**Introduction**

Water97_v13.xla is an Add-In for MS Excel which provides a set of functions for calculating thermodynamic and transport properties of water and steam using the industrial standard IAPWS-IF97. For more information about IAPWS-IF97, underlying equations and references see [http://www.cheresources.com/iapwsif97.shtml](http://www.cheresources.com/iapwsif97.shtml)

**Reference of available functions**

Functions are available for calculating the following properties in the single-phase state for temperatures $273.15 \, \text{K} \leq T \leq 1073.15 \, \text{K}$ and pressures $0 < p \leq 1000 \, \text{bar}$

- density
- specific internal energy
- specific enthalpy
- specific entropy
- specific isobaric heat capacity
- specific isochoric heat capacity
- dynamic viscosity
- thermal conductivity

Additionally there are functions for calculating the boiling point temperature as a function of pressure and
the vapor pressure as a function of temperature as well as above eight properties for the saturated liquid and vapor state both as a function of temperature and pressure between 273.16 K or 611.657 Pa and 647.096 K or 220.64 bar (critical point).

1. Density in single-phase state
   a) Usage: \( \text{densW}(T; P) \)
   b) Argument(s):  
       \( T \) temperature in K
       \( P \) pressure in bar
   c) Unit:  
       density in kg/m\(^3\)
   d) Range of validity: \( 273.15 \leq T \leq 1073.15 \) K and \( 0 < p \leq 1000 \) bar
   e) Error:  
       \( \text{densW} = -1 \), temperature and/or pressure outside range
   f) Example:  
       density of water at 1 bar and 20 °C
       formula in worksheet cell:  
       \( =\text{densW}(20+273.15; 1) \)

2. Specific internal energy in single-phase state
   a) Usage: \( \text{energyW}(T; P) \)
   b) Argument(s):  
       \( T \) temperature in K
       \( P \) pressure in bar
   c) Unit:  
       specific internal energy in kJ/kg
   d) Range of validity: \( 273.15 \leq T \leq 1073.15 \) K and \( 0 < p \leq 1000 \) bar
   e) Error:  
       \( \text{energyW} = -1 \), temperature and/or pressure outside range
   f) Example:  
       specific internal energy of water at 10 bar and 400 K
       formula in worksheet cell:  
       \( =\text{energyW}(400; 10) \)

3. Specific enthalpy in single-phase state
   a) Usage: \( \text{enthalpyW}(T; P) \)
   b) Argument(s):  
       \( T \) temperature in K
       \( P \) pressure in bar
   c) Unit:  
       specific enthalpy in kJ/kg
   d) Range of validity: \( 273.15 \leq T \leq 1073.15 \) K and \( 0 < p \leq 1000 \) bar
   e) Error:  
       \( \text{enthalpyW} = -1 \), temperature and/or pressure outside range
   f) Example:  
       specific enthalpy of water at 10 bar and 400 K
       formula in worksheet cell:  
       \( =\text{enthalpyW}(400; 10) \)

4. Specific entropy in single-phase state
a) Usage: \( \text{entropyW}(T; P) \)

b) Argument(s): 
   - \( T \): temperature in K
   - \( P \): pressure in bar

c) Unit: specific entropy in kJ/(kg K)

d) Range of validity: \( 273.15 \text{ K} \leq T \leq 1073.15 \text{ K} \) and \( 0 < p \leq 1000 \text{ bar} \)

e) Error: \( \text{entropyW} = -1 \), temperature and/or pressure outside range

f) Example: specific entropy of water at 10 bar and 400 K
   formula in worksheet cell: \( =\text{entropyW}(400; 10) \)

5. **Specific isobaric heat capacity in single-phase state**

a) Usage: \( \text{cpW}(T; P) \)

b) Argument(s): 
   - \( T \): temperature in K
   - \( P \): pressure in bar

c) Unit: specific isobaric heat capacity in kJ/(kg K)

d) Range of validity: \( 273.15 \text{ K} \leq T \leq 1073.15 \text{ K} \) and \( 0 < p \leq 1000 \text{ bar} \)

e) Error: \( \text{cpW} = -1 \), temperature and/or pressure outside range

f) Example: specific isobaric heat capacity of steam at 1 bar and 120 °C
   formula in worksheet cell: \( =\text{cpW}(120+273.15; 1) \)

6. **Specific isochoric heat capacity in single-phase state**

a) Usage: \( \text{cvW}(T; P) \)

b) Argument(s): 
   - \( T \): temperature in K
   - \( P \): pressure in bar

c) Unit: specific isochoric heat capacity in kJ/(kg K)

d) Range of validity: \( 273.15 \text{ K} \leq T \leq 1073.15 \text{ K} \) and \( 0 < p \leq 1000 \text{ bar} \)

e) Error: \( \text{cvW} = -1 \), temperature and/or pressure outside range

f) Example: specific isochoric heat capacity of steam at 1 bar and 120 °C
   formula in worksheet cell: \( =\text{cvW}(120+273.15; 1) \)

7. **Dynamic viscosity in single-phase state**

a) Usage: \( \text{viscW}(T; P) \)

b) Argument(s): 
   - \( T \): temperature in K
   - \( P \): pressure in bar

c) Unit: dynamic viscosity in Pa s
d) Range of validity: 273.15 K ≤ T ≤ 1073.15 K and 0 < p ≤ 1000 bar

e) Error: \( \text{viscW} = -1 \), temperature and/or pressure outside range

f) Example: dynamic viscosity of water at 1 bar and 20 °C
   formula in worksheet cell: \( =\text{viscW(20+273.15; 1)} \)

8. Thermal conductivity in single-phase state

a) Usage: \( \text{thconW(T; P)} \)

b) Argument(s): \( T \) temperature in K
   \( P \) pressure in bar

c) Unit: thermal conductivity in W/(m K)

d) Range of validity: 273.15 K ≤ T ≤ 1073.15 K and 0 < p ≤ 1000 bar

e) Error: \( \text{thconW} = -1 \), temperature and/or pressure outside range

f) Example: thermal conductivity of water at 1 bar and 20 °C
   formula in worksheet cell: \( =\text{thconW(20+273.15; 1)} \)

9. Boiling point as a function of pressure

a) Usage: \( \text{tSatW(P)} \)

b) Argument(s): \( P \) pressure in bar

c) Unit: boiling point in K

d) Range of validity: 611.657 Pa ≤ p ≤ 220.64 bar

e) Error: \( \text{tSatW} = -1 \), pressure outside range

f) Example: boiling point of water at 1 bar in °C
   formula in worksheet cell: \( =\text{tSatW(1)-273.15} \)

10. Vapor pressure

a) Usage: \( \text{pSatW(T)} \)

b) Argument(s): \( T \) temperature in K

c) Unit: vapor pressure in bar

d) Range of validity: 273.16 K ≤ T ≤ 647.096 K

e) Error: \( \text{pSatW} = -1 \), temperature outside range

f) Example: vapor pressure of water at 100 °C
   formula in worksheet cell: \( =\text{pSatW(373.15)} \)
11. Density in saturation state

a) Usage:  
densSatLiqTW(T), density of boiling water as a function of temperature  
densSatLiqPW(P), density of boiling water as a function of pressure  
densSatVapTW(T), density of saturated steam as a function of temperature  
densSatVapPW(P), density of saturated steam as a function of pressure  

b) Argument(s):  
T temperature in K or P pressure in bar  

c) Unit:  
density in kg/m³  

d) Range of validity:  
273.16 K ≤ T ≤ 647.096 K or 611.657 Pa ≤ p ≤ 220.64 bar  

e) Error:  
densSatxxxxW = -1, temperature or pressure outside range  

f) Example:  
density of boiling water at 1 bar  
formula in worksheet cell:  
=densSatLiqPW(1)  

12. Specific internal energy in saturation state

a) Usage:  
energySatLiqTW(T), specific internal energy of boiling water as a function of temperature  
energySatLiqPW(P), specific internal energy of boiling water as a function of pressure  
energySatVapTW(T), specific internal energy of saturated steam as a function of temperature  
energySatVapPW(P), specific internal energy of saturated steam as a function of pressure  

b) Argument(s):  
T temperature in K or P pressure in bar  

c) Unit:  
specific internal energy in kJ/kg  

d) Range of validity:  
273.16 K ≤ T ≤ 647.096 K or 611.657 Pa ≤ p ≤ 220.64 bar  

e) Error:  
energySatxxxxW = -1, temperature or pressure outside range  

f) Example:  
specific internal energy of saturated steam at 100 °C  
formula in worksheet cell:  
=energySatVapTW(100+273.15)  

13. Specific enthalpy in saturation state

a) Usage:  
enthalpySatLiqTW(T), specific enthalpy of boiling water as a function of temperature  
enthalpySatLiqPW(P), specific enthalpy of boiling water as a function of pressure  
enthalpySatVapTW(T), specific enthalpy of saturated steam as a function of temperature  
enthalpySatVapPW(P), specific enthalpy of saturated steam as a function of pressure  

b) Argument(s):  
T temperature in K or P pressure in bar  

c) Unit:  
specific enthalpy in kJ/kg  

d) Range of validity: \(273.16 \, \text{K} \leq T \leq 647.096 \, \text{K} \) or \(611.657 \, \text{Pa} \leq p \leq 220.64 \, \text{bar}\)

e) Error: \(\text{enthalpySat}xxxxW = -1\), temperature or pressure outside range

f) Example: specific enthalpy of saturated steam at 100 °C
formula in worksheet cell: \(=\text{enthalpySatVapTW}(100+273.15)\)

14. Specific entropy in saturation state

a) Usage: \(\text{entropySatLiqTW}(T)\), specific entropy of boiling water as a function of temperature
\(\text{entropySatLiqPW}(P)\), specific entropy of boiling water as a function of pressure
\(\text{entropySatVapTW}(T)\), specific entropy of saturated steam as a function of temperature
\(\text{entropySatVapPW}(P)\), specific entropy of saturated steam as a function of pressure

b) Argument(s): \(T\) temperature in K or \(P\) pressure in bar

c) Unit: specific entropy in kJ/(kg K)

d) Range of validity: \(273.16 \, \text{K} \leq T \leq 647.096 \, \text{K} \) or \(611.657 \, \text{Pa} \leq p \leq 220.64 \, \text{bar}\)

e) Error: \(\text{entropy}xxxxW = -1\), temperature or pressure outside range

f) Example: specific entropy of saturated steam at 100 °C
formula in worksheet cell: \(=\text{entropySatVapTW}(100+273.15)\)

15. Specific isobaric heat capacity in saturation state

a) Usage: \(\text{cpSatLiqTW}(T)\), specific isobaric heat capacity of boiling water as a function of temperature
\(\text{cpSatLiqPW}(P)\), specific isobaric heat capacity of boiling water as a function of pressure
\(\text{cpSatVapTW}(T)\), specific isobaric heat capacity of saturated steam as a function of temperature
\(\text{cpSatVapPW}(P)\), specific isobaric heat capacity of saturated steam as a function of pressure

b) Argument(s): \(T\) temperature in K or \(P\) pressure in bar

c) Unit: specific isobaric heat capacity in kJ/(kg K)

d) Range of validity: \(273.16 \, \text{K} \leq T \leq 647.096 \, \text{K} \) or \(611.657 \, \text{Pa} \leq p \leq 220.64 \, \text{bar}\)

e) Error: \(\text{cpSat}xxxxW = -1\), temperature or pressure outside range

f) Example: specific isobaric heat capacity of boiling water at 100 °C
formula in worksheet cell: \(=\text{cpSatLiqTW}(100+273.15)\)

16. Specific isochoric heat capacity in saturation state
a) Usage: cvSatLiqTW(T), specific isochoric heat capacity of boiling water as a function of temperature
   cvSatLiqPW(P), specific isochoric heat capacity of boiling water as a function of pressure
   cvSatVapTW(T), specific isochoric heat capacity of saturated steam as a function of temperature
   cvSatVapPW(P), specific isochoric heat capacity of saturated steam as a function of pressure

b) Argument(s): T temperature in K or P pressure in bar

c) Unit: specific isochoric heat capacity in kJ/(kg K)

d) Range of validity: 273.16 K ≤ T ≤ 647.096 K or 611.657 Pa ≤ p ≤ 220.64 bar

e) Error: cvSatxxxxW = -1, temperature or pressure outside range

f) Example: specific isochoric heat capacity of saturated steam at 500 mbar
   formula in worksheet cell: =cvSatVapPW(0.5)

17. Dynamic viscosity in saturation state

a) Usage: viscSatLiqTW(T), dynamic viscosity of boiling water as a function of temperature
   viscSatLiqPW(P), dynamic viscosity of boiling water as a function of pressure
   viscSatVapTW(T), dynamic viscosity of saturated steam as a function of temperature
   viscSatVapPW(P), dynamic viscosity of saturated steam as a function of pressure

b) Argument(s): T temperature in K or P pressure in bar

c) Unit: dynamic viscosity in Pa s

d) Range of validity: 273.16 K ≤ T ≤ 647.096 K or 611.657 Pa ≤ p ≤ 220.64 bar

e) Error: viscSatxxxxW = -1, temperature or pressure outside range

f) Example: dynamic viscosity of boiling water at 1 bar
   formula in worksheet cell: =viscSatLiqPW(1)

18. Thermal conductivity in saturation state

a) Usage: thconSatLiqTW(T), thermal conductivity of boiling water as a function of temperature
   thconSatLiqPW(P), thermal conductivity of boiling water as a function of pressure
   thconSatVapTW(T), thermal conductivity of saturated steam as a function of temperature
   thconSatVapPW(P), thermal conductivity of saturated steam as a function of pressure

b) Argument(s): T temperature in K or P pressure in bar

c) Unit: thermal conductivity in W/(m K)
d) Range of validity: $273.16 \, \text{K} \leq T \leq 647.096 \, \text{K}$ or $611.657 \, \text{Pa} \leq p \leq 220.64 \, \text{bar}$

e) Error: thconSatxxxxW = -1, temperature or pressure outside range

f) Example: thermal conductivity of boiling water at 1 bar
   formula in worksheet cell: =thconSatLiqPW(1)