

IAPWS-IF97

Water and Steam Properties

Excel® Add-In Library



USER GUIDE

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

OVERVIEW

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OVERVIEW

WaterSteamIF97FLK 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.

The numerical results obtained are suitable for academic, engineering, scientific or industrial use.

1.1 Description

- Performs all the calculations implementing the latest mathematical formulations from the IAPWS (International Association for the Properties of Water and Steam), IAPWS-IF97 Industrial formulation (Revision 2007).
- Calculates the following Thermodynamic and Transport properties of water and steam all over the valid range of the IAPWS-IF97:
 - Pressure
 - Temperature
 - Specific Enthalpy
 - Specific Entropy
 - Specific Internal Energy
 - Specific Volume
 - Density
 - Speed of Sound
 - Dynamic Viscosity
 - Kinematic Viscosity
 - Thermal Conductivity
 - Thermal Diffusivity
 - Specific Isobaric Heat Capacity
 - Specific Isochoric Heat Capacity
 - Isentropic Exponent
 - Isobaric Cubic Expansion Coefficient
 - Isothermal Compressibility
 - Prandtl Number
 - Vapor Fraction
 - IAPWS-IF97 Region
 - Specific Helmholtz Energy
 - Specific Gibbs Energy
 - Compression factor
 - Relative pressure coefficient
 - Isothermal stress coefficient
 - Joule-Thomson coefficient
 - Dielectric constant
 - Surface Tension
 - Refractive index

- Calculates the differential quotients:

$\left(\frac{\partial v}{\partial p}\right)_T$ Partial derivate of specific volume on pressure with constant temperature

$\left(\frac{\partial u}{\partial p}\right)_T$ Partial derivate of specific internal energy on pressure with constant temperature

$\left(\frac{\partial s}{\partial p}\right)_T$ Partial derivate of specific entropy on pressure with constant temperature

$\left(\frac{\partial h}{\partial p}\right)_T$ Partial derivate of specific enthalpy on pressure with constant temperature

$\left(\frac{\partial v}{\partial T}\right)_P$ Partial derivate of specific volume on temperature with constant pressure

$\left(\frac{\partial u}{\partial T}\right)_P$ Partial derivate of specific internal energy on temperature with constant pressure

$\left(\frac{\partial s}{\partial T}\right)_P$ Partial derivate of specific entropy on temperature with constant pressure

$\left(\frac{\partial h}{\partial T}\right)_P$ Partial derivate of specific enthalpy on temperature with constant pressure

$\left(\frac{\partial P}{\partial T}\right)_v$ Partial derivate of pressure on temperature with constant specific volume

$\left(\frac{\partial P}{\partial v}\right)_T$ Partial derivate of pressure on specific volume with constant temperature

- Allows for 14 different combinations of thermodynamic properties to be entered as input parameters in both the SI (metric) and the I-P (English) system of units.
 - Temperature / Pressure
 - Temperature / Enthalpy
 - Temperature / Internal Energy
 - Temperature / Entropy
 - Temperature / Specific Volume
 - Pressure / Enthalpy
 - Pressure / Internal Energy
 - Pressure / Entropy
 - Pressure / Specific Volume
 - Enthalpy / Entropy
 - Enthalpy / Specific Volume
 - Internal Energy / Specific Volume
 - Temperature / Vapor Fraction
 - Pressure / Vapor Fraction

1.2 System Requirements

The following are the requirements in order to install and utilize [WaterSteamIF97FLK](#). 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](#) 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_XLL_x86_Setup	32-bit
WaterSteamIF97_XLL_x64_Setup	64-bit

1.3 Installation

Once you have downloaded the suitable version of **WaterSteamIF97** Add-In Library for your Excel installation, double click the corresponding file:

WaterSteamIF97_XLL_x86_Setup.exe (for 32-bit Excel Installation)
WaterSteamIF97_XLL_x64_Setup.exe (for 64-bit Excel installation)

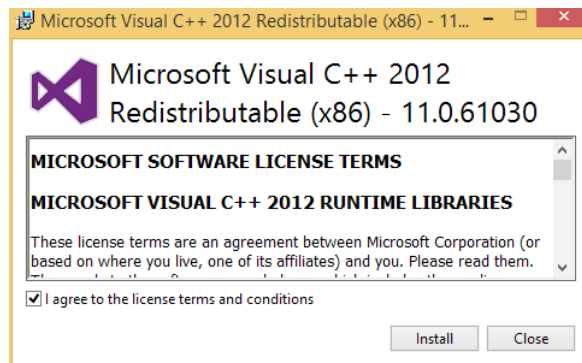
You need to agree to the *License terms and conditions* before installing the software.

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

1.4 License

Introduce the SERIAL KEY that you received in order to install the add-In.

If your system does not include the Microsoft VC++ 2012 Redistributable runtime library, it will be installed by the application. Once you agreed to the license terms and conditions, click on the install button to proceed with the installation.



1.5 Upgrades

Information about upgrades will be send to the email address that was registered.

1.6 Uninstalling the software

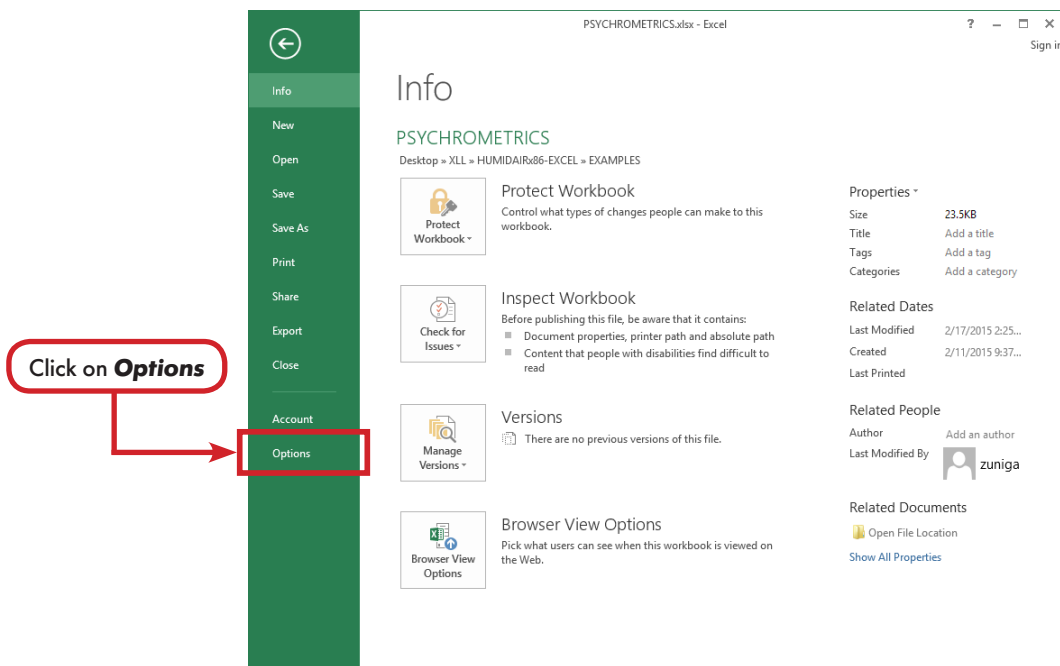
To uninstall the Add-In, double click the installation file and follow the on-screen instructions, or use the standard windows uninstaller, usually located at

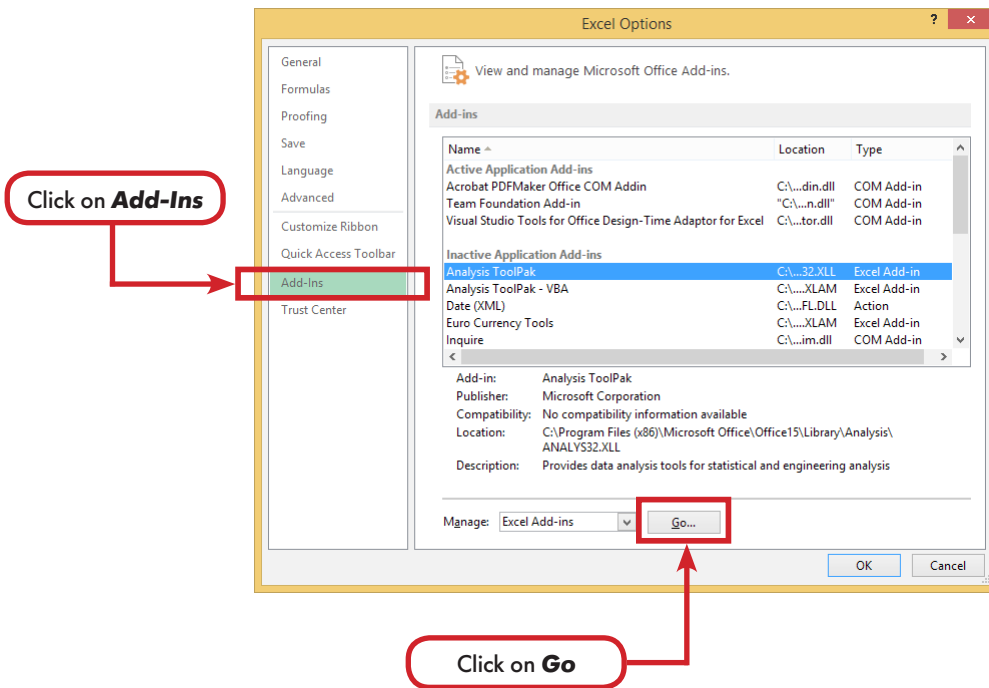
Control Panel → Programs → Programs and Features

1.7 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

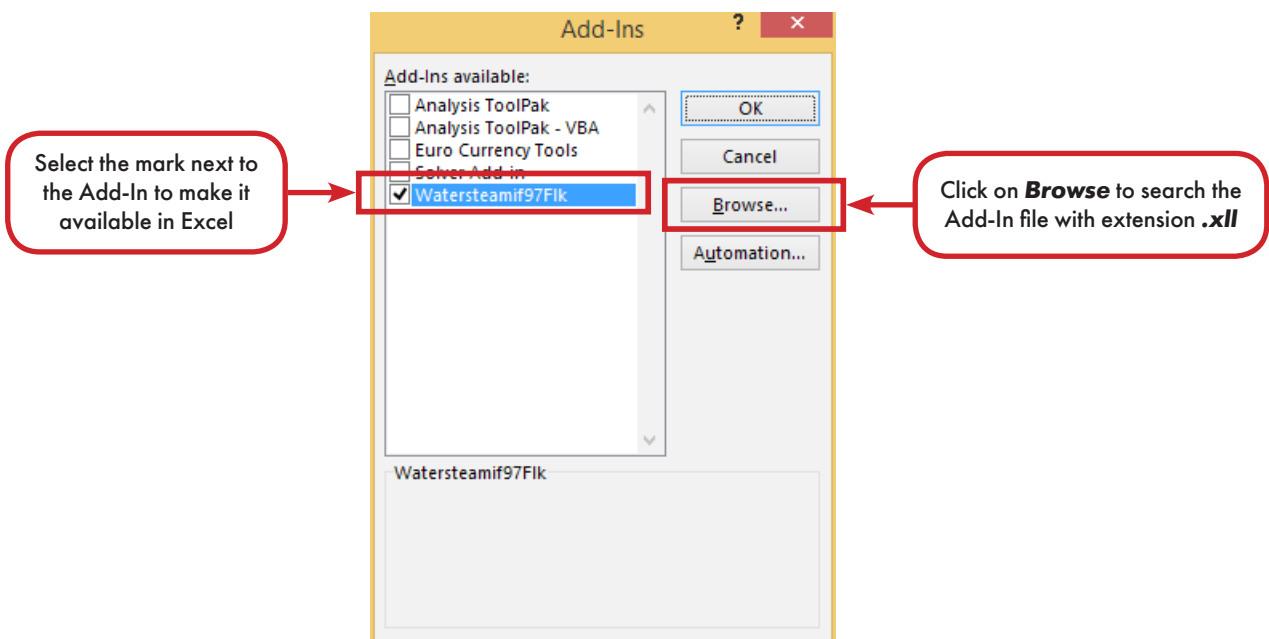
File → Options → Add-Ins → Go





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.xll



The Add-In is now ready for use.

IMPORTANT: Do not rename or move any of the files with extension **.dll** that are located in the same directory as the Add-In (**WATERSTEAMIF97FLK.XLL**).

2.1 Range of validity

The range of validity comprises all the valid range of the IAPWS-IF97 Formulation as stated by the IAPWS, see *References*. This is shown in Figures 1 and 2, together with the region assignment.

In the case of any other combination of input thermodynamic properties other than the combination $\langle p, T \rangle$, **WaterSteamIF97FLK** will determine the corresponding region and properties.

As an example, Figure 3 shows the combination of variables $\langle h, s \rangle$ (enthalpy-entropy).

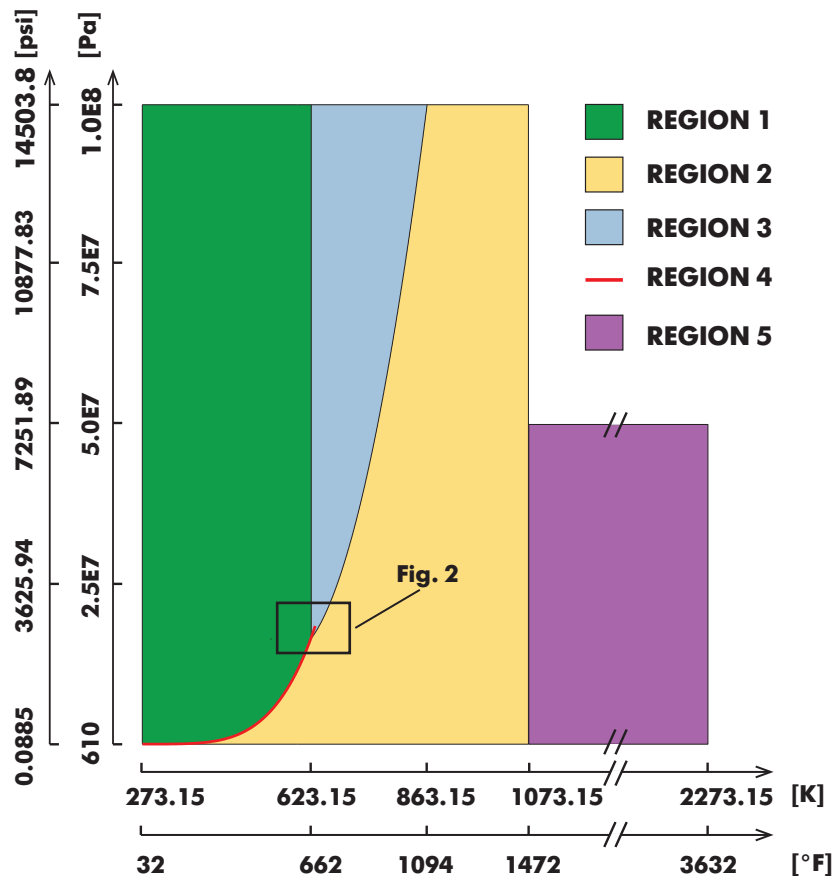


Figure 1. Range validity of the IAPWS-IF97 formulation (p-T)

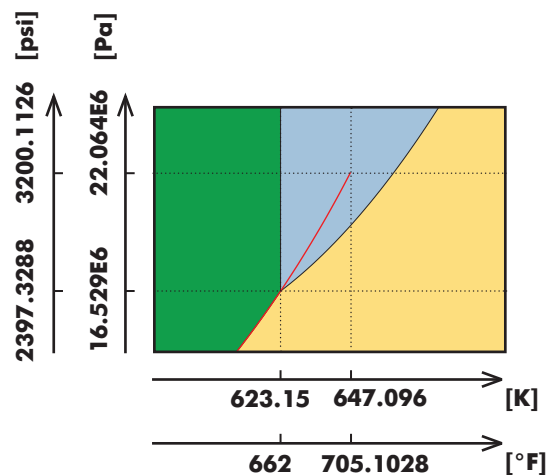


Figure 2. Zoom view of the critical point on the p-T Diagram

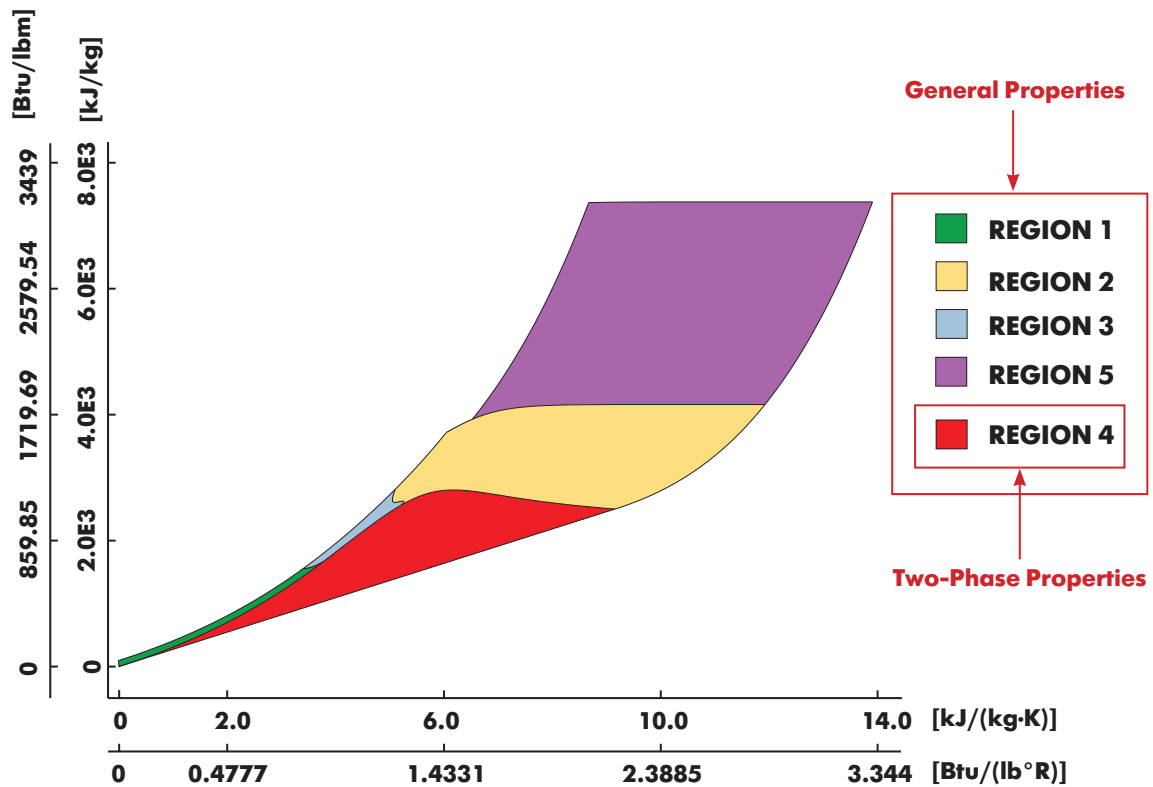


Figure 3. Enthalpy-Entropy Diagram

The IAPWS Formulations divides the calculations into five regions, shown as examples in the previous figures. The input variables used in this library have the following absolute ranges:

Property	Range in SI Units	SI Units
Pressure	$610 \leq p \leq 100.0E6$	Pa
Temperature	$273.15 \leq T \leq 2273.15$	K
Specific Enthalpy	$-41.5878 \leq h \leq 2810.0E3$	J/kg
Specific Internal Energy	$-282.7252 \leq u \leq 6327.862E3$	J/kg
Specific Entropy	$-8.5823 \leq s \leq 13905.8727$	J/(kg·K)
Specific Volume	$1.00007E-4 \leq v \leq 1719.8658$	m ³ /kg
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg
Wavelength	$0.2 \leq n \leq 1.1$	μm

Property	Range in I-P Units	I-P Units
Pressure	$0.088473 \leq p \leq 1450.4$	psi
Temperature	$32.0 \leq T \leq 3632.0$	°F
Specific Enthalpy	$-0.017879 \leq h \leq 3171.5306$	Btu/lbm
Specific Internal Energy	$-0.12155 \leq u \leq 2720.491$	Btu/lbm
Specific Entropy	$-0.0020498 \leq h \leq 3.32136$	Btu/(lbm·°R)
Specific Volume	$1.601958E-2 \leq v \leq 27549.6$	ft ³ /lbm
Vapor Fraction	$0 \leq x \leq 1.0$	lb/lb
Wavelength	$7.8740157 \leq n \leq 43.3070866$	μin

Table 1. Absolute ranges for input variables used in WaterSteamIF97FLK

The upper temperature range for Kinematic Viscosity, Dynamic Viscosity, Thermal Conductivity, Thermal Diffusivity and Prandtl Number is 1173.15 K / 1652 °F.

2.2 User Defined Functions (UDF)

WaterSteamIF97FLK 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**.

Table 2 shows the functions to be used in Excel, both in the SI or I-P system of units. The combinations of input variables considered in these functions is listed in Table 3.

Table 5 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 3.

SI UNITS	I-P UNITS	OUTPUT RESULT
S97FLK_SI_pT_prop	S97FLK_IP_pT_prop	Depending on value of "prop", see Table 5
S97FLK_SI_Th_prop	S97FLK_IP_Th_prop	
S97FLK_SI_Tu_prop	S97FLK_IP_Tu_prop	
S97FLK_SI_Ts_prop	S97FLK_IP_Ts_prop	
S97FLK_SI_Tv_prop	S97FLK_IP_Tv_prop	
S97FLK_SI_ph_prop	S97FLK_IP_ph_prop	
S97FLK_SI_pu_prop	S97FLK_IP_pu_prop	
S97FLK_SI_ps_prop	S97FLK_IP_ps_prop	
S97FLK_SI_pv_prop	S97FLK_IP_pv_prop	
S97FLK_SI_hs_prop	S97FLK_IP_hs_prop	
S97FLK_SI_hv_prop	S97FLK_IP_hv_prop	
S97FLK_SI_uv_prop	S97FLK_IP_uv_prop	
S97FLK_SI_Tx_prop	S97FLK_IP_Tx_prop	
S97FLK_SI_px_prop	S97FLK_IP_px_prop	
S97FLK_SI_VARwl_n	S97FLK_IP_VARwl_n	Refractive index
S97FLK_SI_T_sigma	S97FLK_IP_T_sigma	Surface Tension
S97FLK_SI_p_sigma	S97FLK_IP_p_sigma	Surface Tension
S97FLK_SI_T_psat	S97FLK_IP_T_psat	Vapor Pressure
S97FLK_SI_p_Tsat	S97FLK_IP_p_Tsat	Saturation Temperature

Table 2. Functions defined in **WaterSteamIF97FLK**

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 3. Combination of input thermodynamic 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 4. Additional properties calculated

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	lb·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 5. Properties calculated for each combination of input thermodynamic variables

2.3 Property Functions Reference (SI Units)

FUNCTION NAME: **S97FLK_SI_pT_prop**

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

Input values : **p** : Pressure in Pa.
Range: $610 \leq p \leq 1.0E8$ [Pa]

T : Temperature in K.
Range: $273.15 \leq T \leq 2273.15$ [K]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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(5000000, 300, "h").

	A	B	C	D
1	p	T	prop	
2	5000000	300	h	=S97FLK_SI_pT_prop(A2, B2, C2)

FUNCTION NAME: **S97FLK_SI_hs_prop**

Excel function usage : = S97FLK_SI_hs_prop(h, s, prop)

Input values : **h** : Specific enthalpy in J/kg.
Range: $-41.5878 \leq h \leq 2810.0E3$ [J/kg]

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

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 function of specific enthalpy and specific entropy. Cell D2 is interpreted as: =S97FLK_SI_hs_prop(117167.3473, 391.7371, "v").

	A	B	C	D
1	h	s	prop	
2	117167.3473	391.7371	v	=S97FLK_SI_hs_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_hv_prop**

Excel function usage : = S97FLK_SI_hv_prop(h, v, prop)

Input values : **h** : Specific enthalpy in J/kg.
Range: $-41.5878 \leq h \leq 2810.0E3$ [J/kg]

v : Specific volume in m³/kg.
Range: $1.00007E-4 \leq v \leq 1719.8658$ [m³/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure ("p") as function of specific enthalpy and specific volume. Cell D2 is interpreted as: =S97FLK_SI_hv_prop(117167.3473, 0.00100126, "p").

	A	B	C	D
1	h	v	prop	
2	117167.3473	0.00100126	p	=S97FLK_SI_hv_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_ph_prop**

Excel function usage : = S97FLK_SI_ph_prop(p, h, prop)

Input values : **p** : Pressure in Pa.
Range: $610 \leq p \leq 1.0E8$ [Pa]

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

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and specific enthalpy. Cell D2 is interpreted as: =S97FLK_SI_ph_prop(5000000, 117167.3473, "v").

	A	B	C	D
1	p	h	prop	
2	5000000	117167.3473	v	=S97FLK_SI_ph_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_ps_prop**

Excel function usage : = S97FLK_SI_ps_prop(p, s, prop)

Input values : **p** : Pressure in Pa.
Range: $610 \leq p \leq 1.0E8$ [Pa]

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

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and specific entropy. Cell D2 is interpreted as: =S97FLK_SI_ps_prop(5000000, 391.7371, "v").

	A	B	C	D
1	p	s	prop	
2	5000000	391.7371	v	=S97FLK_SI_ps_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_pu_prop**

Excel function usage : = S97FLK_SI_pu_prop(p, u, prop)

Input values : **p** : Pressure in Pa.
Range: $610 \leq p \leq 1.0E8$ [Pa]

u : Specific internal energy J/Kg.
Range: $-282.7252 \leq u \leq 6327.862E3$ [J/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and specific internal energy. Cell D2 is interpreted as: =S97FLK_SI_pu_prop(5000000, 112161.0764, "v").

	A	B	C	D
1	p	u	prop	
2	5000000	112161.0764	v	=S97FLK_SI_pu_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_pv_prop**

Excel function usage : = S97FLK_SI_pv_prop(p, v, prop)

Input values : **p** : Pressure in Pa.
Range: $610 \leq p \leq 1.0E8$ [Pa]

v: Specific volume in m³/kg.
Range: $1.00007E-4 \leq v \leq 1719.8658$ [m³/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 enthalpy ("h") as a function of pressure and specific volume. Cell D2 is interpreted as: =S97FLK_SI_pv_prop(5000000, 0.00100126, "h").

	A	B	C	D
1	p	v	prop	
2	5000000	0.00100126	h	=S97FLK_SI_pv_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_px_prop**

Excel function usage : = S97FLK_SI_px_prop(p, x, prop)

Input values : **p** : Pressure in Pa.
Range: $610.0 \leq p \leq 22064000.0$ [Pa]

x : Vapor fraction in kg(saturated steam)/kg(wet steam).
Range: $0 \leq x \leq 1$ [kg/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and vapor fraction. Cell D2 is interpreted as: =S97FLK_SI_px_prop(5000000, 0.5, "h").

	A	B	C	D
1	p	x	prop	
2	5000000	0.5	h	=S97FLK_SI_px_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_Th_prop**

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

Input values : **T** : Temperature in K.
Range: $273.15 \leq T \leq 2273.15$ [K]

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

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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, 117167.3473, "v").

	A	B	C	D
1	T	h	prop	
2	300	117167.3473	v	=S97FLK_SI_Th_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_Tu_prop**

Excel function usage : = S97FLK_SI_Tu_prop(T, u, prop)

Input values : **T** : Temperature in K.
Range: $273.15 \leq T \leq 2273.15$ [K]

u : Specific internal energy in J/Kg.
Range: $-282.7252 \leq u \leq 6327.862E3$ [J/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 internal energy. Cell D2 is interpreted as: =S97FLK_SI_Tu_prop(300, 112161.0764, "v").

	A	B	C	D
1	T	u	prop	
2	300	112161.0764	v	=S97FLK_SI_Tu_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_Tv_prop**

Excel function usage : = S97FLK_SI_Tv_prop(T, v, prop)

Input values : **T** : Temperature in K.
Range: $273.15 \leq T \leq 2273.15$ [K]

v: Specific volume in m³/kg.
Range: $1.00007E-4 \leq v \leq 1719.8658$ [m³/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 enthalpy ("h") as a function of temperature and specific volume. Cell D2 is interpreted as: =S97FLK_SI_Tv_prop(300, 0.00100126, "h").

	A	B	C	D
1	T	v	prop	
2	300	0.00100126	h	=S97FLK_SI_Tv_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: $273.15 \leq T \leq 2273.15$ [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 5)

Output Result : See Table 5.

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, 391.7371, "v").

	A	B	C	D
1	T	s	prop	
2	300	391.7371	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: $273.15 \leq T \leq 2273.15$ [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 5)

Output Result : See Table 5.

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, 0.5, "h").

	A	B	C	D
1	T	x	prop	
2	300	0.5	h	=S97FLK_SI_Tx_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_uv_prop**

Excel function usage : = S97FLK_SI_uv_prop(u, v, prop)

Input values : **u** : Specific internal energy in J/Kg.
Range: $-282.7252 \leq u \leq 6327.862E3$ [J/kg]

v: Specific volume in m³/kg.
Range: $1.00007E-4 \leq v \leq 1719.8658$ [m³/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 enthalpy ("h") as a function of specific internal energy and specific volume. Cell D2 is interpreted as: =S97FLK_SI_uv_prop(112161.0764, 0.00100126, "h").

	A	B	C	D
1	u	v	prop	
2	112161.0764	0.00100126	h	=S97FLK_SI_uv_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_SI_T_sigma****Surface Tension****Excel function usage :** = S97FLK_SI_T_sigma(T)**Input values :** **T** : Temperature in K.
Range: $273.15 \leq T \leq 647.096$ [K]**Output Result :** Surface Tension in mPa·m.**Invalid Output Result :** **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.**Example :** Cell B2 returns the value of surface tension as a function of temperature.
Cell B2 is interpreted as: =S97FLK_SI_T_sigma(300).

	A	B
1	T	
2	300	=S97FLK_SI_T_sigma(A2)

FUNCTION NAME:**S97FLK_SI_p_sigma****Surface Tension****Excel function usage :** = S97FLK_SI_p_sigma(p)**Input values :** **p** : Pressure in Pa.
Range: $611.0 \leq p \leq 22064000.0$ [Pa]**Output Result :** Surface Tension in mPa·m.**Invalid Output Result :** **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.**Example :** Cell B2 returns the value of surface tension as a function of pressure.
Cell B2 is interpreted as: =S97FLK_SI_p_sigma(5000000).

	A	B
1	p	
2	5000000	=S97FLK_SI_p_sigma(A2)

FUNCTION NAME:**S97FLK_SI_T_psat****Vapor pressure****Excel function usage :** = S97FLK_SI_T_psat(T)**Input values :** **T** : Input temperature in K.
Range: $273.15 \leq T \leq 647.096$ [K]**Output Result :** Vapor Pressure in Pa.**Invalid Output Result :** **-999** For input values/results outside the valid range for **T**.**Example :** Cell B2 returns the value of vapor pressure as a function of temperature.
Cell B2 is interpreted as: =S97FLK_SI_T_psat(300).

	A	B
1	T	
2	300	=S97FLK_SI_T_psat(A2)

FUNCTION NAME:**S97FLK_SI_p_Tsat****Saturation Temperature****Excel function usage :** = S97FLK_SI_p_Tsat(p)**Input values :** **p** : Pressure in Pa.
Range: $611.0 \leq p \leq 22064000.0$ [Pa]**Output Result :** Saturation Temperature in K.**Invalid Output Result :** **-999** For input values/results outside the valid range for **p**.**Example :** Cell B2 returns the value of saturation temperature as a function of pressure.
Cell B2 is interpreted as: =S97FLK_SI_p_Tsat(5000000).

	A	B
1	p	
2	5000000	=S97FLK_SI_p_Tsat(A2)

FUNCTION NAME:**S97FLK_SI_VARwl_n****Refractive Index**Where **variables** is defined as :

Input variable		Input variable		Variables
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

Excel function usage : =S97FLK_SI_VARwl_n(variables, variable 1, variable2, n)**Input values :** **variables :** See above table.**variable1 :** Depending on value from above table.**variable2 :** Depending on value from above table.**n :** Wavelength in μm .Range: $0.2 \leq n \leq 1.1$ [μm]**Output Result :** Refractive index [-]**Invalid Output Result :** **-999** For input values outside the IAPWS-IF97 valid regions, or values outside the range for **n**.**Notes:** When using S97FLK_SI_VARwl_n, with variables Tx or px the refractive index is calculated only for saturation states, i.e., when $x = 0$, or $x = 1$.**Example :** Cell E2 returns the value of the refractive index as a function of pressure, temperature, and wavelength = 0.2 μm . Cell E2 is interpreted as: =S97FLK_SI_VARwl_n("pT", 5000000, 300, 0.2)

	A	B	C	D	E
1	variables	p	T	n	
2	pT	5000000	300	0.2	=S97FLK_SI_VARwl_n(A2, B2, C2,D2)

2.4 Property Functions Reference (I-P Units)

FUNCTION NAME: **S97FLK_IP_pT_prop**

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

Input values : **p** : Pressure in psi.
Range: $0.088473 \leq p \leq 1450.4$ [psi]

T : Temperature in °F.
Range: $32.0 \leq T \leq 3632.0$ [°F]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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(725.887, 80.33, "h").

	A	B	C	D
1	p	T	prop	
2	725.887	80.33	h	=S97FLK_IP_pT_prop(A2, B2, C2)

FUNCTION NAME: **S97FLK_IP_hs_prop**

Excel function usage : = S97FLK_IP_hs_prop(h, s, prop)

Input values : **h** : Specific enthalpy in Btu/lbm.
Range: $-0.017879 \leq h \leq 3171.5306$ [Btu/lbm]

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

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 function of specific enthalpy and specific entropy. Cell D2 is interpreted as: =S97FLK_IP_hs_prop(50.3748, 0.093564, "v").

	A	B	C	D
1	h	s	prop	
2	50.3748	0.093564	v	=S97FLK_IP_hs_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_hv_prop**

Excel function usage : = S97FLK_IP_hv_prop(h, v, prop)

Input values : **h** : Specific enthalpy in Btu/lbm.
Range: $-0.017879 \leq h \leq 3171.5306$ [Btu/lbm]

v : Specific volume in ft³/lbm.
Range: $1.601958E-2 \leq v \leq 27549.6$ [ft³/lbm]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure ("p") as function of specific enthalpy and specific volume. Cell D2 is interpreted as: =S97FLK_IP_hv_prop(50.3748, 0.01603859, "p").

	A	B	C	D
1	h	v	prop	
2	50.3748	0.01603859	p	=S97FLK_IP_hv_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_ph_prop**

Excel function usage : = S97FLK_IP_ph_prop(p, h, prop)

Input values : **p** : Pressure in psi.
Range: $0.088473 \leq p \leq 1450.4$ [psi]

h : Specific enthalpy in Btu/lbm.
Range: $-0.017879 \leq h \leq 3171.5306$ [Btu/lbm]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and specific enthalpy. Cell D2 is interpreted as: =S97FLK_IP_ph_prop(725.887, 50.3748, "v").

	A	B	C	D
1	p	h	prop	
2	725.887	50.3748	v	=S97FLK_IP_ph_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_ps_prop**

Excel function usage : = S97FLK_IP_ps_prop(p, s, prop)

Input values : **p** : Pressure in psi.
Range: $0.088473 \leq p \leq 1450.4$ [psi]

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

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and specific entropy. Cell D2 is interpreted as: =S97FLK_IP_ps_prop(725.887, 0.09356447, "v").

	A	B	C	D
1	p	s	prop	
2	725.887	0.09356447	v	=S97FLK_IP_ps_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_pu_prop**

Excel function usage : = S97FLK_IP_pu_prop(p, u, prop)

Input values : **p** : Pressure in psi.
Range: $0.088473 \leq p \leq 1450.4$ [psi]

u : Specific internal energy Btu/lbm.
Range: $-0.12155 \leq u \leq 2720.491$ [Btu/lbm]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and specific internal energy. Cell D2 is interpreted as: =S97FLK_IP_pu_prop(725.887, 48.2204141, "v").

	A	B	C	D
1	p	u	prop	
2	725.887	48.2204141	v	=S97FLK_IP_pu_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_pv_prop**

Excel function usage : = S97FLK_IP_pv_prop(p, v, prop)

Input values : **p** : Pressure in psi.
Range: $0.088473 \leq p \leq 1450.4$ [psi]

v: Specific volume in ft³/lbm.
Range: $1.601958E-2 \leq v \leq 27549.6$ [ft³/lbm]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 enthalpy ("h") as a function of pressure and specific volume. Cell D2 is interpreted as: =S97FLK_IP_pv_prop(725.887, 0.01603859, "h").

	A	B	C	D
1	p	v	prop	
2	725.887	0.01603859	h	=S97FLK_IP_pv_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_px_prop**

Excel function usage : = S97FLK_IP_px_prop(p, x, prop)

Input values : **p** : Pressure in psi.
Range: $0.088473 \leq p \leq 3200$ [psi]

x : Vapor fraction in lb(saturated steam)/lb(wet steam).
Range: $0 \leq x \leq 1$ [lb/lb]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 pressure and vapor fraction. Cell D2 is interpreted as: =S97FLK_IP_px_prop(725.887, 0.5, "h").

	A	B	C	D
1	p	x	prop	
2	725.887	0.5	h	=S97FLK_IP_px_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_Th_prop**

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

Input values : **T** : Temperature in °F.
Range: $32.0 \leq T \leq 3632.0$ [°F]

h : Specific enthalpy in Btu/lbm.
Range: $-0.017879 \leq h \leq 3171.5306$ [Btu/lbm]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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, 50.3748, "v").

	A	B	C	D
1	T	h	prop	
2	80.33	50.3748	v	=S97FLK_IP_Th_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_Tu_prop**

Excel function usage : = S97FLK_IP_Tu_prop(T, u, prop)

Input values : **T** : Temperature in °F.
Range: $32.0 \leq T \leq 3632.0$ [°F]

u : Specific internal energy Btu/lbm.
Range: $-0.12155 \leq u \leq 2720.491$ [Btu/lbm]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 internal energy. Cell D2 is interpreted as: =S97FLK_IP_Tu_prop(80.33, 48.2204141, "v").

	A	B	C	D
1	T	u	prop	
2	80.33	48.2204141	v	=S97FLK_IP_Tu_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_Tv_prop**

Excel function usage : = S97FLK_IP_Tv_prop(T, v, prop)

Input values : **T** : Temperature in °F.
Range: $32.0 \leq T \leq 3632.0$ [°F]

v : Specific volume in ft³/lbm.
Range: $1.601958E-2 \leq v \leq 27549.6$ [ft³/lbm]

prop : Output Property. String (see Table 5)

Output Result : See Table 5.

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 enthalpy ("h") as a function of temperature and specific volume. Cell D2 is interpreted as: =S97FLK_IP_Tv_prop(80.33, 0.01603859, "h").

	A	B	C	D
1	T	v	prop	
2	80.33	0.01603859	h	=S97FLK_IP_Tv_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: $32.0 \leq T \leq 3632.0$ [°F]

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

prop : Output Property. String (see Table 5)

Output Result : See Table 5.

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, 0.09356447, "v").

	A	B	C	D
1	T	s	prop	
2	80.33	0.09356447	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: $32.0 \leq T \leq 705.1028$ [°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 5)

Output Result : See Table 5.

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, 0.5, "h").

	A	B	C	D
1	T	x	prop	
2	80.33	0.5	h	=S97FLK_IP_Tx_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_uv_prop**

Excel function usage : = S97FLK_IP_uv_prop(u, v, prop)

Input values : **u** : Specific internal energy Btu/lbm.
Range: $-0.12155 \leq u \leq 2720.491$ [Btu/lbm]

v: Specific volume in ft³/lbm.
Range: $1.601958E-2 \leq v \leq 27549.6$ [ft³/lbm]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 enthalpy ("h") as a function of specific internal energy and specific volume. Cell D2 is interpreted as: =S97FLK_IP_uv_prop(48.2204141, 0.01603859, "h").

	A	B	C	D
1	u	v	prop	
2	48.2204141	0.01603859	h	=S97FLK_IP_uv_prop(A2, B2, C2)

FUNCTION NAME:**S97FLK_IP_T_sigma****Surface Tension****Excel function usage :** = S97FLK_IP_T_sigma(T)**Input values :** **T** : Temperature in °F.
Range: $32.0 \leq T \leq 705.1028$ [°F]**Output Result :** Surface Tension in lbf/ft.**Invalid Output Result :** **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.**Example :** Cell B2 returns the value of surface tension as a function of temperature.
Cell B2 is interpreted as: =S97FLK_IP_T_sigma(80.33).

	A	B
1	T	
2	80.33	=S97FLK_IP_T_sigma(A2)

FUNCTION NAME:**S97FLK_IP_p_sigma****Surface Tension****Excel function usage :** = S97FLK_IP_p_sigma(p)**Input values :** **p** : Pressure in psi.
Range: $0.088473 \leq p \leq 3200.1126$ [psi]**Output Result :** Surface Tension in lbf/ft.**Invalid Output Result :** **-999** For input values/results outside the valid range of the IAPWS-IF97 Formulation, or incorrect string **prop**.**Example :** Cell B2 returns the value of surface tension as a function of pressure.
Cell B2 is interpreted as: =S97FLK_IP_p_sigma(725.887).

	A	B
1	p	
2	725.887	=S97FLK_IP_p_sigma(A2)

FUNCTION NAME:**S97FLK_IP_T_pstat****Vapor pressure****Excel function usage :** =S97FLK_IP_T_pstat(T)**Input values :** **T** : Temperature in °F.
Range: $32.0 \leq T \leq 705.1028$ [°F]**Output Result :** Vapor Pressure in psi.**Invalid Output Result :** **-999** For input values/results outside the valid range for **T**.**Example :** Cell B2 returns the value of vapor pressure as a function of temperature.
Cell B2 is interpreted as: =S97FLK_IP_T_pstat(80.33).

	A	B
1	T	
2	80.33	=S97FLK_IP_T_pstat(A2)

FUNCTION NAME:**S97FLK_IP_p_Tsat****Saturation Temperature****Excel function usage :** =S97FLK_IP_p_Tsat(p)**Input values :** **p** : Pressure in psi.
Range: $610.0 \leq p \leq 3200.1126$ [psi]**Output Result :** Saturation Temperature in °F.**Invalid Output Result :** **-999** For input values/results outside the valid range for **p**.**Example :** Cell B2 returns the value of saturation temperature as a function of pressure.
Cell B2 is interpreted as: =S97FLK_IP_p_Tsat(725.887).

	A	B
1	p	
2	725.887	=S97FLK_IP_p_Tsat(A2)

FUNCTION NAME:**S97FLK_IP_VARwl_n****Refractive Index**Where **variables** is defined as :

Input variable		Input variable		Variables
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

Excel function usage : =S97FLK_IP_VARwl_n(variables, variable1, variable2, n)**Input values :** **variables :** See above table.**variable1 :** Depending on value from above table.**variable2 :** Depending on value from above table.**n :** Wavelength in μm .Range: $7.874015748032 \leq n \leq 43.30708661417$ [μm]**Output Result :** Refractive index [-]**Invalid Output Result :** **-999** For input values outside the IAPWS-IF97 valid regions, or values outside the range for n.**Notes:** When using S97FLK_IP_VARwl_n, with variables Tx or px the refractive index is calculated only for saturation states, i.e., when $x = 0$, or $x = 1$.**Example :** Cell E2 returns the value of the refractive index as a function of pressure, temperature, and wavelength = 10 μm . Cell E2 is interpreted as: =S97FLK_IP_VARwl_n("pT", 725.887, 80.33, 10)

	A	B	C	D	E
1	variables	p	T	n	
2	pT	725.887	80.33	10	=S97FLK_IP_VARwl_n(A2, B2, C2,D2)

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).