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Zittau/Görlitz**

UNIVERSITY OF APPLIED SCIENCES

**Faculty of
MECHANICAL ENGINEERING**

**Department of
TECHNICAL THERMODYNAMICS**

Property Library for Ammonia-Water Mixtures

**FluidMAT
with LibAmWa
for Mathcad®**

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Property Library for the Calculation of the Properties of Ammonia-Water Mixtures

LibAmWa FluidMAT for Mathcad®

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0 Package Contents

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

FluidMAT_LibAmWa_Setup.exe	Self-extracting installation program
FluidMAT_LibAmWa_Docu_Eng.pdf	User's Guide
LibAmWa.dll	DLL including functions of the Ammonia-Water library

1 Property Functions

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

Functional Dependence	Function Name	Call in Fortran	Property or Function	Unit
$h' = f(p, t, \xi'')$	hl_ptxiv_AmWa	HLPTXIVAMWA(P,T,XIV)	Specific enthalpy of saturated liquid	kJ/kg
$h'' = f(p, t, \xi')$	hv_ptxil_AmWa	HVPTXILAMWA(P,T,XIL)	Specific enthalpy of saturated vapor	kJ/kg
$h'' = f(p, t, \xi'')$	hv_ptxiv_AmWa	HVPTXIVAMWA(P,T,XIV)	Specific enthalpy of saturated vapor	kJ/kg
$p = f(h, s, \xi)$	p_hsxi_AmWa	PHSXIAMWA(H,S,XI)	Backward function: Pressure from enthalpy, entropy, and NH ₃ mass fraction	kg/kg
$p = f(t, \xi, x_\delta)$	p_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	-
$\text{region} = f(p, h, \xi)$	region_phxi_AmWa	REGPHXIAMWA(P,H,XI)	Phase region from pressure, enthalpy, and NH ₃ mass fraction	-
$\text{region} = f(p, s, \xi)$	region_psexi_AmWa	REGPSXIAMWA(P,S,XI)	Phase region from pressure, entropy, and NH ₃ mass fraction	-
$\text{region} = f(p, t, \xi)$	region_ptxi_AmWa	REGPTXIAMWA(P,T,XI)	Phase region from pressure, temperature, and NH ₃ mass fraction	-
$\text{region} = f(h, s, \xi)$	region_hsxi_AmWa	REGHSXIAMWA(H,S,XI)	Phase region from enthalpy, entropy, and NH ₃ mass fraction	-
$s = f(p, t, \xi)$	s_ptxi_AmWa	SPTXIAMWA(P,T,XI)	Specific entropy	kJ/(kg K)
$s' = f(p, t, \xi')$	sl_ptxil_AmWa	SLPTXILAMWA(P,T,XIL)	Specific entropy of saturated liquid	kJ/(kg K)
$s' = f(p, t, \xi'')$	sl_ptxiv_AmWa	SLPTXIVAMWA(P,T,XIV)	Specific entropy of saturated liquid	kJ/(kg K)
$s'' = f(p, t, \xi')$	sv_ptxil_AmWa	SVPTXILAMWA(P,T,XIL)	Specific entropy of saturated vapor	kJ/(kg K)
$s'' = f(p, t, \xi'')$	sv_ptxiv_AmWa	SVPTXIVAMWA(P,T,XIV)	Specific entropy of saturated vapor	kJ/(kg K)
$\sigma_l = f(t, \xi')$	sigmaL_txil_AmWa	SIGMALTXILAMWA(T,XIL)	Surface tension of saturated liquid	mN/m

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

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

Units:

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

Details on the calculation of wet steam

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

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

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

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

Range of validity

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

Reference state

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

Note:

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

2 Application of 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.

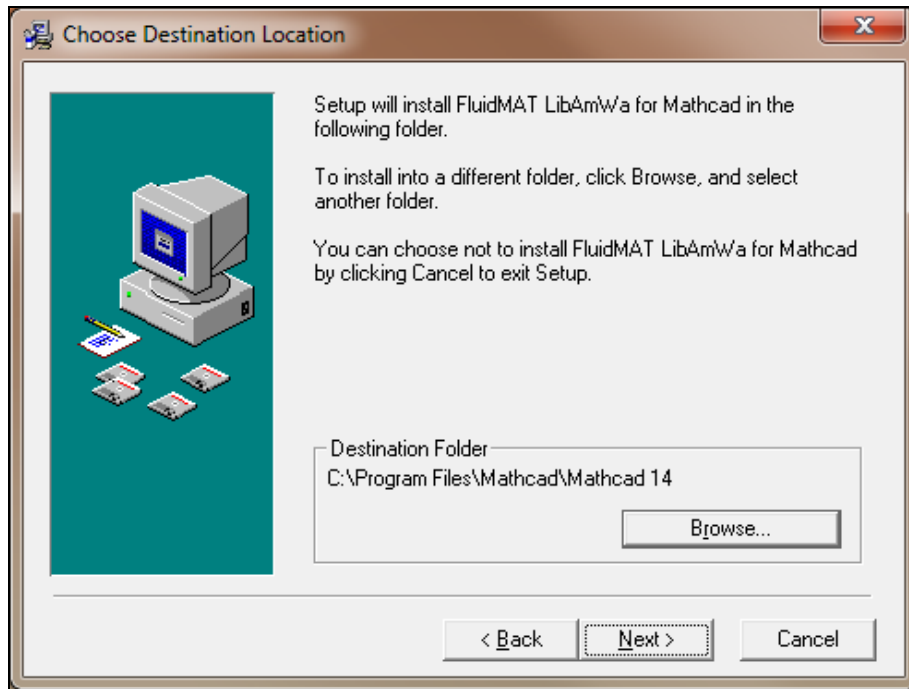
The Read-Me file window will give you information about the FluidMAT product. Click "Next >" to leave this window.

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
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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).

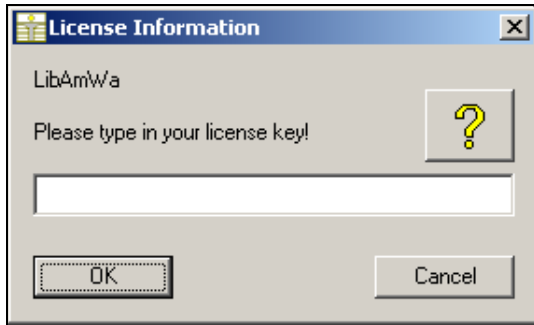


Figure 2.2: "License Information" window

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:

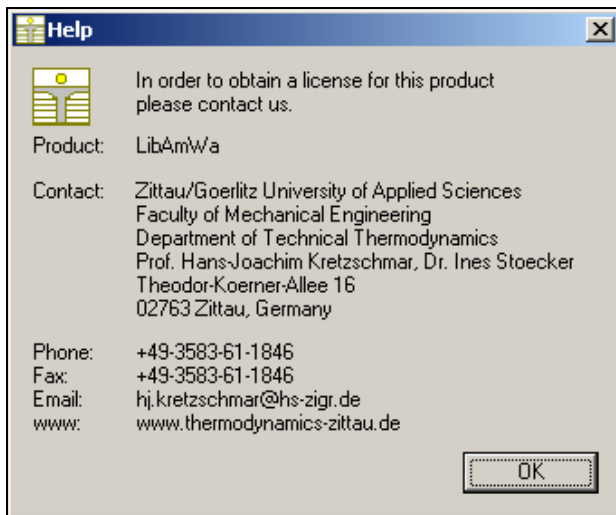


Figure 2.3: "Help" window

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: $p = 0.1 \text{ bar} \dots 400 \text{ bar}$)
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: $t = t_{tr}(\xi) \dots 2 t_c(\xi)$)
⇒ 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 $\text{kg}_{\text{water}} / \text{kg}_{\text{mixture}}$.
(Range of validity: $\xi = 0.0 \text{ kg NH}_3/\text{kg} \dots 1.0 \text{ kg NH}_3/\text{kg}$)
⇒ 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:

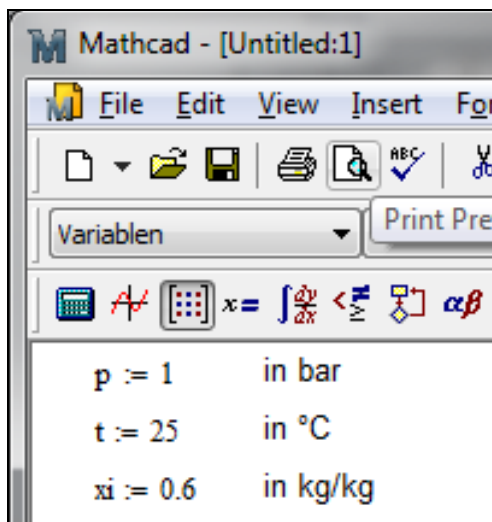


Figure 2.4: Example Mathcad® sheet after input of the given parameters

Now, type "h:" in the Mathcad window. Now, you will see $h := \blacksquare$.

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

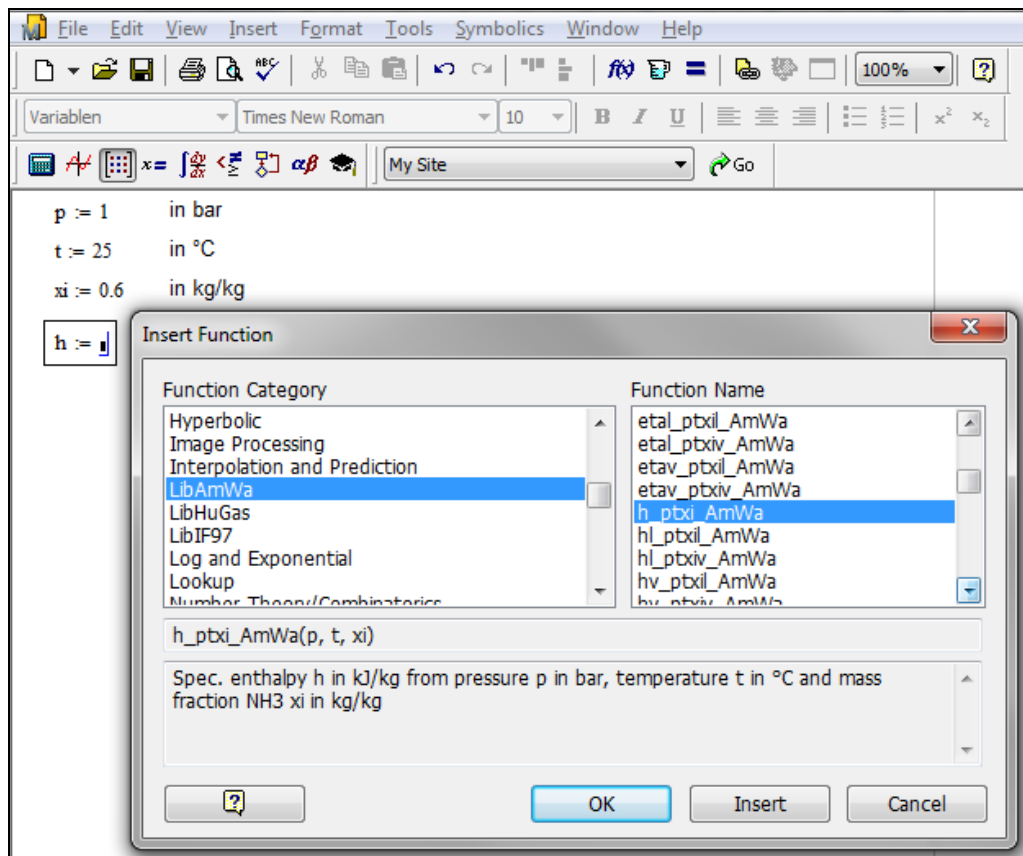


Figure 2.5: Choice of library and function name

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

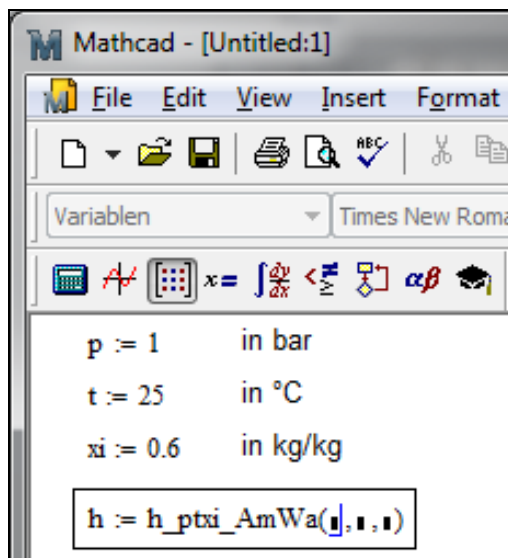


Figure 2.6: Example Mathcad® sheet with formula and placeholders

- 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:

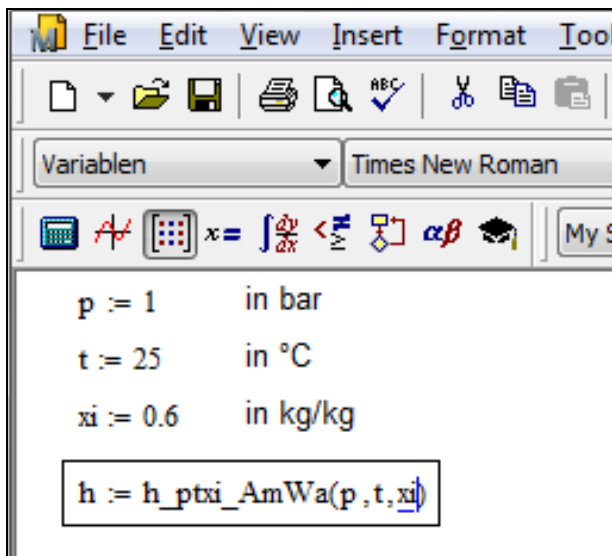


Figure 2.7: Example Mathcad[®] sheet with inserted variables

- 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.

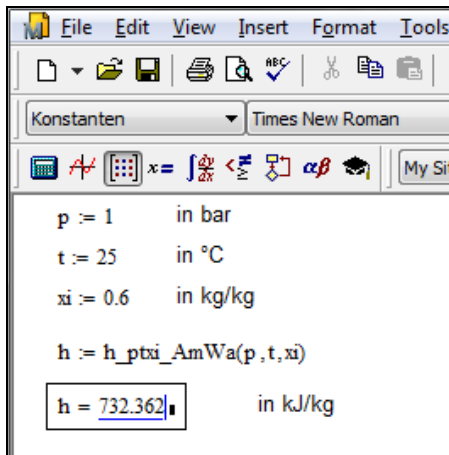


Figure 2.8: Example Mathcad® sheet with finished calculation

2.4 Example: Calculation of the Enthalpy of a Saturated Liquid $h^l = f(p, t, \xi^l)$ 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^l , 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: $p = 0.1 \text{ bar} \dots 400 \text{ bar}$)
⇒ 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 proforma 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: $t = t_{tr}(\xi) \dots 2 t_c(\xi)$)

We are using the input variant $h^l = f(p_s, -1000, \xi^l)$ 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 $\text{kg}_{\text{water}} / \text{kg}_{\text{mixture}}$.
(Range of validity: $\xi = 0.0 \text{ kg NH}_3/\text{kg} \dots 1.0 \text{ kg NH}_3/\text{kg}$)

⇒ 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:

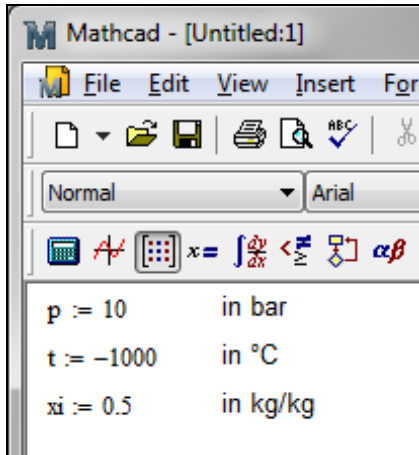


Figure 2.9: Example Mathcad® sheet after input of the given parameters

- 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.

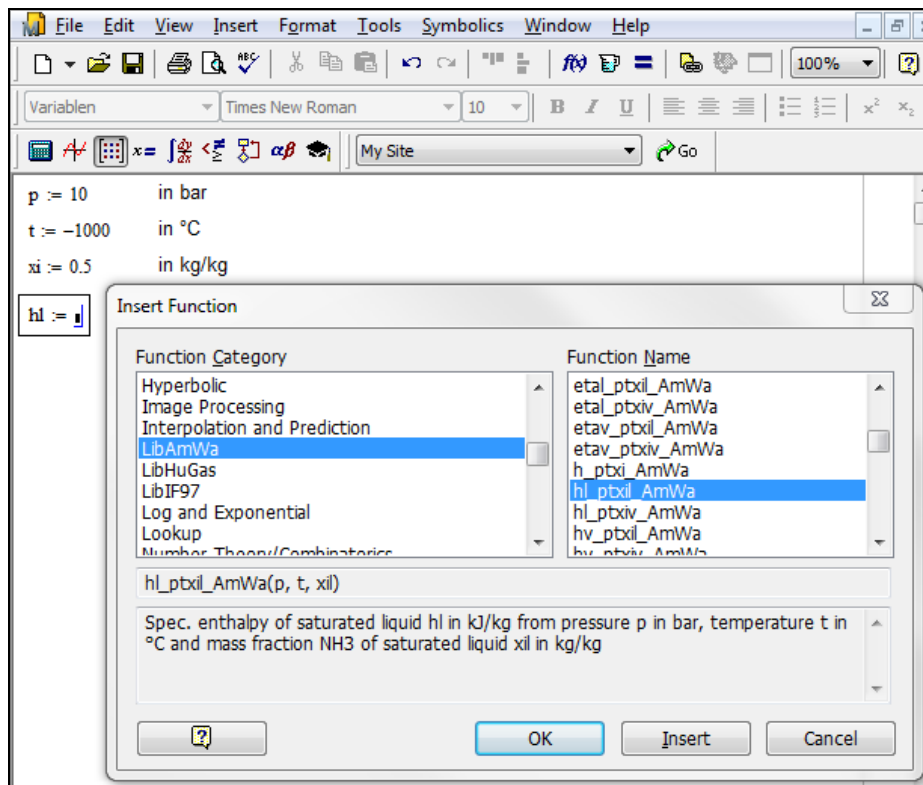


Figure 2.10: Choice of library and function name

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

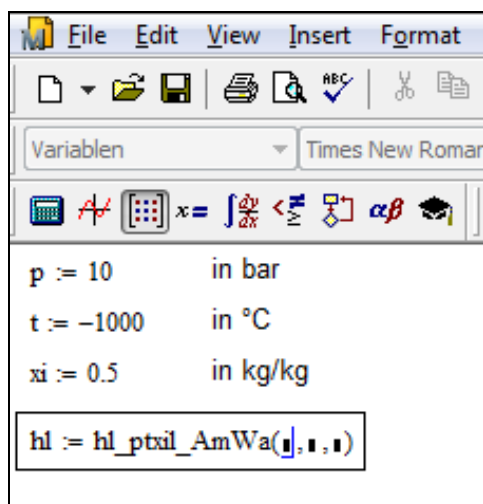


Figure 2.11: Example Mathcad® sheet with formula and placeholders

- 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 h_l 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 h_l in kJ/kg appears. To add the unit, press the tabulator button and enter "**in kJ/kg**".

You will now see the result $h_l = 208.919$ 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.

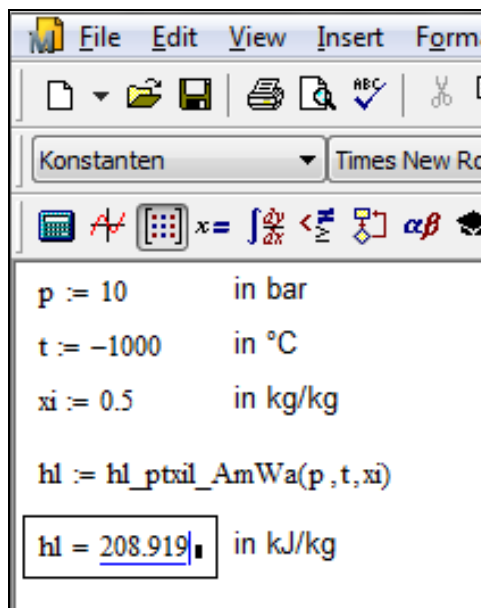


Figure 2.12: Example Mathcad® sheet with finished calculation

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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **al_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 NH₃)/(kg mixture)

Output value

ALPTXILAMWA or **al_ptxil_AmWa** - Thermal diffusivity of saturated liquid a' in m² / s

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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

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

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

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

Function Name: **al_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **av_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 NH₃)/(kg mixture)

Output value

AVPTXILAMWA or **av_ptxil_AmWa** - Thermal diffusivity of saturated vapor a'' in m²/s

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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

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

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

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

Function Name: **av_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

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

Input values

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

Output value

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

Range of validity

Temperature range: $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$
 NH₃ : $t_{tr,NH_3} = -77.655^\circ\text{C}$ H₂O : $t_{tr,H_2O} = 0.01^\circ\text{C}$
 $t_{c,NH_3} = 132.25^\circ\text{C}$ $t_{c,H_2O} = 373.946^\circ\text{C}$

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

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 NH₃)/(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 $t = t_{tr}(\xi') \dots t_c(\xi')$

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on 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:

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

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

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

Function Name: **cpv_ptxiv_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 $c_v = f(p, t, \xi)$

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 NH₃)/(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 $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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

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

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

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

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

Function Name: **cvl_ptxil_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃)/(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 $t = t_{tr}(\xi'') \dots t_c(\xi'')$

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃) / (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 $t = t_{tr}(\xi') \dots t_c(\xi')$

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃)/(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 $t = t_{tr}(\xi'') \dots t_c(\xi'')$

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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: **DI_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 NH₃)/(kg mixture)

Output value

DLTXILAMWA or **DI_txil_AmWa** - Diffusion coefficient in liquid mixture D_l in m²/s

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Results for wrong input values

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

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

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

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

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

Function Name: **etal_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

Temperature range:

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **etal_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

Temperature range:

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **etav_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

Temperature range:

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **etav_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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
 $\xi > 1.0$ 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_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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on 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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on 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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 $\lambda = f(p, t, \xi)$

Function Name: **lambda_ptxi_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

Function Name: **lambdal_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **lambdal_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **lambdav_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

Temperature range:

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **lambdav_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **LAMBDAPTIVAMWA = -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 $\nu = f(p, t, \xi)$

Function Name: **nue_ptxi_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

Function Name: **nuel_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **nuel_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **nuev_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **nuev_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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 $p_s = f(t, \xi')$

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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

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

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

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

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

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

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

Vapor Pressure $p_s = f(t, \xi'')$

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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

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

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

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

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

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

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

Backward Function: Pressure $p = f(h, s, \xi)$

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 NH₃)/(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 $t = t_{tr}(\xi) \dots 2 \cdot t_c(\xi)$

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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

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

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

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

Function Name: **p_txixd_AmWa**

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

Input values

T - Temperature t in °C

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

XD - Vapor fraction x_δ in kg/kg

Output value

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

Range of validity

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

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

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

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

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

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

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

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **Pr_ptxi_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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
- $\xi > 1.0$ kg/kg or $\xi < 0.0$ kg/kg

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

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

Function Name: **Prl_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

Temperature range:

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **Prl_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **Prv_ptxil_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

Temperature range:

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **Prv_ptxiv_AmWa**

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

Input values

P - Pressure p in bar

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

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

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

Function Name: **region_ptxi_AmWa**

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

Input values

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

Output value

REGPTXIAMWA or **region_ptxi_AmWa** - Phase region

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on the function

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

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

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

Results for wrong input values

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

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

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

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

Function Name: **region_phxi_AmWa**

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

Input values

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

Output value

REGPHXIAMWA or **region_phxi_AmWa** - Phase region

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on the function

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

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

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

Results for wrong input values

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

The enthalpy is located outside the range of validity if:

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

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

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

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

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

Function Name: **region_psi_AmWa**

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

Input values

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

Output value

REGPSXIAMWA or **region_psi_AmWa** - Phase region

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on the function

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

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

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

Results for wrong input values

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

The entropy is located outside the range of validity if:

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

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

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

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

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

Function Name: **region_hsxi_AmWa**

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

Input values

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

Output value

REGHSXIAMWA or **region_hsxi_AmWa** - Phase region

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on the function

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

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

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

Results for wrong input values

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

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

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

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

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

Function Name: **s_ptxi_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

The result **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
- $\xi > 1.0$ 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_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 NH₃)/(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 $t = t_{tr}(\xi') \dots t_c(\xi')$

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃)/(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 $t = t_{tr}(\xi'') \dots t_c(\xi'')$

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on 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 NH₃)/(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 $t = t_{tr}(\xi') \dots t_c(\xi')$

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃)/(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 $t = t_{tr}(\xi'') \dots t_c(\xi'')$

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on input types

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

Input types possible:

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

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

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

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

Results for wrong input values

The result **SVPTXIVAMWA = -1000** or **sv_ptxiv_AmWa = -1000** is valid for values which range from:

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

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

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

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

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

Function Name: **signal_txil_AmWa**

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

Input values

T - Temperature t in °C

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Results for wrong input values

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

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

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

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

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

Function Name: **ts_pxil_AmWa**

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

Input values

P - Pressure p in bar

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

Output value

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

Range of validity

Pressure range: from 0.1 bar to $p_c(\xi')$

NH₃: $p_{c,NH_3} = 113.33 \text{ bar}$ H₂O: $p_{c,H_2O} = 220.64 \text{ bar}$

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

Results for wrong input values

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

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

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

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

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

Function Name: **ts_pxiv_AmWa**

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

Input values

P - Pressure p in bar

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

Output value

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

Range of validity

Pressure range: from 0.1 bar to $p_c(\xi'')$

NH₃: $p_{c,NH_3} = 113.33 \text{ bar}$ H₂O: $p_{c,H_2O} = 220.64 \text{ bar}$

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

Results for wrong input values

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

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

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

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

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

Function Name: **t_phxi_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

The enthalpy is located outside the range of validity if:

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

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

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

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

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

Function Name: **t_pssi_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

The entropy is located outside the range of validity if:

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

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

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

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

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

Function Name: **t_pxixd_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

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

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

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

Details on wet steam

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

Results for wrong input values

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

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

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

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

Function Name: **v_ptxi_AmWa**

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

Input values

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

Output value

VPTXIAMWA or **v_ptxi_AmWa** - Specific volume v in m³/kg

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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
 $\xi > 1.0$ 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 NH₃)/(kg mixture)

Output value

VVPTXILAMWA or **vv_ptxil_AmWa** - Specific volume of saturated vapor v'' in m³/kg

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃)/(kg mixture)

Output value

VVPTXIVAMWA or **vv_ptxiv_AmWa** - Specific volume of saturated vapor v'' in m³/kg

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on input types

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

Input types possible:

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

Results for wrong input values

The result **VVPTXIVAMWA = -1000** or **vv_ptxiv_AmWa = -1000** is valid for values which range from:

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

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

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

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

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

Function Name: **w_ptxi_AmWa**

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

Input values

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

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on wet steam

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

Results for wrong input values

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

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

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

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 NH₃)/(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 $t = t_{tr}(\xi') \dots t_c(\xi')$

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on 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 NH₃)/(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 $t = t_{tr}(\xi'') \dots t_c(\xi'')$

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

Details on 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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on 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 NH₃)/(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 $t = t_{tr}(\xi'') \dots t_c(\xi'')$

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

Pressure range: from 0.1 bar to 400 bar
 Composition range: from 0.0 to 1.0 (kg NH₃)/(kg mixture)

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

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 NH₃)/(kg mixture)

Output value

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

Range of validity

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

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

Pressure range: from 0.1 bar to 400 bar

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

Details on the single-phase region

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

Results for wrong input values

The result **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
 $\xi > 1.0$ kg/kg or $\xi \leq 0.0$ kg/kg

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

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

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

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

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

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

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

Pressure range: from 0.1 bar to 400 bar

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

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

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

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

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

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

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

Function Name: **xi_ptxd_AmWa**

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

Input values

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

Output value

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

Range of validity

Pressure range:	$p_{tr}(\xi) \leq p \leq p_c(\xi)$		
Temperature range:	$t = t_{tr}(\xi) \leq t \leq t_c(\xi)$		
	NH ₃ :	$t_{tr,NH_3} = -77.655^\circ\text{C}$	H ₂ O : $t_{tr,H_2O} = 0.01^\circ\text{C}$
		$t_{c,NH_3} = 132.25^\circ\text{C}$	$t_{c,H_2O} = 373.946^\circ\text{C}$
Composition range:	from 0.0 to 1.0 (kg NH ₃)/(kg mixture)		
Vapor fraction range:	$0.0 \leq x_\delta \leq 1.0$ kg/kg		

Details on 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]



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

Water and Steam

Library LibIF97

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

Humid Combustion Gas Mixtures

Library LibHuGas

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

Humid Air

Library LibHuAir

- Model: Ideal mixture of the real fluids:
- Dry Air from Lemmon et al.
 - Steam, water and ice from IAPWS-IF97 and IAPWS-06
- Consideration of:
- Condensation and freezing of steam
 - Dissociation from the VDI 4670
 - Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Formulation 2008 of Feistel and IAPWS-IF97

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

- Model: Ideal mixture of the ideal gases:
- | | | | |
|-----------------|------------------|-----------------|------------|
| Ar | NO | He | Propylene |
| Ne | H ₂ O | F ₂ | Propane |
| N ₂ | SO ₂ | NH ₃ | Iso-Butane |
| O ₂ | H ₂ | Methane | n-Butane |
| CO | H ₂ S | Ethane | Benzene |
| CO ₂ | OH | Ethylene | Methanol |
| Air | | | |

- Consideration of:
- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

- Consideration of:
- Dissociation from the VDI Guideline 4670

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bucker et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bucker et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term (also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

C ₂ H ₆ O ₂	Ethylene glycol
C ₃ H ₈ O ₂	Propylene glycol
C ₂ H ₅ OH	Ethyl alcohol
CH ₃ OH	Methyl alcohol
C ₃ H ₈ O ₃	Glycerol
K ₂ CO ₃	Potassium carbonate
CaCl ₂	Calcium chloride
MgCl ₂	Magnesium chloride
NaCl	Sodium chloride
C ₂ H ₃ KO ₂	Potassium acetate

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

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

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

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

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC5H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide CO **Library LibCO**

Carbonyl sulfide COS **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monoxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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Fax.: +49-3583-61-1846

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

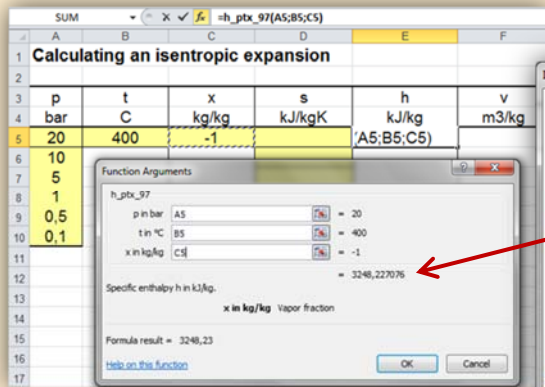
- Partial derivatives can be calculated.

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

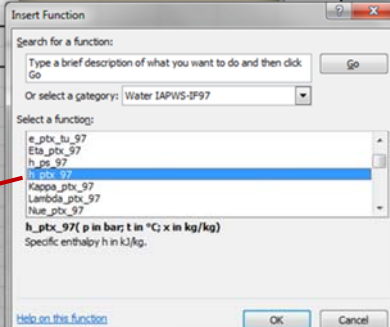


Property Software for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

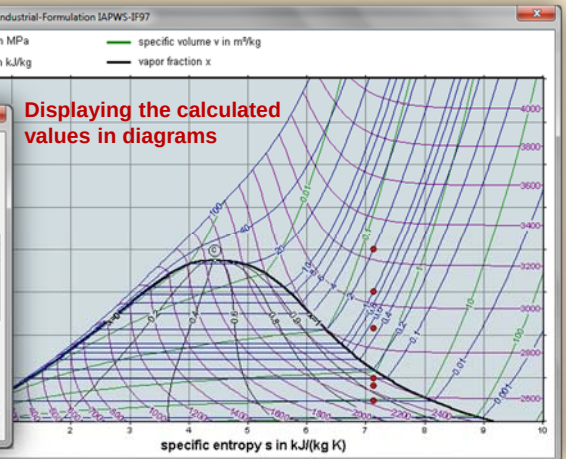
Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function



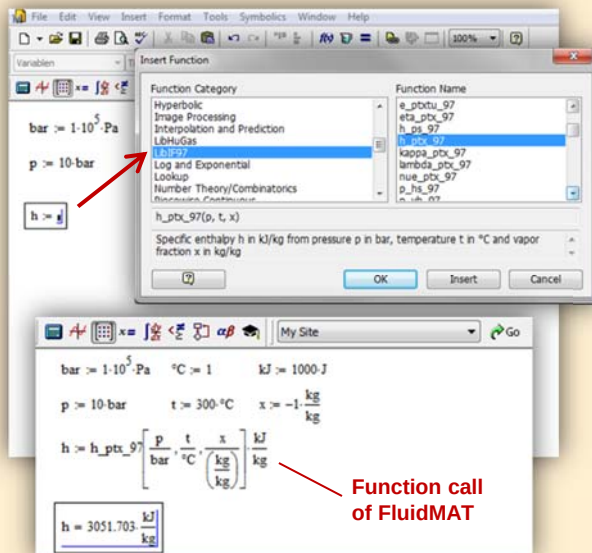
Displaying the calculated values in diagrams



Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

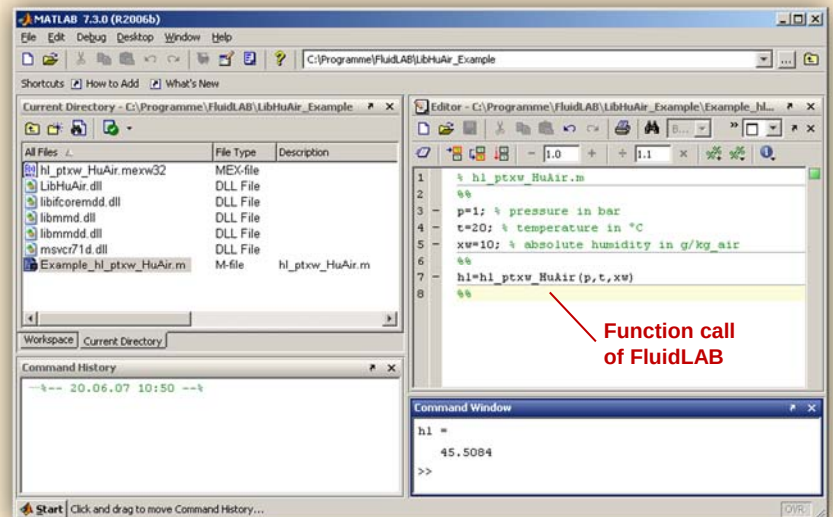
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

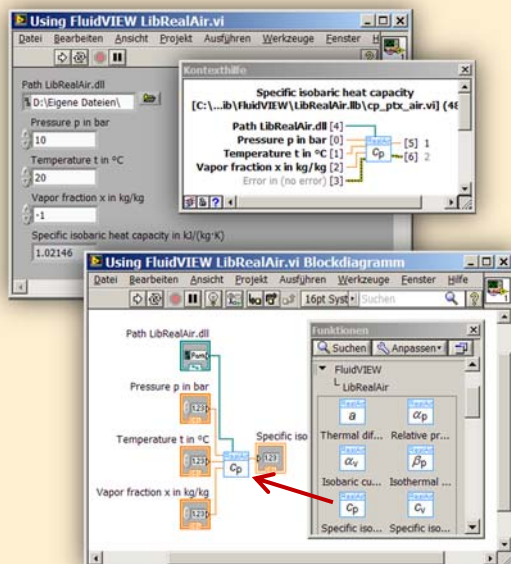
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

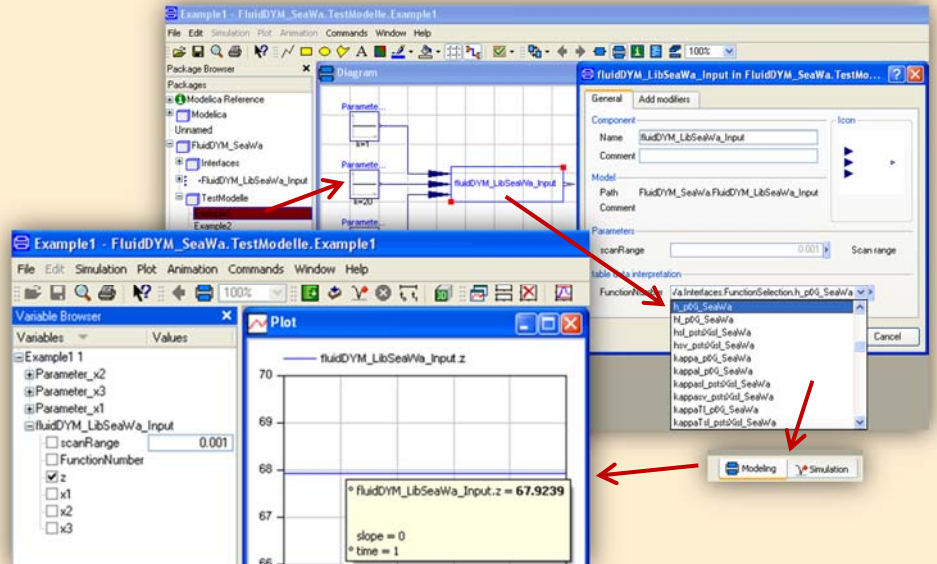
Add-On FluidVIEW for LabVIEW[®]

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

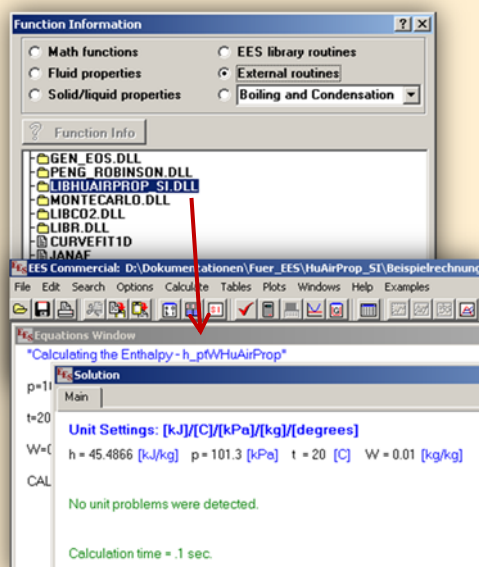


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

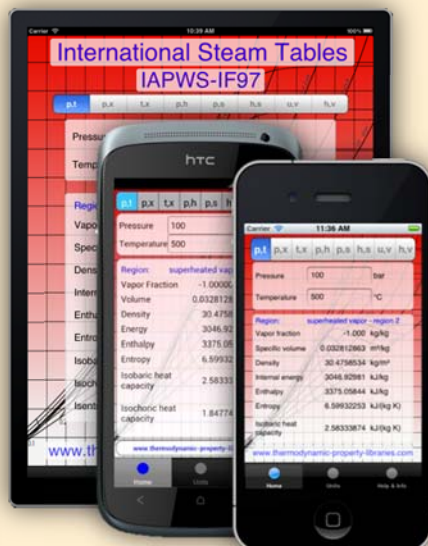
The property functions can be called in DYMOLA[®] and SimulationX[®].



Add-In FluidEES for Engineering Equation Solver®



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



Online Property Calculator at www.thermodynamics-zittau.de

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

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

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = 3097.38 kJ/kg

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

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

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www.thermodynamic-property-libraries.com
www.international-steam-tables.com
www.thermodynamic-formelsammlung.de

Property Software for Pocket Calculators

FluidCasio



fx 9750 G II

CFX 9850
fx-GG20CFX 9860 G
Graph 85ALGEBRA
FX 2.0

FluidHP



HP 48



HP 49

FluidTI

TI Nspire CX CAS
TI Nspire CASTI 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.

5. References

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Springer-Verlag, Berlin (1998)
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6. Satisfied Customers

Date: 10/2011

The following companies and institutions use the property libraries

- FluidEXL^{Graphics} for Excel[®]
- FluidLAB for MATLAB[®]
- FluidMAT for Mathcad[®]
- FluidEES for Engineering Equation Solver[®] EES
- FluidDYM for Dymola[®] (Modelica)
- FluidVIEW for LabVIEW[®]:

2011

Lopez, Munguia, Spain	10/2011
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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
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RWTH Aachen University	07/2011, 08/2011
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2006

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Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

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J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
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2004

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Siemens AG Power Generation, Erlangen	02/2004
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004

Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

2003

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

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

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
FZR Forschungszentrum, Rossendorf/Dresden	03/2002
CompAir, Simmern	03/2002
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
ALSTOM Power Baden, Switzerland (group licenses)	05/2002
InfraServ, Gendorf	05/2002
SoftSolutions, Muehlhausen (company license)	05/2002
DREWAG, Dresden (company license)	05/2002
SOFBID, Zwingenberg (general EBSILON program license)	06/2002
Kleemann Engineering, Dresden	06/2002
Caliqua, Basel, Switzerland (company license)	07/2002
PCK Raffinerie, Schwedt (group license)	07/2002
Fischer-Uhrig Engineering, Berlin	08/2002
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	08/2002
Stadtwerke Duisburg	08/2002

Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

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

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SOFBID, Zwingenberg (general EBSILON program license)	01/2000
AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000

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

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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