Overview

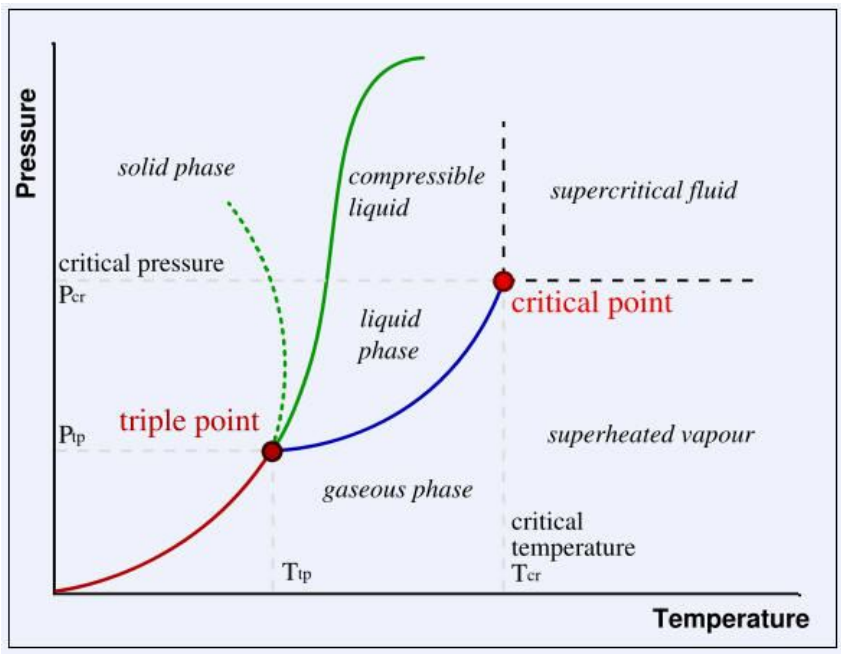
Introduction

Steam systems are a part of almost every major industrial process today. Chemical processes are significant energy consumers in view of their large heating demands. The chemical industry uses steam for a wide variety of purposes, the most important being process heating, drying or concentrating, steam cracking, and distillation.

Steam Calculator is an engineering tool built as an MS Excel add-in used to calculate thermodynamic and transport properties of steam. It calculates 22 properties such as: temperature, pressure, enthalpy, entropy, quality, internal energy, viscosity, thermal conductivity, surface tension, etc.

The calculations are based on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, revised release August 2007, supplemented with additional backward equations and transport properties equations.

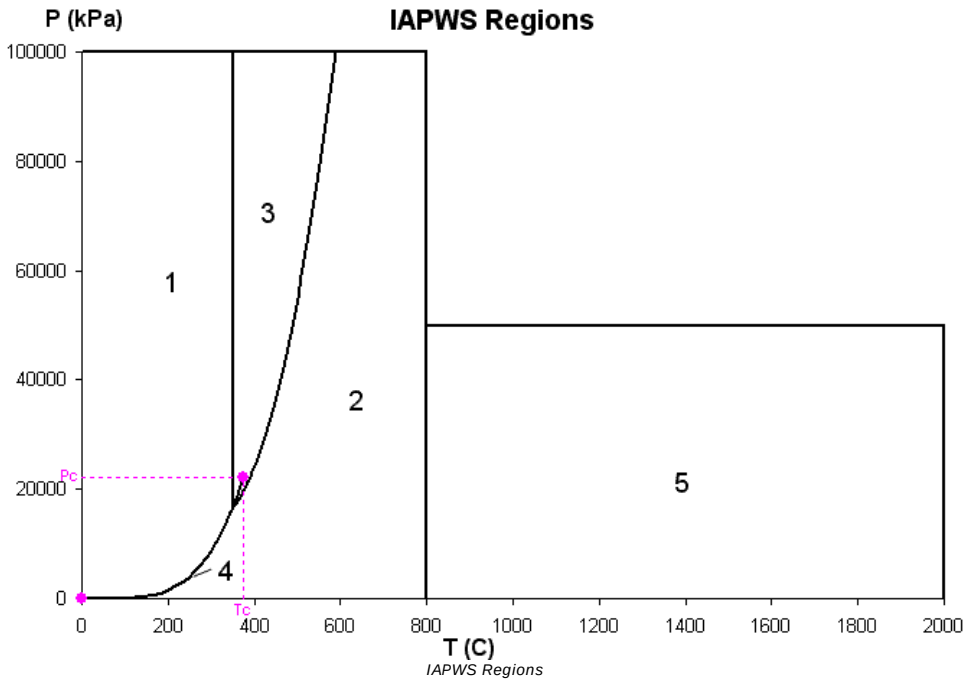
These equations can predict the water and steam properties on a very large scale of pressure and temperature.



Phase diagram

The phase diagram shows that at the interfaces between solid and liquid, liquid and gas and solid and gas it is possible for more than one phase to exist in equilibrium. The point at which all three phases come together is the triple point and represents the temperature and pressure for which all three states of matter coexist. For water this is 273.16 K at 611.2 Pa. The other labeled point on the diagram is called the critical point, also called critical state. At this point the liquid and gaseous phases of a pure stable substance become identical, for water this is at 647.096 K and 22064000 Pa.

IAPWS equations deal with the regions above triple point pressure and 0 ºC, up to 100 MPa and 800 ºC, and for high temperatures, up to 50 MPa and 2000 ºC.



IAPWS Regions

Region 1 corresponds to the liquid phase, region 2 to the vapor phase, region 3 to the supercritical fluid phase, region 4 represents the saturation line between liquid and vapor phase and region 5 the high temperature vapor region.

Most of the Steam Calculator functions use basic or backward equations to calculate the properties of water and steam. However some functions use iterative algorithms which in some cases may fail to converge.

The properties can be calculated in two ways with Steam Calculator.

1. Using the visual interface which is available from the *Steam Calculator* menu item added to the MS Excel *Tools* menu (Excel 200-2003) or *Steam Calculator* ribbon from *ChemGoodies* tab (Excel 2007-2010) ;
2. Using the corresponding spreadsheet functions exposed by the Steam Calculator add-in (Insert Function feature in MS Excel).

Steam Calculator versions

There are two types of installation:

1. **Evaluation version**

   Steam Calculator Evaluation version is a free edition with a restricted set of features. There are only 3 functions enabled in the Insert Functions feature of Excel and 3 tabs enabled in the Steam Calculator Functions dialog (user interface). The functions available in the Evaluation version are:

   - **SCPH** - Calculates the steam properties at the specified pressure and enthalpy;
   - **SCPS** - Calculates the steam properties at the specified pressure and entropy;
   - **SCPX** - Calculates the saturated steam properties at the specified pressure and steam quality.

2. **Full version**

   The full version exposes all the available functions to the user who has to pay a license fee.

Installation

System Requirements

- Operating System: Windows 2000 SP4, Windows XP, Windows 2003, Windows Vista, Windows 7 (32-bit or 64-bit editions)
- MS Excel 2000, MS Excel 2002, MS Excel 2003, MS Excel 2007, MS Excel 2010 (32-bit or 64-bit editions)
- Internet connection to allow prerequisites download (if not already installed)

Note: The following prerequisites will be automatically downloaded and installed if they are not already installed and if an Internet connection is available during the setup process:

- .NET Framework 4.0 Client Profile
- Windows Installer 3.1

Installation

The add-in is delivered as a .zip package containing the installation kit and the necessary prerequisites (downloadable). Steam Calculator is built using the .NET Framework 4.0 technology which is included as web installer in the installation package and will be installed on the target machine during the setup process. Steam Calculator is installed for current user only so the setup does not require elevated privileges. However .NET Framework 4.0 Client Profile requires administrator privileges. If needed, a computer administrator can download and install .NET Framework 4.0 Client Profile prior Steam Calculator installation using the following address: http://go.microsoft.com/fwlink/?LinkId=131000 .

Installation steps:

- Unzip the installation package in a local folder on the target machine;
- Browse the folder and run setup.exe;
- If prerequisites (.NET Framework 4.0 Client Profile, Windows Installer 3.1) are not already installed on the target machine the setup will continue with the prerequisites download and installation. Please accept the *License Agreements* and confirm the prerequisites installation;
- Once the prerequisites are installed the setup may prompt you to restart the machine. Choose yes to restart the machine at this moment;
- After restart the setup will continue with the Steam Calculator components installation. Click on *Next* in the *Welcome* screen select *I Agree* in the *License Agreement* screen and press *Next* to get in the Installation Folder screen;
- Select an installation folder or keep the default entry and press *Next*;
- Press Next in the *Confirm Installation* screen.
- Press Close on the *Installation Complete* screen.

Open Microsoft Excel and make sure that:

- A new ribbon named Steam Calculator is added under **ChemGoodies** tab (MS Excel 2007 or MS Excel 2010)
- Under Excel *Tools* menu there is a new entry named Steam Calculator containing the menu items; (MS Excel 2000, 2002, 2003)
- In the Insert Function dialog there is a new category named Steam Calculator containing the Steam Calculator functions.

Uninstallation

Use *Programs and Features* or *Add/Remove Programs* feature to uninstall Steam Calculator.

Properties

Current release of Steam Calculator operates with the following properties:

Properties Table

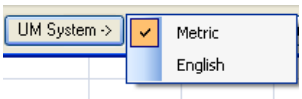
Property	Metric UM	English UM	outputCode
Temperature	°C	°F	0
Pressure	kPa	psia	1
Enthalpy	kJ/kg	Btu/lb	2
Entropy	kJ/kg/°C	Btu/lb/°F	3
Quality	n/a	n/a	4
Density	kg/m^3	lb/ft^3	5
Internal Energy	kJ/kg	Btu/lb	6
Isobaric Heat Capacity	kJ/kg/°C	Btu/lb/°F	7
Isochoric Heat Capacity	kJ/kg/°C	Btu/lb/°F	8
Specific volume	m^3/kg	ft^3/lb	9
Speed of sound	m/s	ft/s	10
Thermal Conductivity	W/m/°C	Btu/h/ft/°F	11
Viscosity	µPa*s	lb/ft/h	12
Surface Tension	N/m	N/m	13
Helmholtz Free Energy	kJ/kg	Btu/lb	14
Gibbs Free Energy	kJ/kg	Btu/lb	15
Compressibility Factor	n/a	n/a	16
Isothermal Compressibility	1/kPa	1/psi	17
Joule-Thompson Coefficient	°C/kPa	°F/psi	18
Isothermal Joule-Thompson	kJ/kg/kPa	Btu/lb/psi	19
Thermal Expansion Coefficient	1/°C	1/°F	20
Prandtl Number	n/a	n/a	21
Static Dielectric constant	n/a	n/a	22

The corresponding **units of measure** for each property, in both Units of Measure systems (**Metric UM System** and **English UM System)**, the add-in operates with, are listed in the above table.

The UM system is specified as a parameter (*umSystem*) when the Excel functions are used: **0** for **Metric** and **1** for **English**

=SCTP(101,100,5,**0**)

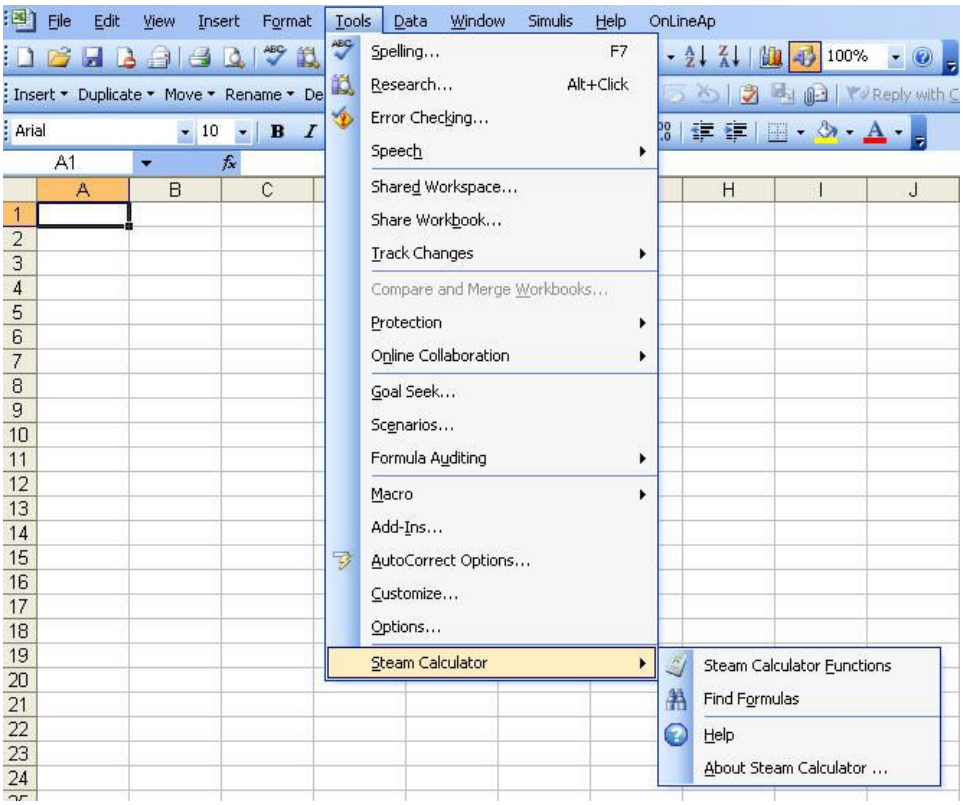
It can be changed also by pressing the *UM System* button when the add-in interface is used.



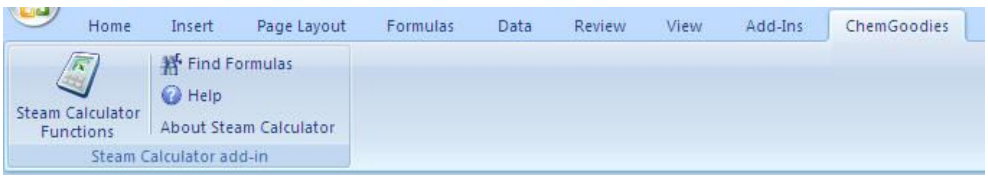
The **outputCode** column represents the code used as a parameter in the Excel spreadsheet functions, which indicates which parameter is calculated.

How to use - User Interface

The Steam Calculator add-in User Interface is available by invoking the *Steam Calculator* menu entries automatically added under Tools (MS Excel 2003 or earlier) or in Steam Calculator ribbon is automatically added under ChemGoodies (MS Excel 2007-2010).

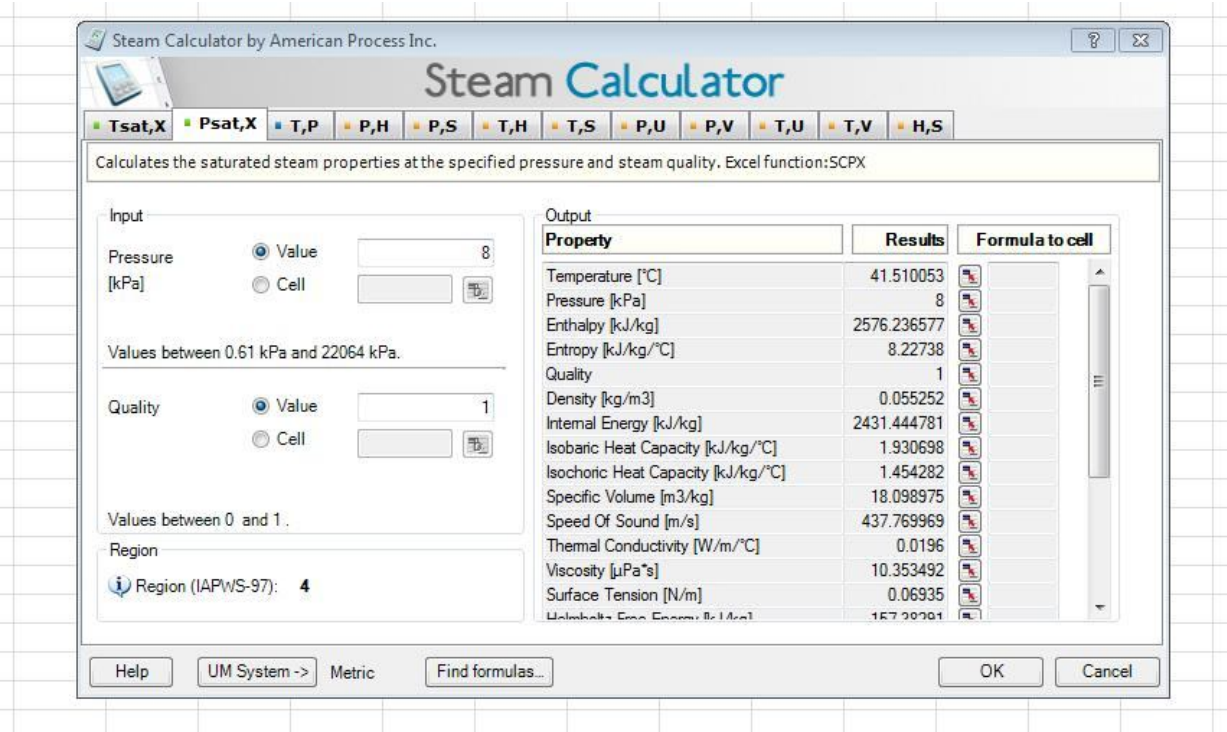


In MS Excel 2007 Steam Calculator ribbon is automatically added under ChemGoodies tab.



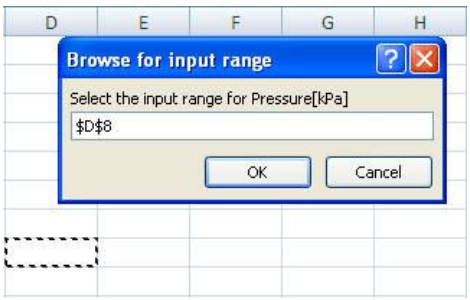
Functions dialog:

A dialog window, containing one tab for each Steam Calculator function, is displayed calling up the Functions menu:



1. Input panel

Input panel is used to provide either a value or a cell reference for the input parameter. The user is able to select a cell reference as an input by clicking on *Cell* radio button and pressing the *Browse* button. A *Browse for input* dialog window is displayed:

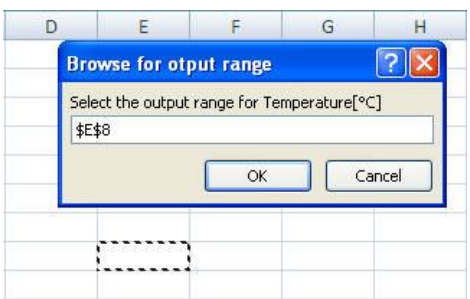


Remarks:

- Once all the input are filled up with values or cell references, the outputs are automatically calculated in the Output panel.
- If the input values are outside limits a warning is displayed next to the input.

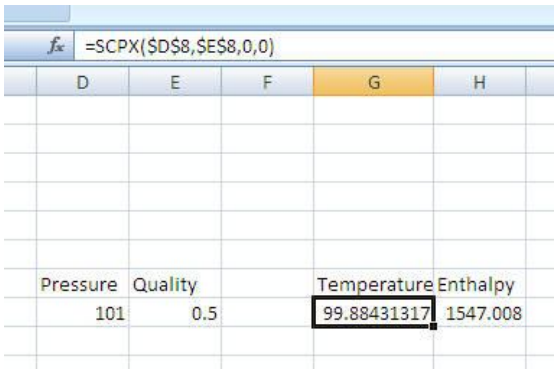
2. Output panel

The *Output* panel is used to display the list of calculated values for the available function outputs. To paste the corresponding formula in an Excel cell click on the corresponding *Browse* button and select a cell to insert the formula.



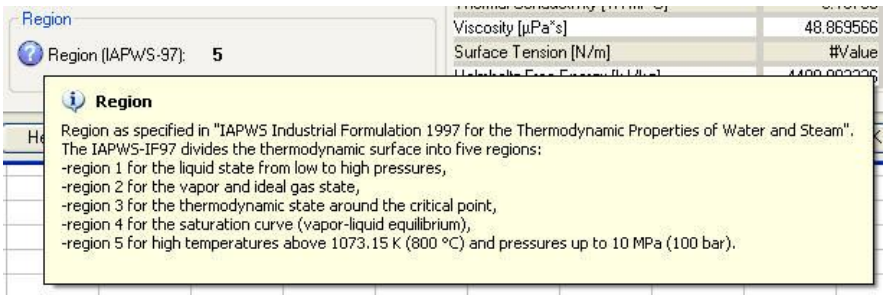
Remarks:

- Some output values may not have meaning in some regions, therefore #Value is displayed.
- To complete the formulas insertions press *OK* button and all the formulas from all tabs are automatically inserted in the corresponding cells.
- The functions can also be inserted using excel Insert Functions or by typing the formula directly into MS Excel cell.



3. Region panel

The *Region* panel displays the corresponding IAPWS regions number.

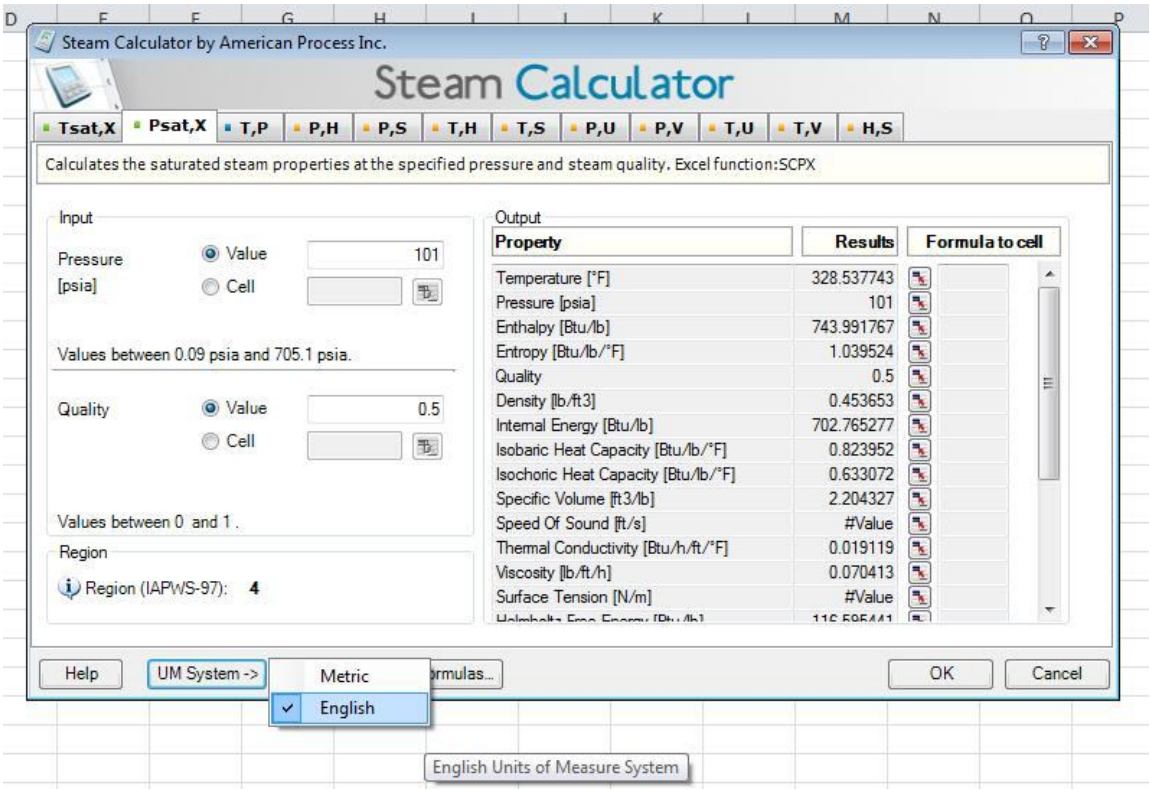


Remarks:

- Some backward functions arise difficulties , and it is possible to show a region and still have #Value as output. this happens because the calculated temperature or pressure is out of the IAPWS limits.

4. Units of Measure System

The Units of Measure System used in the calculations is displayed in the bottom of the screen and can be switched by pressing the UM System button and selecting an item from the drop down list.

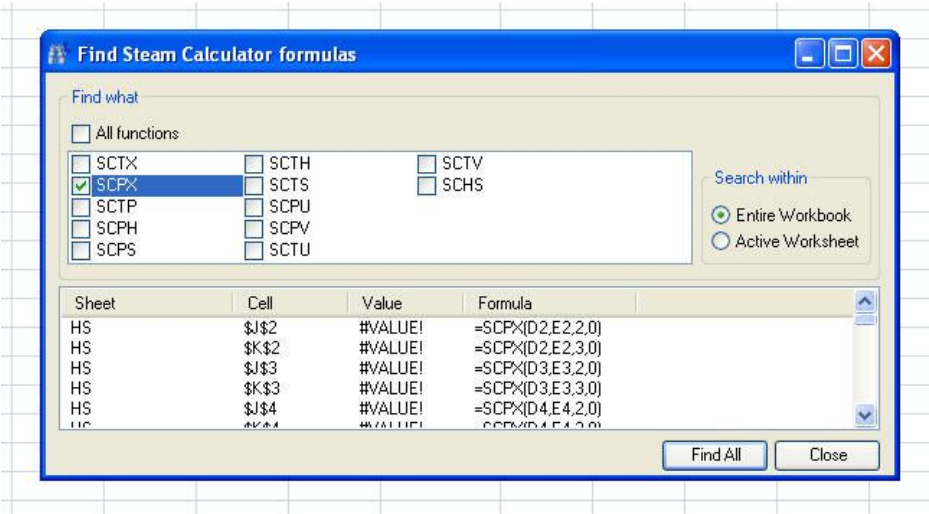


Remarks:

- When switching the UM System all the inputs and outputs are reevaluated according to the new selection. The selection is persisted as a user preference.

5. Find formulas

To find a Steam Calculator formula in the active workbook or worksheet, select Find formulas from the menu or press the Find formulas button. A new dialog window will be opened and you can select the formulas you are searching for.

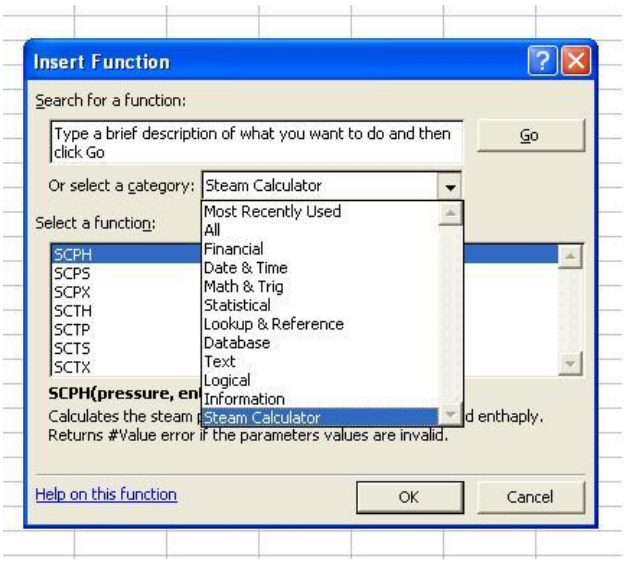


Remarks:

- Click on the item list with found formulas to navigate to the corresponding cell.

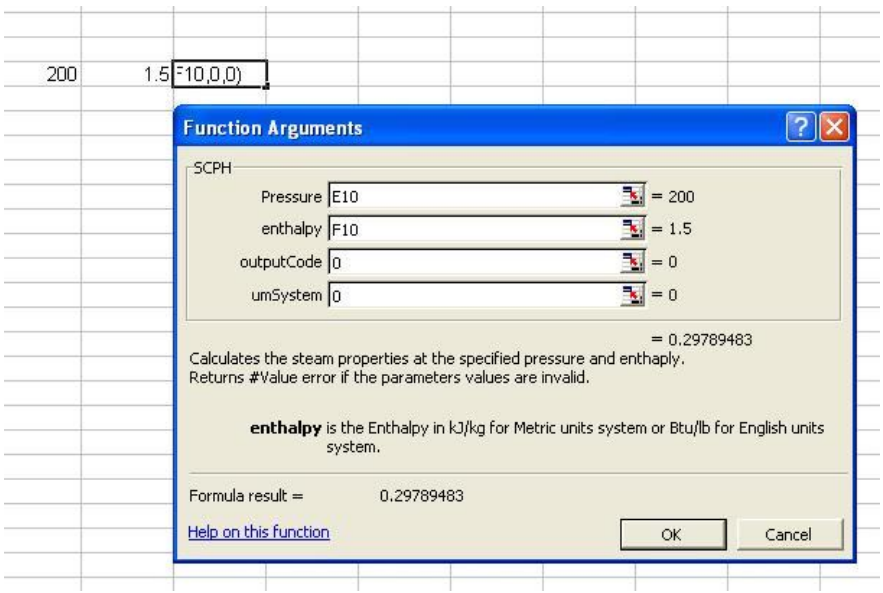
How to use - Insert Functions from Excel

Functions exposed by Steam Calculator add-in are accessible using Insert Function feature of MS Excel. The add-in adds a new functions category named *Steam Calculator* which contains the list of available functions.



Usage:

1. Select the cell to insert formula in;
2. Select Insert/Function menu in an opened MS Excel workbook;
3. Select the Steam Calculator Category;
4. Select the corresponding function and press OK (each function displays a short description when it is selected);
5. The Functions Argument is displayed. Enter a value or browse for a Cell reference for each parameter;



6. Press OK to insert formula or Cancel to abort.

Remarks:

- The functions can be also inserted by typing the formula and its arguments directly into MS Excel cell or using the Steam Calculator user interface.
- The function returns #Value error if the parameters values are invalid.
- Some function solves for the temperature or pressure iteratively. Therefore, it is possible that these functions fail to converge, in which case the function returns the #VALUE! error.
- For the calculated property's output code see the Properties table.

SCPX

Syntax: SCPX(pressure,quality,outputCode,umSystem)

Description: Calculates the saturated steam properties at the specified pressure and steam quality.

Parameters:

- *pressure*: Pressure in kPa for Metric units system or psia for English units system. Acceptable values between 0.611657 kPa and 22064 kPa.
- *quality*: Steam quality. Acceptable values between 0 and 1.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.

SCTX

Syntax: SCTX(temperature,quality,outputCode,umSystem)

Description: Calculates the steam properties at the specified temperature and quality.

Parameters:

- *temperature*: Temperature in °C for Metric units system or °F for English units system. Acceptable values between °0 C and 373.946 °C.
- *quality*: Steam quality. Acceptable values between 0 and 1.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.

SCTP

Syntax: SCTP(temperature,pressure,outputCode,umSystem)

Description: Calculates the steam properties at the specified temperature and pressure.

Parameters:

- *temperature*: Temperature in °C for Metric units system or °F for English units system. Acceptable values between °0 C and 2000 °C .
- *pressure*: Pressure in kPa for Metric units system or psia for English units system. Acceptable values between 0.611657 kPa and 100000 kPa (up to 800°C) and between 0.611657 kPa and 50000 kPa (up to 2000 °C) .
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.

SCPH

Syntax: SCPH(pressure,enthalpy,outputCode,umSystem)

Description: Calculates the steam properties at the specified pressure and enthalpy.

Parameters:

- *pressure*: pressure in kPa for Metric units system or psia for English units system. Acceptable values between 0.611657 kPa and 100000 kPa.
- *enthalpy*: Enthalpy in kJ/kg for Metric units system or Btu/lb for English units system. Acceptable values between -0.041587373 kJ/kg and 4500 kJ/kg.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.

SCPS

Syntax: SCPS(pressure,entropy,outputCode,umSystem)

Description: Calculates the steam properties at the specified pressure and entropy.

Parameters:

- *pressure*: Pressure in kPa for Metric units system or psia for English units system. Acceptable values between 0.611657 kPa and 100000 kPa.
- *entropy*: Entropy in kJ/kg/°C for Metric units system or Btu/lb/°F for English units system. Acceptable values between -0.00015455 kJ/kg/°C and 12 kJ/kg/°C.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.

SCTH

Syntax: SCTH(temperature,enthalpy,outputCode,umSystem)

Description: Calculates the steam properties at the specified temperature and enthalpy.

Parameters:

- *temperature*: Temperature in °C for Metric units system or °F for English units system. Acceptable values between °0 C and 800 °C.
- *pressure*: Enthalpy in kJ/kg for Metric units system or Btu/lb for English units system. Acceptable values between -0.041587373 kJ/kg and 4500 kJ/kg.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.
- This function solves for the pressure iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the #VALUE! error.

SCTS

Syntax: SCTS(temperature,entropy,outputCode,umSystem)

Description: Calculates the steam properties at the specified temperature and entropy.

Parameters:

- *temperature*: Temperature in °C for Metric units system or °F for English units system. Acceptable values between °0 C and 800 °C.
- *entropy*: Entropy in kJ/kg/°C for Metric units system or Btu/lb/°F for English units system. Acceptable values between -0.00015455 kJ/kg/°C and 12 kJ/kg/°C.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.
- This function solves for the pressure iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the #VALUE! error.

SCPU

Syntax: SCPU(pressure,internal energy,outputCode,umSystem)

Description: Calculates the steam properties at the specified pressure and internal energy.

Parameters:

- *pressure*: pressure in kPa for Metric units system or psia for English units system. Acceptable values between 0.611657 kPa and 100000 kPa.
- *internal energy*: Internal energy in kJ/kg for Metric units system or Btu/lb for English units system. Acceptable values between -0.042199 kJ/kg and 4000 kJ/kg.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.
- This function solves for the temperature iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the #VALUE! error.

SCPV

Syntax: SCPV(pressure,specific volume,outputCode,umSystem)

Description: Calculates the steam properties at the specified pressure and specific volume.

Parameters:

- *pressure*: pressure in kPa for Metric units system or psia for English units system. Acceptable values between 0.611657 kPa and 100000 kPa.
- *specific volume: Specific volume in m3/kg for Metric units system or ft3/lb for English units system. Acceptable values between 0.00095669 m3/kg and 1000 m3/kg.*
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.
- This function solves for the temperature iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the #VALUE! error.

SCTU

Syntax: SCTU(temperature, internal energy,outputCode,umSystem)

Description: Calculates the steam properties at the specified temperature and internal energy.

Parameters:

- *temperature*: Temperature in °C for Metric units system or °F for English units system. Acceptable values between °0 C and 800 °C.
- *internal energy*: Internal energy in kJ/kg for Metric units system or Btu/lb for English units system. Acceptable values between -0.042199 kJ/kg and 4000 kJ/kg.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.
- This function solves for the pressure iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the #VALUE! error.

SCTV

Syntax: SCTV(temperature, specific volume,outputCode,umSystem)

Description: Calculates the steam properties at the specified temperature and specific volume.

Parameters:

- *temperature*: Temperature in °C for Metric units system or °F for English units system. Acceptable values between °0 C and 800 °C.
- *specific volume*: Specific volume in m^3/kg for Metric units system or ft^3/lb for English units system. Acceptable values between 0.00095669 m^3/kg and 1000 m^3/kg.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.
- This function solves for the pressure iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the #VALUE! error.

SCHS

Syntax: SCHS(enthalpy,entropy,outputCode,umSystem)

Description: Calculates the steam properties at the specified enthalpy and entropy.

Parameters:

- *enthalpy*: Enthalpy in kJ/kg for Metric units system or Btu/lb for English units system. Acceptable values between -0.041587373 kJ/kg and 4500 kJ/kg.
- *entropy*: Entropy in kJ/kg/°C for Metric units system or Btu/lb/°F for English units system. Acceptable values between -0.00015455 kJ/kg/°C and 12 kJ/kg/°C.
- *outputCode*: specifies the property to be calculated. See the Properties table.
- *umSystem*: specifies the Unit of Measure System used in calculations: 0 for Metric units or 1 for English units.

Remarks:

- The function can be found in the **Steam Calculator** category when using Insert Function feature of MS Excel.
- The function returns #Value error if the parameters values are invalid.

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