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Property Library for Mixtures of Water/Lithium Bromide

**FluidEES
with LibWaLi
for Engineering Equation Solver®**

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Property Library for Mixtures of Water/Lithium Bromide FluidEES LibWaLi

Contents

- 0 Package Contents
- 1 Property Functions
- 2 Application of FluidEES in Engineering Equation Solver[®]
 - 2.1 Installing FluidEES LibWaLi
 - 2.2 The FluidEES Help System
 - 2.3 Licensing the LibWaLi Property Library
 - 2.4 Example: Calculation of the Specific Enthalpy $h = f(p, t, \xi)$
 - 2.5 Removing FluidEES LibWaLi
- 3. Program Documentation
- 4 Property Libraries for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators
- 5 References
- 6 Satisfied Customers

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0 Package Contents

Zip-file "CD_FluidEES_LibWaLi_Eng.zip" for Engineering Equation Solver[®]

Property library LibWaLi for water/lithium bromide mixtures

Including the following files:

FluidEES_LibWaLi_Docu_Eng.pdf	User's Guide
FluidEES_LibWaLi_Setup.exe	Installation program for the FluidEES Add-In for use in Engineering Equation Solver [®]
LibWaLi.ctx	Function registration in EES of the LibWaLi property library
LibWaLi.dll	Dynamic link library including property algorithms for water/lithium bromide mixtures
LibWaLi.hlp	Help file for the LibWaLi property library

1. Property Functions

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

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

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibWaLi as parameter	Property or Function	Unit of the result
$t_{\text{sol}} = f(p)$	tsol_p_WaLi	TSOL_P_WALI(P)	C_TSOL_P_WALI(TSOL,P)	Temperature at the crystallization barrier	°C
$v = f(p, t, \xi)$	v_ptxi_WaLi	V_PTXI_WALI(P,T,XI)	C_V_PTXI_WALI(V,P,T,XI)	Specific volume	m ³ /kg
$v' = f(p_s, t_s, \xi')$	vl_pstxsl_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_pstxsl_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 ₂ O of saturated liquid	kg/kg
$\xi_{\text{sol}} = f(p)$	xisol_p_WaLi	XISOL_P_WALI(P)	C_XISOL_P_WALI(XISOL,P)	Mass fraction H ₂ O 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 ₂ O of saturated steam	kg/kg

Units:

- t in °C
- p in bar
- ξ in (kg H₂O)/(kg mixture)

Important hints for the calculation of wet steam

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

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

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

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

Range of validity

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

Reference state

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

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 Add-In FluidEES for Engineering Equation Solver®

The FluidEES Add-In has been developed to conveniently calculate thermodynamic properties in the Engineering Equation Solver® (EES). It enables, within EES®, the direct call of functions relating to mixtures of water/lithium bromide from the LibWaLi property library.

2.1 Installing FluidEES including LibWaLi

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

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

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

CD_FluidEES_LibWaLi

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

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

Within this folder you will see the following two files:

FluidEES_LibWaLi_Docu_Eng.pdf

FluidEES_LibWaLi_Setup.exe.

In order to run the installation of FluidEES including the LibWaLi property library, first double-click the file

FluidEES_LibWaLi_Setup.exe.

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

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

In the following dialog box, "Destination Location" (see figure below), the default path where Engineering Equation Solver has been installed will be shown (the standard location is:

C:\Program Files\EES32\Userlib\LibWaLi	(for English version of Windows)
C:\Programme\EES32\Userlib\LibWaLi	(for German version of Windows)).

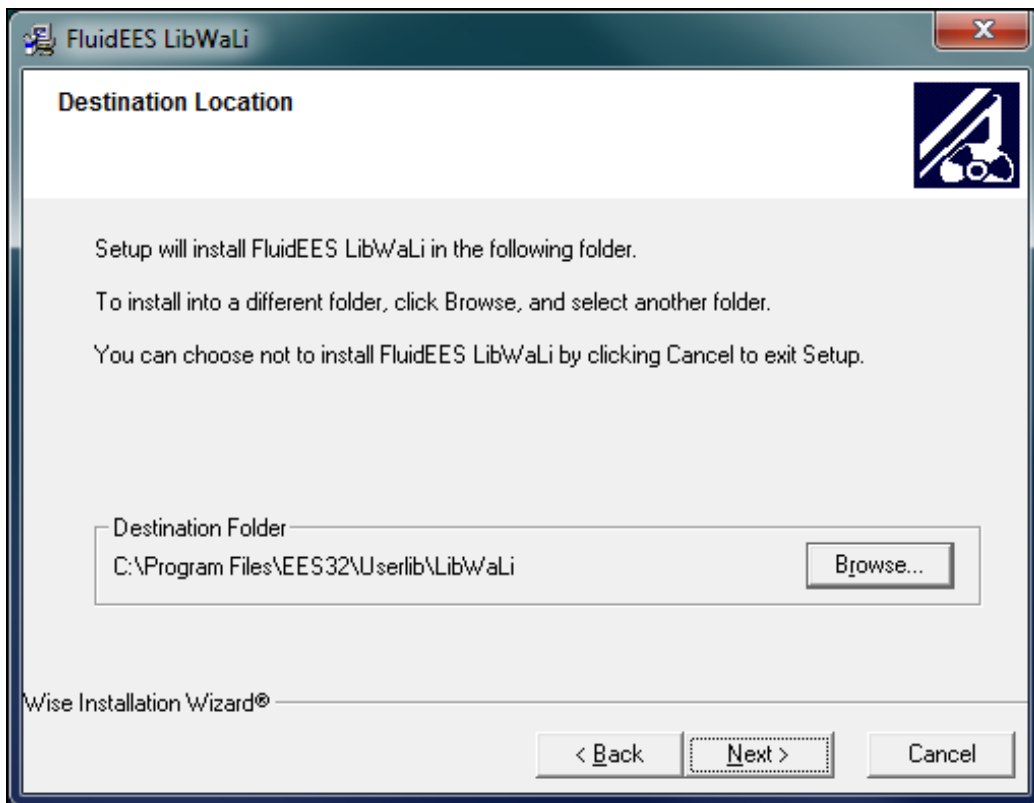


Figure 2.1: "Destination Location"

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

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

The FluidEES files are now being copied into the "\LibWaLi" folder on your hard drive.

Click the "Finish >" button in the next window to complete installation.

The installation program has copied the following files into the directory

C:\Program Files\EES32\Userlib\LibWaLi	(for English version of Windows)
C:\Programme\EES32\Userlib\LibWaLi	(for German version of Windows):

advapi32.dll	- Dynamic link library for use in Windows® programs
Dformd.dll	- Dynamic link library for use in Windows® programs
Dfortt.dll	- Dynamic link library for use in Windows® programs
DFORRTD.dll	- Dynamic link library for use in Windows® programs
INSTALL.LOG	- Log file
LC.dll	- Dynamic link library for use in Windows® programs
LibWaLi.ctx	- Interface including property functions of LibWaLi for EES®
LibWaLi.dll	- Dynamic link library with property functions of LibWaLi
LibWaLi.hlp	- Help file of the LibWaLi property library
msvc60.dll	- Dynamic link library for use in Windows® programs
msvcrt.dll	- Dynamic link library for use in Windows® programs
MSVCRTD.dll	- Dynamic link library for use in Windows® programs
UNWISE.EXE	- File to remove the LibWaLi library
UNWISE.INI	- File belonging to the UNWISE.EXE

Now, you have to overwrite the following files

"LibWaLi.dll"

"LibWaLi.hlp"

"LibWaLi.ctx"

in your Engineering Equation Solver directory with the files of the same names provided in your extracted CD_FluidEES_LibWaLi folder.

To do this, open the "CD_FluidEES_LibWaLi" folder in "My Computer" and click on the file "LibWaLi.dll" in order to highlight it. Then click on the "Edit" menu in your Explorer and select "Copy".

Now, open your EES directory (the standard being:

C:\Program Files\EES32\Userlib\LibWaLi (for English version of Windows)

C:\Programme\EES32\Userlib\LibWaLi (for German version of Windows))

and insert the file "LibWaLi.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button.

Now, you have overwritten the file "LibWaLi.dll" successfully.

Repeat these steps in order to copy the other files listed above.

2.2 The FluidEES Help System

As mentioned earlier, FluidEES also provides detailed online help functions.

If you are running Windows Vista or Windows 7, please note the paragraph

"Using the FluidEES Online-Help in Windows Vista or Windows 7."

Information on individual property functions may be accessed via the following steps:

- Click "Options" in the EES menu bar and select "Function Info".
- The "Function Information" window will appear. Select "External routines" and double-click on the entry "LibWaLi.DLL".
- A list with calculable functions of the "LibWaLi" library appears.
- Find and select the desired function, e.g. "h_ptxi_WaLi" and click the  button above.

If the "LibWaLi.hlp" function help cannot be found, confirm the question whether you want to look for it yourself with "Yes." Select the "LibWaLi.hlp" file in the installation menu of FluidEES in the window which is opened, the standard being

C:\Program Files\EES32\Userlib\LibWaLi (for English version of Windows)

C:\Programme\EES32\Userlib\LibWaLi (for German version of Windows))

and click "Yes" in order to complete the search.

Using the FluidEES Online Help in Windows Vista or Windows 7

If you are running Windows Vista or Windows 7 on your computer, you might not be able to open Help files. To view these files you have to install the Microsoft® Windows Help program which is provided by Microsoft®. Please carry out the following steps in order to download and install the Windows Help program.

Open Microsoft Internet Explorer® and go to the following address:

<http://support.microsoft.com/kb/917607/>

You will see the following web page:



Figure 2.2: Microsoft® Support web page

Scroll down until you see the headline "Resolution." Here you can see the bold hint:

"Download the appropriate version of Windows Help program (WinHlp32.exe), depending on the operating system that you are using."

The following description relates to Windows® 7. The procedure is analogous for Windows® Vista.

Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.3).

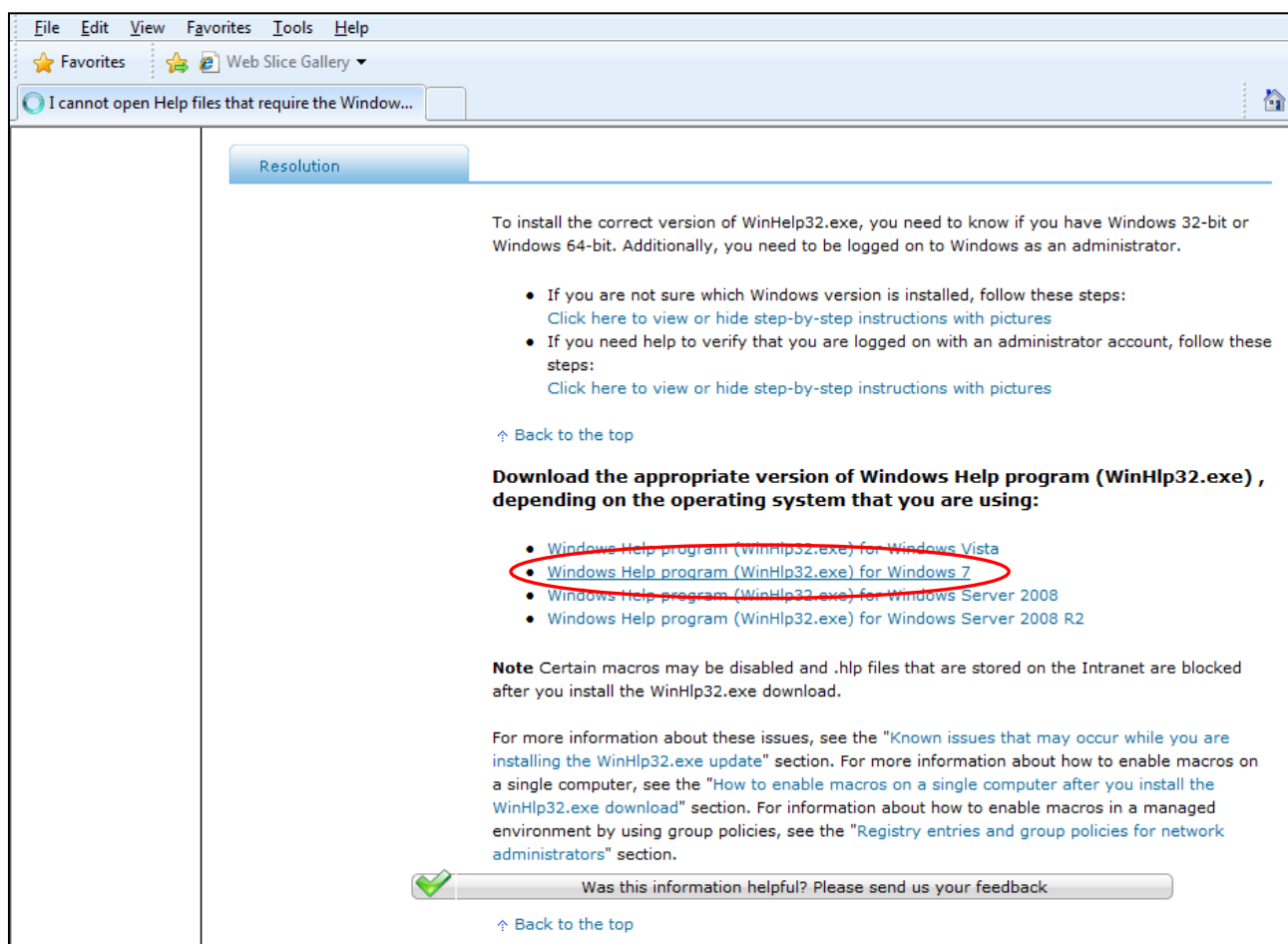


Figure 2.3: Selecting your Windows version

You will be forwarded to the Microsoft Download Center where you can download the Microsoft Windows Help program.

First, a validation of your Windows License is required.

To do this click on the "Continue" button (see Figure 2.4).

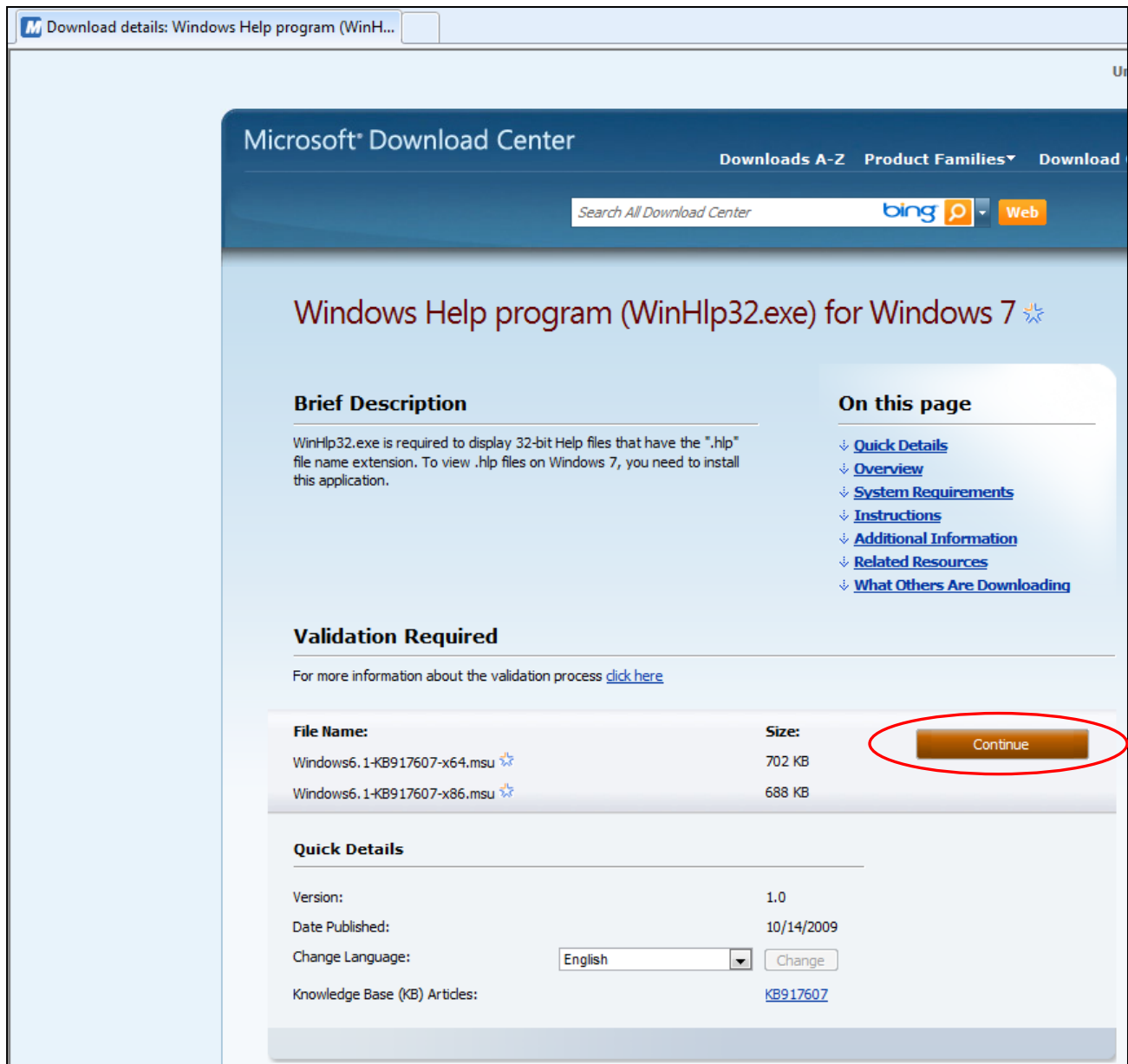


Figure 2.4: Microsoft® Download Center

You will be forwarded to a web page with instructions on how to install the Genuine Windows Validation Component.

At the top of your Windows Internet Explorer you will see a yellow information bar. Right-click this bar and select "Install ActiveX Control" in the context menu (see Figure 2.5).

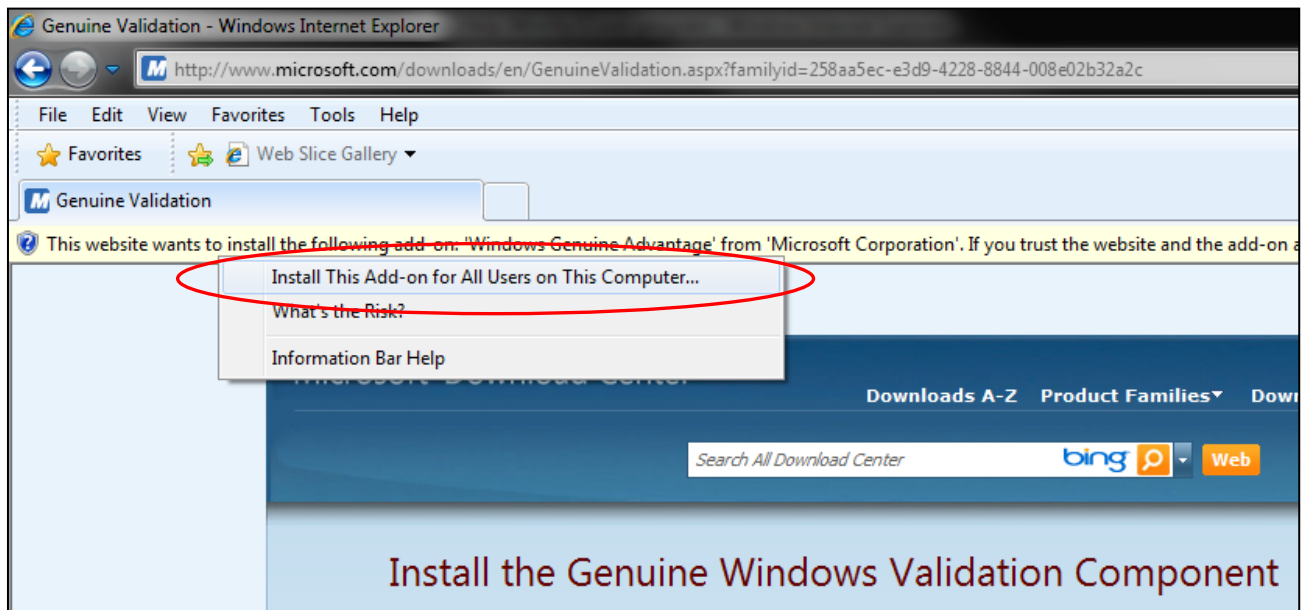


Figure 2.5: Installing the Genuine Windows Validation Component

A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue (see Figure 2.6)

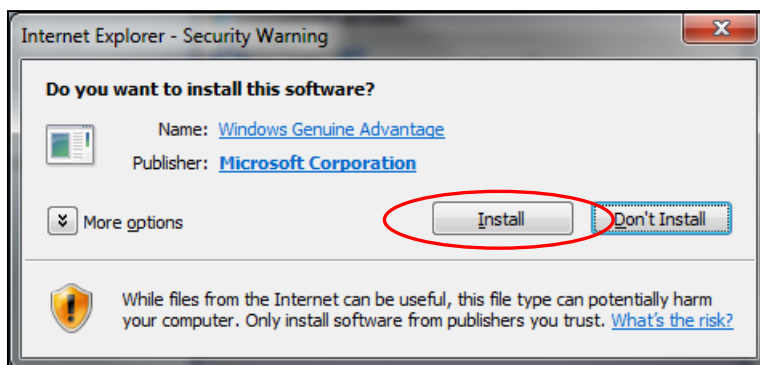


Figure 2.6: Internet Explorer – Security Warning

After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.7).

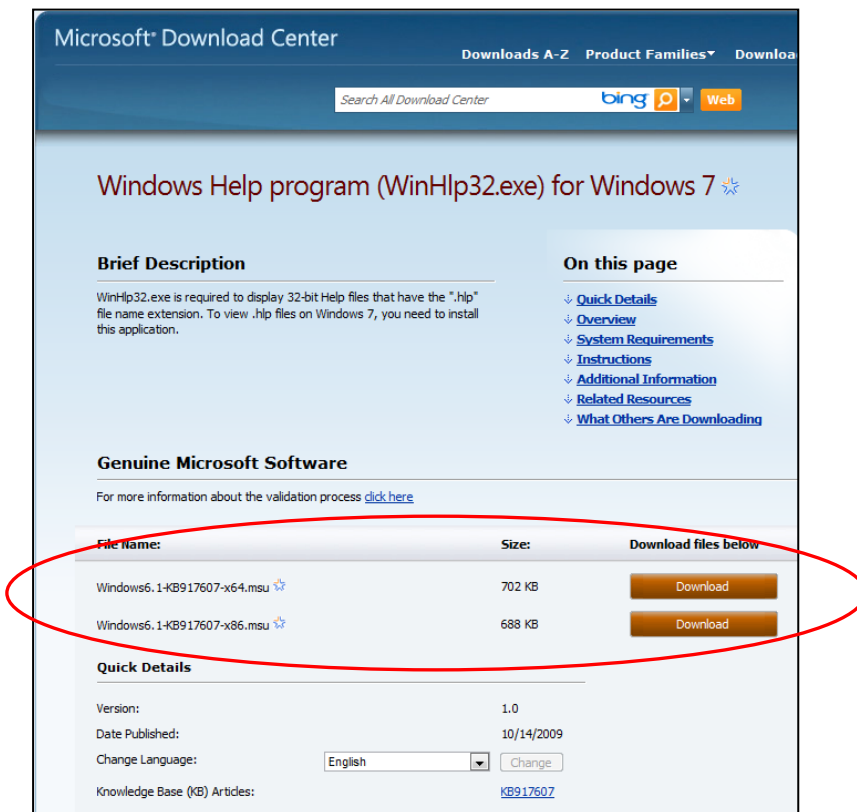


Figure 2.7: Downloading the Windows Help program

To download and install the correct file you need to know which Windows version (32-bit or 64-bit) you are running on your computer.

If you are running a 64-bit operating system, please download the file

Windows6.1-KB917607-x64.msu.

If you are running a 32-bit operating system, please download the file

Windows6.1-KB917607-x86.msu.

In order to run the installation of the Windows Help program double-click the file you have just downloaded on your computer:

Windows6.1-KB917607-x64.msu (for 64-bit operating system)

Windows6.1-KB917607-x86.msu. (for 32-bit operating system).

Installation starts with a window searching for updates on your computer. After the program has finished searching you may see the following window.

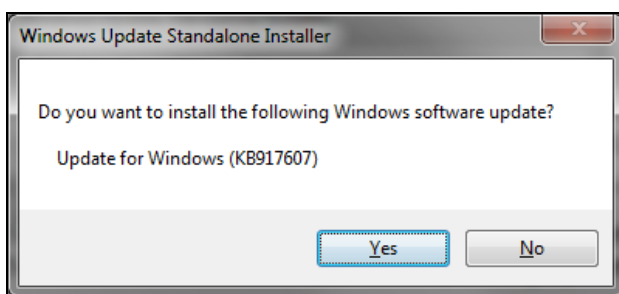


Figure 2.8: Windows Update Standalone Installer

In this case, the installation can be continued by clicking the "Yes" button.

(If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.")

In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept" (see Figure 2.9)

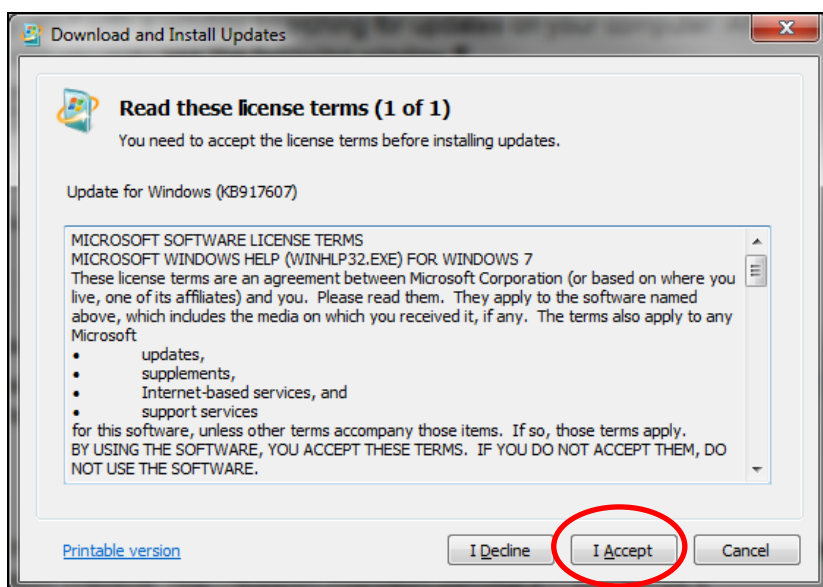


Figure 2.9: Windows License Terms

Installation starts once you have clicked the "I Accept" button (see Figure 2.10).

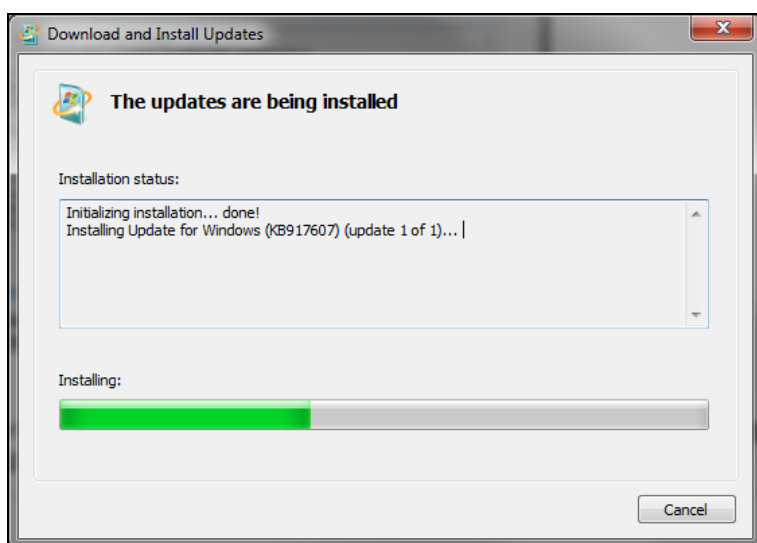


Figure 2.10: Installation process

After the Windows Help program has been installed, the notification "Installation complete" will appear. Confirm this by clicking the "Close" button.

The installation of the Windows Help program has been completed and you will now be able to open the Help files.

2.3 Licensing the LibWaLi Property Library

The licensing procedure must be carried out when Engineering Equation Solver® starts up and a FluidEES prompt message appears. In this case, you will see the "License Information" window for LibWaLi (see figure below).

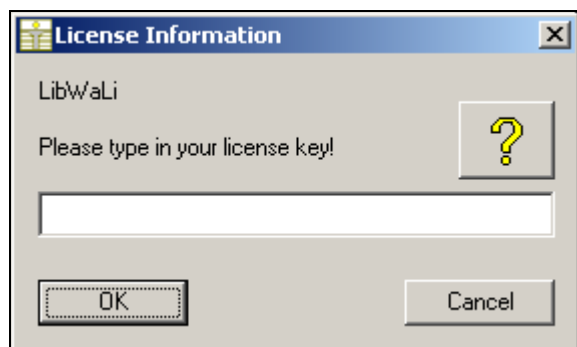


Figure 2.11: "License Information" window

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

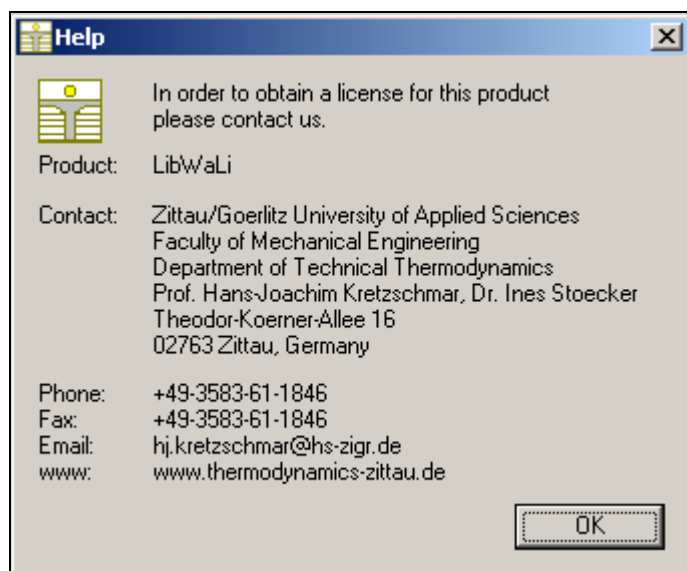


Figure 2.12: "Help" window

If you do not enter a valid license it is still possible to start EES® by clicking "Cancel". In this case, the LibWaLi property library will display the result "-1111111" for every calculation you ask it to make.

The "License Information" window will appear every time you use FluidEES LibWaLi until you enter a license code to complete registration. If you decide not to use FluidEES LibWaLi, you can uninstall the program following the instructions given in section 2.5 of this User's Guide.

With this procedure the LibWaLi property library has been licensed.

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

Now we will calculate, step by step, the specific enthalpy h of a water/lithium bromide mixture as a function of pressure p , temperature t and mass fraction of water ξ , using FluidEES with LibWaLi in the Engineering Equation Solver®.

How to perform a calculation with FluidEES:

- Start Engineering Equation Solver® (EES).
- The LibWaLi library, if installed, is loaded by the program automatically.
- We recommend preparing an EES® sheet, as shown in Figure 2.13.
Note: the units of p , t , and ξ must correspond to those in Chapter 1.

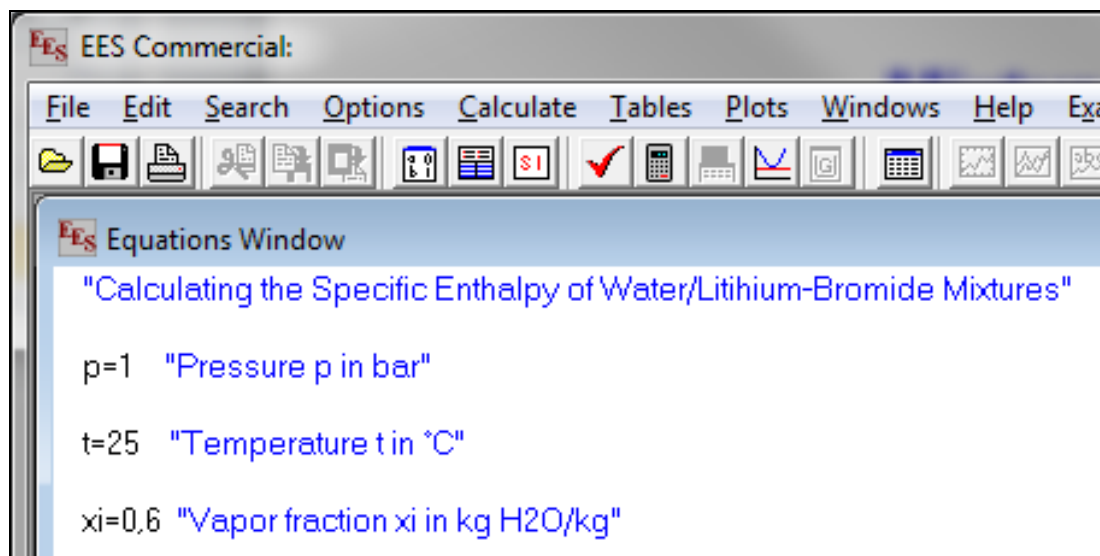


Figure 2.13: Preparing an EES® sheet for the calculation

- The function parameters values stand for:
 - First operand: Total pressure $p = 1$ bar
(Range of validity: $p = 0.00074$ bar ... 10 bar)
 - Second operand: Temperature $t = 25^\circ\text{C}$
(Range of validity: $t = 0^\circ\text{C}$... 210°C)
 - Third operand: Mass fraction $\xi = 0.6$ kg H₂O /kg (kg water per kg)
(Range of validity: $\xi = 0.3$ kg H₂O/kg ... 1.0 kg H₂O/kg)
- Confirm your entry by pressing the "ENTER" key.

Note:

EES® adapts to the language that is set in the "Regional and Language Options," which can be found in the "Control Panel." If you run Engineering Equation Solver® on an English version of Windows®, the standard decimal separator will be a dot. If your computer is set to German, for example, the expected decimal separator will be a comma (as shown in Fig. 2.13 and in the following sample calculation). In this case enter a comma in the values above instead of a dot. You can find additional information on this issue by clicking on "Help" in the EES® menu bar and then select "Help Index". Click on "Search" in the window which appears, type "decimal separator" and press the "ENTER" key.

- For calculating $h = f(p, t, \xi)$, call up the function "h_ptxi_WaLi" of the property library LibWaLi as follows:
- Click on "Options" in the EES® menu bar and select "Function Info".

- The "Function Information" window will appear. Select "External routines" and you will see the screen shown here in Figure 2.14.

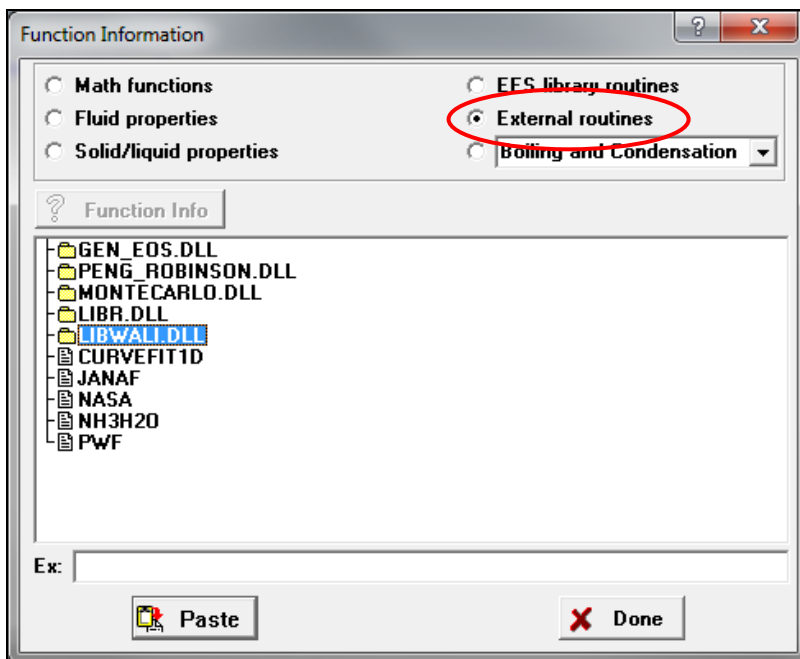


Figure 2.14: "Function Information" window offering different libraries (routines)

- Double-click on the entry "LIBWALI.DLL".
- A list with calculable functions of the "LibWaLi" library appears.
- Find and select the desired function, here "h_ptxi_WaLi_EES" (see Figure 2.15), and click the "Paste" button below.

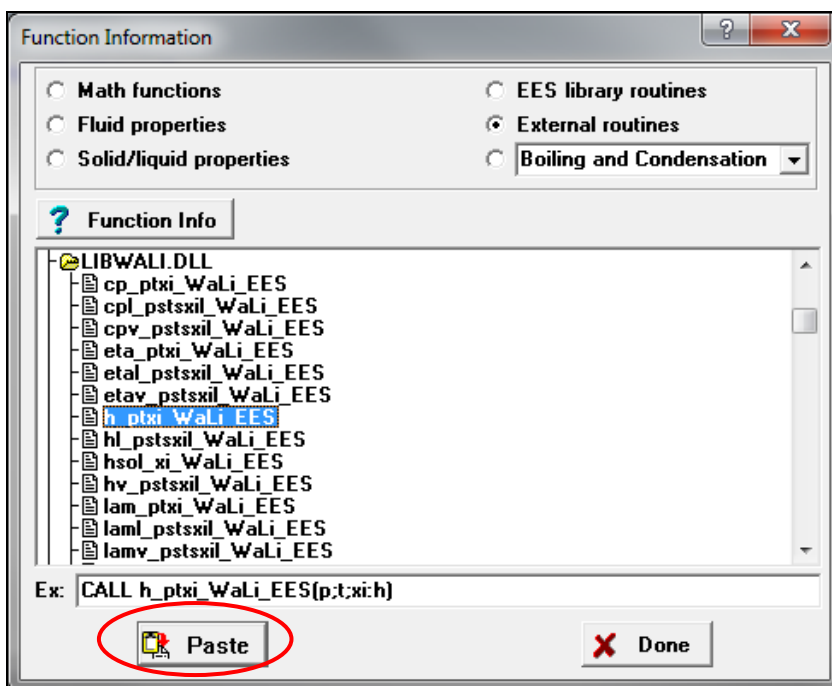


Figure 2.15: Selecting the "h_ptxi_WaLi_EES" function

- The selected function will be copied and now appears in the "Equations Window" (see Figure 2.16).

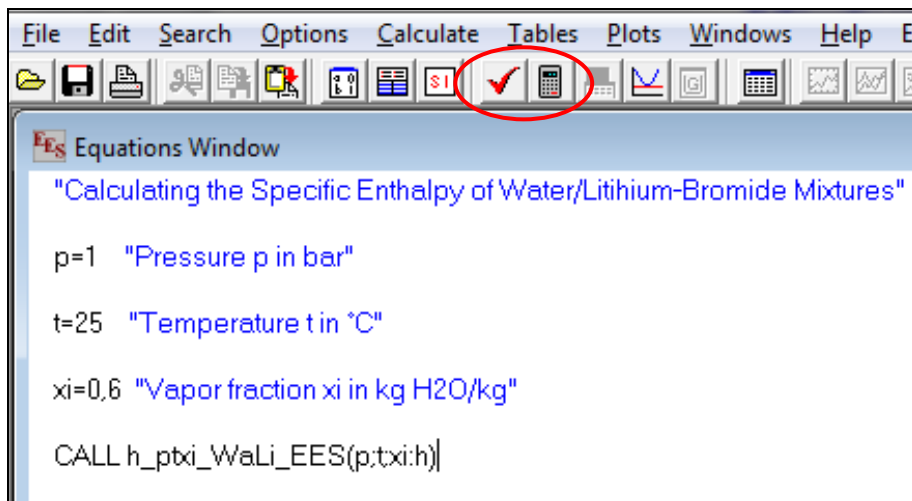


Figure 2.16: "Equations Window" with the call of the property function

- Now, you can check the syntax of the instructions in the "Equations Window" by clicking the  symbol in the upper menu bar of EES®. The program tests whether or not the syntax is correct (e.g. dots as decimal separators versus commas). Confirm the "Information" window which appears by clicking the "OK" button.
- Then click the  symbol in the upper menu bar of EES® to start the calculation.
- Soon you will see the "Calculations Completed" window. Leave this window by clicking the "Continue" button.
- The result for the air-specific enthalpy h appears in the "Solution" window (see Figure 2.17).

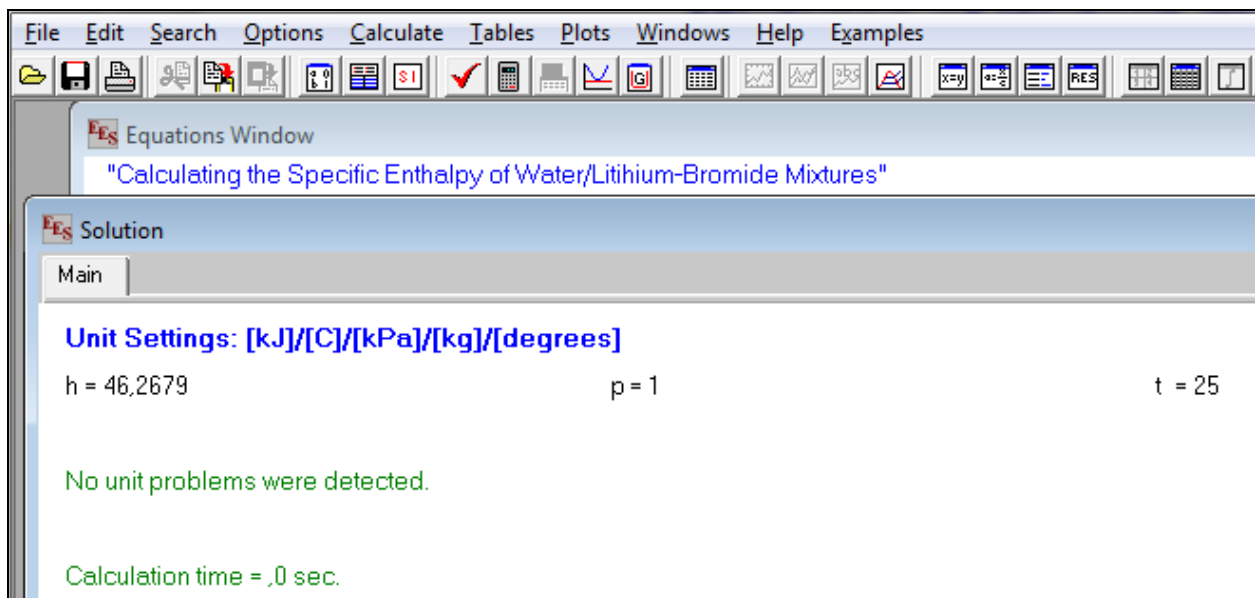


Figure 2.17: "Solution" window showing the result

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

⇒ The result in our sample calculation here is: " $h = 46.2679$ ". The corresponding unit is kg H₂O/kg (see table of the property functions in Chapter 1).

For further property functions calculable in FluidEES see the function table in Chapter 1.

2.5 Removing FluidEES LibWaLi

In order to remove the property library LibWaLi from your hard drive in Windows®, click "Start" in the lower task bar, then "Settings" and "Control Panel."

Afterwards double-click on "Add or Remove Programs."

In the list box of the "Add or Remove Programs" menu which appears, select "FluidEES LibWaLi" by clicking on it and click the "Change/Remove" button.

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

Then confirm the menu "Perform Uninstall" by clicking the "Finish" button.

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

"FluidEES LibWaLi" has now been removed.

3. Program Documentation

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

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

Input Values:

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

Result

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

Range of validity

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

Hints for wet steam

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

Results for wrong input values

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

$p > 10 \text{ bar}$ or $p < 0.00074 \text{ bar}$ or

$t > 210 \text{ °C}$ or $t < 0 \text{ °C}$ or

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

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

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

References: [2], [21], [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: **REAL*8 FUNCTION CPL_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_CPL_WALI(CPL,PS,TS,XIL)**
 for call from DLL **REAL*8 CPL,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

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

Specific Isobaric Heat Capacity of Saturated Steam

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

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

$$c_p^V = f(p_s, t_s, -1)$$

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

Results for wrong input values

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

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

References: [2], [23]

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

Function Name: **eta_ptxi_WaLi**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION ETA_PTXI_WALI(P,T,XI)**
REAL*8 P,T,XI

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_ETA_PTXI_WALI(ETA,P,T,XI)**
REAL*8 ETA,P,T,XI

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

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

Range of validity

Temperature range: from 0 °C to 210 °C

Pressure range: from 0.00074 bar to 10 bar

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

Hints for wet steam

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

Results for wrong input values

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

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

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

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

$$\eta^V = f(p_s, t_s, -1)$$

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

Results for wrong input values

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

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

References: [2], [23]

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

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

Input Values:

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

Result

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

Range of validity

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

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

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

p > 10 bar or p < 0.00074 bar or
t > 210 °C or t < 0 °C or
 $\xi_s > \xi_{sol}(t)$ or
 $\xi > 1.0$ 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: **REAL*8 FUNCTION HL_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_HL_WALI(HL,PS,TS,XIL)**
 for call from DLL **REAL*8 HL,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

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

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

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

References: [2], [23]

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

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

Input Values:

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

Result

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

Range of validity

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

Explanation of the function

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

Results for wrong input values

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

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

References: [23]

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

Function Name: **lam_ptxi_WaLi**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION LAM_PTXI_WALI(P,T,XI)**
REAL*8 P,T,XI

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_LAM_PTXI_WALI(LAM,P,T,XI)**
REAL*8 LAM,P,T,XI

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

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

Range of validity

Temperature range: from 0 °C to 210 °C

Pressure range: from 0.00074 bar to 10 bar

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

Hints for wet steam

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

Results for wrong input values

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

p > 10 bar or p < 0.00074 bar or

t > 210 °C or t < 0 °C oder

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

$\xi > 1.0$ 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: **REAL*8 FUNCTION LAML_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_LAML_WALI(LAML,PS,TS,XIL)**
 for call from DLL **REAL*8 ETAL,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

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

Thermal Conductivity of Saturated Steam $\lambda^V = f(p_S, t_S, \xi^I)$

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

$$\lambda^V = f(-1, t_S, \xi^I)$$

$$\lambda^V = f(p_S, -1, \xi^I)$$

$$\lambda^V = f(p_S, t_S, -1)$$

$$\lambda^V = f(p_S, t_S, \xi^I)$$

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

References: [2], [23]

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

Function Name: **ny_ptxi_WaLi**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION NY_PTXI_WALI(P,T,XI)**
REAL*8 P,T,XI

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_NY_PTXI_WALI(NY,P,T,XI)**
REAL*8 NY,P,T,XI

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

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

Range of validity

Temperature range: from 0 °C to 210 °C

Pressure range: from 0.00074 bar to 10 bar

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

Hints for wet steam

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

Results for wrong input values

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

p > 10 bar or p < 0.00074 bar or

t > 210 °C or t < 0 °C oder

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

$\xi > 1.0$ 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: **REAL*8 FUNCTION NYL_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_NYL_WALI(NYL,PS,TS,XIL)**
 for call from DLL **REAL*8 NYL,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

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

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

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

References: [2], [23]

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

Function Name: **Pr_ptxi_WaLi**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION PR_PTXI_WALI(P,T,XI)**
REAL*8 P,T,XI

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_PR_PTXI_WALI(PR,P,T,XI)**
REAL*8 PR,P,T,XI

Input Values:

P - Pressure p in bar

T - Temperature t in °C

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

Result

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 H₂O)/(kg mixture)

Hints for wet steam

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

Results for wrong input values

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

p > 10 bar or p < 0.00074 bar or

t > 210 °C or t < 0 °C or

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

$\xi > 1.0$ 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: **REAL*8 FUNCTION PRL_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_PRL_WALI(PRL,PS,TS,XIL)**
 for call from DLL **REAL*8 PRL,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

For calculating the Prandtl-Number of the saturated liquid it is necessary to define two parameters (either t_s and ξ^l or p_s and ξ^l or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ^l are entered, the program considers p_s , t_s , and ξ^l 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: **REAL*8 FUNCTION PRV_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_PRV_WALI(PRV,PS,TS,XIL)**
 for call from DLL **REAL*8 PRV,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

For calculating the Prandtl-Number of saturated steam it is necessary to define two parameters (either t_s and ξ^l or p_s and ξ^l or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ^l are entered, the program considers p_s , t_s , and ξ^l 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: **REAL*8 FUNCTION PS_TSXIL_WALI(TS,XIL)**
for call from Fortran **REAL*8 TS,XIL**

Subroutine with parameter: **INTEGER*4 FUNCTION C_PS_TSXIL_WALI(PS,TS,XIL)**
for call from DLL **REAL*8 PS,TS,XIL**

Input Values:

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

Result

PS_TSXIL_WALI, PS or ps_tsxil_WaLi - Vapor pressure p_s in bar

Range of validity

Temperature range: from 0 °C to 210 °C

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

Results for wrong input values

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

$t_s > 210$ °C or $t_s < 0$ °C or

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

$\xi^l < \xi_{sol}(t_s)$ or

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

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

Function Name:	psol_t_WaLi
Subroutine with function value: for call from Fortran	REAL*8 FUNCTION PSOL_T_WALI(T) REAL*8 T
Subroutine with parameter: for call from DLL	INTEGER*4 FUNCTION C_PSOL_T_WALI(PSOL,T) REAL*8 PSOL,T

Input Values:

T - Temperature t in °C

Result

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

Range of validity

Temperature range: from 0 °C to 93.58 °C

Explanation of the function

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

Results for wrong input values

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

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

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

Phase Region Region = f(p,t,ξ)

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

Input Values:

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

Result

REGION_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 ₂ O)/(kg mixture)

Explanation of the function

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

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

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

Results for wrong input values

Result **REGION_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:

ξ < ξ_{sol}(t)

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

Phase Region Region = f(p,h,ξ)

Function Name: **region_phxi_WaLi**

Subroutine with function value:
for call from Fortran **INTEGER*4 FUNCTION REGION_PHXI_WALI(P,H,XI)**
REAL*8 P,H,XI

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_REGION_PHXI_WALI(REGION,P,H,XI)**
INTEGER*4 REGION
REAL*8 P,H,XI

Input Values:

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

Result

REGION_PHXI_WALI, REGION or region_phxi_WaLi – Phase region

Range of validity

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

Explanation of the function

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

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

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

Results for wrong input values

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

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

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

h < h_{sol}(ξ)

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

Phase Region Region = f(p,s,ξ)

Function Name: **region_psexi_WaLi**

Subroutine with function value: **INTEGER*4 FUNCTION REGION_PSEXI_WALI(P,S,XI)**
 for call from Fortran **REAL*8 P,H,XI**

Subroutine with parameter: **INTEGER*4 FUNCTION C_REGION_PSEXI_WALI(REGION,P,S,XI)**
 für Aufruf aus DLL **INTEGER*4 REGION**
REAL*8 P,S,XI

Input Values:

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

Result

REGION_PSEXI_WALI, REGION or region_psexi_WaLi – Phase region

Range of validity

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

Explanation of the function

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

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

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

Results for wrong input values

Result **REGION_PSEXI_WALI = -1000, REGION = -1000 or region_psexi_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_PSEXI_WALI = -2000, REGION = -2000 or region_psexi_WaLi = -2000** for input values:

ξ < ξ_{sol}(p)

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

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

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

Input Values:

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

Result

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

Range of validity

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

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

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

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

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

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

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

For calculating the specific entropy of the saturated liquid it is necessary to define two parameters (either t_s and ξ^l or p_s and ξ^l or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ^l are entered, the program considers p_s , t_s , and ξ^l 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: **REAL*8 FUNCTION SV_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_SV_WALI(SV,PS,TS,XIL)**
 for call from DLL **REAL*8 SV,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

References: [2], [23]

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

Function Name: **t_phxi_WaLi**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION T_PHXI_WALI(P,H,XI)**
REAL*8 P,H,XI

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_T_PHXI_WALI(T,P,H,XI)**
REAL*8 T,P,H,XI

Input Values:

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

Result

T_PHXI_WALI, T or t_phxi_WaLi – Temperature t in °C

Range of validity

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

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

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

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

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

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

Function Name: **t_psxi_WaLi**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION T_PSXI_WALI(P,S,XI)**
REAL*8 P,S,XI

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_T_PSXI_WALI(T,P,S,XI)**
REAL*8 T,P,S,XI

Input Values:

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

Result

T_PSXI_WALI, T or t_psxi_WaLi – Temperature t in °C

Range of validity

Temperature range: from 0 °C to 210 °C

Pressure range: from 0.00074 bar to 10 bar

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

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

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

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

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

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

Function Name: **ts_psxil_WaLi**

Subroutine with function value:
for call from Fortran **REAL*8 FUNCTION TS_PSXIL_WALI(PS,XIL)**
REAL*8 P,XIL

Subroutine with parameter:
for call from DLL **INTEGER*4 FUNCTION C_TS_PSXIL_WALI(TS,PS,XIL)**
REAL*8 TS,PS,XIL

Input Values:

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

Result

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

Range of validity

Pressure range: from 0.00074 bar to 10 bar

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

Results for wrong input values

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

$p_s > 10$ bar or $p_s < 0.00074$ bar or
at calculation result $t_s > 210$ °C or $t_s < 0$ °C or
 $\xi < \xi_{sol}(t)$
 $\xi^l > 1.0$ kg/kg or $\xi^l < 0.3$ kg/kg

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

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

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

Input Values:

P - Pressure p in bar

Result

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

Range of validity

Pressure range: from 0.00074 bar to 0.0373 bar

Explanation of the function

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

Results for wrong input values

Result **TSOL_P_WALI, = -1000, TSOL = -1000** or **tsol_p_WaLi = -1000** for input values:
 $p < 0.0373$ bar or $p > 0.00074$ bar

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

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

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

Input Values:

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

Result

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

Range of validity

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

Hints for wet steam

The wet steam region is calculated automatically by the subprograms:

Results for wrong input values

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

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

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

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

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

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

For calculating the specific volume of the saturated liquid it is necessary to define two parameters (either t_s and ξ^l or p_s and ξ^l or p_s and t_s) and -1 must be entered as a pro-forma value for the value which is not given. When p_s , t_s , and ξ^l are entered, the program considers p_s , t_s , and ξ^l 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: **REAL*8 FUNCTION VV_WALI(PS,TS,XIL)**
 for call from Fortran **REAL*8 PS,TS,XIL**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_VV_WALI(VV,PS,TS,XIL)**
 for call from DLL **REAL*8 VV,PS,TS,XIL**

Input Values:

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

Result

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

Range of validity

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

Hints of the input variants

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

Possible input variants:

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

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

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

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

Results for wrong input values

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

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

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

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

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

Input Values:

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

Result

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

Range of validity

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

Results for wrong input values

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

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

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

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

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

Input Values:

P - Pressure p in bar

Result

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

Range of validity

Pressure range: from 0.00074 bar to 0.0373 bar

Explanation of the function

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

Results for wrong input values

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

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

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

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

Input Values:

T - Temperature t in °C

Result

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

Range of validity

Temperature range: from 0 °C to 93.58 °C

Explanation of the function

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

Results for wrong input values

Result **XISOL_T_WALI = -1000, XISOL = -1000** or **xisol_t_WaLi = -1000** for input values:
t > 93.58 °C or t < 0 °C

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

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

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

Input Values:

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

Result

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

Range of validity

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

Explanation of the function

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

Results for wrong input values

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

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

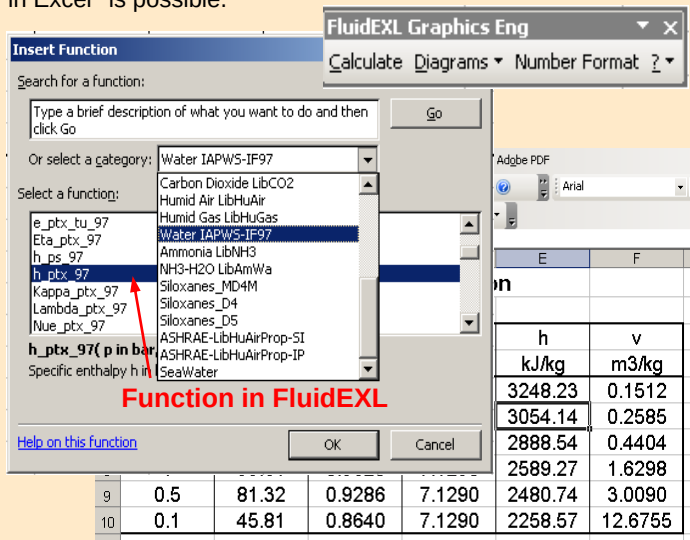
References: [2], [21]

Water and Steam	Humid Combustion Gas Mixtures	Humid Air
Library LibIF97 - Industrial Formulation IAPWS-IF97 (Revision 2007) - Supplementary Standards - IAPWS-IF97-S01 - IAPWS-IF97-S03rev - IAPWS-IF97-S04 - IAPWS-IF97-S05 - IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)	Library LibHuGas Ideal mixture of the real fluids: CO₂ - Span and Wagner O₂ - Schmidt and Wagner H₂O - IAPWS-95 Ar - Tegeler et al. N₂ - Span et al. and of the ideal gases: SO₂, CO, Ne (scientific equations of Bückner et al.) Consideration of Dissociation from VDI 4670 and Poynting effect Library LibIDGAS Ideal gas mixture calculated from the VDI-Guideline 4670	Library LibHuAir Ideal mixture of the real fluids: - Dry air from Lemmon et al. - Steam and water from IAPWS-IF97 Consideration of - Dissociation from VDI-Guideline 4670 - Poynting effect Library LibIdAir Ideal gas mixture calculated from VDI-Guideline 4670

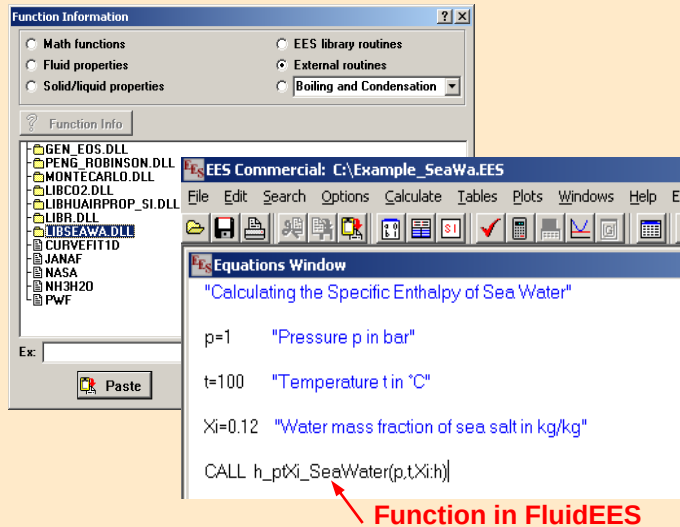
Carbon Dioxide	Ideal Gas Mixtures	Seawater
Library LibCO2 Formulation of Span and Wagner (1994)	Library LibIdGasMix Ideal mixture of the ideal gases: Ar SO₂ Methane Ne H₂ Ethane N₂ H₂S Ethylene O₂ OH Propylene CO He Propane CO₂ F₂ Iso-Butane Air NH₃ n-Butane NO Benzene H₂O Methanol Consideration of - Dissociation from VDI-Guideline 4670	Library LibSeaWa IAPWS Formulation (2008) and IAPWS-IF97
Hydrogen		Refrigerant R134a Library LibR134a Formulation of Tillner-Roth and Baehr (1994)
Library LibH2 Formulation of Leachman et al. (2007)		
Helium		
Library LibHe Formulation of McCarty and Arp (1990)		
Methanol		
Library LibCH3OH Formulation of de Reuck and Craven (1993)		Refrigerant NH3 Library LibNH3 Formulation of Tillner-Roth (1995)

ORC Working Fluids	Mixtures for Absorption Processes	Refrigerants
Library LibMM Siloxane C₆H₁₈OSi₂ (MM) Formulation of Colonna et al. (2006) Library LibD4 Siloxane C₈H₂₄O₄Si₄ (D4) Formulation of Colonna et al. (2006) Library LibD5 Siloxane C₁₀H₃₀O₅Si₅ (D5) Formulation of Colonna et al. (2006) Library LibMD4M Siloxane C₁₄H₄₂O₅Si₆ (MD4M) Formulation of Colonna et al. (2006)	Library LibAmWa Ammonia/Water Mixtures IAPWS Guideline 2005 of Tillner-Roth and Friend (1998) Helmholtz energy formulation for the mixing term Library LibWaLi Water/Lithium Bromide Mixtures Formulation of Kim and Infante Ferreira (2004) Gibbs energy equation for the mixing term	Library LibPropan Refrigerant Propane Formulation of Lemmon et al. (2008) Library LibButan_Iso Refrigerant Iso-Butane Formulation of Bückner et al. (2003) Library LibButan_n Refrigerant n-Butane Formulation of Bückner et al. (2003)

Using the Add-In FluidEXL a direct call of the property functions in Excel® is possible.

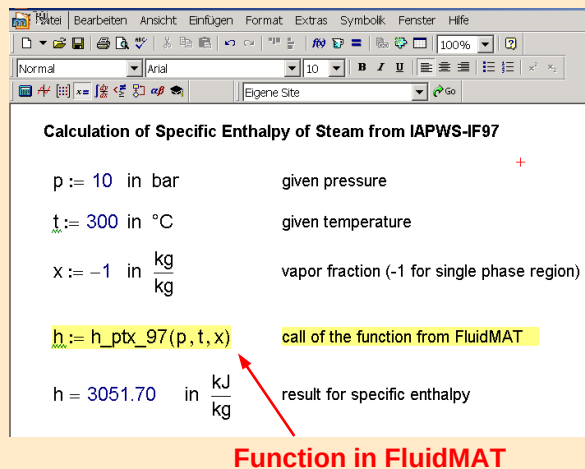


The Add-In FluidEES allows to call the functions of the property libraries within the Engineering Equation Solver EES®.



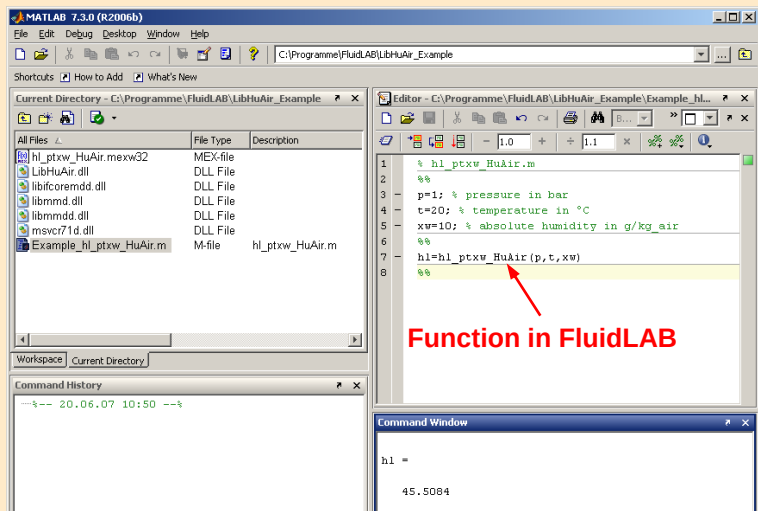
Add-In FluidMAT for Mathcad®

Using the Add-on FluidMAT, the functions of the property libraries can be used in Mathcad®.



Add-In FluidLAB for MATLAB®

The property functions can be called in MATLAB®.



The following thermodynamic and transport properties can be calculated¹:

Thermodynamic Properties

- Saturation pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e

- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Thermodynamic Derivatives

- Partial derivatives can be calculated

Transport Properties

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

Backward Functions

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

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Fax.: +49-3583-61-1846

¹ Not all of these property functions are available in all property libraries listed before.

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