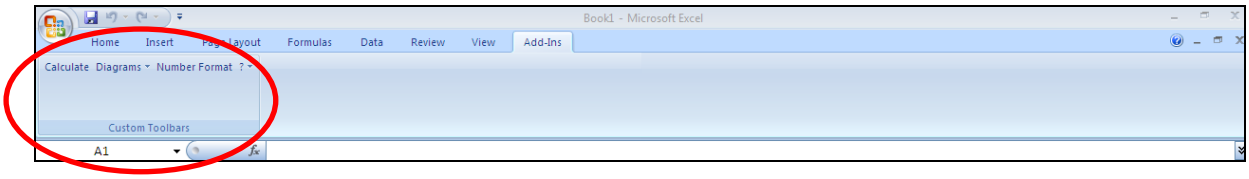

Figure 2.11: FluidEXL*Graphics* menu bar

Installation of FluidEXL*Graphics* in Excel® (versions 2007 and later) is now finished. FluidEXL*Graphics* can be used analogous to the description for using with earlier Excel® versions.

Adding the LibAmWa Library (FluidEXL*Graphics* is already installed)

If FluidEXL*Graphics* has already been installed in the April 2010 version, you only have to copy the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibAmWa.dll	
LibAmWa.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibAmWa_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibAmWa	(for German version of Windows)

into the folder you have chosen for the installation of FluidEXL*Graphics* (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)

using an appropriate program such as Explorer® or Norton Commander.

From within Excel you can now select the "NH3-H2O LibAmWa" DLL library property functions for water and steam via this menu bar (cf. part 2.5).

2.3 The FluidEXL*Graphics* Help System

As mentioned earlier, FluidEXL*Graphics* also provides detailed online help functions.

If you are running Windows Vista or Windows 7, please note the paragraph

"Using the FluidEXL*Graphics* Online-Help in Windows Vista or Windows 7."

For general information in Excel®

- Click on "?" and then "Help" in the FluidEXL*Graphics* menu bar.

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

- Click "Calculate" in the FluidEXL*Graphics* menu bar.
- Click on the "NH3-H2O LibAmWa" library under "Or select a category:" in the "Insert Function" window which will appear.
- Click the "Help on this function" link in the lower left-hand edge of the "Insert Function" window.
- If the "Office Assistant" is active, first double-click "Help on this feature" and in the next menu click "Help on selected function".

If the LibAmWa.hlp file cannot be found, confirm the question whether you want to look for it

yourself with "Yes". Click on the LibAmWa.hlp file in the installation menu of FluidEXL*Graphics* in the window which is opened, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows)

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

Using the FluidEXL*Graphics* 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.

Open Microsoft Internet Explorer® and go to the following address:

http://support.microsoft.com/kb/917607/

You will see the following web page:

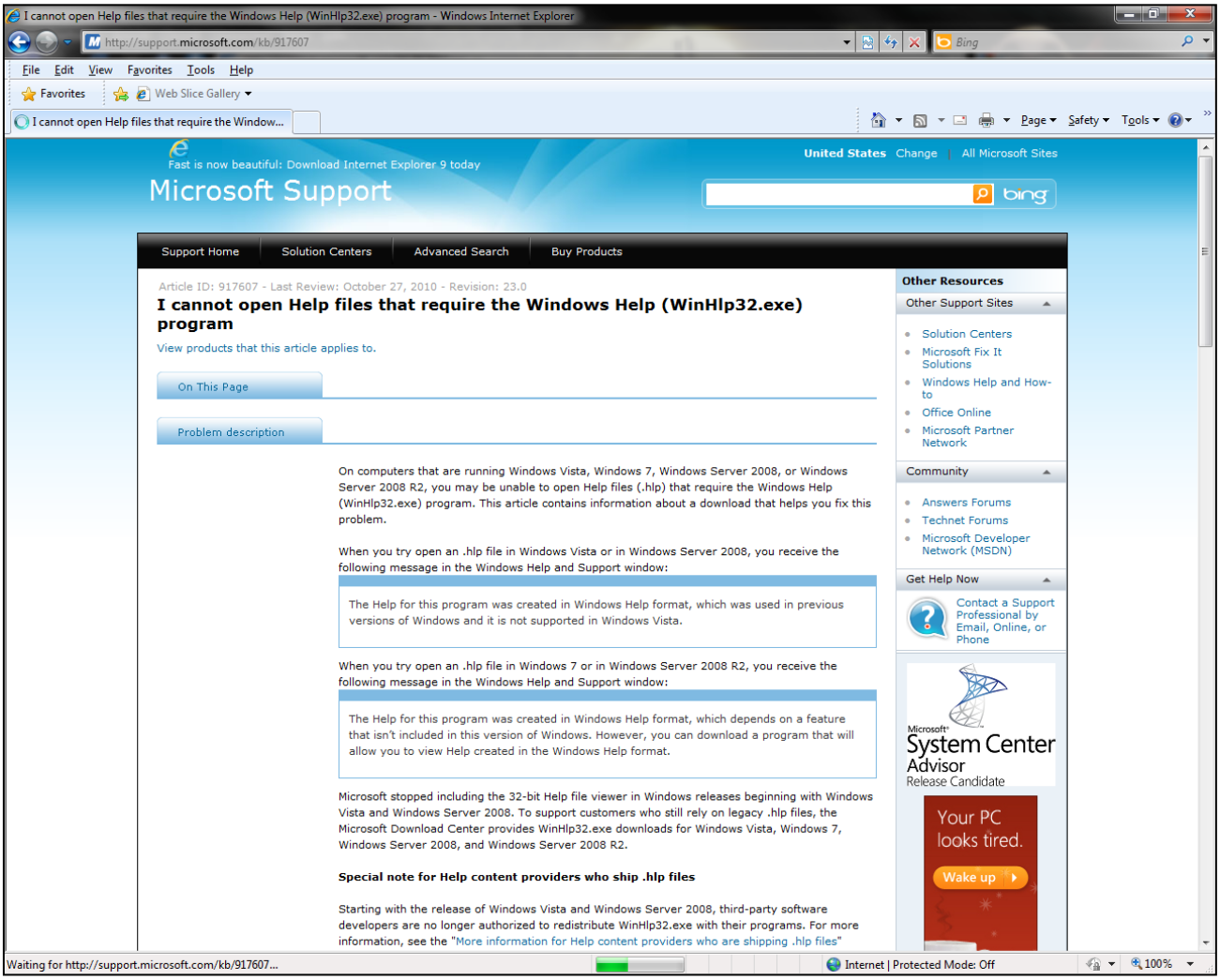

Figure 2.12: Microsoft® Support web page

Scroll down until you see the headline "Resolution." Here you can see the bold hint:

"Download the appropriate version of Windows Help program (WinHlp32.exe), depending on the operating system that you are using:"

The following description relates to Windows® 7. The procedure is analogous for Windows® Vista.

Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.13).

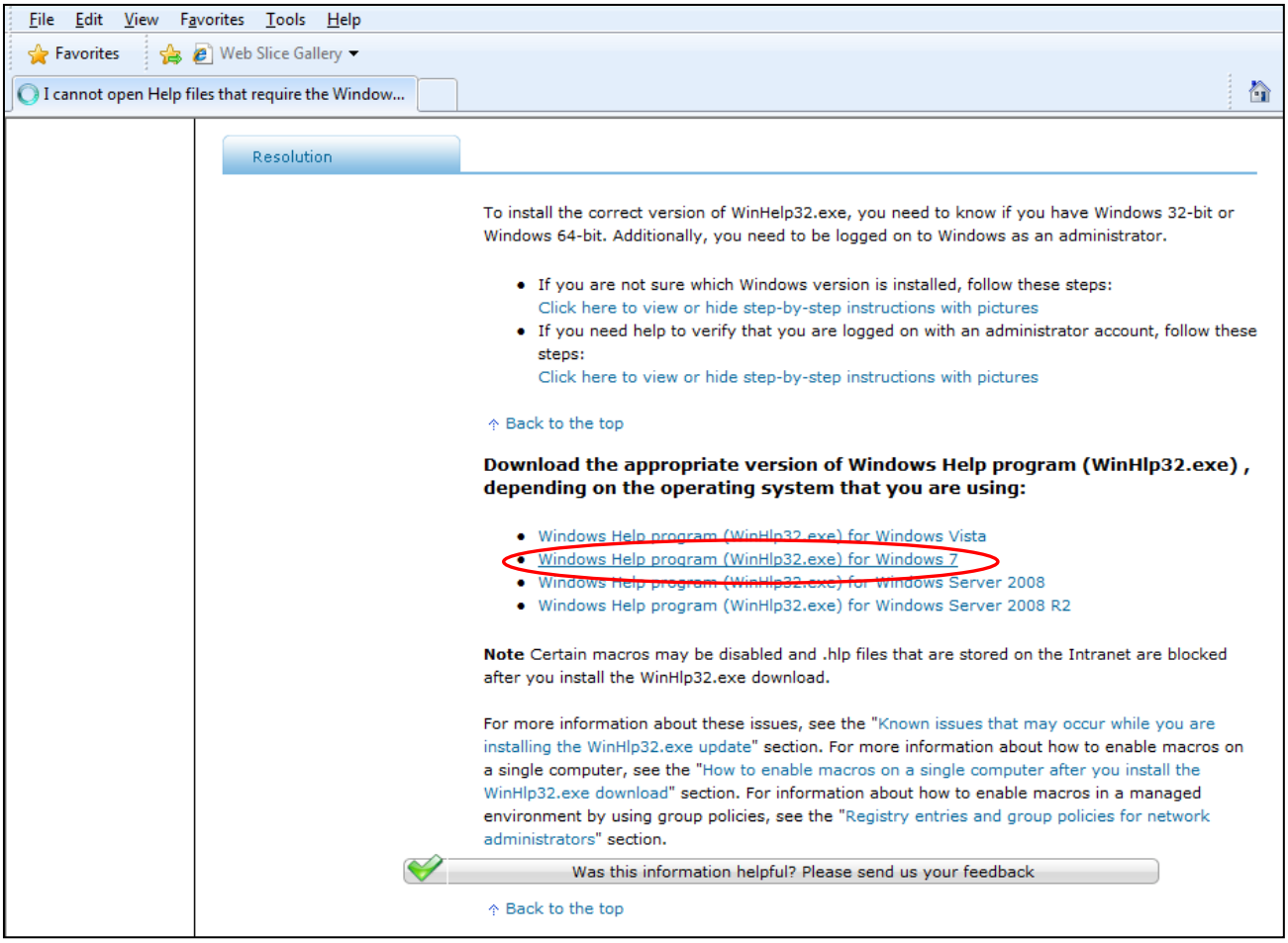

Figure 2.13: Selecting your Windows version

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 2.14).

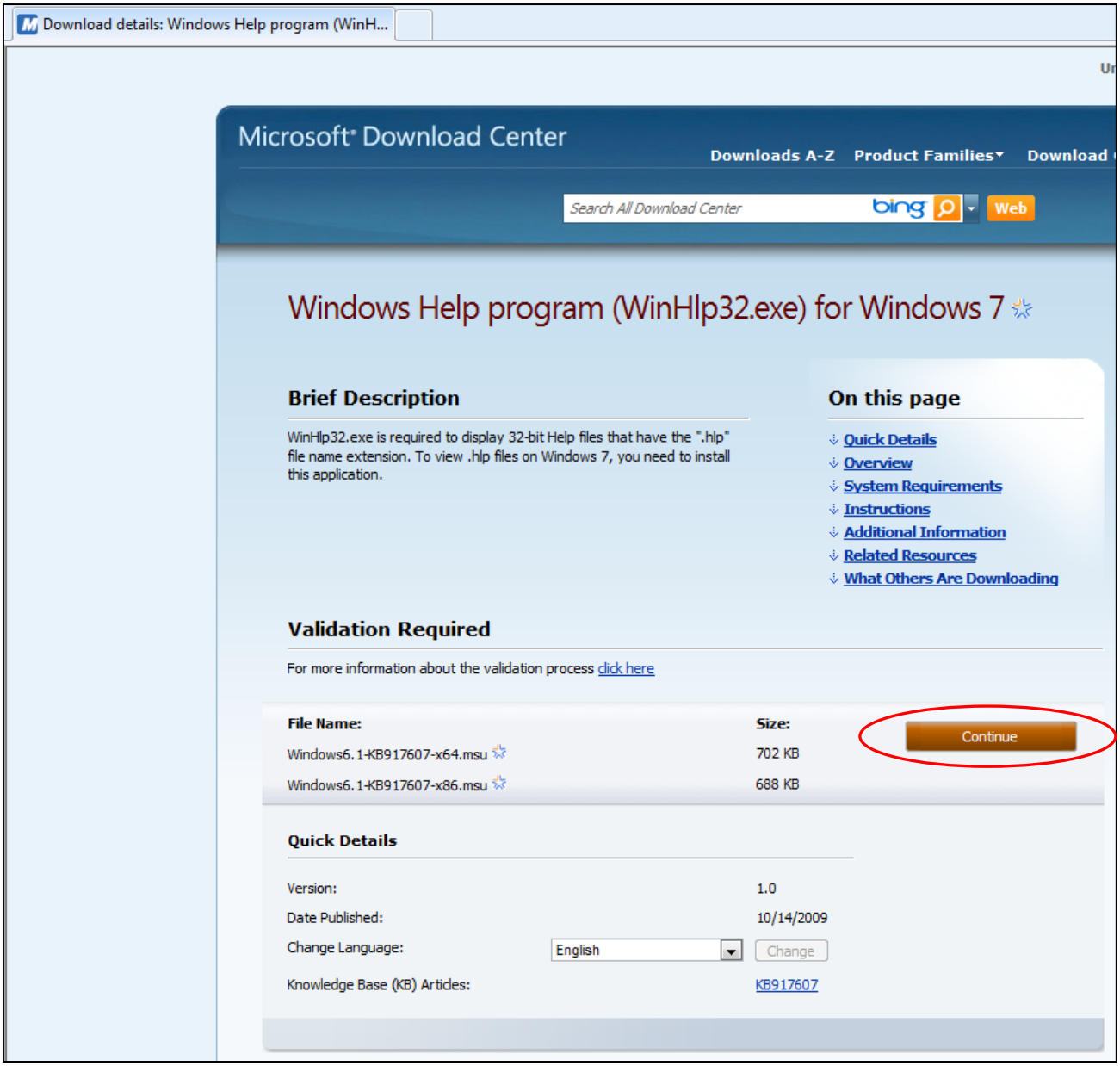

Figure 2.14: Microsoft® Download Center

You will be forwarded to a web page with instructions on how to install the Genuine Windows Validation Component.
At the top of your Windows Internet Explorer you will see a yellow information bar. Right-click this bar and select "Install ActiveX Control" in the context menu (see Figure 2.15).

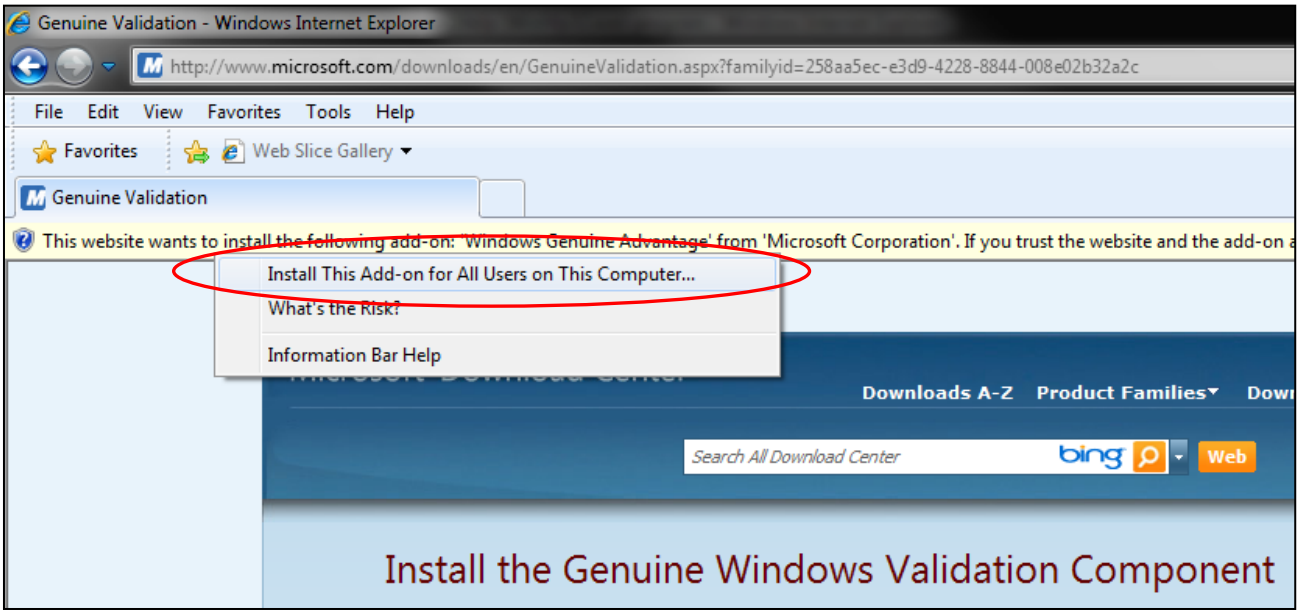

Figure 2.15: Installing the Genuine Windows Validation Component

A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue (see Figure 2.16).

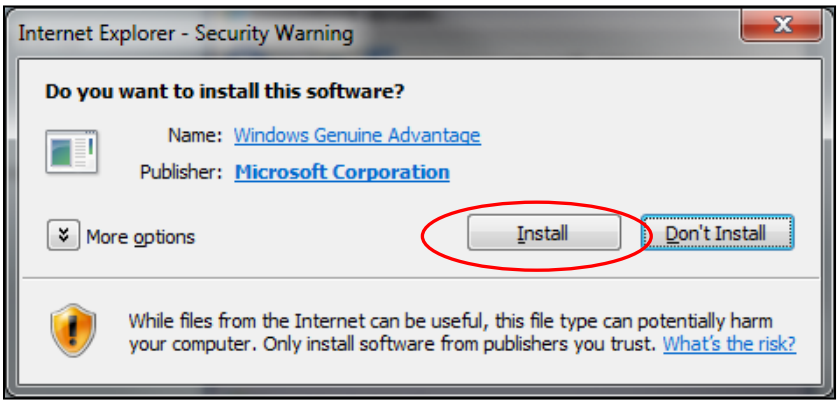

Figure 2.16: Internet Explorer – Security Warning

After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.17).

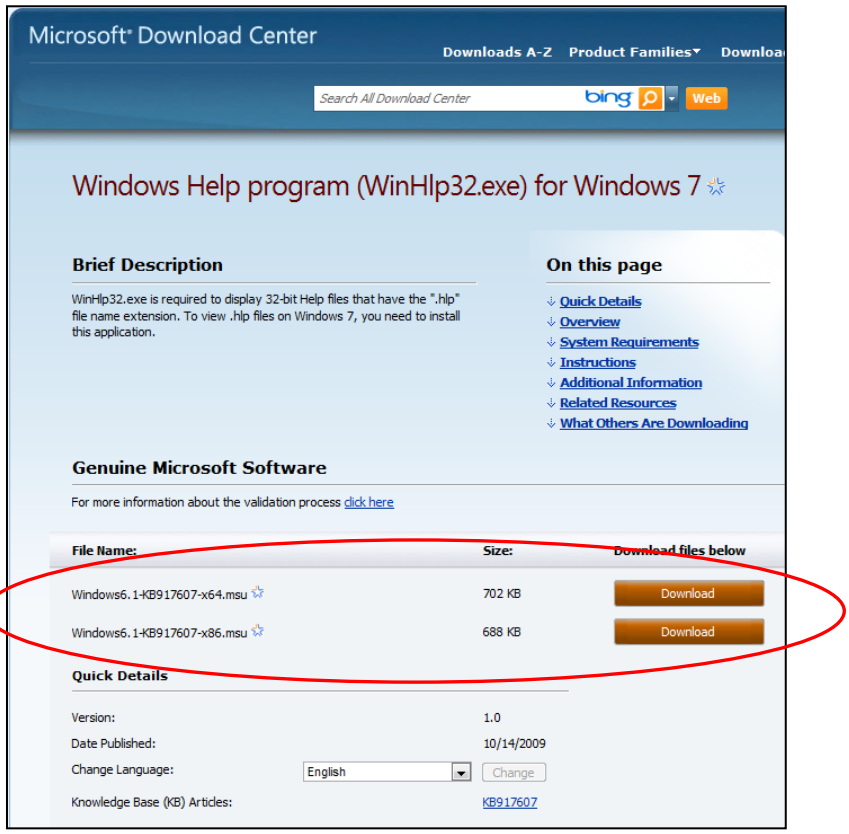

Figure 2.17: Downloading the Windows Help program

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.

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

Windows6.1-KB917607-x64.msu (for 64-bit operating system)
Windows6.1-KB917607-x86.msu. (for 32-bit operating system).

Installation starts with a window searching for updates on your computer. After the program has finished searching you may see the following window.

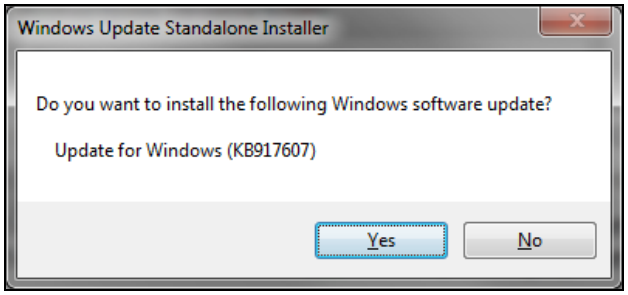

Figure 2.18: Windows Update Standalone Installer

In this case, the installation can be continued by clicking the "Yes" button.

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

In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept" (see Figure 2.19)

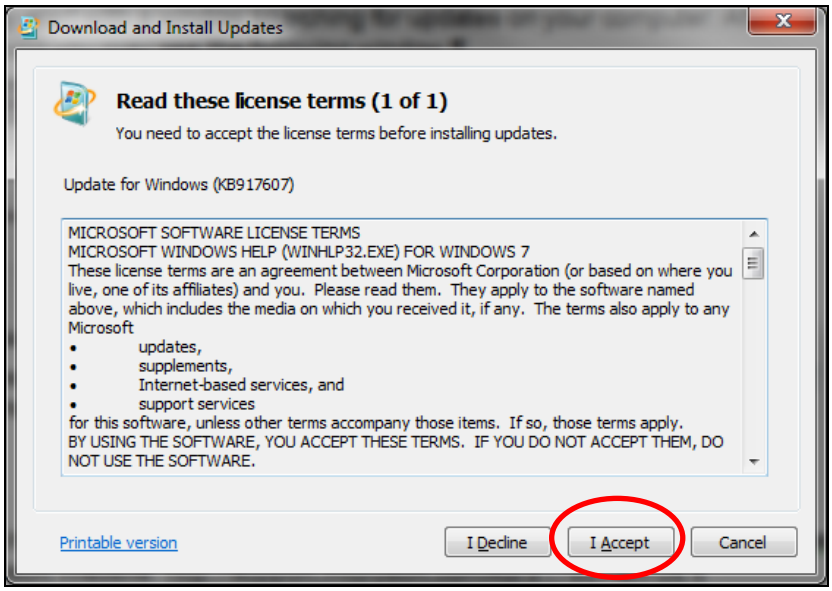

Figure 2.19: Windows License Terms

Installation starts once you have clicked the "I Accept" button (see Figure 2.20).

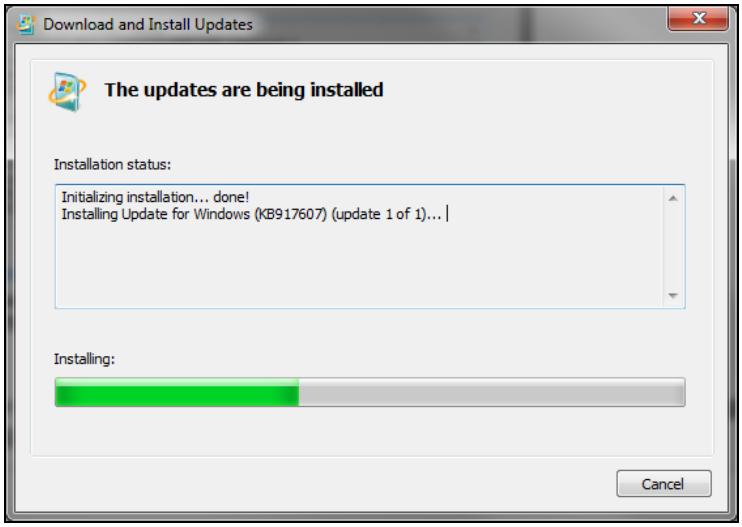

Figure 2.20: Installation process

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.

2.4 Licensing the LibAmWa Property Library

The licensing procedure has to be carried out when Excel® starts up and a FluidEXL*Graphics* prompt message appears. In this case, you will see the "License Information" window (see figure below).

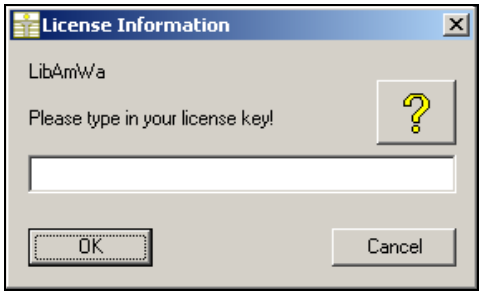

Figure 2.21: "License Information" window

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:

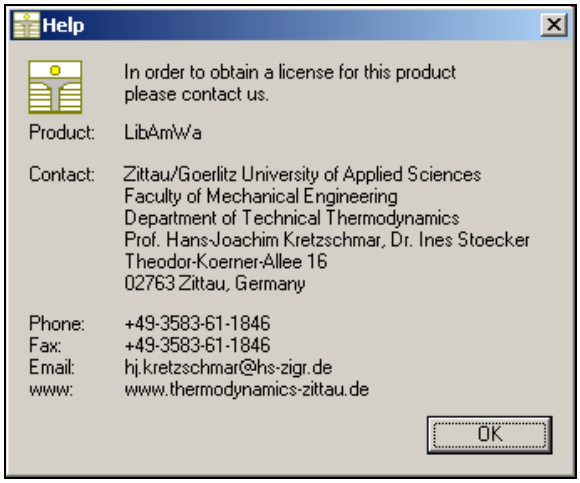

Figure 2.22: "Help" window

If you do not enter a valid license it is still possible to start Excel by clicking "Cancel". In this case, the LibAmWa property library will display the result "–11111111" for every calculation.

The "License Information" window will appear every time you start Excel unless you uninstall FluidEXL*Graphics* according to the description in section 2.7 of this User's Guide.

Should you not wish to license the LibAmWa property library, you have to delete the files

LibAmWa.dll
LibAmWa.hlp

in the installation folder of FluidEXL*Graphics* (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows))

using an appropriate program such as Explorer® or Norton Commander.

2.5 Example: Calculation of $h = f(p,t,\xi)$

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p, temperature t, and water mass fraction ξ, using FluidEXL*Graphics*.

- Start Excel®
- Enter a value for p in bar into a cell.
  (Range of validity: p = 0.1 bar ... 400 bar)
  ⇒ e.g.: Enter 10 into the cell A2.
- Enter a value for t in °C into a cell.
  (Range of validity: $t = t_{tr}(\xi)$ ... $2 \cdot t_c(\xi)$)
  ⇒ e.g.: Enter 130 into the cell B2.
- Enter a value for ξ in kg ammonia / kg mixture into a cell.
  (Range of validity: ξ = 0.0 kg NH_3/kg ... 1.0 kg NH_3/kg)
  ⇒ e.g.: Enter 0.5 into the cell C2.
- Click the cell in which the enthalpy h in kJ/kg is to be displayed.
  ⇒ e.g.: Click the cell D2.
- Click "Calculate" in the menu bar of FluidEXL*Graphics*.
  Now the "Insert Function" window appears (see next figure).

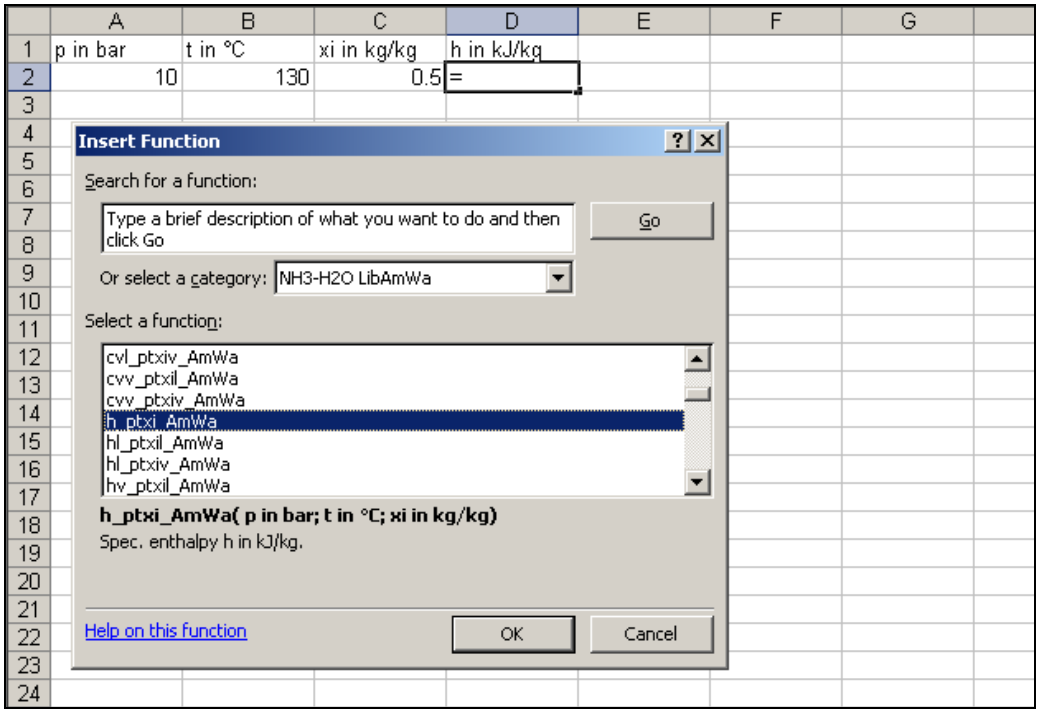

Figure 2.23: Selecting the library and the function

- Search and click the "NH3-H2O LibAmWa" library in the upper list box next to "Or select a category:".
- Search and click the "h_ptxi_AmWa" function in the lower list box under "Select a function:"

  Here it is possible to get more information on scope, measuring units, error responses, etc. by clicking the "Help on this function" button.
- Click "OK".
  The window shown in the next figure will now appear.

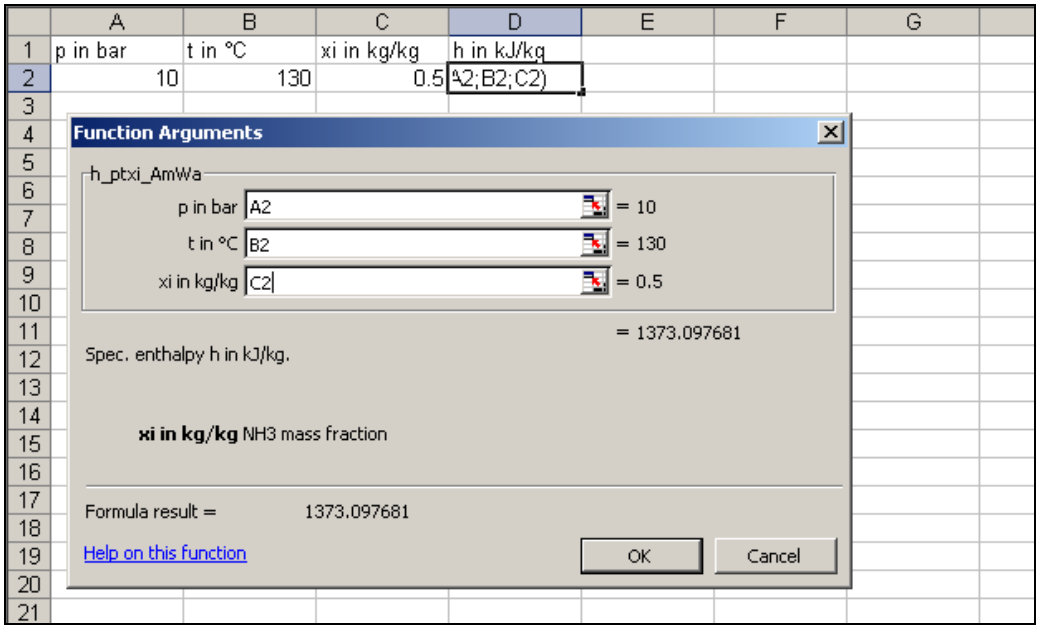

Figure 2.24: Entering the values given for the property calculation

- The cursor is situated on the line next to "*p* in bar". You can now enter the value for *p* either by clicking the cell with the value for *p*, by entering the name of the cell with the value for *p*, or by entering the value for *p* directly.
- Situate the cursor next to "*t* in °C" and enter the value for *t* by clicking the cell with the value for *t*, by entering the name of the cell with the value for *t*, or by entering the value for *t* directly.
- Situate the cursor on the line next to "*xi* in kg NH3/kg" and enter the value of ξ by clicking the cell with the value for ξ, o by entering the name of the cell with the value for ξ, or by entering the value for ξ directly.
- Click the "OK" button.

The result for *h* in kJ/kg appears in the cell selected above.

⇒ The result in our sample calculation here is: h = 1373.097681 kJ/kg.

The calculation of $h = f(p,t,\xi)$ has thus been completed. You can now arbitrarily change the values for *p*, *t*, or ξ in the appropriate cells. The enthalpy is recalculated and updated every time you change the data. This shows that the Excel® data flow and the DLL calculations are working together successfully.

Note.

If the calculation results in –1000, this indicates that the values entered are located outside the range of validity of LibAmWa. More detailed information on each function and its range of validity is available in Chapter 3.

For further property functions calculable in FluidEXL*Graphics*, please see the function table in Chapter 1.

2.6 Example: Calculation of $h' = f(p,t,\xi')$

We will now calculate the specific enthalpy for the boiling liquid h' as a function of pressure p, and the water mass fraction in boiling liquid ξ', using FluidEXL*Graphics*. Please carry out the following steps:

- Enter a value for p in bar into a cell:
  (Range of validity: p = 0.1 bar ... 400 bar)
  ⇒ e.g.: Enter 10 into the cell A2.
- Enter a value for t in °C into a cell.
  (Range of validity: $t = t_{tr}(\xi)$ ... $2 \cdot t_c(\xi)$)

  For the calculation of the specific enthalpy for the boiling liquid h' it is adequate to determine only two parameters, 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 into the cell B2.
- Enter a value for ξ' in kg ammonia/kg mixture into a cell.
  (Range of validity: ξ' = 0.0 kg NH_3/kg ... 1.0 kg NH_3/kg)
  ⇒ e.g.: Enter 0.5 into the cell C2.
- Click the cell in which the enthalpy calculated for the boiling liquid h' in kJ/kg is to be displayed.
  ⇒ e.g.: Click the cell D2.
- Click "Calculate" in the menu bar of FluidEXL*Graphics*.

The "Insert Function" window appears (see Figure 2.25).

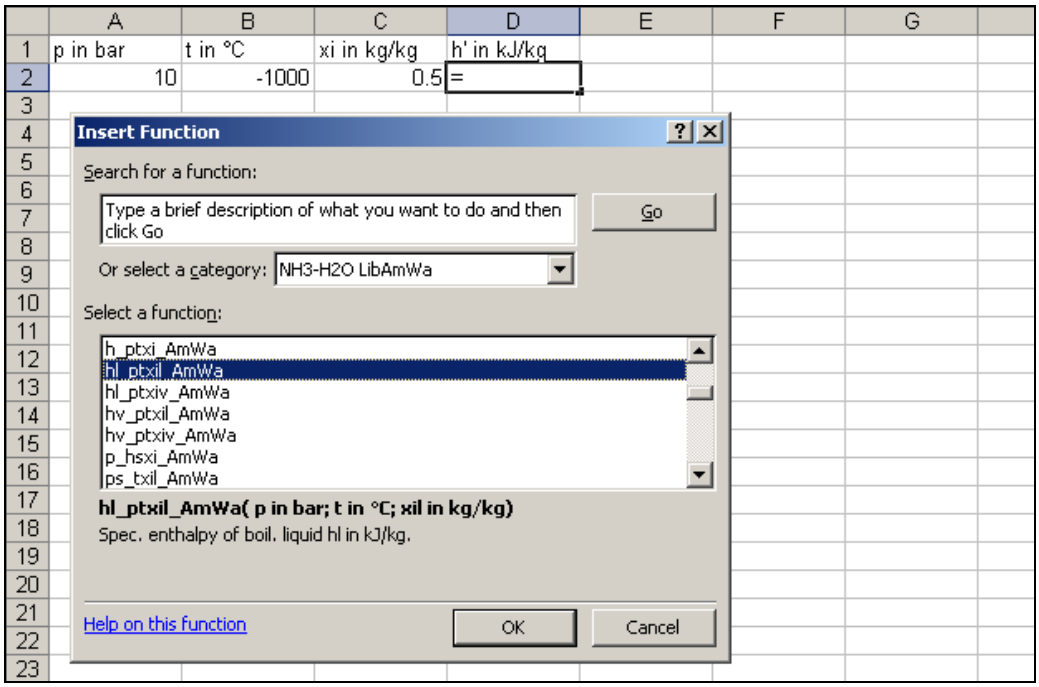

Figure 2.25: Selecting the library and the function

- Search and click the "NH3-H2O LibAmWa" library in the upper list box next to "Or select a category:".
- Search and click the "hl_ptxil_AmWa" function in the lower list box under "Select a function:".

  Here it is possible to get more information on scope, measuring units, error responses, etc. by clicking the "Help on this function" button.
- Click "OK".
  The "Function Arguments" window is displayed (see Figure 2.26).

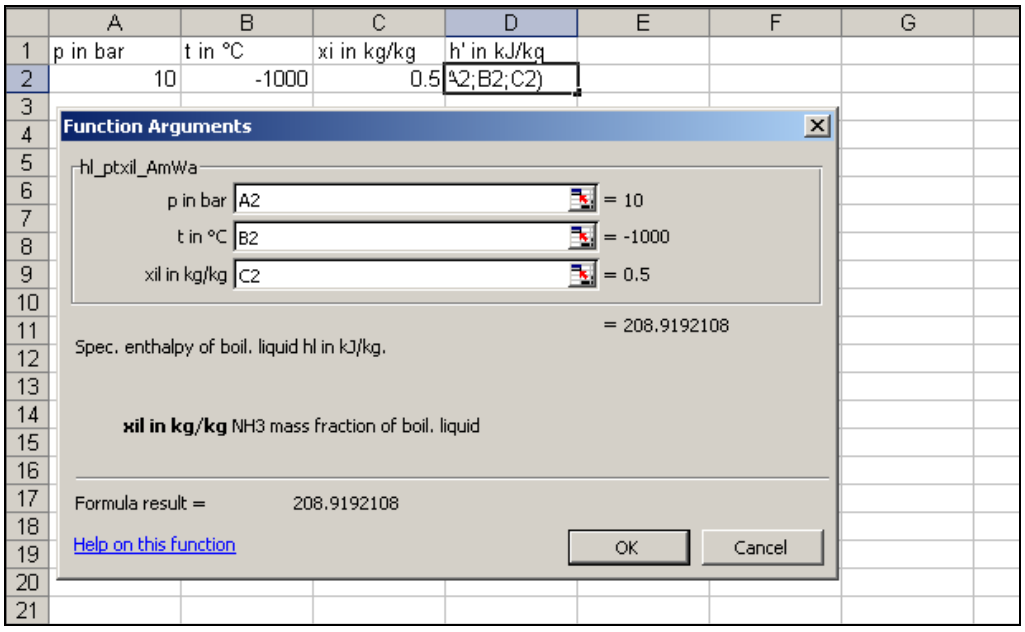

Figure 2.26: Entering the given values for the property calculation

- The cursor is situated on the line next to "*p* in bar". You can now enter the value for *p* either by clicking the cell with the value for *p*, by entering the name of the cell with the value for *p*, or by entering the value for *p* directly.
- Situate the cursor next to "*t* in °C" and enter the value for *t* by clicking the cell with the value for *t*, by entering the name of the cell with the value for *t*, or by entering the value for *t* directly.
- Situate the cursor on the line next to "xil in kg NH3/kg" and enter the value for ξ', by clicking the cell with the value for ξ', by entering the name of the cell with the value for ξ', or by entering the value for ξ' directly.
- Click the "OK" button.

The result for *h* in kJ/kg appears in the cell selected above.

⇒ The result in our sample calculation here is: $h' = 208.9192108$ kJ/kg.

The calculation of $h' = f(p, t, \xi')$ has thus been completed. You can now arbitrarily change the values for *p*, *t,* or ξ' in the appropriate cells. The enthalpy is recalculated and updated every time you change the data. This shows that the Excel® data flow and the DLL calculations are working together successfully.

Note.

If the calculation results in –1000, this indicates that the values entered are located outside the range of validity of LibAmWa. More detailed information on each function and its range of validity is available in Chapter 3.

For further property functions calculable in FluidEXL*Graphics*, please see the function table in Chapter 1.

Number Formats

When using FluidEXL*Graphics* you have the option of choosing special number formats in advance.
Changes can be made as follows:

- Click the cell or select and click on the cells you wish to format.
  (In empty cells the new format will be applied once a value has been entered.)
- Click "Number Format" in the FluidEXL*Graphics* menu bar.
- Select the desired number format in the dialog box which appears:

"STD – Standard":	Insignificant zeros behind the decimal point are not shown.
"FIX – Fixed Number of Digits":	All set decimal places are shown, including insignificant zeros.
"SCI – Scientific Format":	Numbers are always shown in the exponential form with the set number of decimal places.

- Set the "Number of decimal places" by entering the number into the appropriate window.
- Confirm this by clicking the "OK" button.

As an example, the table below shows the three formats for the number 1.230 adjusted for three decimal places:

STD	1.23
FIX	1.230
SCI	1.230E+00

This formatting can also be applied to cells which have already been calculated.

2.7 Removing FluidEXL*Graphics*

Should you wish to remove only the LibAmWa library, delete the files

LibAmWa.dll
LibAmWa.hlp

in the directory selected for the installation of FluidEXL*Graphics* (in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows)

by using an appropriate program such as Explorer®, Windows, or Norton Commander.

Unregistering FluidEXL*Graphics* as Add-In in Excel®, versions 2003 or earlier

To remove FluidEXL*Graphics* completely, proceed as follows: First the registration of

FluidEXL_Graphics_Eng.xla (for English version of Windows)
FluidEXL_Graphics.xla (for German version of Windows)

has to be cancelled in Excel®.

In order to do that, click "Tools" in the upper menu bar of Excel and here "Add-Ins…". Untick the box on the left-hand side of

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

in the window that appears and click the "OK" button. The additional menu bar of FluidEXL*Graphics* disappears from the upper part of the Excel window. Afterwards, we recommend closing Excel.

If the FluidEXL*Graphics* menu bar does not disappear, take the following steps:
Click "View" in the upper menu bar of Excel, then "Toolbars" and then "Customize…" in the list box which appears.

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

is situated at the bottom of the "Toolbars" entries, which must be selected by clicking on it. Delete the entry by clicking "Delete". You will be asked whether you really want to delete the toolbar – click "OK".

Within the next step delete the files

LibAmWa.dll
LibAmWa.hlp

in the directory selected for the installation of FluidEXL*Graphics* (in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows)

using an appropriate program such as Explorer® or Norton Commander.

In order to remove FluidEXL*Graphics* from Windows and the hard disk drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel". Now double-click on "Add or Remove Programs". In the list box of the "Add/Remove Programs" window that appears select

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

by clicking on it and click the "Add/Remove…" button. In the following dialog box click "Automatic" and thereafter "Next >". Click "Finish" in the "Perform Uninstall" window. Answer the question whether all shared components shall be removed with "Yes to All". Finally, close the "Add/Remove Programs" and "Control Panel" windows.

Now FluidEXL*Graphics* has been removed.

Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007 (or later versions)

In order to unregister the FluidEXL*Graphics* Add-In in Excel® 2007 start Excel and carry out the following commands:

- Click the Windows Office® button in the upper left corner of Excel
- Click on the "Excel Options" button in the menu which appears

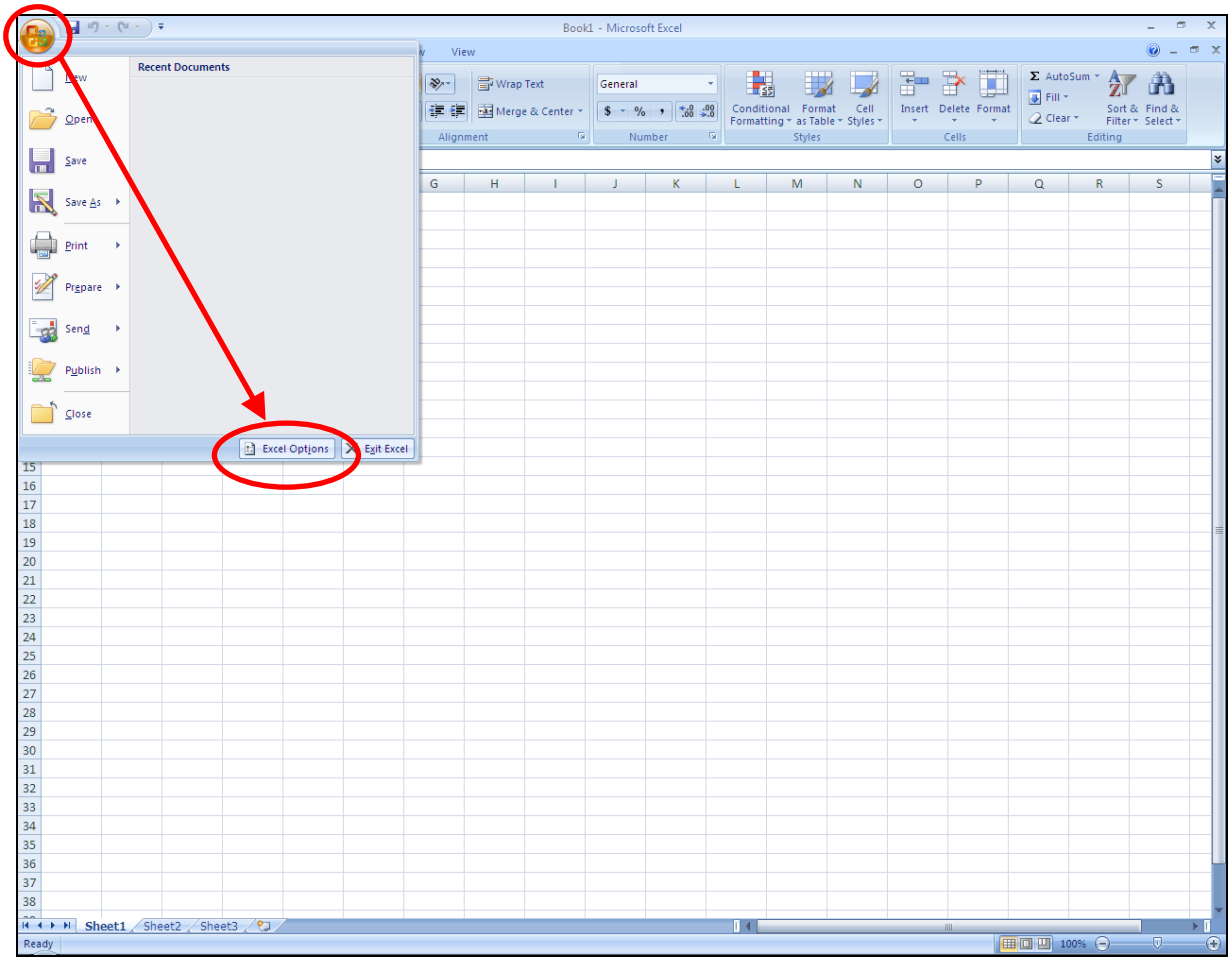

Figure 2.27: Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

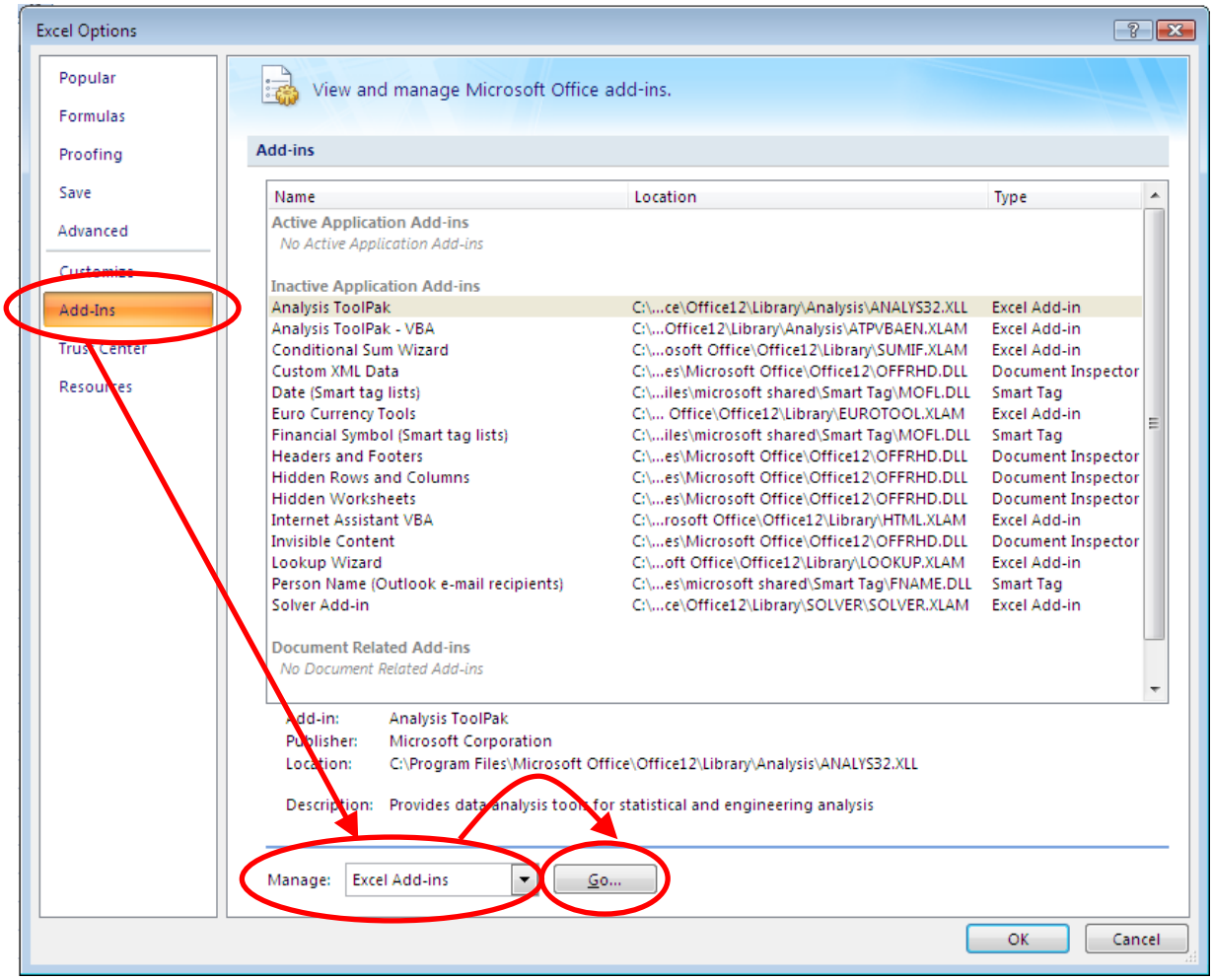

Figure 2.28: Dialog window "Add-Ins"

- If it is not shown in the list automatically, chose and click "Excel Add-ins" next to "Manage:" in the lower area of the menu
- Afterwards click the "Go…" button
- Remove the checkmark in front of

  "FluidEXL Graphics Eng" (for English version of Windows)
  "FluidEXL Graphics" (for German version of Windows)

  in the window which now appears. Click the "OK" button to confirm your entry.

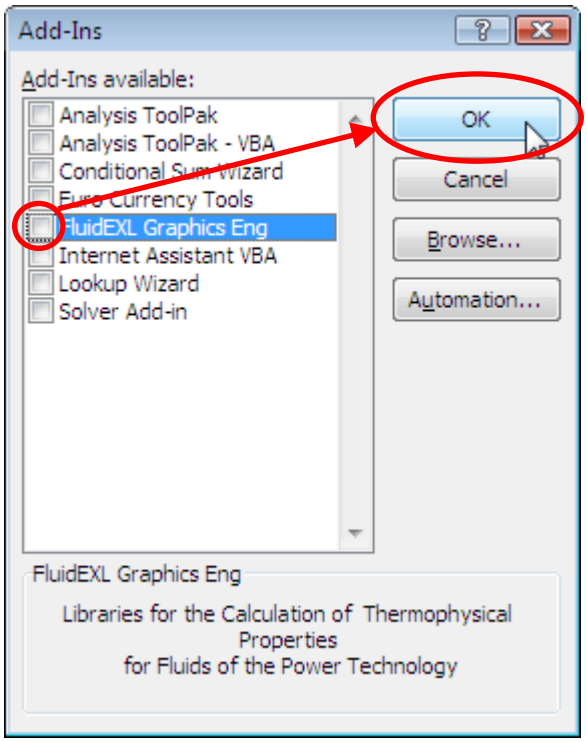

Figure 2.29: Dialog window "Add-Ins"

In order to remove FluidEXL*Graphics* from Windows and the hard drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel."

Now, double click on "Add or Remove Programs."

In the list box of the "Add or Remove Programs" window that appears, select

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

by clicking on it and then clicking the "Add/Remove…" button.

Click "Automatic" in the following dialog box and then the "Next >" button.

Click "Finish" in the "Perform Uninstall" window.

Answer the question of whether all shared components should be removed with "Yes to All." Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidEXL*Graphics* has been completely removed from your computer.

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 NH_3)/(kg mixture)

Output value

APTXIAMWA or **a_ptxi_AmWa** - Thermal diffusivity a in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on 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

ξ > 1.0 kg/kg or ξ < 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_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION ALPTXILAMWA(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 NH_3)/(kg mixture)

Output value

ALPTXILAMWA or **al_ptxil_AmWa** - Thermal diffusivity of saturated liquid a' in m^2 / s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **ALPTXILAMWA = -1000** or **al_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

ξ' > 1.0 kg/kg or ξ' < 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 NH_3)/(kg mixture)

Output value

ALPTXIVAMWA or **al_ptxiv_AmWa** - Thermal diffusivity of saturated liquid a' in m^2 / s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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

ξ'' > 1.0 kg/kg or ξ'' < 0.0 kg/kg

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

Thermal Diffusivity a'' = f(p,t,ξ')

Function Name: **av_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION AVPTXILAMWA(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 NH_3)/(kg mixture)

Output value

AVPTXILAMWA or **av_ptxil_AmWa** - Thermal diffusivity of saturated vapor a'' in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **AVPTXILAMWA = -1000** or **av_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

ξ' > 1.0 kg/kg or ξ' < 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 NH_3)/(kg mixture)

Output value

AVPTXIVAMWA or **av_ptxiv_AmWa** - Thermal diffusivity of saturated vapor a'' in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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
ξ'' > 1.0 kg/kg or ξ'' < 0.0 kg/kg

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

Specific Isobaric Heat Capacity c_p = f(p,t,ξ)

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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

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

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

Function Name: **cpl_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CPLPTXILAMWA(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 NH_3) / (kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **CPLPTXILAMWA = -1000** or **cpl_ptxil_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 Liquid c'_p = f(p,t,ξ'')

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 NH_3)/(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 $t = t_{tr}(\xi'') \ldots t_c(\xi'')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CPVPTXILAMWA(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 NH_3) / (kg mixture)

Output value

CPVPTXILAMWA or **cpv_ptxil_AmWa** - Specific isobaric heat capacity of saturated vapor c''_p in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **CPVPTXILAMWA = -1000** or **cpv_ptxil_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 NH_3) / (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 $t = t_{tr}(\xi'') \ldots t_c(\xi'')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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]

Specific Isobaric Heat Capacity c_v = f(p,t,ξ)

Function Name: **cv_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CVPTXIAMWA(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 NH_3)/(kg mixture)

Output value

CVPTXIAMWA or **cv_ptxi_AmWa** - Specific isochoric heat capacity c_v in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **CVPTXIAMWA = -1000** or **cv_ptxi_AmWa = -1000** 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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

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

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

Function Name: **cvl_ptxil_AmWa**

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 NH_3) / (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 $t = t_{tr}(\xi') \ldots t_c(\xi')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 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 Isochoric Heat Capacity of Saturated Liquid $c'_v = f(p,t,\xi'')$

Function Name: **cvl_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CVLPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

CVLPTXIVAMWA or **cvl_ptxiv_AmWa** - Specific isochoric heat capacity of saturated liquid c'_V in kJ/(kg K)

Range of validity

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

NH_3: $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O: $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **CVLPTXIVAMWA = -1000** or **cvl_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 Isochoric Heat Capacity of Saturated Vapor $c''_V = f(p,t,\xi')$

Function Name: **cvv_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CVVPTXILAMWA(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 NH_3) / (kg mixture)

Output value

CVVPTXILAMWA or **cvv_ptxil_AmWa** - Specific isochoric heat capacity of saturated vapor c''_V in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 isochoric 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:
$c''_v = f(-1000,t,\xi')$
$c''_v = f(p,-1000,\xi')$
$c''_v = f(p,t,-1000)$
$c''_v = f(p,t,\xi')$

Results for wrong input values

The result **CVVPTXILAMWA = -1000** or **cvv_ptxil_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 Isochoric Heat Capacity of Saturated Vapor $c''_v = f(p,t,\xi'')$

Function Name: **cvv_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION CVVPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

CVVPTXIVAMWA or **cvv_ptxiv_AmWa** - Specific isochoric heat capacity of saturated vapor c''_v in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 isochoric 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:
$c''_v = f(-1000,t,\xi'')$
$c''_v = f(p,-1000,\xi'')$
$c''_v = f(p,t,-1000)$
$c''_v = f(p,t,\xi'')$

Results for wrong input values

The result **CVVPTXIVAMWA = -1000** or **cvv_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]

Diffusion Coefficient in Liquid Mixture $D_l = f(t, \xi_l)$

Function Name: **Dl_txil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION DLTXILAMWA(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 steam ξ_l in (kg NH_3)/(kg mixture)

Output value

DLTXILAMWA or **Dl_txil_AmWa** - Diffusion coefficient in liquid mixture D_l in m^2/s

Range of validity

Temperature range: from $t = t_{tr}(\xi_l) \ldots t_c(\xi_l)$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°C

Pressure range: from 0.1 bar to 400 bar

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

Results for wrong input values

The result **DLTXILAMWA= -1000** or **Dl_txil_AmWa = -1000** is valid for values which range from:

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

$\xi_l > 1.0$ kg/kg *or* $\xi_l < 0.0$ kg/kg

References: [1], [2], [3], [4], [11]

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 NH_3)/(kg mixture)

Output value

DGPTXIVAMWA or **Dg_ptxiv_AmWa** - Diffusion coefficient in gaseous mixture D_g in m^2 / s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°C

Pressure range: from 0.1 bar to 400 bar

Composition range: from 0.0 to 1.0 (kg NH_3)/(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 η = f(p,t,ξ)

Function Name: **eta_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION ETAPTXIAMWA(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 NH_3)/(kg mixture)

Output value

ETAPTXIAMWA or **eta_ptxi_AmWa** - Dynamic viscosity η in Pa s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **ETAPTXIAMWA = -1000** or **eta_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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Dynamic Viscosity η' = f(p,t,ξ')

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 NH_3) / (kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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

ξ' > 1.0 kg/kg or ξ' < 0.0 kg/kg

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

Dynamic Viscosity η' = f(p,t,ξ'')

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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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

ξ' > 1.0 kg/kg or ξ' < 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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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]

Specific Enthalpy h = f(p,t,ξ)

Function Name: **h_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION HPTXIAMWA(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 NH_3)/(kg mixture)

Output value

HPTXIAMWA or **h_ptxi_AmWa -** Specific enthalpy h in kJ/kg

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 wet steam

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

Results for wrong input values

The result **HPTXIAMWA = -1000** or **h_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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

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

Function Name: **hl_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION HLPTXILAMWA(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 NH_3)/(kg mixture)

Output value

HLPTXILAMWA or **hl_ptxil_AmWa -** Specific enthalpy of saturated liquid h' in kJ/kg

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 **HLPTXILAMWA = -1000** or **hl_ptxil_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 Enthalpy of Saturated Liquid $h' = f(p,t,\xi'')$

Function Name: **hl_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION HLPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 Enthalpy of Saturated Vapor $h'' = f(p,t,\xi')$

Function Name: **hv_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION HVPTXILAMWA(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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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:

$p > 400$ 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 Enthalpy of Saturated Vapor $h'' = f(p,t,\xi'')$

Function Name: **hv_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION HVPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

HVPTXIVAMWA or **hv_ptxiv_AmWa -** Specific enthalpy of saturated vapor *h*'' in kJ/kg

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

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 **HVPTXIVAMWA = -1000** or **hv_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]

Thermal Conductivity λ = f(p,t,ξ)

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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 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 NH_3)/(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 $t = t_{tr}(\xi') \ldots t_c(\xi')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 NH_3)/(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 $t = t_{tr}(\xi'') \ldots t_c(\xi'')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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]

Thermal Conductivity λ'' = f(p,t,ξ')

Function Name: **lambdav_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION LAMBDAVPTXILAMWA(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 NH_3)/(kg mixture)

Output value

LAMBDAVPTXILAMWA or **lambdav_ptxil_AmWa** - Thermal conductivity of saturated vapor λ'' in W/(m K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **LAMBDAVPTXILAMWA = -1000** or **lambdav_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: **lambdav_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION LAMBDAVPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

LAMBDAVPTXIVAMWA or **lambdav_ptxiv_AmWa** - Thermal conductivity of saturated vapor λ'' in W/(m K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **LAMBDAVPTXIVAMWA = -1000** or **lambdav_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 ν = f(p,t,ξ)

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 NH_3)/(kg mixture)

Output value

NUEPTXIAMWA or **nue_ptxi_AmWa** - Kinematic viscosity ν in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on 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
ξ > 1.0 kg/kg or ξ < 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 NH_3)/(kg mixture)

Output value

NUELPTXILAMWA or **nuel_ptxil_AmWa** - Kinematic viscosity of saturated liquid ν' in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 NH_3)/(kg mixture)

Output value

NUELPTXIVAMWA or **nuel_ptxiv_AmWa** - Kinematic viscosity of saturated liquid ν' in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 NH_3)/(kg mixture)

Output value

NUEVPTXILAMWA or **nuev_ptxil_AmWa** - Kinematic viscosity of saturated vapor ν'' in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 NH_3)/(kg mixture)

Output value

NUELPTXIVAMWA or **nuel_ptxiv_AmWa** - Kinematic viscosity of saturated vapor ν'' in m^2/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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]

Vapor Pressure p_s = f(t, ξ')

Function Name: **ps_txil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION PS_TXIL_AMWA(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 NH_3)/(kg mixture)

Output value

PS_TXIL_AMWA or **ps_txil_AmWa** - Vapor pressure p_s in bar

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C H_2O : $t_{tr,H_2O} = 0.01$°C

$t_{c,NH_3} = 132.25$°C $t_{c,H_2O} = 373.946$°C

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

Results for wrong input values

The result **PS_TXIL_AMWA = -1000** or **ps_txil_AmWa = -1000** is valid for values which range from:

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

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

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

Vapor Pressure p_s = f(t, ξ'')

Function Name: **ps_txiv_AmWa**

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

Input values

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated steam ξ' in (kg NH_3)/(kg mixture)

Output value

PS_TXIV_AMWA or **ps_txiv_AmWa** - Vapor pressure p_s in bar

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°C

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

Results for wrong input values

The result **PS_TXIV_AMWA = -1000** or **ps_txiv_AmWa = -1000** is valid for values which range from:

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

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

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

Backward Function: Pressure p = f(h,s,ξ)

Function Name: **p_hsxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION PHSXIAMWA(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 NH_3)/(kg mixture)

Output value

PHSXIAMWA or **p_hsxi_AmWa -** Pressure p in bar

Range of validity

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

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

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **PHSXIAMWA = -1000** or **p_hsxi_AmWa = -1000** is valid for the following input values:

The value of the enthalpy, entropy or composition entered is located outside the range of validity:

p > 400 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Backward Function: Pressure p = f(t,ξ,x_δ)

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 NH_3)/(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: $p_{tr}(\xi) \le p \le p_c(\xi)$

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

NH_3 : $t_{tr,NH_3} = -77.655$°C H_2O : $t_{tr,H_2O} = 0.01$°C

$t_{c,NH_3} = 132.25$°C $t_{c,H_2O} = 373.946$°C

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

Vapor fraction range: $0.0 \le x_\delta \le 1.0$ 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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

PRANDTL-Number $Pr = f(p,t,\xi)$

Function Name: **Pr_ptxi_AmWa**

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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 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_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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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,ξ'')

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 NH_3)/(kg mixture)

Output value

PRLPTXIVAMWA or **Prl _ptxiv _ AmWa** – Prandtl – Number Pr' of saturated liquid

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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,ξ')

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 NH_3)/(kg mixture)

Output value

PRVPTXILAMWA or **Prv _ ptxil _ AmWa** – Prandtl – Number Pr'' of saturated vapor

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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,ξ)

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 NH_3)/(kg mixture)

Output value

REGPTXIAMWA or **region_ptxi_AmWa -** Phase region

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 fort he following input values:

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

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

Phase Region Region = f(p,h,ξ)

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 NH_3)/(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 $t = t_{tr}(\xi) \ldots 2 \cdot t_c(\xi)$

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Phase Region Region = f(p,s,ξ)

Function Name: **region_psxi_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 NH_3)/(kg mixture)

Output value

REGPSXIAMWA or **region_psxi_AmWa -** Phase region

Range of validity

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

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

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on 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_psxi_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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Phase Region Region = f(*h*,*s*,ξ)

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 NH_3)/(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 $t = t_{tr}(\xi) \ldots 2 \cdot t_c(\xi)$

NH_3 : $t_{tr,NH_3} = -77.655°C$ H_2O : $t_{tr,H_2O} = 0.01°C$

$t_{c,NH_3} = 132.25°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on 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

ξ > 1.0 kg/kg or ξ < 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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Specific Entropy of Saturated Liquid $s' = f(p,t,\xi')$

Function Name: **sl_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION SLPTXILAMWA(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 NH_3)/(kg mixture)

Output value

SLPTXILAMWA or **sl_ptxil_AmWa -** Specific entropy of saturated liquid *s*‘ in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

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 entropy 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: $s' = f(-1000,t,\xi')$
$s' = f(p,-1000,\xi')$
$s' = f(p,t,-1000)$
$s' = f(p,t,\xi')$

Results for wrong input values

The result **SLPTXILAMWA = -1000** or **sl_ptxil_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 Entropy of Saturated Liquid $s' = f(p,t,\xi'')$

Function Name: **sl_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION SLPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

SLPTXIVAMWA or **sl_ptxiv_AmWa -** Specific entropy of saturated liquid s‘ in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 entropy 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: $s' = f(-1000,t,\xi'')$
$s' = f(p,-1000,\xi'')$
$s' = f(p,t,-1000)$
$s' = f(p,t,\xi'')$

Results for wrong input values

The result **SLPTXIVAMWA = -1000** or **sl_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 Entropy of Saturated Vapor $s'' = f(p,t,\xi')$

Function Name: **sv_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION SVPTXILAMWA(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 boiling liquid ξ' in (kg NH_3)/(kg mixture)

Output value

SVPTXILAMWA or **sv_ptxil_AmWa -** Specific entropy of saturated vapor s'' in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 entropy 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:
$s'' = f(-1000,t,\xi')$
$s'' = f(p,-1000,\xi')$
$s'' = f(p,t,-1000)$
$s'' = f(p,t,\xi')$

Results for wrong input values

The result **SVPTXILAMWA = -1000** or **sv_ptxil_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 Entropy of Saturated Vapor $s'' = f(p,t,\xi'')$

Function Name: **sv_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION SVPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

SVPTXIVAMWA or **sv_ptxiv_AmWa -** Specific entropy of saturated vapor s'' in kJ/(kg K)

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 entropy 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:
$s'' = f(-1000,t,\xi'')$
$s'' = f(p,-1000,\xi'')$
$s'' = f(p,t,-1000)$
$s'' = f(p,t,\xi'')$

Results for wrong input values

The result **SVPTXIVAMWA = -1000** or **sv_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]

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

Function Name: **sigmal_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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°C

Pressure range: from 0.1 bar to 400 bar

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

Results for wrong input values

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

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

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

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

Saturation Temperature t_s = f(p, ξ')

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 NH_3)/(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 $p_C(\xi')$

NH_3 : $p_{c,NH_3} = 113.33$bar H_2O : $p_{c,H_2O} = 220.64$ bar

Composition range: from 0.0 to 1.0 (kg NH_3)/(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 $p < 0.1$ bar or

$\xi' > 1.0$ kg/kg or $\xi' < 0.0$ 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 NH_3)/(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 $p_c(\xi'')$

NH_3 : $p_{c,NH_3} = 113.33$bar H_2O : $p_{c,H_2O} = 220.64$ bar

Composition range: from 0.0 to 1.0 (kg NH_3)/(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 $p < 0.1$ bar or

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

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

Backward Function: Temperature t = f(p,h,ξ)

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 NH_3)/(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 $t = t_{tr}(\xi)$ ... $2 \cdot t_c(\xi)$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Backward Function: Temperature t = f(p,s,ξ)

Function Name: **t_psxi_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 NH_3)/(kg mixture)

Output value

TPSXIAMWA or **t_psxi_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 $t = t_{tr}(\xi)$ ... $2 \cdot t_c(\xi)$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 wet steam

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

Results for wrong input values

The result **TPSXIAMWA = -1000** or **t_psxi_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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Backward Function: Temperature t = f(p,ξ,x_δ)

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 NH_3)/(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: $t = t_{tr}(\xi) \leq t \leq t_c(\xi)$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°C

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

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Specific Volume $v = f(p,t,\xi)$

Function Name: **v_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION VPTXIAMWA(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 NH_3)/(kg mixture)

Output value

VPTXIAMWA or **v_ptxi_AmWa** - Specific volume v in m^3/kg

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 wet steam

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

Results for wrong input values

The result **VPTXIAMWA = -1000** or **v_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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Specific Volume of Saturated Liquid $v' = f(p,t,\xi')$

Function Name: **vl_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION VLPTXILAMWA(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 NH_3)/(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 $t = t_{tr}(\xi') \ldots t_c(\xi')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 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 Volume of Saturated Liquid $v' = f(p,t,\xi'')$

Function Name: **vl_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION VLPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **VLPTXIVAMWA = -1000** or **vl_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 Volume of Saturated Vapor $v'' = f(p,t,\xi')$

Function Name: **vv_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION VVPTXILAMWA(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 NH_3)/(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 $t = t_{tr}(\xi') \ldots t_c(\xi')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 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 Volume of Saturated Vapor $v'' = f(p,t,\xi'')$

Function Name: **vv_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION VVPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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 **VVPTXIVAMWA = -1000** or **vv_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]

Speed of Sound w = f(p,t,ξ)

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 NH_3)/(kg mixture)

Output value

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

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on 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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Speed of Sound of Saturated Liquid $w' = f(p,t,\xi')$

Function Name: **wl_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION WLPTXILAMWA(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 in saturated liquid ξ' in (kg NH_3)/(kg mixture)

Output value

WLPTXILAMWA or **wl_ptxil_AmWa -** Speed of sound of saturated liquid w' in m/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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:
$w' = f(-1000,t,\xi')$
$w' = f(p,-1000,\xi')$
$w' = f(p,t,-1000)$
$w' = f(p,t,\xi')$

Results for wrong input values

The result **WLPTXILAMWA = -1000** or **wl_ptxil_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]

Speed of Sound of Saturated Liquid $w' = f(p,t,\xi'')$

Function Name: **wl_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION WLPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

WLPTXIVAMWA or **wl_ptxiv_AmWa -** Speed of sound of saturated liquid w' in m/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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: $w' = f(-1000,t,\xi'')$
$w' = f(p,-1000,\xi'')$
$w' = f(p,t,-1000)$
$w' = f(p,t,\xi'')$

Results for wrong input values

The result **WLPTXIVAMWA = -1000** or **wl_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]

Speed of Sound of Saturated Vapor $w'' = f(p,t,\xi')$

Function Name: **wv_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION WVPTXILAMWA(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 NH_3)/(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 $t = t_{tr}(\xi') \ldots t_c(\xi')$

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 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]

Speed of Sound of Saturated Vapor $w'' = f(p,t,\xi'')$

Function Name: **wv_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION WVPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

WVPTXIVAMWA or **wv_ptxiv_AmWa -** Speed of sound of saturated vapor w'' in m/s

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 **WVPTXIVAMWA = -1000** or **wv_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]

Vapor Fraction x_δ = f(p,t,ξ)

Function Name: **xd_ptxi_AmWa**

Subprogram with function value: **REAL*8 FUNCTION XDPTXIAMWA(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 NH_3)/(kg mixture)

Output value

XDPTXIAMWA or **xd_ptxi_AmWa** - Vapor fraction x_δ in kg/kg

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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 the single-phase region

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

Results for wrong input values

The result **XDPTXIAMWA = -1000** or **xd_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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Backward Function: Vapor Fraction x_δ = f(h,s,ξ)

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 NH_3)/(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 $t = t_{tr}(\xi) \ldots 2 \cdot t_c(\xi)$

NH_3 : $t_{tr,NH_3} = -77.655°C$ $t_{c,NH_3} = 132.25°C$

H_2O : $t_{tr,H_2O} = 0.01°C$ $t_{c,H_2O} = 373.946°C$

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 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: for the call out of Fortran	**REAL*8 FUNCTION XIPTXDAMWA(P,T,XD)** 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 NH_3)/kg

Range of validity

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

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $\quad$ $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $\quad$ $t_{c,H_2O} = 373.946$°C

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

Vapor fraction range: $0.0 \le x_\delta \le 1.0$ 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]

Ammonia Mass Fraction of Saturated Liquid $\xi' = f(p,t,\xi'')$

Function Name: **xil_ptxiv_AmWa**

Subprogram with function value: **REAL*8 FUNCTION XILPTXIVAMWA(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 NH_3)/(kg mixture)

Output value

XILPTXIVAMWA or **xil_ptxiv_AmWa** - Ammonia mass fraction of saturated liquid ξ' in (kg NH_3)/kg

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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

It is adequate to enter two parameters (either t and ξ'', or p and ξ'', or p and t) for the calculation of the ammonia mass fraction of saturated liquid. 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:
$\xi' = f(-1000,t,\xi'')$
$\xi' = f(p,-1000,\xi'')$
$\xi' = f(p,t,-1000)$
$\xi' = f(p,t,\xi'')$

Results for wrong input values

The result **XILPTXIVAMWA = -1000** or **xil_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]

Ammonia Mass Fraction of Saturated Vapor $\xi'' = f(p,t,\xi')$

Function Name: **xiv_ptxil_AmWa**

Subprogram with function value: **REAL*8 FUNCTION XIVPTXILAMWA(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 NH_3)/(kg mixture)

Output value

XIVPTXILAMWA or **xiv_ptxil_AmWa** - Ammonia mass fraction of saturated vapor ξ'' in (kg NH_3)/kg

Range of validity

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

NH_3 : $t_{tr,NH_3} = -77.655$°C $t_{c,NH_3} = 132.25$°C

H_2O : $t_{tr,H_2O} = 0.01$°C $t_{c,H_2O} = 373.946$°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

It is adequate to enter two parameters (either t and ξ', or p and ξ', or p and t) for the calculation of the ammonia mass fraction of saturated vapor. 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:
$\xi'' = f(-1000,t,\xi')$
$\xi'' = f(p,-1000,\xi')$
$\xi'' = f(p,t,-1000)$
$\xi'' = f(p,t,\xi')$

Results for wrong input values

The result **XIVPTXILAMWA = -1000** or **xiv_ptxil_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]

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Department of Technical Thermodynamics
www.thermodynamics-zittau.de

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

and of the ideal gases:

SO_2, CO, Ne (Scientific Formulation of Bücker et al.)

Consideration of:

Dissociation from VDI 4670 and Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Formulation 2008 of Feistel and IAPWS-IF97

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

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bücker et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term

(also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

$C_2H_6O_2$	Ethylene glycol
$C_3H_8O_2$	Propylene glycol
C_2H_5OH	Ethyl alcohol
CH_3OH	Methyl alcohol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

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

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

Tetradecamethylhexasiloxane $C_{14}H_{42}O_5Si_6$ **Library LibMD4M**

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_5H_{14} **Library LibC5H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

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

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

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monooxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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E-mail: hj.kretzschmar@hs-zigr.de
Phone: +49-3583-61-1846
Fax.: +49-3583-61-1846

The following thermodynamic and transport properties can be calculated[a]:

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

www.thermodynamic-property-libraries.com

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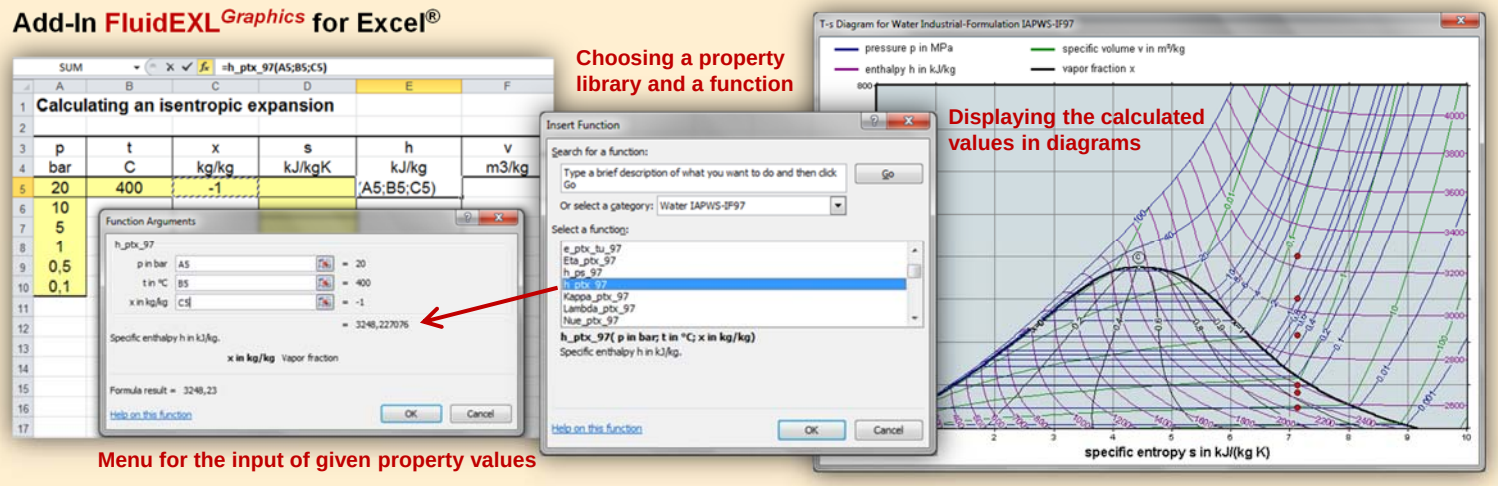
Department of Technical Thermodynamics
www.thermodynamics-zittau.de

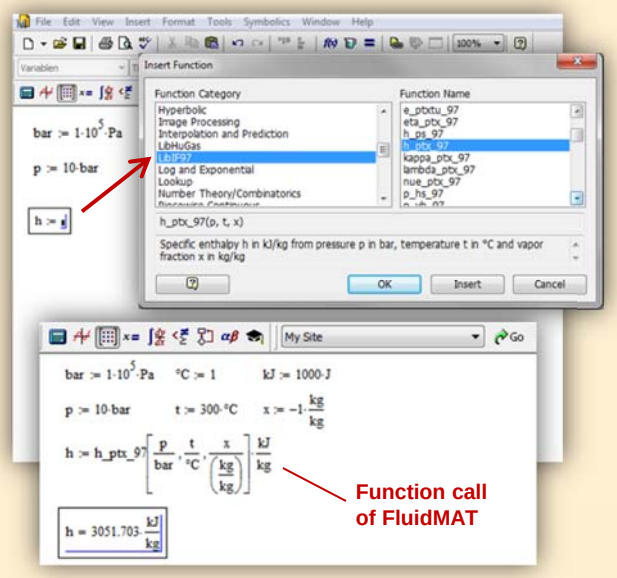
Property Software for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



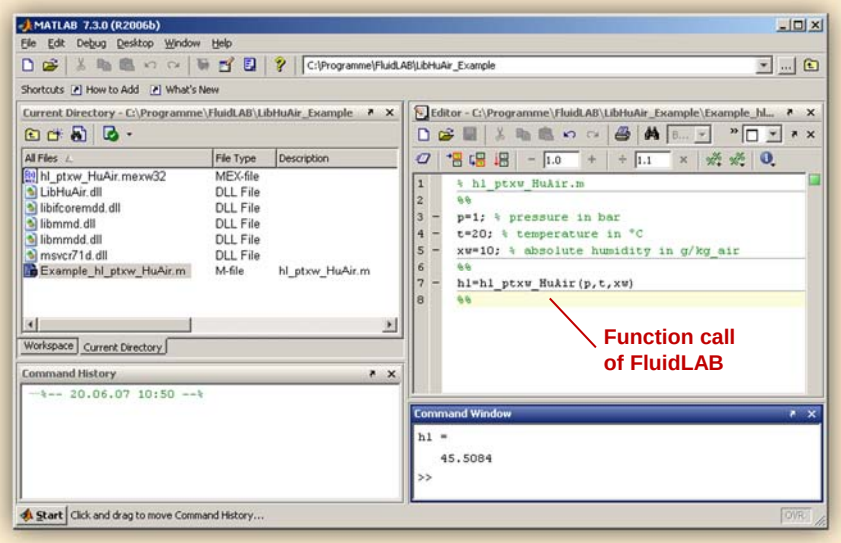
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



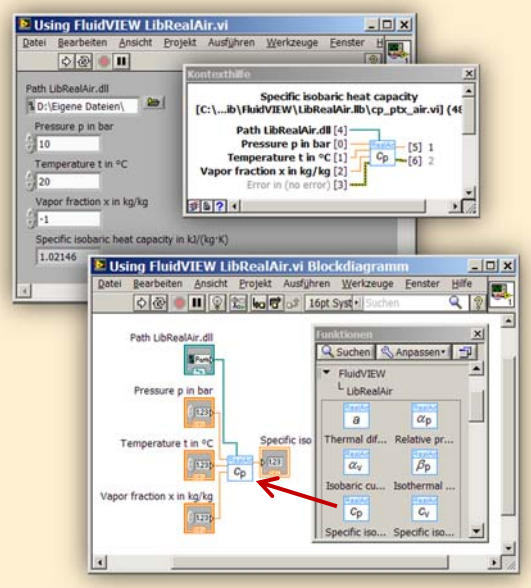
Add-In FluidLAB for MATLAB®

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



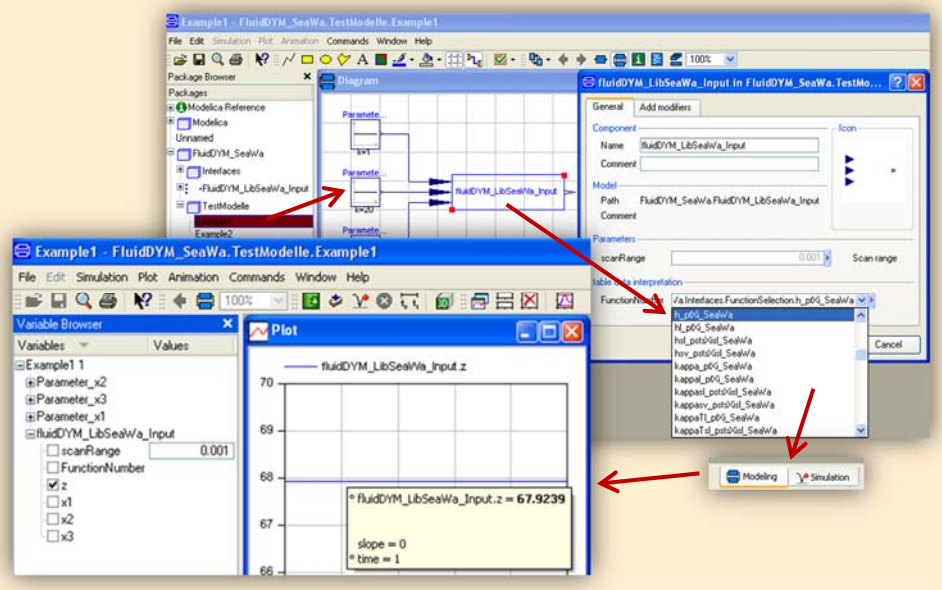
Add-On FluidVIEW for LabVIEW®

The property functions can be calculated in LabVIEW®.

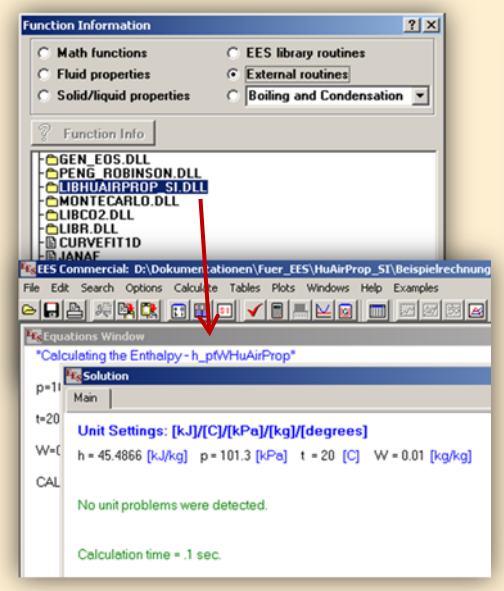


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

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



Add-In FluidEES for Engineering Equation Solver®



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

Online Property Calculator at www.thermodynamics-zittau.de

Property Software for Pocket Calculators

FluidCasio

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

FluidHP

HP 48 | HP 49

FluidTI

TI Nspire CX CAS
TI Nspire CAS
TI 83
TI 84
TI 89
TI Voyage 200
TI 92

For more information please contact:

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Fax.: +49-3583-61-1846

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

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- 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.

www.thermodynamic-property-libraries.com

5. References

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6. Satisfied Customers

Date: 10/2011

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)
- FluidVIEW for LabVIEW®:

2011

Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011
Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011, 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011

Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011, 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010
University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010
Vaillant, Remscheid	10/2010

PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
Saacke, Bremen	09/2010
WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	08/2010
ERGION, Mannheim	07/2010
Fichtner IT Consulting, Stuttgart	07/2010
TF Design, Matieland, South Africa	07/2010
MCE, Berlin	07/2010, 12/2010
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	06/2010
RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
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Universitaet der Bundeswehr, Munich	04/2010
Technical University of Hamburg-Harburg	04/2010
Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
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CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
Technical University of Dresden	02/2010
Siemens Energy, Nuremberg	02/2010
Augsburg University of Applied Sciences	02/2010

ALSTOM Power, Baden, Switzerland	02/2010, 05/2010
MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	01/2010, 12/2010
Technical University of Freiberg	01/2010
ILK, Dresden	01/2010, 12/2010
Fischer-Uhrig Consulting Engineers, Berlin	01/2010

2009

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

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

2008

Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	01/2008
University of Karlsruhe	01/2008
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	02/2008
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008
WEBASTO, Neubrandenburg	04/2008
CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008
Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008

Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

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

Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007
Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006
Technical University of Munich, Chair in Apparatus and Plant Engineering	02/2006
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Department of USET Merseburg incorporated society	05/2006
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	05/2006

Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
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M&M Turbine Technology, Bielefeld	06/2006
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ThyssenKrupp Marine Systems, Kiel	07/2006
Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005, 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden Professorship of Thermic Energy Machines and Plants	04/2005
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005

Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
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Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
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Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005
Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
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KEMA IEV, Dresden	12/2005

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MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
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Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
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HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004

Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
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Enertech EUT, Radebeul (company license)	11/2004
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2003

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

Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
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G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

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Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
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SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
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VEAG, Berlin (group license)	12/2001

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AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000

IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
UMAG W. UDE, Husum	03/2000
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Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
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Bayernwerk, Munich	01/1999
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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
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
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SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

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Siemens Power Generation, Goerlitz	07/1997