



# Steam Plot

© 2019 Fluidika Techlabs  
[www.fluidika.com](http://www.fluidika.com)  
[support@fluidika.com](mailto:support@fluidika.com)

## USER GUIDE

### REQUIREMENTS:

Compatible with iPad. Requires iOS 12.1 or later.

**VERSION:** 2.1

## Description

**Steam Plot** performs calculations and generates plot diagrams of thermodynamic and transport properties of steam based on the latest IAPWS-IF97 Formulation and IAPWS releases.

Given a combination of two thermodynamic properties out of 14 different possible combinations, it calculates 20 thermodynamic and transport properties of steam and 10 partial derivatives.

Calculates and plots isolines of pressure, temperature, specific enthalpy, specific entropy, specific volume and vapor fraction for 4 different plot diagrams.

The numerical results and plots obtained are suitable for engineering, scientific, industrial or academic use.

## Main Features

- Performs all the calculations implementing the latest mathematical formulations from the IAPWS (International Association for the Properties of Water and Steam), IAPWS-IF97 Industrial formulation (Revision 2007).
- Calculates 20 Thermodynamic and Transport properties of steam using the above formulation:
  - Pressure
  - Temperature
  - Specific Enthalpy
  - Specific Entropy
  - Specific Internal Energy
  - Specific Volume
  - Density
  - Speed of Sound
  - Dynamic Viscosity
  - Kinematic Viscosity

- Thermal Conductivity
  - Thermal Diffusivity
  - Isobaric Heat Capacity
  - Isochoric Heat Capacity Isentropic Exponent
  - Isobaric Cubic Expansion Coefficient
  - Isothermal Compressibility
  - Prandtl Number
  - Vapor Fraction
  - IAPWS-IF97 Region
- Calculates 10 partial derivatives:
    - Derivate of specific volume on pressure with constant temperature -  $(dv/dP)_T$
    - Derivate of specific internal energy on pressure with constant temperature -  $(du/dP)_T$
    - Derivate of specific entropy on pressure with constant temperature -  $(ds/dP)_T$
    - Derivate of specific enthalpy on pressure with constant temperature -  $(dh/dP)_T$
    - Derivate of specific volume on temperature with constant pressure -  $(dv/dT)_P$
    - Derivate of specific internal energy on temperature with constant pressure -  $(du/dT)_P$
    - Derivate of specific entropy on temperature with constant pressure -  $(ds/dT)_P$
    - Derivate of specific enthalpy on temperature with constant pressure -  $(dh/dT)_P$
    - Derivate of pressure on temperature with constant specific volume -  $(dP/dT)_v$
    - Derivate of pressure on specific volume with constant temperature -  $(dP/dv)_T$
- It allows for 14 different combinations of thermodynamic properties to be entered as input parameters:
    - Temperature / Pressure
    - Temperature / Enthalpy
    - Temperature / Internal Energy
    - Temperature / Entropy
    - Temperature / Specific Volume
    - Pressure / Enthalpy
    - Pressure / Internal Energy
    - Pressure / Entropy
    - Pressure / Specific Volume
    - Enthalpy / Entropy
    - Enthalpy / Specific Volume
    - Internal Energy / Specific Volume
    - Temperature / Vapor Fraction
    - Pressure / Vapor Fraction
- The calculations operate in two modes denoted as General Properties and Two-Phase Properties:
    - **General Properties:** Input and Output values are all over the range of the IAPWS-IF97 Formulation.
    - **Two-Phase Properties:** Input and Output thermodynamics property values are on the range of the two-phase region (region 4) of the IAPWS-IF97 Formulation, including saturation values of liquid and vapor.
- Supports input parameters and calculation results in both the SI (metric) and the I-P (english) system of units.

- For each combination of input thermodynamic properties, it calculates and provides the user with information about the appropriate input values in the valid range of calculations.
- Results can be sent by email in an HTML file along with a comma-separated value (CSV) file.
- Generates 4 Diagram Plot types with isolines calculated all over the IAPWS-IF97 range:
  - **Temperature - Entropy :**
    - Pressure
    - Specific enthalpy
    - Specific volume
    - Vapor Fraction
  - **Enthalpy - Entropy :**
    - Pressure
    - Temperature
    - Specific volume
    - Vapor Fraction
  - **log Pressure - Enthalpy :**
    - Temperature
    - Specific entropy
    - Specific volume
    - Vapor fraction
  - **Pressure - Temperature :**
    - Specific enthalpy
    - Specific entropy
    - Specific volume
- Steam points calculated from General or Two-Phase properties can be stored in a database for later retrieval.
- Plot diagrams projects allow to add and edit isolines and steam calculation points graphically or numerically directly to plot diagrams that can be saved into a database.
- Plot diagrams can be sent by email as high-resolution PDF files.

## Limited Range of Variables

Certain limitations are applied to **Steam Plot** when the application does not have access to the Full Range of Variables. These limitations are described in Table 1.

	Full Range of Variables	Limited Range of Variables
<b>General and Two-Phase Properties</b>		
Range of value variables for calculation of steam points	FULL RANGE	LIMITED
Combination of variables for calculation of steam points	All COMBINATIONS	LIMITED
Calculation of thermodynamic and transport properties	ALL	LIMITED
Send calculation results by email	ENABLED	DISABLED
Number of calculation points in database	UNLIMITED	3
<b>Plot Diagrams</b>		
Calculate steam points directly in plot diagram	ENABLED	DISABLED
Add steam points manually from plot diagram	ENABLED	DISABLED
Send PDF files of plot diagrams by email	ENABLED	DISABLED
Number of projects per type of plot diagram	UNLIMITED	2 PER TYPE
Number of isolines by type per project	30	1
Range of values for calculation of isolines	FULL RANGE	LIMITED

**Table 1.** Limitations applied when the application does not have access to the Full Range of Variables.



## Range of Validity

The range of validity for the **General Properties** operation mode spans all the valid range of the IAPWS-IF97 Formulation as described in [1]. This is shown in Figures 1 and 2, together with the region assignment. In the case of any other combination of input thermodynamic properties other than  $\langle p, T \rangle$ , **Steam Plot** will determine the corresponding region and properties.

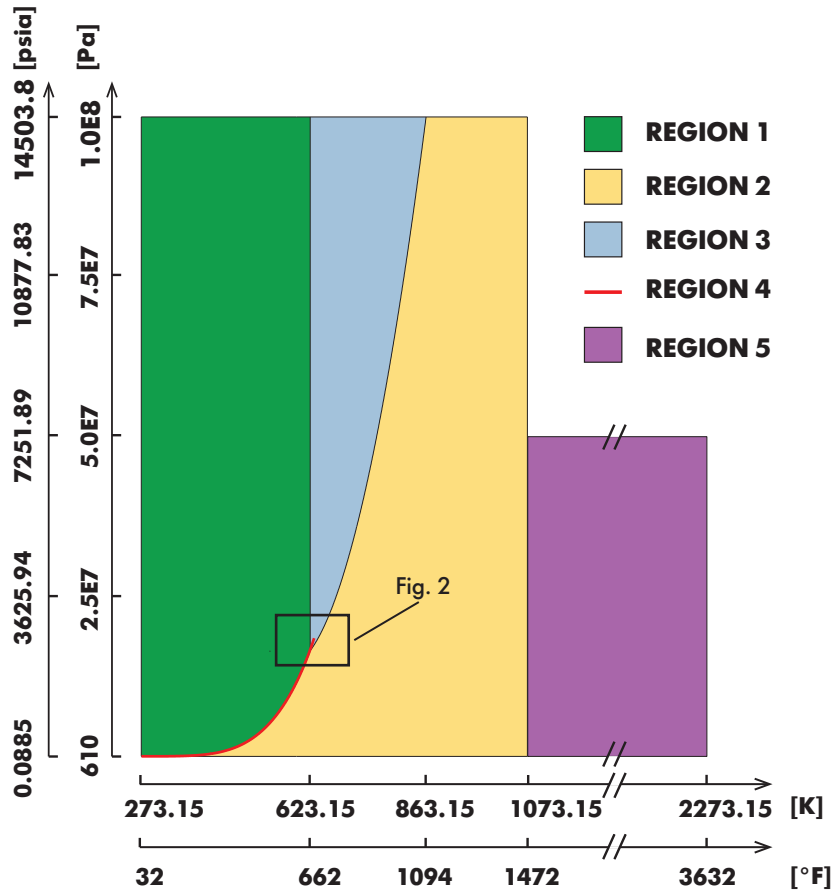


Figure 1. Temperature-Pressure Diagram

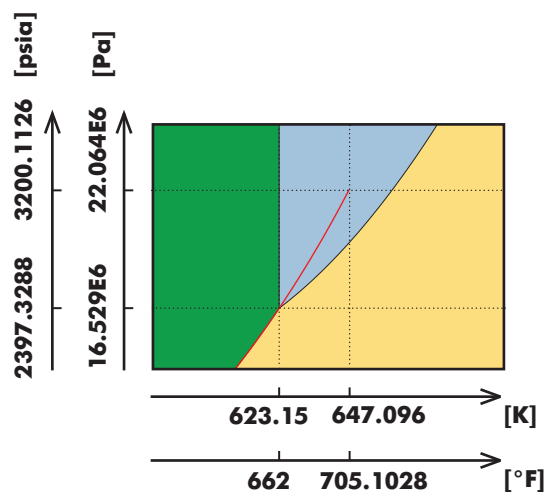


Figure 2. Zoom view of the critical point in the T-P Diagram

## Range of Validity

As an example, Figure 3 shows the combination of variables  $\langle h, s \rangle$  (enthalpy-entropy). In the case of the **Two-Phase Properties** operation mode, the valid range corresponds to that of the region 4 (two-phase) including the boundaries to its adjacent regions, i.e., liquid and vapor state, while the **General Properties** operation mode will take into account all the regions.

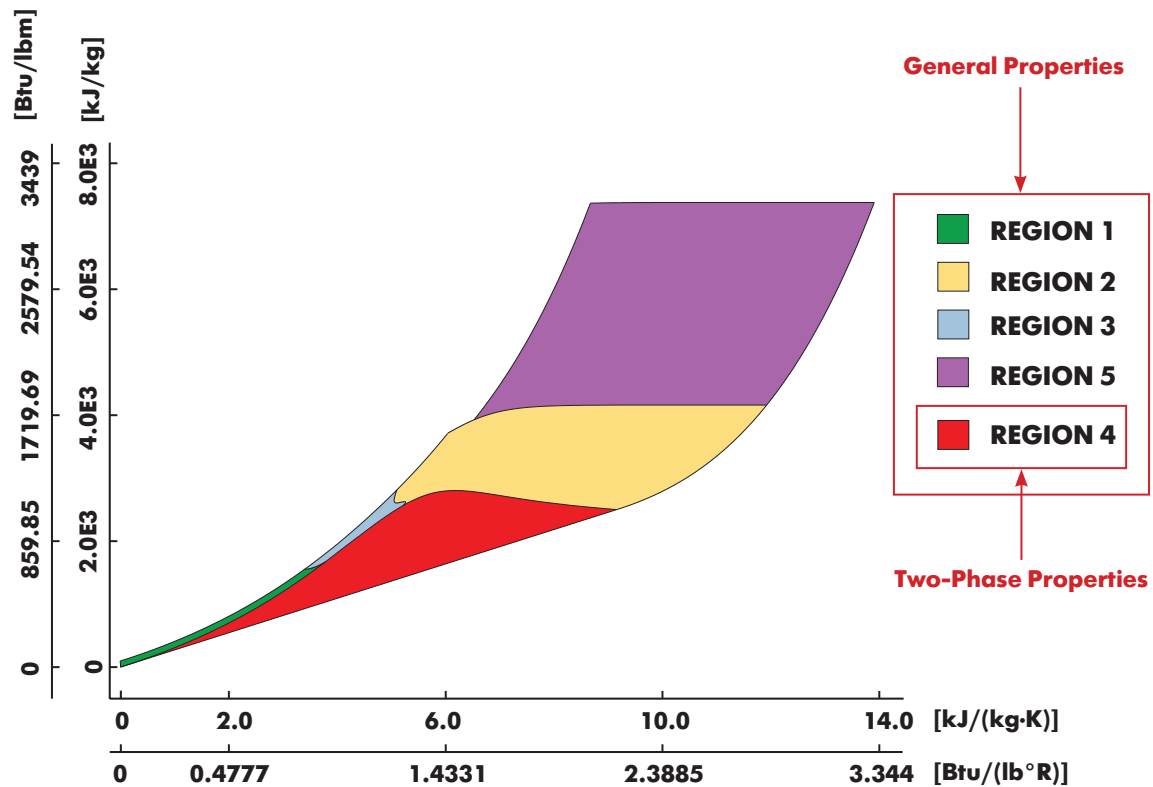


Figure 3. Entropy-Enthalpy Diagram

## Output Result Properties and Units

Thermodynamic properties calculated by **Steam Plot** in the SI (metric) and I-P (english) system of units can be entered and/or the calculation results can be displayed in the following units:

Result Property	SI Units	I-P Units
Pressure	Pa, kPa, bar, mmHg	psia, inHg, inH <sub>2</sub> O, atm
Temperature	°C, K	°F, °R
Specific Enthalpy	kJ/kg, J/kg, kcal/kg	Btu/lbm, ft lbf/lbm
Specific Entropy	kJ/(kg·K), J/(kg·K), kcal/(kg·K)	Btu/(lbm·°R), ft lbf/(lbm·°R)
Specific Internal Energy	kJ/kg, J/kg, kcal/kg	Btu/lbm, ft lbf/lbm
Specific Volume	m <sup>3</sup> /kg, cm <sup>3</sup> /g, l/kg	ft <sup>3</sup> /lbm, in <sup>3</sup> /lbm, gal(US)/lbm
Density	kg/m <sup>3</sup> , g/cm <sup>3</sup> , kg/l	lbm/ft <sup>3</sup> , lbm/in <sup>3</sup> , lbm/gal(US)
Speed of Sound	m/s, km/h	ft/s, mile/h
Dynamic Viscosity	Pa·s, kg/(m·s), P	lbm/(ft·s), lbf·s/ft <sup>2</sup>
Kinematic Viscosity	m <sup>2</sup> /s, St	ft <sup>2</sup> /s, ft <sup>2</sup> /h
Thermal Conductivity	W/(m·K), kcal/(m·s·K)	Btu/(ft·h·°R), W/(in·°F)
Thermal Diffusivity	m <sup>2</sup> /s, m <sup>2</sup> /h	ft <sup>2</sup> /s, ft <sup>2</sup> /h
Isobaric Heat Capacity	kJ/(kg·K)	Btu/(lbm·°R)
Isochoric Heat Capacity	kJ/(kg·K)	Btu/(lbm·°R)
Isentropic Exponent	[-]	[-]
Isobaric Cubic Expansion Coefficient	1/K	1/°R
Isothermal Compressibility	1/kPa	1/psia
Prandtl Number	[-]	[-]
Vapor Fraction	kg/kg	lb/lb
IAPWS-IF97 Region	[-]	[-]
Partial derivative (dvdP)T	m <sup>3</sup> /(kg·MPa)	ft <sup>3</sup> /(lb·psi)
Partial derivative (dudP)T	J/(kg·Pa)	Btu/(lb·psi)
Partial derivative (dsdP)T	J/(kg·K·Pa)	Btu/(lb·°F·psi)
Partial derivative (dhdP)T	J/(kg·Pa)	Btu/(lb·psi)
Partial derivative (dvdT)P	m <sup>3</sup> /(kg·K)	ft <sup>3</sup> /(lb·°F)
Partial derivative (dudT)P	J/(kg·K)	Btu/(lb·°F)
Partial derivative (dsdT)P	J/(kg·K·K)	Btu/(lb·°F·°F)
Partial derivative (dhdT)P	J/(kg·K)	Btu/(lb·°F)
Partial derivative (dPdT)v	MPa/K	psi/°F
Partial derivative (dPdv)T	MPa·kg/m <sup>3</sup>	psi·lb/ft <sup>3</sup>

Table 2. Input/Output Variables and their correspondent units in **Steam Plot**.

## General Properties

The **General Properties** main graphical user interface and a description of its interaction buttons is shown in Figure 4. The combinations of input variables is shown in Table 3.

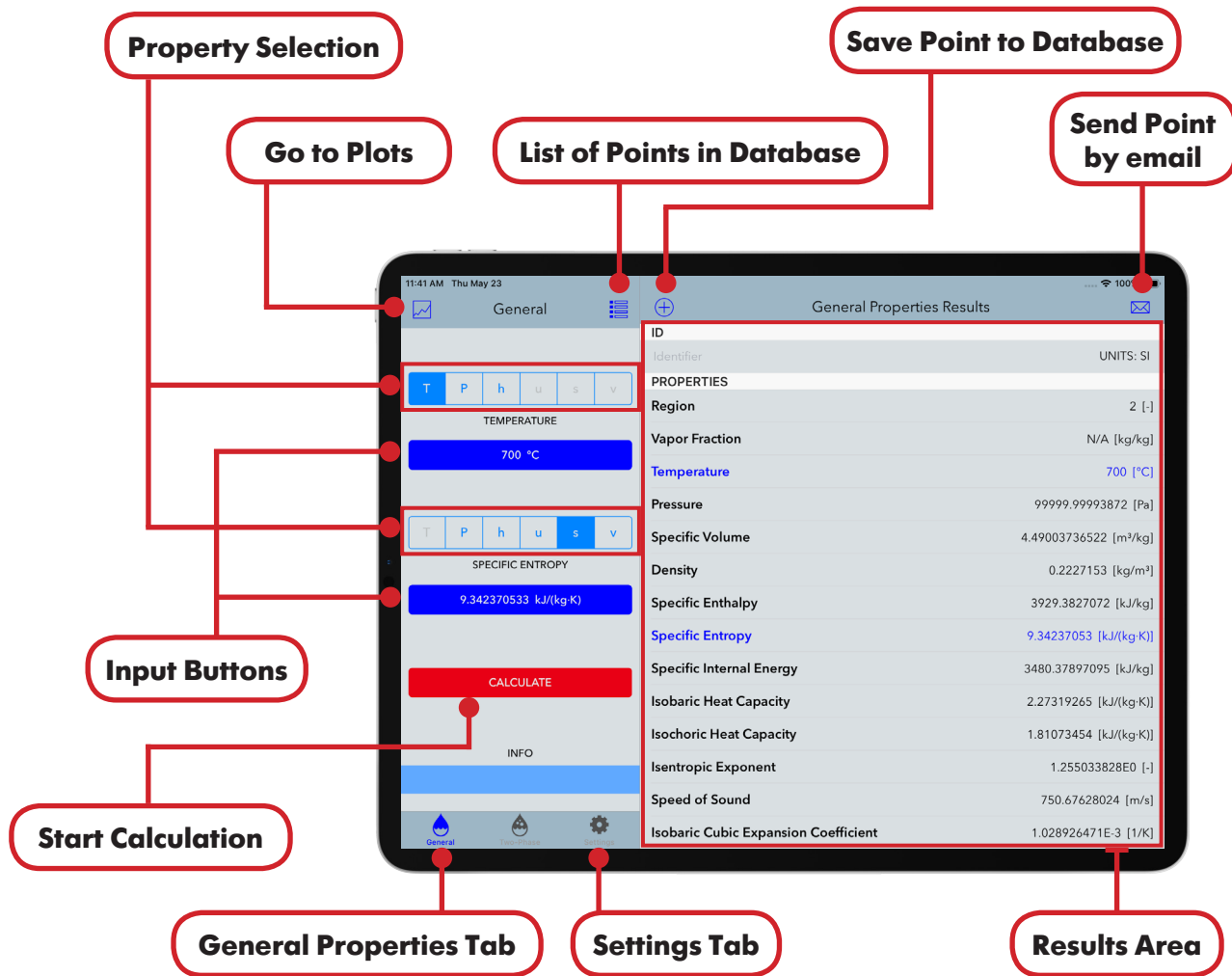


Figure 4. Graphical User Interface for General Properties calculations.

Temperature	(T)	Pressure	(P)
Temperature	(T)	Enthalpy	(h)
Temperature	(T)	Internal Energy	(u)
Temperature	(T)	Entropy	(s)
Temperature	(T)	Specific Volume	(v)
Pressure	(P)	Enthalpy	(h)
Pressure	(P)	Internal Energy	(u)
Pressure	(P)	Entropy	(s)
Pressure	(P)	Specific Volume	(v)
Enthalpy	(h)	Entropy	(s)
Enthalpy	(h)	Specific Volume	(v)
Internal Energy	(u)	Specific Volume	(v)

Combination for Limited Range of Variables

Table 3. Combination of input variables in General Properties calculations.

The full ranges of input/output thermodynamic properties when entering and displaying values are:

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$610 \leq P \leq 100.0E6$	Pa	$0.088473 \leq P \leq 14503.77$	psia
Temperature	$0 \leq T \leq 2000$	°C	$32.0 \leq T \leq 3632.0$	°F
Specific Enthalpy	$-41.5878 \leq h \leq 7376.98E3$	J/kg	$-0.017879 \leq h \leq 3171.5306$	Btu/lbm
Specific Internal Energy	$-282.7252 \leq u \leq 6327.862E3$	J/kg	$-0.12155 \leq u \leq 2720.491$	Btu/lbm
Specific Entropy	$-8.5823 \leq s \leq 13905.8727$	J/(kg·K)	$-0.0020498 \leq s \leq 3.32136$	Btu/(lbm·°R)
Specific Volume	$9.56687E-4 \leq v \leq 1719.8658$	m <sup>3</sup> /kg	$1.601958E-3 \leq v \leq 27549.6$	ft <sup>3</sup> /lbm
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg	$0 \leq x \leq 1.0$	lb/lb

**Table 4.** Full range of input/output variable values for the calculation of steam points (General Properties).

The limited ranges of input/output thermodynamic properties are:

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$610 \leq P \leq 100.0E6$	Pa	$0.088473 \leq P \leq 14503.77$	psia
Temperature	<b><math>T = 700.0</math></b>	°C	<b><math>T = 1292.0</math></b>	°F
Specific Enthalpy	$-41.5878 \leq h \leq 7376.98E3$	J/kg	$-0.017879 \leq h \leq 3171.5306$	Btu/lbm
Specific Internal Energy	$-282.7252 \leq u \leq 6327.862E3$	J/kg	$-0.12155 \leq u \leq 2720.491$	Btu/lbm
Specific Entropy	$-8.5823 \leq s \leq 13905.8727$	J/(kg·K)	$-0.0020498 \leq s \leq 3.32136$	Btu/(lbm·°R)
Specific Volume	$1.00007E-4 \leq v \leq 1719.8658$	m <sup>3</sup> /kg	$1.601958E-3 \leq v \leq 27549.6$	ft <sup>3</sup> /lbm
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg	$0 \leq x \leq 1.0$	lb/lb

**Table 5.** Limited range of input/output variable values for the calculation of steam points (General Properties).

### Notes:

- The upper temperature range for Kinematic Viscosity, Dynamic Viscosity, Thermal Conductivity, Thermal Diffusivity and Prandtl Number is 1173.15 K / 1652 °F.

## Calculation of Steam Points

- Tap on the **General** tab to show the GUI for General Properties calculations.
- Select a combination of property variables. Possible combinations are shown in Table 3.
- Tap on the input buttons to introduce the desired values for the calculation.
- Tap on the **CALCULATE** button to start the calculation.

## Calculation Validation

- In case the calculation cannot proceed, because one or both of the input variables are out of the boundaries defined by the IAPWS-IF97, a message will be displayed in the INFO area showing the condition required for that particular calculation to be valid.

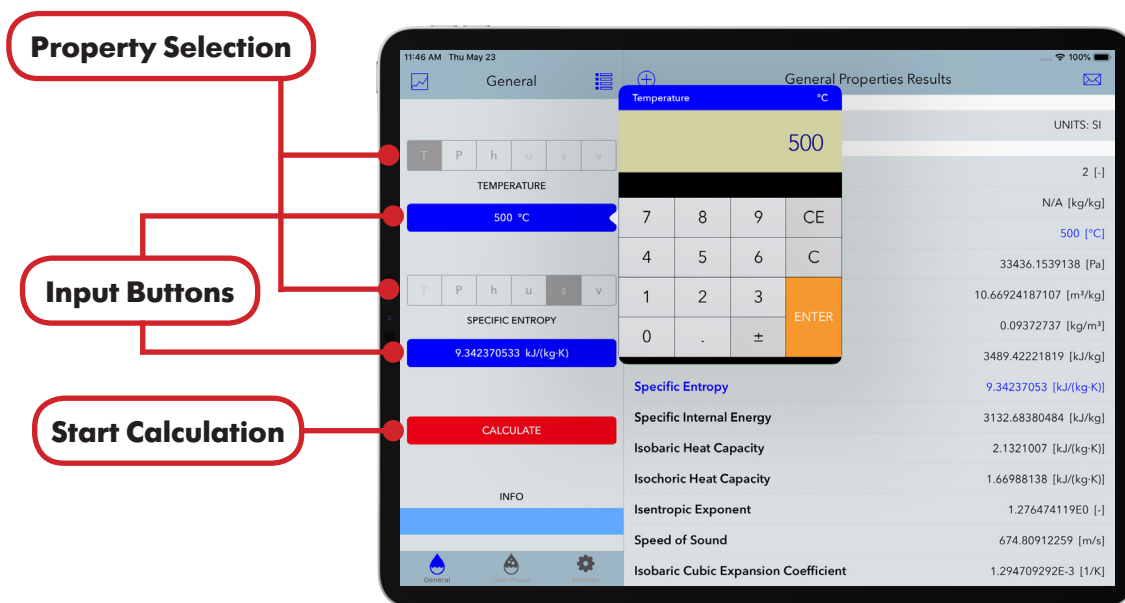


Figure 5. Introducing values for a calculation in General Properties.

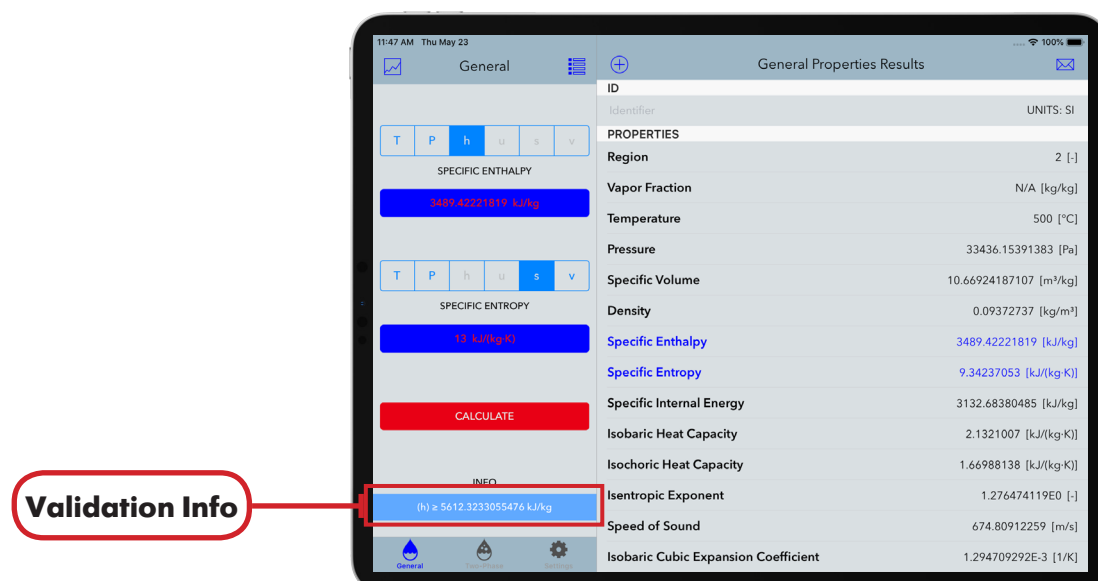





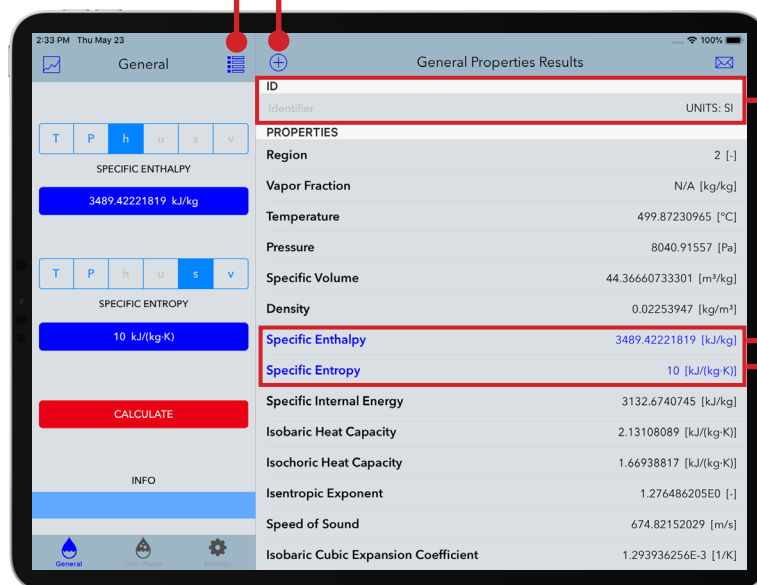
Figure 6. Validation of calculation in General Properties.

## Calculation Points Database

- If a calculation is valid, results are shown in the Results Area, where the combination of variables used for that calculation is indicated with blue color.
- Tap on the  **Add Point to Database** button to add the calculation to the General Properties database. An identifier for that point can be included to identify that point.
- Tap on the  **List of Points** button to access the database containing all the calculation points for General Properties.
- Tap on the  **Hide Point** button switch to show/hide the point in all Plot Diagram projects.
- Tap on the **Edit** button to delete points permanently from the database.

List of Points in Database

Add Point to Database



Point Identifier

Variables used for calculation

Figure 7. Adding a calculation point to the database in General Properties.

Delete Points from Database

Point Selected

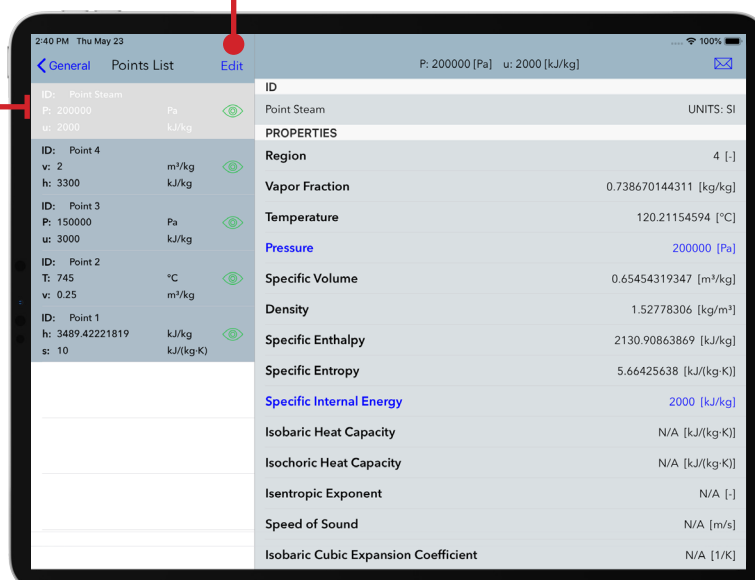



Figure 8. Database of calculation points in General Properties.

## Send Calculation Points by email

- Calculation results can be send by email from the main graphical user interface for General Properties, as well as from the database accessed from the Points List.
- Tap on the  **Send Point by email** button from the GUI or the Points List to create HTML and CSV files that will be attached to the email composer.

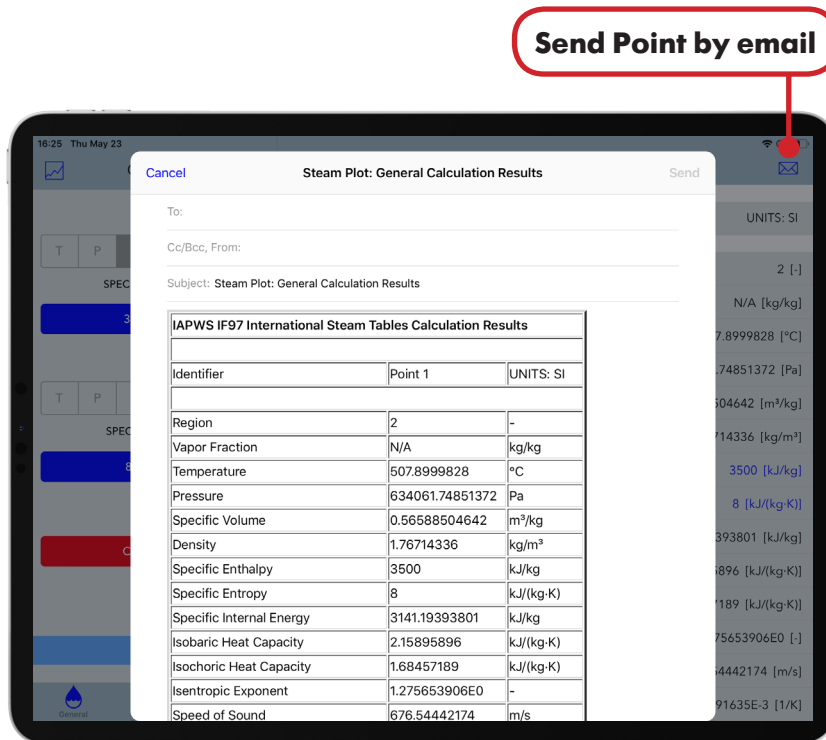


Figure 9. Sending a calculation point by email in main GUI (General Properties).

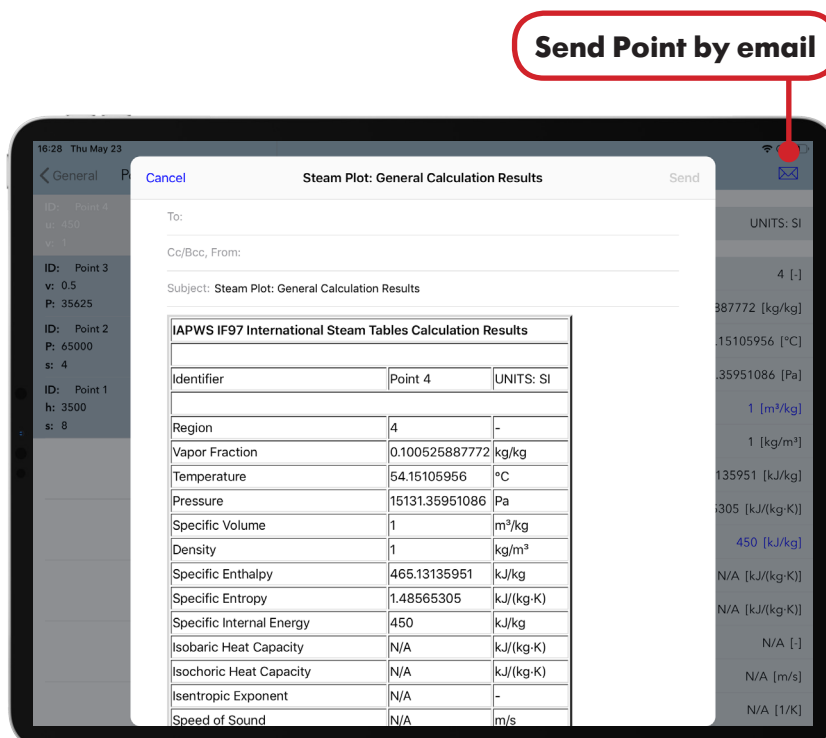


Figure 10. Sending a calculation point by email from the database (General Properties).



## Two-Phase Properties

The **Two-Phase Properties** main graphical user interface and a description of its interaction buttons is shown in Figure 11. The combinations of input variables is shown in Table 6.

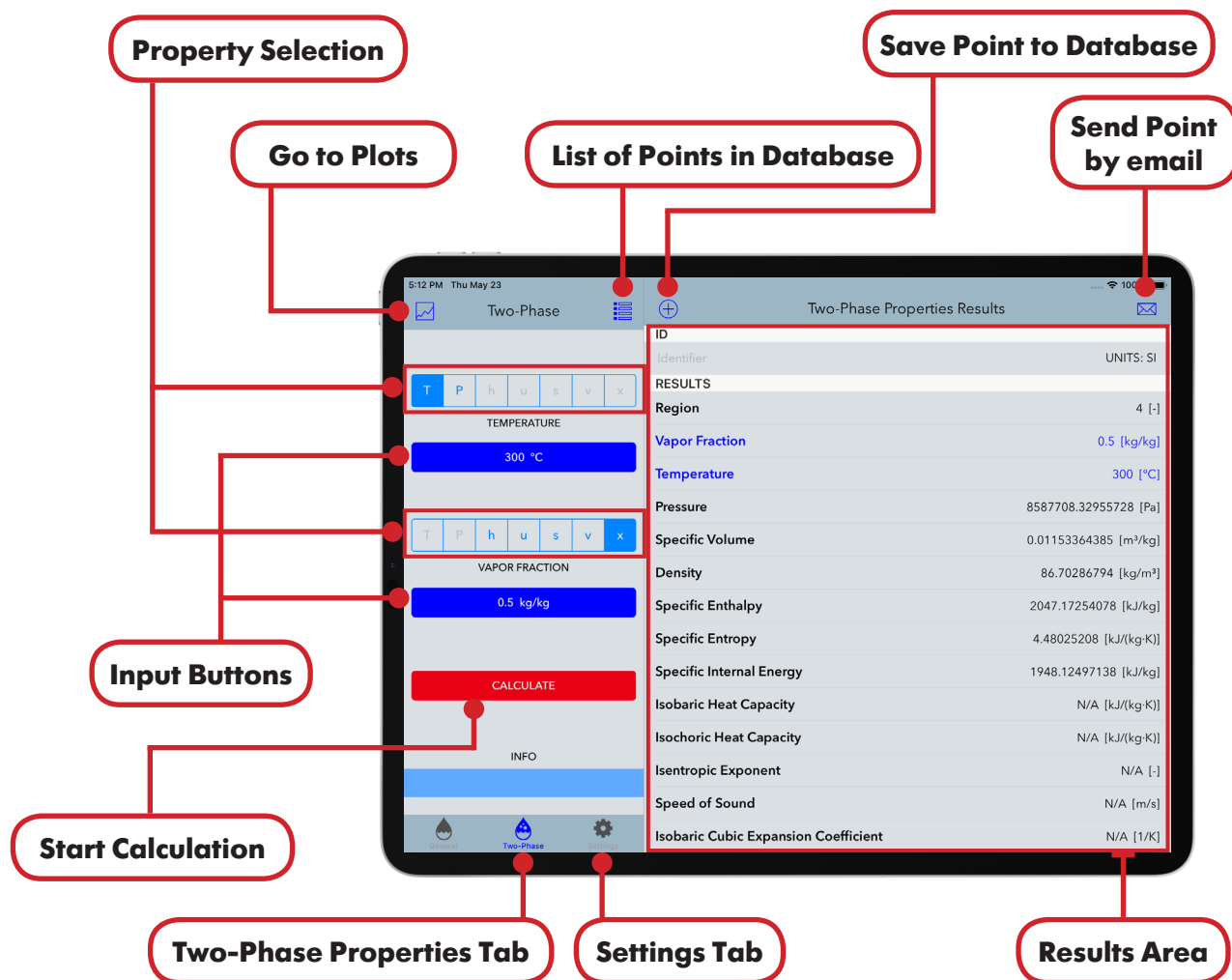


Figure 11. Graphical User Interface for Two-Phase Properties calculations.

Temperature	(T)	Enthalpy	(h)
Temperature	(T)	Internal Energy	(u)
Temperature	(T)	Entropy	(s)
Temperature	(T)	Specific Volume	(v)
Temperature	(T)	Vapor Fraction	(x)
Pressure	(P)	Enthalpy	(h)
Pressure	(P)	Internal Energy	(u)
Pressure	(P)	Entropy	(s)
Pressure	(P)	Specific Volume	(v)
Pressure	(P)	Vapor Fraction	(x)
Enthalpy	(h)	Entropy	(s)
Enthalpy	(h)	Specific Volume	(v)
Internal Energy	(u)	Specific Volume	(v)

Combination for Limited Range of Variables

Table 6. Combination of input variables in Two-Phase Properties calculations.

The full ranges of input/output thermodynamic properties when entering and displaying values are:

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$611.2126 \leq P \leq 22064000.0$	Pa	$0.088648 \leq P \leq 3200.1126$	psia
Temperature	$0 \leq T \leq 373.946$	°C	$32.0 \leq T \leq 705.1028$	°F
Specific Enthalpy	$-41.5878 \leq h \leq 2810.0E3$	J/kg	$-0.017879 \leq h \leq 1208.08$	Btu/lbm
Specific Internal Energy	$-42.1992 \leq u \leq 2606.0E3$	J/kg	$-0.0181424 \leq u \leq 1120.38$	Btu/lbm
Specific Entropy	$-0.15455 \leq s \leq 9155.76$	J/(kg·K)	$-3.69135E-5 \leq s \leq 2.18682$	Btu/(lbm·°R)
Specific Volume	$9.56687E-4 \leq v \leq 206.140$	m³/kg	$1.601958E-3 \leq v \leq 3302.04$	ft³/lbm
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg	$0 \leq x \leq 1.0$	lb/lb

**Table 7.** Full range of input/output variable values for the calculation of steam points (Two-Phase).

The limited ranges of input/output thermodynamic properties are:

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$611.2126 \leq P \leq 22064000.0$	Pa	$0.088648 \leq P \leq 3200.1126$	psia
Temperature	$T = 300.0$	°C	$T = 572.0$	°F
Specific Enthalpy	$-41.5878 \leq h \leq 2810.0E3$	J/kg	$-0.017879 \leq h \leq 1208.08$	Btu/lbm
Specific Internal Energy	$-42.1992 \leq u \leq 2606.0E3$	J/kg	$-0.0181424 \leq u \leq 1120.38$	Btu/lbm
Specific Entropy	$-0.15455 \leq s \leq 9155.76$	J/(kg·K)	$-3.69135E-5 \leq s \leq 2.18682$	Btu/(lbm·°R)
Specific Volume	$9.56687E-4 \leq v \leq 206.140$	m³/kg	$1.601958E-3 \leq v \leq 3302.04$	ft³/lbm
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg	$0 \leq x \leq 1.0$	lb/lb

**Table 8.** Limited range of input/output variable values for the calculation of steam points (Two-Phase).

### Notes:

- The upper temperature range for Kinematic Viscosity, Dynamic Viscosity, Thermal Conductivity, Thermal Diffusivity and Prandtl Number is 1173.15 K / 1652 °F.

## Calculation of Steam Points

- Tap on the **Two-Phase** tab to show the GUI for Two-Phase Properties calculations.
- Select a combination of property variables. Possible combinations are shown in Table 6.
- Tap on the input buttons to introduce the desired values for the calculation.
- Tap on the **CALCULATE** button to start the calculation.

## Calculation Validation

- In case the calculation cannot proceed, because one or both of the input variables are out of the boundaries defined by the IAPWS-IF97, a message will be displayed in the INFO area showing the condition required for that particular calculation to be valid.

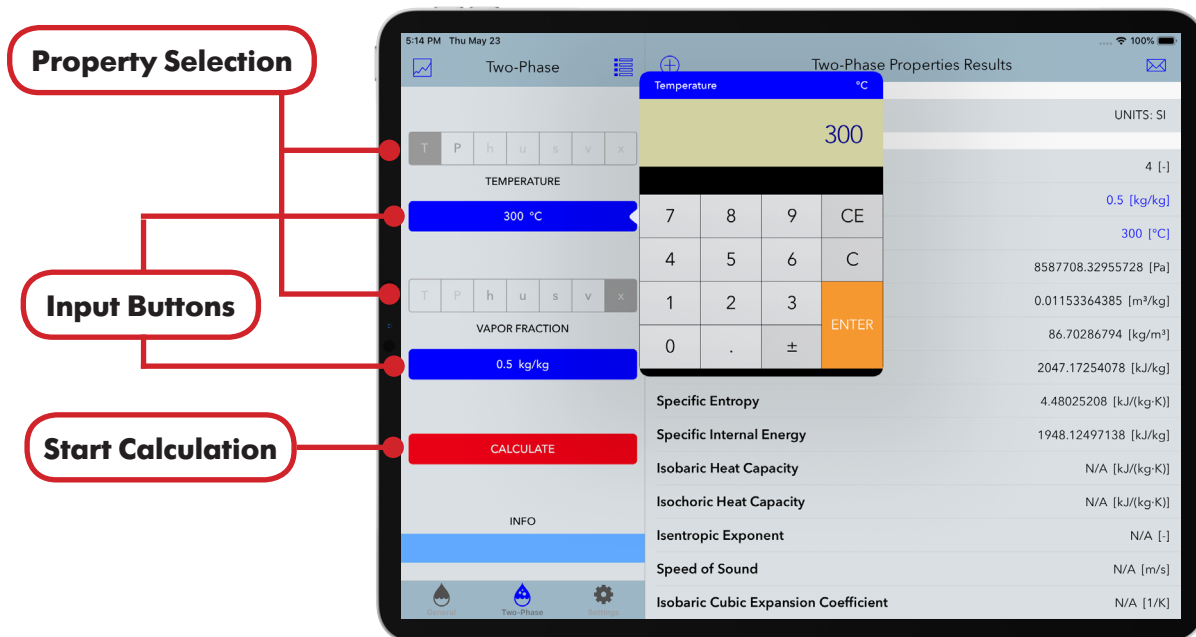


Figure 13. Introducing values for a calculation in Two-Phase Properties.

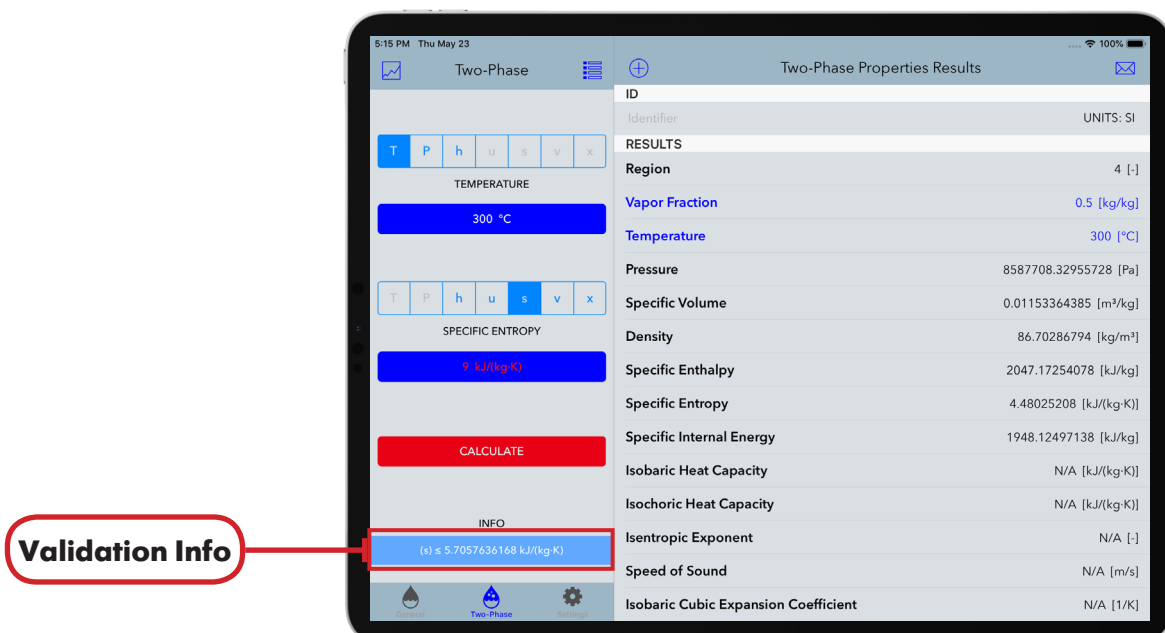





Figure 14. Validation of calculation in Two-Phase Properties.

## Calculation Points Database

- If a calculation is valid, results are shown in the Results Area, where the combination of variables used for that calculation is indicated with blue color.
- Tap on the  **Add Point to Database** button to add the calculation to the Two-Phase Properties database. An identifier for that point can be included to identify that point.
- Tap on the  **List of Points** button to access the database containing all the calculation points for Two-Phase Properties.
- Tap on the  **Hide Point** button switch to show/hide the point in all Plot Diagram Projects.
- Tap on the **Edit** button to delete points permanently from the database.

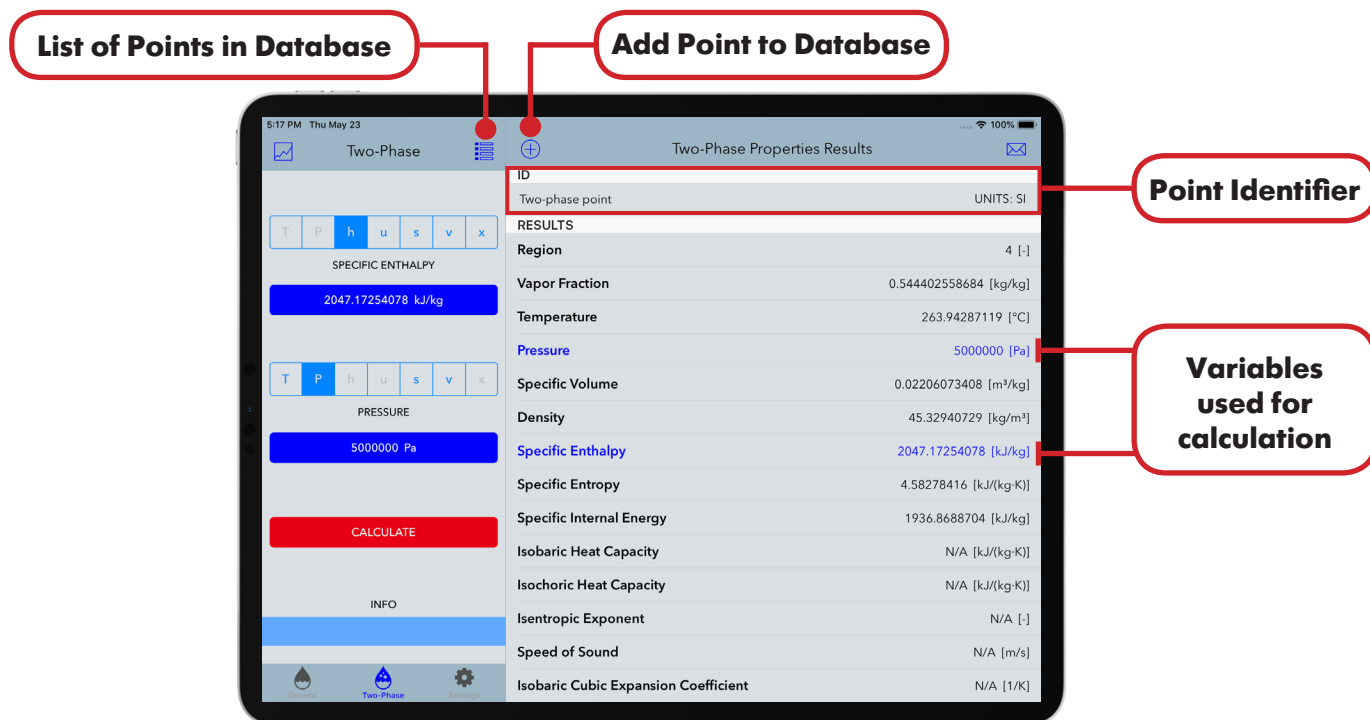


Figure 15. Adding a calculation point to the database in Two-Phase Properties.

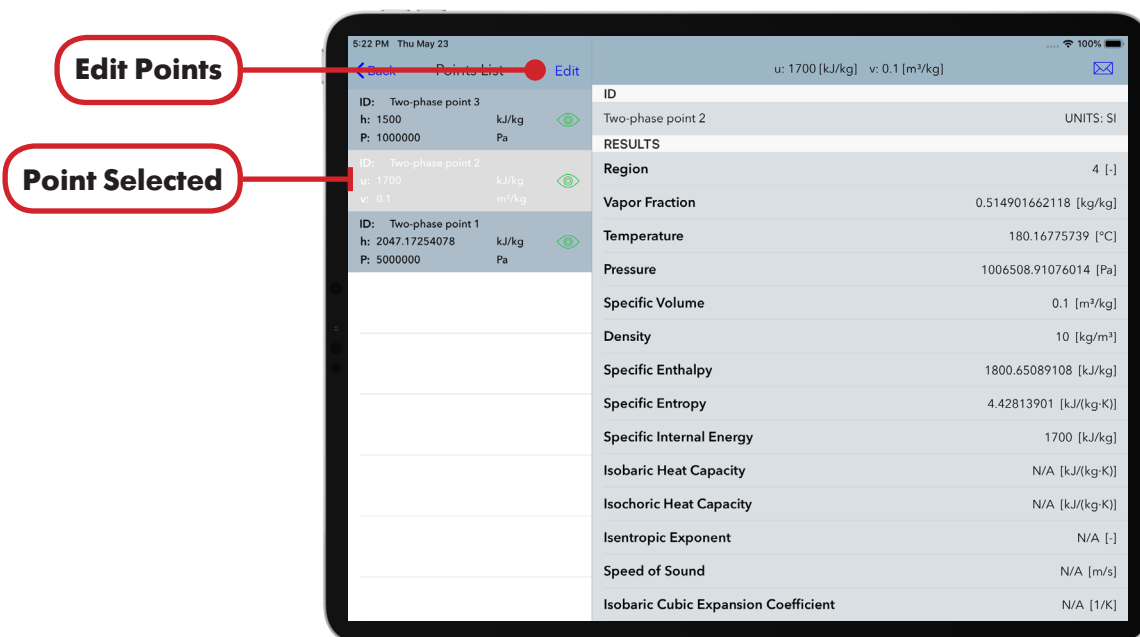



Figure 16. Database of calculation points in Two-Phase Properties.

## Send Calculation Points by email

- Calculation results can be send by email from the main graphical user interface for Two-Phase Properties, as well as from database accessed from the Points List.
- Tap on the  **Send Point by email** button from the GUI or the Points List to create HTML and CSV files that will be attached to the email composer.

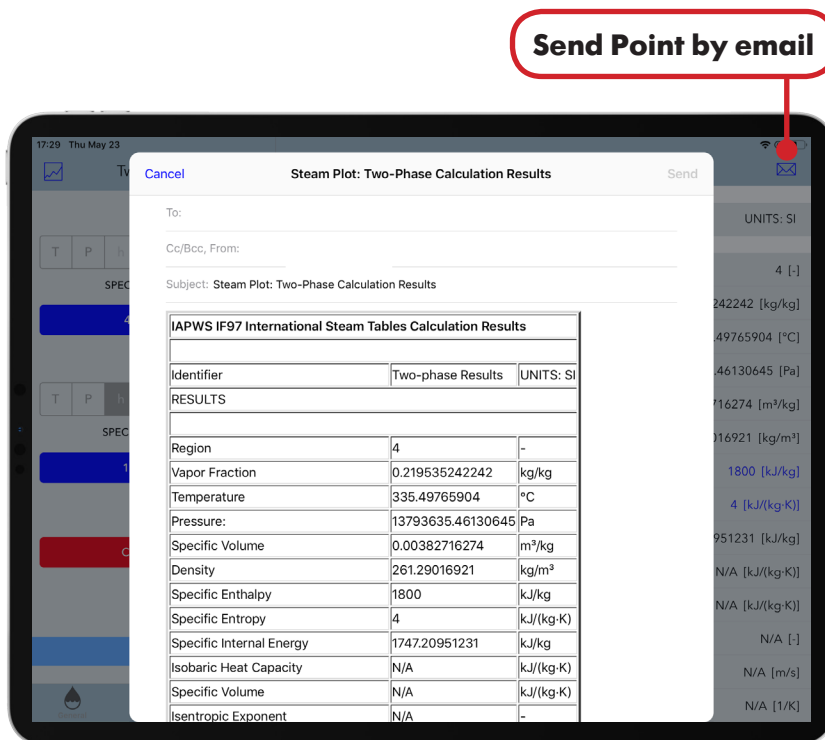


Figure 17. Sending a calculation point by email in main GUI (Two-Phase Properties).

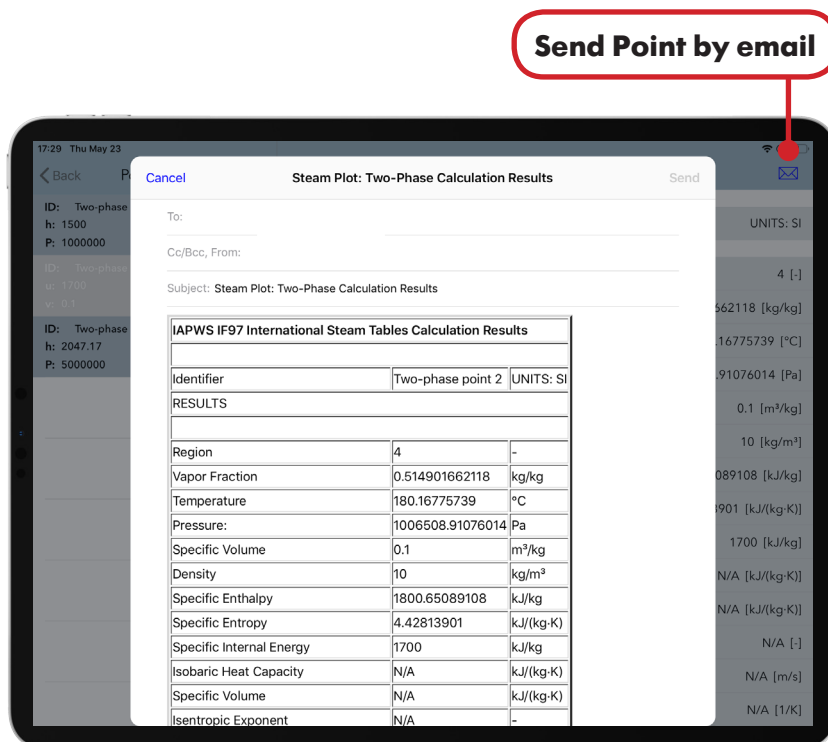


Figure 18. Sending a calculation point by email from the database (General Properties).

## Plot diagrams

**Steam Plot** allows to plot and interact with plot diagrams by calculating and adding isolines and calculations points to specific diagram types and saving these as projects both in SI and I-P units. Figure 19 shows the main interaction buttons in plot diagrams, and Figure 20 shows the main interaction buttons for elements.

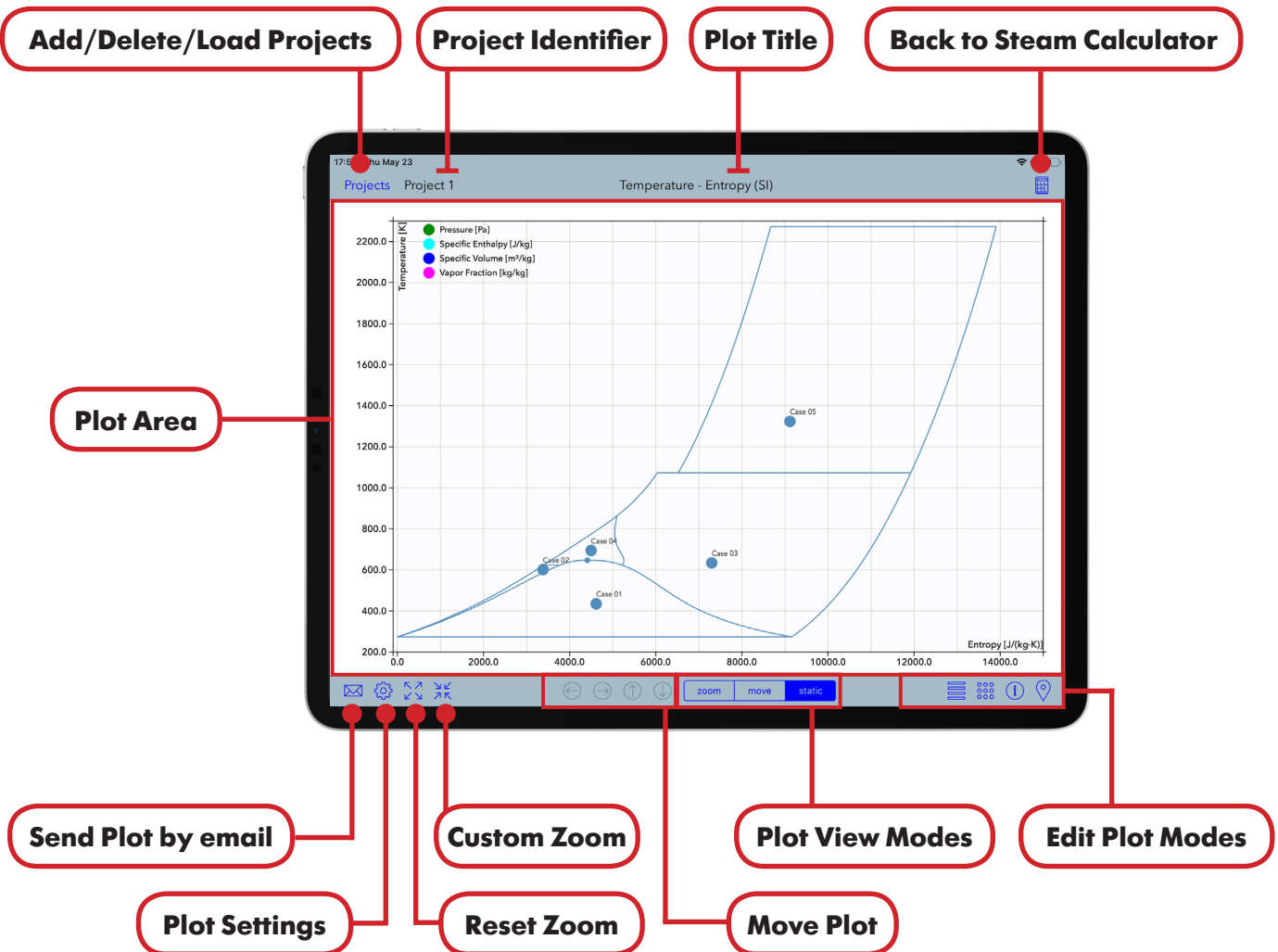


Figure 19. Plot diagram graphical user interface in **Steam Plot**.

### Plot Interaction

Choose one of the 4 Edit plot Modes to add and/or modify elements:





-  **Add Point**
-  **Edit Point**
-  **Add Isoline**
-  **Edit Isoline**

Figure 20. Main interaction modes for plot diagrams in **Steam Plot**.

### Add New Project

- Tap on the **Projects** button to add a new project. Tap the **Add** button on the Projects List popup and enter an identifier for a new project.
- Tap on the **Add** button to add the project to the database. The project is now ready to be loaded or edited.

### Load a Project

- Tap on the **Projects** button to show the project's list. A list of identifiers is shown of all the projects that are currently in the database.
- Tap on a selected identifier to load a particular project into the Plot Area. All the isolines and their respective labels will be loaded from the database. **Any new isolines or labels added or edit are saved automatically to the database when a particular project is loaded in the Plot Area.**

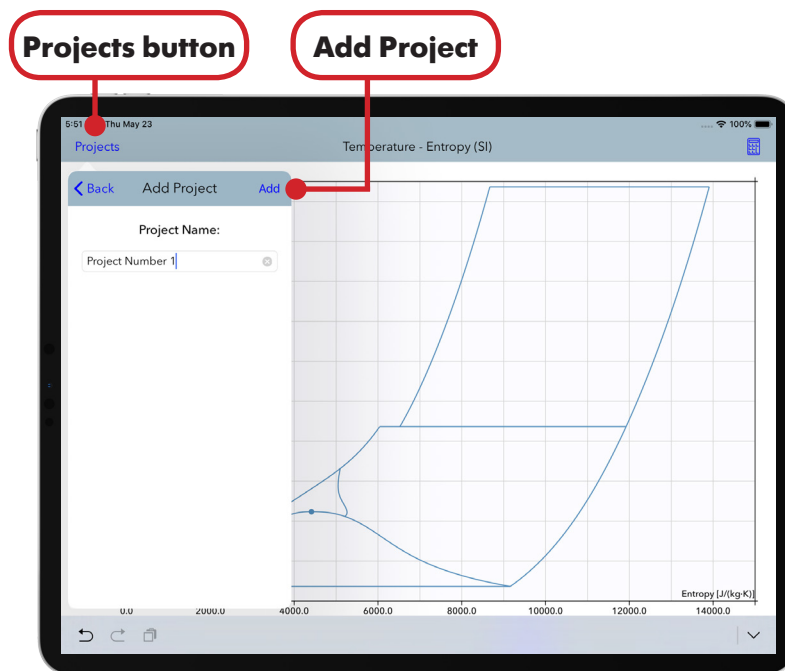


Figure 21. Adding a project to a plot diagram.

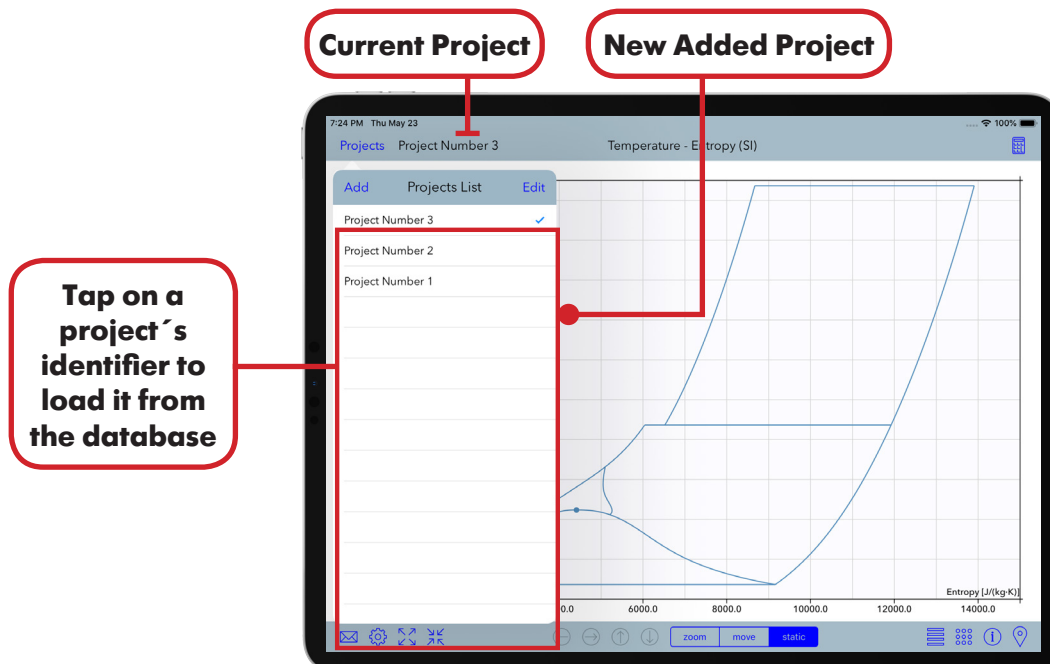


Figure 22. Loading a previously saved project in a plot diagram.

## Delete a Project

- Tap on the **Projects** button to show the project's list. A list of identifiers shows all the projects that are currently in the database.
- Tap on the **Edit** button to allow the selection of a particular project to be deleted.
- Select the desired project to be deleted and tap on the **Delete** button to delete the project from the database. **Once a project is deleted, all isolines and labels are permanently deleted from the database.**
- Tap on the **Done** button to finish the selection of projects.

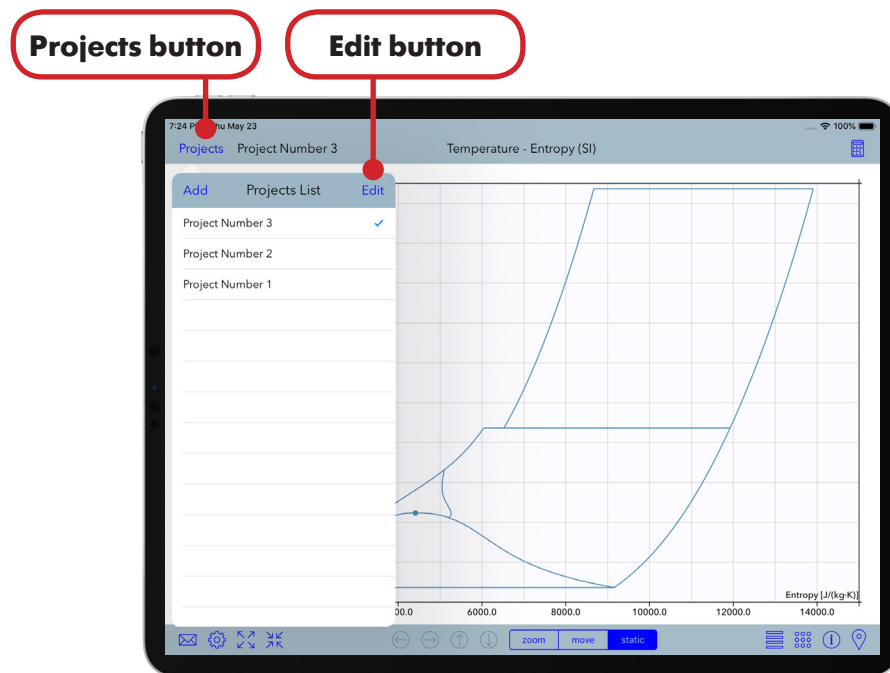


Figure 23. List of plot diagram projects in the database.



Figure 24. Deleting a project in a plot diagram.



## Add Calculation Point Graphically

- Tap on the **Static Mode** of the Plot view Models.
- Tap on the **Add Point** button to start adding points to the Plot Area.
- Tap on the Plot Area and drag the crosshairs to the desired coordinates for a calculation. The coordinate buttons show the current coordinate variable values of the crosshairs.
- Tap on the **Calculate Point** button to start the calculation of the steam point that corresponds to the combination of variables for that particular plot diagram.
- Once the calculation has finished, a popup will appear at the coordinates of the crosshairs with all the variables calculated for that particular point.
- Tap on the **Add Point to Database** button to save the calculation point to the database. This point will be added to the Points List of the **General Properties** database.
- Tap on the **Done** button the finish adding points.

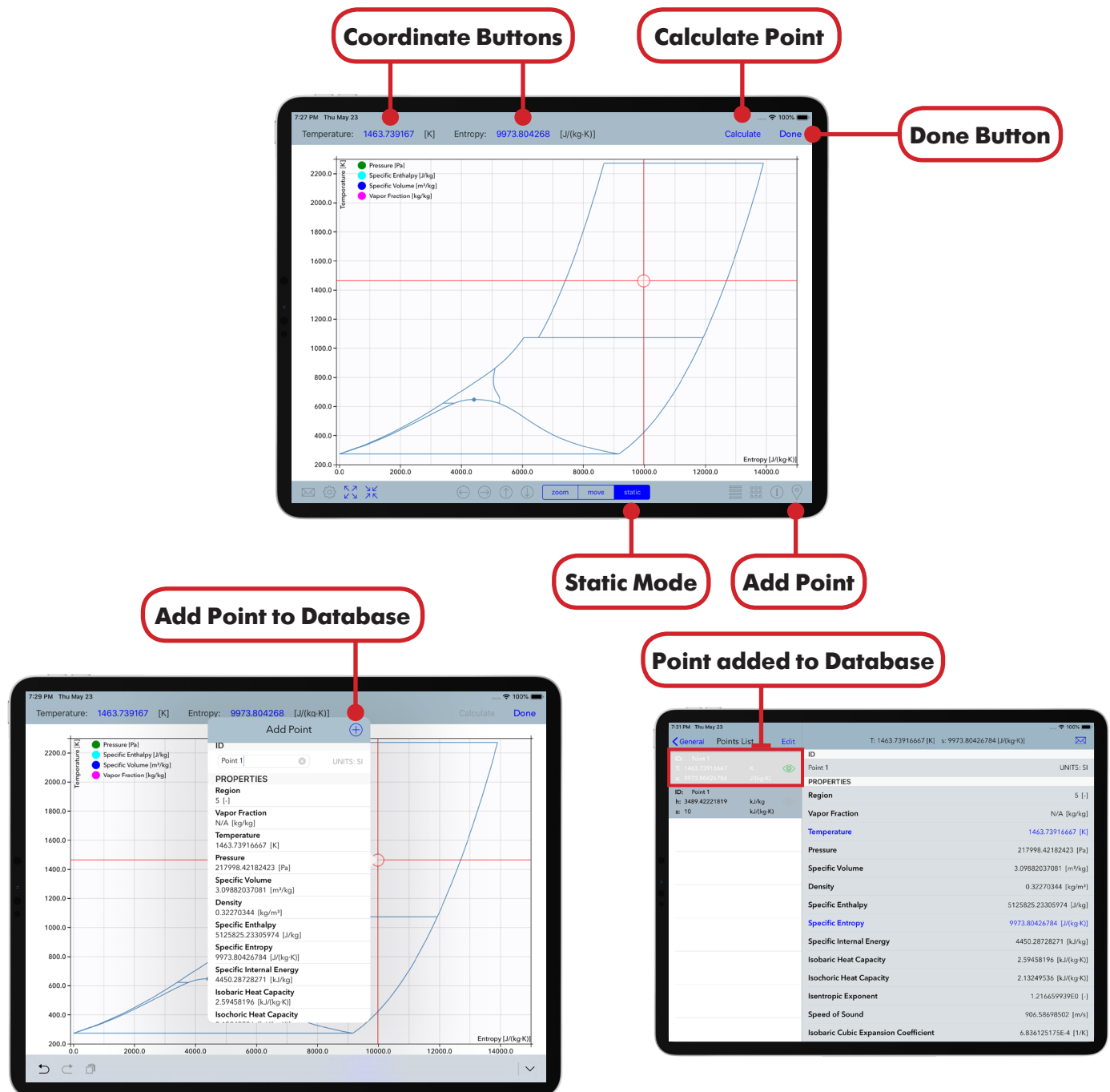


Figure 25. Adding a calculation point manually in a plot diagram.

## Add Calculation Point Numerically

- Tap on the **Static Mode** of the Plot view Models.
- Tap on the **Add Point** button to start adding points to the Plot Area.
- Tap on the Plot Area and then tap on the **Coordinate Buttons** to enter the precise numerical value for the variables. The crosshairs will be moved on the Plot Area to the values introduced.
- Tap on the **Calculate Point** button to start the calculation of the steam point that corresponds to the combination of variables for that particular plot diagram.
- Once the calculation has finished, a popup will appear at the coordinates of the crosshairs with all the variables calculated for that particular point.
- Tap on the **Add Point to Database** button to save the calculation point to the database. This point will be added to the Points List of the **General Properties** database.
- Tap on the **Done** button the finish adding points.



Figure 26. Adding a calculation point numerically in a plot diagram.

## Validation of Calculation Points

- In the case that the location of the crosshairs is outside the boundaries of the IAPWS-IF97 regions for a particular type of plot diagram, the calculation of the steam point cannot proceed.
- A popup message at the location of the crosshairs will indicate the condition for a valid calculation.

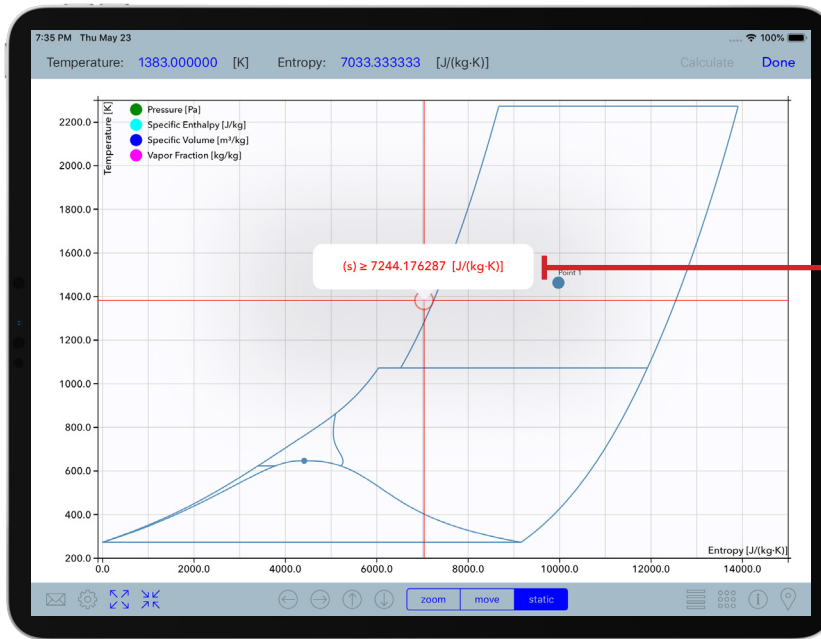


Figure 27. Example of calculation point validation in a plot diagram (Temperature-Entropy diagram).

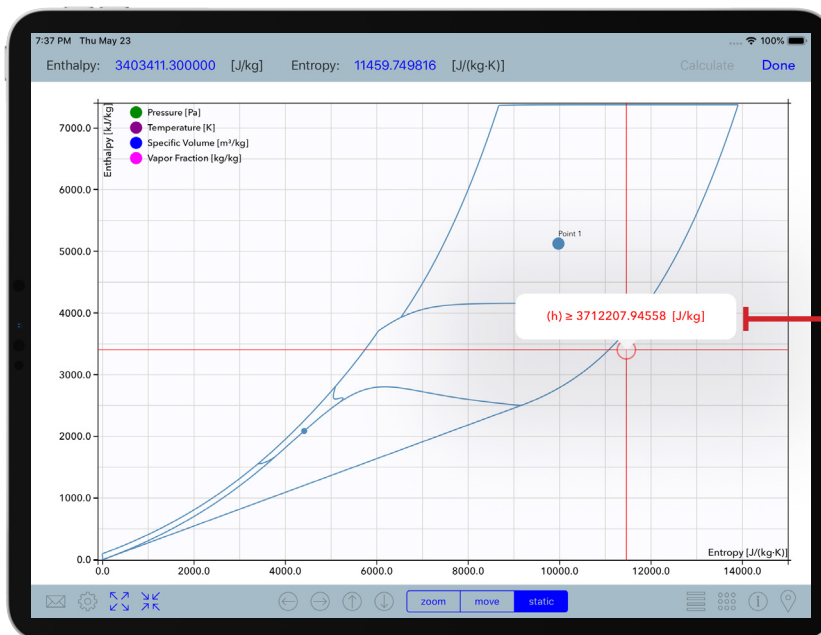


Figure 28. Example of calculation point validation in a plot diagram (Enthalpy-Entropy diagram).

## Get Data/Delete/Hide a selected Calculation Point

- Tap on the **Static Mode** of the Plot View models.
- Tap on the **Edit Point** button to start the selection of calculation points.
- Tap on a calculation point to select it. The coordinate buttons show the current coordinate variable values of the selected point.
- Tap on the **Info Point** button to retrieve all the calculation data. A popup will appear at the location of the crosshairs containing all the calculation results for that point.
- Tap on the **Hide Point** button to hide the calculation point from all Plot Diagrams. The Hide Button switch of the General Properties' List sets the condition for showing/hiding points in Plot Diagrams.
- Tap on the **Delete Point** button to delete the calculation point from the database (General List) permanently and to remove it from the Plot Area.
- Tap on the **Done** button the finish selecting points.

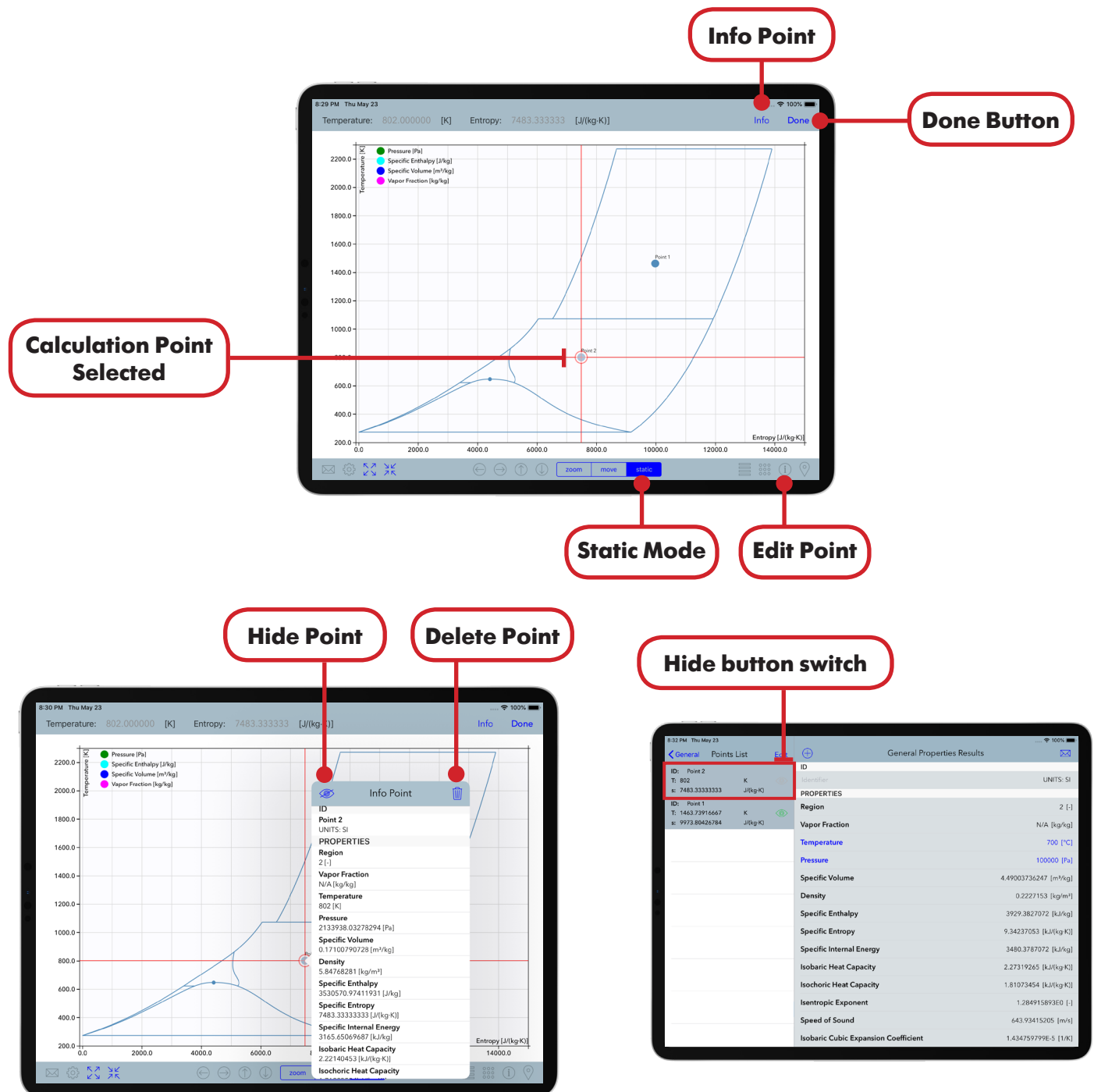



Figure 29. Edition of calculation points in a plot diagram.

## Add Isolines to a Plot Diagram

- Tap on the  **Add Isoline** button to show a keyboard where is possible to select the type and value of an isoline that can be added to a particular type of Plot Diagram.
- Select the type of isoline to be calculated and added to the Plot Diagram.
- Introduce the value of the isoline using the keyboard buttons.
- Tap on the **ENTER** button to calculate and plot the isoline in the Plot Area.
- The isoline has been added and saved automatically to the project that is currently loaded.

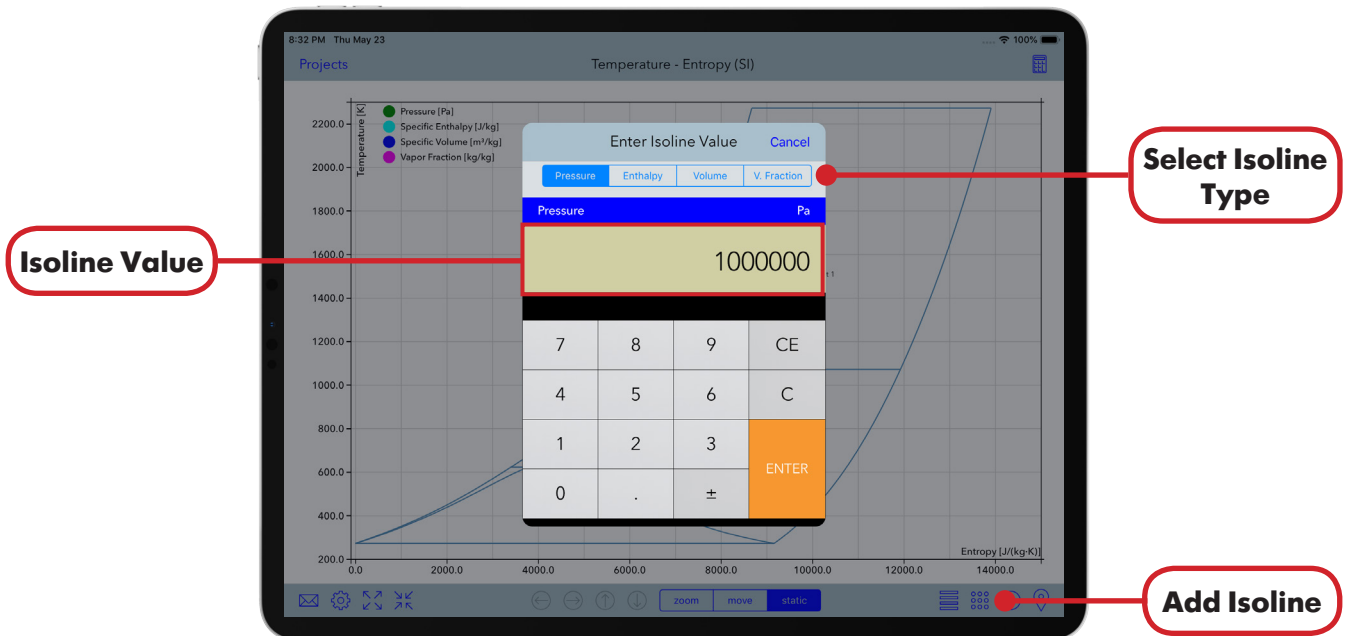


Figure 30. Introducing values for the calculation of isolines in a plot diagram.

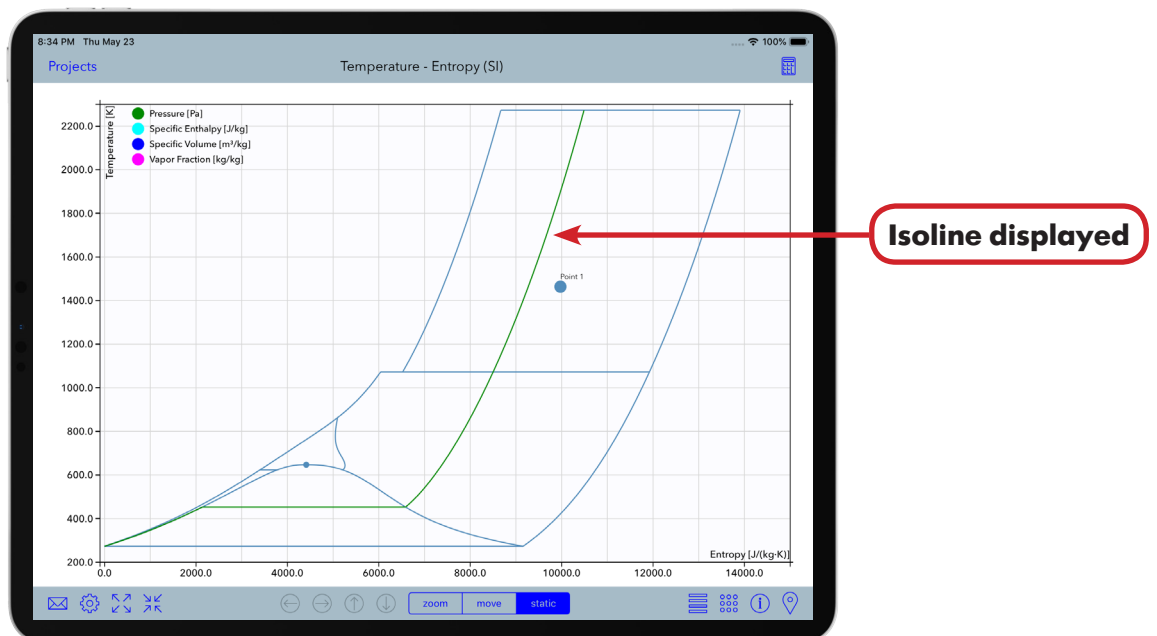




Figure 31. Example of plot diagram with isoline displayed after its calculation.

## Delete Isoline

- Tap on the  **Edit Isolines** button to display a table on the right-hand side of the Plot Area with a list of all the isolines that belong to a particular project.
- Tap on a isoline type header to display the list of the numerical values for all the isolines of that type.
- Tap on a particular value to select the isoline in the Plot Area. The curve will turn red, and the selected isoline's value will appear over the Plot Area.
- Tap on the  **Delete Isoline** button to remove the isoline from the Plot Area and to delete it from the database. **The isoline and its associated label (if any) will be permanently deleted.**

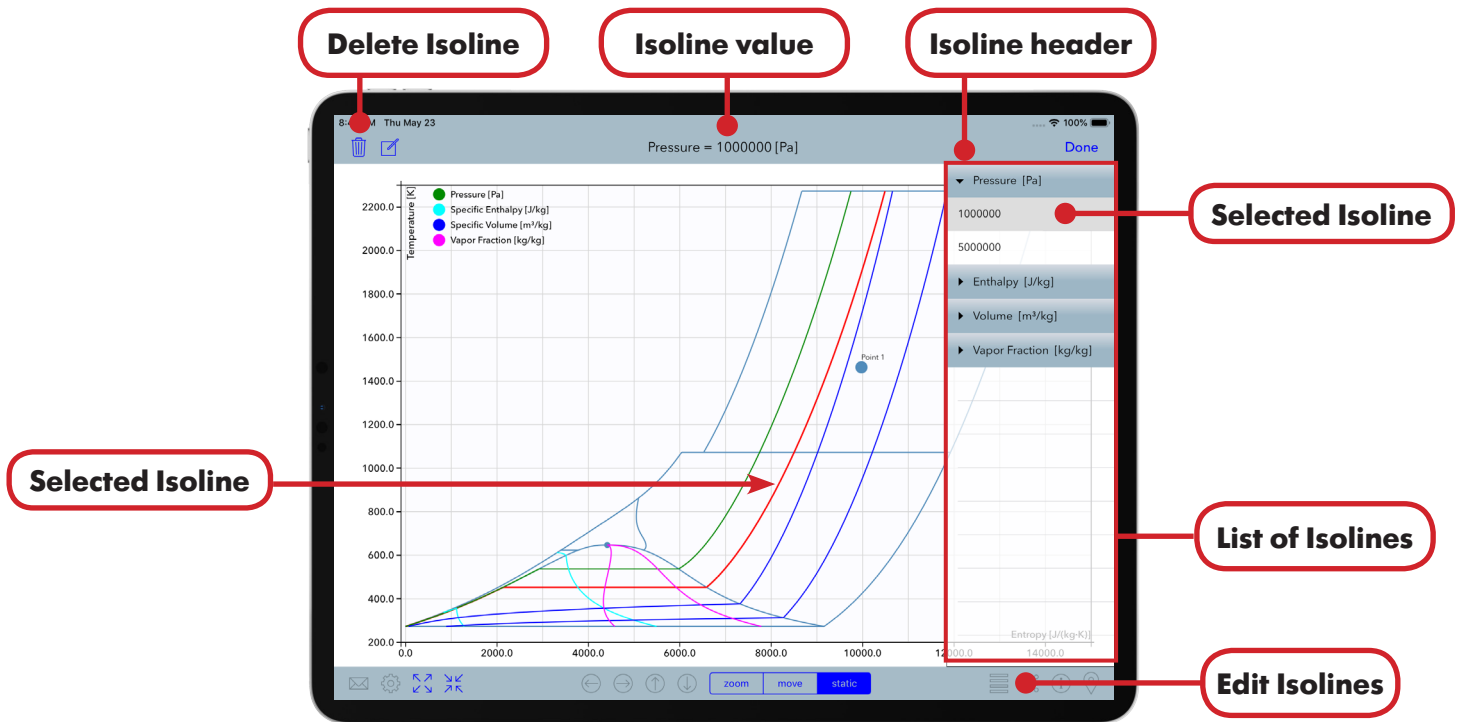


Figure 32. Selection and deletion of isolines in a plot diagram.

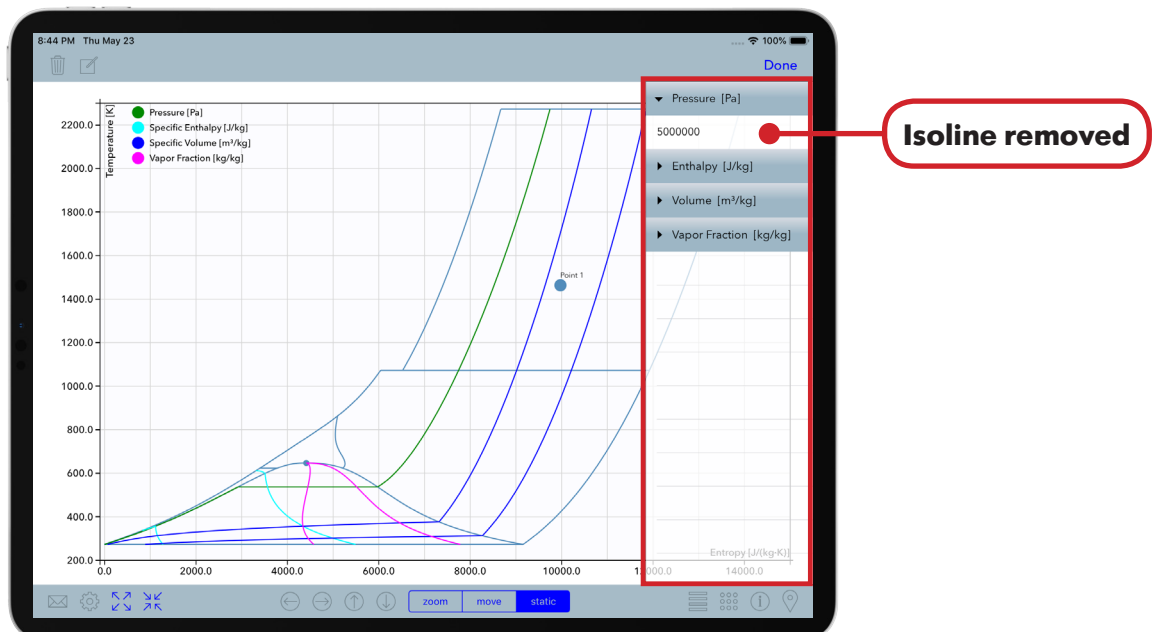


Figure 33. Example of plot diagram display after isoline deletion.

## Add Label to Isoline

- Tap on the **Static Mode** of the Plot View models.
- Tap on the **Edit Isolines** button to display a table on the right-hand side of the Plot Area with a list of all the isolines that belong to a particular project.
- Tap on a isoline type header to display the list of the numerical values for all the isolines of that type.
- Tap on a particular value to select the isoline in the Plot Area. The curve will turn red, and the selected isoline's value will appear over the Plot Area.
- Tap on the **Add Label** button and tap on the Plot Area to drag the isoline's label to a desired position.
- Tap on the **Set Label** button to fix the label at the position on the Plot Area, or the **Cancel** button to finish the edition of labels.
- Tap on the **Remove** button to remove the label when editing a previously added label.

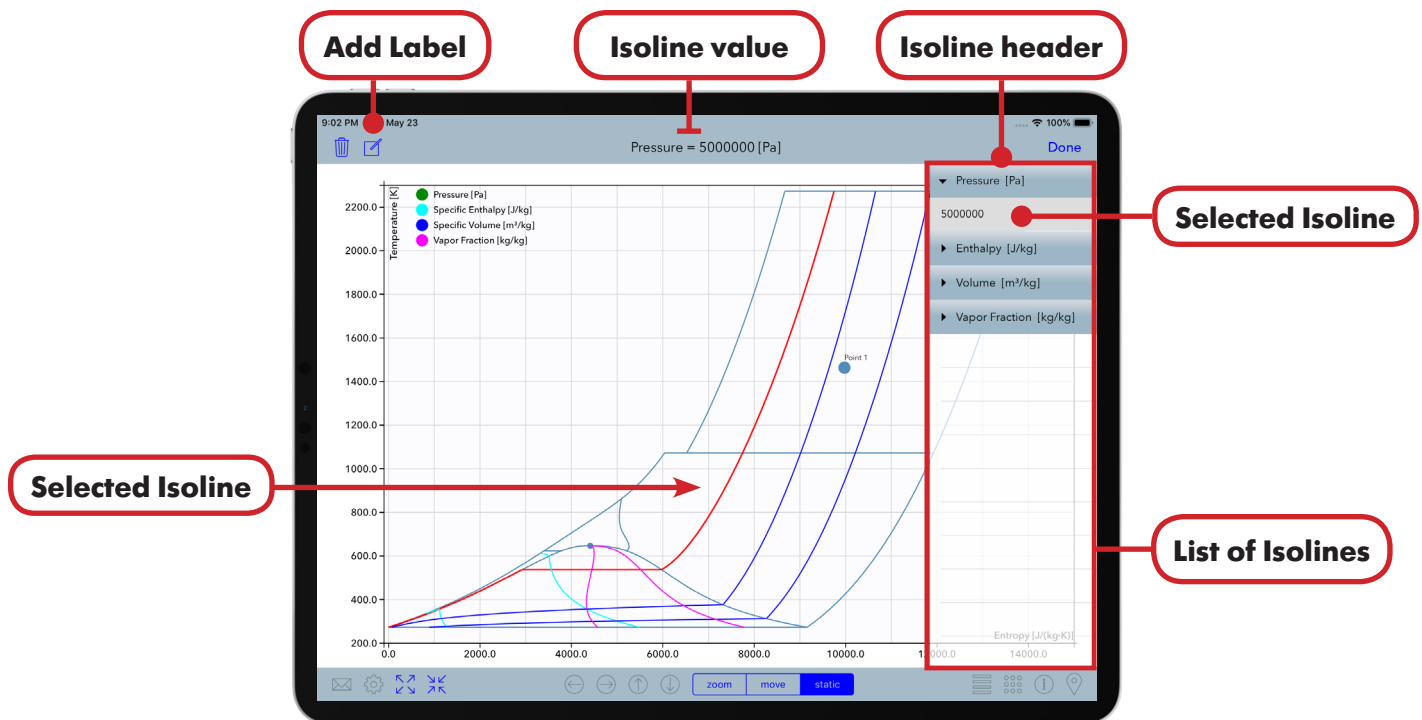


Figure 34. Selection of isoline and label addition in a plot diagram.

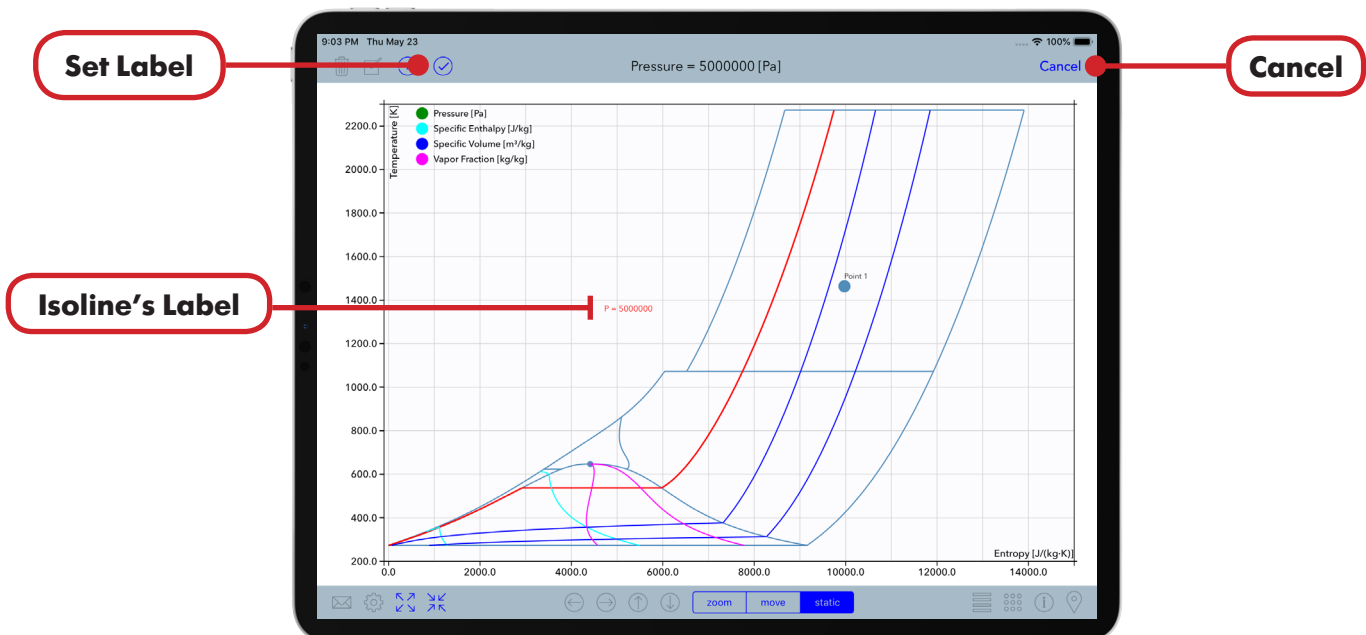


Figure 35. Example of label addition to an isoline in a plot diagram.

## Edit Isoline Label

- Tap on the **Static Mode** of the Plot View models.
- Tap on the **Edit Isolines** button to display a table on the right-hand side of the Plot Area with a list of all the isolines that belong to a particular project.
- Tap on a isoline type header to display the list of the numerical values for all the isolines of that type.
- Tap on a particular value to select the isoline in the Plot Area. The curve will turn red, and the selected isoline's value will appear over the Plot Area.
- Tap on the **Add Label** button and tap on the Plot Area to drag the isoline's label to a desired position.
- Tap on the **Angle Label** button to change the angle of the label with respect to the Plot Area. Tap on the **SET** button of the angle's popup to set the angle of the label.
- Tap on the **Set Label** button to fix the label at the position on the Plot Area, or the **Cancel** button to finish the edition of labels.

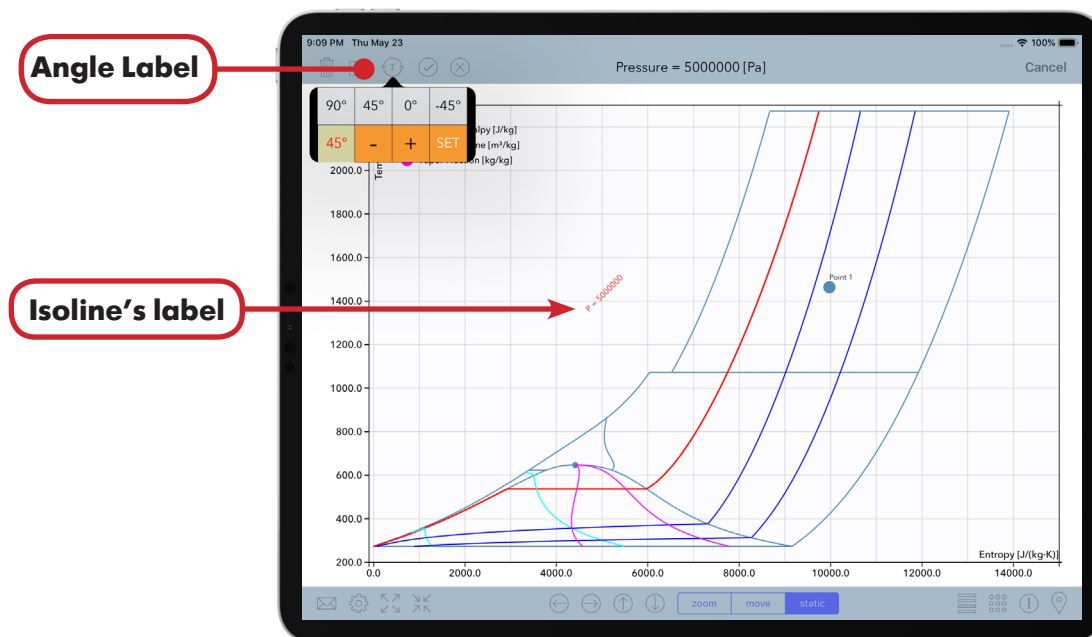


Figure 36. Label edition of an isoline in a plot diagram.

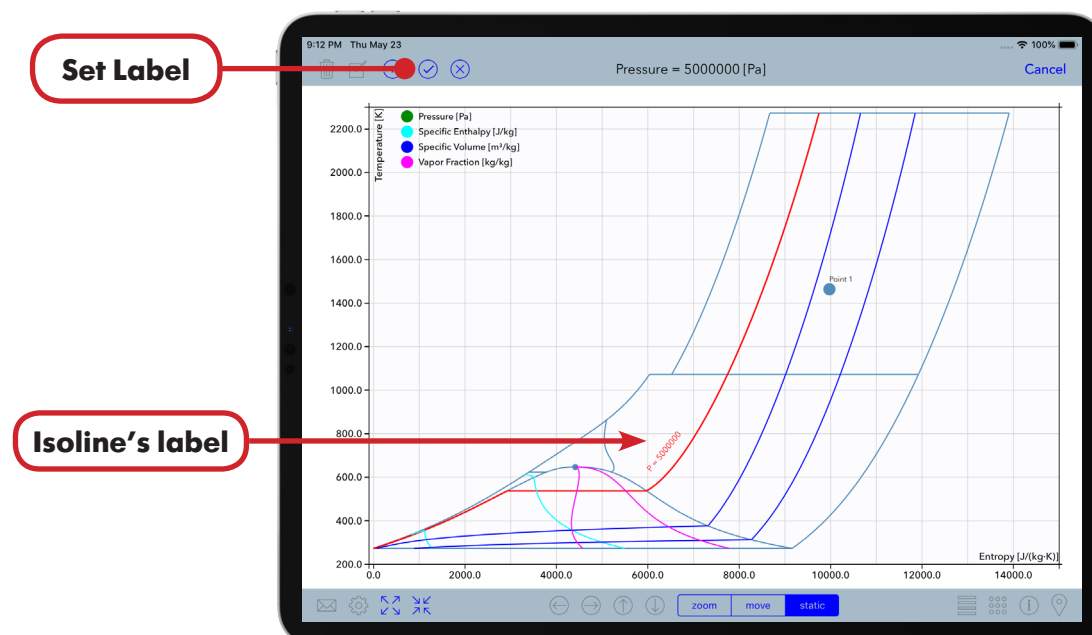


Figure 37. Example of the final label position of an isoline in a plot diagram.



## Zoom In

- Tap on the **Zoom Mode** of the Plot View models.
- Touch on the Plot Area and drag the rectangle to the desired area to zoom in.

## Reset Zoom

- Tap on the **Reset Zoom** button to zoom out the Plot Area to its full coordinates.

## Custom Zoom

- Tap on the **Custom Zoom** button to zoom in/out the Plot Area to the previously saved zooming area in the plot settings.

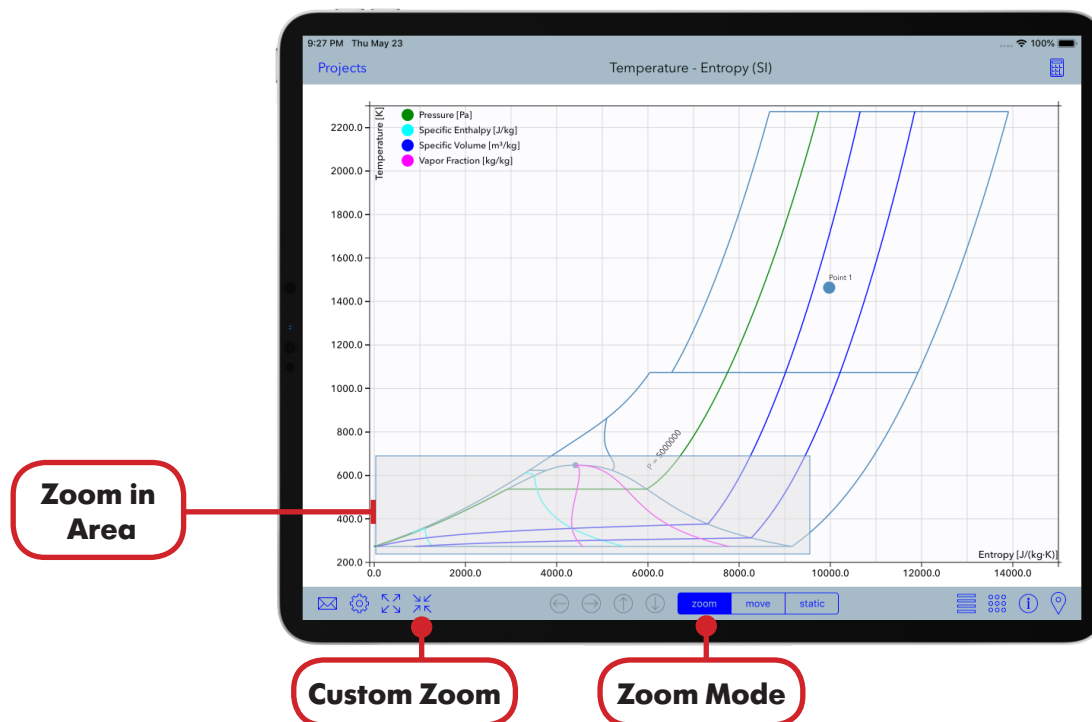


Figure 38. Example of zooming selection in a plot diagram.

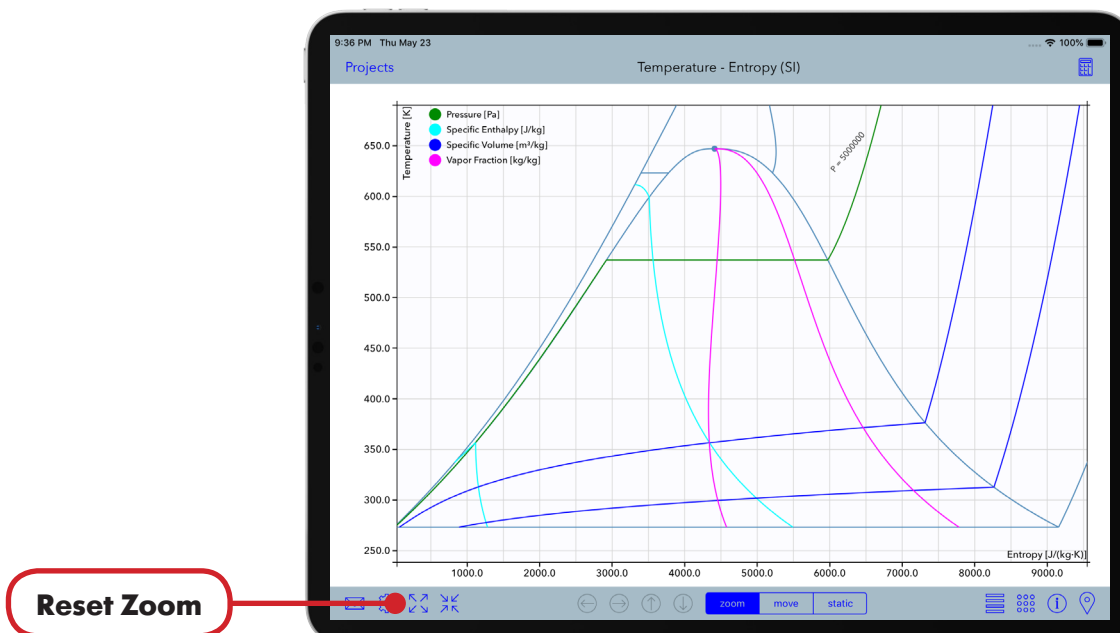


Figure 39. Example of plot diagram display after selecting a zooming area.

## Move the Plot

- Tap on the **Move Mode** of the Plot View models.
- Tap on the **Incremental** buttons to shift the plot to the left, right, up and down respectively inside the Plot Area.

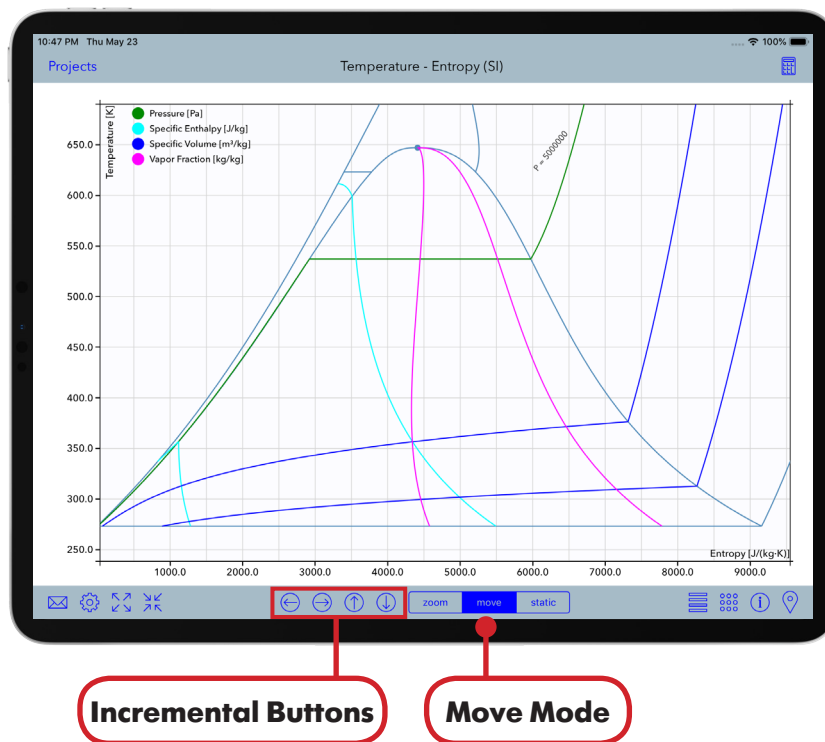


Figure 40. Selection of Move Mode in a plot diagram.

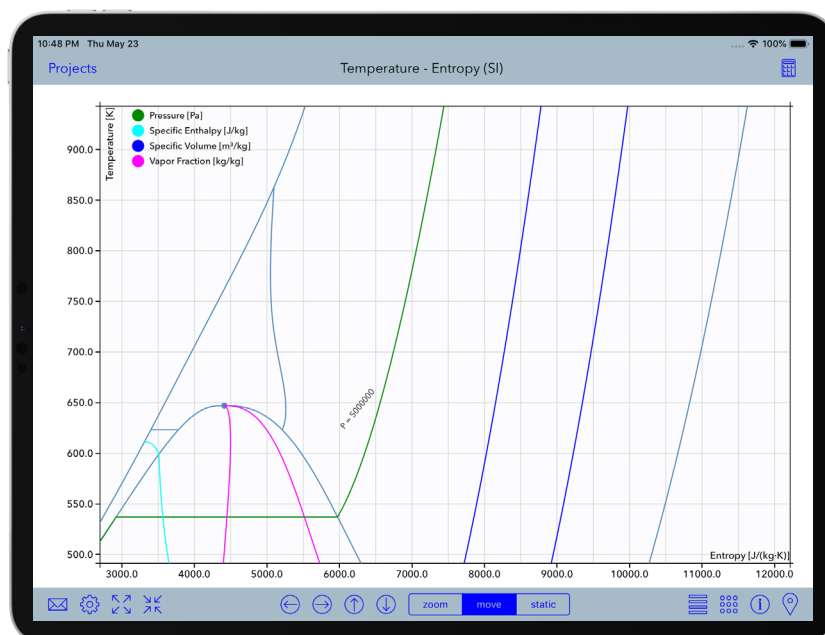
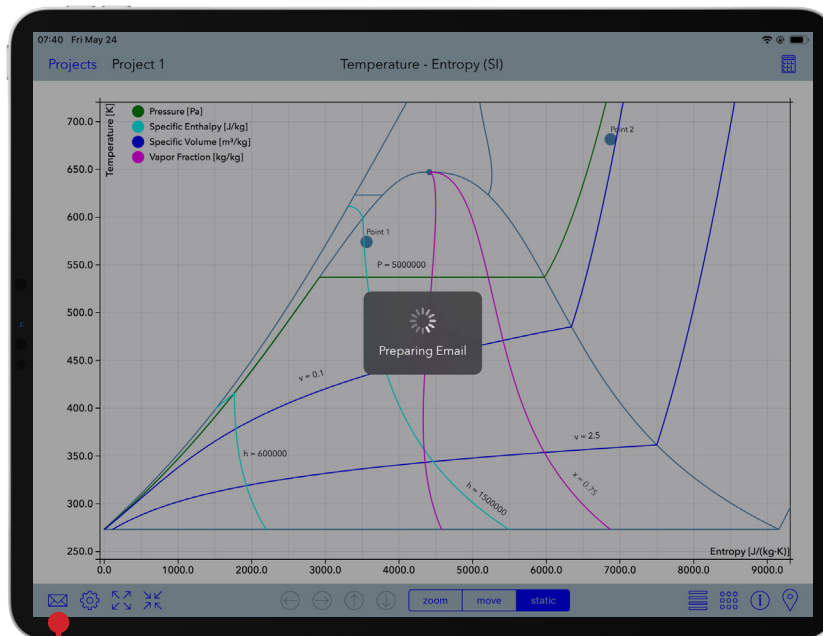


Figure 41. Example of plot diagram display after moving the plot area.

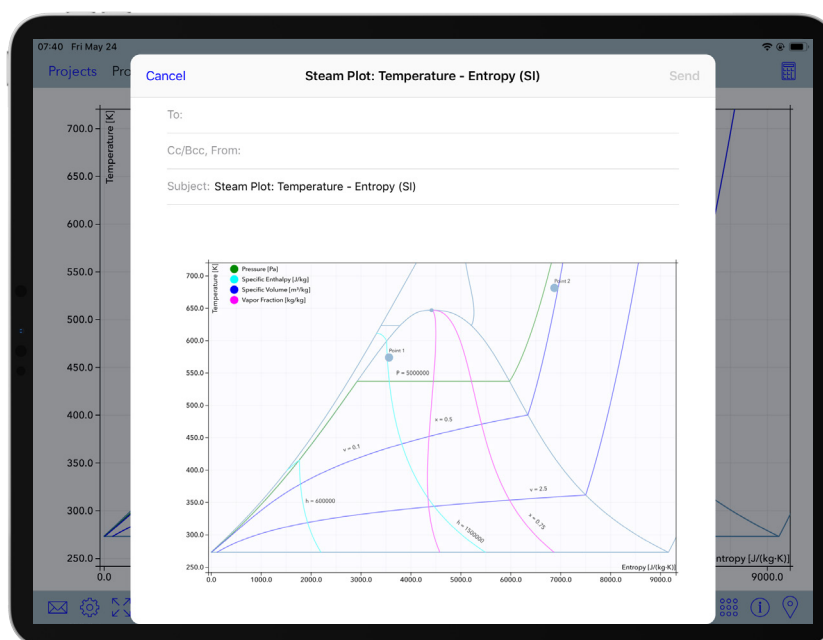
## Send Plot by email

- Tap on the **Send Plot by email** button to create a high-resolution PDF file of the current Plot Area.
- The mail composer is displayed, and the email is ready to be sent with the attached PDF plot file.




**Send Plot by email**

**Figure 42.** Preparation of the PDF plot file to be sent by email.



**Figure 43.** Mail composer with PDF plot file attached and ready to be sent by email.

## Plot Settings

- Tap on the  **Plot Settings** button to modify certain graphical aspects of a particular plot diagram project.
- Changes are reflected instantly, and saved automatically for each particular project.
- To save the current zoom displayed in the Plot Area, tap on the **Save Custom Zoom** button.
- To reset the plot settings to its defaults, tap on the button **Reset Values**.

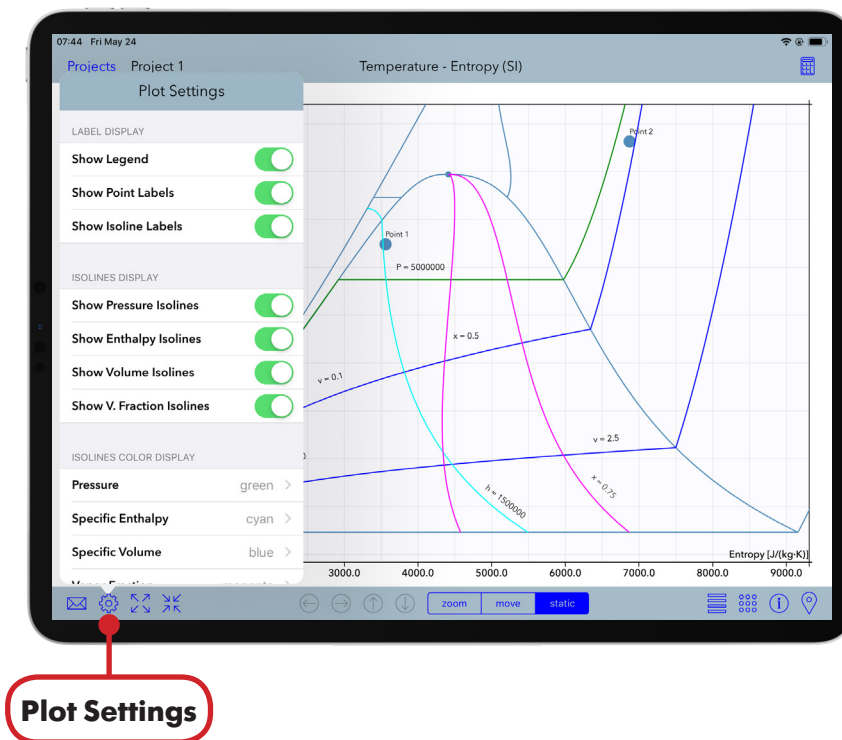


Figure 44. Selection of plot settings in a plot diagram.

## Settings Options

Each particular project has its own set of settings, and are applied every time a project is loaded into the Plot Area. Modifications are implemented instantly and saved to the database. The following are the settings options for each project:

- Show Legend.
- Show Point Labels.
- Show Isoline Labels.
- Show / Set Color Pressure Isolines.
- Show / Set Color Temperature Isolines.
- Show / Set Color Enthalpy Isolines.
- Show / Set Color Entropy Isolines.
- Show / Set Color Volume Isolines.
- Show / Set Color Vapor Fraction Isolines.
- Save current Plot Area viewport coordinates (save custom zoom).

**Steam Plot** allows to plot and interact with four type of plot diagrams: Temperature - entropy, entropy - enthalpy, log pressure - enthalpy, pressure - temperature in SI or I-P units. Each of these plots are selected after tapping on the **Go to Plots** button either in the **General Properties** of **Two-Phase Properties** calculations main GUI. Figures 46-47 show the plot area of each diagram after selecting a type of plot.

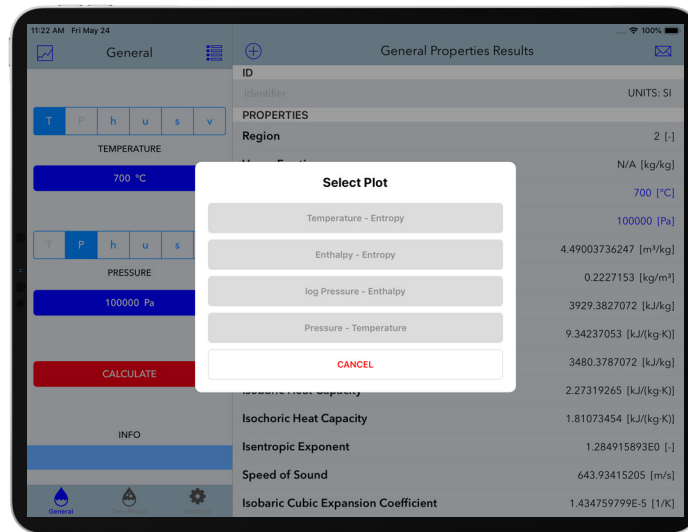


Figure 45. Selecting a plot diagram type in **Steam Plot**.

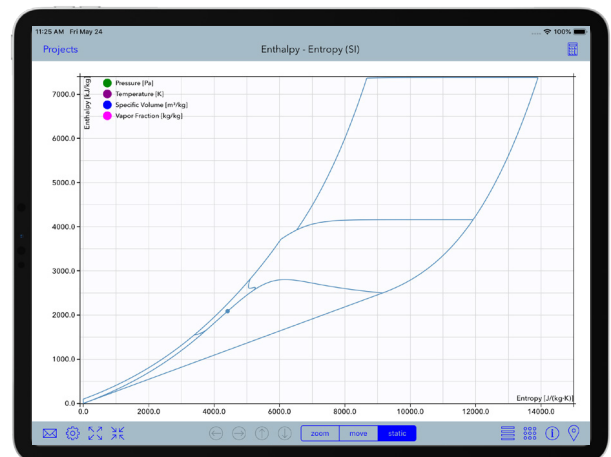
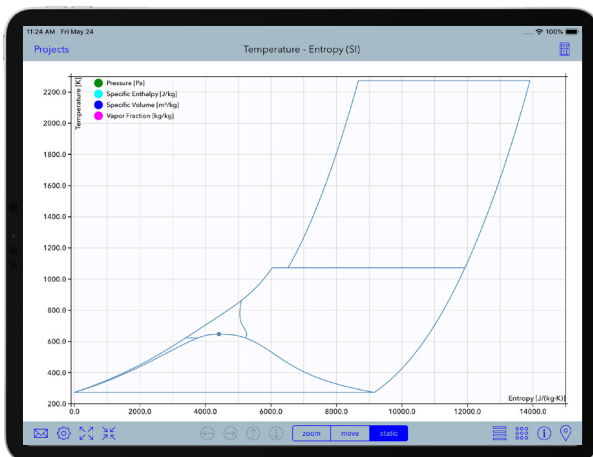


Figure 46. Temperature - entropy (left), enthalpy - entropy (right)

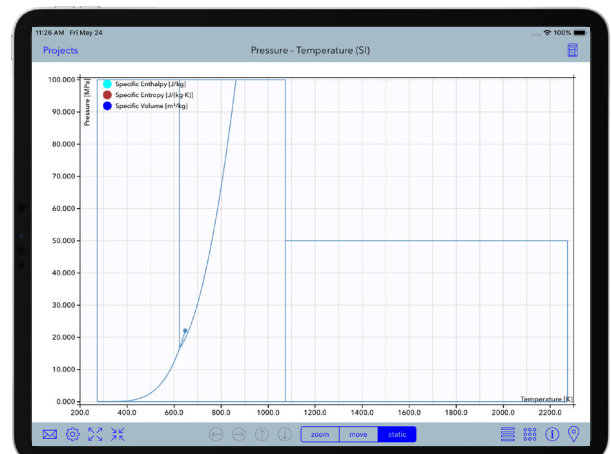
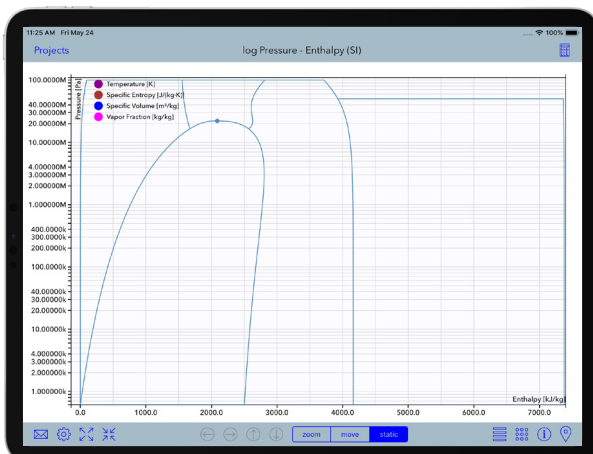
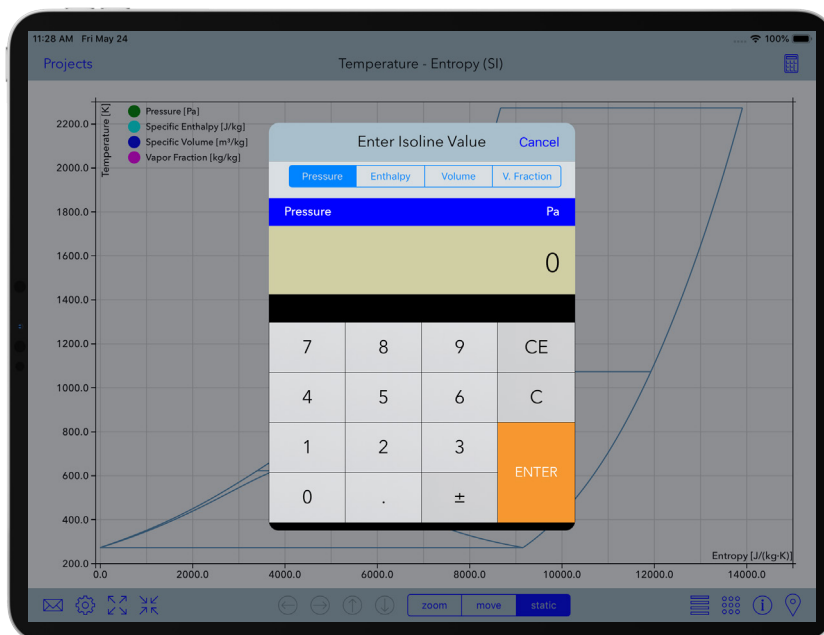


Figure 47. Log Pressure - enthalpy (left), pressure - temperature (right).

The range of input values and types of isoline calculation for temperature - entropy plot diagrams is shown in Table 9.



**Figure 48.** Input isolines for temperature - entropy plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$610 \leq P \leq 100.0E6$	Pa	$0.088473 \leq P \leq 14503.77$	psia
Specific Enthalpy	$100000.0 \leq h \leq 7376980.0$	J/kg	$42.9922 \leq h \leq 3171.53$	Btu/lbm
Specific Volume	$0.00096 \leq v \leq 1719.0$	m³/kg	$0.015377 \leq v \leq 27535.73$	ft³/lbm
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg	$0 \leq x \leq 1.0$	lb/lb

**Table 9.** Full range of isoline values for the temperature - entropy plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$P = 1000000.0$	Pa	$P = 145.0$	psia
Specific Enthalpy	$h = 3500000.0$	J/kg	$T = 1504.0$	Btu/lbm
Specific Volume	$v = 2.5$	m³/kg	$v = 40.0$	ft³/lbm
Vapor Fraction	$x = 0.5$	kg/kg	$x = 0.5$	lb/lb

**Table 10.** Limited range of isoline values for the temperature - entropy plot diagram.

The range of input values and types of isoline calculation for enthalpy - entropy plot diagrams is shown in Table 11.



Figure 49. Input isolines for enthalpy - entropy plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$610 \leq P \leq 100.0E6$	Pa	$0.088473 \leq P \leq 14503.77$	psia
Temperature	$273.15 \leq T \leq 2273.15$	K	$32.0 \leq T \leq 3632.0$	°F
Specific Volume	$0.00096 \leq v \leq 1719.0$	m³/kg	$0.015377 \leq v \leq 27535.73$	ft³/lbm
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg	$0 \leq x \leq 1.0$	lb/lb

Table 11. Full range of isoline values for the enthalpy - entropy plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$P = 1000000.0$	Pa	$P = 145.0$	psia
Temperature	$T = 450.0$	K	$T = 350.33$	°F
Specific Volume	$v = 2.5$	m³/kg	$v = 40.0$	ft³/lbm
Vapor Fraction	$x = 0.5$	kg/kg	$x = 0.5$	lb/lb

Table 12. Limited range of isoline values for the enthalpy - entropy plot diagram.

The range of input values and types of isoline calculation for log pressure - enthalpy plot diagrams is shown in Table 13.

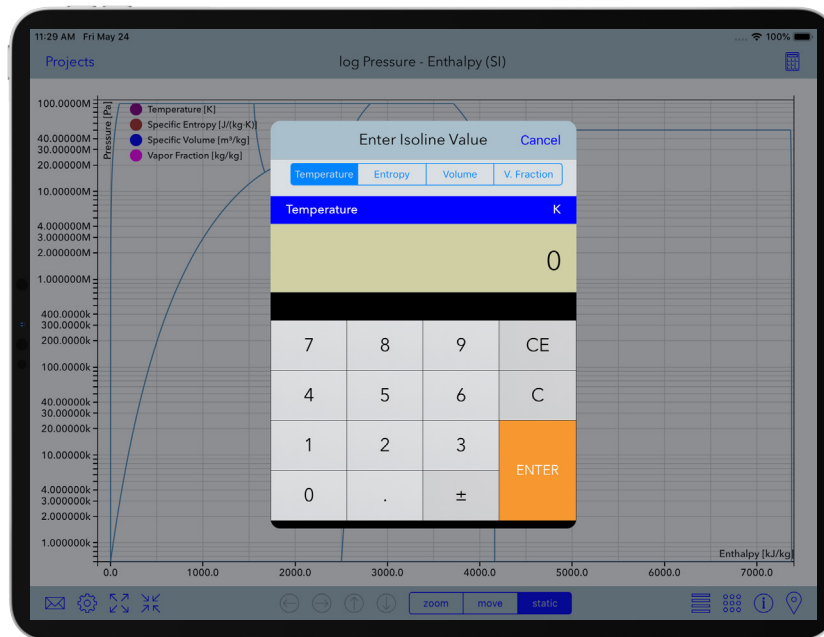


Figure 50. Input isolines for log pressure - temperature plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$610 \leq P \leq 100.0E6$	Pa	$0.088473 \leq P \leq 14503.77$	psia
Specific Entropy	$1.0 \leq s \leq 13850.0$	J/(kg·K)	$0.0002388 \leq s \leq 3.308015$	Btu/(lbm·°R)
Specific Volume	$0.00096 \leq v \leq 1719.0$	m³/kg	$0.015377 \leq v \leq 27535.73$	ft³/lbm
Vapor Fraction	$0 \leq x \leq 1.0$	kg/kg	$0 \leq x \leq 1.0$	lb/lb

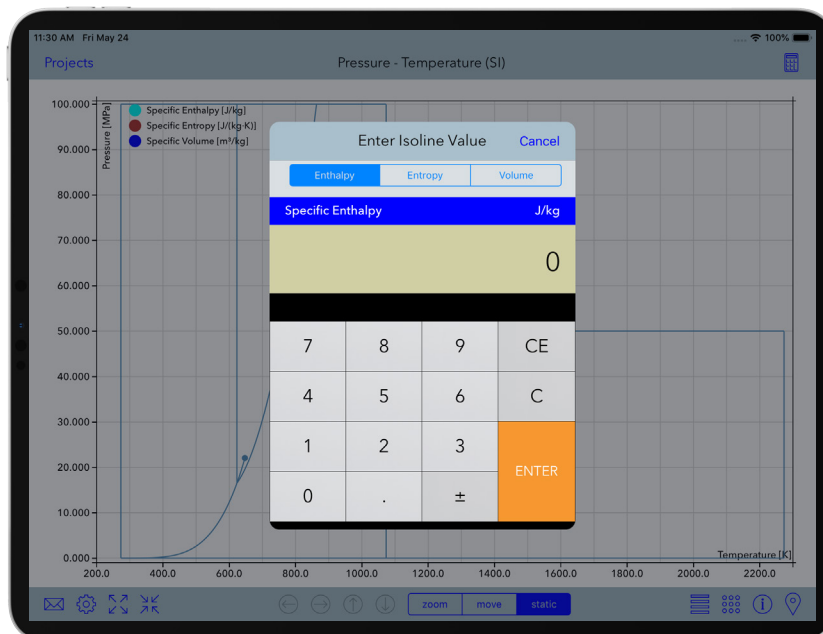
Table 13. Full range of isoline values for the log pressure - enthalpy plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$P = 1000000.0$	Pa	$P = 145.0$	psia
Specific Entropy	$s = 6500.0$	J/(kg·K)	$s = 1.55$	Btu/(lbm·°R)
Specific Volume	$v = 2.5$	m³/kg	$v = 40.0$	ft³/lbm
Vapor Fraction	$x = 0.5$	kg/kg	$x = 0.5$	lb/lb

Table 14. Limited range of isoline values for the log pressure - enthalpy plot diagram.



The range of input values and types of isoline calculation for pressure - temperature diagrams is shown in Table 15.



**Figure 51.** Input isolines for pressure - temperature plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$610 \leq P \leq 100.0E6$	Pa	$0.088473 \leq P \leq 14503.77$	psia
Specific Entropy	$1.0 \leq s \leq 13850.0$	J/(kg·K)	$0.0002388 \leq s \leq 3.308015$	Btu/(lbm·°R)
Specific Volume	$0.00096 \leq v \leq 1719.0$	m³/kg	$0.015377 \leq v \leq 27535.73$	ft³/lbm

**Table 15.** Full range of isoline values for the pressure - temperature plot diagram.

Property	Range in SI Units	SI Units	Range in I-P Units	I-P Units
Pressure	$P = 1000000.0$	Pa	$P = 145.0$	psia
Specific Entropy	$s = 6500.0$	J/(kg·K)	$s = 1.55$	Btu/(lbm·°R)
Specific Volume	$v = 2.5$	m³/kg	$v = 40.0$	ft³/lbm

**Table 16.** Limited range of isoline values for the pressure - temperature plot diagram.

### Modifying the Application Settings

- Tap on the **Settings** tab to access the system of units and their correspondent units to be used in the calculation of steam points (General and Two-Phase properties).
- Once the system of units or a particular variable unit has been modified, the graphical user interface, input variables and calculation results are automatically converted to the selected units.

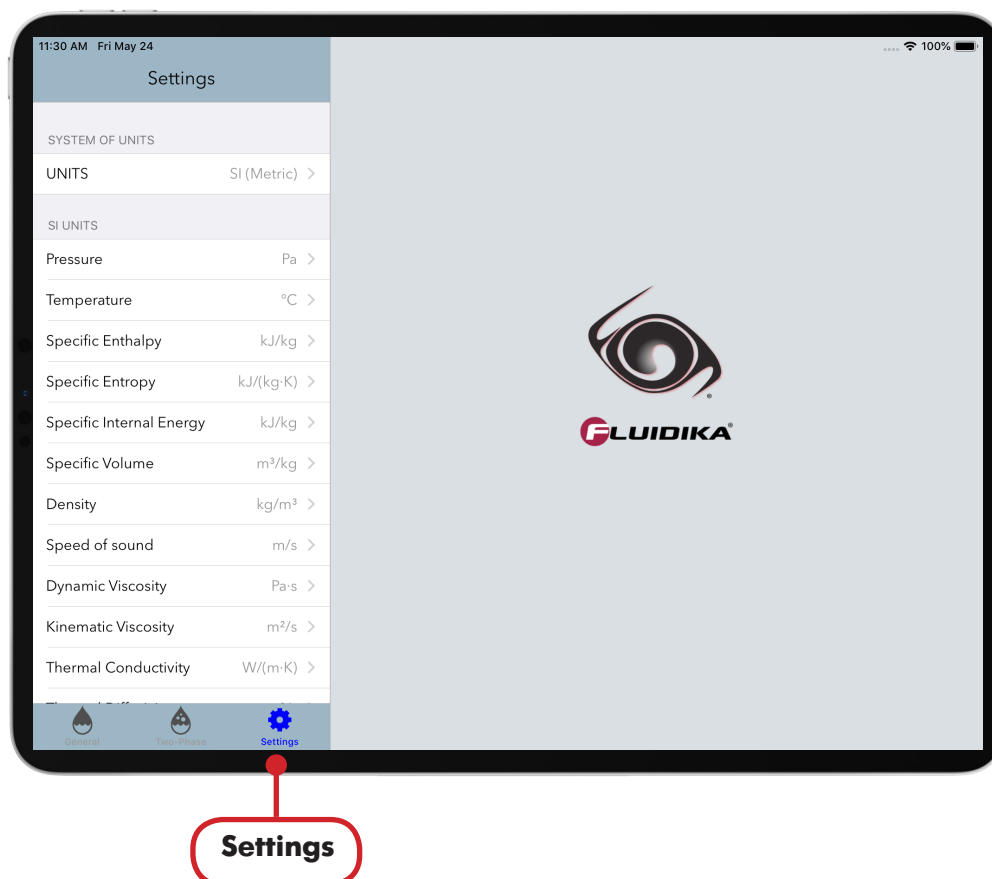


Figure 52. Application Settings tab in [Steam Plot](#).

System of Units
Pressure
Temperature
Specific Enthalpy
Specific Entropy
Specific Internal Energy
Specific volume
Density
Speed of Sound
Dynamic Viscosity
Kinematic Viscosity
Thermal Conductivity
Thermal Diffusivity

Table 17. Properties for which their units can be set in both the (SI) of (I-P) system of units.

## Application Settings - Two-Phase Calculation (T-h)

Considering the Temperature-Enthalpy <T,h> Diagram in Figure 53, the IAPWS-IF97 Formulation for region 1 overlaps the two-phase region 4. Set the *Two-phase Calculation* Switch to ON in the **Settings** tab to calculate values in this region by setting them as part of region 4 as shown in Figure 54.

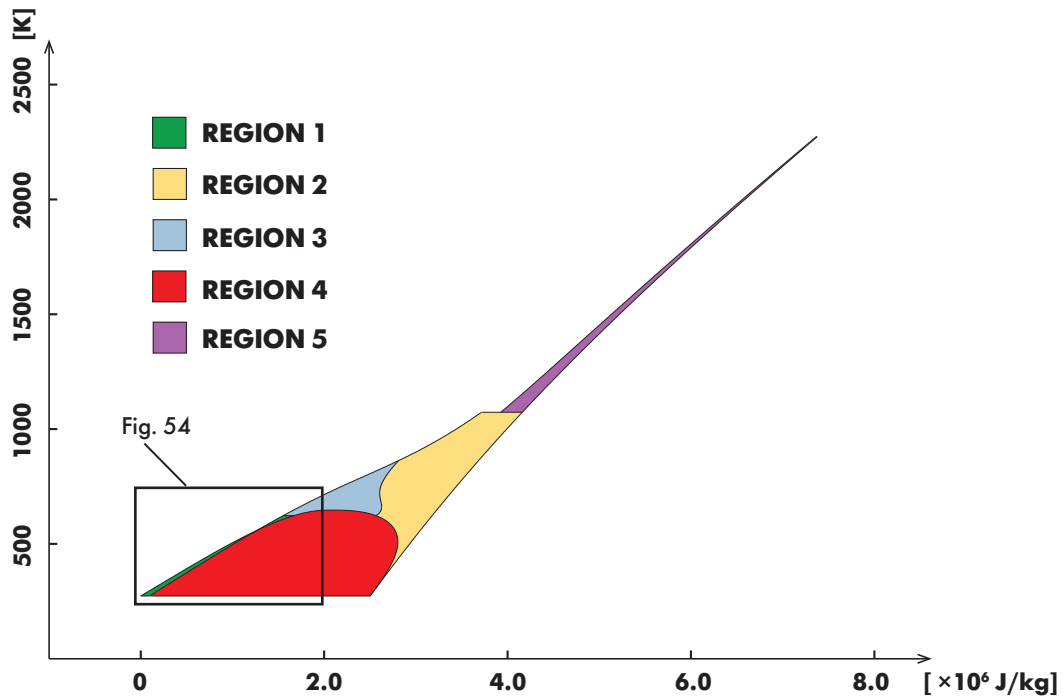


Figure 53. Enthalpy-Temperature Diagram with two-phase calculation set to OFF.

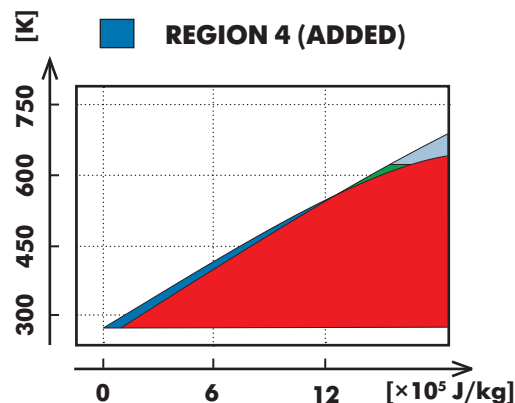


Figure 54. Zoom view of T-h Diagram with two-phase calculation set to ON.

## Application Settings - Two-Phase Calculation (P-v)

Considering the Pressure-volume <P,v> Diagram in Figure 55, the IAPWS-IF97 Formulation for region 1 overlaps the two-phase region 4. Set the *Two-phase Calculation* Switch to ON in the **Settings** tab to calculate values in this region by setting them as part of region 4 as shown in Figure 56.

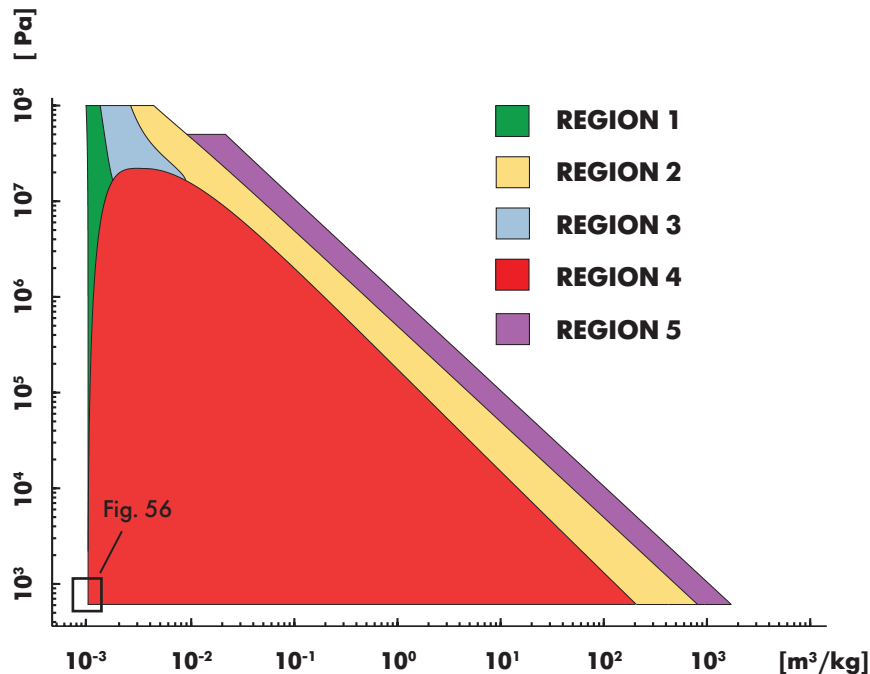


Figure 55. Pressure-volume (log-log) Diagram with Two-phase Calculation set to OFF.

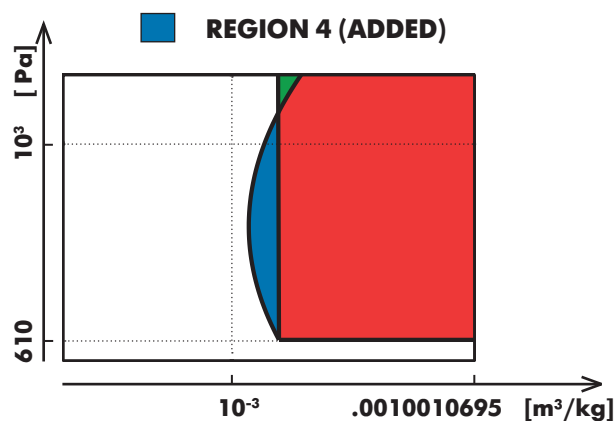


Figure 56. Zoom view of P-v Diagram with Two-phase Calculation set to ON.

## Purchase / Restore full range of variables

### Purchase access to the full range of variables

- In order to access the full range of variables for the application, tap on the **Settings** tab, and then tap on the [Purchase full range of variables](#) button. An internet connection and credentials for the iTunes Store are required to complete the transaction.

### Restore purchase to access the full range of variables

- Information of your purchase is stored in the iTunes Store if you have previously purchased access to the full range of variables, or a prior version of the application. If you require to reactivate full access once again (when for example, reinstalling the application), tap on the **Settings** tab and then tap on the [Restore your purchase](#) button. If the restore transaction is successful, access to the full range of variables will be activated. An internet connection and credentials for the iTunes Store are required to complete the restore transaction.

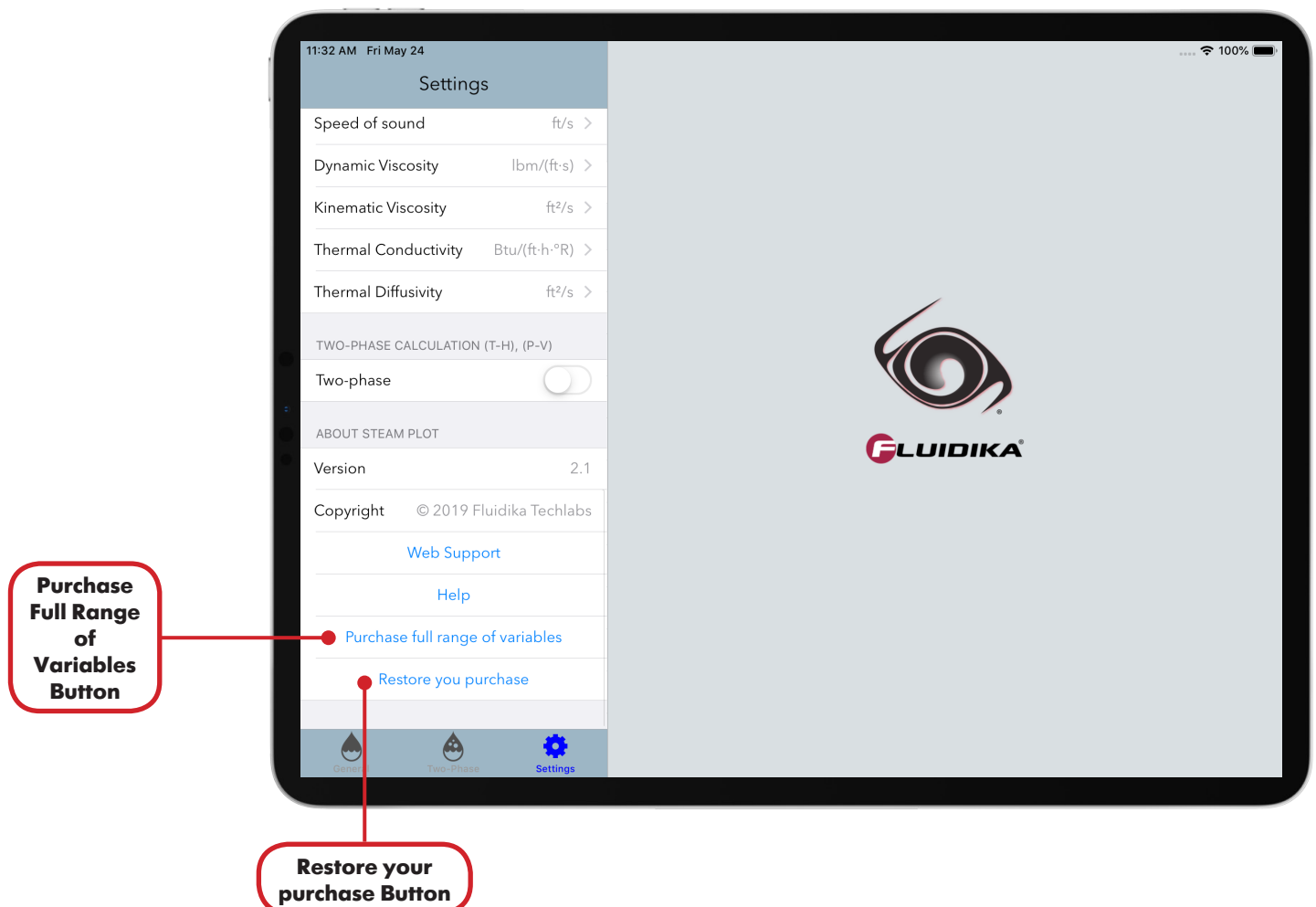


Figure 57. [Purchase full range of variables](#) and [Restore your purchase](#) buttons on the **Settings** tab.

## References

- [1] Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, IAPWS (2007).
- [2] Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance, IAPWS (2008).
- [3] Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance, IAPWS (2011).
- [4] Supplementary Release on Backward Equations for Pressure as a Function of Enthalpy and Entropy  $p(h,s)$  to the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, IAPWS (2001).
- [5] Wagner, W.; Pruß, A.: The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. J. Phys. Chem. Ref. Data 31, 387-535 (2002).
- [6] Wagner, W.; Kretzschmar, H.-J.: International Steam Tables. Springer, Berlin (2008).