

Property Library for the Industrial Formulation IAPWS-IF97 for Water and Steam

FluidPRIME with LibIF97_Stud for Mathcad Prime[®]

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Property Library for the Industrial Formulation IAPWS-IF97 for Water and Steam

LibIF97_Stud FluidPRIME for Mathcad Prime[®]

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0. Package Contents

Zip file "CD_FluidPRIME_LibIF97_Stud.zip" includes the following files:

FluidPRIME_LibIF97_Stud_Docu.pdf

- User's Guide

Functions_LibIF97_Stud.mcdx

- Mathcad Prime[®] worksheet with all functions
- LibIF97_Stud.msi

setup.exe

- MSI installer
- Setup installer

1. Program Functions

1.1 Range of Validity

The International Association for the Properties of Water and Steam IAPWS issued the

"Release on the IAPWS Industrial Formulation 1997

for the Thermodynamic Properties of Water and Steam IAPWS-IF97"

in September 1997 [1], [2]. It will be abbreviated as IAPWS-IF97. This industrial standard must be applied worldwide in acceptance and guarantees calculations of facilities and plants working with water or steam.

Figure 1.1 shows the entire range of validity for the equation set of the Industrial Formulation IAPWS-IF97. It includes temperatures from 0 °C to 800 °C at pressures from 0.00611 bar to 1000 bar and temperatures to 2000 °C for pressures to 500 bar.



Figure 1.1 Entire Range of Validity of the IAPWS-IF97

The range of validity is divided into five calculation regions. Each of the calculation regions contains its own equations of state. They are described in detail in the official Release of the IAPWS [1] and in the publication of *Kretzschmar* and *Wagner* [2].

The sub-programs of the LibIF97_Stud library are valid in Regions 1,2, and 4.

1.2 Functions

Functional Dependence	Function Name	Property or Function	Unit of the Result	References
$c_p = f(p,t,x)$	cp_ptx_97_Stud	Specific isobaric heat capacity	kJ/(kg·K)	[1], [2]
$\eta = f(p,t,x)$	eta_ptx_97_Stud	Dynamic viscosity	Pa s = kg/(m s)	[1], [2], [5]
h = f(p,t,x)	h_ptx_97_Stud	Specific enthalpy	kJ/kg	[1], [2], [7]
$\lambda = f(p,t,x)$	lambda_ptx_97_stud	Heat conductivity	W/(m·K)	[1], [2], [4]
$p_{\rm s} = f(t)$	ps_t_97_Stud	Vapor pressure	bar	[1], [2], [8]
s = f(p,t,x)	s_ptx_97_stud	Specific entropy	kJ/(kg⋅K)	[1], [2], [7]
<i>t</i> = f(<i>p</i> , <i>h</i>)	t_ph_97_Stud	Backward function: Temperature from pressure and enthalpy	°C	[1], [2], [7]
<i>t</i> = f(<i>p</i> , <i>s</i>)	t_ps_97_Stud	Backward function: Temperature from pressure and entropy	°C	[1], [2], [7]
v = f(p,t,x)	v_ptx_97_Stud	Specific volume	m ³ /kg	[1], [2]
x = f(p,h)	x_ph_97_Stud	Backward function: Vapor fraction from pressure and enthalpy	kg/kg	[1], [2], [7]
x = f(p,s)	x_ps_97_Stud	Backward function: Vapor fraction from pressure and entropy	kg/kg	[1], [2], [7]

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U	III.J.	

t in °C

p in bar

x in kg saturated steam/kg wet steam

Range of validity of the property library

Temperature:	from 0 °C to 350 °C
Pressure:	from 0.00611 bar to 1000 bar

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

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

Single-phase region

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

Wet-steam region

If the state point to be calculated is located in the wet steam region

-> a value for x between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

In this case, the backward functions result in the appropriate value between 0 and 1 for *x*.

When calculating wet steam <u>either</u> the given value for t and p = -1 or the given value for p and t = -1 and1 and

in both cases the value for x between 0 and 1 must be entered.

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

If this is not the case the calculation for the property of the chosen function results in -1.

Wet steam region of the IAPWS-IF97: Temperature from 0 °C to 350 °C

Pressure from 0.00611 bar to 15.29164 bar

Note.

If the calculation results in -1, the values entered represent a state point beyond the range of validity of IAPWS-IF97.

1.3 Thermodynamic Diagrams

FluidEXL^{Graphics}Stud enables the user to represent the calculated properties in the following thermodynamic diagrams:

- <i>T-s</i> diagram	- <i>T-h</i> diagram
- h-s diagram	- <i>T-log(v)</i> diagram
- <i>log(p)-h</i> diagram	- <i>log(p)-s</i> diagram
- <i>log(p)-log(v)</i> diagram	- <i>h-log(v)</i> diagram
- <i>log(p)-T</i> diagram	- <i>s-log(v)</i> -diagram

- p-T diagram

The diagrams, in which the calculated state point will be displayed, are shown on the following pages.









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KCE-ThermoFluidProperties, Prof. Dr. Hans-Joachim Kretzschmar

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 LibIF97 property library.

2.1 Installing FluidPRIME

In this section, the installation of FluidPRIME LibIF97_Stud is described. After you have downloaded and extracted the zip-file "CD_FluidPRIME_LibIF97_Stud.zip", you will see the folder

CD_FluidPRIME_LibIF97_Stud

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_LibIF97_Stud_Docu.pdf Functions_LibIF97_Stud.mcdx LibIF97_Stud.msi setup.exe

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 double click

LibIF97_Stud.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.

, ciu <u> </u>			
Please n	ote:		
In the next window yo Please click on "Brow for your Mathcad Prin	u will find the a se" and selection the Version.	selection for the ct the "custom	e installation path. function"-folder
Example for the stand C:\Program Files\PTC	ard path: Mathcad Prin	ne 5.0.0.0\cust	om functions\

Figure 2.2: Note Window

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

员 Lib	
Select Installation Folder	5
The installer will install Lib to the following folder.	
To install in this folder, click "Next". To install to a different folder, e	nter it below or click "Browse".
Folder	
C:\Program Files\PTC\	Browse
	Disk Cost
Install Likkle for yourself, or for anyone who uses this computer:	
instali done foi yoursell, of foi anyone who uses this computer.	
Everyone	
Just me	

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 $\mathsf{Prime}^{\texttt{R}}$ version folder. For example

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

or

C:\Program Files\PTC\Mathcad Prime 7.0.0.0 (Version 7.0.0.0).

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 7.0.0.0\Custom Functions\ or

C:\Program Files\PTC\Mathcad Prime 7.0.0.0\Custom Functions\ that you can also see in Figure 2.4.

older 🗾 🔜
Custom Functions 🗸 🖻 🛅
C:\Program Files\PTC\Mathcad Prime 5.0.0.0\Custom Functions\

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".

😸 FluidPRIME - Lib 🗉 🛛 🖂
Select Installation Folder
The installer will install FluidPRIME - Lib to the following folder.
To install in this folder, click "Next". To install to a different folder, enter it below or click "Browse".
Eolder: C:\Program Files\PTC\Mathcad Prime 5.0.0.0\Custom Functions\ Disk Cost Install EluidPBIME - Lib for yourself, or for anyone who uses this computer:
© Everyone
Just me
Cancel < Back Next >

Figure 2.5: "Select Installation Folder"-window

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

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

The installation of FluidPRIME with the library LibIF97_Stud is finished.

Note:

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

2.2 Licensing the LibIF97 Property Library

Within the installation that was shown in chapter 2.1 the licensing key has been 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-IF97, using FluidPRIME.

- Start Mathcad Prime.
- Type "*p*:" and enter the value for the pressure *p* in bar. (Range of validity of the IF97: $p = 0.00611 \dots 1000$ bar)

e. g.: Enter "p: 100 bar" for the first operand

Type "t:" and enter the value for the temperature t in °C.
 (Range of validity of the IF97: 0 °C ... 2000.00 °C for p ≤ 100 bar
 0 °C ... 800.00 °C for 100 bar

e. g.: Enter "t: 400 °C" for the second operand

Type "x:" and enter the value for the vapor fraction x in kg_{sat. steam} / kg_{wet steam}.
 Since the wet steam region is calculated automatically by the subprograms, the following fixed details on the vapor fraction x are to be considered when the value for x is entered:

Single-phase region

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

Wet-steam region

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

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

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

Wet steam region of the IAPWS-IF97: $t_{t} = 0 \text{ °C} \dots t_{c} = 373.946 \text{ °C}$ $p_{t} = 0.00611 \text{ bar} \dots p_{c} = 220.64 \text{ bar}$

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

- Confirm your entry by pressing the "ENTER" key.
- To insert units you can type it directly behind the value or you can use the units menu to search for the desired units (see Figure 2.6, marked red).

M) 🖂 🛯	$\mathbf{n} \simeq$										PTC Math	cad Prime 7.0.0.0 -
	Math	Input/Output	Functions	Matrices	/Tables	Plots	Math	Formatting	Text Formatting	Calculation	Document	Resources	
x+y Math	= } Solve Block	Chart Component	Text Block A Text Block A Text Box Image Image	Delete Region	∛ Operators	; * Sy	β mbols ∗	if Programming	π • Constants •	$x \rightarrow$ Symbolics \cdot	Galabels (-) • a Subscript Lequation Break	m Units •	MUnit System: SI MBase Units
		Region	s					Operators and Syr	mbols		Style		Units

Figure 2.6: Mathcad Prime[®] menu bar with the units function

- Your Mathcad Prime calculation window should look like Figure 2.7.

p:	=1	00	ba	r	
t	=4	00	°C		
x:	=-	-1			

Figure 2.7: Example Mathcad Prime[®] sheet after input of the given parameters

- Now, open the file Functions_LibIF97_Stud.mcdx. In this Mathcad Prime[®] worksheet you can find all functions of the library (see Figure 2.8).

M 🗅 🖆 🖬 🗠 📨 PTC Mathcad Prime 7.0.0.0 - (AKADEMISCH]						
Rechnen Eingabe/Ausgabe Funktionen	Matrizen/Tabellen Diagramme	Mathematische Formatierung Textformatierung Berechnung Dokument Ressourcen				
Tex nen Lösungsblock Diagrammkomponente - Siller	block feid Bereich Iöschen Syn	$ \begin{array}{c c} \beta & \text{if} & \pi & x \rightarrow \\ \text{bole} & \text{Programmierung} & \text{Konstanten} & \text{Symbolische} \\ \text{Mothematik} & \text{Intelligentiation of the state of the symbolic state } \\ \text{Mothematik} & \text{Intelligentiation of the symbolic state } \end{array} $	2 ∰Einheitensystem: SI ▼ ≥m ▼ Basiseinheiten SI ▼ Einfügen			
Sereiche		Operatoren und Symbole Stil	Einheiten Zwischenablage			
enannt Functions_LibIF97_Stud						
	Functions of LibIFS	7_Stud property calculation library for Mathcad Prime	Property or			
	Dependence	Madicad Prime Paredon	Function			
	$c_p = f(p,t,x)$	$cp_ptx_97_Stud\left(\frac{p}{bar}, t-273.15 \ K, x\right) \frac{10^3 \ J}{kg \cdot K}$	Specific isobaric heat capacity			
	$\eta = f(p,t,x)$	$eta_ptx_97_Stud\left(\frac{p}{bar}, t-273.15 \ \textbf{K}, x\right) \frac{kg}{m \cdot s}$	Dynamic viscosity			
	h = f(p,t,x)	$h_ptx_97_Stud\left(\frac{p}{bar}, t-273.15\ K, x\right)\frac{10^3\ J}{kg}$	Specific enthalpy			
	$\lambda = f(p, t, x)$	$lambda_ptx_97_Stud\left(rac{p}{bar}, t-273.15\ K, x ight)rac{W}{m\cdot K}$	Heat conductivity			
	$\rho_{\rm S} = f(t)$	$ps_t_97_Stud(t-273.15 \text{ K}) \cdot bar$	Saturation pressure (vapor pressure)			
	s = f(p, t, x)	$s_ptx_97_Stud\left(\frac{p}{bar}, t-273.15 \textbf{K}, x\right)\frac{10^3 \textbf{J}}{\textbf{kg} \cdot \textbf{K}}$	Specific entropy			
	t = f(p,h)	$t_ph_97_Stud\left(\frac{p}{bar},h\cdot\frac{kg}{10^3 J}\right)K+273.15 K$	Backward function: Temperature from pressure and enthalpy			
	t = f(p,s)	$t_ps_97_Stud\left(rac{p}{bar},s\cdotrac{kg\cdot K}{10^3} ight)K+273.15~K$	Backward function: Temperature from pressure and entropy			
	v = f(p,t,x)	$v_ptx_97_Stud\left(\frac{p}{bar}, t-273.15 \ K, x\right)\frac{m^3}{kg}$	Specific volume			
	x = f(p,h)	$x_ph_97_Stud\left(rac{p}{bar},h\cdotrac{kg}{10^3 J} ight)$	Backward function: Vapor fraction from pressure and enthalpy			
	x = f(p,s)	$x_ps_97_Stud\left(\frac{p}{bar}, s \cdot \frac{kg \cdot K}{10^3 I}\right)$	Backward function: Vapor fraction from pressure and entropy			

Figure 2.8: Mathcad Prime® worksheet with LibIF97_Stud-Functions

- Find the function

h_ptx_IF97_Stud

and mark the corresponding table cell.

- 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 2.9.



Figure 2.9: Example Mathcad Prime® sheet

- 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 $h=3.097 \times 10^6 \text{ m}^2/\text{s}^{-1}$. The corresponding unit is kJ/kg (see table of the property functions in Chapter 1). In Mathcad Prime® the final unit (given behind the function call) changed to base units. To display the result in the unit you have chosen, you can change the unit after the result value.

In the next figure you can see the calculated value.



Figure 2.10: Example Mathcad Prime® sheet with finished calculation

2.4 Removing FluidPRIME

To remove FluidPRIME with the library LibIF97_Stud 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_LibIF97_Stud" 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 LibIF97_Stud has been removed.



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

Water and Steam

Library LiblF97

- Industrial Formulation IAPWS-IF97 (Revision 2007)
- Supplementary Standards IAPWS-IF97-S01, -S03rev, -S04, and -S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic 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: CO₂ - Span, Wagner H₂O - IAPWS-95

- O_2 Schmidt, Wagner N₂ Span et al. Ar - Tegeler et al.
 - and of the ideal gases: SO₂, 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

lce

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 ₂ O	F ₂	Propane
N ₂	SO ₂	NH ₃	Iso-Butane
0 ₂	H ₂	Methane	n-Butane
CO	H₂S	Ethane	Benzene
CO ₂	ОН	Ethylene	Methanol
Δir			

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								
C₂H₅OH	Ethanol								
CH₃OH	Methanol								
C ₃ H ₈ O ₃	Glycerol								
K₂CO₃	Potassium carbonate								
CaCl ₂	Calcium chloride								
MgCl ₂	Magnesium chloride								
NaCl	Sodium chloride								
C ₂ H ₃ KO 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 SO₂ Library LibSO2 Acetone C_3H_6O Library LibC3H6O Formulation of Lemmon and Span (2006)



For more information please contact:

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The following thermodynamic and transport properties can be calculated^a:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature $T_{\rm s}$
- 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
- Speed of sound *w* Surface tension *σ*

- Transport Properties
- Dynamic viscosity η
- Kinematic viscosity ν
 Thermal conductivity λ
- mermai conductivity
- 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.



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



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

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



Function call of FluidMAT

Add-On FluidLAB for MATLAB[®] and SIMULINK[®]

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

Image: Mail Lab 7.3.0 (R2006b) File Edit Debug Debug Desktop Window Debug Desktop Window Shortcuts How to Add What's I	Help E C D	2 C:\Programme\Flui	ilab\lit	oHu	Ar_Example
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Command History	5	(۲	c fa h >	.1	of FluidLAB

Add-On FluidVIEW for LabVIEW™

t := 300·°C

kg kg kg/

°C bar

 $h = 3051.703 \cdot \frac{kJ}{k}$ kg

h := 🖠

The property functions can be calculated in LabVIEW™.

 $x := -1 \cdot \frac{kg}{kg}$

] kJ



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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[®]

?× Function Informatio C EES library routines Math functions Fluid properties External routines ○ Boiling and Condensation 💌 C Solid/liquid properties CIENCONTINO uer_EES\HuAirProp_SI\Be Tables Plots Windows Help Exa E_{ES} Equ ulating the Enthalpy - h_ptWHuAirPi p=11 Main t=20 Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees] W=(h = 45.4866 [kJ/kg] p = 101.3 [kPa] t = 20 [C] W = 0.01 [kg/kg] CAL No unit problems were detected. Calculation time = .1 sec.

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

International Steam Tables

IAPWS-IF97

p,x t,x p,h p,s

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Online Property Calculator at www.thermofluidprop.com

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Property Software for Pocket Calculators



For more information please contact:



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

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature $T_{\rm s}$
- 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 v
- 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.

4. References

- IAPWS,R7-97(2012): Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam.
 Available at the IAPWS website http://www.iapws.org.
- [2] Kretzschmar, H.-J., Wagner, W.: International Steam Tables, 3rd. Ed. Springer-Verlag, Berlin (2019).
- [3] IAPWS, AN3-07: Revised Advisory Note No. 3: Calculation of Thermodynamic Derivatives for Water and Steam from the IAPWS Formulations (2014). Available at the IAPWS website http://www.iapws.org.
- [4] IAPWS, R15-11: Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance (2011).
 Available at the IAPWS website http://www.iapws.org.
- IAPWS, R12-08: Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance (2008).
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