Humid Air Properties

Psychrometrics

Dynamic-Link Library (DLL)

USER GUIDE

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

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1.1 Introduction

HUMID AIR DLL is a C++ Dynamic-Link Library used in the development of Windows applications that incorporate 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.

Any Windows client application that supports C++ function imports can make use of this library by including it in its deployment.

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

1.2 Description

- Full support of .NET, C++, C# framework development environments.

- 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 Water 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
- 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

1.3 Deployment Requirements

The following are the requirements in order to deploy HUMID AIR DLL as part of a Windows application.

Please note that if the operating system in which the client application will be deployed doesn't have the corresponding C++ Runtime Library or the necessary files from this library to operate, HUMID AIR DLL will not work as expected.

The C++ Runtime Library should be distributed and installed as part of the client application, or the necessary core files from this library should be accessible to the dll file.

Operating System (64 and 32-bit)	Windows 7 Windows 8 Windows 8.1 Windows 10
C++ Runtime Library (64-bit)	Microsoft Visual C++ 2015-2019 Redistributable (x64)
C++ Runtime Library (32-bit)	Microsoft Visual C++ 2015-2019 Redistributable(x86)

Table 1. Requirements to deploy HUMID AIR DLL in a client Windows application.

1.4 Installation

Double-click on the installation file and follow the on-screen instructions. When prompted, introduce the **License Key** that was delivered to you. Contact **support@fluidika.com** if you require assistance.

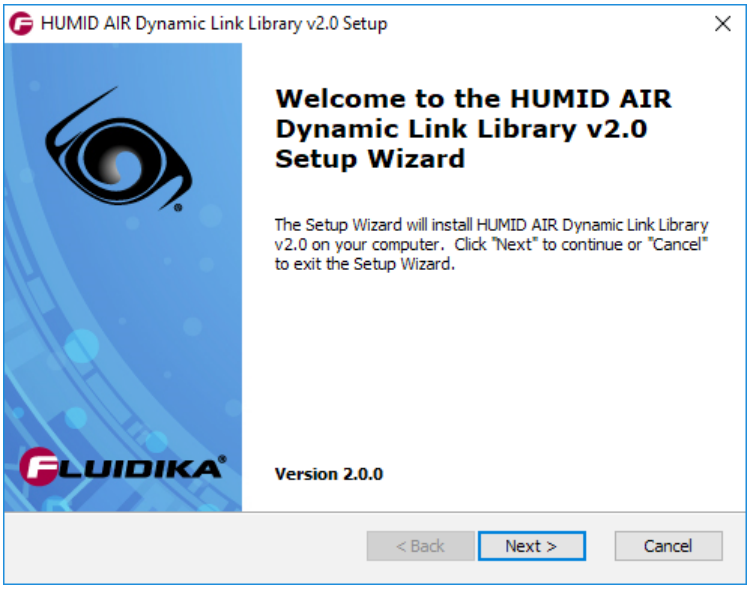

Figure 1. Installation screen of HUMID AIR DLL.

1.5 Contents of installation

```
+---DOCS
|       EULA.rtf
|       HUMIDAIR_DLL_KEY_DEFINITIONS.pdf
|       HUMIDAIR_DLL_USER_GUIDE.pdf
|
+---EXAMPLES
|   \---VS2019
|       +---32BIT
|       |   +---TEST_LIB_CPP32
|       |   |
|       |   \---TEST_LIB_NET32
|       |
|       \---64BIT
|           +---TEST_LIB_CPP64
|           |
|           \---TEST_LIB_NET64
|
+---VC
|       vc_redist.x64.exe
|       vc_redist.x86.exe
|
\--LIBS
    +---32BIT
    |       HUMIDAIRFLK32.dll
    |
    \---64BIT
            HUMIDAIRFLK64.dll
```

Figure 2. Tree view of directories and main files after installation of HUMID AIR DLL.

Figure 2 shows the contents of the installation as a tree view of the directories and main files included in HUMID AIR DLL. Figures 3 and 4 show a detailed description of the main files and directories installed.

```
+---DOCS
|       EULA.rtf
|                   End-User License Agreement for the Dynamic Link Libraries and related
|                   material included in this installation.
|
|       HUMIDAIR_DLL_KEY_DEFINITIONS.pdf
|                   Document that comprises all the key constants needed to call, in the client
|                   application, the export calculation functions defined in HUMID AIR DLL.
|
|       HUMIDAIR_DLL_USER_GUIDE.pdf
|                   This document.
|
+---EXAMPLES
|   \---VS2019
|       +---32BIT
|       |   +---TEST_LIB_CPP32
|       |   |       Application example of the HUMID AIR dll used in a Visual Studio 2019
|       |   |       console app developed in C++ (32-bit).
|       |   |
|       |   \---TEST_LIB_NET32
|       |           Application example of the HUMID AIR dll used in a Visual Studio 2019
|       |           console app developed in .NET C#  (32-bit).
|       |
|       \---64BIT
|           +---TEST_LIB_CPP64
|           |       Application example of the HUMID AIR dll used in a Visual Studio 2019
|           |       console app developed in C++ (64-bit).
|           |
|           \---TEST_LIB_NET64
|                   Application example of the HUMID AIR dll used in a Visual Studio 2019
|                   console app developed in .NET C#  (64-bit).
|
+---VC
        vc_redist.x64.exe
                  Microsoft Visual C++ 2015-2019 Redistributable (x64) 14.21.27702
        vc_redist.x86.exe
                  Microsoft Visual C++ 2015-2019 Redistributable (x86) 14.21.27702
```

Figure 3. Detailed description of directories and main files after installation of HUMID AIR DLL.

```
\---LIBS
    +---32BIT
    |       HUMIDAIRFLK32.dll
    |       Dynamic -Link Library file of HUMID AIR in 32-bit for release. This is the file to
    |       be included when releasing 32-bit client applications.
    |
    \---64BIT
            HUMIDAIRFLK64.dll
            Dynamic -Link Library file of HUMID AIR in 64-bit for release. This is the file to
            be included when releasing 64-bit client applications.
```

Figure 4. Detailed description of directories and main files after installation of HUMID AIR DLL (continuation).

1.6 Upgrades

Information about upgrades will be send to the email address that was registered at the time of acquiring the **License Key**. Contact **support@fluidika.com** if you require assistance.

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 (IAPWS) are used to delimitate the calculations according to the pressure-temperature diagram in Figure 5.

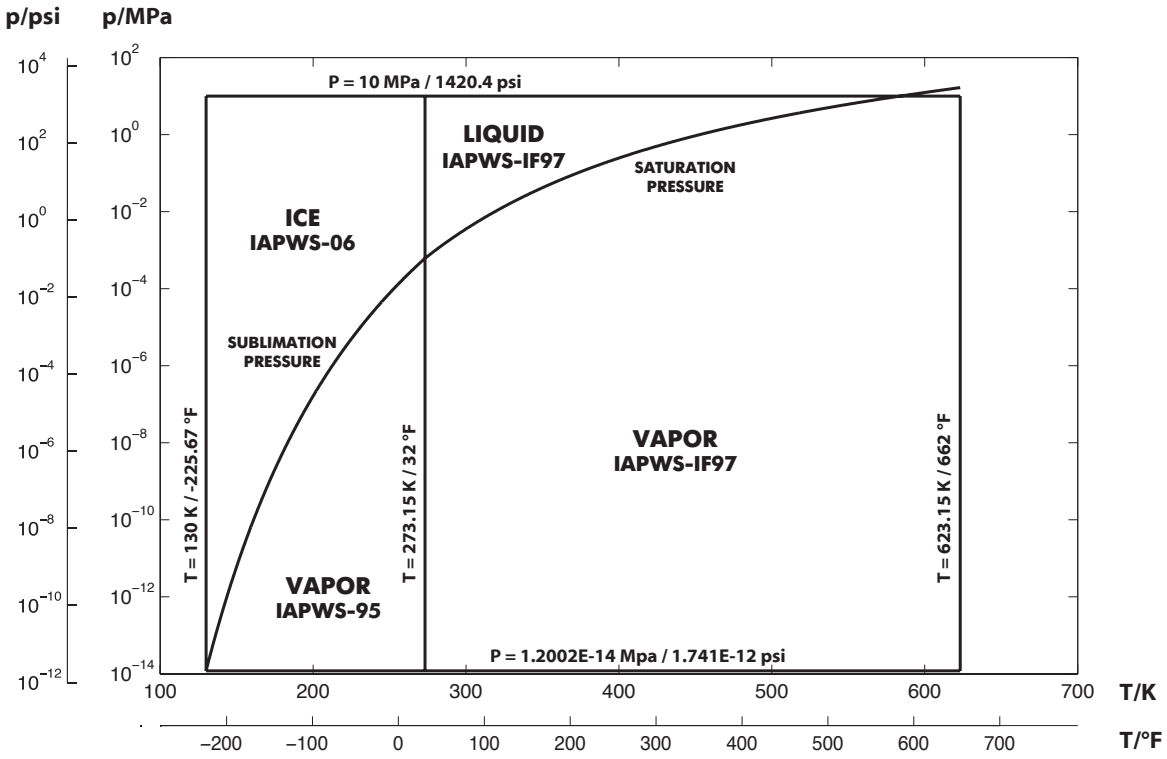

Figure 5. Range of validity of the functions defined in HUMID AIR DLL

The absolute range for input and output variables is shown in Table 2. These values delimitate the numerical calculations. 17 possible combination of input variables plus pressure are shown in Table 3. For each of these possible combinations of input variables, the properties that are calculated are described in Table 8.

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 2. Absolute ranges for input variables used in HUMID AIR DLL

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 3. Combination of input variables used in HUMID AIR DLL

2.2 Export Functions

HUMID AIR DLL Dynamic-Link Library is composed of Export Functions that take parameters (char * and double) and returns a double (result number).

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

-9999

Table 4 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 5 and 6. Additional functions are shown in Table 7.

SI UNITS	I-P UNITS	OUTPUT RESULT
HUMIDAIRFLK_SI_pTdbTwb_prop	HUMIDAIRFLK_IP_pTdbTwb_prop	**Depending on value of "prop", see Table 8**
HUMIDAIRFLK_SI_pTdbTd_prop	HUMIDAIRFLK_IP_pTdbTd_prop	
HUMIDAIRFLK_SI_pTdbPHI_prop	HUMIDAIRFLK_IP_pTdbPHI_prop	
HUMIDAIRFLK_SI_pTdbW_prop	HUMIDAIRFLK_IP_pTdbW_prop	
HUMIDAIRFLK_SI_pTdbh_prop	HUMIDAIRFLK_IP_pTdbh_prop	
HUMIDAIRFLK_SI_pTdbv_prop	HUMIDAIRFLK_IP_pTdbv_prop	
HUMIDAIRFLK_SI_pTwbTd_prop	HUMIDAIRFLK_IP_pTwbTd_prop	
HUMIDAIRFLK_SI_pTwbPHI_prop	HUMIDAIRFLK_IP_pTwbPHI_prop	
HUMIDAIRFLK_SI_pTwbW_prop	HUMIDAIRFLK_IP_pTwbW_prop	
HUMIDAIRFLK_SI_pTdPHI_prop	HUMIDAIRFLK_IP_pTdPHI_prop	
HUMIDAIRFLK_SI_pTdh_prop	HUMIDAIRFLK_IP_pTdh_prop	
HUMIDAIRFLK_SI_pTdv_prop	HUMIDAIRFLK_IP_pTdv_prop	
HUMIDAIRFLK_SI_pWPHI_prop	HUMIDAIRFLK_IP_pWPHI_prop	
HUMIDAIRFLK_SI_pWh_prop	HUMIDAIRFLK_IP_pWh_prop	
HUMIDAIRFLK_SI_pWv_prop	HUMIDAIRFLK_IP_pWv_prop	
HUMIDAIRFLK_SI_pPHIh_prop	HUMIDAIRFLK_IP_pPHIh_prop	
HUMIDAIRFLK_SI_pPHIv_prop	HUMIDAIRFLK_IP_pPHIv_prop	

Table 4. Functions based on combination of input variables

SI UNITS	I-P UNITS	OUTPUT RESULT
HUMIDAIRFLK_SI_pT_hlw	HUMIDAIRFLK_IP_pT_hlw	**Specific enthalpy of liquid water**
HUMIDAIRFLK_SI_T_hlws	HUMIDAIRFLK_IP_T_hlws	**Specific enthalpy of saturated liquid water**
HUMIDAIRFLK_SI_T_hwvs	HUMIDAIRFLK_IP_T_hwvs	**Specific enthalpy of saturated water vapor**
HUMIDAIRFLK_SI_pT_slw	HUMIDAIRFLK_IP_pT_slw	**Specific entropy of liquid water**
HUMIDAIRFLK_SI_T_slws	HUMIDAIRFLK_IP_T_slws	**Specific entropy of saturated liquid water**
HUMIDAIRFLK_SI_T_swvs	HUMIDAIRFLK_IP_T_swvs	**Specific entropy of saturated water vapor**
HUMIDAIRFLK_SI_pT_vlw	HUMIDAIRFLK_IP_pT_vlw	**Specific volume of liquid water**
HUMIDAIRFLK_SI_T_vlws	HUMIDAIRFLK_IP_T_vlws	**Specific volume of saturated liquid water**
HUMIDAIRFLK_SI_T_vwvs	HUMIDAIRFLK_IP_T_vwvs	**Specific volume of saturated water vapor**
HUMIDAIRFLK_SI_T_Pws	HUMIDAIRFLK_IP_T_Pws	**Saturation pressure of water**
HUMIDAIRFLK_SI_p_Tws	HUMIDAIRFLK_IP_p_Tws	**Saturation temperature of water**

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

SI UNITS	I-P UNITS	OUTPUT RESULT
HUMIDAIRFLK_SI_T_hiws	HUMIDAIRFLK_IP_T_hiws	**Specific enthalpy of saturated ice**
HUMIDAIRFLK_SI_T_hwvs_sub	HUMIDAIRFLK_IP_T_hwvs_sub	**Specific enthalpy of saturated water vapor**
HUMIDAIRFLK_SI_T_siws	HUMIDAIRFLK_IP_T_siws	**Specific entropy of saturated ice**
HUMIDAIRFLK_SI_T_swvs_sub	HUMIDAIRFLK_IP_T_swvs_sub	**Specific entropy of saturated water vapor**
HUMIDAIRFLK_SI_T_viws	HUMIDAIRFLK_IP_T_viws	**Specific volume of saturated ice**
HUMIDAIRFLK_SI_T_vwvs_sub	HUMIDAIRFLK_IP_T_vwvs_sub	**Specific volume of saturated water vapor**
HUMIDAIRFLK_SI_T_Pmel	HUMIDAIRFLK_IP_T_Pmel	**Melting pressure of ice**
HUMIDAIRFLK_SI_T_Psub	HUMIDAIRFLK_IP_T_Psub	**Sublimation pressure of ice**
HUMIDAIRFLK_SI_p_Tmel	HUMIDAIRFLK_IP_p_Tmel	**Melting temperature of ice**
HUMIDAIRFLK_SI_p_Tsub	HUMIDAIRFLK_IP_p_Tsub	**Sublimation temperature of ice**

Table 6. **Functions for T ≤ 273.15 K / 32 °F**

SI UNITS	I-P UNITS	OUTPUT RESULT
HUMIDAIRFLK_SI_pT_Pwvs	HUMIDAIRFLK_IP_pT_Pwvs	**Partial saturation pressure of water vapor**
HUMIDAIRFLK_SI_pT_f	HUMIDAIRFLK_IP_pT_f	**Enhancement factor**
HUMIDAIRFLK_SI_pT_Ws	HUMIDAIRFLK_IP_pT_Ws	**Saturation humidity ratio**
HUMIDAIRFLK_SI_pW_Td	HUMIDAIRFLK_IP_pW_Td	**Dew/frost point temperture**
HUMIDAIRFLK_SI_W_PSIda	HUMIDAIRFLK_IP_W_PSIda	**Mole fraction of dry air**
HUMIDAIRFLK_SI_W_PSIwv	HUMIDAIRFLK_IP_W_PSIwv	**Mole fraction of water vapor**
HUMIDAIRFLK_SI_W_XIda	HUMIDAIRFLK_IP_W_XIda	**Mass fraction of dry air**
HUMIDAIRFLK_SI_W_XIwv	HUMIDAIRFLK_IP_W_XIwv	**Mass fraction of water vapor**
HUMIDAIRFLK_SI_Zele_p	HUMIDAIRFLK_IP_Zele_p	**Pressure of humid air**

Table 7. **Additional functions defined in HUMID AIR DLL**

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 8. **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 9. Additional properties calculated

2.3 Export Functions Reference (SI Units)

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdbTwb_prop

Function call : HUMIDAIRFLK_SI_pTdbTwb_prop(p, Tdb, Twb, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdbTwb (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdbTd_prop

Function call : HUMIDAIRFLK_SI_pTdbTd_prop(p, Tdb, Td, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdbTd (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdbPHI_prop

Function call : HUMIDAIRFLK_SI_pTdbPHI_prop(p, Tdb, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdbPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdbW_prop

Function call : HUMIDAIRFLK_SI_pTdbW_prop(p, Tdb, W, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdbW (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdbh_prop

Function call : HUMIDAIRFLK_SI_pTdbh_prop(p, Tdb, h, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdbh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdbv_prop

Function call : HUMIDAIRFLK_SI_pTdbv_prop(p, Tdb, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdbv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pWv_prop

Function call : HUMIDAIRFLK_SI_pWv_prop(p, W, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pWv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pWh_prop

Function call : HUMIDAIRFLK_SI_pWh_prop(p, W, h, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pWh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTwbW_prop

Function call : HUMIDAIRFLK_SI_pTwbW_prop(p, Twb, W, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTwbW (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTwbPHI_prop

Function call : HUMIDAIRFLK_SI_pTwbPHI_prop(p, Twb, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTwbPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTwbTd_prop

Function call : HUMIDAIRFLK_SI_pTwbTd_prop(p, Twb, Td, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTwbTd (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdh_prop

Function call : HUMIDAIRFLK_SI_pTdh_prop(p, Td, h, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdv_prop

Function call : HUMIDAIRFLK_SI_pTdv_prop(p, Td, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pWPHI_prop

Function call : HUMIDAIRFLK_SI_pWPHI_prop(p, W, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pWPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pTdPHI_prop

Function call : HUMIDAIRFLK_SI_pTdPHI_prop(p, Td, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pTdPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_SI_pPHIh_prop

Function call : HUMIDAIRFLK_SI_pPHIh_prop(p, PHI, h, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pPHIh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pPHIv_prop**

Function call : HUMIDAIRFLK_SI_pPHIv_prop(p, PHI, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_SI_pPHIv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pT_hlw** **Specific enthalpy of liquid water**

Function call : HUMIDAIRFLK_SI_pT_hlw(p, T, key)

Input values :

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

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

key [const char *]: KEY_SI_pT_hlw (see attachment)

Output Result : **[double]** Specific enthalpy of liquid water [J/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_hlws** **Specific enthalpy of saturated liquid water**

Function call : HUMIDAIRFLK_SI_T_hlws(T, key)

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

key [const char *]: KEY_SI_T_hlws (see attachment)

Output Result : **[double]** Specific enthalpy of saturated liquid water [J/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_hwvs** **Specific enthalpy of saturated water vapor**

Function call : HUMIDAIRFLK_SI_T_hwvs(T, key)

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

key [const char *]: KEY_SI_T_hwvs (see attachment)

Output Result : **[double]** Specific enthalpy of saturated water vapor [J/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pT_slw** **Specific entropy of liquid water**

Function call : HUMIDAIRFLK_SI_pT_slw(p, T, key)

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

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

key [const char *]: KEY_SI_pT_slw (see attachment)

Output Result : **[double]** Specific entropy of liquid water [J/(kg·K)]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_slws** **Specific entropy of saturated liquid water**

Function call : HUMIDAIRFLK_SI_T_slws(T, key)

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

key [const char *]: KEY_SI_T_slws (see attachment)

Output Result : **[double]** Specific entropy of saturated liquid water [J/(kg·K)]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_swvs** **Specific entropy of saturated water vapor**

Function call : HUMIDAIRFLK_SI_T_swvs(T, key)

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

key [const char *]: KEY_SI_T_swvs (see attachment)

Output Result : **[double]** Specific entropy of saturated water vapor [J/(kg·K)]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pT_vlw** **Specific volume of liquid water**

Function call : HUMIDAIRFLK_SI_pT_vlw(p, T, key)

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

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

key [const char *]: KEY_SI_pT_vlw (see attachment)

Output Result : **[double]** Specific volume of liquid water [m^3/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_vlws** **Specific volume of saturated liquid water**

Function call : HUMIDAIRFLK_SI_T_vlws(T, key)

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

key [const char *]: KEY_SI_T_vlws (see attachment)

Output Result : **[double]** Specific volume of saturated liquid water [m^3/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_vwvs** **Specific volume of saturated water vapor**

Function call : HUMIDAIRFLK_SI_T_vwvs(T, key)

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

key [const char *]: KEY_SI_T_vwvs (see attachment)

Output Result : **[double]** Specific volume of saturated water vapor [m^3/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_Pws** **Saturation pressure of water**

Function call : HUMIDAIRFLK_SI_T_Pws(T, key)

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

key [const char *]: KEY_SI_T_Pws (see attachment)

Output Result : **[double]** Saturation pressure of water [Pa]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_p_Tws** **Saturation temperature of water**

Function call : HUMIDAIRFLK_SI_p_Tws(p, key)

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

key [const char *]: KEY_SI_p_Tws (see attachment)

Output Result : **[double]** Saturation temperature of water [K]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_hiws** **Specific enthalpy of saturated ice**

Function call : HUMIDAIRFLK_SI_T_hiws(T, key)

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

key [const char *]: KEY_SI_T_hiws (see attachment)

Output Result : **[double]** Specific enthalpy of saturated ice [J/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_hwvs_sub** **Specific enthalpy of saturated water vapor**

Function call : HUMIDAIRFLK_SI_T_hwvs_sub(T, key)

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

key [const char *]: KEY_SI_T_hwvs_sub (see attachment)

Output Result : **[double]** Specific enthalpy of saturated water vapor [J/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_siws** **Specific entropy of saturated ice**

Function call : HUMIDAIRFLK_SI_T_siws(T, key)

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

key [const char *]: KEY_SI_T_siws (see attachment)

Output Result : **[double]** Specific entropy of saturated ice [J/(kg·K)]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_swvs_sub** **Specific entropy of saturated water vapor**

Function call : HUMIDAIRFLK_SI_T_swvs_sub(T, key)

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

key [const char *]: KEY_SI_T_swvs_sub (see attachment)

Output Result : **[double]** 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.

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_viws** **Specific volume of saturated ice**

Function call : HUMIDAIRFLK_SI_T_viws(T, key)

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

key [const char *]: KEY_SI_T_viws (see attachment)

Output Result : **[double]** Specific volume of saturated ice [m^3/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_vwvs_sub** **Specific volume of saturated water vapor**

Function call : HUMIDAIRFLK_SI_T_vwvs_sub(T, key)

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

key [const char *]: KEY_SI_T_vwvs_sub (see attachment)

Output Result : **[double]** Specific volume of saturated water vapor [m^3/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_Pmel** **Melting pressure of ice**

Function call : HUMIDAIRFLK_SI_T_Pmel(T, key)

Input values : **T [double]:** Temperature in K.
Range: 251.165 ⩽ T ⩽ 273.15 [K]

key [const char *]: KEY_SI_T_Pmel (see attachment)

Output Result : **[double]** Melting pressure of ice [Pa]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_T_Psub** **Sublimation pressure of ice**

Function call : HUMIDAIRFLK_SI_T_Psub(T, key)

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

key [const char *]: KEY_SI_T_Psub (see attachment)

Output Result : **[double]** Sublimation pressure of ice [Pa]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_p_Tmel** **Melting temperature of ice**

Function call : HUMIDAIRFLK_SI_p_Tmel(p, key)

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

key [const char *]: KEY_SI_p_Tmel (see attachment)

Output Result : **[double]** Melting temperature of ice [K]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_p_Tsub** **Sublimation temperature of ice**

Function call : HUMIDAIRFLK_SI_p_Tsub(p, key)

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

key [const char *]: KEY_SI_p_Tsub (see attachment)

Output Result : **[double]** Sublimation temperature of ice [K]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pT_Pwvs** **Partial saturation pressure of water vapor**

Function call : HUMIDAIRFLK_SI_pT_f(p, T, key)

Input values :

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

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

key [const char *]: KEY_SI_pT_Pwvs (see attachment)

Output Result : **[double]** Partial saturation pressure of water vapor [Pa]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pT_f** **Enhancement factor**

Function call : HUMIDAIRFLK_SI_pT_f(p, T, key)

Input values :

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

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

key [const char *]: KEY_SI_pT_f (see attachment)

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

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pT_Ws** **Saturation humidity ratio**

Function call : HUMIDAIRFLK_SI_pT_Ws(p, T, key)

Input values :

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

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

key [const char *]: KEY_SI_pT_Ws (see attachment)

Output Result : **[double]** Saturation humidity ratio [kg(water)/kg(dry air)]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_pW_Td** **Dew/frost point temperature**

Function call : HUMIDAIRFLK_SI_pW_Td(p,W, key)

Input values :

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

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

key [const char *]: KEY_SI_pW_Td (see attachment)

Output Result : **[double]** Dew/frost point temperature[K]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_W_PSIda** **Mole fraction of dry air**

Function call : HUMIDAIRFLK_SI_W_PSIda(W, key)

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

key [const char *]: KEY_SI_W_PSIda (see attachment)

Output Result : **[double]** Mole fraction of dry air [mol(da)/mol]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_W_PSIwv** **Mole fraction of water vapor**

Function call : HUMIDAIRFLK_SI_W_PSIwv(W, key)

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

key [const char *]: KEY_SI_W_PSIwv (see attachment)

Output Result : **[double]** Mole fraction of water vapor [mol(wv)/mol]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_W_XIda** **Mass fraction of dry air**

Function call : HUMIDAIRFLK_SI_W_XIda(W, key)

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

key [const char *]: KEY_SI_W_XIda (see attachment)

Output Result : **[double]** Mass fraction of dry air [kg(da)/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_W_XIwv** **Mass fraction of water vapor**

Function call : HUMIDAIRFLK_SI_W_XIwv(W, key)

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

key [const char *]: KEY_SI_W_XIwv (see attachment)

Output Result : **[double]** Mass fraction of water vapor [kg(wv)/kg]

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

FUNCTION NAME:	**HUMIDAIRFLK_SI_Zele_p** **Pressure of humid air as function of elevation**

Function call : HUMIDAIRFLK_SI_Zele_p(Zele, key)

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

key [const char *]: KEY_SI_Zele_p (see attachment)

Output Result : **[double]** Humid air pressure [Pa]

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

2.4 Export Functions Reference (I-P Units)

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdbTwb_prop

Function call : HUMIDAIRFLK_IP_pTdbTwb_prop(p, Tdb, Twb, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_TdbTwb (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdbTd_prop

Function call : HUMIDAIRFLK_IP_pTdbTd_prop(p, Tdb, Td, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdbTd (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdbPHI_prop

Function call : HUMIDAIRFLK_IP_pTdbPHI_prop(p, Tdb, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdbPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdbW_prop

Function call : HUMIDAIRFLK_IP_pTdbW_prop(p, Tdb, W, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdbW (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdbh_prop

Function call : HUMIDAIRFLK_IP_pTdbh_prop(p, Tdb, h, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdbh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdbv_prop

Function call : HUMIDAIRFLK_IP_pTdbv_prop(p, Tdb, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdbv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pWv_prop

Function call : HUMIDAIRFLK_IP_pWv_prop(p, W, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pWv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pWh_prop

Function call : HUMIDAIRFLK_IP_pWh_prop(p, W, h, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pWh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTwbW_prop

Function call : HUMIDAIRFLK_IP_pTwbW_prop(p, Twb, W, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTwbW (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTwbPHI_prop

Function call : HUMIDAIRFLK_IP_pTwbPHI_prop(p, Twb, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTwbPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTwbTd_prop

Function call : HUMIDAIRFLK_IP_pTwbTd_prop(p, Twb, Td, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTwbTd (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdh_prop

Function call : HUMIDAIRFLK_IP_pTdh_prop(p, Td, h, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdv_prop

Function call : HUMIDAIRFLK_IP_pTdv_prop(p, Td, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pWPHI_prop

Function call : HUMIDAIRFLK_IP_pWPHI_prop(p, W, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pWPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pTdPHI_prop

Function call : HUMIDAIRFLK_IP_pTdPHI_prop(p, Td, PHI, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pTdPHI (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	HUMIDAIRFLK_IP_pPHIh_prop

Function call : HUMIDAIRFLK_IP_pPHIh_prop(p, PHI, h, prop, key)

Input values :

p [double]: Pressure inpsi.
Range: 0.00145 ⩽ p ⩽ 1450.4 [psi]

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pPHIh (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pPHIv_prop**

Function call : HUMIDAIRFLK_IP_pPHIv_prop(p, PHI, v, prop, key)

Input values :

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

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

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

prop [const char *]: Output Property (see Table 8)

key [const char *]: KEY_IP_pPHIv (see attached document)

Output Result : **[double]** (see Table 8)

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pT_hlw** **Specific enthalpy of liquid water**

Function call : HUMIDAIRFLK_IP_pT_hlw(p, T, key)

Input values :

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

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

key [const char *]: KEY_IP_pT_hlw (see attachment)

Output Result : **[double]** Specific enthalpy of liquid water [Btu/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_hlws** **Specific enthalpy of saturated liquid water**

Function call : HUMIDAIRFLK_IP_T_hlws(T, key)

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

key [const char *]: KEY_IP_T_hlws (see attachment)

Output Result : **[double]** Specific enthalpy of saturated liquid water [Btu/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_hwvs** **Specific enthalpy of saturated water vapor**

Function call : HUMIDAIRFLK_IP_T_hwvs(T, key)

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

key [const char *]: KEY_IP_T_hwvs (see attachment)

Output Result : **[double]** Specific enthalpy of saturated water vapor [Btu/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pT_slw** **Specific entropy of liquid water**

Function call : HUMIDAIRFLK_IP_pT_slw(p, T, key)

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

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

key [const char *]: KEY_IP_pT_slw (see attachment)

Output Result : **[double]** Specific entropy of liquid water [Btu/(lb·°R)]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_slws** **Specific entropy of saturated liquid water**

Function call : HUMIDAIRFLK_IP_T_slws(T, key)

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

key [const char *]: KEY_IP_T_slws (see attachment)

Output Result : **[double]** Specific entropy of saturated liquid water [Btu/(lb·°R)]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_swvs** **Specific entropy of saturated water vapor**

Function call : HUMIDAIRFLK_IP_T_swvs(T, key)

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

key [const char *]: KEY_IP_T_swvs (see attachment)

Output Result : **[double]** Specific entropy of saturated water vapor [Btu/(lb·°R)]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pT_vlw** **Specific volume of liquid water**

Function call : HUMIDAIRFLK_IP_pT_vlw(p, T, key)

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

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

key [const char *]: KEY_IP_pT_vlw (see attachment)

Output Result : **[double]** Specific volume of liquid water [ft^3/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_vlws** **Specific volume of saturated liquid water**

Function call : HUMIDAIRFLK_IP_T_vlws(T, key)

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

key [const char *]: KEY_IP_T_vlws (see attachment)

Output Result : **[double]** Specific volume of saturated liquid water [ft³/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_vwvs** **Specific volume of saturated water vapor**

Function call : HUMIDAIRFLK_IP_T_vwvs(T, key)

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

key [const char *]: KEY_IP_T_vwvs (see attachment)

Output Result : **[double]** Specific volume of saturated water vapor [ft³/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_Pws** **Saturation pressure of water**

Function call : HUMIDAIRFLK_IP_T_Pws(T, key)

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

key [const char *]: KEY_IP_T_Pws (see attachment)

Output Result : **[double]** Saturation pressure of water [psi]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_p_Tws** **Saturation temperature of water**

Function call : HUMIDAIRFLK_IP_p_Tws(p, key)

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

key [const char *]: KEY_IP_p_Tws (see attachment)

Output Result : **[double]** Saturation temperature of water [°F]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_hiws** **Specific enthalpy of saturated ice**

Function call : HUMIDAIRFLK_IP_T_hiws(T, key)

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

key [const char *]: KEY_IP_T_hiws (see attachment)

Output Result : **[double]** Specific enthalpy of saturated ice [Btu/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_hwvs_sub** **Specific enthalpy of saturated water vapor**

Function call : HUMIDAIRFLK_IP_T_hwvs_sub(T, key)

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

key [const char *]: KEY_IP_T_hwvs_sub (see attachment)

Output Result : **[double]** Specific enthalpy of saturated water vapor [Btu/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_siws** **Specific entropy of saturated ice**

Function call : HUMIDAIRFLK_IP_T_siws(T, key)

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

key [const char *]: KEY_IP_T_siws (see attachment)

Output Result : **[double]** Specific entropy of saturated ice [Btu/(lb·°R)]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_swvs_sub** **Specific entropy of saturated water vapor**

Function call : HUMIDAIRFLK_IP_T_swvs_sub(T, key)

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

key [const char *]: KEY_IP_T_swvs_sub (see attachment)

Output Result : **[double]** 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.

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_viws** **Specific volume of saturated ice**

Function call : HUMIDAIRFLK_IP_T_viws(T, key)

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

key [const char *]: KEY_IP_T_viws (see attachment)

Output Result : **[double]** Specific volume of saturated ice [ft³/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_vwvs_sub** **Specific volume of saturated water vapor**

Function call : HUMIDAIRFLK_IP_T_vwvs_sub(T, key)

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

key [const char *]: KEY_IP_T_vwvs_sub (see attachment)

Output Result : **[double]** Specific volume of saturated water vapor [ft³/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_Pmel** **Melting pressure of ice**

Function call : HUMIDAIRFLK_IP_T_Pmel(T, key)

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

key [const char *]: KEY_IP_T_Pmel (see attachment)

Output Result : **[double]** Melting pressure of ice [psi]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_T_Psub** **Sublimation pressure of ice**

Function call : HUMIDAIRFLK_IP_T_Psub(T, key)

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

key [const char *]: KEY_IP_T_Psub (see attachment)

Output Result : **[double]** Sublimation pressure of ice [psi]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_p_Tmel** **Melting temperature of ice**

Function call : HUMIDAIRFLK_IP_p_Tmel(p, key)

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

key [const char *]: KEY_IP_p_Tmel (see attachment)

Output Result : **[double]** Melting temperature of ice [°F]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_p_Tsub** **Sublimation temperature of ice**

Function call : HUMIDAIRFLK_IP_p_Tsub(p, key)

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

key [const char *]: KEY_IP_p_Tsub (see attachment)

Output Result : **[double]** Sublimation temperature of ice [°F]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pT_Pwvs** **Partial saturation pressure of water vapor**

Function call : HUMIDAIRFLK_IP_pT_f(p, T, key)

Input values :

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

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

key [const char *]: KEY_IP_pT_Pwvs (see attachment)

Output Result : **[double]** Partial saturation pressure of water vapor [psi]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pT_f** **Enhancement factor**

Function call : HUMIDAIRFLK_IP_pT_f(p, T, key)

Input values :

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

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

key [const char *]: KEY_IP_pT_f (see attachment)

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

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pT_Ws** **Saturation humidity ratio**

Function call : HUMIDAIRFLK_IP_pT_Ws(p, T, key)

Input values :

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

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

key [const char *]: KEY_IP_pT_Ws (see attachment)

Output Result : **[double]** Saturation humidity ratio [lb(water)/lb(dry air)]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_pW_Td** **Dew/frost point temperature**

Function call : HUMIDAIRFLK_IP_pW_Td(p,W, key)

Input values :

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

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

key [const char *]: KEY_IP_pW_Td (see attachment)

Output Result : **[double]** Dew/frost point temperature [°F]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_W_PSIda** **Mole fraction of dry air**

Function call : HUMIDAIRFLK_IP_W_PSIda(W, key)

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

key [const char *]: KEY_IP_W_PSIda (see attachment)

Output Result : **[double]** Mole fraction of dry air [mol(da)/mol]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_W_PSIwv** **Mole fraction of water vapor**

Function call : HUMIDAIRFLK_IP_W_PSIwv(W, key)

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

key [const char *]: KEY_IP_W_PSIwv (see attachment)

Output Result : **[double]** Mole fraction of water vapor [mol(wv)/mol]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_W_XIda** **Mass fraction of dry air**

Function call : HUMIDAIRFLK_IP_W_XIda(W, key)

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

key [const char *]: KEY_IP_W_XIda (see attachment)

Output Result : **[double]** Mass fraction of dry air [lb(da)/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_W_XIwv** **Mass fraction of water vapor**

Function call : HUMIDAIRFLK_IP_W_XIwv(W, key)

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

key [const char *]: KEY_IP_W_XIwv (see attachment)

Output Result : **[double]** Mass fraction of water vapor [lb(wv)/lb]

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

FUNCTION NAME:	**HUMIDAIRFLK_IP_Zele_p** **Pressure of humid air as function of elevation**

Function call : HUMIDAIRFLK_IP_Zele_p(Zele, key)

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

key [const char *]: KEY_IP_Zele_p (see attachment)

Output Result : **[double]** Humid air pressure [psi]

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

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).