



Property Library for Mixtures of Water/Lithium Bromide

**FluidPRIME
with LibSeaWa
for Mathcad Prime®**

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Software for the Calculation of the Properties of Water/Lithium Bromide Mixtures

LibWaLi

FluidPRIME for Mathcad Prime®

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0. Package Contents

Zip file "CD_FluidPRIME_LibWaLi.zip" includes the following files:

FluidPRIME_LibWaLi_Docu.pdf	- User's Guide
Functions_LibWaLi.mcdx	- Mathcad Prime® worksheet with all functions
LibWaLi.msi	- MSI installer
setup.exe	- Setup installer
LibWaLi.dll	- DLL with functions of the LibWaLi library

1. Property Functions

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibWaLi as parameter	Property or Function	Unit of the result
$c_p = f(p, t, \xi)$	cp_ptxi_WaLi	CP_PTXI_WALI(P,T,XI)	C_CP_PTXI_WALI(CP,P,T,XI)	Specific isobaric heat capacity	kJ/(kg K)
$c'_p = f(p_s, t_s, \xi')$	cpl_pstsxil_WaLi	CPL_WALI(PS,TS,XIL)	C_CPL_WALI(CPL,PS,TS,XIL)	Specific isobaric heat capacity of saturated liquid	kJ/(kg K)
$c''_p = f(p_s, t_s, \xi')$	cpv_pstsxil_WaLi	CPV_WALI(PS,TS,XIL)	C_CPV_WALI(CPV,PS,TS,XIL)	Specific isobaric heat capacity of saturated steam	kJ/(kg K)
$\eta = f(p, t, \xi)$	eta_ptxi_WaLi	ETA_PTXI_WALI(P,T,XI)	C_ETA_PTXI_WALI(ETA,P,T,XI)	Dynamic viscosity	Pa s
$\eta' = f(p_s, t_s, \xi')$	etal_pstsxil_WaLi	ETAL_WALI(PS,TS,XIL)	C_ETAL_WALI(ETAL,PS,TS,XIL)	Dynamic viscosity of saturated liquid	Pa s
$\eta'' = f(p_s, t_s, \xi')$	etav_pstsxil_WaLi	ETAV_WALI(PS,TS,XIL)	C_ETAV_WALI(ETAV,PS,TS,XIL)	Dynamic viscosity of saturated steam	Pa s
$h = f(p, t, \xi)$	h_ptxi_WaLi	H_PTXI_WALI(P,T,XI)	C_H_PTXI_WALI(H,P,T,XI)	Specific enthalpy	kJ/kg
$h' = f(p_s, t_s, \xi')$	hl_pstsxil_WaLi	HL_WALI(PS,TS,XIL)	C_HL_WALI(HL,PS,TS,XIL)	Specific enthalpy of saturated liquid	kJ/kg
$h'' = f(p_s, t_s, \xi')$	hv_pstsxil_WaLi	HV_WALI(PS,TS,XIL)	C_HV_WALI(HV,PS,TS,XIL)	Specific enthalpy of saturated steam	kJ/kg
$h_{\text{sol}} = f(\xi)$	hsol_xi_WaLi	HSOL_XI_WALI(XI)	C_HSOL_XI_WALI(HSOL,XI)	Specific enthalpy at the crystallization barrier	kJ/kg
$\lambda = f(p, t, \xi)$	lam_ptxi_WaLi	LAM_PTXI_WALI(P,T,XI)	C_LAM_PTXI_WALI(LAM,P,T,XI)	Thermal conductivity	W/(m K)
$\lambda' = f(p_s, t_s, \xi')$	laml_pstsxil_WaLi	LAML_WALI(PS,TS,XIL)	C_LAML_WALI(LAML,PS,TS,XIL)	Thermal conductivity of saturated liquid	W/(m K)
$\lambda'' = f(p_s, t_s, \xi')$	lamv_pstsxil_WaLi	LAMV_WALI(PS,TS,XIL)	C_LAMV_WALI(LAMV,PS,TS,XIL)	Thermal conductivity of saturated steam	W/(m K)
$\nu = f(p, t, \xi)$	ny_ptxi_WaLi	NY_PTXI_WALI(P,T,XI)	C_NY_PTXI_WALI(NY,P,T,XI)	Kinematic viscosity	m ² /s
$\nu' = f(p_s, t_s, \xi')$	nyl_pstsxil_WaLi	NYL_WALI(PS,TS,XIL)	C_NYL_WALI(NYL,PS,TS,XIL)	Kinematic viscosity of saturated liquid	m ² /s
$\nu'' = f(p_s, t_s, \xi')$	nyv_pstsxil_WaLi	NYV_WALI(PS,TS,XIL)	C_NYV_WALI(NYV,PS,TS,XIL)	Kinematic viscosity of saturated steam	m ² /s
$Pr = f(p, t, \xi)$	Pr_ptxi_WaLi	PR_PTXI_WALI(P,T,XI)	C_PR_PTXI_WALI(PR,P,T,XI)	Prandtl-Number	-

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibWaLi as parameter	Property or Function	Unit of the result
$Pr' = f(p_s, t_s, \xi')$	Prl_pstsxil_WaLi	PRL_WALI(PS,TS,XIL)	C_PRL_WALI(PRL,PS,TS,XIL)	Prandtl-Number of saturated liquid	-
$Pr'' = f(p_s, t_s, \xi')$	Prv_pstsxil_WaLi	PRV_WALI(PS,TS,XIL)	C_PRV_WALI(PRV,PS,TS,XIL)	Prandtl-Number of saturated steam	-
$p_s = f(t_s, \xi')$	ps_tsxil_WaLi	PS_TSXIL_WALI(TS,XIL)	C_PS_TSXIL_WALI(PS,TS,XIL)	Vapor pressure	bar
$p_{sol} = f(t)$	psol_t_WaLi	PSOL_T_WALI(T)	C_PSOL_T_WALI(PSOL,T)	Pressure at the crystallization barrier	bar
$Region = f(p, t, \xi)$	region_ptxi_WaLi	REGION_PTIXI_WALI(P,T,XI)	C_REGION_PTIXI_WALI(REGION,P,T,XI)	Phase region from pressure, temperature and mass fraction of H ₂ O	-
$Region = f(p, h, \xi)$	region_phxi_WaLi	REGION_PHXI_WALI(P,H,XI)	C_REGION_PHXI_WALI(REGION,P,H,XI)	Phase region from pressure, enthalpy and mass fraction of H ₂ O	-
$Region = f(p, s, \xi)$	region_psxi_WaLi	REGION_PSXI_WALI(P,S,XI)	C_REGION_PSXI_WALI(REGION,P,S,XI)	Phase region from pressure, entropy and mass fraction of H ₂ O	-
$s = f(p, t, \xi)$	s_ptxi_WaLi	S_PTIXI_WALI(P,T,XI)	C_S_PTIXI_WALI(S,P,T,XI)	Specific entropy	kJ/(kg K)
$s' = f(p_s, t_s, \xi')$	sl_pstsxil_WaLi	SL_WALI(PS,TS,XIL)	C_SL_WALI(SL,PS,TS,XIL)	Specific entropy of saturated liquid	kJ/(kg K)
$s'' = f(p_s, t_s, \xi')$	sv_pstsxil_WaLi	SV_WALI(PS,TS,XIL)	C_SV_WALI(SV,PS,TS,XIL)	Specific entropy of saturated steam	kJ/(kg K)
$t = f(p, h, \xi)$	t_phxi_WaLi	T_PHXI_WALI(P,H,XI)	C_T_PHXI_WALI(T,P,H,XI)	Backward function: Temperature from pressure, enthalpy and mass fraction of H ₂ O	°C
$t = f(p, s, \xi)$	t_psxi_WaLi	T_PSXI_WALI(P,S,XI)	C_T_PSXI_WALI(T,P,S,XI)	Backward function: Temperature from pressure, entropy and mass fraction of H ₂ O	°C
$t_s = f(p_s, \xi')$	ts_psxil_WaLi	TS_PSXIL_WALI(PS,XIL)	C_TS_PSXIL_WALI(TS,PS,XIL)	Saturation temperature	°C

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibWaLi as parameter	Property or Function	Unit of the result
$t_{\text{sol}} = f(p)$	tsol_p_WaLi	TSOL_P_WALI(P)	C_TSOL_P_WALI(TSOL,P)	Temperature at the crystallization barrier	°C
$v = f(p, t, \xi)$	v_ptxi_WaLi	V_PTXI_WALI(P,T,XI)	C_V_PTXI_WALI(V,P,T,XI)	Specific volume	m³/kg
$v' = f(p_s, t_s, \xi')$	vl_pstsxil_WaLi	VL_WALI(PS,TS,XIL)	C_VL_WALI(HL,PS,TS,XIL)	Specific volume of saturated liquid	m³/kg
$v'' = f(p_s, t_s, \xi'')$	vv_pstsxil_WaLi	VV_WALI(PS,TS,XIL)	C_VV_WALI(HV,PS,TS,XIL)	Specific volume of saturated steam	m³/kg
$\xi' = f(p_s, t_s)$	xil_psts_WaLi	XIL_PSTS_WALI(PS,TS)	C_XIL_PSTS_WALI(XIL,PS,TS)	Mass fraction H₂O of saturated liquid	kg/kg
$\xi_{\text{sol}} = f(p)$	xisol_p_WaLi	XISOL_P_WALI(P)	C_XISOL_P_WALI(XISOL,P)	Mass fraction H₂O at the crystallization barrier	kg/kg
$\xi'' = f(p_s, t_s)$	xiv_psts_WaLi	XIV_PSTS_WALI(PS,TS)	C_XIV_PSTS_WALI(XIV,PS,TS)	Mass fraction H₂O of saturated steam	kg/kg

Units:	t in °C
	p in bar
	ξ in (kg H ₂ O)/(kg mixture)

Important hints for the calculation of wet steam

The wet steam region is calculated automatically by the subprograms, which are valid within the entire range of state.

It is necessary to define two parameters for the functions of saturated liquids (...) and saturated steam (...').

- either t_s and ξ'
- or p_s and ξ'
- or p_s and t_s

and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program will consider p_s , t_s , and ξ' to be appropriate to represent the saturation curve p_s . If this is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Reference state

Water:	Triple point for saturated liquid $h_{\text{H}_2\text{O}} = 0.000611783 \text{ kJ/kg}$ and $s_{\text{H}_2\text{O}} = 0$ at $p_{\text{tr}} = 0.00611657 \text{ bar}$ and $t_{\text{tr}} = 0.01 \text{ °C}$
Mixture of water/lithium bromide:	saturated liquid $h_{0.5} = -0.0209415 \text{ kJ/kg}$ and $s_{0.5} = -0.0000780433 \text{ kJ/(kg K)}$ at $t = 0 \text{ °C}$ and $\xi = 0.5 \text{ kg H}_2\text{O / kg}$

Note.

If the calculation results in -1000, the values entered represent a state point outside the range of validity of LibWaLi. 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 FluidPRIME in Mathcad Prime®

FluidPRIME has been developed to calculate thermodynamic properties in Mathcad Prime® more conveniently. Within Mathcad Prime, it enables the direct call of functions relating to humid air from the LibWaLi property library.

2.1 Installing FluidPRIME

In this section, the installation of FluidPRIME LibWaLi is described.

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

CD_FluidPRIME_LibWaLi

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 and a folders:

- FluidPRIME_LibWaLi_Docu.pdf
- Functions_LibWaLi.mcdx
- LibWaLi(msi)
- setup.exe
- LibWaLi.dll

In order to run the installation of FluidPRIME double-click the file

setup.exe.

Note: If you get an error message during the installation, please try the LibWaLi.msi instead of the setup.exe for the installation. The steps through the install assistant are similar on both the .exe and the .msi file.

After opening the installer-file you get the start window of the setup wizard (Figure 1.1). Please confirm with "Next".

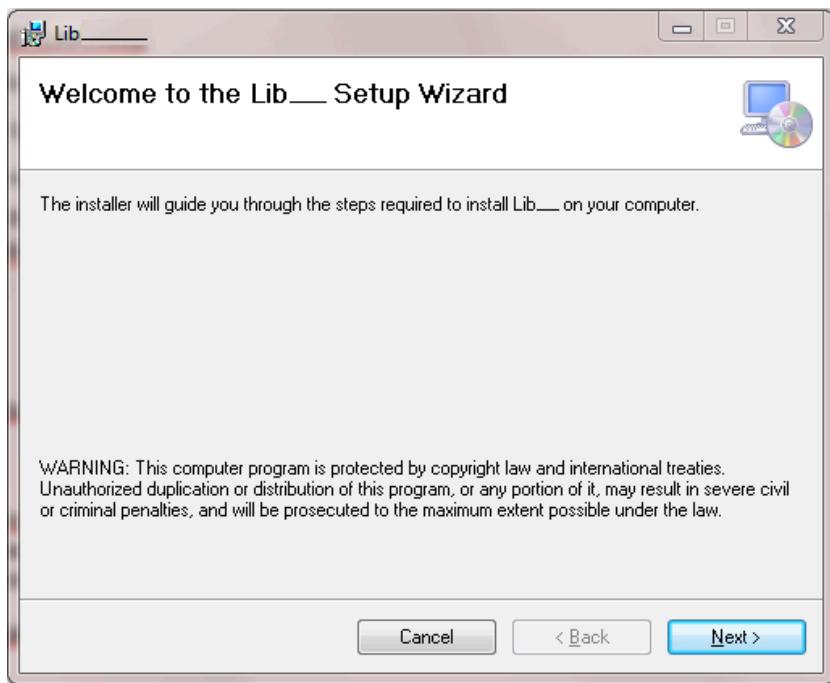


Figure 2.1: Setup Wizard

In Figure 2.2 you can see a note window that will inform you additionally to the next steps.

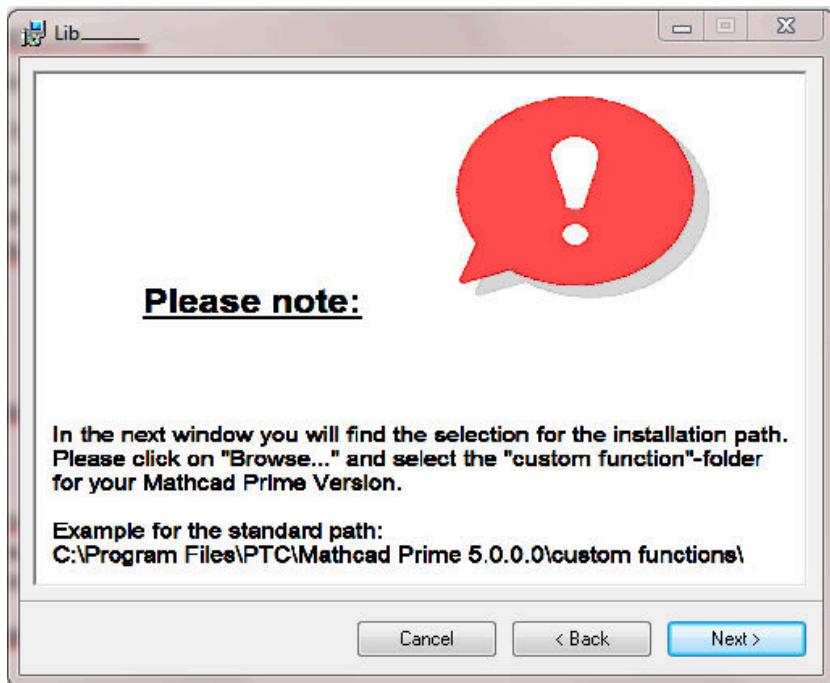


Figure 2.2: Note Window

Click on the "Next" button to get the "Select Installation Folder"-window (Figure 2.3).

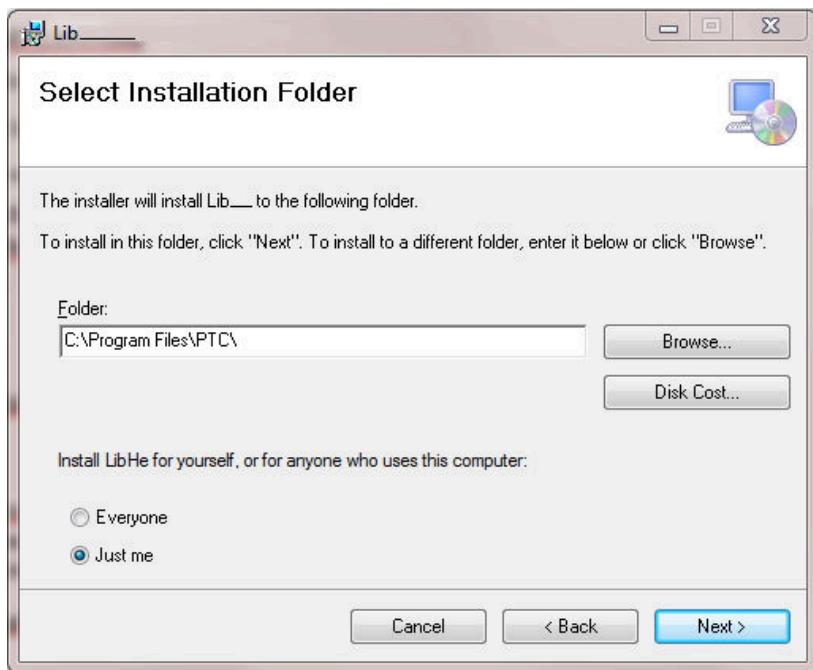


Figure 2.3: Select Installation Folder

Please click on "Browse..." to get another window where you can select the installation path.

You will get the standard path:

C:\Program Files\PTC\

Now select your Mathcad Prime® version folder. For example

C:\Program Files\PTC\Mathcad Prime 5.0.0.0 (Version 5.0.0.0).

On the next step you have to choose the "Custom Functions" folder, so that your final installation path looks like

C:\Program Files\PTC\Mathcad Prime 5.0.0.0\Custom Functions\

that you can also see in Figure 2.4.

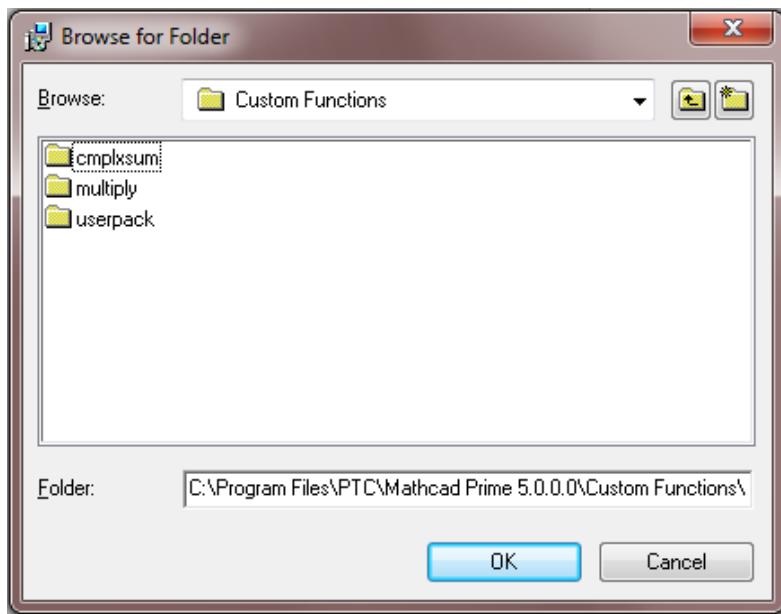


Figure 2.4: "Browse for Folder"-window with the full installation path

Please confirm with "OK" and continue in the further window (Figure 2.5) with "Next".

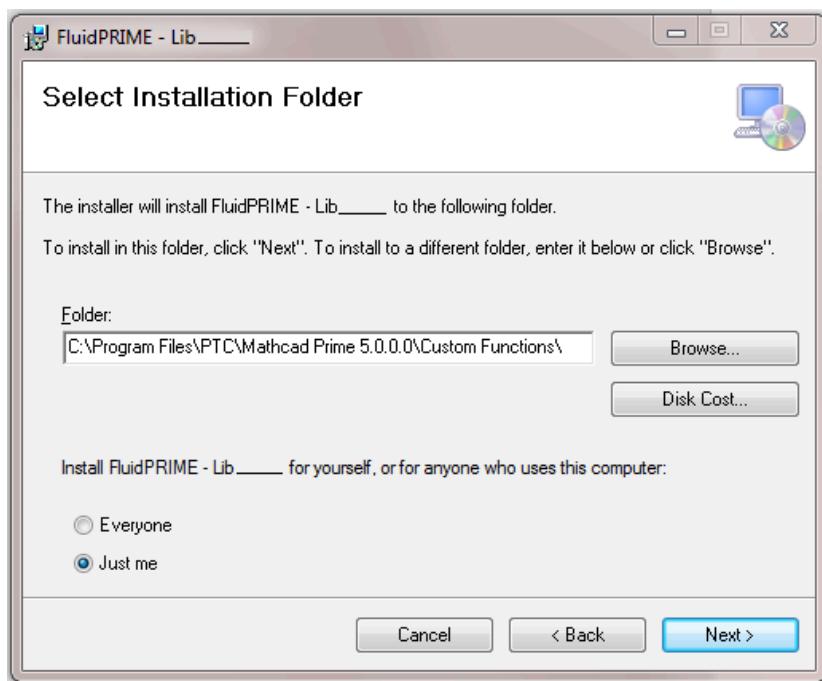


Figure 2.5: "Select Installation Folder"-window

To start the installation you have to click again on "Next".

After a few moments, you gets a message that the installation was successful and you can exit the setup with "Close".

The installation of FluidPRIME with the library LibWaLi is finished.

Finally, please copy or overwrite the LibWaLi.dll-file in the installation folder that is described before, with the file in the zip-file.

During the installation process the following files will have been copied into the destination folder chosen, the standard being

"C:\Program Files\PTC\Mathcad Prime 5.0.0.0\Custom Functions\":
LC.dll LibWaLi.dll PRIME_LibWaLi.dll
libifcoremd.dll libomp5.dll libmmd.dll.

Note:

The shown default installation path for Mathcad Prime® may be different depending on the installation on your machine. In addition, the Mathcad Prime® version can be another than 5.0.0.0 that is used in this manual.

The underscore after "Lib" in the figures before, is representative of the library name of the library to be installed.

2.2 Licensing the LibWaLi Property Library

Within the installation that was shown in chapter 2.1 the licensing key will be registered on your computer automatically.

2.3 Example: Calculation of the Enthalpy $h = f(p,t,x)$ for Water and Steam

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p , temperature t and vapor fraction x for water and steam from the Industrial Formulation IAPWS-WaLi, using FluidPRIME.

- Start Mathcad Prime.
- Type "p:" and enter the value for the pressure p in bar.
(Range of validity: $p = 0.00074 \text{ bar} \dots 10 \text{ bar}$)
 - e. g.: Enter "p:1" for the first operand
- Type "t:" and enter the value for the temperature t in °C.
(Range of validity: $t = 0 \text{ }^\circ\text{C} \dots 210 \text{ }^\circ\text{C}$)
 - e. g.: Enter "t:25" for the second operand
- Type "xi:" and enter the value for the mass fraction ξ in $\text{kg}_{\text{water}} / \text{kg}_{\text{mixture}}$.
(Range of validity: $\xi = 0.3 \text{ kg H}_2\text{O/kg} \dots 1.0 \text{ kg H}_2\text{O/kg}$)
 - e. g.: Enter "xi:0.6" for the third operand
- Confirm your entry by pressing the "ENTER" key.
- Your Mathcad Prime calculation window should look like Figure 2.3:

```

p:=1
t:=25
xi:=0.6

```

Figure 2.3: Example Mathcad Prime® sheet after input of the given parameters

- Now, type open the file Functions_LibWaLi.mcdx. In this Mathcad Prime® worksheet you can find all the functions of the library
- Search the function $h_{\text{ptx}}_{\text{WaLi}}(, ,)$ and mark it by drag a selection rectangle around it.
- Copy the marked function and paste it into your example worksheet
- Click it the function and type "h:" in front of it.
- Your Mathcad Prime calculation window should look like Figure 2.4:

```

p:=1
t:=25
xi:=0.6

h:=h_ptxi_WaLi(, , )

```

Figure 2.4: Example Mathcad Prime® sheet i

- Now click in the first operand in the brackets of the function. . 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 and set all the variables we set above.
- Close the input formula by pressing the "Enter"-Key.
- You can now go on working with the variable h which we have just calculated.
- If you wish to see the result, you have to type the following command on the next line in the Mathcad Prime window:
"h =".

You will now see the result $h=46.268$. The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

In the next figure you can see the calculated value.

```

p:=1
t:=25
xi:=0.6

h:=h_ptxi_WaLi(p,t,xi)

h=46.268

```

Figure 2.5: Example Mathcad Prime® sheet with finished calculation

2.4 Removing FluidPRIME

To remove FluidPRIME with the library LibWaLi from your hard drive, carry out the following steps:

- Click "Start" in the lower task bar of your desktop, then "Settings" and then "Control Panel".
- Now, double click on "Add or Remove Programs".
- In the list box of the "Add or Remove Programs" window that appears select "FluidPRIME - LibWaLi" by clicking on it and click the "Add/Remove..." button.
- In the following dialog box click "Yes" and wait until the windows is closing.
- Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidPRIME with the library LibWaLi has been removed.

3. Program Documentation

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

Function Name:	cp_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION CP_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_CP_PTXI_WALI(CP,P,T,XI) REAL*8 CP,P,T,XI

Input Values:

- P** - Pressure p in bar
T - Temperature t in °C
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

CP_PTXI_WALI, CP or cp_ptxi_WaLi - Specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Hints for wet steam

In the wet steam region the calculation is carried out for saturated liquid and saturated steam only. The value -1000 will be shown for the wet steam region lying between.

Results for wrong input values

Result **CP_PTXI_WALI = -1000, CP = -1000** or **cp_ptxi_WaLi = -1000** for input values:

$p > 10$ bar or $p < 0.00074$ bar or

$t > 210$ °C or $t < 0$ °C or

$\xi_s > \xi_{sol}(t)$ or

$\xi > 1.0$ kg/kg or $\xi < 0.3$ kg/kg

Points in the wet steam region between saturated liquid and saturated steam

References: [2], [21], [23]

Specific Isobaric Heat Capacity of Saturated Liquid $c_p^l = f(p_s, t_s, \xi^l)$

Function Name:	cpl_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION CPL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_CPL_WALI(CPL,PS,TS,XIL) REAL*8 CPL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

CPL_WALI, CPL or cpl_pstsxil_WaLi - Specific isobaric heat capacity of the saturated liquid
 c_p^l in kJ / (kg K)

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific isobaric heat capacity of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- | |
|------------------------------|
| $c_p^l = f(-1, t_s, \xi^l)$ |
| $c_p^l = f(p_s, -1, \xi^l)$ |
| $c_p^l = f(p_s, t_s, -1)$ |
| $c_p^l = f(p_s, t_s, \xi^l)$ |

Results for wrong input values

Result **CPL_WALI = -1000, CPL = -1000** or **cpl_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References:

[2], [21], [23]

Specific Isobaric Heat Capacity of Saturated Steam

$$c_p^v = f(p_s, t_s, \xi^l)$$

Function Name:	cpv_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION CPV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_CPV_WALI(CPV,PS,TS,XIL) REAL*8 CPV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

CPV_WALI, **CPV** or **cpv_pstsxil_WaLi** - Specific isobaric heat capacity of saturated steam
 c_p^v in kJ/(kg K)

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific isobaric heat capacity of saturated steam it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $c_p^v = f(-1, t_s, \xi^l)$
 - $c_p^v = f(p_s, -1, \xi^l)$
 - $c_p^v = f(p_s, t_s, -1)$
 - $c_p^v = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **CPV_WALI = -1000**, **CPV = -1000** or **cpv_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References:

[2], [23]

Dynamic Viscosity $\eta = f(p, t, \xi)$

Function Name:	eta_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION ETA_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_ETA_PTXI_WALI(ETA,P,T,XI) REAL*8 ETA,P,T,XI

Input Values:

- P - Pressure p in bar
 T - Temperature t in °C
 XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

ETA_PTXI_WALI, ETA or eta_ptxi_WaLi – Dynamic viscosity η in Pa s

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Hints for wet steam

In the wet steam region the calculation is carried out for saturated liquid and saturated steam only. The value -1000 will be shown for the wet steam region lying between.

Results for wrong input values

Result **ETA_PTXI_WALI = -1000, ETA = -1000** or **eta_ptxi_PROP = -1000** for input values:

- p > 10 bar or p < 0.00074 bar or
 t > 210 °C or t < 0 °C or
 $\xi_s > \xi_{sol}(t)$ or
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$
 Points in the wet steam region between saturated liquid and saturated steam

References: [2], [22], [23]

Dynamic Viscosity of Saturated Liquid $\eta^l = f(p_s, t_s, \xi^l)$

Function Name:	etal_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION ETAL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_ETAL_WALI(ETAL,PS,TS,XIL) REAL*8 ETAL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

ETAL_WALI, ETAL or etal_pstsxil_WaLi - Dynamic viscosity of saturated liquid η^l in Pa s

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Hints of the input variants

For calculating the dynamic viscosity of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\eta^l = f(-1, t_s, \xi^l)$
 - $\eta^l = f(p_s, -1, \xi^l)$
 - $\eta^l = f(p_s, t_s, -1)$
 - $\eta^l = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **ETAL_WALI = -1000, ETAL = -1000** or **etal_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [22], [23]

Dynamic Viscosity of Saturated Steam $\eta^V = f(p_s, t_s, \xi^l)$

Function Name:	etav_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION ETAV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_ETAV_WALI(ETAV,PS,TS,XIL) REAL*8 ETAV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

ETAV_WALI, ETAV or etav_pstsxil_WaLi - Dynamic viscosity of saturated steam η^V in Pa s

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the dynamic viscosity of saturated steam it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\eta^V = f(-1, t_s, \xi^l)$
 - $\eta^V = f(p_s, -1, \xi^l)$
 - $\eta^V = f(p_s, t_s, -1)$
 - $\eta^V = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **ETAV_WALI = -1000, ETAV = -1000** or **etav_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [23]

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

Function Name:	h_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION H_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_H_PTXI_WALI(H,P,T,XI) REAL*8 H,P,T,XI

Input Values:

- P** - Pressure p in bar
T - Temperature t in °C
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

H_PTXI_WALI, **H** or **h_ptxi_WaLi** – Specific enthalpy h in kJ/kg

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

Result **H_PTXI_WALI = -1000**, **H = -1000** or **h_ptxi_WaLi = -1000** for input values:

- p > 10 bar or p < 0.00074 bar or
 t > 210 °C or t < 0 °C or
 $\xi_s > \xi_{sol}(t)$ or
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$

References:

[2], [21], [23]

Specific Enthalpy of Saturated Liquid $h^l = f(p_s, t_s, \xi^l)$

Function Name:	hl_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION HL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_HL_WALI(HL,PS,TS,XIL) REAL*8 HL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

HL_WALI, HL or hl_pstsxil_WaLi - Specific enthalpy of saturated liquid h^l in kJ/kg

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific enthalpy of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $h^l = f(-1, t_s, \xi^l)$
 - $h^l = f(p_s, -1, \xi^l)$
 - $h^l = f(p_s, t_s, -1)$
 - $h^l = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **HL_WALI = -1000, HL = -1000** or **hl_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [21], [23]

Specific Enthalpy of Saturated Steam $h^v = f(p_s, t_s, \xi^l)$

Function Name:	hv_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION HV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_HV_WALI(HV,PS,TS,XIL) REAL*8 HV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

HV_WALI, HV or hv_pstsxil_WaLi - Specific enthalpy of saturated steam h^v in kJ/kg

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific enthalpy of saturated steam it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $h^v = f(-1, t_s, \xi^l)$
 - $h^v = f(p_s, -1, \xi^l)$
 - $h^v = f(p_s, t_s, -1)$
 - $h^v = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **HV_WALI = -1000, HV = -1000** or **hv_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [23]

Specific Enthalpy at the Crystallization Barrier $h_{sol} = f(\xi)$

Function Name:	hsol_xi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION HSOL_XI_WALI(XI) REAL*8 XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_HSOL_XI_WALI(HSOL,XI) REAL*8 HSOL,XI

Input Values:

XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

HSOL_XI_WALI, HSOL or hsol_xi_WaLi - Specific enthalpy at the crystallization barrier h_{sol} in kJ/kg

Range of validity

Composition range: from 0.3 to 0.45 (kg H₂O)/(kg mixture)

Explanation of the function

This function calculates the specific enthalpy at the crystallization barrier. If the actual specific enthalpy calculated in the liquid phase of the mixture lies below the enthalpy calculated by the function then the Lithium Bromide crystallizes out. This case is recognised by the other functions. A calculation of properties below the crystallization barrier is not possible.

Results for wrong input values

Result **HSOL_XI_WALI = -1000, HSOL = -1000** or **hsol_xi_WaLi = -1000** for input values:

$\xi > 0.45$ kg/kg or $\xi < 0.3$ kg/kg

References: [23]

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

Function Name:	lam_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION LAM_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_LAM_PTXI_WALI(LAM,P,T,XI) REAL*8 LAM,P,T,XI

Input Values:

- P** - Pressure p in bar
T - Temperature t in °C
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

LAM_PTXI_WALI, LAM or **lam_ptxi_WaLi** – Thermal conductivity λ in W/m K

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints for wet steam

In the wet steam region the calculation is carried out for saturated liquid and saturated steam only. The value -1000 will be shown for the wet steam region lying between.

Results for wrong input values

Result **LAM_PTXI_WALI = -1000, LAM = -1000** or **lam_ptxi_WaLi = -1000** for input values:

p > 10 bar or p < 0.00074 bar or

t > 210 °C or t < 0 °C oder

$\xi_s > \xi_{sol}(t)$ or

$\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$

Points in the wet steam region between saturated liquid and saturated steam

References: [2], [22], [23]

Thermal Conductivity of Saturated Liquid $\lambda^l = f(p_s, t_s, \xi^l)$

Function Name:	laml_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION LAML_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_LAML_WALI(LAML,PS,TS,XIL) REAL*8 ETAL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

LAML_WALI, LAML or laml_pstsxil_WaLi - Thermal conductivity of saturated liquid λ^l in W / (m K)

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the thermal conductivity of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\lambda^l = f(-1, t_s, \xi^l)$
 - $\lambda^l = f(p_s, -1, \xi^l)$
 - $\lambda^l = f(p_s, t_s, -1)$
 - $\lambda^l = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **LAML_WALI = -1000, LAML = -1000** or **laml_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [22], [23]

Thermal Conductivity of Saturated Steam $\lambda^v = f(p_s, t_s, \xi^l)$

Function Name:	lamv_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION LAMV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_LAMV_WALI(LAMV,PS,TS,XIL) REAL*8 LAMV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

LAMV_WALI, LAMV or lamv_pstsxil_WaLi - Thermal conductivity of saturated steam λ^v in W / (m K)

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the thermal conductivity of saturated steam it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\lambda^v = f(-1, t_s, \xi^l)$
 - $\lambda^v = f(p_s, -1, \xi^l)$
 - $\lambda^v = f(p_s, t_s, -1)$
 - $\lambda^v = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **LAMV_WALI = -1000, LAMV = -1000** or **lamv_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References:

[2], [23]

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

Function Name:	ny_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION NY_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_NY_PTXI_WALI(NY,P,T,XI) REAL*8 NY,P,T,XI

Input Values:

- P** - Pressure p in bar
T - Temperature t in °C
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

NY_PTXI_WALI, **NY** or **ny_ptxi_WaLi** - Kinematic viscosity $\nu = \eta \cdot v$ in m²/s

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints for wet steam

In the wet steam region the calculation is carried out for saturated liquid and saturated steam only. The value -1000 will be shown for the wet steam region lying between.

Results for wrong input values

Result **NY_PTXI_WALI = -1000**, **NY = -1000** or **ny_ptxi_WaLi = -1000** for input values:

p > 10 bar or p < 0.00074 bar or

t > 210 °C or t < 0 °C oder

$\xi_s > \xi_{sol}(t)$ or

$\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$

Points in the wet steam region between saturated liquid and saturated steam

References: [2], [21], [22], [23]

Kinematic Viscosity of Saturated Liquid $\nu^l = f(p_s, t_s, \xi^l)$

Function Name:	nyl_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION NYL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_NYL_WALI(NYL,PS,TS,XIL) REAL*8 NYL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

NYL_WALI, NYL or nyl_pstsxil_WaLi - Kinematic viscosity of saturated liquid $\nu^l = \eta^l \cdot v^l$ in m²/s

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the kinematic viscosity of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\nu^l = f(-1, t_s, \xi^l)$
 - $\nu^l = f(p_s, -1, \xi^l)$
 - $\nu^l = f(p_s, t_s, -1)$
 - $\nu^l = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **NYL_WALI = -1000, NYL = -1000** or **nyl_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [21], [22], [23]

Kinematic Viscosity of Saturated Steam $\nu^v = f(p_s, t_s, \xi^l)$

Function Name:	nyv_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION NYV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_NYV_WALI(NYV,PS,TS,XIL) REAL*8 NYV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

NYV_WALI, NYV or nyv_pstsxil_WaLi - Kinematic viscosity of saturated steam
 $\nu^v = \eta^v \cdot v^v$ in m²/s

Range of validity

- Temperature range: from 0 °C to 210 °C
Pressure range: from 0.00074 bar to 10 bar
Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the kinematic viscosity of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\nu^v = f(-1, t_s, \xi^l)$
 - $\nu^v = f(p_s, -1, \xi^l)$
 - $\nu^v = f(p_s, t_s, -1)$
 - $\nu^v = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **NYV_WALI = -1000, NYV = -1000** or **nyv_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References:

[2], [23]

Prandtl-Number $\text{Pr} = f(p, t, \xi)$

Function Name:	Pr_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION PR_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_PR_PTXI_WALI(PR,P,T,XI) REAL*8 PR,P,T,XI

Input Values:

- P** - Pressure p in bar
T - Temperature t in °C
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

$$\text{PR_PTXI_WALI, PR or Pr_ptxi_WALI} - \text{Prandtl-Number } \text{Pr} = \frac{\eta \cdot c_p}{\lambda}$$

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints for wet steam

In the wet steam region the calculation is carried out for saturated liquid and saturated steam only. The value -1000 will be shown for the wet steam region lying between.

Results for wrong input values

Result **PR_PTXI_WALI = -1000, PR = -1000** or **Pr_ptxi_WaLi = -1000** for input values:

- p > 10 bar or p < 0.00074 bar or
 t > 210 °C or t < 0 °C or
 $\xi_s > \xi_{sol}(t)$ or
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$

Points in the wet steam region between saturated liquid and saturated steam

References: [2], [21], [22], [23]

Prandtl-Number of Saturated Liquid $\text{Pr}^l = f(p_s, t_s, \xi^l)$

Function Name:	PrI_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION PRL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_PRL_WALI(PRL,PS,TS,XIL) REAL*8 PRL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

$$\text{PRL_WALI, PRL or PrI_pstsxil_WaLi} - \text{Prandtl-Number of saturated liquid } \text{Pr}^l = \frac{\eta^l \cdot c_p^l}{\lambda^l}$$

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the Prandtl-Number of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\text{Pr}^l = f(-1, t_s, \xi^l)$
 - $\text{Pr}^l = f(p_s, -1, \xi^l)$
 - $\text{Pr}^l = f(p_s, t_s, -1)$
 - $\text{Pr}^l = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **PRL_WALI = -1000**, **PRL = -1000** or **PrI_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{\text{sol}}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References:

[2], [21], [22], [23]

Prandtl-Number of Saturated Steam $\text{Pr}^V = f(p_s, t_s, \xi^l)$

Function Name:	Prv_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION PRV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_PRV_WALI(PRV,PS,TS,XIL) REAL*8 PRV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

$$\text{PRV_WALI, PRV or Prv_pstsxil_WaLi} - \text{Prandtl-Number of saturated steam } \text{Pr}^V = \frac{\eta^V \cdot c_p^V}{\lambda^V}$$

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the Prandtl-Number of saturated steam it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $\text{Pr}^V = f(-1, t_s, \xi^l)$
 - $\text{Pr}^V = f(p_s, -1, \xi^l)$
 - $\text{Pr}^V = f(p_s, t_s, -1)$
 - $\text{Pr}^V = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **PRV_WALI = -1000**, **PRV = -1000** or **Prv_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{\text{sol}}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References:

[2], [23]

Vapor Pressure $p_s = f(t_s, \xi^l)$

Function Name:	ps_tsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION PS_TSXIL_WALI(TS,XIL) REAL*8 TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_PS_TSXIL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL

Input Values:

- TS** - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

PS_TSXIL_WALI, PS or ps_tsxil_WaLi - Vapor pressure p_s in bar

Range of validity

- Temperature range: from 0 °C to 210 °C
Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Results for wrong input values

Result **PS_TSXIL_WALI = -1000, PS = -1000** or **ps_tsxil_WALI = -1000** for input values:

- $t_s > 210$ °C or $t_s < 0$ °C or
 $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg
 $\xi^l < \xi_{sol}(t_s)$ or

References:

[2], [21], [23]

Pressure at the Crystallization Barrier $p_{sol} = f(t)$

Function Name: **psol_t_WaLi**
 Subroutine with function value:
 for call from Fortran **REAL*8 FUNCTION PSOL_T_WALI(T)**
REAL*8 T

Subroutine with parameter:
 for call from DLL **INTEGER*4 FUNCTION C_PSOL_T_WALI(PSOL,T)**
REAL*8 PSOL,T

Input Values:

T - Temperature t in °C

Result

PSOL_T_WALI, PSOL or psol_t_WaLi - Pressure at the Crystallization barrier p_{sol} in bar

Range of validity

Temperature range: from 0 °C to 93.58 °C

Explanation of the function

This function calculates the pressure at the crystallization barrier. If the actual pressure calculated in the liquid phase of the mixture lies below the pressure calculated by the function then the Lithium Bromide crystallizes out. This case is recognised by the other functions. A calculation of properties below the crystallization barrier is not possible. Please note that this function puts out expedient results only if a liquid phase is calculated since there is pure water in the gas phase.

Results for wrong input values

Result **PSOL_T_WALI = -1000, PSOL = -1000** or **psol_t_WaLi = -1000** for input values:

$t > 93.58 \text{ } ^\circ\text{C}$ or $t < 0 \text{ } ^\circ\text{C}$

References:

[2], [21], [23]

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

Function Name:	region_ptxi_WaLi
Subroutine with function value: for call from Fortran	INTEGER*4 FUNCTION REGION_PTIXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_REGION_PTIXI_WALI(REGION,P,T,XI) INTEGER*4 REGION REAL*8 P,T,XI

Input Values:

- P - Pressure p in bar
 T - Temperature t in °C
 XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

REGION_PTIXI_WALI, REGION or region_ptxi_WaLi – Phase region

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Explanation of the function

This function defines the phase region at hand. The results have the following meaning:

- 1 – Subcooled fluid
- 2 – Two phase region
- 3 – Gas phase

If a point of state is entered below the crystallization barrier the result will be – 2000.

Results for wrong input values

Result **REGION_PTIXI_WALI = -1000, REGION = -1000** or **region_ptxi_WaLi = -1000** for input values:

p > 10 bar or p < 0.00074 bar or
 t > 210 °C or t < 0 °C oder
 ξ > 1.0 kg/kg or ξ < 0.3 kg/kg

Result **REGION_PTIXI_WALI = -2000, REGION = -2000** or **region_ptxi_WaLi = -2000** for input values:

$\xi < \xi_{\text{sol}}(t)$

References:

[2], [21], [23]

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

Function Name:	region_phxi_WaLi
Subroutine with function value: for call from Fortran	INTEGER*4 FUNCTION REGION_PHXI_WALI(P,H,XI) REAL*8 P,H,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_REGION_PHXI_WALI(REGION,P,H,XI) INTEGER*4 REGION REAL*8 P,H,XI

Input Values:

- P - Pressure p in bar
- H - Specific enthalpy h in kJ/kg
- XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

REGION_PHXI_WALI, REGION or region_phxi_WaLi – Phase region

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Explanation of the function

This function defines the phase region at hand. The results have the following meaning:

- 1 – Subcooled fluid
- 2 – Two phase region
- 3 – Gas phase

If a point of state is entered below the crystallization barrier the result will be – 2000.

Results for wrong input values

Result **REGION_PHXI_WALI = -1000, REGION = -1000** or **region_phxi_WaLi = -1000** for input values:

p > 10 bar or p < 0.00074 bar or
h > 2899.46775 kJ/kg or h < 14 kJ/kg or
 ξ > 1.0 kg/kg or ξ < 0.3 kg/kg

Result **REGION_PHXI_WALI = -2000, REGION = -2000** or **region_phxi_WaLi = -2000** for input values:

h < h_{sol}(ξ)

References: [2], [21], [23]

Phase Region Region = f(p,s, ξ)

Function Name:	region_psxi_WaLi
Subroutine with function value: for call from Fortran	INTEGER*4 FUNCTION REGION_PSXI_WALI(P,S,XI) REAL*8 P,H,XI
Subroutine with parameter: für Aufruf aus DLL	INTEGER*4 FUNCTION C_REGION_PSXI_WALI(REGION,P,S,XI) INTEGER*4 REGION REAL*8 P,S,XI

Input Values:

- P** - Pressure p in bar
S - Specific entropy s in kJ/(kg K)
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

REGION_PSXI_WALI, **REGION** or **region_psxi_WaLi** – Phase region

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Explanation of the function

This function defines the phase region at hand. The results have the following meaning:

- 1 – Subcooled fluid
- 2 – Two phase region
- 3 – Gas phase

If a point of state is entered below the crystallization barrier the result will be – 2000.

Results for wrong input values

Result **REGION_PHXI_WALI = -1000**, **REGION = -1000** or **region_phxi_WaLi = -1000** for input values:

p > 10 bar or p < 0.00074 bar or
 at intermediate result t > 210 °C or t < 0 °C or
 ξ > 1.0 kg/kg or ξ < 0.3 kg/kg

Result **REGION_PSXI_WALI = -2000**, **REGION = -2000** or **region_psxi_WaLi = -2000** for input values:

$\xi < \xi_{\text{sol}}(p)$

References: [2], [21], [23]

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

Function Name:	s_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION S_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_S_PTXI_WALI(S,P,T,XI) REAL*8 S,P,T,XI

Input Values:

- P** - Pressure p in bar
T - Temperature t in °C
XI - Mass fraction from water ξ in (kg H₂O)/(kg mixture)

Result

S_PTXI_WALI, S or s_ptxi_WaLi - Specific entropy s in kJ/kg K

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

Result **S_PTXI_WALI = -1000, S = -1000** or **s_ptxi_WaLi = -1000** for input values:

- p > 10 bar or p < 0.00074 bar or
 t > 210 °C or t < 0 °C oder
 $\xi < \xi_{\text{sol}}(t)$
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$

References: [2], [21], [23]

Specific Entropy of Saturated Liquid $s^l = f(p_s, t_s, \xi^l)$

Function Name:	sl_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION SL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_SL_WALI(HL,PS,TS,XIL) REAL*8 SL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

SL_WALI, SL or sl_pstsxil_WaLi - Specific entropy of the saturated liquid s^l in kJ / (kg K)

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific entropy of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $s^l = f(-1, t_s, \xi^l)$
 - $s^l = f(p_s, -1, \xi^l)$
 - $s^l = f(p_s, t_s, -1)$
 - $s^l = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **SL_WALI = -1000, SL = -1000** or **sl_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [21], [23]

Specific Entropy of Saturated Steam $s^v = f(p_s, t_s, \xi^l)$

Function Name:	sv_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION SV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_SV_WALI(SV,PS,TS,XIL) REAL*8 SV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

SV_WALI, SV or sv_pstsxil_WaLi - Specific entropy of saturated steam s^v in kJ/(kg K)

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific entropy of saturated steam it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $s^v = f(-1, t_s, \xi^l)$
 - $s^v = f(p_s, -1, \xi^l)$
 - $s^v = f(p_s, t_s, -1)$
 - $s^v = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **SV_WALI = -1000, SV = -1000** or **sv_pstsxil_WaLi = -1000** for input values:

$p_s > 10$ bar or $p_s < 0.00074$ bar or

$t_s > 210$ °C or $t_s < 0$ °C or

$t_s > t_{sol}(p_s)$ or

$\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [23]

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

Function Name:	t_phxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION T_PHXI_WALI(P,H,XI) REAL*8 P,H,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_T_PHXI_WALI(T,P,H,XI) REAL*8 T,P,H,XI

Input Values:

- P** - Pressure p in bar
H - Specific enthalpy h in kJ/kg
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

T_PHXI_WALI, **T** or **t_phxi_WaLi** – Temperature t in °C

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

Result **T_PHXI_WALI = -1000**, **T = -1000** or **t_phxi_WaLi = -1000** for input values:

- p > 10 bar or p < 0.00074 bar or
 at calculation result t > 210 °C or t < 0 °C or
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$ or
 $h < h_{\text{sol}}(\xi)$

References: [2], [21], [23]

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

Function Name:	t_psxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION T_PSXI_WALI(P,S,XI) REAL*8 P,S,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_T_PSXI_WALI(T,P,S,XI) REAL*8 T,P,S,XI

Input Values:

- P** - Pressure p in bar
S - Specific entropy s in kJ/(kg K)
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

T_PSXI_WALI, **T** or **t_psxi_WaLi** – Temperature t in °C

Range of validity

Temperature range:	from 0 °C to 210 °C
Pressure range:	from 0.00074 bar to 10 bar
Composition range:	from 0.3 to 1.0 (kg H ₂ O)/(kg mixture)

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

Result **T_PSXI_WALI = -1000**, **T = -1000** or **t_psxi_WaLi = -1000** for input values:

p > 10 bar or p < 0.00074 bar or
 at calculation result t > 210 °C oder t < 0 °C oder
 $\xi < \xi_{\text{sol}}(t)$
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$

References:

[2], [21], [23]

Saturation Temperature $t_s = f(p_s, \xi^l)$

Function Name:	ts_psxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION TS_PSXIL_WALI(PS,XIL) REAL*8 P,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_TS_PSXIL_WALI(TS,PS,XIL) REAL*8 TS,PS,XIL

Input Values:

PS - Vapor pressure p_s in bar

XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

TS_PSXIL_WALI, TS or ts_psxil_WaLi - Saturation temperature t_s in °C

Range of validity

Pressure range: from 0.00074 bar to 10 bar

Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Results for wrong input values

Result **TS_PSXIL_WALI = -1000, TS = -1000** or **ts_psxil_WaLi = -1000** for input values:

$p_s > 10$ bar or $p_s < 0.00074$ bar or

at calculation result $t_s > 210$ °C or $t_s < 0$ °C or

$\xi < \xi_{sol}(t)$

$\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References:

[2], [21], [23]

Temperature at the Crystallization Barrier $t_{sol} = f(p)$

Function Name:	tsol_p_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION TSOL_P_WALI(P) REAL*8 P
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_TSOL_P_WALI(TSOL,P) REAL*8 TSOL,P

Input Values:

P - Pressure p in bar

Result

TSOL_P_WALI, TSOL or tsol_p_WaLi - Temperature at the crystallization barrier t_{sol} in °C

Range of validity

Pressure range: from 0.00074 bar to 0.0373 bar

Explanation of the function

This function calculates the temperature at the crystallization barrier. If the actual temperature calculated in the liquid phase of the mixture lies above the temperature calculated by the function then the Lithium Bromide crystallizes out. This case is recognised by the other functions. A calculation of properties below the crystallization barrier is not possible. Please note that this function puts out expedient results only if a liquid phase is calculated since there is pure water in the gas phase.

Results for wrong input values

Result **TSOL_P_WALI, = -1000, TSOL = -1000** or **tsol_p_WaLi = -1000** for input values:

$p < 0.0373$ bar or $p > 0.00074$ bar

References:

[2], [21], [23]

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

Function Name:	v_ptxi_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION V_PTXI_WALI(P,T,XI) REAL*8 P,T,XI
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_V_PTXI_WALI(V,P,T,XI) REAL*8 V,P,T,XI

Input Values:

- P** - Pressure p in bar
T - Temperature t in °C
XI - Mass fraction of water ξ in (kg H₂O)/(kg mixture)

Result

V_PTXI_WALI, **V** or **v_ptxi_WaLi** - Specific volume v in m³/kg

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

Result **V_PTXI_WALI = -1000**, **V = -1000** or **v_ptxi_WaLi = -1000** for input values:

- p > 10 bar or p < 0.00074 bar or
 t > 210 °C or t < 0 °C oder
 $\xi < \xi_{\text{sol}}(t)$
 $\xi > 1.0 \text{ kg/kg}$ or $\xi < 0.3 \text{ kg/kg}$

References: [2], [21], [23]

Specific Volume of Saturated Liquid $v^l = f(p_s, t_s, \xi^l)$

Function Name:	vl_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION VL_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_VL_WALI(VL,PS,TS,XIL) REAL*8 VL,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

VL_WALI, VL or vl_pstsxil_WaLi - Specific volume of saturated liquid v^l in m³/kg

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific volume of the saturated liquid it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $v^l = f(-1, t_s, \xi^l)$
 - $v^l = f(p_s, -1, \xi^l)$
 - $v^l = f(p_s, t_s, -1)$
 - $v^l = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **VL_WALI = -1000, VL = -1000** or **vl_pstsxil_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
- $t_s > 210$ °C or $t_s < 0$ °C or
- $t_s > t_{sol}(p_s)$ or
- $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [21], [23]

Specific Volume of Saturated Steam $v^v = f(p_s, t_s, \xi^l)$

Function Name:	vv_pstsxil_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION VV_WALI(PS,TS,XIL) REAL*8 PS,TS,XIL
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_VV_WALI(VV,PS,TS,XIL) REAL*8 VV,PS,TS,XIL

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C
XIL - Mass fraction of water as saturated liquid ξ^l in (kg H₂O)/(kg mixture)

Result

VV_WALI, VV or vv_pstsxil_WaLi - Specific volume of saturated steam v^v in m³/kg

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar
 Composition range: from 0.3 to 1.0 (kg H₂O)/(kg mixture)

Hints of the input variants

For calculating the specific volume of saturated steam it is necessary to define two parameters (either t_s and ξ' or p_s and ξ' or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ' are entered, the program considers p_s , t_s , and ξ' to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

- Possible input variants:
- $v^v = f(-1, t_s, \xi^l)$
 - $v^v = f(p_s, -1, \xi^l)$
 - $v^v = f(p_s, t_s, -1)$
 - $v^v = f(p_s, t_s, \xi^l)$

Results for wrong input values

Result **VV_WALI = -1000, VV = -1000** or **vv_pstsxil_WaLi = -1000** for input values:

$p_s > 10$ bar or $p_s < 0.00074$ bar or

$t_s > 210$ °C or $t_s < 0$ °C or

$t_s > t_{sol}(p_s)$ or

$\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

References: [2], [21], [23]

Mass Fraction H₂O of Saturated Liquid $\xi^l = f(p_s, t_s)$

Function Name:	xil_psts_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION XIL_PSTS_WALI(PS,TS) REAL*8 PS,TS
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_XIL_PSTS_WALI(XIL,PS,TS) REAL*8 XIL,PS,TS

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C

Result

XIL_PSTS_WALI, XIL or xil_psts_WaLi - Mass fraction H₂O of saturated liquid ξ^l in kg H₂O / kg

Range of validity

- Temperature range: from 0 °C to 210 °C
 Pressure range: from 0.00074 bar to 10 bar

Results for wrong input values

Result **XIL_PSTS_WALI = -1000, XIL = -1000** or **xil_psts_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
 $t_s > 210$ °C or $t_s < 0$ °C or
 $t_s > t_{sol}(p_s)$ or

References: [2], [21], [23]

Mass Fraction H₂O at the Crystallization Barrier $\xi_{\text{sol}} = f(p)$

Function Name:	xisol_p_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION XISOL_P_WALI(P) REAL*8 P
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_XISOL_P_WALI(XISOL,P) REAL*8 XISOL,P

Input Values:

P - Pressure p in bar

Result

XISOL_P_WALI, XISOL or **xisol_p_WaLi** - Mass fraction H₂O at the crystallization barrier ξ_{sol}
in kg H₂O /kg

Range of validity

Pressure range: from 0.00074 bar to 0.0373 bar

Explanation of the function

This function calculates the mass fraction H₂O at the crystallization barrier. If the actual mass fraction H₂O calculated in the liquid phase of the mixture lies below the mass fraction calculated by the function then the Lithium Bromide crystallizes out. This case is recognised by the other functions. A calculation of properties below the crystallization barrier is not possible.

Results for wrong input values

Result **XISOL_P_WALI, = -1000, XISOL = -1000** or **xisol_p_WaLi = -1000** for input values:
 $p < 0.0373$ bar or $p > 0.00074$ bar

References:

[2], [21], [23]

Mass Fraction H₂O at the Crystallization Barrier $\xi_{\text{sol}} = f(t)$

Function Name:	xisol_t_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION XISOL_T_WALI(T) REAL*8 T
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_XISOL_T_WALI(XISOL,T) REAL*8 XISOL,T

Input Values:

T - Temperature t in °C

Result

XISOL_T_WALI, XISOL or xisol_t_WaLi - Mass fraction H₂O at the crystallization barrier ξ_{sol}
in kg H₂O /kg

Range of validity

Temperature range: from 0 °C to 93.58 °C

Explanation of the function

This function calculates the mass fraction H₂O at the crystallization barrier. If the actual mass fraction H₂O calculated in the liquid phase of the mixture lies below the mass fraction calculated by the function then the Lithium Bromide crystallizes out. This case is recognised by the other functions. A calculation of properties below the crystallization barrier is not possible.

Results for wrong input values

Result **XISOL_T_WALI = -1000, XISOL = -1000** or **xisol_t_WaLi = -1000** for input values:

t > 93.58 °C or t < 0 °C

References: [2], [21], [23]

Mass Fraction H₂O of Saturated Steam $\xi^V = f(p_s, t_s)$

Function Name:	xiv_psts_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION XIV_PSTS_WALI(PS,TS) REAL*8 PS,TS
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_XIV_PSTS_WALI(XIV,PS,TS) REAL*8 XIV,PS,TS

Input Values:

- PS** - Vapor pressure p_s in bar
TS - Saturation temperature t_s in °C

Result

XIV_PSTS_WALI, XIV or xiv_psts_WaLi - Mass fraction H₂O of saturated steam ξ^V
in kg H₂O / kg

Range of validity

- Temperature range: from 0 °C to 210 °C
Pressure range: from 0.00074 bar to 10 bar

Explanation of the function

This function calculates the mass fraction of water in the gas phase. Since only very few Lithium Bromide enters the gas phase, the program library acts on the assumption that there is only water in the gas phase. This is also the case for all other functions. For there is only water in the saturated steam, the function will always calculate a result of – 1 within the range of validity.

Results for wrong input values

Result **XIV_PSTS_WALI = -1000, XIV = -1000** or **xiv_psts_WaLi = -1000** for input values:

- $p_s > 10$ bar or $p_s < 0.00074$ bar or
 $t_s > 210$ °C or $t_s < 0$ °C or

References:

[2], [21]

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, -S03rev, -S04, and -S05
- IAPWS Revised Advisory Note No. 3 on Thermo-dynamic Derivatives (2008)

Library LibIF97_META

- Industrial Formulation IAPWS-IF97 (Revision 2007) for metastable steam

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:
 CO_2 - Span, Wagner H_2O - IAPWS-95
 O_2 - Schmidt, Wagner N_2 - Span et al.
 Ar - Tegeler et al.

and of the ideal gases:

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

Consideration of:

- Dissociation from VDI 4670
- Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

Extremely Fast Property Calculations

Spline-Based Table Look-up Method (SBTL)

Library LibSBTL_IF97

Library LibSBTL_95

Library LibSBTL_HuAir

For steam, water, humid air, carbon dioxide and other fluids and mixtures according IAPWS Guideline 2015 for Computational Fluid Dynamics (CFD), real-time and non-stationary simulations

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

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

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

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

- Dry air
- Steam

Consideration of:

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

www.ashrae.org/bookstore

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bücker and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

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

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

$\text{C}_2\text{H}_6\text{O}_2$	Ethylene glycol
$\text{C}_3\text{H}_8\text{O}_2$	Propylene glycol
$\text{C}_2\text{H}_5\text{OH}$	Ethanol
CH_3OH	Methanol
$\text{C}_3\text{H}_8\text{O}_3$	Glycerol
K_2CO_3	Potassium carbonate
CaCl_2	Calcium chloride
MgCl_2	Magnesium chloride
NaCl	Sodium chloride
$\text{C}_2\text{H}_3\text{KO}_2$	Potassium acetate
CHKO_2	Potassium formate
LiCl	Lithium chloride
NH_3	Ammonia

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2014)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Propane

Library LibPropane

Formulation of Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $C_8H_{24}O_4Si_4$ Library LibD4

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

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

Hexamethyldisiloxane $C_6H_{18}OSi_2$ Library LibMM

Formulation of Colonna et al. (2006)

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

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

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

Octamethyltrisiloxane $C_8H_{24}O_2Si_3$ Library LibMDM

Formulation of Colonna et al. (2008)

Nitrogen and Oxygen

Libraries

LibN2 and LibO2

Formulations of Span et al. (2000) and Schmidt and Wagner (1985)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2009)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} Library LibC5H12_Iso

Neopentane C_5H_{12} Library LibC5H12_Neo

Isohexane C_6H_{14} Library LibC6H14

Toluene C_7H_8 Library LibC7H8

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide CO Library LibCO

Carbonyl sulfide COS Library LibCOS

Hydrogen sulfide H_2S Library LibH2S

Nitrous oxide N_2O Library LibN2O

Sulfur dioxide SO_2 Library LibSO2

Acetone C_3H_6O Library LibC3H6O

Formulation of Lemmon and Span (2006)



For more information please contact:

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Fax: +49-3222-1095810

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
- Thermal diffusivity a

Backward Functions

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

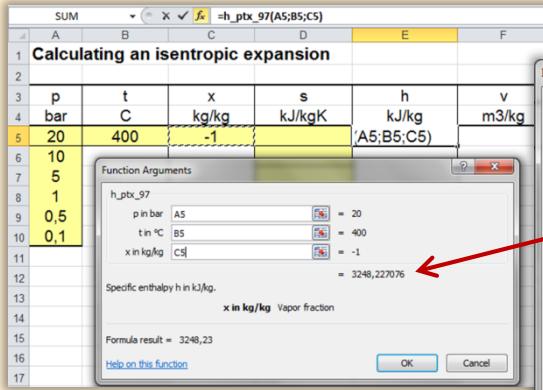
Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

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

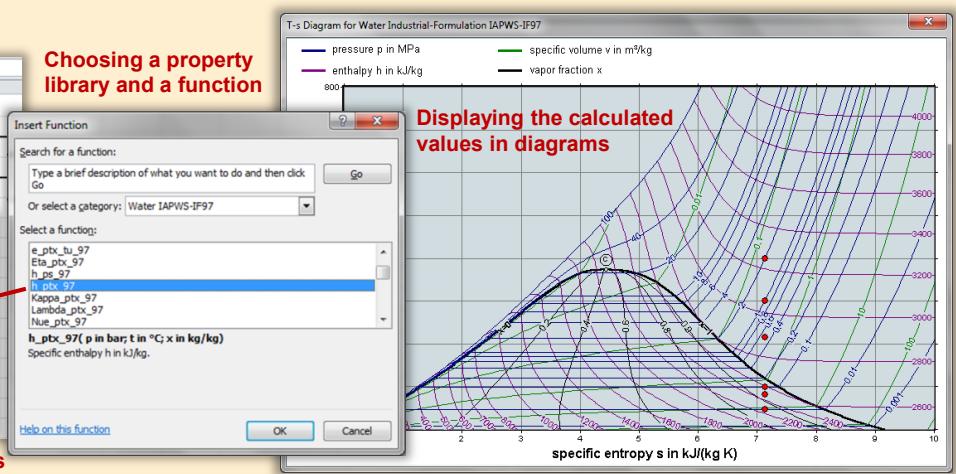
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL Graphics for Excel®



Menu for the input of given property values

Choosing a property library and a function

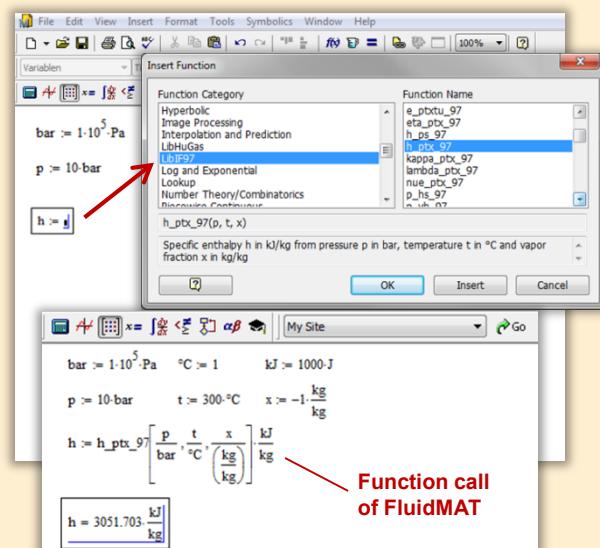


Displaying the calculated values in diagrams

Add-On FluidMAT for Mathcad®

Add-On FluidPRIME for Mathcad Prime®

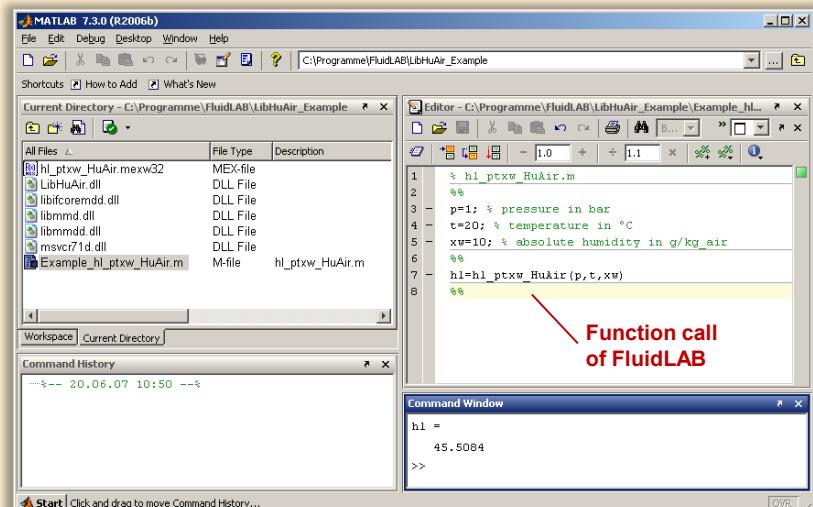
The property libraries can be used in Mathcad® and Mathcad Prime®.



Function call of FluidMAT

Add-On FluidLAB for MATLAB® and SIMULINK®

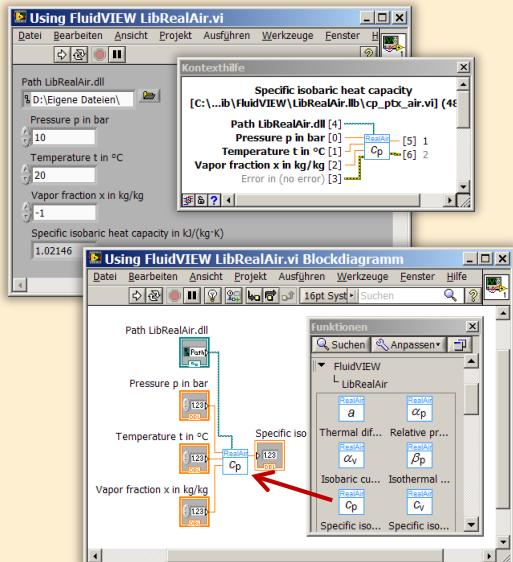
Using the Add-In FluidLAB the property functions can be called in MATLAB® and SIMULINK®.



Function call of FluidLAB

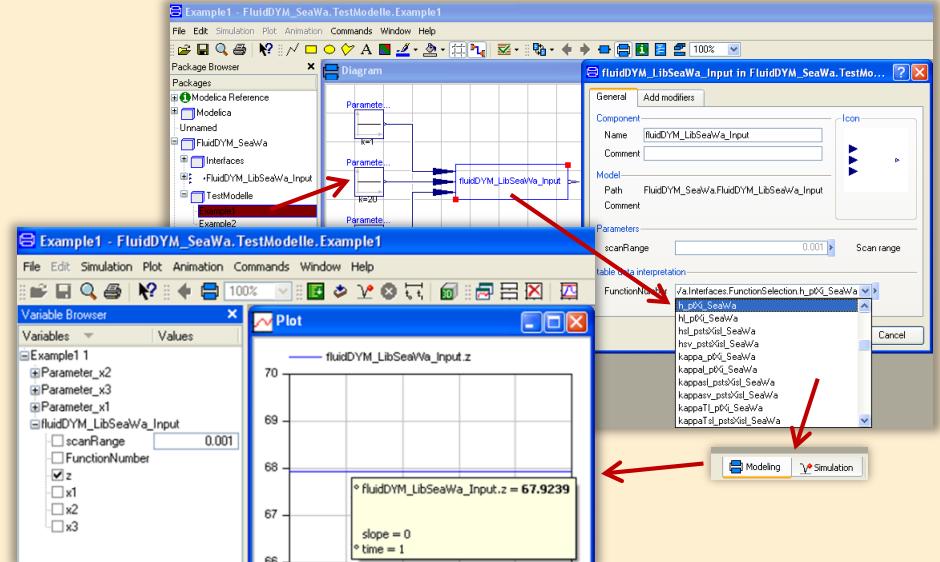
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

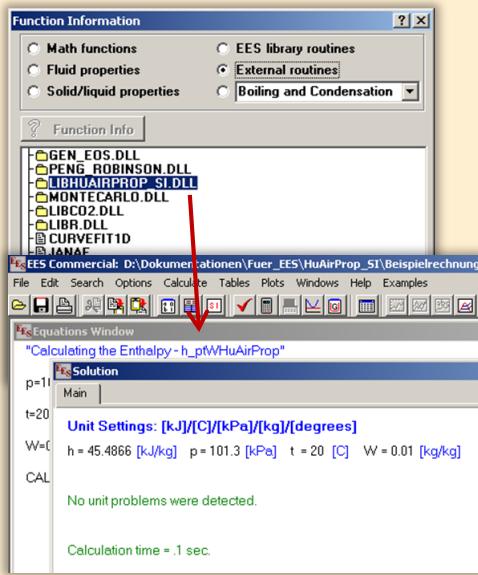


Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

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



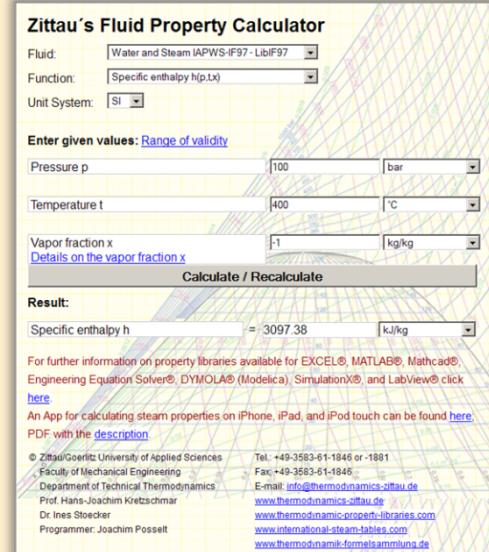
Add-On FluidEES for Engineering Equation Solver®



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



Online Property Calculator at www.thermofluidprop.com



Property Software for Pocket Calculators

FluidCasio



FluidHP



FluidTI



For more information please contact:



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Mobile: +49-172-7914607
Fax: +49-3222-1095810

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
- Thermal diffusivity a

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 used in process modeling can be calculated.

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

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6. Satisfied Customers

Date: 05/2018

The following companies and institutions use the property libraries

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

2018

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

2017

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

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

2016

BOGE Druckluftsysteme, Bielefeld	12/2016
BFT Planung, Aachen	11/2016
Midiplan, Bietigheim-Bissingen	11/2016
BBE Barnich IB	11/2016
Wenisch IB,	11/2016
INL, Idaho Falls	11/2016
TU Kältetechnik, Dresden	11/2016
Kopf SynGas, Sulz	11/2016
INTVEN, Bellevue (USA)	11/2016
DREWAG Dresden, Dresden	10/2016
AGO AG Energie+Anlagen, Kulmbach	10/2016
Universität Stuttgart, ITW, Stuttgart	09/2016
Pöyry Deutschland GmbH, Dresden	09/2016
Siemens AG, Erlangen	09/2016
BASF über Fichtner IT Consulting AG	09/2016
B+B Engineering GmbH, Magdeburg	09/2016
Wilhelm Büchner Hochschule, Pfungstadt	08/2016

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

2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	12/2015
Allborg University, Department of Energie, Aalborg, Denmark	12/2015
University of Lyubljana, Slovenia	12/2015
Steinbrecht IB, Berlin	11/2015
Universidad Carlos III de Madrid, Madrid, Spain	11/2015
STEAK, Essen	11/2015

Bosch, Lohmar	10/2015
Team Turbo Machines, Rouen, France	09/2015
BTC – Business Technology Consulting AG, Oldenburg	07/2015
KIT Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen	07/2015
ILK, Dresden	07/2015
Schniewindt GmbH & Co. KG, Neuenwalde	08/2015

2014

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

2013

TRANTER-GmbH, Artern	12/2013
SATAKE, Shanghai, China	12/2013
VOITH, Kunshan, China	12/2013
ULT, Löbau	12/2013
MAN, Copenhagen, Dänemark	11/2013
DREWAG, Dresden	11/2013
Haarslev Industries, Herlev, Dänemark	11/2013
STEAG, Herne	11/2013, 12/2013
Ingersoll-Rand, Oberhausen	11/2013
Wilhelm-Büchner HS, Darmstadt	10/2013

IAV, Chemnitz	10/2013
Technical University of Regensburg	10/2013
PD-Energy, Bitterfeld	09/2013
Thermofin, Heinsdorfergrund	09/2013
SHI, New Jersey, USA	09/2013
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	08/2013
TIG-Group, Husum	08/2013
COMPAREX, Leipzig for RWE Essen	08/2013, 11/2013 12/2013
University of Budapest, Hungary	08/2013
Siemens, Frankenthal	08/2013, 10/2013 11/2013
VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
Technical University of Deggendorf	07/2013
University of Maryland, USA	07/2013, 08/2013
University of Princeton, USA	07/2013
NIST, Boulder, USA	06/2013
IGUS GmbH, Dresden	06/2013
BHR Bilfinger, Essen	06/2013
SÜDSALZ, Bad Friedrichshall	06/2013, 12/2013
Technician School of Berlin	05/2013
KIER, Gajeong-ro, Südkorea	05/2013
Schwing/Stetter GmbH, Memmingen	05/2013
Vattenfall, Berlin	05/2013
AUTARK, Kleinmachnow	05/2013
STEAG, Zwingenberg	05/2013
Hochtief, Düsseldorf	05/2013
University of Stuttgart	04/2013
Technical University -Bundeswehr, Munich	04/2013
Rerum Cognitio Forschungszentrum, Frankfurt	04/2013
Kältetechnik Dresen + Bremen, Alfhausen	04/2013
University Auckland, New Zealand	04/2013
MASDAR Institut, Abu Dhabi, United Arab Emirates	03/2013
Simpelkamp, Dresden	02/2013
VEO, Eisenhüttenstadt	02/2013
ENTEC, Auerbach	02/2013
Caterpillar, Kiel	02/2013
Technical University of Wismar	02/2013
Technical University of Dusseldorf	02/2013

ILK, Dresden	01/2013, 08/2013
Fichtner IT, Stuttgart	01/2013, 11/2013
Schnepf Ingenierbüro, Nagold	01/2013
Schütz Engineering, Wadgassen	01/2013
Endress & Hauser, Reinach, Switzerland	01/2013
Oschatz GmbH, Essen	01/2013
frischli Milchwerke, Rehburg-Loccum	01/2013

2012

Voith, Bayreuth	12/2012
Technical University of Munich	12/2012
Dillinger Huette	12/2012
University of Stuttgart	11/2012
Siemens, Muehlheim	11/2012
Sennheiser, Hannover	11/2012
Oschatz GmbH, Essen	10/2012
Fichtner IT, Stuttgart	10/2012, 11/2012
Helbling Technik AG, Zurich, Switzerland	10/2012
University of Duisburg	10/2012
Rerum Cognitio Forschungszentrum, Frankfurt	09/2012
Pöyry Deutschland GmbH, Dresden	08/2012
Extracciones, Guatemala	08/2012
RWE, Essen	08/2012
Weghaus Consulting Engineers, Wuerzburg	08/2012
GKS, Schweinfurt	07/2012
COMPAREX, Leipzig for RWE Essen	07/2012
GEA, Nobitz	07/2012
Meyer Werft, Papenburg	07/2012
STEAG, Herne	07/2012
GRS, Cologne	06/2012
Fichtner IT Consult, Chennai, India	06/2012
Siemens, Freiburg	06/2012
Nikon Research of America, Belmont, USA	06/2012
Niederrhein University of Applied Sciences, Krefeld	06/2012
STEAG, Zwingenberg	06/2012
Mainova, Frankfurt on Main via Fichtner IT Consult	05/2012
Endress & Hauser	05/2012
PEU, Espenheim	05/2012
Luzern University of Applied Sciences, Switzerland	05/2012

BASF, Ludwigshafen (general license)	05/2012
via Fichtner IT Consult	
SPX Balcke-Dürr, Ratingen	05/2012, 07/2012
Gruber-Schmidt, Wien, Austria	04/2012
Vattenfall, Berlin	04/2012
ALSTOM, Baden	04/2012
SKW, Piesteritz	04/2012
TERA Ingegneria, Trento, Italy	04/2012
Siemens, Erlangen	04/2012, 05/2012
LAWI Power, Dresden	04/2012
Stadtwerke Leipzig	04/2012
SEITZ, Wetzikon, Switzerland	03/2012, 07/2012
M & M, Bielefeld	03/2012
Sennheiser, Wedemark	03/2012
SPG, Montreuil Cedex, France	02/2012
German Destilation, Sprendlingen	02/2012
Lopez, Munguia, Spain	02/2012
Endress & Hauser, Hannover	02/2012
Palo Alto Research Center, USA	02/2012
WIPAK, Walsrode	02/2012
Freudenberg, Weinheim	01/2012
Fichtner, Stuttgart	01/2012
airinotec, Bayreuth	01/2012, 07/2012
University Auckland, New Zealand	01/2012
VPC, Vetschau	01/2012
Franken Guss, Kitzingen	01/2012

2011

XRG-Simulation, Hamburg	12/2011
Smurfit Kappa PPT, AX Roermond, Netherlands	12/2011
AWTEC, Zurich, Switzerland	12/2011
eins-energie, Bad Elster	12/2011
BeNow, Rodenbach	11/2011
Luzern University of Applied Sciences, Switzerland	11/2011
GMVA, Oberhausen	11/2011
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	10/2011
PLANAIR, La Sagne, Switzerland	10/2011
LAWI, Dresden	10/2011
Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011

Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elsnerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Calqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010

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

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

2009

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

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

2008

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

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

2007

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

Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006
Technical University of Munich, Chair in Apparatus and Plant Engineering	02/2006
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Department of USET Merseburg incorporated society	05/2006
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	05/2006
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
Suedzucker, Ochsenfurt	06/2006
M&M Turbine Technology, Bielefeld	06/2006
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006

Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden	04/2005
Professorship of Thermic Energy Machines and Plants	
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	01/2004
University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
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Enertech EUT, Radebeul (company license)	11/2004
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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
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DLR, Leupholdhausen	04/2003
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Muenstermann GmbH, Telgte-Westbevern	06/2003
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ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003
Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
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Neusiedler AG, Ulmerfeld, Austria	09/2001

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DVO Data Processing Service, Oberhausen	05/2000
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Ostendorf Engineering, Gummersbach	12/1999

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SCA Hygiene Products, Munich	10/1998
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Wilhelmshaven University of Applied Sciences	10/1998
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Energieversorgung, Offenbach	11/1998

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