X STEAM FOR MATLAB

By Magnus Holmgren, www.x-eng.com

Date: 2006-01-20

By Magnus Holmgren, www.x-eng.com
The steam tables are free and provided as is.
We take no responsibilities for any errors in the code or damage thereby.
You are free to use, modify and distribute the code as long as authorship is properly acknowledged.
Please notify me at magnus@x-eng.com if the code is used in commercial applications

Conclusion

X Steam for Matlab is a implementation of the IAPWS IF97 standard formulation. It provides accurate data for water and steam and mixtures of water and steam properties from 0 - 1000 bar and from 0 - 2000 deg C. It is programmed as a matlab .m file. XSteam are also available for MS Excel or OpenOffice at **www.x-eng.com**.

The initial units of XSteam are SI units as denoted in this document**.** All functions however call unit conversion functions so the units can be easily changed. A text file with unit conversion functions for English units are enclosed with the file.

Calling syntax: XSteam('fun',In1.[In2])
XSteam take 2 or 3 arguments. The first argument must always be the steam table function you want to use. The other arguments are the inputs to that function.

- Example: XSteam('h_pt',1,20) Returns the enthalpy of water at 1 bar and 20 degC
- Example: XSteam('TSat_p',1) Returns the saturation temperature of water at 1 bar.

For a list of valid Steam Table functions se section 3 or the XSteam macros for MS Excel.

Contents

1 INTRODUCTION

X Steam for matlab is a implementation of the IAPWS IF97 standard formulation. It provides accurate thermo hydraulic data for water and steam and mixtures of water and steam in the region:

- 0°C < temperature < 2000°C for
  0.00611 bar a < pressure < 100 bar a

- 0°C < temperature < 1000°C for
  0.00611 bar a < pressure < 1000 bar a

For accuracy and further information on IAPWS IF97 formulation, se homepage of the international association for properties of water and steam (www.iapws.org).

2 USING THE MATLAB IMPLEMENTATION

X Steam are available both for matlab and for MS excel. The MS Excel version can be useful also for matlab users to get valid calling functions.

The XSteam code are used in the following way:

- **Out=XSteam('function name',In1,In2)**

Function name are the name on the XSteam function and In1 and In2 are the inputs to that function. The results are returned (in this case to Out).

Example: **XSteam('rho_pT',1,200)** returns the density at 1 bar and 200°C.

Valid XSteam functions are listed in section 3. The notaions used in XSteam are listed in the table bellow with the currently implemented.

Notation	Quantity	Unit
T	Temperature	°C
p	Pressure	bar
h	Enthalpy	kJ/kg
v	Specific volume	m^3/kg
rho	Density	kg/ m^3
s	Specific entropy	kJ/(kg °C)
u	Specific internal energy	kJ/kg
Cp	Specific isobaric heat capacity	kJ/(kg °C)
Cv	Specific isochoric heat capacity	kJ/(kg °C)
w	Speed of sound	m/s
my	Viscosity	Pa s
tc	Thermal Conductivity	W/(m °C)
st	Surface Tension	N/m
x	Vapour fraction (0-1)	-
vx	Vapour Volume Fraction (0-1)	-

3 XSTEAM CALLING FUNCTIONS

3.1 Temperature

Function	In1	In2	Out
Tsat_p	p		Saturation temperature
T_ph	p	H	Temperture as a function of pressure and enthalpy
T_ps	p	S	Temperture as a function of pressure and entropy
T_hs	h	S	Temperture as a function of enthalpy and entropy

3.2 Pressure

Function	In1	In2	Out
psat_T	T		Saturation pressure
p_hs	h	s	Pressure as a function of h and s.
p_hrho	h	rho	Pressure as a function of h and rho (density). Very unaccurate for solid water region since it's almost incompressible!

3.3 Enthalpy

Function	In1	In2	Out
hV_p	p		Saturated vapour enthalpy
hL_p	p		Saturated liquid enthalpy
hV_T	T		Saturated vapour enthalpy
hL_T	T		Saturated liquid enthalpy
h_pT	p	T	Entalpy as a function of pressure and temperature.
h_ps	p	s	Entalpy as a function of pressure and entropy.
h_px	p	x	Entalpy as a function of pressure and vapour fraction
h_Tx	T	X	Entalpy as a function of temperature and vapour fraction
h_prho	p	rho	Entalpy as a function of pressure and density. Observe for low temperatures (liquid) this equation has 2 solutions. (Not valid!!)

3.4 Specific volume

Function	In1	In2	Out
vV_p	p		Saturated vapour volume
vL_p	p		Saturated liquid volume
vV_T	T		Saturated vapour volume
vL_T	T		Saturated liquid volume
v_pT	p	T	Specific volume as a function of pressure and temperature.
v_ph	p	h	Specific volume as a function of pressure and enthalpy
v_ps	p	s	Specific volume as a function of pressure and entropy.

3.5 Density

Function	In1	In2	Out
rhoV_p	p		Saturated vapour density
rhoL_p	p		Saturated liquid density
rhoV_T	T		Saturated vapour density
rhoL_T	T		Saturated liquid density
rho_pT	p	T	Density as a function of pressure and temperature.
rho_ph	p	h	Density as a function of pressure and enthalpy
rho_ps	p	s	Density as a function of pressure and entropy.

3.6 Specific entropy

Function	In1	In2	Out
sV_p	p		Saturated vapour entropy
sL_p	p		Saturated liquid entropy
sV_T	T		Saturated vapour entropy
sL_T	T		Saturated liquid entropy
s_pT	p	T	Specific entropy as a function of pressure and temperature (Returns saturated vapour entalpy if mixture.)
s_ph	p	h	Specific entropy as a function of pressure and enthalpy

3.7 Specific internal energy

Function	In1	In2	Out
uV_p	p		Saturated vapour internal energy
uL_p	p		Saturated liquid internal energy
uV_T	T		Saturated vapour internal energy
uL_T	T		Saturated liquid internal energy
u_pT	p	T	Specific internal energy as a function of pressure and temperature.
u_ph	p	h	Specific internal energy as a function of pressure and enthalpy
u_ps	p	s	Specific internal energy as a function of pressure and entropy.

3.8 Specific isobaric heat capacity

Function	In1	In2	Out
CpV_p	p		Saturated vapour heat capacity
CpL_p	p		Saturated liquid heat capacity
CpV_T	T		Saturated vapour heat capacity
CpL_T	T		Saturated liquid heat capacity
Cp_pT	p	T	Specific isobaric heat capacity as a function of pressure and temperature.
Cp_ph	p	h	Specific isobaric heat capacity as a function of pressure and enthalpy
Cp_ps	p	s	Specific isobaric heat capacity as a function of pressure and entropy.

3.9 Specific isochoric heat capacity

Function	In1	In2	Out
CvV_p	p		Saturated vapour isochoric heat capacity
CvL_p	p		Saturated liquid isochoric heat capacity
CvV_T	T		Saturated vapour isochoric heat capacity
CvL_T	T		Saturated liquid isochoric heat capacity
Cv_pT	p	T	Specific isochoric heat capacity as a function of pressure and temperature.
Cv_ph	p	h	Specific isochoric heat capacity as a function of pressure and enthalpy
Cv_ps	p	s	Specific isochoric heat capacity as a function of pressure and entropy.

3.10 Speed of sound

Function	In1	In2	Out
wV_p	p		Saturated vapour speed of sound
wL_p	p		Saturated liquid speed of sound
wV_T	T		Saturated vapour speed of sound
wL_T	T		Saturated liquid speed of sound
w_pT	p	T	Speed of sound as a function of pressure and temperature.
w_ph	p	h	Speed of sound as a function of pressure and enthalpy
w_ps	p	s	Speed of sound as a function of pressure and entropy.

3.11 Viscosity

Viscosity is not part of IAPWS Steam IF97. Equations from "Revised Release on the IAPWS Formulation 1985 for the Viscosity of Ordinary Water Substance", 2003 are used.

Viscosity in the mixed region (4) is interpolated according to the density. This is not true since it will be two fases.

Function	In1	In2	Out
my_pT	p	T	Viscosity as a function of pressure and temperature.
my_ph	p	h	Viscosity as a function of pressure and enthalpy
my_ps	p	s	Viscosity as a function of pressure and entropy.

3.12 Thermal Conductivity

Revised release on the IAPS Formulation 1985 for the Thermal Conductivity of ordinary water substance (IAPWS 1998)

Function	In1	In2	Out
tcL_p	p		Saturated vapour thermal conductivity
tcV_p	p		Saturated liquid thermal conductivity
tcL_T	T		Saturated vapour thermal conductivity
tcV_T	T		Saturated liquid thermal conductivity
tc_pT	p	T	Thermal conductivity as a function of pressure and temperature.
tc_ph	p	h	Thermal conductivity as a function of pressure and enthalpy
tc_hs	h	s	Thermal conductivity as a function of enthalpy and entropy

3.13 Surface Tension

IAPWS Release on Surface Tension of Ordinary Water Substance, September 1994

Function	In1	In2	Out
st_T	T		Surface tension for two phase water/steam as a function of T
st_p	p		Surface tension for two phase water/steam as a function of T

3.14 Vapour fraction

Function	In1	In2	Out
x_ph	p	h	Surface tension for two phase water/steam as a function of T
x_ps	p	s	Surface tension for two phase water/steam as a function of T

3.15 Vapour Volume Fraction

Observe that vapour volume fraction is very sensitive. Vapour volume is about 1000 times greater than liquid volume and therefore vapour volume fraction gets close to the accurancy of IAPWS IF-97

Function	In1	In2	Out
vx_ph	p	h	Vapour volume fraction as a function of pressure and enthalpy
vx_ps	p	s	Vapour volume fraction as a function of pressure and entropy.