Property Library for Iso-Butane

FluidPRIME
with LibButane_Iso
for Mathcad Prime®

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Property Library for Iso-Butane

LibButane_Iso

FluidPRIME for Mathcad Prime®

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0. Package Contents

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

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

1. Property Functions

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibButan_iso as parameter	Property or Function	Unit of the result
$a = f(p,t,x)$	a_ptx_BUTI	APTXBUTI(P,T,X)	C_APTXBUTI(A,P,T,X)	Thermal diffusivity	m^2/s
$c_p = f(p,t,x)$	cp_ptx_BUTI	CPPTXBUTI(P,T,X)	C_CPPTXBUTI(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$\eta = f(p,t,x)$	eta_ptx_BUTI	ETAPTXBUTI(P,T,X)	C_ETAPTXBUTI(ETA,P,T,X)	Dynamic viscosity	Pa s
$h = f(p,t,x)$	h_ptx_BUTI	HPTXBUTI(P,T,X)	C_HPTXBUTI(H,P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_BUTI	KAPTXBUTI(P,T,X)	C_KAPTXBUTI(KAP,P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lambda_ptx_BUTI	LAMPTXBUTI(P,T,X)	C_LAMPTXBUTI(LAM,P,T,X)	Thermal conductivity	W/(m K)
$\nu = f(p,t,x)$	ny_ptx_BUTI	NYPTXBUTI(P,T,X)	C_NYPTXBUTI(NY,P,T,X)	Kinematic viscosity	m^2/s
$p_{mel} = f(t)$	pmel_t_BUTI	PMELBUTI(T)	C_PMELBUTI(PMEL,T)	Melting pressure from temperature	bar
$p_s = f(t)$	ps_t_BUTI	PSTBUTI(T)	C_PSTBUTI(PS,T)	Vapor pressure from temperature	bar
$Pr = f(p,t,x)$	Pr_ptx_BUTI	PRPTXBUTI(P,T,X)	C_PRPTXBUTI(PR,P,T,X)	*Prandtl*-Number	-
$\rho = f(p,t,x)$	rho_ptx_BUTI	ROPTXBUTI(P,T,X)	C_ROPTXBUTI(RHO,P,T,X)	Density	kg/m^3
$s = f(p,t,x)$	s_ptx_BUTI	SPTXBUTI(P,T,X)	C_SPTXBUTI(S,P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_BUTI	TPHBUTI(P,H)	C_TPHBUTI(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_BUTI	TPSBUTI(P,S)	C_TPSBUTI(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t_{mel} = f(p)$	tmel_p_BUTI	TMELBUTI(P)	C_TMELBUTI(TMEL,P)	Melting temperature from pressure	°C
$t_s = f(p)$	ts_p_BUTI	TSPBUTI(P)	C_TSPBUTI(TS,P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_BUTI	UPTXBUTI(P,T,X)	C_UPTXBUTI(U,P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_BUTI	VPTXBUTI(P,T,X)	C_VPTXBUTI(V,P,T,X)	Specific volume	m^3/kg

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibButan_iso as parameter	Property or Function	Unit of the result
w = f(*p*,*t*,*x*)	w_ptx_BUTI	WPTXBUTI(P,T,X)	C_WPTXBUTI(W,P,T,X)	Isentropic speed of sound	m/s
x = f(*p*,*h*)	x_ph_BUTI	XPHBUTI(P,H)	C_XPHBUTI(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
x = f(*p*,*s*)	x_ps_BUTI	XPSBUTI(P,S)	C_XPSBUTI(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 t: from $t_{mel}(p)$ to 301.85 °C

Pressure p: from $p_t = 2.19 \times 10^{-7}$ bar to 350 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.

Wet steam region: Temperature from t_t = –159.42 °C to t_c = 134.66 °C

Pressure from $p_t = 2.19 \times 10^{-7}$ bar to 36.29 bar

Note!

If the input values are located outside the range of validity, the result for the calculated function will always be –1000. You can 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_iso property library.

2.1 Installing FluidPRIME

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

CD_FluidPRIME_LibButan_iso

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_iso_Docu.pdf
Functions_LibButan_iso.mcdx
LibButan_iso.msi
setup.exe
LibButan_iso.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_iso.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".

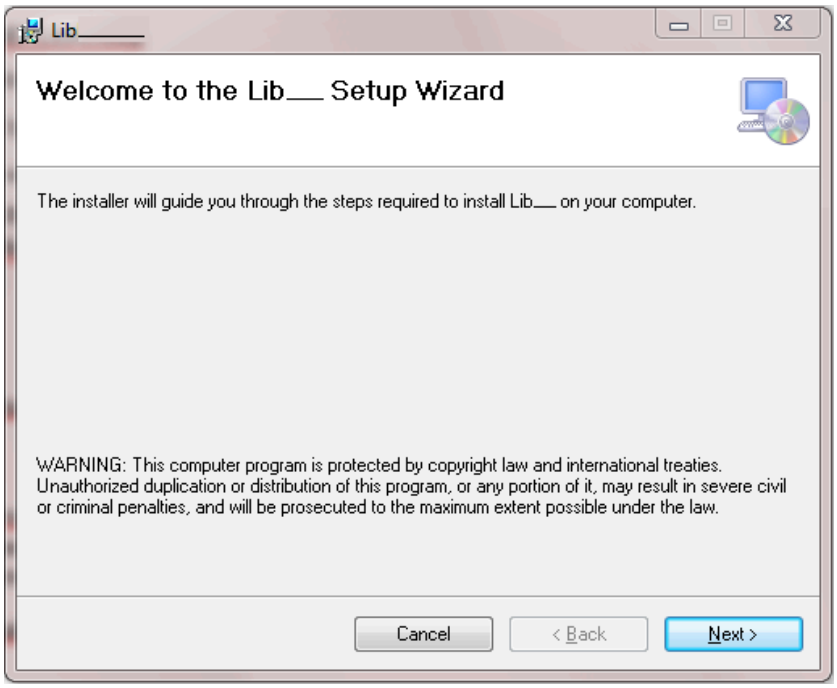

Figure 2.1: Setup Wizard

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

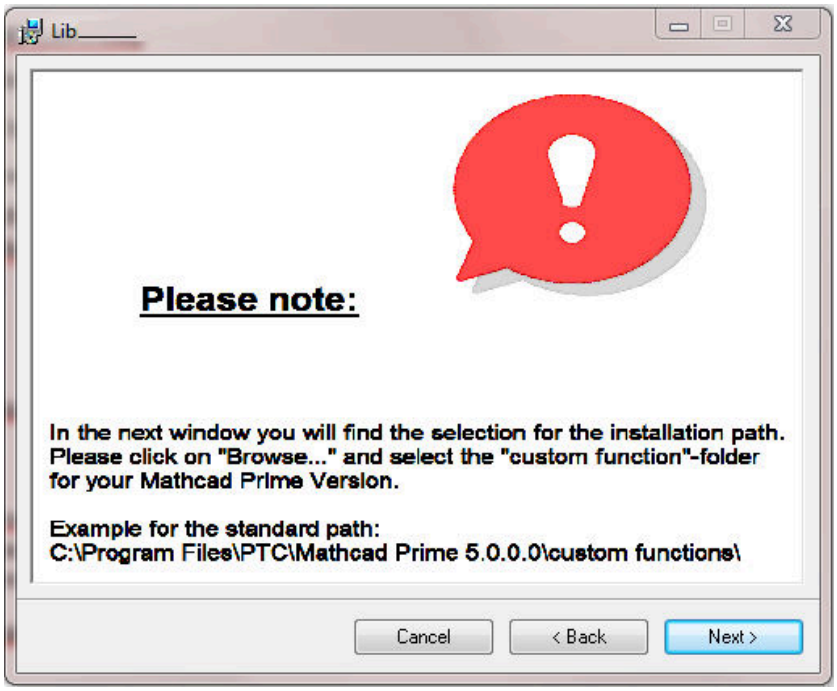

Figure 2.2: Note Window

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

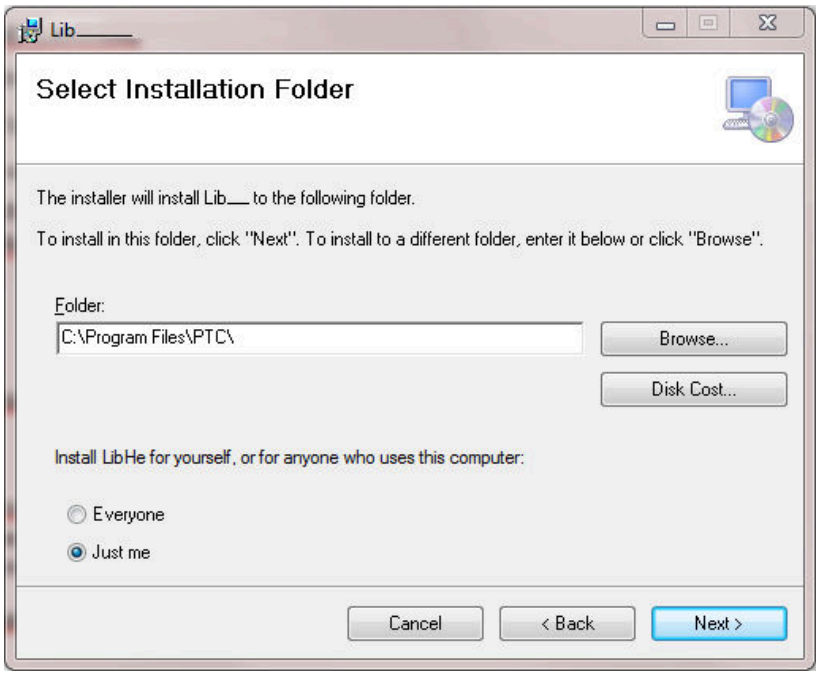

Figure 2.3: Select Installation Folder

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.

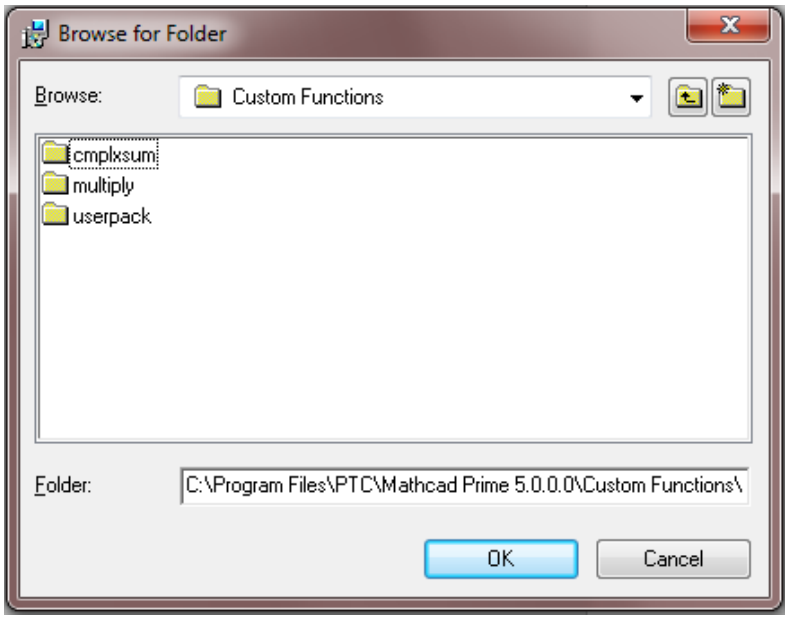

Figure 2.4: "Browse for Folder"-window with the full installation path

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

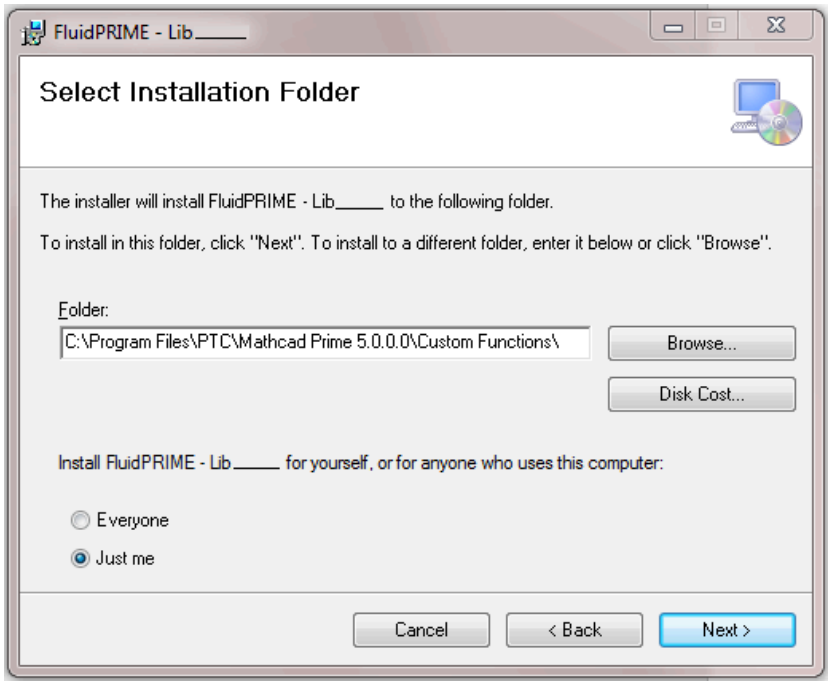

Figure 2.5: "Select Installation Folder"-window

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_iso is finished.

Finally, please copy or overwrite the LibButan_iso.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_iso.dll	PRIME_LibButan_iso.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_iso 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_iso, using FluidPRIME.

- Start Mathcad Prime.
- Type "p:" and enter the value for the pressure *p* in bar.
  (Range of validity of the Butan_iso: from p_t = 2.19 x 10^{-7} bar to 350 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_iso: from $t_{mel}(p)$ 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.

Wet steam region: Temperature from t_t = –159.42 °C to t_c = 134.66 °C

Pressure from p_t = 2.19 x 10^{-7} bar to 36.29 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:

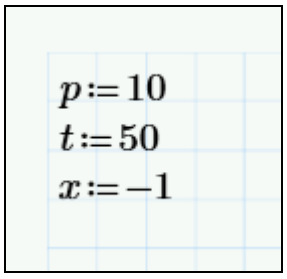

Figure 2.3: Example Mathcad Prime® sheet after input of the given parameters

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

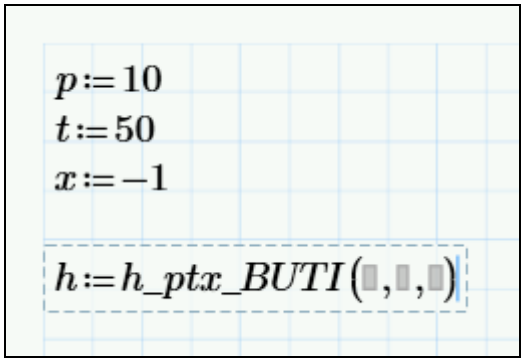

Figure 2.4: Example Mathcad Prime® sheet

- 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=322.112. 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.

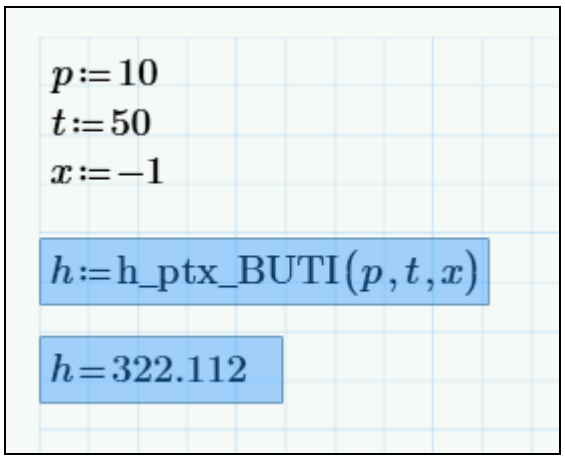

Figure 2.5: Example Mathcad Prime® sheet with finished calculation

2.4 Removing FluidPRIME

To remove FluidPRIME with the library LibButan_Iso 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_Iso" 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_Iso has been removed.

3. Program Documentation

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

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

APTXBUTI, **A** or **a_ptx_BUTI** – 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 $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **APTXBUTI = –1000**, **A = –1000** or **a_ptx_BUTI = –1000** for input values

Single phase region: ($x = -1$)
$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
$t > 301.85$°C or $t < t_{mel}$

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or

at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and
$t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25], [27]

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

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

CPTXBUTI, **CP** or **cp_ptx_BUTI** – 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 $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **CPPTXBUTI = –1000**, **CP = –1000** or **cp_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

Dynamic Viscosity η = f(p,t,x)

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

ETAPTXBUTI, **ETA** or **eta_ptx_BUTI** – Dynamic viscosity η in Pa s

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **ETAPTXBUTI= –1000**, **ETA = –1000** or **eta_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25], [26]

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

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

HPTXBUTI, **H** or **h_ptx_BUTI** - Specific enthalpy *h* in kJ/kg

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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.

(Boiling and dew curve: Temperature ranges from t_t = -159.42°C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **HPTXBUTI = –1000**, **H = –1000** or **h_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

Isentropic Exponent κ = f(p,t,x)

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

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

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **KAPTXBUTI**, **KAP = –1000** or **kappa_ptx_BUTI = –1000** for input values

Boiling or dew curve: at p = –1000 and $t > tc$ = 134.66 °C or $t < t_t$ = –159.42 °C

Single phase region: (x = –1)
$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
$t > 301.85$°C or $t < t_{mel}$

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or

at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and
$t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

Thermal Conductivity λ = f(p,t,x)

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

LAMPTXBUTI, **LAM** or **lambda_ptx_BUTI** – Thermal conductivity λ in W / m K

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **LAMPTXBUTI = –1000**, **LAM = –1000** or **lambda_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25], [27]

Kinematic Viscosity ν = f(p,t,x)

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

NYPTXBUTI, **NY** or **ny_ptx_BUTI** – 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 $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **NYPTXBUTI = –1000**, **NY = –1000** or **ny_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25], [26]

Melting Pressure p_{mel} = f(t)

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

Input Values

T - Temperature t in °C

Result

PMELTBUTI, **PMEL** or **pmel_t_BUTI** – Melting pressure p_{mel} in bar

Range of validity

Temperature range : from $t_t = -159.42$°C to -147.751 °C

Results for wrong input values

Result **PMELBUTI = –1000**, **PMEL = –1000** or **pmel_t_BUTI = –1000** for input values

$t < t_t = -159.42$°C or $t > -147.751$°C

References: [22], [25]

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

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

PRPTXBUTI, **PR** or **Pr _ptx _BUTI** – Prandtl – Number $\mathrm{Pr} = \frac{\eta * c_p}{\lambda}$

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **PRPTXBUTI = –1000**, **PR = –1000** or **Pr_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25], [26], [27]

Vapor Pressure p_s = f(t)

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

Input Values

T - Temperature t in °C

Result

PSTBUTI, **PS** or **ps_t_BUTI** – Vapor pressure p_s in bar

Range of validity

Temperature range : from $t_t = -159.42$°C to $t_c = 134.66$°C

Results for wrong input values

Result **PSTBUTI = –1000**, **PS = –1000** or **ps_t_BUTI = –1000** for input values

$t < t_t = -159.42$°C or $t > t_c = 134.66$°C

References: [22], [25]

Density ρ = f(p,t,x)

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

RHOPTXBUTI, **RHO** or **rho_ptx_BUTI** – Density ρ in kg / m^3

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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.

(Boiling and dew curve: Temperature ranges from t_t = -159.42°C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **ROPTXBUTI = –1000**, **RHO = –1000** or **rho_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

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

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

SPTXBUTI, **S** or **s_ptx_BUTI** - Specific entropy *s* in kJ/kg K

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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.

(Boiling and dew curve: Temperature ranges from t_t = -159.42°C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **SPTXBUTI = –1000**, **S = –1000** or **s_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

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

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

Input Values

P – Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

TPHBUTI, **T** or **t_ph_BUTI** – Temperature *t* in °C

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = 2.19 x 10^{-7} bar to p_c = 36.29 bar

Results for wrong input values

Result **T_PH_BUTI**, **T = –1000** or **t_ph_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or at result $t > 301.85$°C, $t < t_t = -159.42$°C or $t < t_{mel}(p)$
Boiling or dew curve:	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or at result $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

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

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

Input Values

P – Pressure p in bar

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

Result

TPSBUTI, **T** or **t_ps_BUTI** – Temperature t in °C

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = 2.19 x 10^{-7} bar to p_c = 36.29 bar

Results for wrong input values

Result **T_PS_BUTI, T = –1000** or **t_ps_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or at result $t > 301.85$°C, $t < t_t = -159.42$°C or $t < t_{mel}(p)$
Boiling or dew curve:	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or at result $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

Saturation Temperature t_s = f(p)

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

Input Values

P – Pressure p in bar

Result

TSPBUTI, **TS** or **ts_p_BUTI** - Saturation temperature t_s in °C

Range of validity

Pressure range: from $p_t = 2.19 \times 10^{-7}$ bar to $p_c = 36.29$ bar

Results for wrong input values

Result **TSPBUTI = –1000**, **TS = –1000** or **ts_p_BUTI = –1000** for input values

$p < p_t = 2.19 \times 10^{-7}$ bar or $p > p_c = 36.29$ bar

References: [22], [25]

Melting Temperature t_{mel} = f(p)

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

Input Values

P – Pressure p in bar

Result

TMELPBUTI, **TMEL** or **tmel_p_BUTI** - Melting temperature t_{mel} in °C

Range of validity

Pressure range: from $p_t = 2.19 \times 10^{-7}$ bar to 350 bar

Results for wrong input values

Result **TMELBUTI = –1000**, **TMEL = –1000** or **tmel_p_BUTI = –1000** for input values

$p < p_t = 2.19 \times 10^{-7}$ bar or $p > p_c = 36.29$ bar

References: [22], [25]

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

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

UPTXBUTI, **H** or **u_ptx_BUTI** - Specific internal energy *u* in kJ/kg

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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.

(Boiling and dew curve: Temperature ranges from t_t = -159.42°C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **UPTXBUTI = –1000**, **H = –1000** or **u_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

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

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

VPTXBUTI, **V** or **v_ptx_BUTI** - Specific volume v in m^3/kg

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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.

(Boiling and dew curve: Temperature ranges from t_t = -159.42°C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **VPTXBUTI = –1000**, **H = –1000** or **v_ptx_BUTI = –1000** for input values

Single phase region: (x = –1)	$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or $t > 301.85$°C or $t < t_{mel}$
Boiling or dew curve:	at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C
	at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
	at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

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

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

WPTXBUTI, **W** or **w_ptx_BUTI** – Speed of sound w in m/s

Range of validity

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

Pressure range : from $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = -159.42 °C to t_c = 134.66 °C

Pressure ranges from p_t = 2.19 x 10^{-7} bar to p_c = 36.29 bar)

Results for wrong input values

Result **WPTXBUTI = –1000** or **w_ptx_BUTI = –1000** for input values

Single phase region: ($x = -1$)
$p > 350$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or
$t > 301.85$°C or $t < t_{mel}$

Boiling or dew curve:
at $p = -1000$ and $t > t_c = 134.66$°C or $t < t_t = -159.42$°C

at $t = -1000$ and $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar or

at $p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar and
$t > t_c = 134.66$°C or $t < t_t = -159.42$°C

References: [22], [25]

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

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

Input Values

P – Pressure *p* in bar

H - Specific enthalpy *h* in kJ/kg

Result

XPHBUTI, **X** or **x_ph_BUTI** – 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 $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = 2.19 x 10^{-7} bar to p_c = 36.29 bar

Results for wrong input values

Result **X_PH_BUTI**, **X =** –1 or **x_ph_BUTI =** –1 for input values

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

$p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ bar

References: [22], [25]

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

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

Input Values

P – Pressure *p* in bar

S - Specific entropy in kJ/(kg K)

Result

XPSBUTI, **X** or **x_ps_BUTI** – 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 $p_t = 2.19 \times 10^{-7}$ bar to 350 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 = 2.19 x 10^{-7} bar to p_c = 36.29 bar

Results for wrong input values

Result **X_PS_BUTI**, **X =** –1 or **x_ps_BUTI =** –1 for input values

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

$p > p_c = 36.29$ bar or $p < p_t = 2.19 \times 10^{-7}$ 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:

KCE-ThermoFluidProperties UG & Co. KG
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01307 Dresden, Germany

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

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

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

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

www.thermofluidprop.com

KCE-ThermoFluidProperties
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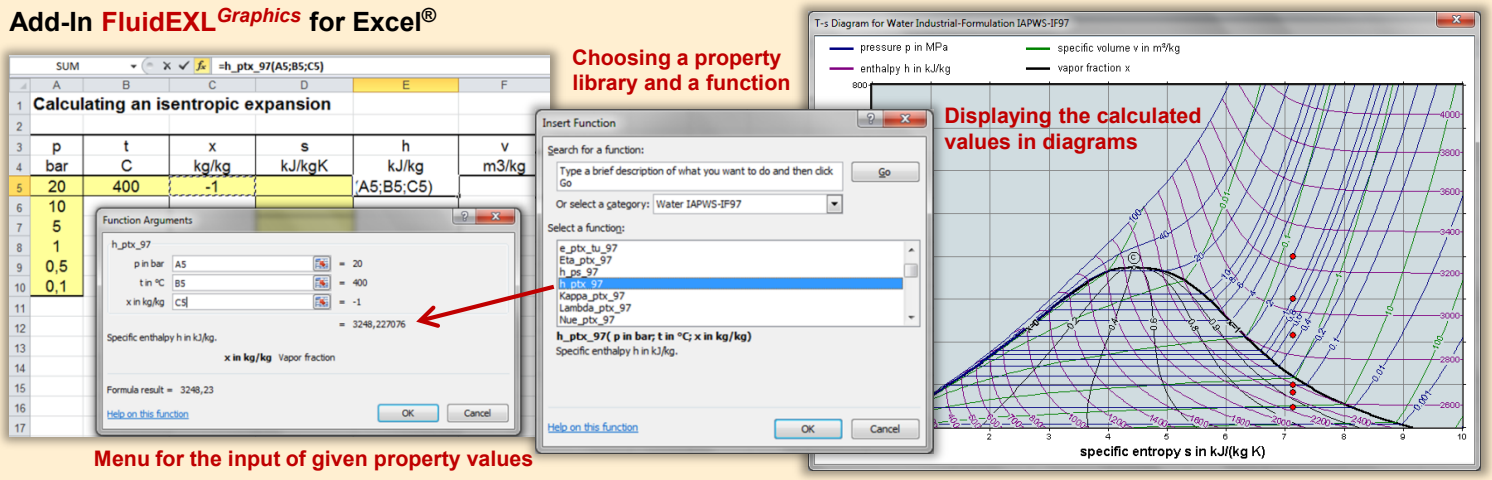
KCE ThermoFluidProperties

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

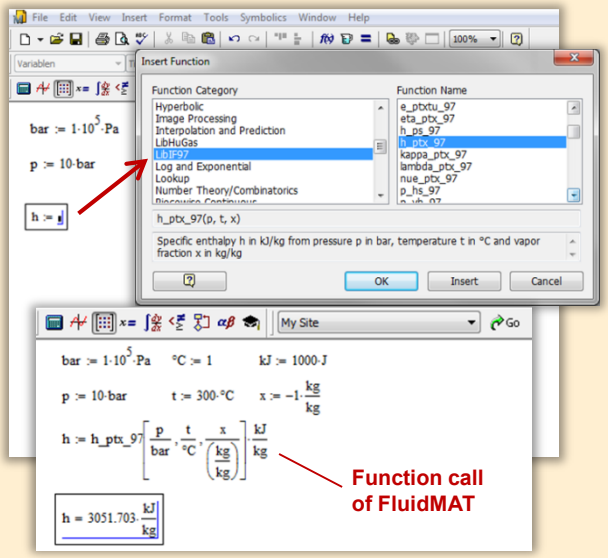
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



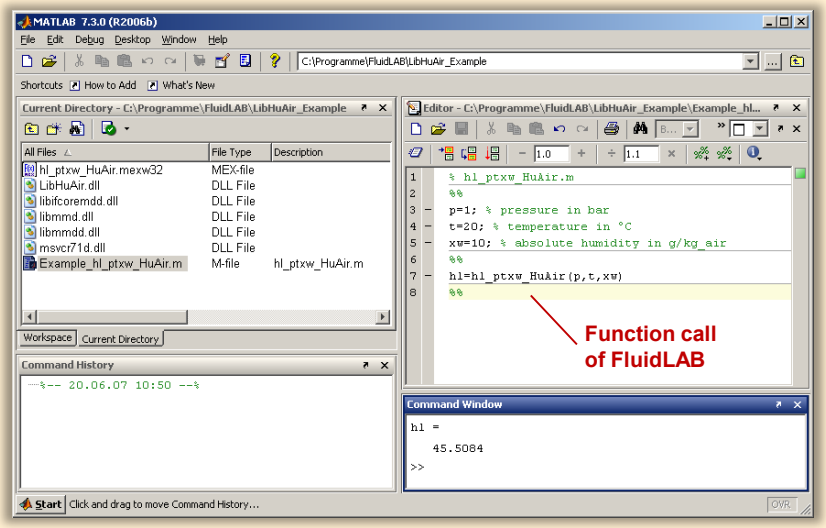
Add-On FluidMAT for Mathcad®
Add-On FluidPRIME for Mathcad Prime®

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



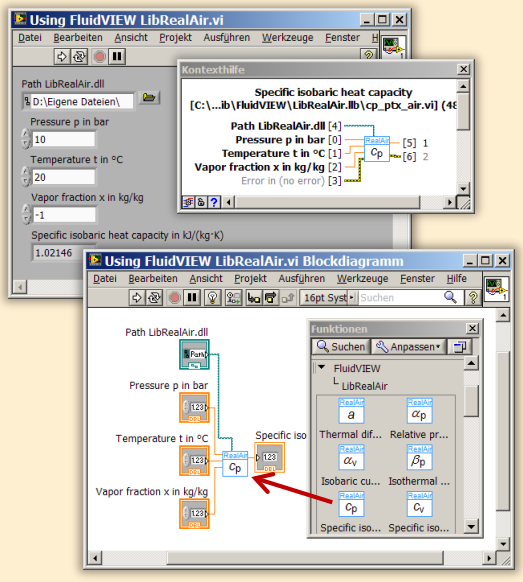
Add-On FluidLAB for MATLAB® and SIMULINK®

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



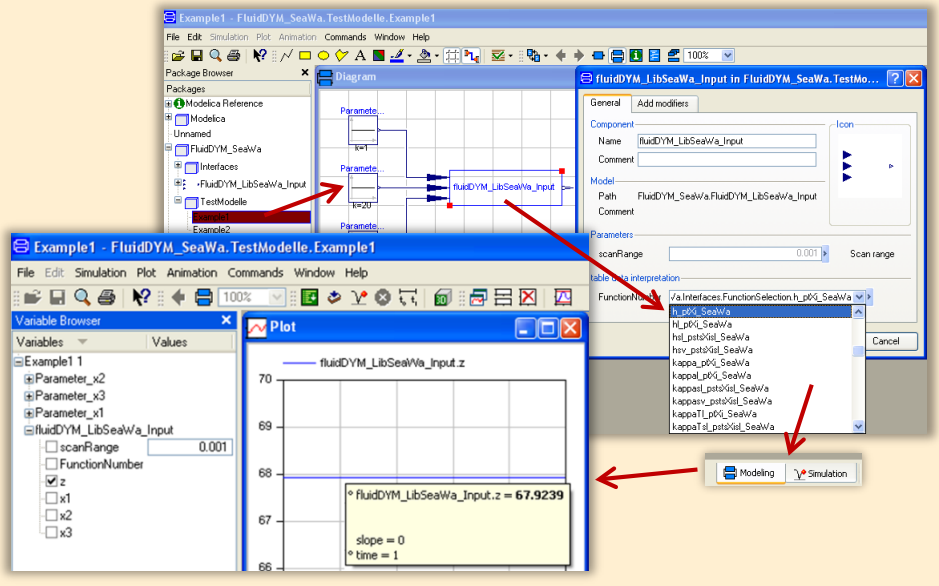
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

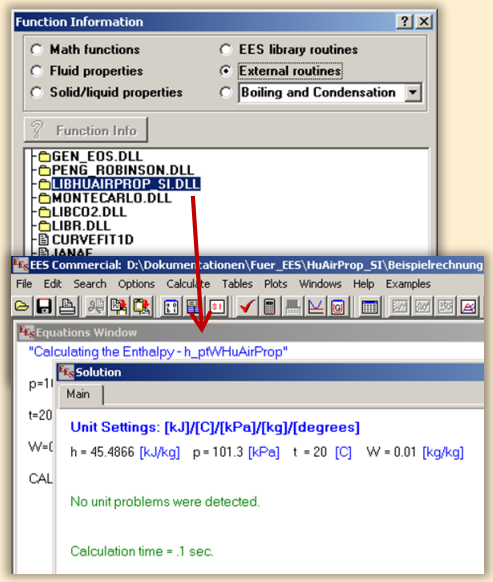


Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

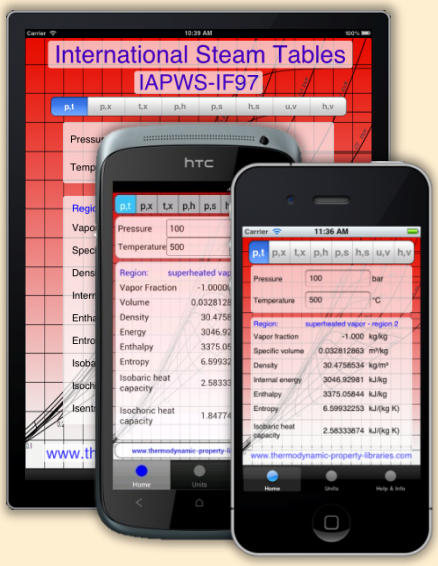
The property functions can be called in DYMOLA® and SimulationX®.



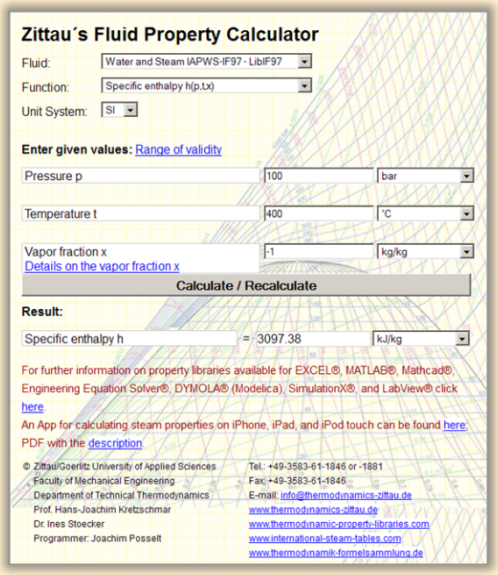
Add-On FluidEES for Engineering Equation Solver®



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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6. Satisfied Customers

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GRS, Köln	03/2018
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	02/2018
AIXPROCESS, Aachen	02/2018
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Doosan Lentjes, Ratingen	01/2018

2017

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Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	12/2017
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Haarslev Industries, Søndersø, Denmark	11/2017
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ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	10/2017
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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BORSIG Service, Berlin	06/2017

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CES clean energy solutions, Wien, Austria	04/2017
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B2P Bio-to-Power, Wadersloh	04/2017
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SAINT-GOBAIN, Vaujours, France	03/2017
TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
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KAESER Kompressoren, Gera	03/2017
F&R, Praha, Czech Republic	03/2017
ULT Umwelt-Lufttechnik, Löbau	02/2017
JS Energie & Beratung, Erding	02/2017
Kelvion Brazed PHE, Nobitz-Wilchwitz	02/2017
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Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	01/2017
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2016

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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
Voith, Heidenheim-Mergelstetten	09/2011
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AGO, Kulmbach	03/2011
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BASF, Ludwigshafen	02/2011
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EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
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Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
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HUBER Consulting Engineers, Berching	04/2010
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MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
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2009

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BOSCH, Stuttgart	06/2009, 07/2009
Dr. Nickolay, Consulting Engineers, Gommersheim	06/2009
Ferrostal Power, Saarlouis	06/2009
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Intraserv, Wiesbaden	06/2009
Lausitz University of Applied Sciences, Senftenberg	06/2009
Nuernberg University of Applied Sciences	06/2009

Technical University of Berlin	06/2009
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Fichtner IT Consulting, Stuttgart	07/2009
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Vattenfall, Hamburg	10/2009
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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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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RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
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Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008

Technip Benelux BV, Zoetermeer, Netherlands	08/2008
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TUEV Sued, Dresden	10/2008
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AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
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Tissue Europe Technologie, Mannheim	06/2007
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National Energy Technology Laboratory, Pittsburg, USA	10/2007
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Grenzebach BSH, Bad Hersfeld	10/2007

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University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

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

2005

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

2004

Vattenfall Europe (group license)	01/2004
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University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004
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
Munich University of Applied Sciences	12/2004
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
Ingenieurbuero Ostendorf, Gummersbach	05/2003
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
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002

FZR Forschungszentrum, Rossendorf/Dresden	03/2002
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GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
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SoftSolutions, Muehlhausen (company license)	05/2002
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PCK Raffinerie, Schwedt (group license)	07/2002
Fischer-Uhrig Engineering, Berlin	08/2002
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	08/2002
Stadtwerke Duisburg	08/2002
Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

2001

ALSTOM Power, Baden, Switzerland	01/2001, 06/2001 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001

h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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

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

1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
M&M Turbine Technology Bielefeld	06/1998
B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998
SCA Hygiene Products, Munich	10/1998
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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Gerb, Dresden	06/1997
Siemens Power Generation, Goerlitz	07/1997