KCE
ThermoFluidProperties

Property Library for Ammonia-Water Mixtures

FluidMAT with LibAmWa for Mathcad®

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Software for the Calculation of the Properties of Ammonia-Water Mixtures

FluidMAT
LibAmWa

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0 Package Contents

Zip-file "CD_FluidMAT_LibAmWa.zip" includes the following files:

FluidMAT_LibAmWa_Setup.exe	- Self-extracting and self-installing program
LibAmWa.dll	- DLL with functions of the LibAmWa library
FluidMAT_LibAmWa_Docu.pdf	- User's Guide

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 FluidMAT in Mathcad®

FluidMAT has been developed to calculate thermodynamic properties in Mathcad® more conveniently. Within Mathcad, it enables the direct call of functions relating to ammonia-water mixtures from the LibAmWa property library.

2.1 Installing FluidMAT

This section describes the installation of FluidMAT 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_FluidMAT_LibAmWa_Eng.zip", you will see the folder

CD_FluidMAT_LibAmWa_Eng

in your Windows Explorer®, Norton Commander® etc.

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

Within this folder you will see the following files:

LibAmWa_Users_Guide.pdf
FluidMAT_LibAmWa_Setup.exe.

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

FluidMAT_LibAmWa_Setup.exe.

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

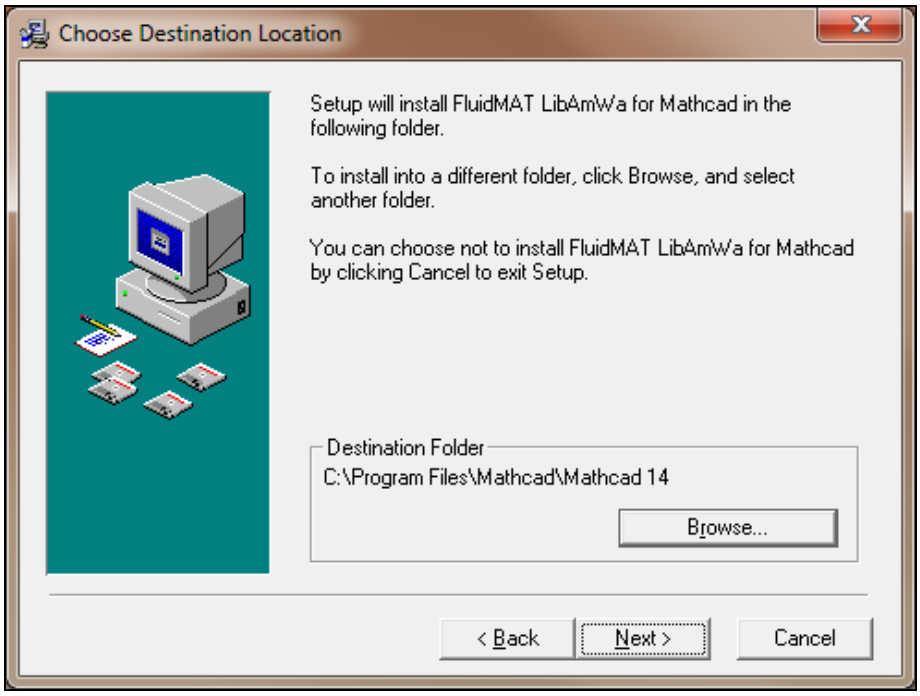
When this is the case, the installation can be continued. Click the "Next >" button.

The Read-Me file window will give you information about the FluidMAT product. Click "Next >" to leave this window.

In the following dialog box, "Choose Destination Location" (see Figure 2.1), the default path where Mathcad® has been installed will be shown:

C:\Program Files\Mathcad\Mathcad 14\ (for English version of Windows)
C:\Programme\Mathcad\Mathcad 14\ (for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation.



The path will be displayed in the window.

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

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

After FluidMAT LibAmWa has been installed, the sentence "FluidMAT LibAmWa has been successfully installed" will be shown.

Confirm this by clicking the "Finish >" button.

During the installation process the following files are copied into the chosen destination folder (the same folder where Mathcad® was initially installed in):

advapi32.dll	Dynamic link library for use in Windows® programs
Dforrt.dll	Dynamic link library for use in Windows programs
Dformd.dll	Dynamic link library for use in Windows programs
LC.dll	Dynamic link library for use in Windows programs
LibAmWa.dll	Property library for ammonia-water mixtures
msvcp60.dll	Dynamic link library for use in Windows programs
Msvcrt.dll	Dynamic link library for use in Windows programs
Readme.txt	ReadMe file
INSTALL_MAT_LibAmWa.LOG	Installation log-file

The following files were installed into your Mathcad® subdirectory \userEFI:

MAT_LibAmWa.dll	Function definition of LibAmWa

The following files were installed into your Mathcad® subdirectory \doc\funcdoc:

MAT_LibAmWa_DE.xml	Function registration in the dialog window "Insert Function" for LibAmWa (German Mathcad version 12 or higher)
MAT_LibAmWa_EN.xml	Function registration in the dialog window "Insert Function" for LibAmWa (English Mathcad version 12 or higher)
MAT_LibAmWa.xml	Function registration in the dialog window "Insert Function" for LibAmWa (Mathcad version 11 or lower)

Now, you have to overwrite the file "LibAmWa.dll" in your Mathcad directory with the file of the same name provided in your CD folder with FluidMAT.
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 Mathcad directory (the standard being

C:\Program Files\Mathcad\Mathcad 14 (for English version of Windows)

C:\Programme\Mathcad\Mathcad 14 (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.

From within Mathcad you can now select the FluidMAT LibAmWa property functions.

2.2 Licensing the LibAmWa Property Library

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

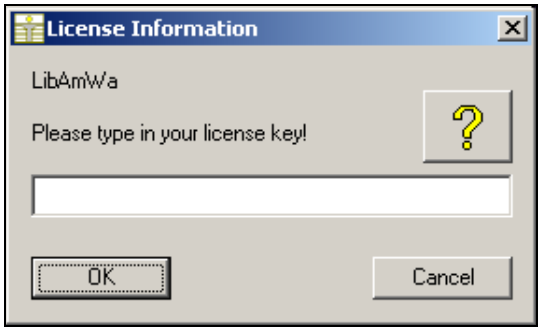


Figure 2.2: "License Information" window

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

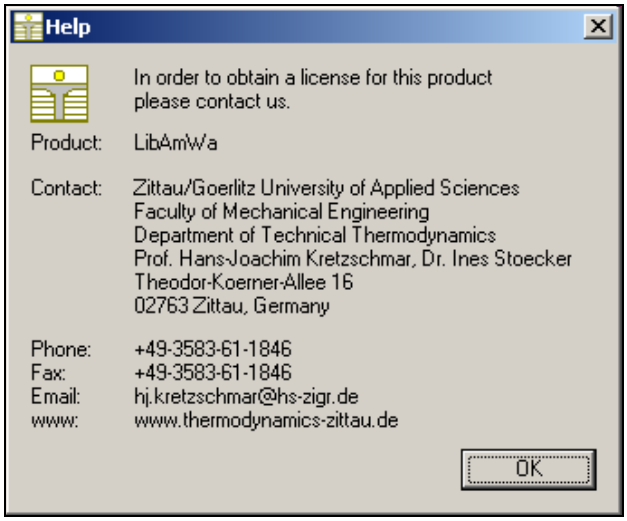


Figure 2.3: "Help" window

If you do not enter a valid license it is still possible to use Mathcad 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 FluidMAT LibAmWa until you enter a license code to complete registration. If you decide not to use FluidMAT LibAmWa, you can uninstall the program following the instructions given in section 2.4 of this User's Guide.

2.3 Example: Calculation of the Enthalpy $h = f(p,t,\xi)$ for Ammonia-Water Mixtures

Now, we will calculate, step by step, the specific enthalpy *h* as a function of pressure *p*, temperature *t* and mass fraction of water ξ for an ammonia-water mixture, using Mathcad.

Please carry out the following instructions:

- Start Mathcad®.
- Type "p:" and enter the value for the pressure *p* in bar.
  (Range of validity: p = 0.1 bar ... 400 bar)
  e. g.: Enter "p:1", then press the tabulator key and enter "in bar".

Note:

When typing in the comment containing the unit of the input parameter, Mathcad switches into the text mode, since you type in a space using the space bar, e.g. "in<space>bar". The text modus is marked by a red cursor instead of a blue one in the math mode. After typing a comment, always finish by positioning the mouse pointer below the variable typed in before and clicking the left mouse button to switch back to math mode.

- Type "t:" and enter the value for temperature *t* in °C
  (Range of validity: $t = t_{tr}(\xi) \ldots 2\, t_c(\xi)$)
  ⇒ e.g.: Enter "t:25", then press the tabulator key and enter "in °C".
- Type "x:" and enter the value for the vapor fraction ξ in $kg_{water}/kg_{mixture}$.
  (Range of validity: ξ = 0.0 kg NH_3/kg ... 1.0 kg NH_3/kg)
  ⇒ e.g.: Enter "xi:0.6", then press the tabulator key and enter "in kg/kg".
- Confirm your entry by pressing the "ENTER" key.
- Your Mathcad calculation window should like the following figure:

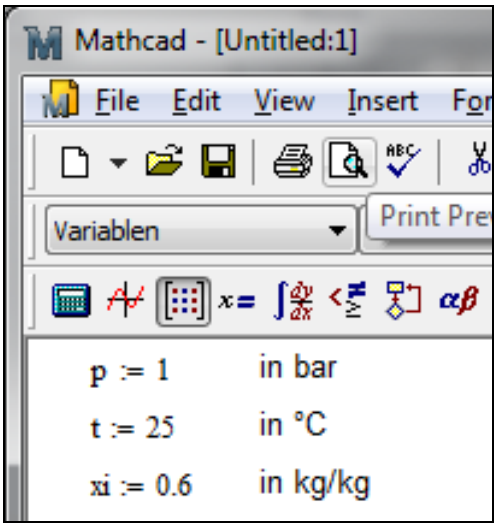


Figure 2.4: Example Mathcad® sheet after input of the given parameters

Now, type "h:" in the Mathcad window. Now, you will see **h : =** ■ .

- Click on "Insert" in the upper menu bar and then click "Function…". Now, the "Insert function" window appears (see next figure).

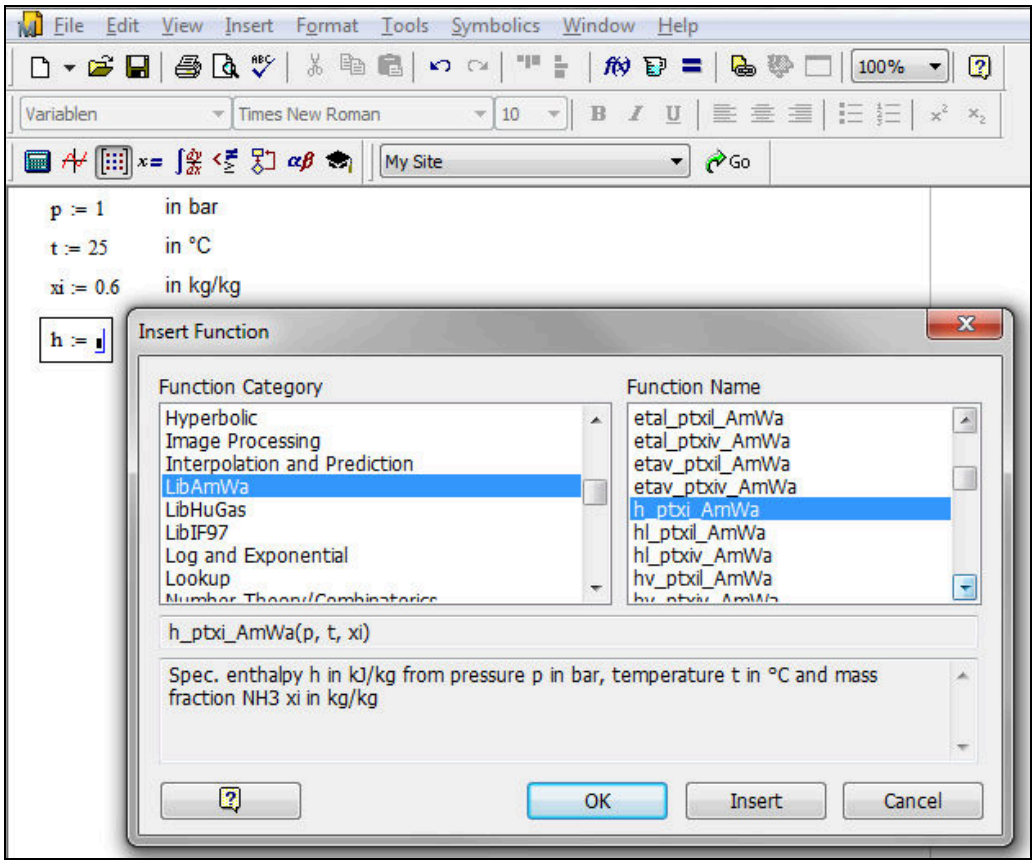


Figure 2.5: Choice of library and function name

- Now, click "OK" and you will see **h : = h_ptxi_AmWa(■ , ■ , ■)** in the Mathcad window (see next figure).

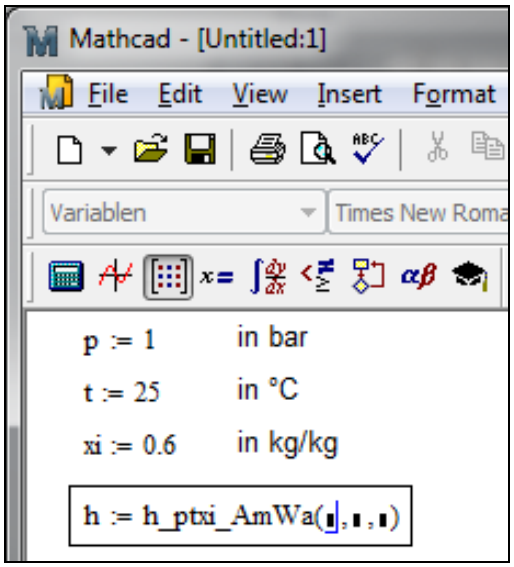


Figure 2.6: Example Mathcad® sheet with formula and placeholders

- The cursor is situated behind the first operand. You can now enter the value for *p* either by entering the value directly or by entering the name of the variable where the value was saved.

  ⇒ e.g.: Enter "p" because this property function works with this value only.

- Situate the cursor behind the next placeholder. You can now enter the value for the temperature *t* either by entering the value for *t* directly or by typing the name of the variable in which the value of the temperature has been saved.

  ⇒ e.g.: Enter "t" because this property function works with this value only.

- Situate the cursor behind the next placeholder. You can now enter the value for the vapor fraction ξ either by entering the value for ξ directly or by typing the name of the variable in which the value of the vapor fraction has been saved.

  ⇒ e.g.: Enter "xi" because this property function works with this value only.

- Now, enter the unit of the enthalpy *h* after the brackets, by typing "*kJ/kg"
- Close the input formula by pressing the "Enter"-Key.
- Your Mathcad calculation window should like the following figure:

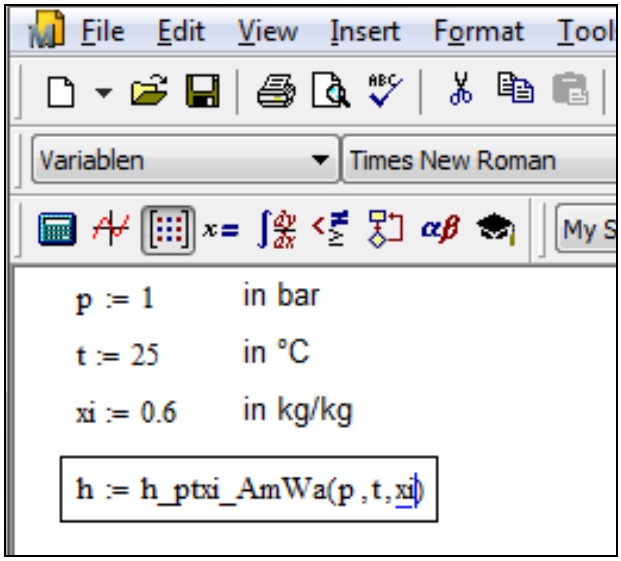


Figure 2.7: Example Mathcad® sheet with inserted variables

- You can now go on working with the variable *h* which we have just calculated, or you can have the result for this calculated. If you wish to see the result, type the command **"h="** on the next line in the Mathcad® window
- The result for *h* in kJ/kg_a appears. To add the unit, press the tabulator button twice and enter "in kJ/kg".

⇒ The result in our sample calculation here is: h = 45.487 kJ/kg.

The representation of the result depends on the amount of places and decimal places which you have set before. In the next figure you can see that we have chosen the amount of three decimal places, an exponential threshold of four and the unit of the enthalpy has been entered by typing "*kJ/kg" behind the result.

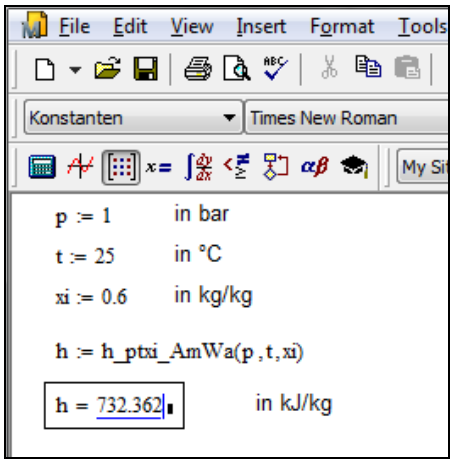


Figure 2.8: Example Mathcad® sheet with finished calculation

2.4 Example: Calculation of the Enthalpy of a Saturated Liquid $h^l = f(p,t,\xi^d)$ for Ammonia-Water Mixtures

Now we will calculate, step by step, the specific enthalpy of a saturated liquid h^l as a function of vapor pressure p, temperature t and mass fraction of water in a saturated liquid ξ^d, using FluidMAT. To do this, you have to carry out the following steps:

- Start Mathcad®.
- Type "p:" and enter the value for pressure p in bar.
  (Range of validity: p = 0.1 bar ... 400 bar)
  ⇒ e.g.: Enter "p:10", then press the tabulator button and enter "in bar".

Note:

When typing in the comment containing the unit of the input parameter, Mathcad switches into the text mode, since you type in a space using the space bar, e.g. "in<space>kPa". The text modus is marked by a red cursor instead of a blue one in the math mode. After typing a comment, always finish by positioning the mouse pointer below the variable typed in before and clicking the left mouse button to switch back to math mode.

- Type "t:" and the value for the temperature t in °C.
  For calculating the specific enthalpy of the saturated liquid it suffices to define two parameters (either t and ξ^l or p and ξ^l or p and t). It is necessary to enter -1000 as a pro-forma value for the parameter which is not defined. In case p, t, and ξ^l are entered, the program tests whether p, t, and ξ^l. fulfill the vapor pressure curve. If this is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.
  Possible input variants: $h^l = f(-1000, t_s, \xi^l)$
  $h^l = f(p_s, -1000, \xi^l)$
  $h^l = f(p_s, t_s, -1000)$
  $h^l = f(p_s, t_s, \xi^l)$
  (Range of validity: $t = t_{tr}(\xi) \ldots 2\, t_c(\xi)$)

We are using the input variant $h^l = f(p_s, -1000, \xi^g)$ in this example. You therefore have to enter the value "t:−1000" for the second operand.

⇒ e.g.: Enter "t:-1000", then press the tabulator button and enter "in °C".

- Type "xi:" and enter the value for the vapor fraction ξ in $kg_{water}/ kg_{mixture}$.
  (Range of validity: ξ^g = 0.0 kg NH_3/kg ... 1.0 kg NH_3/kg)
  ⇒ e.g.: Enter "xi:0.5", then press the tabulator button and enter "in kg/kg".
- Confirm your entry by pressing the "ENTER" key.
- Your Mathcad calculation window should like the following figure:

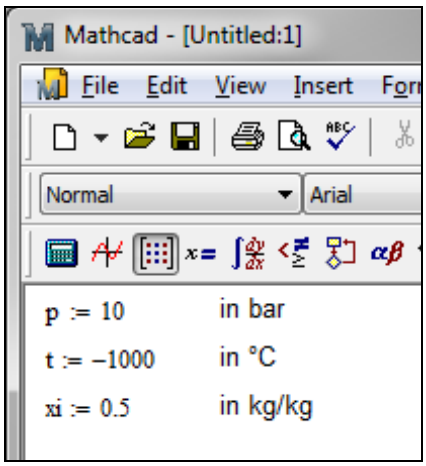


Figure 2.9: Example Mathcad® sheet after input of the given parameters

- Enter the symbol **hl** for the result and then a colon. Now, you will see **hl : =** ■ .
- Click "Insert" in the Mathcad® menu bar and then "Function…"
  The "Insert function" window appears (see Figure 2.10)
- Click "LibAmWa" under "Function Category" on the left hand side (see Figure 2.10)
- Chose "hl_ptxil_AmWa" under "Function Name" on the right hand side of the window.
  The function category and the function name will be inverted, highlighted and furthermore the description of the function and the measuring units of the variables are shown.

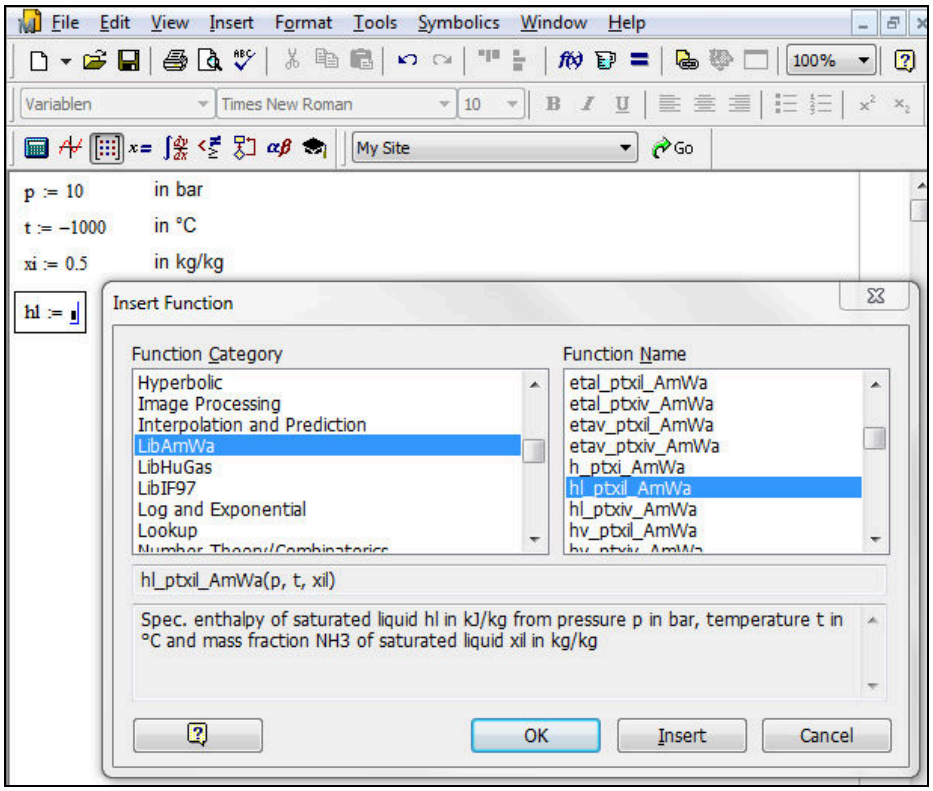


Figure 2.10: Choice of library and function name

- Click the "OK" button
- Now you will see the line **hl : = hl_ptxil_AmWa(■ , ■ , ■)** in the Mathcad window (see next figure).

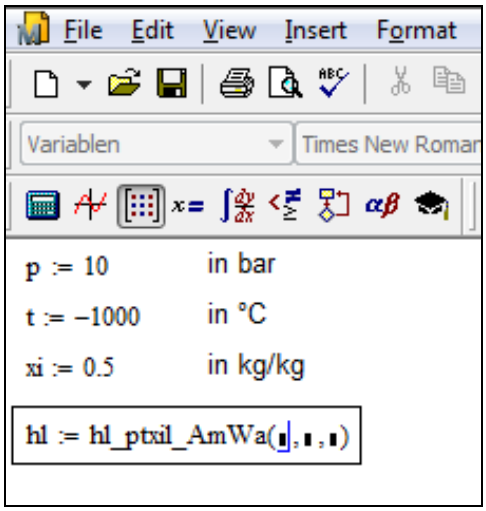


Figure 2.11: Example Mathcad® sheet with formula and placeholders

- The cursor is now situated on the first operand. You can now enter the value for *p* either by entering the value directly or by entering the name of the variable where the value was saved.

  ⇒ e.g.: Enter "p".
- Situate the cursor on the next placeholder. You can now enter the value for the temperature *t* either by entering the value for *t* directly or by typing the name of the variable in which the value of the temperature has been saved.

⇒ e.g.: Enter "t".

- Situate the cursor on the next placeholder. You can now enter the value for the vapor fraction ξ either by entering the value for ξ directly or by typing the name of the variable in which the value of the vapor fraction has been saved.

  ⇒ e.g.: Enter "xi".

- Close the input formula by pressing the "Enter" key.
- You can now go on working with the variable *hl* which we have just calculated, or you can have the result for this calculated. If you wish to see the result, type the command **"hl="** on the next line in the Mathcad® window
- The result for *hl* in kJ/kg appears. To add the unit, press the tabulator button and enter "in kJ/kg".

  You will now see the result hl = 208.919 in kJ/kg.

The representation of the result depends on the amount of places and decimal places which you have set before. In the next figure you can see that we have chosen the amount of three decimal places, an exponential threshold of four and the unit of the enthalpy has been entered by typing "*kJ/kg" behind the result.

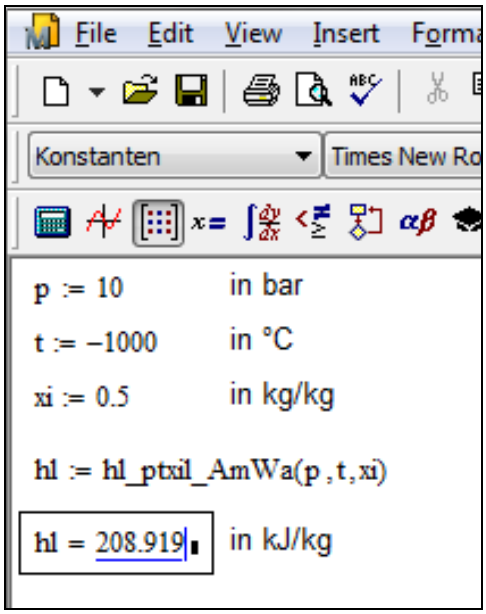


Figure 2.12: Example Mathcad® sheet with finished calculation

2.4 Removing FluidMAT

To remove FluidMAT LibAmWa from Mathcad® and your hard drive, carry out the following steps:

- Click the "Start" button in the Windows® task bar
- Click "Settings"
- Click "Control Panel"
- Double click "Add or Remove Programs"
- Click on "FluidMAT LibAmWa" in the list box
- Click the "Add or Remove" button
- Mark "Automatic" and click the "Next >" button
- Click "Finish" in the "Perform Uninstall" window

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

Now FluidMAT LibAmWa has been removed.

3. Program Documentation

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

Function Name: **a_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Thermal Diffusivity a' = f(p,t,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,ξ'')

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,ξ'')

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

Function Name: **cpv_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on input types

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

Input types possible:

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

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

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

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **cv_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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,ξ')

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 $t > t_c(\xi_v)$

ξ_v > 1.0 kg/kg or ξ_v < 0.0 kg/kg

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

Dynamic Viscosity η = f(p,t,ξ)

Function Name: **eta_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **ETAPTXIAMWA = -1000** or **eta_ptxi_AmWa = -1000** is valid for the following input values:

p > 400 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

Dynamic Viscosity η' = f(p,t,ξ')

Function Name: **etal_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH_3) / (kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

ξ' > 1.0 kg/kg or ξ' < 0.0 kg/kg

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

Dynamic Viscosity η' = f(p,t,ξ'')

Function Name: **etal_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

ξ" > 1.0 kg/kg or ξ" < 0.0 kg/kg

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

Dynamic Viscosity η'' = f(p,t,ξ')

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

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 **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 λ' = f(p,t,ξ'')

Function Name: **lambdal_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

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

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

Thermal Conductivity λ'' = f(p,t,ξ')

Function Name: **lambdav_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **LAMBDAVPTXILAMWA = -1000** or **lambdav_ptxil_AmWa = -1000** is valid for the following input values:

p > 400 bar or p < 0.1 bar or

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

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

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

Thermal Conductivity λ'' = f(p,t,ξ'')

Function Name: **lambdav_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **LAMBDAVPTXIVAMWA = -1000** or **lambdav_ptxiv_AmWa = -1000** is valid for the following input values:

p > 400 bar or p < 0.1 bar or

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

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

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

Kinematic Viscosity ν = f(p,t,ξ)

Function Name: **nue_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

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

Function Name: **nuel_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

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

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

Kinematic Viscosity ν' = f(p,t,ξ'')

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 ν'' = f(p,t,ξ')

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,ξ'')

Function Name: **Prl_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

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

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

PRANDTL-Number Pr'' = f(p,t,ξ')

Function Name: **Prv_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

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

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

PRANDTL-Number Pr'' = f(p,t,ξ'')

Function Name: **Prv_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

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

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

Phase Region Region = f(p,t,ξ)

Function Name: **region_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH_3)/(kg mixture)

Output value

REGPTXIAMWA or **region_ptxi_AmWa -** Phase region

Range of validity

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

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

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 **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, ξ'')

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,ξ)

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,ξ)

Function Name: **w_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

p > 400 bar or p < 0.1 bar or

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

ξ > 1.0 kg/kg or ξ < 0.0 kg/kg

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

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

Function Name: **wl_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction in saturated liquid ξ' in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on input types

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

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

Results for wrong input values

The result **WLPTXILAMWA = -1000** or **wl_ptxil_AmWa = -1000** is valid for values which range from:

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

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

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

Function Name: **wl_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on input types

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

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

Results for wrong input values

The result **WLPTXIVAMWA = -1000** or **wl_ptxiv_AmWa = -1000** is valid for values which range from:

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

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

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

Function Name: **wv_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XIL - Ammonia mass fraction of saturated liquid ξ' in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on input types

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

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

Results for wrong input values

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

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

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

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

Function Name: **wv_ptxiv_AmWa**

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

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on input types

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

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

Results for wrong input values

The result **WVPTXIVAMWA = -1000** or **wv_ptxiv_AmWa = -1000** is valid for values which range from:

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

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

Vapor Fraction x_δ = f(p,t,ξ)

Function Name: **xd_ptxi_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

XI - Ammonia mass fraction ξ in (kg NH_3)/(kg mixture)

Output value

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

Range of validity

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

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 $t_{c,NH_3} = 132.25$°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)

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

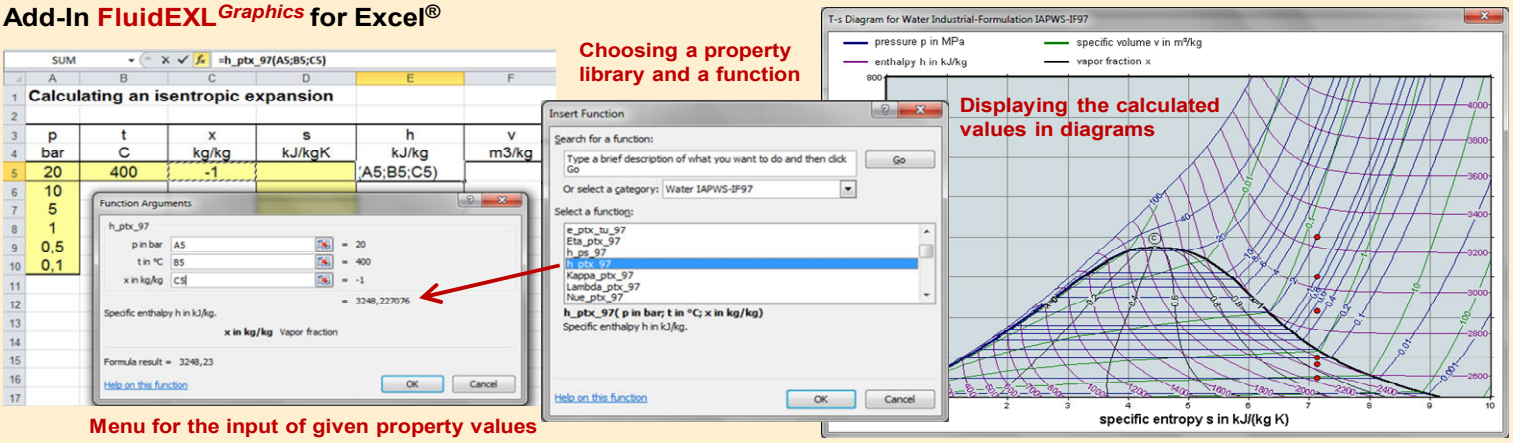
- Partial derivatives can be calculated.

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

KCE-ThermoFluidProperties
www.thermofluidprop.com

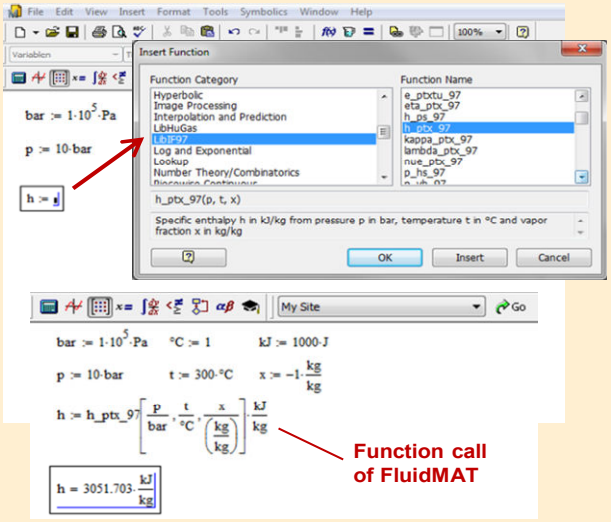
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



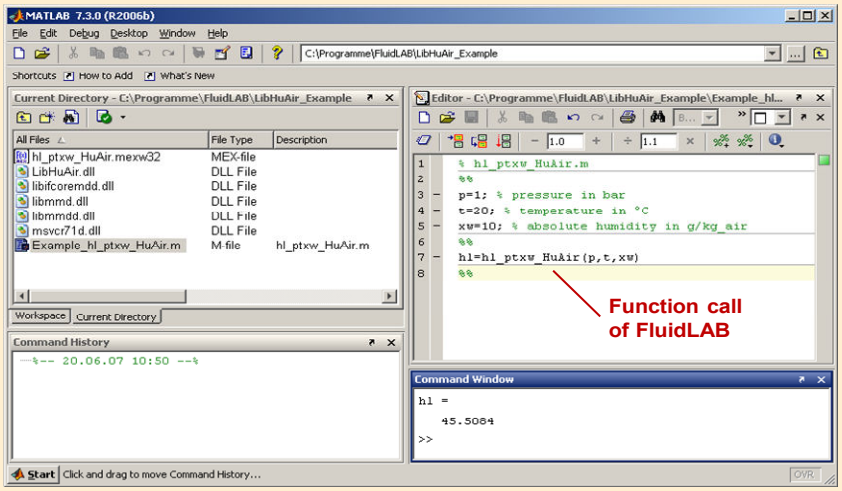
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



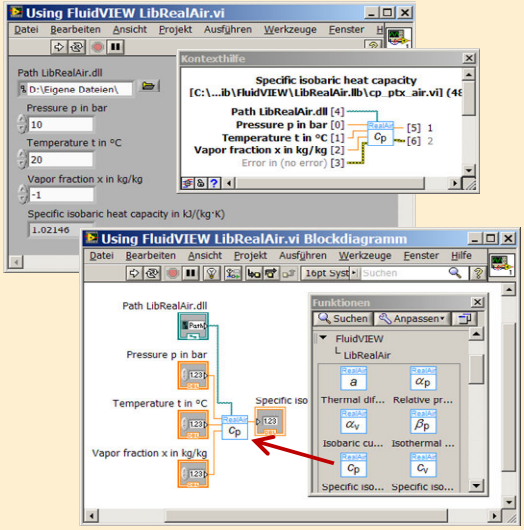
Add-In FluidLAB for MATLAB®

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



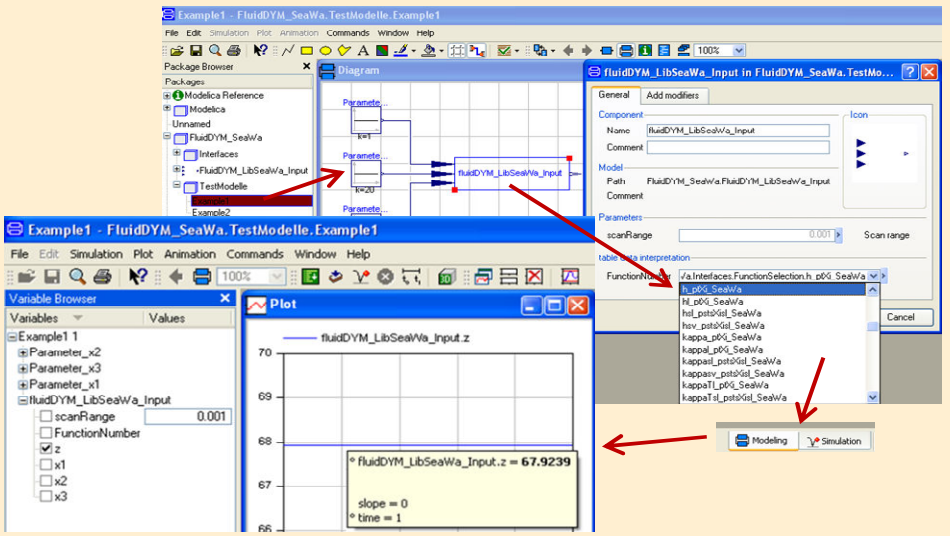
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

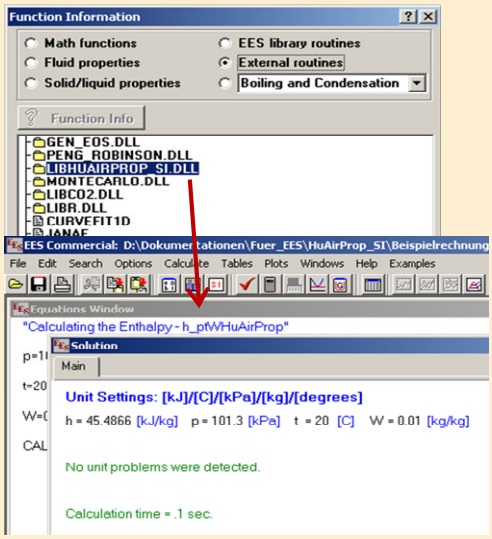


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

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

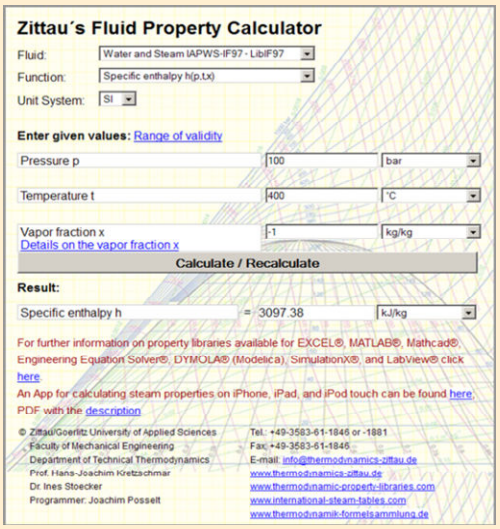


Add-In FluidEES for Engineering Equation Solver®



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

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives can be calculated.

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

www.thermofluidprop.com

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6. Satisfied Customers

Date: 07/2019

The following companies and institutions use the property libraries:

- FluidEXL*Graphics* for Excel®
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- FluidMAT for Mathcad®
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2019

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

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

2018

Jaguar Energy, Guatemala	12/2018
WEBASTO, Gilching	12/2018
Smurfit Kappa, Oosterhout, Netherlands	12/2018
Univ. BW München	12/2018
RAIV, Liberec for VALEO, Prague, Czech Republic	11/2018
VPC Group Vetschau	11/2018
SEITZ, Wetzikon, Switzerland	11/2018
MVV, Mannheim	10/2018
IB Troche	10/2018
KANIS Turbinen, Nürnberg	10/2018
TH Ingolstadt, Institut für neue Energiesysteme	10/2018
IB Kristl & Seibt, Graz, Austria	09/2018
INEOS, Köln	09/2018
IB Lücke, Paderborn	09/2018
Südzucker, Ochsenfurt	08/2018
K&K Turbinenservice, Bielefeld	07/2018
OTH Regensburg, Elektrotechnik	07/2018
Comparex Leipzig for LEAG, Berlin	06/2018
Münstermann, Telgte	05/2018
TH Nürnberg, Verfahrenstechnik	05/2018
Universität Madrid, Madrid, Spanien	05/2018
HS Zittau/Görlitz, Wirtschaftswissenschaften und Wirtschaftsingenieurwesen	05/2018
HS Niederrhein, Krefeld	05/2018
Wilhelm-Büchner HS, Pfungstadt	03/2018
GRS, Köln	03/2018
WIB, Dennheritz	03/2018
RONAL AG, 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
Pöyry Deutschland GmbH, Dresden	09/2016
Siemens AG, Erlangen	09/2016
BASF über Fichtner IT Consulting AG	09/2016
B+B Engineering GmbH, Magdeburg	09/2016
Wilhelm Büchner Hochschule, Pfungstadt	08/2016

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

2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	12/2015
Allborg University, Department of Energie, Aalborg, Denmark	12/2015
University of Lyubljana, Slovenia	12/2015
Steinbrecht IB, Berlin	11/2015
Universidad Carlos III de Madrid, Madrid, Spain	11/2015
STEAK, Essen	11/2015
Bosch, Lohmar	10/2015
Team Turbo Machines, Rouen, France	09/2015
BTC – Business Technology Consulting AG, Oldenburg	07/2015
KIT Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen	07/2015
ILK, Dresden	07/2015
Schniewindt GmbH & Co. KG, Neuenwalde	08/2015

2014

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

2013

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

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

2012

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

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

2011

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

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

2010

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

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

2009

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

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

2008

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

2007

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

2006

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

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

2005

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

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

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

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

2003

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

2002

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

SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe	02/2002
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CompAir, Simmern	03/2002
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
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SoftSolutions, Muehlhausen (company license)	05/2002
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Fichtner Consulting & IT, Stuttgart	08/2002
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Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
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Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel	12/2002
(general license and training test benches)	
VEAG, Berlin (group license)	12/2002

2001

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

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ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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

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

1998

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

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

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