

IAPWS-IF97

Water and Steam Properties

Excel[®] Add-In Library



DEMO VERSION USER GUIDE

*Windows[®] Operating System
SI and I-P Units
Version 2.0*

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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.

REQUIREMENTS

The following are the requirements in order to install and utilize **WaterSteamIF97 (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.

	OPERATING SYSTEM
Windows OS	Windows 7 Windows 8 Windows 8.1 Windows 10

	MINIMUM VERSION	REQUIREMENT
Office Excel	Excel 2010	32-bit or 64-bit

	BITNESS	REQUIREMENT
C++ Runtime Library	32-bit	Microsoft Visual C++ 2012 Redistributable (32-bit) - 11.0.6.61030
	64-bit	Microsoft Visual C++ 2012 Redistributable (64-bit) - 11.0.6.61030

- Please note that the minimum supported Windows OS is Windows 7, and the minimum supported Excel version is Office 2010.

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.

Installation File	Excel Version
WaterSteamIF97_XLLDemo_x86_Setup	32-bit
WaterSteamIF97_XLLDemo_x64_Setup	64-bit

INSTALLATION

Unzip the file that corresponds to your Excel version. Double-click on the `_Setup.exe` file that is on the unzipped directory and follow the screen instructions.

Once installed, the next step is to register the following file as an Add-in in Excel (located in your installation directory):

WATERSTEAMIF97FLK_DEMO.xll

Now you are ready to evaluate [WaterSteamIF97FLK](#).

A sample excel file with all the functions available in this demo version can be found in the `/EXAMPLE` directory of your installation.

Note : All files with extension `.dll` need to be located in the same directory of the add-in (file with extension `.xll`).

Please check www.fluidika.com for information on how to register an add-in in Excel.

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

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

S97FLK_SI_XX_prop

or

S97FLK_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
S97FLK_SI_pT_prop	S97FLK_IP_pT_prop	DEMO - PRESSURE FIXED AT 700000 Pa/101.5264 psi TEMPERATURE RANGE : 273.15 - 350 K/ 32 - 170.3 °F
S97FLK_SI_Th_prop	S97FLK_IP_Th_prop	TEMPERATURE RANGE : 273.15 - 350 K/ 32 - 170.3 °F
S97FLK_SI_Ts_prop	S97FLK_IP_Ts_prop	TEMPERATURE RANGE : 273.15 - 350 K/ 32 - 170.3 °F
S97FLK_SI_Tx_prop	S97FLK_IP_Tx_prop	TEMPERATURE RANGE : 273.15 - 350 K/ 32 - 170.3 °F
<i>S97FLK_SI_Tu_prop</i>	<i>S97FLK_IP_Tu_prop</i>	Depending on value of "prop", see Table 4 NOT AVAILABLE IN DEMO VERSION (VALUE = -1)
<i>S97FLK_SI_Tv_prop</i>	<i>S97FLK_IP_Tv_prop</i>	
<i>S97FLK_SI_ph_prop</i>	<i>S97FLK_IP_ph_prop</i>	
<i>S97FLK_SI_pu_prop</i>	<i>S97FLK_IP_pu_prop</i>	
<i>S97FLK_SI_ps_prop</i>	<i>S97FLK_IP_ps_prop</i>	
<i>S97FLK_SI_pv_prop</i>	<i>S97FLK_IP_pv_prop</i>	
<i>S97FLK_SI_hs_prop</i>	<i>S97FLK_IP_hs_prop</i>	
<i>S97FLK_SI_hv_prop</i>	<i>S97FLK_IP_hv_prop</i>	
<i>S97FLK_SI_uv_prop</i>	<i>S97FLK_IP_uv_prop</i>	
<i>S97FLK_SI_px_prop</i>	<i>S97FLK_IP_px_prop</i>	
<i>S97FLK_SI_VARwl_n</i>	<i>S97FLK_IP_VARwl_n</i>	Refractive index N/A IN DEMO VERSION
<i>S97FLK_SI_T_sigma</i>	<i>S97FLK_IP_T_sigma</i>	Surface Tension N/A IN DEMO VERSION
<i>S97FLK_SI_p_sigma</i>	<i>S97FLK_IP_p_sigma</i>	Surface Tension N/A IN DEMO VERSION
<i>S97FLK_SI_T_psat</i>	<i>S97FLK_IP_T_psat</i>	Vapor Pressure N/A IN DEMO VERSION
<i>S97FLK_SI_p_Tsat</i>	<i>S97FLK_IP_p_Tsat</i>	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)
Refractive index	[-]	[-]
Surface tension	mPa·m	lbf/ft
Vapor Pressure	Pa	psi
Saturation Temperature	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 (dPdT)v	MPa/K	psi/°F	dPdTv
Differential quotient (dPdV)T	MPa·kg/m ³	psi·lb/ft ³	dPdVt

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

USER-DEFINED FUNCTIONS REFERENCE (SI UNITS) - DEMO VERSION

FUNCTION NAME:	S97FLK_SI_pT_prop
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Excel function usage : = S97FLK_SI_pT_prop(p, T, prop)

Input values : **p** : Pressure in Pa.
FIXED PRESSURE AT : 10000 Pa

T : Temperature in K.
Range: $273.15 \leq T \leq 350.0$ [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: =S97FLK_SI_pT_prop(10000, 300, "h").

	A	B	C	D
1	p	T	prop	
2	10000	300	h	=S97FLK_SI_pT_prop(A2, B2, C2)

FUNCTION NAME:	S97FLK_SI_Th_prop
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Excel function usage : = S97FLK_SI_Th_prop(T, h, prop)

Input values : **T** : Temperature in K.
Range: $273.15 \leq T \leq 350.0$ [K]

h : Specific enthalpy in J/kg.
Range: $-41.5878 \leq h \leq 2810.0E3$ [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: =S97FLK_SI_Th_prop(300, 112580.9431, "v").

	A	B	C	D
1	T	h	prop	
2	300	112580.9431	v	=S97FLK_SI_Th_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_Ts_prop**

Excel function usage : = S97FLK_SI_Ts_prop(T, s, prop)

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

Range: 273.15 ≤ T ≤ 350.0 [K]

s : Specific entropy in J/(kg·K).

Range: -8.5823 ≤ s ≤ 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: =S97FLK_SI_Ts_prop(300, 393.1218225, "v").

	A	B	C	D
1	T	s	prop	
2	300	393.1218225	v	=S97FLK_SI_Ts_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_Tx_prop**

Excel function usage : = S97FLK_SI_Tx_prop(T, x, prop)

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

Range: 273.15 ≤ T ≤ 350.0 [K]

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

Range: 0 ≤ x ≤ 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: =S97FLK_SI_Tx_prop(300, 0, "h").

	A	B	C	D
1	T	x	prop	
2	300	0	h	=S97FLK_SI_Tx_prop(A2, B2, C2)

USER-DEFINED FUNCTIONS REFERENCE (I-P UNITS) - DEMO VERSION

FUNCTION NAME:	S97FLK_IP_pT_prop
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Excel function usage : = S97FLK_IP_pT_prop(p, T, prop)

Input values : **p** : Pressure in psi.
FIXED PRESSURE AT : 1.4504 psi

T : Temperature in °F.
Range: 32.0 ≤ T ≤ 170.3 [°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: =S97FLK_IP_pT_prop(1.4504, 80.33, "h").

	A	B	C	D
1	p	T	prop	
2	1.4504	80.33	h	=S97FLK_IP_pT_prop(A2, B2, C2)

FUNCTION NAME:	S97FLK_IP_Th_prop
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Excel function usage : = S97FLK_IP_Th_prop(T, h, prop)

Input values : **T** : Temperature in °F.
Range: 32.0 ≤ T ≤ 170.3 [°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: =S97FLK_IP_Th_prop(80.33, 48.40109184, "v").

	A	B	C	D
1	T	h	prop	
2	80.33	48.40109184	v	=S97FLK_IP_Th_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_Ts_prop**

Excel function usage : = S97FLK_IP_Ts_prop(T, s, prop)

Input values : **T** : Temperature in °F.
Range: $32.0 \leq T \leq 170.3$ [°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: =S97FLK_IP_Ts_prop(80.33, 0.093895532, "v").

	A	B	C	D
1	T	s	prop	
2	80.33	0.093895532	v	=S97FLK_IP_Ts_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_Tx_prop**

Excel function usage : = S97FLK_IP_Tx_prop(T, x, prop)

Input values : **T** : Temperature in °F.
Range: $32.0 \leq T \leq 170.3$ [°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: =S97FLK_IP_Tx_prop(80.33, 0, "h").

	A	B	C	D
1	T	x	prop	
2	80.33	0	h	=S97FLK_IP_Tx_prop(A2, B2, C2)

REFERENCES

- Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, IAPWS (2007).
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- 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).