

Humid Air Properties

Psychrometrics

MATLAB[®] Functions Library



DEMO VERSION

USER GUIDE

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

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OVERVIEW

Psychrometrics (Demo Version) 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.

This Demo Version includes limitations in the range of the input variables that are included.

REQUIREMENTS

The following are the requirements in order to install and utilize **Psychrometrics (Demo Version)**. 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 Windows 8 Windows 8.1 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 (Demo Version) 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_MatlabDemo_x86_Setup	32-bit
Psychrometrics_MatlabDemo_x64_Setup	64-bit

INSTALLATION

Unzip the file that corresponds to your MATLAB version. Double-click on the `_Setup.exe` file that is located on the unzipped directory and follow the screen instructions.

Once the function libraries are installed (all files with extension `.mexw32` for a 32-bit installation or `.mexw64` for a 64-bit installation and all files with extension `.dll`), you need to add this directory to your working PATH environment in MATLAB.

Note : When including another working directory different from the original installation, be sure to include all files with extension `.dll`. These files are necessary for the numerical evaluation of the library functions.

Please check www.fluidika.com for information on how to add a working directory to your PATH environment in MATLAB.

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

LIBRARY FUNCTIONS

Psychrometrics (Demo Version) 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 1 shows the functions defined as a combinations of input properties. Properties calculated based on these functions are described in Table 5.

Functions that return a single property are described in Tables 2 and 3; their properties and units are shown in Table 6.

SI UNITS	I-P UNITS	OUTPUT RESULT
HAFLK_SI_pTdbW_prop	HAFLK_IP_pTdbW_prop	Depending on value of "prop", see Table 5 PRESSURE FIXED AT 700000 Pa/101.5264 psi
HAFLK_SI_pTdh_prop	HAFLK_IP_pTdh_prop	
HAFLK_SI_pWv_prop	HAFLK_IP_pWv_prop	
<i>HAFLK_SI_pTdbTwb_prop</i>	<i>HAFLK_IP_pTdbTwb_prop</i>	NOT AVAILABLE IN DEMO VERSION
<i>HAFLK_SI_pTdbTd_prop</i>	<i>HAFLK_IP_pTdbTd_prop</i>	
<i>HAFLK_SI_pTdbPHI_prop</i>	<i>HAFLK_IP_pTdbPHI_prop</i>	
<i>HAFLK_SI_pTdbh_prop</i>	<i>HAFLK_IP_pTdbh_prop</i>	
<i>HAFLK_SI_pTdbv_prop</i>	<i>HAFLK_IP_pTdbv_prop</i>	
<i>HAFLK_SI_pTwbTd_prop</i>	<i>HAFLK_IP_pTwbTd_prop</i>	
<i>HAFLK_SI_pTwbPHI_prop</i>	<i>HAFLK_IP_pTwbPHI_prop</i>	
<i>HAFLK_SI_pTwbW_prop</i>	<i>HAFLK_IP_pTwbW_prop</i>	
<i>HAFLK_SI_pTdPHI_prop</i>	<i>HAFLK_IP_pTdPHI_prop</i>	
<i>HAFLK_SI_pTdv_prop</i>	<i>HAFLK_IP_pTdv_prop</i>	
<i>HAFLK_SI_pWPHI_prop</i>	<i>HAFLK_IP_pWPHI_prop</i>	
<i>HAFLK_SI_pWh_prop</i>	<i>HAFLK_IP_pWh_prop</i>	
<i>HAFLK_SI_pPHIh_prop</i>	<i>HAFLK_IP_pPHIh_prop</i>	
<i>HAFLK_SI_pPHIv_prop</i>	<i>HAFLK_IP_pPHIv_prop</i>	

Table 1. 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 2. Functions for $T \geq 273.15 \text{ K} / 32 \text{ }^\circ\text{F}$
DEMO - PRESSURE FIXED AT 700000 Pa/101.5264 psi
DEMO - TEMPERATURE RANGE : 273.15 - 275 K/32 - 35.33 °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 3. Functions for $T \leq 273.15 \text{ K} / 32 \text{ }^\circ\text{F}$
DEMO - PRESSURE FIXED AT 700000 Pa/101.5264 psi
DEMO - TEMPERATURE RANGE : 272 - 273.15 K/29.93 - 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 temperature
SWFLK_SI_W_PSI _{da}	SWFLK_IP_W_PSI _{da}	Mole fraction of dry air
SWFLK_SI_W_PSI _{wv}	SWFLK_IP_W_PSI _{wv}	Mole fraction of water vapor
SWFLK_SI_W_XI _{da}	SWFLK_IP_W_XI _{da}	Mass fraction of dry air
SWFLK_SI_W_XI _{wv}	SWFLK_IP_W_XI _{wv}	Mass fraction of water vapor
SWFLK_SI_Zele_p	SWFLK_IP_Zele_p	Pressure of humid air

Table 4. Functions NOT included in Psychrometrics (Demo Version)

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 5. 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 6. Additional properties calculated

LIBRARY FUNCTIONS REFERENCE (SI UNITS) - DEMO VERSION

FUNCTION NAME: HAFLK_SI_pTdbW_prop

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

Input values : **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000 Pa

Tdb : Dry-bulb temperature in K.
Range: $130.0 \leq Tdb \leq 623.15$ [K]

W : Humidity ratio kg(water)/kg(dry air).
Range: $0 \leq W \leq 10$ [kg/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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(700000, 380, 0.01, 'h')
h =
    133892.205614483
```

FUNCTION NAME: HAFLK_SI_pTdh_prop

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

Input values : **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000 Pa

Td : Dew point temperature in K.
Range: $130.0 \leq Td \leq 623.15$ [K]

h: Specific enthalpy of humid air in J/kg.
Range: $-311357 \leq h \leq 32135848$ [J/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 specific enthalpy of humid air.

```
>> s = HAFLK_SI_pTdh_prop(700000, 320.5785744, 133892.205614483, 's')
s =
    -135.4012509
```

FUNCTION NAME:**HAFLK_SI_pWv_prop**

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

Input values : **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000 Pa

W : Humidity ratio kg(water)/kg(dry air).
Range: $0 \leq W \leq 10$ [kg/kg]

v : Specific volume of humid air in m³/kg(dry air).
Range: $1.469E-3 \leq v \leq 3.055E5$ [m³/kg]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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(700000, 0.01, 0.158457326, 'h')
h =
    133892.2056
```

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

MATLAB function usage : SWFLK_SI_pT_hlw(p, T)

Input values : **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000 Pa

T : Temperature in K.
Range: $273.15 \leq T \leq 275.0$ [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(700000, 275)
hlw =
    8465.368047
```


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: $273.15 \leq T \leq 275.0$ [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(275)
hlws =
    7759.557576
```

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: $273.15 \leq T \leq 275.0$ [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(275)
hlws =
    2504291.11
```

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.
FIXED PRESSURE AT : 700000 Pa**T** : Temperature in K.
Range: $273.15 \leq T \leq 275.0$ [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(700000, 275)
slw =
    28.33263704
```

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: $273.15 \leq T \leq 275.0$ [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(275)
hlws =
    28.30880584
```

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: $273.15 \leq T \leq 275.0$ [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(275)
swvs =
    9106.616824
```

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.
FIXED PRESSURE AT : 700000 Pa**T** : Temperature in K.
Range: $273.15 \leq T \leq 275.0$ [K]**Output Result :** **Specific volume of liquid water in m³/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(700000, 275)
vlw =
    0.000999761
```

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: $273.15 \leq T \leq 275.0$ [K]**Output Result :** **Specific volume of saturated liquid water in m³/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(275)
vlws =
    0.001000112
```

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: $273.15 \leq T \leq 275.0$ [K]**Output Result :** **Specific volume of saturated water vapor in m³/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(275)
vwvs =
    181.6044467
```

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: $273.15 \leq T \leq 275.0$ [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(275)
Pws =
    698.4535147
```

FUNCTION NAME:**SWFLK_SI_p_Tws****Saturation temperature of water****MATLAB function usage :** SWFLK_SI_p_Tws(p)**Input values :** **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000 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(700000)
TwS =
    438.1027526
```

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: $272.0 \leq T \leq 273.15$ [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: $272.0 \leq T \leq 273.15$ [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(273.15)
hwvs_sub =
    -333465.22
```

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: $272.0 \leq T \leq 273.15$ [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(273.15)
siws =
-1220.7711
```

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: $272.0 \leq T \leq 273.15$ [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(273.15)
swvs_sub =
9155.804659
```

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: $272.0 \leq T \leq 273.15$ [K]**Output Result :** **Specific volume of saturated ice in m³/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(273.15)
viws =
    0.001090856
```

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: $272.0 \leq T \leq 273.15$ [K]**Output Result :** **Specific volume of saturated water vapor in m³/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(273.15)
swvs_sub =
    206.1527083
```


FUNCTION NAME:**SWFLK_SI_T_Pmel****Melting pressure of ice****MATLAB function usage :** SWFLK_SI_T_Pmel(T)**Input values :** **T** : Temperature in K.
Range: $272.0 \leq T \leq 273.15$ [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(273.15)
Pmel =
    135228.879
```

FUNCTION NAME:**SWFLK_SI_T_Psub****Sublimation pressure of ice****MATLAB function usage :** SWFLK_SI_T_Psub(T)**Input values :** **T** : Temperature in K.
Range: $272.0 \leq T \leq 273.15$ [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(273.15)
Psub =
    611.1534751
```

FUNCTION NAME:**SWFLK_SI_p_Tmel****Melting temperature of ice****MATLAB function usage :** SWFLK_SI_p_Tmel(p)**Input values :** **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000 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(700000)
Tmel =
    273.1079837
```

FUNCTION NAME:**SWFLK_SI_p_Tsub****Sublimation temperature of ice****MATLAB function usage :** SWFLK_SI_p_Tsub(p)**Input values :** **p** : Pressure in Pa.
FIXED PRESSURE AT : 700000 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(700000)
Tsub =
    273.1270635
```

LIBRARY FUNCTIONS REFERENCE (I-P UNITS) - DEMO VERSION

FUNCTION NAME: HAFLK_IP_pTdbW_prop

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

Input values : **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 psi

Tdb : Dry-bulb temperature in °F.
Range: $-225.67 \leq Tdb \leq 662$ [°F]

W : Humidity ratio lb(water)/lb(dry air).
Range: $0 \leq W \leq 10$ [lb/lb]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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(101.5264, 224.3304283, 0.01, 'h')  
h =  
    65.24904485
```

FUNCTION NAME: HAFLK_IP_pTdh_prop

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

Input values : **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 psi

Td : Dew point temperature in °F.
Range: $-225.67 \leq Td \leq 662$ [°F]

h: Specific enthalpy of humid air in Btu/lb.
Range: $-126.174 \leq h \leq 13823.61$ [Btu/lb]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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 specific enthalpy of humid air.

```
>> s = HAFLK_IP_pTdh_prop(101.5264, 117.3714339, 65.24904485, 's')  
s =  
   -0.01617623
```

FUNCTION NAME:**HAFLK_IP_pWv_prop**

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

Input values : **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 psi

W : Humidity ratio lb(water)/lb(dry air).
Range: $0 \leq W \leq 10$ [lb/lb]

v : Specific volume of humid air in ft³/lb(dry air).
Range: $2.353E-2 \leq v \leq 4.893E6$ [ft³/lb]

prop: Output Property. String (see Table 5)

Output Result : See Table 5.

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(101.5264, 0.01, 2.538242875, 'h')  
h =  
    65.24904485
```

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

MATLAB function usage : SWFLK_IP_pT_hlw(p, T)

Input values : **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 psi

T : Temperature in °F.
Range: $32 \leq T \leq 35.33$ [°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(101.5264, 35.33)  
hlw =  
    3.639453041
```

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: $32 \leq T \leq 35.33$ [°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(35.33)
hlws =
    3.336009168
```

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: $32 \leq T \leq 35.33$ [°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 = SWFLK_IP_T_hwvs(35.33)
hwvs =
    1076.651345
```

FUNCTION NAME:**SWFLK_IP_pT_slw****Specific entropy of liquid water****MATLAB function usage :** SWFLK_IP_pT_slw(p, T)**Input values :** **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 psi**T** : Temperature in °F.
Range: $32 \leq T \leq 35.33$ [°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(101.5264, 35.33)
slw =
    0.006767134
```

FUNCTION NAME:**SWFLK_IP_T_slws****Specific entropy of saturated liquid water****MATLAB function usage :** SWFLK_IP_T_slws(T)**Input values :** **T** : Temperature in °F.
Range: $32 \leq T \leq 35.33$ [°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(35.33)
slws =
    0.006761442
```

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: $32 \leq T \leq 35.33$ [°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(35.33)
swvs =
    2.175078
```

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.
FIXED PRESSURE AT : 101.5264 psi**T** : Temperature in °F.
Range: $32 \leq T \leq 35.33$ [°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(101.5264, 35.33)
vlw =
    0.016014622
```

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: $32 \leq T \leq 35.33$ [°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(35.33)
vlws =
    0.016020241
```

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: $32 \leq T \leq 35.33$ [°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(35.33)
vwvs =
    2909.022294
```


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: $32 \leq T \leq 35.33$ [°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(35.33)
Pws =
    0.101302118
```

FUNCTION NAME:**SWFLK_IP_p_Tws****Saturation temperature of water****MATLAB function usage :** SWFLK_IP_p_Tws(p)**Input values :** **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 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(101.5264)
Tws =
    328.9149546
```

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: $29.93 \leq T \leq 32$ [°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(32)
hiws =
    -143.3642352
```

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: $29.93 \leq T \leq 32$ [°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(32)
hwvs_sub =
    1075.192101
```

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: $29.93 \leq T \leq 32$ [°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(32)
siws =
-0.29157616
```

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: $29.93 \leq T \leq 32$ [°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(32)
swvs_sub =
2.186826313
```

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: $29.93 \leq T \leq 32$ [°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(32)
viws =
    0.017473832
```

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: $29.93 \leq T \leq 32$ [°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(32)
swvs_sub =
    3302.247469
```

FUNCTION NAME:**SWFLK_IP_T_Pmel****Melting pressure of ice****MATLAB function usage :** SWFLK_IP_T_Pmel(T)**Input values :** **T** : Temperature in °F.
Range: $29.93 \leq T \leq 32$ [°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(32)
Pmel =
    19.61329072
```

FUNCTION NAME:**SWFLK_IP_T_Psub****Sublimation pressure of ice****MATLAB function usage :** SWFLK_IP_T_Psub(T)**Input values :** **T** : Temperature in °F.
Range: $29.93 \leq T \leq 32$ [°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(32)
Psub =
    0.088640318
```

FUNCTION NAME:**SWFLK_IP_p_Tmel****Melting temperature of ice****MATLAB function usage :** SWFLK_IP_p_Tmel(p)**Input values :** **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 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(101.5264)
Tmel =
    31.92437059
```

FUNCTION NAME:**SWFLK_IP_p_Tsub****Sublimation temperature of ice****MATLAB function usage :** SWFLK_IP_p_Tsub(p)**Input values :** **p** : Pressure in psi.
FIXED PRESSURE AT : 101.5264 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(101.5264)
Tsub =
    31.94067171
```

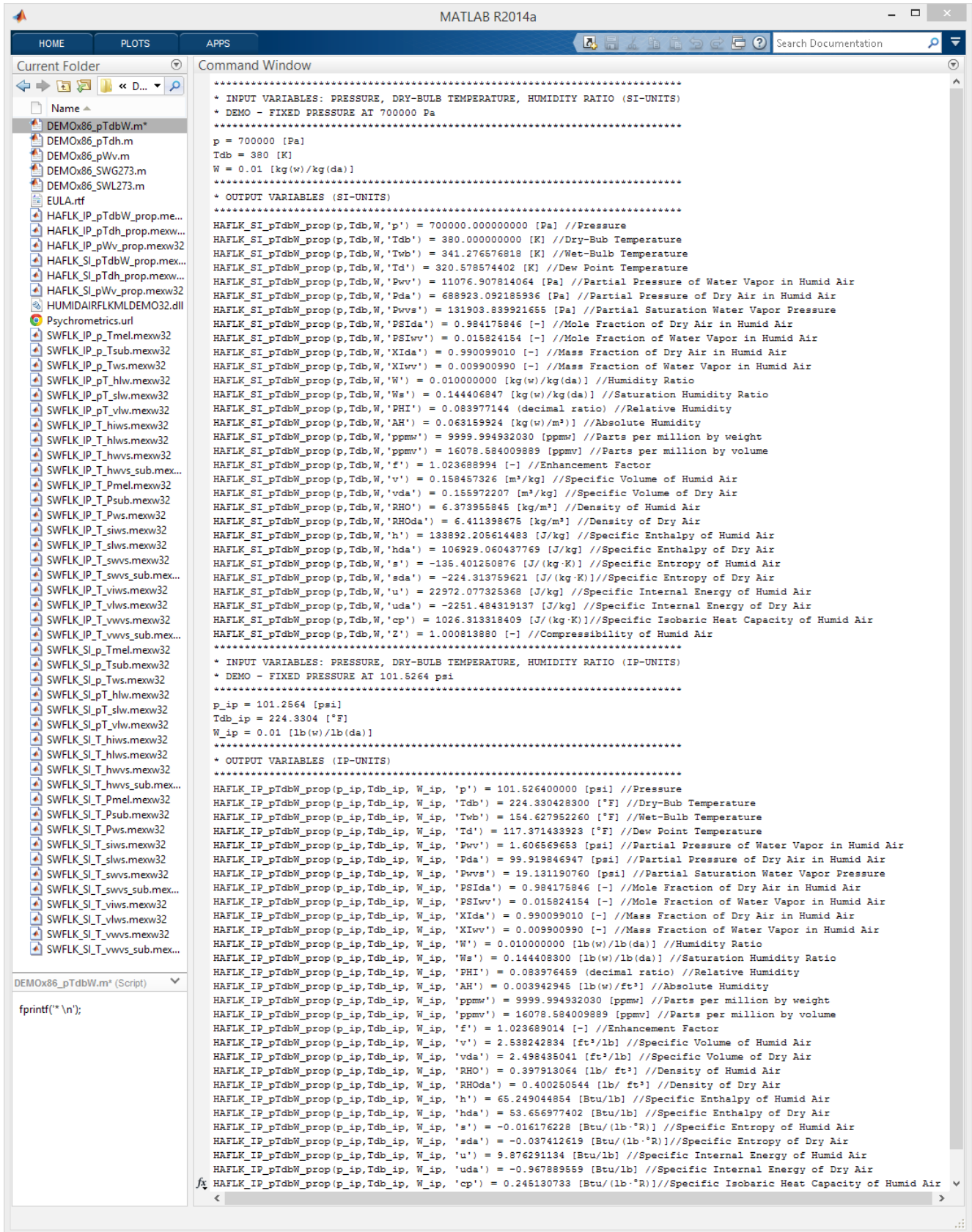


Figure 1. Screenshot of MATLAB Command Window with results from the pressure, dry-bulb temperature and humidity ratio combination of variables.

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