Property Library for Ammonia-Water Mixtures

FluidLAB
with LibAmWa
for MATLAB®

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Property Software for Ammonia-Water Mixtures

FluidLAB LibAmWa

for MATLAB®

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0 Package Contents

0.1 Zip file for 32-bit MATLAB®

The following zip file is delivered for your computer running a 32-bit version of MATLAB®.

"CD_FluidLAB_LibAmWa.zip"

Including the following files:

FluidLAB_LibAmWa_Setup.exe	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibAmWa.dll	- Dynamic Link Library for ammonia-water mixtures for use in MATLAB®
FluidLAB_LibAmWa_Docu_Eng.pdf	- User's Guide

0.2 Zip file for 64-bit MATLAB®

The following zip file is delivered for your computer running a 64-bit version of MATLAB®.

"CD_FluidLAB_LibAmWa_x64.zip"

Including the following files and folders:

Files:

Setup.exe	- Self-extracting and self-installing program for FluidLAB
FluidLAB_LibAmWa_64.msi	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibAmWa.dll	- Dynamic Link Library for ammonia-water mixtures for use in MATLAB®
FluidLAB_LibAmWa_Docu_Eng.pdf	- User's Guide

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
$t = \mathrm{f}(p,h,\xi)$	t_phxi_AmWa	TPHXIAMWA(P,H,XI)	Backward function: Temperature from pressure, enthalpy, and NH_3 mass fraction	°C
$t = \mathrm{f}(p,s,\xi)$	t_psxi_AmWa	TPSXIAMWA(P,S,XI)	Backward function: Temperature from pressure, entropy, and NH_3 mass fraction	°C
$t = \mathrm{f}(p,\xi,x_\delta)$	t_pxixd_AmWa	TPXIXDAMWA(P,XI,XD)	Temperature from pressure, NH_3 mass fraction, and vapor fraction	°C
$t_s = \mathrm{f}(p,\xi')$	ts_pxil_AmWa	TSPXILAMWA(P,XIL)	Saturation temperature	°C
$t_s = \mathrm{f}(p,\xi'')$	ts_pxiv_AmWa	TSPXIVAMWA(P,XIV)	Saturation temperature	°C
$v = \mathrm{f}(p,t,\xi)$	v_ptxi_AmWa	VPTXIAMWA(P,T,XI)	Specific volume	m^3/kg
$v' = \mathrm{f}(p,t,\xi')$	vl_ptxil_AmWa	VLPTXILAMWA(P,T,XIL)	Specific volume of saturated liquid	m^3/kg
$v' = \mathrm{f}(p,t,\xi'')$	vl_ptxiv_AmWa	VLPTXIVAMWA(P,T,XIV)	Specific volume of saturated liquid	m^3/kg
$v'' = \mathrm{f}(p,t,\xi')$	vv_ptxil_AmWa	VVPTXILAMWA(P,T,XIL)	Specific volume of saturated vapor	m^3/kg
$v'' = \mathrm{f}(p,t,\xi'')$	vv_ptxiv_AmWa	VVPTXIVAMWA(P,T,XIV)	Specific volume of saturated vapor	m^3/kg
$w = \mathrm{f}(p,t,\xi)$	w_ptxi_AmWa	WPTXIAMWA(P,T,XI)	Speed of sound	m/s
$w' = \mathrm{f}(p,t,\xi')$	wl_ptxil_AmWa	WLPTXILAMWA(P,T,XIL)	Speed of sound of saturated liquid	m/s
$w' = \mathrm{f}(p,t,\xi'')$	wl_ptxiv_AmWa	WLPTXIVAMWA(P,T,XIV)	Speed of sound of saturated liquid	m/s
$w'' = \mathrm{f}(p,t,\xi')$	wv_ptxil_AmWa	WVPTXILAMWA(P,T,XIL)	Speed of sound of saturated vapor	m/s
$w'' = \mathrm{f}(p,t,\xi'')$	wv_ptxiv_AmWa	WVPTXIVAMWA(P,T,XIV)	Speed of sound of saturated vapor	m/s
$\eta = \mathrm{f}(p,t,\xi)$	eta_ptxi_AmWa	ETAPTXIAMWA(P,T,XI)	Dynamic viscosity	Pa s
$\eta' = \mathrm{f}(p,t,\xi')$	etal_ptxil_AmWa	ETALPTXILAMWA(P,T,XIL)	Dynamic viscosity of saturated liquid	Pa s
$\eta' = \mathrm{f}(p,t,\xi'')$	etal_ptxiv_AmWa	ETALPTXIVAMWA(P,T,XIV)	Dynamic viscosity of saturated liquid	Pa s
$\eta'' = \mathrm{f}(p,t,\xi')$	etav_ptxil_AmWa	ETAVPTXILAMWA(P,T,XIL)	Dynamic viscosity of saturated vapor	Pa s
$\eta'' = \mathrm{f}(p,t,\xi'')$	etav_ptxiv_AmWa	ETAVPTXIVAMWA(P,T,XIV)	Dynamic viscosity of saturated vapor	Pa s
$\lambda = \mathrm{f}(p,t,\xi)$	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 (…^{I}) and saturated vapor (…^{II}) 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 FluidLAB in MATLAB

The FluidLAB Add-In has been developed to calculate thermodynamic properties in MATLAB® more conveniently. Within MATLAB®, it enables the direct call of functions relating to water/lithium bromide from the LibAmWa property library.

2.1 Installing FluidLAB LibAmWa

Installing FluidLAB including LibAmWa for 32-bit MATLAB®

This section describes the installation of FluidLAB LibAmWa for a 32-bit version of MATLAB®.

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

After you have downloaded and extracted the zip-file "CD_FluidLAB_LibAmWa.zip", you will see the folder

CD_FluidLAB_LibAmWa

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

Open this folder by double-clicking on it.

In this folder you will see the following files:

FluidLAB_LibAmWa_Docu_Eng.pdf
FluidLAB_LibAmWa_Setup.exe
LibAmWa.dll.

In order to run the installation of FluidLAB including, the LibAmWa property library, double-click on the file

FluidLAB_LibAmWa_Setup.exe.

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

In the following dialog box, "Destination Location", the default path offered automatically for the installation of FluidLAB is

C:\Program Files\FluidLAB\LibAmWa (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa (for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.1).

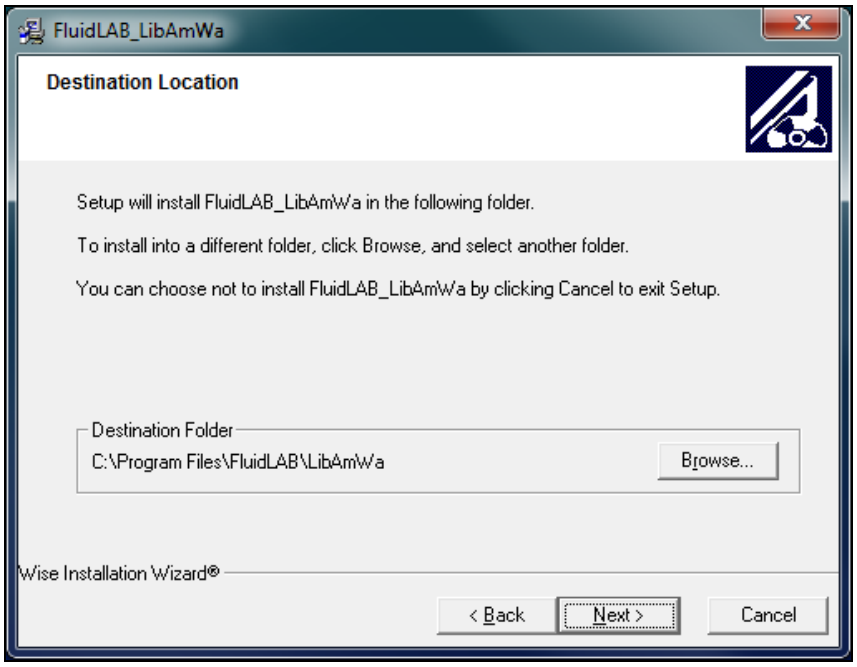

Figure 2.1: Dialog window "Destination Location"

If you wish to change directories, click the "Browse…" button and select your desired directory. The instructions in this documentation refer to the stated default directory. Leave this window by clicking the "Next >" button.

The dialog window "Start Installation" appears. Click the "Next >" button to continue installation. The FluidLAB files are now being copied into the created directory on your hard drive. Click the "Finish >" button in the following window to complete installation.

The installation program has copied the following files for LibAmWa into the directory

"C:\Program Files\FluidLAB\LibAmWa" (for English version of Windows):
"C:\Programme\FluidLAB\LibAmWa" (for German version of Windows):

advapi32.dll	LC.dll
Dformd.dll	msvcp60.dll
Dforrt.dll	msvcrt.dll
INSTALL.LOG	Unwise.exe
LibAmWa.dll	Unwise.ini

Now, you have to overwrite the file "LibAmWa.dll" in your FluidLAB directory with the file of the same name provided in your CD folder with FluidLAB.

To do this, open the CD folder in "My Computer" and click on the file "LibAmWa.dll" in order to highlight it.

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

Now, open your FluidLAB directory (the standard being

C:\Program Files\FluidLAB\LibAmWa (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa (for German version of Windows))

and insert the file "LibAmWa.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button. Now, you have overwritten the file "LibAmWa.dll" successfully and the property functions are available in MATLAB®.

Installing FluidLAB including LibAmWa for 64-bit MATLAB®

This section describes the installation of FluidLAB LibAmWa.

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

After you have downloaded and extracted the zip-file "CD_FluidLAB_LibAmWa_x64.zip", you will see the folder

CD_FluidLAB_LibAmWa

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

Open this folder by double-clicking on it.

In this folder you will see the following files

FluidLAB_LibAmWa_Docu_Eng.pdf
FluidLAB_LibAmWa_64_Setup.msi
LibAmWa.dll
Setup.exe.

and folders

/vcredist_x64
/WindowsInstaller3_1.

In order to run the installation of FluidLAB including, the LibAmWa property library, double-click on the file

Setup.exe.

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

In the following dialog box, "Destination Location", the default path offered automatically for the installation of FluidLAB is

C:\Program Files\FluidLAB\LibAmWa (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa (for German version of Windows)

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.2).

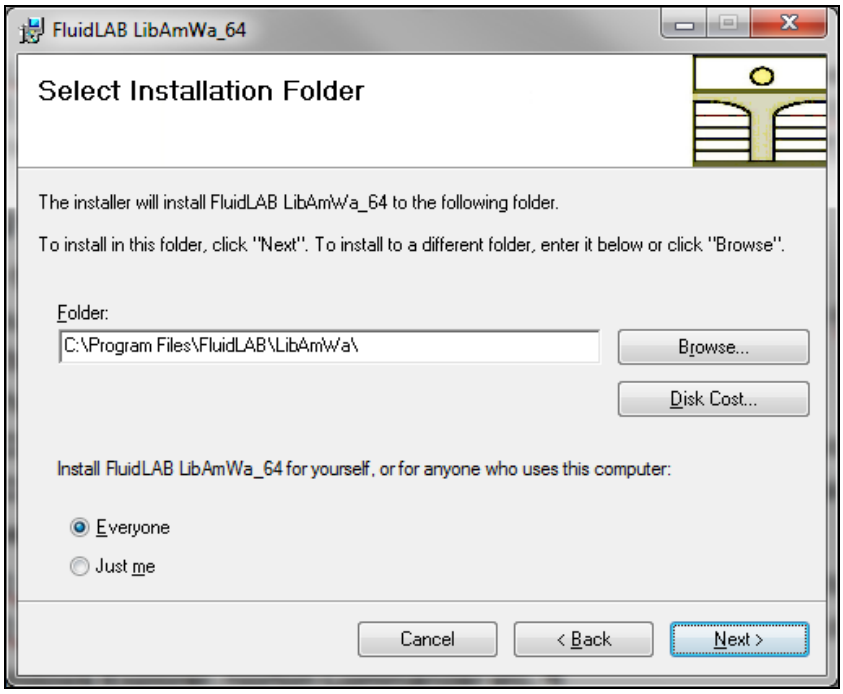

Figure 2.2: "Select Installation Folder"

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

After FluidLAB has been installed, you will see the sentence "FluidLAB LibAmWa 64 has been successfully installed." Confirm this by clicking the "Close" button.

The installation program has copied the following files for LibAmWa into the directory

"C:\Program Files\FluidLAB\LibAmWa" (for English version of Windows)
"C:\Programme\FluidLAB\LibAmWa" (for German version of Windows):

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

Now, you have to overwrite the file "LibAmWa.dll" in your FluidLAB directory with the file of the same name provided in your CD folder with FluidLAB.
To do this, open the CD folder in "My Computer" and click on the file "LibAmWa.dll" in order to highlight it.
Then click on the "Edit" menu in your Explorer and select "Copy".
Now, open your FluidLAB directory (the standard being

C:\Program Files\FluidLAB\LibAmWa (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa (for German version of Windows))

and insert the file "LibAmWa.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button. Now, you have overwritten the file "LibAmWa.dll" successfully and the property functions are available in MATLAB.

The installation programs for both the 32-bit and the 64-bit Windows version have copied the following function files for LibAmWa into the directory

"C:\Program Files\FluidLAB\LibAmWa" (for English version of Windows)
"C:\Programme\FluidLAB\LibAmWa" (for German version of Windows):

- MATLAB®-Interface-Program for calculable functions

a_ptxi_AmWa
al_ptxil_AmWa
al_ptxiv_AmWa
av_ptxil_AmWa
av_ptxiv_AmWa
cp_ptxi_AmWa
cpl_ptxil_AmWa
cpl_ptxiv_AmWa
cpv_ptxil_AmWa
cpv_ptxiv_AmWa
cv_ptxi_AmWa
cvl_ptxil_AmWa
cvl_ptxiv_AmWa
cvv_ptxil_AmWa
cvv_ptxiv_AmWa
Dg_ptxiv_AmWa
Dl_txil_AmWa
h_ptxi_AmWa
hl_ptxil_AmWa
hl_ptxiv_AmWa
hv_ptxil_AmWa
hv_ptxiv_AmWa
p_hsxi_AmWa
p_txixd_AmWa
ps_txil_AmWa
ps_txiv_AmWa
Pr_ptxi_AmWa
Prl_ptxil_AmWa
Prl_ptxiv_AmWa
Prv_ptxil_AmWa
Prv_ptxiv_AmWa
region_phxi_AmWa
region_psxi_AmWa
region_ptxi_AmWa
region_hsxi_AmWa
s_ptxi_AmWa
sl_ptxil_AmWa
sl_ptxiv_AmWa
sv_ptxil_AmWa
sv_ptxiv_AmWa
sigmal_txil_AmWa
t_phxi_AmWa
t_psxi_AmWa
t_pxixd_AmWa
ts_pxil_AmWa
ts_pxiv_AmWa
v_ptxi_AmWa
vl_ptxil_AmWa
vl_ptxiv_AmWa
vv_ptxil_AmWa
vv_ptxiv_AmWa
w_ptxi_AmWa
wl_ptxil_AmWa
wl_ptxiv_AmWa
wv_ptxil_AmWa
wv_ptxiv_AmWa
eta_ptxi_AmWa
etal_ptxil_AmWa
etal_ptxiv_AmWa
etav_ptxil_AmWa
etav_ptxiv_AmWa
lambda_ptxi_AmWa
lambdal_ptxil_AmWa
lambdal_ptxiv_AmWa
lambdav_ptxil_AmWa
lambdav_ptxiv_AmWa
nue_ptxi_AmWa
nuel_ptxil_AmWa
nuel_ptxiv_AmWa
nuev_ptxil_AmWa
nuev_ptxiv_AmWa
xd_ptxi_AmWa
xd_ptxi_AmWa
xd_hsxi_AmWa
xil_ptxiv_AmWa
xiv_ptxil_AmWa

Please note that there is a difference in the file extension of the function files.

The 32-bit installation program has copied function files with the file extension

.mexw32

and the 64-bit installation program has copied function files with the file extension

.mexw64

into your LibAmWa directory (the standard being

C:\Program Files\FluidLAB\LibAmWa (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa (for German version of Windows).

Now, you have to overwrite the file "LibAmWa.dll" in your LibAmWa directory with the file of the same name provided in your CD folder with FluidLAB.
To do this, open the CD folder in "My Computer" and click on the file "LibAmWa.dll" in order to highlight it.

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

Now, open your FluidLAB directory (the standard being

C:\Program Files\FluidLAB\LibAmWa (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa (for German version of Windows))

and insert the file "LibAmWa.dll" by clicking the "Edit" menu in your Explorer and then select "Paste".
Answer the question whether you want to replace the file by clicking the "Yes" button. Now, you have overwritten the file "LibAmWa.dll" successfully.

2.2 Licensing the LibAmWa Property Library

The licensing procedure has to be carried out when a FluidLAB prompt message appears in MATLAB®. In this case, you will see the "License Information" window for LibAmWa (see figure below).

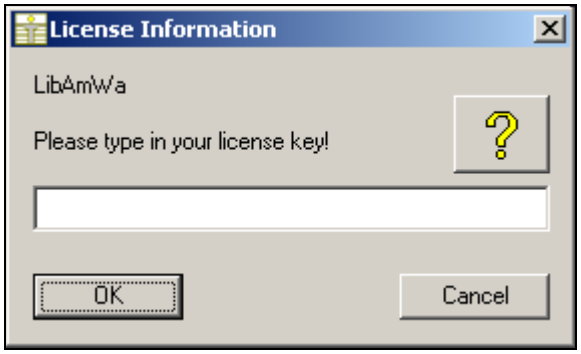

Figure 2.3: "License Information" window

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:

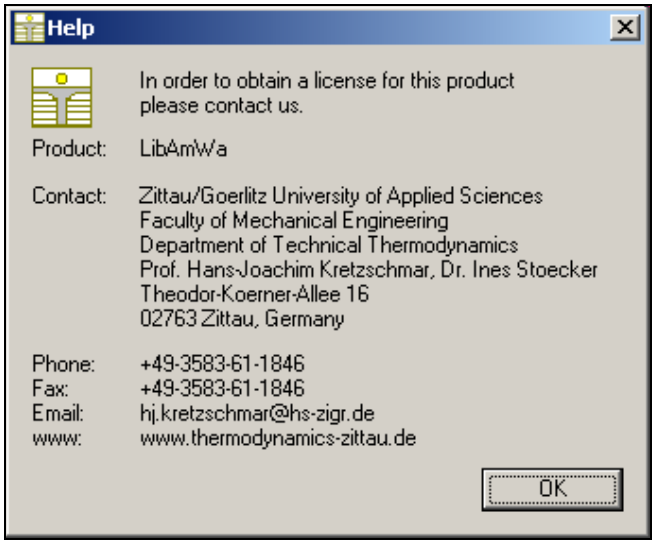

Figure 2.4: "Help" window

If you do not enter a valid license it is still possible to use MATLAB® 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 use FluidLAB LibAmWa unless you uninstall FluidLAB according to the description in section 2.6 of this User's Guide.
Should you not wish to license the LibAmWa property library, you have to delete the file

LibAmWa.dll

in the installation folder of FluidLAB (the standard being

C:\Program Files\FluidLAB\LibAmWa (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa (for German version of Windows))

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

2.3 Example: Calculation of the Specific Enthalpy $h = f(p,t,\xi)$ in an M-File

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p, temperature t and mass fraction ξ for ammonia-water mixtures using FluidLAB.
Please carry out the following instructions:

- Start Windows Explorer®, Total Commander®, My Computer® or another file manager program.
  The following description refers to Windows Explorer®
- Your Windows Explorer® should be set to "Details" for easier viewing. Click the "Views" button and select "Details."
- Switch into the program directory of FluidLAB in which you will find the folder "\LibAmWa"; it is generally saved under:

  "C:\Program Files\FluidLAB" (for English version of Windows)
  "C:\Programme\FluidLAB" (for German version of Windows)

- Create the folder "\LibAmWa_Example" by clicking on "File" in the Explorer® menu, then "New" in the menu which appears and afterwards selecting "Folder". Name the new folder "\LibAmWa_Example ".
- You will now see the following window:

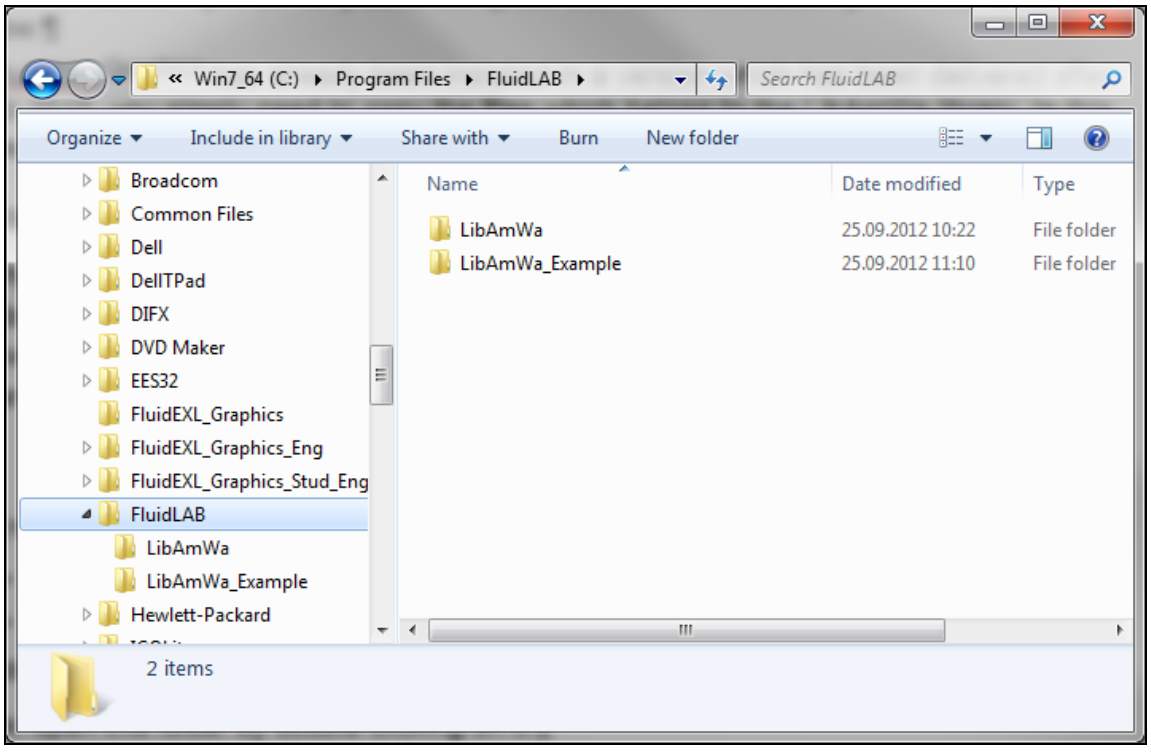

Figure 2.5: Folder "FluidLAB"

- Switch into the directory "\LibAmWa" within "\FluidLAB", in the standard being

  "C:\Program Files\FluidLAB\LibAmWa" (for English version of Windows)
  "C:\Programme\FluidLAB\LibAmWa" (for German version of Windows).

- If you have installed the 32-bit version of FluidLAB LibAmWa you will see the following window:

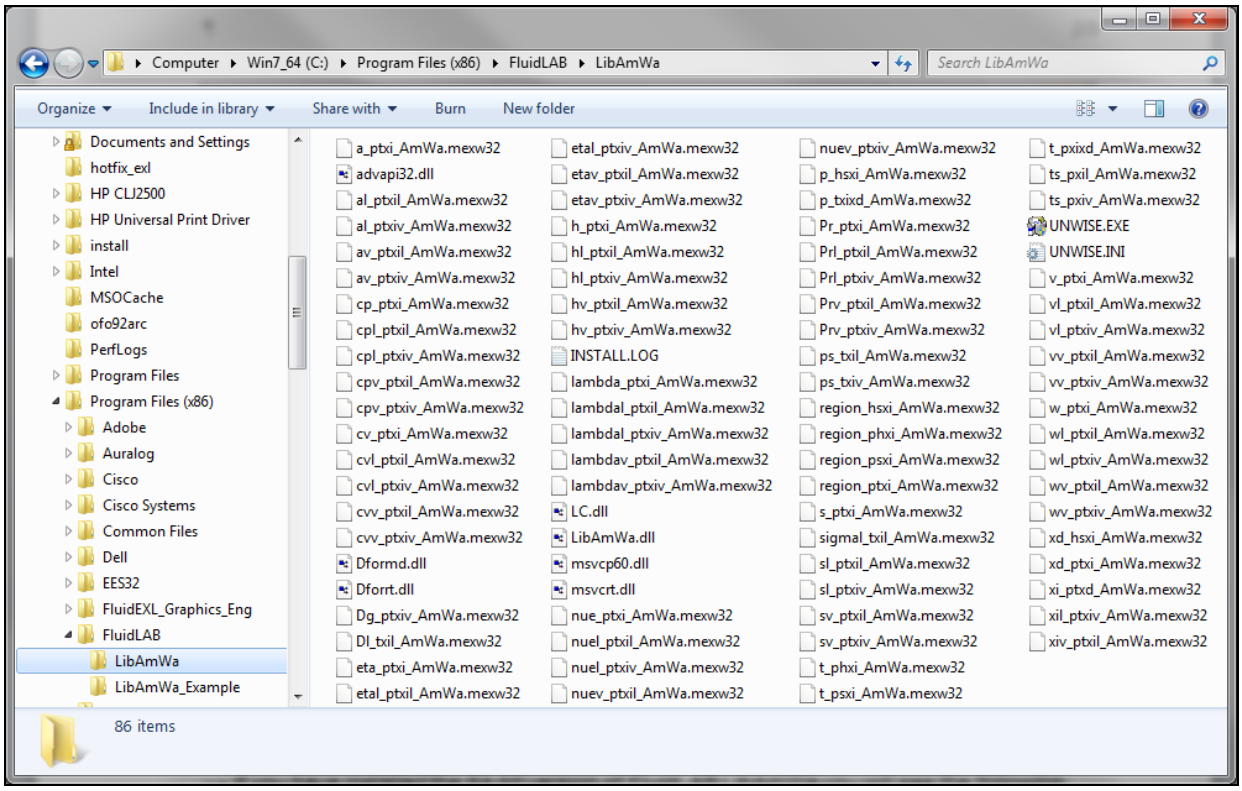

Figure 2.6: Contents of the folder "LibAmWa" (32-bit version)

- If you have installed the 64-bit version of FluidLAB LibAmWa you will see the following window:

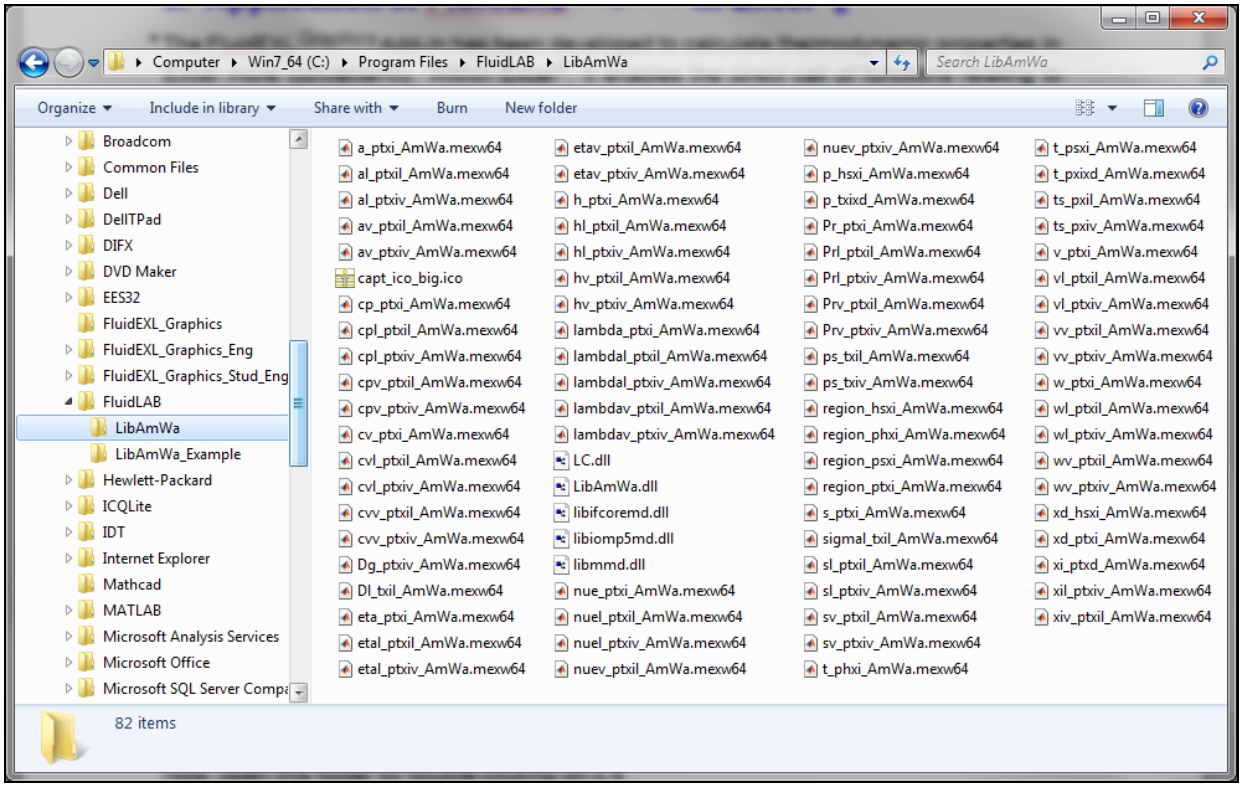

Figure 2.7: Contents of the folder "LibAmWa" (64-bit version)

If you have installed the 32-bit version of LibAmWa you will now have to copy the following

files into the directory

"C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
"C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows)

in order to calculate the functions $h = f(p,t,\xi)$ and $h^l = f(p,t,\xi^l)$.

- The following files are needed:
  - "advapi32.dll"
  - "Dformd.dll"
  - "Dforrt.dll"
  - "h_ptxi_AmWa.mexw32"
  - "hl_ptxil_AmWa.mexw32"
  - "LC.dll"
  - "LibAmWa.dll"
  - "msvcp60.dll"
  - "msvcrt.dll"
- Click the file "h_ptxi_AmWa.mexw32", then click "Edit" in the upper menu bar and select "Copy".
- Switch into the directory
  "C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows),
  click "Edit" and select "Paste".
- Repeat these steps in order to copy the other files listed above. You may also select all the above-named files and then copy them as a group (press the Control button to enable multiple markings).
- You will see the following window:

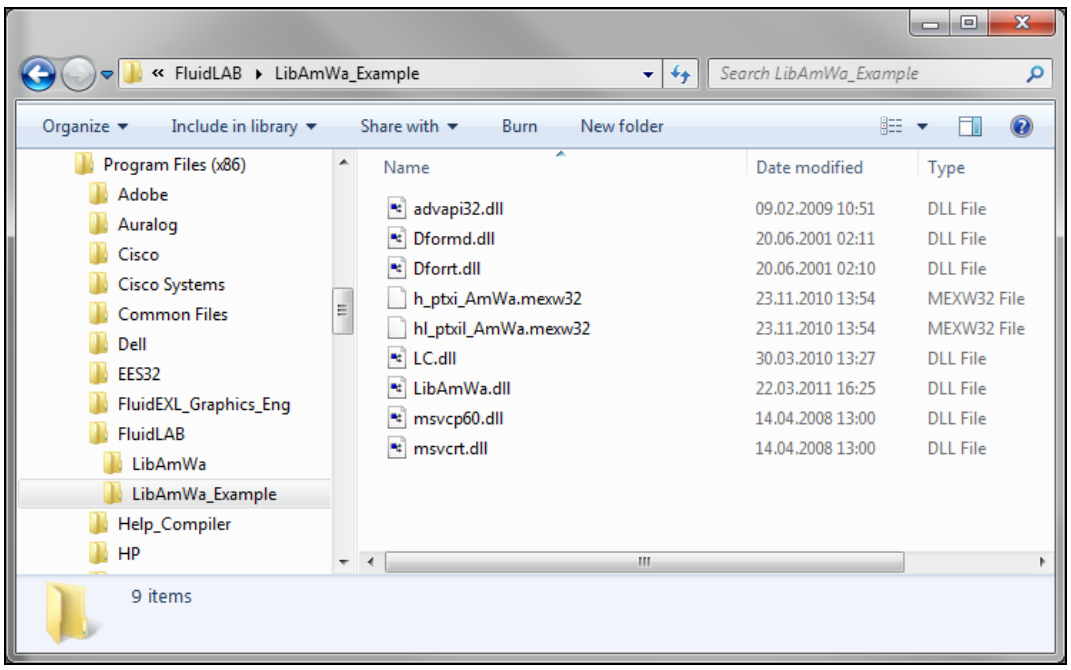

Figure 2.8: Contents of the folder "LibAmWa_Example" (32-bit version)

If you have installed the 64-bit version of LibAmWa you will now have to copy the following files into the directory

"C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
"C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows)

in order to calculate the functions $h = f(p,t,\xi)$ and $h^l = f(p,t,\xi^l)$.

- The following files are needed:
  - "h_ptxi_AmWa.mexw64"
  - "hl_pstsxil_AmWa.mexw64"
  - "LC.dll"
  - "LibAmWa.dll"
  - "libifcoremd.dll"
  - "libiomp5.dll"
  - "libmmd.dll."
- Click the file "h_ptxi_AmWa.mexw64", then click "Edit" in the upper menu bar and select "Copy."
- Switch into the directory

  "C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows),

  click "Edit" and then "Paste."
- Repeat these steps in order to copy the other files listed above. You may also select all the above-named files and then copy them as a group (press the Control button to enable multiple markings).
- You will see the following window:

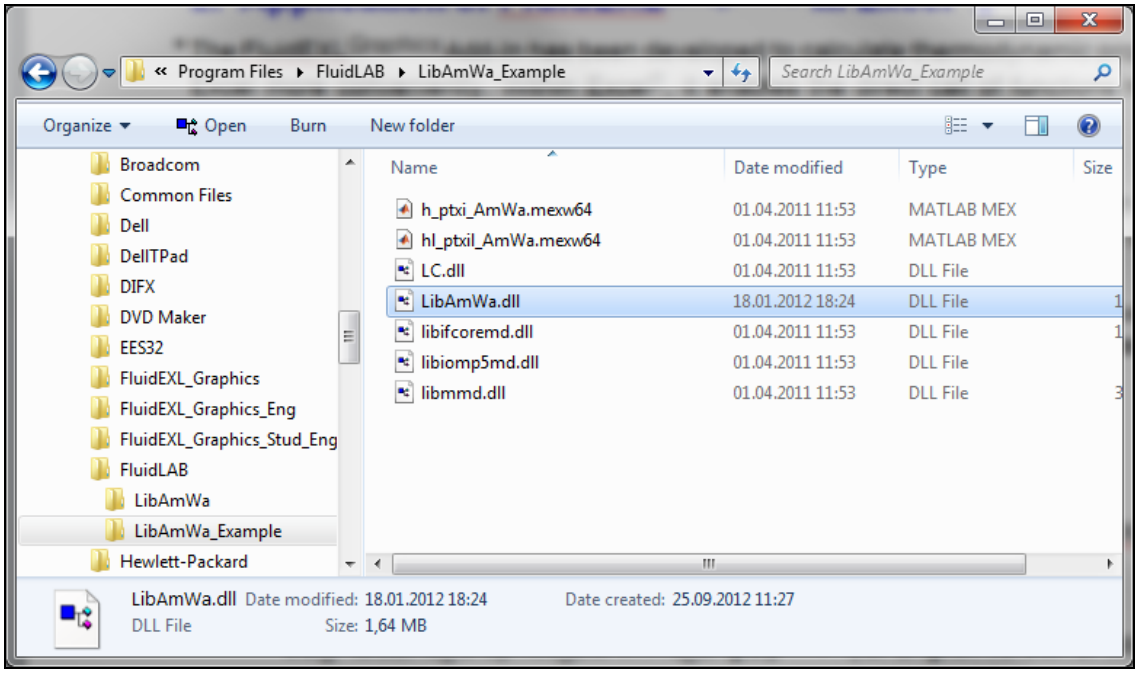

Figure 2.9: Contents of the folder "LibAmWa_Example"

- Start MATLAB® (if you have not started it already).
- Click the button marked in the next figure in order to open the folder "\LibAmWa_Example" in the "Current Directory" window.

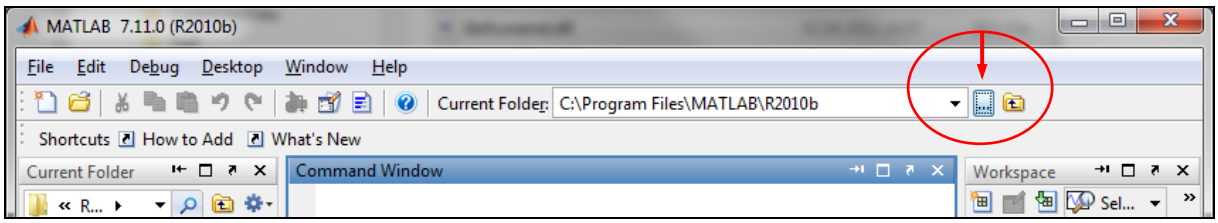

Figure 2.10: Selection of the working directory

- Find and select the directory

  "C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows)

  in the menu which appears (see the following figure).

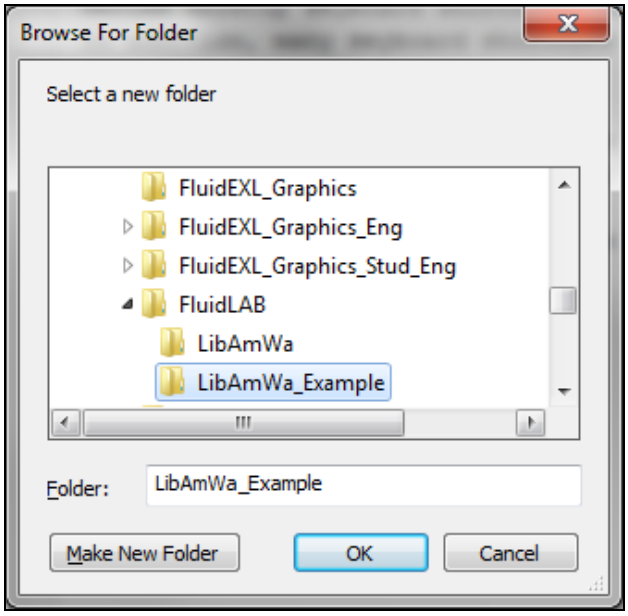

Figure 2.11: Choosing the "LibAmWa_Example" folder

- Confirm your selection by clicking the "OK" button.
- First of all you need to create an M–File in MATLAB®. Within MATLAB® click "File", then select "New" and afterwards click "M-File" in MATLAB 2006 or earlier versions or click "Script" in MATLAB 2010.
- If the "Editor" window appears as a separate window, you can embed it into MATLAB® by clicking the insertion arrow (see next figure) in order to obtain a better view.

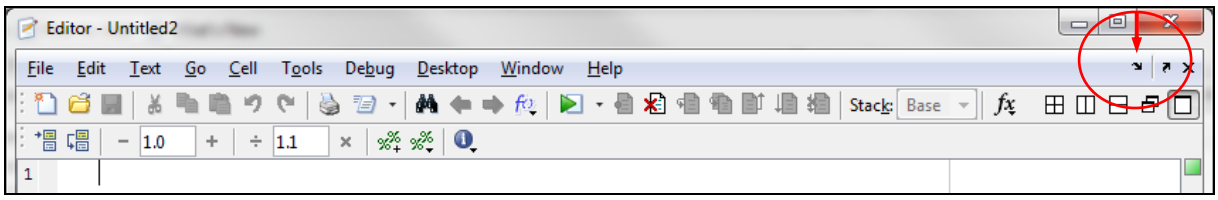

Figure 2.12: Embedding the "Editor" window

- In the figure below you will see the "Editor - Untitled" window.

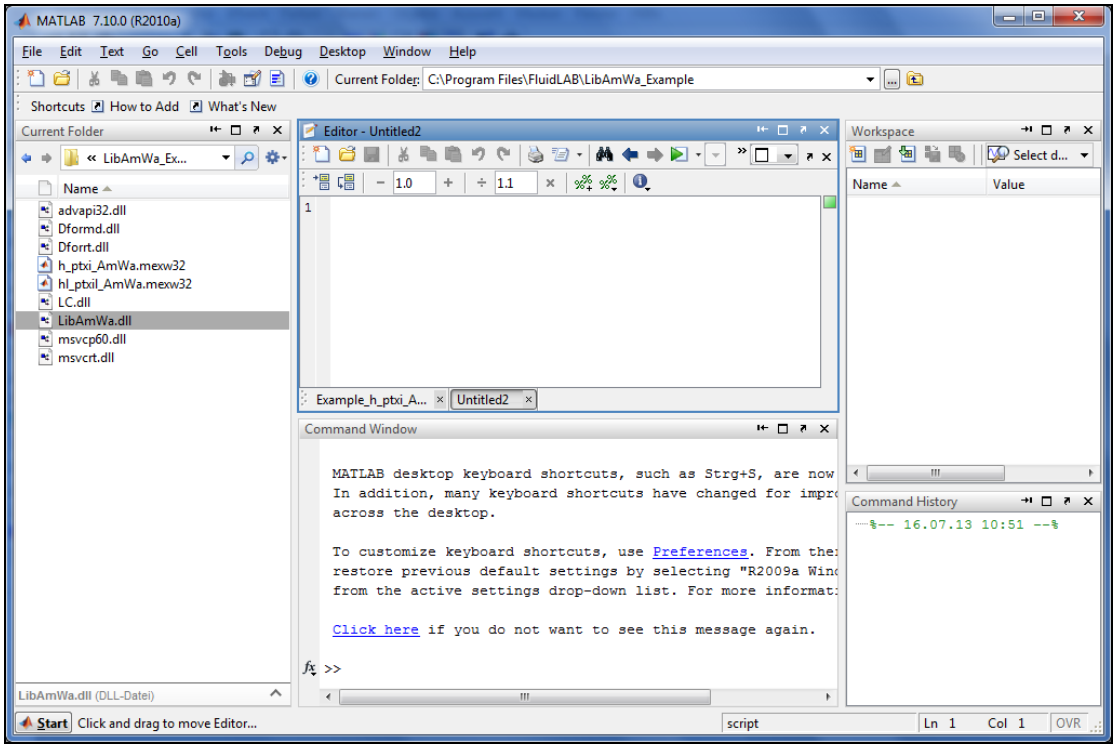

Figure 2.13: Embedded "Editor" window

- Now type the following lines in the "Editor - Untitled" window:

Text to be written:	Explanation:
`% h_ptxi_AmWa.m`	file name as comment
`%%`	paragraph separation
`p=10; % pressure in bar`	declaration of the variables pressure, temperature and mass fraction NH_3
`t=130; % temperature in °C`	
`xi=0.5; % mass fraction in kgNH3/kg`	
`%%`	paragraph separation
`h=h_ptxi_AmWa(p,t,xi)`	function call
`%%`	paragraph separation

- Remarks:

  - The program interprets the first line which starts with " % " to be a data description in "Current Directory"
  - Paragraph separations which are mandatory are being realised through " %%". By this, declaration of variables and calculation instructions are also being separated.
  - The words which are printed in green, start with "%" and stand behind the variables are comments. In fact they are not necessary but they are reasonable for your overview and comprehensibility.
  - You have to leave out the semicolons behind the numerical values if you wish to see the result for *h* and the input parameters as well.

The values of the function parameters in their corresponding units stand for:

- First operand: Value for p = 10 bar
  (Range of validity: p = 0.1 bar ... 400 bar)

- Second operand: Value for t = 130 °C
  (Range of validity: $t = t_{tr}(\xi)$ ... $2 \cdot t_c(\xi)$)
- Third operand: Value for ξ = 0.5
  (Range of validity: ξ = 0.0 kg NH_3/kg ... 1.0 kg NH_3/kg)

- Save the "M-File" by clicking the "File" button and then click "Save As...".
- The menu "Save file as:" appears; In this menu, the folder name "LibAmWa_Example" must be displayed in the "Save in:" field
- Next to "File name" you have to type in "Example_h_ptxi_AmWa.m" and afterwards click the "Save" button.

Note.
The name of the example file has to be different in comparison to the name of the used function. For example, the file could not be named "h_ptxi_AmWa.m" in this case. Otherwise an error message will appear during the calculation.

- You will now see the following window:

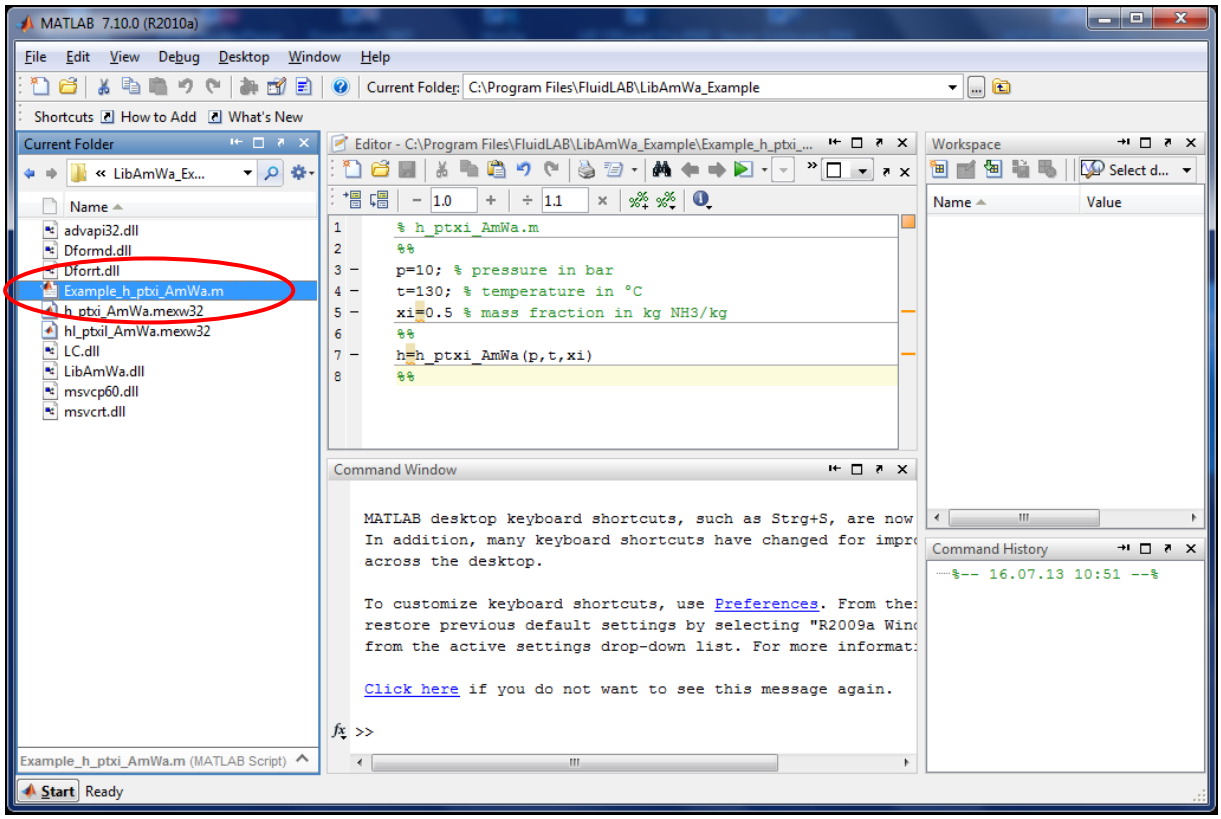

Figure 2.14: "Example_h_ptxi_AmWa.m" M-file

- Within the "Current Folder" window the file "Example_h_ptxi_AmWa.m" appears.
- Right-click on this file and select "Run" in the menu which appears (see next figure).

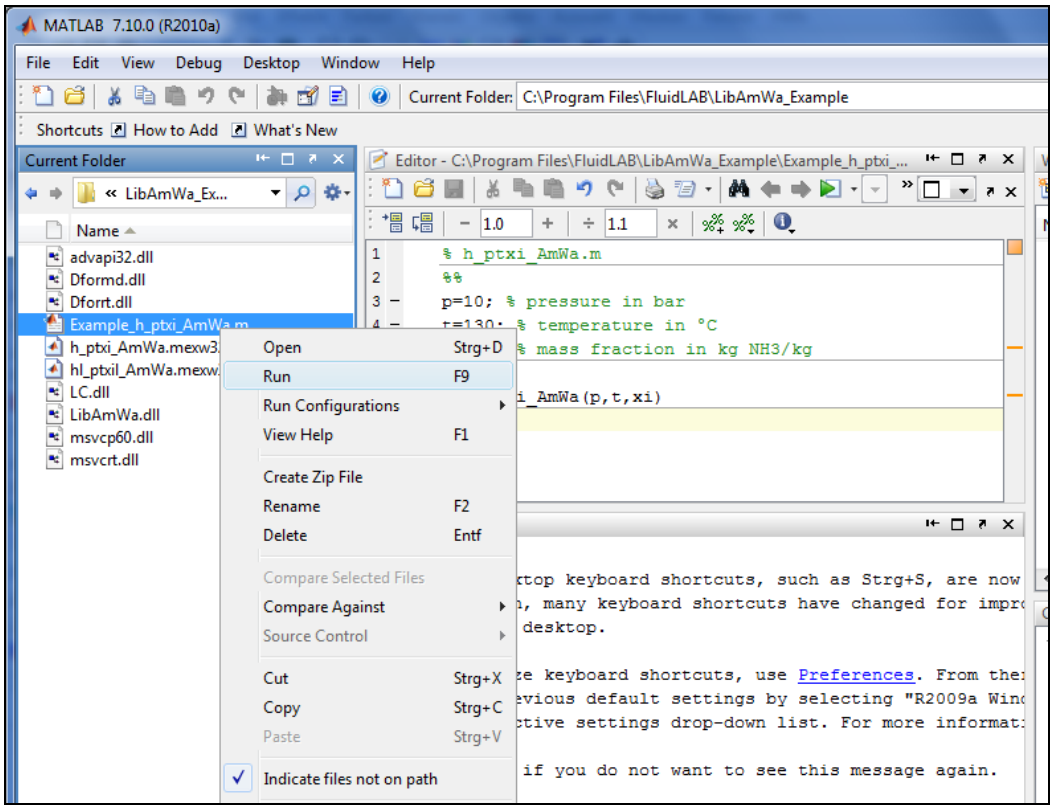

Figure 2.15: Running the "Example_h_ptxi_AmWa.m" M-file

- You will see the following window:

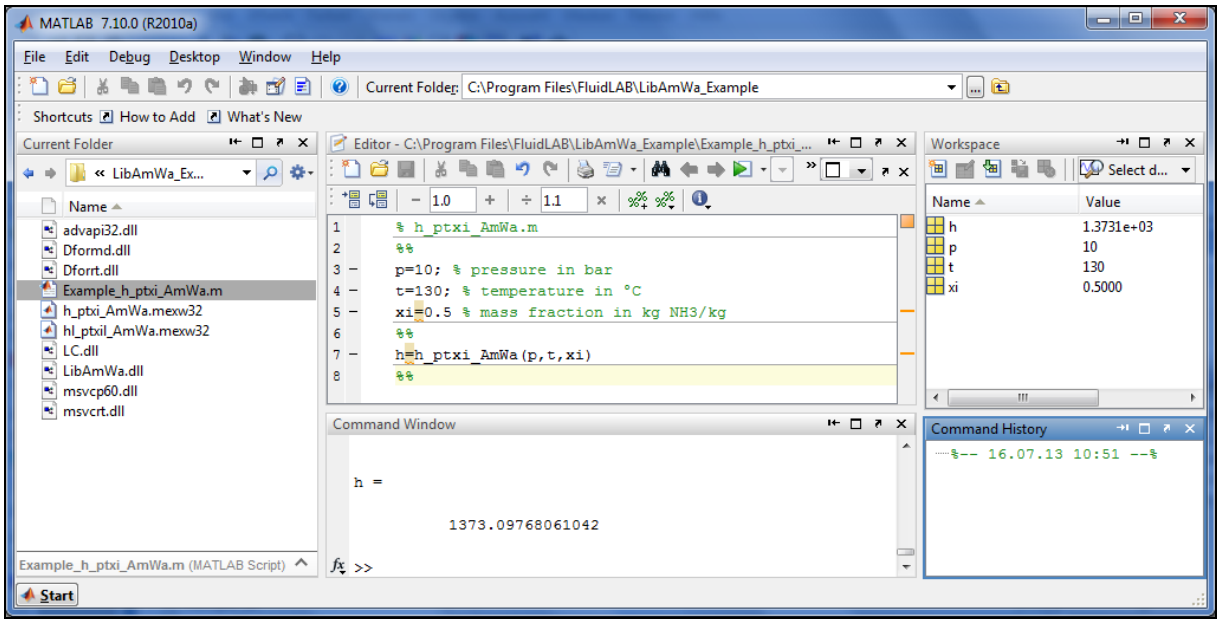

Figure 2.16: MATLAB® with calculated result

The result for *h* appears in the "Command Window".

⇒ The result in our sample calculation here is: "h = 1373.09768". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

To be able to calculate other values, you have to copy the associated mexw32 or mexw64 files as well because MATLAB® can only access functions that are located in the

"Current Directory" window. The example calculated can be found in the directory

C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)

C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows),

and you may use it as a basis for further calculations using FluidLAB.

Hint!

If the input values are located outside the range of validity of LibAmWa, the calculation of the chosen function to be calculated function results in -1000. You can find more exact details on every function and its corresponding range of validity in the enclosed program documentation in Chapter 3.

2.4 Example: Calculation of the Specific Enthalpy $h = f(p,t,\xi)$ in Command Window

- Please follow the instructions from page 2/8 to 2/11.
- Start MATLAB® (if you have not started it already).
- Click the button marked in the following figure in order to open the folder "\LibAmWa_Example" in the window "Current Directory".

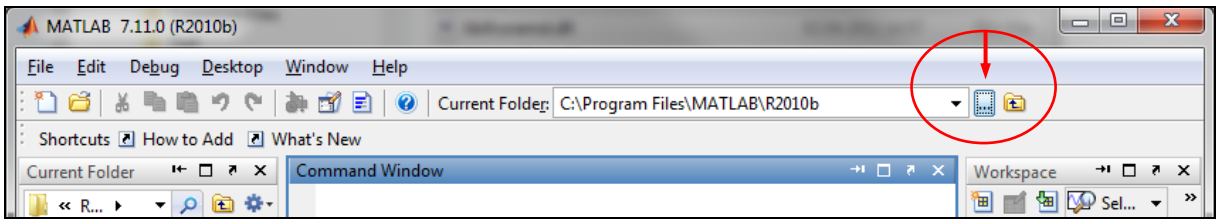

Figure 2.17: Selection of the working directory

- Find and select the directory

  "C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows)

  in the menu that appears (see figure below).

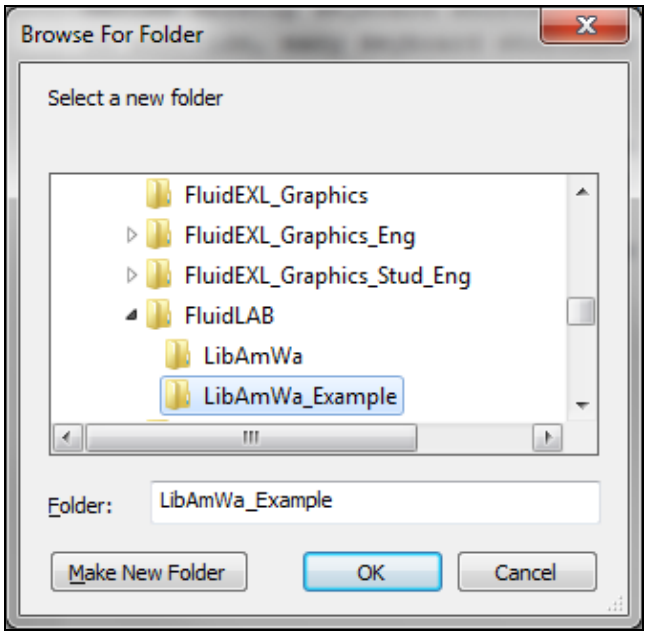

Figure 2.18: Choosing the "LibAmWa_Example" folder

- Confirm your selection by clicking the "OK" button.

- You will see the following window:

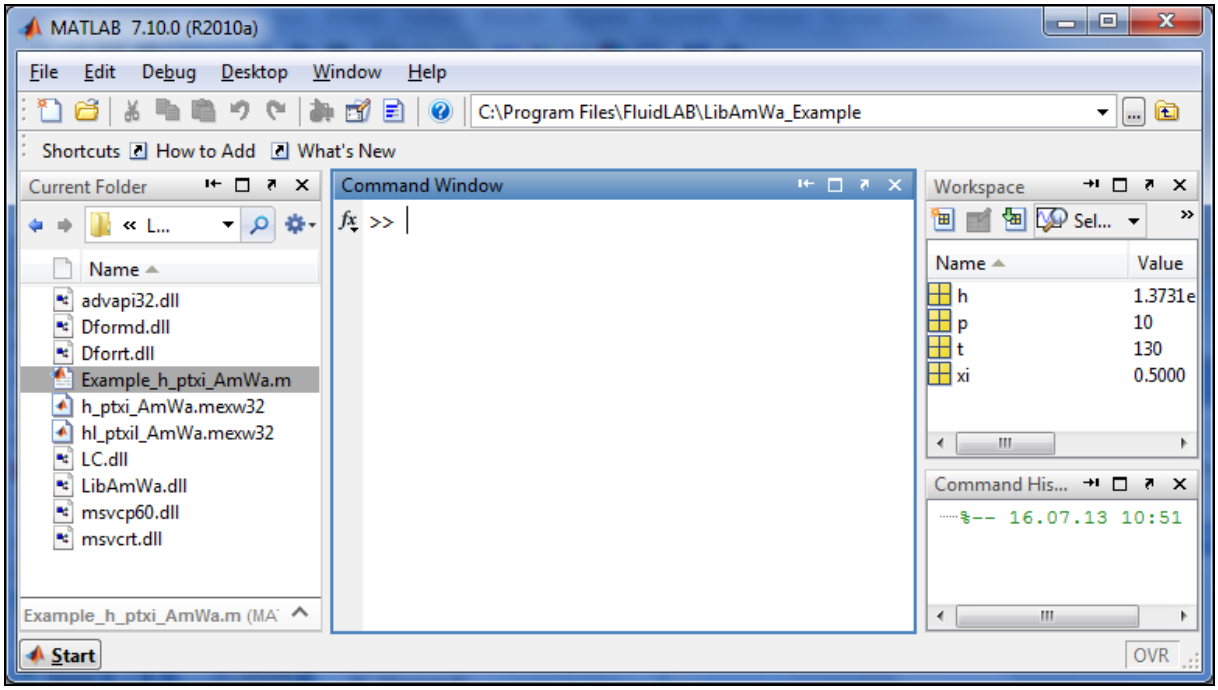

Figure 2.19: MATLAB® with necessary files

Corresponding to the table of property functions in Chapter 1 you have to call up the function "**h_ptxi_AmWa**" as follows for calculating h=f(p,t,ξ):

- Write "**h=h_ptxi_AmWa(10,130,0.5)**" within the "Command Window".

  The values of the function parameters in their corresponding units stand for:

  - First operand: Value for p = 10 bar
    (Range of validity: p = 0.1 bar ... 400 bar)
  - Second operand: Value for t = 130 °C
    (Range of validity: $t = t_{tr}(\xi)$ ... $2 \cdot t_c(\xi)$)
  - Third operand: Value for ξ = 0.5
    (Range of validity: ξ = 0.0 kg NH_3/kg ... 1.0 kg NH_3/kg)

- Confirm your entry by pressing the "ENTER" button.
- You will see the following window:

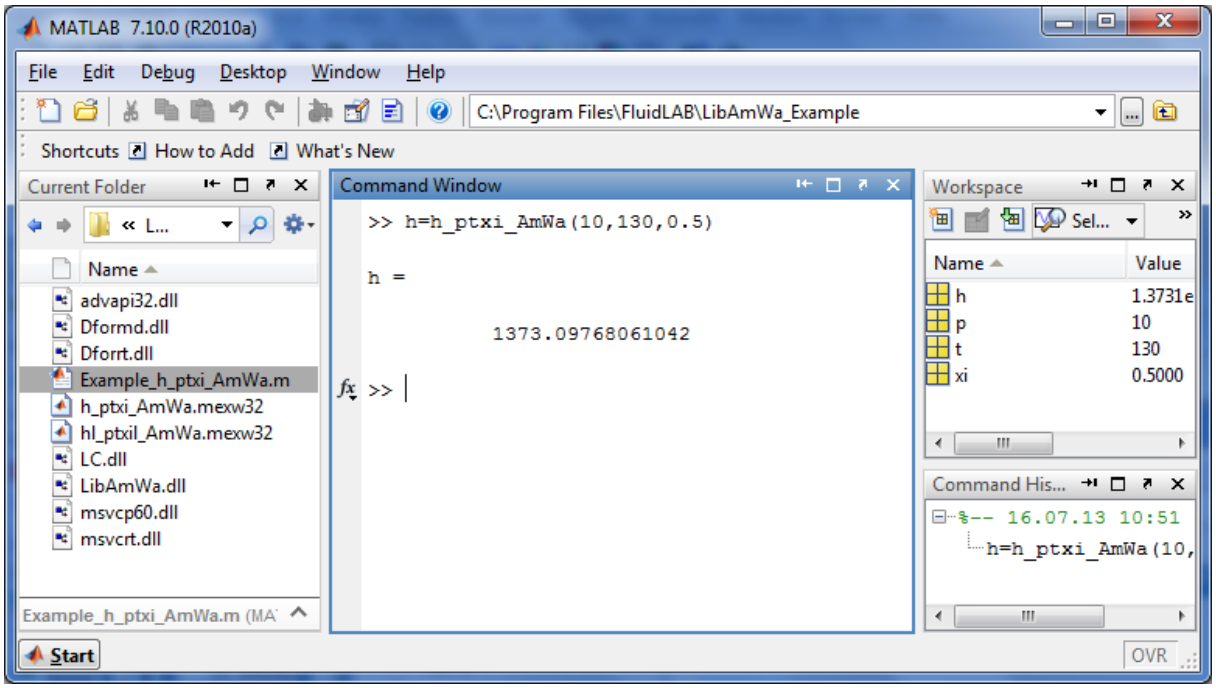

Figure 2.20: MATLAB® with calculated result

In the "Command Window" you will see the result "h = 1373.09768". The corresponding unit is kJ/kg (see table of the property functions in chapter 1).

To be able to calculate other values, you will have to copy the respective mexw32 or mexw64 files into the working directory as well, because MATLAB® can only access functions that are located in the "Current Directory" window. The example calculated can be found in the directory

C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows),

and you may use it as a basis for further calculations using FluidLAB.

Note:

If the input values are located outside the range of validity, the result for the chosen function to be calculated results in -1000. You can find more exact details on every function and its corresponding range of validity in the enclosed program documentation in Chapter 3.

2.5 Example: Calculation of the Specific Enthalpy $h^l = f(p_s,t_s,\xi^\beta)$ in an M-File

- Please follow the instructions from page 2/7 to 2/10.
- Start MATLAB® (if you have not started it already).
- Click the button marked in the following figure in order to open the folder "\LibAmWa_Example" in the window "Current Directory".

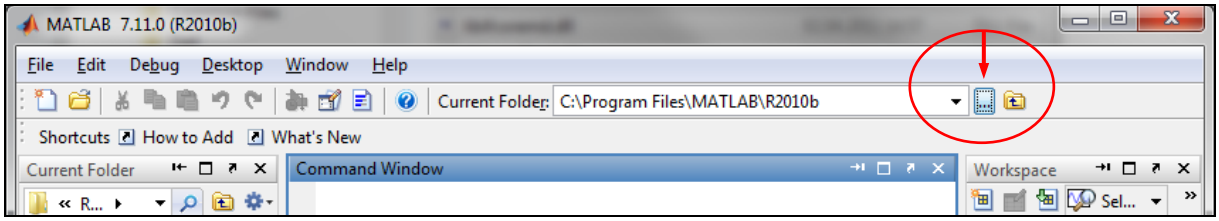

Figure 2.21: Selection of the working directory

- Find and select the directory

  "C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows)

  in the menu which appears (see the following figure).

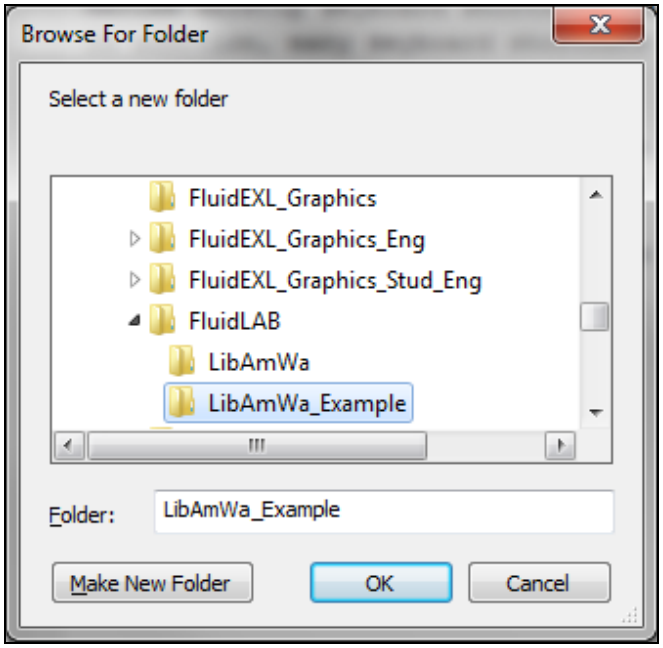

Figure 2.22: Choosing the "LibAmWa_Example" folder

- Confirm your selection by clicking the "OK" button.

- First of all you need to create an M–File in MATLAB®. Within MATLAB® click "File", then select "New" and afterwards click "M-File" in MATLAB 2006 or earlier versions or click "Script" in MATLAB 2010.
- If the "Editor" window appears as a separate window, you can embed it into MATLAB® by clicking the insertion arrow (see next figure) in order to obtain a better view.

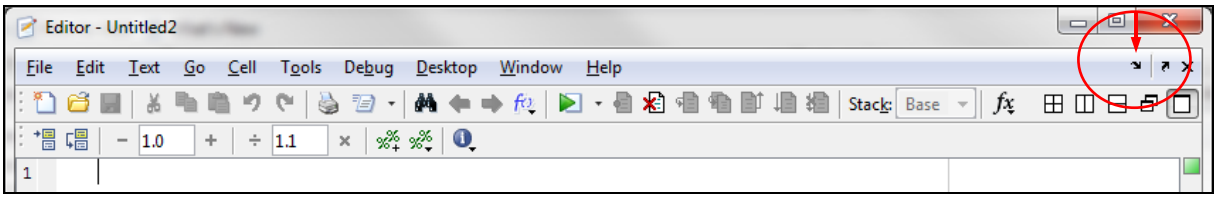

Figure 2.23: Embedding the "Editor" window

- In the figure below you will see the "Editor - Untitled" window.

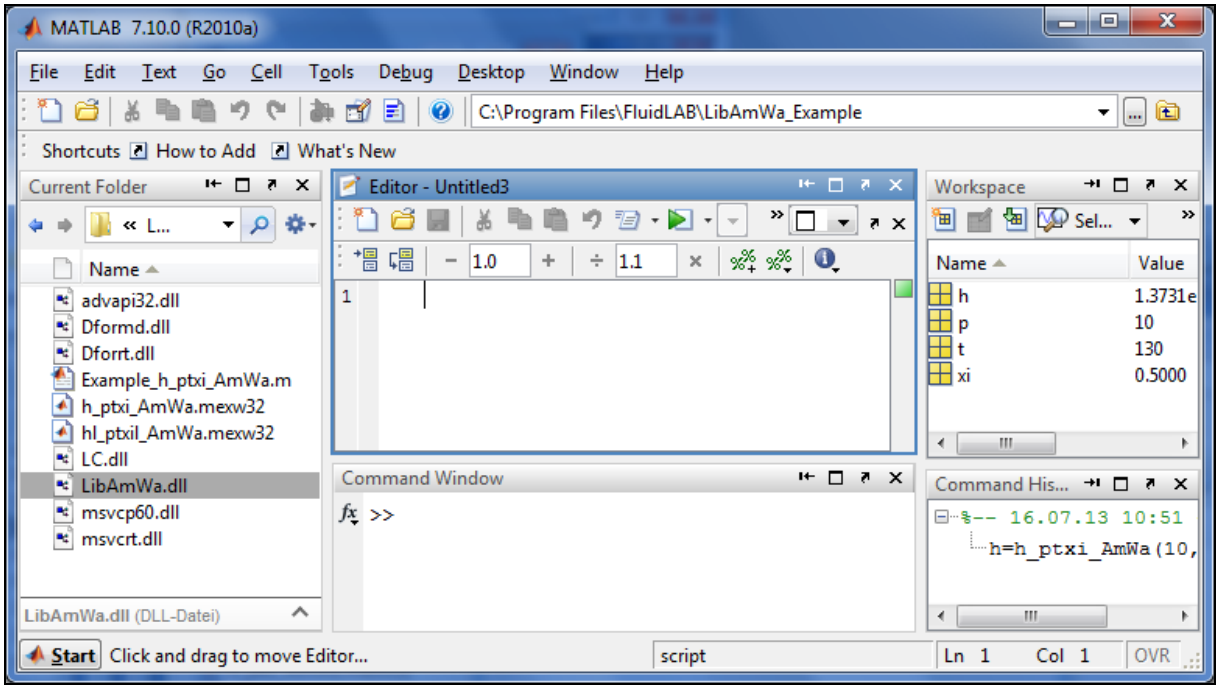

Figure 2.24: Embedded "Editor" window

- Now type the following lines in the "Editor - Untitled" window:

Text to be written:	Explanation:
`% hl_ptxil_AmWa.m`	file name as comment
`%%`	paragraph separation
`p=10; % vapor pressure in bar`	declaration of the variables vapor pressure, saturation temperature and mass fraction NH_3 of saturated liquid
`t=-1000; % saturation temperature in °C`	
`xil=0.5; % mass fraction saturated liquid in kg NH3/kg`	
`%%`	paragraph separation
`hl=hl_ptxil_AmWa(p,t,xil)`	function call
`%%`	paragraph separation

- Remarks:

  - The program interprets the first line, starting with "%," to be a data description in "Current Directory."
  - Paragraph separations which are mandatory are marked with "%%". This also serves to separate the declaration of variables and calculation instructions.
  - The words which are printed in green, start with "%" and come after the variables are comments. They are not in fact absolutely necessary, but they are very helpful for your overview and to make the process more easily understood.
  - Omit the semicolons after the numerical values if you wish to see the result for *hl* and the input parameters.

The values of the function parameters in their corresponding units stand for:

- First operand: Value for p = 10 bar
  (Range of validity: p = 0.1 bar ... 400 bar)
- Second operand: Value for t = -1000

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.

Possible input variants:

$h' = f(-1, t_s, \xi')$
$h' = f(p_s, -1, \xi')$
$h' = f(p_s, t_s, -1)$
$h' = f(p_s, t_s, \xi')$

(Range of validity: $t = t_{tr}(\xi)$ ... $2 \cdot t_c(\xi)$)

- Third operand: Value for ξ' = 0.5 kg NH_3/kg
  (Range of validity: ξ' = 0.0 kg NH_3/kg ... 1.0 kg NH_3/kg)

- Save the "M-File" by clicking the "File" button and then click "Save As...".
- The menu "Save file as:" appears; In this menu, the folder name "LibAmWa_Example" must be displayed in the "Save in:" field.
- Next to "File name" you have to type in "Example_hl_ptxil_AmWa.m" and afterwards click the "Save" button.

Note.
The name of the example file has to be different in comparison to the name of the used function. For example, the file could not be named "hl_ptxil_AmWa.m" in this case. Otherwise an error message will appear during the calculation.

- You will see the following window:

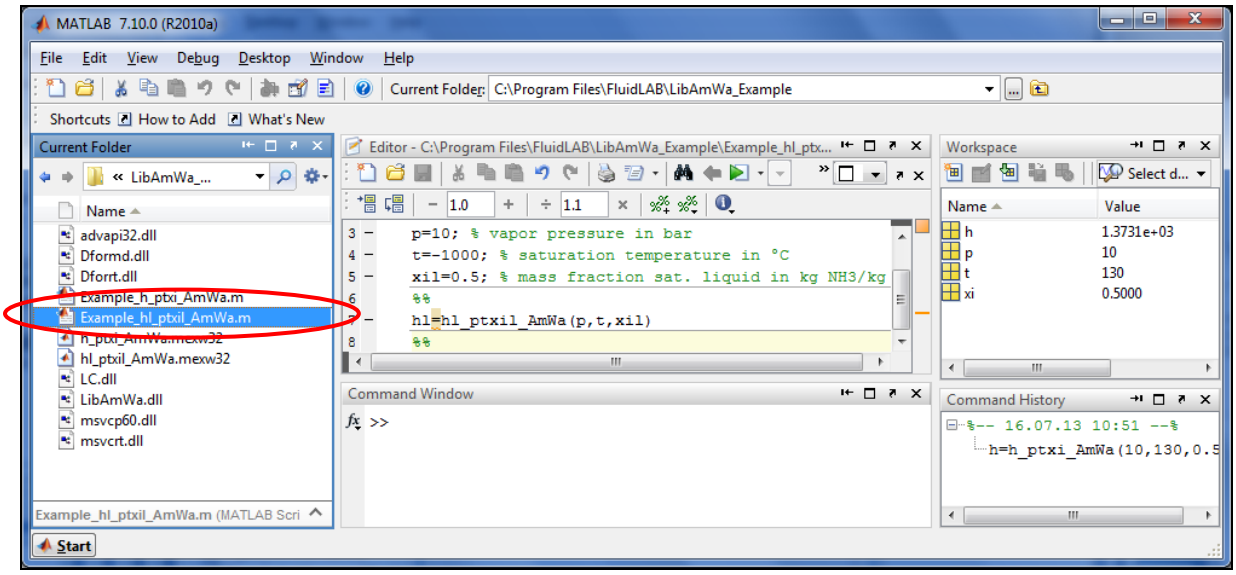

Figure 2.25: "Example_hl_ptxil_AmWa.m" M-file

- Within the "Current Directory" window, the file "Example_hl_ptxil_AmWa.m" appears.
- Right-click on this file and select "Run" in the menu which appears (see next image).

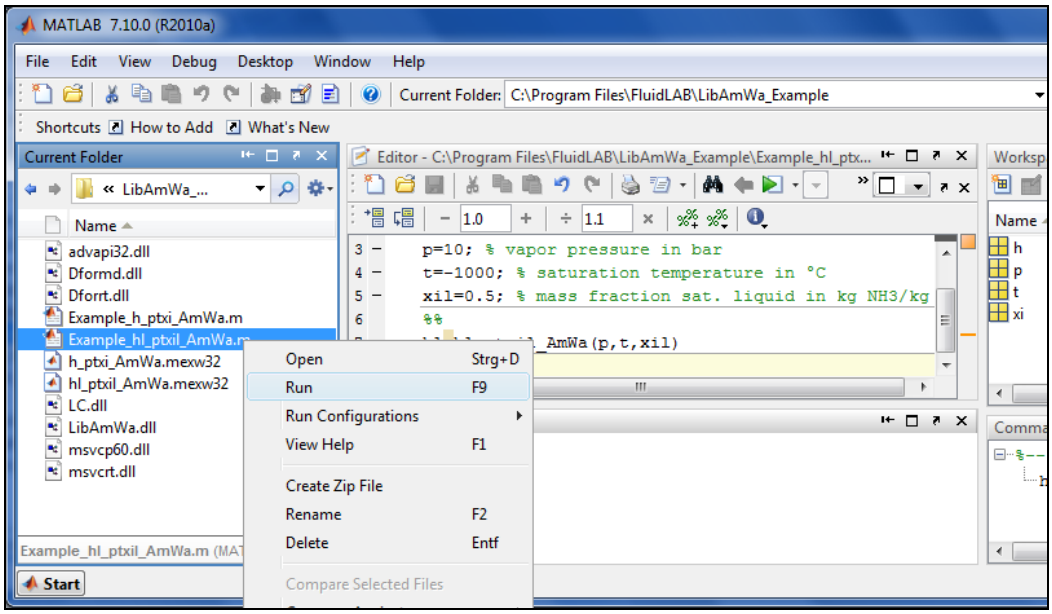

Figure 2.26: Running the "Example_hl_ptxil_AmWa.m" M-file

- You will see the following window:

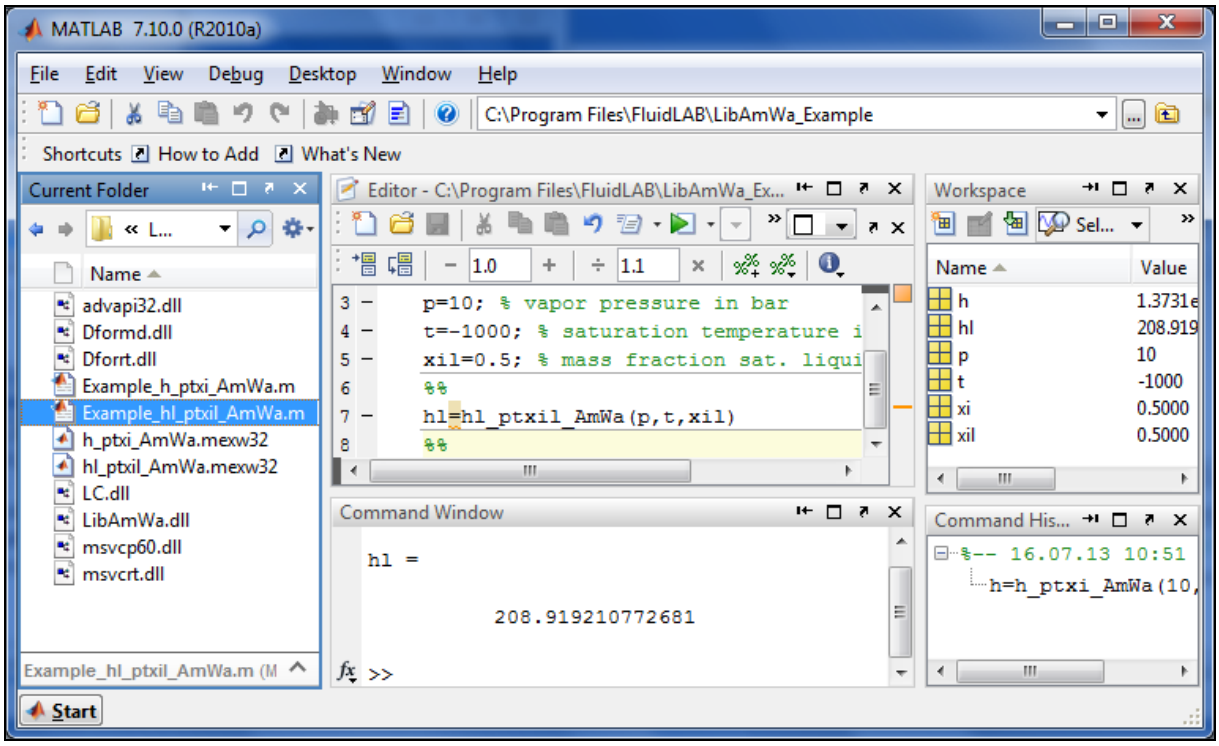

Figure 2.27: MATLAB® with calculated result

In the "Command Window" you will see the result "hl = 208.91921". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

To be able to calculate other values, you have to copy the associated mexw32 or mexw64 files as well because MATLAB® can only access functions that are located in the "Current Directory" window. The example calculated can be found in the directory

C:\Program Files\FluidLAB\LibAmWa_Example" (for English version of Windows)
C:\Programme\FluidLAB\LibAmWa_Example" (for German version of Windows),

and you may use it as a basis for further calculations using FluidLAB.

Note:

If the input values are located outside the range of validity of LibAmWa, the calculation of the chosen function to be calculated results in -1000. You can find more exact details on every function and its corresponding range of validity in the enclosed program documentation in Chapter 3.

2.5 Using FluidLAB with SIMULINK

To use the functions of FluidLAB with the simulation program SIMULINK you have to start SIMULINK in MATLAB® by clicking on Simulink in the upper menu bar shown in Figure 2.19.

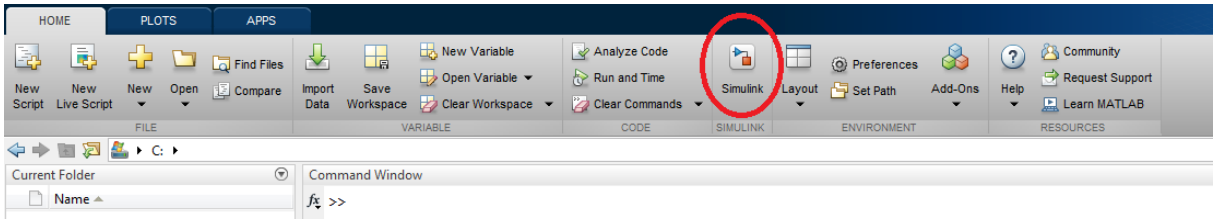

Figure 2.20: Starting Simulink

Then choose a blank model or a simulation in which you would like to use FluidLAB. Now you need to add a MATLAB function block that you can find in the library browser shown in Figure 2.20.

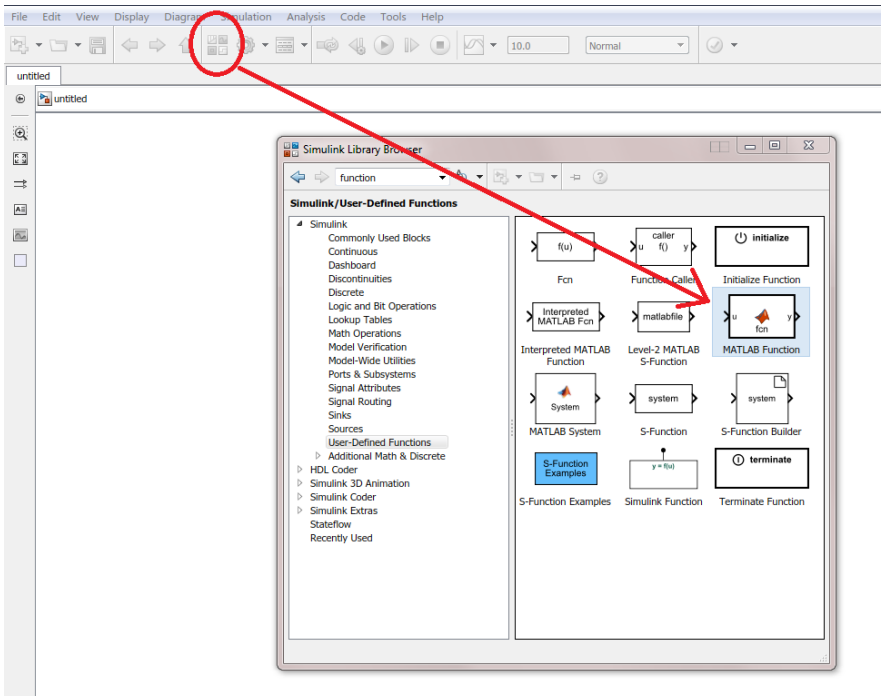

Figure 2.20: Simulink library browser and choosing a MATLAB Function

By dragging and dropping you can drag a Simulink block in your model. The function needs inputs and output that you can find in the Simulink library browser under sources and sinks. For this example constants were taken for the inputs and a display block were taken for outputting.

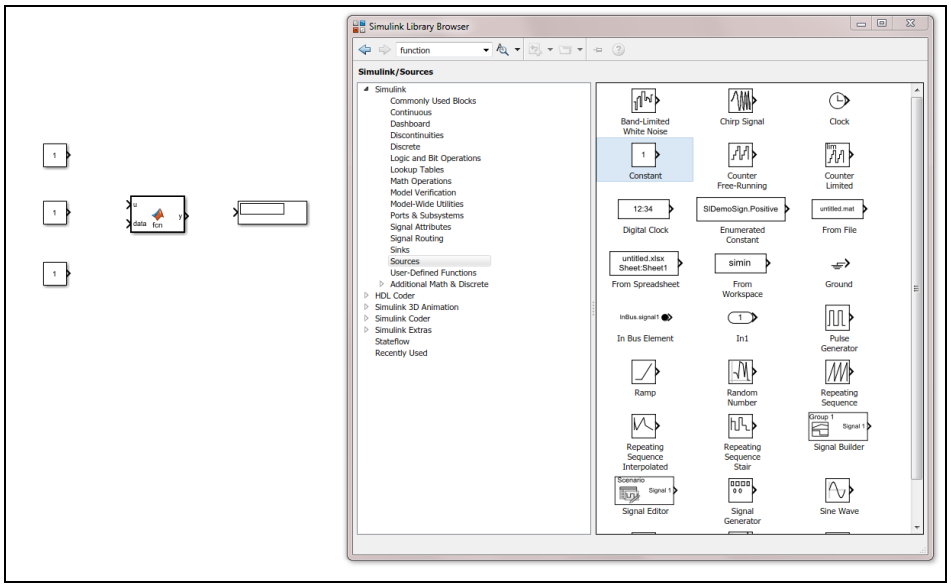

Figure 2.21: Inputs and outputs of the example

Now you have to link inputs and outputs to the MATLAB function block. By pressing and holding the left mouse button on the arrow of a block, you can draw a line and drag it to the MATLAB function block. With this method you can link all blocks together.

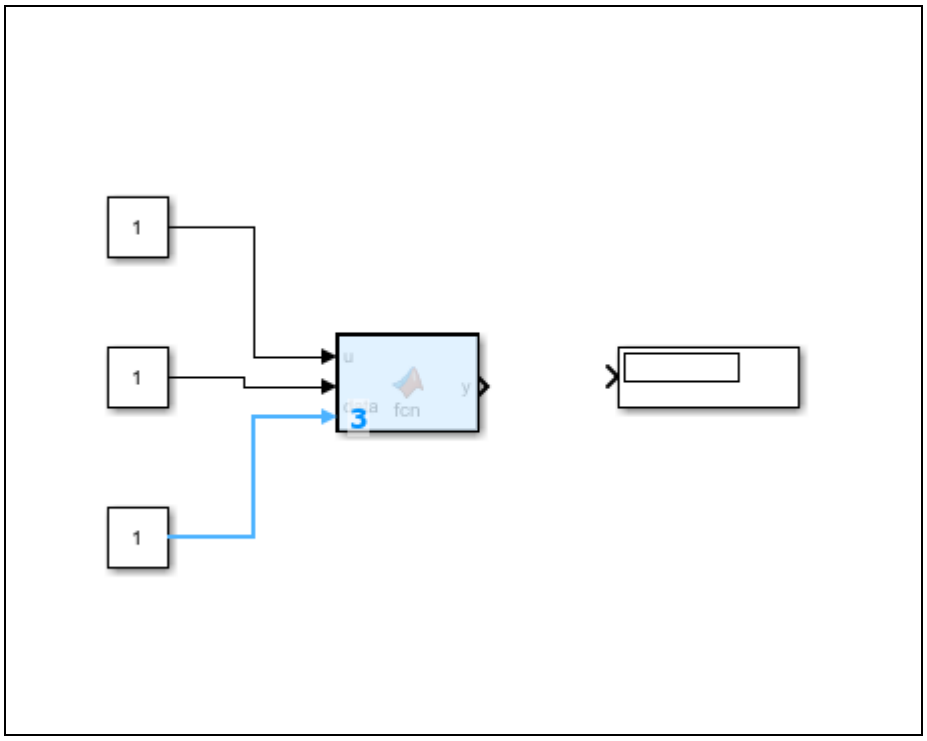

Figure 2.22: Linking blocks in Simulink

You can define the value of a constant block by double-click on them. If you want to calculate the example use the values you can find in section 2.3 and 2.4. With a double-click on the MATLAB function block you can define the function in MATLAB®. The following source code is for the example calculation and the table below describes the source code closer. You can adapt these few lines to call all other function of FluidLAB.

```
function h = fcn(p, t, x)
coder.extrinsic('addpath');
```

```
coder.extrinsic('h_ptx_97');
addpath('C:\Program Files\FluidLAB\LibIF97');
h = h_ptx_97(p,t,x);
```

Matlab source code	Explanation
`function h = fcn(p, t, x)`	function header, you can define the function name and the inputs like p, t and x of the example
`coder.extrinsic('addpath');`	necessary to add a path
`coder.extrinsic('h_ptx_97');`	Choose the function name of the FluidLAB function
`addpath('C:\Program Files\FluidLAB\LibIF97');`	Add the installation path of FluidLAB
`h = h_ptx_97(p,t,x);`	Linking the FluidLAB function to the MATLAB function block

You can copy and paste the sourcecode in MATLAB® or write it into the MATLAB® editor. The simulation will start by clicking the run button in Matlab or Simulink and you can see the example in the display block of the simulation which is shown in figure 2.23.

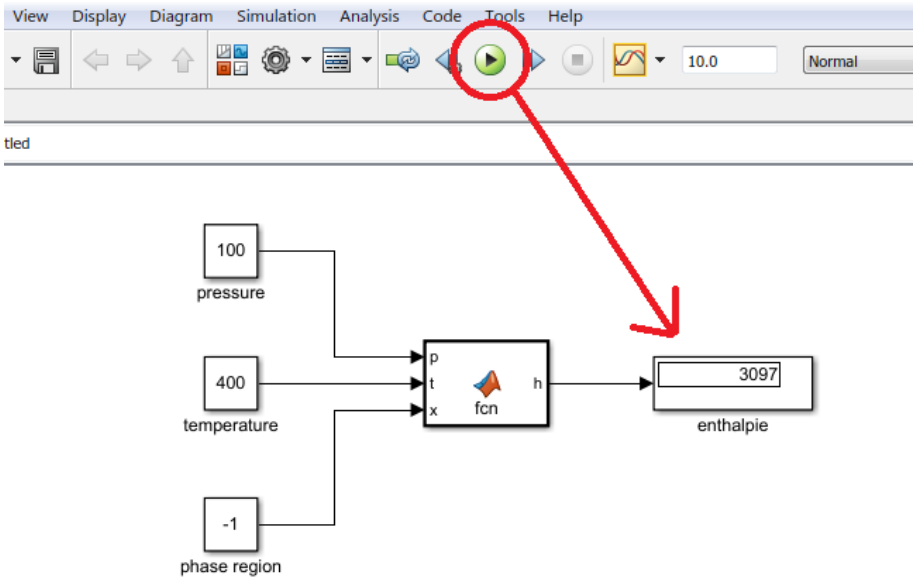

Figure 2.23: Starting the simulation and result of the calculation

You result is may an other than shown in figure 2.23. If you want to calculate the example please use the values from section 2.3 and 2.4.

2.6 Removing FluidLAB LibAmWa

To remove FluidLAB LibAmWa from your hard drive in Windows®, 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 "FluidLAB LibAmWa" by clicking on it and click the "Change/Remove" button.

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

Confirm the following menu "Perform Uninstall" by clicking the "Finish" button.

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

Now, FluidLAB has been removed.

If there is no library other than LibAmWa installed, the directory "FluidLAB" will be removed as well.

3. Program Documentation

Thermal Diffusivity a = f(p,t,ξ)

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,ξ')

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

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

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

Function Name: **cpl_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg 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,ξ'')

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

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

Function Name: **etal_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg 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 $\eta' = f(p,t,\xi'')$

Function Name: **etal_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg 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 $t = t_{tr}(\xi'')$ ... $t_c(\xi'')$

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 η'' = f(p,t,ξ'')

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 $h = f(p,t,\xi)$

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

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

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: **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 $t = t_{tr}(\xi)$ … $2 \cdot t_c(\xi)$

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*,ξ)

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

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg 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: for the call out of Fortran	**REAL*8 FUNCTION PRVPTXIVAMWA(P,T,XIV)** REAL*8 P,T,XIV

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

XIV - Ammonia mass fraction of saturated vapor ξ'' in (kg 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 $t = t_{tr}(\xi) \ldots 2 \cdot t_c(\xi)$

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

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

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 **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 σ_l = f(t, ξ')

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

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

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 **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 $t = f(p,\xi,x_\delta)$

Function Name: **t_pxixd_AmWa**

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

Input values

P - Pressure p in bar

XI - Ammonia mass fraction ξ in (kg 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: $t = t_{tr}(\xi) \le t \le t_c(\xi)$

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

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 **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 $t = t_{tr}(\xi)$ … $2 \cdot t_c(\xi)$

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 $w = f(p,t,\xi)$

Function Name: **w_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg 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 $t = t_{tr}(\xi) \ldots 2 \cdot t_c(\xi)$

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 **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 ξ = f(p,t,x_δ)

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]

KCE

KCE-ThermoFluidProperties
www.thermofluidprop.com

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)

Library LibSBTL_IF97
Library LibSBTL_95

Extremely fast property calculations according to the IAPWS Guideline 2015
Spline-based Table Look-up Method (SBTL)
applied to the Industrial Formulation IAPWS-IF97 and to the Scientific Formulation IAPWS-95
for Computational Fluid Dynamics and simulating non-stationary processes

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

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

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

Consideration of:
- Dissociation from VDI 4670
- Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:
- Dry air from Lemmon et al.
- Steam, water and ice from IAPWS-IF97 and IAPWS-06

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

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

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

Consideration of:
- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:
- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

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

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

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bücker and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term

(also useable for calculating the Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol
Library LibC2H5OH
Formulation of
Schroeder (2012)

Methanol
Library LibCH3OH
Formulation of
de Reuck and Craven (1993)

Propane
Library LibPropane
Formulation of
Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

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

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

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

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Nitrogen and Oxygen
Libraries
LibN2 and LibO2
Formulations of Span et al. (2000)
and Schmidt and Wagner (1985)

Hydrogen
Library LibH2
Formulation of
Leachman et al. (2009)

Helium
Library LibHe
Formulation of
Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

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

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

Hydrogen sulfide H_2S **Library LibH2S**

Nitrous oxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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Mobile: +49-172-7914607
Fax: +49-3222-4262250

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.

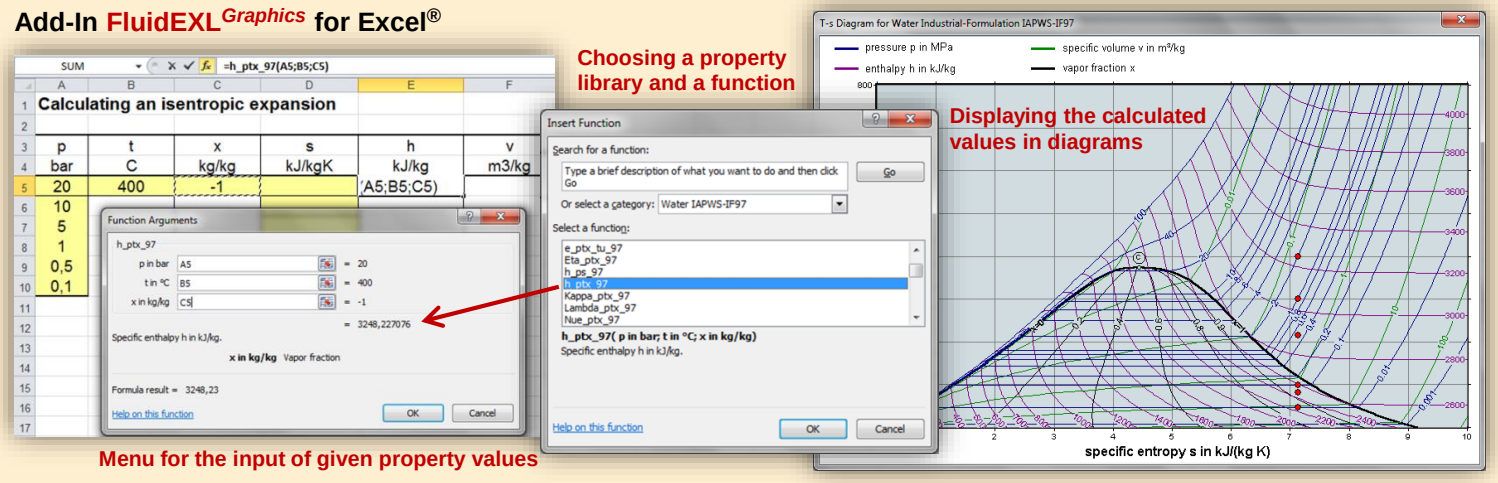
[a] Not all of these property functions are available in all property libraries.

KCE

KCE-ThermoFluidProperties
www.thermofluidprop.com

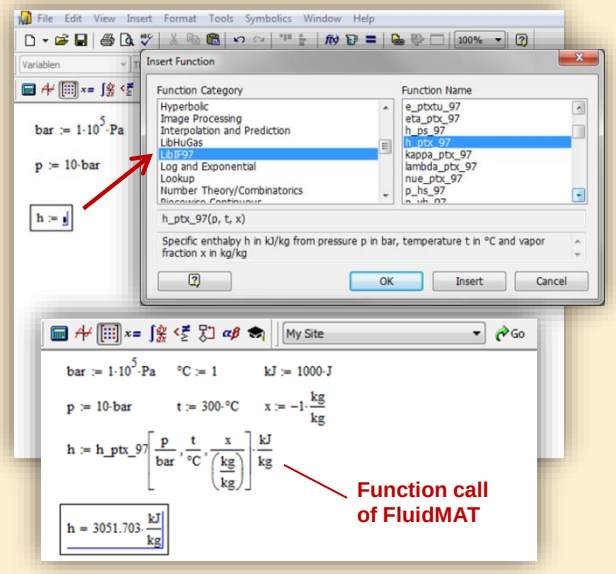
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



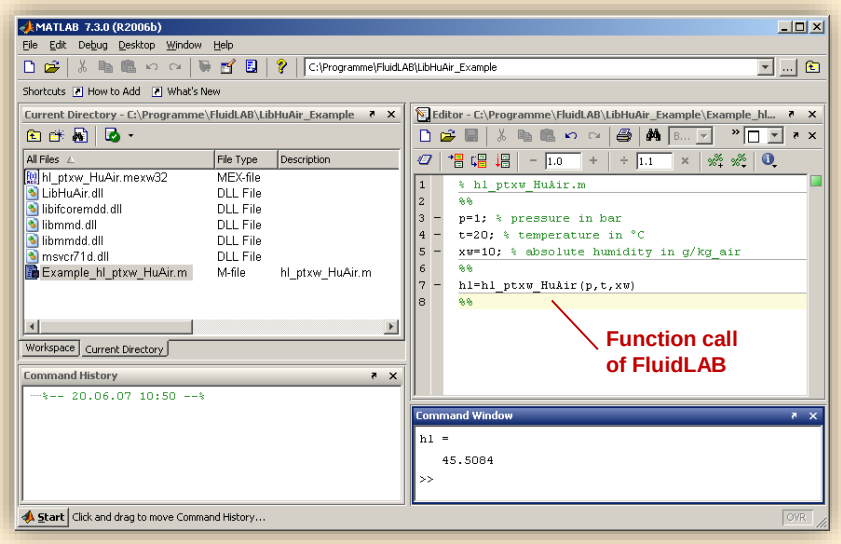
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



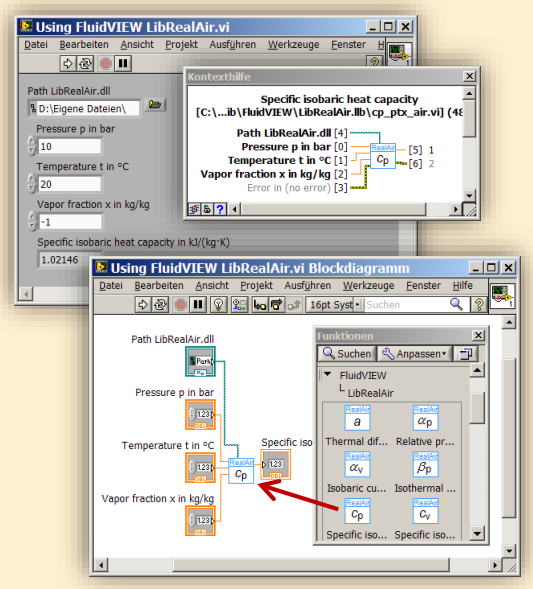
Add-In FluidLAB for MATLAB®

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



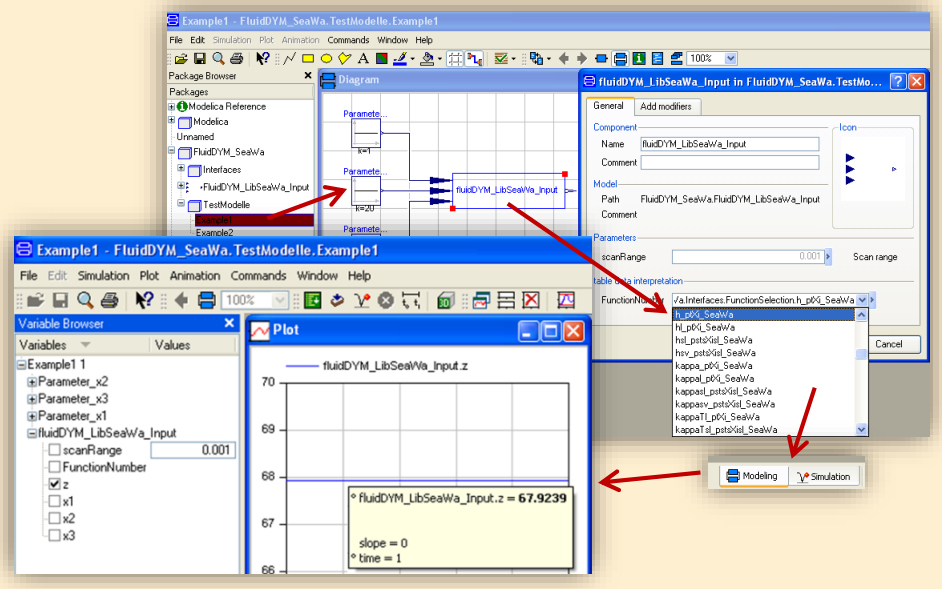
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

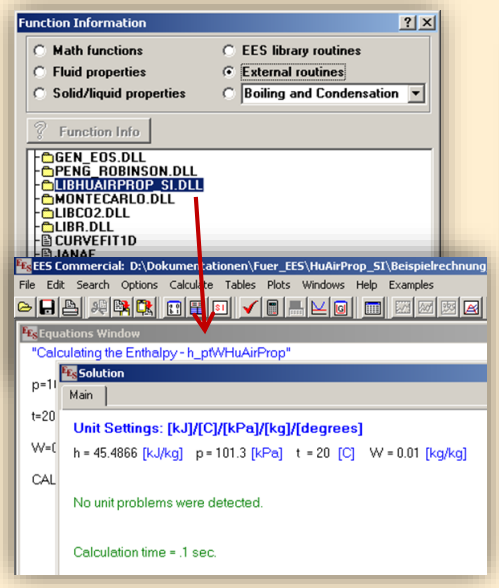


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

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

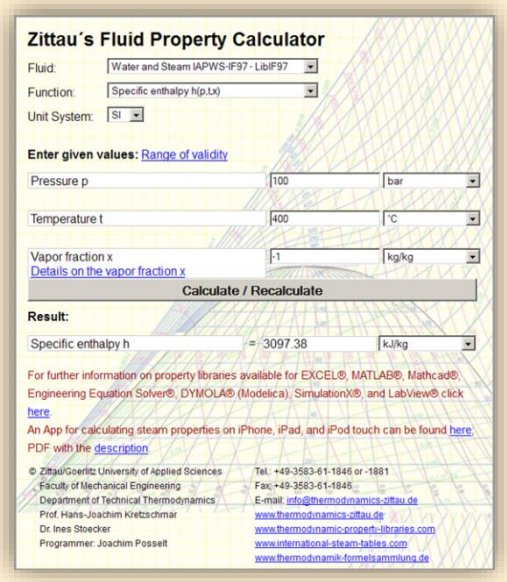


Add-In FluidEES for Engineering Equation Solver®



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

Online Property Calculator at www.thermofluidprop.com



Property Software for Pocket Calculators

FluidCasio

fx 9750 G II

CFX 9850
fx-GG20

CFX 9860 G
Graph 85

ALGEBRA
FX 2.0

FluidHP

HP 48 HP 49

FluidTI

TI Nspire CX CAS
TI Nspire CAS

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

For more information please contact:

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Fax: +49-3222-4262250

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.thermofluidprop.com

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6. Satisfied Customers

Date: 05/2018

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2018

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HS Zittau/ Görlitz, Fakultät Wirtschaft, Zittau	05/2018
HS Niederrhein, Krefeld	05/2018
GRS, Köln	03/2018
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	02/2018
AIXPROCESS, Aachen	02/2018
KRONES, Neutraubling	02/2018
Doosan Lentjes, Ratingen	01/2018

2017

Compact Kältetechnik, Dresden	12/2017
Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	12/2017
TH Mittelhessen, Gießen	11/2017
Haarslev Industries, Søndersø, Denmark	11/2017
Hochschule Zittau/Görlitz, Fachgebiet Energiesystemtechnik	11/2017
ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	10/2017
Fels-Werke GmbH, Elbingerode	10/2017
KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik	09/2017
Air-Consult, Jena	09/2017
Papierfabrik Koehler, Oberkirch	09/2017
ZWILAG, Würenlingen, Switzerland	09/2017
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017
Fichtner IT Consulting AG, Stuttgart	07/2017
Hochschule Ansbach, Ansbach	06/2017
RONAL, Härkingen, Switzerland	06/2017
BORSIG Service, Berlin	06/2017

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

2016

BOGE Druckluftsysteme, Bielefeld	12/2016
BFT Planung, Aachen	11/2016
Midiplan, Bietigheim-Bissingen	11/2016
BBE Barnich IB	11/2016
Wenisch IB,	11/2016
INL, Idaho Falls	11/2016
TU Kältetechnik, Dresden	11/2016
Kopf SynGas, Sulz	11/2016
INTVEN, Bellevne (USA)	11/2016
DREWAG Dresden, Dresden	10/2016
AGO AG Energie+Anlagen, Kulmbach	10/2016
Universität Stuttgart, ITW, Stuttgart	09/2016
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Siemens AG, Erlangen	09/2016
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Wilhelm Büchner Hochschule, Pfungstadt	08/2016

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Endress+Hauser Messtechnik GmbH+Co. KG, Hannover	08/2016
D + B Kältetechnik, Althausen	07/2016
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AB Electrolux, Krakow, Poland	07/2016
ENEXIO Germany GmbH, Herne	07/2016
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INWAT, Lodz, Poland	07/2016
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Planungsbüro Waidhas GmbH, Chemnitz	07/2016
EEB Enerko, Aldershoven	07/2016
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	07/2016
SSP Kälteplaner AG, Wolfertschwenden	07/2016
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	07/2016
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
Universidad Carlos III de Madrid, Madrid, Spain	04/2016
INWAT, Lodzi, Poland	04/2016
Planungsbüro WAIDHAS GmbH, Chemnitz	04/2016
STEAG Energy Services GmbH, Laszlo Küppers, Zwingenberg	03/2016
WULFF & UMAG Energy Solutions GmbH, Husum	03/2016
FH Bielefeld, Bielefeld	03/2016
EWT Eckert Wassertechnik GmbH, Celle	03/2016
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016, 06/2016 (2x)
IEV KEMA - DNV GV – Energie, Dresden	02/2016
Allborg University, Department of Energie, Aalborg, Denmark	02/2016
G.A.M. Heat GmbH, Gräfenhainichen	02/2016
Institut für Luft- und Kältetechnik, Dresden	02/2016, 05/2016, 06/2016
Bosch, Stuttgart	02/2016
INL Idaho National Laboratory, Idaho, USA	11/2016, 01/2016
Friedl ID, Wien, Austria	01/2016
Technical University of Dresden, Dresden	01/2016

2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	12/2015
Allborg University, Department of Energie, Aalborg, Denmark	12/2015
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Universidad Carlos III de Madrid, Madrid, Spain	11/2015
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Bosch, Lohmar	10/2015
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2013

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2011

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GMVA, Oberhausen	11/2011
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	10/2011
PLANAIR, La Sagne, Switzerland	10/2011
LAWI, Dresden	10/2011
Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011

Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011 10/2011
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INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
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Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
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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
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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
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WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
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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
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RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010
Universitaet der Bundeswehr, Munich	04/2010

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

2009

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

Technical University of Berlin	06/2009
Fraunhofer Institut UMSICHT, Oberhausen	07/2009
Bischoff, Aurich	07/2009
Fichtner IT Consulting, Stuttgart	07/2009
Techsoft, Linz, Austria	08/2009
DLR, Stuttgart	08/2009
Wienstrom, Vienna, Austria	08/2009
RWTH Aachen University	09/2009
Vattenfall, Hamburg	10/2009
AIC, Chemnitz	10/2009
Midiplan, Bietigheim-Bissingen	11/2009
Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
FZD, Rossendorf	11/2009
Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
EC, Heidelberg	11/2009
MCI, Innsbruck, Austria	12/2009
Saacke, Bremen	12/2009
ENERKO, Aldenhoven	12/2009

2008

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

Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008
Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
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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
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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
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BEG Bremerhavener Entsorgungsgesellschaft	02/2006
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University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006
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Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
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Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
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Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
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Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
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2005

TUEV Nord, Hannover	01/2005
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FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
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Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
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Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
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Dumas Verfahrenstechnik, Hofheim	06/2005
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Stadtwerke Leipzig	07/2005
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Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
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MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
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Freudenberg Service, Weinheim	12/2004

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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
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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
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Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
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h s energieanlagen, Freising	09/2001
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DVO Data Processing Service, Oberhausen	05/2000
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VAUP Process Automation, Landau	08/2000
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Compania Electrica, Bogota, Colombia	10/2000
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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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SCA Hygiene Products, Munich	10/1998
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