Property Library for N-Butane

FluidPrime
with LibButane_n
for Mathcad Prime®

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Property Library for N-Butane

LibButane_n

FluidPRIME for Mathcad Prime®

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0. Package Contents

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

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

1. Property Functions

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibButan_n as parameter	Property or Function	Unit of the result
$a = f(p,t,x)$	a_ptx_BUTN	APTXBUTN(P,T,X)	C_APTXBUTN(A,P,T,X)	Thermal diffusivity	m^2/s
$c_p = f(p,t,x)$	cp_ptx_BUTN	CPPTXBUTN(P,T,X)	C_CPPTXBUTN(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$\eta = f(p,t,x)$	eta_ptx_BUTN	ETAPTXBUTN(P,T,X)	C_ETAPTXBUTN(ETA,P,T,X)	Dynamic viscosity	Pa s
$h = f(p,t,x)$	h_ptx_BUTN	HPTXBUTN(P,T,X)	C_HPTXBUTN(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_BUTN	KAPTXBUTN(P,T,X)	C_KAPTXBUTN(KAP,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lambda_ptx_BUTN	LAMPTXBUTN(P,T,X)	C_LAMPTXBUTN(LAM,P,T,X)	Thermal conductivity	W/(m K)
$\nu = f(p,t,x)$	ny_ptx_BUTN	NYPTXBUTN(P,T,X)	C_NYPTXBUTN(NY,P,T,X)	Kinematic viscosity	m^2/s
$p_{mel} = f(t)$	pmel_t_BUTN	PMELBUTN(T)	C_PMELBUTN(PMEL,T)	Melting pressure from temperature	bar
$p_s = f(t)$	ps_t_BUTN	PSTBUTN(T)	C_PSTBUTN(PS,T)	Vapor pressure from temperature	bar
$Pr = f(p,t,x)$	Pr_ptx_BUTN	PRPTXBUTN(P,T,X)	C_PRPTXBUTN(PR,P,T,X)	*Prandtl*-Number	-
$\rho = f(p,t,x)$	rho_ptx_BUTN	ROPTXBUTN(P,T,X)	C_ROPTXBUTN(RHO,P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_BUTN	SPTXBUTN(P,T,X)	C_SPTXBUTN(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_BUTN	TPHBUTN(P,H)	C_TPHBUTN(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_BUTN	TPSBUTN(P,S)	C_TPSBUTN(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_{mel} = f(p)$	tmel_p_BUTN	TMELBUTN(P)	C_TMELBUTN(TMEL,P)	Melting temperature from pressure	°C
$t_s = f(p)$	ts_p_BUTN	TSPBUTN(P)	C_TSPBUTN(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_BUTN	UPTXBUTN(P,T,X)	C_UPTXBUTN(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_BUTN	VPTXBUTN(P,T,X)	C_VPTXBUTN(V,P,T,X)	Specific volume	m^3/kg
$w = f(p,t,x)$	w_ptx_BUTN	WPTXBUTN(P,T,X)	C_WPTXBUTN(W,P,T,X)	Isentropic speed of sound	m/s
$x = f(p,h)$	x_ph_BUTN	XPHBUTN(P,H)	C_XPHBUTN(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	x_ps_BUTN	XPSBUTN(P,S)	C_XPSBUTN(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 $t_{mel}(p)$ to 301.85 °C
Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Reference state

h = 200 kJ/kg and *s* = 1 kJ/(kg K) at *t* = 0 °C on the boiling curve (*x* = 0)

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 true, the calculated result will be –1000.

Wet steam region: Temperature range from t_t = –138.255 °C to t_c = 151.975 °C

Pressure range from $p_t = 6.53 \times 10^{-6}$ bar to 37.96 bar

Hint!

If the input values are located outside the range of validity, the result for the calculated function will always be –1000. Please find more exact details on every function and its corresponding range of validity in the enclosed program documentation in chapter 3.

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 LibButan_n property library.

2.1 Installing FluidPRIME

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

CD_FluidPRIME_LibButan_n

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_LibButan_n_Docu.pdf
Functions_LibButan_n.mcdx
LibButan_n.msi
setup.exe
LibButan_n.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 LibButan_n.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".

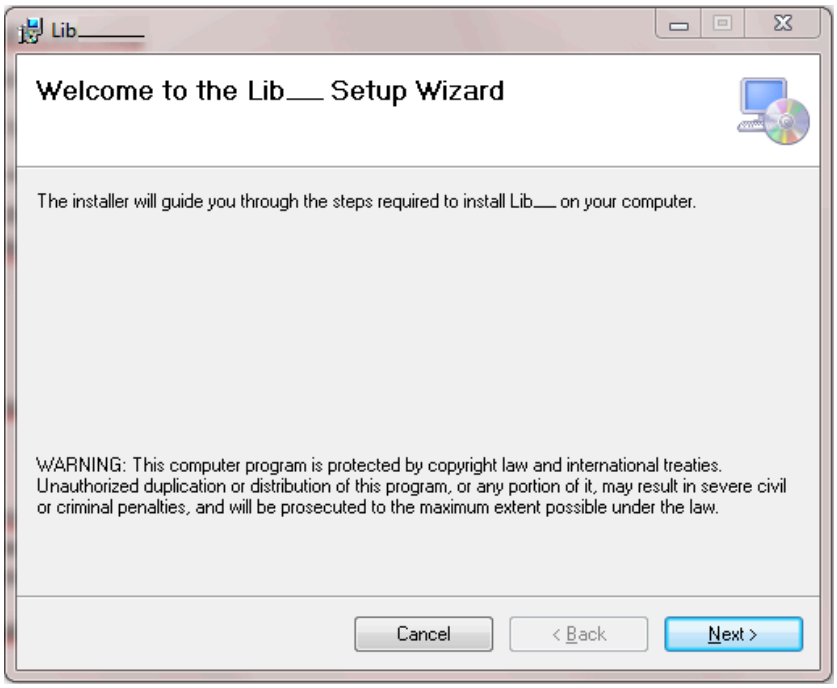

Figure 2.1: Setup Wizard

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

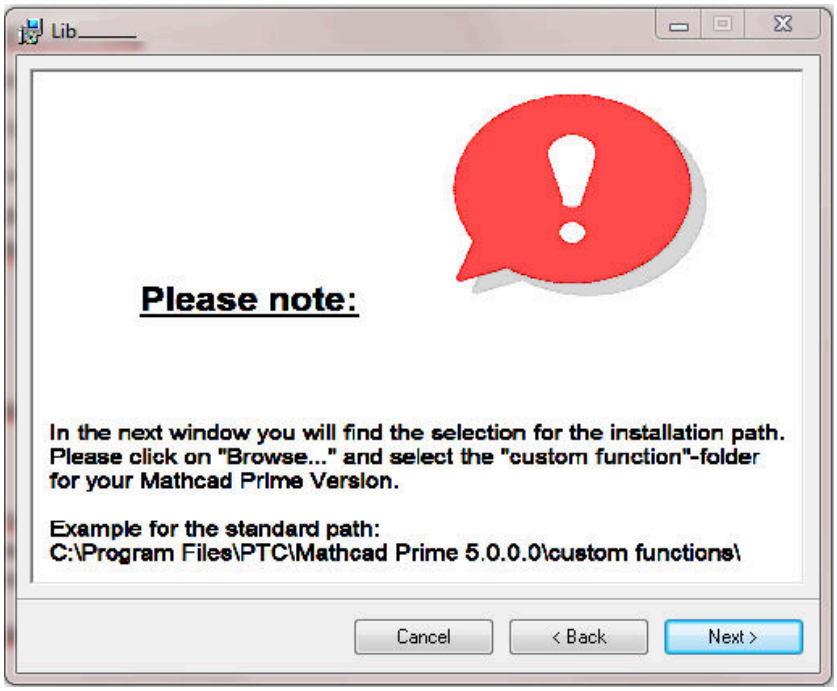

Figure 2.2: Note Window

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

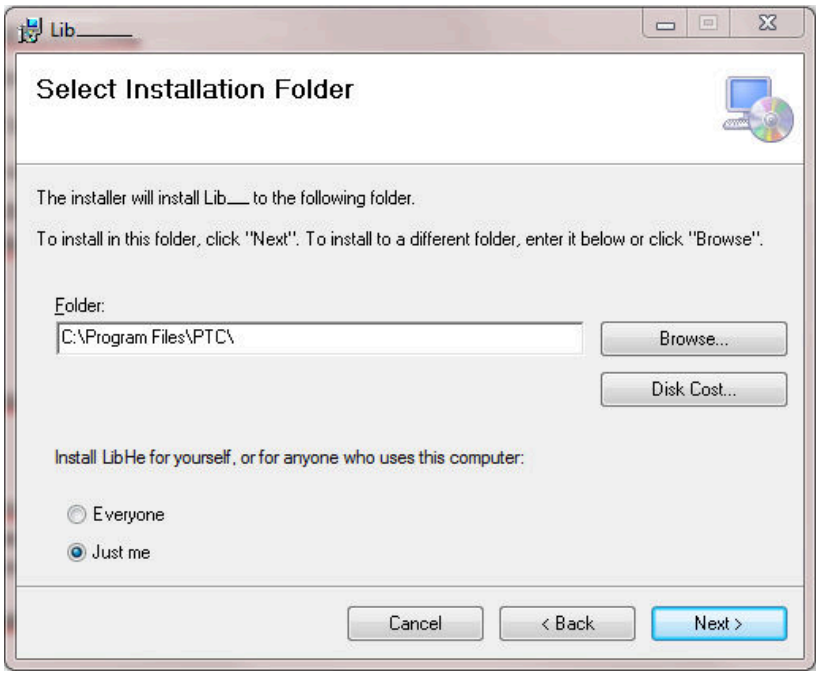

Figure 2.3: Select Installation Folder

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.

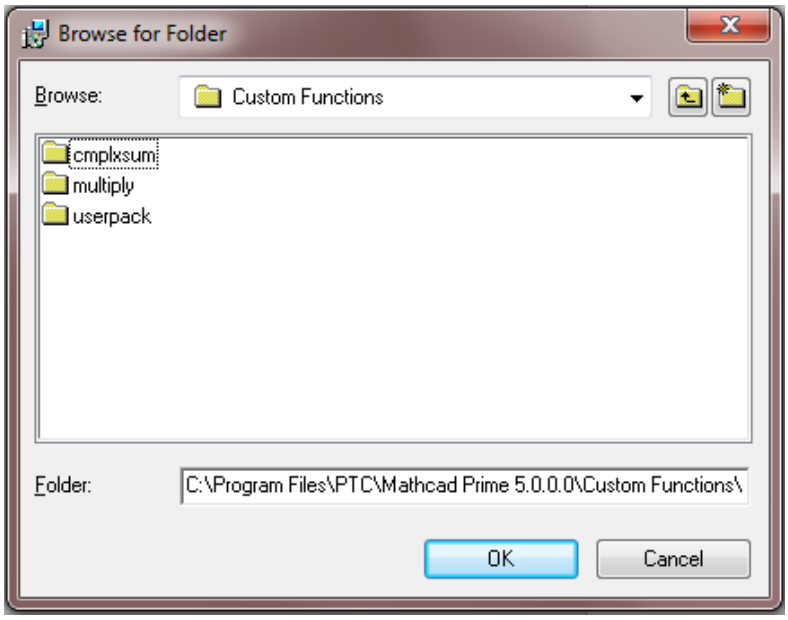

Figure 2.4: "Browse for Folder"-window with the full installation path

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

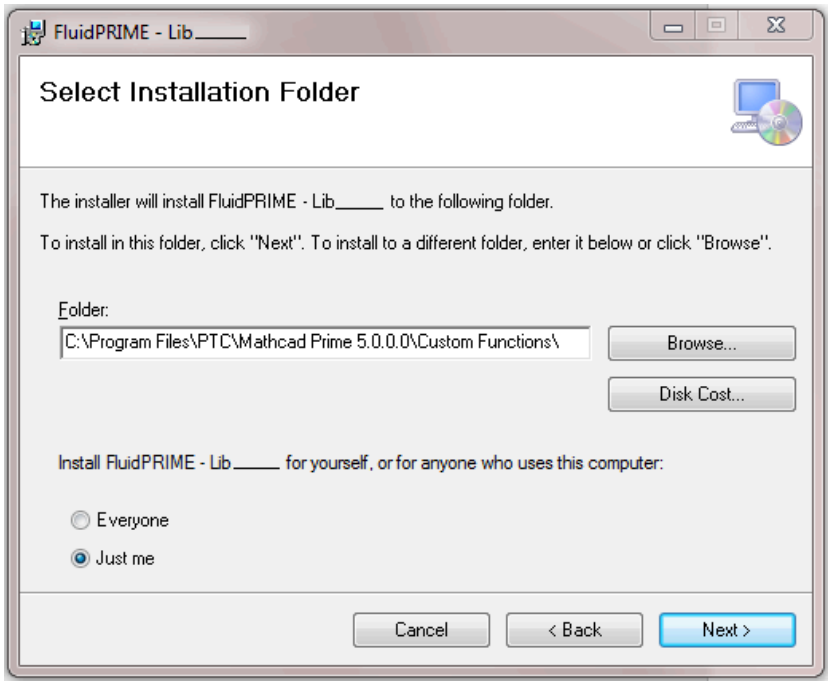

Figure 2.5: "Select Installation Folder"-window

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 LibButan_n is finished.

Finally, please copy or overwrite the LibButan_n.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	LibButan_n.dll	PRIME_LibButan_n.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 LibButan_n 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-Butan_n, using FluidPRIME.

- Start Mathcad Prime.
- Type "p:" and enter the value for the pressure *p* in bar.
  (Range of validity of the Butan_n: from pt = 6.53 x 10-6 bar to 690 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 of the Butan_n: from tmel(p) to 301.85 °C)
  e. g.: Enter "t:50" for the second operand
- Type "x:" and enter the value for the vapor fraction *x* in $kg_{sat.\ steam}$ / $kg_{wet\ steam.}$
  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 true, the calculated result will be –1000.
  Wet steam region: Temperature range from tt = –138.255 °C to tc = 151.975 °C
  Pressure range from pt = 6.53 x 10-6 bar to 37.96 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:

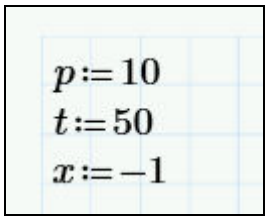

Figure 2.3: Example Mathcad Prime® sheet after input of the given parameters

- Now, type open the file Functions_LibButan_n.mcdx. In this Mathcad Prime® worksheet you can find all the functions of the library
- Search the function h_ptx_Butan_n(, ,) 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:

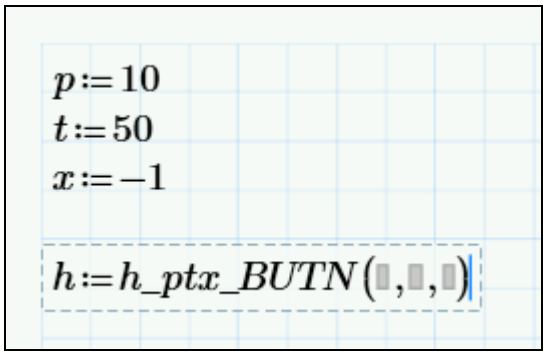

Figure 2.4: Example Mathcad Prime® sheet

- 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=322.719. 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.

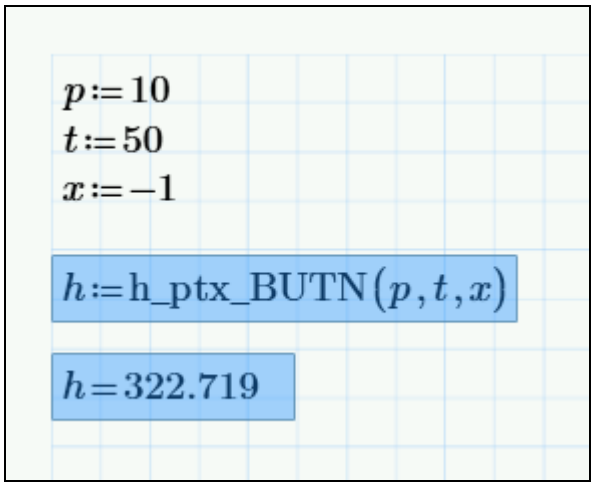

Figure 2.5: Example Mathcad Prime® sheet with finished calculation

2.4 Removing FluidPRIME

To remove FluidPRIME with the library LibButan_n 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 - LibButan_n" 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 LibButan_n has been removed.

3. Program Documentation

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

Function Name:	**a_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION APTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_APTXBUTN(A,P,T,X)** 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

APTXBUTN, **A** or **a_ptx_BUTN** – Thermal diffusivity $a = \frac{\lambda * v}{c_p}$ in m^2 / s

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **APTXBUTN = –1000**, **A = –1000** or **a_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [24], [25]

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

Function Name:	**cp_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION CPPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_CPPTXBUTN(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

CPTXBUTN, **CP** or **cp_ptx_BUTN** – Specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range: from t_{mel} to 301.85°C

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **CPPTXBUTN = –1000**, **CP = –1000** or **cp_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Dynamic Viscosity η = f(p,t,x)

Function Name:	**eta_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION ETAPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ETAPTXBUTN(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

ETAPTXBUTN, **ETA** or **eta_ptx_BUTN** – Dynamic viscosity η in Pa s

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from	t_t = -138.255 °C to t_c = 151.975 °C
Pressure ranges from	p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **ETAPTXBUTN= –1000**, **ETA = –1000** or **eta_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [23], [25]

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

Function Name:	**h_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION HPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_HPTXBUTN(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

HPTXBUTN, **H** or **h_ptx_BUTN** - Specific enthalpy *h* in kJ/kg

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **HPTXBUTN = –1000**, **H = –1000** or **h_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Isentropic Exponent κ = f(p,t,x)

Function Name:	**kappa_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION KAPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_KAPTXBUTN(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

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

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **KAPTXBUTN**, **KAP = –1000** or **kappa_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Thermal Conductivity λ = f(*p*,*t*,*x*)

Function Name:	**lambda_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION LAMPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_LAMPTXBUTN(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

LAMPTXBUTN, **LAM** or **lambda_ptx_BUTN** – Thermal conductivity λ in W / m K

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **LAMPTXBUTN = –1000**, **LAM = –1000** or **lambda_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [24], [25]

Kinematic Viscosity ν = f(p,t,x)

Function Name:	**ny_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION NYPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_NYPTXBUTN(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

NYPTXBUTN, **NY** or **ny_ptx_BUTN** – Kinematic viscosity $\nu = \eta \cdot v$ in m^2 / s

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **NYPTXBUTN = –1000**, **NY = –1000** or **ny_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [23], [25]

Melting Pressure p_{mel} = f(t)

Function Name:	**pmel_t_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION PMELBUTN(T)** REAL*8 T
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PMELBUTN(PMEL,T)** REAL*8 PMEL,P,T,X

Input Values:

T - Temperature t in °C

Result

PMELTBUTN, **PMEL** or **pmel_t_BUTN** – Melting pressure p_{mel} in bar

Range of validity

Temperature range : from $t_t = -138.255$°C to -127.233°C

Results for wrong input values

Result **PMELBUTN = –1000**, **PMEL = –1000** or **pmel_t_BUTN = –1000** for input values:

$t < t_t = -138.255$°C or $t > -127.233$°C

References: [22], [25]

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

Function Name:	**Pr_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION PRPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PRPTXBUTN(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

PRPTXBUTN, **PR** or **Pr_ptx_BUTN** – Prandtl – Number $Pr = \frac{\eta * c_p}{\lambda}$

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from	t_t = -138.255 °C to t_c = 151.975 °C
Pressure ranges from	p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **PRPTXBUTN = –1000**, **PR = –1000** or **Pr_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [23], [24], [25]

Vapor Pressure p_s = f(t)

Function Name:	**ps_t_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION PSTBUTN(T)** REAL*8 T
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_PSTBUTN(PS,T)** REAL*8 PS,T

Input Values:

T - Temperature t in °C

Result

PSTBUTN, **PS** or **ps_t_BUTN** – Vapor pressure p_s in bar

Range of validity

Temperature range : from $t_t = -138.255$°C to $t_c = 151.975$°C

Results for wrong input values

Result **PSTBUTN = –1000**, **PS = –1000** or **ps_t_BUTN = –1000** for input values:

$t < t_t = -138.255$°C or $t > t_c = 151.975$°C

References: [22], [25]

Density ρ = f(p,t,x)

Function Name:	**rho_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION ROPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_ROPTXBUTN(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_BUTN, **RHO** or **rho_ptx_BUTN** - Density ρ in kg/m^3

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **ROPTXBUTN = –1000**, **RHO = –1000** or **rho_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**s_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION SPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_SPTXBUTN(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

SPTXBUTN, **S** or **s_ptx_BUTN** - Specific entropy *s* in kJ/kg K

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **SPTXBUTN = –1000**, **S = –1000** or **s_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**t_ph_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TPHBUTN(P,H)** REAL*8 P,H
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TPHBUTN(T,P,H)** REAL*8 T,P,H

Input Values:

P – Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

TPHBUTN, **T** or **t_ph_BUTN** – Temperature t in °C

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **T_PH_BUTN**, **T = –1000** or **t_ph_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > 301.85$°C, $t < t_t = -138.255$°C or $t < t_{mel}(p)$
Saturated liquid or saturated vapor line:	at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

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

Input Values:

P – Pressure p in bar

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

Result

TPSBUTN, **T** or **t_ps_BUTN** – Temperature t in °C

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 = 6.53 x 10^{-6} bar to p_c = 37.96 bar

Results for wrong input values

Result **T_PS_BUTN, T = –1000** or **t_ps_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > 301.85$°C, $t < t_t = -138.255$°C or $t < t_{mel}(p)$
Saturated liquid or saturated vapor line:	at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at result $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

Saturation Temperature t_s = f(p)

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

Input Values:

P – Pressure p in bar

Result

TSPBUTN, **TS** or **ts_p_BUTN** - Saturation temperature t_s in °C

Range of validity

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to $p_c = 37.96$ bar

Results for wrong input values

Result **TSPBUTN = –1000**, **TS = –1000** or **ts_p_BUTN = –1000** for input values:

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

Melting Temperature t_{mel} = f(p)

Function Name:	**tmel_p_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION TMELBUTN(P)** REAL*8 P
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_TMELBUTN(TMEL,P)** REAL*8 TMEL,P

Input Values:

P – Pressure p in bar

Result

TMELPBUTN, **TMEL** or **tmel_p_BUTN** - Melting temperature t_{mel} in °C

Range of validity

Pressure range: from $p_t = 6.53 \times 10^{-6}$ bar to 690 bar

Results for wrong input values

Result **TMELBUTN = –1000**, **TMEL = –1000** or **tmel_p_BUTN = –1000** for input values:

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

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

Function Name:	**u_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION UPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_UPTXBUTN(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

UPTXBUTN, **U** or **u_ptx_BUTN** - Specific internal energy *u* in kJ/kg

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **UPTXBUTN = –1000**, **U = –1000** or **u_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**v_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION VPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_VPTXBUTN(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

VPTXBUTN, **V** or **v_ptx_BUTN** - Specific volume v in m^3/kg

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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.

(Saturated liquid and saturated vapor line:

Temperature ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **VPTXBUTN = –1000**, **V = –1000** or **v_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

Function Name:	**w_ptx_BUTN**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION WPTXBUTN(P,T,X)** REAL*8 P,T,X
Subroutine with parameter: for call from DLL	**INTEGER*4 FUNCTION C_WPTXBUTN(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

WPTXBUTN, **W** or **w_ptx_BUTN** – Speed of sound *w* in m/s

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 ranges from t_t = -138.255 °C to t_c = 151.975 °C

Pressure ranges from p_t = 6.53 x 10^{-6} bar to p_c = 37.96 bar)

Results for wrong input values

Result **WPTXBUTN = –1000** or **w_ptx_BUTN = –1000** for input values:

Single phase region: (x = –1)	$p > 690$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or $t > 301.85$°C or $t < t_{mel}$
Saturated liquid or saturated vapor line:	at $p = -1000$ and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C at $t = -1000$ and $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar or at $p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar and $t > t_c = 151.975$°C or $t < t_t = -138.255$°C

References: [22], [25]

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

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

Input Values:

P – Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

XPHBUTN, **X** or **x_ph_BUTN** – Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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. 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 = 6.53 x 10^{-6} bar to p_c = 37.96 bar

Results for wrong input values

Result **X_PH_BUTN**, **X = –1** or **x_ph_BUTN = –1** for input values:

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

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

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

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

Input Values:

P – Pressure *p* in bar

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

Result

XPSBUTN, **X** or **x_ps_BUTN** – Vapor fraction *x* in (kg saturated steam/kg wet steam)

Range of validity

Temperature range : from t_{mel} to 301.85°C

Pressure range : from $p_t = 6.53 \times 10^{-6}$ bar to 690 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 *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. 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 = 6.53 x 10^{-6} bar to p_c = 37.96 bar

Results for wrong input values

Result **X_PS_BUTN**, **X = –1** or **x_ps_BUTN = –1** for input values:

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

$p > p_c = 37.96$ bar or $p < p_t = 6.53 \times 10^{-6}$ bar

References: [22], [25]

KCE ThermoFluidProperties

KCE-ThermoFluidProperties
www.thermofluidprop.com

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

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

Water and Steam

Library LibIF97

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

Library LibIF97_META

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

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

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

and of the ideal gases:

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

Consideration of:

- Dissociation from VDI 4670
- Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

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

Consideration of:

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

Extremely Fast Property Calculations

Spline-Based Table Look-up Method (SBTL)

Library LibSBTL_IF97
Library LibSBTL_95
Library LibSBTL_HuAir

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

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

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

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

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

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

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

Consideration of:

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

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bücker and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

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

Helmholtz energy equation for the mixing term

(also useable for calculating the Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

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

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol

Library LibC2H5OH

Formulation of
Schroeder et al. (2014)

Methanol

Library LibCH3OH

Formulation of
de Reuck and Craven (1993)

Propane

Library LibPropane

Formulation of
Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

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

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

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

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

Formulation of Colonna et al. (2006)

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

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

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

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

Formulation of Colonna et al. (2008)

Nitrogen and Oxygen

**Libraries
LibN2 and LibO2**

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

Hydrogen

Library LibH2

Formulation of
Leachman et al. (2009)

Helium

Library LibHe

Formulation of
Arp et al. (1998)

Hydrocarbons

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

Isopentane C_5H_{12} **Library LibC5H12_Iso**

Neopentane C_5H_{12} **Library LibC5H12_Neo**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

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

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

Hydrogen sulfide H_2S **Library LibH2S**

Nitrous oxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

KCE
ThermoFluidProperties

For more information please contact:

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01307 Dresden, Germany

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

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

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density 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

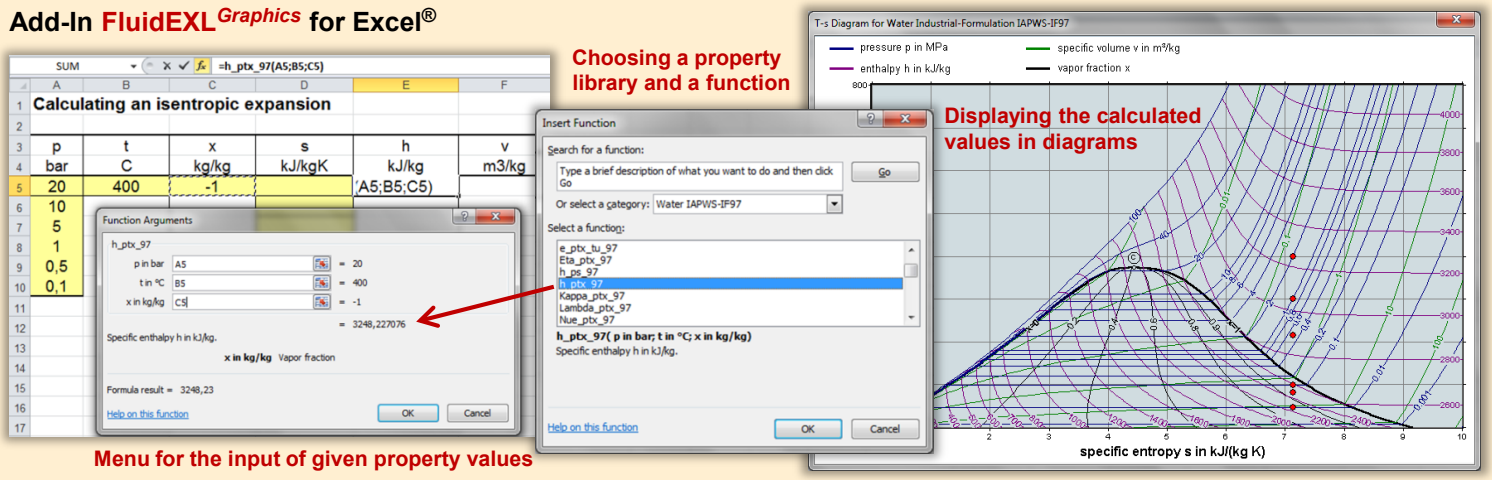
KCE-ThermoFluidProperties
www.thermofluidprop.com

KCE ThermoFluidProperties

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

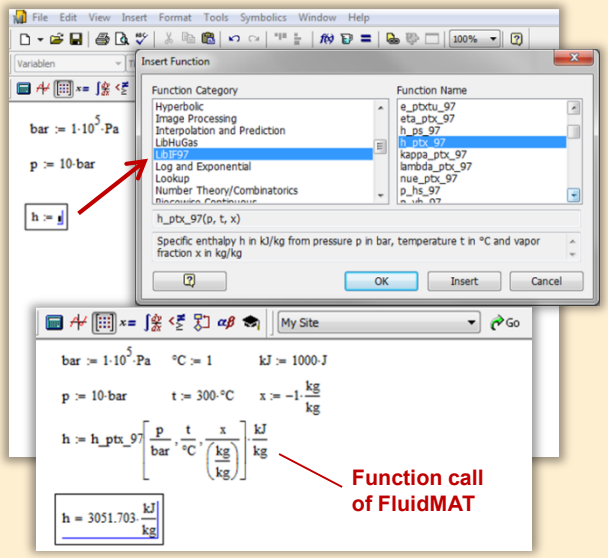
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



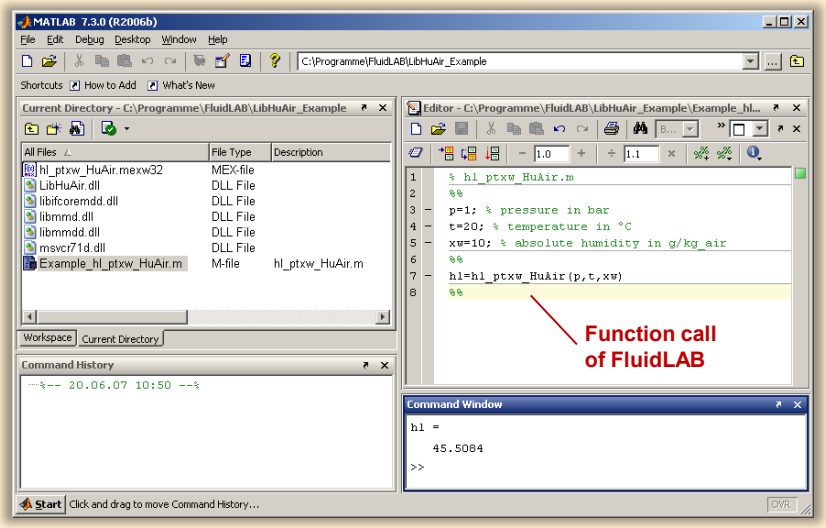
Add-On FluidMAT for Mathcad®
Add-On FluidPRIME for Mathcad Prime®

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



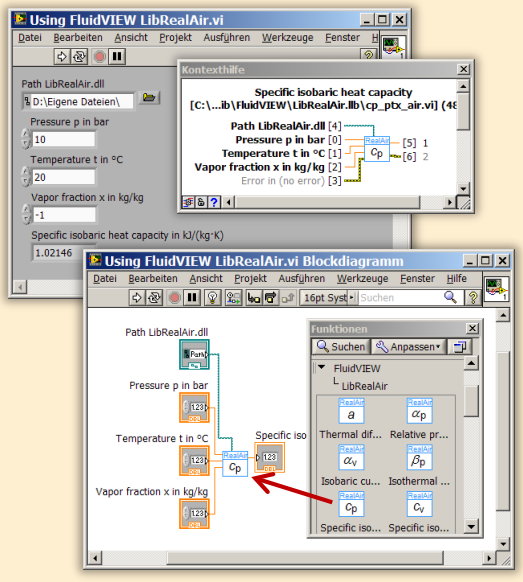
Add-On FluidLAB for MATLAB® and SIMULINK®

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



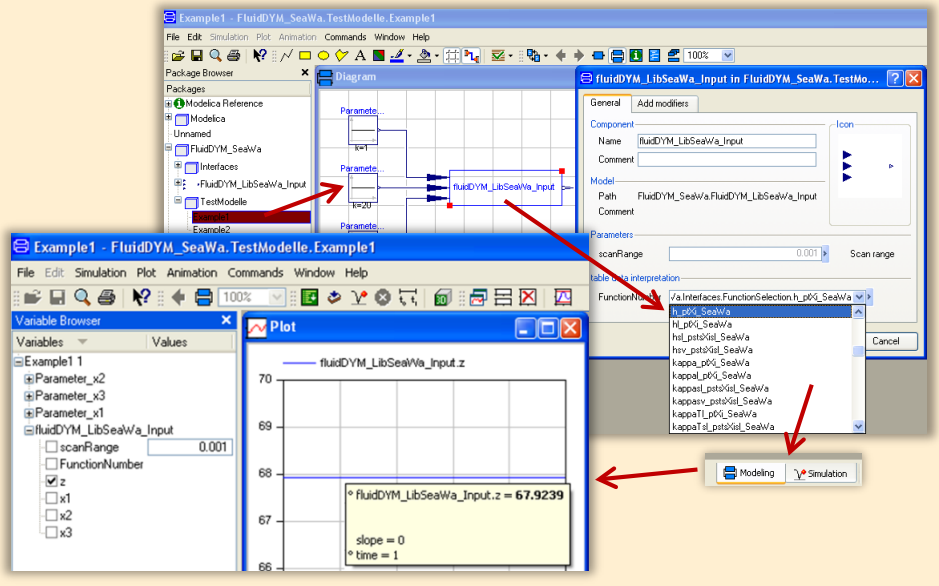
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

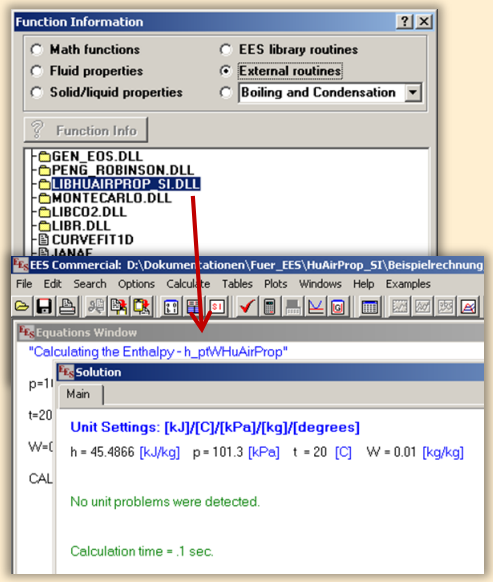


Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

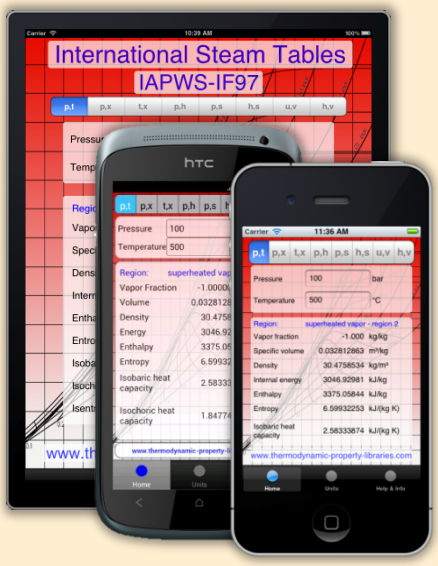
The property functions can be called in DYMOLA® and SimulationX®.



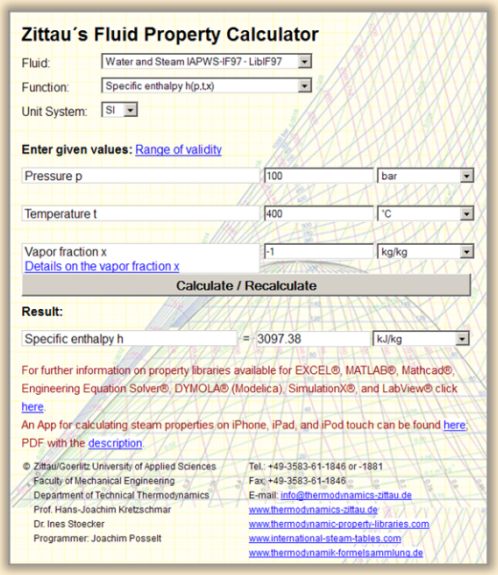
Add-On FluidEES for Engineering Equation Solver®



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:

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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

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IAPWS Sekretariat, Dooley, B, EPRI, Palo Alto CA (1997)

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The IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam.
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in: Steam, Water and Hydrothermal Systems: Physics and Chemistry Meeting the Needs of Industry, Proceedings of the 13th International Conference on the Properties of Water and Steam, Eds. P.G. Hill et al., NRC Press, Ottawa, 2000

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Springer-Verlag, Berlin (1998)

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IAPWS Sekretariat, Dooley, B., EPRI, Palo Alto CA, (1997)

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in: Steam, Water and Hydrothermal Systems: Physics and Chemistry Meeting the Needs of Industry, Proceedings of the 13th International Conference on the Properties of Water and Steam, Eds. P.G. Hill et al., NRC Press, Ottawa, 2000

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6. Satisfied Customers

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AIXPROCESS, Aachen	02/2018
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Doosan Lentjes, Ratingen	01/2018

2017

Compact Kältetechnik, Dresden	12/2017
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Fels-Werke GmbH, Elbingerode	10/2017
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Papierfabrik Koehler, Oberkirch	09/2017
ZWILAG, Würenlingen, Switzerland	09/2017
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017
Fichtner IT Consulting AG, Stuttgart	07/2017
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TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
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ULT Umwelt-Lufttechnik, Löbau	02/2017
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Kelvion Brazed PHE, Nobitz-Wilchwitz	02/2017
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Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	01/2017
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MARTEC Education Center, Frederikshaven, Denmark	01/2017
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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
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University of KwaZulu-Natal, Westville, South Africa	10/2011

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SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
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RWE, Essen	07/2011
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BASF, Ludwigshafen	02/2011
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EVONIK Energy Services, Zwingenberg	12/2010
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Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
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MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
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2009

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Dr. Nickolay, Consulting Engineers, Gommersheim	06/2009
Ferrostal Power, Saarlouis	06/2009
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Intraserv, Wiesbaden	06/2009
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Nuernberg University of Applied Sciences	06/2009

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AIC, Chemnitz	10/2009
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Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
FZD, Rossendorf	11/2009
Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
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MCI, Innsbruck, Austria	12/2009
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2008

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
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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
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AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
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2006

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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
Suedzucker, Ochsenfurt	06/2006
M&M Turbine Technology, Bielefeld	06/2006
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006

Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, 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
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
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

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MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
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Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
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STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003

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

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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Stadtwerke Hannover	09/2002
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G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

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KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
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Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001

h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
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VEAG, Berlin (group license)	12/2001

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AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000
IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
UMAG W. UDE, Husum	03/2000
VEAG, Berlin (group license)	03/2000
Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
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Bayernwerk, Munich	01/1999
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KEMA IEV, Dresden	03/1999
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
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
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SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

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Siemens Power Generation, Goerlitz	07/1997