

Steam IF97

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USER GUIDE

REQUIREMENTS:

Compatible with iPhone. Requires iOS 12.1 or later.

VERSION: 3.1

Description

Steam IF97 is an application that performs calculations of Thermodynamic and Transport properties of steam based on the latest IAPWS-IF97 Formulation and IAPWS releases.

Given a combination of two thermodynamic properties, it calculates 20 Thermodynamic and Transport properties of steam.

The numerical results obtained are suitable for engineering, scientific or industrial 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).
- It 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
- The calculations operate in two modes denoted as General Properies and Saturation 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.
- 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
 - Pressure / Internal Energy
 - Pressure / Entropy
 - Pressure / Specific Volume
 - Enthalpy / Entropy
 - Enthalpy / Specific Volume
 - Internal Energy / Specific Volume
 - Temperature / Vapor Fraction
 - Pressure / Vapor Fraction
- 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 as an HTML file and a comma-separated value (CSV) file.



Limited Range of Variables

Certain limitations are applied to **Steam IF97** 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	
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	
Sending calculation results by email	ALLOWED	DISABLED	

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

Output Result Properties and Units

Thermodynamic properties calculated by **Steam IF97** 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	psi, inHg, inH2O, 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	m³/kg, cm³/g, l/kg	ft³/lbm, in³/lbm, gal(US)/lbm	
Density	kg/m³, g/cm³, kg/l	lbm/ft³, lbm/in³, 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/ft²	
Kinematic Viscosity	m²/s, St	ft²/s, ft²/h	
Thermal Conductivity	W/(m·K), kcal/(m·s·K)	Btu/(ft·h·°R), W/(in·°F)	
Thermal Diffusivity	m²/s, m²/h	ft²/s, ft²/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/psi	
Prandtl Number	[-]	[-]	
Vapor Fraction	kg/kg	lb/lb	
IAPWS-IF97 Region	[-]	[-]	

Table 2. Result Output Variables of Steam IF97.



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 <p, T>, **Steam IF97** will determine the corresponding region and properties.



Fig. 1. Temperature-Pressure Diagram.



Fig. 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 <h, s> (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.



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 described in Table 3.



Figure 4. Graphical User Interface for General Properties calculations.

				Combination for Limite
Temperature	(T)	Pressure	(P)	Range of Variables
Temperature	(T)	Enthalpy	(h)	kunge of vurtubles
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)	

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



Property	Range in SI Units	SI Units	SI Units Range in I-P Units	
Pressure	610 ≤ P ≤ 100.0E6	Pa	0.088473 ≤ P ≤ 14503.77	psi
Temperature	0 ≤ T ≤ 2000	°C	32.0 ≤ T ≤ 3632.0	°F
Specific Enthalpy	-41.5878 ≤ h ≤ 7376.98E3	J/kg	-0.017879 ≤ h ≤ 3171.5306	Btu/lbm
Specific Internal Energy	-282.7252 ≤ u ≤ 6327.862E3	J/kg	-0.12155 ≤ u ≤ 2720.491	Btu/lbm
Specific Entropy	-8.5823 ≤ s ≤ 13905.8727	J/(kg·K)	-0.0020498 ≤ s ≤ 3.32136	Btu∕(lbm∙°R)
Specific Volume	1.00007E-4 ≤ v ≤ 1719.8658	m³/kg	1.601958E-3 ≤ v ≤ 27549.6	ft³/lbm
Vapor Fraction	0 ≤ x ≤ 1.0	kg/kg	0 ≤ x ≤ 1.0	lb/lb

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

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	
Pressure	610 ≤ P ≤ 100.0E6	Pa	0.088473 ≤ P ≤ 14503.77	psi
Temperature	T = 700.0	°C	T = 1292.0	°F
Specific Enthalpy	-41.5878 ≤ h ≤ 7376.98E3	J/kg	-0.017879 ≤ h ≤ 3171.5306	Btu/lbm
Specific Internal Energy	-282.7252 ≤ u ≤ 6327.862E3	J/kg	-0.12155 ≤ u ≤ 2720.491	Btu/lbm
Specific Entropy	-8.5823 ≤ s ≤ 13905.8727	J/(kg·K)	-0.0020498 ≤ s ≤ 3.32136	Btu∕(lbm∙°R)
Specific Volume	1.00007E-4 ≤ v ≤ 1719.8658	m³/kg	1.601958E-3 ≤ v ≤ 27549.6	ft³/lbm
Vapor Fraction	0 ≤ x ≤ 1.0	kg/kg	0 ≤ x ≤ 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.



General Properties

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. General Properties calculation setup.

Figure 6. Calculation validation for General Properties



General Properties

Show Calculation Results

- Once a calculation has finished successfully, the RESULTS button is enabled and the input buttons are in green color, indicating that the app is ready to load the calculation results.
- Tap on the RESULTS button to load the calculation results into a table. Variables that were used for that particular calculation are in color blue.

Send Calculation Results by email

• Tap on the Send by email button to send the calculation results by email in a HTML and CSV format in case your device supports this feature. An identifier can be included for the calculation.



Figure 7. GUI of General Properties after the calculation has finished and is ready to load the calculation results.





Two-Phase Properties

The Two-Phase Properties main graphical user interface and a description of its interaction buttons is shown in Figure 9. The combinations of input variables is described in Table 6.



Figure 9. Graphical User Interface for Two-Phase Properties calculations.

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

Combination for Limited Range of Variables

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



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

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

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	
Pressure	611.2126 ≤ P ≤ 22064000.0	Pa	0.088648 ≤ P ≤ 3200.1126	psi
Temperature	T = 300.0	°C	T = 572.0	°F
Specific Enthalpy	-41.5878 ≤ h ≤ 2810.0E3	J/kg	-0.017879 ≤ h ≤ 1208.08	Btu/lbm
Specific Internal Energy	al Energy -42.1992 ≤ u ≤ 2606.0E3		-0.0181424 ≤ u ≤1120.38	Btu/lbm
Specific Entropy	-0.15455 ≤ s ≤ 9155.76	J/(kg·K)	-3.69135E-5 ≤ s ≤ 2.18682	Btu∕(lbm∙°R)
Specific Volume	9.56687E-4 ≤ v ≤ 206.140	m³/kg	1.601958E-3 ≤ v ≤ 3302.04	ft³/lbm
Vapor Fraction	0 ≤ x ≤ 1.0	kg/kg	0 ≤ x ≤ 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.



Two-Phase Properties

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 11. Validation of calculation for Two-Phase Properties



Two-Phase Properties

Show Calculation Results

- Once a calculation has finished successfully, the **RESULTS** button is enabled and the input buttons are in green color, indicating that the application is ready to load the calculation results.
- Tap on the RESULTS button to load the calculation results into a table. Variables that were used for that particular calculation are in blue color.

Send Calculation Results by email

• Tap on the Send by email button to send the calculation results by email in a HTML and CSV format in case your device supports this feature. An identifier can be included for the calculation results.



Figure 12. GUI of Two-Phase Properties after the calculation has finished and is ready to load the calculation results.

Figure 13. Calculation results for the current input variables.



Application Settings

- Tap on the **Settings** Tab to modify the input/output units for the input variables and calculation results.
- Select the System of Units to used (SI or I-P) for the calculation and/or individual properties in order to set their correspondent units (Table 9).
- Changes to the calculation results and input variables are automatically updated after tapping on the **General** or **Two-Phase** Tab.

8					
Carrier 🗢 2:58 PM Settings					
SYSTEM OF UNITS					
UNITS	SI (Metric)	>			
SI UNITS					
Pressure	Pa	>			
Temperature	°C	>			
Specific Enthalpy	kJ/kg	>			
Specific Entropy	kJ/(kg∙K)	>			
Specific Internal Energy	kJ/kg	>			
Specific Volume	m³/kg	>			
Density	kg/m³	>			
Speed of sound	m/s	>			
Dynamic Viscosity	Pa·s	>			
General Two-Phase	Settings	•		Setti	ngs T
\bigcirc			J		

Figure 14. Settings tab of Steam IF97.

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

 Table 9. Settings options of Steam IF97.



Application Settings - Two-Phase Calcuation (T-h)

Considering the Temperature-Enthalpy <T,h> Diagram in Figure 15, 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 16.



Figure 15. Enthalpy-Temperature Diagram with two-phase calculation set to OFF.



Figure 16. Zoom view of T-h Diagram with two-phase calculation set to ON.



Application Settings - Two-Phase Calcuation (P-v)

Considering the Pressure-volume <P,v> Diagram in Figure 17, 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 18.



Figure 17. Pressure-volume (log-log) Diagram with Two-phase Calculation set to OFF.



Figure 18. 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 19. Purchase full range of variables and Restore your purchase buttons on the Settings tab.



[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).

