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Property Library for R134a

**FluidMAT
with LibR134a
for Mathcad®**

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Property Library for the Calculation of the Properties of R134a

LibR134a FluidMAT for Mathcad®

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0 Package Contents

Zip-file "CD_FluidMAT_LibR134a_Eng.zip" includes the following files:

FluidMAT_LibR134a_Setup.exe	Self-extracting installation program
FluidMAT_LibR134a_Docu_Eng.pdf	User's Guide
LibR134a.dll	DLL including functions of the R134a property 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 $t(p, p_{\max})$ 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 FluidMAT in Mathcad®

FluidMAT has been developed to calculate thermodynamic properties in Mathcad® more conveniently. Within Mathcad, it enables the direct call of functions relating to R134a from the LibR134a property library.

2.1 Installing FluidMAT

In this section, the installation of FluidMAT LibR134A is described.

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

After you have downloaded and extracted the zip-file

"CD_FluidMAT_LibR134a_Eng.zip" (for English version of Windows)

"CD_FluidMAT_LibR134a.zip" (for German version of Windows),

you will see the folder

CD_FluidMAT_LibR134a_Eng (for English version of Windows)

CD_FluidMAT_LibR134a (for German version of Windows)

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:

FluidMAT_LibR134a_Docu_Eng.pdf

FluidMAT_LibR134a_Setup.exe

LibR134a.dll.

In order to run the installation of FluidMAT including the LibR134A property library double-click the file

FluidMAT_LibR134a_Setup.exe.

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

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

Now, you will be informed on the FluidMAT product in the "ReadMe-File" window. Click "Next >" to leave this window.

In the following dialog box, "Choose Destination Location" (see following figure), the default path where Mathcad has been installed will be shown

C:\Program Files\Mathcad\Mathcad 14\ (for English version of Windows)

C:\Programme\Mathcad\Mathcad 14\ (for German version of Windows).

By clicking the "Browse..." button, you can change the installation directory before installation.

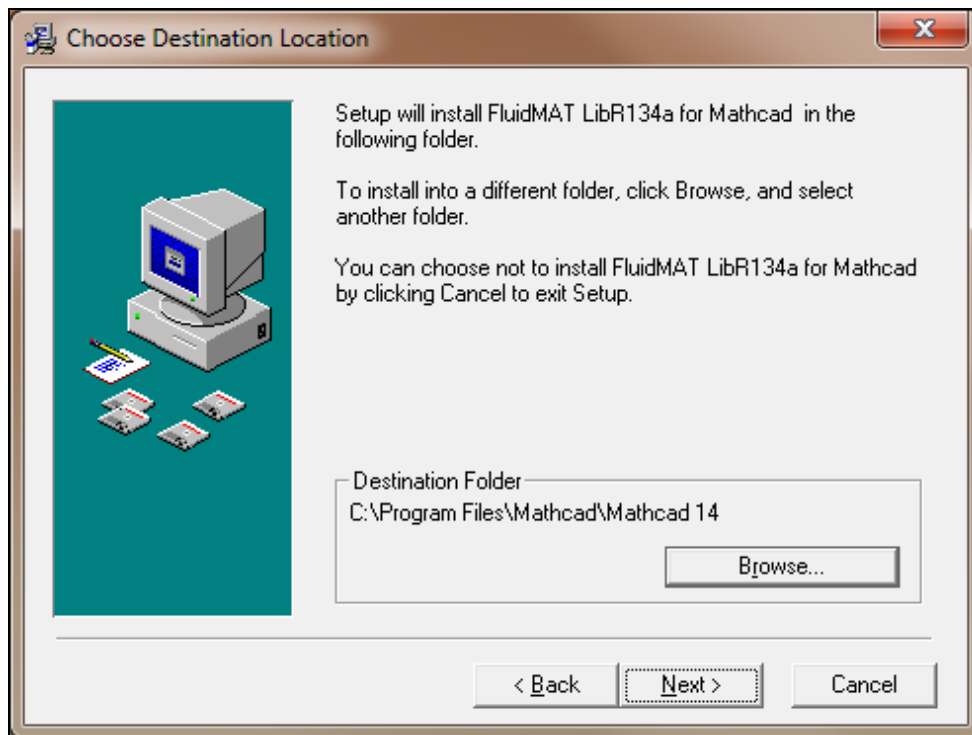


Figure 2.1: "Choose Destination Location" dialog window

The path will be displayed in the window.

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

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

After FluidMAT LibR134a has been installed, the sentence "FluidMAT LibR134a for Mathcad Professional has been successfully installed" will be shown.

Confirm this by clicking the "Finish >" button.

During the installation process the following files have been copied into the chosen destination folder (which is the folder, where Mathcad was installed):

advapi32.dll	Dynamic link library for use in Windows [®] programs
Dforrt.dll	Dynamic link library for use in Windows programs
Dformd.dll	Dynamic link library for use in Windows programs
LC.dll	Dynamic link library for use in Windows programs
LibR134a.dll	Property library for R134a
msvcp60.dll	Dynamic link library for use in Windows programs
Msvcrt.dll	Dynamic link library for use in Windows programs
Readme.txt	ReadMe file
INSTALL_MAT_LibR134a.LOG	Installation log-file

The following files were installed into your Mathcad subdirectory \userEFI:

MAT_LibR134a.dll	Function definition of LibR134a
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The following files were installed into your Mathcad subdirectory \doc\funcdoc:

MAT_LibR134a_DE.xml	Function registration in the dialog window "Insert Function" for LibR134a (German Mathcad version 12 or higher)
MAT_LibR134a_EN.xml	Function registration in the dialog window "Insert Function" for LibR134a (English Mathcad version 12 or higher)
MAT_LibR134a.xml	Function registration in the dialog window "Insert Function" for LibR134a (Mathcad version 11 or lower)

Now, you have to overwrite the file "LibR134a.dll" in your Mathcad directory with the file of the same name provided on your CD with FluidMAT.

To do this, open the CD in "My Computer" and click on the file "LibR134a.dll" in order to highlight it. Then click on the "Edit" menu in your Explorer and select "Copy". Now, open your Mathcad directory (the standard being

C:\Program Files\Mathcad\Mathcad 14 (for English version of Windows)

C:\Programme\Mathcad\Mathcad 14 (for German version of Windows))

and insert the file "LibR134a.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button.

You have overwritten the file "LibR134a.dll" successfully.

From within Mathcad you can now select the FluidMAT LibR134a property functions.

Licensing the LibR134A Property Library

The licensing procedure has to be carried out when you are calculating a function with LibR134a in Mathcad® and a FluidMAT prompt message appears. In this case, you will see the "License Information" window for LibR134a (see figure below).

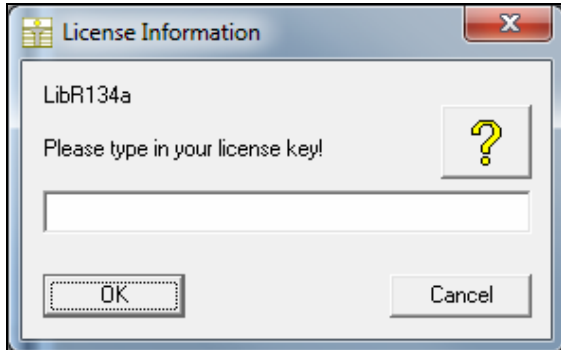


Figure 2.2: "License Information" window

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:

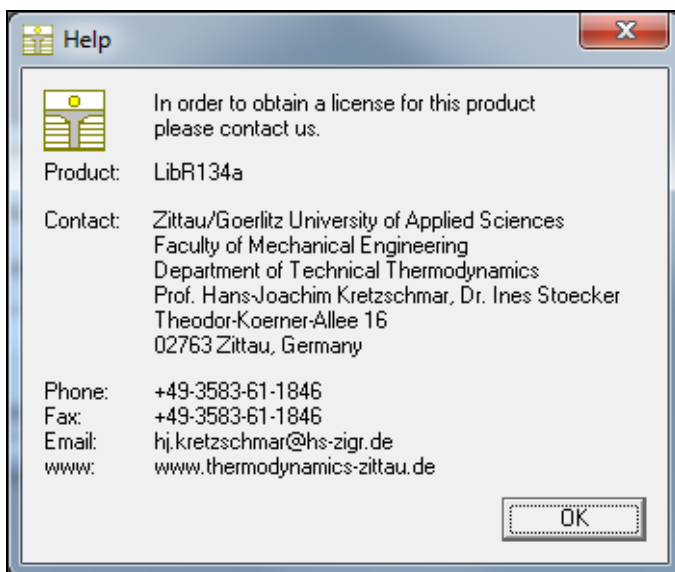


Figure 2.3: "Help" window

If you do not enter a valid license it is still possible to use Mathcad by clicking "Cancel". In this case, the LibR134a property library will display the result "-11111111" for every calculation.

The "License Information" window will appear every time you use the LibR134a property library in Mathcad unless you uninstall FluidMAT according to the description in section 2.3 of this User's Guide.

Should you not wish to license the LibR134a property library, you have to delete the files

LibR134a.dll
MAT_LibR134a.dll
MAT_LibR134a.xml

MAT_LibR134a_DE.xml

MAT_LibR134a_EN.xml

in the installation folder of FluidMAT (the standard being

C:\Program Files\Mathcad\Mathcad 14 (for English version of Windows)

C:\Programme\Mathcad\Mathcad 14 (for German version of Windows)

using an appropriate program such as Explorer® or Norton Commander.

2.2 Example: Calculation of the Enthalpy $h = f(p, t, x)$

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p , temperature t and vapor fraction x for R134a, using FluidMAT.

Please carry out the following instructions:

- Start Mathcad.
- Type "p:" and enter the value for the pressure p in bar.
(Range of validity: $p = 0.00389564 \text{ bar} \dots 700 \text{ bar}$)
e. g.: Enter "p:10" for the first operand
- Type "t:" and enter the value for the temperature t in °C.
(Range of validity: $t = -103.30 \text{ °C} \dots 181.85 \text{ °C}$)
e. g.: Enter "t:25" for the second operand
- Type "x:" and enter the value for the vapor fraction x in $\text{kg}_{\text{sat. steam}} / \text{kg}_{\text{wet steam}}$.

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

e. g.: Enter "x:-1" for the third operand

- Confirm your entry by pressing the "ENTER" key.
- Your Mathcad calculation window should like Figure 2.4:

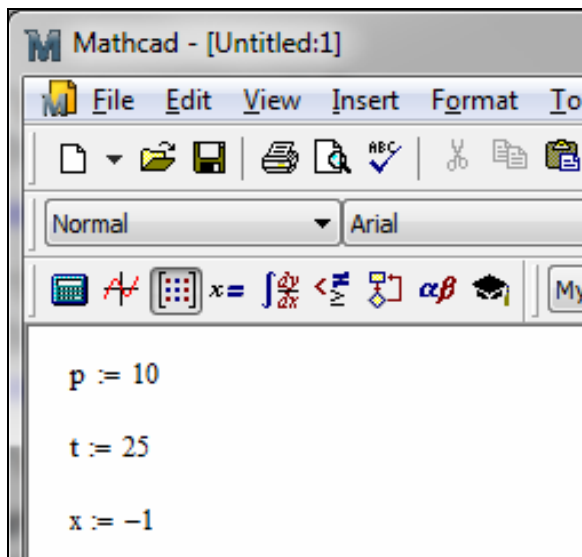
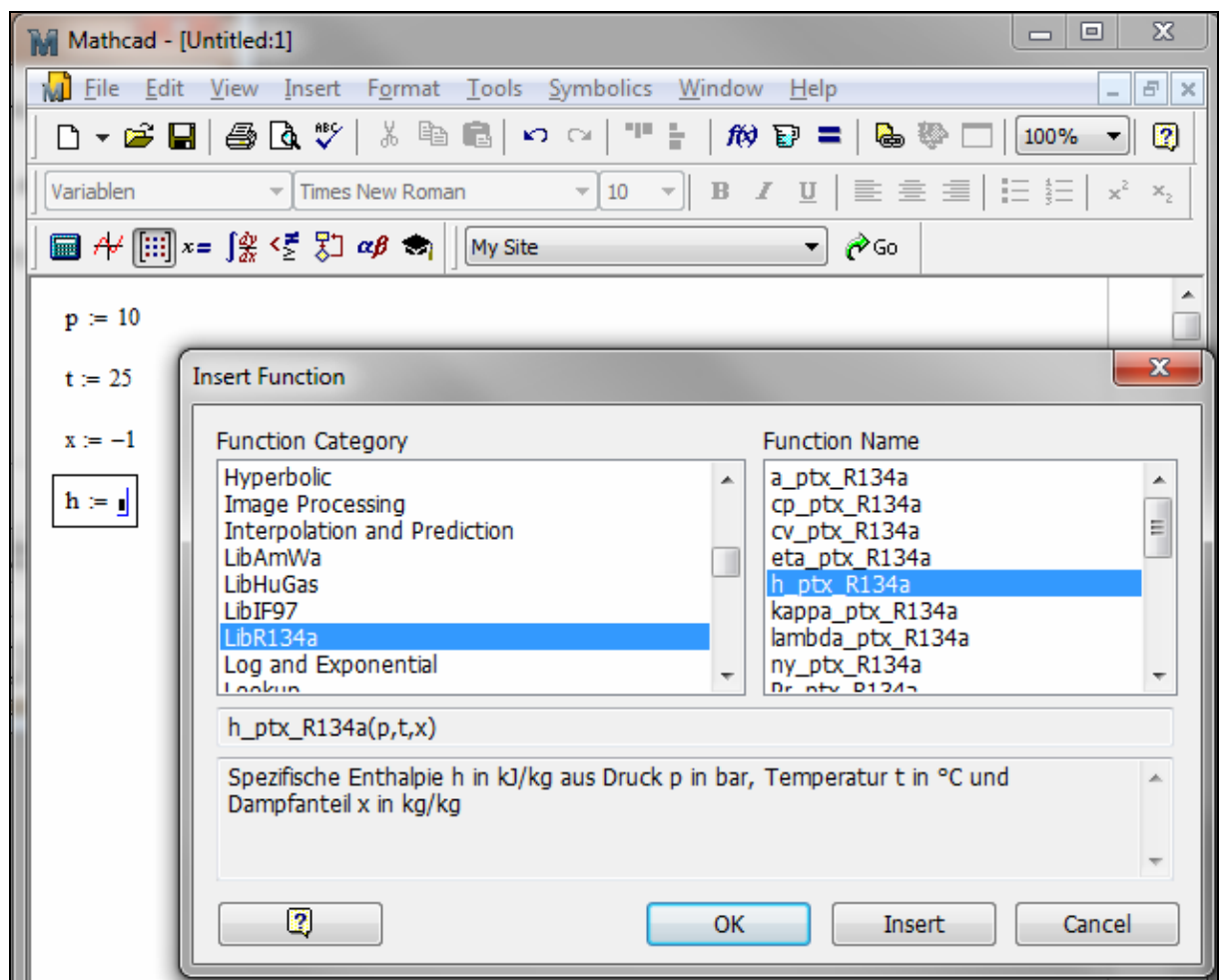


Figure 2.4: Example Mathcad® sheet after input of the given parameters

- Now, type "h:" in the Mathcad window. Now, you will see **h :=** ■ .
- Click on "Insert" in the upper menu bar and then click "Function...". Now, the "Insert function" window appears (see next figure).



- **Figure 2.5:** Choice of library and function name

- Search and click the "LibR134a" library under "Function Category" in the left part of the window.
- Now, search and click the "h_ptx_R134a" function under "Function Name" on the right hand side of the window.

The function category and the function name will be inverted, highlighted and furthermore the description of the function and the measuring units of the variables are shown.

- Now, click "OK" and you will see $h := h_ptx_R134a(\blacksquare, \blacksquare, \blacksquare)$ in the Mathcad window (see next figure).

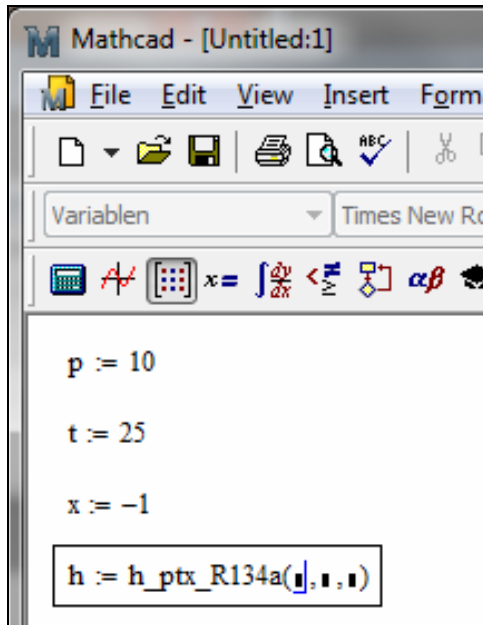


Figure 2.6: Example Mathcad® sheet with formula and placeholders

- The cursor is now situated on the first operand. 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. You can now enter the value for the temperature t either by entering the value for t directly or by typing the name of the variable in which the value of the temperature has been saved.
⇒ e.g.: Enter "t".
- Situate the cursor on the next placeholder. You can now enter the value for the humidity ratio x either by entering the value for x directly or by typing the name of the variable in which the value of the humidity ratio has been saved.
⇒ e.g.: Enter "x".
- Close the input formula by pressing the "Enter"-Key.
- Your Mathcad calculation window should like the following figure:

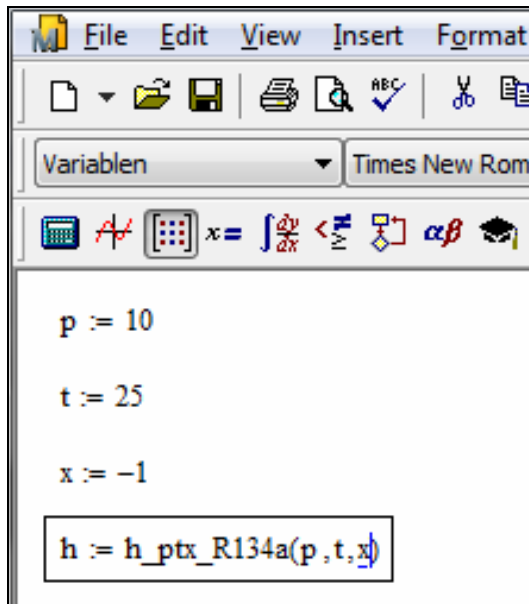


Figure 2.7: Example Mathcad® sheet with formula and variables

- 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 window:
"h =".

The result for $h = 234.557$ in kJ/kg appears.

The representation of the result depends on the amount of places and decimal places which have been set before. In the next figure you can see that we have chosen the amount of three decimal places and an exponential threshold of four.

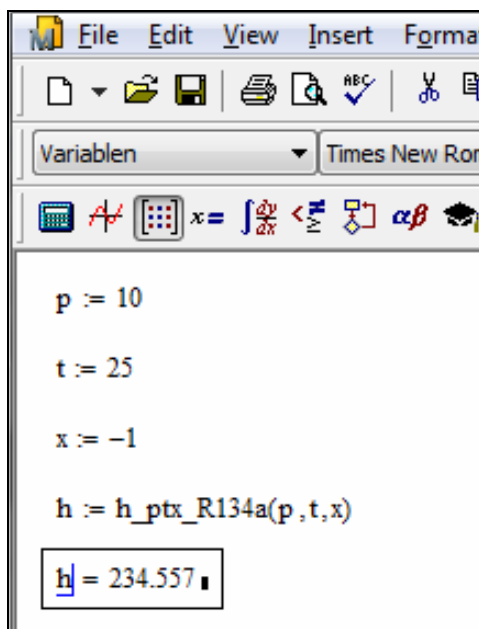


Figure 2.8: Example Mathcad® sheet with finished calculation

2.3 Removing FluidMAT

To remove FluidMAT from Mathcad® and 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 "FluidMAT LibR134a for Mathcad Professional" by clicking on it and click the "Add/Remove..." button.
- In the following dialog box click "Automatic" and thereafter "Next >".
- Click "Finish" in the "Perform Uninstall" window.
- Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidMAT 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 $a = \frac{\lambda \cdot v}{c_p}$ in m^2 / 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 $p_l = 0.00389564$ 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: **REAL*8 FUNCTION CP_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_CP_PTX_R134A(CP,P,T,X)**
 for call from DLL: **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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the vapor fraction x and on the calculation of 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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to $t_c = 101.03 \text{ °C}$
Pressure range	from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

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

Saturation lines: at $p = -1000$ and $t > 101.03 \text{ °C}$ or $t < t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$
 at $t = -1000$ and $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ or
 at $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ and
 $t > 101.03 \text{ °C}$ or $t < t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$

References: [16]

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

Function Name: **cv_ptx_R134a**
 Subroutine with function value: **REAL*8 FUNCTION CV_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_CV_PTX_R134A(CV,P,T,X)**
 for call from DLL: **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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to 181.85 °C

Pressure range: from 0.00389564 bar to 700 bar

Details on the vapor fraction x and on the calculation of 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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to $t_c = 101.03 \text{ °C}$
Pressure range	from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

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

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

Details on the vapor fraction x and on the calculation of 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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to $t_c = 101.03 \text{ °C}$
Pressure range	from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

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

Saturation lines: at $p = -1000$ and $t > 101.03 \text{ °C}$ or $t < t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$
 at $t = -1000$ and $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ or
 at $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ and
 $t > 101.03 \text{ °C}$ or $t < t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$

References: [16], [22]

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

Function Name: **h_ptx_R134a**
 Subroutine with function value: **REAL*8 FUNCTION H_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_H_PTX_R134A(H,P,T,X)**
 for call from DLL: **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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to $181.85 \text{ }^\circ\text{C}$

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 $t_c = 101.03 \text{ }^\circ\text{C}$
 Pressure range from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

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

References: [16]

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

Function Name: **kappa_ptx_R134a**
 Subroutine with function value: **REAL*8 FUNCTION KAP_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_KAP_PTX_R134A(KAP,P,T,X)**
 for call from DLL: **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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to 181.85 °C
 Pressure range: from 0.00389564 bar to 700 bar

Details on the vapor fraction x and on the calculation of 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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to $t_c = 101.03 \text{ °C}$
Pressure range	from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

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

References: [16]

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

Function Name: **lambda_ptx_R134a**
 Subroutine with function value: **REAL*8 FUNCTION LAM_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_LAM_PTX_R134A(LAM,P,T,X)**
 for call from DLL: **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 /m³ to 1550 kg / m³

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 $\rho > 1550$ m³ / 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: **REAL*8 FUNCTION NY_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_NY_PTX_R134A(NY,P,T,X)**
 for call from DLL: **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 $\nu = \eta * \nu$ in m^2 / 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 $Pr = \frac{\eta^* c_p}{\lambda}$

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 m³ / kg to 1550 m³ / 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 $\rho > 1550$ m³ / 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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to 101.03 °C

Results for wrong input values

Result **PS_T_R134A**, **PS** = -1000 or **ps_t_R134a** = -1000 for input values:

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

References: [16]

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

Function Name: **rho_ptx_R134a**
 Subroutine with function value: **REAL*8 FUNCTION RHO_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_RHO_PTX_R134A(RHO,P,T,X)**
 for call from DLL: **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 / m³

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 $t_c = 101.03 \text{ °C}$
 Pressure range from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

Single phase region: $p > 700 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ or
 ($x = -1$) $t > 181.85 \text{ °C}$ 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 $t > 101.03 \text{ °C}$ or $t < -73.15 \text{ °C}$
 at $t = -1000$ and $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ or
 at $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ and
 $t > 101.03 \text{ °C}$ 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 $t_c = 101.03 \text{ °C}$
 Pressure range from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

Single phase region: $p > 700 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ or
 ($x = -1$) $t > 181.85 \text{ °C}$ or $t < -73.15 \text{ °C}$ or $\rho > 1550 \text{ m}^3 / \text{kg}$
 Saturation lines: at $p = -1000$ and $t > 101.03 \text{ °C}$ or $t < -73.15 \text{ °C}$
 at $t = -1000$ and $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ or
 at $p > 40.566 \text{ bar}$ or $p < 0.00389564 \text{ bar}$ and
 $t > 101.03 \text{ °C}$ 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: **REAL*8 FUNCTION SIGMA_T_R134A(T)**
 for call from Fortran: **REAL*8 T**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_SIGMA_T_R134A(SIGMA,T)**
 for call from DLL: **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
 ($x = -1$) $t > 181.85^\circ\text{C}$ 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
 $t > 101.03^\circ\text{C}$ 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
 ($x = -1$) $t > 181.85^\circ\text{C}$ 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
 $t > 101.03^\circ\text{C}$ 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: **REAL*8 FUNCTION TS_P_R134A(P)**
 for call from Fortran: **REAL*8 P**
 Subroutine with parameter: **INTEGER*4 FUNCTION C_TS_P_R134A(TS,P)**
 for call from DLL: **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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ 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 $t_c = 101.03 \text{ °C}$
 Pressure range from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

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

References: [16]

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

Function Name: **v_ptx_R134a**

Subroutine with function value: **REAL*8 FUNCTION V_PTX_R134A(P,T,X)**
 for call from Fortran: **REAL*8 P,T,X**

Subroutine with parameter: **INTEGER*4 FUNCTION C_V_PTX_R134A(V,P,T,X)**
 for call from DLL: **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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to $181.85 \text{ }^\circ\text{C}$
 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 $t_c = 101.03 \text{ }^\circ\text{C}$
 Pressure range from $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

Results for wrong input values

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

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

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

Details on the vapor fraction x and on the calculation of 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 $t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$ to $t_c = 101.03 \text{ °C}$
 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
 ($x = -1$) $t > 181.85 \text{ °C}$ 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 $t > 101.03 \text{ °C}$ or $t < -73.15 \text{ °C}$
 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
 $t > 101.03 \text{ °C}$ or $t < t(p, \rho_{\max} = 1550 \text{ kg/m}^3)$

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 $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

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

$$p < 40.566 \text{ bar or } p > 0.00389564 \text{ bar}$$

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 $p_t = 0.00389564 \text{ bar}$ to $p_c = 40.566 \text{ bar}$

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

$$p < 40.566 \text{ bar or } p > 0.00389564 \text{ bar}$$

References: [16]



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
 - IAPWS-IF97-S03rev
 - IAPWS-IF97-S04
 - IAPWS-IF97-S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)

Humid Combustion Gas Mixtures

Library LibHuGas

Model: 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 Formulation of Bückner et al.)
Consideration of:
Dissociation from VDI 4670 and 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 the VDI 4670
- Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

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 H₂O F₂ Propane
N₂ SO₂ NH₃ Iso-Butane
O₂ H₂ Methane n-Butane
CO H₂S Ethane Benzene
CO₂ 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

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bückner et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bückner et al. (2003)

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 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
C₂H₆O₂ Ethylene glycol
C₃H₈O₂ Propylene glycol
C₂H₅OH Ethyl alcohol
CH₃OH Methyl alcohol
C₃H₈O₃ Glycerol
K₂CO₃ Potassium carbonate
CaCl₂ Calcium chloride
MgCl₂ Magnesium chloride
NaCl Sodium chloride
C₂H₃KO₂ Potassium acetate
Formulation of the International Institute of Refrigeration (1997)

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 $C_{14}H_{42}O_6Si_6$ **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)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

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**

Dinitrogen monoxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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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

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

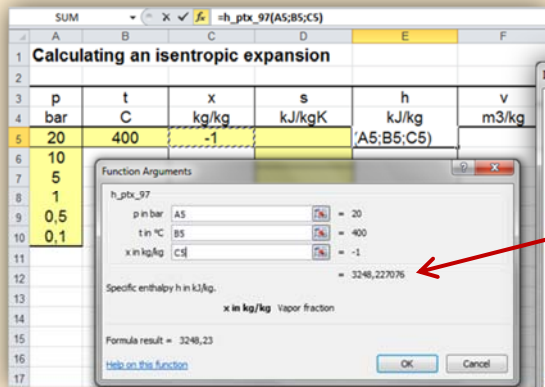
- Partial derivatives can be calculated.

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



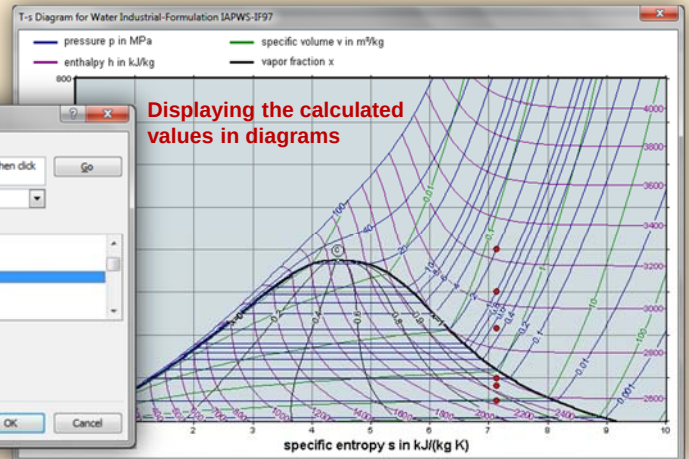
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function

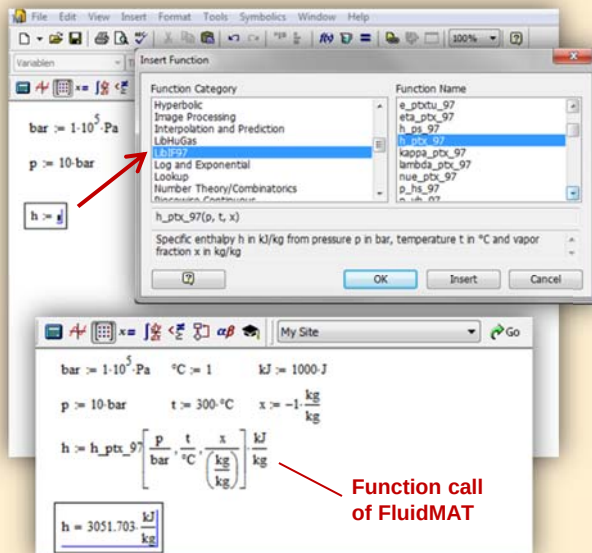
Displaying the calculated values in diagrams



Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

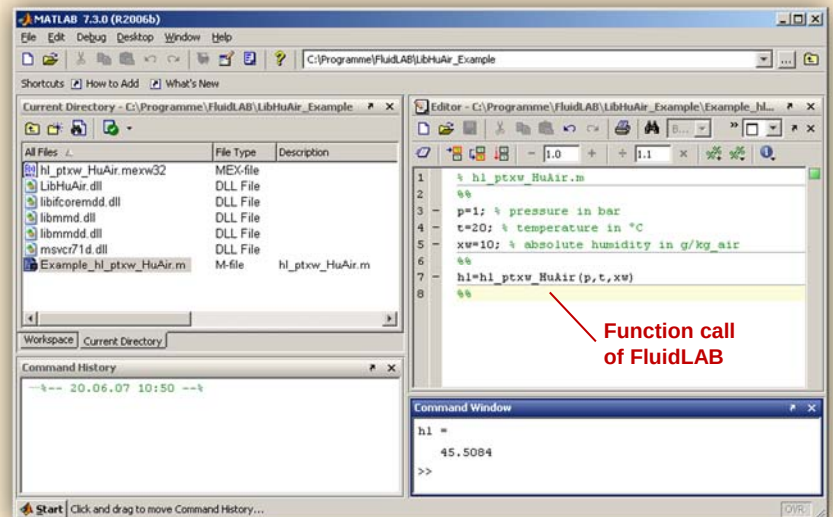
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

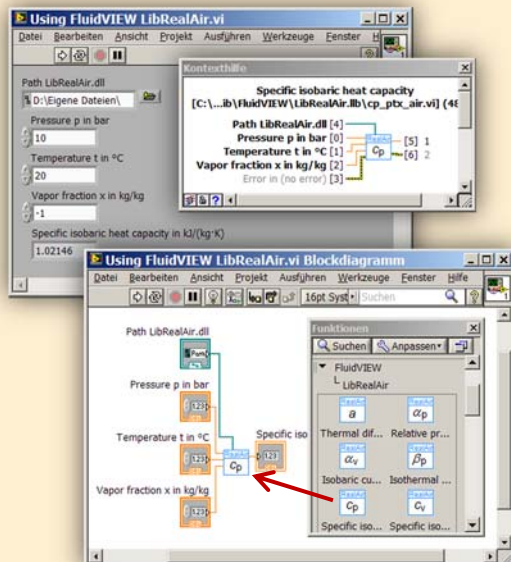
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

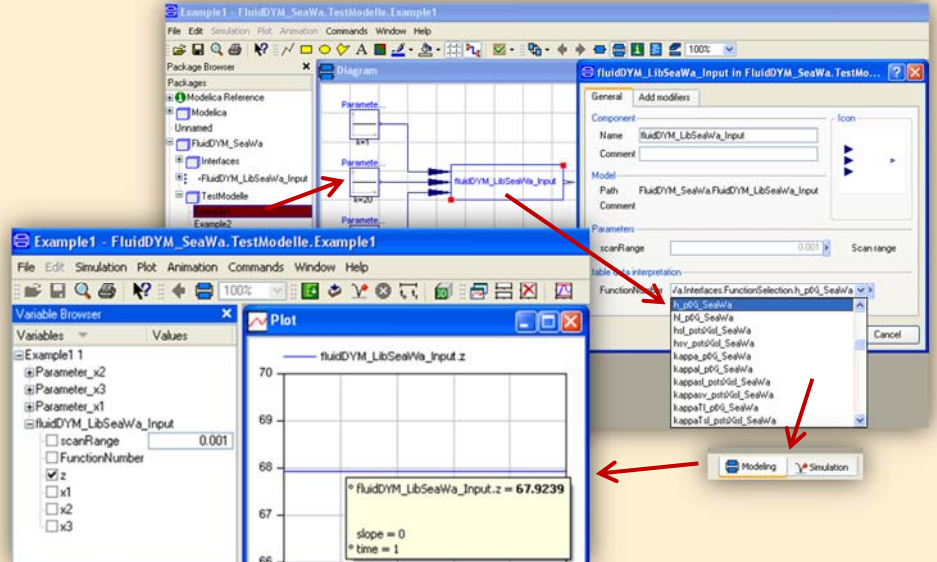
Add-On FluidVIEW for LabVIEW[®]

The property functions can be calculated in LabVIEW[®].

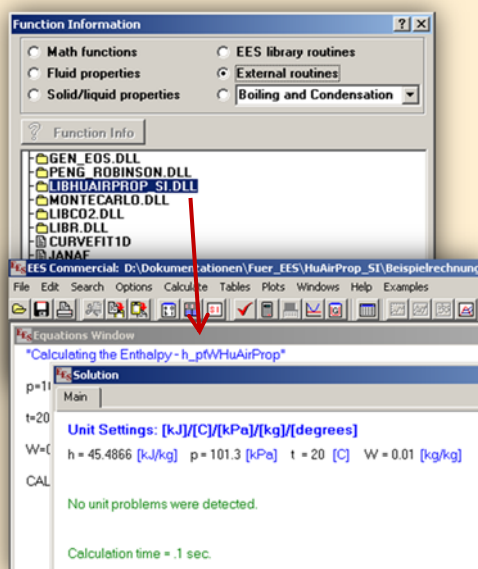


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

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



Add-In FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android smart phones and tablets



Online Property Calculator at www.thermodynamics-zittau.de

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

Enter given values: [Range of validity](#)

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = 3097.38 kJ/kg

For further information on property libraries available for EXCEL®, MATLAB®, Mathcad®, Engineering Equation Solver®, DYMOLA® (Modelica), SimulationX®, and LabView® click [here](#)

An App for calculating steam properties on iPhone, iPad, and iPod touch can be found [here](#)

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Property Software for Pocket Calculators

FluidCasio



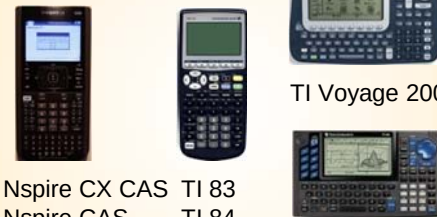
fx 9750 G II CFX 9850 fx-GG20 CFX 9860 G Graph 85 ALGEBRA FX 2.0

FluidHP



HP 48 HP 49

FluidTI



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For more information please contact:

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

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density 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

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 can be calculated.

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

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6. Satisfied Customers

Date: 04/2014

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
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Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006
Caliqua, Basel, Switzerland (company license)	09/2006
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Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

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TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
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FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005 07/2005
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Technical University of Dresden	04/2005
Professorship of Thermic Energy Machines and Plants	
Grenzebach BSH, Bad Hersfeld	04/2005
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Dumas Verfahrenstechnik, Hofheim	06/2005
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Stadtwerke Leipzig	07/2005
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Vattenfall Europe, Berlin (group license)	08/2005
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Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005
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Rerum Cognitio, Zwickau	04/2004
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HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
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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
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Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
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ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
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exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
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LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
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VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
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Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
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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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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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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
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SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
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