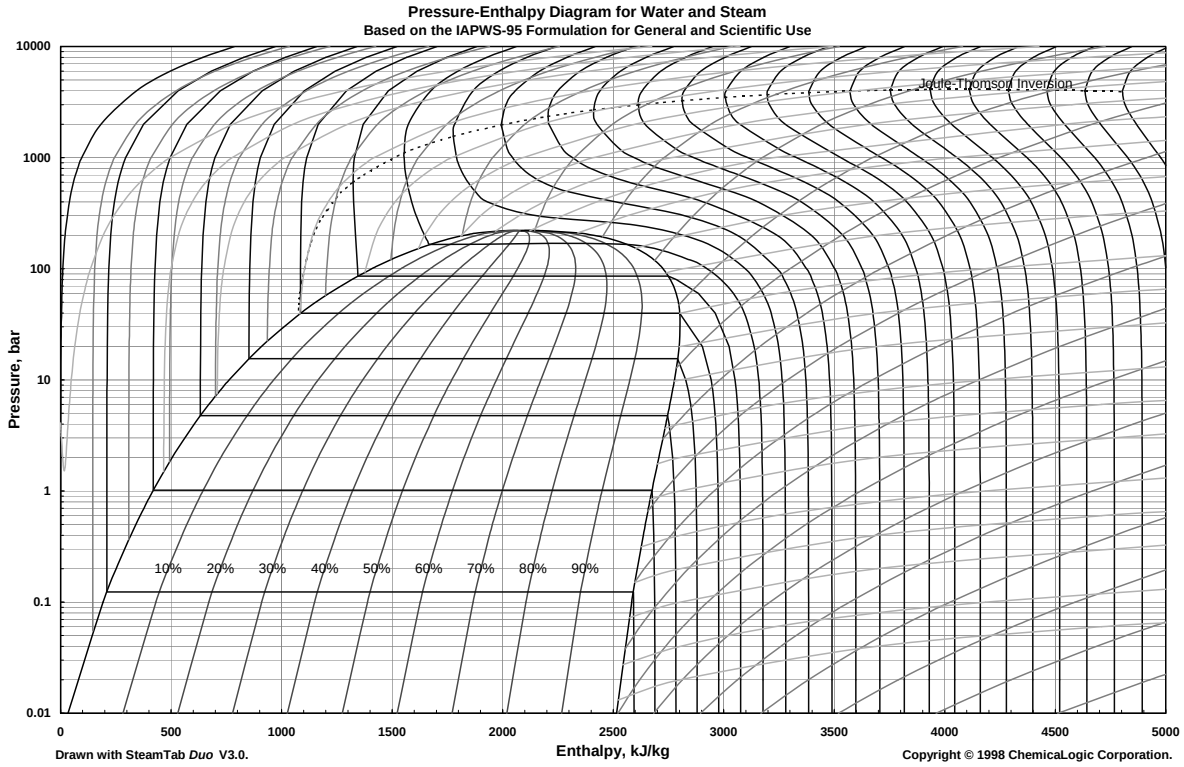
SteamTab® V4.0 User's Guide

THERMODYNAMIC AND TRANSPORT PROPERTIES OF WATER AND STEAM



CHEMICALOGIC

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SteamTab® Thermodynamic and Transport Properties of Water and Steam

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Chapter 1

Introduction to SteamTab®

Whatever creativity is, it is in part a solution to a problem.
– Brian Aldiss (b. 1925),
Bury My Heart at W. H. Smith's, "Apéritif" (1990).

Overview and Features

Designers of steam processing systems and equipment use a variety of conventional methods to look up steam properties for engineering calculation, including printed steam tables in different units, stand-alone steam property software, proprietary design software, general-purpose process simulators and long-hand calculations from fundamental equations. Lookup from printed steam tables remains the most frequently used method for daily use of steam properties. The interpolation of property values between fixed state points is a tedious, boring and prone-to-error exercise that has plagued many generations of engineers.

SteamTab, designed as an add-in package to popular spreadsheet applications, allows users the convenient access, without leaving the spreadsheet computation environment, to a variety of steam property values. SteamTab contains a comprehensive set of thermodynamic and transport properties applicable over a wide range of conditions, with selected derivative and dimensionless properties.

SteamTab uses fundamental equations to calculate all steam properties with no interpolation or curve fits to raw steam data. SteamTab uses formulations that are approved the International Association of the Properties of Water and Steam (IAPWS) in 1995 for general and scientific use. This formulation is thermodynamically rigorous, accurate, and applicable over wider range of conditions. The formulations used in SteamTab are given in the following reference:

Reference

Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use, The International Association for the Properties of Water and Steam, Frederica, Denmark, Sept. 1996.

The scientific formulation is valid in the entire stable fluid region of water from the melting pressure curve starting at 251.165 K to 1273 K at pressures up to 1,000 MPa. The formulation can also be extrapolated to pressures up to about 100 GPa and temperatures up to 5000 K.

SteamTab imposes the following temperature and pressure restrictions:

- Pressure (P, bar): $0 \le P \le 100{,}000$
- Temperature (T, K): $190 \le T \le 5000$

Note

SteamTab does not include properties for ice.

SteamTab is designed as a low-cost, personal productivity-enhancement tool, for steam property users in the scientific, engineering, plant operation and educational communities.

SteamTab contains the following features:

- Easy access to a comprehensive set of thermodynamic and transport steam properties from the spreadsheet's Tools menu
- Direct "live" links to variable steam conditions by cell reference
- Choice of Metric/SI or English units
- Direct calculation of steam outlet conditions for isentropic, isenthalpic, constant internal energy or constant volume process
- SteamTab functions for saturated vapor-liquid, superheated, subcooled, and constant steam properties
- Generation of your own steam property diagrams using the spreadsheet's charting capability
- Export of steam property values to other applications – limited only by the spreadsheet's file transfer capability

- Examples for Expander, Compressor, Pressure Letdown, Relative Humidity, etc.

What's New in Version 4.0

SteamTab Version 4.0 offers a number of enhancements:

- SteamTab V4.0 supports Excel versions 2003, 2007 and 2010 running on Windows 7, Windows Vista and Windows XP.
- Supports both 32-bit and 64-bit Excel 2010.
- Includes automatic installation (and uninstalling) on the supported platforms.
- Fully compatible with all previous versions of SteamTab.
- The ability to use a numeric property code as well as a mnemonic string (the string version is *case insensitive*). For example, to calculate the enthalpy of steam you can use either 8 or "H".
- Added two new properties: the isentropic exponent and latent heat of vaporization.

Technical Support and Contact Information

ChemicaLogic offers free technical support with the purchase of SteamTab. If you have any problems during installation or use of SteamTab, please contact us at one of the addresses listed below.

Before requesting support, it would save both your time and our time if you could first do the following:

- Make sure you have read any relevant portions of the manual
- Isolate the problem to a small test case
- Have the version number of your copy of SteamTab ready
- Have the version number of the spreadsheet application and the operating system on which it is installed ready

You can contact us via any of the following paths:

By Telephone:	781.425.6738 (9 AM to 5 PM, EST)
By Fax:	781.425.6741
By Email:	clc.support@chemicalogic.com
By Web:	http://www.chemicalogic.com
By Mail:	ChemicaLogic Corporation 99 South Bedford Street, Suite 207 Burlington, Massachusetts 01803 USA

Car·not, Nicolas Léonard Sadi

Car·not (kär-no[1]), **Nicolas Léonard Sadi**
1796-1832
French physicist and engineer who founded the science of thermodynamics.

Chapter 2

Getting Started

The reality is that zero defects in products plus zero pollution plus zero risk on the job is equivalent to maximum growth of government plus zero economic growth plus runaway inflation.
– Dixie Lee Ray (1924–94), U.S. Democratic politician, government official.
"Scientists and Engineers for Secure Energy," speech, 1980.
Quoted in: Esther Stineman, American Political Women (1980).

Minimum System Requirements

You should not encounter any hardware or software problems in using SteamTab on any hardware that has one of the following spreadsheet applications pre-installed:

- Microsoft Excel 2003 or later running on Windows XP or later (32-bit and 64-bit operating systems are both supported).

Installation

SteamTab contains an automatic installation program that will install the add-in within Excel as well as certain example files, document files and the online help file.

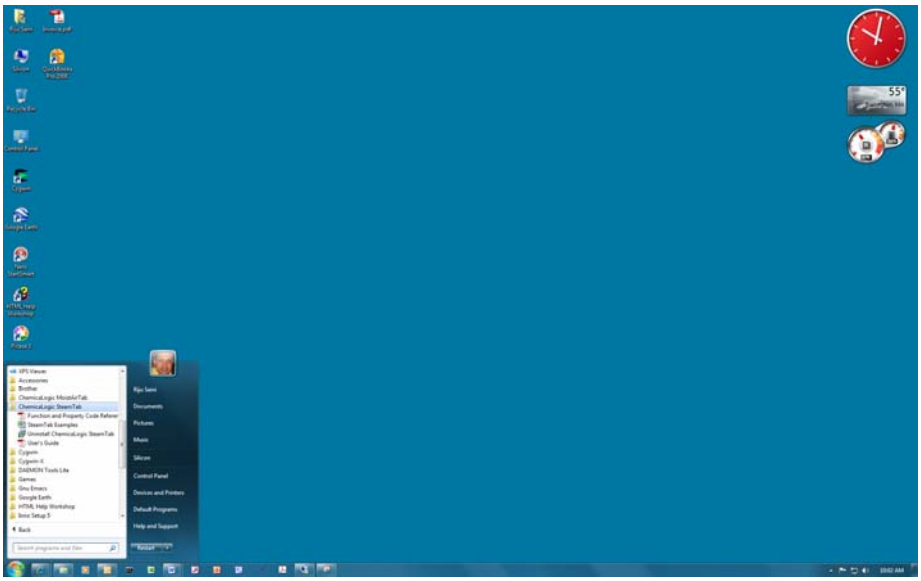
To install SteamTab, simply click on the file `SETUP-STEAMTAB.EXE` and follow the instructions on the screen.

Note

Before installing SteamTab on your machine, please make sure that Excel is **not** running.

Once installation is complete you can access SteamTab from Excel. If you need to access the User's Guide and other documents at are installed, go to Window's Start menu, click on Programs and you should see a folder called ChemicaLogic SteamTab as shown below:

Figure 1: ChemicaLogic SteamTab on Window's Start Menu



Using SteamTab

The following sections describe how to access and use the various features of SteamTab.

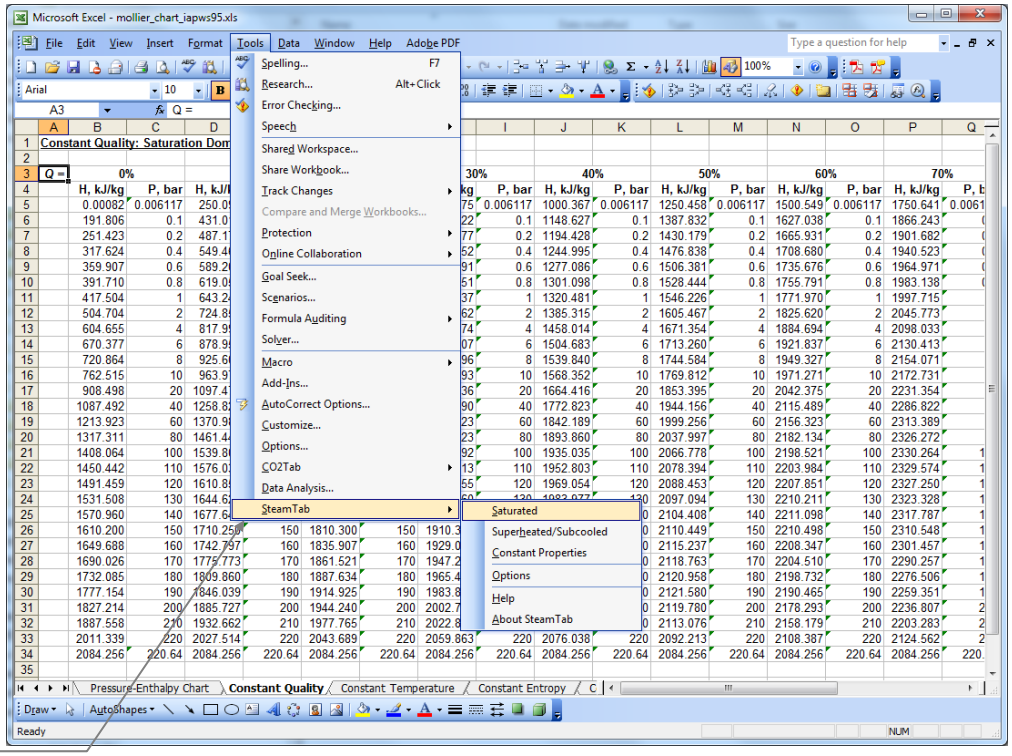
Where is SteamTab?

As an add-in package to your spreadsheet application, SteamTab quietly becomes a part of your spreadsheet. You only see it when you need to use it. Just to make sure that SteamTab is available,

1. Start your spreadsheet application (if you have not already started it)
2. Excel 2003 Users: Click on the Tools menu. You should see a SteamTab pop-up menu somewhere near the bottom of the Tools menu
   Excel 2007 or 2010 Users: Click on the Add-ins ribbon and you will see the SteamTab menu.
3. Expand the SteamTab pop-up menu by clicking on it
4. The following figures show what you should see

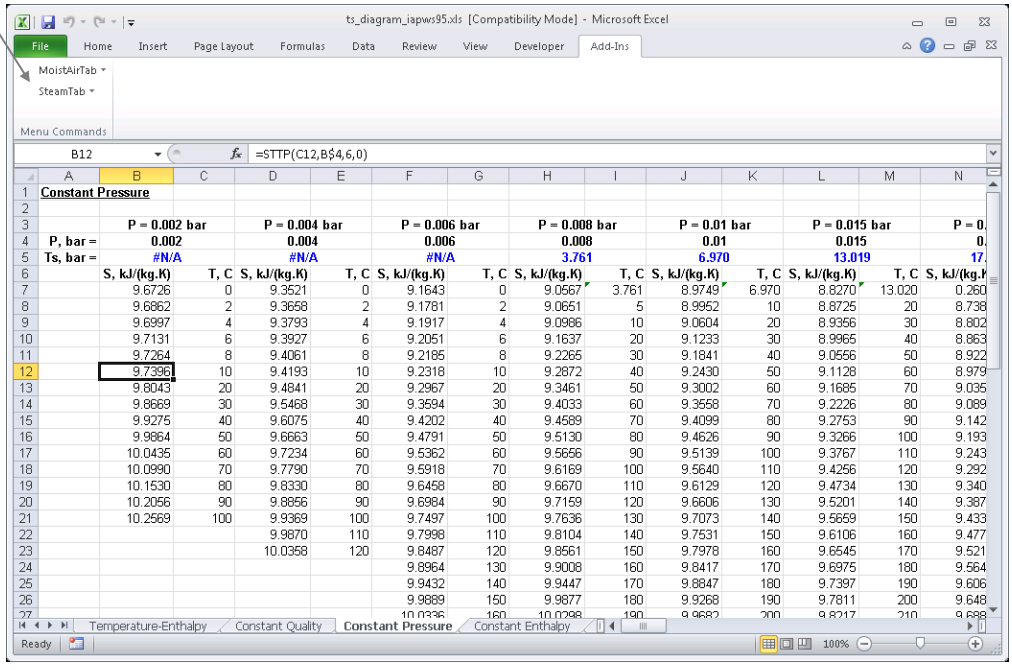
A pop-up menu (which is also known as a drop-down menu) is a special menu item that displays a sublist of menu items when it is selected.

Figure 2: Access to SteamTab in Excel 2003



SteamTab Menu

Figure 3: Access to SteamTab in Excel 2007 or Excel 2010



The SteamTab pop-up menu contains the following menu items:

1. Saturated
   Selecting this menu item brings up the saturated steam properties dialog box which helps you obtain saturated vapor or liquid steam properties, or two-phase steam properties.
2. Superheated/Subcooled
   The menu item displays the dialog box for obtaining supercritical or subcooled steam properties. This dialog box is also used for constant property processes, such as, isenthalpic, isentropic, constant volume, etc. SteamTab uses a highly efficient iterative search algorithm to quickly calculate all constant-process properties.
3. Constant Properties
   Selecting this menu item brings up the constant properties dialog box which you can use to select the required constant steam property.
4. Options
   This menu item allows you to select the units and other configuration options. You can also change the units and model formulation from any of the SteamTab dialog-boxes.
5. Help
   Provides you with easy access to online help.
6. About SteamTab
   Gives you information regarding the version of SteamTab installed on your machine.

The following sections describe how to use the various capabilities of SteamTab.

Setting Steam Property Options

The options dialog box helps you in setting up the units to base your property calculations. All of the SteamTab dialog-boxes use the same options that you specify from the option dialog box.

If you are using the Worksheet functions directly in you spreadsheet, then you do not have to set the options. The options dialog is only used by the SteamTab dialog boxes.

You can access the SteamTab options from either the SteamTab pop-up menu or from any of the other SteamTab dialog boxes.

Use the following steps to set the SteamTab options (see Figure 4 for an illustration of the SteamTab options dialog box):

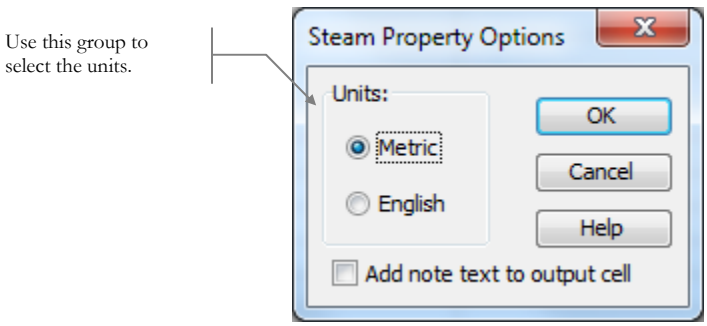
See Table 1 on page 31 for a listing of steam properties and their Metric/SI and English units

1. Select units
   Select the Metric radio button if you want properties in Metric/SI units or select the English radio button for properties English units.

2. Select comment option
   Check the comments box if you want SteamTab to place a comment regarding the property calculated and the units in the output cell.
3. Click OK
   Click on the OK button to accept the changes. After you have clicked OK, all of the SteamTab dialog-boxes will use the specified units options.

> **Note**
>
> If you typically work with only one set of options, you need to only specify them once. SteamTab will remember the options even in subsequent sessions.

Figure 4: Steam Property Options Dialog



Using the Saturated Steam Properties Dialog Box

The saturated steam properties dialog box helps you in calculating saturated vapor or liquid steam properties at either specified temperature or specified pressure.

See the Chapter: Function Reference on page 29 for a description of SteamTab functions

This dialog box automatically creates a call (with all the correct arguments) to the appropriate SteamTab function based on the input parameters you supply.

Use the following steps to calculate a saturated steam property (see Figure 5 for an illustration of the saturated steam properties dialog box):

1. Select Options
   Click on the Options button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.

2. Select independent variable
   Choose either Temperature or Pressure as the independent variable (the variable you wish to specify) by clicking on the appropriate radio button.

Depending on your choice of units and independent variable, the value text will show you the units in which the value is required

3. Provide a value for the independent variable
   Type in a number for the independent variable in the Value edit box. Alternatively, you can type in or select a cell reference that contains a value for the specified independent variable.
4. Select phase
   Select either Vapor or Liquid for saturated properties. For two-phase properties, select Quality and specify the steam quality as a value between 0 and 1.
5. Select steam property required
   Using the drop-down combo-box, select the steam property you want. Use the mouse or the cursor keys to scroll through the list of available steam properties until you come to the one you desire.

Tip: Click on a cell where you want the results before opening the saturated dialog box. SteamTab will automatically fill in the Output cell reference

6. Provide an output cell reference
   Notice that SteamTab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.
7. Click OK
   SteamTab will calculate the requested steam property and place it in the specified output cell as a formula.

You can determine the triple point and the critical point of steam by using the Constant steam properties dialog box. See page 15.

Note

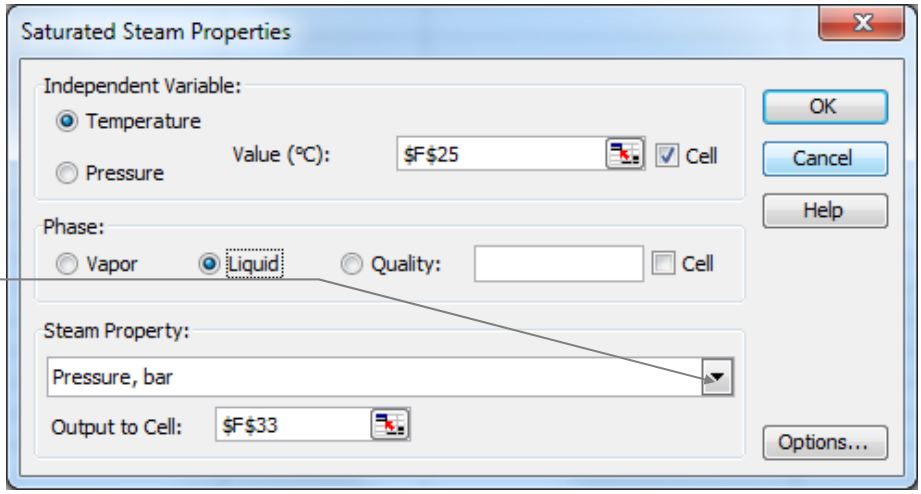
The specified independent variable must be greater or equal to the triple point and less than or equal to the critical point of steam. If the specified independent variable is outside these bounds, the SteamTab function returns the #VALUE! error in Excel versions or the ERR error in Lotus versions.

If you activate the saturated dialog box on a cell that already contains a saturated SteamTab function, then SteamTab will automatically initialize the dialog box with the correct values.

If you want a different saturated steam property, simply repeat the above steps. Alternatively, you could copy the cell containing the saturated steam property function and paste it in the location you want. You can then use the saturated dialog box to change the output steam property.

Figure 5: Saturated Steam Properties Dialog

Click here to drop down the list box and to select the desired output steam property



Using the Superheated/Subcooled Steam Properties Dialog Box

The superheated/subcooled dialog box helps you in calculating supercritical or subcooled steam properties. You also use this dialog box to model constant property processes, such as, isenthalpic, isentropic, constant volume, etc.

See the Chapter: Function Reference on page 29 for a description of SteamTab functions

Using this dialog box automatically creates a call to the appropriate SteamTab function based on the input parameters you supply.

The following steps show you how to use this dialog box (see Figure 6 for an illustration of the superheated/subcooled dialog box):

1. Select Options
   Click on the Options button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.
2. Select independent variables
   Unlike saturated properties, calculating superheated or subcooled properties requires two independent variables. SteamTab gives you 9 combinations of independent variables that you can choose from: Temperature and any one of Pressure, Volume, Enthalpy, Entropy, or Internal energy
   or
   Pressure and any one of Volume, Enthalpy, Entropy, or Internal energy
   a. Select the first independent variable
      Use the drop down list to select either Temperature or Pressure as the first independent variable

b. Select the second independent variable
Use the drop down list box to select the second independent variable. The choices available will depend on what you chose as the first independent variable.

Depending on your choice of units and independent variables, the drop-down list box will show you the units in which the values are required

3. Provide values for the independent variables
Type a number in each of the edit boxes next to the independent variable selections. Alternatively, you can type in or select a cell reference that contains a value for the specified independent variables.

4. Select steam property required
Using the drop-down combo-box, select the steam property you want. Use the mouse or the cursor keys to scroll through the list of available steam properties until you come to the one you desire.

Tip: Click on a cell where you want the results before opening this dialog box. SteamTab will automatically fill in the Output cell reference

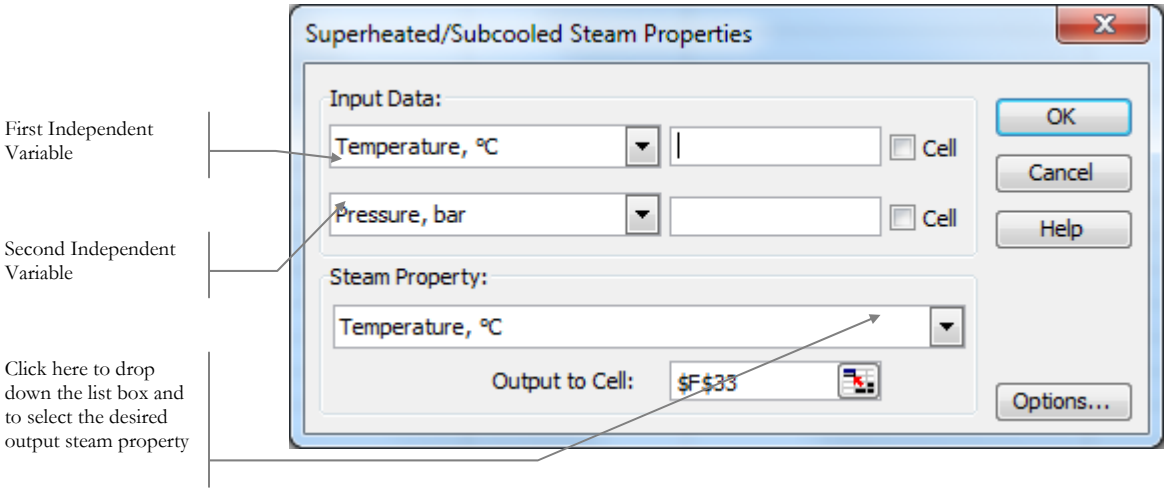
5. Provide an output cell reference
Notice that SteamTab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.

6. Click OK
SteamTab will calculate the requested steam property and place it in the specified output cell as a formula.

If you activate the superheated /subcooled dialog box on a cell that already contains a SteamTab function, then SteamTab will automatically initialize the dialog box with the correct values.

If you want a different superheated or subcooled steam property, simply repeat the above steps. Alternatively, you could copy the cell containing the superheated/subcooled steam property function and paste it in the location you want. You can then use the superheated/subcooled dialog box to change the output steam property.

Figure 6: Superheated/Subcooled Dialog Box



Using the Constant Steam Properties Dialog Box

The constant steam properties dialog box gives you access to fundamental steam properties, such as, molecular weight, critical properties, and triple point properties.

The following steps illustrate how to use this dialog box (see the figure below for an illustration of this dialog box):

1. Select Options
   Click on the Options button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.
2. Select constant steam property required
   Using the drop-down combo-box, select the constant steam property you want. Use the mouse or the cursor keys to scroll through the list of available steam properties until you come to the one you desire.

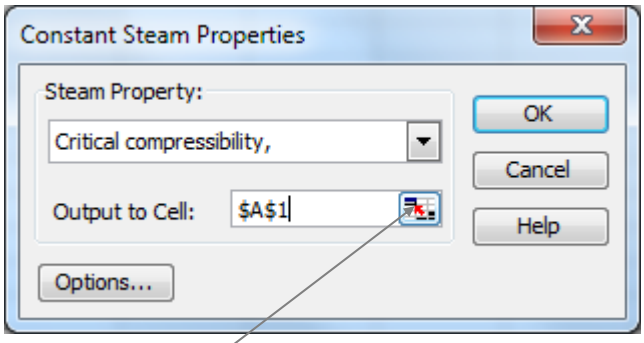
Tip: Click on a cell where you want the results before opening this dialog box. SteamTab will automatically fill in the Output cell reference

1. Provide an output cell reference
   Notice that SteamTab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.
2. Click OK
   SteamTab will calculate the requested steam property and place it in the specified output cell as a formula.

If you activate the constant property dialog box on a cell that already contains a constant property SteamTab function, then SteamTab will automatically initialize the dialog box with the correct values.

If you want a different constant steam property, simply repeat the above steps. Alternatively, you could copy the cell containing the constant steam property function and paste it in the location you want. You can then use the constant properties dialog box to change the output steam property.

Figure 7: Constant Property Dialog Box

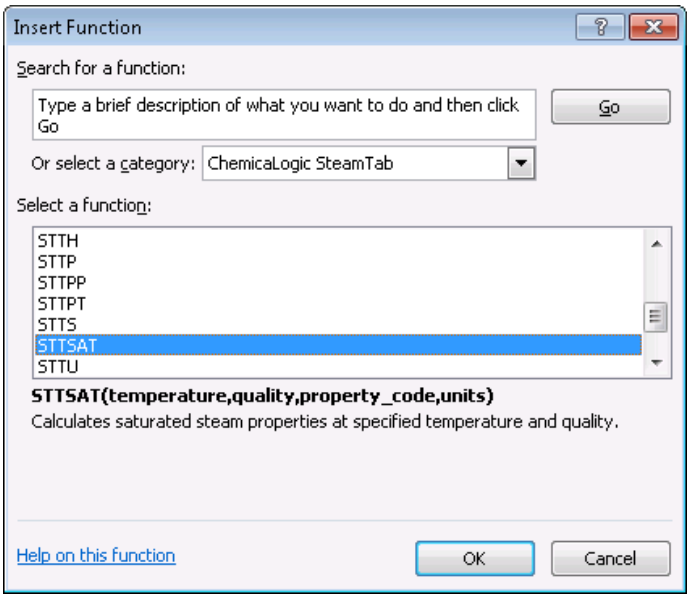


Click here to drop down the list box and to select the desired output steam property

Using Excel's Function Wizard

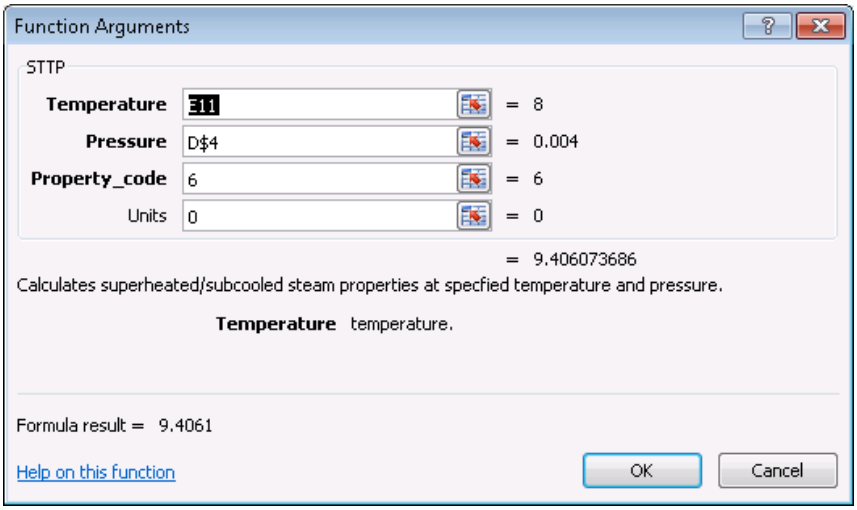
If you know the SteamTab function that you want to use, you can use Excel's function wizard to generate the function call. SteamTab installs all of the functions in a category called ChemicaLogic SteamTab as shown below:

Figure 8: ChemicaLogic SteamTab functions in Excel's Function Wizard



Selecting the STTP function to shows the function wizard:

Figure 9: Excel's Function Wizard for SteamTab Function



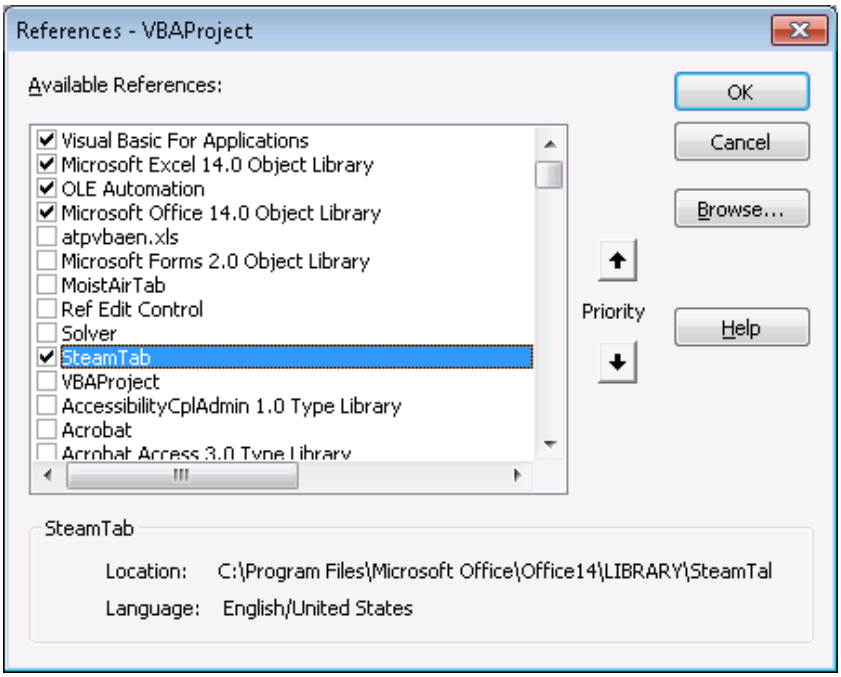
If you need help on the function arguments or need to lookup the property codes click on the "Help on this function" located on the lower left corner of the function wizard.

Using SteamTab in Excel's Visual Basic for Applications (VBA)

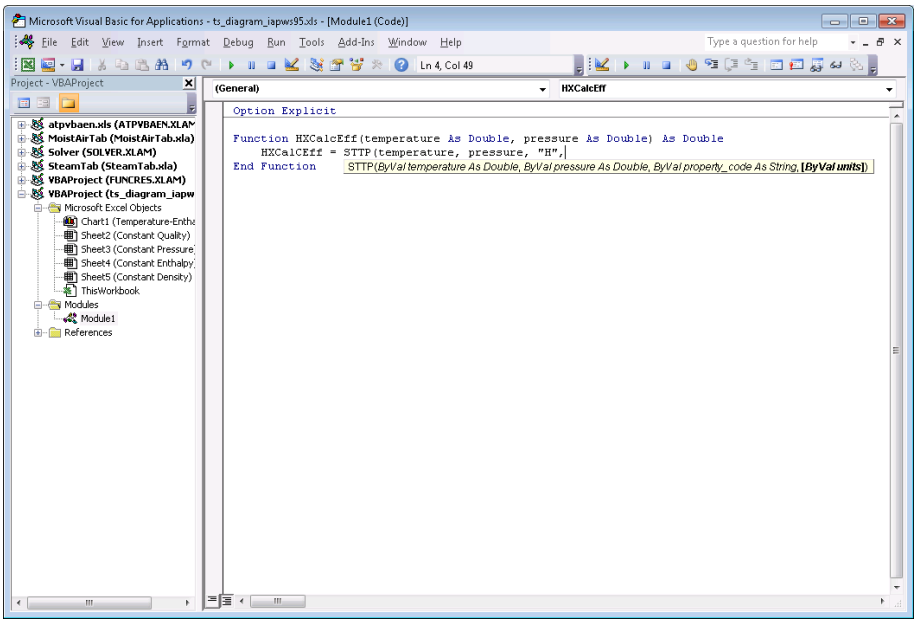
You can also use the SteamTab functions in you own macros or functions in Excel's VBA. But before you use the SteamTab functions, you need to establish a reference to the add-in from the VBA editor.

To establish a reference to the SteamTab add-in, start the VBA editor in Excel 2003 from the **Tools**, **Macro**, **Start Visual Basic Editor** (or press the **Alt+F11** keys) or in Excel 2007/2010 from the **Developer** tab select Visual Basic (if you do not see the **Developer** tab, please refer to this document on how to show the **Developer** tab: http://msdn.microsoft.com/en-us/library/bb608625.aspx). The Visual Basic editor comes up and from the **Tools** menu Select **References** and place a check mark next to SteamTab and select **OK**:

Figure 10: Excel VBA Reference to SteamTab



Once a reference to SteamTab is established you can use the SteamTab functions in VBA just as you would any other function, as shown below:



Tips and Tricks

Below is a list of tips that users like you have contributed to help the SteamTab user community gain the best possible benefit of using SteamTab in a spreadsheet-computing environment.

We encourage you to submit your tips and tricks to us for inclusion in future releases and upgrades. See page 5 for information on how to contact us.

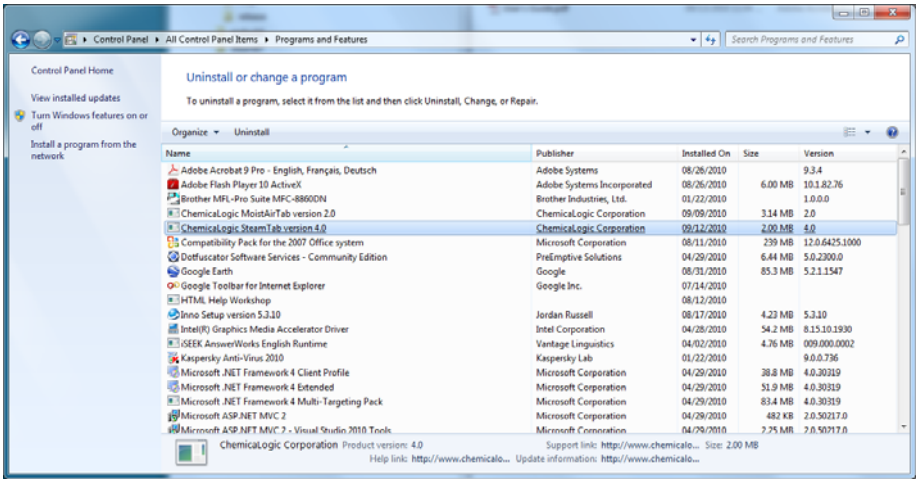
Tips and tricks to help you become more productive (in no particular order):

- You may notice a slight delay the first time you use SteamTab. This is normal, because the spreadsheet application loads the full SteamTab package only when you first use it. This helps conserve memory.
- You do not have to remember the calling sequence of SteamTab functions. Use the SteamTab dialog boxes to generate the correct function with the right arguments.
- Click on the cell where you want the results before opening any of the SteamTab dialog boxes. SteamTab will automatically fill in the Output cell reference for you.

Uninstalling SteamTab

To uninstall SteamTab, from Window's **Start** menu, select **Programs**, **ChemicaLogic SteamTab** and then select **Uninstall ChemicaLogic SteamTab**. This will completely uninstall SteamTab from your computer.

You can also uninstall SteamTab from the Control Panel, Add or Remove Programs (or Programs and Features in Windows 7) and selecting ChemicaLogic SteamTab version 2.0 to uninstall.



Joule, James Prescott

Joule (j¡l, joul), **James Prescott**
1818-1889
British physicist who established the mechanical theory of heat and discovered the first law of thermodynamics.

Chapter

3

Tutorial

sty·mie
To thwart; stump: a problem in thermodynamics that stymied half the class.
– The American Heritage Dictionary of the English Language, Third Edition, 1996.

Introduction

The SteamTab package you purchased contains several examples and templates that you can use in your work. The examples included in the SteamTab package illustrate the following concepts:

- Steam Quality
- Constant-temperature process
- Constant-pressure process
- Constant-volume process
- Constant-entropy process
- Constant-internal energy process
- Irreversible adiabatic expansion
- Irreversible adiabatic compression
- Moisture content in air and dew point calculations
- Relative humidity
- Charting of steam properties

The following sections give you step-by-step instructions on how to solve two steam-related problems using the power of SteamTab:

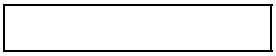
1. Calculating the enthalpy of vaporization, and
2. Constant property process

Example 1: Enthalpy of Vaporization

This rather simple example will illustrate how to use SteamTab to obtain the enthalpy of vaporization of steam. Note that the enthalpy of vaporization is not one of the properties that is automatically calculated by SteamTab. (**Note: SteamTab V4.0 now includes this property**). However, it is nearly effortless, given the ease-of-use of SteamTab in a spreadsheet-computing environment.

Problem Statement: Calculate the enthalpy of vaporization of water at temperatures of 225°C and 231.3°C.

Solution: The enthalpy of vaporization of water is defined as the difference between the enthalpies of the vapor and the liquid:



Therefore, all that we need to do is use SteamTab to get the saturated vapor and liquid enthalpies at the specified temperature and take the difference of the two values to get the enthalpy of vaporization.

If you have access to printed steam tables, looking up the enthalpy of vaporization at a particular temperature is very easy, especially if you do not have to interpolate between the tabulated temperatures. For example, you could easily look up the enthalpy of vaporization at 225°C since most printed steam tables are tabulated at increments of 5°C and some even at 1°C increments. However, you would have to interpolate to get the enthalpy of vaporization at a temperature of 231.3°C. This process becomes tedious if you have several such points to compute or if you need to interpolate several different properties.

Using the power of SteamTab and the ease-of-use of spreadsheets, this process becomes nearly effortless. The solution to this problem is show in Figure 11 below.

Figure 11: Tutorial Example 1

	A	B	C	D	E
1	Specified Temperature	C	225	231.3	
2	Vapor Enthalpy	kJ/kg	2802.148	2803.015	
3	Liquid Enthalpy	kJ/kg	966.796	996.3022	
4	Enthalpy of Vaporization	kJ/kg	1835.352	1806.713	
5					
6					

The first step in solving a problem in a spreadsheet is to layout the problem definition. As shown in the figure above, the known and computed variable names are documented in Column A. Column B contains the units in which the properties are computed. Column C contains the specified and computed properties at the first temperature and column D contains the same at the other temperature.

Using SteamTab, obtain the saturated vapor and liquid enthalpies at 225°C, shown in cells C2 and C3. In cell C4 take the difference between C2 and C3 to get the enthalpy of vaporization at 225°C. Then simply copy cells C1 through C4 and paste it in cells D1 through D4. Change the temperature in cell D1 to 231.3 and instantly you have the solution to the second part of the problem.

Step-by-step Instructions:

The step-by-step instructions for this example are given below.

1. Layout the problem definition
   It is good practice to first lay out the problem definition. Follow these steps:
   a. In cell A1 type Specified Temperature
   b. In cell B1 type C (for the units)
   c. In cell C1 type 225
   d. In cell A2 type Vapor Enthalpy
   e. In cell B2 type kJ/kg (the units in which SteamTab is to return the enthalpy)
   f. In cell A3 type Liquid Enthalpy
   g. In cell A4 type Enthalpy of Vaporization
   h. Copy the contents of cell B2 to cell B3 and B4
   i. Expand the width of column A so that you can see all of its contents

See Table 1 on page 19 for a listing of steam properties and their Metric/SI and English units

2. Set the steam property options
   Since we will be using the SteamTab dialogs to obtain properties, we will first the steam property options to use the metric/SI units.

a. From the SteamTab pop-up menu select Options
b. Click on the Metric/SI radio buttons
c. Click OK

2. Use SteamTab to get the vapor enthalpy
In this step you will use SteamTab to get the vapor enthalpy at a temperature of 225°C.
   a. Click on cell C2 to make it the active cell
   b. From the Tools menu pop-up the SteamTab menu and select Saturated
   c. In the saturated steam properties dialog box, select Temperature as the independent variable. Type C1 in the value edit box. Select Vapor as the phase. Use the drop-down list box and locate Enthalpy as the required steam property. Note that the Output Cell is already filled in with C2. Click OK.

Excel users should first check on the cell check-box next to the value edit box before typing in C1.

   d. The cell C2 should now contain the value 2802.148. Notice that cell C2 actually contains a formula which looks like the following:
   For Excel users: =STTSAT(C2,1, 8,0)
   For Lotus 1-2-3 users: @STTSAT(C2,1,8,0)

You may notice a slight delay the first time you use SteamTab. This is normal, because the spreadsheet application loads the full SteamTab package only when you first use it. This helps conserve memory.

3. Use SteamTab to get the liquid enthalpy
Use the following steps to get the enthalpy of liquid at 225°C.
   a. Copy the contents of cell C2 to cell C3
   b. Make sure that cell C3 is the active cell
   c. From the Tools menu pop-up the SteamTab menu and select Saturated
   d. Notice how SteamTab fills-in all of the right values in the dialog-box. Select Liquid as the phase and click OK.
   e. The cell C3 should contain the value 966.796, which is the specific enthalpy of liquid at 225°C.

4. Calculate the enthalpy of vaporization
In cell C4 type the formula: C2-C3 and press Enter. You now have the answer: 1835.352 kJ/kg.

5. Extend the result to 231.3°C
Copy the cells C1 through C4 to cells D1 through D4. Then change the value in D1 to 231.3. The numbers is D2, D3, and D4 change automatically to their proper values.

If you have been working along, Figure 11 on page 23 shows what your spreadsheet should look like.

Example 2: Constant Property Process

Problem Statement:

A steam line is connected to an evacuated well-insulated tank via a valve. The line pressure is 120 psia and temperature is 800°F. If the valve is opened and the steam is allowed to expand into the tank, what is the final temperature in the tank? Assume that the steam line is connected to an inexhaustible source of steam at the other end.

Solution:

Based on the laws of thermodynamics, since no heat is added or removed from the system the only work done by the steam in expanding into the tank is to change the internal energy of the steam in the tank. In other words, the final internal energy in the tank must equal the initial enthalpy of steam in the line. Also, the final pressure in the tank must be equal to the pressure of steam in the line:

where U is internal energy and H is the enthalpy. The solution to this problem is shown in Figure 12.

Solution Strategy:

The temperature and pressure in the line are specified to be 800°F and 120 psia. Since the line temperature is greater than the critical temperature of steam (705.16°F) the steam is not saturated. Therefore, we use the superheated/subcooled SteamTab functions to compute the thermodynamic properties of the steam in the line.

The final conditions in the tank are thus determined: the final pressure in the tank is 120 psia and the internal energy is equal to the enthalpy of steam in the line. Given these two variables, the rest of the thermodynamic properties of steam can easily be computed. SteamTab contains 9 combinations of independent variables you can specify, and one of them is pressure (P) and internal energy (U).

Figure 12: Tutorial Example 2

This example is included in your SteamTab package.

	A	B	C	D	E
1			**Line**	**Tank**	
2			**Initial (1)**	**Final (2)**	
3	Pressure (P)	psia	120.00	120.00	$P_2 = P_1$
4	Temperature (T)	°F	800.00	1137.92	*Answer*
5	Enthalpy (H)	Btu/lb	1428.97	1604.45	
6	Internal Energy (U)	Btu/lb	1291.41	1428.97	$U_2 = H_1$
7					

Using a strategy similar to the one in tutorial example 1, we first design and layout the problem definition. The known and computed variable names are

documented in Column A. Column B contains the units in which the properties are computed. Column C contains the line conditions and column D the tank conditions.

Cells C3 and C4 contain the specified line pressure and temperature, respectively. Cell D3 simply refers to the value in cell C3, since the final pressure is the same as the line pressure. Using SteamTab's superheated/subcooled dialog box and using temperature and pressure as the independent variables, we compute the enthalpy and internal energy shown in cells C5 and C6. We then refer the contents of cell D6 to the value in cell C5, since the final internal energy is the same as the initial enthalpy. Again using SteamTab's superheated/subcooled dialog box with pressure and internal energy as the independent variables, we obtain the final thermodynamic properties including the final temperature of 1137.92°F.

Step-by-step Instructions:

The step-by-step instructions are left as an exercise for the user. You should follow the general solution strategy described above and re-create this example on your own. You can use the example included in your SteamTab package as a guide.

Templates and Examples

The SteamTab package you purchased contains several examples and templates that you can use in your work. Based on your version of SteamTab for a particular spreadsheet application, these templates and examples are installed and used differently. This is described below.

SteamTab for Excel 2007/2010

If you used the automatic installation program, the templates and examples are installed in My Templates directory within a sub-directory called ChemicaLogic. You can access these templates from within Excel, by performing these steps:

1. Start Excel
2. From the File menu select New…
3. Select My Templates to see the templates and examples (Shown in Figure 13 below)
4. Select any one of the shown templates to create a working copy of the template

An example of how to use the Compressor template is illustrated below.

Figure 13: SteamTab Templates for Excel 2007/2010

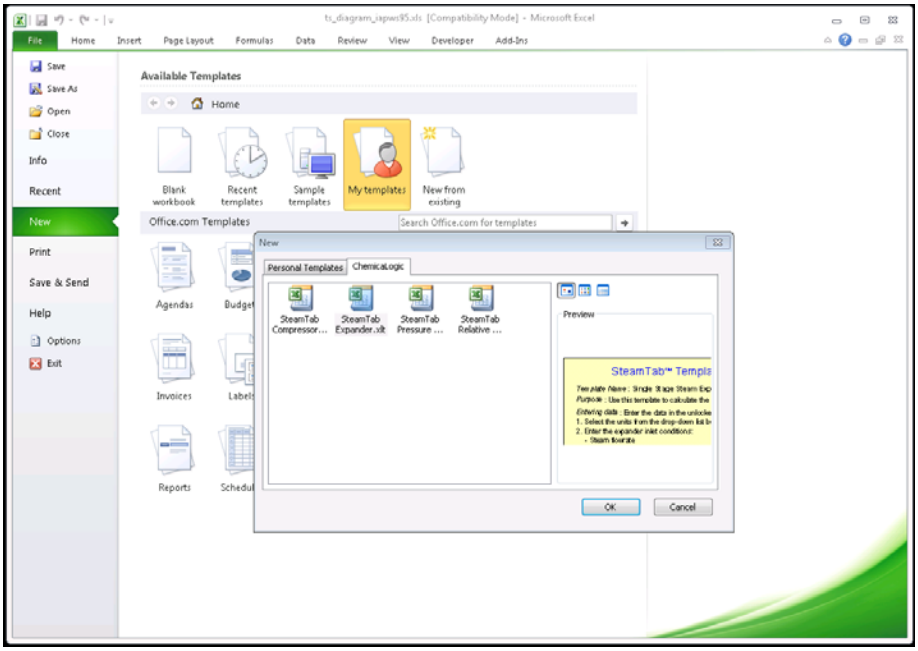


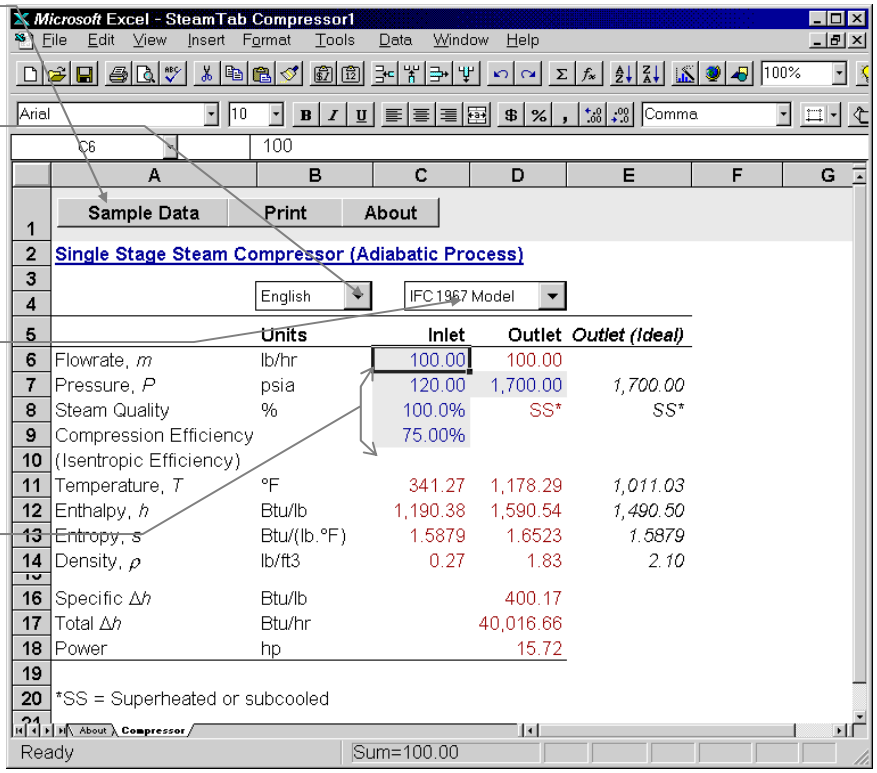
Figure 14: SteamTab Compressor Template Example

Click here to display or erase the sample data shown.

Click on the drop-down list box to select the units you want to work on. The units column will then change automatically.

Click on the drop-down list box to select the model formulation you want to work on.

Enter the problem specification in the shaded area (the un-shaded cells are protected). After you have entered each of the 5 values, the answer will automatically appear.



Nernst, Walther Hermann

Nernst (nèrnst), **Walther Hermann**
1864-1941
German physicist and chemist. He won a 1920 Nobel Prize for his work in thermochemistry, particularly his proposal of the third law of thermodynamics (1906)

Chapter 4

Function Reference

My spelling is Wobbly. It's good spelling but it Wobbles, and the letters get in the wrong places.
– A. A. Milne (1882–1958)
Winnie-the-Pooh, ch. 6 (1926).

Overview

The SteamTab add-in package is based on a set of 19 core functions that together calculate over 30 thermodynamic and transport properties of steam. You can use these functions directly in your spreadsheet or you can use SteamTab's easy-to-use dialog boxes to automatically generate the appropriate function call with the correct arguments.

SteamTab functions are divided into three categories:

1. Functions for saturated vapor, liquid or two-phase properties (2 functions)
   These two functions calculate saturated vapor, liquid and two-phase properties from the triple point up to the critical point. You can choose either temperature or pressure as the independent variable.
2. Functions for superheated vapor or subcooled liquid properties (9 functions)
   The functions in this category provide you with a rich set of tools for conducting several constant-property processes. Depending on the choice of independent variables, you can model isentropic, isenthalpic, constant volume, or constant internal energy processes.
3. Functions for constant steam properties (8 functions)
   The 8 functions in this category give you access to fundamental steam properties that are not functions of temperature or pressure, such as, molecular weight, critical properties, and triple point properties.

Note

All SteamTab functions begin with the prefix ST.

Table 1: Overview of SteamTab Functions

Function	Calculates	Calling Sequence
Saturated vapor, liquid or two-phase functions		
STPSAT	at specified pressure	STPSAT(pressure, quality, code, *units*)
STTSAT	at specified temperature	STTSAT(temperature, quality, code, *units*)
Superheated or subcooled functions		
STTP	at specified temperature and pressure *(T-P)*	STTP(temperature, pressure, code, *units*)
STTV	at specified temperature and volume *(T-V)*	STTV(temperature, volume, code, *units*)
STTH	at specified temperature and enthalpy *(T-H)*	STTH(temperature, enthalpy, code, *units*)
STTS	at specified temperature and entropy *(T-S)*	STTS(temperature, entropy, code, *units*)
STTU	at specified temperature and internal energy *(T-U)*	STTU(temperature, internal_energy, code, *units*)
STPV	at specified pressure and volume *(P-V)*	STPV(pressure, volume, code, *units*)
STPH	at specified pressure and enthalpy *(P-H)*	STPH(pressure, enthalpy, code, *units*)
STPS	at specified pressure and entropy *(P-S)*	STPS(pressure, entropy, code, *units*)
STPU	at specified pressure and internal energy *(P-U)*	STPU(pressure, internal_energy, code, *units*)
Constant properties functions		
STMW	Molecular weight	STMW(*units*)
STTC	Critical temperature	STTC(*units*)
STPC	Critical pressure	STPC(*units*)
STVC	Critical specific volume	STVC(*units*)
STRC	Critical specific density	STRC(*units*)
STZC	Critical compressibility factor	STZC(*units*)
STTPT	Triple point temperature	STTPT(*units*)
STTPP	Triple point pressure	STTPP(*units*)

In Microsoft Excel *units* is an optional argument. You need not specify *units*, in which case all requested properties are returned in Metric/SI units, that is, the default value is 0. For steam properties in English units, set *units* to 1.

The argument quality is used to specify the saturated steam quality (vapor fraction) or to specify the two-phase steam quality. Use a value of 1 for saturated vapor, 0 for saturated liquid and between 0 and 1 for two-phase. The SteamTab functions also return quality as a calculated property. If the quality cannot be determined, then a value of -1 is returned. If the phase is superheated vapor, then a quality of -2 is returned, and if the phase is subcooled liquid a quality of -3 is returned.

The argument code, is an integer or string argument (the string is *case insensitive*) that specifies the type of steam property requested. Valid values of code and the units in which they are returned are shown in the table below.

Table 2: Property Codes for Thermodynamic and Transport Properties of Steam

Code		Steam Property	Metric/SI Units	English Units
0	T	Temperature, T	°C	°F
1	P	Pressure, P	bar	psia
2	V	Volume, V	m^3/kg	ft^3/lb
3	D	Density, ρ	kg/m^3	lb/ft^3
4	Z	Compressibility factor, Z	dimensionless	dimensionless
5	A	Helmoltz free energy, A	kJ/kg	Btu/lb
6	S	Entropy, S	kJ/(kg·°C)	Btu/(lb·°F)
7	U	Internal energy, U	kJ/kg	Btu/lb
8	H	Enthalpy, H	kJ/kg	Btu/lb
9	G	Gibbs free energy, G	kJ/kg	Btu/lb
10	CV	Heat capacity at constant volume, C_v	kJ/(kg·°C)	Btu/(lb·°F)
11	CP	Heat capacity at constant pressure, C_p	kJ/(kg·°C)	Btu/(lb·°F)
12	W	Speed of sound, v	m/s	ft/s
13	ALPHA	Coefficient of thermal expansion, $\alpha = \rho(\partial V/\partial T)_P$	1/°C	1/°F
14	KAPPA	Isothermal compressibility, $\kappa = -\rho(\partial V/\partial P)_T$	1/bar	1/psia
15	DPDT	dpdt, $(\partial P/\partial T)_V$	bar/°C	psia/°F
16	DVDT	dvdt, $(\partial V/\partial T)_P$	$m^3/(kg·°C)$	$ft^3/(lb·°F)$
17	DVDP	dvdp, $(\partial V/\partial P)_T$	$m^3/(kg·bar)$	$ft^3/(lb·psi)$
18	MU	Viscosity (dynamic), μ	μPa·s	lb/(ft·hr)
19	KT	Thermal conductivity, K	W/(m·°C)	Btu/(hr·ft·°F)
20	ST	Surface tension, σ	N/m	N/m
21	PR	Prandtl number, N_{Pr}	dimensionless	dimensionless
22	DC	Static dielectric constant	dimensionless	dimensionless
23	IJT	Isothermal Joule-Thomson coefficient	kJ/(kg·bar)	Btu/(lb·psia)
24	JT	Joule-Thomson coefficient	°C/bar	°F/psia
25	Q	Quality (vapor mass fraction)	dimensionless	dimensionless
26	GAMMA	Isentropic exponent, $\gamma = -V / P(\partial P / \partial V)_S$	dimensionless	dimensionless
27	HV	Latent heat of vaporization	kJ/kg	Btu/lb

Note

By definition, the thermodynamic Reference State of steam is the liquid at the triple point (0.01°C), at which the internal energy and entropy are set to zero.

Functions for Saturated Steam Properties

The functions for saturated steam properties calculate vapor, liquid or two-phase properties at either specified pressure or specified temperature. The applicable range of these functions is from the triple point up to the critical point.

Depending on your choice of independent variable, the two functions you can choose are:

Independent Variable	Use Function
Pressure	STPSAT
Temperature	STTSAT

These functions are described in detail below.

STPSAT

Calculates the saturated vapor or liquid property at the specified pressure

Syntax

STPSAT(pressure, quality, property_code, *units*)

Arguments

pressure	is the pressure at which the saturated steam property is required. See the Remarks section for acceptable pressure units.
quality	is 1 for vapor phase properties, 0 for liquid phase properties and between 0 and 1 for two-phase.
property_code	is an integer property code that specifies the type of property required. See `Table 2`: Property Codes for Thermodynamic and Transport Properties of Steam (page 31) for a listing of valid property codes.
units	is an integer argument (optional in Excel). For Metric/SI units, specify a value of 0 (or leave empty in Excel). For English units, specify a value of 1.

Remarks

- The specified pressure unit must be in bar if *units* is 0; and must be in psia if *units* is 1.

- The pressure must be greater than or equal to the Triple Point Pressure (0.0061173 bar) and less than or equal to the Critical Pressure (220.55 bar).
- If any of the arguments are invalid or if the arguments are outside the acceptable bounds, the function returns the following error codes:
  - In Excel versions: #VALUE! error
  - In Lotus versions: ERR error

Examples

1. STPSAT(14.7,1,0,1) returns 212.02 which is the boiling point of water (in °F) at a pressure of 14.7 psia.
2. STPSAT(14.7,1,8,1)-STPSAT(14.7,0,8,1) returns 970.18 which is the enthalpy of vaporization (in Btu/lb) of water at a pressure of 14.7 psia.
3. STPSAT(100,0,11) returns 6.124 which is the specific heat capacity at constant pressure (in kJ/(kg.°C)) at a pressure of 100 bar.

STTSAT

Calculates the saturated vapor, liquid or two-phase property at the specified temperature.

Syntax

STTSAT(temperature, quality, property_code, *units*)

Arguments

temperature	is the temperature at which the saturated steam property is required. See the Remarks section for acceptable temperature units.
quality	is 1 for vapor phase properties, 0 for liquid phase properties and between 0 and 1 for two-phase.
property_code	is an integer property code that specifies the type of property required. See Table 2: Property Codes for Thermodynamic and Transport Properties of Steam (page 31) for a listing of valid property codes and their meaning.
Units	is an integer argument (optional in Excel). For Metric/SI units, specify a value of 0 (or leave empty in Excel). For English units, specify a value of 1.

Remarks

- The specified temperature unit must be in °C if *units* is 0; and must be in °F if *units* is 1.

- The specified temperature must be greater than or equal to the Triple Point Temperature (0.01°C) and less than or equal to the Critical Temperature (373.976°C).
- If any of the arguments are invalid or if the arguments are outside the acceptable bounds, the function returns the following error codes:
  - In Excel versions: `#VALUE!` error
  - In Lotus versions: `ERR` error

Examples

1. `STTSAT(212,1,1,1)` returns `14.696` which is the vapor pressure (in psia) of water at a temperature of 212°F.
2. `STTSAT(212,1,8,1)-STTSAT(212,0,8,1)` returns `970.19` which is the enthalpy of vaporization (in Btu/lb) of water at a temperature of 212°F.
3. `STTSAT(300,0,11)` returns `5.75` which is the specific heat capacity of liquid at constant pressure (in kJ/(kg.°C)) at a temperature of 300°C.

Functions for Superheated or Subcooled Steam Properties

The functions in this category calculate the superheated vapor or subcooled liquid property at any two specified independent variables. These functions have a wide range of applicability. Generally, the properties returned by these functions are acceptable within the following ranges:

- Pressure (P, bar): $0 \le P \le 100{,}000$
- Temperature (T, K): $190 \le T \le 5000$

The superheated/subcooled functions require two independent variables as input. Use the following table as a guide to select the appropriate function.

Specified Independent Variable		
First Variable	**Second Variable**	**Use Function**
Temperature, *T*	Pressure, *P*	STTP
Temperature, *T*	Volume, *V*	STTV
Temperature, *T*	Enthalpy, *H*	STTH
Temperature, *T*	Entropy, *S*	STTS
Temperature, *T*	Internal Energy, *U*	STTU
Pressure, *P*	Volume, *V*	STPV
Pressure, *P*	Enthalpy, *H*	STPH
Pressure, *P*	Entropy, *S*	STPS
Pressure, *P*	Internal Energy, *U*	STPU

All of these functions have a similar syntax and arguments as described below.

General Description

General Syntax

STXX(first_variable, second_variable, property_code, *units*)

Replace STXX with the appropriate function name .

General Arguments

first_variable	is the first independent variable.
second_variable	is the second independent variable .
property_code	is an integer property code that specifies the type of property required. See Table 2: Property Codes for Thermodynamic and Transport Properties of Steam (page 31) for a listing of valid property codes and their meaning.
Units	is an integer argument (optional in Excel). For Metric/SI units, specify a value of 0 (or leave empty in Excel). For English units, specify a value of 1.

General Remarks

- If any of the arguments are invalid or if the arguments are outside the acceptable bounds, the function returns the following error codes:

  - In Excel versions: #VALUE! error
  - In Lotus versions: ERR error
- Some of these functions solve for the pressure iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the above error codes.

The individual functions are documented below.

STTP

Calculates superheated vapor or subcooled liquid property at the specified temperature and pressure.

Syntax

STTP(temperature, pressure, property_code, *units*)

Remarks

- The specified temperature unit must be in °C if *units* is 0; and must be in °F if *units* is 1.
- The specified pressure unit must be in bar if *units* is 0; and must be in psia if *units* is 1.

Examples

1. `STTP(500,200,12,1)` returns `1810.1` which is the speed of sound in ft/s at a temperature of 500°F and a pressure of 200 psia.
2. `STTP(5000,1200,21,1)` return `0.779` which is the Prandlt number at a temperature of 5000°F and a pressure of 1200 psia.

STTV

Calculates superheated vapor or subcooled liquid property at the specified temperature and volume.

Syntax

STTV(temperature, volume, property_code, *units*)

Remarks

- The specified temperature unit must be in °C if *units* is 0; and must be in °F if *units* is 1.
- The specified volume unit must be in m^3/kg if *units* is 0; and must be in ft^3/lb if *units* is 1.

STTH

Calculates superheated vapor or subcooled liquid property at the specified temperature and enthalpy.

Syntax

STTH(temperature, enthalpy, property_code, *units*)

Remarks

- The specified temperature unit must be in °C if *units* is 0; and must be in °F if *units* is 1.
- The specified enthalpy unit must be in kJ/kg if *units* is 0; and must be in Btu/lb if *units* is 1.

STTS

Calculates superheated vapor or subcooled liquid property at the specified temperature and entropy.

Syntax

STTS(temperature, entropy, property_code, *units*)

Remarks

- The specified temperature unit must be in °C if *units* is 0; and must be in °F if *units* is 1.
- The specified entropy unit must be in kJ/(kg.°C) if *units* is 0; and must be in Btu/(lb.°F) if *units* is 1.

STTU

Calculates superheated vapor or subcooled liquid property at the specified temperature and internal energy.

Syntax

STTU(temperature, internal_energy, property_code, *units*)

Remarks

- The specified temperature unit must be in °C if *units* is 0; and must be in °F if *units* is 1.
- The specified internal energy unit must be in kJ/kg if *units* is 0; and must be in Btu/lb if *units* is 1.

STPV

Calculates superheated vapor or subcooled liquid property at the specified pressure and volume.

Syntax

STPV(pressure, volume, property_code, *units*)

Remarks

- The specified pressure unit must be in bar if *units* is 0; and must be in psia if *units* is 1.
- The specified volume unit must be in m^3/kg if *units* is 0; and must be in ft^3/lb if *units* is 1.

STPH

Calculates superheated vapor or subcooled liquid steam property at the specified pressure and enthalpy.

Syntax

STPH(pressure, enthalpy, property_code, *units*)

Remarks

- The specified pressure unit must be in bar if *units* is 0; and must be in psia if *units* is 1.
- The specified enthalpy unit must be in kJ/kg if *units* is 0; and must be in Btu/lb if *units* is 1.

STPS

Calculates superheated vapor or subcooled liquid property at the specified pressure and entropy.

Syntax

STPS(pressure, entropy, property_code, *units*)

Remarks

- The specified pressure unit must be in bar if *units* is 0; and must be in psia if *units* is 1.
- The specified entropy unit must be in kJ/(kg.ºC) if *units* is 0; and must be in Btu/(lb.ºF) if *units* is 1.

STPU

Calculates superheated vapor or subcooled liquid property at the specified pressure and internal energy.

Syntax

STPU(pressure, internal_energy, property_code, *units*)

Remarks

- The specified pressure unit must be in bar if *units* is 0; and must be in psia if *units* is 1.
- The specified internal energy unit must be in kJ/kg if *units* is 0; and must be in Btu/lb if *units* is 1.

Functions for Constant Steam Properties

The functions in this category return constant steam properties, such as, the molecular weight, critical properties, and triple point properties.

The constant steam property functions are:

Function	Calculates	Metric/SI Units	English Units
STMW	Molecular weight	kg/kmol	lb/lbmol
STTC	Critical temperature	ºC	ºF
STPC	Critical pressure	bar	psia
STVC	Critical specific volume	m^3/kg	ft^3/lb
STRC	Critical specific density	kg/m^3	lb/ft^3
STZC	Critical compressibility factor	dimensionless	dimensionless
STTPT	Triple point temperature	ºC	ºF
STTPP	Triple point pressure	bar	psia

All of the functions in this category take an integer argument: *units* (optional in Excel) which is 0 or Metric units. For constant properties in English units set this argument to 1.

Note (Excel Only)

If you want to use the default argument you need not specify any value. In this case, Excel users must use the "empty" parenthesis, for example, `=STTC()`.

Examples

1. `STMW()` returns `18.0152` which is the molecular weight of steam in kg/kmol
2. `STPC(1)` returns `3198.8` which is the critical pressure of steam in psia
3. `STTPT(0)` returns `0.01` which is the triple point temperature of steam in ºC

en·tro·py

en·tro·py *noun*
plural **en·tro·pies**

1. *Symbol* **S**. For a closed thermodynamic system, a quantitative measure of the amount of thermal energy not available to do work.
2. A measure of the disorder or randomness in a closed system.
3. A measure of the number of bits necessary to transmit a message as a function of the probability that the message will consist of a specific set of symbols.
4. A hypothetical tendency for all matter and energy in the universe to evolve toward a state of inert uniformity.
5. Inevitable and steady deterioration of a system or society.