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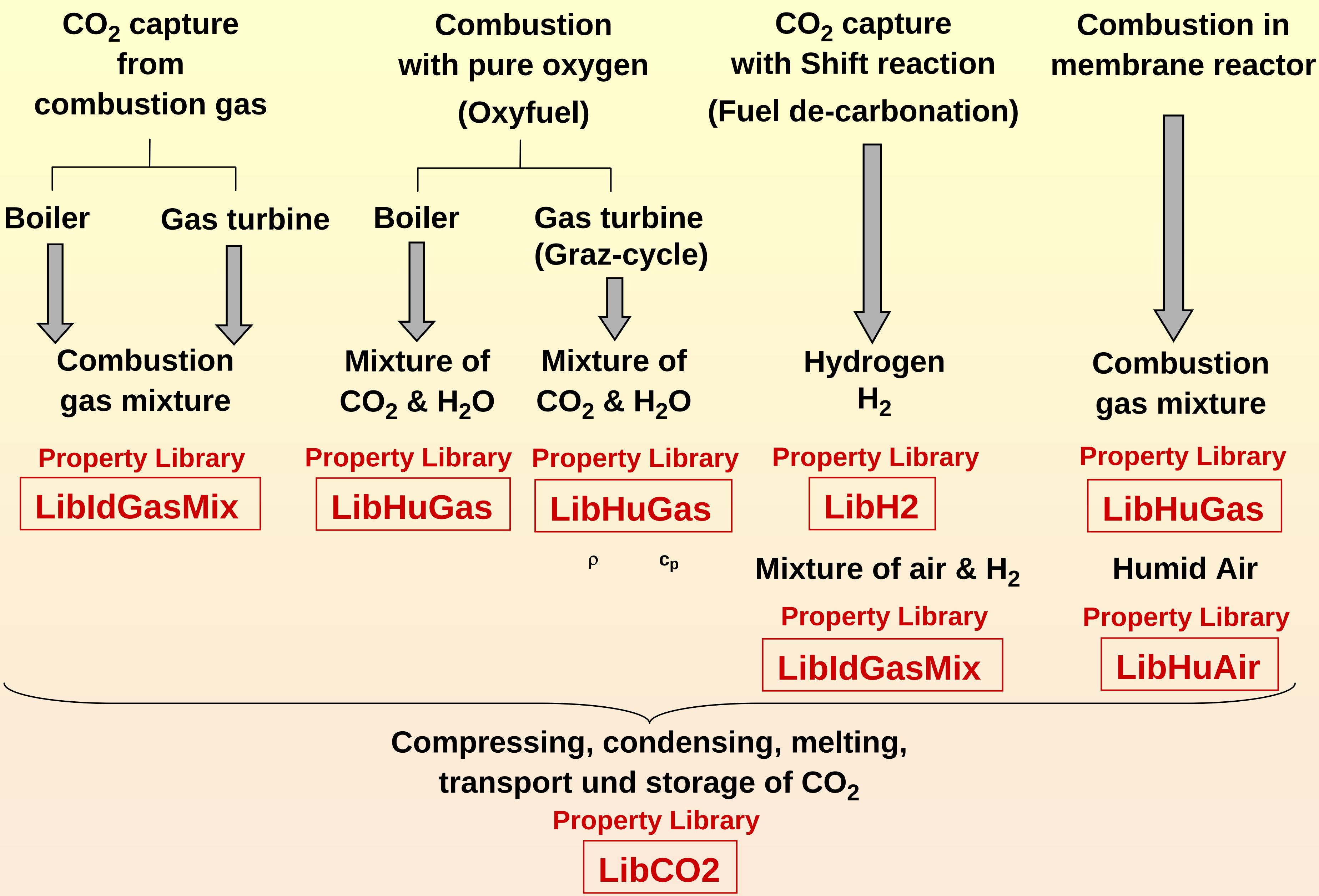
Property Libraries for Working Fluids for Calculating Heat Cycles, Turbines, Heat Pumps, and Refrigeration Processes

Contents

Energy Conversion Processes with CO_2 Capture



Energy Storage and Hydrogen Supply

Compressed air storage

Humid Air at high pressures

Property Library

LibHuAir

Ideal mixture of the real fluids dry air and steam, water or ice

ρ c_p

Hydrogen storage and supply

Hydrogen at high pressures

Liquid hydrogen

Property Library

LibH2

Equation of state of Leachman, Jacobson, and Lemmon

ρ c_p

Energy Conversion Processes with Working Fluid Mixtures

- **Power stations with Mixtures of NH_3 & H_2O (Kalina-process)**
  - Mixture NH_3 & H_2O
- **Absorption refrigerators**
  - Mixtures
    - NH_3 & H_2O
    - H_2O & LiBr

Property Library (for NH_3 & H_2O)

LibAmWa

IAPWS Guideline of Tillner-Roth and Friend (2001)

Property Library (for H_2O & LiBr)

LibWaLi

Mixture model of Kim and Infante Ferreira (2003)

Property Libraries

Water and Steam **Library LibIF97** Industrial Formulation IAPWS-IF97	**Humid Combustion Gases** **Library LibHuGas** Ideal mixture of the real fluids **Library LibIdGas** Ideal gas mixture (VDI-Guideline 4670)	**Humid Air** **Library LibAirWa** Ideal mixture of the real fluids **Library LibIdAir** Ideal gas mixture
Carbon Dioxide **Library LibCO2** Formulation of Span and Wagner **Hydrogen** **Library LibH2** Formulation of Leachman et al. **Helium** **Library LibHe** Formulation of McCarty	**Ideal Gas Mixtures** **Library LibIdGasMix** Ideal mixture of the ideal fluids: Ar, Ne, N_2, O_2, CO, CO_2 Air, NO, H_2O, SO_2, H_2, H_2S OH, He, F_2, NH_3, Methane, Ethane Ethylene, Propylene, Propane, n-Butane, Iso-Butane, Benzene, Methanol **Mixtures in Absorption Processes** Ammonia & Water **Library LibAmWa** Water & Lithiumbromide **Library LibWaLi**	**Refrigerants** Ammonia **Library LibNH3** R134a **Library LibR134a** Propane **Library LibPropan** Iso-Butane **Library LibButan_Iso** n-Butane **Library LibButan_n**

The following thermodynamic and transport properties can be calculated:

Thermodynamic Properties

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

Transport Properties

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

Backward Functions

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

Thermodynamic Derivatives

- All partial derivatives can be calculated.

Example

Calculation of the specific enthalpy *h* for given pressure *p* and temperature *t* for steam using the Industrial Formulation IAPWS-IF97.

Given Values: p = 10 bar

T = 300 °C

Calculation: $h = h\,(p,t,x)$

Vapor fraction x = -1 formally for single-phase regions liquid or superheated steam

($0 \leq x \leq 1$ for wet steam)

Property library: LibIF97

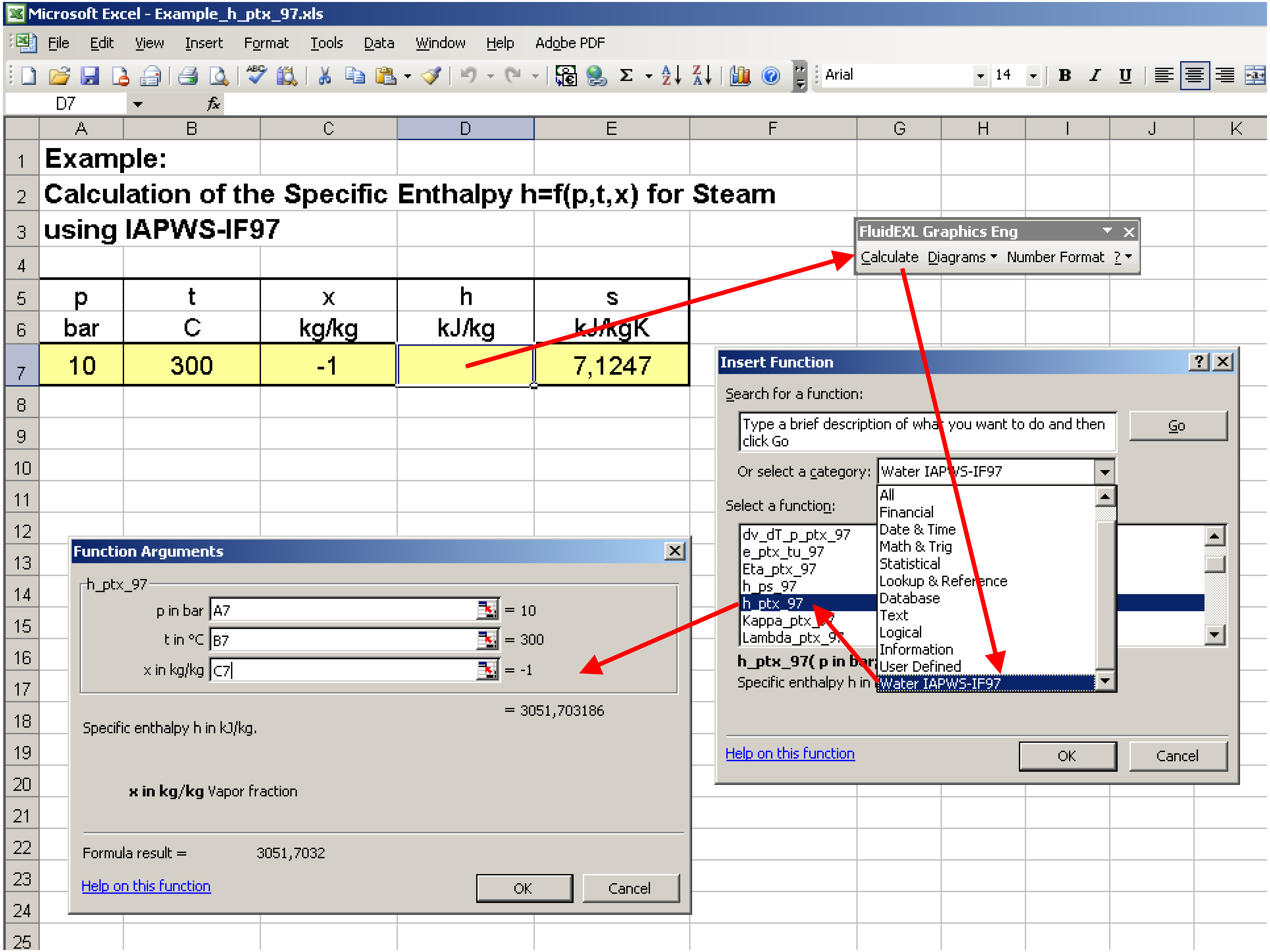
Function: h_ptx_97

Interfaces:

Add-In FluidEXL*Graphics* for Excel®

Add-On FluidLAB for MATLAB®

Add-On FluidMAT for Mathcad®


Microsoft Excel - Example_h_ptx_97.xls
File Edit View Insert Format Tools Data Window Help Adobe PDF
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Example:
Calculation of the Specific Enthalpy h=f(p,t,x) for Steam
using IAPWS-IF97
p
bar
10
t
C
300
x
kg/kg
-1
h
kJ/kg
s
kJ/kgK
7,1247
FluidEXL Graphics Eng
Calculate Diagrams Number Format ?
Insert Function
Search for a function:
Type a brief description of what you want to do and then click Go
Go
Or select a category: Water IAPWS-IF97
All
Financial
Date & Time
Math & Trig
Statistical
Lookup & Reference
Database
Text
Logical
Information
User Defined
Water IAPWS-IF97
Select a function:
dv_dT_p_ptx_97
e_ptx_tu_97
Eta_ptx_97
h_ps_97
h_ptx_97
Kappa_ptx_97
Lambda_ptx_97
h_ptx_97(p in bar
Specific enthalpy h in
Help on this function
OK
Cancel
Function Arguments
h_ptx_97
p in bar A7 = 10
t in °C B7 = 300
x in kg/kg C7 = -1
= 3051,703186
Specific enthalpy h in kJ/kg.
x in kg/kg Vapor fraction
Formula result = 3051,7032
Help on this function
OK
Cancel

Example:

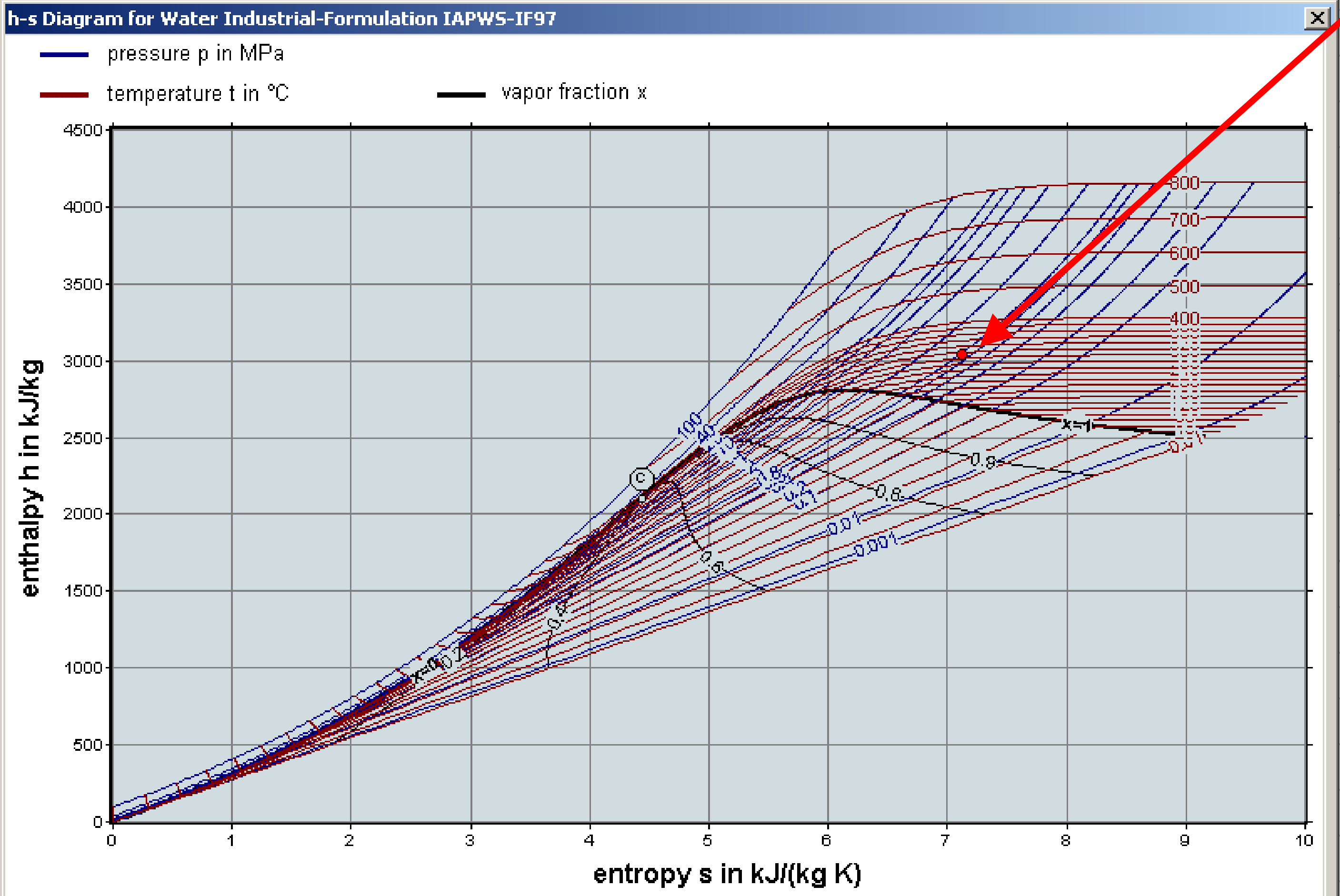
Calculation of the Specific Enthalpy h = f(p,t,x) for Steam using IAPWS-IF97

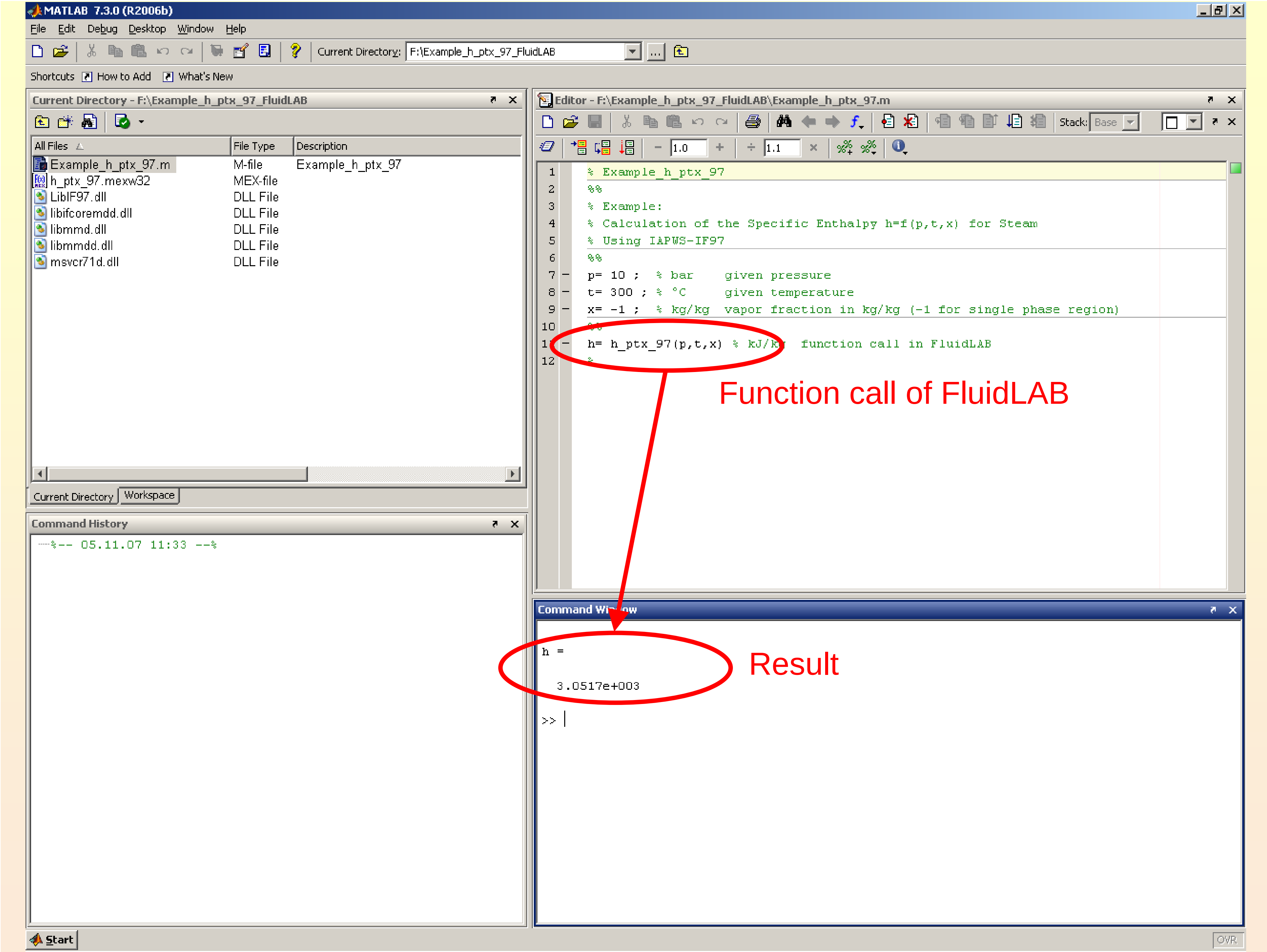
p	t	x	h	s
bar	C	kg/kg	kJ/kg	kJ/kgK
10	300	-1	3051,7032	7,1247

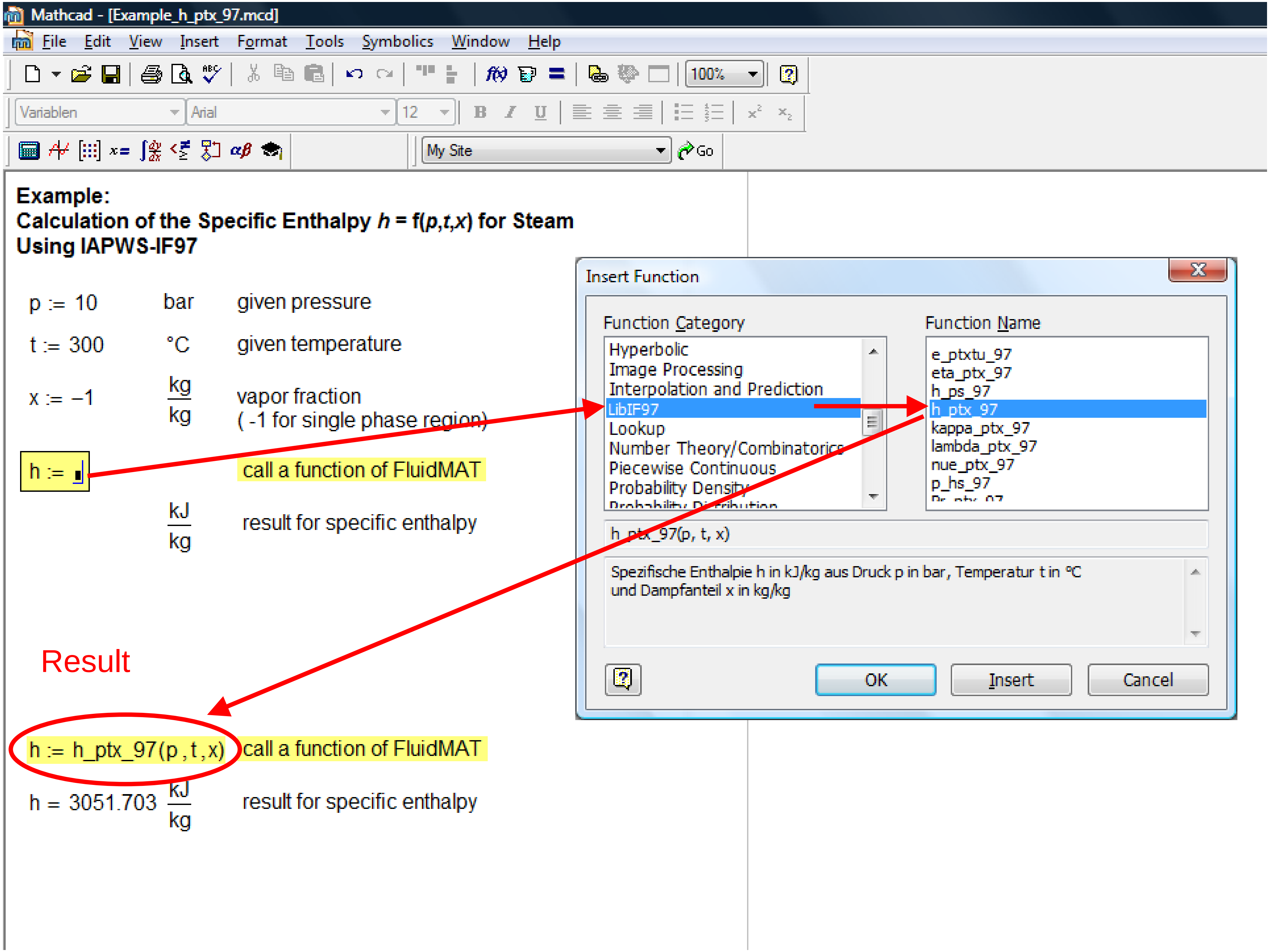
FluidEXL Graphics Eng

Calculate | Diagrams | Number Format | ?

- T-s Diagram
- h-s Diagram
- lg p-h Diagram
- lg p-lg v Diagram
- lg p-T Diagram
- p-T Diagram
- T-h Diagram
- T-lg v Diagram
- lg p-s Diagram
- h-lg v Diagram
- s-lg v Diagram
- h-x Diagram 0.101325 MPa
- h-x Diagram 0.11 MPa




MATLAB 7.3.0 (R2006b)
Current Directory: F:\Example_h_ptx_97_FluidLAB
Example_h_ptx_97.m M-file Example_h_ptx_97
h_ptx_97.mexw32 MEX-file
LibIF97.dll DLL File
libifcoremdd.dll DLL File
libmmd.dll DLL File
libmmdd.dll DLL File
msvcr71d.dll DLL File
Editor - F:\Example_h_ptx_97_FluidLAB\Example_h_ptx_97.m
% Example_h_ptx_97
%%
% Example:
% Calculation of the Specific Enthalpy h=f(p,t,x) for Steam
% Using IAPWS-IF97
%%
p= 10 ; % bar given pressure
t= 300 ; % °C given temperature
x= -1 ; % kg/kg vapor fraction in kg/kg (-1 for single phase region)
h= h_ptx_97(p,t,x) % kJ/kg function call in FluidLAB
Function call of FluidLAB
Command History
%-- 05.11.07 11:33 --%
h =
3.0517e+003
Result


Mathcad - [Example_h_ptx_97.mcd]
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12
100%
My Site
Go
Example:
Calculation of the Specific Enthalpy h = f(p,t,x) for Steam
Using IAPWS-IF97
p := 10 bar given pressure
t := 300 °C given temperature
x := −1 kg/kg vapor fraction
(-1 for single phase region)
h := call a function of FluidMAT
kJ/kg result for specific enthalpy
Result
h := h_ptx_97(p,t,x) call a function of FluidMAT
h = 3051.703 kJ/kg result for specific enthalpy
Insert Function
Function Category
Hyperbolic
Image Processing
Interpolation and Prediction
LibIF97
Lookup
Number Theory/Combinatorics
Piecewise Continuous
Probability Density
Function Name
e_ptxtu_97
eta_ptx_97
h_ps_97
h_ptx_97
kappa_ptx_97
lambda_ptx_97
nue_ptx_97
p_hs_97
h_ptx_97(p, t, x)
Spezifische Enthalpie h in kJ/kg aus Druck p in bar, Temperatur t in °C
und Dampfanteil x in kg/kg
OK
Insert
Cancel

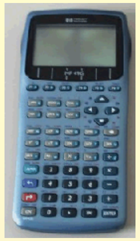
Property Software for Pocket Calculators

www.steamtables-pocket-calculators.com

Software for calculating thermodynamic and transport properties for
- Water and steam
- Combustion Gases and
- Humid air

FluidHP

HP 48



HP 49

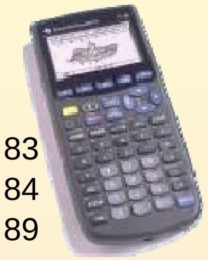
FluidCasio

CFX-9850

FX1.0
ALGEBRA
FX 2.0

FluidTI

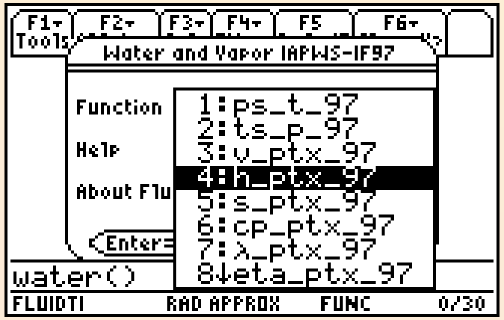
TI 83
TI 84
TI 89



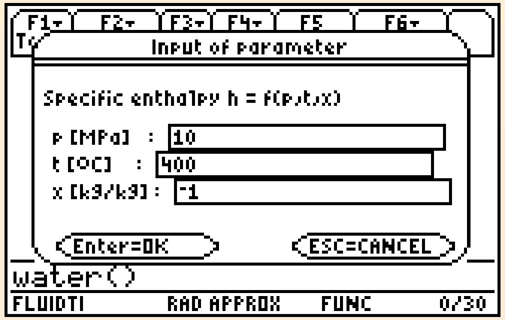
TI Voyage 200

TI 92

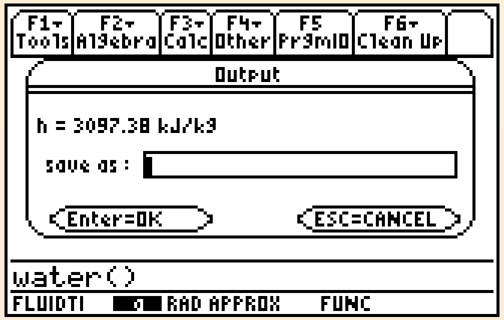
Example: Calculation of the Enthalpy of Steam Using FluidTI



Choice of the function h = f(p,t,x)



Input of the parameters p, t and x



Result for enthalpy

Summary

- Property Libraries for working fluids used in energy conversion processes were developed.
- Thermodynamic properties, transport properties, thermodynamic derivatives, and backward functions can be calculated.
- The property libraries are available for
  - Excel®
  - MATLAB®
  - Mathcad®
  - Applications in Windows®, Unix® or Linux®
  - Pocket Calculators.
- Student versions of all property libraries are available.
- The libraries can be used by engineers, who routinely calculate heat cycles, turbines, boilers, heat pumps or other thermal or refrigeration processes.

Paper available at: www.thermodynamics-zittau.de.