KCE
ThermoFluidProperties

Property Library for the Industrial Formulation IAPWS-IF97 for Water and Steam

LibIF97IT

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Program Functions

Range of Validity

The International Association for the Properties of Water and Steam IAPWS issued the

"Release on the IAPWS Industrial Formulation 1997
for the Thermodynamic Properties of Water and Steam IAPWS-IF97"

in September 1997 [1], [2], [3]. It will be abbreviated as IAPWS-IF97. This new industrial standard must be applied worldwide in acceptance and guarantees calculations of facilities and plants working with water or steam. The IAPWS-IF97 Formulation replaces the former Industrial Formulation IFC-67 [12].

Figure 1.1 shows the entire range of validity for the equation set of the new Industrial Formulation IAPWS-IF97. It includes temperatures from 0 °C to 800 °C at pressures from 0.00611 bar to 1000 bar and temperatures to 2000 °C for pressures to 500 bar.

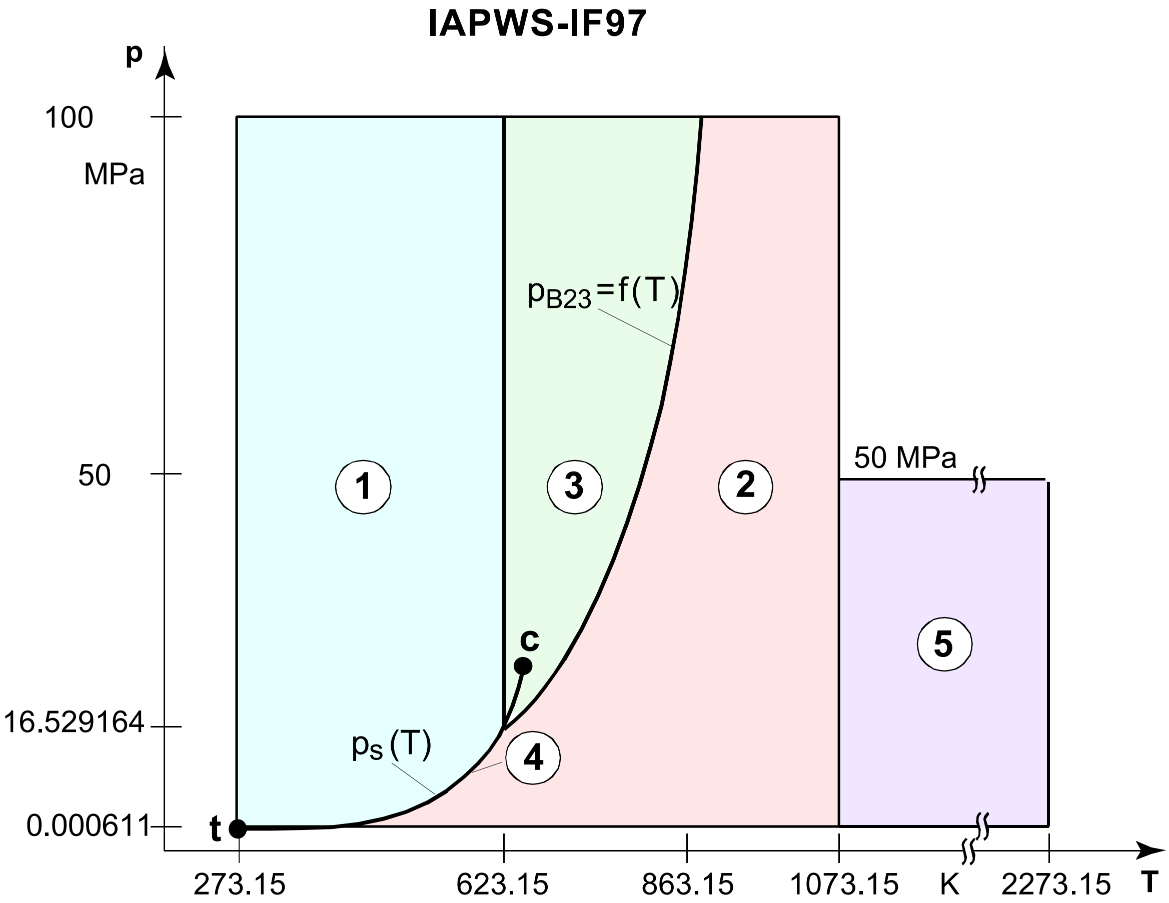


Figure 1.1 Entire Range of Validity of the IF97

The range of validity is divided into five calculation regions. Each of the calculation regions contains its own equations of state. They are described in detail in the official Release of the IAPWS [1] and in the publications by *Wagner et al.* [2] and [3].

The sub-programs of the LibIF97IT DLL and the functions of the Add-In FluidEXL$^{\textit{Graphics}}$ for Excel are listed in the following section.

All sub-programs and functions can be applied in the entire range of validity of the IF97. The call of the necessary equation of state for each calculation region will be realized within the program.

Functions

Functional Dependence	Function Name	Call as Function from DLL LibIF97IT	Call from DLL LibIF97IT, Result as Parameter	Property or Function	Unit of the Result
a = f(p,t,x)	a_ptx_97IT	= A_PTX_97IT(P,T,X)	= C_APTX97IT(A,P,T,X)	Thermal diffusivity	m^2/s
α_p = f(p,t,x)	alphap_ptx_97IT	= ALPHAP_PTX_ 97IT(P,T,X)	=C_ALPHAPPTX97IT (ALPHAP,P,T,X)	Relative pressure coefficient	K^{-1}
α_v = f(p,t,x)	alphav_ptx_97IT	= ALPHAV_PTX_ 97IT(P,T,X)	=C_ALPHAVPTX97IT (ALPHAV,P,T,X)	Isobaric cubic expansion coefficient	K^{-1}
b = f(p)	b_p_97IT	= B_P_97IT(P)	=C_BP97IT(B,P)	Laplace coefficient	m
b = f(t)	b_t_97IT	= B_T_97IT(T)	=C_BT97IT(B,T)	Laplace coefficient	m
β_p = f(p,t,x)	betap_ptx_97IT	= BETAP_PTX_ 97IT(P,T,X)	= C_BETAPPTX97IT (BETAP,P,T,X)	Isothermal stress coefficient	kg/m³
c_p = f(p,t,x)	cp_ptx_97IT	= CP_PTX_97IT(P,T,X)	= C_CPPTX97IT(CP,P,T,X)	Specific isobaric heat capacity	kJ/(kg · K)
c_v = f(p,t,x)	cv_ptx_97IT	= CV_PTX_97IT(P,T,X)	= C_CVPTX97IT(CV,P,T,X)	Specific isochoric heat capacity	kJ/(kg · K)
δ_T = f(p,t,x)	deltat_ptx_97IT	= DELTAT_PTX_97IT (P,T,X)	= C_DELTATPTX97IT (DELTAT,P,T,X)	Isothermal throttling coefficient	kJ/(kg · kPa^{-1})
$\left(\frac{\partial v}{\partial p}\right)_T = \mathrm{f}(p,t,x)$	dv_dp_T_ptx_97IT	= DVDP_T_97IT(P,T,X)	= C_DVDPT97IT(DVDP,P,T,X)	Differential quotient $\left(\frac{\partial v}{\partial p}\right)_\mathrm{T}(p,t,x)$	m^3/(kg · kPa)
$\left(\frac{\partial v}{\partial T}\right)_p = \mathrm{f}(p,t,x)$	dv_dT_p_ptx_97IT	= DVDT_P_97IT(P,T,X)	= C_DVDTP97IT(DVDT,P,T,X)	Differential quotient $\left(\frac{\partial v}{\partial T}\right)_\mathrm{p}(p,t,x)$	m^3/(kg · K)
e = f(p,t,x,t_U)	e_ptx_tu_97IT	= E_PTXTU_97IT (P,T,X,TU)	= C_EPTXTU97IT(E;P,T,X,TU)	Specific exergy	kJ/kg
ε = f(p,t,x)	epsilon_ptx_97IT	= EPS_PTX_97IT (P,T,X)	= C_EPSPTX97IT(EPS,P,T,X)	Dielectric constant	-
η = f(p,t,x)	eta_ptx_97IT	= ETA_PTX_97IT(P,T,X)	= C_ETAPTX97IT(ETA,P,T,X)	Dynamic viscosity	Pa · s = kg/(m · s)
f = f(p,t,x)	f_ptx_97IT	= F_PTX_97IT (P,T,X)	= C_FPTX97IT(F,P,T,X)	Specific Helmholtz energy	kJ/kg
f^* = f(p,t,x)	fug_ptx_97IT	= FUG_PTX_97IT (P,T,X)	= C_FUGPTX97IT(FUG,P,T,X)	Fugacity	bar
g = f(p,t,x)	g_ptx_97IT	= G_PTX_97IT (P,T,X)	= C_GPTX97IT(G,P,T,X)	Specific Gibbs energy	kJ/kg
h = f(p,s)	h_ps_97IT	= H_PS_97IT(P,S)	= C_HPS97IT(H,P,S)	Backward function: Specific enthalpy from pressure and entropy	kJ/kg

Functional Dependence	Function Name	Call as Function from DLL LibIF97IT	Call from DLL LibIF97IT, Result as Parameter	Property or Function	Unit of the Result
h = f(p,t,x)	h_ptx_97IT	= HPTX97IT(P,T,X)	= C_HPTX97IT(H,P,T,X)	Specific enthalpy	kJ/kg
κ = f(p,t,x)	kappa_ptx_97IT	= KAPPA_PTX_97IT(P,T,X)	= C_KAPPTX97IT(KAP,P,T,X)	Isentropic exponent	-
κ_T = f(p,t,x)	kappat_ptx_97IT	= KAPPAT_PTX_97IT(P,T,X)	= C_KAPPATPTX97IT(KAPPAT,P,T,X)	Isothermal compressibility	kPa^{-1}
λ = f(p,t,x)	lambda_ptx_97IT	= LAMBDA_PTX_97IT(P,T,X)	= C_LAMPTX97IT(LAM,P,T,X)	Heat conductivity	W/(m · K)
μ = f(p,t,x)	my_ptx_97IT	= MY_PTX_97IT(P,T,X)	= C_ MYPTX97IT(MY,P,T,X)	Joule-Thomson coefficient	K kPa^{-1}
n = f(p,t,x,wl)	n_ptxwl_97IT	= N_PTXWL_97IT(P,T,X,WL)	= C_NPTXWL97IT(N,P,T,X,WL)	Refractive index	-
ν = f(p,t,x)	ny_ptx_97IT	= NY_PTX_97IT(P,T,X)	= C_NYPTX97IT(NY,P,T,X)	Kinematic viscosity	m^2/s
p = f(h,s)	p_hs_97IT	= P_HS_97IT(H,S)	= C_PHS97IT(P,H,S)	Backward function: Pressure from enthalpy and entropy	bar
p = f(t,h)	p_th_97IT	= P_TH_97IT(T,H)	= C_PTH97IT(P,T,H)	Backward function: Pressure from Temperature and enthalpie	bar
p = f(t,v)	p_tv_97IT	= P_TV_97IT(T,V)	= C_PTV97IT(P,T,V)	Backward function: Pressure from Temperature and volume	bar
p = f(v,h)	p_vh_97IT	= P_VH_97IT(V,H)	= C_PVH97IT(P,V,H)	Backward function: Pressure from volume and enthalpy	bar
p = f(v,s)	p_vs_97IT	= P_VS_97IT(V,S)	= C_PVS97IT(P,V,S)	Backward function: Pressure from volume and entropie	bar
p = f(v,u)	p_vu_97IT	= P_VU_97IT(V,U)	= C_PVU97IT(P,V,U)	Backward function: Pressure from volume and internal energy	bar
Pr = f(p,t,x)	Pr_ptx_97IT	= PR_PTX_97IT(P,T,X)	= C_PRPTX97IT(PR,P,T,X)	*Prandtl*-number	-
p_s = f(h')	ps_h1_97IT	= PS_H1_97IT(H)	= C_PSH197IT(PS,H1)	Vapor pressure	bar
p_s = f(t)	ps_t_97IT	= PS_T_97IT(T)	= C_PST97IT(PS,T)	Vapor pressure	bar
ρ = f(p,t,x)	rho_ptx_97IT	= RHO_PTX_97IT(P,T,X)	= C_RHOPTX97IT(RHO,P,T,X)	Density	kg/m^3
s = f(p,h)	s_ph_97IT	= S_PH_97IT(P,H)	= C_SPH97IT(S,P,H)	Backward function: Specific entropy from pressure and enthalpy	kJ/(kg · K)

Functional Dependence	Function Name	Call as Function from DLL LibIF97IT	Call from DLL LibIF97IT, Result as Parameter	Property or Function	Unit of the Result
$s = \mathrm{f}(p,t,x)$	s_ptx_97IT	= S_PTX_97IT(P,T,X)	= C_SPTX97IT(S,P,T,X)	Specific entropy	kJ/(kg · K)
$\sigma = \mathrm{f}(p)$	sigma_p_97IT	= SIGMA_P_97IT(P)	= C_SIGMAP97IT(SIG,P)	Surface tension from pressure	mN/m = mPa · m
$\sigma = \mathrm{f}(t)$	sigma_t_97IT	= SIGMA_T_97IT(T)	= C_SIGMAT97IT(SIG,T)	Surface tension from temperature	mN/m = mPa · m
$t = \mathrm{f}(h,s)$	t_hs_97IT	= T_HS_97IT(H,S)	= C_THS97IT(T,H,S)	Backward function: Temperature from enthalpy and entropy	°C
$t = \mathrm{f}(p,h)$	t_ph_97IT	= T_PH_97IT(P,H)	= C_TPH97IT(T,P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = \mathrm{f}(p,s)$	t_ps_97IT	= T_PS_97IT(P,S)	= C_TPS97IT(T,P,S)	Backward function: Temperature from pressure and entropy	°C
$t = \mathrm{f}(p,v)$	t_pv_97IT	= T_PV_97IT(P,S)	= C_TPV97IT(T,P,V)	Backward function: Temperature from Temperature and volume	°C
$t = \mathrm{f}(v,h)$	t_vh_97IT	= T_VH_97IT(P,H)	= C_TVH97IT(T,V,H)	Backward function: Temperature from volume and enthalpy	°C
$t = \mathrm{f}(v,s)$	t_vs_97IT	= T_VS_97IT(P,S)	= C_TVS97IT(T,V,S)	Backward function: Temperature from volume and entropie	°C
$t = \mathrm{f}(v,u)$	t_vu_97IT	= T_VU_97IT(P,H)	= C_TVU97IT(T,V,H)	Backward function: Temperature from volume and internal energy	°C
$t_s = \mathrm{f}(p)$	ts_p_97IT	= TS_P_97IT(P)	= C_TSP97IT(T,S,P)	Saturation temperature	°C
$u = \mathrm{f}(p,t,x)$	u_ptx_97IT	= U_PTX_97IT(P,T,X)	= C_UPTX97IT(U,P,T,X)	Specific internal energy	kJ/kg
$v = \mathrm{f}(h,s)$	v_hs_97IT	= V_HS_97IT(H,S)	= C_VHS97IT(V,H,S)	Backward function: Specific volume from enthalpy an entropie	m^3/kg
$v = \mathrm{f}(p,h)$	v_ph_97IT	= V_PH_97IT(P,S)	= C_VPH97IT(V,P,H)	Backward function: Specific volume from pressure and enthalpy	m^3/kg
$v = \mathrm{f}(p,s)$	v_ps_97IT	= V_PS_97IT(P,S)	= C_VPS97IT(V,P,S)	Backward function: Specific volume from pressure and entropy	m^3/kg
$v = \mathrm{f}(p,t,x)$	v_ptx_97IT	= V_PTX_97IT(P,T,X)	= C_VPTX97IT(V,P,T,X)	Specific volume	m^3/kg
$v = \mathrm{f}(t,h)$	v_th_97IT	= V_TH_97IT(T,H)	= C_VTH97IT(V,T,H)	Backward function: Spec. volume from Temperature and enthalpie	bar
$w = \mathrm{f}(p,t,x)$	w_ptx_97IT	= W_PTX_97IT(P,T,X)	= C_WPTX97IT(W,P,T,X)	Isentropic speed of sound	m/s

x = f(h,s)	x_hs_97IT	= X_HS_97IT(H,S)	= C_XHS97IT(X,H,S)	Backward function: Vapor fraction from enthalpy and entropy	kg/kg
x = f(p,h)	x_ph_97IT	= X_PH_97IT(P,H)	= C_XPH97IT(X,P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
x = f(p,s)	x_ps_97IT	= X_PS_97IT(P,S)	= C_XPS97IT(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
x = f(p,v)	x_pv_97IT	= X_PV_97IT(P,V)	= C_XPV97IT(X,P,V)	Backward function: Vapor fraction from pressure and volume	kg/kg
x = f(t,h)	x_th_97IT	= X_TH_97IT(T,H)	= C_XTH97IT(X,T,H)	Backward function: Vapor fraction from Temperature and enthalpie	bar
x = f(t,v)	x_tv_97IT	= X_TV_97IT(P,H)	= C_XTV97IT(X,T,V)	Backward function: Vapor fraction from temperature and volume	kg/kg
x = f(v,h)	x_vh_97IT	= X_VH_97IT(P,H)	= C_XVH97IT(X,V,H)	Backward function: Vapor fraction from volume and enthalpy	kg/kg
x = f(v,s)	x_vs_97IT	= X_VS_97IT(P,S)	= C_XVS97IT(X,V,S)	Backward function: Vapor fraction from volume and entropie	kg/kg
x = f(v,u)	x_vu_97IT	= X_VU_97IT(P,H)	= C_XVU97IT(X,V,H)	Backward function: Vapor fraction from volume and internal energy	kg/kg
z = f(p,t,x)	z_ptx_97IT	= Z_PTX_97IT(P,T,X)	= C_ZPTX97IT(Z,P,T,X)	Compression factor	-

Units:

t in °C

p in bar

x in kg saturated steam/kg wet steam

Range of validity of IAPWS-IF97

Temperature:	from 0 °C to 800 °C
Pressure:	from 0.00611 bar to 1000 bar
High temperature region:	to 2000 °C for pressures less than 500 bar
	Exception to 900°C for the functions for *a*, *η*, *λ*, *ν*, *Pr*

Details on the vapor fraction *x* and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

Single-phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

Wet-steam region

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for *x*. When calculating wet steam either the given value for *t* and p = -1 or the given value for *p* and t = -1 and in both cases the value for *x* between 0 and 1 must be entered.

If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in –1.

[Wet steam region of the IAPWS-IF97: t_t = 0 °C ... t_c = 373.946 °C
p_t = 0.00611 bar ... p_c = 220.64 bar (c – critical point)]

Note.

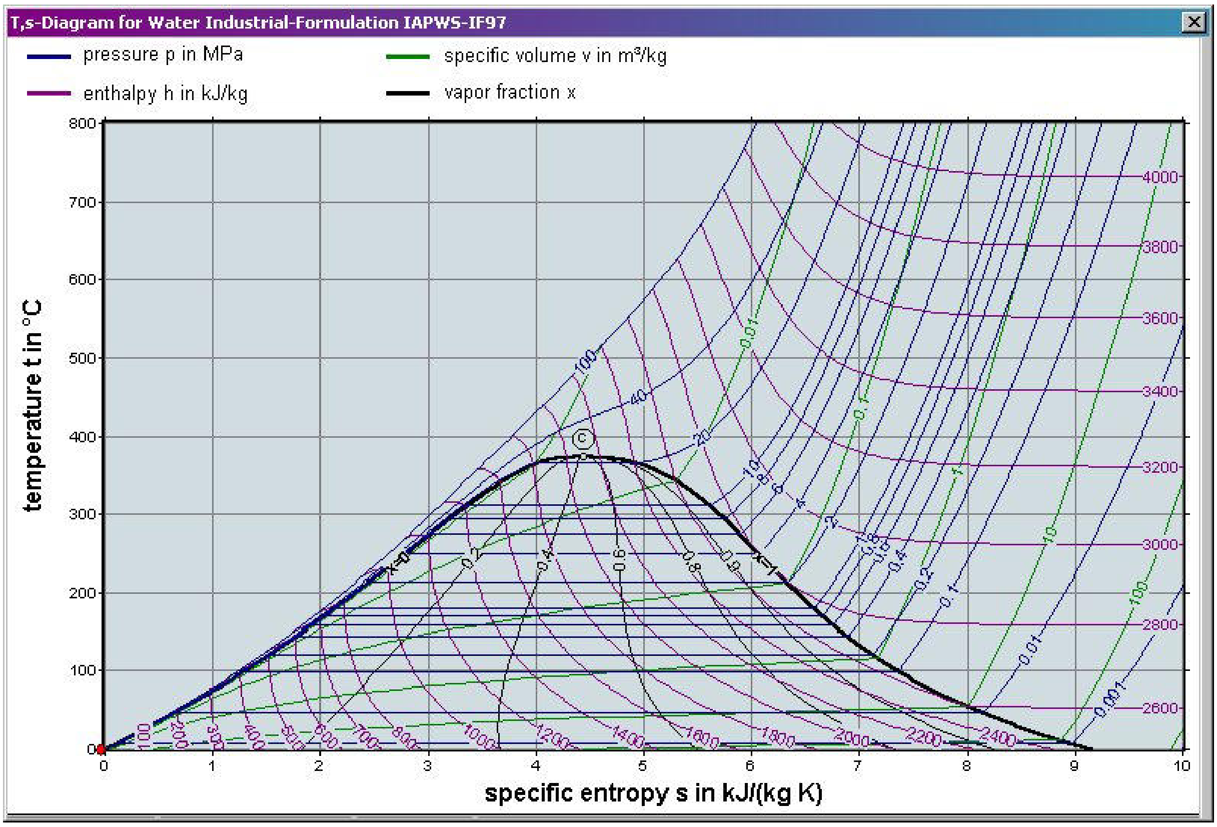
If the calculation results in –1E16, the values entered represent a state point beyond the range of validity of IAPWS-IF97. For further information on each function and its range of validity see Chapter 3. The same information may also be accessed via the online help pages.

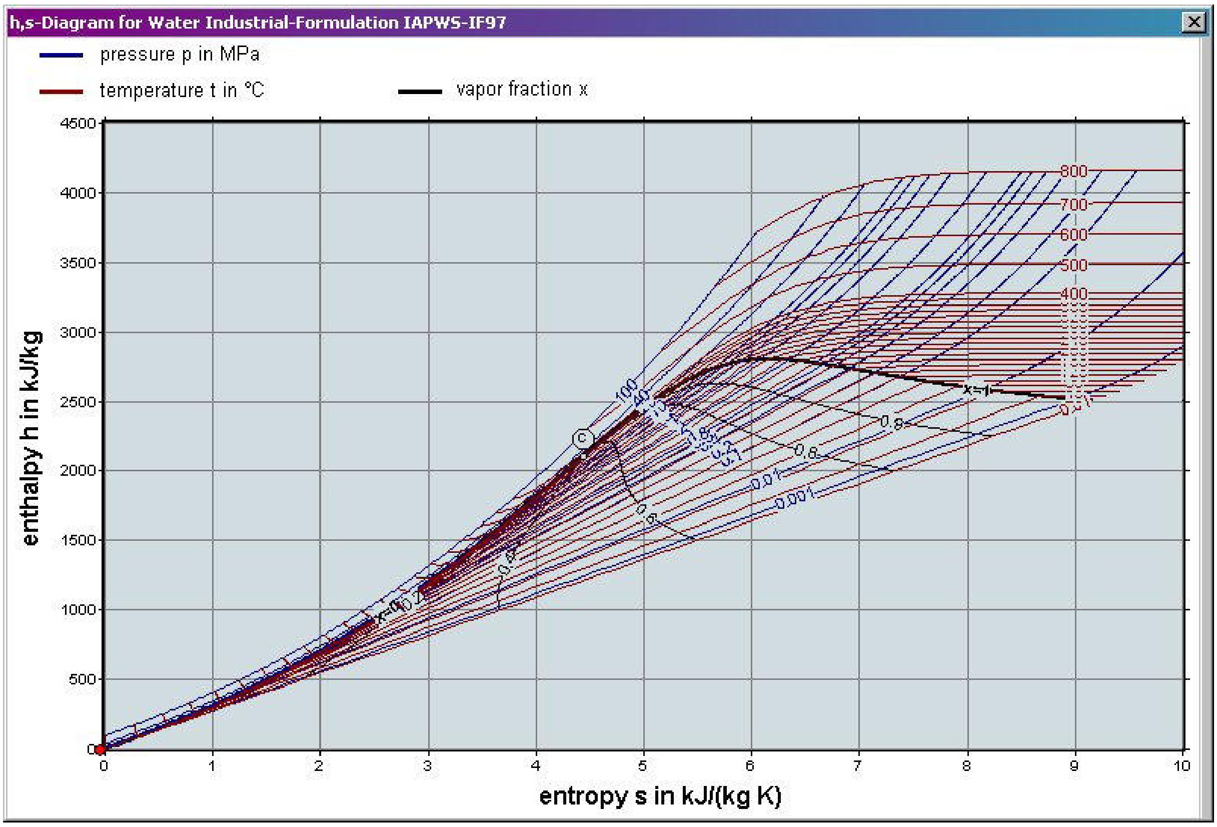
Thermodynamic Diagrams

FluidEXL*Graphics* enables the user to represent the calculated properties in the following thermodynamic diagrams:

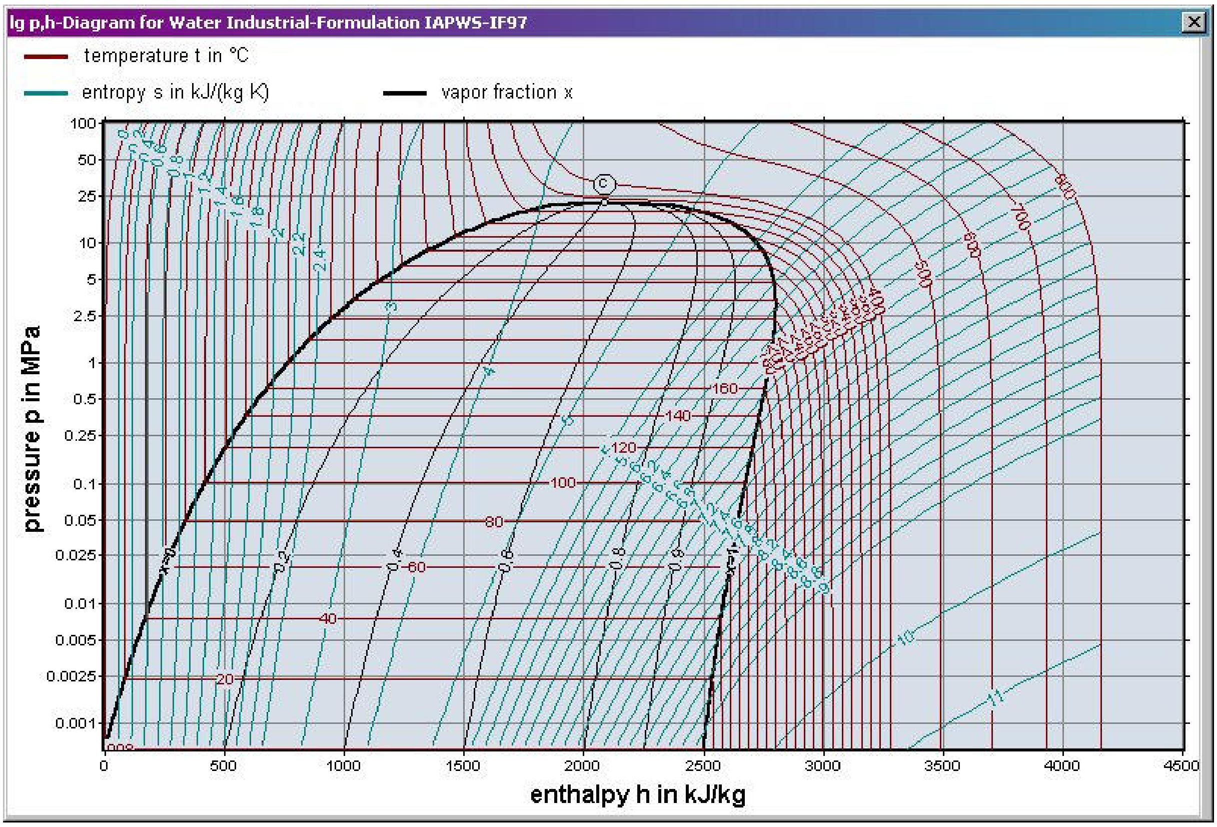
- *T*-*s* diagram
- *h*-*s* diagram
- *lg p*-*h* diagram
- *lg p*-*lg v* diagram
- *lg p*-*T* diagram
- *p*-*T* diagram
- *T*-*h* diagram
- *T*-*lg v* diagram
- *lg p*-*s* diagram
- *h*-*lg v* diagram
- *s*-*lg v*-diagram

The diagrams, in which the calculated state point will be displayed, are shown on the following pages.

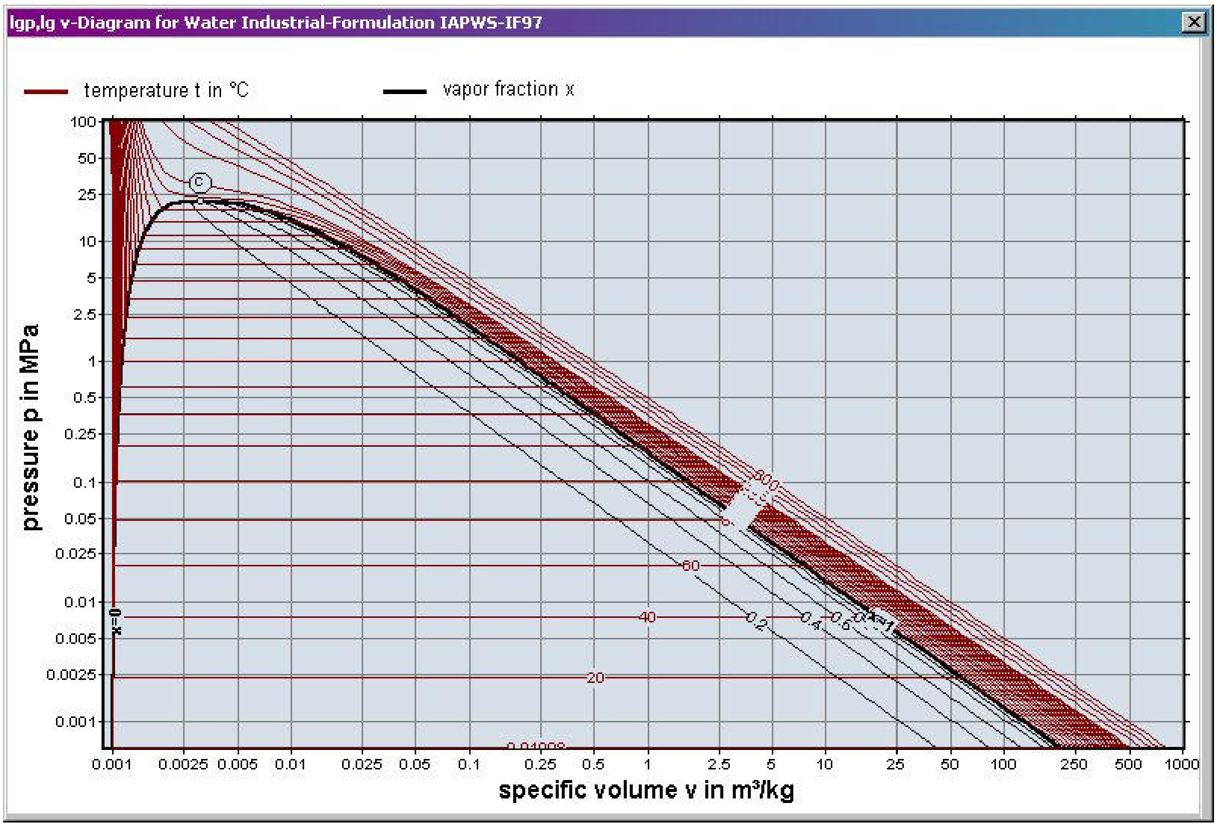


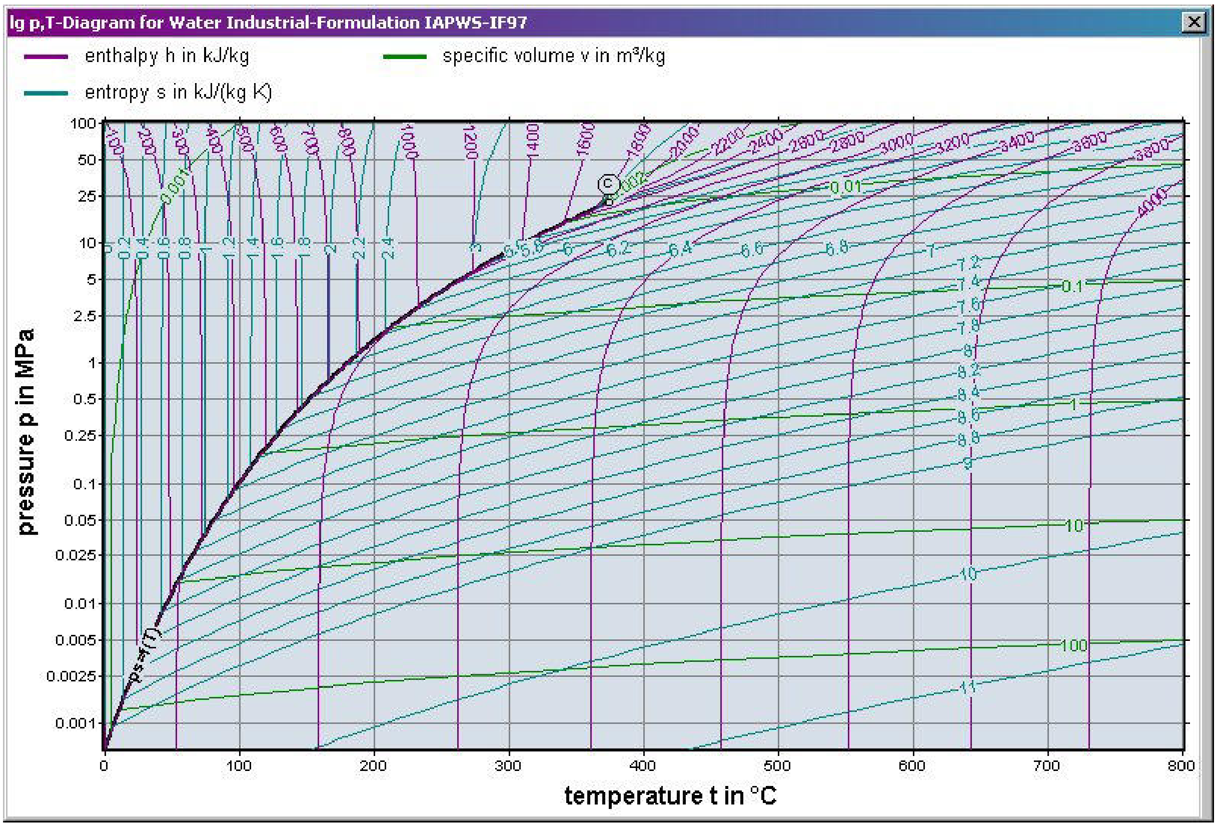


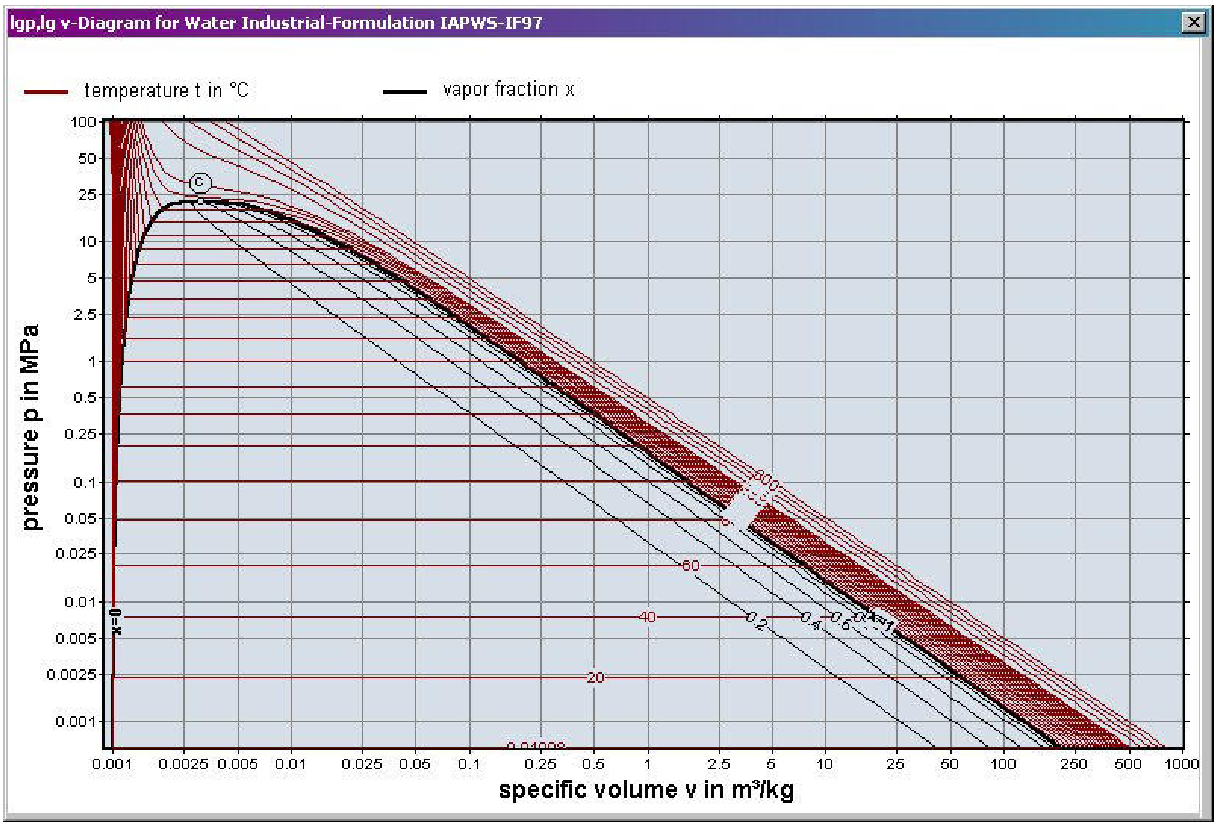
h,s-Diagram for Water Industrial-Formulation IAPWS-IF97



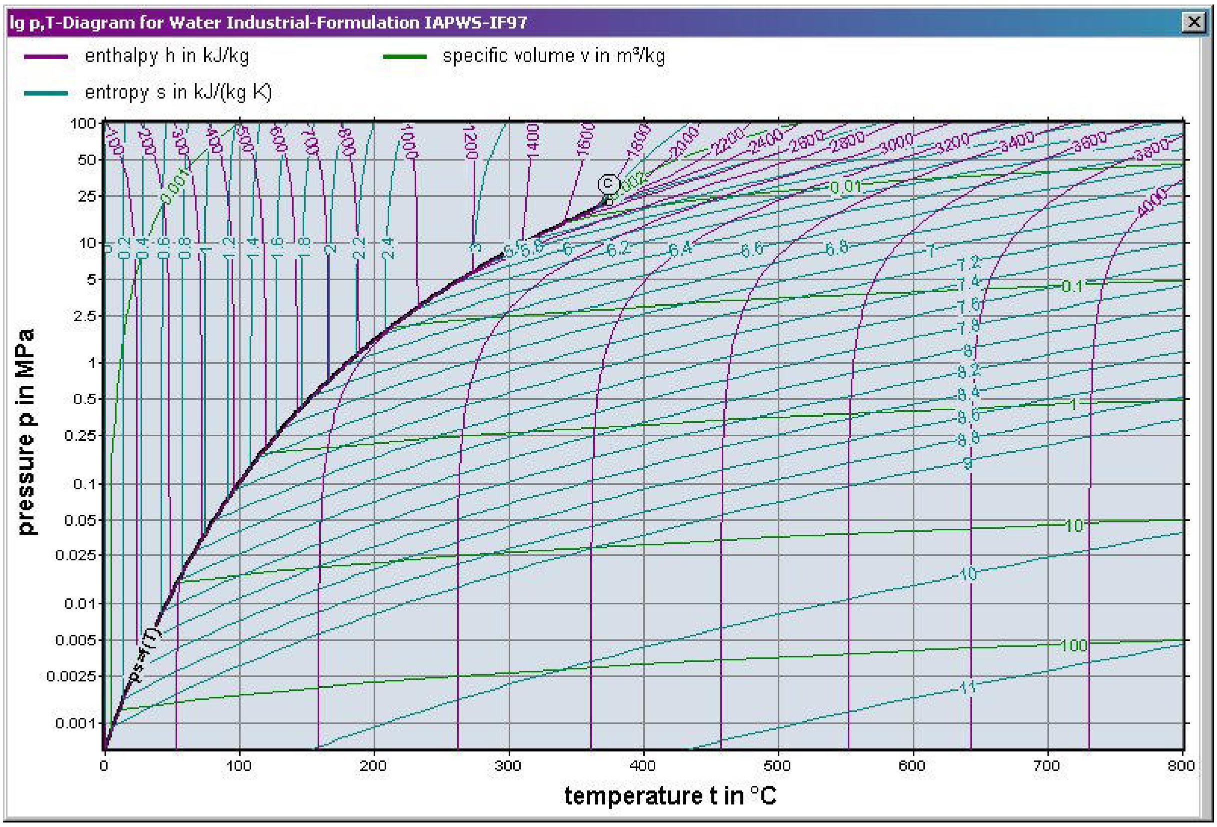
lg p,h-Diagram for Water Industrial-Formulation IAPWS-IF97


lgp,lg v-Diagram for Water Industrial-Formulation IAPWS-IF97

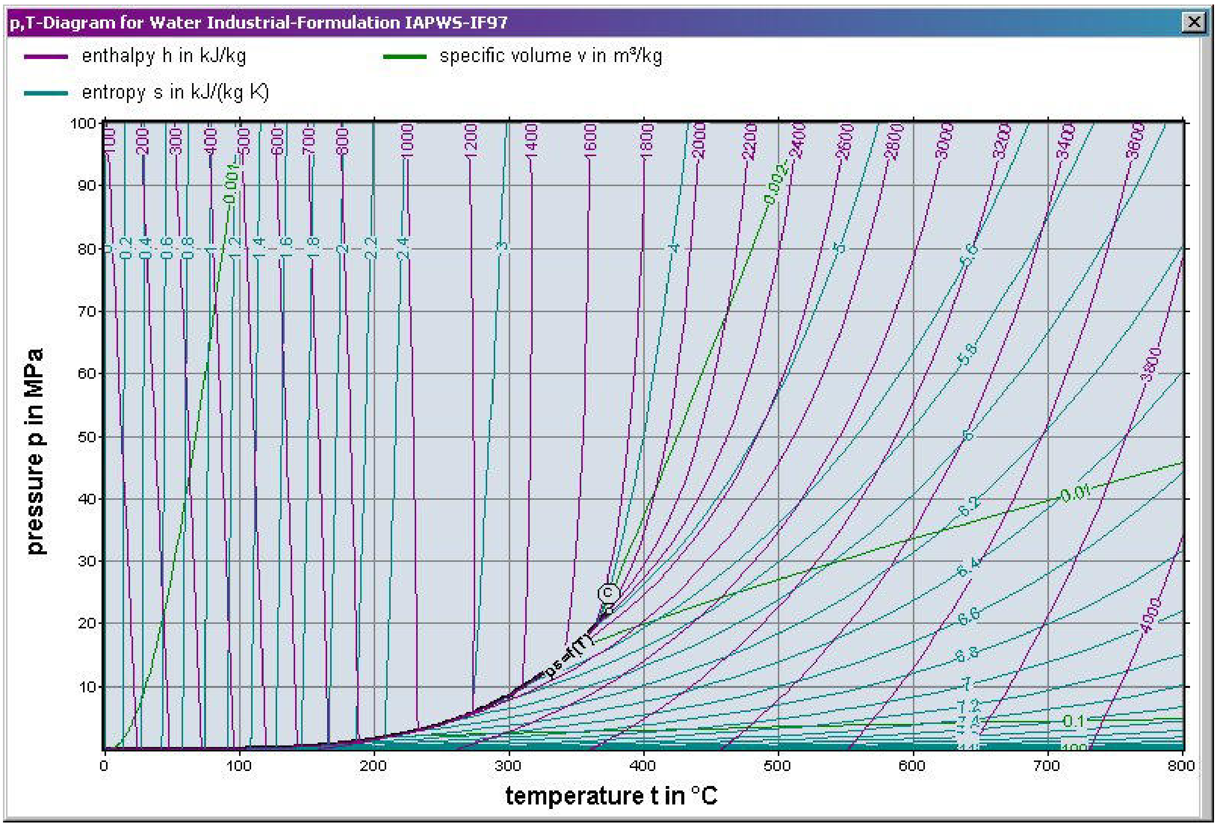

lg p,T-Diagram for Water Industrial-Formulation IAPWS-IF97



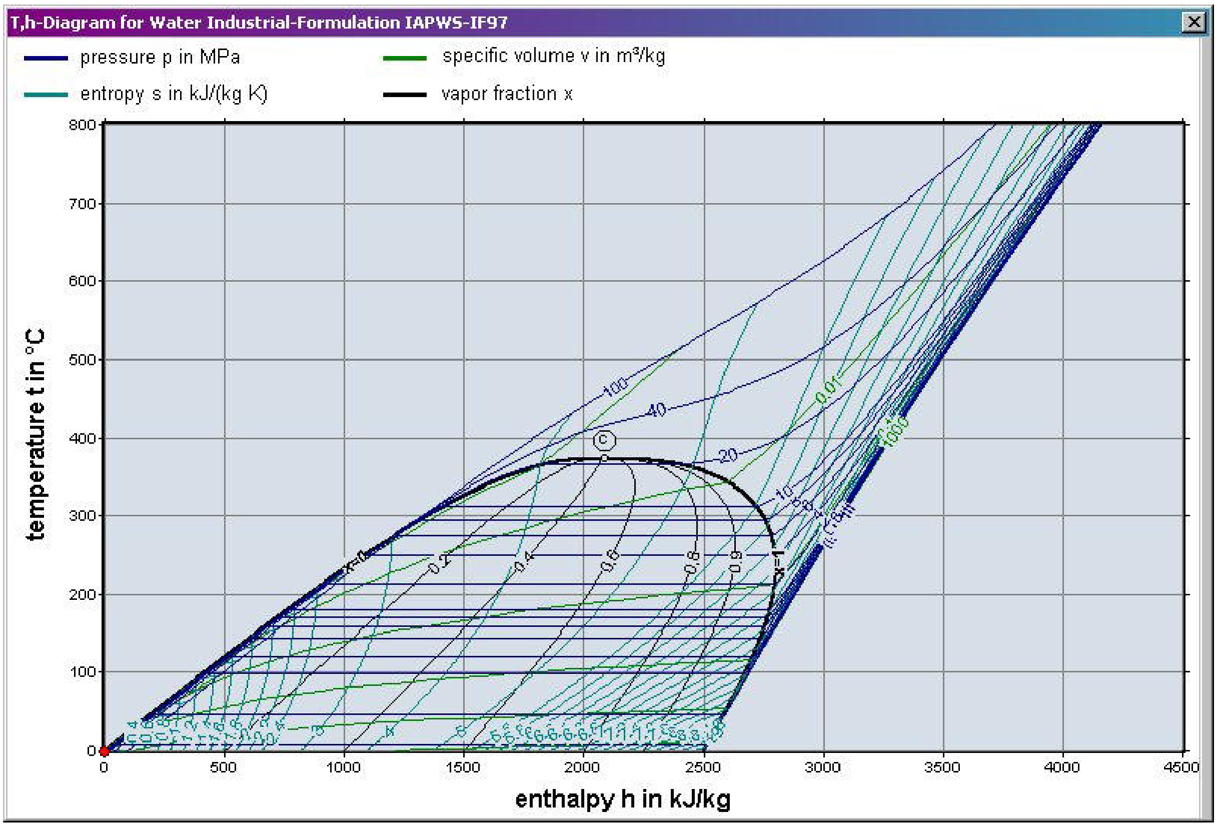
lgp,lg v-Diagram for Water Industrial-Formulation IAPWS-IF97



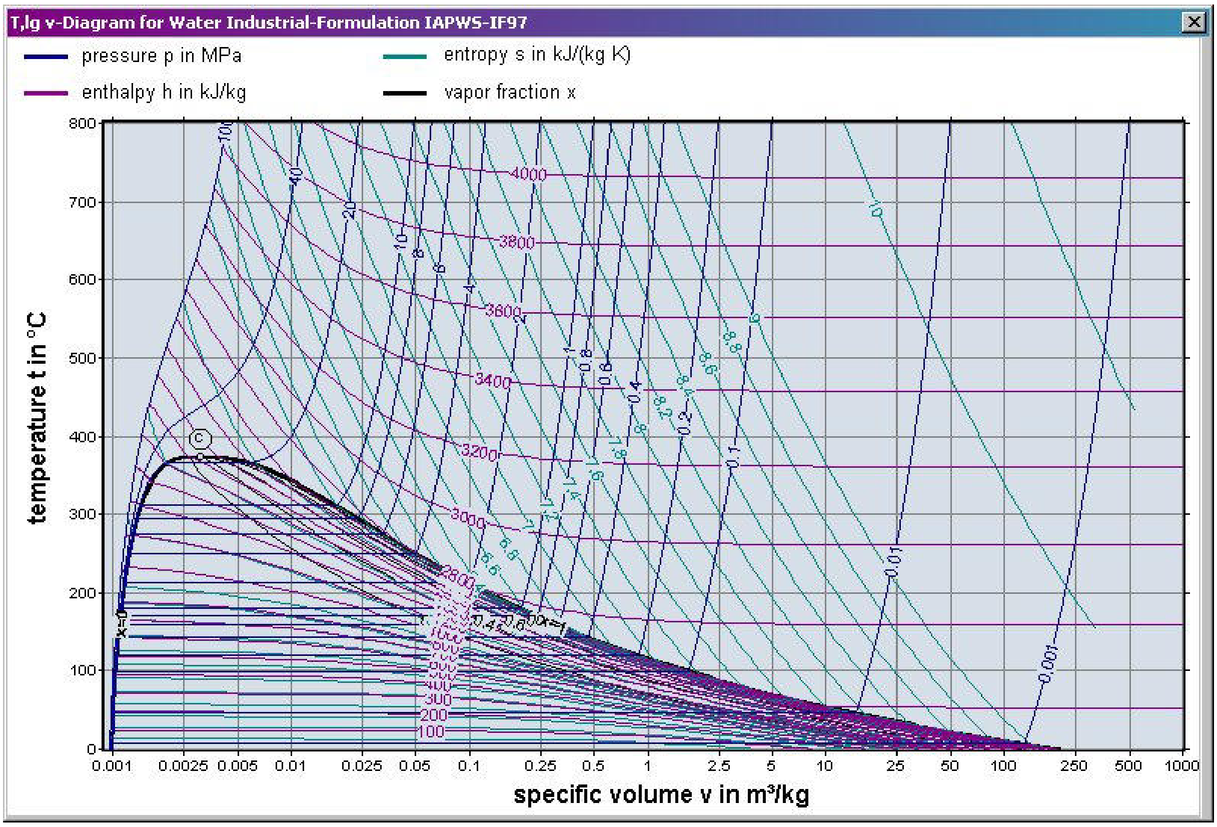
lg p,T-Diagram for Water Industrial-Formulation IAPWS-IF97



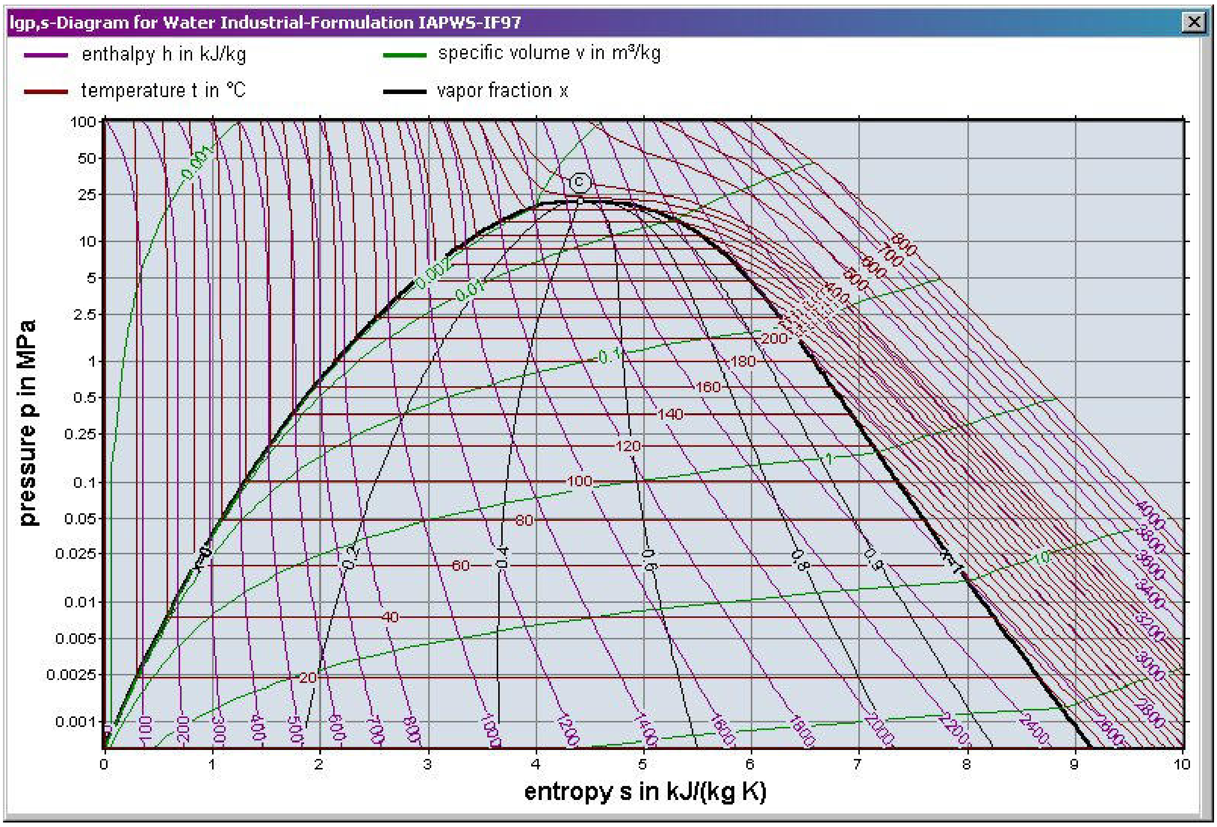
p,T-Diagram for Water Industrial-Formulation IAPWS-IF97



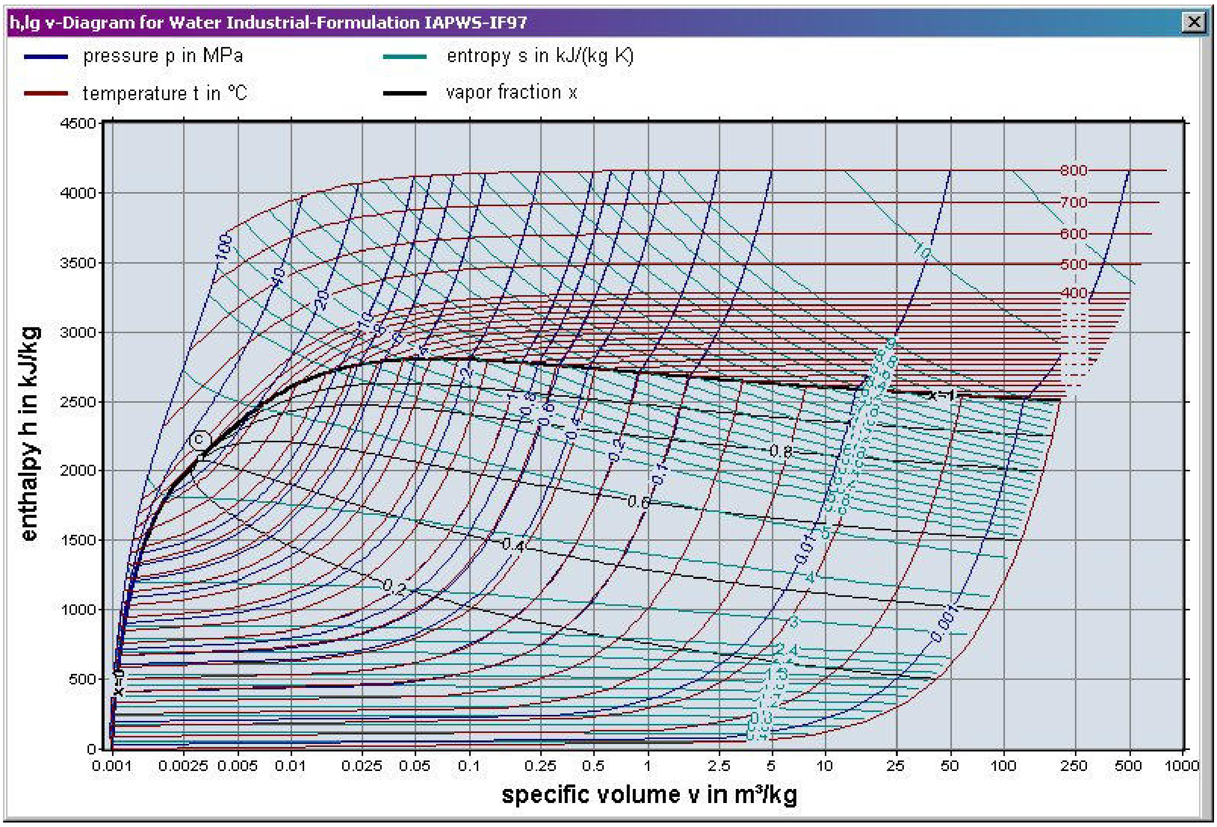
T,h-Diagram for Water Industrial-Formulation IAPWS-IF97



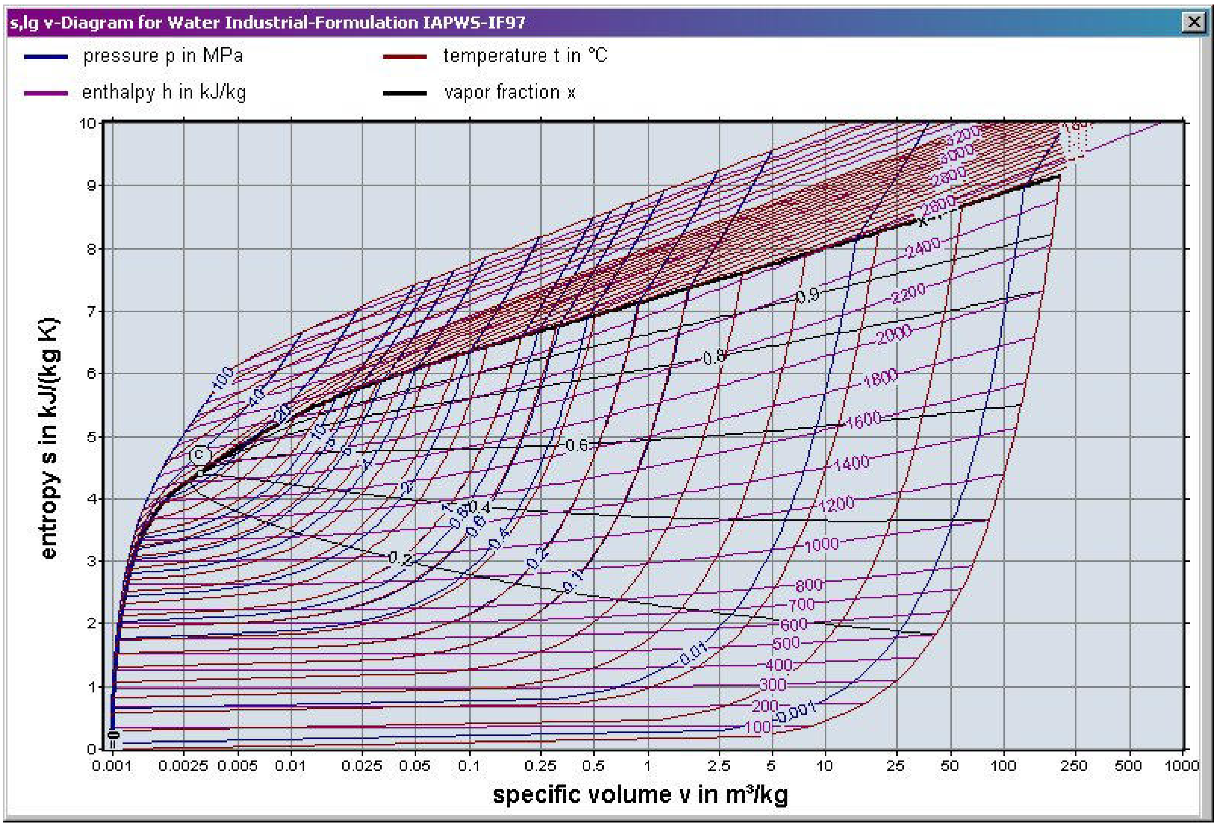
T,lg v-Diagram for Water Industrial-Formulation IAPWS-IF97



lgp,s-Diagram for Water Industrial-Formulation IAPWS-IF97



h,lg v-Diagram for Water Industrial-Formulation IAPWS-IF97



s,lg v-Diagram for Water Industrial-Formulation IAPWS-IF97