Humid Air Properties

# Psychrometrics

## MATLAB® Functions Library

# USER GUIDE

*Windows® Operating System*
*SI and I-P Units*
*Version 2.0*

# Table of Contents





www.fluidika.com
support@fluidika.com

# OVERVIEW

**Psychrometrics** is a MATLAB Functions Library that allows the calculation of thermodynamic and psychrometric properties of humid air, dry air, water, water vapor and ice based entirely on the mathematical formulation of the 2009 ASHRAE Handbook of Fundamentals.

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

## 1.1 Description

• Performs all the calculations implementing the latest mathematical models used to generate the tables for moist air properties and thermodynamic properties of water in the 2009 ASHRAE Handbook of Fundamentals, namely:

- Thermodynamic and psychrometric property algorithms from the ASHRAE Research Project 1485.
- Properties of steam, water and ice from the Industrial Formulation IAPWS-IF97, the Scientific Formulation IAPWS-95, IAPWS Formulation 2008 and IAPWS Formulation 2006. Properties of dry air are from the NIST Reference equation of Lemmon et al.

• Calculates the following thermodynamic properties of humid air, dry air, water, water vapor and ice:

- Dry-Bulb Temperature
- Wet-Bulb Temperature
- Dew/Frost Point Temperature
- Partial Pressure of Water Vapor in Humid Air
- Partial Pressure of Dry Air in Humid Air
- Partial Saturation Water Vapor Pressure
- Mole Fraction of Dry Air in Humid Air
- Mole Fraction of Water Vapor in Humid Air
- Mass Fraction of Dry Air in Humid Air
- Mass Fraction of Wate Vapor in Humid Air
- Humidity Ratio
- Saturation Humidity Ratio
- Relative Humidity
- Absolute Humidity
- Parts per million by weight
- Parts per million by volume
- Enhancement Factor
- Specific Volume of Humid Air
- Specific Volume of Dry Air
- Density of Humid Air
- Density of Dry Air
- Specific Enthalpy of Humid Air
- Specific Enthalpy of Dry Air
- Specific Entropy of Humid Air
- Specific Entropy of Dry Air
- Specific Internal Energy of Humid Air
- Specific Internal Energy of Dry Air

- Specific Isobaric Heat Capacity of Humid Air
- Compressibility of Humid Air
- Specific Enthalpy of Liquid Water
- Specific Enthalpy of Saturated Liquid Water
- Specific Enthalpy of Saturated Water Vapor (for T ≥ 273.15 K / 32 °F)
- Specific Entropy of Liquid Water
- Specific Entropy of Saturated Liquid Water
- Specific Entropy of Saturated Water Vapor (for T ≥ 273.15 K / 32 °F)
- Specific Volume of Liquid Water
- Specific Volume of Saturated Liquid Water
- Specific Volume of Saturated Water Vapor (for T ≥ 273.15 K / 32 °F)
- Saturation Pressure of Water
- Saturation Temperature of Water
- Specific Enthalpy of Saturated Ice
- Specific Enthalpy of Saturated Water Vapor (for T ≤ 273.15 K / 32 °F )
- Specific Entropy of Saturated Ice
- Specific Entropy of Saturated Water Vapor (for T ≤ 273.15 K / 32 °F )
- Specific Volume of Saturated Ice
- Specific Volume of Saturated Water Vapor (for T ≤ 273.15 K / 32 °F )
- Melting Pressure of Ice
- Sublimation Pressure of Ice
- Melting Temperature of Ice
- Sublimation Temperature of Ice

- Allows for 17 different combinations of thermodynamic properties to be entered as input parameters in both the SI (metric) and the I-P (English) system of units.
  - Dry-bulb Temperature / Wet-bulb Temperature
  - Dry-bulb Temperature / Dew Point Temperature
  - Dry-bulb Temperature / Relative Humidity
  - Dry-bulb Temperature / Humidity Ratio
  - Dry-bulb Temperature / Specific Enthalpy
  - Dry-bulb Temperature / Specific Volume
  - Wet-bulb Temperature / Dew Point Temperature
  - Wet-bulb Temperature / Relative Humidity
  - Wet-bulb Temperature / Humidity Ratio
  - Dew Point Temperature / Relative Humidity
  - Dew Point Temperature / Specific Enthalpy
  - Dew Point Temperature / Specific Volume
  - Relative Humidity / Humidity Ratio
  - Relative Humidity / Specific Enthalpy
  - Relative Humidity / Specific Volume
  - Humidity Ratio / Specific Enthalpy
  - Humidity Ratio / Specific Volume

## 1.2 System Requirements

The following are the requirements in order to install and utilize Psychrometrics. Please note that if your operating system does not include the corresponding C++ Runtime Library it will be installed by the installation file.

| | OPERATING SYSTEM |
|---|---|
| Windows OS | Windows 7<br>Windows 8<br>Windows 8.1<br>Windows 10 |

| | MINIMUM VERSION | REQUIREMENT |
|---|---|---|
| MATLAB | R2009a (7.8) | 32-bit or 64-bit |

| | BITNESS | REQUIREMENT |
|---|---|---|
| C++ Runtime Library | 32-bit | Microsoft Visual C++ 2012 Redistributable (32-bit) - 11.0.6.61030 |
| | 64-bit | Microsoft Visual C++ 2012 Redistributable (64-bit) - 11.0.6.61030 |

- Please note that the minimum supported Windows OS is Windows 7, and the minimum supported MATLAB version is R2009a (7.8).

**Psychrometrics is available as a 32-bit or 64-bit Functions Library in accordance with the MATLAB version. Please select the right installation file that matches your MATLAB installation.**

| Installation File | MATLAB Version |
|---|---|
| Psychrometrics_Matlab_x86_Setup | 32-bit |
| Psychrometrics_Matlab_x64_Setup | 64-bit |

## 1.3 Installation

Once you have downloaded the suitable version of Psychrometrics Library that matches your MATLAB installation, double click the corresponding file:

**Psychrometrics_Matlab_x86_Setup.exe** (for 32-bit MATLAB Installation)
**Psychrometrics_Matlab_x64_Setup.exe** (for 64-bit MATLAB installation)

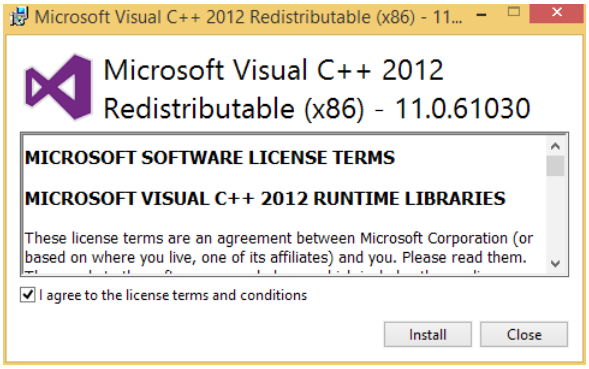
You need to agree to the *License terms and conditions* before installing the software.

You need to have **Administrator** privileges on your computer in order to install the software

## 1.4 License

Introduce the **SERIAL KEY** that you received in order to install Library.

If your system does not include the Microsoft VC++ 2012 Redistributable runtime library, it will be installed by the application. Once you agreed to the license terms and conditions, click on the install button to proceed with the installation.




## 1.5 Upgrades

Information about upgrades will be send to the email address that was registered.

## 1.6 Uninstalling the software

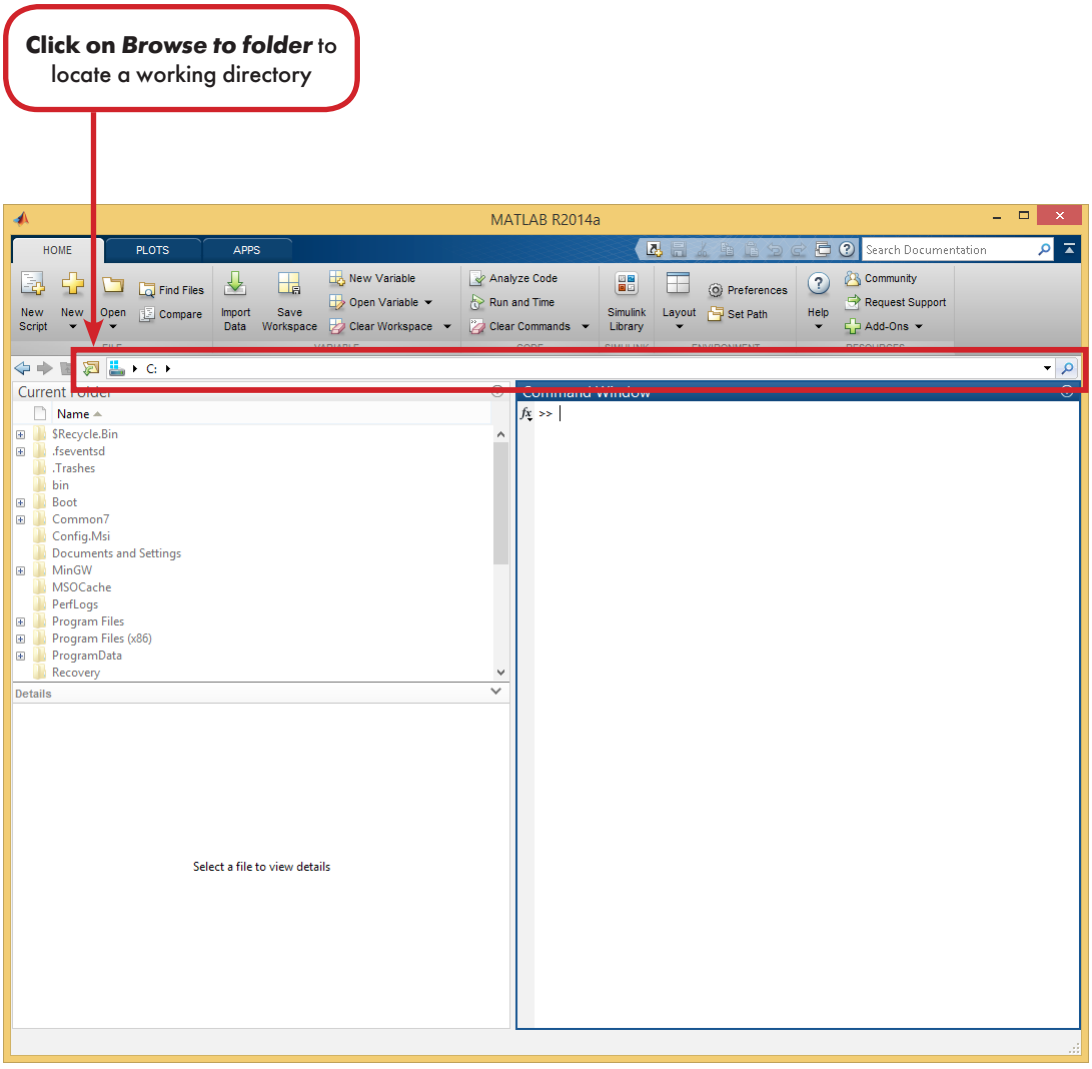
To uninstall the Matlab Functions, double click the installation file and follow the on-screen instructions, or use the standard windows uninstaller, usually located at

*Control Panel* → *Programs* → *Programs and Features*

## 1.7 Use of Library Functions in MATLAB

In order to utilize the installed library functions, it is necessary to add the directory where the function files (files with extension ***.mexw32*** for a 32-bit installation or ***.mexw64*** for a 64-bit) together with all the files with extension ***.dll*** to the *Matlab Path*. Several approaches exist to accomplish this. One possibility is to click on the ***Browse for folder*** button on the Matlab toolbar to navigate to this folder. This action will set the *Current Folder Window* to the selected directory.

In order to maintain a clean installation of the library, the recommended usage is to copy the set of function files that are required **together with all the files with extension *.dll*** to a new directory, and then add this directory to the *Matlab Path*.




IMPORTANT: **Do not rename or move any of the files with extension *.dll* that are located in the current working directory of the function files.**

## 2.1 Range of validity

In order to calculate thermodynamic properties associated with liquid water, ice and vapor, the formulations from the International Association for the Properties of Water and Steam are used to delimitate the calculations according to the pressure-temperature diagram in Figure 1.

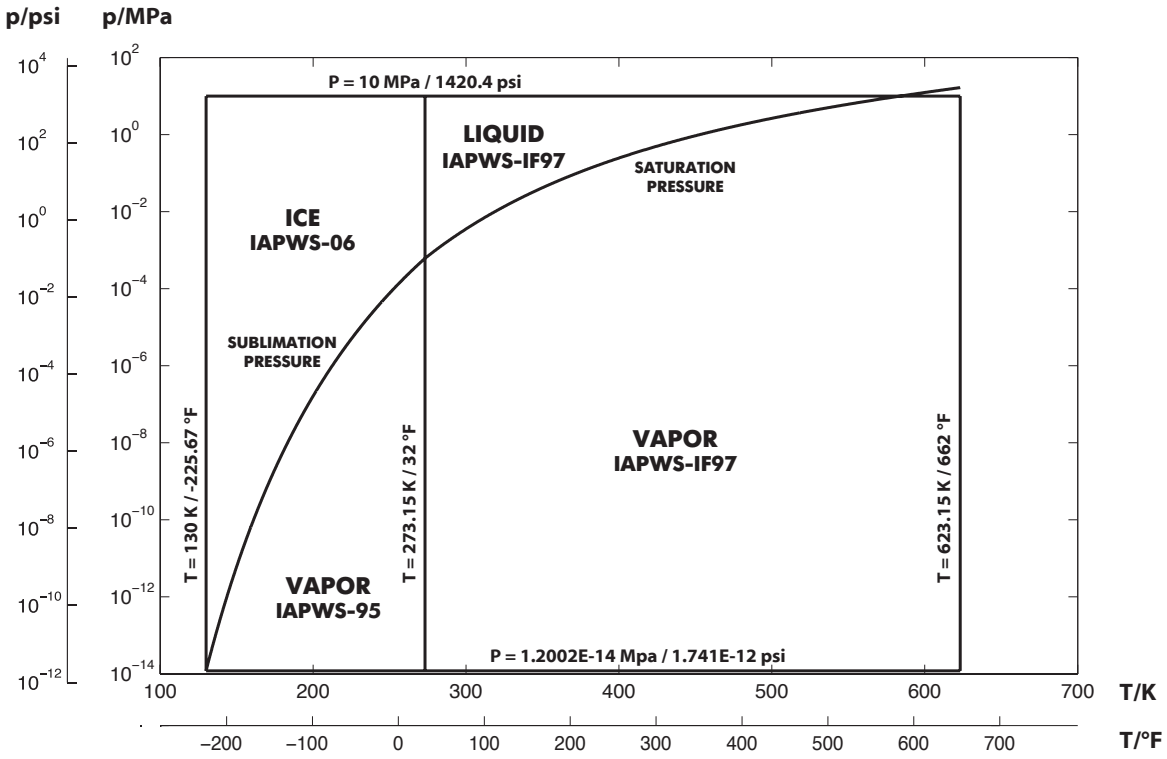



**Figure 1. Range of validity of the functions defined in Psychrometrics**

The absolute range for input and output variables is shown in Table 1. These values delimitate the numerical calculations. 17 possible combination of input variables plus pressure are shown in Table 2. For each of these possible combinations of input variables, the properties that are calculated are described in Table 7.

| Property | | Range in SI Units | SI Units |
|---|---|---|---|
| Dry-bulb Temperature | (Tdb) | 130 ⩽ Tdb ⩽ 623.15 | K |
| Wet-bulb Temperature | (Twb) | 130 ⩽ Twb ⩽ 623.15 | K |
| Dew Point Temperature | (Td) | 130 ⩽ Td ⩽ 623.15 | K |
| Relative Humidity | (PHI) | 0 ⩽ PHI ⩽ 1.0 | (decimal ratio) |
| Humidity Ratio | (W) | 0 ⩽ W ⩽ 10 | kg/kg |
| Specific Enthalpy | (h) | -311357 ⩽ h ⩽ 32135848 | J/kg |
| Specific Volume | (v) | 1.469E-3 ⩽ v ⩽ 3.055E5 | $m^3/kg$ |
| Pressure | (p) | 10 ⩽ p ⩽ 10.0E6 | Pa |

| Property | | Range in I-P Units | I-P Units |
|---|---|---|---|
| Dry-bulb Temperature | (Tdb) | -225.67 ⩽ Tdb ⩽ 662.0 | °F |
| Wet-bulb Temperature | (Twb) | -225.67 ⩽ Twb ⩽ 662.0 | °F |
| Dew Point Temperature | (Td) | -225.67 ⩽ Td ⩽ 662.0 | °F |
| Relative Humidity | (PHI) | 0 ⩽ PHI ⩽ 1.0 | (decimal ratio) |
| Humidity Ratio | (W) | 0 ⩽ W ⩽ 10 | lb/lb |
| Specific Enthalpy | (h) | -126.174 ⩽ h ⩽ 13823.61 | Btu/lbm |
| Specific Volume | (v) | 2.353E-2 ⩽ v ⩽ 4.893E6 | $ft^3/lbm$ |
| Pressure | (p) | 0.00145 ⩽ p ⩽ 1450.4 | psi |

**Table 1. Absolute ranges for input variables used in Psychrometrics**

| Input Variable | | Input Variable | | Combination |
|---|---|---|---|---|
| Dry-bulb Temperature | (Tdb) | Wet-bulb Temperature | (Twb) | **TdbTwb** |
| Dry-bulb Temperature | (Tdb) | Dew point Temperature | (Td) | **TdbTd** |
| Dry-bulb Temperature | (Tdb) | Relative Humidity | (PHI) | **TdbPHI** |
| Dry-bulb Temperature | (Tdb) | Humidity Ratio | (W) | **TdbW** |
| Dry-bulb Temperature | (Tdb) | Specific Enthalpy | (h) | **Tdbh** |
| Dry-bulb Temperature | (Tdb) | Specific Volume | (v) | **Tdbv** |
| Wet-bulb Temperature | (Twb) | Dew point Temperature | (Td) | **TwbTd** |
| Wet-bulb Temperature | (Twb) | Relative Humidity | (PHI) | **TwbPHI** |
| Wet-bulb Temperature | (Twb) | Humidity Ratio | (W) | **TwbW** |
| Dew point Temperature | (Td) | Relative Humidity | (PHI) | **TdPHI** |
| Dew point Temperature | (Td) | Specific Enthalpy | (h) | **Tdh** |
| Dew point Temperature | (Td) | Specific Volume | (v) | **Tdv** |
| Humidity Ratio | (W) | Relative Humidity | (PHI) | **WPHI** |
| Humidity Ratio | (W) | Specific Enthalpy | (h) | **Wh** |
| Humidity Ratio | (W) | Specific Volume | (v) | **Wv** |
| Relative Humidity | (PHI) | Specific Enthalpy | (h) | **PHIh** |
| Relative Humidity | (PHI) | Specific Volume | (v) | **PHIv** |

**Table 2. Combination of input variables used in Psychrometrics**

## 2.2 User Defined Functions (UDF)

**Psychrometrics** MATLAB Functions Library is composed of User Defined Functions (UDF) that take parameters (string and/or double) and returns a double (number).

If incorrect or out of bounds input parameters are entered, the function will return the value of

**-9999**

Table 3 shows the functions defined as a combinations of input variables. Functions defined whether the input temperature (T) is

$$T \geqslant 273.15 \text{ [K]} / 32 \text{ [°F]}$$

or

$$T \leqslant 273.15 \text{ [K]} / 32 \text{ [°F]}$$

are described in Tables 4 and 5. Additional functions are shown in Table 6.

| SI UNITS | I-P UNITS | OUTPUT RESULT |
|---|---|---|
| HAFLK_SI_pTdbTwb_prop | HAFLK_IP_pTdbTwb_prop | **Depending on value of "prop", see Table 7** |
| HAFLK_SI_pTdbTd_prop | HAFLK_IP_pTdbTd_prop | |
| HAFLK_SI_pTdbPHI_prop | HAFLK_IP_pTdbPHI_prop | |
| HAFLK_SI_pTdbW_prop | HAFLK_IP_pTdbW_prop | |
| HAFLK_SI_pTdbh_prop | HAFLK_IP_pTdbh_prop | |
| HAFLK_SI_pTdbv_prop | HAFLK_IP_pTdbv_prop | |
| HAFLK_SI_pTwbTd_prop | HAFLK_IP_pTwbTd_prop | |
| HAFLK_SI_pTwbPHI_prop | HAFLK_IP_pTwbPHI_prop | |
| HAFLK_SI_pTwbW_prop | HAFLK_IP_pTwbW_prop | |
| HAFLK_SI_pTdPHI_prop | HAFLK_IP_pTdPHI_prop | |
| HAFLK_SI_pTdh_prop | HAFLK_IP_pTdh_prop | |
| HAFLK_SI_pTdv_prop | HAFLK_IP_pTdv_prop | |
| HAFLK_SI_pWPHI_prop | HAFLK_IP_pWPHI_prop | |
| HAFLK_SI_pWh_prop | HAFLK_IP_pWh_prop | |
| HAFLK_SI_pWv_prop | HAFLK_IP_pWv_prop | |
| HAFLK_SI_pPHIh_prop | HAFLK_IP_pPHIh_prop | |
| HAFLK_SI_pPHIv_prop | HAFLK_IP_pPHIv_prop | |

**Table 3. Functions based on combination of input variables**

| SI UNITS | I-P UNITS | OUTPUT RESULT |
|---|---|---|
| SWFLK_SI_pT_hlw | SWFLK_IP_pT_hlw | **Specific enthalpy of liquid water** |
| SWFLK_SI_T_hlws | SWFLK_IP_T_hlws | **Specific enthalpy of saturated liquid water** |
| SWFLK_SI_T_hwvs | SWFLK_IP_T_hwvs | **Specific enthalpy of saturated water vapor** |
| SWFLK_SI_pT_slw | SWFLK_IP_pT_slw | **Specific entropy of liquid water** |
| SWFLK_SI_T_slws | SWFLK_IP_T_slws | **Specific entropy of saturated liquid water** |
| SWFLK_SI_T_swvs | SWFLK_IP_T_swvs | **Specific entropy of saturated water vapor** |
| SWFLK_SI_pT_vlw | SWFLK_IP_pT_vlw | **Specific volume of liquid water** |
| SWFLK_SI_T_vlws | SWFLK_IP_T_vlws | **Specific volume of saturated liquid water** |
| SWFLK_SI_T_vwvs | SWFLK_IP_T_vwvs | **Specific volume of saturated water vapor** |
| SWFLK_SI_T_Pws | SWFLK_IP_T_Pws | **Saturation pressure of water** |
| SWFLK_SI_p_Tws | SWFLK_IP_p_Tws | **Saturation temperature of water** |

**Table 4.** **Functions for T ⩾ 273.15 K / 32 °F**

| SI UNITS | I-P UNITS | OUTPUT RESULT |
|---|---|---|
| SWFLK_SI_T_hiws | SWFLK_IP_T_hiws | **Specific enthalpy of saturated ice** |
| SWFLK_SI_T_hwvs_sub | SWFLK_IP_T_hwvs_sub | **Specific enthalpy of saturated water vapor** |
| SWFLK_SI_T_siws | SWFLK_IP_T_siws | **Specific entropy of saturated ice** |
| SWFLK_SI_T_swvs_sub | SWFLK_IP_T_swvs_sub | **Specific entropy of saturated water vapor** |
| SWFLK_SI_T_viws | SWFLK_IP_T_viws | **Specific volume of saturated ice** |
| SWFLK_SI_T_vwvs_sub | SWFLK_IP_T_vwvs_sub | **Specific volume of saturated water vapor** |
| SWFLK_SI_T_Pmel | SWFLK_IP_T_Pmel | **Melting pressure of ice** |
| SWFLK_SI_T_Psub | SWFLK_IP_T_Psub | **Sublimation pressure of ice** |
| SWFLK_SI_p_Tmel | SWFLK_IP_p_Tmel | **Melting temperature of ice** |
| SWFLK_SI_p_Tsub | SWFLK_IP_p_Tsub | **Sublimation temperature of ice** |

**Table 5.** **Functions for T ⩽ 273.15 K / 32 °F**

| SI UNITS | I-P UNITS | OUTPUT RESULT |
|---|---|---|
| SWFLK_SI_pT_Pwvs | SWFLK_IP_pT_Pwvs | **Partial saturation pressure of water vapor** |
| SWFLK_SI_pT_f | SWFLK_IP_pT_f | **Enhancement factor** |
| SWFLK_SI_pT_Ws | SWFLK_IP_pT_Ws | **Saturation humidity ratio** |
| SWFLK_SI_pW_Td | SWFLK_IP_pW_Td | **Dew/frost point temperture** |
| SWFLK_SI_W_PSIda | SWFLK_IP_W_PSIda | **Mole fraction of dry air** |
| SWFLK_SI_W_PSIwv | SWFLK_IP_W_PSIwv | **Mole fraction of water vapor** |
| SWFLK_SI_W_XIda | SWFLK_IP_W_XIda | **Mass fraction of dry air** |
| SWFLK_SI_W_XIwv | SWFLK_IP_W_XIwv | **Mass fraction of water vapor** |
| SWFLK_SI_Zele_p | SWFLK_IP_Zele_p | **Pressure of humid air** |

**Table 6.** **Additional functions defined in Psychrometrics**

| Result Property | SI Units | I-P Units | prop |
|---|---|---|---|
| Dry-Bub Temperature | K | °F | **Tdb** |
| Wet-Bulb Temperature | K | °F | **Twb** |
| Dew Point Temperature | K | °F | **Td** |
| Partial Pressure of Water Vapor in Humid Air | Pa | psi | **Pwv** |
| Partial Pressure of Dry Air in Humid Air | Pa | psi | **Pda** |
| Partial Saturation Water Vapor Pressure | Pa | psi | **Pwvs** |
| Mole Fraction of Dry Air in Humid Air | [-] | [-] | **PSIda** |
| Mole Fraction of Water Vapor in Humid Air | [-] | [-] | **PSIwv** |
| Mass Fraction of Dry Air in Humid Air | [-] | [-] | **XIda** |
| Mass Fraction of Water Vapor in Humid Air | [-] | [-] | **XIwv** |
| Humidity Ratio | kg(w)/kg(da) | lb(w)/lb(da) | **W** |
| Saturation Humidity Ratio | kg(w)/kg(da) | lb(w)/lb(da) | **Ws** |
| Relative Humidity | (decimal ratio) | (decimal ratio) | **PHI** |
| Absolute Humidity | kg(w)/$m^3$ | lb(w)/$ft^3$ | **AH** |
| Parts per million by weight | ppmw | ppmw | **ppmw** |
| Parts per million by volume | ppmv | ppmv | **ppmv** |
| Enhancement Factor | [-] | [-] | **f** |
| Specific Volume of Humid Air | $m^3$/kg(da) | $ft^3$/lb(da) | **v** |
| Specific Volume of Dry Air | $m^3$/kg(da | $ft^3$/lb(da) | **vda** |
| Density of Humid Air | kg/$m^3$ | lb/ $ft^3$ | **RHO** |
| Density of Dry Air | kg/$m^3$ | lb/ $ft^3$ | **RHOda** |
| Specific Enthalpy of Humid Air | J/kg | Btu/lb | **h** |
| Specific Enthalpy of Dry Air | J/kg | Btu/lb | **hda** |
| Specific Entropy of Humid Air | J/(kg·K) | Btu/(lb °R) | **s** |
| Specific Entropy of Dry Air | J/(kg·K) | Btu/(lb °R) | **sda** |
| Specific Internal Energy of Humid Air | J/kg | Btu/lb | **u** |
| Specific Internal Energy of Dry Air | J/kg | Btu/lb | **uda** |
| Specific Isobaric Heat Capacity of Humid Air | J/(kg·K) | Btu/(lb °R) | **cp** |
| Compressibility of Humid Air | [-] | [-] | **Z** |

**Table 7.** **Properties calculated for each combination of input thermodynamic variables**

| Property | SI Units (output) | I-P Units (output) |
|---|---|---|
| Specific Enthalpy of Liquid Water | J/kg | Btu/lb |
| Specific Enthalpy of Saturated Liquid Water | J/kg | Btu/lb |
| Specific Enthalpy of Saturated Water Vapor | J/kg | Btu/lb |
| Specific Entropy of Liquid Water | J/(kg·K) | Btu/(lb·°R) |
| Specific Entropy of Saturated Liquid Water | J/(kg·K) | Btu/(lb·°R) |
| Specific Entropy of Saturated Water Vapor | J/(kg·K) | Btu/(lb·°R) |
| Specific Volume of Liquid Water | $m^3/kg$ | $ft^3/lb$ |
| Specific Volume of Saturated Liquid Water | $m^3/kg$ | $ft^3/lb$ |
| Specific Volume of Saturated Water Vapor | $m^3/kg$ | $ft^3/lb$ |
| Saturation Pressure of Water | Pa | psi |
| Saturation Temperature of Water | K | °F |
| Specific Enthalpy of Saturated Ice | J/kg | Btu/lb |
| Specific Entropy of Saturated Ice | J/(kg·K) | Btu/(lb·°R) |
| Specific Volume of Saturated Ice | $m^3/kg$ | $ft^3/lb$ |
| Melting Pressure of Ice | Pa | psi |
| Sublimation Pressure of Ice | Pa | psi |
| Melting Temperature of Ice | K | °F |
| Sublimation Temperature of Ice | K | °F |

**Table 8. Additional properties calculated**

## 2.3 Library Functions Reference (SI Units)

| FUNCTION NAME: | HAFLK_SI_pTdbTwb_prop |
|---|---|

**MATLAB function usage :** HAFLK_SI_pTdbTwb_prop(p, Tdb, Twb, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Tdb :** Dry-bulb temperature in K.
Range: 130.0 ⩽ Tdb ⩽ 623.15 [K]

**Twb :** Wet-bulb temperature in K.
Range: 130.0 ⩽ Twb ⩽ 623.15 [K]

**Output Result :** **prop:** Output Property. String (see Table 7)

**Invalid Output Result :** See Table 7.

**-9999** For input values outside the valid range ,
an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and wet-bulb temperature.

```
>> h = HAFLK_SI_pTdbTwb_prop(101325, 350, 320, 'h')
h  =
      2.322237342742833e+05
```

| FUNCTION NAME: | HAFLK_SI_pTdbTd_prop |
|---|---|

**MATLAB function usage :** HAFLK_SI_pTdbTd_prop(p, Tdb, Td, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Tdb :** Dry-bulb temperature in K.
Range: 130.0 ⩽ Tdb ⩽ 623.15 [K]

**Td :** Dew point temperature in K.
Range: 130.0 ⩽ Td ⩽ 623.15 [K]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range ,
an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and dew point temperature.

```
>> h = HAFLK_SI_pTdbTd_prop(101325, 350, 316.2147, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pTdbPHI_prop

**MATLAB function usage :** HAFLK_SI_pTdbPHI_prop(p, Tdb, PHI, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Tdb :** Dry-bulb temperature in K.
Range: 130.0 ⩽ Tdb ⩽ 623.15 [K]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and relative humidity.

```
>> h = HAFLK_SI_pTdbPHI_prop(101325, 350, 0.208032661, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pTdbW_prop

**MATLAB function usage :** HAFLK_SI_pTdbW_prop(p, Tdb, W, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Tdb :** Dry-bulb temperature in K.
Range: 130.0 ⩽ Tdb ⩽ 623.15 [K]

**W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and humidity ratio.

```
>> h = HAFLK_SI_pTdbW_prop(101325, 350, 0.05858452, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pTdbh_prop

**MATLAB function usage :** HAFLK_SI_pTdbh_prop(p, Tdb, h, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Tdb :** Dry-bulb temperature in K.
Range: 130.0 ⩽ Tdb ⩽ 623.15 [K]

**h:** Specific enthalpy of humid air in J/kg.
Range: -311357 ⩽ h ⩽ 32135848 [J/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of humidity ratio "W" as function of pressure , dry-bulb temperature and specific enthalpy of humid air.

```
>> W = HAFLK_SI_pTdbh_prop(101325, 350, 2.322237342742833e+05, 'W')
W  =
      0.05858452
```

## FUNCTION NAME: HAFLK_SI_pTdbv_prop

**MATLAB function usage :** HAFLK_SI_pTdbv_prop(p, Tdb, v, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Tdb :** Dry-bulb temperature in K.
Range: 130.0 ⩽ Tdb ⩽ 623.15 [K]

**v :** Specific volume of humid air in $m^3$/kg(dry air).
Range: 1.469E-3 ⩽ v ⩽ 3.055E5 [$m^3$/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and specific volume of humid air.

```
>> h = HAFLK_SI_pTdbv_prop(101325, 350, 1.084645803, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pWv_prop

**MATLAB function usage :** HAFLK_SI_pWv_prop(p, W, v, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**v :** Specific volume of humid air in $m^3$/kg(dry air).
Range: 1.469E-3 ⩽ v ⩽ 3.055E5 [$m^3$/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , humidity ratio and specific volume of humid air.

```
>> h = HAFLK_SI_pWv_prop(101325, 0.05858452, 1.084645803, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pWh_prop

**MATLAB function usage :** HAFLK_SI_pWh_prop(p, W, h, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**h:** Specific enthalpy of humid air in J/kg.
Range: -311357 ⩽ h ⩽ 32135848 [J/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure , humidity ratio and specific enthalpy of humid air.

```
>> s = HAFLK_SI_pWh_prop(101325, 0.05858452, 2.322237342742833e+05, 's')
s  =
      767.109362
```

## FUNCTION NAME: HAFLK_SI_pTwbW_prop

**MATLAB function usage :** HAFLK_SI_pTwbW_prop(p, Twb, W, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Twb :** Wet-bulb temperature in K.
Range: 130.0 ⩽ Twb ⩽ 623.15 [K]

**W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , wet-bulb temperature and humidity ratio.

```
>> h = HAFLK_SI_pTwbW_prop(101325, 320, 0.05858452, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pTwbPHI_prop

**MATLAB function usage :** HAFLK_SI_pTwbPHI_prop(p, Twb, PHI, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Twb :** Wet-bulb temperature in K.
Range: 130.0 ⩽ Twb ⩽ 623.15 [K]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure , wet-bulb temperature and relative humidity.

```
>> s = HAFLK_SI_pTwbPHI_prop(101325, 320, 0.208032661, 's')
s  =
      767.109362
```

## FUNCTION NAME: HAFLK_SI_pTwbTd_prop

**MATLAB function usage :** HAFLK_SI_pTwbTd_prop(p, Twb, Td, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Twb :** Wet-bulb temperature in K.
Range: 130.0 ⩽ Twb ⩽ 623.15 [K]

**Td :** Dew point temperature in K.
Range: 130.0 ⩽ Td ⩽ 623.15 [K]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , wet-bulb temperature and dew point temperature.

```
>> h = HAFLK_SI_pTwbTd_prop(101325, 320, 316.2147093, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pTdh_prop

**MATLAB function usage :** HAFLK_SI_pTdh_prop(p, Td, h, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Td :** Dew point temperature in K.
Range: 130.0 ⩽ Td ⩽ 623.15 [K]

**h:** Specific enthalpy of humid air in J/kg.
Range: -311357 ⩽ h ⩽ 32135848 [J/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, dew point temperature and specifc enthalpy of humid air.

```
>> s = HAFLK_SI_pTdh_prop(101325, 316.2147093, 2.322237342742833e+05, 's')
s  =
      767.109362
```

## FUNCTION NAME: HAFLK_SI_pTdv_prop

**MATLAB function usage :** HAFLK_SI_pTdv_prop(p, Td, v, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Td :** Dew point temperature in K.
Range: 130.0 ⩽ Td ⩽ 623.15 [K]

**v :** Specific volume of humid air in $m^3$/kg(dry air).
Range: 1.469E-3 ⩽ v ⩽ 3.055E5 [$m^3$/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dew point temperature and specific volume of humid air.

```
>> h = HAFLK_SI_pTdv_prop(101325, 316.2147093, 1.084645803, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pWPHI_prop

**MATLAB function usage :** HAFLK_SI_pWPHI_prop(p, W, PHI, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, humidity ratio and relative humidity.

```
>> s = HAFLK_SI_pWPHI_prop(101325, 0.05858452, 0.208032661, 's')
s  =
      767.109362
```

## FUNCTION NAME: HAFLK_SI_pTdPHI_prop

**MATLAB function usage :** HAFLK_SI_pTdPHI_prop(p, Td, PHI, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**Td :** Dew point temperature in K.
Range: 130.0 ⩽ Td ⩽ 623.15 [K]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dew point temperature and relative humidity.

```
>> h = HAFLK_SI_pTdPHI_prop(101325, 316.2147093, 0.208032661, 'h')
h  =
      2.322237342742833e+05
```

## FUNCTION NAME: HAFLK_SI_pPHIh_prop

**MATLAB function usage :** HAFLK_SI_pPHIh_prop(p, PHI, h, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**h:** Specific enthalpy of humid air in J/kg.
Range: -311357 ⩽ h ⩽ 32135848 [J/kg]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, relative humidity and specific enthalpy of humid air.

```
>> s = HAFLK_SI_pPHIh_prop(101325, 0.208032661, 2.322237342742833e+05, 's')
s  =
      767.109362
```

| FUNCTION NAME: | HAFLK_SI_pPHIv_prop |
|---|---|

**MATLAB function usage :** HAFLK_SI_pPHIv_prop(p, PHI, v, prop)

**Input values :**

**p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**v :** Specific volume of humid air in $m^3/kg$(dry air).
Range: 1.469E-3 ⩽ v ⩽ 3.055E5 [$m^3/kg$]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, relative humidity and specific volume of humid air.

```
>> s = HAFLK_SI_pPHIv_prop(101325, 0.208032661, 1.084645803, 's')
s  =
      767.109362
```

| FUNCTION NAME: | SWFLK_SI_pT_hlw<br>**Specific enthalpy of liquid water** |
|---|---|

**MATLAB function usage :** SWFLK_SI_pT_hlw(p, T)

**Input values :**

**p :** Pressure in Pa.
Range: 611.2 ⩽ p ⩽ 10.0E6 [Pa]

**T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific enthalpy of liquid water in J/kg.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of liquid water as function of pressure and temperature.

```
>> hlw = SWFLK_SI_pT_hlw(101325, 350)
hlw  =
      321779.8144
```

**FUNCTION NAME:** **SWFLK_SI_T_hlws**

**Specific enthalpy of saturated liquid water**

**MATLAB function usage :** SWFLK_SI_T_hlws(T)

**Input values :** **T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific enthalpy of saturated liquid water in J/kg.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated liquid water as function of temperature.

```
>> hlws = SWFLK_SI_T_hlws(350)
hlws  =
      327131.9361
```

**FUNCTION NAME:** **SWFLK_SI_T_hwvs**

**Specific enthalpy of saturated water vapor**

**MATLAB function usage :** SWFLK_SI_T_hwvs(T)

**Input values :** **T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific enthalpy of saturated water vapor in J/kg.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated water vapor as function of temperature.

```
>> hlws = SWFLK_SI_T_hwvs(350)
hlws  =
      2637726.102
```

**FUNCTION NAME:** **SWFLK_SI_pT_slw**

**Specific entropy of liquid water**

**MATLAB function usage :** SWFLK_SI_pT_slw(p, T)

**Input values :** **p :** Pressure in Pa.
Range: 611.2 ⩽ p ⩽ 10.0E6 [Pa]

**T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific entropy of liquid water in J/(kg·K).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of liquid water as function of pressure and temperature.

```
>> slw = SWFLK_SI_pT_slw(101325, 350)
slw  =
      1037.776726
```

**FUNCTION NAME:** **SWFLK_SI_T_slws**

**Specific entropy of saturated liquid water**

**MATLAB function usage :** SWFLK_SI_T_slws(T)

**Input values :** **T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific entropy of saturated liquid water in J/(kg·K).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated liquid water as function of temperature.

```
>> hlws = SWFLK_SI_T_slws(350)
hlws  =
      327131.9361
```

**FUNCTION NAME:** **SWFLK_SI_T_swvs**

**Specific entropy of saturated water vapor**

**MATLAB function usage :** SWFLK_SI_T_swvs(T)

**Input values :** **T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific entropy of saturated water vapor in J/(kg·K).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated water vapor as function of temperature.

```
>> swvs = SWFLK_SI_T_swvs(350)
swvs  =
      7654.916038
```

**FUNCTION NAME:** **SWFLK_SI_pT_vlw**

**Specific volume of liquid water**

**MATLAB function usage :** SWFLK_SI_pT_vlw(p, T)

**Input values :** **p :** Pressure in Pa.
Range: 611.2 ⩽ p ⩽ 10.0E6 [Pa]

**T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific volume of liquid water in $m^3/kg$.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of liquid water as function of pressure and temperature.

```
>> vlw = SWFLK_SI_pT_vlw(101325, 350)
vlw  =
      0.001026966
```

**FUNCTION NAME:** **SWFLK_SI_T_vlws**

**Specific volume of saturated liquid water**

**MATLAB function usage :** SWFLK_SI_T_vlws(T)

**Input values :** **T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific volume of saturated liquid water in $m^3/kg$.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated liquid water as function of temperature.

```
>> vlws = SWFLK_SI_T_vlws(350)
vlws  =
      0.001026994
```

**FUNCTION NAME:** **SWFLK_SI_T_vwvs**

**Specific volume of saturated water vapor**

**MATLAB function usage :** SWFLK_SI_T_vwvs(T)

**Input values :** **T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Specific volume of saturated water vapor in $m^3/kg$.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated water vapor as function of temperature.

```
>> vwvs = SWFLK_SI_T_vwvs(350)
vwvs  =
      3.842011713
```

**FUNCTION NAME:** **SWFLK_SI_T_Pws**

**Saturation pressure of water**

**MATLAB function usage :** SWFLK_SI_T_Pws(T)

**Input values :** **T :** Temperature in K.
Range: 273.15 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Saturation pressure of water in Pa.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of saturation pressure of water as function of temperature.

```
>> Pws = SWFLK_SI_T_Pws(350)
Pws  =
      41681.80041
```

**FUNCTION NAME:** **SWFLK_SI_p_Tws**

**Saturation temperature of water**

**MATLAB function usage :** SWFLK_SI_p_Tws(p)

**Input values :** **p :** Pressure in Pa.
Range: 611.2 ⩽ p ⩽ 10.0E6 [Pa]

**Output Result :** **Saturation temperature of water in K.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of saturation temperature of water as function of pressure.

```
>> Tws = SWFLK_SI_p_Tws(101325)
Tws  =
      373.1243
```

**FUNCTION NAME:** **SWFLK_SI_T_hiws**

**Specific enthalpy of saturated ice**

**MATLAB function usage :** SWFLK_SI_T_hiws(T)

**Input values :** **T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 273.15 [K]

**Output Result :** **Specific enthalpy of saturated ice in J/kg.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated ice as function of temperature.

```
>> hiws = SWFLK_SI_T_hiws(200)
hiws  =
      -467356.9273
```

**FUNCTION NAME:** **SWFLK_SI_T_hwvs_sub**

**Specific enthalpy of saturated water vapor**

**MATLAB function usage :** SWFLK_SI_T_hwvs_sub(T)

**Input values :** **T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 273.15 [K]

**Output Result :** **Specific enthalpy of saturated water vapor in J/kg.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated water vapor as function of temperature.

```
>> hwvs_sub = SWFLK_SI_T_hwvs_sub(200)
hwvs_sub  =
      2365799.978
```

**FUNCTION NAME:** **SWFLK_SI_T_siws**

**Specific entropy of saturated ice**

**MATLAB function usage :** SWFLK_SI_T_siws(T)

**Input values :** **T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 273.15 [K]

**Output Result :** **Specific entropy of saturated ice in J/(kg·K).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated ice as function of temperature.

```
>> siws = SWFLK_SI_T_siws(200)
siws  =
      -1787.03005
```

**FUNCTION NAME:** **SWFLK_SI_T_swvs_sub**

**Specific entropy of saturated water vapor**

**MATLAB function usage :** SWFLK_SI_T_swvs_sub(T)

**Input values :** **T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 273.15 [K]

**Output Result :** **Specific entropy of saturated water vapor in J/(kg·K).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated water vapor as function of temperature.

```
>> swvs_sub = SWFLK_SI_T_swvs_sub(200)
swvs_sub  =
      12378.72979
```

**FUNCTION NAME:** **SWFLK_SI_T_viws**

**Specific volume of saturated ice**

**MATLAB function usage :** SWFLK_SI_T_viws(T)

**Input values :** **T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 273.15 [K]

**Output Result :** **Specific volume of saturated ice in $m^3/kg$.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated ice as function of temperature.

```
>> viws = SWFLK_SI_T_viws(200)
viws  =
      0.00107977154859
```

**FUNCTION NAME:** **SWFLK_SI_T_vwvs_sub**

**Specific volume of saturated water vapor**

**MATLAB function usage :** SWFLK_SI_T_vwvs_sub(T)

**Input values :** **T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 273.15 [K]

**Output Result :** **Specific volume of saturated water vapor in $m^3/kg$.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated water vapor as function of temperature.

```
>> swvs_sub = SWFLK_SI_T_swvs_sub(200)
swvs_sub  =
      567657.8133
```

| FUNCTION NAME: | **SWFLK_SI_T_Pmel**<br>**Melting pressure of ice** |
|---|---|

**MATLAB function usage :** SWFLK_SI_T_Pmel(T)

**Input values :** **T :** Temperature in K.
Range: 251.165 ⩽ T ⩽ 27315 [K]

**Output Result :** **Melting pressure of ice in Pa.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of melting pressure of ice as function of temperature.

```
>> Pmel = SWFLK_SI_T_Pmel(260)
Pmel  =
      138268113.002
```

| FUNCTION NAME: | **SWFLK_SI_T_Psub**<br>**Sublimation pressure of ice** |
|---|---|

**MATLAB function usage :** SWFLK_SI_T_Psub(T)

**Input values :** **T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 273.15 [K]

**Output Result :** **Sublimation pressure of ice in Pa.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of sublimation pressure of ice as function of temperature.

```
>> Psub = SWFLK_SI_T_Psub(260)
Psub  =
      195.801674
```

| FUNCTION NAME: | **SWFLK_SI_p_Tmel**<br>**Melting temperature of ice** |
|---|---|

**MATLAB function usage :** SWFLK_SI_p_Tmel(p)

**Input values :** **p :** Pressure in Pa.
Range: 611.2 ⩽ p ⩽ 10.0E6 [Pa]

**Output Result :** **Melting temperature of ice in K.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of melting temperature of ice as function of pressure.

```
>> Tmel = SWFLK_SI_p_Tmel(1000000)
Tmel  =
      273.085624
```

| FUNCTION NAME: | **SWFLK_SI_p_Tsub**<br>**Sublimation temperature of ice** |
|---|---|

**MATLAB function usage :** SWFLK_SI_p_Tsub(p)

**Input values :** **p :** Pressure in Pa.
Range: 1.2002E-8 ⩽ p ⩽ 611.2 [Pa]

**Output Result :** **Sublimation temperature of ice in K.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of sublimation temperature of ice as function of pressure.

```
>> Tsub = SWFLK_SI_p_Tsub(50)
Tsub  =
      245.815229
```

**FUNCTION NAME:** **SWFLK_SI_pT_Pwvs**

**Partial saturation pressure of water vapor**

**MATLAB function usage :** SWFLK_SI_pT_f(p, T)

**Input values :** **p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Partial saturation pressure of water vapor in Pa.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of the partial saturation pressure of water vapor as function of pressure and temperature.

```
>> Pwvs = SWFLK_SI_pT_Pwvs(101325, 300)
Pwvs  =
      3551.919133
```

**FUNCTION NAME:** **SWFLK_SI_pT_f**

**Enhancement factor**

**MATLAB function usage :** SWFLK_SI_pT_f(p, T)

**Input values :** **p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Enhancement factor in [-].**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of enhancement factor as function of pressure and temperature.

```
>> f = SWFLK_SI_pT_f(101325, 350)
f  =
      1.004334605
```

**FUNCTION NAME:** **SWFLK_SI_pT_Ws**

**Saturation humidity ratio**

**MATLAB function usage :** SWFLK_SI_pT_Ws(p, T)

**Input values :** **p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**T :** Temperature in K.
Range: 130.0 ⩽ T ⩽ 623.15 [K]

**Output Result :** **Saturation humidity ratio in kg(water)/kg(dry air).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of saturation humidity ratio as function of pressure and temperature.

```
>> Ws = SWFLK_SI_pT_Ws(101325, 300)
Ws  =
      0.022594148
```

**FUNCTION NAME:** **SWFLK_SI_pW_Td**

**Dew/frost point temperature**

**MATLAB function usage :** SWFLK_SI_pW_Td(p,W)

**Input values :** **p :** Pressure in Pa.
Range: 10 ⩽ p ⩽ 10.0E6 [Pa]

**W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**Output Result :** **Dew/frost point temperature in K.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of dew /frost point temperature as function of pressure and humidity ratio.

```
>> Td = SWFLK_SI_pW_Td(101325, 0.5)
Td  =
      351.8068
```

**FUNCTION NAME:** **SWFLK_SI_W_PSIda**

**Mole fraction of dry air**

**MATLAB function usage :** SWFLK_SI_W_PSIda(W)

**Input values :** **W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**Output Result :** **Mole fraction of dry air in mol(dry air)/mol.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mole fraction of dry air in humid air as function of humidity ratio.

```
>> PSIda = SWFLK_SI_W_PSIda(0.5)
PSIda  =
      0.554345481
```

**FUNCTION NAME:** **SWFLK_SI_W_PSIwv**

**Mole fraction of water vapor**

**MATLAB function usage :** SWFLK_SI_W_PSIwv(W)

**Input values :** **W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**Output Result :** **Mole fraction of water vapor in mol(water vapor)/mol.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mole fraction of water vapor in humid air as function of humidity ratio.

```
>> PSIwv = SWFLK_SI_W_PSIwv(0.5)
PSIwv  =
      0.44565419
```

**FUNCTION NAME:** **SWFLK_SI_W_XIda**

**Mass fraction of dry air**

**MATLAB function usage :** SWFLK_SI_W_XIda(W)

**Input values :** **W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**Output Result :** **Mass fraction of dry air in kg(dry air)/kg.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mass fraction of dry air in humid air as function of humidity ratio.

```
>> XIda = SWFLK_SI_W_XIda(0.5)
XIda  =
      0.666666
```

**FUNCTION NAME:** **SWFLK_SI_W_XIwv**

**Mass fraction of water vapor**

**MATLAB function usage :** SWFLK_SI_W_XIwv(W)

**Input values :** **W :** Humidity ratio kg(water)/kg(dry air).
Range: 0 ⩽ W ⩽ 10 [kg/kg]

**Output Result :** **Mass fraction of water vapor in kg(water vapor)/kg.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mass fraction of water vapor in humid air as function of humidity ratio.

```
>> XIwv = SWFLK_SI_W_XIwv(0.5)
XIwv  =
      0.333333
```

| **FUNCTION NAME:** | **SWFLK_SI_Zele_p**<br>**Pressure of humid air as function of elevation** |
|---|---|

**MATLAB function usage :** SWFLK_SI_Zele_p(Zele)

**Input values :** **Zele :** Elevation in m.
Range: -5000 ⩽ Zele ⩽ 11000 [m]

**Output Result :** **Humid air pressure in Pa.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of pressure of humid air as function elevation.

```
>> p = SWFLK_SI_Zele_p(0)
p  =
      101325
```

## 2.3 Library Functions Reference (I-P Units)

| FUNCTION NAME: | HAFLK_IP_pTdbTwb_prop |
|---|---|

**MATLAB function usage :** HAFLK_IP_pTdbTwb_prop(p, Tdb, Twb, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Tdb :** Dry-bulb temperature in °F.
Range: -225.67 ⩽ Tdb ⩽ 662 [°F]

**Twb :** Wet-bulb temperature in °F.
Range: -225.67 ⩽ Twb ⩽ 662 [°F]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and wet-bulb temperature.

```
>> h = HAFLK_IP_pTdbTwb_prop(14.7, 170.33, 116.33878, 'h')
h  =
      107.5238512
```

| FUNCTION NAME: | HAFLK_IP_pTdbTd_prop |
|---|---|

**MATLAB function usage :** HAFLK_IP_pTdbTd_prop(p, Tdb, Td, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Tdb :** Dry-bulb temperature in °F.
Range: -225.67 ⩽ Tdb ⩽ 662 [°F]

**Td :** Dew point temperature in °F.
Range: -225.67 ⩽ Td ⩽ 662 [°F]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and dew point temperature.

```
>> h = HAFLK_IP_pTdbTd_prop(14.7, 170.33, 109.525955, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pTdbPHI_prop

**MATLAB function usage :** HAFLK_IP_pTdbPHI_prop(p, Tdb, PHI, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Tdb :** Dry-bulb temperature in °F.
Range: -225.67 ⩽ Tdb ⩽ 662 [°F]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and relative humidity.

```
>> h = HAFLK_IP_pTdbPHI_prop(14.7, 170.33, 0.208089695, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pTdbW_prop

**MATLAB function usage :** HAFLK_IP_pTdbW_prop(p, Tdb, W, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Tdb :** Dry-bulb temperature in °F.
Range: -225.67 ⩽ Tdb ⩽ 662 [°F]

**W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and humidity ratio.

```
>> h = HAFLK_IP_pTdbW_prop(14.7, 170.33, 0.05858452, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pTdbh_prop

**MATLAB function usage :** HAFLK_IP_pTdbh_prop(p, Tdb, h, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Tdb :** Dry-bulb temperature in °F.
Range: -225.67 ⩽ Tdb ⩽ 662 [°F]

**h:** Specific enthalpy of humid air in Btu/lb.
Range: -126.174 ⩽ h ⩽ 13823.61 [Btu/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of humidity ratio "W" as function of pressure , dry-bulb temperature and specific enthalpy of humid air.

```
>> W = HAFLK_IP_pTdbh_prop(14.7, 170.33, 107.5238512, 'W')
W  =
      0.05858452
```

## FUNCTION NAME: HAFLK_IP_pTdbv_prop

**MATLAB function usage :** HAFLK_IP_pTdbv_prop(p, Tdb, v, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Tdb :** Dry-bulb temperature in °F.
Range: -225.67 ⩽ Tdb ⩽ 662 [°F]

**v :** Specific volume of humid air in $ft^3$/lb(dry air).
Range: 2.353E-2 ⩽ v ⩽ 4.893E6 [$ft^3$/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dry-bulb temperature and specific volume of humid air.

```
>> h = HAFLK_IP_pTdbv_prop(14.7, 170.33, 17.36955915, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pWv_prop

**MATLAB function usage :** HAFLK_IP_pWv_prop(p, W, v, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**v :** Specific volume of humid air in $ft^3$/lb(dry air).
Range: 2.353E-2 ⩽ v ⩽ 4.893E6 [$ft^3$/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , humidity ratio and specific volume of humid air.

```
>> h = HAFLK_IP_pWv_prop(14.7, 0.05858452, 17.36955915, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pWh_prop

**MATLAB function usage :** HAFLK_IP_pWh_prop(p, W, h, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**h:** Specific enthalpy of humid air in Btu/lb.
Range: -126.174 ⩽ h ⩽ 13823.61 [Btu/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure , humidity ratio and specific enthalpy of humid air.

```
>> s = HAFLK_IP_pWh_prop(14.7, 0.05858452, 107.5238512, 's')
s  =
     0.199362086
```

| FUNCTION NAME: | HAFLK_IP_pTwbW_prop |
|---|---|

**MATLAB function usage :** HAFLK_IP_pTwbW_prop(p, Twb, W, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Twb :** Wet-bulb temperature in °F.
Range: -225.67 ⩽ Twb ⩽ 662 [°F]

**W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , wet-bulb temperature and humidity ratio.

```
>> h = HAFLK_IP_pTwbW_prop(14.7, 116.33878764, 0.05858452, 'h')
h  =
      107.5238512
```

| FUNCTION NAME: | HAFLK_IP_pTwbPHI_prop |
|---|---|

**MATLAB function usage :** HAFLK_IP_pTwbPHI_prop(p, Twb, PHI, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Twb :** Wet-bulb temperature in °F.
Range: -225.67 ⩽ Twb ⩽ 662 [°F]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure , wet-bulb temperature and relative humidity.

```
>> s = HAFLK_IP_pTwbPHI_prop(14.7, 116.33878764, 0.208089695, 's')
s  =
      0.199362086
```

## FUNCTION NAME: HAFLK_IP_pTwbTd_prop

**MATLAB function usage :** HAFLK_IP_pTwbTd_prop(p, Twb, Td, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Twb :** Wet-bulb temperature in °F.
Range: -225.67 ⩽ Twb ⩽ 662 [°F]

**Td :** Dew point temperature in °F.
Range: -225.67 ⩽ Td ⩽ 662 [°F]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , wet-bulb temperature and dew point temperature.

```
>> h = HAFLK_IP_pTwbTd_prop(14.7, 116.33878764, 109.5259551, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pTdh_prop

**MATLAB function usage :** HAFLK_IP_pTdh_prop(p, Td, h, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Td :** Dew point temperature in °F.
Range: -225.67 ⩽ Td ⩽ 662 [°F]

**h:** Specific enthalpy of humid air in Btu/lb.
Range: -126.174 ⩽ h ⩽ 13823.61 [Btu/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, dew point temperature and specifc enthalpy of humid air.

```
>> s = HAFLK_IP_pTdh_prop(14.7, 109.5259551, 107.5238512, 's')
s  =
      0.199362086
```

## FUNCTION NAME: HAFLK_IP_pTdv_prop

**MATLAB function usage :** HAFLK_IP_pTdv_prop(p, Td, v, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Td :** Dew point temperature in °F.
Range: -225.67 ⩽ Td ⩽ 662 [°F]

**v :** Specific volume of humid air in $ft^3/lb$(dry air).
Range: 2.353E-2 ⩽ v ⩽ 4.893E6 [$ft^3/lb$]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dew point temperature and specific volume of humid air.

```
>> h = HAFLK_IP_pTdv_prop(14.7, 109.5259551, 17.36955915, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pWPHI_prop

**MATLAB function usage :** HAFLK_IP_pWPHI_prop(p, W, PHI, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, humidity ratio and relative humidity.

```
>> s = HAFLK_IP_pWPHI_prop(14.7, 0.05858452, 0.208089695, 's')
s  =
      0.199362086
```

## FUNCTION NAME: HAFLK_IP_pTdPHI_prop

**MATLAB function usage :** HAFLK_IP_pTdPHI_prop(p, Td, PHI, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**Td :** Dew point temperature in °F.
Range: -225.67 ⩽ Td ⩽ 662 [°F]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of humid air "h" as function of pressure , dew point temperature and relative humidity.

```
>> h = HAFLK_IP_pTdPHI_prop(14.7, 109.5259551, 0.208089695, 'h')
h  =
      107.5238512
```

## FUNCTION NAME: HAFLK_IP_pPHIh_prop

**MATLAB function usage :** HAFLK_IP_pPHIh_prop(p, PHI, h, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**h:** Specific enthalpy of humid air in Btu/lb.
Range: -126.174 ⩽ h ⩽ 13823.61 [Btu/lb]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, relative humidity and specific enthalpy of humid air.

```
>> s = HAFLK_IP_pPHIh_prop(14.7, 0.208089695, 107.5238512, 's')
s  =
      0.199362086
```

| FUNCTION NAME: | HAFLK_IP_pPHIv_prop |
|---|---|

**MATLAB function usage :** HAFLK_IP_pPHIv_prop(p, PHI, v, prop)

**Input values :**

**p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**PHI :** Relative Humidity in (decimal ratio)
Range: 0 ⩽ PHI ⩽ 1 [-]

**v :** Specific volume of humid air in $ft^3/lb$(dry air).
Range: 2.353E-2 ⩽ v ⩽ 4.893E6 [$ft^3/lb$]

**prop:** Output Property. String (see Table 7)

**Output Result :** See Table 7.

**Invalid Output Result :** **-9999** For input values outside the valid range , an incorrect string **prop**, or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of humid air "s" as function of pressure, relative humidity and specific volume of humid air.

```
>> s = HAFLK_IP_pPHIv_prop(14.7, 0.208089695, 17.36955915, 's')
s  =
      0.199362086
```

| FUNCTION NAME: | SWFLK_IP_pT_hlw<br>**Specific enthalpy of liquid water** |
|---|---|

**MATLAB function usage :** SWFLK_IP_pT_hlw(p, T)

**Input values :**

**p :** Pressure in psi.
Range: 0.08865 ⩽ p ⩽ 1450.4 [psi]

**T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific enthalpy of liquid water in Btu/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of liquid water as function of pressure and temperature.

```
>> hlw = SWFLK_IP_pT_hlw(14.7, 170.33)
hlw  =
      138.3404241
```

**FUNCTION NAME:** **SWFLK_IP_T_hlws**

**Specific enthalpy of saturated liquid water**

**MATLAB function usage :** SWFLK_IP_T_hlws(T)

**Input values :** **T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific enthalpy of saturated liquid water in Btu/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated liquid water as function of temperature.

```
>> hlws = SWFLK_IP_T_hlws(170.33)
hlws  =
          138.3198305
```

**FUNCTION NAME:** **SWFLK_IP_T_hwvs**

**Specific enthalpy of saturated water vapor**

**MATLAB function usage :** SWFLK_IP_T_hwvs(T)

**Input values :** **T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific enthalpy of saturated water vapor in Btu/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated water vapor as function of temperature.

```
>> hlws = SWFLK_IP_T_hwvs(170.33)
hlws  =
      1134.018064
```

| FUNCTION NAME: | **SWFLK_IP_pT_slw**<br>**Specific entropy of liquid water** |
|---|---|

**MATLAB function usage :** SWFLK_IP_pT_slw(p, T)

**Input values :** **p :** Pressure in psi.
Range: 0.08865 ⩽ p ⩽ 1450.4 [psi]

**T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific entropy of liquid water in Btu/(lb·°R).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of liquid water as function of pressure and temperature.

```
>> slw = SWFLK_IP_pT_slw(14.7, 170.33)
slw  =
      0.2478687127
```

| FUNCTION NAME: | **SWFLK_IP_T_slws**<br>**Specific entropy of saturated liquid water** |
|---|---|

**MATLAB function usage :** SWFLK_IP_T_slws(T)

**Input values :** **T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific entropy of saturated liquid water in Btu/(lb·°R).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated liquid water as function of temperature.

```
>> slws = SWFLK_IP_T_slws(170.33)
slws  =
      0.247877833
```

**FUNCTION NAME:** **SWFLK_IP_T_swvs**

**Specific entropy of saturated water vapor**

**MATLAB function usage :** SWFLK_IP_T_swvs(T)

**Input values :** **T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific entropy of saturated water vapor in Btu/(lb·°R).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated water vapor as function of temperature.

```
>> swvs = SWFLK_IP_T_swvs(170.33)
swvs  =
      1.828345234
```

**FUNCTION NAME:** **SWFLK_IP_pT_vlw**

**Specific volume of liquid water**

**MATLAB function usage :** SWFLK_IP_pT_vlw(p, T)

**Input values :** **p :** Pressure in psi.
Range: 0.08865 ⩽ p ⩽ 1450.4 [psi]

**T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific volume of liquid water in ft³/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of liquid water as function of pressure and temperature.

```
>> vlw = SWFLK_IP_pT_vlw(14.7, 170.33)
vlw  =
      0.016450411
```

**FUNCTION NAME:** **SWFLK_IP_T_vlws**

**Specific volume of saturated liquid water**

**MATLAB function usage :** SWFLK_IP_T_vlws(T)

**Input values :** **T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific volume of saturated liquid water in ft³/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated liquid water as function of temperature.

```
>> vlws = SWFLK_IP_T_vlws(170.33)
vlws  =
      0.016450859
```

**FUNCTION NAME:** **SWFLK_IP_T_vwvs**

**Specific volume of saturated water vapor**

**MATLAB function usage :** SWFLK_IP_T_vwvs(T)

**Input values :** **T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Specific volume of saturated water vapor in ft³/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated water vapor as function of temperature.

```
>> vwvs = SWFLK_IP_T_vwvs(170.33)
vwvs  =
      61.543084
```

**FUNCTION NAME:** **SWFLK_IP_T_Pws**

**Saturation pressure of water**

**MATLAB function usage :** SWFLK_IP_T_Pws(T)

**Input values :** **T :** Temperature in °F.
Range: 32 ⩽ T ⩽ 662 [°F]

**Output Result :** **Saturation pressure of water in psi.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of saturation pressure of water as function of temperature.

```
>> Pws = SWFLK_IP_T_Pws(170.33)
Pws  =
      6.045437047
```

**FUNCTION NAME:** **SWFLK_IP_p_Tws**

**Saturation temperature of water**

**MATLAB function usage :** SWFLK_IP_p_Tws(p)

**Input values :** **p :** Pressure in psi.
Range: 0.08865 ⩽ p ⩽ 1450.4 [psi]

**Output Result :** **Saturation temperature of water in °F.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of saturation temperature of water as function of pressure.

```
>> Tws = SWFLK_IP_p_Tws(14.7)
Tws  =
      211.9676389
```

**FUNCTION NAME:** **SWFLK_IP_T_hiws**

**Specific enthalpy of saturated ice**

**MATLAB function usage :** SWFLK_IP_T_hiws(T)

**Input values :** **T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 32 [°F]

**Output Result :** **Specific enthalpy of saturated ice in Btu/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated ice as function of temperature.

```
>> hiws = SWFLK_IP_T_hiws(-120)
hiws  =
      -208.351286
```

**FUNCTION NAME:** **SWFLK_IP_T_hwvs_sub**

**Specific enthalpy of saturated water vapor**

**MATLAB function usage :** SWFLK_IP_T_hwvs_sub(T)

**Input values :** **T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 32 [°F]

**Output Result :** **Specific enthalpy of saturated water vapor in Btu/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific enthalpy of saturated water vapor as function of temperature.

```
>> hwvs_sub = SWFLK_IP_T_hwvs_sub(-120)
hwvs_sub  =
      1008.123578
```

**FUNCTION NAME:** **SWFLK_IP_T_siws**

**Specific entropy of saturated ice**

**MATLAB function usage :** SWFLK_IP_T_siws(T)

**Input values :** **T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 32 [°F]

**Output Result :** **Specific entropy of saturated ice in Btu/(lb·°R).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated ice as function of temperature.

```
>> siws = SWFLK_IP_T_siws(-120)
siws  =
      -0.44804684
```

**FUNCTION NAME:** **SWFLK_IP_T_swvs_sub**

**Specific entropy of saturated water vapor**

**MATLAB function usage :** SWFLK_IP_T_swvs_sub(T)

**Input values :** **T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 32 [°F]

**Output Result :** **Specific entropy of saturated water vapor in Btu/(lb·°R).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific entropy of saturated water vapor as function of temperature.

```
>> swvs_sub = SWFLK_IP_T_swvs_sub(-120)
swvs_sub  =
      3.133285178
```

**FUNCTION NAME:** **SWFLK_IP_T_viws**

**Specific volume of saturated ice**

**MATLAB function usage :** SWFLK_IP_T_viws(T)

**Input values :** **T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 32 [°F]

**Output Result :** **Specific volume of saturated ice in ft³/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated ice as function of temperature.

```
>> viws = SWFLK_IP_T_viws(-120)
viws  =
      0.01727435811
```

**FUNCTION NAME:** **SWFLK_IP_T_vwvs_sub**

**Specific volume of saturated water vapor**

**MATLAB function usage :** SWFLK_IP_T_vwvs_sub(T)

**Input values :** **T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 32 [°F]

**Output Result :** **Specific volume of saturated water vapor in ft³/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of specific volume of saturated water vapor as function of temperature.

```
>> swvs_sub = SWFLK_IP_T_vwvs_sub(-120)
swvs_sub  =
      5.3799986E+07
```

| FUNCTION NAME: | **SWFLK_IP_T_Pmel**<br>**Melting pressure of ice** |
|---|---|

**MATLAB function usage :** SWFLK_IP_T_Pmel(T)

**Input values :** **T :** Temperature in °F.
Range: -7.57 ⩽ T ⩽ 32 [°F]

**Output Result :** **Melting pressure of ice in psi.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of melting pressure of ice as function of temperature.

```
>> Pmel = SWFLK_IP_T_Pmel(-2)
Pmel  =
      26857.35023
```

| FUNCTION NAME: | **SWFLK_IP_T_Psub**<br>**Sublimation pressure of ice** |
|---|---|

**MATLAB function usage :** SWFLK_IP_T_Psub(T)

**Input values :** **T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 32 [°F]

**Output Result :** **Sublimation pressure of ice in psi.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of sublimation pressure of ice as function of temperature.

```
>> Psub = SWFLK_IP_T_Psub(-120)
Psub  =
      3.76091E-06
```

| FUNCTION NAME: | **SWFLK_IP_p_Tmel**<br>**Melting temperature of ice** |
|---|---|

**MATLAB function usage :** SWFLK_IP_p_Tmel(p)

**Input values :** **p :** Pressure in psi.
Range: 0.08865 ⩽ p ⩽ 1450.4 [psi]

**Output Result :** **Melting temperature of ice in °F.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of melting temperature of ice as function of pressure.

```
>> Tmel = SWFLK_IP_p_Tmel(500)
Tmel  =
      31.553877
```

| FUNCTION NAME: | **SWFLK_IP_p_Tsub**<br>**Sublimation temperature of ice** |
|---|---|

**MATLAB function usage :** SWFLK_IP_p_Tsub(p)

**Input values :** **p :** Pressure in psi.
Range: 1.741E-12 ⩽ p ⩽ 0.08865 [psi]

**Output Result :** **Sublimation temperature of ice in °F.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of sublimation temperature of ice as function of pressure.

```
>> Tsub = SWFLK_IP_p_Tsub(0.5)
Tsub  =
      19.79945515
```

**FUNCTION NAME:** **SWFLK_IP_pT_Pwvs**

**Partial saturation pressure of water vapor**

**MATLAB function usage :** SWFLK_IP_pT_Pwvs(p, T)

**Input values :** **p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 662 [°F]

**Output Result :** **Partial saturation pressure of water vapor in psi.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of the partial saturation pressure of water vapor as function of pressure and temperature.

```
>> Pwvs = SWFLK_IP_pT_Pwvs(14.7, 170.33)
Pwvs  =
      6.0813839
```

**FUNCTION NAME:** **SWFLK_IP_pT_f**

**Enhancement factor**

**MATLAB function usage :** SWFLK_IP_pT_f(p, T)

**Input values :** **p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 662 [°F]

**Output Result :** **Enhancement factor in [-].**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of enhancement factor as function of pressure and temperature.

```
>> f = SWFLK_IP_pT_f(14.7, 170.33)
f  =
      1.005946623
```

| FUNCTION NAME: | **SWFLK_IP_pT_Ws**<br>**Saturation humidity ratio** |
|---|---|

**MATLAB function usage :** SWFLK_IP_pT_Ws(p, T)

**Input values :** **p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**T :** Temperature in °F.
Range: -225.67 ⩽ T ⩽ 662 [°F]

**Output Result :** **Saturation humidity ratio in lb(water)/lb(dry air).**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of saturation humidity ratio as function of pressure and temperature.

```
>> Ws = SWFLK_IP_pT_Ws(14.7, 170.33)
Ws  =
      0.4388510306
```

| FUNCTION NAME: | **SWFLK_IP_pW_Td**<br>**Dew/frost point temperature** |
|---|---|

**MATLAB function usage :** SWFLK_IP_pW_Td(p,W)

**Input values :** **p :** Pressure in psi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

**W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**Output Result :** **Dew/frost point temperature in °F.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of dew point temperature as function of pressure and humidity ratio.

```
>> Td = SWFLK_IP_pW_Td(14.7, 0.5)
Td  =
      173.594303
```

**FUNCTION NAME:** **SWFLK_IP_W_PSIda**

**Mole fraction of dry air**

**MATLAB function usage :** SWFLK_IP_W_PSIda(W)

**Input values :** **W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**Output Result :** **Mole fraction of dry air in mol(dry air)/mol.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mole fraction of dry air in humid air as function of humidity ratio.

```
>> PSIda = SWFLK_IP_W_PSIda(0.5)
PSIda  =
      0.554345481
```

**FUNCTION NAME:** **SWFLK_IP_W_PSIwv**

**Mole fraction of water vapor**

**MATLAB function usage :** SWFLK_IP_W_PSIwv(W)

**Input values :** **W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**Output Result :** **Mole fraction of water vapor in mol(water vapor)/mol.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mole fraction of water vapor in humid air as function of humidity ratio.

```
>> PSIwv = SWFLK_IP_W_PSIwv(0.5)
PSIwv  =
      0.44565419
```

**FUNCTION NAME:** **SWFLK_IP_W_XIda**

**Mass fraction of dry air**

**MATLAB function usage :** SWFLK_IP_W_XIda(W)

**Input values :** **W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**Output Result :** **Mass fraction of dry air in lb(dry air)/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mass fraction of dry air in humid air as function of humidity ratio.

```
>> XIda = SWFLK_IP_W_XIda(0.5)
XIda  =
      0.666666
```

**FUNCTION NAME:** **SWFLK_IP_W_XIwv**

**Mass fraction of water vapor**

**MATLAB function usage :** SWFLK_IP_W_XIwv(W)

**Input values :** **W :** Humidity ratio lb(water)/lb(dry air).
Range: 0 ⩽ W ⩽ 10 [lb/lb]

**Output Result :** **Mass fraction of water vapor in lb(water vapor)/lb.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of mass fraction of water vapor in humid air as function of humidity ratio.

```
>> XIwv = SWFLK_IP_W_XIwv(0.5)
XIwv  =
      0.333333
```

| **FUNCTION NAME:** | **SWFLK_IP_Zele_p**<br>**Pressure of humid air as function of elevation** |
|---|---|

**MATLAB function usage :** SWFLK_IP_Zele_p(W)

**Input values :** **Zele :** Elevation in ft.
Range: -16404 ⩽ Zele ⩽ 36089 [ft]

**Output Result :** **Humid air pressure in psi.**

**Invalid Output Result :** **-9999** For input values outside the valid range or invalid calculation result.

**Example :** Calculation returns the value of pressure of humid air as a function of elevation.

```
>> p = SWFLK_IP_Zele_p(0)
p  =
      14.695948
```

# References


- American Society of Heating; Owen, Mark. S.: *2009 ASHRAE Handbook: Fundamentals. ASHRAE* (2009)
- Herrmann , Sebastian .; Kretzschmar, Hans-Joachim.; Gatley, Donald P.: *Thermodynamic properties of real moist air, dry air, steam, water, and ice (RP-1485).* HVAC & R Research, (2011).
- Herrmann, S.; Kretzschmar, H.-J.; Teske, V.; Vogel, E.; Ulbig, P.; Span, R.; Gatley, D.P.: Determination of Thermodynamic and Transport Properties for Humid Air for Power-Cycle Calculations. PTB-Verlag, Braunschweig (2009).
- Lemmon, E. W.; Jacobsen, R. T.; Penoncello, S. G.; Friend, D. G.: *Thermodynamic Properties of Air and Mixture of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa.* J. Phys. Chem. Ref. Data 29, 331-385 (2000).
- Nelson, H.F.; Sauer, H.J.: *Formulation of High-Temperature Properties for Moist Air.* HVAC & R Research 8, 311-334 (2002).
- 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).
- Wagner, W.; Kretzschmar, H.-J.: *International Steam Tables.* Springer, Berlin (2008).