

IAPWS-IF97

# Water and Steam Properties

Excel<sup>®</sup> Add-In Library



## USER GUIDE

*Windows<sup>®</sup> Operating System  
SI and I-P Units  
Version 2.1*

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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.

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

**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.

## 1.3 Installation

Double-click on the installation file and follow the on-screen instructions. Contact [support@fluidika.com](mailto:support@fluidika.com) if you require assistance.

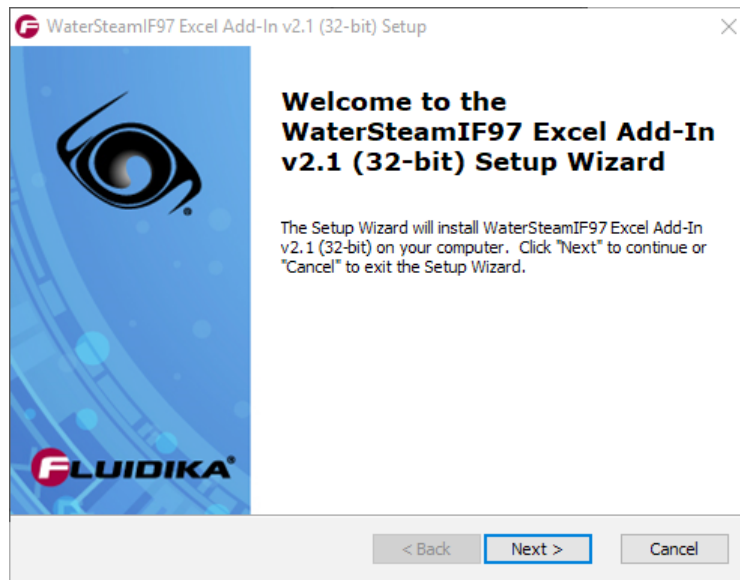


Figure 1. Installation screen of WaterSteamIF97FLK Add-in.

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

## 1.4 License

Introduce the **License Key** that you received in order to install the add-In during the installation process.

Contact [support@fluidika.com](mailto:support@fluidika.com) if you require assistance during the activation process.

## 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*

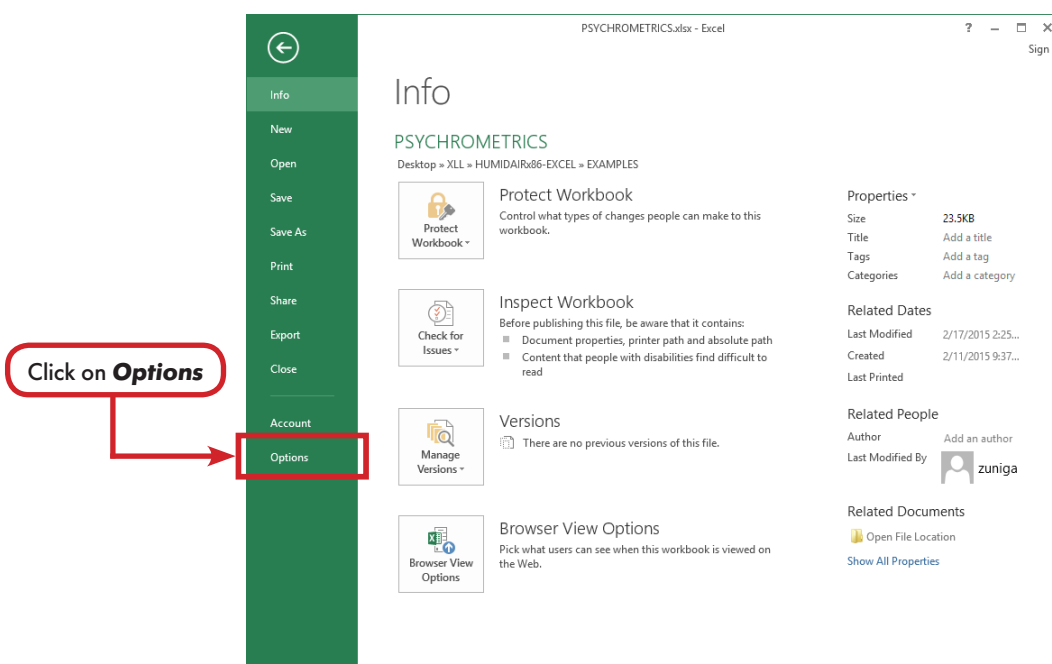


Figure 2. Registration of the add-in in Excel.

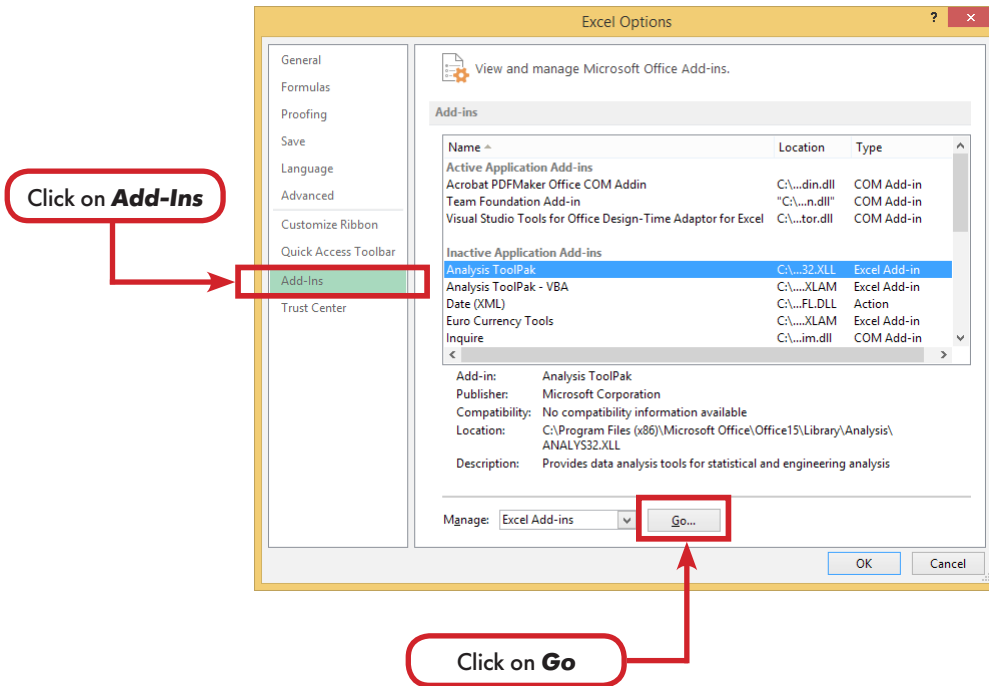


Figure 3. Registration of the add-in in Excel.

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.xll

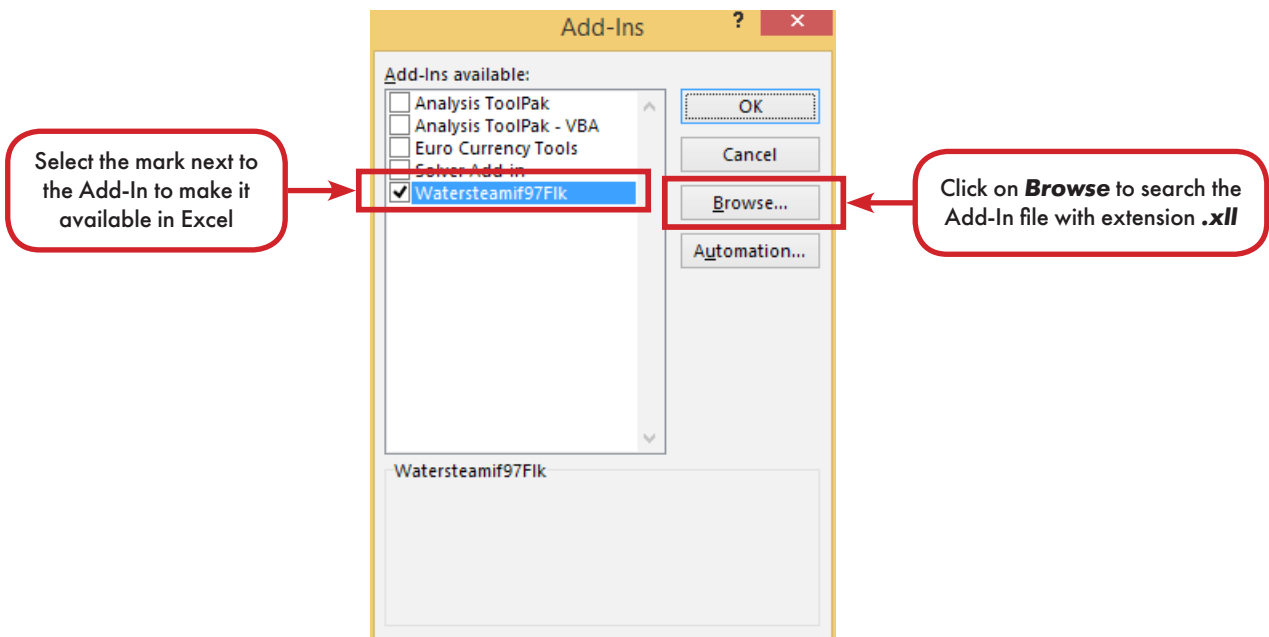


Figure 4. Registration of the add-in in Excel.

The Add-In is now ready for use.

## 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 5 and 6, 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 7 shows the combination of variables  $\langle h, s \rangle$  (enthalpy-entropy).

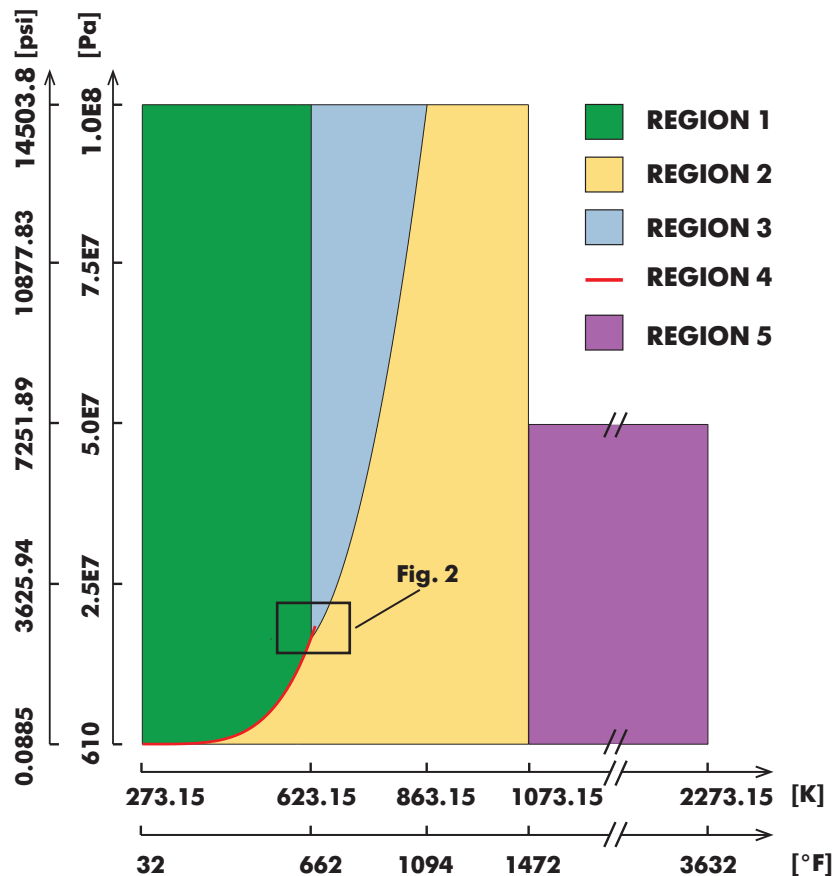


Figure 5. Range validity of the IAPWS-IF97 formulation (p-T).

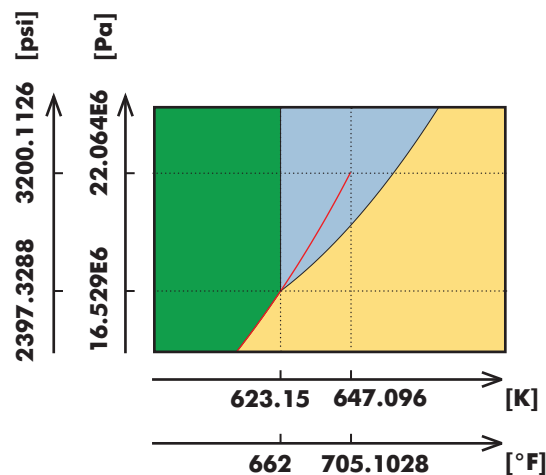


Figure 6. Zoom view of the critical point on the p-T Diagram.



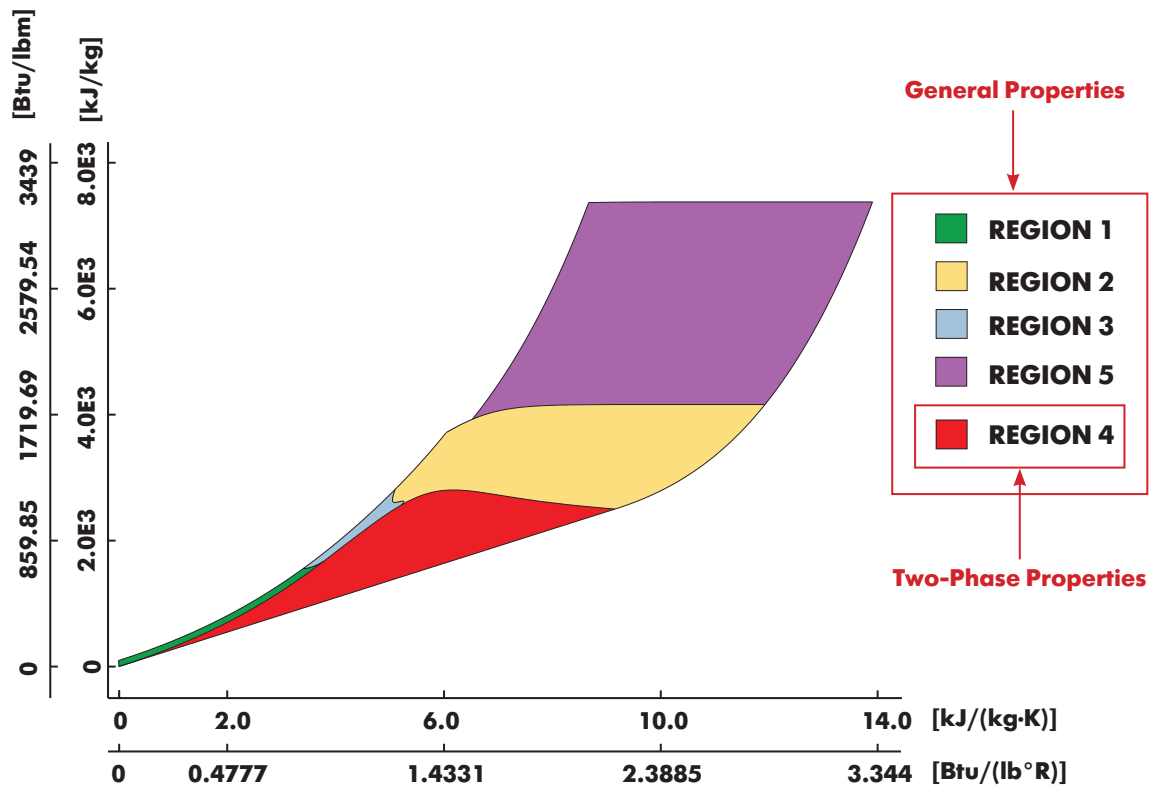


Figure 7. Enthalpy-Entropy Diagram.

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 <sup>3</sup> /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 <sup>3</sup> /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

**STEAMFLK\_SI\_XX\_prop**

or

**STEAMFLK\_IP\_XX\_prop**

where **XX** is one of the combinations in Table 3.

SI UNITS	I-P UNITS	OUTPUT RESULT
STEAMFLK_SI_pT_prop	STEAMFLK_IP_pT_prop	<b>Depending on value of "prop", see Table 5</b>
STEAMFLK_SI_Th_prop	STEAMFLK_IP_Th_prop	
STEAMFLK_SI_Tu_prop	STEAMFLK_IP_Tu_prop	
STEAMFLK_SI_Ts_prop	STEAMFLK_IP_Ts_prop	
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_Tx_prop	STEAMFLK_IP_Tx_prop	
STEAMFLK_SI_px_prop	STEAMFLK_IP_px_prop	
STEAMFLK_SI_REFRACTIVE	STEAMFLK_IP_REFRACTIVE	<b>Refractive index</b>
STEAMFLK_SI_T_sigma	STEAMFLK_IP_T_sigma	<b>Surface Tension</b>
STEAMFLK_SI_p_sigma	STEAMFLK_IP_p_sigma	<b>Surface Tension</b>
STEAMFLK_SI_T_psat	STEAMFLK_IP_T_psat	<b>Vapor Pressure</b>
STEAMFLK_SI_p_Tsat	STEAMFLK_IP_p_Tsat	<b>Saturation Temperature</b>

Table 2. Functions defined in **WaterSteamIF97FLK**.

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

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

Table 5. Properties calculated for each combination of input thermodynamic variables.

## 2.3 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.  
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: =STEAMFLK\_SI\_pT\_prop(5000000, 300, "h").

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

### FUNCTION NAME: **STEAMFLK\_SI\_hs\_prop**

**Excel function usage :** =STEAMFLK\_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: =STEAMFLK\_SI\_hs\_prop(117167.3473, 391.7371, "v").

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

**FUNCTION NAME:****STEAMFLK\_SI\_hv\_prop**

**Excel function usage :** =STEAMFLK\_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 m<sup>3</sup>/kg.  
Range:  $1.00007E-4 \leq v \leq 1719.8658$  [m<sup>3</sup>/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: =STEAMFLK\_SI\_hv\_prop(117167.3473, 0.00100126, "p").

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

**FUNCTION NAME:****STEAMFLK\_SI\_ph\_prop**

**Excel function usage :** =STEAMFLK\_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: =STEAMFLK\_SI\_ph\_prop(5000000, 117167.3473, "v").

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

**FUNCTION NAME:****STEAMFLK\_SI\_ps\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_SI\_ps\_prop(5000000, 391.7371, "v").

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

**FUNCTION NAME:****STEAMFLK\_SI\_pu\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_SI\_pu\_prop(5000000, 112161.0764, "v").

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

**FUNCTION NAME:****STEAMFLK\_SI\_pv\_prop**

**Excel function usage :** = STEAMFLK\_SI\_pv\_prop(p, v, prop)

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

**v**: Specific volume in m<sup>3</sup>/kg.  
Range:  $1.00007E-4 \leq v \leq 1719.8658$  [m<sup>3</sup>/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: =STEAMFLK\_SI\_pv\_prop(5000000, 0.00100126, "h").

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

**FUNCTION NAME:****STEAMFLK\_SI\_px\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_SI\_px\_prop(5000000, 0.5, "h").

	A	B	C	D
1	p	x	prop	
2	5000000	0.5	h	=STEAMFLK_SI_px_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:  $273.15 \leq T \leq 2273.15$  [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: =STEAMFLK\_SI\_Th\_prop(300, 117167.3473, "v").

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

**FUNCTION NAME:****STEAMFLK\_SI\_Tu\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_SI\_Tu\_prop(300, 112161.0764, "v").

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

**FUNCTION NAME:****STEAMFLK\_SI\_Tv\_prop**

**Excel function usage :** = STEAMFLK\_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 m<sup>3</sup>/kg.  
Range:  $1.00007E-4 \leq v \leq 1719.8658$  [m<sup>3</sup>/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: =STEAMFLK\_SI\_Tv\_prop(300, 0.00100126, "h").

	A	B	C	D
1	T	v	prop	
2	300	0.00100126	h	=STEAMFLK_SI_Tv_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:  $273.15 \leq T \leq 2273.15$  [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: =STEAMFLK\_SI\_Ts\_prop(300, 391.7371, "v").

	A	B	C	D
1	T	s	prop	
2	300	391.7371	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:  $273.15 \leq T \leq 2273.15$  [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: =STEAMFLK\_SI\_Tx\_prop(300, 0.5, "h").

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

**FUNCTION NAME:****STEAMFLK\_SI\_uv\_prop**

**Excel function usage :** =STEAMFLK\_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 m<sup>3</sup>/kg.  
Range:  $1.00007E-4 \leq v \leq 1719.8658$  [m<sup>3</sup>/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: =STEAMFLK\_SI\_uv\_prop(112161.0764, 0.00100126, "h").

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

**FUNCTION NAME:****STEAMFLK\_SI\_T\_sigma****Surface Tension****Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_SI\_T\_sigma(300).

	A	B
1	T	
2	300	=STEAMFLK_SI_T_sigma(A2)

**FUNCTION NAME:****STEAMFLK\_SI\_p\_sigma****Surface Tension****Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_SI\_p\_sigma(5000000).

	A	B
1	p	
2	5000000	=STEAMFLK_SI_p_sigma(A2)

**FUNCTION NAME:****STEAMFLK\_SI\_T\_psat****Vapor pressure****Excel function usage :** =STEAMFLK\_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: =STEAMFLK\_SI\_T\_psat(300).

	A	B
1	T	
2	300	=STEAMFLK_SI_T_psat(A2)

**FUNCTION NAME:****STEAMFLK\_SI\_p\_Tsat****Saturation Temperature****Excel function usage :** =STEAMFLK\_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: =STEAMFLK\_SI\_p\_Tsat(5000000).

	A	B
1	p	
2	5000000	=STEAMFLK_SI_p_Tsat(A2)

**FUNCTION NAME:****STEAMFLK\_SI\_REFRACTIVE****Refractive Index**Where **variables** is defined as :

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

**Excel function usage :** =STEAMFLK\_SI\_REFRACTIVE(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  $\mu\text{m}$ .  
Range:  $0.2 \leq n \leq 1.1$  [ $\mu\text{m}$ ]**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 STEAMFLK\_SI\_REFRACTIVE with variables Tx or px the refractive index is calculated only for saturated 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  $\mu\text{m}$ . Cell E2 is interpreted as: =STEAMFLK\_SI\_VARwl\_n("pT", 5000000, 300, 0.2)

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

## 2.4 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.  
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: =STEAMFLK\_IP\_pT\_prop(725.887, 80.33, "h").

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

### FUNCTION NAME:

### STEAMFLK\_IP\_hs\_prop

**Excel function usage :** =STEAMFLK\_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: =STEAMFLK\_IP\_hs\_prop(50.3748, 0.093564, "v").

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

**FUNCTION NAME:****STEAMFLK\_IP\_hv\_prop**

**Excel function usage :** = STEAMFLK\_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 ft<sup>3</sup>/lbm.  
Range:  $1.601958E-2 \leq v \leq 27549.6$  [ft<sup>3</sup>/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: =STEAMFLK\_IP\_hv\_prop(50.3748, 0.01603859, "p").

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

**FUNCTION NAME:****STEAMFLK\_IP\_ph\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_IP\_ph\_prop(725.887, 50.3748, "v").

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



**FUNCTION NAME:****STEAMFLK\_IP\_ps\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_IP\_ps\_prop(725.887, 0.09356447, "v").

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

**FUNCTION NAME:****STEAMFLK\_IP\_pu\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_IP\_pu\_prop(725.887, 48.2204141, "v").

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

**FUNCTION NAME:****STEAMFLK\_IP\_pv\_prop**

**Excel function usage :** = STEAMFLK\_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 ft<sup>3</sup>/lbm.  
Range:  $1.601958E-2 \leq v \leq 27549.6$  [ft<sup>3</sup>/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: =STEAMFLK\_IP\_pv\_prop(725.887, 0.01603859, "h").

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

**FUNCTION NAME:****STEAMFLK\_IP\_px\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_IP\_px\_prop(725.887, 0.5, "h").

	A	B	C	D
1	p	x	prop	
2	725.887	0.5	h	=STEAMFLK_IP_px_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:  $32.0 \leq T \leq 3632.0$  [°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: =STEAMFLK\_IP\_Th\_prop(80.33, 50.3748, "v").

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

**FUNCTION NAME:****STEAMFLK\_IP\_Tu\_prop**

**Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_IP\_Tu\_prop(80.33, 48.2204141, "v").

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

**FUNCTION NAME:****STEAMFLK\_IP\_Tv\_prop**

**Excel function usage :** =STEAMFLK\_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 ft<sup>3</sup>/lbm.  
Range:  $1.601958E-2 \leq v \leq 27549.6$  [ft<sup>3</sup>/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: =STEAMFLK\_IP\_Tv\_prop(80.33, 0.01603859, "h").

	A	B	C	D
1	T	v	prop	
2	80.33	0.01603859	h	=STEAMFLK_IP_Tv_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:  $32.0 \leq T \leq 3632.0$  [°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: =STEAMFLK\_IP\_Ts\_prop(80.33, 0.09356447, "v").

	A	B	C	D
1	T	s	prop	
2	80.33	0.09356447	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:  $32.0 \leq T \leq 705.1028$  [°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: =STEAMFLK\_IP\_Tx\_prop(80.33, 0.5, "h").

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

**FUNCTION NAME:****STEAMFLK\_IP\_uv\_prop**

**Excel function usage :** =STEAMFLK\_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 ft<sup>3</sup>/lbm.  
Range:  $1.601958E-2 \leq v \leq 27549.6$  [ft<sup>3</sup>/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: =STEAMFLK\_IP\_uv\_prop(48.2204141, 0.01603859, "h").

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

**FUNCTION NAME:****STEAMFLK\_IP\_T\_sigma**  
**Surface Tension****Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_IP\_T\_sigma(80.33).

	A	B
1	T	
2	80.33	=STEAMFLK_IP_T_sigma(A2)

**FUNCTION NAME:****STEAMFLK\_IP\_p\_sigma**  
**Surface Tension****Excel function usage :** = STEAMFLK\_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: =STEAMFLK\_IP\_p\_sigma(725.887).

	A	B
1	p	
2	725.887	=STEAMFLK_IP_p_sigma(A2)

**FUNCTION NAME:****STEAMFLK\_IP\_T\_psat****Vapor pressure****Excel function usage :** =STEAMFLK\_IP\_T\_psat(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: =STEAMFLK\_IP\_T\_psat(80.33).

	A	B
1	T	
2	80.33	=STEAMFLK_IP_T_psat(A2)

**FUNCTION NAME:****STEAMFLK\_IP\_p\_Tsat****Saturation Temperature****Excel function usage :** =STEAMFLK\_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: =STEAMFLK\_IP\_p\_Tsat(725.887).

	A	B
1	p	
2	725.887	=STEAMFLK_IP_p_Tsat(A2)

**FUNCTION NAME:****STEAMFLK\_IP\_REFRACTIVE****Refractive Index**Where **variables** is defined as :

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

**Excel function usage :** =STEAMFLK\_IP\_REFRACTIVE(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  $\mu\text{in}$ .Range:  $7.874015748032 \leq n \leq 43.30708661417$  [ $\mu\text{in}$ ]**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 STEAMFLK\_IP\_REFRACTIVE with variables Tx or px the refractive index is calculated only for saturated 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  $\mu\text{in}$ . Cell E2 is interpreted as: =STEAMFLK\_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	=STEAMFLK_IP_REFRACTIVE(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).
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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).