KCE
ThermoFluidProperties

# Property Library for Mixtures of Water/Lithium Bromide

## FluidVIEW with LibWaLi for LabVIEW™

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# Property Library of Ammonia-Water Mixtures

# Including DLL and Add-on for LabVIEW™

# FluidVIEW
# LibWaLi

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# 0 Package Contents

### 0.1 Zip files for 32-bit LabVIEW™

In order to install FluidVIEW on a computer running a 32-bit version of LabVIEW™ the zip file **CD_FluidVIEW_LibWaLi.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.1, 0.2, 0.3 and 0.4.

**Table 0.1** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi\vi.lib \FluidVIEW\LibWaLi**

| Filename | Effects |
|---|---|
| LibWaLi.llb | LabVIEW™ library file, containing every function of the LibWaLi property library in the form of subprograms (SubVIs) |

**Table 0.2** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi\menus \Categories\FluidVIEW**

| Filename | Effects |
|---|---|
| dir.mnu | The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items) |

**Table 0.3** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi\source**

| Filename | Effects |
|---|---|
| LibWaLi.dll | Dynamic-link library containing the algorithms for the calculation of the property functions of carbon dioxide |
| advapi32.dll | Runtime library |
| Dformd.dll | Runtime library for the Fortran DLL |
| Dforrt.dll | Runtime library for the Fortran DLL |
| LC.dll | Auxiliary library |
| msvcp60.dll | Runtime library |
| msvcrt.dll | Runtime library |

**Table 0.4** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi\help \FluidVIEW-help**

| Filename | Effects |
|---|---|
| FluidVIEW_LibWaLi.pdf | User's guide of the property library LibWaLi for the LabVIEW™ Add-On FluidVIEW |
| LibWaLi.chm | Help file with descriptions for each function |
| OpenLibWaLi_doc.vi | LabVIEW™ instrument to open the user's guide via the help menu |
| LibWaLi.txt | Text file to change the name of the menu item of the help file |
| OpenLibWaLi_doc.txt | Text file to change the name of the menu item of the file OpenLibWaLi_doc.vi |

### 0.2 Zip files for 64-bit LabVIEW™

In order to install FluidVIEW on a computer running a 64-bit version of LabVIEW™ the zip file **CD_FluidVIEW_LibWaLi_x64.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™.

The effects of the fifteen files, which are stored in the different directories of the zip archive, are shown in the Tables 0.5, 0.6, 0.7, 0.8 and 0.9.

**Table 0.5** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi_x64\vi.lib \FluidVIEW\LibWaLi**

| Filename | Effects |
|---|---|
| LibWaLi.llb | LabVIEW™ library file, containing every function of the LibWaLi property library in the form of subprograms (SubVIs) |

**Table 0.6** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi_x64\menus \Categories\FluidVIEW**

| Filename | Effects |
|---|---|
| dir.mnu | The palette view of LabVIEW™ is based on the palette files (*.mnu). They include the palette data (e. g. the display name, the palette icon, the palette description, the help information, the synchronize information and the items) |

**Table 0.7** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi_x64\source**

| Filename | Effects |
|---|---|
| LibWaLi.dll | Dynamic-link library containing the algorithms for the calculation of the property functions of carbon dioxide |
| Capt_ico_big.ico | Icon file |
| Libmmd.dll | Runtime library |
| Libifcoremd.dll | Runtime library |
| LC.dll | Auxiliary library |
| Libiomp5md.dll | Runtime library |

**Table 0.8** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi_x64\help \FluidVIEW-help**

| Filename | Effects |
|---|---|
| FluidVIEW_LibWaLi.pdf | User's guide of the LibWaLi property library for the LabVIEW™ Add-On FluidVIEW |
| LibWaLi.chm | Help file with descriptions for each function |
| OpenLibWaLi_doc.vi | LabVIEW™ instrument to open the user's guide via the help menu |
| LibWaLi.txt | Text file to change the name of the menu item of the help file |
| OpenLibWaLi_doc.txt | Text file to change the name of the menu item of the file OpenLibWaLi_doc.vi |

**Table 0.9** Effects of the files located in the archive directory **CD_FluidVIEW_LibWaLi_x64 \vcredist_x64**

| Filename | Effects |
|---|---|
| vcredist_x64.exe | Executable file to install the Microsoft Visual C++ 2008 Redistributable Package (x64). Within runtime components of Visual C++ Libraries required to run 64-bit applications developed with Visual C++ on a computer that does not have Visual C++ 2010 installed. |

# 1. Property Functions

| Functional Dependence | Function Name | Call from Fortran program | Call in DLL LibWaLi as parameter | Property or Function | Unit of the result |
|---|---|---|---|---|---|
| $c_p = \mathrm{f}(p,t,\xi)$ | cp_ptxi_WaLi | CP_PTXI_WALI(P,T,XI) | C_CP_PTXI_WALI(CP,P,T,XI) | Specific isobaric heat capacity | kJ/(kg K) |
| $c'_p = \mathrm{f}(p_s,t_s,\xi')$ | 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) |
| $c''_p = \mathrm{f}(p_s,t_s,\xi')$ | 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) |
| $\eta = \mathrm{f}(p,t,\xi)$ | eta_ptxi_WaLi | ETA_PTXI_WALI(P,T,XI) | C_ETA_PTXI_WALI(ETA,P,T,XI) | Dynamic viscosity | Pa s |
| $\eta' = \mathrm{f}(p_s,t_s,\xi')$ | etal_pstsxil_WaLi | ETAL_WALI(PS,TS,XIL) | C_ETAL_WALI(ETAL,PS,TS,XIL) | Dynamic viscosity of saturated liquid | Pa s |
| $\eta'' = \mathrm{f}(p_s,t_s,\xi')$ | etav_pstsxil_WaLi | ETAV_WALI(PS,TS,XIL) | C_ETAV_WALI(ETAV,PS,TS,XIL) | Dynamic viscosity of saturated steam | Pa s |
| $h = \mathrm{f}(p,t,\xi)$ | h_ptxi_WaLi | H_PTXI_WALI(P,T,XI) | C_H_PTXI_WALI(H,P,T,XI) | Specific enthalpy | kJ/kg |
| $h' = \mathrm{f}(p_s,t_s,\xi')$ | hl_pstsxil_WaLi | HL_WALI(PS,TS,XIL) | C_HL_WALI(HL,PS,TS,XIL) | Specific enthalpy of saturated liquid | kJ/kg |
| $h'' = \mathrm{f}(p_s,t_s,\xi')$ | hv_pstsxil_WaLi | HV_WALI(PS,TS,XIL) | C_HV_WALI(HV,PS,TS,XIL) | Specific enthalpy of saturated steam | kJ/kg |
| $h_{sol} = \mathrm{f}(\xi)$ | hsol_xi_WaLi | HSOL_XI_WALI(XI) | C_HSOL_XI_WALI(HSOL,XI) | Specific enthalpy at the crystallization barrier | kJ/kg |
| $\lambda = \mathrm{f}(p,t,\xi)$ | lam_ptxi_WaLi | LAM_PTXI_WALI(P,T,XI) | C_LAM_PTXI_WALI(LAM,P,T,XI) | Thermal conductivity | W/(m K) |
| $\lambda' = \mathrm{f}(p_s,t_s,\xi')$ | laml_pstsxil_WaLi | LAML_WALI(PS,TS,XIL) | C_LAML_WALI(LAML,PS,TS,XIL) | Thermal conductivity of saturated liquid | W/(m K) |
| $\lambda'' = \mathrm{f}(p_s,t_s,\xi')$ | lamv_pstsxil_WaLi | LAMV_WALI(PS,TS,XIL) | C_LAMV_WALI(LAMV,PS,TS,XIL) | Thermal conductivity of saturated steam | W/(m K) |
| $\nu = \mathrm{f}(p,t,\xi)$ | ny_ptxi_WaLi | NY_PTXI_WALI(P,T,XI) | C_NY_PTXI_WALI(NY,P,T,XI) | Kinematic viscosity | $m^2/s$ |
| $\nu' = \mathrm{f}(p_s,t_s,\xi')$ | nyl_pstsxil_WaLi | NYL_WALI(PS,TS,XIL) | C_NYL_WALI(NYL,PS,TS,XIL) | Kinematic viscosity of saturated liquid | $m^2/s$ |
| $\nu'' = \mathrm{f}(p_s,t_s,\xi')$ | nyv_pstsxil_WaLi | NYV_WALI(PS,TS,XIL) | C_NYV_WALI(NYV,PS,TS,XIL) | Kinematic viscosity of saturated steam | $m^2/s$ |
| $Pr = \mathrm{f}(p,t,\xi)$ | 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 |
|---|---|---|---|---|---|
| $Pr' = \mathrm{f}(p_\mathrm{s}, t_\mathrm{s}, \xi')$ | Prl_pstsxil_WaLi | PRL_WALI(PS,TS,XIL) | C_PRL_WALI(PRL,PS,TS,XIL) | *Prandtl*-Number of saturated liquid | - |
| $Pr'' = \mathrm{f}(p_\mathrm{s}, t_\mathrm{s}, \xi')$ | Prv_pstsxil_WaLi | PRV_WALI(PS,TS,XIL) | C_PRV_WALI(PRV,PS,TS,XIL) | *Prandtl*-Number of saturated steam | - |
| $p_\mathrm{s} = \mathrm{f}(t_\mathrm{s}, \xi')$ | ps_tsxil_WaLi | PS_TSXIL_WALI(TS,XIL) | C_PS_TSXIL_WALI(PS,TS,XIL) | Vapor pressure | bar |
| $p_\mathrm{sol} = \mathrm{f}(t)$ | psol_t_WaLi | PSOL_T_WALI(T) | C_PSOL_T_WALI(PSOL,T) | Pressure at the crystallization barrier | bar |
| $Region = \mathrm{f}(p, t, \xi)$ | region_ptxi_WaLi | REGION_PTXI_WALI(P,T,XI) | C_REGION_PTXI_WALI(REGION,P,T,XI) | Phase region from pressure, temperature and mass fraction of $H_2O$ | - |
| $Region = \mathrm{f}(p, h, \xi)$ | 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 $H_2O$ | - |
| $Region = \mathrm{f}(p, s, \xi)$ | 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 $H_2O$ | - |
| $s = \mathrm{f}(p, t, \xi)$ | s_ptxi_WaLi | S_PTXI_WALI(P,T,XI) | C_S_PTXI_WALI(S,P,T,XI) | Specific entropy | kJ/(kg K) |
| $s' = \mathrm{f}(p_\mathrm{s}, t_\mathrm{s}, \xi')$ | sl_pstsxil_WaLi | SL_WALI(PS,TS,XIL) | C_SL_WALI(SL,PS,TS,XIL) | Specific entropy of saturated liquid | kJ/(kg K) |
| $s'' = \mathrm{f}(p_\mathrm{s}, t_\mathrm{s}, \xi')$ | sv_pstsxil_WaLi | SV_WALI(PS,TS,XIL) | C_SV_WALI(SV,PS,TS,XIL) | Specific entropy of saturated steam | kJ/(kg K) |
| $t = \mathrm{f}(p, h, \xi)$ | 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 $H_2O$ | °C |
| $t = \mathrm{f}(p, s, \xi)$ | 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 $H_2O$ | °C |
| $t_\mathrm{s} = \mathrm{f}(p_\mathrm{s}, \xi')$ | 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 |
|---|---|---|---|---|---|
| $t_{sol} = f(p)$ | 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 | $m^3/kg$ |
| $v' = f(p_s,t_s,\xi')$ | vl_pstsxil_WaLi | VL_WALI(PS,TS,XIL) | C_VL_WALI(HL,PS,TS,XIL) | Specific volume of saturated liquid | $m^3/kg$ |
| $v'' = f(p_s,t_s,\xi')$ | vv_pstsxil_WaLi | VV_WALI(PS,TS,XIL) | C_VV_WALI(HV,PS,TS,XIL) | Specific volume of saturated steam | $m^3/kg$ |
| $\xi' = f(p_s,t_s)$ | xil_psts_WaLi | XIL_PSTS_WALI(PS,TS) | C_XIL_PSTS_WALI(XIL,PS,TS) | Mass fraction $H_2O$ of saturated liquid | kg/kg |
| $\xi_{sol} = f(p)$ | xisol_p_WaLi | XISOL_P_WALI(P) | C_XISOL_P_WALI(XISOL,P) | Mass fraction $H_2O$ 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 $H_2O$ of saturated steam | kg/kg |

**Units:**

$t$ in °C

$p$ in bar

$\xi$ in (kg $H_2O$)/(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 $\xi'$
- or $p_s$ and $\xi'$
- 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 $\xi'$ are entered, the program will consider $p_s$, $t_s$, and $\xi'$ 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 $H_2O$)/(kg mixture) |

## Reference state

| | |
|---|---|
| Water: | Triple point for saturated liquid |
| | $h_{H2O}$ = 0.000611783 kJ/kg and |
| | $s_{H2O}$ = 0 |
| | at $p_{tr}$ = 0.00611657 bar and $t_{tr}$ = 0.01 °C |
| Mixture of water/lithium bromide: | saturated liquid |
| | $h_{0.5}$ = −0.0209415 kJ/kg and |
| | $s_{0.5}$ = −0,0000780433 kJ/(kg K) |
| | at $t$ = 0 °C and $\xi$ = 0.5 kg $H_2O$ / 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 FluidVIEW in LabVIEW™

The FluidVIEW Add-on has been developed to calculate thermodynamic properties in LabVIEW™ (version 10.0 or higher) more conveniently. Within LabVIEW™, it enables the direct call of functions relating to water/lithium bromide mixtures from the LibWaLi property library.

## 2.1 Installing FluidVIEW

If a FluidVIEW property library has not yet been installed, please complete the initial installation procedure described below.

If a FluidVIEW property library has already been installed, you only need to copy several files which belong to the LibWaLi library. In this case, follow the subsection "Adding the LibWaLi Library" on page 2/3.

In both cases folders and files from the zip archive

CD_FluidVIEW_LibWaLi.zip (for 32-bit version of Windows®)

CD_FluidVIEW_LibWaLi_x64.zip (for 64-bit version of Windows®)

have to be copied into the default directory of the LabVIEW™ development environment. In the following text these zipped directories for the 32-bit or 64-bit operating system will be symbolised with the term **<CD>**.

You can see the current default directory of LabVIEW™ in the paths page (options dialog box). To display this page please select *Tools* and click on *Options* to open the options dialog box and then select *Paths* from the category list.

By choosing *Default Directory* from the drop-down list the absolute pathname to the default directory, where LabVIEW™ automatically stores information, is displayed. In the following sections the pathname of the default directory will be symbolised by the term **<LV>**.

### Additional Requirement When Using the 64-bit Operating System

If you want to use FluidVIEW on a 64-bit computer that does not have Visual C++ installed, please make sure the Microsoft Visual C++ 2010 x64 Redistributable Package is installed.

If it is not the case, please install it by double clicking the file

vcredist_x64.exe

which you find in the folder **\vcredist_x64** in the **64-bit** CD folder "CD_FluidVIEW_LibWaLi_x64."

In the following window you are required to accept the Microsoft® license terms to install the Microsoft Visual C++ 2010 runtime libraries by ticking the box next to "I have read and accept the license terms" (see Figure 2.1).

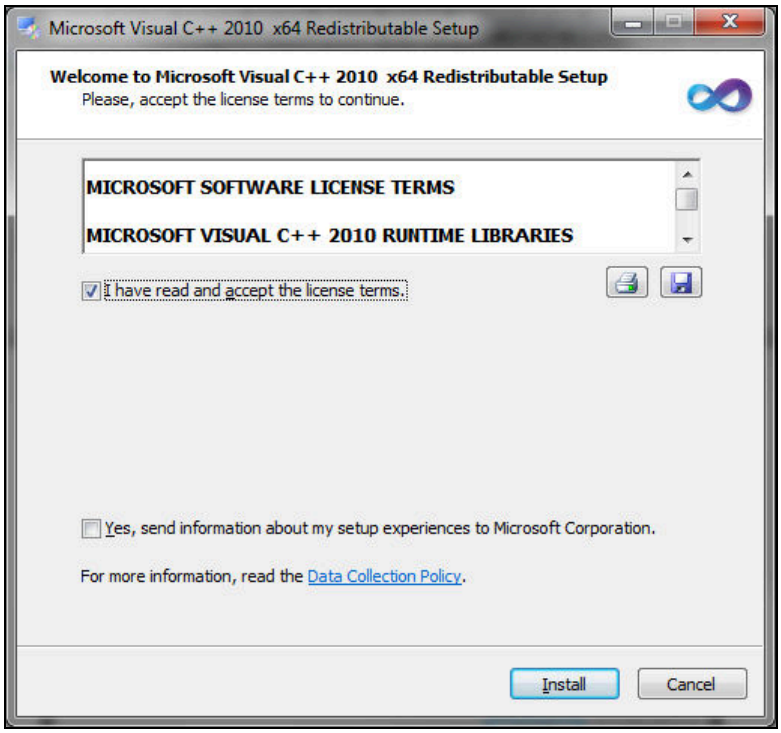


**Figure 2.1** Accepting the license terms to install the Microsoft Visual C++ 2010 x64 Redistributable Package

Now click on "Install" to continue installation.

After the "Microsoft Visual C++ 2010 x64 Redistributable Pack" has been installed, you will see the sentence "Microsoft Visual C++ 2010 x64 Redistributable has been installed." Confirm this by clicking "Finish."

Now you can use the FluidVIEW Add-On on your 64-bit operating system. Please follow the instructions below to install FluidVIEW.

## Initial Installation of FluidVIEW

The initial installation of FluidVIEW is carried out by copying three directories with its contents from the zip archive to the standard directory of LabVIEW™.

The directories that have to be copied, their paths in the zip archive and their target paths are listed in Table 2.1.

The installation is complete after copying the files and restarting LabVIEW™.

Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory **<CD>\source** can be stored in a random directory on the harddisc. The pathname of LibHuAir.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9).

All source files have to be stored in the same directory to make the property functions of the LibWaLi library work. These files are for the

- **32-bit system**: LibWaLi.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system**: LibWaLi.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll.

**Table 2.1** Directories which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for the initial installation of FluidVIEW

| Name of the directory | Parent directory in the zip archive | Target path in the default directory of LabVIEW (<LV>) |
|---|---|---|
| FluidVIEW | <CD>\vi.lib | <LV>\vi.lib |
| FluidVIEW | <CD>\menus\Categories | <LV>\menus\Categories |
| FluidVIEW-Help | <CD>\help | <LV>\help |

## Adding the LibWaLi Library

In order to add the LibWaLi property library to an existing FluidVIEW installation, one folder with its contents and five files have to be copied from the zip archive to the standard directory of LabVIEW™. This directory, the files plus their pathnames in the zip archive and their target paths are listed in Table 2.2.

The installation is complete after copying the files and restarting LabVIEW™.

Due to the fact, that the functions of the DLL are called with a variable pathname, the source files you will find in the directory **<CD>\source** can stored in a random directory on the harddisc. The pathname of LibHuAir.dll, which is located in this directory, has to be indicated in order to calculate the property functions (see example calculation in section 2.4 on page 2/9).

All source files have to be stored in the same directory to make the property functions of the LibWaLi library work. These files are for the

- **32-bit system**: LibWaLi.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcrt.dll

and for the

- **64-bit system**: LibWaLi.dll, capt_ico_big.ico, LC.dll, libifcoremd.dll, libiomp5md.dll, and libmmd.dll

**Table 2.2** Data which have to be copied from the zip archive in the default directory of LabVIEW™ (<LV>) for adding the LibWaLi property library to an existing installation of FluidVIEW

| File name with file extension or name of the directory | Parent directory in the zip archive | Target path in the default directory of LabVIEW (<LV>) |
|---|---|---|
| LibWaLi.llb | <CD>\vi.lib\FluidVIEW | <LV>\vi.lib\FluidVIEW |
| LibWaLi | <CD>\menus\Categories \FluidVIEW | <LV>\menus\Categories \FluidVIEW |
| LibWaLi.hlp | <CD>\\help\FluidVIEW-Help | <LV>\help\FluidVIEW-Help |
| LibWaLi.txt | <CD>\\help\FluidVIEW-Help | <LV>\help\FluidVIEW-Help |
| FluidVIEW_LibWaLi.pdf | <CD>\\help\FluidVIEW-Help | <LV>\help\FluidVIEW-Help |
| Open_LibWaLi_doc.vi | <CD>\\help\FluidVIEW-Help | <LV>\help\FluidVIEW-Help |
| Open_LibWaLi_doc.txt | <CD>\\help\FluidVIEW-Help | <LV>\help\FluidVIEW-Help |

After you have restarted LabVIEW™ you will find the functions of the LibWaLi property library in the functions palette under the sub palette FluidVIEW. An example calculation of the specific enthalpy *h* and the specific entropy *s* is shown in section 2.4.

## 2.2 The FluidVIEW Help System

FluidVIEW provides detailed online help functions.

### General Information

The FluidVIEW Help System consists of the Microsoft WinHelp file **LibWaLi.chm** and this user's guide as PDF document **FluidVIEW_LibWaLi_Docu_Eng.pdf**. Both files can be opened via the help menu. To do this please click *Help* in the menu bar. In the submenu *FluidVIEW-Help* you will find the commands *LibWaLi Help File* and *LibWaLi User's Guide* to open an appropriate file.

### Context-Sensitive Help

If you have activated the context help function in LabVIEW™ (Ctrl-H) and move the cursor over a FluidVIEW object basic information is displayed in the context help window. The in- and output parameters plus a short information text are displayed for a property function. By clicking the **Detailed help** button in the **Context help** window the online help will be opened. The context help window of the function h_ptx_WaLi.vi is shown in Figure 2.2.

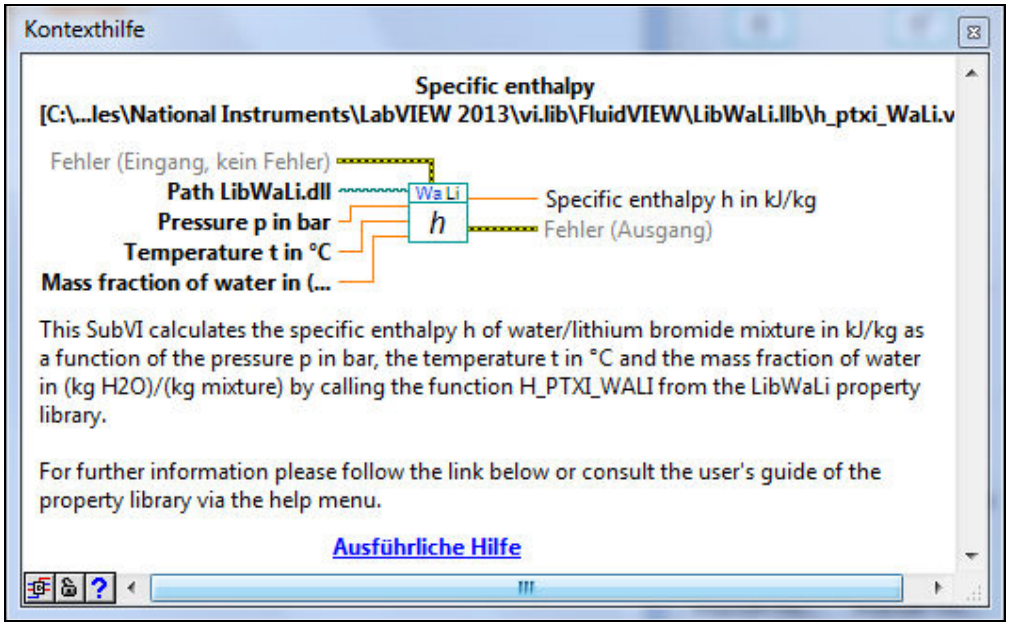


**Figure 2.2** Context help window of the function h_ptxi_WaLi.vi

## 2.3 Licensing the LibWaLi Property Library

The licensing procedure has to be carried out when calculating a LibWaLi function and a FluidVIEW prompt message appears. In this case, you will see the "License Information" window (see figure below).

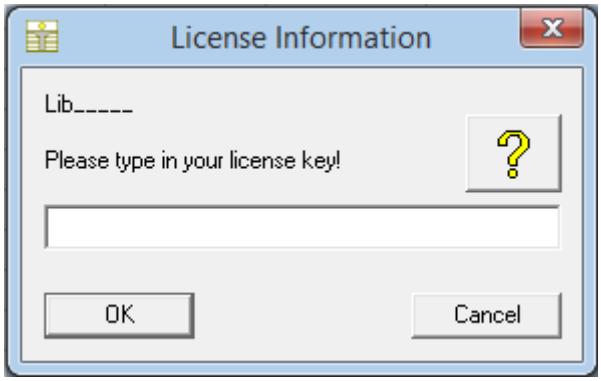


**Figure 2.3** "License Information" window

Here you will have to type in the license key. You can find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:

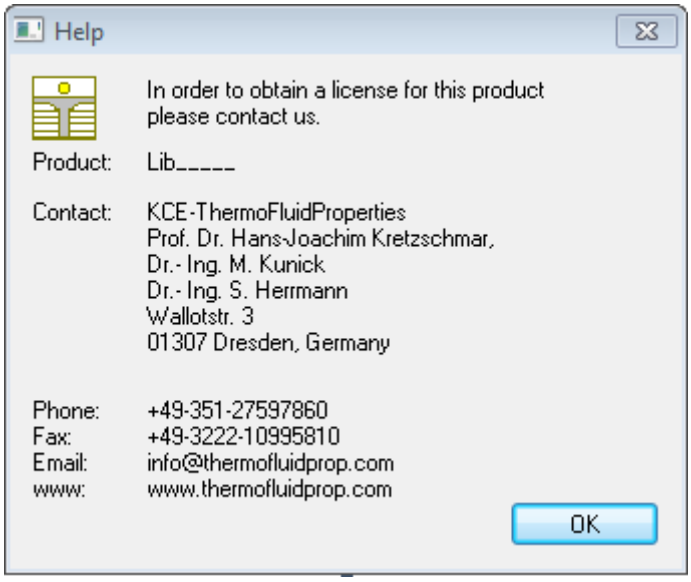


**Figure 2.4** "Help" window

If you do not enter a valid license it is still possible to run your VI by clicking "Cancel". In this case, the LibWaLi property library will display the result "-1.11111E+7" for every calculation.

The "License Information" window will appear every time you reopen your Virtual Instrument (VI) or reload the path of the LibWaLi.dll. Should you not wish to license the LibWaLi property library, you have to uninstall FluidVIEW according to the description in section 2.5 of this User's Guide.

***Note:***

*The product name "Lib_ _ _ _ _ in the Figures above stands for the Library you are installing.*

## 2.4 Example: Calculation of $h = f(p,t,\xi)$ and $h' = f(p_s, t_s, \xi')$

After the delivered files have been copied in the appropriate folders of the default directory LabVIEW™ (described in section 2.1), the LibWaLi property library is ready to use. The function nodes of the LibWaLi property library can be used by dragging them from the functions palette into the block diagram and connecting them with the wires representing the required input parameters.

First we will calculate, step by step, the specific enthalpy *h* as a function of pressure *p*, temperature *t*, and mass fraction of water $\xi$, using FluidVIEW.

- Start LabVIEW™ and wait for the *Getting Started* window to be displayed. Then select *Blank VI*. The *Blank VI* will be displayed in two windows, the front panel and the block diagram.
- Open the functions palette in the block diagram **via view / Functions Palette** (or by clicking the right mouse button anywhere in the free area of the block diagram) if not yet displayed.
- In addition to the default LabVIEW™ palettes the functions palette contains the sub palette *FluidVIEW* (see Figure 2.5) with the sub palette *LibWaLi* (see Figure 2.6).

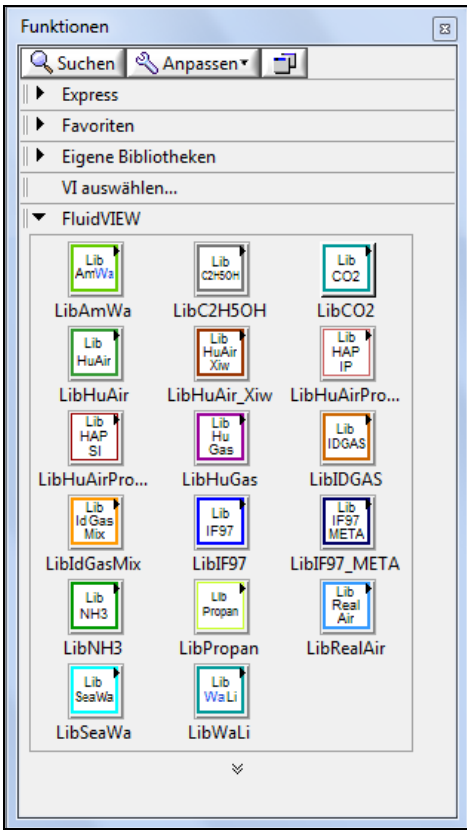


**Figure 2.5**
Functions palette with the sub palettes FluidVIEW and LibWaLi

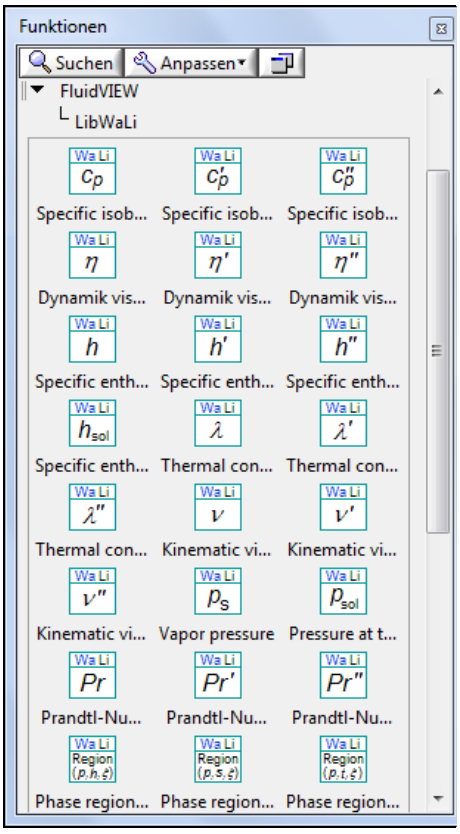


**Figure 2.6**
Functions palette with the property functions of the LibWaLi library

In order to calculate the specific enthalpy *h*, drag the function (SubVI) whose symbol shows the *h* from the functions palette into the block diagram.
While the short names of the SubVIs behind the symbols will be shown in the control tip, the full names and brief descriptions of the property functions are displayed in the

*Context Help* window (see Figure 2.2). To use the context help press <Ctrl>+<H> on your keyboard.

- After placing the node of the SubVI **h_ptxi_WaLi.vi** on your block diagram the required input parameters have to be defined.
  The input parameters which are set as required appear in bold type in the Context Help window. In this case these input parameters are **Path LibWaLi.dll** (LabVIEW™ data type: Path), **Pressure p in bar** (LabVIEW™ data type: Double precision, floating-point), **Temperature t in °C** (LabVIEW™ data type: Double precision, floating-point) and **Mass fraction of water $\xi$ in kg/kg** (LabVIEW™ data type: Double precision, floating-point).
- To define these variables wire their input terminals with input elements on the front panel. You can accomplish this in one step by choosing **Create / Control** in the context menu of all required input terminals. In order to wire the output terminal of the function node with an output element on the front panel, choose **Create / Indicator** in the context menu of the output terminal **Specific enthalpy h in kJ/kg** (LabVIEW™ data type: Double precision, floating-point). After cleaning up the block diagram by pressing <Ctrl>+<U> it has the appearance illustrated in Figure 2.7. The same input and output elements are available on the appropriate front panel (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

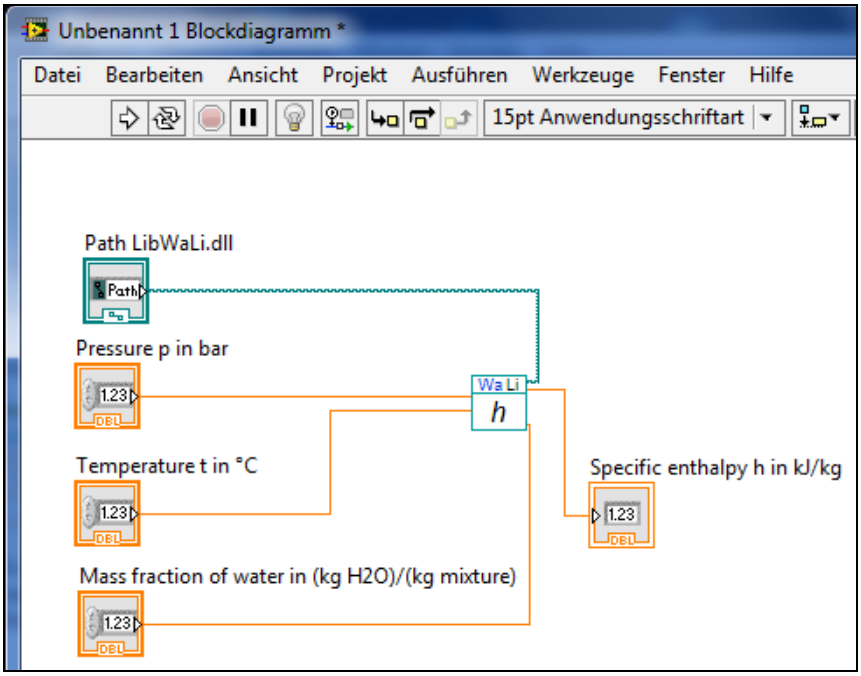


**Figure 2.7**
Block diagram of the example calculation

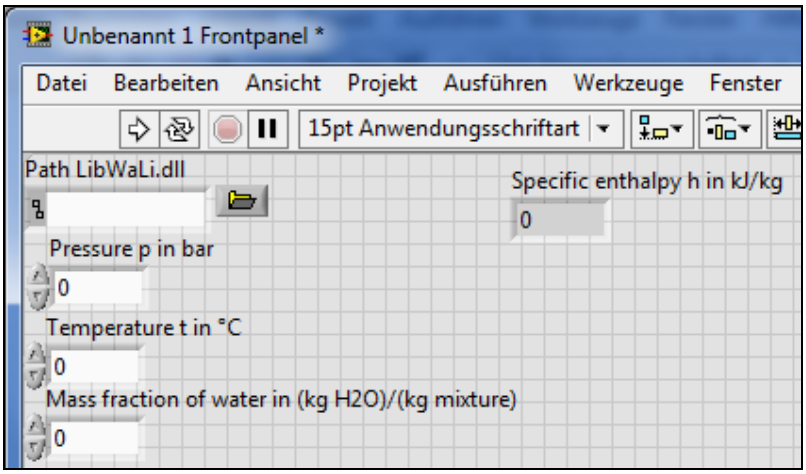


**Figure 2.8**
Front panel of the example calculation

- Enter a value in the input element *pressure p in bar* on the front panel
  (Range of validity: $p$ = 0.00074 bar ... 10 bar)

  ⇒ e. g.: Enter the value 1.

- Enter a value in the input element *temperature t in °C* on the front panel
  (Range of validity: $t$ = 0 °C ... 210 °C)

  ⇒ e. g.: Enter the value 25.

  Enter a value in the input element *mass fraction $\xi$ in kg* water/kg mixture on the front panel.
  (Range of validity: $\xi$ = 0.3 kg $H_2O$/kg ... 1.0 kg $H_2O$/kg)

⇒ e. g.: Enter the value 0.6.

- Enter the path of the LibWaLi.dll in the input element *Path LibWaLi.dll* on the front panel (as explained in section 2.1 the LibWaLi.dll and the other library files from the directory **<CD>\source** have to be stored in the same directory which is arbitrary). To do this you can use the *File Open Dialog* which appears by clicking the yellow folder symbol on the right of the input element.
- To run the calculation of the specific enthalpy click on the *Run* button or press <Ctrl>+<R>. The result for *h* in kJ/kg appears in the output element (see Figure 2.9).

  ⇒ The result for *h* in our sample calculation is h = 46.267854 kJ/kg.

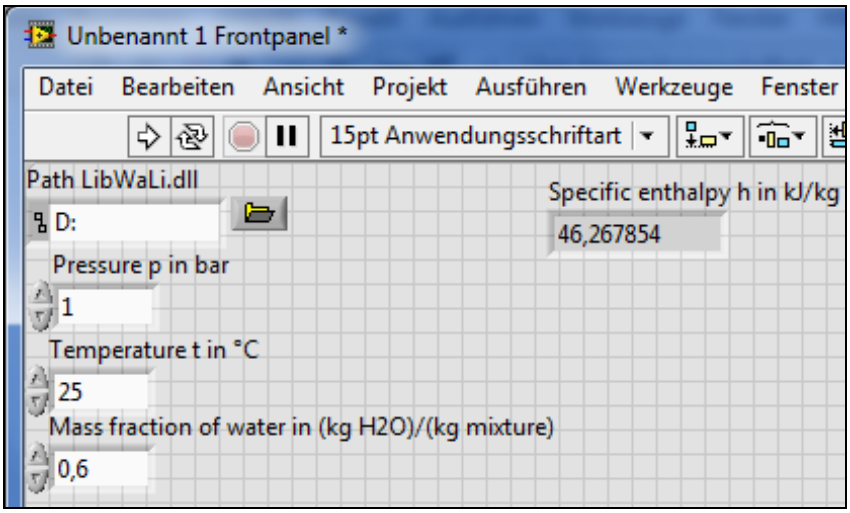


**Figure 2.9** Result of the example calculation of *h*

The calculation of $h = f(p,t,\xi)$ has thus been completed.

Correspondingly, the specific enthalpy of saturated liquid $h' = f(p_s,t_s,\xi')$ can be calculated now. The following changes need to be implemented.

- Open the context menu of the function node *specific enthalpy* on the block diagram. Under **Replace / Palette LibWaLi** you will find the function **Specific enthalpy of saturated liquid** symbolized with *hl*. The node on the block diagram changes to **Specific enthalpy** by clicking on this symbol.
- The label of the input parameter *p* must be changed to $p_s$ and a new value must be entered.

  (Range of validity: $p_s$ = 0.00074 bar ... 10 bar)

  Enter the value 1 for $p_s$.
- The label of the input parameter *t* must be changed to $t_s$ and a new value must be entered.

  For calculating the specific enthalpy of the boiling liquid it is necessary to define two parameters (either $t_S$ and $\xi'$ or $p_S$ and $\xi'$ or $p_S$ and $t_S$) and x = –1 must be entered as a pro-forma value for the value which is not given. When $p_S$, $t_S$, and $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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:** $h' = f(-1, t_s, \xi')$
  $h' = f(p_s, -1, \xi')$
  $h' = f(p_s, t_s, -1)$
  $h' = f(p_s, t_s, \xi')$

  (Range of validity: $t_s$ = 0 °C ... 210 °C)

⇒ In our example here the input variety $h' = f(p, -1, \xi')$ has been chosen. The value -1 has to be entered as the new value for $t_s$.

- The label of the input parameter *xi* must be changed to *xil* and a new value must be entered.

  (Range of validity: $\xi'$ = 0.3 kg $H_2O$/kg ... 1.0 kg $H_2O$/kg)

  Enter the value 0.6 for $\xi'$.

- The output parameter can be changed from *specific enthalpy h in kJ/kg* to *specific enthalpy for saturated liquid hl in kJ/kg* by double clicking on it and typing the new name.
- On the front panel you can see that the new label for the output element *specific enthalpy for saturated liquid hl in kJ/kg* was taken automatically. Since the values in the input elements have been changed before the calculation can be started now by pressing <Ctrl>+<R> or clicking the *Run* button. The result for *hl* in kJ/kg·K appears in the output element.

  ⇒ The result for *hl* in our sample calculation is $h'$ = 274.881498 kJ/kg.

The calculation of $h' = f(p_s, t_s, \xi')$ has been carried out. You can now arbitrarily change the values for $p_s$, $t_s$, or $\xi'$ in the appropriate input elements.

**Note**:
If the calculation results in –1000, this indicates that the values entered are located outside the range of validity. More detailed information on each function and its range of validity is available in chapter 3. For further property functions calculable with FluidVIEW, see the function table in chapter 1.

## 2.5 Removing FluidVIEW

Should you wish to remove the LibWaLi library or the complete FluidVIEW Add-on you have to delete the files that have been copied in the default directory of the LabVIEW™ development environment **<LV>**.

### Removing the FluidVIEW Add-on

To remove the FluidVIEW Add-on please delete the folders listed in Table 2.3 from the default directory of LabVIEW™.

**Table 2.3** Directories that have to be deleted from the default directory of LabVIEW™ to remove the FluidVIEW Add-on

| Name of the directory | Parent directory in the default directory of LabVIEW™ (<LV>) |
|---|---|
| FluidVIEW | <LV>\vi.lib |
| FluidVIEW | <LV>\menus\Categories |
| FluidVIEW-Help | <LV>\help |

### Removing only the LibWaLi library

To remove only the LibWaLi library please delete the folders or files listed in Table 2.4 from the default directory of LabVIEW™.

**Table 2.4** Data that have to be deleted from the default directory of LabVIEW™ (<LV>) to remove only the LibWaLi library.

| File name with file extension or name of the directory | Parent directory in the default directory of LabVIEW (<LV>) |
|---|---|
| LibWaLi.llb | <LV>\vi.lib\FluidVIEW |
| LibWaLi | <LV>\menus\Categories\FluidVIEW |
| LibWaLi.hlp | <LV>\help\FluidVIEW-Help |
| LibWaLi.txt | <LV>\help\FluidVIEW-Help |
| FluidVIEW_LibWaLi.pdf | <LV>\help\FluidVIEW-Help |
| Open_LibWaLi_doc.vi | <LV>\help\FluidVIEW-Help |
| Open_LibWaLi_doc.txt | <LV>\help\FluidVIEW-Help |

The changes will take effect after restarting LabVIEW™.

# 3. Program Documentation

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

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

### Input Values:

**P** - Pressure p in bar

**T** - Temperature t in °C

**XI** - Mass fraction of water $\xi$ in (kg $H_2O$)/(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 $H_2O$)/(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 $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter: for call from DLL | **INTEGER*4 FUNCTION C_CPV_WALI(CPV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION ETA_PTXI_WALI(P,T,XI)**<br>REAL*8 P,T,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_ETA_PTXI_WALI(ETA,P,T,XI)**<br>REAL*8 ETA,P,T,XI |

## Input Values:

- **P** - Pressure p in bar
- **T** - Temperature t in °C
- **XI** - Mass fraction of water $\xi$ in (kg $H_2O$)/(kg mixture)

## Result

**ETA_PTXI_WALI**, **ETA** or **eta_ptxi_WaLi** – Dynamic viscosity $\eta$ 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 $H_2O$)/(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
$\xi > 1.0$ kg/kg or $\xi < 0.3$ 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:<br>for call from Fortran | **REAL*8 FUNCTION ETAL_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_ETAL_WALI(ETAL,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

### Result

**ETAL_WALI**, **ETAL** or **etal_pstsxil_WaLi** - Dynamic viscosity of saturated liquid $\eta^l$ 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 $H_2O$)/(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 $\xi'$ or $p_S$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION ETAV_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_ETAV_WALI(ETAV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

### Result

**ETAV_WALI**, **ETAV** or **etav_pstsxil_WaLi** - Dynamic viscosity of saturated steam $\eta^v$ 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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION H_PTXI_WALI(P,T,XI)**<br>REAL*8 P,T,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_H_PTXI_WALI(H,P,T,XI)**<br>REAL*8 H,P,T,XI |

## Input Values:

**P** - Pressure p in bar

**T** - Temperature t in °C

**XI** - Mass fraction of water $\xi$ in (kg $H_2O$)/(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 $H_2O$)/(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 kg/kg or $\xi$ < 0.3 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:<br>for call from Fortran | **REAL*8 FUNCTION HL_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_HL_WALI(HL,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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 $\xi'$ or $p_S$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION HV_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_HV_WALI(HV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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 $\xi'$ or $p_S$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION HSOL_XI_WALI(XI)**<br>REAL*8 XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_HSOL_XI_WALI(HSOL,XI)**<br>REAL*8 HSOL,XI |

## Input Values:

**XI** - Mass fraction of water $\xi$ in (kg $H_2O$)/(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 $H_2O$)/(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:<br>for call from Fortran | **REAL*8 FUNCTION LAM_PTXI_WALI(P,T,XI)**<br>REAL*8 P,T,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_LAM_PTXI_WALI(LAM,P,T,XI)**<br>REAL*8 LAM,P,T,XI |

## Input Values:

**P** - Pressure p in bar

**T** - Temperature t in °C

**XI** - Mass fraction of water $\xi$ in (kg $H_2O$)/(kg mixture)

## Result

**LAM_PTXI_WALI**, **LAM** or **lam_ptxi_WaLi** – Thermal conductivity $\lambda$ 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 $H_2O$)/(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 kg/kg or $\xi$ < 0.3 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:<br>for call from Fortran | **REAL*8 FUNCTION LAML_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_LAML_WALI(LAML,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

### Result

**LAML_WALI**, **LAML** or **laml_pstsxil_WaLi** - Thermal conductivity of saturated liquid $\lambda^l$ 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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION LAMV_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_LAMV_WALI(LAMV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

### Result

**LAMV_WALI**, **LAMV** or **lamv_pstsxil_WaLi** - Thermal conductivity of saturated steam $\lambda^v$ 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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION NY_PTXI_WALI(P,T,XI)**<br>REAL*8 P,T,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_NY_PTXI_WALI(NY,P,T,XI)**<br>REAL*8 NY,P,T,XI |

## Input Values:

**P** - Pressure p in bar

**T** - Temperature t in °C

**XI** - Mass fraction of water $\xi$ in (kg $H_2O$)/(kg mixture)

## Result

**NY_PTXI_WALI**, **NY** or **ny_ptxi_WaLi** - Kinematic viscosity $\nu = \eta \cdot v$ in $m^2/s$

## 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 $H_2O$)/(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 kg/kg or $\xi$ < 0.3 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:<br>for call from Fortran | **REAL*8 FUNCTION NYL_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_NYL_WALI(NYL,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

### Result

**NYL_WALI**, **NYL** or **nyl_pstsxil_WaLi** - Kinematic viscosity of saturated liquid $\nu^l = \eta^l \cdot v^l$ in $m^2/s$

### 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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION NYV_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_NYV_WALI(NYV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

## Result

**NYV_WALI**, **NYV** or **nyv_pstsxil_WaLi** - Kinematic viscosity of saturated steam
$\nu^v = \eta^v \cdot v^v$ in $m^2/s$

## 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 $H_2O$)/(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 $\xi'$ or $p_S$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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 $Pr = f(p,t,\xi)$

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

## Input Values:

- **P** - Pressure p in bar
- **T** - Temperature t in °C
- **XI** - Mass fraction of water $\xi$ in (kg $H_2O$)/(kg mixture)

## Result

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

## 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 $H_2O$)/(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 kg/kg or $\xi$ < 0.3 kg/kg
Points in the wet steam region between saturated liquid and saturated steam

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

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

| | |
|---|---|
| Function Name: | **Prl_pstsxil_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION PRL_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_PRL_WALI(PRL,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

### Result

**PRL_WALI**, **PRL** or **Prl_pstsxil_WaLi** - Prandtl-Number of saturated liquid $Pr^l = \dfrac{\eta^l \cdot {c_p}^l}{\lambda^l}$

### 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 $H_2O$)/(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 $\xi'$ or $p_S$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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:

$Pr^l = f(-1, t_s, \xi^l)$

$Pr^l = f(p_s, -1, \xi^l)$

$Pr^l = f(p_s, t_s, -1)$

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

### Results for wrong input values

Result **PRL_WALI = −1000**, **PRL = −1000** or **Prl_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]

# Prandtl-Number of Saturated Steam $Pr^v = f(p_s, t_s, \xi^l)$

| | |
|---|---|
| Function Name: | **Prv_pstsxil_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION PRV_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_PRV_WALI(PRV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

## Result

**PRV_WALI**, **PRV** or **Prv_pstsxil_WaLi** - Prandtl-Number of saturated steam $Pr^v = \dfrac{\eta^v \cdot {c_p}^v}{\lambda^v}$

## 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 $H_2O$)/(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 $\xi'$ or $p_S$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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:

$Pr^v = f(-1, t_s, \xi^l)$

$Pr^v = f(p_s, -1, \xi^l)$

$Pr^v = f(p_s, t_s, -1)$

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

## 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

$t_s > t_{sol}(p_s)$ 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:<br>for call from Fortran | **REAL*8 FUNCTION PS_TSXIL_WALI(TS,XIL)**<br>REAL*8 TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_PS_TSXIL_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |

### Input Values:

**TS** - Saturation temperature $t_s$ in °C

**XIL** - Mass fraction of water as saturated liquid $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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:<br>for call from Fortran | **REAL*8 FUNCTION PSOL_T_WALI(T)**<br>REAL*8 T |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_PSOL_T_WALI(PSOL,T)**<br>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 °C or t < 0 °C

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

# Phase Region Region = f(p,t,ξ)

| | |
|---|---|
| Function Name: | **region_ptxi_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **INTEGER*4 FUNCTION REGION_PTXI_WALI(P,T,XI)**<br>REAL*8 P,T,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_REGION_PTXI_WALI(REGION,P,T,XI)**<br>INTEGER*4 REGION<br>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 $H_2O$)/(kg mixture)

### Result

**REGION_PTXI_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 $H_2O$)/(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_PTXI_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_PTXI_WALI = −2000, REGION = −2000** or **region_ptxi_WaLi = −2000** for input values:

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

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

# Phase Region Region = f(p,h,ξ)

| | |
|---|---|
| Function Name: | **region_phxi_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **INTEGER*4 FUNCTION REGION_PHXI_WALI(P,H,XI)**<br>REAL*8 P,H,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_REGION_PHXI_WALI(REGION,P,H,XI)**<br>INTEGER*4 REGION<br>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 $H_2O$)/(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 $H_2O$)/(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:

$h < h_{sol}(\xi)$

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

# Phase Region Region = f(p,s,ξ)

| | |
|---|---|
| Function Name: | **region_psxi_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **INTEGER*4 FUNCTION REGION_PSXI_WALI(P,S,XI)**<br>REAL*8 P,H,XI |
| Subroutine with parameter:<br>für Aufruf aus DLL | **INTEGER*4 FUNCTION C_REGION_PSXI_WALI(REGION,P,S,XI)**<br>INTEGER*4 REGION<br>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 $H_2O$)/(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 $H_2O$)/(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:

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

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

# Specific Entropy s = f(p,t,ξ)

| | |
|---|---|
| Function Name: | **s_ptxi_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION S_PTXI_WALI(P,T,XI)**<br>REAL*8 P,T,X |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_S_PTXI_WALI(S,P,T,XI)**<br>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 $H_2O$)/(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 $H_2O$)/(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
$\xi < \xi_{sol}(t)$
$\xi$ > 1.0 kg/kg or $\xi$ < 0.3 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:<br>for call from Fortran | **REAL*8 FUNCTION SL_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_SL_WALI(HL,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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 $\xi'$ or $p_S$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_S$, $t_S$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION SV_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_SV_WALI(SV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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,ξ)

| | |
|---|---|
| Function Name: | **t_phxi_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION T_PHXI_WALI(P,H,XI)**<br>REAL*8 P,H,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_T_PHXI_WALI(T,P,H,XI)**<br>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 $H_2O$)/(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 $H_2O$)/(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
ξ > 1.0 kg/kg or ξ < 0.3 kg/kg or
$h < h_{sol}(\xi)$

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

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

| | |
|---|---|
| Function Name: | **t_psxi_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION T_PSXI_WALI(P,S,XI)**<br>REAL*8 P,S,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_T_PSXI_WALI(T,P,S,XI)**<br>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 $H_2O$)/(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 $H_2O$)/(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
$\xi < \xi_{sol}(t)$
ξ > 1.0 kg/kg or ξ < 0.3 kg/kg

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

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

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

## Input Values:

**PS** - Vapor pressure $p_s$ in bar

**XIL** - Mass fraction of water as saturated liquid $\xi^l$ in (kg $H_2O$)/(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 $H_2O$)/(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:<br>for call from Fortran | **REAL*8 FUNCTION TSOL_P_WALI(P)**<br>REAL*8 P |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_TSOL_P_WALI(TSOL,P)**<br>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,ξ)

| | |
|---|---|
| Function Name: | **v_ptxi_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION V_PTXI_WALI(P,T,XI)**<br>REAL*8 P,T,XI |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_V_PTXI_WALI(V,P,T,XI)**<br>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 $H_2O$)/(kg mixture)

### Result

**V_PTXI_WALI**, **V** or **v_ptxi_WaLi** - Specific volume v in $m^3$/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 $H_2O$)/(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
$\xi < \xi_{sol}(t)$
ξ > 1.0 kg/kg or ξ < 0.3 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:<br>for call from Fortran | **REAL*8 FUNCTION VL_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_VL_WALI(VL,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

### Result

**VL_WALI**, **VL** or **vl_pstsxil_WaLi** - Specific volume of saturated liquid $v^l$ in $m^3$/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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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:<br>for call from Fortran | **REAL*8 FUNCTION VV_WALI(PS,TS,XIL)**<br>REAL*8 PS,TS,XIL |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_VV_WALI(VV,PS,TS,XIL)**<br>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 $\xi^l$ in (kg $H_2O$)/(kg mixture)

## Result

**VV_WALI**, **VV** or **vv_pstsxil_WaLi** - Specific volume of saturated steam $v^v$ in $m^3$/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 $H_2O$)/(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 $\xi'$ or $p_s$ and $\xi'$ 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 $\xi'$ are entered, the program considers $p_s$, $t_s$, and $\xi'$ 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 $H_2O$ of Saturated Liquid $\xi^l = f(p_s, t_s)$

| | |
|---|---|
| Function Name: | **xil_psts_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION XIL_PSTS_WALI(PS,TS)**<br>REAL*8 PS,TS |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_XIL_PSTS_WALI(XIL,PS,TS)**<br>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 $H_2O$ of saturated liquid $\xi^l$ in kg $H_2O$ / 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 $H_2O$ at the Crystallization Barrier $\xi_{sol} = f(p)$

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

## Input Values:

**P** - Pressure p in bar

## Result

**XISOL_P_WALI**, **XISOL** or **xisol_p_WaLi** - Mass fraction $H_2O$ at the crystallization barrier $\xi_{sol}$ in kg $H_2O$ /kg

## Range of validity

Pressure range: from 0.00074 bar to 0.0373 bar

## Explanation of the function

This function calculates the mass fraction $H_2O$ at the crystallization barrier. If the actual mass fraction $H_2O$ 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 $H_2O$ at the Crystallization Barrier $\xi_{sol} = f(t)$

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

### Input Values:

**T** - Temperature t in °C

### Result

**XISOL_T_WALI**, **XISOL** or **xisol_t_WaLi** - Mass fraction $H_2O$ at the crystallization barrier $\xi_{sol}$ in kg $H_2O$ /kg

### Range of validity

Temperature range: from 0 °C to 93.58 °C

### Explanation of the function

This function calculates the mass fraction $H_2O$ at the crystallization barrier. If the actual mass fraction $H_2O$ 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 $H_2O$ of Saturated Steam $\xi^v = f(p_s, t_s)$

| | |
|---|---|
| Function Name: | **xiv_psts_WaLi** |
| Subroutine with function value:<br>for call from Fortran | **REAL*8 FUNCTION XIV_PSTS_WALI(PS,TS)**<br>REAL*8 PS,TS |
| Subroutine with parameter:<br>for call from DLL | **INTEGER*4 FUNCTION C_XIV_PSTS_WALI(XIV,PS,TS)**<br>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 $H_2O$ of saturated steam $\xi^v$ in kg $H_2O$ / 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]

KCE ThermoFluidProperties

# KCE-ThermoFluidProperties
# www.thermofluidprop.com

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

## 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

### Dry Air Including Liquid Air

**Library LibRealAir**

Formulation of Lemmon et al. (2000)

### Refrigerants

**Ammonia**

**Library LibNH3**

Formulation of Tillner-Roth et al. (1993)

**R134a**

**Library LibR134a**

Formulation of Tillner-Roth and Baehr (1994)

**Iso-Butane**

**Library LibButane_Iso**

Formulation of Bücker and Wagner (2006)

**n-Butane**

**Library LibButane_n**

Formulation of Bücker and Wagner (2006)

### Mixtures for Absorption Processes

**Ammonia/Water Mixtures**

**Library LibAmWa**

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

Helmholtz energy equation for the mixing term

(also useable for calculating the Kalina Cycle)

**Water/Lithium Bromide Mixtures**

**Library LibWaLi**

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

### Liquid Coolants

**Liquid Secondary Refrigerants**

**Library LibSecRef**

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (IIR 2010)

### Ethanol

**Library LibC2H5OH**

Formulation of
Schroeder 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)

KCE
ThermoFluidProperties


**For more information please contact:**

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Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
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 $\rho$
- Specific volume $v$
- Enthalpy $h$
- Internal energy $u$
- Entropy $s$
- Exergy $e$
- Isobaric heat capacity $c_p$
- Isochoric heat capacity $c_v$
- Isentropic exponent $\kappa$
- Speed of sound $w$
- Surface tension $\sigma$

### Transport Properties

- Dynamic viscosity $\eta$
- Kinematic viscosity $\nu$
- Thermal conductivity $\lambda$
- 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.

**www.thermofluidprop.com**

# KCE-ThermoFluidProperties
# www.thermofluidprop.com

KCE ThermoFluidProperties

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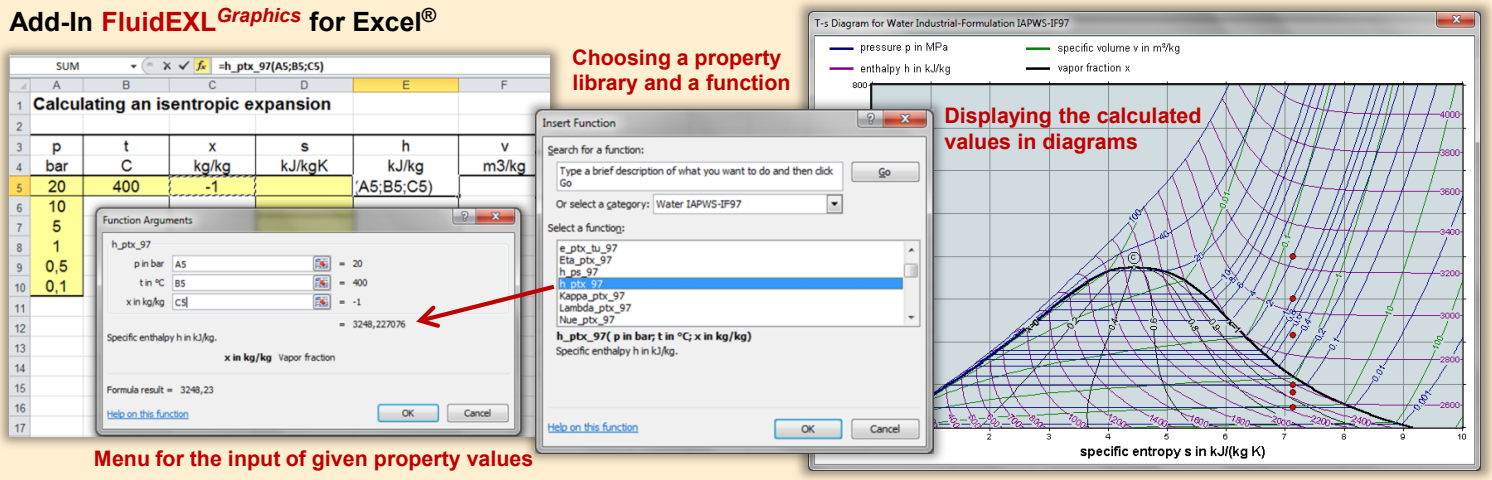
UNIVERSITY OF APPLIED SCIENCES

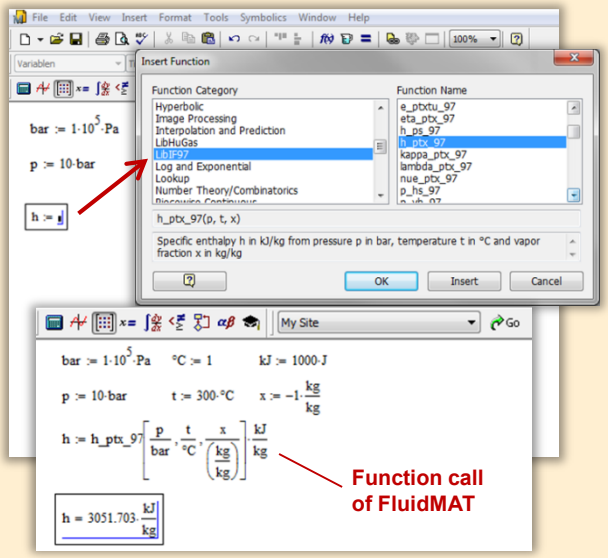
## Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

### Add-In FluidEXL*Graphics* for Excel®



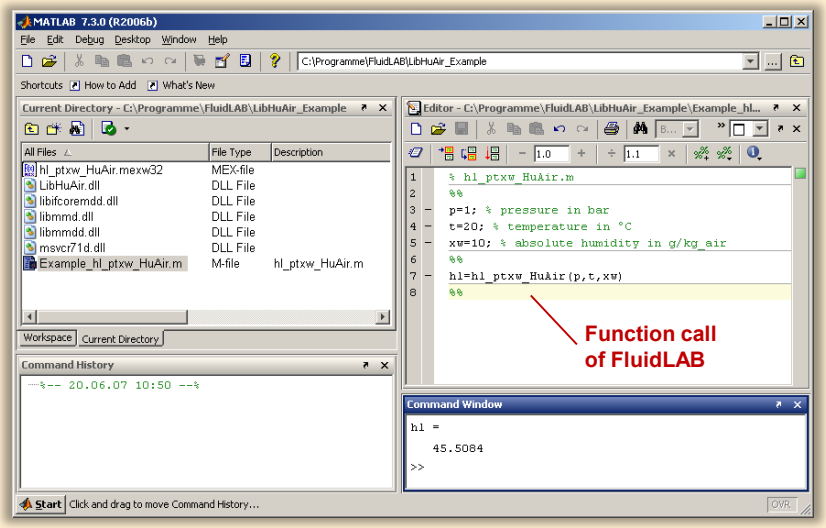

### Add-On FluidMAT for Mathcad®
### Add-On FluidPRIME for Mathcad Prime®

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



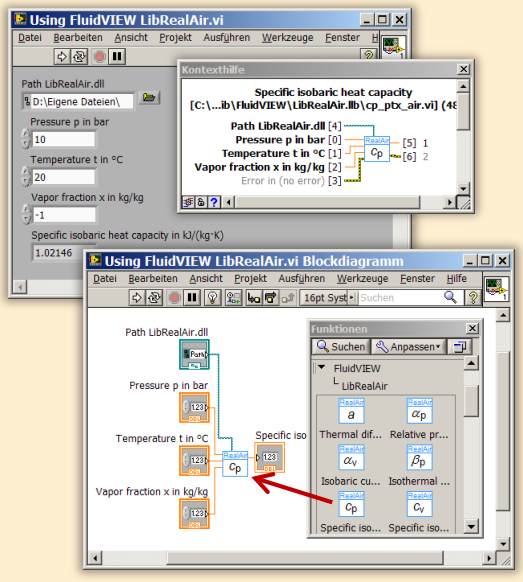

### Add-On FluidLAB for MATLAB® and SIMULINK®

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



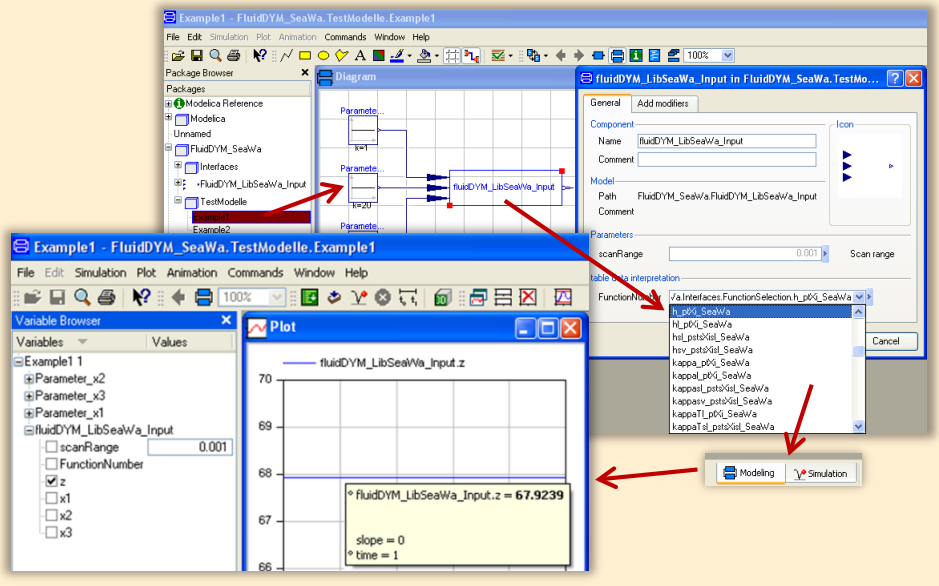

### Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

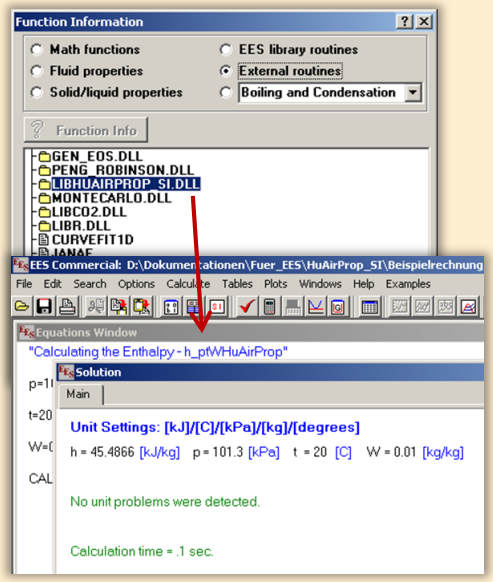



### Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

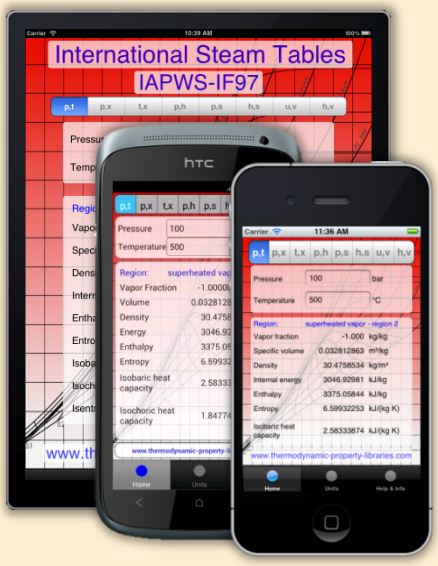
The property functions can be called in DYMOLA® and SimulationX®.



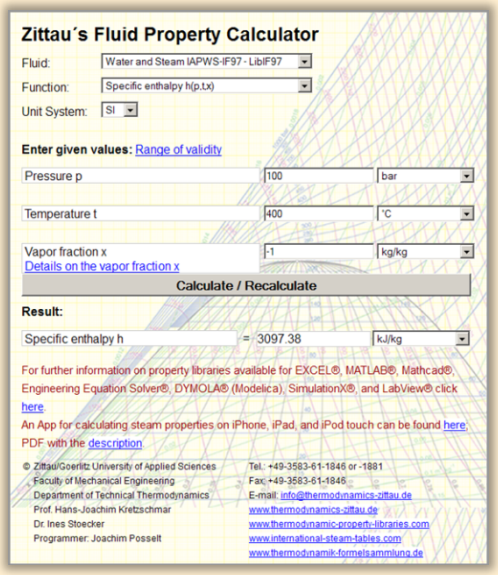
## Add-On FluidEES for Engineering Equation Solver®




## 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

fx 9750 G II

CFX 9850 fx-GG20

CFX 9860 G Graph 85

ALGEBRA FX 2.0

### FluidHP

HP 48

HP 49

### FluidTI

TI Nspire CX CAS
TI Nspire CAS

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

## For more information please contact:

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**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 $\rho$
- Specific volume $v$
- Enthalpy $h$
- Internal energy $u$
- Entropy $s$
- Exergy $e$
- Isobaric heat capacity $c_p$
- Isochoric heat capacity $c_v$
- Isentropic exponent $\kappa$
- Speed of sound $w$
- Surface tension $\sigma$

### Transport Properties

- Dynamic viscosity $\eta$
- Kinematic viscosity $\nu$
- Thermal conductivity $\lambda$
- 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.

**www.thermofluidprop.com**

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# 6. Satisfied Customers

Date: 07/2019

The following companies and institutions use the property libraries:

- FluidEXL*Graphics* for Excel®
- FluidLAB for MATLAB® and Simulink
- FluidMAT for Mathcad®
- FluidPRIME for Mathcad Prime®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica) and SimulationX®
- FluidVIEW for LabVIEW™
- DLLs for Windows™
- Shared Objects for Linux®.

**2019**

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

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

**2018**

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|---|---|
| Jaguar Energy, Guatemala | 12/2018 |
| WEBASTO, Gilching | 12/2018 |
| Smurfit Kappa, Oosterhout, Netherlands | 12/2018 |
| Univ. BW München | 12/2018 |
| RAIV, Liberec for VALEO, Prague, Czech Republic | 11/2018 |
| VPC Group Vetschau | 11/2018 |
| SEITZ, Wetzikon, Switzerland | 11/2018 |
| MVV, Mannheim | 10/2018 |
| IB Troche | 10/2018 |
| KANIS Turbinen, Nürnberg | 10/2018 |
| TH Ingolstadt, Institut für neue Energiesysteme | 10/2018 |
| IB Kristl & Seibt, Graz, Austria | 09/2018 |
| INEOS, Köln | 09/2018 |
| IB Lücke, Paderborn | 09/2018 |
| Südzucker, Ochsenfurt | 08/2018 |
| K&K Turbinenservice, Bielefeld | 07/2018 |
| OTH Regensburg, Elektrotechnik | 07/2018 |
| Comparex Leipzig for LEAG, Berlin | 06/2018 |
| Münstermann, Telgte | 05/2018 |
| TH Nürnberg, Verfahrenstechnik | 05/2018 |
| Universität Madrid, Madrid, Spanien | 05/2018 |
| HS Zittau/Görlitz, Wirtschaftswissenschaften und Wirtschaftsingenieurwesen | 05/2018 |
| HS Niederrhein, Krefeld | 05/2018 |
| Wilhelm-Büchner HS, Pfungstadt | 03/2018 |
| GRS, Köln | 03/2018 |
| WIB, Dennheritz | 03/2018 |
| RONAL AG, Härklingen, Schweiz | 02/2018 |
| Ingenieurbüro Leipert, Riegelsberg | 02/2018 |
| AIXPROCESS, Aachen | 02/2018 |
| KRONES, Neutraubling | 02/2018 |
| Doosan Lentjes, Ratingen | 01/2018 |

**2017**

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|---|---|
| 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 |

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|---|---|
| KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik | 09/2017 |
| Air-Consult, Jena | 09/2017 |
| Papierfabrik Koehler, Oberkirch | 09/2017 |
| ZWILAG, Würenlingen, Switzerland | 09/2017 |
| TLK-Thermo Universität Braunschweig, Braunschweig | 08/2017 |
| Fichtner IT Consulting AG, Stuttgart | 07/2017 |
| Hochschule Ansbach, Ansbach | 06/2017 |
| RONAL, Härkingen, Switzerland | 06/2017 |
| BORSIG Service, Berlin | 06/2017 |
| BOGE Kompressoren, Bielefeld | 06/2017 |
| STEAG Energy Services, Zwingenberg | 06/2017 |
| CES clean energy solutions, Wien, Austria | 04/2017 |
| Princeton University, Princeton, USA | 04/2017 |
| B2P Bio-to-Power, Wadersloh | 04/2017 |
| TU Dresden, Institute for Energy Engineering, Dresden | 04/2017 |
| SAINT-GOBAIN, Vaujours, France | 03/2017 |
| TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg | 03/2017 |
| SCHMIDT + PARTNER, Therwil, Switzerland | 03/2017 |
| KAESER Kompressoren, Gera | 03/2017 |
| F&R, Praha, Czech Republic | 03/2017 |
| ULT Umwelt-Lufttechnik, Löbau | 02/2017 |
| JS Energie & Beratung, Erding | 02/2017 |
| Kelvion Brazed PHE, Nobitz-Wilchwitz | 02/2017 |
| MTU Aero Engines, München | 02/2017 |
| Hochschule Zittau/Görlitz, IPM | 01/2017 |
| CombTec ProCE, Zittau | 01/2017 |
| SHELL Deutschland Oil, Wesseling | 01/2017 |
| MARTEC Education Center, Frederikshaven, Denmark | 01/2017 |
| SynErgy Thermal Management, Krefeld | 01/2017 |

**2016**

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

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

**2015**

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|---|---|
| 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**

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| 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**

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|---|---|
| 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 |

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

**2012**

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|---|---|
| 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 |

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

**2011**

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

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

**2010**

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| 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 |

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| Universitaet der Bundeswehr, Munich | 04/2010 |
| Technical University of Hamburg-Harburg | 04/2010 |
| Vattenfall Europe, Berlin | 04/2010 |
| HUBER Consulting Engineers, Berching | 04/2010 |
| 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**

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|---|---|
| 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 |

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|---|---|
| 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**

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

**2007**

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

**2006**

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

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

**2005**

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|---|---|
| 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 |

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|---|---|
| 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**

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|---|---|
| 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 |
| SorTech, Halle | 11/2004 |

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

**2003**

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

**2002**

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

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|---|---|
| SAAS, Possendorf/Dresden | 02/2002 |
| Siemens, Karlsruhe | 02/2002 |
| (general license for the WinIS information system) | |
| FZR Forschungszentrum, Rossendorf/Dresden | 03/2002 |
| CompAir, Simmern | 03/2002 |
| GKS Gemeinschaftskraftwerk, Schweinfurt | 04/2002 |
| ALSTOM Power Baden, Switzerland (group licenses) | 05/2002 |
| InfraServ, Gendorf | 05/2002 |
| SoftSolutions, Muehlhausen (company license) | 05/2002 |
| DREWAG, Dresden (company license) | 05/2002 |
| SOFBID, Zwingenberg | 06/2002 |
| (general EBSILON program license) | |
| Kleemann Engineering, Dresden | 06/2002 |
| Caliqua, Basel, Switzerland (company license) | 07/2002 |
| PCK Raffinerie, Schwedt (group license) | 07/2002 |
| Fischer-Uhrig Engineering, Berlin | 08/2002 |
| Fichtner Consulting & IT, Stuttgart | 08/2002 |
| (company licenses and distribution) | |
| Stadtwerke Duisburg | 08/2002 |
| Stadtwerke Hannover | 09/2002 |
| Siemens Power Generation, Goerlitz | 10/2002 |
| Energieversorgung Halle (company license) | 10/2002 |
| Bayer, Leverkusen | 11/2002 |
| Dillinger Huette, Dillingen | 11/2002 |
| G.U.N.T. Geraetebau, Barsbuettel | 12/2002 |
| (general license and training test benches) | |
| VEAG, Berlin (group license) | 12/2002 |

**2001**

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

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| eta Energieberatung, Pfaffenhofen | 11/2001 |
| ALSTOM Power Baden, Switzerland | 12/2001 |
| VEAG, Berlin (group license) | 12/2001 |

**2000**

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

**1999**

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

**1998**

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

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

**1997**

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