

IAPWS-IF97

Water and Steam Properties

Excel® Add-In Library



DEMO VERSION USER GUIDE

Windows® Operating System
SI and I-P Units
Version 2.1

OVERVIEW

1 SOFTWARE

1.1 System Requirements

1.2 Installation

1.3 Uninstalling the software

1.4 Registering the Add-In in Excel

2 USER DEFINED FUNCTIONS

2.1 User Defined Functions (UDF)

2.2 Property Functions Reference (SI Units)

2.3 Property Functions Reference (I-P Units)

REFERENCES

© 2015-2020 Fluidika Techlabs
www.fluidika.com
support@fluidika.com

Windows and Excel are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

Other product and company names herein may be the trademarks of their respective owners.

OVERVIEW

WaterSteamIF97FLK (Demo Version) is an Excel Add-In Library that allows the calculation of thermodynamic and transport properties of Water and Steam based on the latest IAPWS-IF97 Formulation and IAPWS releases for evaluation purposes.

This Demo Version includes limitations in the range of the input variables that are included.

1.1 System Requirements

The following are the requirements in order to install and utilize **WaterSteamIF97FLK (Demo Version)**. Please note that if your operating system does not include the corresponding C++ Runtime Library it will be installed by the installation file.

Windows OS	Windows 7 Windows 8 Windows 8.1 Windows 10
Office Excel	Minimum Version : Excel 2010 (32-bit or 64-bit)
C++ Runtime Library	(32-bit): Microsoft Visual C++ 2015-2019 Redistributable (x86) (64-bit) : Microsoft Visual C++ 2015-2019 Redistributable (x64)

WaterSteamIF97FLK (Demo Version) is available as a 32-bit or 64-bit Excel Add-in in accordance with the Excel version. Please select the right installation file that matches your Office version.

1.2 Installation

Double-click on the installation file and follow the on-screen instructions. Contact support@fluidika.com if you require assistance.



Figure 1. Installation screen of WaterSteamIF97FLK Add-in (Demo Version).

You need to have **Administrator** privileges on your computer in order to install this software.

1.3 Uninstalling the software

To uninstall the Add-In, double click the installation file and follow the on-screen instructions, or use the standard windows uninstaller, usually located at

Control Panel → Programs → Programs and Features

1.4 Registering the Add-In in Excel

Once the installation has been completed, it is necessary to manually register the Add-In with Excel (here shown in Excel 2013). From an opened document, navigate to

File → Options → Add-Ins → Go

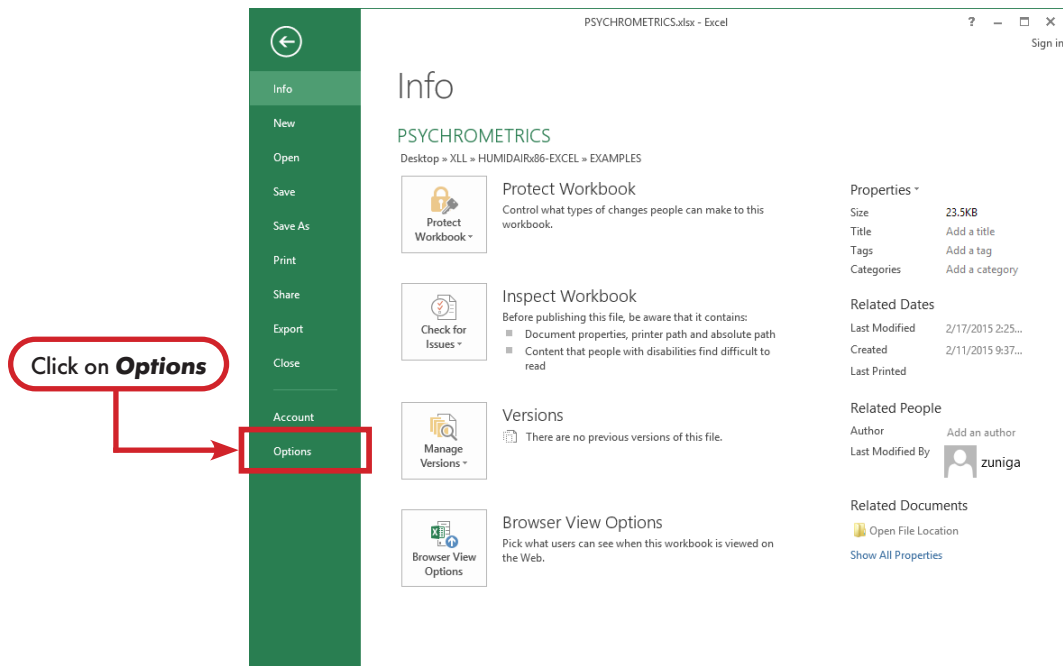


Figure 2. Registration of the add-in in Excel.

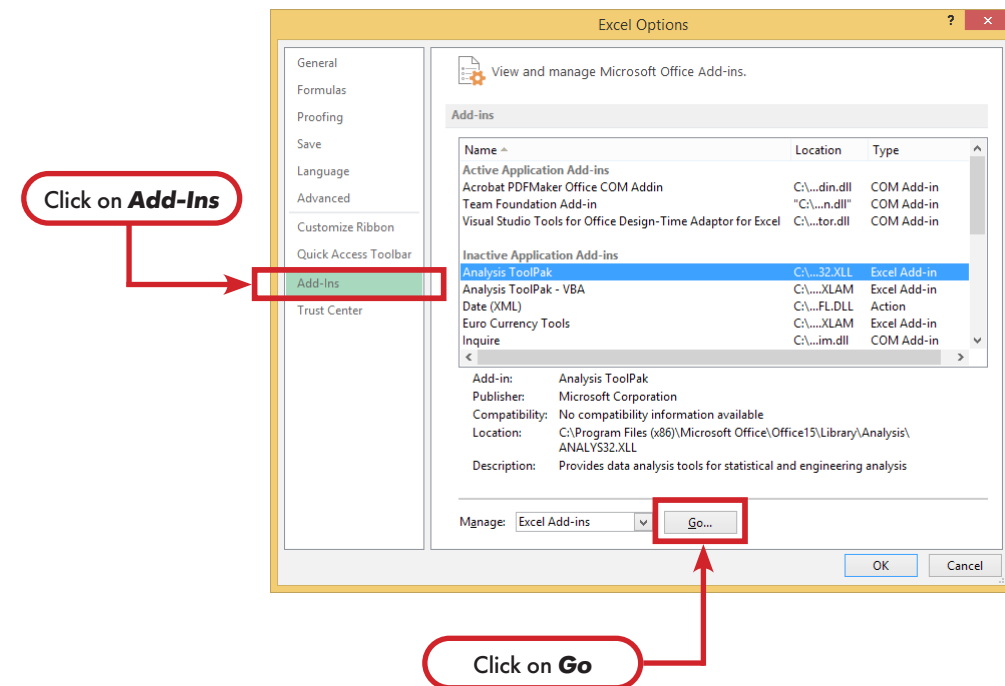


Figure 3. Registration of the add-in in Excel.

The *Add-Ins* Window appears, showing the current Add-Ins available. Click on the *Browse* button to search on the installation directory for the file

WATERSTEAMIF97FLK_DEMO.xll

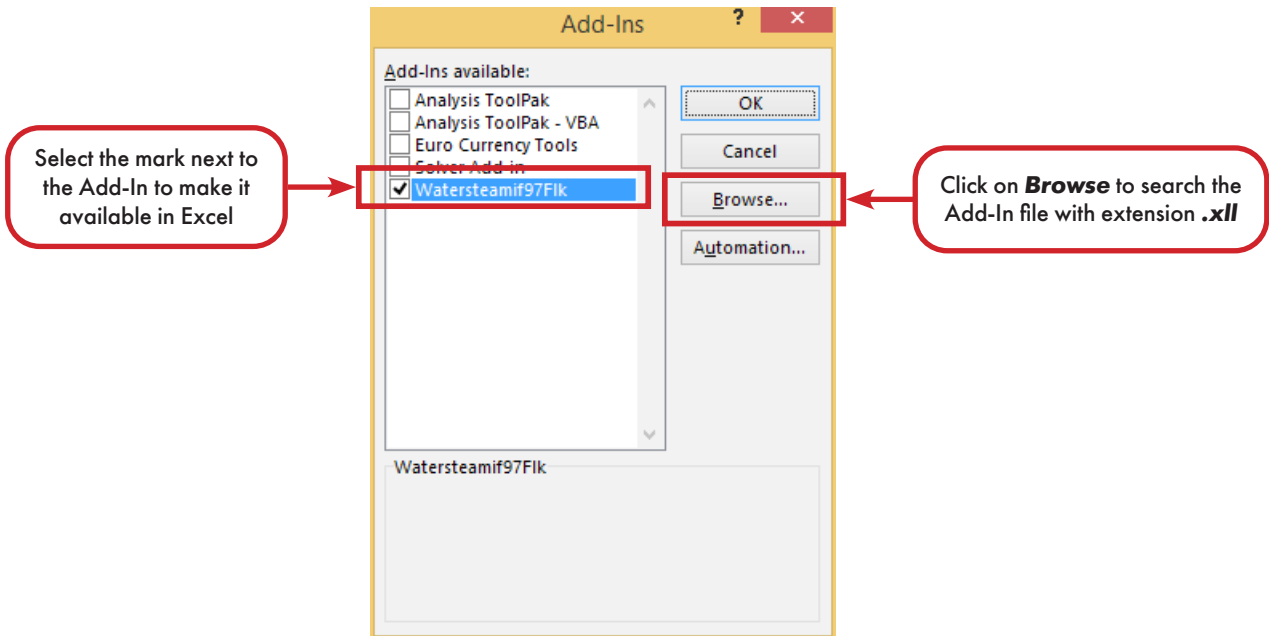


Figure 4. Registration of the add-in in Excel.

The Add-In is now ready for use.

2.1 User Defined Functions (UDF)

WaterSteamIF97FLK (Demo Version) Excel Add-In Library is composed of User Defined Functions (UDF) that take parameters (string and/or double) and returns a double (number). If incorrect or out of bounds input parameters are entered, the function will return the value of **-999**.

The functions to be used in an Excel worksheet are shown in Table 1, both in the SI and I-P system of units. Only the first 3 combinations of input variables are available in this demo version (from all 14 possible combinations, see Table 2).

Table 4 lists the properties together with their output units that are calculated for each combination of input thermodynamic variables, where the strings defined in column **prop** correspond to the string variables used as input parameter in functions of the form

STEAMFLK_SI_XX_prop

or

STEAMFLK_IP_XX_prop

where **XX** is one of the combinations in Table 2.

Properties not available in this Demo Version return a value of -1.

SI UNITS	I-P UNITS	OUTPUT RESULT
STEAMFLK_SI_pT_prop	STEAMFLK_IP_pT_prop	DEMO - PRESSURE FIXED AT 700000 Pa/101.5264 psi TEMPERATURE RANGE : 273.15 - 300 K/ 32 - 80.3 °F
STEAMFLK_SI_Th_prop	STEAMFLK_IP_Th_prop	TEMPERATURE RANGE : 273.15 - 300 K/ 32 - 80.3 °F
STEAMFLK_SI_Ts_prop	STEAMFLK_IP_Ts_prop	TEMPERATURE RANGE : 273.15 - 300 K/ 32 - 80.3 °F
STEAMFLK_SI_Tx_prop	STEAMFLK_IP_Tx_prop	TEMPERATURE RANGE : 273.15 - 300 K/ 32 - 80.3 °F
STEAMFLK_SI_Tu_prop	STEAMFLK_IP_Tu_prop	Depending on value of "prop", see Table 4 NOT AVAILABLE IN DEMO VERSION(VALUE = -1)
STEAMFLK_SI_Tv_prop	STEAMFLK_IP_Tv_prop	
STEAMFLK_SI_ph_prop	STEAMFLK_IP_ph_prop	
STEAMFLK_SI_pu_prop	STEAMFLK_IP_pu_prop	
STEAMFLK_SI_ps_prop	STEAMFLK_IP_ps_prop	
STEAMFLK_SI_pv_prop	STEAMFLK_IP_pv_prop	
STEAMFLK_SI_hs_prop	STEAMFLK_IP_hs_prop	
STEAMFLK_SI_hv_prop	STEAMFLK_IP_hv_prop	
STEAMFLK_SI_uv_prop	STEAMFLK_IP_uv_prop	
STEAMFLK_SI_px_prop	STEAMFLK_IP_px_prop	
STEAMFLK_SI_VARwl_n	STEAMFLK_IP_VARwl_n	Refractive index N/A IN DEMO VERSION
STEAMFLK_SI_T_sigma	STEAMFLK_IP_T_sigma	Surface Tension N/A IN DEMO VERSION
STEAMFLK_SI_p_sigma	STEAMFLK_IP_p_sigma	Surface Tension N/A IN DEMO VERSION
STEAMFLK_SI_T_psat	STEAMFLK_IP_T_psat	Vapor Pressure N/A IN DEMO VERSION
STEAMFLK_SI_p_Tsat	STEAMFLK_IP_p_Tsat	Saturation Temperature N/A IN DEMO VERSION

Table 1. Functions defined in [WaterSteamIF97FLK \(Demo Version\)](#)

Input variable		Input variable		Combination
Pressure	(p)	Temperature	(T)	pT
Temperature	(T)	Specific Enthalpy	(h)	Th
Temperature	(T)	Specific Internal Energy	(u)	Tu
Temperature	(T)	Specific Entropy	(s)	Ts
Temperature	(T)	Specific Volume	(v)	Tv
Pressure	(p)	Specific Enthalpy	(h)	ph
Pressure	(p)	Specific Internal Energy	(u)	pu
Pressure	(p)	Specific Entropy	(s)	ps
Pressure	(p)	Specific Volume	(v)	pv
Specific Enthalpy	(h)	Specific Entropy	(s)	hs
Specific Enthalpy	(h)	Specific Volume	(v)	hv
Specific Internal Energy	(u)	Specific Volume	(v)	uv
Temperature	(T)	Vapor Fraction	(x)	Tx
Pressure	(p)	Vapor Fraction	(x)	px

Table 2. Combination of input variables

Property	SI Units (output)	I-P Units (output)
<i>Refractive index</i>	[-]	[-]
<i>Surface tension</i>	mPa·m	lbf/ft
<i>Vapor Pressure</i>	Pa	psi
<i>Saturation Temperature</i>	K	°F

Table 3. Properties NOT included in [WaterSteamIF97FLK \(Demo Version\)](#)

Property	SI Units (output)	I-P Units (output)	String (prop)
Pressure	Pa	psi	p
Temperature	K	°F	T
Specific Enthalpy	J/kg	Btu/lbm	h
Specific Entropy	J/(kg·K)	Btu/(lbm·°R)	s
Specific Internal Energy	J/kg	Btu/lbm	u
Specific Volume	m ³ /kg	ft ³ /lbm	v
Density	kg/m ³	lbm/ft ³	rho
Speed of Sound	m/s	ft/s	w
Dynamic Viscosity	Pa·s	lbf·s/ft ²	eta
Kinematic Viscosity	m ² /s	ft ² /s	ny
Thermal Conductivity	W/(m·K)	Btu/(ft·h·°R)	lambda
Thermal Diffusivity	m ² /s	ft ² /s	a
Specific Isobaric Heat Capacity	J/(kg·K)	Btu/(lbm·°R)	cp
Specific Isochoric Heat Capacity	J/(kg·K)	Btu/(lbm·°R)	cv
Isentropic Exponent	[-]	[-]	kappa
Isobaric Cubic Expansion Coefficient	1/K	1/°R	alphav
Isothermal Compressibility	1/kPa	1/psi	kappaT
Prandtl Number	[-]	[-]	prandtl
Vapor Fraction	kg/kg	lb/lb	x
IAPWS-IF97 Region			region
Specific Helmholtz Energy	J/kg	Btu/lbm	f
Specific Gibbs Energy	J/kg	Btu/lbm	g
Compression factor	[-]	[-]	z
Relative pressure coefficient	1/K	1/°R	alphap
Isothermal stress coefficient	kg/m ³	lbm/ft ³	betap
Joule-Thomson coefficient	K/MPa	°F/psi	my
Dielectric constant	[-]	[-]	epsilon
Differential quotient (dvdP)T	m ³ /(kg·MPa)	ft ³ /(lb·psi)	dvdpT
Differential quotient (dudP)T	J/(kg·Pa)	Btu/(lb·psi)	dudpT
Differential quotient (dsdP)T	J/(kg·K·Pa)	Btu/(lb·°F·psi)	dsdpT
Differential quotient (dhdP)T	J/(kg·Pa)	Btu/(lb·psi)	dhdpT
Differential quotient (dvdT)P	m ³ /(kg·K)	ft ³ /(lb·°F)	dvdTp
Differential quotient (dudT)P	J/(kg·K)	Btu/(lb·°F)	dudTp
Differential quotient (dsdT)P	J/(kg·K·K)	Btu/(lb·°F·°F)	dsdTp
Differential quotient (dhdT)P	J/(kg·K)	Btu/(lb·°F)	dhdTp
Differential quotient (dPdTv)	MPa/K	psi/°F	dPdTv
Differential quotient (dPdTv)	MPa·kg/m ³	psi·lb/ft ³	dPdTv

Table 4. Properties calculated for each combination of input thermodynamic variables.
PROPERTIES IN ITALIC ARE NOT INCLUDED IN THE DEMO VERSION AND RETURN A VALUE = -1

2.2 Property Functions Reference (SI Units)

FUNCTION NAME: STEAMFLK_SI_pT_prop

Excel function usage : = STEAMFLK_SI_pT_prop(p, T, prop)

Input values : **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000.0 Pa

T : Temperature in K.
Range: 273.15 ≤ T ≤ 300.0 [K]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Notes : It is not possible to calculate points over the two-phase region. When prop = "x". i.e., vapor fraction, the result will be -999.

Example : Cell D2 returns the value of specific enthalpy("h") as function of pressure and temperature. Cell D2 is interpreted as: =STEAMFLK_SI_pT_prop(700000.0, 300, "h").

	A	B	C	D
1	p	T	prop	
2	700000.0	300	h	=STEAMFLK_SI_pT_prop(A2, B2, C2)

FUNCTION NAME: STEAMFLK_SI_Th_prop

Excel function usage : = STEAMFLK_SI_Th_prop(T, h, prop)

Input values : **T** : Temperature in K.
Range: 273.15 ≤ T ≤ 300.0 [K]

h : Specific enthalpy in J/kg.
Range: -41.5878 ≤ h ≤ 2810.0E3 [J/kg]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Example : Cell D2 returns the value of specific volume ("v") as a function of temperature and specific enthalpy. Cell D2 is interpreted as: =STEAMFLK_SI_Th_prop(300, 112580.9431, "v").

	A	B	C	D
1	T	h	prop	
2	300	112580.9431	v	=STEAMFLK_SI_Th_prop(A2, B2, C2)

FUNCTION NAME:**STEAMFLK_SI_Ts_prop**

Excel function usage : =STEAMFLK_SI_Ts_prop(T, s, prop)

Input values : **T** : Temperature in K.

Range: $273.15 \leq T \leq 300.0$ [K]

s : Specific entropy in J/(kg·K).

Range: $-8.5823 \leq s \leq 13905.8727$ [J/(kg·K)]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Example : Cell D2 returns the value of specific volume ("v") as a function of temperature and specific entropy. Cell D2 is interpreted as: =STEAMFLK_SI_Ts_prop(300, 393.1218225, "v").

	A	B	C	D
1	T	s	prop	
2	300	393.1218225	v	=STEAMFLK_SI_Ts_prop(A2, B2, C2)

FUNCTION NAME:**STEAMFLK_SI_Tx_prop**

Excel function usage : =STEAMFLK_SI_Tx_prop(T, x, prop)

Input values : **T** : Temperature in K.

Range: $273.15 \leq T \leq 300.0$ [K]

x : Vapor fraction in kg(saturated steam)/kg(wet steam).

Range: $0 \leq x \leq 1$ [kg/kg]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Notes : Setting $x = 1$ or $x = 0$, returns the corresponding value of **prop** at saturation.

Example : Cell D2 returns the value of specific enthalpy ("h") as a function of temperature and vapor fraction. Cell D2 is interpreted as: =STEAMFLK_SI_Tx_prop(300, 0, "h").

	A	B	C	D
1	T	x	prop	
2	300	0	h	=STEAMFLK_SI_Tx_prop(A2, B2, C2)

2.3 Property Functions Reference (I-P Units)

FUNCTION NAME: STEAMFLK_IP_pT_prop

Excel function usage : =STEAMFLK_IP_pT_prop(p, T, prop)

Input values : **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 psi

T : Temperature in °F.
Range: 32.0 ≤ T ≤ 80.3 [°F]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Notes : It is not possible to calculate points over the two-phase region. When prop = "x". i.e., vapor fraction, result will always be -999.

Example : Cell D2 returns the value of specific enthalpy("h") as function of pressure and temperature. Cell D2 is interpreted as: =STEAMFLK_IP_pT_prop(101.5264, 80.33, "h").

	A	B	C	D
1	p	T	prop	
2	101.5264	80.33	h	=STEAMFLK_IP_pT_prop(A2, B2, C2)

FUNCTION NAME: STEAMFLK_IP_Th_prop

Excel function usage : =STEAMFLK_IP_Th_prop(T, h, prop)

Input values : **T** : Temperature in °F.
Range: 32.0 ≤ T ≤ 80.3 [°F]

h : Specific enthalpy in Btu/lbm.
Range: -0.017879 ≤ h ≤ 3171.5306 [Btu/lbm]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Example : Cell D2 returns the value of specific volume ("v") as a function of temperature and specific enthalpy. Cell D2 is interpreted as: =STEAMFLK_IP_Th_prop(80.33, 48.40109184, "v").

	A	B	C	D
1	T	h	prop	
2	80.33	48.40109184	v	=STEAMFLK_IP_Th_prop(A2, B2, C2)

FUNCTION NAME:**STEAMFLK_IP_Ts_prop**

Excel function usage : = STEAMFLK_IP_Ts_prop(T, s, prop)

Input values : **T** : Temperature in °F.

Range: $32.0 \leq T \leq 80.3$ [°F]

s : Specific entropy Btu/(lbm·°R).

Range: $-0.0020498 \leq s \leq 3.32136$ [Btu/(lbm·°R)]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Example : Cell D2 returns the value of specific volume ("v") as a function of temperature and specific entropy. Cell D2 is interpreted as: =STEAMFLK_IP_Ts_prop(80.33, 0.093895532, "v").

	A	B	C	D
1	T	s	prop	
2	80.33	0.093895532	v	=STEAMFLK_IP_Ts_prop(A2, B2, C2)

FUNCTION NAME:**STEAMFLK_IP_Tx_prop**

Excel function usage : = STEAMFLK_IP_Tx_prop(T, x, prop)

Input values : **T** : Temperature in °F.

Range: $32.0 \leq T \leq 80.3$ [°F]

x : Vapor fraction in lb(saturated steam)/lb(wet steam).

Range: $0 \leq x \leq 1$ [lb/lb]

prop: Output Property. String (see Table 4)

Output Result : See Table 4. **VALUE = -1 : RESULT NOT AVAILABLE IN DEMO**

Invalid Output Result : **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.

Notes : Setting $x = 1$ or $x = 0$, returns the corresponding value of **prop** at saturation.

Example : Cell D2 returns the value of specific enthalpy ("h") as a function of temperature and vapor fraction. Cell D2 is interpreted as: =STEAMFLK_IP_Tx_prop(80.33, 0, "h").

	A	B	C	D
1	T	x	prop	
2	80.33	0	h	=STEAMFLK_IP_Tx_prop(A2, B2, C2)

DEMO - FIXED PRESSURE AT 700000 Pa/101.5264 psi					
DEMO - TEMPERATURE RANGE : 273.15 - 300 K/32 - 80.3 °F					
VALUE = -1 : RESULT NOT AVAILABLE IN DEMO					
INPUT VARIABLES: PRESSURE, TEMPERATURE					
INPUT		SI UNITS		I-P UNITS	
Pressure		700000 Pa		101.5264 psi	
Temperature		280 K		44.3 °F	
parameter	OUTPUT	SI UNITS		I-P UNITS	
p	Pressure	700000	Pa	101.5263959	psi
T	Temperature	280	K	44.3	°F
h	Specific Enthalpy	29485.84706	J/kg	12.64654785	Btu/lbm
s	Specific Entropy	104.0844839	J/(kg·K)	0.024800459	Btu/(lbm·°R)
u	Specific Internal Energy	28785.98821	J/kg	12.3456634	Btu/lbm
v	Specific Volume	0.000999798	m³/kg	0.016015211	ft³/lbm
rho	Density	1000.201682	kg/m³	62.44063815	lbm/ft³
cp	Specific Isobaric Heat Capacity	4198.52454	J/(kg·K)	1.002808045	Btu/(lbm·°R)
cv	Specific Isochoric Heat Capacity	4197.31498	J/(kg·K)	1.002522242	Btu/(lbm·°R)
w	Speed of Sound	1435.31843	m/s	4708.812959	ft/s
eta	Dynamic Viscosity	0.001432847	Pa·s	2.99408E-05	lbf·s/ft²
ny	Kinematic Viscosity	-1	m²/s	-1	ft²/s
lambda	Thermal Conductivity	-1	W/(m·K)	-1	Btu/(ft·h·°R)
a	Thermal Diffusivity	-1	m²/s	-1	ft²/s
kappa	Isentropic Exponent	-1	[-]	-1	[-]
alphav	Isobaric Cubic Expansion Coefficient	-1	1/K	-1	1/°R
kappaT	Isothermal Compressibility	-1	1/kPa	-1	1/psi
prandtl	Prandtl Number	-1	[-]	-1	[-]
x	Vapor Fraction	-1	kg/kg	-1	lb/lb
region	IAPWS-IF97 Region	-1		-1	
f	Specific Helmholtz Energy	-1	J/kg	-1	Btu/lbm
g	Specific Gibbs Energy	-1	J/kg	-1	Btu/lbm
z	Compression factor	-1	[-]	-1	[-]
alphap	Relative pressure coefficient	-1	1/K	-1	1/°R
betap	Isothermal stress coefficient	-1	kg/m³	-1	lbm/ft³
my	Joule-Thomson coefficient	-1	K/MPa	-1	°F/psi
epsilon	Dielectric constant	-1	[-]	-1	[-]
dvdP	Differential quotient (dvdP)T	-1	m³/(kg·MPa)	-1	ft³/(lb·psi)
dudP	Differential quotient (dudP)T	-1	J/(kg·Pa)	-1	Btu/(lb·psi)
dsdP	Differential quotient (dsdP)T	-1	J/(kg·K·Pa)	-1	Btu/(lb·°F·psi)
dhdP	Differential quotient (dhdP)T	-1	J/(kg·Pa)	-1	Btu/(lb·psi)
dvdTp	Differential quotient (dvdT)P	-1	m³/(kg·K)	-1	ft³/(lb·°F)
dudTp	Differential quotient (dudT)P	-1	J/(kg·K)	-1	Btu/(lb·°F)
dsdT	Differential quotient (dsdT)P	-1	J/(kg·K·K)	-1	Btu/(lb·°F·°F)
dhdTp	Differential quotient (dhdT)P	-1	J/(kg·K)	-1	Btu/(lb·°F)
dPdTv	Differential quotient (dPdTv)	-1	MPa/K	-1	psi/°F
dPdTv	Differential quotient (dPdTv)T	-1	MPa·kg/m³	-1	psi·lb/ft³

Figure 5. Screenshot of Excel sheet with results from the pressure-temperature combination of variables.

References

- Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, IAPWS (2007).
- Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance, IAPWS (2008).
- Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance IAPWS (2011).
- Supplementary Release on Backward Equations for Pressure as a Function of Enthalpy and Entropy $p(h,s)$ to the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, IAPWS (2001).
- Wagner, W.; Pruß, A.: The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. *J. Phys. Chem. Ref. Data* 31, 387-535 (2002).
- Wagner, W.; Kretzschmar, H.-J.: *International Steam Tables*. Springer, Berlin (2008).