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Property Library for Standard Dry Air

FluidVIEW
with **LibRealAir**
for LabVIEW®

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Property Library for Standard Dry Air
Including DLL and Add-on for LabVIEW™
FluidVIEW
LibRealAir

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0. Package Contents

0.1 Zip files for 32-bit Windows®

In order to install FluidVIEW on a computer running a 32-bit version of Windows® the zip file **CD_FluidVIEW_LibRealAir.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™. All contained files, their paths and the structure of the archive are shown in the screenshot of the WinRAR file archiver and compression tool illustrated in Figure 0.1.

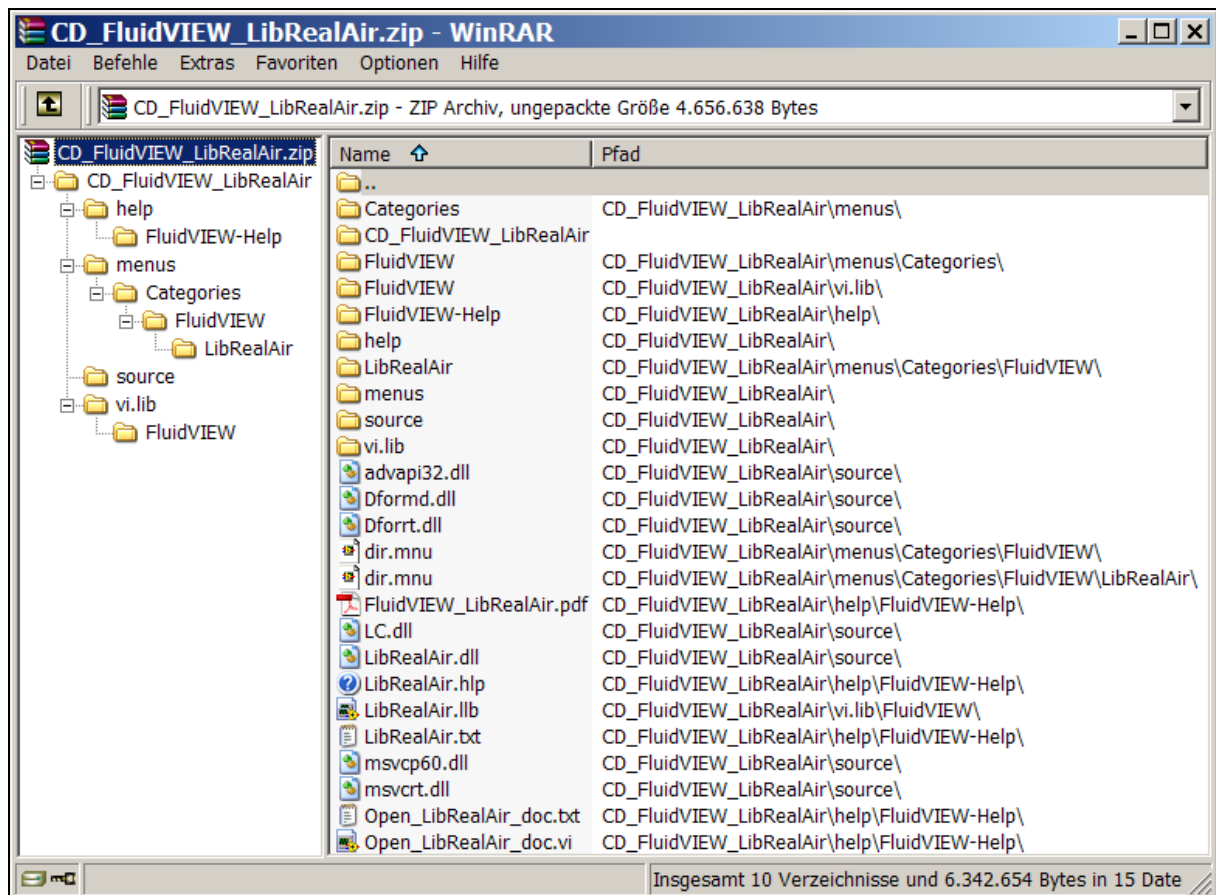


Figure 0.1 Screenshot of WinRAR showing the **CD_FluidVIEW_LibRealAir.zip** archive.

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_LibRealAir\vi.lib\FluidVIEW\LibRealAir**

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

Table 0.2 Effects of the files located in the archive directory **CD_FluidVIEW_LibRealAir\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_LibRealAir\source**

Filename	Effects
LibRealAir.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of standard dry air from Lemmon et al. [1], [2]
advapi32.dll	Runtime library
Dformd.dll	Runtime library for the Fortran DLL
Dfortrt.dll	Runtime library for the Fortran DLL
LC.dll	Auxiliary library
msvc60.dll	Runtime library
msvcrt.dll	Runtime library

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

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

0.2 Zip files for 64-bit Windows®

In order to install FluidVIEW on a computer running a 64-bit version of Windows® the zip file **CD_FluidVIEW_LibRealAir_x64.zip** is delivered. The directory structure of the archive is corresponding to the default directory of LabVIEW™. All contained files, their paths and the structure of the archive are shown in the screenshot of the WinRAR file archiver and compression tool illustrated in Figure 0.2.

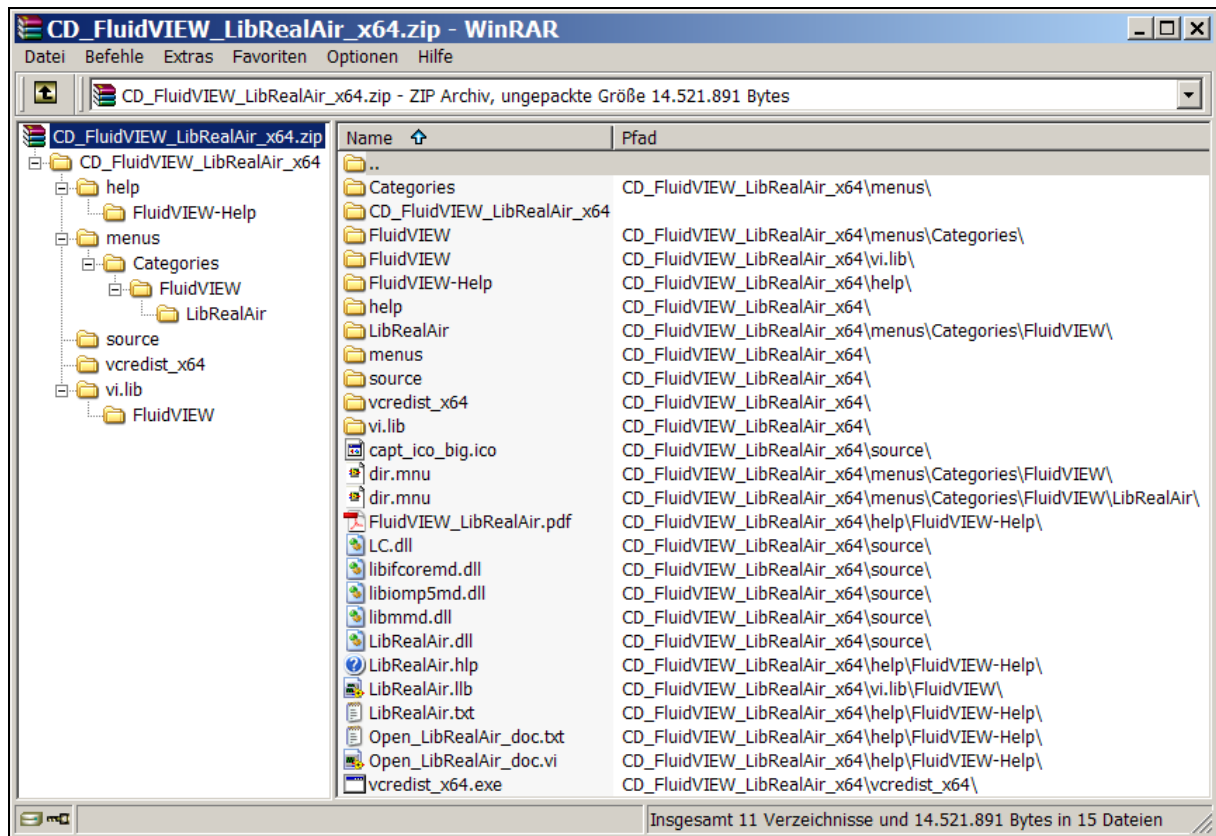


Figure 0.2 Screenshot of WinRAR showing the **CD_FluidVIEW_LibRealAir_x64.zip** archive.

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 and 0.8.

Table 0.5 Effects of the files located in the archive directory **CD_FluidVIEW_LibRealAir_x64\vi.lib\FluidVIEW\LibRealAir**

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

Table 0.6 Effects of the files located in the archive directory **CD_FluidVIEW_LibRealAir_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_LibRealAir_x64\source**

Filename	Effects
LibRealAir.dll	Dynamic-link library containing the algorithms for the calculation of the property functions of standard dry air from Lemmon et al. [1], [2]
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_LibRealAir_x64\help\FluidVIEW-help**

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

Table 0.9 Effects of the files located in the archive directory **CD_FluidVIEW_LibRealAir_x64\vc redistrib_x64**

Filename	Effects
vc redistrib_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

1.1 Range of Validity

The LibRealAir property library uses the thermodynamic property formulation for standard dry air released by *LEMMON* et al. [1], [2]. Whereas the atmospheric air is a mixture of fluids including nitrogen, oxygen, argon, carbon dioxide, steam, and other trace elements. The standard air this formulation is based on is dry and contains no carbon dioxide or trace elements. Due to the fact that the caused change is less than the experimental error in the measurements, this assumption has been made [1]. The composition is given in Table 1.1.

Table 1.1: Composition of air with N₂, O₂ and Ar as constituents

Component name	Chemical symbol	Mole fraction
Nitrogen	N ₂	0.7812
Oxygen	O ₂	0.2096
Argon	Ar	0.0092

The LibRealAir property library is valid for liquid, steam and supercritical air. This includes temperatures from 59.75 K (-213.4 °C) at the solidification point on the saturated liquid line to 2000 K (1726.85 °C) and pressures from 0.00001 bar to 20000 bar. The range of validity of the LibRealAir property library is shown in Figure 1.1 and Figure 1.3. Values for the points marked on these Figures are listed in Table 1.2 and Table 1.3.

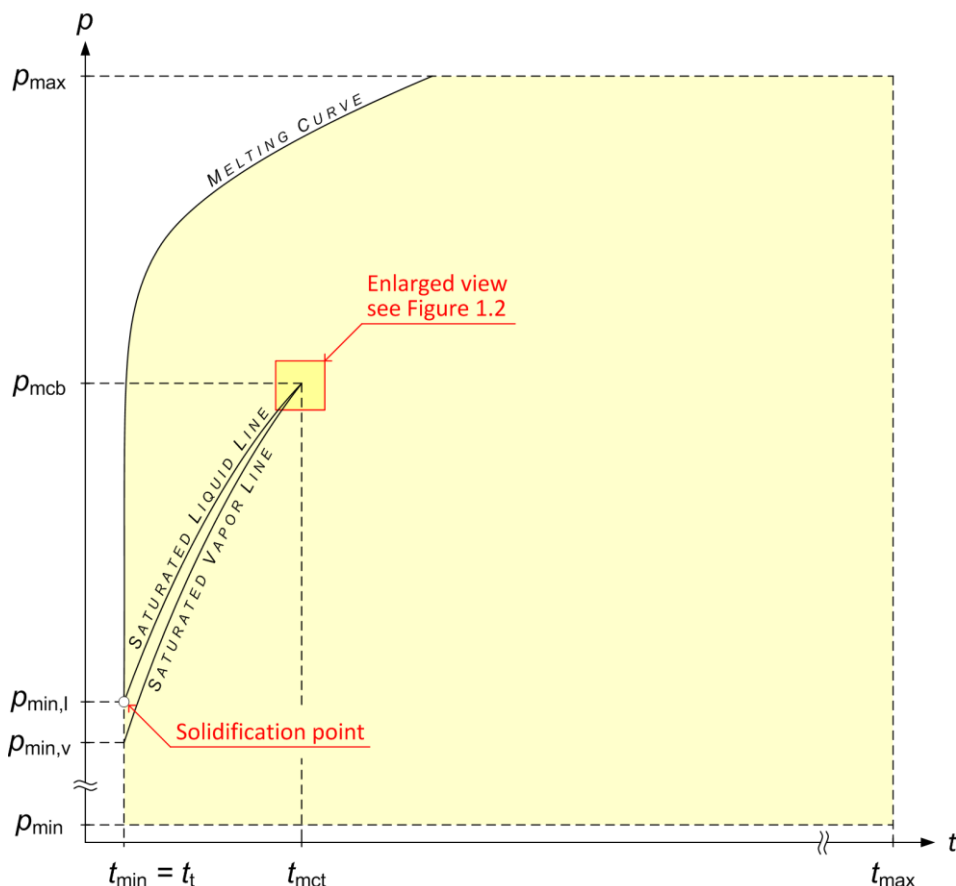


Figure 1.1: Entire range of validity in an $\lg p$, $\lg t$ – diagram
(see Figure 1.2 for an enlarged view of the critical region phase boundaries)

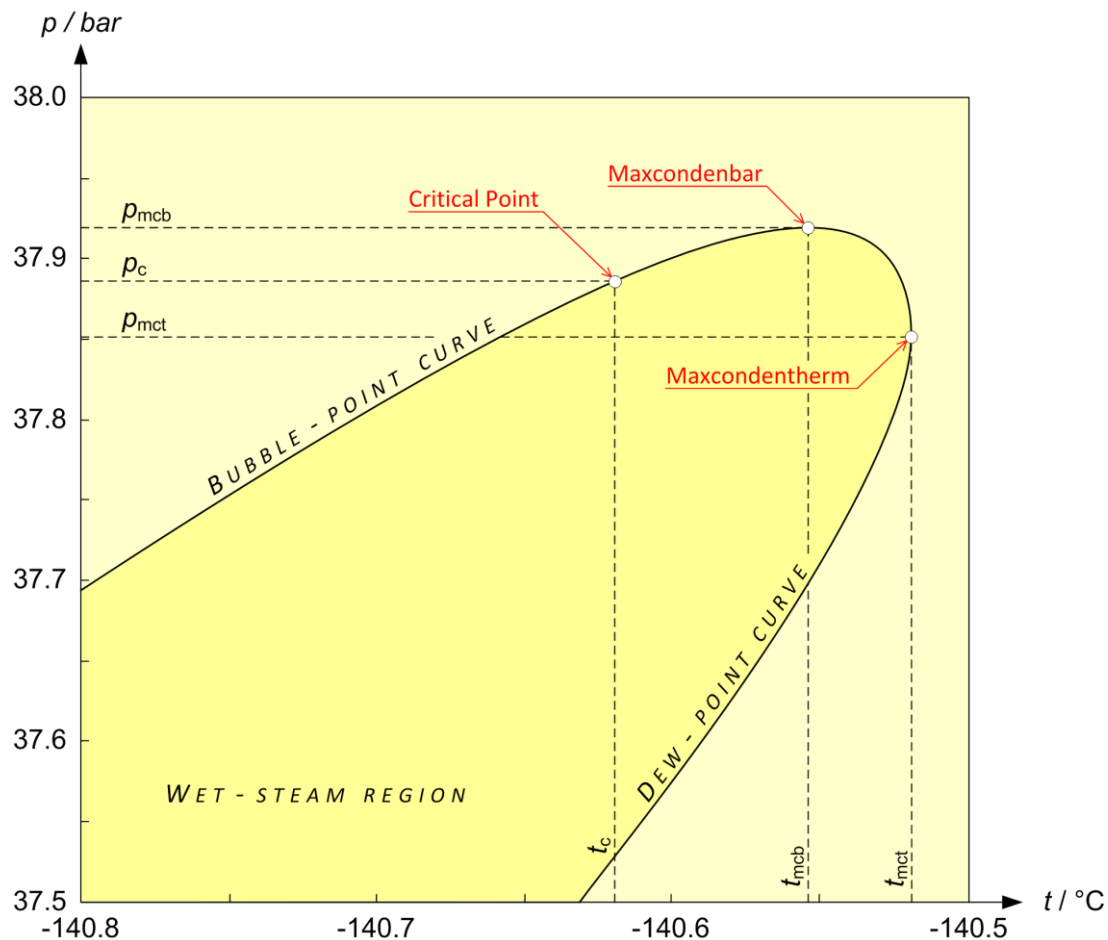


Figure 1.2: Enlarged view of the critical region phase boundaries in an p, t -diagram

Owing to the different boiling point temperatures of the mixture components in the p, T -diagram the saturation lines (liquid and vapor) of air do not overlap. In addition to the critical point a state point of maximum temperature (maxcondentherm) and a state point of maximum pressure (maxcondenbar) were determined on the saturation line. The maxcondentherm, maxcondenbar and critical point properties of air are shown in Table 1.3.

Table 1.2: Range of validity

Pressure	Abbreviations	Values in bar
Minimum pressure	$p_{\min}$	$1 \cdot 10^{-5}$
Minimum pressure on the dew-point curve	$p_{\min, l}$	0.024316
Minimum pressure on the bubble-point curve	$p_{\min, v}$	0.052646
Maximum pressure	$p_{\max}$	20000
Temperature	Abbreviations	Values in °C
Minimum temperature eq. triple point temperature	$t_{\min} = t_t$	-213.4
Maximum temperature	$t_{\max}$	1726.85
Specific Volume	Abbreviations	Values in m ³ /kg
Minimum specific volume	$v_{\min}$	0.00071991
Minimum specific volume on the bubble point curve	$v_{\min, l}$	0.00104112
Maximum specific volume on the dew-point curve	$v_{\max, v}$	7.037519
Maximum specific volume	$v_{\max}$	574234.252

Table 1.3: Maxcondentherm, maxcondenbar and critical point of air
(calculated with the formulation by LEMMON et al.)

Condition	Pressure in bar	Temperature in °C	Spec. volume in m ³ /kg
Maxcondentherm (mct)	37.8502	-140.5188	0.003323
Maxcondenbar (mcb)	37.9195	-140.5539	0.003018
Critical point (c)	37.8869	-140.6194	0.002853

Figure 1.3 shows the entire range of validity for the equation in an p, v -diagram. An enlarged view of the critical region phase boundaries in an p, v -diagram is shown in Figure 1.4.

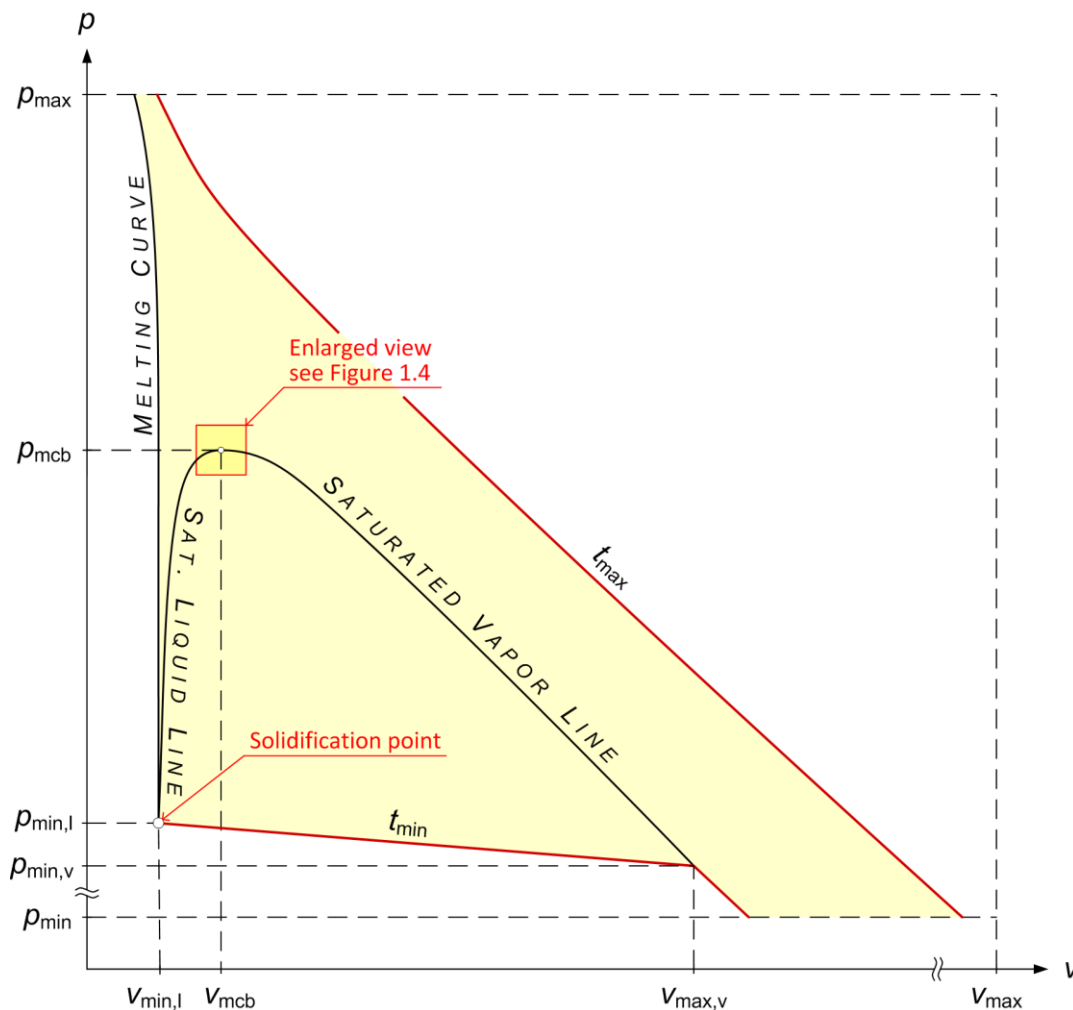


Figure 1.3: Entire range of validity in an $\lg p, \lg v$ - diagram

All sub-programs and functions can be applied in the entire range of validity of the LibRealAir. The call of the equation of state for each calculation region will be carried out within the program. The sub-programs of the LibRealAir DLL and the functions of the Add-In are listed in the following section.

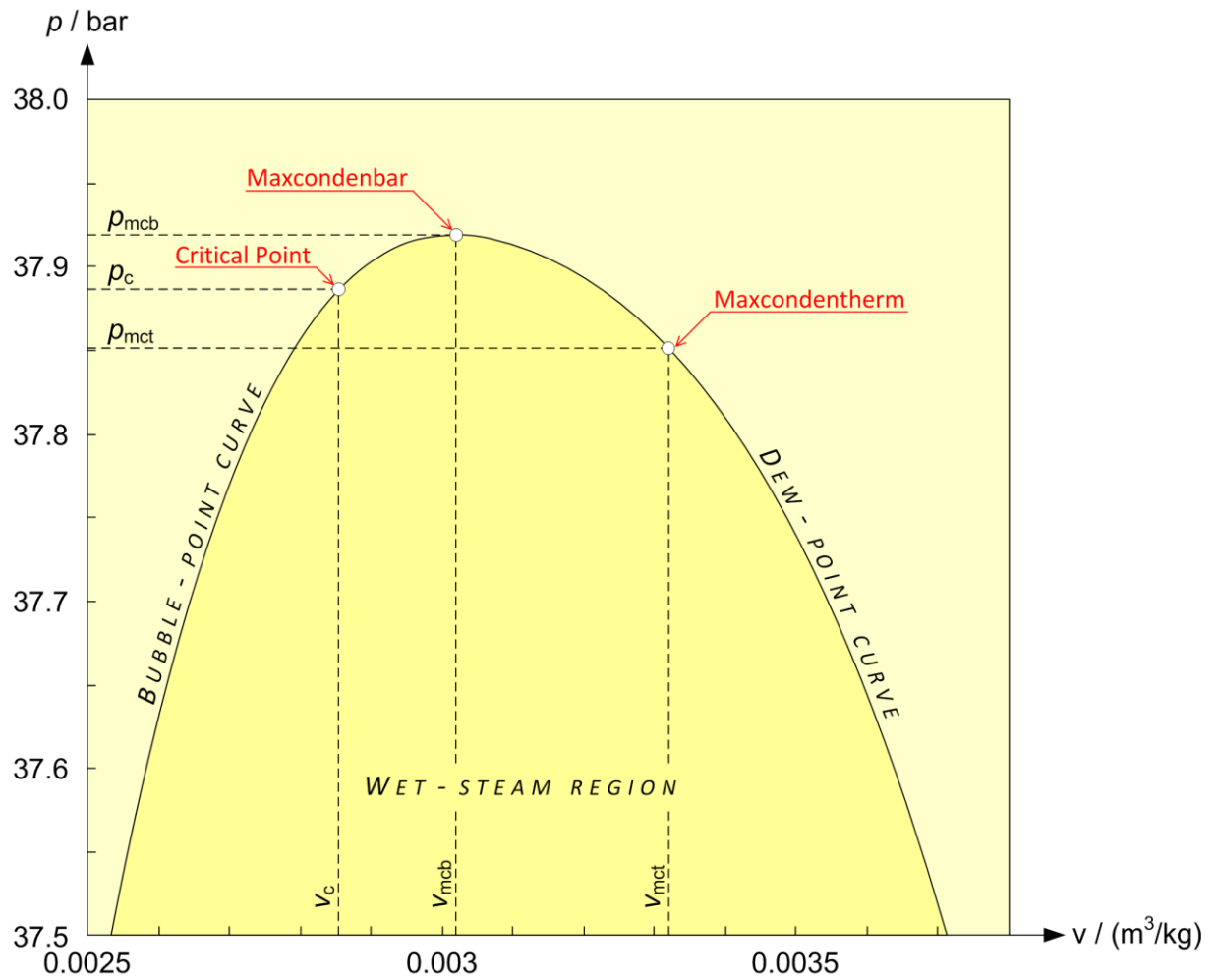


Figure 1.4: Enlarged view of the critical region phase boundaries in an p, v -diagram

1.2 Functions

Functional dependence	Function Name	Call from DLL LibRealAir, Result as Parameter	Property or Function	Unit of the Result
$a = f(p, t, x)$	a_ptx_air	= APTXAIR(P,T,X)	Thermal diffusivity	m ² /s
$\alpha_p = f(p, t, x)$	alphap_ptx_air	= ALPHAPPTXAIR(P,T,X)	Relative pressure coefficient	1/K
$\alpha_v = f(p, t, x)$	alphav_ptx_air	= ALPHAVPTXAIR(P,T,X)	Isobaric cubic expansion coefficient	1/K
$\beta_p = f(p, t, x)$	betap_ptx_air	= BETAPPTXAIR(P,T,X)	Isothermal stress coefficient	kg/m ³
$c_p = f(p, t, x)$	cp_ptx_air	= CPPTXAIR(P,T,X)	Specific isobaric heat capacity	kJ/(kg·K)
$c_v = f(p, t, x)$	cv_ptx_air	= CVPTXAIR(P,T,X)	Specific isochoric heat capacity	kJ/(kg·K)
$\eta = f(p, t, x)$	eta_ptx_air	= ETAPTXAIR(P,T,X)	Dynamic viscosity	Pa·s
$h = f(p, t, x)$	h_ptx_air	= HPTXAIR(P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p, t, x)$	kappa_ptx_air	= KAPPAPTXAIR(P,T,X)	Isentropic exponent	-
$\kappa_T = f(p, t, x)$	kappat_ptx_air	= KAPPATPTXAIR(P,T,X)	Isothermal compressibility	1/kPa
$\lambda = f(p, t, x)$	lambda_ptx_air	= LAMBDAPTXAIR(P,T,X)	Thermal conductivity	W/(m·K)
$\nu = f(p, t, x)$	nu_ptx_air	= NUPTXAIR(P,T,X)	Kinematic viscosity	m ² /s
$p_{\text{mel}} = f(t)$	pmel_t_air	= PMELTAIR(T)	Pressure on the melting curve	bar
$Pr = f(p, t, x)$	prandtl_ptx_air	= PRANDTLPTXAIR(P,T,X)	Prandtl number	-
$p_{\text{sl}} = f(t)$	psl_t_air	= PSLTAIR(T)	Pressure on the saturated liquid line	bar
$p_{\text{sv}} = f(t)$	psv_t_air	= PSVTAIR(T)	Pressure on the saturated vapor line	bar
$\rho = f(p, t, x)$	rho_ptx_air	= RHOPTXAIR(P,T,X)	Density	kg/m ³
$s = f(p, t, x)$	s_ptx_air	= SPTXAIR(P,T,X)	Specific entropy	kJ/(kg·K)
$t_{\text{mel}} = f(p)$	tmel_p_air	= TMELPAIR(P)	Temperature on the melting curve	°C
$t = f(p, h)$	t_ph_air	= TPHAIR(P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p, s)$	t_ps_air	= TPSAIR(P,S)	Backward function: Temperature from pressure and entropy	°C
$t_{\text{sl}} = f(p)$	tsl_p_air	= TSLPAIR(P)	Temperature on the saturated liquid line	°C
$t_{\text{sv}} = f(p)$	tsv_p_air	= TSVPAIR(P)	Temperature on the saturated vapor line	°C
$u = f(p, t, x)$	u_ptx_air	= UPTXAIR(P,T,X)	Specific internal energy	kJ/kg
$v = f(p, t, x)$	v_ptx_air	= VPTXAIR(P,T,X)	Specific volume	m ³ /kg
$w = f(p, t, x)$	w_ptx_air	= WPTXAIR(P,T,X)	Speed of sound	m/s
$x = f(p, h)$	x_ph_air	= XPHAIR(P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p, s)$	x_ps_air	= XPSAIR(P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg

Units:

Temperature	t in °C
Pressure	p in bar
Vapor fraction	x in kg saturated steam/kg wet steam

Range of validity of LibRealAir:

Temperature: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure: from 0.00001 bar to 20000 bar

Details on the vapor fraction x and on the calculation of wet steam:

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation for the property of the chosen function to be calculated results in -1000 . In this case, the backward functions result in the appropriate value between 0 and 1 for x .

Boundaries for wet steam region

The boundaries for the wet steam region are

$$t_t = -213.4 \text{ °C}; \quad p_{\min,l} = 0.052646 \text{ bar}; \quad p_{\min,v} = 0.024316 \text{ bar}$$

$$t_{mct} = -140.5188 \text{ °C}; \quad p_{mcb} = 37.9195 \text{ bar}.$$

They are illustrated in Figure 1.1 and Figure 1.2 and listed in Table 1.2 and Table 1.3.

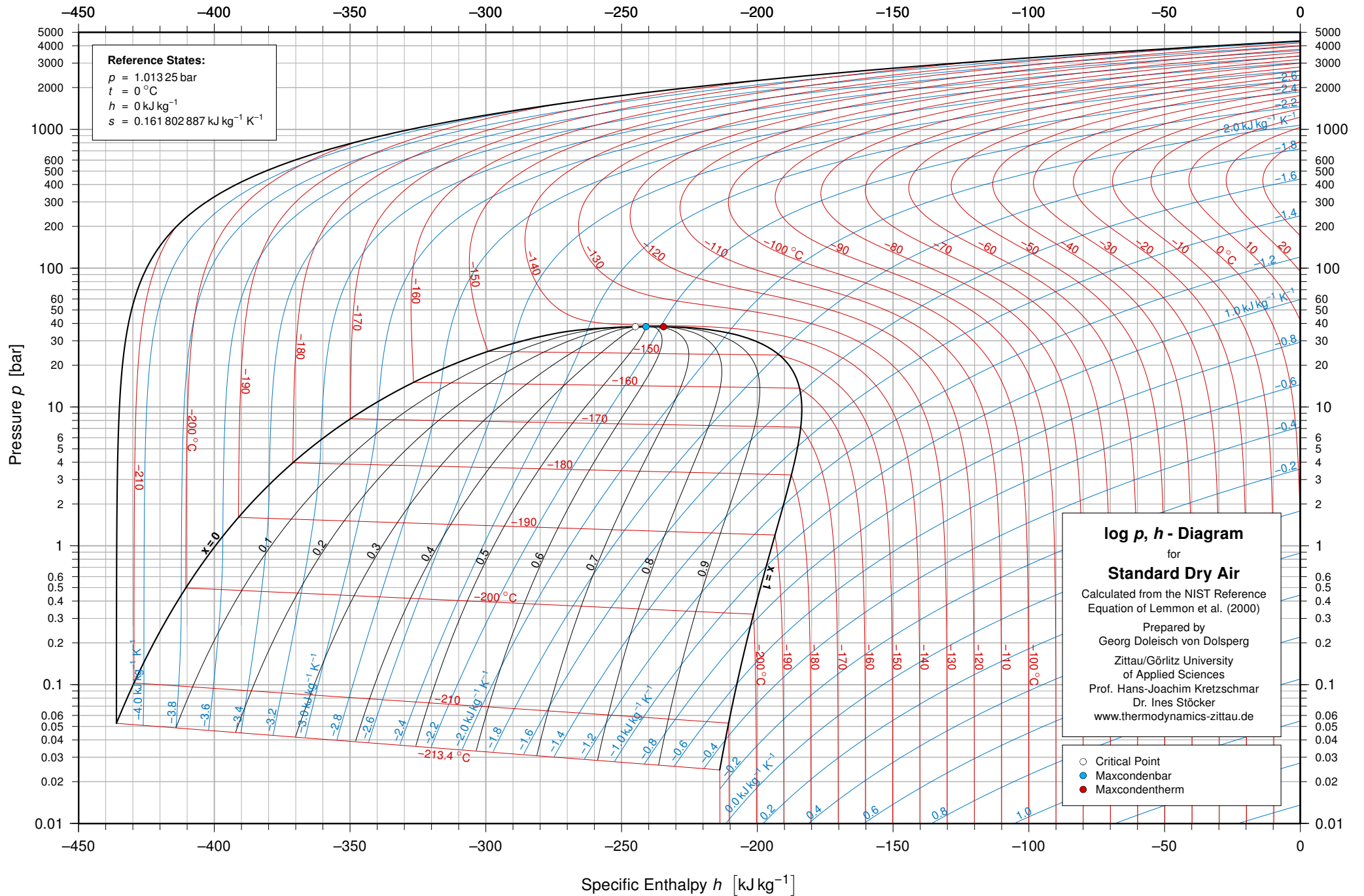
Note:

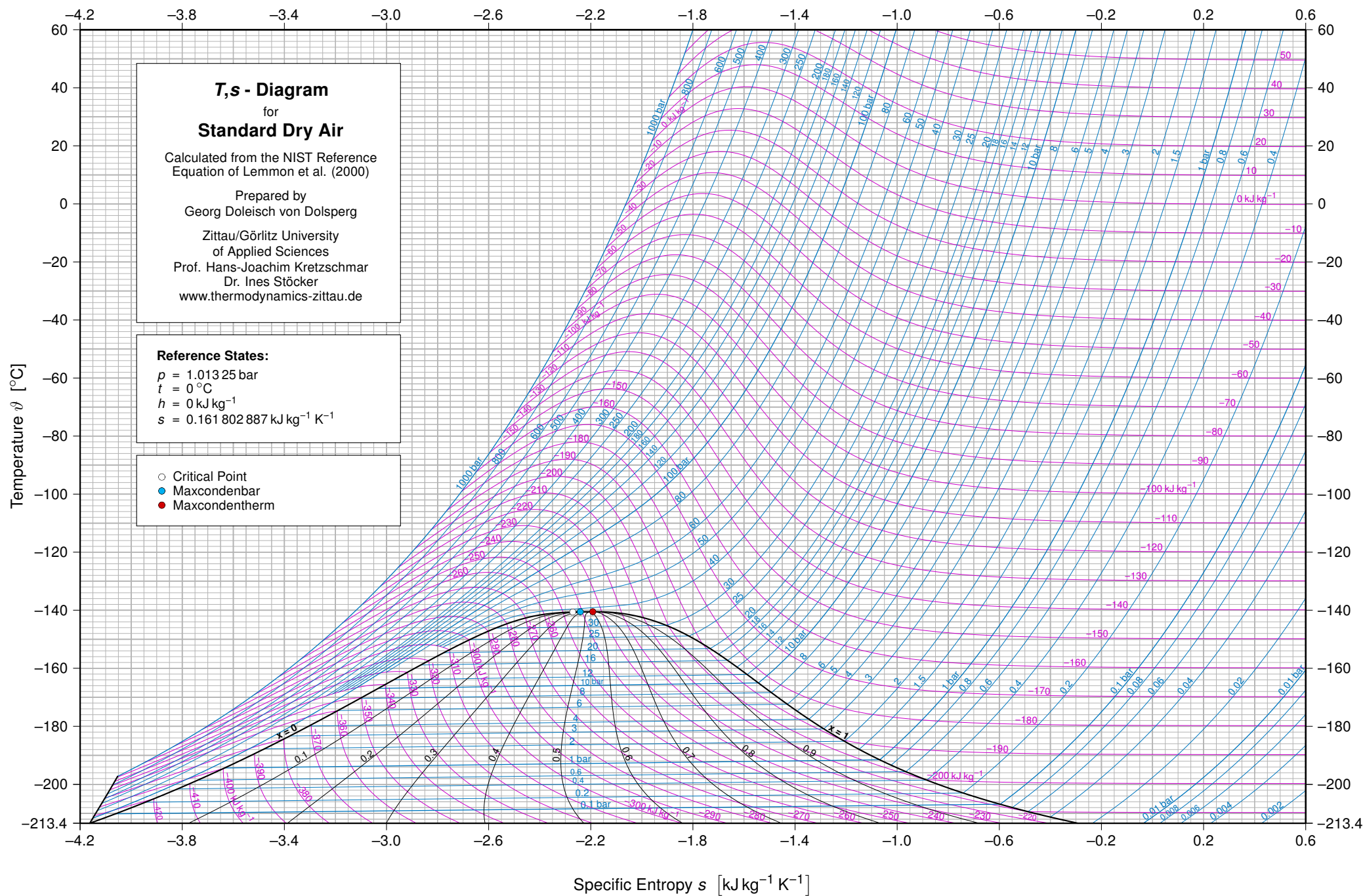
If the calculation results in -1000 , the values entered represent a state point beyond the range of validity. For further information on each function and its range of validity see Chapter 3. The same information may also be accessed via the online help pages.

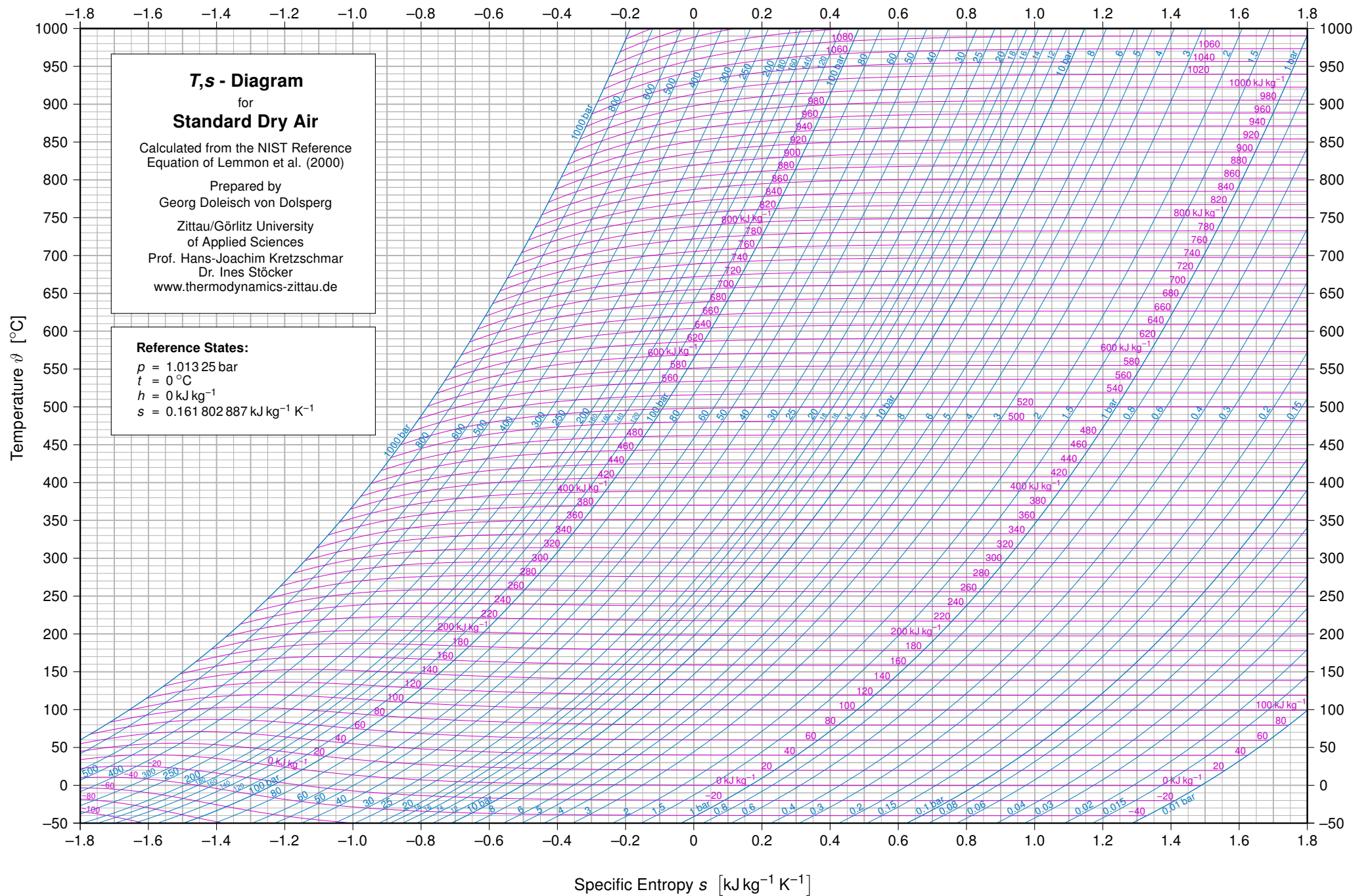
1.3 Thermodynamic Diagrams

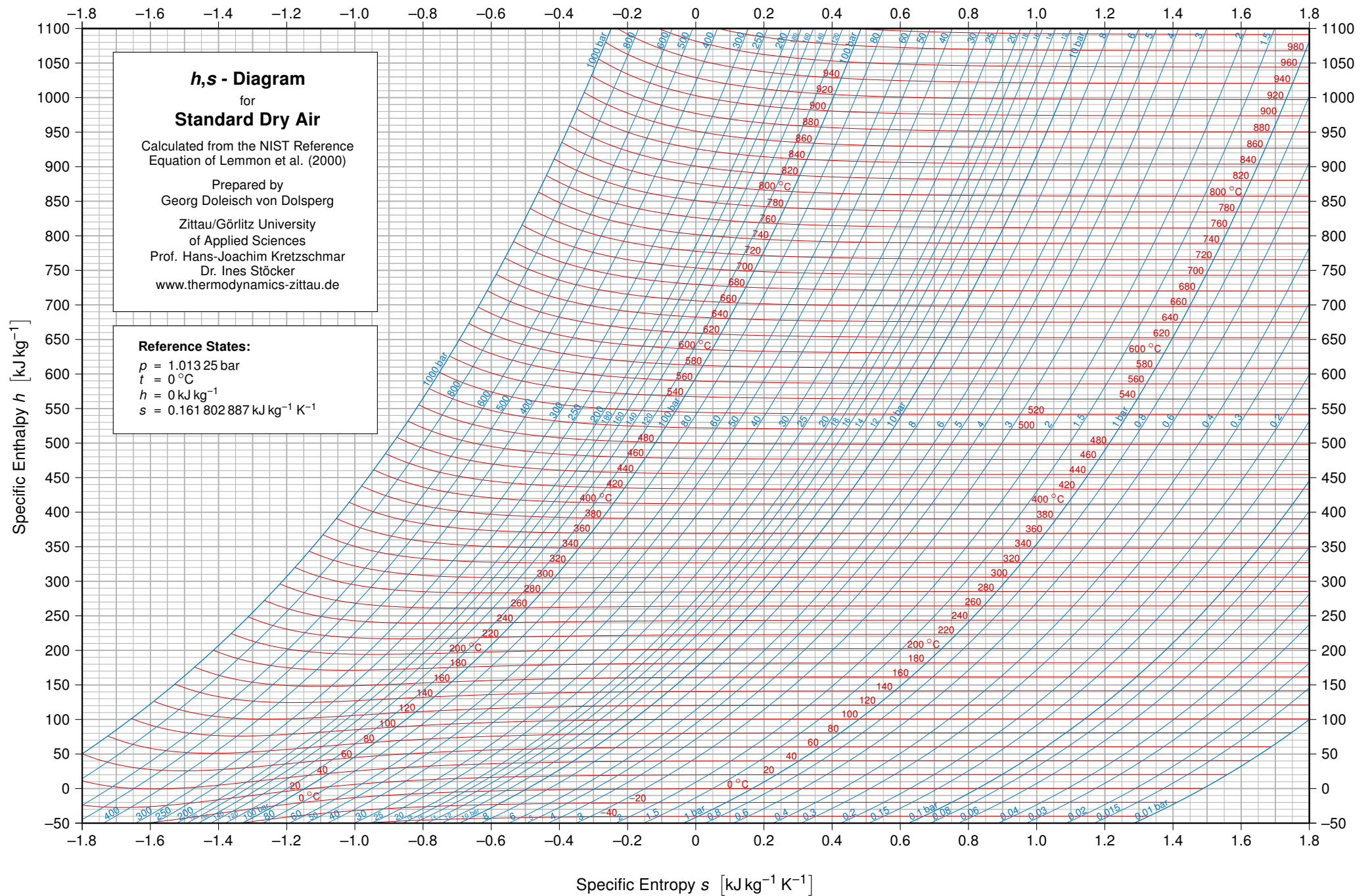
The next pages provide the following thermodynamic diagrams showing the properties of standard dry air.

- **lg p,h -diagram** from
 $p = 0.01 \text{ bar}$ to $p = 5000 \text{ bar}$,
 $t = -213.4 \text{ °C}$ to $t = 0 \text{ °C}$ and
 $\Delta h = 450 \text{ kJ/kg}$
- **T,s -diagram** from
 $t = -213.4 \text{ °C}$ to $t = 60 \text{ °C}$,
 $p = 0.01 \text{ bar}$ to $p = 1000 \text{ bar}$ and
 $\Delta s = 4.8 \text{ kJ/(kg·K)}$
- **T,s -diagram** from
 $t = -50 \text{ °C}$ to $t = 1000 \text{ °C}$,
 $p = 0.01 \text{ bar}$ to $p = 1000 \text{ bar}$ and
 $\Delta s = 3.6 \text{ kJ/(kg·K)}$
- **h,s -diagram** from
 $t = -40 \text{ °C}$ to $t = 1000 \text{ °C}$,
 $p = 0.01 \text{ bar}$ to $p = 1000 \text{ bar}$ and
 $\Delta s = 3.6 \text{ kJ/(kg·K)}$









2 Application of FluidVIEW in LabVIEW™

The FluidVIEW Add-on has been developed to calculate thermodynamic properties in LabVIEW™ more conveniently. Within LabVIEW™, it enables the direct call of functions relating to standard dry air from the LibRealAir 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 LibRealAir library. In this case, follow the subsection "Adding the LibRealAir Library" on page 2/3.

In both cases folders and files from the zip archive

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

CD_FluidVIEW_LibRealAir_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 **lvcredist_x64** in the **64-bit** CD folder

"CD_FluidVIEW_LibRealAir_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).

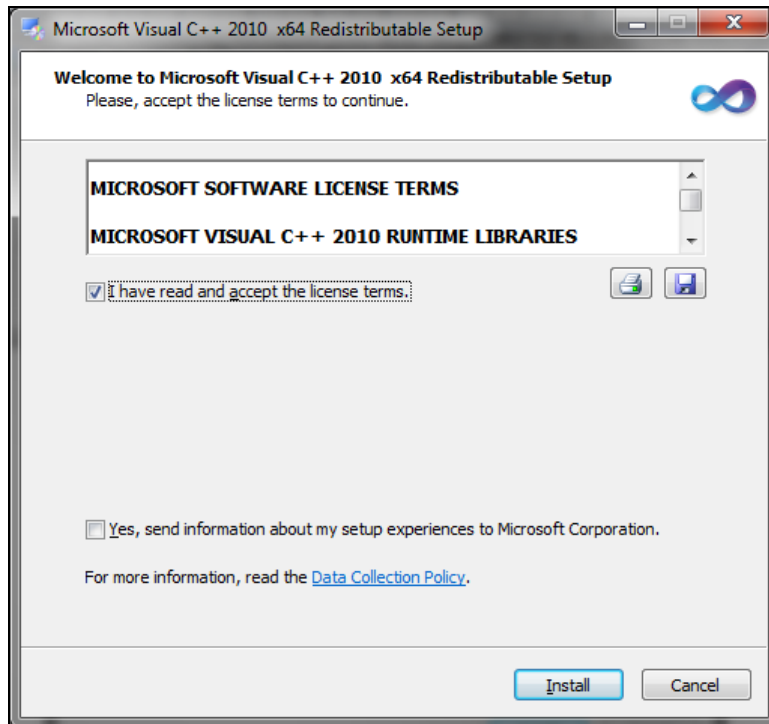


Figure 2.1 Accepting the license terms to install the Microsoft Visual C++ 2010 x64 Redistributable Package

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. The pathname has to be indicated in order to calculate the property functions.

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

- **32-bit system:** LibRealAir.dll, advapi32.dll, Dformd.dll, Dforrt.dll, LC.dll, msvcp60.dll, and msvcr7.dll

and for the

- **64-bit system:** LibRealAir.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	Pathname 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 LibRealAir Library

In order to add the LibRealAir 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 be stored in a random directory. The pathname has to be indicated in order to calculate the property functions.

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

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

and for the

- **64-bit system:** LibRealAir.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 LibRealAir property library to an existing installation of FluidVIEW

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

After you have restarted LabVIEW™ you will find the functions of the LibRealAir 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 0.

2.2 The FluidVIEW Help System

FluidVIEW provides detailed online help functions. If you are running Windows Vista or Windows 7, please note the paragraph

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

General Information

The FluidVIEW Help System consists of the Microsoft WinHelp file **LibRealAir.hlp** and this user's guide as PDF document **FluidVIEW_LibRealAir_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 *LibRealAir Help File* and *LibRealAir 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 `v_ptx_air.vi` is shown in Figure 2.2.

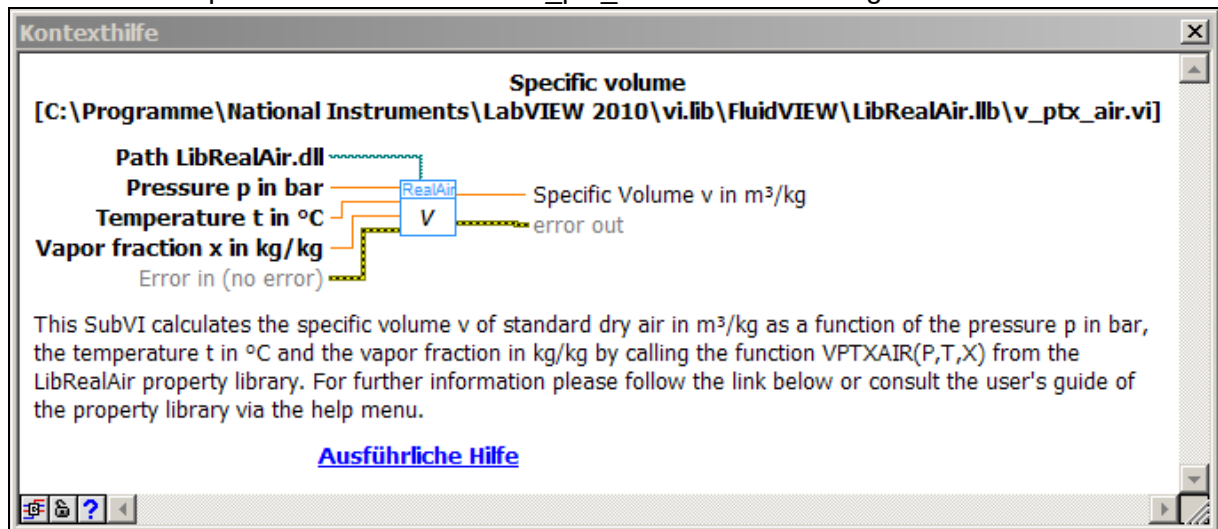


Figure 2.2 Context help window of the function `v_ptx_air.vi`

Using the FluidVIEW 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. The description relates to Windows® 7.

The procedure is analogous for Windows® Vista.

Open Microsoft Internet Explorer® and go to <http://support.microsoft.com/kb/917607>. Scroll down until you see the headline "Resolution". Under the first Point you'll find the links to

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

RESOLUTION

To resolve this issue, obtain the Windows Help program (WinHlp32.exe) for the versions of Windows that support it. To obtain the correct version for your operating system, you must know whether you have a Windows 32-bit or Windows 64-bit system. If you are not sure which version of Windows you are running, follow the steps under "If you are not sure which Windows version is installed."

Note To determine which version of Windows you are running, you must be logged on as an administrator. To verify that you are logged on as an administrator, follow the steps under "To verify that you are logged on as an administrator."

[Back to the top](#)

If you are not sure which Windows version is installed

If you are not sure which version of Windows is installed on your computer, follow the steps in the following wizard.

[Click here to view or hide step-by-step instructions with pictures](#)

[Back to the top](#)

To verify that you are logged on as an administrator

To verify that you are logged on as an administrator, follow the steps in the following wizard.

[Click here to view or hide step-by-step instructions with pictures](#) **How to obtain the correct version of the Windows Help program (WinHlp32.exe)**

- Click one of the following "Windows Help program" links, depending on the operating system that you are running:
 - [Windows Help program \(WinHlp32.exe\) for Windows Vista](#)
 - [Windows Help program \(WinHlp32.exe\) for Windows 7](#)
 - [Windows Help program \(WinHlp32.exe\) for Windows Server 2008](#)
 - [Windows Help program \(WinHlp32.exe\) for Windows Server 2008 R2](#)

Note The Windows Help program is not supported for Windows 8 Server Beta, and no download will be provided for this Windows version. The Windows Help program is supported for the x64 and x86 editions of the Windows 8 client, and a download package for these editions will be made available in this article at a later date.

- Click **Continue** to run Genuine Windows Validation. For more information about how to install Genuine Windows Validation Component, visit the following Microsoft website:
<http://www.microsoft.com/download/en/genuine-validation.aspx?id=5143>
- Download and install **Windows6.*-KB917607-x64.msu** or **Windows6.*-KB917607-x86.msu**, depending on the edition of the operating system that you are running.

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).

Validation Required

For more information about the validation process, [click here](#).

Quick details

Version:	1.0	Date published:	10/14/2009
Change language:	English		

KB articles:	KB917607
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Files in this download

The links in this section correspond to files available for this download. Download the files appropriate for you.

File name	Size
Windows6.1-KB917607-x64.msu	702 KB
Windows6.1-KB917607-x86.msu	688 KB

CONTINUE

Figure 2.4 Microsoft® Download Center

Afterwards a web page with instructions on how to install the Genuine Windows Validation Component opens. At the top of your Windows Internet Explorer you will see a yellow information bar. It reads

"This website wants to install the following add-on: 'Windows Genuine Advantage' from 'Microsoft Corporation'. If you trust this website and the add-on and want to install it, click here."

Right-click this bar and select "Install ActiveX Control" in the context menu. A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue. After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.5).

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.

Genuine Microsoft Software

Please click **Download** to download the software.

Quick details

Version: 1.0

Date published: 10/14/2009

Change language: English

KB articles: [KB917607](#)

Files in this download

The links in this section correspond to files available for this download. Download the files appropriate for you.

File name	Size	
Windows6.1-KB917607-x64.msu	702 KB	DOWNLOAD
Windows6.1-KB917607-x86.msu	688 KB	DOWNLOAD

Figure 2.5 Downloading the Windows Help Program

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

Installation starts with a window searching for updates on your computer.

After the program has finished searching you may be asked, if you want to install the "Update for Windows (KB917607)."

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

The installation can be continued by clicking the "Yes" button.

In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept".

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 LibRealAir Property Library

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

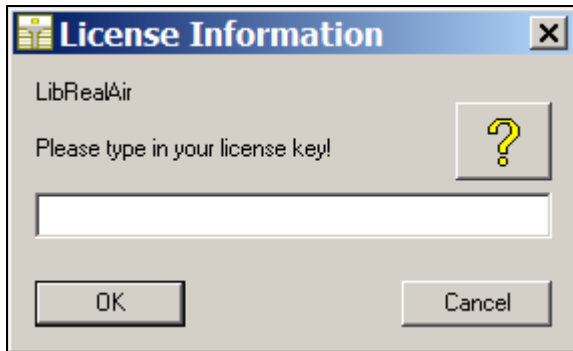


Figure 2.6 "License Information" window

Here you will have to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. 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:

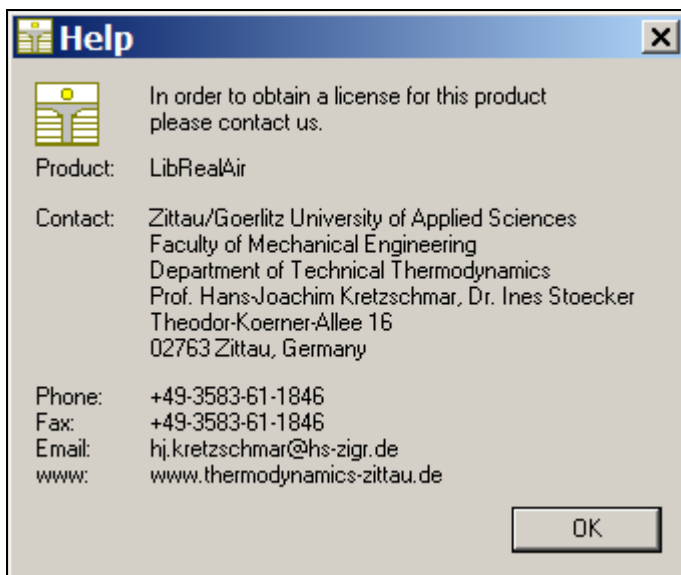


Figure 2.7 "Help" window

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

The "License Information" window will appear every time you start LabVIEW unless you uninstall FluidVIEW.

Should you not wish to license the LibRealAir property library, you have to uninstall FluidVIEW according to the description in section 2.5 of this User's Guide.

2.4 Example: Calculation of $h = f(p, t, x)$ and $s = f(p, t, x)$

After the delivered files have been copied in the appropriate folders of the default directory LabVIEW™ (described in section 2.1), the LibRealAir property library is ready to use. The function nodes of the LibRealAir 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.

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p , temperature t , and vapor fraction x , 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 2.8) with the sub palette *LibRealAir* (see Figure 2.9).

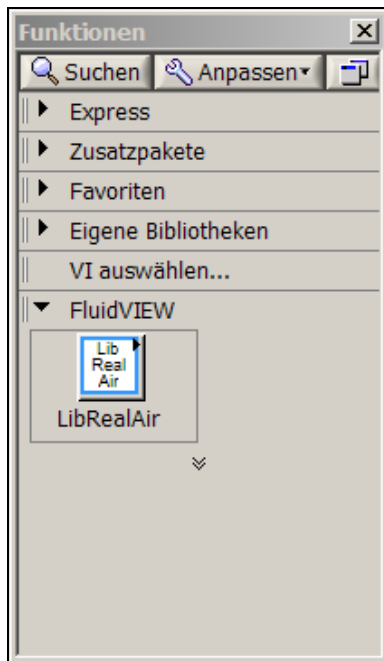


Figure 2.8

Functions palette with the sub palettes FluidVIEW and LibRealAir

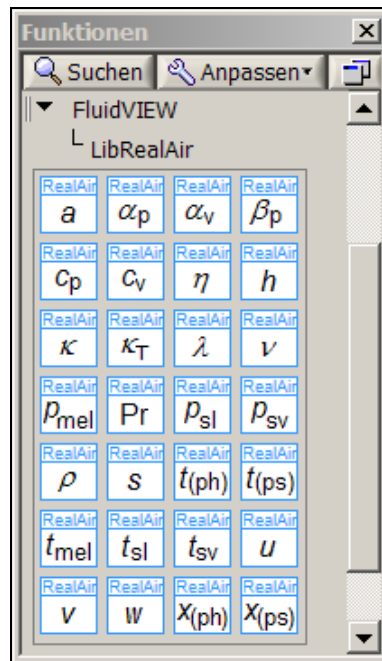


Figure 2.9

Functions palette with the property functions of the LibRealAir 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_ptx_air.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 LibRealAir.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 **Vapor fraction x 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 2.10. The same input and output elements are available on the appropriate front panel (see Figure 2.11).

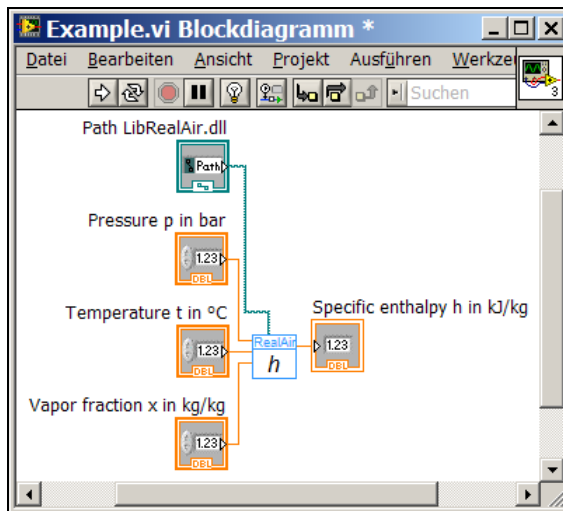


Figure 2.10
Block diagram of the example calculation

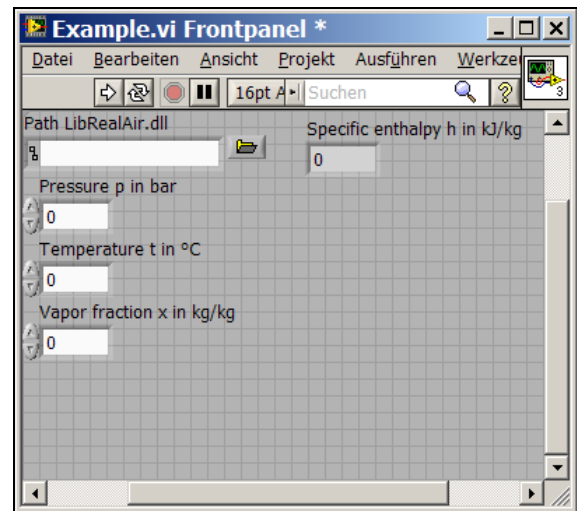


Figure 2.11
Front panel of the example calculation

- Enter a value in the input element *Pressure p in bar* on the front panel (Range of validity corresponding to LEMMON: $p = 0.00001 \dots 20000$ bar)
⇒ e. g.: Enter the value 10.
- Enter a value in the input element *Temperature t in °C* on the front panel (Range of validity corresponding to LEMMON: $t = -213.4 \dots 1726.85$ bar)
⇒ e. g.: Enter the value 20.
- Enter a value in the input element *Vapor fraction x in kg/kg* on the front panel. Since the wet steam region is calculated automatically by the subprograms, the following fixed details on the vapor fraction x are to be considered when the value for x is entered:

Single-phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet-steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for x . It is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in -1000 .

⇒ e. g.: Enter the value -1.

- Enter the path of the LibRealAir.dll in the input element *Path LibRealAir.dll* on the front panel (as explained in section 2.1 the LibRealAir.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 2.12).

⇒ The result for h in our sample calculation is 18.004689125 in kJ/kg.

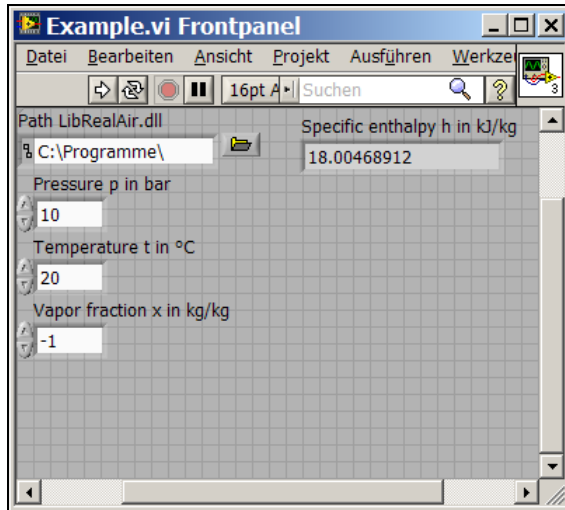


Figure 2.12 Result of the example calculation of h

The calculation of $h = f(p, t, x)$ has thus been completed. Correspondingly, the specific entropy $s = f(p, t, x)$ can be calculated with the same values for p , t , and x . The following changes need to be implemented.

- Open the context menu of the function node *Specific enthalpy* on the block diagram. Under **Replace / Palette LibRealAir** you will find the function **Specific entropy** symbolized with s . The node on the block diagram changes to **Specific entropy** by clicking on this symbol. Since the input parameters are the same as before their labels need not be changed. Only the label of the output parameter can be changed from *Specific enthalpy h in kJ/kg* to *Specific entropy s in kJ/(kg·K)* 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 entropy s in kJ/(kg·K)* was taken automatically. Since the values in the input elements are still present the calculation can be started now by pressing <Ctrl>+<R> or clicking the *Run* button. The result for s in kJ/(kg·K) appears in the output element.

⇒ The result for s in our sample calculation is -0.430733041 in kJ/(kg·K).

The calculation of $s = f(p, T, x)$ has been carried out. You can now arbitrarily change the values for p , t , or x 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 of *LEMMON*. 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 LibRealAir library or the complete FluidVIEW Add-on you merely 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	Path in the default directory of LabVIEW™ (<LV>)
FluidVIEW	<LV>\vi.lib
FluidVIEW	<LV>\menus\Categories
FluidVIEW-Help	<LV>\help

Removing only the LibRealAir library

To remove only the LibRealAir 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 LibRealAir library.

File name with file extension or name of the directory	Path in the default directory of LabVIEW (<LV>)
LibRealAir.llb	<LV>\vi.lib\FuildVIEW
LibRealAir	<LV>\menus\Categories\FuildVIEW
LibRealAir.hlp	<LV>\help\FuildVIEW-Help
LibRealAir.txt	<LV>\help\FuildVIEW-Help
FluidVIEW_LibRealAir.pdf	<LV>\help\FuildVIEW-Help
Open_LibRealAir_doc.vi	<LV>\help\FuildVIEW-Help
Open_LibRealAir_doc.txt	<LV>\help\FuildVIEW-Help

The changes will take effect after restarting LabVIEW™.

3. Program Documentation

Thermal Diffusivity $a = f(p, t, x)$

Function Name: **a_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION APTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

a_ptx_air or **APTXAIR** - Thermal diffusivity $a = \frac{\lambda}{\rho \cdot c_p} = \frac{\lambda \cdot v}{c_p}$

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function a will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

The result is **a_ptx_air = -1000** or **APTXAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$
 Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,l}} = 0.052646$ bar or

at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,l}} = 0.052646 \text{ bar}$ and
 $|t - t_{\text{sl}}(p)| > 0.1 \text{ K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

References

[1], [2]

Relative Pressure Coefficient $\alpha_p = f(p, t, x)$

Function Name: **alphap_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION ALPHAPPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

alphap_ptx_air or **ALPHAPPTXAIR** – Relative pressure coefficient $\alpha_p = -\frac{1}{p} \left(\frac{\partial p}{\partial T} \right)_v$ in 1/K

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function α_p will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **alphap_ptx_air** = **-1000** or **ALPHAPPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{l}} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, \text{l}} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Isobaric Cubic Expansion Coefficient $\alpha_v = f(p, t, x)$

Function Name: **alphav_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION ALPHAVPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

alphav_ptx_air or **ALPHAVPTXAIR**

Isobaric cubic expansion coefficient $\alpha_v = \frac{1}{\rho} \left(\frac{\partial \rho}{\partial p} \right)_T \left(\frac{\partial p}{\partial T} \right)_\rho$ in 1/K

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function α_v will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **alphav_ptx_air** = **-1000** or **ALPHAVPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min},l} = 0.052646$ bar or

at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,l}} = 0.052646 \text{ bar}$ and
 $|t - t_{\text{sl}}(p)| > 0.1 \text{ K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Isothermal Stress Coefficient $\beta_p = f(p, t, x)$

Function Name: **betap_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION BETAPPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

betap_ptx_air or **BETAPPTXAIR** – Isothermal stress coefficient $\beta_p = \frac{\rho^2}{p} \left(\frac{\partial p}{\partial \rho} \right)_T$ in kg / m³

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function β_p will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **betap_ptx_air** = **-1000** or **BETAPPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,l}} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\text{min,l}} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

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

Function Name: **cp_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION CPPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

cp_ptx_air or **CPPTXAIR** – Specific isobaric heat capacity c_p in kJ/(kg·K)

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function c_p will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **cp_ptx_air = -1000** or **CPPTXAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, l} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, l} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Specific Isochoric Heat Capacity $c_v = f(p, t, x)$

Function Name: **cv_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION CVPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

cv_ptx_air or **CVPTXAIR** – Specific isochoric heat capacity c_v in kJ/(kg·K)

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function c_v will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **cv_ptx_air = -1000** or **CVPTXAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{I}} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, \text{I}} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

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

Function Name: **eta_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION ETAPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

eta_ptx_air or **ETAPTXAIR** – Dynamic viscosity η in Pa·s

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function η will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **eta_ptx_air** = **-1000** or **ETAPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,l}} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\text{min,l}} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

References

[1], [2]

Specific Enthalpy $h = f(p, t, x)$

Function Name: **h_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION HPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

h_ptx_air or **HPTXAIR** – Specific enthalpy h in kJ/kg

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function h will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **h_ptx_air** = **-1000** or **HPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,l}} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\text{min,l}} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1$ K

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,v}} = 0.024316$ bar or

at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Isentropic Exponent $\kappa = f(p, t, x)$

Function Name: **kappa_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION KAPPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

kappa_ptx_air or **KAPPAPTXAIR** – Isentropic exponent $\kappa = -\frac{v}{p} \left(\frac{\partial p}{\partial v} \right)_s = \frac{w^2}{p \cdot v}$

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function κ will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **kappa_ptx_air** = **-1000** or **KAPPAPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, l} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, l} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Isothermal Compressibility $\kappa_T = f(p, t, x)$

Function Name: **kappat_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION KAPPATPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

kappat_ptx_air or **KAPPATPTXAIR** - Isothermal compressibility $\kappa_T = -\frac{1}{v} \left(\frac{\partial v}{\partial p} \right)_T = v \left(\frac{\partial p}{\partial v} \right)_T^{-1}$

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function κ_T will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **kappat_ptx_air = -1000** or **KAPPATPTXAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,l}} = 0.052646 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,l}} = 0.052646 \text{ bar}$ and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1\text{K}$

Reference

[1]

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

Function Name: **lambda_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION LAMBDAPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

lambda_ptx_air or **LAMBDAPTXAIR** – Thermal conductivity λ in W/(m·K)

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function λ will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **lambda_ptx_air** = **-1000** or **LAMBDAPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$
 Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{l}} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, \text{l}} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

References

[1], [2]

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

Function Name: **nu_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION NUPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

nu_ptx_air or **NUPTXAIR** – Kinematic viscosity $\nu = \frac{\eta}{\rho} = \eta \cdot \nu$ in m²/s

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function ν will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **nu_ptx_air = -1000** or **NUPTXAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$
 Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, l} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, l} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1$ K

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

References

[1], [2]

Pressure on the Melting Curve $p_{\text{mel}} = f(t)$

Function Name: **pmel_t_air**
 Subroutine with function value: **REAL*8 FUNCTION PMELTAIR(T)**
 Variable Types: **REAL*8 T**

Input values

T - Temperature t in °C

Result

pmel_t_air or **PMELTAIR** – Pressure on the melting curve p_{mel} in bar

Range of validity

Temperature range: from $t_t = t_{\text{min}} = -213.4$ °C to $t_{\text{mel}}(20000 \text{ bar}) = -36.9508$ °C

Results for wrong input values

Result **pmel_t_air = -1000** or **PMELTAIR = -1000** for the following input values:

$t > t_{\text{mel}}(20000 \text{ bar}) = -36.9508$ °C or $t < t_{\text{min}} = -213.4$ °C or

Reference

[1]

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

Function Name: **prandtl_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION PRANDTLPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

prandtl_ptx_air or **PRANDTLPTXAIR** – Prandtl-number $Pr = \frac{\nu}{a} = \frac{\eta \cdot c_p}{\lambda}$

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function Pr will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **prandtl_ptx_air = -1000** or **PRANDTLPTXAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$
 Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, l} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, l} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

References

[1], [2]

Pressure on the Saturated Liquid Line $p_{sl} = f(t)$

Function Name: **psl_t_air**
 Subroutine with function value: **REAL*8 FUNCTION PSLTAIR(T)**
 Variable Types: **REAL*8 T**

Input values

T - Temperature t in °C

Result

psl_t_air or **PSLTAIR** – Pressure on the saturated liquid line p_{sl} in bar

Range of validity

Temperature range: from $t_{\min} = -213.4$ °C to $t_{\text{mct}} = -140.5188$ °C

Details on the saturation lines

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2. In order that the function $p_{sv} = f(t)$ will not be double-valued in the critical region, the saturated vapor line ($x = 1$) is partially represented by the function $p_{sl} = f(t)$ calculating pressures on the saturated liquid line ($x = 0$). This concerns the segment between the critical point and the maxcondentherm point.

Results for wrong input values

Result **psl_t_air** = **-1000** or **PSLTAIR** = **-1000** for the following input values:

$t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C

Reference

[1]

Pressure on the Saturated Vapor Line $p_{sv} = f(t)$

Function Name: **psv_t_air**
 Subroutine with function value: **REAL*8 FUNCTION PSVTAIR(T)**
 Variable Types: **REAL*8 T**

Input values

T - Temperature t in °C

Result

psv_t_air or **PSVTAIR** – Pressure on the saturated vapor line p_{sv} in bar

Range of validity

Temperature range: from $t_{\min} = -213.4$ °C to $t_{\text{mct}} = -140.5188$ °C

Details on the saturation lines

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2. In order that the function $p_{sv} = f(t)$ will not be double-valued in the critical region, the saturated vapor line ($x = 1$) is partially represented by the function $p_{sl} = f(t)$ calculating pressures on the saturated liquid line ($x = 0$). This concerns the segment between the critical point and the maxcondentherm point.

Results for wrong input values

Result **psv_t_air** = **−1000** or **PSVTAIR** = **−1000** for the following input values:

$t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C

Reference

[1]

Density $\rho = f(p, t, x)$

Function Name: **rho_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION RHOPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

rho_ptx_air or **RHOPTXAIR** – Density $\rho = \frac{1}{v}$ in kg/m³

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function ρ will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **rho_ptx_air** = **-1000** or **RHOPTXAIR** = **-1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, l} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, l} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, v} = 0.024316$ bar or

at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Specific Entropy $s = f(p, t, x)$

Function Name: **s_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION SPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

s_ptx_air or **SPTXAIR** – Specific entropy s in kJ/kg

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function s will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **s_ptx_air** = **-1000** or **SPTXAIR** = **-1000** for the following input values:

Single phase region:	$p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
($x = -1$)	$t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$
Saturated liquid line:	at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
($x = 0$)	at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{l}} = 0.052646$ bar or
	at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, \text{l}} = 0.052646$ bar and
	$ t - t_{\text{sl}}(p) > 0.1\text{K}$
Saturated vapor line:	at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
($x = 1$)	at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{v}} = 0.024316$ bar or

at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Temperature on the Melting Curve $t_{\text{mel}} = f(p)$

Function Name: **tmel_p_air**
 Subroutine with function value: **REAL*8 FUNCTION TMELPAIR(P)**
 Variable Types: **REAL*8 P**

Input values

P – Pressure p in bar

Result

tmel_p_air or **TMELPAIR** – Temperature on the melting curve t_{mel} in °C

Range of validity

Pressure range: from $p_t = p_{\text{min},l} = 0.052646$ bar to $p_{\text{max}} = 20000$ bar

Results for wrong input values

Result **tmel_t_air** = **–1000** or **TMELPAIR** = **–1000** for the following input values:

$p > p_{\text{max}} = 20000$ bar or $p < p_{\text{min},l} = 0.052646$ bar

Reference

[1]

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

Function Name: **t_ph_air**
 Subroutine with function value: **REAL*8 FUNCTION TPHAIR(P,H)**
 Variable Types: **REAL*8 P,H**

Input values

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

t_ph_air or **TPHAIR** – Temperature t in °C

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. Using the given values for p and h the program determines whether the state point to be calculated is located within the single phase region (liquid or superheated steam) or the wet steam region. After that, the calculation is carried out for the specific region.

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **t_ph_air = -1000** or **TPHAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,l}} = 0.052646$ bar or
 at result $t > t_{\text{mcb}} = -140.5539$ °C or $t < t_{\min} = -213.4$ °C

Saturated vapor line: at $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,v}} = 0.024316$ bar or
 at result $t > t_{\text{mcb}} = -140.5539$ °C or $t < t_{\min} = -213.4$ °C or

Reference

[1]

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

Function Name: **t_ps_air**
 Subroutine with function value: **REAL*8 FUNCTION TPSAIR(P,S)**
 Variable Types: **REAL*8 P,S**

Input values

P - Pressure p in bar
S - Specific entropy s in kJ/(kg·K)

Result

t_ps_air or **TPSAIR** – Temperature t in °C

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. Using the given values for p and s the program determines whether the state point to be calculated is located within the single phase region (liquid or superheated steam) or the wet steam region. After that, the calculation is carried out for the specific region.

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **t_ps_air = -1000** or **TPSAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{mcb}} = 0.052646$ bar or
 at result $t > t_{\text{mcb}} = -140.5539$ °C or $t < t_{\min} = -213.4$ °C

Saturated vapor line: at $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\text{min,v}} = 0.024316$ bar or
 at result $t > t_{\text{mcb}} = -140.5539$ °C or $t < t_{\min} = -213.4$ °C or

Reference

[1]

Temperature on the Saturated Liquid Line $t_{sl} = f(p)$

Function Name: **tsl_p_air**
 Subroutine with function value: **REAL*8 FUNCTION TSLPAIR(P)**
 Variable Types: **REAL*8 P**

Input values

P - Pressure p in bar

Result

tsl_p_air or **TSLPAIR** – Temperature on the saturated liquid line t_{sl} in °C

Range of validity

Pressure range: from $p_{\min,l} = 0.052646$ bar to $p_{\text{mcb}} = 37.9195$ bar

Details on the saturation lines

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2. In order that the function $t_{sv} = f(p)$ will not be double-valued in the critical region, the saturated vapor line ($x = 1$) is partially represented by the function $t_{sl} = f(p)$ calculating temperatures on the saturated liquid line ($x = 0$). This concerns the segment between the critical point and the maxcondenbar point.

Results for wrong input values

Result **tsl_p_air = -1000** or **TSLPAIR = -1000** for the following input values:

$p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min,l} = 0.052646$ bar

Reference

[1]

Temperature on the Saturated Vapor Line $t_{sv} = f(p)$

Function Name: **tsv_p_air**
 Subroutine with function value: **REAL*8 FUNCTION TSVPAIR(P)**
 Variable Types: **REAL*8 P**

Input values

P - Pressure p in bar

Result

tsv_p_air or **TSVPAIR** – Temperature on the saturated vapor line t_{sv} in °C

Range of validity

Pressure range: from $p_{\min,v} = 0.024316$ bar to $p_{mcb} = 37.9195$ bar

Details on the saturation lines

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2. In order that the function $t_{sv} = f(p)$ will not be double-valued in the critical region, the saturated vapor line ($x = 1$) is partially represented by the function $t_{sl} = f(p)$ calculating temperatures on the saturated liquid line ($x = 0$). This concerns the segment between the critical point and the maxcondenbar point.

Results for wrong input values

Result **tsv_p_air** = **−1000** or **TSVPAIR** = **−1000** for the following input values:

$p > p_{mcb} = 37.9195$ bar or $p < p_{\min,v} = 0.024316$ bar

Reference

[1]

Specific Internal Energy $u = f(p, t, x)$

Function Name: **u_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION UPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

u_ptx_air or **UPTXAIR** – Specific internal energy u in kJ/kg

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function u will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **u_ptx_air** = **-1000** or **UPTXAIR** = **-1000** for the following input values:

Single phase region:	$p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
($x = -1$)	$t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$
Saturated liquid line:	at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
($x = 0$)	at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, l} = 0.052646$ bar or
	at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, l} = 0.052646$ bar and
	$ t - t_{\text{sl}}(p) > 0.1$ K
Saturated vapor line:	at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
($x = 1$)	at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, v} = 0.024316$ bar or

at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Specific Volume $v = f(p, t, x)$

Function Name: **v_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION VPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

v_ptx_air or **VPTXAIR** – Specific volume v in m³/kg

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Wet steam region

When calculating wet steam, a value between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function v will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **v_ptx_air = -1000** or **VPTXAIR = -1000** for the following input values:

Single phase region: ($x = -1$)	$p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$
Saturated liquid line: ($x = 0$)	at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{l}} = 0.052646$ bar or at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, \text{l}} = 0.052646$ bar and $ t - t_{\text{sl}}(p) > 0.1\text{K}$
Saturated vapor line: ($x = 1$)	at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{v}} = 0.024316$ bar or

at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

Reference

[1]

Isentropic Speed of Sound $w = f(p, t, x)$

Function Name: **w_ptx_air**
 Subroutine with function value: **REAL*8 FUNCTION WPTXAIR(P,T,X)**
 Variable Types: **REAL*8 P,T,X**

Input values

P - Pressure p in bar
T - Temperature t in °C
X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

w_ptx_air or **WPTXAIR** – Isentropic speed of sound w in m/s

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the vapor fraction x

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single phase region

If the state point to be calculated is located in the single phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

Saturation lines

If the state point to be calculated is located on the saturated liquid line, the value 0 has to be entered for x . When calculating saturated steam (saturated vapor line) $x = 1$ has to be entered. The calculation for x values between 0 and 1 is not possible. It is adequate to enter either the given value for t and $p = -1000$, or the given value for p and $t = -1000$, plus the value for x (0 or 1). When p and t and x are entered as given values, the program will consider whether p and t fit together. If it is not the case the calculation of the function w will result in -1000 .

Boundaries for wet steam region

The boundaries for the wet steam region are illustrated in Figure 1.1 and Figure 1.2.

Results for wrong input values

Result **w_ptx_air = -1000** or **WPTXAIR = -1000** for the following input values:

Single phase region: $p > p_{\max} = 20000$ or $p < p_{\min} = 0.00001$ bar or
 ($x = -1$) $t > t_{\max} = 1726.85$ °C or $t < t_{\min} = -213.4$ °C or $t < t_{\text{mel}}(p)$

Saturated liquid line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188$ °C or $t < t_{\min} = -213.4$ °C or
 ($x = 0$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195$ bar or $p < p_{\min, \text{I}} = 0.052646$ bar or
 at $p < p_{\text{mcb}} = 37.9195$ bar and $p > p_{\min, \text{I}} = 0.052646$ bar and
 $|t - t_{\text{sl}}(p)| > 0.1\text{K}$

Saturated vapor line: at $p = -1$ and $t > t_{\text{mct}} = -140.5188 \text{ °C}$ or $t < t_{\text{min}} = -213.4 \text{ °C}$ or
 ($x = 1$) at $t = -1$ and $p > p_{\text{mcb}} = 37.9195 \text{ bar}$ or $p < p_{\text{min,v}} = 0.024316 \text{ bar}$ or
 at $p < p_{\text{mcb}} = 37.9195 \text{ bar}$ and $p > p_{\text{min,v}} = 0.024316 \text{ bar}$ and
 $|t - t_{\text{sv}}(p)| > 0.1 \text{ K}$

References

[1], [2]

Backward Function: Vapor Fraction $x = f(p, h)$

Function Name: **x_ph_air**
 Subroutine with function value: **REAL*8 FUNCTION XPHAIR(P,H)**
 Variable Types: **REAL*8 P,H**

Input values

P - Pressure p in bar
H - Specific enthalpy h in kJ/kg

Result

x_ph_air or **XPHAIR** – Vapor fraction x in (kg saturated steam)/(kg wet steam)

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. Using the given values of p and h , the program determines whether the state point to be calculated is located within the single phase region (liquid or superheated steam) or the wet steam region. When the given state point is located in the wet steam region, x will be calculated, otherwise the result is set to $x = -1$

Results for wrong input values

Result **x_ph_air = -1** or **XPHAIR = -1** for the following input values:

$$p > p_{\text{mcb}} = 37.9195 \text{ bar or } p < p_{\text{min,v}} = 0.024316 \text{ bar}$$

Reference:

[1]

Backward Function: Vapor Fraction $x = f(p,s)$

Function Name: **x_ps_air**
 Subroutine with function value: **REAL*8 FUNCTION XPSAIR(P,S)**
 Variable Types: **REAL*8 P,S**

Input values

P - Pressure p in bar
S - Specific entropy s in kJ/(kg·K)

Result

x_ps_air or **XPSAIR** – Vapor fraction x in (kg saturated steam)/(kg wet steam)

Range of validity

Temperature range: from -213.4 °C (59.75 K) to 1726.85 °C (2000 K)
 Pressure range: from 0.00001 bar to 20000 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. Using the given values of p and s , the program determines whether the state point to be calculated is located within the single phase region (liquid or superheated steam) or the wet steam region. When the given state point is located in the wet steam region, x will be calculated, otherwise the result is set to $x = -1$

Results for wrong input values

Result **x_ps_air = -1** or **XPSAIR = -1** for the following input values:

$$p > p_{\text{mcb}} = 37.9195 \text{ bar or } p < p_{\text{min,v}} = 0.024316 \text{ bar}$$

Reference:

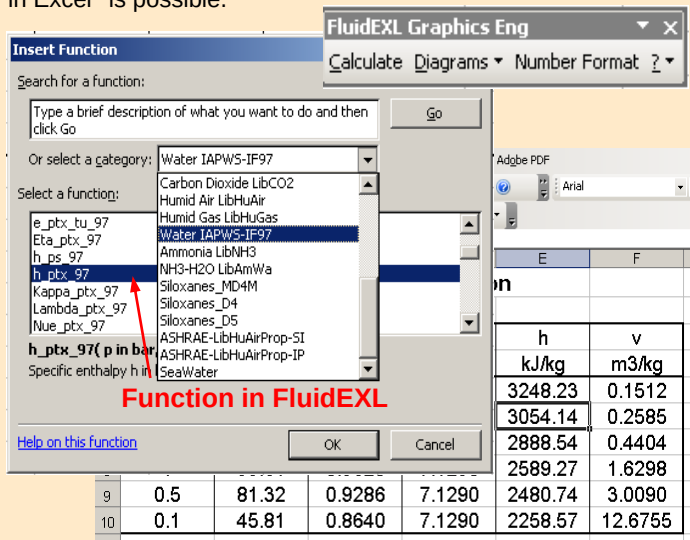
[1]

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

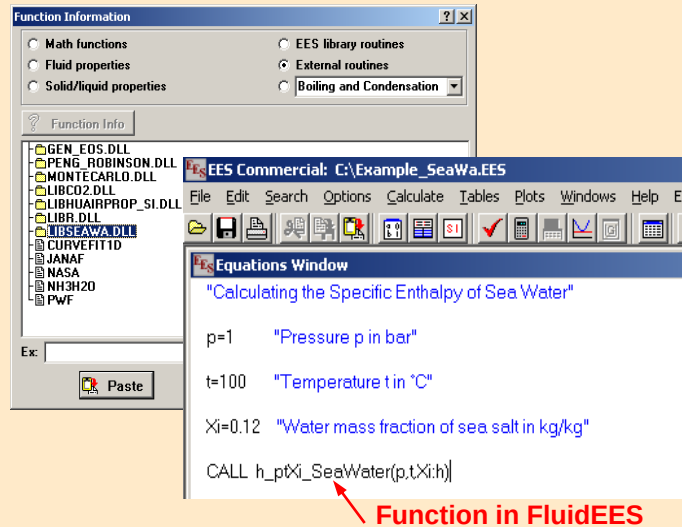
Carbon Dioxide	Ideal Gas Mixtures	Seawater
Library LibCO2 Formulation of Span and Wagner (1994)	Library LibIdGasMix Ideal mixture of the ideal gases: Ar SO₂ Methane Ne H₂ Ethane N₂ H₂S Ethylene O₂ OH Propylene CO He Propane CO₂ F₂ Iso-Butane Air NH₃ n-Butane NO Benzene H₂O Methanol Consideration of -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

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.

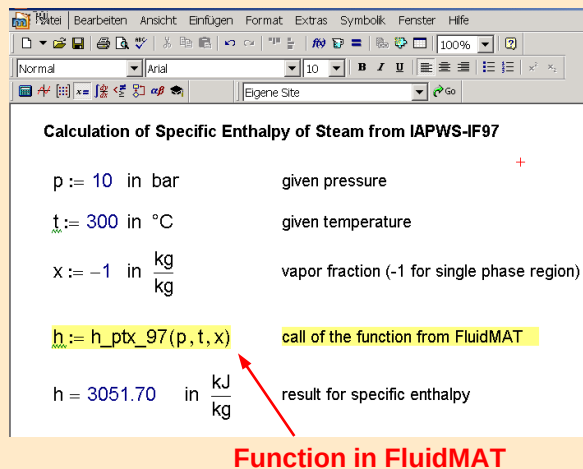


The Add-In FluidEES allows to call the functions of the property libraries within the Engineering Equation Solver EES®.



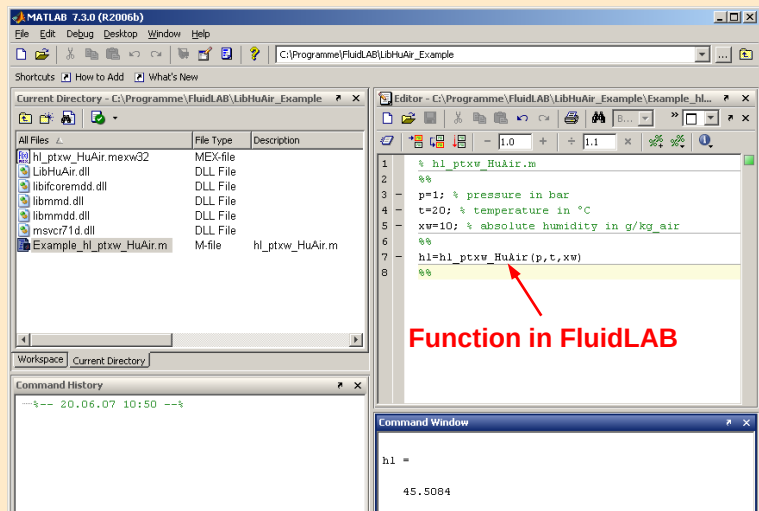
Add-In FluidMAT for Mathcad®

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

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

For information please contact:

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Internet: www.thermodynamics-zittau.de
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Fax.: +49-3583-61-1846

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

5. References

- [1] Lemmon, E. W.; Jacobsen, R. T.; Friend D. G.: *Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen From 60 to 2000 K at Pressures to 2000 MPa*. Journal of Physical and Chemical Reference Data, Volume 29, No. 3, 2000.
- [2] Lemmon, E. W.; Jacobsen, R. T.: *Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air*. International Journal of Thermophysics, Volume 25, No. 1, 2004.

6. Satisfied Customers

Date: 10/2011

The following companies and institutions use the property libraries

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

2011

Lopez, Munguia, Spain	10/2011
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
Voith, Zschopau	07/2011
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
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Technical University of Dresden	01/2011, 05/2011, 06/2011, 08/2011

2010

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YIT Austria, Vienna, Austria	12/2010
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University of Stuttgart	12/2010
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University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

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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
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Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
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TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
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energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
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Paper Factory, Utzenstorf, Switzerland	01/2003
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STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003

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

2002

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

Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	08/2002
Stadtwerke Duisburg	08/2002
Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
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ALSTOM Power, Baden, Switzerland	01/2001, 06/2001, 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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SOFBID, Zwingenberg (general EBSILON program license)	01/2000
AG KKK - PGW Turbo, Leipzig	01/2000

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

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

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998

VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998
SCA Hygiene Products, Munich	10/1998
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Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

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