# SteamTab *Quad*® V4.0 User's Guide

**Pressure-Enthalpy Diagram for Water and Steam**
**Based on the IAPWS-95 Formulation for General and Scientific Use**



Joule-Thomson Inversion

Pressure, bar

10%  20%  30%  40%  50%  60%  70%  80%  90%

**Drawn with SteamTab *Duo* V3.0.**

**Enthalpy, kJ/kg**

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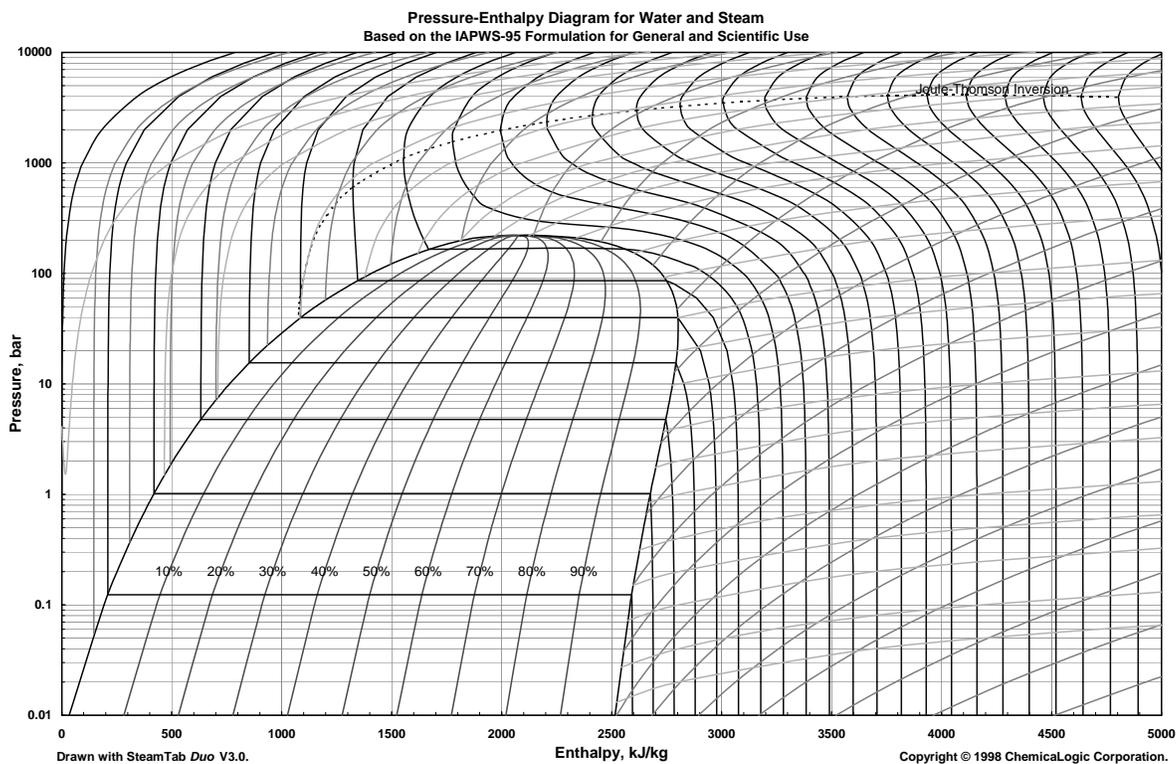
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## SteamTab *Quad*® Thermodynamic and Transport Properties of Water and Steam

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# Introduction to SteamTab *Quad*®

*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 *Quad*, 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 *Quad* contains a comprehensive set of thermodynamic and transport properties applicable over a wide range of conditions, with selected derivative and dimensionless properties.

SteamTab Quad sets a new standard in capability and ease of use for steam property generation. SteamTab Quad contains all of the features of SteamTab Duo Version 4.0. In addition, with SteamTab Quad, you can choose from 4 different formulations to base steam property calculations:

1. **Scientific Formulation (IAPWS-95)**: This is the formulation approved by the International Association of the Properties of Water and Steam (IAPWS) in 1995 for general and scientific use. This formulation is more

thermodynamically rigorous, accurate, and applicable over wider range of conditions.

2. **Industrial Formulation (IAPWS-IF97)**: This is the IAPWS approved formulation of industrial and special use. The industrial formulation is based on an approximation of the scientific formulation and is generally used in situations where computational speed is of importance.

3. **Old Scientific Formulation (NBS/NRC-84)**: This is the older scientific formulation approved in 1984 and also available in our SteamTab V2 and SteamTab Duo V1 products.

4. **Old Industrial Formulation (IFC-67)**: This is the older, but widely accepted formulation in the power industry. This formulation is based on the 1967 IFC formulation for industrial use (ASME Steam Tables, 6th Edition).

SteamTab *Quad* uses fundamental equations to calculate all steam properties with no interpolation or curve fits to raw steam data. With SteamTab *Quad*, users have a choice of basing their steam property calculations from either the scientific formulation, or the industrial formulation. The formulations used in SteamTab *Quad* and their references are shown in the following table.

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

SteamTab *Quad* 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.

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<p align="center">**Table 1**: SteamTab *Quad* Model Formulations</p>

| SteamTab *Quad* Formulations | Description |
|---|---|
| **Scientific Formulation (IAPWS-95)** | The scientific formulation is described in the following 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 *Quad* imposes the following temperature and pressure restrictions: |
| | Pressure ($P$, bar): $\quad 0 \leq P \leq 100{,}000$ |
| | Temperature ($T$, K): $\quad 190 \leq T \leq 5000$ |
| **Industrial Formulation (IAPWS-97)** | The industrial formulation is described in the following reference: |
| | *Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam*, The International Association for the Properties of Water and Steam, Erlangen, Germany, 1997. |
| | This formulation has the following range of applicability: |
| | Pressure ($P$, bar): $\quad 0 \leq P \leq 1{,}000$ |
| | Temperature ($T$, K): $\quad 273.15\text{ K} \leq T \leq 1073.15$ (for $P \leq 1{,}000$) |
| | $\qquad\qquad 1073.15\text{ K} \leq T \leq 2273.17$ (for $P \leq 100$) |
| **Old Scientific Formulation (NBS/NRC-84)** | The NBS/NRC formulation is described in the following reference: |
| | *NBS/NRC Steam Tables*, L. Haar, J. S. Gallagher and G. S. Hell. Hemisphere Publishing Corporation, 1984. |
| | Generally, the NBS/NRC formulation has the following range of applicability: |
| | Pressure (P, bar): $\quad 0 \leq P \leq 30{,}000$ |
| | Temperature (T, K): $\quad 260 \leq T \leq 2500$ |
| **Old Industrial Formulation (IFC-67)** | The IFC 1967 formulation is described in the following reference: |
| | *The 1967 IFC Formulation for Industrial Use*, ASME Steam Tables, 6th Edition, ASME Press. |
| | Generally, the IFC 1967 formulation has the following range of applicability: |
| | Pressure (P, bar): $\quad 0 \leq P \leq 1{,}000$ |
| | Temperature (T, K): $273.16 \leq T \leq 1073.15$ |

> **Note**
>
> SteamTab *Quad* does not include properties for ice.

## What's New in Version 4.0

SteamTab *Quad* Version 4.0 offers a number of enhancements:

- SteamTab *Quad* V4.0 supports Excel versions 2010, 2007 and 2003 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 *Quad*.

- 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 *Quad*. If you have any problems during installation or use of SteamTab *Quad*, 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 *Quad* 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

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| | |
|---|---|
| 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 *Quad* 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 *Quad* 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 *Quad*, simply click on the file SETUP-STEAMTAB_QUAD.EXE and follow the instructions on the screen.

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

Once installation is complete you can access SteamTab *Quad* 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 *Quad* as shown below:

**Figure 1:** ChemicaLogic SteamTab *Quad* on Window's Start Menu
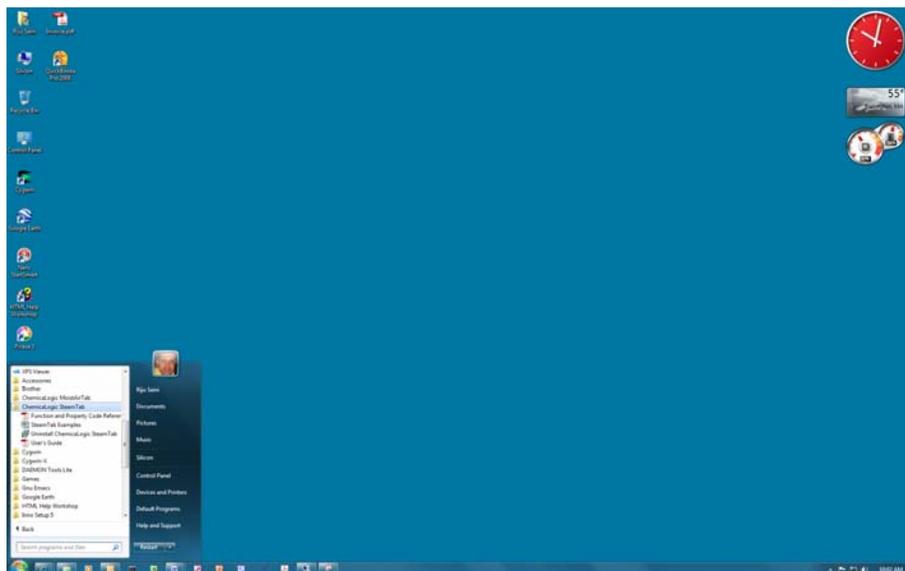


## Using SteamTab *Quad*

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

### Where is SteamTab *Quad*?

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

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**Figure 2:** Access to SteamTab *Quad* in Excel 2003
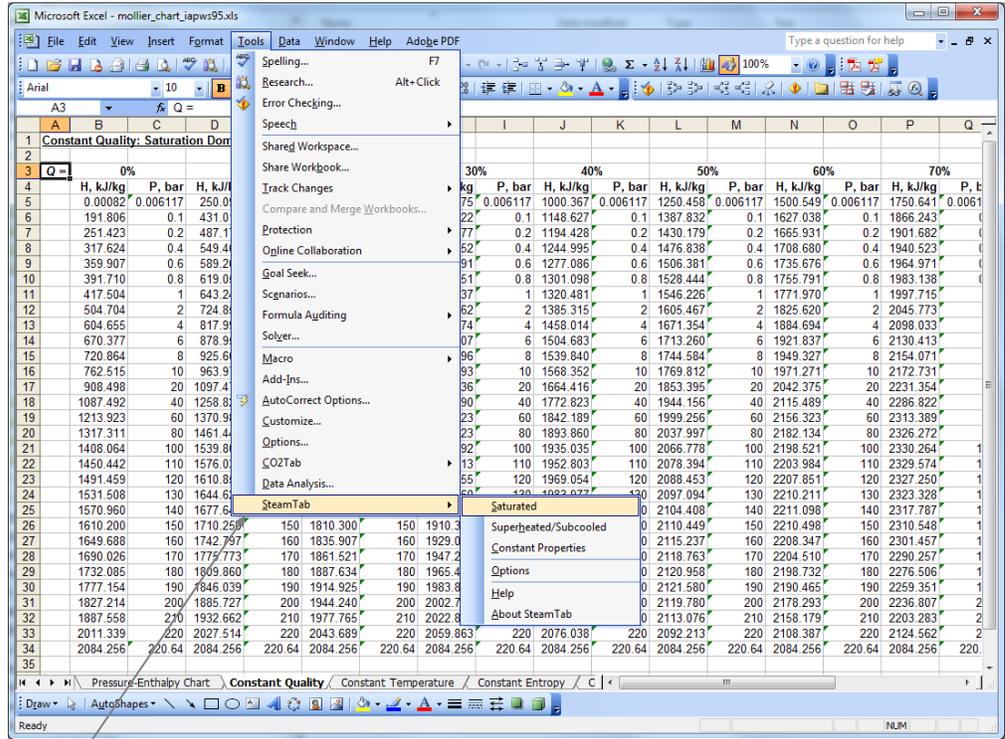


SteamTab *Quad* Menu

**Figure 3:** Access to SteamTab *Quad* in Excel 2007 or Excel 2010
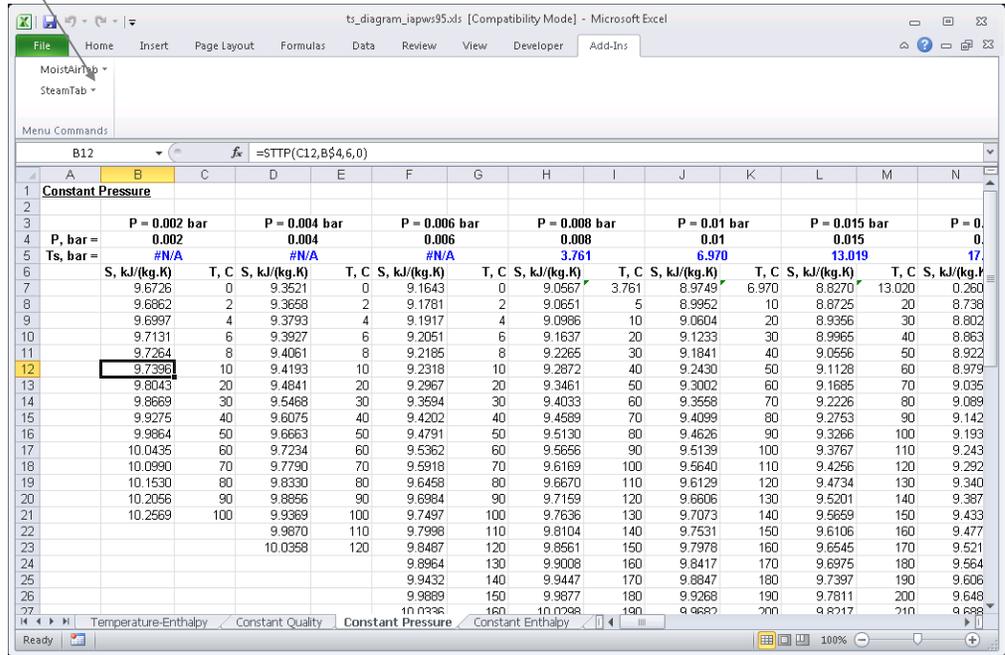
The SteamTab *Quad* pop-up menu contains the following menu items:

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 *Quad* 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 *Quad* dialog-boxes.

5. **Help**
   Provides you with easy access to online help.

6. **About SteamTab *Quad***
   Gives you information regarding the version of SteamTab *Quad* installed on your machine.

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

## Setting Steam Property Options

The options dialog box helps you in setting up the units to base your property calculations. All of the SteamTab *Quad* 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 *Quad* dialog boxes.

on page 29 for a listing of steam properties and their Metric/SI and English units

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

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

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 model formulation**
   Select the Scientific (IAPWS-95) radio button if you want to use the scientific formulation or select the Industrial (IAPWS-97) radio button if you want to use the industrial formulation.

3. **Select comment option**
   Check the comments box if you want SteamTab *Quad* to place a comment regarding the property calculated and the units in the output cell.

4. **Click OK**
   Click on the OK button to accept the changes. After you have clicked OK, all of the SteamTab *Quad* 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 *Quad* will remember the options even in subsequent sessions.

**Figure 4:** Steam Property Options Dialog
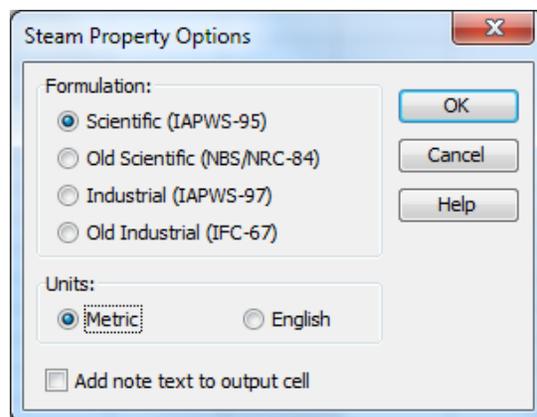


## Using the Saturated Steam Properties Dialog Box

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

This dialog box automatically creates a call (with all the correct arguments) to the appropriate SteamTab *Quad* 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 *Quad* will automatically fill in the Output cell reference

**6. Provide an output cell reference**
Notice that SteamTab *Quad* 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 *Quad* 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 16.

> **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 *Quad* 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 *Quad* function, then SteamTab *Quad* 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
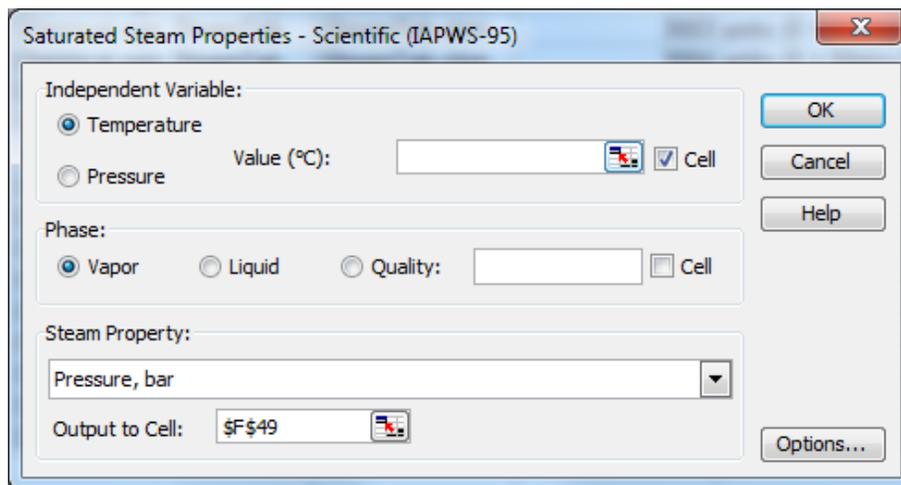
## Using the Superheated/Subcooled Steam Properties Dialog Box

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 Quad functions*

Using this dialog box automatically creates a call to the appropriate SteamTab *Quad* 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 *Quad* 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 *Quad* will automatically fill in the Output cell reference

**5.** **Provide an output cell reference**
Notice that SteamTab *Quad* 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 *Quad* 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 *Quad* function, then SteamTab *Quad* 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



First Independent Variable

Second Independent Variable

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

## 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 *Quad* will automatically fill in the Output cell reference

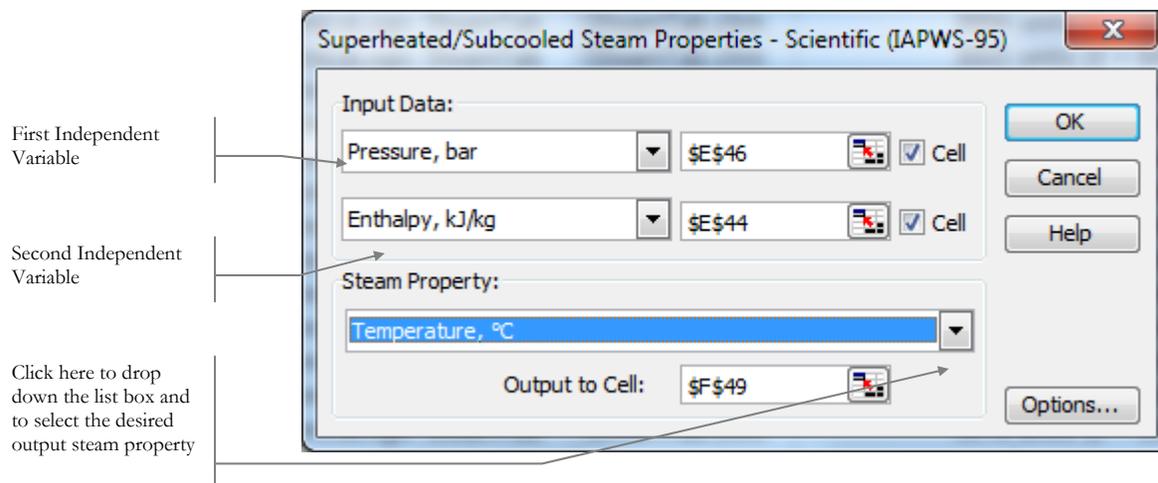1. **Provide an output cell reference**
   Notice that SteamTab *Quad* has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.

2. **Click OK**
   SteamTab *Quad* 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 *Quad* function, then SteamTab *Quad* 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
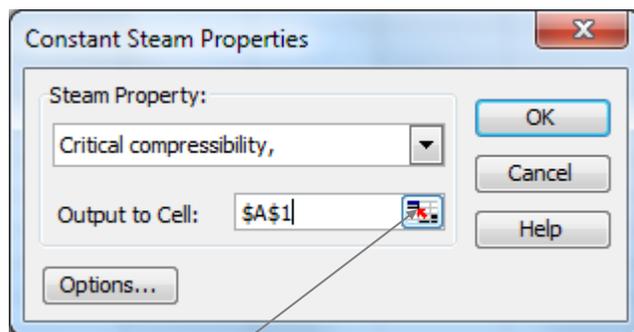


Click here to drop down the list box and to select the desired output steam property

## Using Excel's Function Wizard

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

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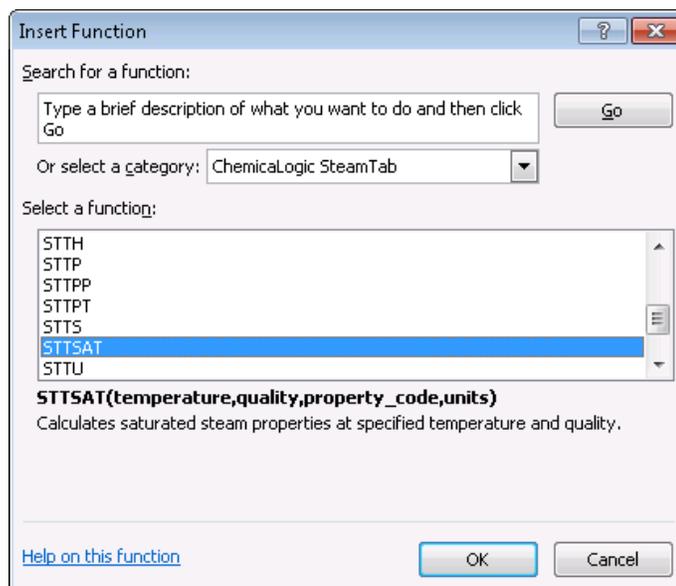


Selecting the STTP function to shows the function wizard:

**Figure 9:** Excel's Function Wizard for SteamTab *Quad* Function
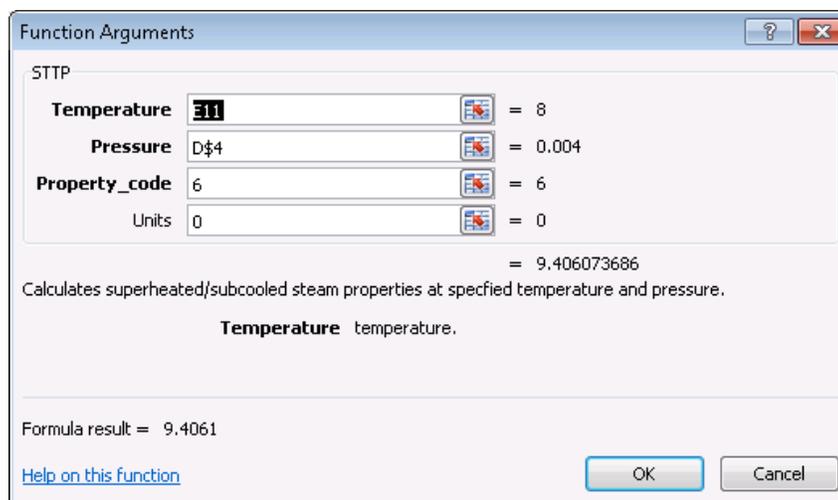
If you need help on the function arguments or need to lookup the property codes click on the "**Help on this function**" located on the lower left corner of the function wizard.

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

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

To establish a reference to the SteamTab *Quad* 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 *Quad* and select **OK**:

**Figure 10:** Excel VBA Reference to SteamTab *Quad*
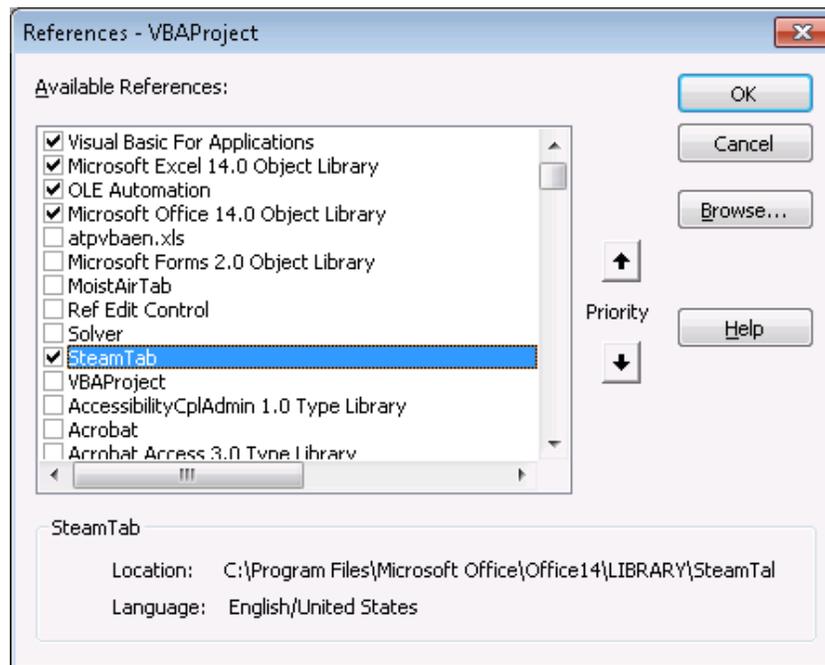


Once a reference to SteamTab *Quad* is established you can use the SteamTab *Quad* functions in VBA just as you would any other function, as shown below:
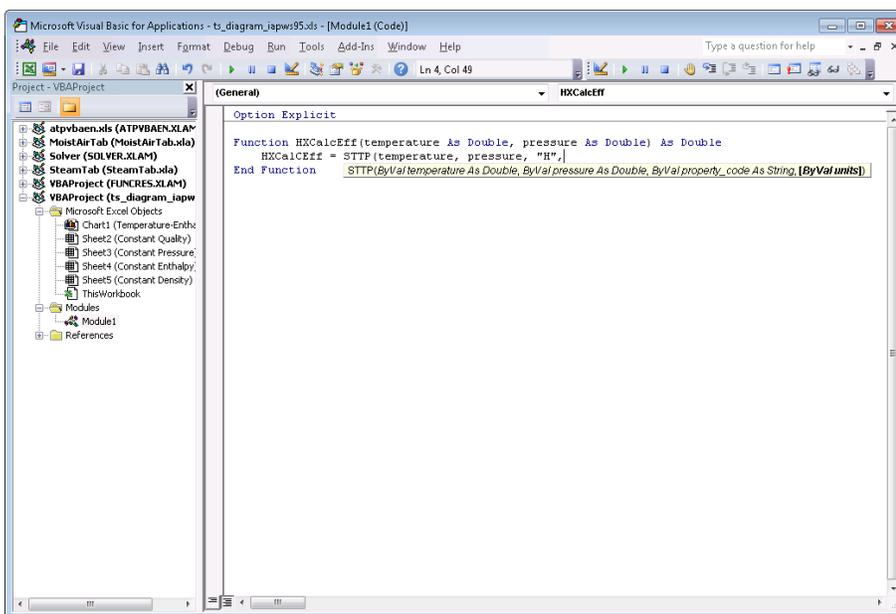
## Tips and Tricks

Below is a list of tips that users like you have contributed to help the SteamTab *Quad* user community gain the best possible benefit of using SteamTab *Quad* 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 6 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 *Quad*. This is normal, because the spreadsheet application loads the full SteamTab *Quad* package only when you first use it. This helps conserve memory.
- You do not have to remember the calling sequence of SteamTab *Quad* functions. Use the SteamTab *Quad* 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 *Quad* dialog boxes. SteamTab *Quad* will automatically fill in the Output cell reference for you.

## Uninstalling SteamTab *Quad*

To uninstall SteamTab *Quad*, from Window's Start menu, select Programs, ChemicaLogic SteamTab *Quad* and then select Uninstall ChemicaLogic

SteamTab *Quad*. This will completely uninstall SteamTab *Quad* from your computer.

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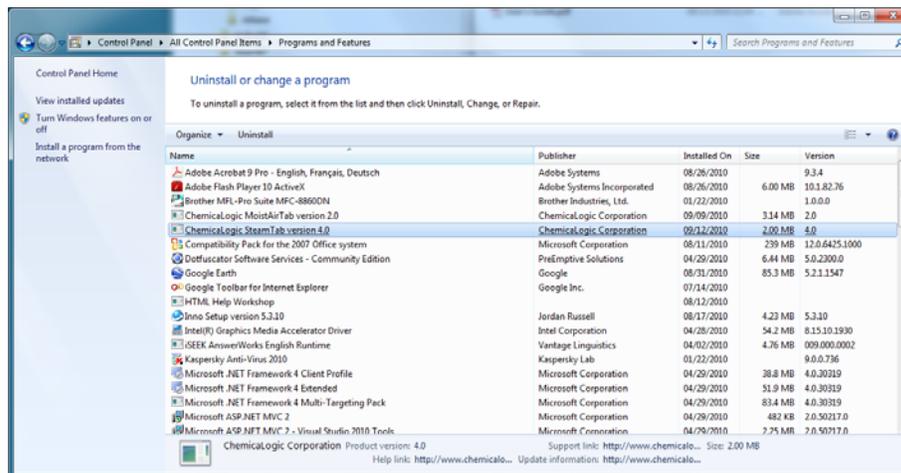


**Joule, James Prescott**

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

**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 *Quad* 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 *Quad*. (**Note: SteamTab *Quad* V4.0 now includes this property**). However, it is nearly effortless, given the ease-of-use of SteamTab *Quad* 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:

$$\boxed{\phantom{xxxxxxxxxxxxxxx}}$$

Therefore, all that we need to do is use SteamTab *Quad* 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 *Quad* 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 *Quad*, 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 *Quad* 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 *Quad* dialogs to obtain properties, we will first the steam property options to use the metric/SI units.

  **a.** From the SteamTab *Quad* pop-up menu select Options

  **b.** Click on the Metric/SI radio buttons

  **c.** Click OK

2. **Use SteamTab *Quad* to get the vapor enthalpy**
   In this step you will use SteamTab *Quad* 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 *Quad* 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.

  **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)

3. **Use SteamTab *Quad* 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 *Quad* menu and select Saturated

  **d.** Notice how SteamTab *Quad* 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:
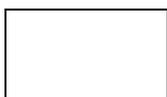
where $U$ is internal energy and $H$ is the enthalpy. The solution to this problem is shown in **Figure 12**.

**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 *Quad* 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 *Quad* 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 *Quad* 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 *Quad*'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 *Quad*'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 *Quad* package as a guide.

## Templates and Examples

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

### SteamTab *Quad* 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 *Quad* Templates for Excel 2007/2010

# CHEMICALOGIC
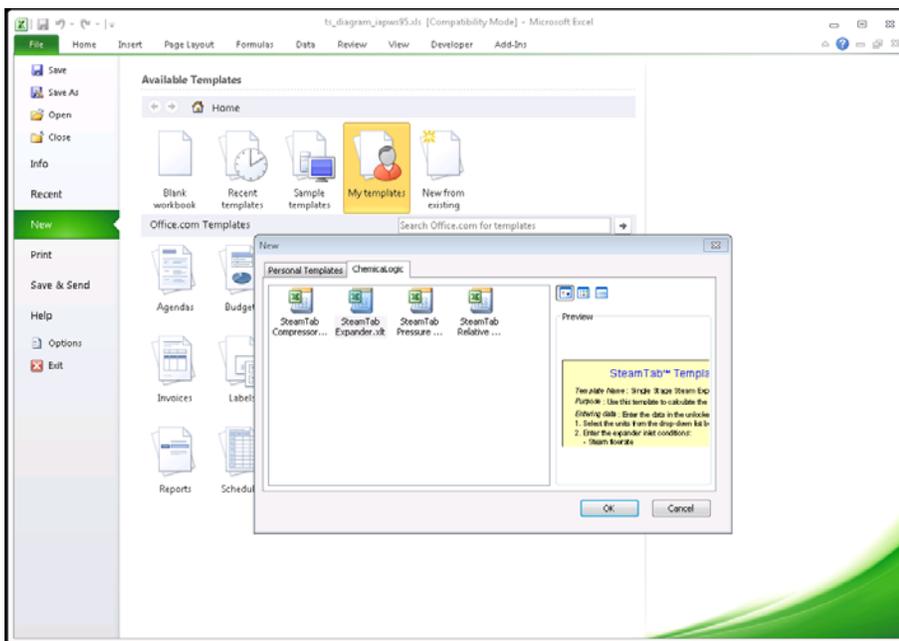
**Figure 14:** SteamTab *Quad* Compressor Template Example

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 *Quad* add-in package is based on a set of 19 core functions (for both the Scientific formulations and the Industrial formulations) 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 *Quad*'s easy-to-use dialog boxes to automatically generate the appropriate function call with the correct arguments.

SteamTab *Quad* 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.

SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) are shown in **Table 2** and those based on the industrial formulation (IAPWS-97) are shown in **Table 3**.

> **Note**
>
> All SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) begin with the prefix ST, and all of the SteamTab *Quad* functions based on the industrial formulation (IAPWS-97) begin with the prefix AST.
>
> SteamTab *Quad* functions based on the old scientific formulation (NBS/NRC-84) begin with the prefix OST, and all of the SteamTab *Quad* functions based on the old industrial formulation (IFC-67) begin with the prefix OAST

**Table 2:** Overview of SteamTab *Quad* Functions: Scientific Formulation (IAPWS-95)

| 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*) |

Note: Append the letter O the function names to use the old scientific formulation (NBS/NRC-84).

# CHEMICALOGIC

**Table 3**: Overview of SteamTab *Quad* Functions: Industrial Formulation (IAPWS-97)

| Function | Calculates | Calling Sequence |
|---|---|---|
| **Saturated vapor, liquid or two-phase functions** | | |
| ASTPSAT | at specified pressure | ASTPSAT(pressure, quality, code, *units*) |
| ASTTSAT | at specified temperature | ASTTSAT(temperature, quality, code, *units*) |
| **Superheated or subcooled functions** | | |
| ASTTP | at specified temperature and pressure *(T-P)* | ASTTP(temperature, pressure, code, *units*) |
| ASTTV | at specified temperature and volume *(T-V)* | ASTTV(temperature, volume, code, *units*) |
| ASTTH | at specified temperature and enthalpy *(T-H)* | ASTTH(temperature, enthalpy, code, *units*) |
| ASTTS | at specified temperature and entropy *(T-S)* | ASTTS(temperature, entropy, code, *units*) |
| ASTTU | at specified temperature and internal energy *(T-U)* | ASTTU(temperature, internal_energy, code, *units*) |
| ASTPV | at specified pressure and volume *(P-V)* | ASTPV(pressure, volume, code, *units*) |
| ASTPH | at specified pressure and enthalpy *(P-H)* | ASTPH(pressure, enthalpy, code, *units*) |
| ASTPS | at specified pressure and entropy *(P-S)* | ASTPS(pressure, entropy, code, *units*) |
| ASTPU | at specified pressure and internal energy *(P-U)* | ASTPU(pressure, internal_energy, code, *units*) |
| **Constant properties functions** | | |
| ASTMW | Molecular weight | ASTMW(*units*) |
| ASTTC | Critical temperature | ASTTC(*units*) |
| ASTPC | Critical pressure | ASTPC(*units*) |
| ASTVC | Critical specific volume | ASTVC(*units*) |
| ASTRC | Critical specific density | ASTRC(*units*) |
| ASTZC | Critical compressibility factor | ASTZC(*units*) |
| ASTTPT | Triple point temperature | ASTTPT(*units*) |
| ASTTPP | Triple point pressure | ASTTPP(*units*) |

Note: Append the letter O the function names to use the old industrial formulation (IFC-67).

> **Note**
>
> 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 *Quad* 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 argument 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 4:** 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, $V$ | m³/kg | ft³/lb |
| 3 | D | Density, $\rho$ | kg/m³ | lb/ft³ |
| 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, $(\partial V / \partial T)_P$ | m³/(kg·°C) | ft³/(lb·°F) |
| 17 | DVDP | dvdp, $(\partial V / \partial P)_T$ | m³/(kg·bar) | ft³/(lb·psi) |
| 18 | MU | Viscosity (dynamic), $\mu$ | µPa·s | lb/(ft·hr) |
| 19 | KT | Thermal conductivity, $K$ | W/(m·°C) | Btu/(hr·ft·°F) |
| 20 | ST | Surface tension, $\sigma$ | 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 model formulation and independent variable, the two functions you can choose are:

| Independent Variable | Scientific Formulation (IAPWS-95) | Industrial Formulation (IAPWS-97) |
|---|---|---|
| Pressure | STPSAT | ASTPSAT |
| Temperature | STTSAT | ASTTSAT |

These functions are described in detail below.

## STPSAT, ASTPSAT

Calculates the saturated vapor or liquid property at the specified pressure and quality.

### Syntax: Scientific Formulation (IAPWS-95)
    STPSAT(pressure, quality, code, *units*)

### Syntax: Industrial Formulation (IAPWS-97)
    ASTPSAT(pressure, quality, 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.

code                is an integer property code that specifies the type of property required. See **The SteamTab** Quad add-in package is based on a set of 19 core functions (for both the Scientific formulations and the Industrial formulations) 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 *Quad's* easy-to-use dialog boxes to automatically generate the appropriate

function call with the correct arguments.

SteamTab *Quad* functions are divided into three categories:

4. **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.

5. **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.

6. **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.

SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) are shown in **Table 2** and those based on the industrial formulation (IAPWS-97) are shown in **Table 3.**

### Note

All SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) begin with the prefix ST, and all of the SteamTab *Quad* functions based on the industrial formulation (IAPWS-97) begin with the prefix AST.

SteamTab *Quad* functions based on the old scientific formulation (NBS/NRC-84) begin with the prefix OST, and all of the SteamTab *Quad* functions based on the old industrial formulation (IFC-67) begin with the prefix OAST

**Table 2:** Overview of SteamTab *Quad* Functions: Scientific Formulation (IAPWS-95)

| 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) |

Note: Append the letter O the function names to use the old scientific formulation (NBS/NRC-84).

**Table 3:** Overview of SteamTab *Quad* Functions: Industrial Formulation (IAPWS-97)

| Function | Calculates | Calling Sequence |
|---|---|---|
| **Saturated vapor, liquid or two-phase functions** | | |
| ASTPSAT | at specified pressure | ASTPSAT(pressure, quality, code, *units)* |
| ASTTSAT | at specified temperature | ASTTSAT(temperature, quality, code, *units)* |
| **Superheated or subcooled functions** | | |
| ASTTP | at specified temperature and pressure *(T-P)* | ASTTP(temperature, pressure, code, *units)* |
| ASTTV | at specified temperature and volume *(T-V)* | ASTTV(temperature, volume, code, *units)* |
| ASTTH | at specified temperature and enthalpy *(T-H)* | ASTTH(temperature, enthalpy, code, *units)* |
| ASTTS | at specified temperature and entropy *(T-S)* | ASTTS(temperature, entropy, code, *units)* |
| ASTTU | at specified temperature and internal energy *(T-U)* | ASTTU(temperature, internal_energy, code, *units)* |
| ASTPV | at specified pressure and volume *(P-V)* | ASTPV(pressure, volume, code, *units)* |
| ASTPH | at specified pressure and enthalpy *(P-H)* | ASTPH(pressure, enthalpy, code, *units)* |
| ASTPS | at specified pressure and entropy *(P-S)* | ASTPS(pressure, entropy, code, *units)* |
| ASTPU | at specified pressure and internal energy *(P-U)* | ASTPU(pressure, internal_energy, code, *units)* |

**Constant properties functions**

| | | |
|---|---|---|
| ASTMW | Molecular weight | ASTMW(units) |
| ASTTC | Critical temperature | ASTTC(units) |
| ASTPC | Critical pressure | ASTPC(units) |
| ASTVC | Critical specific volume | ASTVC(units) |
| ASTRC | Critical specific density | ASTRC(units) |
| ASTZC | Critical compressibility factor | ASTZC(units) |
| ASTTPT | Triple point temperature | ASTTPT(units) |
| ASTTPP | Triple point pressure | ASTTPP(units) |

Note: Append the letter O the function names to use the old industrial formulation (IFC-67).

**Note**

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 *Quad* 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 argument 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 4:** Property Codes for Thermodynamic and Transport Properties of Steam (page 29) 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 pressure must be greater than or equal to the Triple Point Pressure and less than or equal to the Critical Pressure.

- 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, ASTTSAT

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

### Syntax: Scientific Formulation (IAPWS-95)

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

### Syntax: Industrial Formulation (IAPWS-97)

STTSAT(temperature, quality, 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. |
| code | is an integer property code that specifies the type of property required. See **The SteamTab** Quad add-in package is based on a set of 19 core functions (for both the Scientific formulations and the Industrial formulations) 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 *Quad's* easy-to-use dialog boxes to automatically generate the appropriate |

function call with the correct arguments.

SteamTab *Quad* functions are divided into three categories:

**7. 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.

**8. 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.

**9. 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.

SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) are shown in **Table 2** and those based on the industrial formulation (IAPWS-97) are shown in **Table 3.**

**Note**

All SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) begin with the prefix ST, and all of the SteamTab *Quad* functions based on the industrial formulation (IAPWS-97) begin with the prefix AST.

SteamTab *Quad* functions based on the old scientific formulation (NBS/NRC-84) begin with the prefix OST, and all of the SteamTab *Quad* functions based on the old industrial formulation (IFC-67) begin with the prefix OAST

**Table 2:** Overview of SteamTab *Quad* Functions: Scientific Formulation (IAPWS-95)

| 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) |

Note: Append the letter O the function names to use the old scientific formulation (NBS/NRC-84).

**Table 3:** Overview of SteamTab *Quad* Functions: Industrial Formulation (IAPWS-97)

| Function | Calculates | Calling Sequence |
|---|---|---|
| **Saturated vapor, liquid or two-phase functions** | | |
| ASTPSAT | at specified pressure | ASTPSAT(pressure, quality, code, *units)* |
| ASTTSAT | at specified temperature | ASTTSAT(temperature, quality, code, *units)* |
| **Superheated or subcooled functions** | | |
| ASTTP | at specified temperature and pressure *(T-P)* | ASTTP(temperature, pressure, code, *units)* |
| ASTTV | at specified temperature and volume *(T-V)* | ASTTV(temperature, volume, code, *units)* |
| ASTTH | at specified temperature and enthalpy *(T-H)* | ASTTH(temperature, enthalpy, code, *units)* |
| ASTTS | at specified temperature and entropy *(T-S)* | ASTTS(temperature, entropy, code, *units)* |
| ASTTU | at specified temperature and internal energy *(T-U)* | ASTTU(temperature, internal_energy, code, *units)* |
| ASTPV | at specified pressure and volume *(P-V)* | ASTPV(pressure, volume, code, *units)* |
| ASTPH | at specified pressure and enthalpy *(P-H)* | ASTPH(pressure, enthalpy, code, *units)* |
| ASTPS | at specified pressure and entropy *(P-S)* | ASTPS(pressure, entropy, code, *units)* |
| ASTPU | at specified pressure and internal energy *(P-U)* | ASTPU(pressure, internal_energy, code, *units)* |

**Constant properties functions**

| | | |
|---|---|---|
| ASTMW | Molecular weight | ASTMW(units) |
| ASTTC | Critical temperature | ASTTC(units) |
| ASTPC | Critical pressure | ASTPC(units) |
| ASTVC | Critical specific volume | ASTVC(units) |
| ASTRC | Critical specific density | ASTRC(units) |
| ASTZC | Critical compressibility factor | ASTZC(units) |
| ASTTPT | Triple point temperature | ASTTPT(units) |
| ASTTPP | Triple point pressure | ASTTPP(units) |

Note: Append the letter O the function names to use the old industrial formulation (IFC-67).

### Note

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 *Quad* 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 argument 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 4:** Property Codes for Thermodynamic and Transport Properties of Steam (page 29) 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 must be greater than or equal to the Triple Point Temperature and less than or equal to the Critical Temperature.

- 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. Depending on the model formulation, the properties returned by these functions are acceptable within the following ranges:

| Variable | Range for Scientific Formulation | Range for Industrial Formulation |
| --- | --- | --- |
| Pressure ($P$, bar) | $0 \leq P \leq 100{,}000$ | $0 \leq P \leq 1{,}000$ |
| Temperature ($T$, K) | $190 \leq T \leq 5000$ | $273.16 \leq T \leq 1073.15$ (for P ≤ 1,000) $273.15 \leq T \leq 2273.15$ (for P ≤ 100) |

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 | | Use Function | |
|---|---|---|---|
| **First Variable** | **Second Variable** | **Scientific** | **Industrial** |
| Temperature, $T$ | Pressure, $P$ | STTP | ASTTP |
| Temperature, $T$ | Volume, $V$ | STTV | ASTTV |
| Temperature, $T$ | Enthalpy, $H$ | STTH | ASTTH |
| Temperature, $T$ | Entropy, $S$ | STTS | ASTTS |
| Temperature, $T$ | Internal Energy, $U$ | STTU | ASTTU |
| Pressure, $P$ | Volume, $V$ | STPV | ASTPV |
| Pressure, $P$ | Enthalpy, $H$ | STPH | ASTPH |
| Pressure, $P$ | Entropy, $S$ | STPS | ASTPS |
| Pressure, $P$ | Internal Energy, $U$ | STPU | ASTPU |

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

## General Description

**General Syntax: Scientific Formulation (IAPWS-95)**
    STXX(first_variable, second_variable, code, *units*)


**General Syntax: Industrial Formulation (IAPWS-97)**
    ASTXX(first_variable, second_variable, code, *units*)


    Replace STXX or ASTXX with the appropriate function name.


**General Arguments**

first_variable          is the first independent variable.

second_variable      is the second independent variable .

code                       is an integer property code that specifies the type of property
                              required. See **The SteamTab** Quad add-in package is based
                              on a set of 19 core functions (for both the Scientific
                              formulations and the Industrial formulations) 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 *Quad's* easy-to-use
                              dialog boxes to automatically generate the appropriate

function call with the correct arguments.

SteamTab *Quad* functions are divided into three categories:

10. **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.

11. **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.

12. **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.

SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) are shown in **Table 2** and those based on the industrial formulation (IAPWS-97) are shown in **Table 3.**

### Note

All SteamTab *Quad* functions based on the scientific formulation (IAPWS-95) begin with the prefix ST, and all of the SteamTab *Quad* functions based on the industrial formulation (IAPWS-97) begin with the prefix AST.

SteamTab *Quad* functions based on the old scientific formulation (NBS/NRC-84) begin with the prefix OST, and all of the SteamTab *Quad* functions based on the old industrial formulation (IFC-67) begin with the prefix OAST

**Table 2:** Overview of SteamTab *Quad* Functions: Scientific
Formulation (IAPWS-95)

| 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) |

Note: Append the letter O the function names to use the old
scientific formulation (NBS/NRC-84).

**Table 3:** Overview of SteamTab *Quad* Functions: Industrial
Formulation (IAPWS-97)

| Function | Calculates | Calling Sequence |
| --- | --- | --- |
| **Saturated vapor, liquid or two-phase functions** | | |
| ASTPSAT | at specified pressure | ASTPSAT(pressure, quality, code, *units)* |
| ASTTSAT | at specified temperature | ASTTSAT(temperature, quality, code, *units)* |
| **Superheated or subcooled functions** | | |
| ASTTP | at specified temperature and pressure *(T-P)* | ASTTP(temperature, pressure, code, *units)* |
| ASTTV | at specified temperature and volume *(T-V)* | ASTTV(temperature, volume, code, *units)* |
| ASTTH | at specified temperature and enthalpy *(T-H)* | ASTTH(temperature, enthalpy, code, *units)* |
| ASTTS | at specified temperature and entropy *(T-S)* | ASTTS(temperature, entropy, code, *units)* |
| ASTTU | at specified temperature and internal energy *(T-U)* | ASTTU(temperature, internal_energy, code, *units)* |
| ASTPV | at specified pressure and volume *(P-V)* | ASTPV(pressure, volume, code, *units)* |
| ASTPH | at specified pressure and enthalpy *(P-H)* | ASTPH(pressure, enthalpy, code, *units)* |
| ASTPS | at specified pressure and entropy *(P-S)* | ASTPS(pressure, entropy, code, *units)* |
| ASTPU | at specified pressure and internal energy *(P-U)* | ASTPU(pressure, internal_energy, code, *units)* |

**Constant properties functions**

| | | |
|---|---|---|
| ASTMW | Molecular weight | ASTMW(units) |
| ASTTC | Critical temperature | ASTTC(units) |
| ASTPC | Critical pressure | ASTPC(units) |
| ASTVC | Critical specific volume | ASTVC(units) |
| ASTRC | Critical specific density | ASTRC(units) |
| ASTZC | Critical compressibility factor | ASTZC(units) |
| ASTTPT | Triple point temperature | ASTTPT(units) |
| ASTTPP | Triple point pressure | ASTTPP(units) |

Note: Append the letter O the function names to use the old industrial formulation (IFC-67).

### Note

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 *Quad* 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 argument 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 4:** Property Codes for Thermodynamic and Transport Properties of Steam (page 29) 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, ASTTP

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

### Syntax: Scientific Formulation (IAPWS-95)
STTP(temperature, pressure, code, *units*)

### Syntax: Industrial Formulation (IAPWS-97)
ASTTP(temperature, pressure, 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, ASTTV

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

### Syntax: Scientific Formulation (IAPWS-95)
STTV(temperature, volume, code, *units*)

*Syntax: Industrial Formulation (IAPWS-97)*
ASTTV(temperature, volume, 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 m³/kg if *units* is 0; and must be in ft³/lb if *units* is 1.

## STTH, ASTTH
Calculates superheated vapor or subcooled liquid property at the specified temperature and enthalpy.

*Syntax: Scientific Formulation (IAPWS-95)*
STTH(temperature, enthalpy, code, *units*)

*Syntax: Industrial Formulation (IAPWS-97)*
ASTTH(temperature, enthalpy, 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, ASTTS
Calculates superheated vapor or subcooled liquid property at the specified temperature and entropy.

*Syntax: Scientific Formulation (IAPWS-95)*
STTS(temperature, entropy, code, *units*)

*Syntax: Industrial Formulation (IAPWS-97)*
ASTTS(temperature, entropy, 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, ASTTU
Calculates superheated vapor or subcooled liquid property at the specified temperature and internal energy.

*Syntax: Scientific Formulation (IAPWS-95)*
STTU(temperature, internal_energy, code, *units*)

*Syntax: Industrial Formulation (IAPWS-97)*
ASTTU(temperature, internal_energy, 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, ASTPV
Calculates superheated vapor or subcooled liquid property at the specified pressure and volume.

*Syntax: Scientific Formulation (IAPWS-95)*
STPV(pressure, volume, code, *units*)

*Syntax: Industrial Formulation (IAPWS-97)*
ASTPV(pressure, volume, 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, ASTPH
Calculates superheated vapor or subcooled liquid steam property at the specified pressure and enthalpy.

*Syntax: Scientific Formulation (IAPWS-95)*
STPH(pressure, enthalpy, code, *units*)

*Syntax: Industrial Formulation (IAPWS-97)*
ASTPH(pressure, enthalpy, 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, ASTPS

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

### *Syntax: Scientific Formulation (IAPWS-95)*
STPS(pressure, entropy, code, *units*)

### *Syntax: Industrial Formulation (IAPWS-97)*
ASTPS(pressure, entropy, 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.°C) if *units* is 0; and must be in Btu/(lb.°F) if *units* is 1.

## STPU, ASTPU

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

### *Syntax: Scientific Formulation (IAPWS-95)*
STPU(pressure, internal_energy, code, *units*)

### *Syntax: Industrial Formulation (IAPWS-97)*
ASTPU(pressure, internal_energy, 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:

| Scientific Formulation | Industrial Formulation | Calculates | Metric/SI Units | English Units |
|---|---|---|---|---|
| STMW | ASTMW | Molecular weight | kg/kmol | lb/lbmol |
| STTC | ASTTC | Critical temperature | °C | °F |
| STPC | ASTPC | Critical pressure | bar | psia |
| STVC | ASTVC | Critical specific volume | $m^3/kg$ | $ft^3/lb$ |
| STRC | ASTRC | Critical specific density | $kg/m^3$ | $lb/ft^3$ |
| STZC | ASTZC | Critical compressibility factor | dimensionless | dimensionless |
| STTPT | ASTTPT | Triple point temperature | °C | °F |
| STTPP | ASTTPP | 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 °C

**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.