ThermoFluidProperties

Property Library for Humid Air Calculated as Ideal Mixture of Real Fluids

LibHuAir

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1. Property Functions

Functional Dependence	Function Name	Call as Fortran Program	Property or Function	Unit of the Result	Source or Algorithm	Site Info
$a = f(p,t,x_w)$	a_ptxw_HuAir	= A_PTXW_HUAIR(p,t,xw)	Thermal diffusivity	m^2/s	[1-4], [6], [12], [14], [15]	3/1
$c_p = f(p,t,x_w)$	cp_ptxw_HuAir	= CP_PTXW_HUAIR(p,t,xw)	Specific isobaric heat capacity, related to mass of humid air	kJ/(kg K)	[1-4], [13], [14]	3/2
$c_v = f(p,t,x_w)$	cv_ptxw_HuAir	= CV_PTXW_HUAIR(p,t,xw)	Specific isochoric heat capacity, related to mass of humid air	kJ/(kg K)	[1-4], [13], [14]	3/3
$\eta = f(p,t,x_w)$	Eta_ptxw_HuAir	= ETA_PTXW_HUAIR(p,t,xw)	Dynamic viscosity	Pa s	[7], [12], [15]	3/4
$h_l = f(p,t,x_w)$	hl_ptxw_HuAir	= HL_PTXW_HUAIR(p,t,xw)	Air-specific enthalpy	kJ/kg_{Air}	[1-4], [13], [14], [18], [19]	3/5
$\kappa = f(p,t,x_w)$	Kappa_ptxw_HuAir	= KAPPA_PTXW_HUAIR(p,t,xw)	Isentropic exponent	-	[1-4], [13], [14]	3/6
$\lambda = f(p,t,x_w)$	Lambda_ptxw_HuAir	= LAMBDA_PTXW_HUAIR(p,t,xw)	Thermal conductivity	W/(m K)	[6], [12], [15]	3/7
$\nu = f(p,t,x_w)$	Ny_ptxw_HuAir	= NY_PTXW_HUAIR(p,t,xw)	Kinematic viscosity	m^2/s	[1-4], [7], [12], [14], [15]	3/8
$p_d = f(p,t,x_w)$	pd_ptxw_HuAir	= PD_PTXW_HUAIR(p,t,xw)	Partial pressure of steam	bar	[1-4], [16], [17], [25], [26]	3/9
$p_{ds} = f(p,t)$	pds_pt_HuAir	= PDS_PT_HUAIR(p,t)	Saturation pressure of water	bar	[1-4], [16], [17], [25], [26]	3/10
$\varphi = f(p,t,x_w)$	Phi_ptxw_HuAir	= PHI_PTXW_HUAIR(p,t,xw)	Relative humidity	%	[1-4], [16], [17], [25], [26]	3/11
$p_l = f(p,t,x_w)$	pl_ptxw_HuAir	= PL_PTXW_HUAIR(p,t,xw)	Partial pressure of air	bar	[1-4], [16], [17], [25], [26]	3/12
$Pr = f(p,t,x_w)$	Pr_ptxw_HuAir	= PR_PTXW_HUAIR(p,t,xw)	PRANDTL-number	-	[1-4], [6], [7], [12-15]	3/13
$\psi_l = f(x_w)$	Psil_xw_HuAir	= PSIL_XW_HUAIR(xw)	Mole fraction of air	$kmol_{Air}/kmol$	-	3/14

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$\psi_w = f(x_w)$	Psiw_xw_HuAir	= PSIW_XW_HUAIR(xw)	Mole fraction of water	$kmol_{Water}/kmol$	-	3/15
$\rho = f(p,t,x_w)$	Rho_ptxw_HuAir	= RHO_PTXW_HUAIR(p,t,xw)	Density, related to mass of humid air	kg/m^3	[1-4], [14], [18], [19]	3/16
$s_l = f(p,t,x_w)$	sl_ptxw_HuAir	= SL_PTXW_HUAIR(p,t,xw)	Air-specific entropy	$kJ/(kg_{Air}\ K)$	[1-4], [13], [14], [18], [19]	3/17
$t = f(p,h_l,x_w)$	t_phlxw_HuAir	= T_PHLXW_HUAIR(p,hl,xw)	Backward function: temperature from air-specific enthalpy and humidity ratio (absolute humidity)	°C	[1-4], [13], [14], [18], [19]	3/18
$t = f(p,s_l,x_w)$	t_pslxw_HuAir	= T_PSLXW_HUAIR(p,hl,xw)	Backward function: temperature from air-specific entropy and humidity ratio (absolute humidity)	°C	[1-4], [13], [14], [18], [19]	3/19
$t = f(p,t_f,x_w)$	t_ptfxw_HuAir	= T_PTFXW_HUAIR(p,tf,xw)	Temperature	°C	[1-4], [13], [14]	3/20
$t_f = f(p,t,x_w)$	tf_ptxw_HuAir	= TF_PTXW_HUAIR(p,t,xw)	Wet bulb temperature	°C	[1-4], [13], [14]	3/21
$t_\tau = f(p,x_w)$	tTau_pxw_HuAir	= TTAU_PXW_HUAIR(p,xw)	Dew point temperature	°C	[1-4], [16], [17]	3/22
$u_l = f(p,t,x_w)$	ul_ptxw_HuAir	= UL_PTXW_HUAIR(p,t,xw)	Air-specific internal energy	kJ/kg_{Air}	[1-4], [13], [14], [18], [19]	3/23
$v_l = f(p,t,x_w)$	vl_ptxw_HuAir	= VL_PTXW_HUAIR(p,t,xw)	Air-specific volume	m^3/kg_{Air}	[1-4], [14], [18], [19]	3/24
$\xi_l = f(x_w)$	Xil_xw_HuAir	= XIL_XW_HUAIR(xw)	Mass fraction of air	kg_{Air}/kg	-	3/25
$\xi_w = f(x_w)$	Xiw_xw_HuAir	= XIW_XW_HUAIR(xw)	Mass fraction of water	kg_{Water}/kg	-	3/26
$x_w = f(p,t,p_d)$	xw_ptpd_HuAir	= XW_PTPD_HUAIR(p,t,pd)	Humidity ratio (Absolute humidity) from partial pressure of steam	g_{Water}/kg_{Air}	[1-4], [16], [17], [25], [26]	3/27
$x_w = f(p,t,\varphi)$	xw_ptPhi_HuAir	= XW_PTPHI_HUAIR(p,t,Phi)	Humidity ratio (Absolute humidity) from temperature and relative humidity	g_{Water}/kg_{Air}	[1-4], [16], [17], [25], [26]	3/28

Functional Dependence	Function Name	Cal as Fortran Program	Property or Function	Unit of the Result	Source or Algorithm	Site Info
$x_w = f(p,t_\tau)$	xw_ptTau_HuAir	= XW_PTTAU_HUAIR(p,tTau)	Humidity ratio (Absolute humidity) from dew point temperature	g_{Water}/kg_{Air}	[1-4], [16], [17], [25], [26]	3/29
$x_w = f(p,t,t_f)$	xw_pttf_HuAir	= XW_PTTF_HUAIR(p,t,tf)	Humidity ratio (Absolute humidity) from temperature and wet bulb temperature	g_{Water}/kg_{Air}	[1-4], [13], [14]	3/30
$x_w = f(p,t,v_l)$	xw_ptvl_HuAir	= XW_PTVL_HUAIR(p,t,vl)	Backward function: Humidity ratio (Absolute humidity) from temperature and air-specific volume	g_{Water}/kg_{Air}	[1-4], [16], [17], [25], [26]	3/31
$x_{ws} = f(p,t)$	xws_pt_HuAir	= XWS_PT_HUAIR(p,t)	Humidity ratio (Absolute humidity) of saturated humid air	g_{Water}/kg_{Air}	[1-4], [16], [17], [25], [26]	3/32
$z = f(p,t,x_w)$	z_ptxw_HuAir	= Z_PTXW_HUAIR(p,t,xw)	Compression factor	-	[1-4], [13], [14]	3/33

Variable Types for Function Call

All functions not starting with C_ :	REAL*8
All functions starting with C_ :	INTEGER*4
All variables:	REAL*8

Reference States

Property	Dry air	Water
Pressure	1.01325 bar	6.11657 mbar
Temperature	0 °C	0.01 °C
Enthalpy	0 kJ/ kg_{Air}	0.000611783 kJ/kg_{Water}
Internal energy	−78.37885533 kJ/kg_{Air}	0 kJ/kg_{Water}
Entropy	0.161802887 kJ/(kg_{Air} K)	0 kJ/(kg_{Water} K)

Composition of Dry Air (from *Lemmon* et al. [14], [15]) :

Component		Mole Fraction
Nitrogen	N_2	0.7812
Oxygen	O_2	0.2096
Argon	Ar	0.0092

Units

p - Mixture pressure in bar

t - Temperature in °C

x_W - Humidity ratio (Absolute humidity) in g steam(water, ice)/kg dry air

φ - Relative humidity in % (only defined for unsaturated and saturated humid air)

Range of Validity

Temperature: t = - 143.15 °C ... 1726.85 °C

Mixture pressure: p = 6.112 mbar ... 1000 bar

Calculation Algorithm

Saturated and unsaturated air $(0 < x_W \leq x_{WS})$:

Ideal mixture of dry air and steam

- Dry air:
  - v_l, h_l, u_l, s_l c_p from *Lemmon* et al. [14]
  - λ, η from *Lemmon* et al. [15]
- Steam:
  - v, h, u, s, c_p of steam from IAPWS-IF97 [1], [2], [3], [4]
  - λ, η for $0°C \leq t \leq 800°C$ from IAPWS-85 [6], [7]
    for t < 0°C and t > 800°C from *Brandt* [12]

Supersaturated humid air (liquid fog or ice fog)

- Liquid fog $(x_w > x_{ws})$ and $t \geq 0.01°C$

  Ideal mixture of saturated humid air and water
  - Saturated humid air (see above)
  - v, h, u, s, c_p of liquid droplets from IAPWS-IF97 [1], [2], [3], [4]
  - λ, η of liquid droplets from IAPWS-85 [6], [7]
- Ice fog $(x_w > x_{ws})$ and $t < 0.01°C$

Ideal mixture of saturated humid air and ice

- Saturated humid air (see above)
- v, h, s of ice crystals from IAPWS-06 [18], [19]
- λ, c_p of ice crystals as constant value
- η, κ, w of saturated humid air

$x_{ws}(p,t)$ from saturation pressure $p_{ds}(p,t)$ of water in gas mixtures

$p_{ds}(p,t)$ is the saturation vapor pressure from $p_{ds}(p,t) = \mathrm{f}(p,t) \cdot p_s(t)$

- $\mathrm{f}(p,T)$ from Herrmann et al. [25], [26],
- $p_s(t)$ for $t \geq 273.15$ K from IAPWS-IF97 [1], [2], [3], [4],
- $p_s(t)$ for $t < 273.15$ K from IAPWS-08 [16], [17].

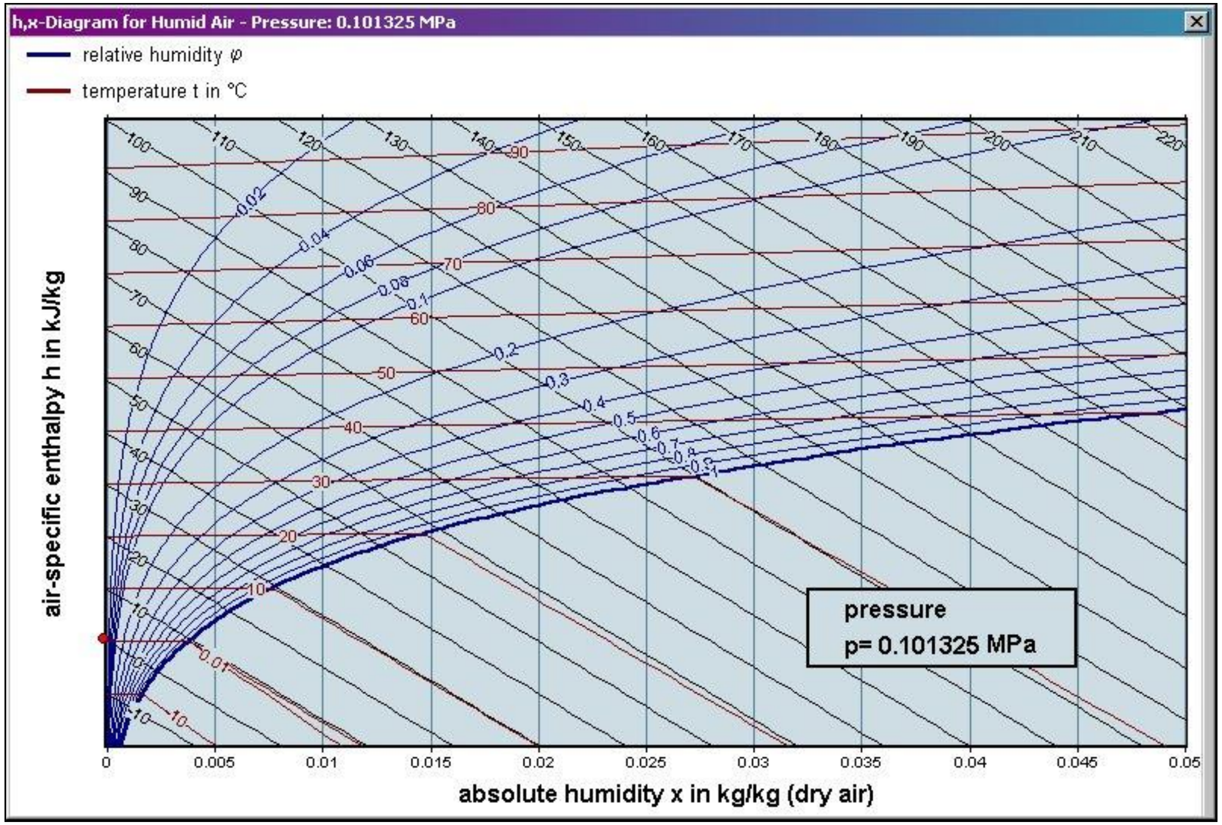
Thermodynamic Diagrams

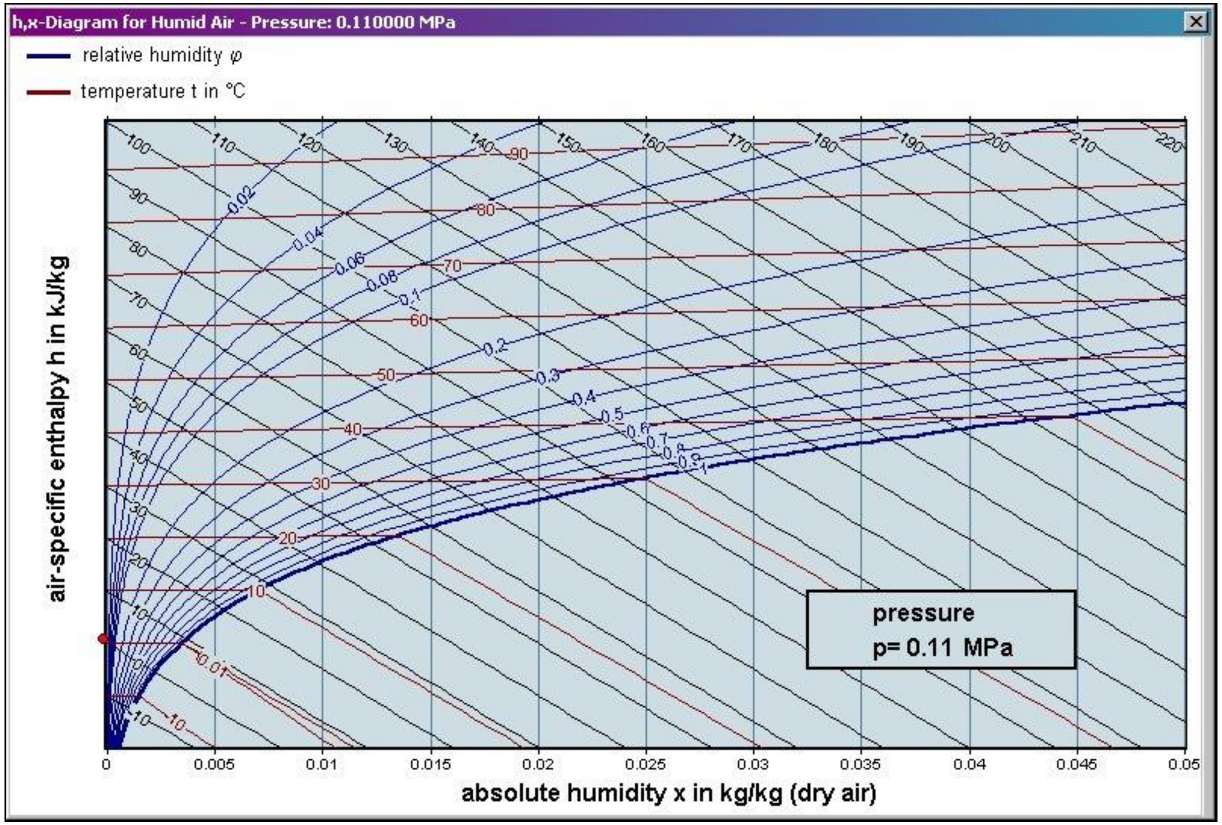
FluidEXL*Graphics* enables representation of the calculated property values in the following thermodynamic diagrams:

- *h*,*x* Diagram *p* = 0.101325 MPa

- *h*,*x* Diagram *p* = 0.11 MPa

The diagrams, in which the calculated state point will be represented are shown below.




h,x-Diagram for Humid Air - Pressure: 0.110000 MPa
relative humidity φ
temperature t in °C
air-specific enthalpy h in kJ/kg
absolute humidity x in kg/kg (dry air)
pressure
p= 0.11 MPa