Property Library for R134a

FluidPRIME with LibR134a for Mathcad Prime®

Prof. Hans-Joachim Kretzschmar
Matthias Kunick
S. Herrmann
M. Sünder

Property Library for the Calculation of the Properties of R134a

LibR134a

FluidPRIME for Mathcad Prime®

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© KCE-ThermoFluidProperties UG & Co. KG
Prof. Dr. Hans-Joachim Kretzschmar
Wallotstr. 3, 01307 Dresden, Germany
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-4262250
Email: info@thermofluidprop.com
Internet: www.thermofluidprop.com

0. Package Contents

Zip file "CD_FluidPRIME_LibR134a.zip" includes the following files:

FluidPRIME_LibR134a_Docu.pdf	- User's Guide
Functions_LibR134a.mcdx	- Mathcad Prime® worksheet with all functions
LibR134a.msi	- MSI installer
setup.exe	- Setup installer
LibR134a.dll	- DLL with functions of the LibR134a library

1. Property Functions

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibR134a as parameter	Property or Function	Unit of the result
$a = f(p,t,x)$	a_ptx_R134a	A_PTX_R134A(P,T,X)	C_A_PTX_R134A(A,P,T,X)	Thermal diffusivity	m^2/s
$c_p = f(p,t,x)$	cp_ptx_R134a	CP_PTX_R134A(P,T,X)	C_CP_PTX_R134A(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_R134a	CV_PTX_R134A(P,T,X)	C_CV_PTX_R134A(CV,P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\eta = f(p,t,x)$	eta_ptx_R134a	ETA_PTX_R134A(P,T,X)	C_ETA_PTX_R134A(ETA,P,T,X)	Dynamic viscosity	Pa s
$h = f(p,t,x)$	h_ptx_R134a	H_PTX_R134A(P,T,X)	C_H_PTX_R134A(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_R134a	KAP_PTX_R134A(P,T,X)	C_KAP_PTX_R134A(KAP,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lambda_ptx_R134a	LAM_PTX_R134A(P,T,X)	C_LAM_PTX_R134A(LAM,P,T,X)	Thermal conductivity	W/m K
$\nu = f(p,t,x)$	ny_ptx_R134a	NY_PTX_R134A(P,T,X)	C_NY_PTX_R134A(NY,P,T,X)	Kinematic viscosity	m^2/s
$p_s = f(t)$	ps_t_R134a	PS_T_R134A(T)	C_PS_T_R134A(PS,T)	Vapor pressure from temperature	Bar
$Pr = f(p,t,x)$	Pr_ptx_R134a	PR_PTX_R134A(P,T,X)	C_PR_PTX_R134A(PR,P,T,X)	*Prandtl*-Number	-
$\rho = f(p,t,x)$	rho_ptx_R134a	RHO_PTX_R134A(P,T,X)	C_RHO_PTX_R134A(RHO,P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_R134a	S_PTX_R134A(P,T,X)	C_S_PTX_R134A(S,P,T,X)	Specific entropy	kJ/(kg K)
$\sigma = f(t)$	sigma_t_R134a	SIGMA_T_R134A(T)	C_SIGMA_T_R134A(SIGMA,T)	Surface tension	N/m
$t = f(p,h)$	t_ph_R134a	T_PH_R134A(P,H)	C_T_PH_R134A(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_R134a	T_PS_R134A(P,S)	C_T_PS_R134A(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_R134a	TS_P_R134A(P)	C_TS_P_R134A(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_R134a	U_PTX_R134A(P,T,X)	C_U_PTX_R134A(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_R134a	V_PTX_R134A(P,T,X)	C_V_PTX_R134A(V,P,T,X)	Specific volume	m^3/kg
$w = f(p,t,x)$	w_ptx_R134a	W_PTX_R134A(P,T,X)	C_W_PTX_R134A(W,P,T,X)	Isentropic speed of sound	m/s^2
$x = f(p,h)$	x_ph_R134a	X_PH_R134A(P,H)	C_X_PH_R134A(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	x_ps_R134a	X_PS_R134A(P,S)	C_X_PS_R134A(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg

Units: t in °C
p in bar
x in (kg of saturated steam)/(kg wet steam)

Range of validity

Temperature range: from $t(p, \rho_{max})$ to 181.85 °C

Pressure range: from p_t = 0.000389564 bar to 700 bar

Reference state

h = 200 kJ/kg and s = 1 kJ/(kg K) at t = 0 °C on the saturated liquid line (x = 0)

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.

Wet-steam region

If the state point to be calculated is located in the wet steam region, a value for x 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. When calculating wet steam either the given value for t and p = -1000 or the given value for p and t = -1000 and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in –1000.

Wet steam region: Temperature ranges from t_t = –103.30 °C to t_c = 101.03 °C

Pressure ranges from p_t = 0. 000389564 bar to p_c = 40.566 bar

Hint:

If the calculation results in –1000, the values entered represent a state point beyond the range of validity of LibR134a. For further information on each function and its range of validity see Chapter 3. The same information may also be accessed via the online help pages.

2 Application of FluidPRIME in Mathcad Prime®

FluidPRIME has been developed to calculate thermodynamic properties in Mathcad Prime® more conveniently. Within Mathcad Prime, it enables the direct call of functions relating to humid air from the LibR134a property library.

2.1 Installing FluidPRIME

In this section, the installation of FluidPRIME LibR134a is described.
After you have downloaded and extracted the zip-file "CD_FluidPRIME_LibR134a.zip", you will see the folder

CD_FluidPRIME_LibR134a

in your Windows Explorer, Norton Commander etc.

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

Within this folder you will see the following files and a folders:

FluidPRIME_LibR134a_Docu.pdf
Functions_LibR134a.mcdx
LibR134a.msi
setup.exe
LibR134a.dll

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

setup.exe.

Note: If you get an error message during the installation, please try the LibR134a.msi instead of the setup.exe for the installation. The steps trough the install assistent are similiary on both the .exe and the .msi file.

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

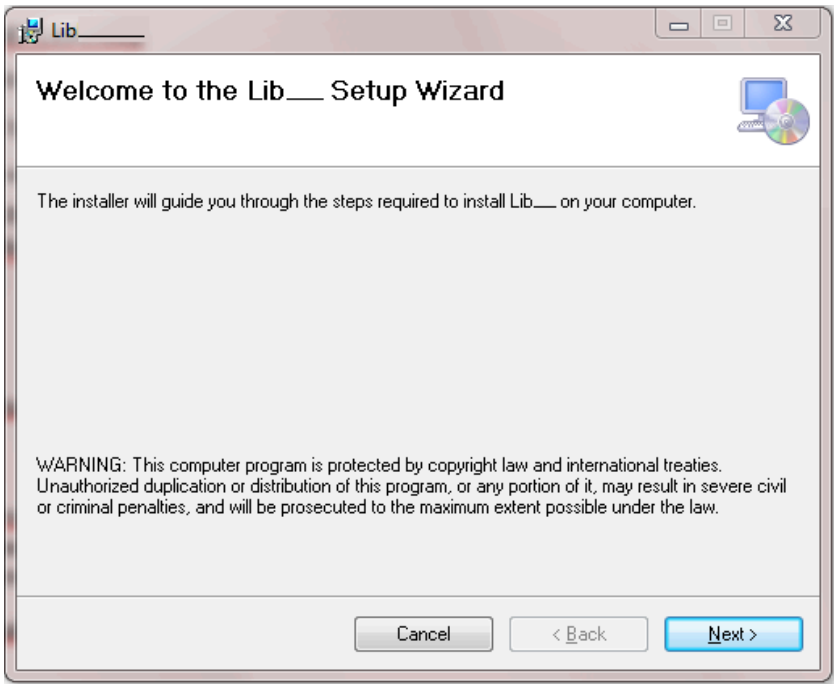


Figure 2.1: Setup Wizard

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

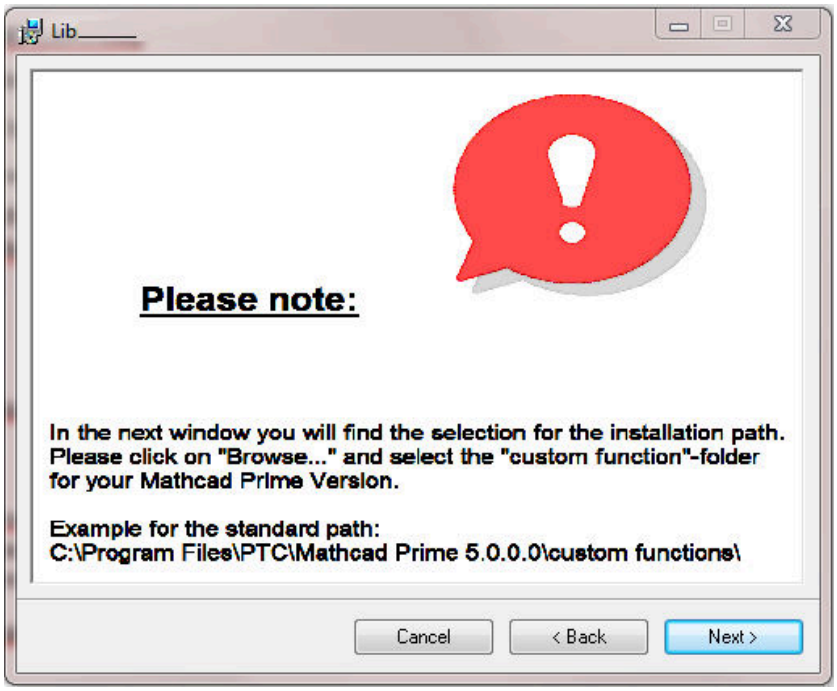


Figure 2.2: Note Window

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

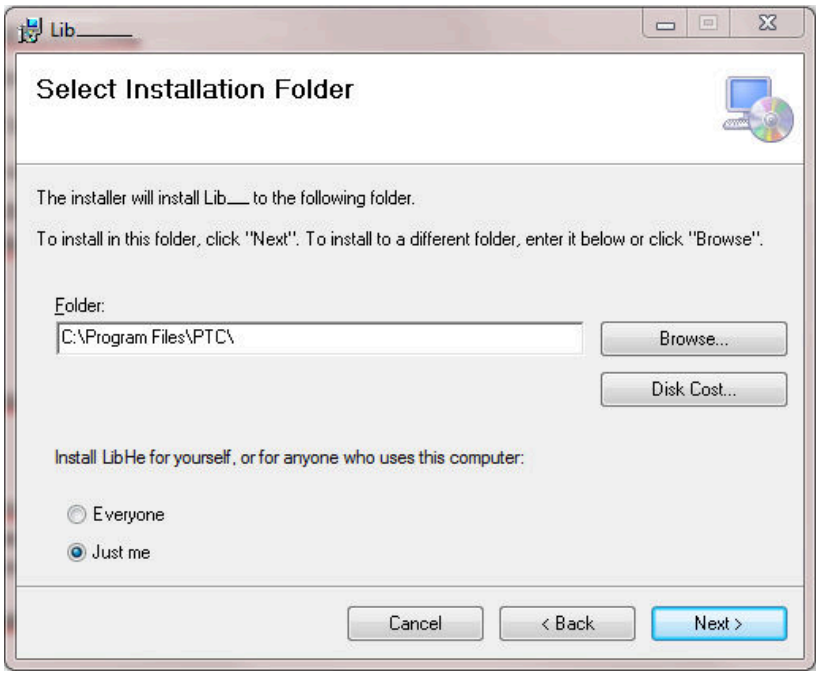


Figure 2.3: Select Installation Folder

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

You will get the standard path:

C:\Program Files\PTC\

Now select your Mathcad Prime® version folder. For example

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

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

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

that you can also see in Figure 2.4.

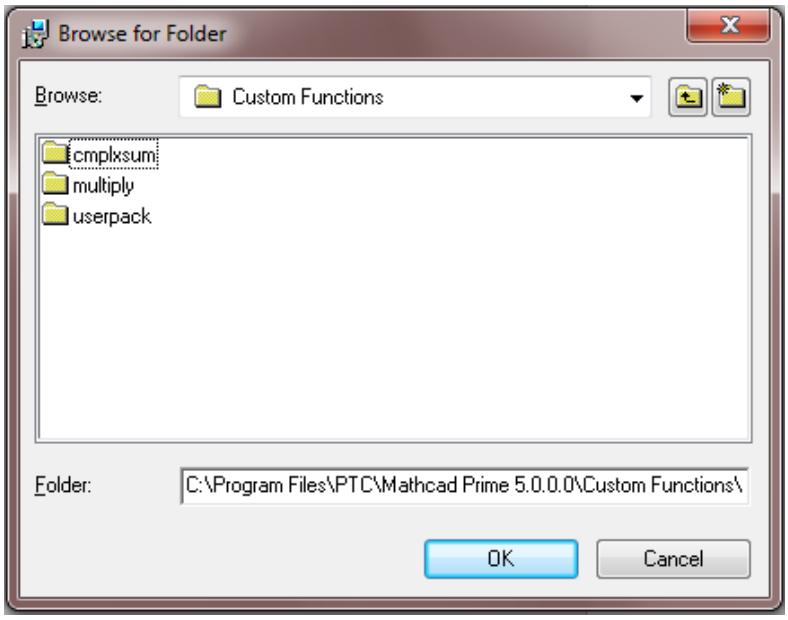


Figure 2.4: "Browse for Folder"-window with the full installation path

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

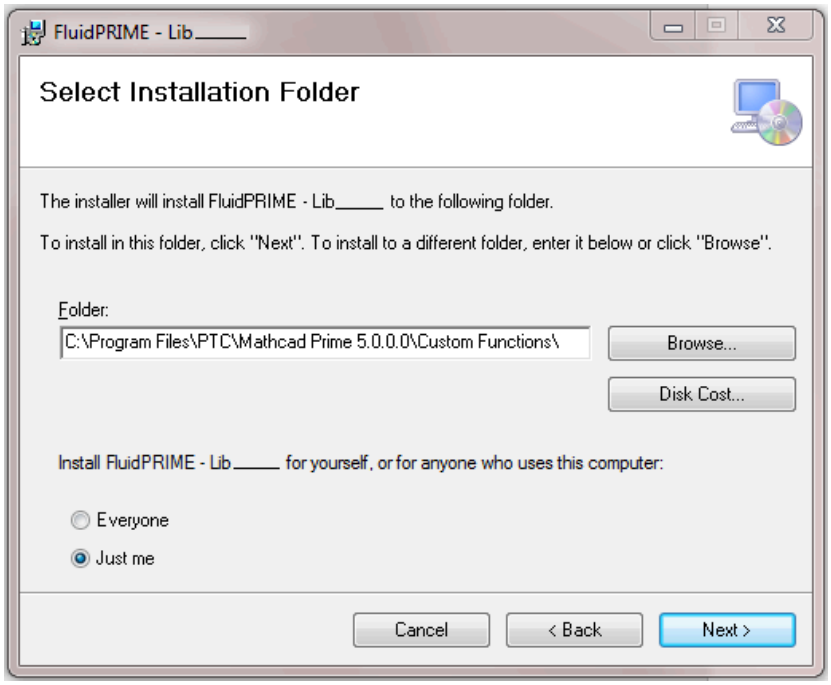


Figure 2.5: "Select Installation Folder"-window

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

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

The installation of FluidPRIME with the library LibR134a is finished.

Finally, please copy or overwrite the LibR134a.dll-file in the installation folder that is described before, with the file in the zip-file.

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

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

LC.dll	LibR134a.dll	PRIME_LibR134a.dll
libifcoremd.dll	libiomp5.dll	libmmd.dll.

Note:

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

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

2.2 Licensing the LibR134a Property Library

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

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

Now we will calculate, step by step, the specific enthalpy *h* as a function of pressure *p*, temperature *t* and vapor fraction *x* for water and steam from the Industrial Formulation IAPWS-R134a, using FluidPRIME.

- Start Mathcad Prime.
- Type "p:" and enter the value for the pressure *p* in bar.
  (Range of validity: p = 0.00389564 bar ... 700 bar)

  e. g.: Enter "p:10" for the first operand
- Type "t:" and enter the value for the temperature *t* in °C.
  (Range of validity: t = –103.30 °C ... 181.85 °C)

  e. g.: Enter "t:25" for the second operand
- Type "x:" and enter the value for the vapor fraction *x* in $kg_{sat.\ steam}$ / $kg_{wet\ steam.}$
  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

  If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

  When calculating wet steam either the given value for *t* and p = -1 or the given value for *p* and t = -1 and in both cases the value for *x* between 0 and 1 must be entered.

  If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1.

  (Vapor pressure curve of R134a: $t(p, \rho_{max} = 1550\ kg/m^3)$ ... t_c = 101.03 °C
  p_t = 0.00389564 bar ... p_c = 40.566 bar)

  e. g.: Enter "x:-1" for the third operand
- Confirm your entry by pressing the "ENTER" key.
- Your Mathcad Prime calculation window should look like Figure 2.3:

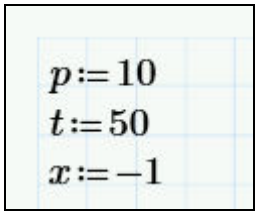


Figure 2.3: Example Mathcad Prime® sheet after input of the given parameters

- Now, type open the file Functions_LibR134a.mcdx. In this Mathcad Prime® worksheet you can find all the functions of the library
- Search the function h_ptx_R134a(, ,) and mark it by drag a selection rectangle around it.
- Copy the marked function and paste it into your example worksheet
- Click it the function and type "h:" in front of it.
- Your Mathcad Prime calculation window should look like Figure 2.4:

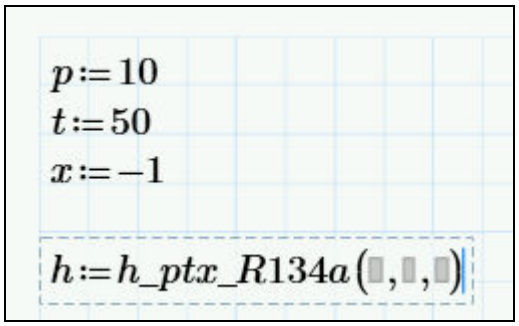


Figure 2.4: Example Mathcad Prime® sheet

- Now click in the first operand in the brackets of the function. . You can now enter the value for *p* either by entering the value directly or by entering the name of the variable where the value was saved.

  ⇒ e.g.: Enter "p".
- Situate the cursor on the next placeholder and set all the variables we set above.
- Close the input formula by pressing the "Enter"-Key.
- You can now go on working with the variable *h* which we have just calculated.
- If you wish to see the result, you have to type the following command on the next line in the Mathcad Prime window:
  "h =".

  You will now see the result h=430.884. The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

In the next figure you can see the calculated value.

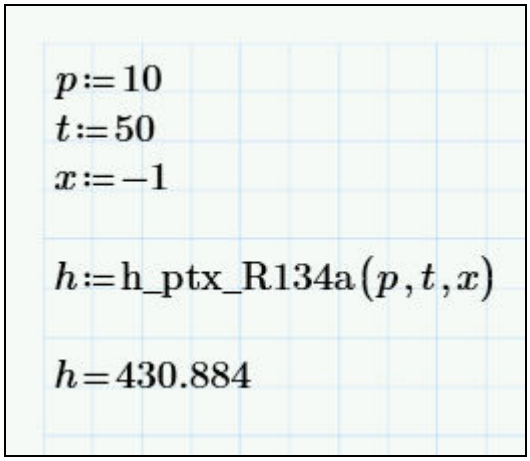


Figure 2.5: Example Mathcad Prime® sheet with finished calculation

2.4 Removing FluidPRIME

To remove FluidPRIME with the library LibR134a from your hard drive, carry out the following steps:

- Click "Start" in the lower task bar of your desktop, then "Settings" and then "Control Panel".
- Now, double click on "Add or Remove Programs".
- In the list box of the "Add or Remove Programs" window that appears select "FluidPRIME - LibR134a" by clicking on it and click the "Add/Remove…" button.
- In the following dialog box click "Yes" and wait until the windows is closing.
- Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidPRIME with the library LibR134a has been removed.

3. Program Documentation

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

Function Name: **a_ptx_R134a**

Subroutine with function value: **REAL*8 FUNCTION A_PTX_R134A(P,T,X)**
for call from Fortran: REAL*8 P,T,X

Subroutine with parameter: **INTEGER*4 FUNCTION C_A_PTX_R134A(A,P,T,X)**
for call from DLL: REAL*8 A,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

A_PTX_R134A, A or **a_ptx_R134a** – Thermal diffusivity $a = \frac{\lambda * v}{c_p}$ in m² / s

Range of validity

Temperature range: from - 73.15 °C to 176.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Density range: from 0.00105455 kg /m^3 to 1550 kg / m^3

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Saturated liquid and saturated vapor line :

Temperature range	from $t = -73.15$ °C to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **A_PTX_R134A, A = -1000** or **a_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < -103.3$ °C or $\rho > 1550$ m^3 / kg
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < 73.15$°C
	at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$bar or
	at $p > 40.566$ bar or $p < 0.00389564$ bar and
	$t > 101.03$ °C or $t < -103.3$ °C

References: [16], [23]

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

Function Name:	**cp_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION CP_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_CP_PTX_R134A(CP,P,T,X)** REAL*8 CP,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

CP_PTX_R134A, **CP** or **cp_ptx_R134a** – Specific isobaric heat capacity c_p in $kJ/(kg\,K)$

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to $t_c =$ 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **CP_PTX_R134A, CP = -1000**, or **cp_ptx_R134a = -1000** for input values:

Single phase region: $(x = -1)$	p > 700 bar or p < 0.00389564bar or $t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ kg/m^3$
Saturation lines:	at p = -1000 and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**cv_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION CV_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_CV_PTX_R134A(CV,P,T,X)** REAL*8 CV,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

CV_PTX_R134A, **CV** or **cv_ptx_R134a** – Specific isochoric heat capacity c_v in $kJ/(kg\,K)$

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **CV_PTX_R134A, CV = -1000** or **cv_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$
	at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and
	$t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**eta_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION ETA_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_ETA_PTX_R134A(ETA,P,T,X)** REAL*8 ETA,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

ETA_PTX_R134A, **ETA** or **eta_ptx_R134a** – Dynamic viscosity η in Pa s

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **ETA_PTX_R134A, ETA = -1000** or **eta_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at $p = -1000$ and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$
	at $t = -1000$ and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and
	$t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16], [22]

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

Function Name:	**h_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION H_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_H_PTX_R134A(H,P,T,X)** REAL*8 H,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

H_PTX_R134A, **H** or **h_ptx_R134a** - Specific enthalpy *h* in kJ/kg

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 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:

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.

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **H_PTX_R134A, H = -1000** or **eta_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$
	at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and
	$t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**kappa_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION KAP_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_KAP_PTX_R134A(KAP,P,T,X)** REAL*8 KAP,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

KAP_PTX_R134A, **KAP** or **kappa_ptx_R134a** – Isentropic exponent $\kappa = \frac{w^2}{p^* v}$

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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 (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **KAP_PTX_R134A**, **KAP = -1000** or **kappa_ptx_R134a = -1000** for input values:

Single phase region: $(x = -1)$	p > 700 bar or p < 0.00389564 bar or $t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**lambda_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION LAM_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_LAM_PTX_R134A(LAM,P,T,X)** REAL*8 LAM,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

LAM_PTX_R134A, **LAM** or **lambda_ptx_R134a** – Thermal conductivity λ in W / m K

Range of validity

Temperature range:	from - 73.15 °C to 176.85 °C
Pressure range:	from 0.00389564 bar to 700 bar
Density range:	from 0.00105455 kg /m^3 to 1550 kg / m^3

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t = -103.30$ °C to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **LAM_PTX_R134A, LAM = - 1000** or **lambda_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < -103.3$ °C or $\rho > 1550$ m^3 / kg
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < 73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < -103.30$ °C

References: [16], [23]

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

Function Name:	**ny_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION NY_PTX_ R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_NY _PTX_ R134A(NY,P,T,X)** REAL*8 NY,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

NY _PTX _ R134A, **NY** or **ny _ptx _ R134a** – Kinematic viscosity $\nu = \eta * v$ in m² / s

Range of validity

Temperature range:	from - 73.15 °C to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar
Density range:	from 0.00105455 m^3 / kg to 1550 m^3 / kg

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t = -103.30$ °C to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **NY_PTX_ R134A, NY= -1000** or **ny_ptx_ R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < -103.3$ °C or $\rho > 1550$ m^3 / kg
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < 73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < -103.30$ °C

References: [16], [22]

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

Function Name:	**Pr_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION PR_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_PR _PTX_R134A(PR,P,T,X)** REAL*8 PR,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

PR_PTX_R134A, **PR** or **Pr_ptx_R134a** – Prandtl-Number $\mathrm{Pr} = \frac{\eta * c_p}{\lambda}$

Range of validity

Temperature range:	from - 73.15 °C to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar
Density range:	from 0.00105455 m^3 / kg to 1550 m^3 / kg

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from t = – 103.30 °C to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **PR_PTX_ R134A, PR= -1000** or **Pr_ptx_ R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564 bar or
$(x = -1)$	t > 181.85°C or t < –103.3 °C or ρ > 1550 m^3 / kg
Saturation lines:	at p = -1000 and t > 101.03 °C or t < -73.15°C at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or t < -103.30 °C

References: [16], [22], [23]

Vapor Pressure $p_s = f(t)$

Function Name:	**ps_t_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION PS_T_ R134A(T)** REAL*8 T
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_PS_T_ R134A(PS,T)** REAL*8 PS,T

Input Values:

T - Temperature *t* in °C

Result

PS_T_ R134A, **PS** or **ps_t_ R134a** – Vapor pressure p_S in bar

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 101.03 °C

Results for wrong input values

Result **PS_T_ R134A, PS = -1000** or **ps_t_ R134a = -1000** for input values:

t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**rho_ptx_ R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION RHO_PTX_ R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_RHO_PTX_ R134A(RHO,P,T,X)** REAL*8 RHO,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

RHO_PTX_R134A, **RHO** or **rho_ptx_R134a** – Density ρ in kg / m^3

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 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:

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.

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve.If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **RHO_PTX_R134a, RHO= -1000** or **rho_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < -73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

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

Function Name:	**s_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION S_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_S_PTX_R134A(S,P,T,X)** REAL*8 S,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

S_PTX_R134A, **S** or **s_ptx_R134a** - Specific entropy *s* in kJ/kg K

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 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:

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.

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve.

If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **S_PTX_R134A, S = -1000** or **s_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < -73.15$ °C or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at p = -1000 and $t > 101.03$ °C or $t < -73.15$°C at t = -1000 and $p > 40.566$ bar or $p < 0.00389564$ bar or at $p > 40.566$ bar or $p < 0.00389564$ bar and $t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

Surface Tension $\sigma = f(t)$

Function Name:	**sigma_t_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION SIGMA_T_R134A(T)** REAL*8 T
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_SIGMA_T_R134A(SIGMA,T)** REAL*8 SIGMA,T

Input Values:

T - Temperature *t* in °C

Result

SIGMA_T_R134A, **SIGMA** or **sigma_t_R134a** – Surface tension σ in N/m

Range of validity

Temperature range: from - 103.30 °C to 181.85 °C

Results for wrong input values

Result **SIGMA_T_R134A, SIGMA= -1000** or **sigma_t_R134a = -1000** for input values:

References: [16], [22]

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

Function Name:	**t_ph_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION T_PH_R134A(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_T _PH_R134A(T,P,H)** REAL*8 T,P,H

Input Values:

P - Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

T_PH_R134A, **T** or **t_ph_R134a** - Temperature t in °C

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **T_PH_R134A**, **T = -1000** or **t_ph_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at $p > 70.54$ bar or $p < 0.00389564$ bar or
	$t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

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

Function Name:	**t_ps_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION T_PS_R134A(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_T_PS_R134A(T,P,S)** REAL*8 T,P,S

Input Values:

P - Pressure *p* in bar

S - Specific entropy *s* in kJ/(kg K)

Result

T_PS_R134A, **T** or **t_ps_R134a** - Temperature *t* in °C

Range of validity

Temperature range: from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of *p* and *s* the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of *t* in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **T_PS_R134A**, **T = -1000** or **t_ps_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ or $\rho > 1550\ \text{m}^3/\text{kg}$
Saturation lines:	at $p > 70.54$ bar or $p < 0.00389564$ bar or
	$t > 101.03$ °C or $t < t(p, \rho_{max} = 1550\ \text{kg/m}^3)$

References: [16]

Saturation Temperature $t_s = f(p)$

Function Name:	**ts_p_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION TS_P_R134A(P)** REAL*8 P
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_TS_P_R134A(TS,P)** REAL*8 TS,P

Input Values:

P - Pressure *p* in bar

Result

TS_P_R134A, **TS** or **ts_p_R134a** – Saturation temperature t_s in °C

Range of validity

Pressure range: from 0.00389564 bar to 40.566 bar

Results for wrong input values

Result **TS_P_R134A**, **TS = -1000** or **ts_p_R134a = -1000** for input values:

$p < 0.00389564$ bar or $p > 40.566$ bar

References: [16]

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

Function Name:	**u_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION U_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_U_PTX_R134A(U,P,T,X)** REAL*8 U,P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

U_PTX_R134A, **U** or **u_ptx_R134a** - Specific internal energy *u* in kJ/kg

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 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:

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.

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to $t_c = 101.03$ °C
Pressure range	from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **U_PTX_R134A, U = -1000** or **u_ptx_R134a = -1000** for input values:

Single phase region:	$p > 700$ bar or $p < 0.00389564$ bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at *p* = -1000 and *t* > 101.03 °C or *t* < -73.15°C at *t* = -1000 and *p* > 40.566 bar or *p* < 0.00389564 bar or at *p* > 40.566 bar or *p* < 0.00389564 bar and *t* > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**v_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION V_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_V_PTX_R134A(V,P,T,X)** REAL*8 V,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

V_PTX_R134A, **V** or **v_ptx_R134a** – Specific volume v in m^3 / kg

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 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:

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.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

When calculating wet steam either the given value for t and p = -1000 or the given value for p and t = -1000 and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in -1000.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **V_PTX_R134A, V = -1000** or **v_ptx_R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564 bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and t > 101.03 °C or t < -73.15°C at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**w_ptx_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION W_PTX_R134A(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_W_PTX_R134A(W,P,T,X)** REAL*8 W,P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

W_PTX_R134A, **W** or **w_ptx_R134a** - Speed of sound w in m/s

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated 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:

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.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, 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 (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and saturated vapor line :

Temperature range	from $t(p, \rho_{max} = 1550\ kg/m^3)$ to t_c = 101.03 °C
Pressure range	from p_t = 0.00389564 bar to p_c = 40.566 bar

Results for wrong input values

Result **W_PTX_R134A, W = -1000** or **w_ptx_R134a = -1000** for input values:

Single phase region:	p > 700 bar or p < 0.00389564 bar or
$(x = -1)$	$t > 181.85$°C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$ or $\rho > 1550\ m^3/kg$
Saturation lines:	at p = -1000 and t > 101.03 °C or t < -73.15°C at t = -1000 and p > 40.566 bar or p < 0.00389564 bar or at p > 40.566 bar or p < 0.00389564 bar and t > 101.03 °C or $t < t(p, \rho_{max} = 1550\ kg/m^3)$

References: [16]

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

Function Name:	**x_ph_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION X_PH_R134A(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_X_PH_R134A(T,P,H)** REAL*8 X,P,H

Input Values:

P - Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

X_PH_R134A, **X** or **x_ph_R134a** - Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 181.85 °C
Pressure range:	from 0.00389564 bar to 700 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of *v* and *u* the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result x = - 1 will be returned.

Wet steam region: Pressure ranges from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **X_PH_R134A**, **X = -1** or **x_ph_R134a = -1** for input values:

In case the state point is located in the single phase region

$p < 40.566$ bar or $p > 0.00389564$ bar

References: [16]

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

Function Name:	**x_ps_R134a**
Subroutine with function value: for call from Fortran:	**REAL*8 FUNCTION X_PS_R134A(P,S)** REAL*8 P,S
Subroutine with parameter: for call from DLL:	**INTEGER*4 FUNCTION C_X_PS_R134A(X,P,S)** REAL*8 X,P,S

Input Values:

P - Pressure *p* in bar

S - Specific entropy *s* in kJ/(kg K)

Result

X_PS_R134A, **X** or **x_ps_R134a** - Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range:	from $t(p, \rho_{max} = 1550\ \text{kg/m}^3)$ to 101.03 °C
Pressure range:	from 0.00389564 bar to 700 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of *p* and *s* the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result x = - 1 will be returned.

Wet steam region: Pressure ranges from $p_t = 0.00389564$ bar to $p_c = 40.566$ bar

Results for wrong input values

Result **X_PS_R134A**, **X = -1** or **x_ps_R134a = -1** for input values:

In case the state point is located in the single phase region

$p < 40.566$ bar or $p > 0.00389564$ bar

References: [16]

KCE ThermoFluidProperties

KCE-ThermoFluidProperties
www.thermofluidprop.com

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

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

Water and Steam

Library LibIF97

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

Library LibIF97_META

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

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

CO_2 - Span, Wagner H_2O - IAPWS-95
O_2 - Schmidt, Wagner N_2 - Span et al.
Ar - Tegeler et al.

and of the ideal gases:

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

Consideration of:

- Dissociation from VDI 4670
- Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

Extremely Fast Property Calculations

Spline-Based Table Look-up Method (SBTL)

Library LibSBTL_IF97
Library LibSBTL_95
Library LibSBTL_HuAir

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

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

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

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

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

Consideration of:

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

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bücker and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term

(also useable for calculating the Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol

Library LibC2H5OH

Formulation of
Schroeder et al. (2014)

Methanol

Library LibCH3OH

Formulation of
de Reuck and Craven (1993)

Propane

Library LibPropane

Formulation of
Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

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

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

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

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Nitrogen and Oxygen

**Libraries
LibN2 and LibO2**

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

Hydrogen

Library LibH2

Formulation of
Leachman et al. (2009)

Helium

Library LibHe

Formulation of
Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_Iso**

Neopentane C_5H_{12} **Library LibC5H12_Neo**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**

Carbonyl sulfide **COS** **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Nitrous oxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

KCE
ThermoFluidProperties

For more information please contact:

KCE-ThermoFluidProperties UG & Co. KG
Prof. Dr. Hans-Joachim Kretzschmar
Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

The following thermodynamic and transport properties can be calculated[a]:

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

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

www.thermofluidprop.com

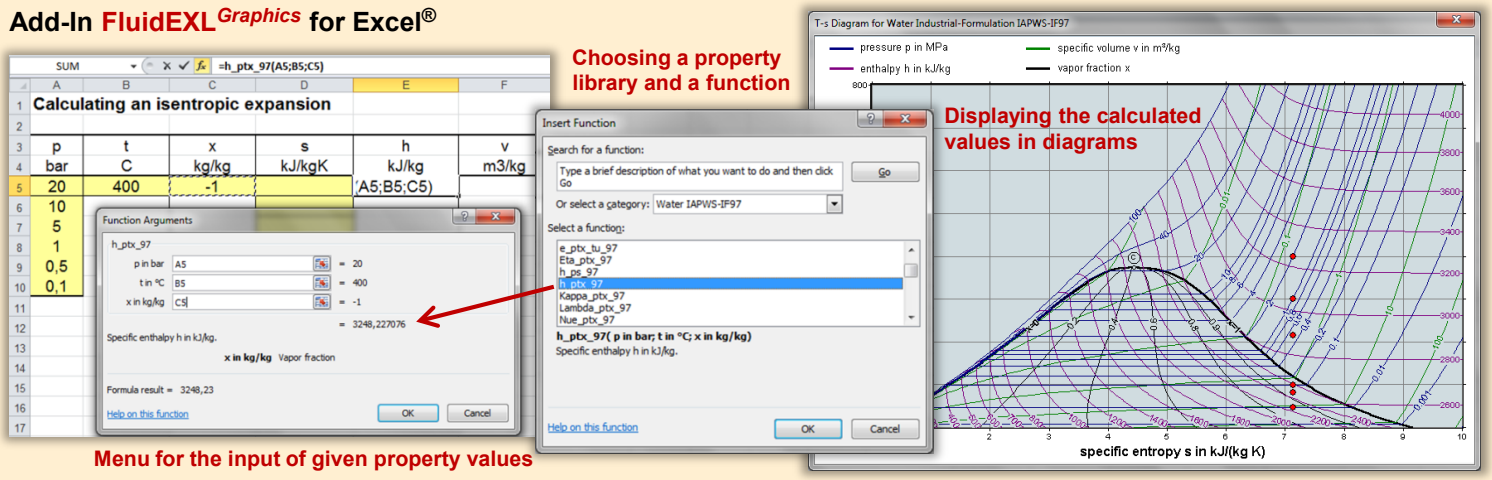
KCE-ThermoFluidProperties
www.thermofluidprop.com

KCE ThermoFluidProperties

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

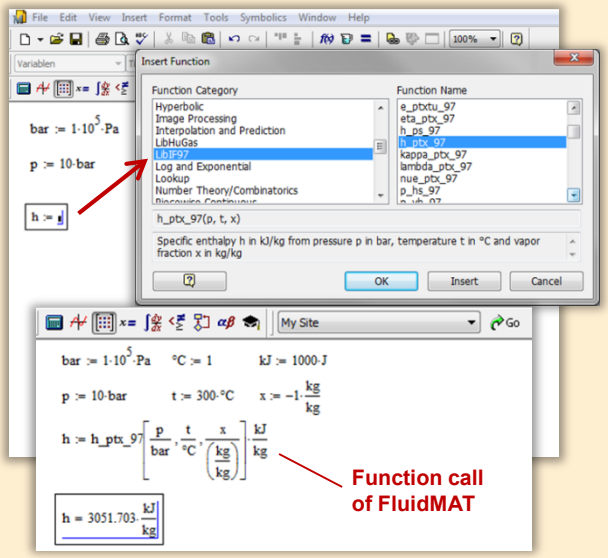
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



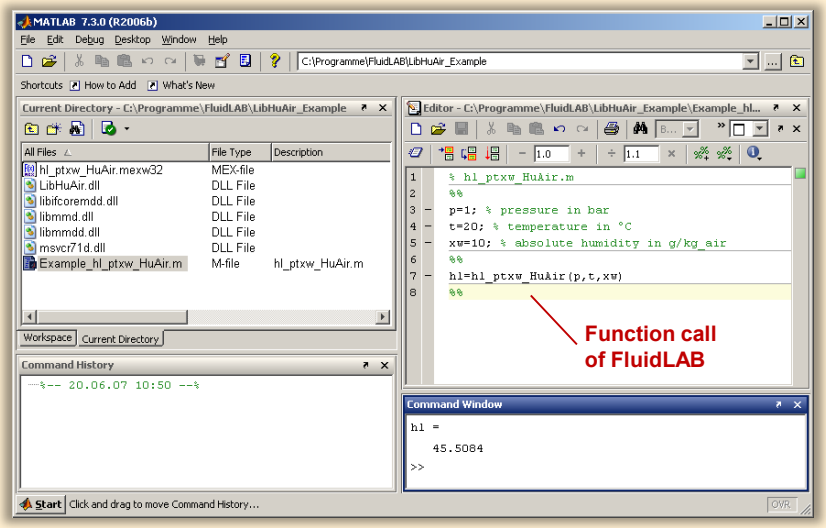
Add-On FluidMAT for Mathcad®
Add-On FluidPRIME for Mathcad Prime®

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



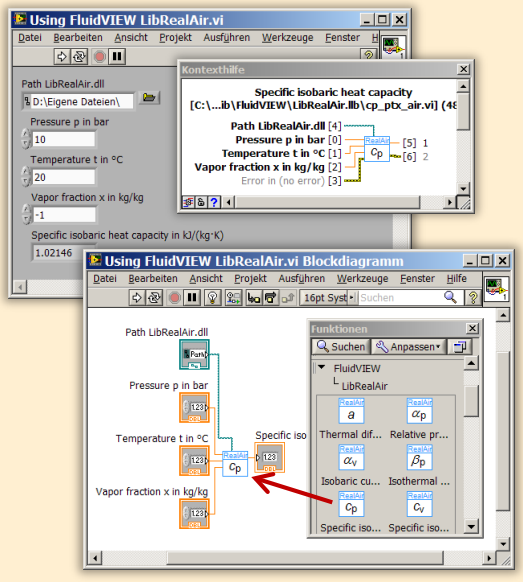
Add-On FluidLAB for MATLAB® and SIMULINK®

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



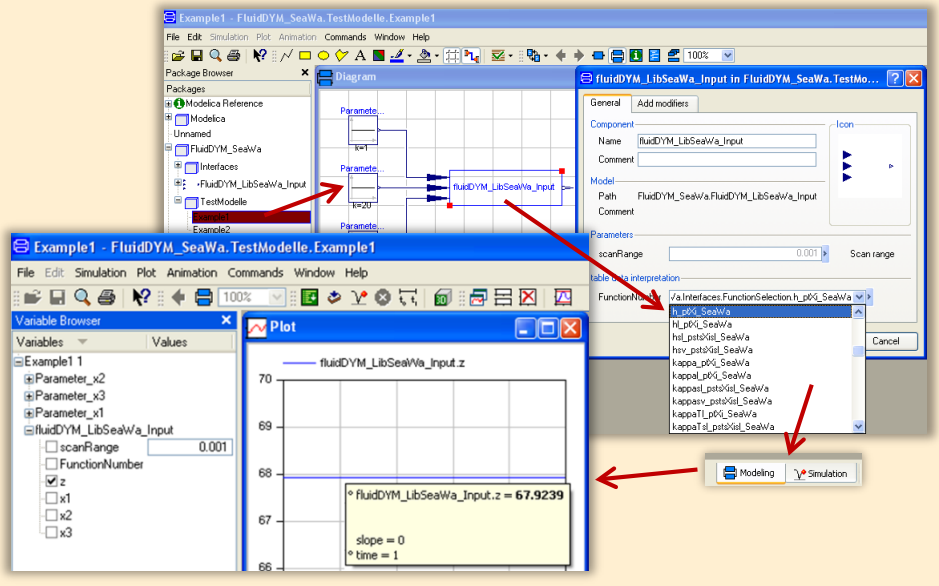
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

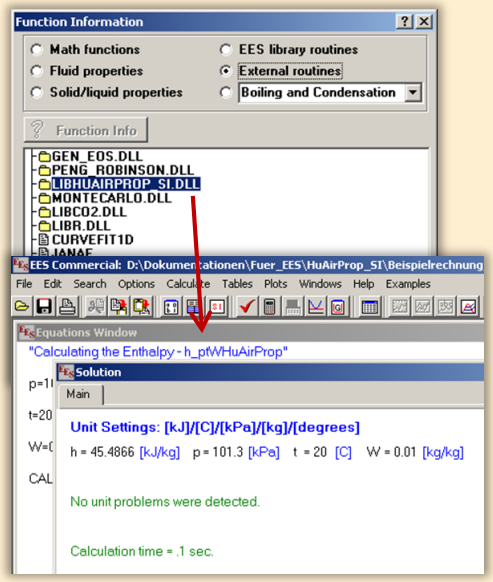


Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

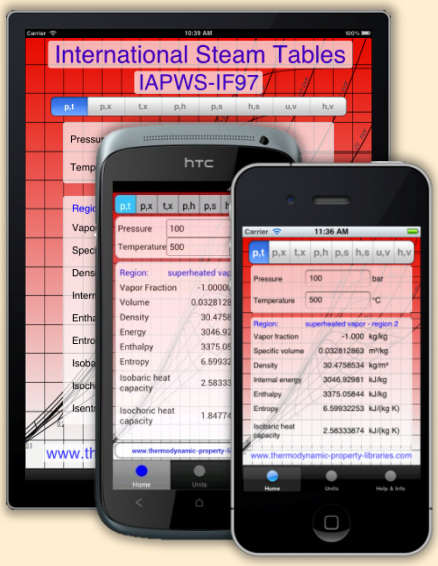
The property functions can be called in DYMOLA® and SimulationX®.



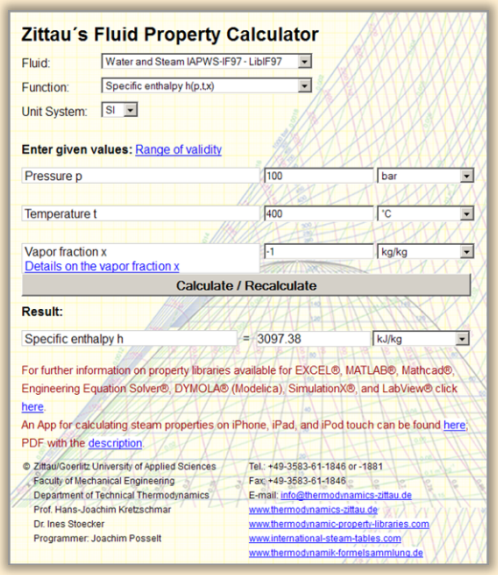
Add-On FluidEES for Engineering Equation Solver®



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



Online Property Calculator at www.thermofluidprop.com



Property Software for Pocket Calculators

FluidCasio

fx 9750 G II

CFX 9850 fx-GG20

CFX 9860 G Graph 85

ALGEBRA FX 2.0

FluidHP

HP 48

HP 49

FluidTI

TI Nspire CX CAS
TI Nspire CAS

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

For more information please contact:

KCE ThermoFluidProperties

KCE-ThermoFluidProperties UG & Co. KG
Prof. Dr. Hans-Joachim Kretzschmar
Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

The following thermodynamic and transport properties[a] can be calculated in Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® (EES), DYMOLA® (Modelica), SimulationX® and LabVIEW™:

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

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

www.thermofluidprop.com

5. References

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6. Satisfied Customers

Date: 05/2018

The following companies and institutions use the property libraries

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

2018

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

2017

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

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

2016

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

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INWAT, Lodz, Poland	07/2016
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Planungsbüro Waidhas GmbH, Chemnitz	07/2016
EEB Enerko, Aldershoven	07/2016
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	07/2016
SSP Kälteplaner AG, Wolfertschwenden	07/2016
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	07/2016
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
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INWAT, Lodzi, Poland	04/2016
Planungsbüro WAIDHAS GmbH, Chemnitz	04/2016
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WULFF & UMAG Energy Solutions GmbH, Husum	03/2016
FH Bielefeld, Bielefeld	03/2016
EWT Eckert Wassertechnik GmbH, Celle	03/2016
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016, 06/2016 (2x)
IEV KEMA - DNV GV – Energie, Dresden	02/2016
Allborg University, Department of Energie, Aalborg, Denmark	02/2016
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Institut für Luft- und Kältetechnik, Dresden	02/2016, 05/2016, 06/2016
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INL Idaho National Laboratory, Idaho, USA	11/2016, 01/2016
Friedl ID, Wien, Austria	01/2016
Technical University of Dresden, Dresden	01/2016

2015

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BASF, Ludwigshafen (general license) via Fichtner IT Consult	05/2012
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2011

XRG-Simulation, Hamburg	12/2011
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LAWI, Dresden	10/2011
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University of KwaZulu-Natal, Westville, South Africa	10/2011

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

2010

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

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

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

2009

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

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

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

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

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

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

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

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Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
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BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

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TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden Professorship of Thermic Energy Machines and Plants	04/2005
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
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Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
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Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
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Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

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Visteon, Kerpen	03/2004, 10/2004
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University of Saarbruecken	04/2004
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HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
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Enertech EUT, Radebeul (company license)	11/2004
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Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003

Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
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Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
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Petterssson+Ahrends, Ober-Moerlen	05/2003
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Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003
Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
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Energieversorgung Halle	12/2003

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
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PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
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SaarEnergie, Saarbruecken	05/2001
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Neusiedler AG, Ulmerfeld, Austria	09/2001

h s energieanlagen, Freising	09/2001
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IBR Engineering Reis, Nittendorf-Undorf	02/2000
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Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
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VAUP Process Automation, Landau	08/2000
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AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
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Bayernwerk, Munich	01/1999
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Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
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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
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B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
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SCA Hygiene Products, Munich	10/1998
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Gerb, Dresden	06/1997
Siemens Power Generation, Goerlitz	07/1997