Property Library for Seawater Calculated from the IAPWS Industrial Formulation 2013

FluidLAB
with LibSeaWa
for MATLAB®

Prof. Hans-Joachim Kretzschmar
Dr. Sebastian Herrmann
Dr. Matthias Kunick

Property Library for Seawater Calculated from the IAPWS Industrial Formulation 2013

FluidLAB
LibSeaWa
for MATLAB®

Content

For steam tables and further property libraries for Excel®, MATLAB® and Mathcad® see the following link:

www.international-steam-tables.com

Professor Hans-Joachim Kretzschmar
Wallotstr. 3, 01307 Dresden, Germany
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-4262250
Email: info@thermofluidprop.com
Internet: www.thermofluidprop.com

0. Package Contents

0.1 Zip file for 32-bit MATLAB®

The following zip file is delivered for your computer running a 32-bit version of MATLAB®.

"CD_FluidLAB_LibSeaWa.zip"

Including the following files:

FluidLAB_LibSeaWa_Setup.exe	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibSeaWa.dll	- Dynamic Link Library for helium for use in MATLAB®
FluidLAB_LibSeaWa_Docu_Eng.pdf	- User's Guide

0.2 Zip file for 64-bit MATLAB®

The following zip file is delivered for your computer running a 64-bit version of MATLAB®.

"CD_FluidLAB_LibSeaWa_x64.zip"

Including the following files and folders:

Files:

Setup.exe	- Self-extracting and self-installing program for FluidLAB
FluidLAB_LibSeaWa_64.msi	- Installation program for the FluidLAB Add-On for use in MATLAB®
LibSeaWa.dll	- Dynamic Link Library for helium for use in MATLAB®
FluidLAB_LibSeaWa_Docu_Eng.pdf	- User's Guide

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

1. Property Functions

1.1 Functions

Functional Dependence	Function Name in Excel®	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$a = \mathrm{f}(p,t,\xi)$	a_ptXI_SeaWa	= A_PTXI_SEAWA(P,T,XI)	Thermal diffusivity	m²/s	[1], [2]	3/2
$a_{\mathrm{l}} = \mathrm{f}(t,\xi)$	al_tXI_SeaWa	= AL_TXI_SEAWA(T,XI)	Thermal diffusivity of subcooled liquid	m²/s	[1], [2]	3/3
$a_{\mathrm{sl}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}},\xi_{\mathrm{sl}})$	asl_pstsXisl_SeaWa	= ASL_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal diffusivity of saturated liquid	m²/s	[1], [2]	3/4
$a_{\mathrm{sv}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}},\xi_{\mathrm{sl}})$	asv_pstsXisl_SeaWa	= ASV_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal diffusivity of saturated vapor	m²/s	[1], [2]	3/5
$\alpha_{\mathrm{l}} = \mathrm{f}(p,t,\xi)$	alphal_ptXi_SeaWa	= ALPHAL_PTXI_SEAWA(P,T,XI)	Thermal expansion coefficient of subcooled liquid	1/K	[1]	3/6
$\alpha_{\mathrm{sl}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}},\xi_{\mathrm{sl}})$	alphasl_pstsXisl_SeaWa	= ALPHASL_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal expansion coefficient of saturated liquid	1/K	[1]	3/7
$\beta_{\mathrm{l}} = \mathrm{f}(p,t,\xi)$	betal_ptXi_SeaWa	= BETAL_PTXI_SEAWA(P,T,XI)	Haline contraction coefficient of subcooled liquid	kg/kg	[1]	3/8
$\beta_{\mathrm{sl}} = \mathrm{f}(p,t,\xi_{\mathrm{sl}})$	betasl_pstsXisl_SeaWa	= BETASL_PSTSXISL_SEAWA(PS,TS,XISL)	Haline contraction coefficient of saturated liquid	kg/kg	[1]	3/9
$\beta_{\mathrm{Isl}} = \mathrm{f}(p,t,\xi)$	betaIsl_ptXi_SeaWa	= BETAISL_PTXI_SEAWA(P,T,XI)	Isentropic temperature-pressure coefficient of subcooled liquid	K/kPa	[1]	3/10
$\beta_{\mathrm{Issl}} = \mathrm{f}(p,t,\xi_{\mathrm{sl}})$	betaIssl_pstsXisl_SeaWa	= BETAISSL_PSTSXISL_SEAWA(PS,TS,XISL)	Isentropic temperature-pressure coefficient of saturated liquid	K/kPa	[1]	3/11
$c_p = \mathrm{f}(p,t,\xi)$	cp_ptXI_SeaWa	= CP_PTXI_SEAWA(P,T,XI)	Specific isobaric heat capacity	kJ/(kg·K)	[1], [2]	3/12
$c_{p\_\mathrm{l}} = \mathrm{f}(p,t,\xi)$	cpl_ptXI_SeaWa	= CPL_PTXI_SEAWA(P,T,XI)	Specific isobaric heat capacity of subcooled liquid	kJ/(kg·K)	[1], [2]	3/13
$c_{p\_\mathrm{sl}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}},\xi_{\mathrm{sl}})$	cpsl_pstsXIsl_SeaWa	= CPSL_PSTSXISL_SEAWA(PS,TS,XISL)	Specific isobaric heat capacity of saturated liquid	kJ/(kg·K)	[1], [2]	3/14

Functional Dependence	Function Name in Excel®	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$c_{p\_sv} = \mathrm{f}(p_s, t_s, \xi_{sl})$	cpsv_pstsXisl_SeaWa	= CPSV_PSTSXISL_SEAWA(PS,TS,XISL)	Specific isobaric heat capacity of saturated vapor	kJ/(kg·K)	[1], [2]	3/15
$\eta = \mathrm{f}(p, t, \xi)$	eta_ptXI_SeaWa	= ETA_PTXI_SEAWA(P,T,XI)	Dynamic viscosity	Pa·s	[1], [2]	3/16
$\eta_l = \mathrm{f}(t, \xi)$	etal_tXI_SeaWa	= ETAL_TXI_SEAWA(T,XI)	Dynamic viscosity of subcooled liquid	Pa·s	[1], [2]	3/17
$\eta_{sl} = \mathrm{f}(p_s, t_s, \xi_{sl})$	etasl_pstsXIsl_SeaWa	= ETASL_PSTSXISL_SEAWA(PS,TS,XISL)	Dynamic viscosity of saturated liquid	Pa·s	[1], [2]	3/18
$\eta_{sv} = \mathrm{f}(p_s, t_s, \xi_{sl})$	etasv_pstsXisl_SeaWa	= ETASV_PSTSXISL_SEAWA(PS,TS,XISL)	Dynamic viscosity of saturated vapor	Pa·s	[1], [2}	3/19
$f_l = \mathrm{f}(p, t, \xi)$	fl_ptXI_SeaWa	= FL_PTXI_SEAWA(P,T,XI)	Specific Helmholtz energy of subcooled liquid	kJ/kg	[1]	3/20
$f_{sl} = \mathrm{f}(p_s, t_s, \xi_{sl})$	fsl_pstsXIsl_SeaWa	= FSL_PSTSXISL_SEAWA(PS,TS,XISL)	Specific Helmholtz energy of saturated liquid	kJ/kg	[1]	3/21
$\phi_l = \mathrm{f}(p, t, \xi)$	phil_ptXI_SeaWa	= PHIL_PTXI_SEAWA(P,T,XI)	Osmotic coefficient of subcooled liquid	[-]	[1]	3/22
$\phi_{sl} = \mathrm{f}(p_s, t_s, \xi_{sl})$	phisl_pstsXIsl_SeaWa	= PHISL_PSTSXISL_SEAWA(PS,TS,XISL)	Osmotic coefficient of saturated liquid	[-]	[1]	3/23
$h = \mathrm{f}(p, t, \xi)$	h_ptXI_SeaWa	= H_PTXI_SEAWA(P,T,XI)	Specific enthalpy	kJ/kg	[1], [2]	3/24
$h_l = \mathrm{f}(p, t, \xi)$	hl_ptXI_SeaWa	= HL_PTXI_SEAWA(P,T,XI)	Specific enthalpy of subcooled liquid	kJ/kg	[1], [2]	3/25
$h_{sl} = \mathrm{f}(p_s, t_s, \xi_{sl})$	hsl_pstsXisl_SeaWa	= HSL_PSTSXISL_SEAWA(PS,TS,XISL)	Specific enthalpy of saturated liquid	kJ/kg	[1], [2]	3/26
$h_{sv} = \mathrm{f}(p_s, t_s, \xi_{sl})$	hsv_pstsXisl_SeaWa	= HSV_PSTSXISL_SEAWA(PS,TS,XISL)	Specific enthalpy of saturated steam	kJ/kg	[1], [2]	3/27
$\kappa = \mathrm{f}(p, t, \xi)$	kappa_ptXI_SeaWa	= KAPPA_PTXI_SEAWA(P,T,XI)	Isentropic exponent	[-]	[1]	3/28
$\kappa_l = \mathrm{f}(p, t, \xi)$	kappal_ptXI_SeaWa	= KAPPAL_PTXI_SEAWA(P,T,XI)	Isentropic exponent of subcooled liquid	[-]	[1]	3/29
$\kappa_{sl} = \mathrm{f}(p_s, t_s, \xi_{sl})$	kappasl_pstsXisl_SeaWa	= KAPPASL_PSTSXISL_SEAWA(PS,TS,XISL)	Isentropic exponent of saturated liquid	[-]	[1]	3/30

Functional Dependence	Function Name in Excel®	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$\kappa_{sv} = f(p_s, t_s, \xi_{sl})$	kappasv_pstsXisl_SeaWa	= KAPPASV_PSTSXISL_SEAWA(PS,TS,XISL)	Isentropic exponent of saturated vapor	[-]	[1]	3/31
$\kappa_{T\_l} = f(p, t, \xi)$	kappaTl_ptXI_SeaWa	= KAPPATL_PTXI_SEAWA(P,T,XI)	Isothermal compressibility of subcooled liquid	1/kPa	[1]	3/32
$\kappa_{T\_sl} = f(p_s, t_s, \xi_{sl})$	kappaTsl_pstsXisl_SeaWa	= KAPPATSL_PSTSXISL_SEAWA(PS,TS,XISL)	Isothermal compressibility of saturated liquid	1/kPa	[1]	3/33
$\kappa_{Is\_l} = f(p, t, \xi)$	kappaIsl_ptXI_SeaWa	= KAPPAISL_PTXI_SEAWA(P,T ,XI)	Isentropic compressibility of subcooled liquid	1/kPa	[1]	3/34
$\kappa_{Is\_sl} = f(p_s, t_s, \xi_{sl})$	kappaIssl_pstsXisl_SeaWa	= KAPPAISSL_PSTSXISL_SEAWA(PS,TS,XISL)	Isentropic compressibility of saturated liquid	1/kPa	[1]	3/35
$\lambda = f(p, t, \xi)$	lambda_ptXI_SeaWa	= LAMBDA_PTXI_SEAWA(P,T,XI)	Thermal conductivity	W/(m*K)	[3], [4], [15]	3/36
$\lambda_l = f(t, \xi)$	lambdal_tXI_SeaWa	= LAMBDAL_TXI_SEAWA(T,XI)	Thermal conductivity of subcooled liquid	W/(m*K)	[3], [4], [15]	3/37
$\lambda_{sl} = f(p_s, t_s, \xi_{sl})$	lambdasl_pstsXisl_SeaWa	= LAMBDASL_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal conductivity of saturated liquid	W/(m*K)	[3], [4], [15]	3/38
$\lambda_{sv} = f(p_s, t_s, \xi_{sl})$	lambdasv_pstsXisl_SeaWa	= LAMBDASV_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal conductivity of saturated vapor	W/(m*K)	[3], [4], [15]	3/39
$\mu_l = f(p, t, \xi)$	myl_ptXI_SeaWa	= MYL_PTXI_SEAWA(P,T,XI)	Relative chem. potential of subcooled liquid	kJ/kg	[1]	3/40
$\mu_{sl} = f(p_s, t_s, \xi_{sl})$	mysl_pstsXisl_SeaWa	= MYSL_PSTSXISL_SEAWA(PS,TS,XISL)	Relative chem. potential of saturated liquid	kJ/kg	[1]	3/41
$\mu_{W\_l} = f(p, t, \xi)$	mywl_ptXI_SeaWa	= MYWL_PTXI_SEAWA(P,T,XI)	Relative chem. potential of H_2O of subcooled liquid	kJ/kg	[1]	3/42
$\mu_{W\_sl} = f(p_s, t_s, \xi_{sl})$	mywsl_pstsXisl_SeaWa	= MYWSL_PSTSXISL_SEAWA(PS,TS,XISL)	Relative chem. potential of H_2O of saturated liquid	kJ/kg	[1]	3/43
$\mu_{Salt\_l} = f(p, t, \xi)$	mySaltl_ptXI_SeaWa	= MYSALTL_PTXI_SEAWA(P,T,XI)	Relative chem. potential of sea salt of subcooled liquid	kJ/kg	[1]	3/44
$\mu_{Salt\_sl} = f(p_s, t_s, \xi_{sl})$	mySaltsl_pstsXisl_SeaWa	= MYSALTSL_PSTSXISL_SEAWA(PS,TS,XISL)	Relative chem. potential of sea salt of saturated liquid	kJ/kg	[1]	3/45

Functional Dependence	Function Name in Excel®	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$v = \mathrm{f}(p,t,\xi)$	ny_ptXI_SeaWa	= NY_PTXI_SEAWA(P,T,XI)	Kinematic viscosity	m²/s	[1], [2]	3/46
$v_\mathrm{l} = \mathrm{f}(t,\xi)$	nyl_tXI_SeaWa	= NYL_TXI_SEAWA(T,XI)	Kinematic viscosity of subcooled liquid	m²/s	[1], [2]	3/47
$v_\mathrm{sl} = \mathrm{f}(p_\mathrm{s},t_\mathrm{s},\xi_\mathrm{sl})$	nysl_pstsXIsl_SeaWa	= NYSL_PSTSXISL_SEAWA(PS,TS,XISL)	Kinematic viscosity of saturated liquid	m²/s	[1], [2]	3/48
$v_\mathrm{sv} = \mathrm{f}(p_\mathrm{s},t_\mathrm{s},\xi_\mathrm{sl})$	nysv_pstsXisl_SeaWa	= NYSV_PSTSXISL_SEAWA(PS,TS,XISL)	Kinematic viscosity of saturated vapor	m²/s	[1], [2]	3/49
$p_\mathrm{s} = \mathrm{f}(t_\mathrm{s},\xi_\mathrm{sl})$	ps_tsXisl_SeaWa	= PS_TSXISL_SEAWA(TS,XISL)	Boiling pressure	bar	[1] ,[2] ,[4]	3/50
$p_\mathrm{mel} = \mathrm{f}(t,\xi)$	pmel_tXi_SeaWa	= PMEL_TXI_SEAWA(T,XI)	Freezing pressure	bar	[1] ,[4], [5]	3/51
$p_\mathrm{tr} = \mathrm{f}(\xi)$	ptr_Xi_SeaWa	= PTR_XI_SEAWA(T,XI)	Triple point pressure	bar	[1] ,[4], [5]	3/52
$\mathrm{Pr} = \mathrm{f}(p,t,\xi)$	Pr_ptXI_SeaWa	= PR_PTXI_SEAWA(P,T,XI)	Prandtl Number	[-]	[1], [2], [3]	3/53
$\mathrm{Pr}_\mathrm{l} = \mathrm{f}(t,\xi)$	Prl_tXI_SeaWa	= PRL_TXI_SEAWA(T,XI)	Prandtl Number of subcooled liquid	[-]	[1], [2], [3]	3/54
$\mathrm{Pr}_\mathrm{sl} = \mathrm{f}(p_\mathrm{s},t_\mathrm{s},\xi_\mathrm{sl})$	Prsl_pstsXisl_SeaWa	= PRSL_PSTSXISL_SEAWA(PS,TS,XISL)	Prandtl Number of saturated liquid	[-]	[1], [2], [3]	3/55
$\mathrm{Pr}_\mathrm{sv} = \mathrm{f}(p_\mathrm{s},t_\mathrm{s},\xi_\mathrm{sl})$	Prsv_pstsXisl_SeaWa	= PRSV_PSTSXISL_SEAWA(PS,TS,XISL)	Prandtl Number of saturated vapor	[-]	[1], [2], [3]	3/56
$\rho = \mathrm{f}(p,t,\xi)$	rho_ptXI_SeaWa	= RHO_PTXI_SEAWA(P,T,XI)	Density	kg/m³	[1], [2]	3/57
$\rho_\mathrm{l} = \mathrm{f}(p,t,\xi)$	rhol_ptXI_SeaWa	= RHOL_PTXI_SEAWA(P,T,XI)	Density of subcooled liquid	kg/m³	[1], [2]	3/58
$\rho_\mathrm{sl} = \mathrm{f}(p_\mathrm{s},t_\mathrm{s},\xi_\mathrm{sl})$	rhosl_pstsXisl_SeaWa	= RHOSL_PSTSXISL_SEAWA(PS,TS,XISL)	Density of saturated liquid	kg/m³	[1], [2]	3/59
$\rho_\mathrm{sv} = \mathrm{f}(p_\mathrm{s},t_\mathrm{s},\xi_\mathrm{sl})$	rhosv_pstsXisl_SeaWa	= RHOSV_PSTSXISL_SEAWA(PS,TS,XISL)	Density of saturated vapor	kg/m³	[1], [2]	3/60
$s = \mathrm{f}(p,t,\xi)$	s_ptXI_SeaWa	= S_PTXI_SEAWA(P,T,XI)	Specific entropy	kJ/(kg*K)	[1], [2]	3/61
$s_\mathrm{l} = \mathrm{f}(p,t,\xi)$	sl_ptXI_SeaWa	= SL_PTXI_SEAWA(P,T,XI)	Specific entropy of subcooled liquid	kJ/(kg*K)	[1], [2]	3/62
$s_\mathrm{sl} = \mathrm{f}(p_\mathrm{s},t_\mathrm{s},\xi_\mathrm{sl})$	ssl_pstsXisl_SeaWa	= SSL_PSTSXISL_SEAWA(PS,TS,XISL)	Specific entropy of saturated liquid	kJ/(kg*K)	[1], [2]	3/63

Functional Dependence	Function Name in Excel®	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$s_{sv} = f(p_s, t_s, \xi_{sl})$	ssv_pstsXisl_SeaWa	= SSV_PSTSXISL_SEAWA(PS,TS,XISL)	Specific entropy of saturated vapor	kJ/(kg*K)	[1], [2]	3/64
$t_s = f(p_s, \xi_{sl})$	ts_psXisl_SeaWa	= TS_PSXISL_SEAWA(PS,XISL)	Boiling temperature	°C	[1] ,[2], [4]	3/65
$t_{mel} = f(p, \xi)$	tmel_pXi_SeaWa	= TMEL_PXI_SEAWA(P,XI)	Freezing temperature	°C	[1] ,[4], [5]	3/66
$t_{tr} = f(\xi)$	ttr_Xi_SeaWa	= TTR_XI_SEAWA(T,XI)	Triple point temperature	°C	[1] ,[4], [5]	3/67
$\mathrm{Region} = f(p, t, \xi)$	Region_ptXI_SeaWa	= REGION_PTXI_SEAWA(P,T,XI)	Region	[-]	[1], [2], [4]	3/68
$\mathrm{Region} = f(p, h, \xi)$	Region_phXI_SeaWa	= REGION_PHXI_SEAWA(P,H,XI)	Region	[-]	[1], [2], [4]	3/69
$\mathrm{Region} = f(p, s, \xi)$	Region_psXI_SeaWa	= REGION_PSXI_SEAWA(P,S,XI)	Region	[-]	[1], [2], [4]	3/70
$t = f(p, h, \xi)$	t_phXI_SeaWa	= T_PHXI_SEAWA(P,H,XI)	Backward function: Temperature from pressure and specific enthalpy	°C	[1], [2], [4]	3/71
$t = f(p, s, \xi)$	t_psXI_SeaWa	= T_PSXI_SEAWA(P,S,XI)	Backward function: Temperature from pressure and specific entropy	°C	[1], [2], [4]	3/72
$u = f(p, t, \xi)$	u_ptXI_SeaWa	= U_PTXI_SEAWA(P,T,XI)	Specific internal energy	kJ/kg	[1], [2]	3/73
$u_l = f(p, t, \xi)$	ul_ptXI_SeaWa	= UL_PTXI_SEAWA(P,T,XI)	Specific internal energy of subcooled liquid	kJ/kg	[1], [2]	3/74
$u_{sl} = f(p_s, t_s, \xi_{sl})$	usl_pstsXisl_SeaWa	= USL_PSTSXISL_SEAWA(PS,TS,XISL)	Specific internal energy of saturated liquid	kJ/kg	[1], [2]	3/75
$u_{sv} = f(p_s, t_s, \xi_{sl})$	usv_pstsXisl_SeaWa	= USV_PSTSXISL_SEAWA(PS,TS,XISL)	Specific internal energy of saturated vapor	kJ/kg	[1], [2]	3/76
$\upsilon = f(p, t, \xi)$	v_ptXI_SeaWa	= V_PTXI_SEAWA(P,T,XI)	Specific volume	m³/kg	[1], [2]	3/77
$\upsilon_l = f(p, t, \xi)$	vl_ptXI_SeaWa	= VL_PTXI_SEAWA(P,T,XI)	Specific internal energy of subcooled liquid	m³/kg	[1], [2]	3/78
$\upsilon_{sl} = f(p_s, t_s, \xi_{sl})$	vsl_pstsXisl_SeaWa	= VSL_PSTSXISL_SEAWA(PS,TS,XISL)	Specific volume of saturated liquid	m³/kg	[1], [2]	3/79
$\upsilon_{sv} = f(p_s, t_s, \xi_{sl})$	vsv_pstsXisl_SeaWa	= VSV_PSTSXISL_SEAWA(PS,TS,XISL)	Specific volume of saturated	m³/kg	[1], [2]	3/80

			vapor			
Functional Dependence	**Function Name in Excel®**	**Call as Fortran Program**	**Property or Function**	**Unit of the Result**	**Reference**	**Page**
$w = \mathrm{f}(p,t,\xi)$	w_ptXI_SeaWa	= W_PTXI_SEAWA(P,T,XI)	Speed of sound	m/s	[1]	3/81
$w_{\mathrm{l}} = \mathrm{f}(p,t,\xi)$	wl_ptXI_SeaWa	= WL_PTXI_SEAWA(P,T,XI)	Speed of sound of liquid	m/s	[1]	3/82
$w_{\mathrm{sl}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}},\xi_{\mathrm{sl}})$	wsl_pstsXisl_SeaWa	= WSL_PSTSXISL_SEAWA(PS,TS,XISL)	Speed of sound of saturated liquid	m/s	[1]	3/83
$w_{\mathrm{sv}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}},\xi_{\mathrm{sl}})$	wsv_pstsXisl_SeaWa	= WSV_PSTSXISL_SEAWA(PS,TS,XISL)	Speed of sound of saturated vapor	m/s	[1]	3/84
$x = \mathrm{f}(p,t,\xi)$	x_ptXI_SeaWa	= X_PTXI_SEAWA(P,T,XI)	Vapor fraction	kg/kg	[1]	3/85
$\xi_{\mathrm{sl}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}})$	Xisl_psts_SeaWa	= XISL_PSTS_SEAWA(PS,TS)	Mass fraction of sea salt in saturated liquid	kg/kg	[1]	3/86
$\xi_{\mathrm{sv}} = \mathrm{f}(p_{\mathrm{s}},t_{\mathrm{s}})$	Xisv_psts_SeaWa	= XISV_PSTS_SEAWA(PS,TS)	Mass fraction of sea salt in saturated vapor	kg/kg	[1]	3/87

Range of Validity

Pressure:	0.002 093	≤	p	≤	1000	bar
Temperature:	0	≤	t	≤	220	°C
Salinity:	0	≤	ξ	≤	0.2	$kg_{salt}/kg_{mixture}$

Reference State

Property	SeaWater
Pressure	1.01325 bar
Temperature	0 °C
Salinity	0.003516504 kg/kg
Enthalpy	0 kJ/ kg
Entropy	0 kJ/(kg K)

Variable Types for Function Call

All functions and variables:	REAL*8

Property functions with deviation to the range of validity (cp. Chapter. 3)

2 Application of FluidLAB in MATLAB

The FluidLAB Add-In has been developed to calculate thermodynamic properties in MATLAB®. Within FluidLAB, it enables the direct call of functions relating to seawater from the LibSeaWa property library.

2.1 Installing FluidLAB

Installing FluidLAB including LibSeaWa for 32-bit MATLAB®

This section describes the installation of FluidLAB LibSeaWa for a 32-bit version of MATLAB®.

Before you begin, it is best to close any Windows® applications, since Windows® may need to be rebooted during the installation process.

After you have downloaded and extracted the zip-file "CD_FluidLAB_LibSeaWa.zip", you will see the folder

CD_FluidLAB_LibSeaWa

in your Windows Explorer®, Norton Commander® or another similar program you are using.

Open this folder by double-clicking on it.

In this folder you will see the following files:

FluidLAB_LibSeaWa_Docu_Eng.pdf
FluidLAB_LibSeaWa_Setup.exe
LibSeaWa.dll.

In order to run the installation of FluidLAB including, the LibSeaWa property library, double-click on the file

FluidLAB_LibSeaWa_Setup.exe.

Installation may start with a window noting that all Windows® programs should be closed. When this is the case, the installation can be continued. Click the "Next >" button.

In the following dialog box, "Destination Location", the default path offered automatically for the installation of FluidLAB is

C:\Program Files\FluidLAB\LibSeaWa (for English version of Windows)
C:\Programme\FluidLAB\LibSeaWa (for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.1).

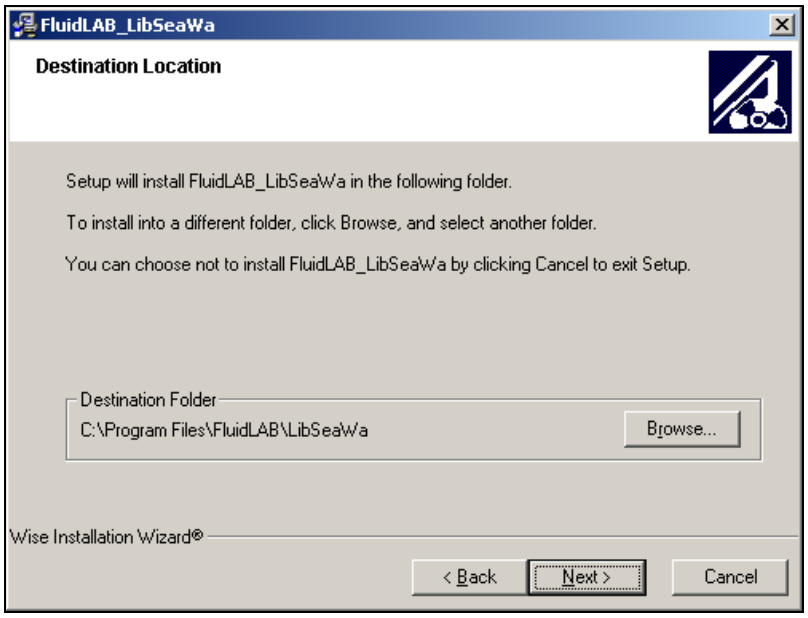


Figure 2.1: "Destination Location"

If you wish to change directories, click the "Browse…" button and select your desired directory. The instructions in this documentation refer to the stated default directory. Leave this window by clicking the "Next >" button.

The dialog window "Start Installation" appears. Click the "Next >" button to continue installation. The FluidLAB files are now being copied into the created directory on your hard drive. Click the "Finish >" button in the following window to complete installation.

The installation program has copied the following files:

capt_ico_big.ico	LC.dll
libifcoremd.dll	limmd.dll
libiomp5md.dll	LibSeaWa.dll

for LibSeaWa into the directory

"C:\Program Files\FluidLAB\LibSeaWa"	(for English version of Windows)
"C:\Programme\FluidLAB\LibSeaWa"	(for German version of Windows)

Now, you have to overwrite the file "LibSeaWa.dll" in your FluidLAB directory with the file of the same name provided on your CD with FluidLAB.

To do this, open the CD in "My Computer" and click on the file "LibSeaWa.dll" in order to highlight it.

Then click on the "Edit" menu in your Explorer and select "Copy".

Now, open your FluidLAB directory (the standard being

C:\Program Files\FluidLAB\LibSeaWa	(for English version of Windows)
C:\Programme\FluidLAB\LibSeaWa	(for German version of Windows))

and insert the file "LibSeaWa.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button. Now, you have overwritten the file "LibSeaWa.dll" successfully and the property functions are available in MATLAB.

Installing FluidLAB including LibSeaWa for 64-bit MATLAB®

This section describes the installation of FluidLAB LibSeaWa.

Before you begin, it is best to close any Windows® applications, since Windows® may need to be rebooted during the installation process.

After you have downloaded and extracted the zip-file "CD_FluidLAB_LibSeaWa_x64.zip", you will see the folder

CD_FluidLAB_LibSeaWa

in your Windows Explorer®, Norton Commander® or other similar program you are using.

Open this folder by double-clicking on it.

In this folder you will see the following two files:

FluidLAB_LibSeaWa_Docu_Eng.pdf
FluidLAB_LibSeaWa_64_Setup.msi
LibSeaWa.dll
Setup.exe.

In order to run the installation of FluidLAB including, the LibSeaWa property library, double-click on the file

Setup.exe.

Installation of FluidLAB LibSeaWa starts with a window noting that the installer will guide you through the installation process. Click the "Next >" button to continue.

In the following dialog box, "Destination Location", the default path offered automatically for the installation of FluidLAB is

C:\Program Files\FluidLAB\LibSeaWa (for English version of Windows)
C:\Programme\FluidLAB\LibSeaWa (for German version of Windows)

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.2).

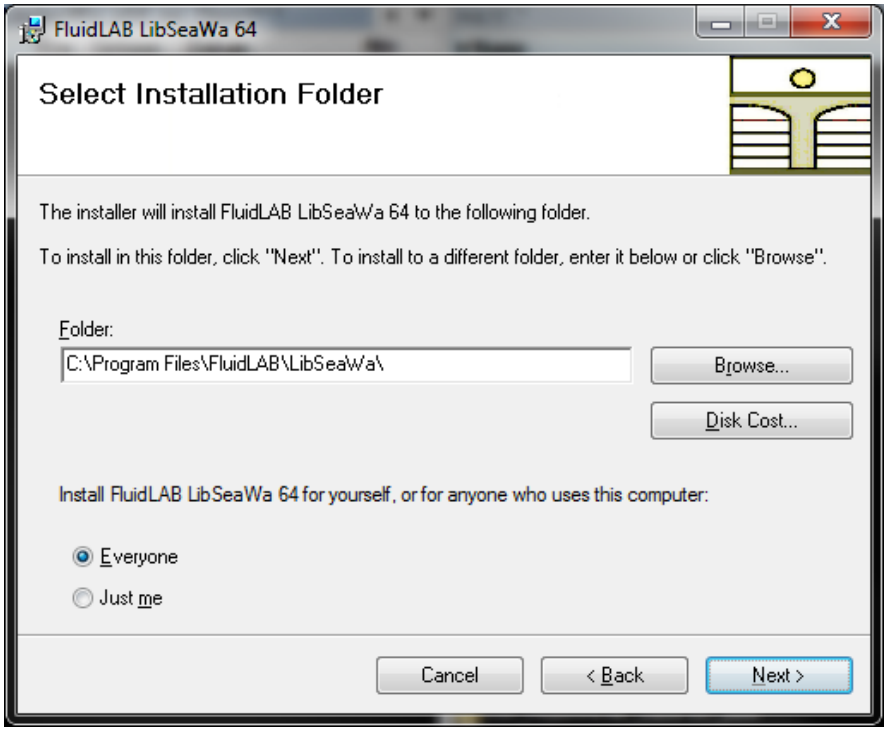


Figure 2.2: "Select Installation Folder"

Finally, click on "Next >" to continue installation; click "Next >" again in the "Confirm Installation" window which follows in order to start the installation of FluidLAB.

After FluidLAB has been installed, you will see the sentence "FluidLAB LibSeaWa 64 has been successfully installed." Confirm this by clicking the "Close" button.

The installation program has copied the following files for LibSeaWa into the directory

"C:\Program Files\FluidLAB\LibSeaWa" (for English version of Windows)
"C:\Programme\FluidLAB\LibSeaWa" (for German version of Windows):

capt_ico_big.ico	libifcoremd.dll
LC.dll	libiomp5md.dll
LibSeaWa.dll	libmmd.dll

Now, you have to overwrite the file "LibSeaWa.dll" in your FluidLAB directory with the file of the same name provided on your CD with FluidLAB.
To do this, open the CD in "My Computer" and click on the file "LibSeaWa.dll" in order to highlight it. Then click on the "Edit" menu in your Explorer and select "Copy".
Now, open your FluidLAB directory (the standard being C:\Program Files\FluidLAB\LibSeaWa) and insert the file "LibSeaWa.dll" by clicking the "Edit" menu in your Explorer and then select "Paste". Answer the question whether you want to replace the file by clicking the "Yes" button. Now, you have overwritten the file "LibSeaWa.dll" successfully and the property functions are available in MATLAB.

The installation programs for both the 32-bit and the 64-bit Windows version have copied the following function files for LibSeaWa into the directory

"C:\Program Files\FluidLAB\LibSeaWa" (for English version of Windows)
"C:\Programme\FluidLAB\LibSeaWa" (for German version of Windows):

- Dynamic link library "LibSeaWa.dll" and other necessary system DLL files.

- MATLAB®-Interface-Program for calculable functions

a_ptXI_SeaWa	mywl_ptXI_SeaWa
al_ptXI_SeaWa	mywsl_pstsXisl_SeaWa
asl_pstsXisl_SeaWa	mySaltl_ptXI_SeaWa
asv_pstsXisl_SeaWa	mySaltsl_pstsXisl_SeaWa
alphal_ptXi_SeaWa	ny_ptXI_SeaWa
alphasl_pstsXisl_SeaWa	nyl_ptXI_SeaWa
betal_ptXi_SeaWa	nysl_pstsXIsl_SeaWa
betasl_pstsXisl_SeaWa	nysv_pstsXisl_SeaWa
betaIsl_ptXi_SeaWa	ps_tsXisl_SeaWa
betaIssl_pstsXisl_SeaWa	pmel_tXi_SeaWa
cp_ptXI_SeaWa	ptr_Xi_SeaWa
cpl_ptXI_SeaWa	Pr_ptXI_SeaWa
cpsl_pstsXIsl_SeaWa	Prl_ptXI_SeaWa
cpsv_pstsXisl_SeaWa	Prsl_pstsXisl_SeaWa
eta_ptXI_SeaWa	Prsv_pstsXisl_SeaWa
etal_ptXI_SeaWa	rho_ptXI_SeaWa
etasl_pstsXIsl_SeaWa	rhol_ptXI_SeaWa
etasv_pstsXisl_SeaWa	rhosl_pstsXisl_SeaWa
fl_ptXI_SeaWa	rhosv_pstsXisl_SeaWa

fsl_pstsXIsl_SeaWa
phil_ptXI_SeaWa
phisl_pstsXIsl_SeaWa
h_ptXI_SeaWa
hl_ptXI_SeaWa
hsl_pstsXisl_SeaWa
hsv_pstsXisl_SeaWa
kappa_ptXI_SeaWa
kappal_ptXI_SeaWa
kappasl_pstsXisl_SeaWa
kappasv_pstsXisl_SeaWa
kappaTl_ptXI_SeaWa
kappaTsl_pstsXisl_SeaWa
kappaIsl_ptXI_SeaWa
kappaIssl_pstsXisl_SeaWa
lambda_ptXI_SeaWa
lambdal_ptXI_SeaWa
lambdasl_pstsXisl_SeaWa
lambdasv_pstsXisl_SeaWa
myl_ptXI_SeaWa
mysl_pstsXisl_SeaWa
wl_ptXI_SeaWa
wsl_pstsXisl_SeaWa
wsv_pstsXisl_SeaWa
s_ptXI_SeaWa
sl_ptXI_SeaWa
ssl_pstsXisl_SeaWa
ssv_pstsXisl_SeaWa
ts_psXisl_SeaWa
tmel_pXi_SeaWa
ttr_Xi_SeaWa
Region_ptXI_SeaWa
Region_phXI_SeaWa
Region_psXI_SeaWa
t_phXI_SeaWa
t_psXI_SeaWa
u_ptXI_SeaWa
ul_ptXI_SeaWa
usl_pstsXisl_SeaWa
usv_pstsXisl_SeaWa
v_ptXI_SeaWa
vl_ptXI_SeaWa
vsl_pstsXisl_SeaWa
vsv_pstsXisl_SeaWa
w_ptXI_SeaWa
x_ptXI_SeaWa
Xisl_psts_SeaWa
Xisv_psts_SeaWa

Please note that there is a difference in the file extension of the function files.

The 32-bit installation program has copied function files with the file extension

.mexw32

and the 64-bit installation program has copied function files with the file extension

.mexw64

into your LibSeaWa directory (the standard being

C:\Program Files\FluidLAB\LibSeaWa (for English version of Windows)
C:\Programme\FluidLAB\LibSeaWa (for German version of Windows).

2.2 Licensing the LibSeaWa Property Library

The licensing procedure must be carried out when the prompt message appears. In this case, you will see the "License Information" window for LibSeaWa (see figure below).

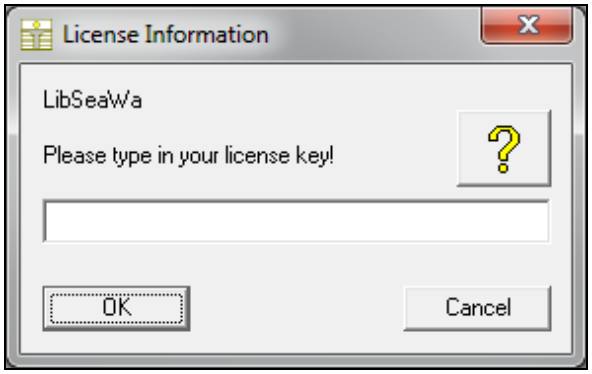


Figure 2.3: "License Information" window

Here you are asked to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. If you do not have this, or have any questions, you will find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:

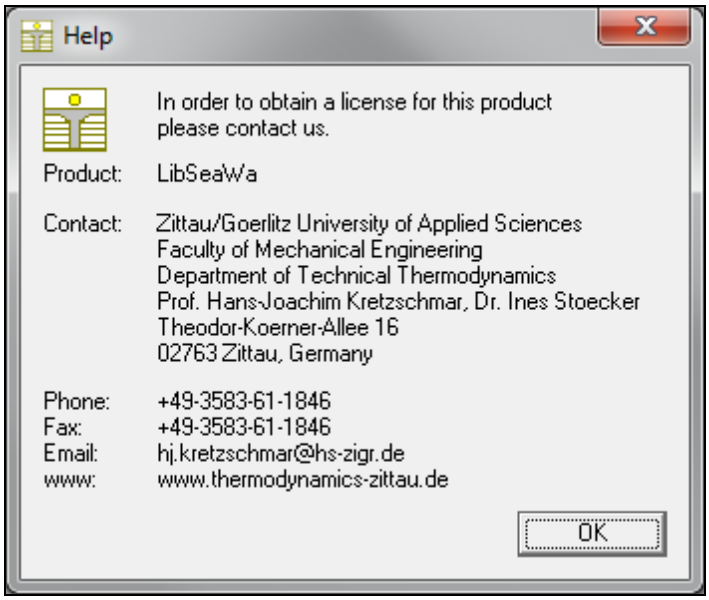


Figure 2.4: "Help" window

If you do not enter a valid license it is still possible to use MATLAB® by clicking "Cancel" twice. In this case, the LibSeaWa property library will display the result "–11111111" for every calculation.

The "License Information" window will appear every time you use FluidLAB LibSeaWa until you enter a license code to complete registration. If you decide not to use FluidLAB LibSeaWa, you can uninstall the program following the instructions given in section 2.5 of this User's Guide.

2.3 Example: Calculation of the Specific Enthalpy $h = f(p,t,\xi)$ for Seawater in an M-File

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p, temperature t and water mass fraction of sea salt ξ, for seawater using FluidLAB.

Please carry out the following instructions:

- Start Windows-Explorer, Total Commander, My Computer or another file manager program.
  The following description refers to Windows-Explorer
- Your Windows-Explorer should be set to Details for a better view. Click the "Views" button and select "Details".
- Switch into the program directory of FluidLAB in which you will find the folder "\LibSeaWa"; in the standard case:

  "C:\Program Files\FluidLAB" (for English version of Windows)
  "C:\Programme\FluidLAB" (for German version of Windows)

- Create the folder "\LibSeaWa_Example". Click "File", then click "New" in the pop-up menu and afterwards select "Folder". Name the new folder "\LibSeaWa_Example ".
- You will see the following window:

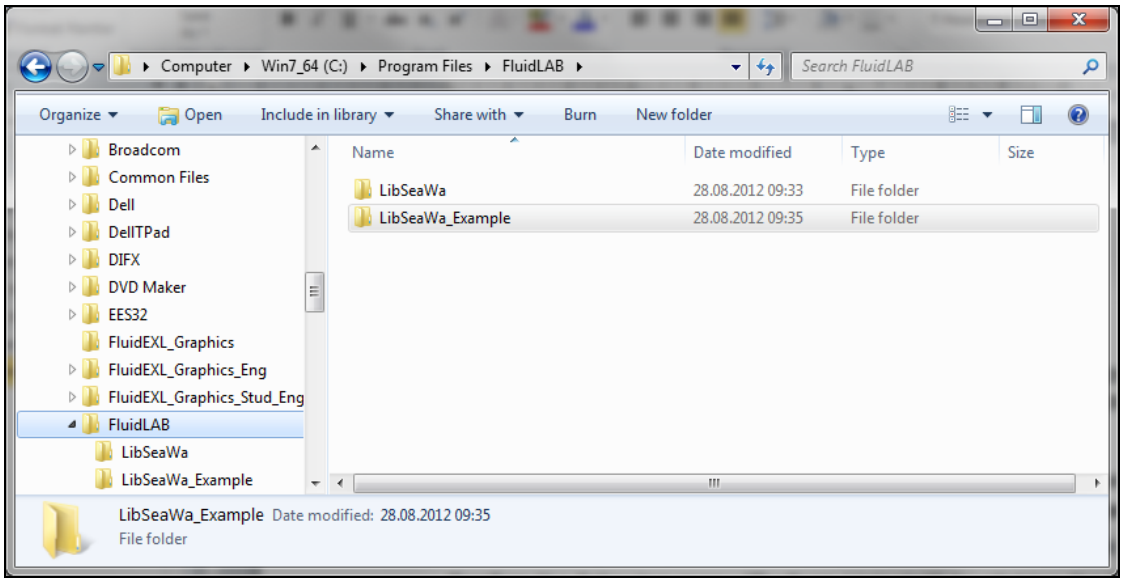


Figure 2.5: Folders "LibSeaWa" and "LibSeaWa_Example"

- Switch into the directory "\LibSeaWa" within "\FluidLAB", the standard being:
  "C:\Program Files\FluidLAB" (for English version of Windows)
  "C:\Programme\FluidLAB" (for German version of Windows)

- If you have installed the 32-bit version of FluidLAB LibSeaWa you will see the following window:

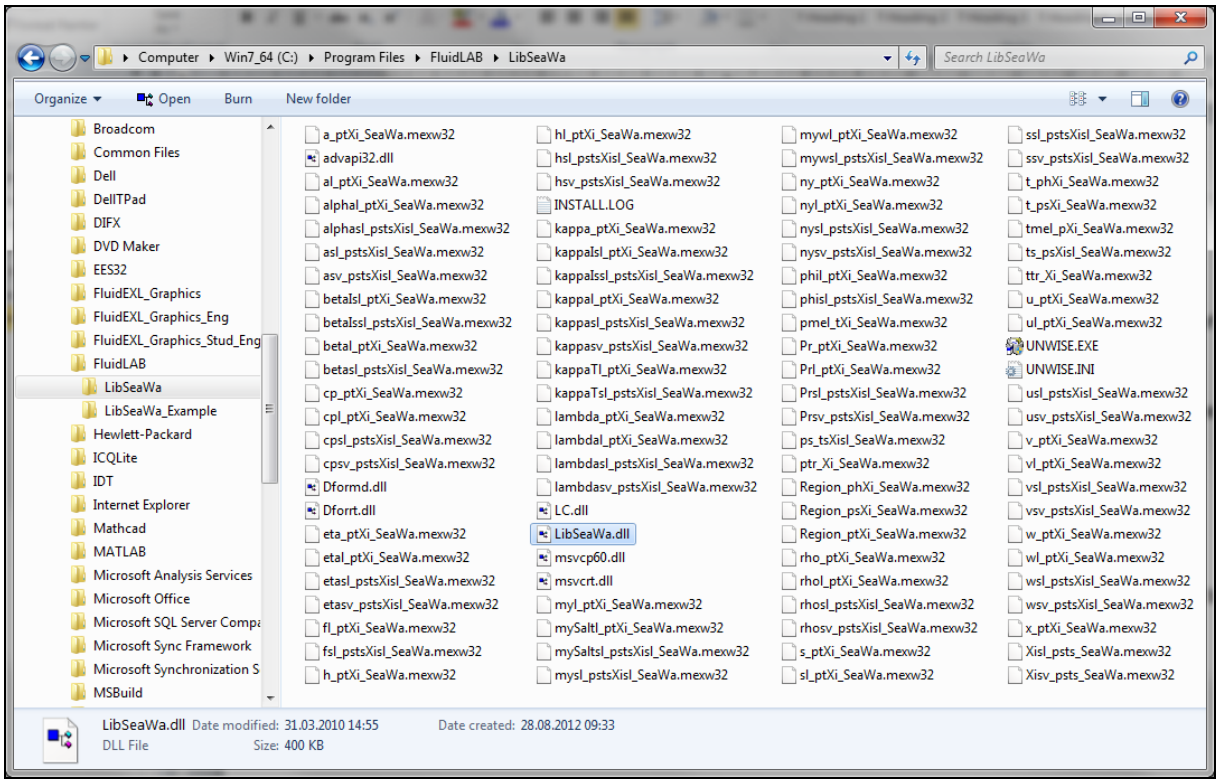


Figure 2.6: Contents of the folder "LibSeaWa" (32-bit version)

- If you have installed the 64-bit version of FluidLAB LibSeaWa you will see the following window:

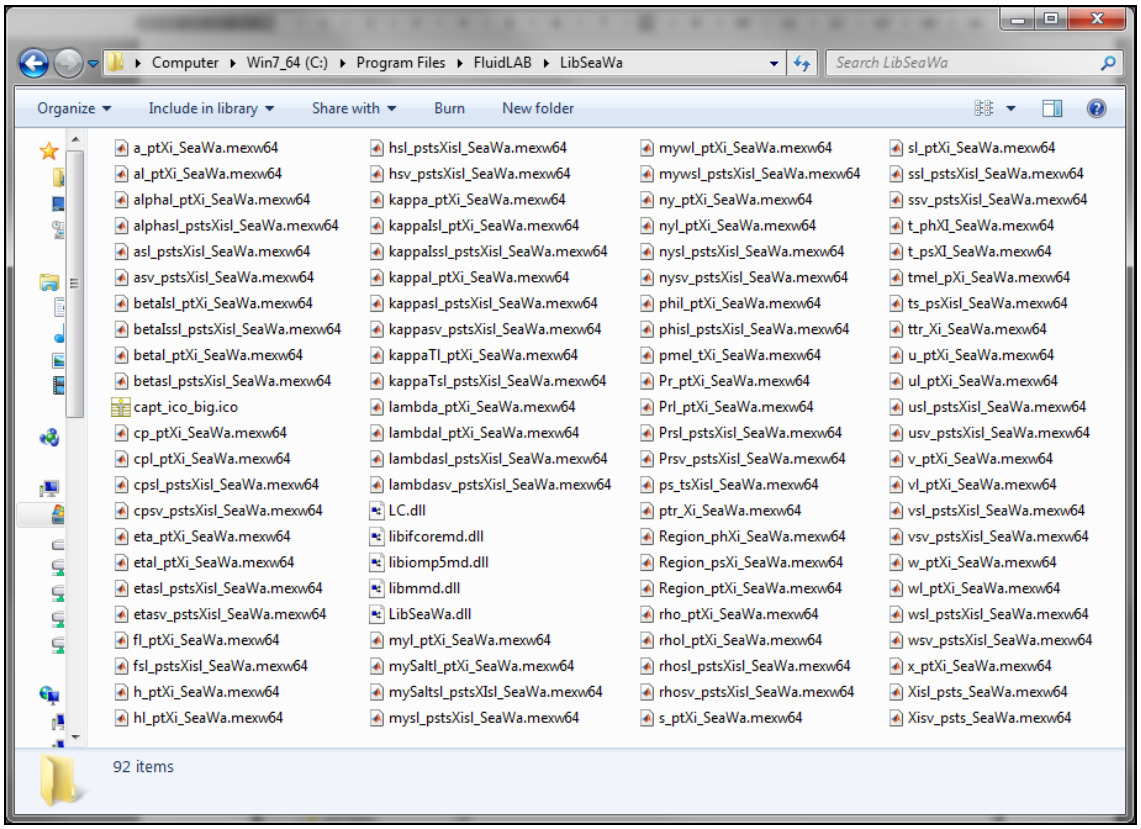


Figure 2.7: Contents of the folder "LibSeaWa" (64-bit version)

If you have installed the **32-bit** version of LibSeaWa you will now have to copy the following files into the directory

"C:\Program Files\FluidLAB\LibSeaWa_Example" (for English version of Windows)
"C:\Programme\FluidLAB\LibSeaWa_Example" (for German version of Windows)

in order to calculate the function $h = f(p,t,xi)$.

- The following files are needed:
  - "advapi32.dll"
  - "Dformd.dll"
  - "Dforrt.dll"
  - "h_ptxi_SeaWa.mexw32"
  - "LibSeaWa.dll"
  - "LC.dll.dll"
  - "msvcp60.dll"
  - "msvcrt.dll"
- Click the file "h_ptxi_SeaWa.mexw32", then click "Edit" in the upper menu bar and select "Copy".
- Switch into the directory

  "C:\Program Files\FluidLAB\LibSeaWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibSeaWa_Example" (for German version of Windows),

  click "Edit" and select "Paste".

- Repeat these steps in order to copy the other files listed above.
- You will see the following window:

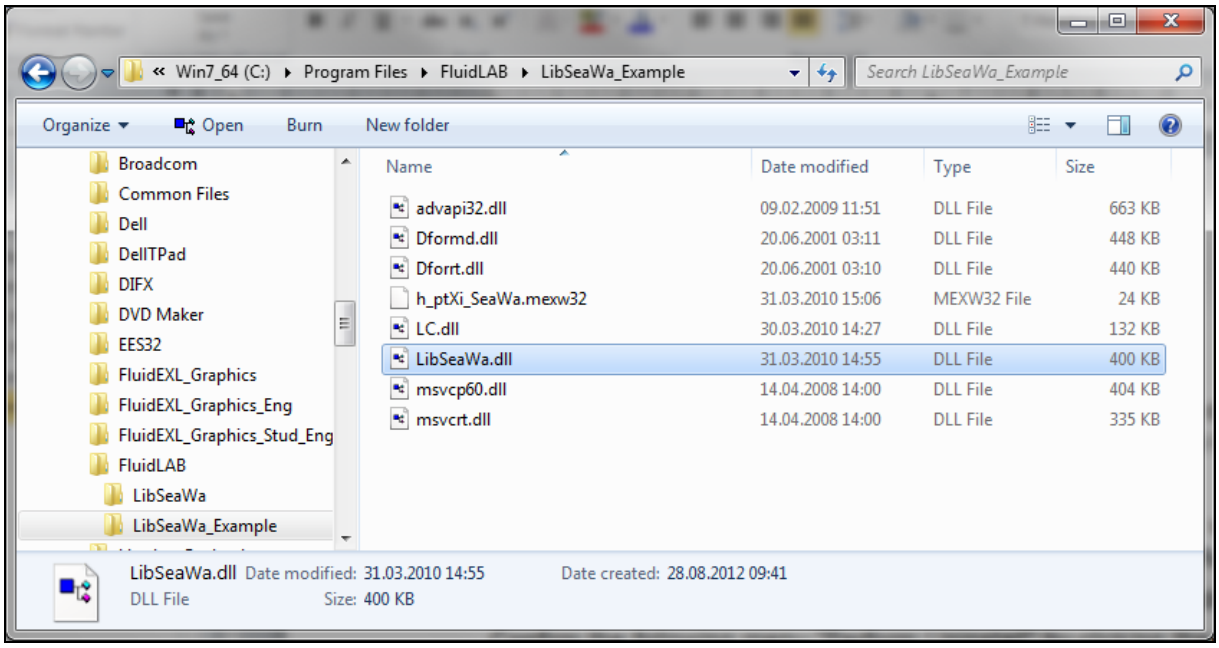


Figure 2.8: Contents of the folder "LibSeaWa_Example" (32-bit)

If you have installed the **64-bit** version of LibSeaWa you will now have to copy the following files into the directory

"C:\Program Files\FluidLAB\LibSeaWa_Example" (for English version of Windows)

"C:\Programme\FluidLAB\LibSeaWa_Example" (for German version of Windows)

in order to calculate the function $h = f(p,t,xi)$.

- The following files are needed:
  - "h_ptxi_SeaWa.mexw64"
  - "LC.dll"
  - "LibSeaWa.dll"
  - "libifcoremd.dll"
  - "libiomp5.dll"
  - "libmmd.dll."
- Click the file "h_ptx_LibSeaWa.mexw64", then click "Edit" in the upper menu bar and select "Copy."
- Switch into the directory

  "C:\Program Files\FluidLAB\LibSeaWa_Example" (for English version of Windows)

  "C:\Programme\FluidLAB\LibSeaWa_Example" (for German version of Windows),

click "Edit" and then "Paste."

- Repeat these steps in order to copy the other files listed above. You may also select all the above-named files and then copy them as a group (press the Control button to enable multiple markings).
- You will see the following window:

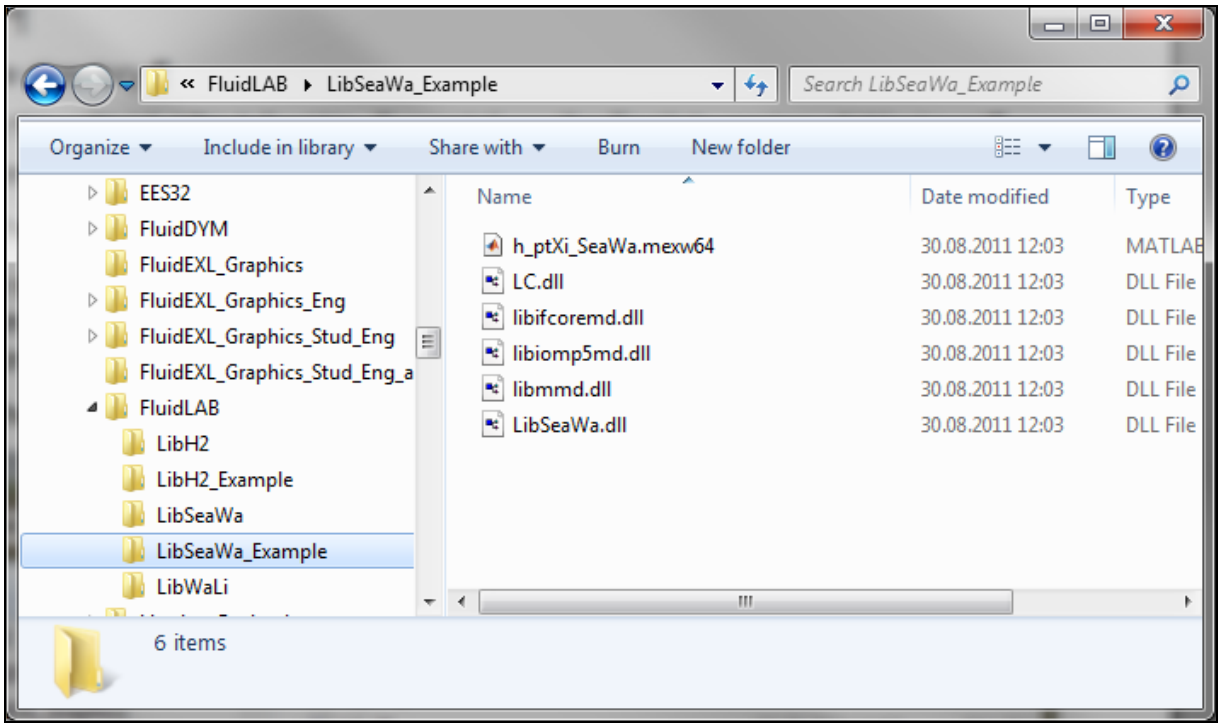


Figure 2.9: Contents of the folder "LibSeaWa_Example" (64-bit)

- Start MATLAB® (if you have not started it already).
- Click the button marked in the next figure in order to open the folder "\LibSeaWa_Example" in the "Current Directory" window.

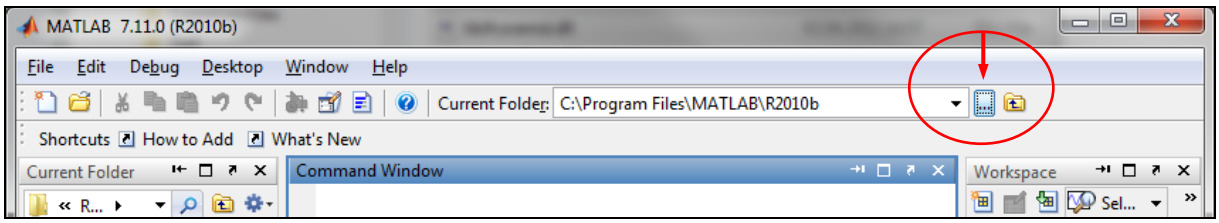


Figure 2.10: Selection of the working directory

- Find and select the directory

  "C:\Program Files\FluidLAB\LibSeaWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibSeaWa_Example" (for German version of Windows)

  in the menu which appears (see the following figure).

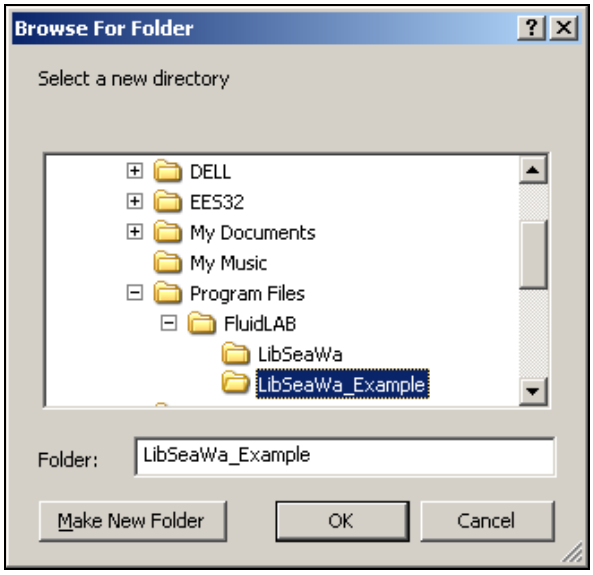


Figure 2.11: Choosing the "LibSeaWa_Example" folder

- Confirm your selection by clicking the "OK" button.
- First of all you need to create an M–File in MATLAB®. Within MATLAB® click "File", then select "New" and afterwards click "M-File" in MATLAB 2006 or earlier versions or click "Script" in MATLAB R2010 or later versions.
- If the "Editor" window appears as a separate window, you can embed it into MATLAB® by clicking the insertion arrow (see next figure) in order to obtain a better view.

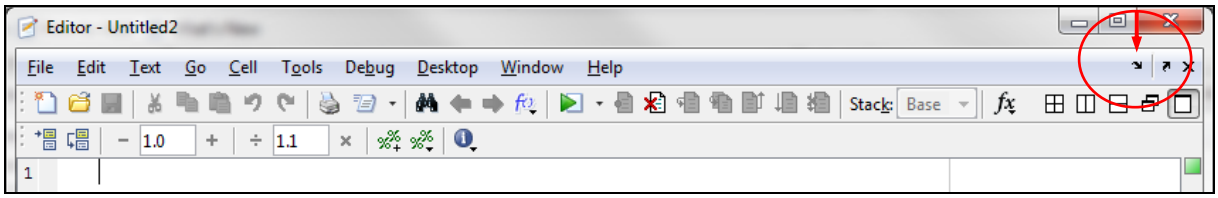


Figure 2.12: Embedding the "Editor" window

- In the figure below you will see the "Editor - Untitled" window.

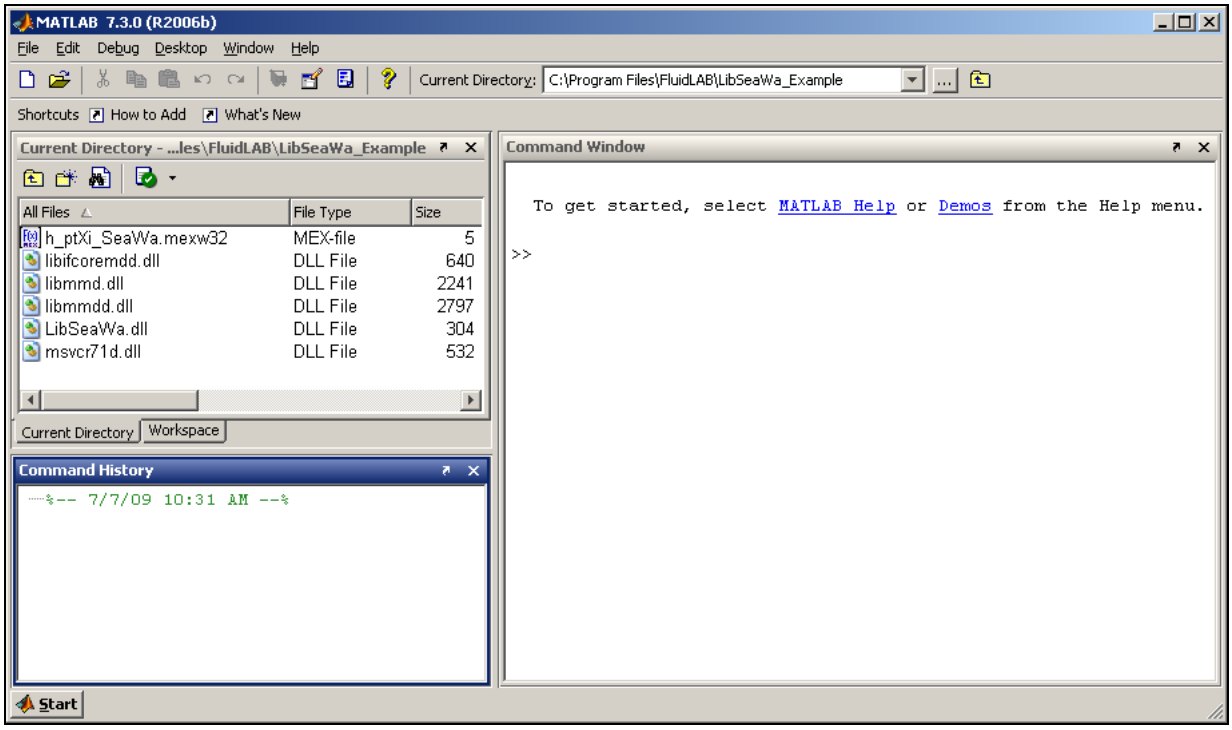


Figure 2.13: Embedded "Editor" window

- Now type the following lines in the "Editor - Untitled" window:

Text to be written:	Explanation:
`% h_ptXi_SeaWa.m`	file name as comment
`%%`	paragraph separation
`p=1;  % pressure in bar`	declaration of the variables pressure, temperature, art and composition of mixture
`t=100;  % temperature in °C`	
`Xi=0.12;  % mass fraction of sea salt in kg/kg`	
`%%`	paragraph separation
`h=h_ptXi_SeaWa(p,t,Xi)`	function call
`%%`	paragraph separation

- Remarks:
  - The program interprets the first line which starts with " % " to be a data description in "Current Directory"
  - Paragraph separations which are mandatory are being realised through " %%". By this, declaration of variables and calculation instructions are also being separated.
  - The words which are printed in green, start with " % " and stand behind the variables are comments. In fact they are not necessary but they are reasonable for your overview and comprehensibility.
  - You have to leave out the semicolons behind the numerical values if you wish to see the result for *h* and the input parameters as well.

The values of the function parameters in their corresponding units stand for:

- First operand: Value for p = 1 bar
  (Range of validity: p = 0.01 bar ... 800 bar)
- Second operand: Value for t = 100 °C
  (Range of validity: t = -6 °C … 220 °C
- Third operand: Value for ξ = 0.12 in kg sea salt/kg mixture)
  (Range of validity: ξ = 0.0 kg /kg ... 0.2 kg /kg)

- Save the "M-File" by clicking the "File" button and then click "Save As...".
- The menu "Save file as:" appears; therein the folder name "LibSeaWa_Example" must be displayed next to "Save in:"
- Next to "File name" you have to type "Example_h_ptxi_SeaWa.m" and afterwards click the "Save" button.

Note.
The name of the example file has to be different in comparison to the name of the used function. For example, the file could not be named "h_ptxi_SeaWa.m" in this case. Otherwise an error message will appear during the calculation.

- You will now see the following window:

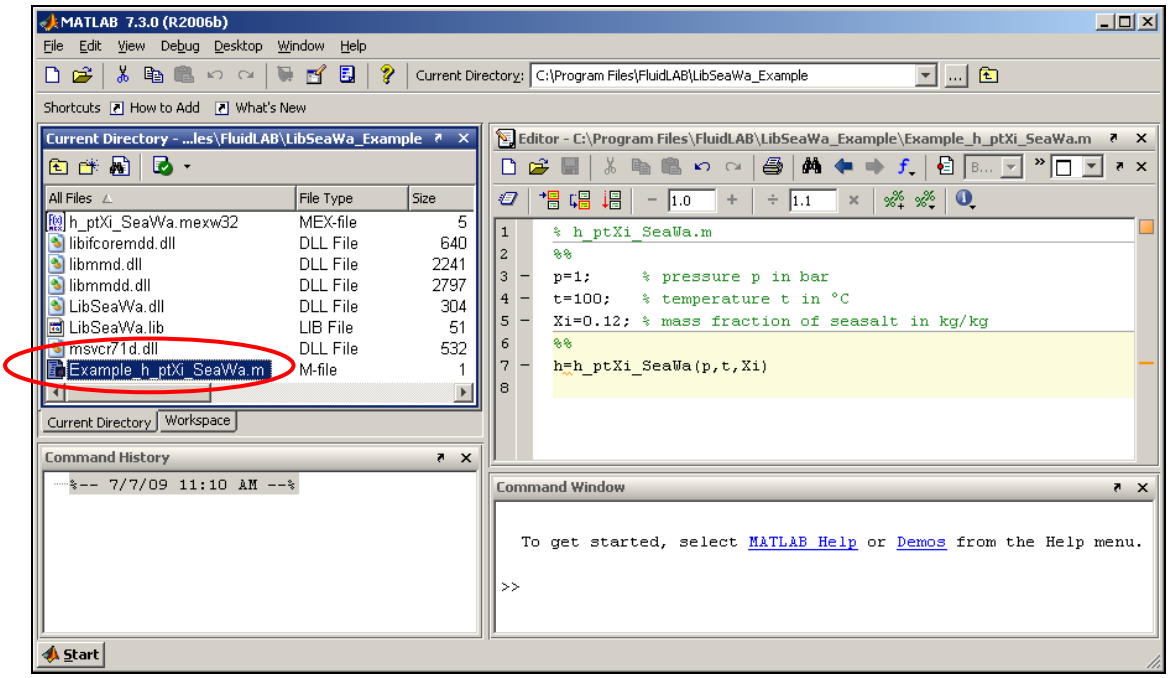


Figure 2.14: "Example_h_ptxi_SeaWa.m" M-file

- Within the "Current Directory" window the file "Example_h_ptxi_SeaWa.m" appears.
- Right-click this file and select "Run" in the menu which appears (see next Figure).

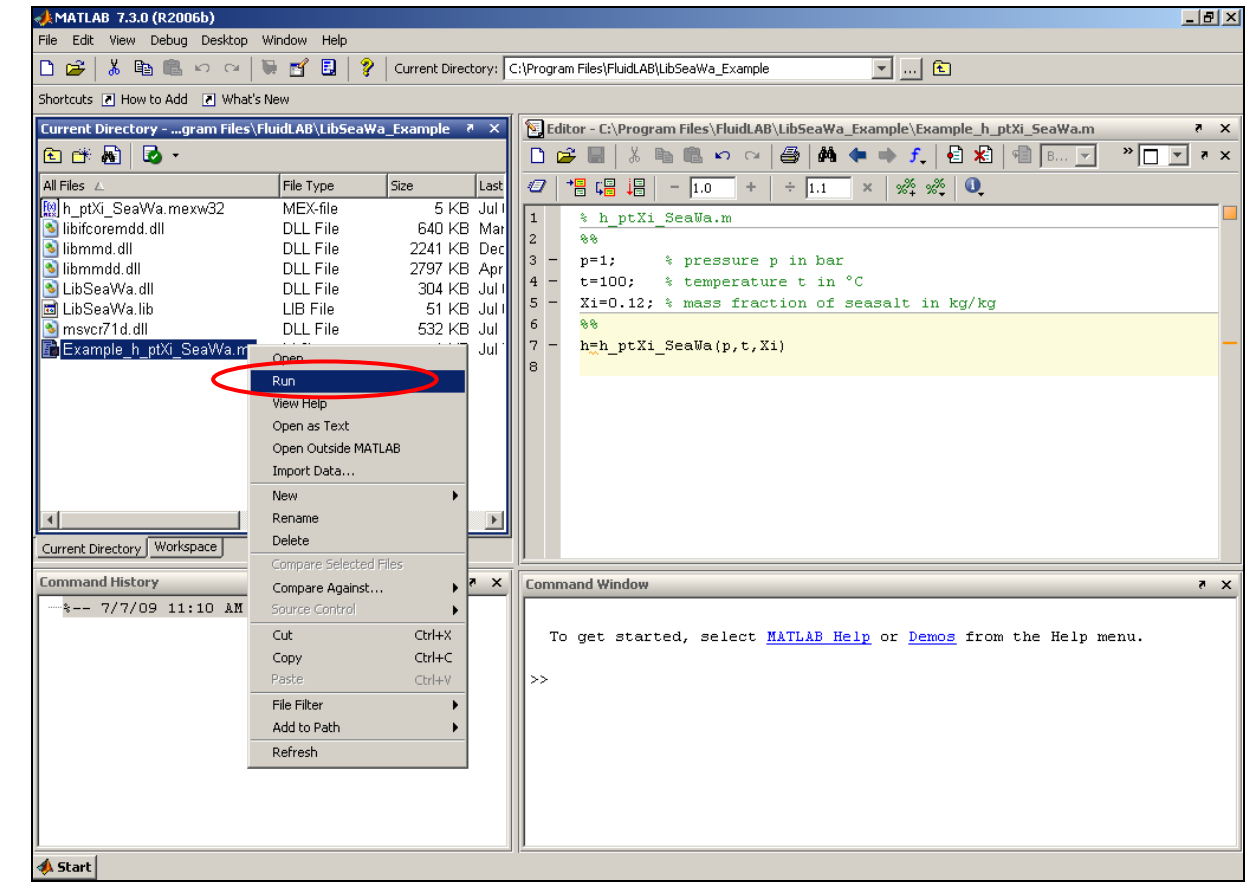


Figure 2.15: Running the "Example_h_ptxi_SeaWa.m" M-file

- You will see the following window:

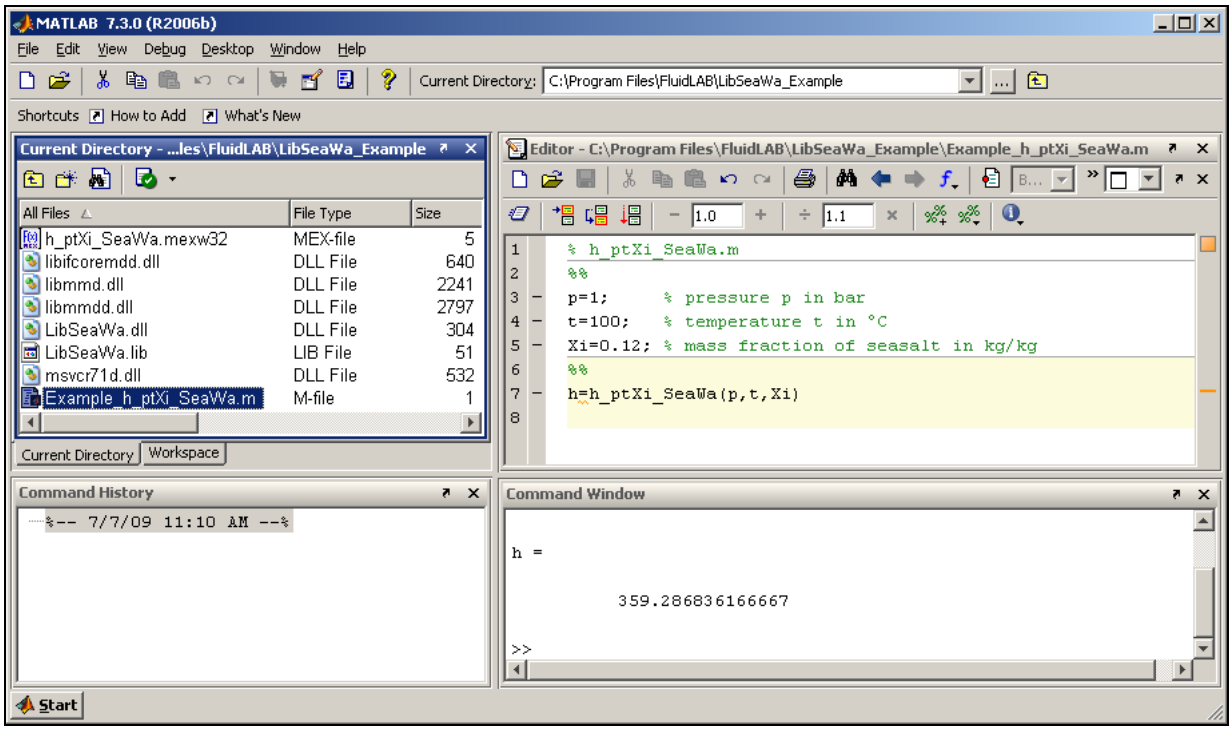


Figure 2.16: MATLAB® with calculated result

The result for *h* appears in the "Command Window".

⇒ The result in our sample calculation here is: " h = 359.286836166667". The corresponding unit is kJ/kg (see table of the property functions in Chapter 1).

To be able to calculate other values, you have to copy the associated mexw32 or mexw64 files as well because MATLAB® can only access functions that are located in the "Current Directory" window. The example calculated can be found in the directory

C:\Program Files\FluidLAB\He_Example" (for English version of Windows)

C:\Programme\FluidLAB\He_Example" (for German version of Windows),

and you may use it as a basis for further calculations using FluidLAB.

Hint!

If the input values are located outside the range of validity of LibSeaWa, the calculation of the chosen function to be calculated function results in -1000. You can find more exact details on every function and its corresponding range of validity in the enclosed program documentation in Chapter 3.

2.4 Example: Calculation of the Specific Enthalpy $h = f(p,t,\xi)$ for Seawater in the Command Window

- Please follow the instructions from page 2/6 to 2/9.
- Start MATLAB® (if you have not started it already).
- Click the button marked in the following figure in order to open the folder "\LibSeaWa_Example" in the window "Current Directory".

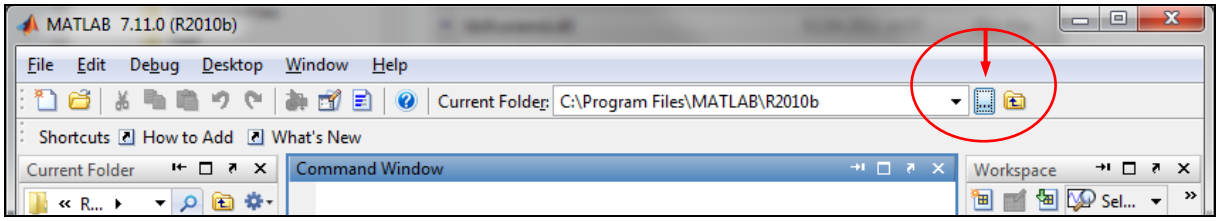


Figure 2.17: Selection of the working directory

- Find and select the directory

  "C:\Program Files\FluidLAB\LibSeaWa_Example" (for English version of Windows)
  "C:\Programme\FluidLAB\LibSeaWa_Example" (for German version of Windows)

  in the menu that appears (see figure below).

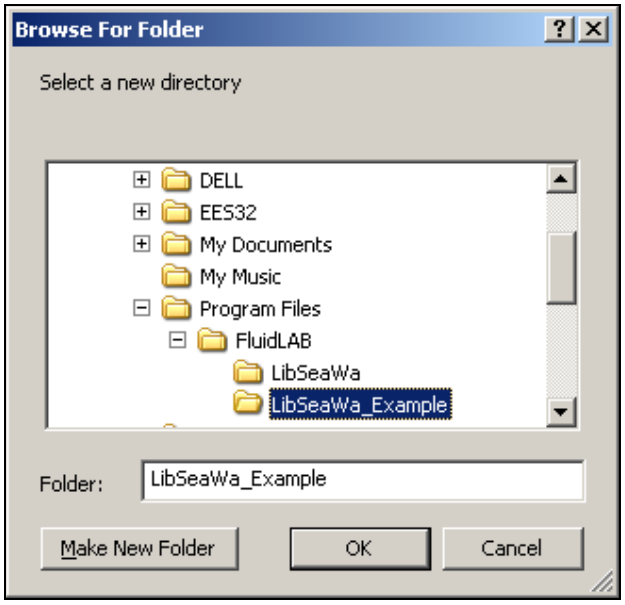


Figure 2.18: Choosing the "LibSeaWa_Example" folder

- Confirm your selection by clicking the "OK" button.

- You will see the following window:

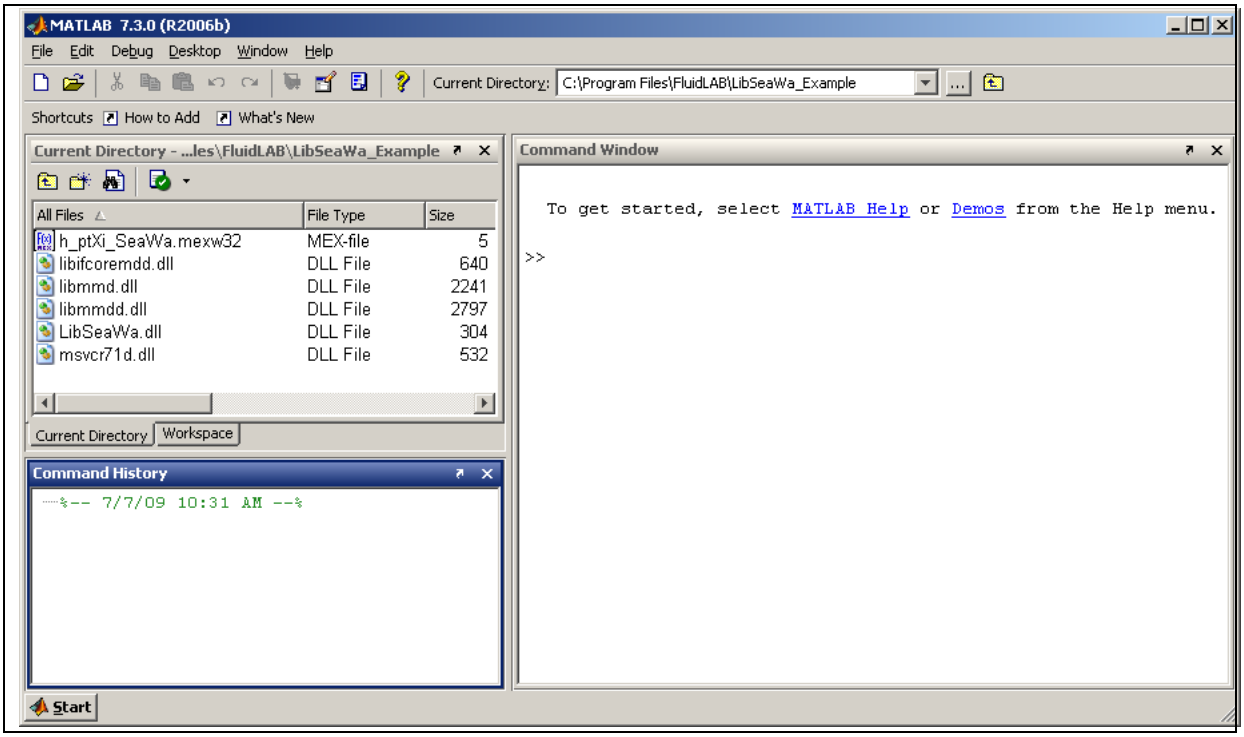


Figure 2.19: MATLAB® with necessary files

Corresponding to the table of property functions in Chapter 1 you have to call up the function "**h_ptxi_SeaWa**" as follows for calculating h=f(p,t,x):

- Write "**h=h_ptxi_SeaWa(10,100,0.12)**" within the "Command Window".

The values of the function parameters in their corresponding units stand for:

- First operand: Value for p = 1 bar
  (Range of validity: p = 0.01 bar ... 800 bar)
- Second operand: Value for t = 100 °C
  (Range of validity: t = -6°C … 220°C
- Third operand: Value for ξ = 0.12 in kg sea salt/kg mixture)
  (Range of validity: ξ = 0.0 kg/kg ... 0.2 kg/kg)

- Confirm your entry by pressing the "ENTER" button.
- You will see the following window:

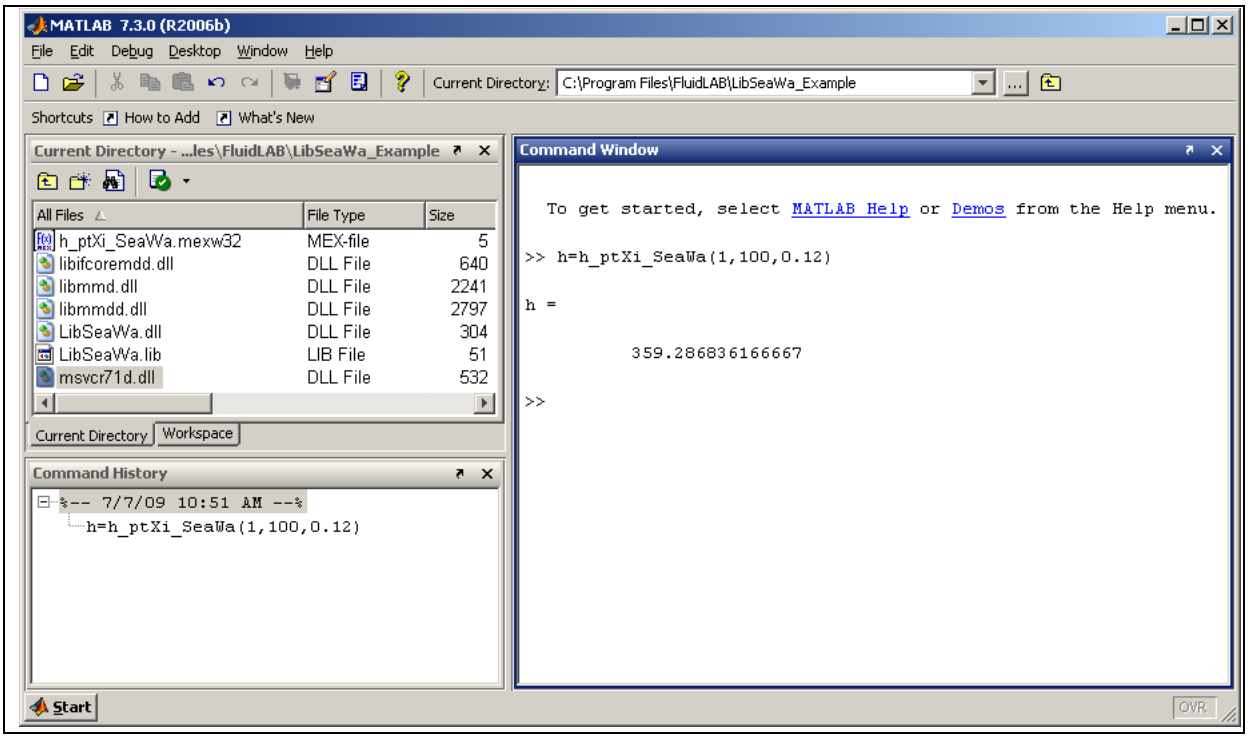


Figure 2.20: MATLAB® with calculated result

⇒ In the "Command Window" you will see the result " h = 359.286836166667".
The corresponding unit is kJ/kg (see table of the property functions in chapter 1).

To be able to calculate other values, you will have to copy the respective mexw32 or mexw64 files into the working directory as well, because MATLAB® can only access functions that are located in the "Current Directory" window. The example calculated can be found in the directory

C:\Program Files\FluidLAB\LibSeaWa_Example" (for English version of Windows)
C:\Programme\FluidLAB\LibSeaWa_Example" (for German version of Windows),

and you may use it as a basis for further calculations using FluidLAB.

Note:

If the input values are located outside the range of validity, the result for the chosen function to be calculated results in -1000. You can find more exact details on every function and its corresponding range of validity in the enclosed program documentation in Chapter 3.

2.4 Using FluidLAB with SIMULINK

To use the functions of FluidLAB with the simulation program SIMULINK you have to start SIMULINK in MATLAB® by clicking on Simulink in the upper menu bar shown in Figure 2.19.

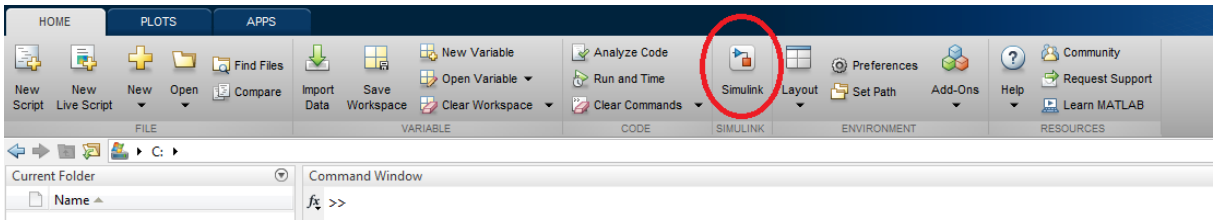


Figure 2.21: Starting Simulink

Then choose a blank model or a simulation in which you would like to use FluidLAB. Now you need to add a MATLAB function block that you can find in the library browser shown in Figure 2.22.

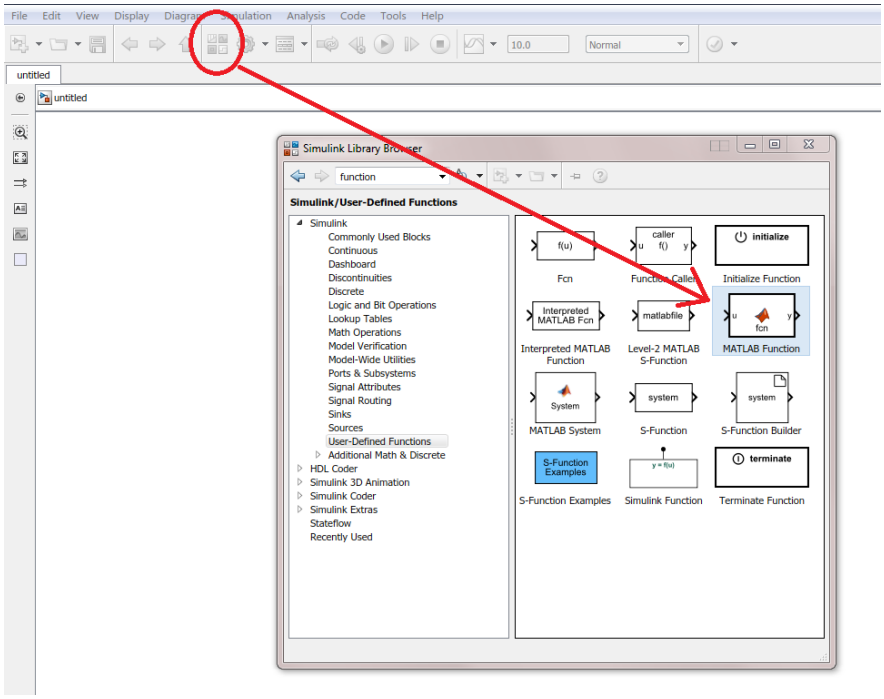


Figure 2.22: Simulink library browser and choosing a MATLAB Function

By dragging and dropping you can drag a Simulink block in your model. The function needs inputs and output that you can find in the Simulink library browser under sources and sinks. For this example constants were taken for the inputs and a display block were taken for outputting.

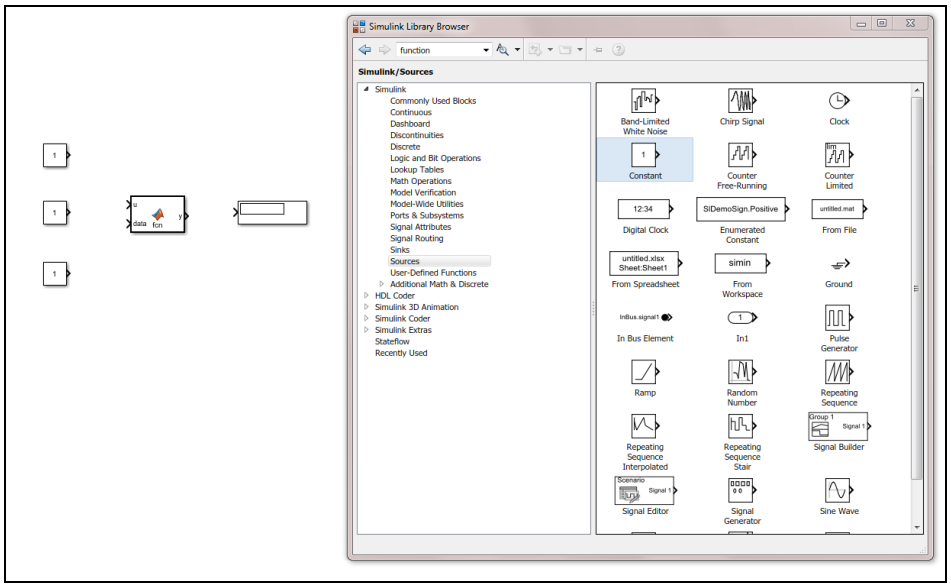


Figure 2.23: Inputs and outputs of the example

Now you have to link inputs and outputs to the MATLAB function block. By pressing and holding the left mouse button on the arrow of a block, you can draw a line and drag it to the MATLAB function block. With this method you can link all blocks together.

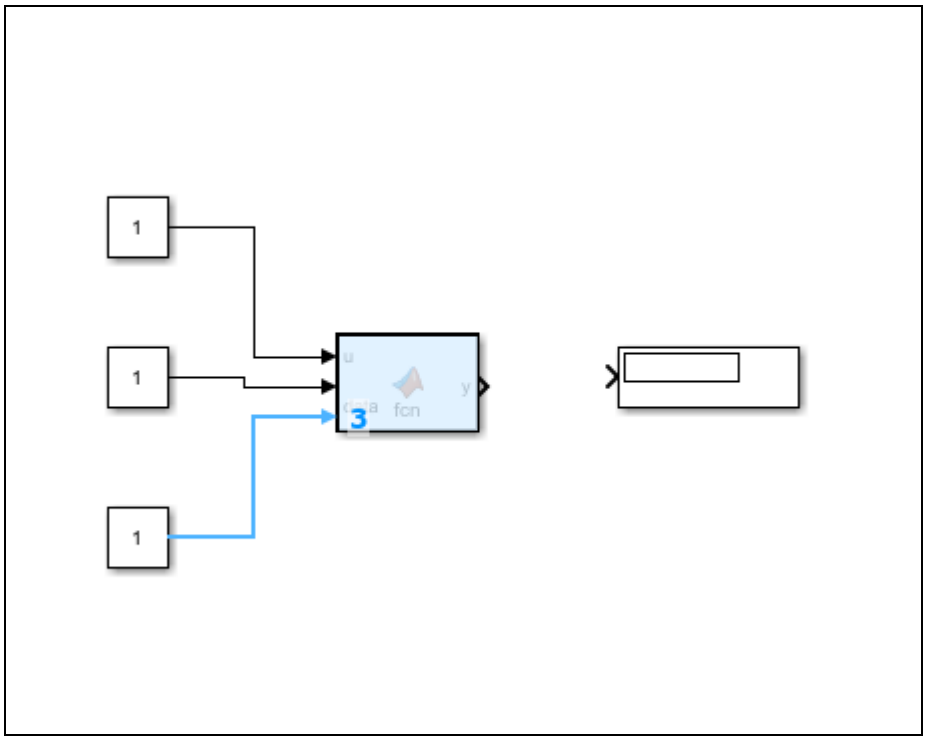


Figure 2.24: Linking blocks in Simulink

You can define the value of a constant block by double-click on them. If you want to calculate the example use the values you can find in section 2.2 and 2.3. With a double-click on the MATLAB function block you can define the function in MATLAB®. The following source code is for the example calculation and the table below describes the source code closer. You can adapt these few lines to call all other function of FluidLAB.

```
function h = fcn(p, t, x)
coder.extrinsic('addpath');
```

```
coder.extrinsic('h_ptx_SeaWa');
addpath('C:\Program Files\FluidLAB\LibSEAWA');
h = h_ptx_SeaWa(p,t,x);
```

Matlab source code	Explanation
`function h = fcn(p, t, x)`	function header, you can define the function name and the inputs like p, t and x of the example
`coder.extrinsic('addpath');`	necessary to add a path
`coder.extrinsic('h_ptx_SeaWa');`	Choose the function name of the FluidLAB function
`addpath('C:\Program Files\FluidLAB\LibSEAWA');`	Add the installation path of FluidLAB
`h = h_ptx_SeaWa(p,t,x);`	Linking the FluidLAB function to the MATLAB function block

You can copy and paste the sourcecode in MATLAB® or write it into the MATLAB® editor. The simulation will start by clicking the run button in Matlab or Simulink and you can see the example in the display block of the simulation which is shown in figure 2.23.

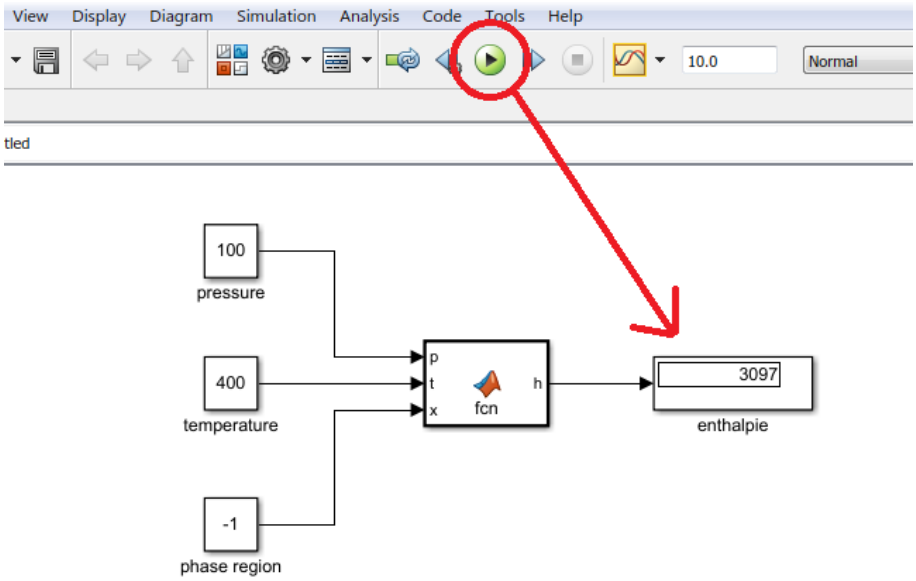


Figure 2.25: Starting the simulation and result of the calculation

Your result is may an other than shown in figure 2.25. If you want to calculate the example please use the values from section 2.2 and 2.3.

2.5 Removing FluidLAB including LibSeaWa

To remove the LibSeaWa property library from your hard drive in Windows®, click "Start" in the Windows® task bar, select "Settings" and click "Control Panel".

Now double-click on "Add or Remove Programs".

Now double-click on "Add or Remove Programs". In the list box of the "Add or Remove Programs" window that appears select "FluidLAB LibSeaWa" by clicking on it and click the "Change/Remove" button.

In the following dialog box click "Automatic" and then click the "Next>" button.

Confirm the following menu "Perform Uninstall" by clicking the "Finish" button.

Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now, FluidLAB has been removed.

If there is no library other than LibSeaWa installed, the directory "FluidLAB" will be removed as well.

3. Program Documentation

Thermal Diffusivity $a = f(p,t,\xi)$

Function Name:

a_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION A_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

a_ptXi_SeaWa, a - Thermal diffusivity in m²/s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 100 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$

Mass fraction ξ: $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Thermal diffusivity $a = \dfrac{\lambda}{\rho * c_p}$
- This function is <u>not</u> defined in the wet steam region.

Result for Wrong Input Values:

a_ptXi_SeaWa, a = – 1000

References:

$a(p,t,\xi)$ [1], [2]

Thermal Diffusivity of Liquid Seawater $a_l = f(t,\xi)$

Function Name:

al_tXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION AL_TXI_SEAWA(T, XI), REAL*8 T, XI

Input Values:

t - Temperature *t* in °C

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

al_tXi_SeaWa, al - Thermal diffusivity of liquid seawater in m²/s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mass fraction ξ: $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Thermal diffusivity $a = \dfrac{\lambda}{\rho * c_p}$

Result for Wrong Input Values:

al_tXi_SeaWa, al = – 1000

References:

$a(t,\xi)$ [1]

Thermal Diffusivity of Saturated Liquid $a_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

asl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION ASL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

asl_pstsXisl_SeaWa, asl - Thermal diffusivity of saturated seawater in m²/s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to $p_s\left(t = 220\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Comments:

- Thermal diffusivity $a = \dfrac{\lambda}{\rho * c_p}$

Possible input variants:

$$a^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$a^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$a^{sl} = f\left(p_s, t_s, -1000\right)$$
$$a^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

asl_pstsXisl_SeaWa, asl = –1000

References:

$a(p,t,\xi)$ [1],[2]

Thermal Diffusivity of Saturated Vapor $a_{sv} = f(p_s, t_s, \xi^{sl})$

Function Name:

asv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION ASV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS, TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

asv_pstsXisl_SeaWa, asv - Thermal diffusivity of saturated seawater in m²/s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Comments:

- Thermal diffusivity $a = \dfrac{\lambda}{\rho * c_p}$

Result for Wrong Input Values:

asv_pstsXisl_SeaWa, asv = –1000

References:

$a(p,t,\xi)$ [1],[2]

Thermal Expansion Coefficient of Liquid Seawater $\alpha_l = f(p,t,\xi)$

Function Name:

alphal_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION ALPHAL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

alphal_ptXi_SeaWa, alphal - Thermal expansion of liquid seawater in 1/K

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.12\right)$ bar to 1000 bar and $p \geq p_{mel}\left(t,\xi\right)$

Mass fraction ξ: $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

alphal_ptXi_SeaWa, alphal = –1000

References:

$\alpha(p,t,\xi)$ [1]

Thermal Expansion Coefficient of Saturated Liquid $a_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

alphasl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   ALPHASL_PSTSXISL_SEAWA(PS, TS, XISL),
REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

alphasl_pstsXisl_SeaWa, alphasl - Thermal expansion of saturated seawater in 1/K

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\alpha^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$\alpha^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$\alpha^{sl} = f\left(p_s, t_s, -1000\right)$$
$$\alpha^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

alphasl_pstsXisl_SeaWa, alphasl = –1000

References:

$\alpha(p,t,\xi)$ [1]

Haline Contraction Coefficient of Liquid Seawater $\beta_l = f(p,t,\xi)$

Function Name:

betal_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION BETAL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

betal_ptXi_SeaWa, betal - Haline contraction coefficient of liquid seawater in kg/kg

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ bar to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$

Mass fraction ξ: $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

betal_ptXi_SeaWa, betal = –1000

References:

$\beta(p,t,\xi)$ [1]

Haline Contraction Coefficient of Saturated Liquid $\beta_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

betasl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   BETASL_PSTSXISL_SEAWA(PS, TS, XISL),
REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

betasl_pstsXisl_SeaWa, betasl - Haline contraction coefficient of saturated seawater in 1/K

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Mixture pressure *p*: from $p_s(t = 0\ °C, \xi = 0.12)$ to $p_s(t = 80\ °C, \xi = 0)$

Mass fraction ξ: $0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\beta^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$

$$\beta^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$

$$\beta^{sl} = f\left(p_s, t_s, -1000\right)$$

$$\beta^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

betasl_ptXi_SeaWa, betasl = –1000

References:

$\beta(p,t,\xi)$ [1]

Isentropic Temperature - Pressure Coefficient (Adiabatic Lapse Rate) of Liquid Seawater β_{lsl} = f(p,t,ξ)

Function Name:

betaIsl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION BETAISL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p	- Pressure *p* in bar
t	- Temperature *t* in °C
Xi	- Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

betaIsl_ptXi_SeaWa, betaISl - adiabatic lapse rate in K/kPa

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\mathrm{C}, \xi = 0.12\right)$bar to 1000 bar and $p \geq p_{\mathrm{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

betaIsl_ptXi_SeaWa, betaIsl = –1000

References:

$\beta_{\mathrm{is}}(p,t,\xi)$	[1]

Isentropic Temperature - Pressure Coefficient (Adiabatic Lapse Rate) of Saturated Liquid $\beta_{\mathrm{ls\ sl}} = \mathrm{f}(p_{\mathrm{s}}, t_{\mathrm{s}}, \xi^{\mathrm{sl}})$

Function Name:

betaIssl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   BETAISSL_PSTSXISL_SEAWA(PS, TS, XISL),
                  REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

betaIssl_pstsXisl_SeaWa, betaIssl - Adiabatic lapse rate of saturated seawater in K/kPa

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °\mathrm{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\mathrm{C}, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\beta_{\mathrm{ls}}{}^{\mathrm{sl}} = \mathrm{f}\left(-1000, t_s, \xi^{\mathrm{sl}}\right)$$

$$\beta_{\mathrm{ls}}{}^{\mathrm{sl}} = \mathrm{f}\left(p_s, -1000, \xi^{\mathrm{sl}}\right)$$

$$\beta_{\mathrm{ls}}{}^{\mathrm{sl}} = \mathrm{f}\left(p_s, t_s, -1000\right)$$

$$\beta_{\mathrm{ls}}{}^{\mathrm{sl}} = \mathrm{f}\left(p_s, t_s, \xi^{\mathrm{sl}}\right)$$

Result for Wrong Input Values:

betaIssl_pstsXisl_SeaWa, betaIssl = –1000

References:

$\beta_{\mathrm{ls}}(p, t, \xi)$ [1]

Specific Isobaric Heat Capacity c_p = f(p,t,ξ)

Function Name:

cp_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION CP_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

cp_ptXi_SeaWa, cp - Specific isobaric heat capacity in kJ/(kg*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ bar to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- This function is <u>not</u> defined in the wet steam region.

Result for Wrong Input Values:

cp_ptXi_SeaWa, cp = –1000

References:

$c_p(p,t,\xi)$	[1], [2]

Specific Isobaric Heat Capacity of Liquid Seawater $c_{pl} = f(p,t,\xi)$

Function Name:

cpl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION CPL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

cpl_ptXi_SeaWa, cpl - Specific isobaric heat capacity of liquid seawater in kJ/(kg*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s(t = 0\ °C, \xi = 0.2)$ bar to 1000 bar and $p \geq p_{mel}(t,\xi)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

cpl_ptXi_SeaWa, cpl = –1000

References:

$c_p(p,t,\xi)$ [1], [2]

Specific Isobaric Heat Capacity of Saturated Liquid $c_{p\mathrm{sl}} = \mathrm{f}(p_\mathrm{s}, t_\mathrm{s}, \xi^\mathrm{sl})$

Function Name:

cpsl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION CPSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

cpsl_pstsXisl_SeaWa, cpsl - Specific isobaric heat capacity of saturated seawater in kJ/(kg*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °\mathrm{C}, \xi = 0.2\right)$ to $p_s\left(t = 220\ °\mathrm{C}, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$c_p^{\mathrm{sl}} = \mathrm{f}\left(-1000, t_s, \xi^{\mathrm{sl}}\right)$$

$$c_p^{\mathrm{sl}} = \mathrm{f}\left(p_s, -1000, \xi^{\mathrm{sl}}\right)$$

$$c_p^{\mathrm{sl}} = \mathrm{f}\left(p_s, t_s, -1000\right)$$

$$c_p^{\mathrm{sl}} = \mathrm{f}\left(p_s, t_s, \xi^{\mathrm{sl}}\right)$$

Result for Wrong Input Values:

cpsl_ptXi_SeaWa, cpsl = –1000

References:

$c_p(p,t,\xi)$ [1],[2]

Specific Isobaric Heat Capacity of Saturated Vapor $c_{p_{sv}} = f(p_s, t_s, \xi^{sl})$

Function Name:

cpsv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION CPSV_PSTSXISL_SEAWA(PS,TS,XISL) REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

cpsv_pstsXisl_SeaWa, cpsv - Specific isobaric heat capacity of saturated seawater in kJ/(kg*K)

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to $p_s\left(t = 220\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

cpsv_pstsXisl_SeaWa, cpsv = –1000

References:

$c_p(p,t,\xi)$ [1], [2]

Dynamic Viscosity η = f(p,t,ξ)

Function Name:

eta_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION ETA_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

eta_ptXi_SeaWa, eta - Dynamic Viscosity in Pa*s

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 100 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- This function is <u>not</u> defined in the wet steam region.

Result for Wrong Input Values:

eta_ptXi_SeaWa, eta = –1000

References:

$\eta(p,t,\xi)$	[1],[2]

Dynamic Viscosity of Liquid Seawater $\eta_l = f(t,\xi)$

Function Name:

etal_tXI_SeaWa

Fortran Programs:

REAL*8 FUNCTION ETAL_PTXI_SEAWA(T, XI), REAL*8 T, XI

Input Values:

t - Temperature *t* in °C

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

etal_tXI_SeaWa, etal - Dynamic Viscosity in Pa*s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mass fraction ξ: $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

etal_tXi_SeaWa, etal = –1000

References:

$\eta(p,t,\xi)$ [1], [2]

Dynamic Viscosity of Saturated Liquid $\eta_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

etasl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION ETASL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

etasl_pstsXisl_SeaWa, etasl - Dynamic Viscosity in Pa*s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to $p_s\left(t = 220\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$\eta^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$\eta^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$\eta^{sl} = f\left(p_s, t_s, -1000\right)$$
$$\eta^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

etasl_ptXi_SeaWa, etasl = –1000

References:

$\eta(p,t,\xi)$ [1], [2]

Dynamic Viscosity of Saturated Vapor $\eta_{sv} = f(p_s, t_s, \xi^{sl})$

Function Name:

etasv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION ETASV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

etasv_pstsXisl_SeaWa, etasv - Dynamic Viscosity of saturated seawater in Pa*s

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

etasv_pstsXisl_SeaWa, etasv = –1000

References:

$\eta(p,t,\xi)$	[1], [2]

Specific Helmholtz Energy of Liquid Seawater $f_l = f(p,t,\xi)$

Function Name:

fl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION FL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

fl_ptXi_SeaWa, fl - Specific Helmholtz energy in kJ/kg

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °\mathrm{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\mathrm{mel}}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

fl_ptXi_SeaWa, fl = –1000

References:

$f(p,t,\xi)$	[1]

Specific Helmholtz Energy of Saturated Liquid $f_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

fsl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION FSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

fsl_pstsXisl_SeaWa, fsl - Specific Helmholtz energy in kJ/kg

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$f^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$f^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$f^{sl} = f\left(p_s, t_s, -1000\right)$$
$$f^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

fsl_pstsXisl_SeaWa, fsl = –1000

References:

$f(p,t,\xi)$ [1]

Osmotic Coefficient of Liquid Seawater $\phi_l = f(p,t,\xi)$

Function Name:

phil_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION PHIL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

phil_ptXi_SeaWa, phil - Osmotic Coefficient in [-]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\mathrm{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\mathrm{mel}}\left(t,\xi\right)$
Mass fraction ξ:	$0 < \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

phil_ptXi_SeaWa, phil = –1000

References:

$\phi(p,t,\xi)$ [1]

Osmotic Coefficient of Saturated Liquid $\phi_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

phisl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION PHISL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

phisl_pstsXisl_SeaWa, phisl - Osmotic Coeffiecient in [-]

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 < \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\phi^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$\phi^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$\phi^{sl} = f\left(p_s, t_s, -1000\right)$$
$$\phi^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

phisl_pstsXisl_SeaWa, fsl = – 1000

References:

$\phi(p, t, \xi)$ [1]

Specific Enthalpy $h = f(p,t,\xi)$

Function Name:

h_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION H_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

h_ptXi_SeaWa, h - specific enthalpy in kJ/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

h_ptXi_SeaWa, h = –1000

References:

$h(p,t,\xi)$	[1], [2]

Specific Enthalpy of Liquid Seawater $h_l = f(p,t,\xi)$

Function Name:

hl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION HL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

hl_ptXi_SeaWa, hl - Specific Enthalpy of liquid seawater in kJ/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

hl_ptXi_SeaWa, hl = –1000

References:

$h(p,t,\xi)$	[1], [2]

Specific Enthalpy of Saturated Fluid $h_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

hsl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION HSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

hsl_pstsXisl_SeaWa, hsl - Specific Enthaply of saturated seawater in kJ/kg

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to $p_s\left(t = 220\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$h^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$h^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$h^{sl} = f\left(p_s, t_s, -1000\right)$$
$$h^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

hsl_pstsXisl_SeaWa, hsl = –1000

References:

$h(p,t,\xi)$ [1] , [2]

Specific Enthalpy of Saturated Steam h_{sv} = f(p_S,t_S,ξ^{sl})

Function Name:

hsv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION HSV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS, TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

hsv_pstsXisl_SeaWa, hsv - Specific Enthalpy of saturated seawater in kJ/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_S\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to $p_S\left(t = 220\ °\text{C}, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

hsv_pstsXisl_SeaWa, hsv = –1000

References:

$h(p,t,\xi)$	[1] , [2]

Isentropic Exponent κ = f(p,t,ξ)

Function Name:

kappa_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION KAPPA_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappa_ptXi_SeaWa, kappa - Isentropic Exponent in [-]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- Isentropic Exponent $\kappa = \dfrac{w^2}{p * v}$
- This function is <u>not</u> defined in the wet steam region.

Result for Wrong Input Values:

kappa_ptXi_SeaWa, kappa = –1000

References:

$\kappa(p,t,\xi)$ [1]

Isentropic Exponent of Liquid Seawater $\kappa_l = f(p,t,\xi)$

Function Name:

kappal_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION KAPPAL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappal_ptXi_SeaWa, kappal - Isentropic Exponent of liquid seawater in [-]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- Isentropic Exponent $\kappa = \dfrac{w^2}{p * v}$

Result for Wrong Input Values:

kappal_ptXi_SeaWa, kappal = –1000

References:

$\kappa(p,t,\xi)$ [1]

Isentropic Exponent of Saturated Fluid $\kappa_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

kappasl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   KAPPASL_PSTSXISL_SEAWA(PS, TS, XISL)
REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappasl_pstsXisl_SeaWa, kappasl - Isentropic Exponent of saturated seawater in [-]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.12\right)$ to $p_s\left(t = 80\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.12$ kg sea salt/kg mixture

Comments:

- Isentropic Exponent $\kappa = \dfrac{w^2}{p * v}$

Possible input variants:

$$\kappa^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$

$$\kappa^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$

$$\kappa^{sl} = f\left(p_s, t_s, -1000\right)$$

$$\kappa^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

kappasl_pstsXisl_SeaWa, kappasl = –1000

References:

$\kappa(p,t,\xi)$ [1]

Isentropic Exponent of Saturated Vapor $\kappa_{sv} = f(p_s, t_s, \xi^{sl})$

Function Name:

kappasv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION KAPPASV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappasv_pstsXisl_SeaWa, kappasv - Isentropic Exponent of saturated seawater in [-]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.12\right)$ to $p_s\left(t = 80\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.12$ kg sea salt/kg mixture

Comments:

- Isentropic Exponent $\kappa = \dfrac{w^2}{p * v}$

Result for Wrong Input Values:

kappasv_pstsXisl_SeaWa, kappasv = –1000

References:

$\kappa(p,t,\xi)$ [1]

Isothermal Compressibility of Liquid Seawater κ_{Tl} = f(p,t,ξ)

Function Name:

kappaTl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION KAPPATL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappaTl_ptXi_SeaWa, kappaTl - Isothermal Compressibility of liquid seawater in [1/kPa]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

kappaTl_ptXi_SeaWa, kappaTl = –1000

References:

$\kappa_T(p,t,\xi)$ [1]

Isothermal Compressibility of Saturated Fluid $\kappa_{T\,sl} = f(p_S, t_S, \xi^{sl})$

Function Name:

kappaTsl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   KAPPATSL_PSTSXISL_SEAWA(PS, TS, XISL)
                  REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappaTsl_pstsXisl_SeaWa, kappaTsl - Isothermal Compressibility of saturated fluid in [1/kPa]

Range of Validity

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\kappa_T^{\text{sl}} = \text{f}\left(-1000, t_s, \xi^{\text{sl}}\right)$$

$$\kappa_T^{\text{sl}} = \text{f}\left(p_s, -1000, \xi^{\text{sl}}\right)$$

$$\kappa_T^{\text{sl}} = \text{f}\left(p_s, t_s, -1000\right)$$

$$\kappa_T^{\text{sl}} = \text{f}\left(p_s, t_s, \xi^{\text{sl}}\right)$$

Result for Wrong Input Values:

kappaTsl_pstsXisl_SeaWa, kappaTsl = –1000

References:

$\kappa_T(p,t,\xi)$ [1]

Isothermal Compressibility of Liquid Seawater $\kappa_{\mathrm{Is\,l}} = f(p,t,\xi)$

Function Name:

kappaIsl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION KAPPAISL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappaIsl_ptXi_SeaWa, kappaIsl - Isentropic Compressibility of liquid seawater in [1/kPa]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\mathrm{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\mathrm{mel}}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

kappaIsl_ptXi_SeaWa, kappaIsl = –1000

References:

$\kappa_{\mathrm{Is}}(p,t,\xi)$ [1]

Isothermal Compressibility of Saturated Seawater $\kappa_{ls\ sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

kappaIssl_pstsXIsl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   KAPPAISSL_PSTSXISL_SEAWA(PS, TS, XISL)
REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappaIssl_pstsXisl_SeaWa, kappaIssl - Isentropic Compressibility of saturated seawater in [1/kPa]

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\kappa_{ls}{}^{\text{sl}} = \text{f}\left(-1000, t_s, \xi^{\text{sl}}\right)$$

$$\kappa_{ls}{}^{\text{sl}} = \text{f}\left(p_s, -1000, \xi^{\text{sl}}\right)$$

$$\kappa_{ls}{}^{\text{sl}} = \text{f}\left(p_s, t_s, -1000\right)$$

$$\kappa_{ls}{}^{\text{sl}} = \text{f}\left(p_s, t_s, \xi^{\text{sl}}\right)$$

Result for Wrong Input Values:

kappaIssl_pstsXisl_SeaWa, kappaIssl = –1000

References:

$\kappa_{ls}(p, t, \xi)$ [1]

Thermal Conductivity λ = f(p,t,ξ)

Function Name:

lambda_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION LAMBDA_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

lambda_ptXi_SeaWa, lambda - Thermal Conductivity in W/(m*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 100 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- This function is <u>not</u> defined in the wet steam region.

Result for Wrong Input Values:

lambda_ptXi_SeaWa, lambda = –1000

References:

$\lambda(p,t,\xi)$	[3], [4], [15]

Thermal Conductivity of Liquid Seawater $\lambda_l = f(t,\xi)$

Function Name:

lambdal_tXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION LAMBDAL_TXI_SEAWA(T, XI), REAL*8 T, XI

Input Values:

t - Temperature *t* in °C

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

lambdal_tXi_SeaWa, lambdal - Thermal Conductivity of liquid seawater in W/(m*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

lambdal_tXi_SeaWa, lambdal = –1000

References:

$\lambda(p,t,\xi)$	[3], [4], [15]

Thermal Conductivity of Saturated Fluid $\lambda_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

lambdasl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   LAMBDASL_PSTSXISL_SEAWA(PS, TS, XISL)
REAL*8 PS, TS, XISL
```

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

lambdasl_pstsXisl_SeaWa, lambdasl - Thermal Conductivity of saturated fluid in W/(m*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C,\ \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$\lambda^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$

$$\lambda^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$

$$\lambda^{sl} = f\left(p_s, t_s, -1000\right)$$

$$\lambda^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

lambdasl_pstsXisl_SeaWa, lambdasl = –1000

References:

$\lambda(p,t,\xi)$	[3], [4], [15]

Thermal Conductivity of Saturated Vapor λ_{sv} = f(p_s,t_s,ξ^{sl})

Function Name:

lambdasv_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   LAMBDASV_PSTSXISL_SEAWA(PS,TS,XISL)
REAL*8 PS,TS,XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

lambdasvXisl_psts_SeaWa, lambdasv - Thermal Conductivity of saturated seawater in W/(m*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

lambdasv_pstsXisl_SeaWa, lambdasv = –1000

References:

$\lambda(p,t,\xi)$	[3], [4], [15]

Relative Chemical Potential of Liquid Seawater μ_l = f(p,t,ξ)

Function Name:

myl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION MYL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

myl_ptXi_SeaWa, myl - Relative chemical potential of liquid seawater in [kJ/kg]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

myl_ptXi_SeaWa, myl = –1000

References:

$\mu(p,t,\xi)$ [1]

Relative Chemical Potential of Saturated Fluid $\mu_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

mysl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   MYSL_PSTSXISL_SEAWA(PS, TS, XISL)
REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

mysl_pstsXisl_SeaWa, mysl - Relative chemical potential of saturated seawater in [kJ/kg]

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\mu^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$

$$\mu^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$

$$\mu^{sl} = f\left(p_s, t_s, -1000\right)$$

$$\mu^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

mysl_pstsXisl_SeaWa, mysl = –1000

References:

$\mu(p,t,\xi)$ [1]

Chemical Potential of H_2O of Liquid Seawater $\mu_{wl} = f(p,t,\xi)$

Function Name:

mywl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION MYWL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

mywl_ptXi_SeaWa, mywl - Chemical potential of H2O of liquid seawater in [kJ/kg]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{mel}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

mywl_ptXi_SeaWa, mywl = –1000

References:

$\mu_W(p,t,\xi)$ [1]

Chemical Potential of H_2O of Saturated Fluid $\mu_{w\,sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

mywsl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   MYWSL_PSTSXISL_SEAWA(PS, TS, XISL)
REAL*8 PS, TS, XISL
```

Input Values:

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

mywsl_pstsXisl_SeaWa, mywsl - Relative chemical potential of H2O of saturated seawater in [kJ/kg]

Range of Validity:

Temperature *t*: from 0 °C to 80 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\mu_w^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$

$$\mu_w^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$

$$\mu_w^{sl} = f\left(p_s, t_s, -1000\right)$$

$$\mu_w^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

mywsl_pstsXisl_SeaWa, mywsl = –1000

References:

$\mu_w(p,t,\xi)$ [1]

Chemical Potential of Sea Salt of Liquid Seawater $\mu_{\text{Salt l}}$ = f(p,t,ξ)

Function Name:

mySaltl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION MYSALTL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar

t - Temperature *t* in °C

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

mySaltl_ptXi_SeaWa, mysaltl - Chemical potential of sea salt of liquid seawater in [kJ/kg]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

mySaltl_ptXi_SeaWa, mySaltl = –1000

References:

$\mu_S(p,t,\xi)$ [1]

Chemical Potential of Sea Salt of Saturated Liquid $\mu_{\text{Salt sl}} = f(p_S, t_S, \xi^{sl})$

Function Name:

mySaltsl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION   MYSALTSL_PSTSXISL_SEAWA(PS, TS, XISL)
REAL*8 PS, TS, XISL
```

ps - Pressure *p* in bar

ts - Temperature *t* in °C

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

mySaltsl_pstsXisl_SeaWa, mySaltsl - Relative chemical potential of H2O of saturated seawater in [kJ/kg]

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 80\ °\text{C}, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\mu_{\text{Salt}}^{\text{sl}} = f\left(-1000, t_s, \xi^{\text{sl}}\right)$$

$$\mu_{\text{Salt}}^{\text{sl}} = f\left(p_s, -1000, \xi^{\text{sl}}\right)$$

$$\mu_{\text{Salt}}^{\text{sl}} = f\left(p_s, t_s, -1000\right)$$

$$\mu_{\text{Salt}}^{\text{sl}} = f\left(p_s, t_s, \xi^{\text{sl}}\right)$$

Result for Wrong Input Values:

mySaltsl_pstsXisl_SeaWa, mySaltsl = –1000

References:

$\mu_S(p,t,\xi)$ [1]

Kinematic Viscosity ν = f(p,t,ξ)

Function Name:

ny_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION NY_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ny_ptXi_SeaWa, ny - Kinematic Viscosity in m²/s

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 100 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Kinematic Viscosity $v = \dfrac{\eta}{\rho}$
- This function is <u>not</u> defined in the wet steam region.

Result for Wrong Input Values:

ny_ptXi_SeaWa, ny = –1000

References:

$v(p,t,\xi)$	[1], [2]

Kinematic Viscosity of Liquid Seawater $\nu_l = f(t,\xi)$

Function Name:

nyl_tXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION NYL_TXI_SEAWA(T, XI), REAL*8 T, XI

Input Values:

t - Temperature *t* in °C

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

nyl_tXi_SeaWa, nyl - Kinematic Viscosity of liquid seawater in m²/s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mass fraction ξ: $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Kinematic Viscosity $v = \frac{\eta}{\rho}$

Result for Wrong Input Values:

nyl_tXi_SeaWa, nyl = –1000

References:

$v(p,t,\xi)$ [1],[2]

Kinematic Viscosity of Saturated Liquid $\nu_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

nysl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION NYSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

nysl_pstsXisl_SeaWa, nysl - Kinematic Viscosity of saturated seawater in m²/s

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C,\ \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Comments:

- Kinematic Viscosity $v = \dfrac{\eta}{\rho}$

Possible input variants:

$$\nu^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$\nu^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$\nu^{sl} = f\left(p_s, t_s, -1000\right)$$
$$\nu^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

nysl_pstsXisl_SeaWa, nysl = –1000

References:

$v(p,t,\xi)$ [1],[2]

Kinematic Viscosity of Saturated Vapor $\nu_{sv} = f(p_s, t_s, \xi^{sl})$

Function Name:

nysv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION ASV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

nysv_pstsXisl_SeaWa, nysv - Kinematic Viscosity of saturated seawater in m²/s

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s(t = 0\ °C, \xi = 0.2)$ to $p_s(t = 220\ °C, \xi = 0)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Comments:

- Kinematic Viscosity $v = \frac{\eta}{\rho}$

Result for Wrong Input Values:

nysv_pstsXisl_SeaWa, nysv = –1000

References:

$v(p,t,\xi)$ [1],[2]

Boiling Pressure $p_s = f(t_s, \xi^{sl})$

Function Name:

ps_tsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION PS_TSXISL_SEAWA(TS, XISL), REAL*8 TS, XISL

Input Values:

ts - Saturated Temperature t_s in °C

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ps_tsXisl_SeaWa, ps - Saturation Pressure in bar

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mass fraction ξ: $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

ps_tsXisl_SeaWa, ps = –1000

References:

$p_s(t_s, \xi_{sl})$ [1], [2],[4]

Freezing Pressure p_{mel} = f(t,ξ)

Function Name:

pmel_tXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION PMEL_TXI_SEAWA(T, XI), REAL*8 T, XI

Input Values:

t - Temperature *t* in °C

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

pmel_tXi_SeaWa, pmel - Melting Pressure in bar

Range of Validity:

Temperature *t*: from 0 °C to 0.01 °C

Mass fraction ξ: $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- If p_{mel} > 1000 bar then pmel_tXi_SeaWa, pmel = –1000
- If $p_{mel} < p_{tr}(\xi)$ then pmel_tXi_SeaWa, pmel = –1000

Result for Wrong Input Values:

pmel_tXi_SeaWa, pmel = –1000

References:

$p_{mel}(t,\xi)$ [1], [4], [5]

Triple Point Pressure p_{tr} = f(ξ)

Function Name:

ptr_Xi_SeaWa

Fortran Programs:

REAL*8 FUNCTION PTR_XI_SEAWA(XI), REAL*8 XI

Input Values:

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ptr_Xi_SeaWa, ptr - Triplepoint Pressure in bar

Range of Validity:

Mass fraction ξ: $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

ptr_Xi_SeaWa, ptr = –1000

References:

$p_{tr}(\xi)$ [1], [4], [5]

Prandtl Number $Pr = f(p,t,\xi)$

Function Name:

Pr_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION PR_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Pr_ptXi_SeaWa, Pr - Prandtl Number in [-]

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 100 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Prandtl Number $Pr = \dfrac{v}{a}$
- This function is <u>not</u> defined in the wet steam region.

Result for Wrong Input Values:

Pr_ptXi_SeaWa, Pr = –1000

References:

$Pr(p,t,\xi)$	[1], [2], [3]

Prandtl Number of Liquid Seawater $Pr_l = f(t,\xi)$

Function Name:

Prl_tXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION PRL_TXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Prl_ptXi_SeaWa, Prl - Prandtl Number of liquid seawater in [-]

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mass fraction ξ: $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Prandtl Number $Pr = \frac{v}{a}$

Result for Wrong Input Values:

Prl_tXi_SeaWa, Prl = –1000

andtl Number **References:**

$Pr(p,t,\xi)$ [1], [2], [3]

Prandtl Number of Saturated Liquid $Pr_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

Prsl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION PRSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Prsl_pstsXisl_SeaWa, Prsl - Prandtl Number of saturated seawater in [-]

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to $p_s\left(t = 220\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$Pr^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$Pr^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$Pr^{sl} = f\left(p_s, t_s, -1000\right)$$
$$Pr^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Comments:

- Prandtl Number $Pr = \dfrac{v}{a}$

Result for Wrong Input Values:

Prsl_ptXi_SeaWa, Prsl = –1000

References:

$Pr(p, t, \xi)$ [1], [2], [3]

Prandtl Number of Saturated Vapor $Pr_{sv} = f(p_s, t_s, \xi^{sl})$

Function Name:

Prsv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION PRSV_PSTSXISL_SEAWA(PS,TS), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Prsv_pstsXisl_SeaWa, Prsv - Prandtl Number of saturated seawater in m²/s

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Comments:

- Prandtl Number $Pr = \frac{v}{a}$

Result for Wrong Input Values:

Prsv_pstsXisl_SeaWa, Prsv = –1000

References:

$Pr(p, t, \xi)$	[1], [2], [3]

Density ρ = f(p,t,ξ)

Function Name:

rho_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION RHO_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

rho_ptXi_SeaWa, rho - Density in kg/m³

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

rho_ptXi_SeaWa, rho = –1000

References:

$\rho(p,t,\xi)$	[1], [2]

Density of Liquid Seawater $\rho_l = f(p,t,\xi)$

Function Name:

rhol_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION RHOL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

rhol_ptXi_SeaWa, rhol - Density of liquid seawater in kg/m³

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

rhol_ptXi_SeaWa, rhol = –1000

References:

$\rho(p,t,\xi)$	[1], [2], [3]

Density of Saturated Liquid $\rho_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

rhosl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION RHOSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

rhosl_pstsXisl_SeaWa, rhosl - Density of saturated seawater in kg/m³

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to $p_s\left(t = 220\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$\rho^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$\rho^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$\rho^{sl} = f\left(p_s, t_s, -1000\right)$$
$$\rho^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

rhosl_pstsXisl_SeaWa, rhosl = –1000

References:

$\rho(p, t, \xi)$ [1], [2], [3]

Density of Saturated Vapor ρ_{sv} = f(p_s,t_s,ξ^{sl})

Function Name:

rhosv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION RHOSV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

rhosv_pstsXisl_SeaWa, rhosv - Density of saturated seawater in kg/m³

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

rhosv_pstsXisl_SeaWa, rhosv = –1000

References:

$\rho(p,t,\xi)$ [1], [2], [3]

Specific Entropy $s = f(p,t,\xi)$

Function Name:

s_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION S_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

s_ptXi_SeaWa, s - specific entropy in kJ/(kg*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

s_ptXi_SeaWa, s = –1000

References:

s(p,t,ξ)	[1], [2]

Specific Entropy of Liquid Seawater $s_l = f(p,t,\xi)$

Function Name:

sl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION SL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

sl_ptXi_SeaWa, sl - Specific Entropy of liquid seawater in kJ/(kg*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{mel}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

sl_ptXi_SeaWa, sl = –1000

References:

s(p,t,ξ)	[1], [2]

Specific Entropy of Saturated Liquid $s_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

ssl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION SSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ssl_pstsXisl_SeaWa, ssl - Specific Entropy of saturated seawater in kJ/(kg*K)

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$s^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$s^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$s^{sl} = f\left(p_s, t_s, -1000\right)$$
$$s^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

ssl_pstsXi_SeaWa, ssl = –1000

References:

s(p, t, ξ) [1] , [2]

Specific Entropy of Saturated Vapor $s_{sv} = f(p_S, t_S, \xi^{sl})$

Function Name:

ssv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION SSV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ssv_pstsXisl_SeaWa, ssv - Specific Entropy of saturated seawater in kJ/(kg*K)

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_S\left(t = 0\ °C, \xi = 0.2\right)$ to $p_S\left(t = 220\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

ssv_pstsXisl_SeaWa, ssv = –1000

References:

$s(p,t,\xi)$	[1] , [2]

Boiling Temperature $t_s = f(p_s, \xi^{sl})$

Function Name:

ts_psXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION TS_PSXISL_SEAWA(PS, XISL), REAL*8 PS, XISL

Input Values:

ps - Pressure *p* in bar

Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ts_psXisl_SeaWa, ts - Saturation Temperature in °C

Range of Validity:

Pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$

Mass fraction ξ: $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

ts_psXisl_SeaWa, ts = –1000

References:

$t_s(p_s, \xi_{sl})$ [1], [2], [4]

Freezing Temperature t_{mel} = f(p,ξ)

Function Name:

tmel_pXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION TMEL_PXI_SEAWA(P, XI), REAL*8 P, XI

Input Values:

p - Pressure *p* in bar

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

tmel_pXi_SeaWa, tmel - Melting Temperature in °C

Range of Validity:

Pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.12\right)$ to 1000 bar

Mass fraction ξ: $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- If $t_{mel}(p,\xi) < -12.15$ °C then tmel_pXi_SeaWa, tmel = –1000

Result for Wrong Input Values:

tmel_pXi_SeaWa, tmel = –1000

References:

$t_{mel}(p,\xi)$ [1], [4], [5]

Triple Point Temperature t_{tr} = f(ξ)

Function Name:

ttr_Xi_SeaWa

Fortran Programs:

REAL*8 FUNCTION TTR_XI_SEAWA(XI), REAL*8 XI

Input Values:

Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ttr_Xi_SeaWa, ttr - Triplepoint Temperature in °C

Range of Validity:

Mass fraction ξ: $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

ttr_Xi_SeaWa, ttr = –1000

References:

$t_{tr}(\xi)$ [1], [4], [5]

Region *Region* = f(p,t,ξ)

Function Name:

Region_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION REGION_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Region_ptXi_SeaWa, Region - Region in [-]

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Region : 1 subcooled liquid calculated from IAPWS Industrial Formulation 2013
  2 wet steam region calculated from IAPWS Industrial Formulation 2013
  3 superheated steam calculated from IAPWS Industrial Formulation 2013
  11 subcooled liquid calculated from Fichtner-Handbook
  22 wet steam region calculated from Fichtner-Handbook
  33 superheated steam calculated from Fichtner-Handbook

Result for Wrong Input Values:

Region_ptXi_SeaWa, Region = –1000

References:

Region(p,t,ξ)	[1], [2], [4]

Region *Region* = f(p,h,ξ)

Function Name:

Region_phXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION REGION_PHXI_SEAWA(P, H, XI), REAL*8 P, H, XI

Input Values:

p - Pressure *p* in bar
h - Specific Enthalpy *h* in kJ/kg
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Region_phXiI_SeaWa, Region - Region in [-]

Range of Validity:

Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Enthalpy h:	from h_{min} kJ/kg to h_{max} kJ/kg
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Region : 1 subcooled liquid calculated from IAPWS Industrial Formulation 2013
  2 wet steam region calculated from IAPWS Industrial Formulation 2013
  3 superheated steam calculated from IAPWS Industrial Formulation 2013
  11 subcooled liquid calculated from Fichtner-Handbook
  22 wet steam region calculated from Fichtner-Handbook
  33 superheated steam calculated from Fichtner-Handbook

Result for Wrong Input Values:

Region_phXi_SeaWa, Region = –1000

References:

Region(p,h,ξ)	[1], [2], [4]

Region *Region* = f(p,s,ξ)

Function Name:

Region_psXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION REGION_PSXI_SEAWA(P, S, XI), REAL*8 P, S, XI

Input Values:

p - Pressure *p* in bar
s - Specific Entropy *s* in kJ/(kg*K)
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Region_psXi_SeaWa, Region - Region in [-]

Range of Validity:

Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Entropy s:	from s_{min} kJ/(kg K) to s_{max} kJ/(kg K)
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Region : 1 subcooled liquid calculated from IAPWS Industrial Formulation 2013
  2 wet steam region calculated from IAPWS Industrial Formulation 2013
  3 superheated steam calculated from IAPWS Industrial Formulation 2013
  11 subcooled liquid calculated from Fichtner-Handbook
  22 wet steam region calculated from Fichtner-Handbook
  33 superheated steam calculated from Fichtner-Handbook

Result for Wrong Input Values:

Region_psXi_SeaWa, Region = –1000

References:

Region(p,s,ξ)	[1], [2], [4]

Backward Function: Temperature t = f(p,h,ξ)

Function Name:

t_phXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION T_PHXI_SEAWA(P, H, XI), REAL*8 P, H, XI

Input Values:

p - Pressure *p* in bar
h - Specific Enthalpy *h* in kJ/kg
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

t_phXi_SeaWa, t - Temperature in °C

Range of Validity:

Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Enthalpy h:	from h_{min} kJ/kg to h_{max} kJ/kg
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

t_phXi_SeaWa, t = –1000

References:

$t(p,h,\xi)$	[1], [2], [4]

Backward Function: Temperature t = f(p,s,ξ)

Function Name:

t_psXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION T_PSXI_SEAWA(P, S, XI), REAL*8 P, S, XI

Input Values:

p - Pressure *p* in bar
s - Specific Entropy *h* in kJ/(kg*K)
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

t_psXi_SeaWa, t - Temperature in °C

Range of Validity:

Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Entropy s:	from s_{min} kJ/(kg K) to s_{max} kJ/(kg K)
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

t_psXi_SeaWa, t = –1000

References:

$t(p,s,\xi)$	[1], [2], [4]

Specific Internal Energy u = f(p,t,ξ)

Function Name:

u_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION U_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

u_ptXi_SeaWa, u - Specific internal energy in kJ/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Specific internal energy $u = h - (p * v)$

Result for Wrong Input Values:

u_ptXi_SeaWa, u= –1000

References:

$u(p,t,\xi)$	[1], [2]

Specific Internal Energy of Liquid Seawater $u_l = f(p,t,\xi)$

Function Name:

ul_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION UL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

ul_ptXi_SeaWa, ul - Specific internal energy of liquid seawater in kJ/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{mel}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Specific internal energy $u = h - (p * v)$

Result for Wrong Input Values:

ul_ptXi_SeaWa, ul = –1000

References:

$u(p,t,\xi)$	[1] , [2]

Specific Internal Energy of Saturated Liquid $u_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

usl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION USL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

usl_pstsXisl_SeaWa, usl - Specific internal energy of saturated seawater in kJ/kg

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$u^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$u^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$u^{sl} = f\left(p_s, t_s, -1000\right)$$
$$u^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Comments:

- Specific internal energy $u = h - (p * v)$

Result for Wrong Input Values:

usl_pstsXisl_SeaWa, usl = –1000

References:

$u(p,t,\xi)$ [1] , [2]

Specific Internal Energy of Saturated Vapor $u_{sv} = f(p_S, t_S, \xi^{sl})$

Function Name:

usv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION USV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

usv_pstsXisl_SeaWa, usv - Specific internal energy of saturated seawater in kJ/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Comments:

- Specific internal energy $u = h - (p * v)$

Result for Wrong Input Values:

usv_pstsXisl_SeaWa, usv = –1000

References:

$u(p,t,\xi)$	[1] , [2]

Specific Volume v = f(p,t,ξ)

Function Name:

v_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION V_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

v_ptXi_SeaWa, v - Specific volume in m³/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

v_ptXi_SeaWa, v= –1000

References:

$v(p,t,\xi)$	[1], [2]

Specific Volume of Liquid Seawater $v_l = f(p,t,\xi)$

Function Name:

vl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION VL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

vl_ptXi_SeaWa, vl - Specific volume of liquid seawater in m³/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t,\xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

vl_ptXi_SeaWa, vl = –1000

References:

$v(p,t,\xi)$	[1] , [2]

Specific Volume of Saturated Liquid $v_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

vsl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION VSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

vsl_pstsXisl_SeaWa, vsl - Specific volume of saturated seawater in m³/kg

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to $p_s\left(t = 220\ °\text{C}, \xi = 0\right)$

Mass fraction ξ: $0 \le \xi \le 0.2$ kg sea salt/kg mixture

Possible input variants:

$$v^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$v^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$v^{sl} = f\left(p_s, t_s, -1000\right)$$
$$v^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Result for Wrong Input Values:

vsl_pstsXisl_SeaWa, vsl = –1000

References:

$v(p,t,\xi)$ [1] , [2]

Specific Volume of Saturated Vapor $v_{sv} = f(p_S, t_S, \xi^{sl})$

Function Name:

vsv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION VSV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

vsv_pstsXisl_SeaWa, vsv - Specific volume of saturated seawater in m³/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

vsv_pstsXisl_SeaWa, vsv = –1000

References:

$v(p,t,\xi)$	[1] , [2]

Speed of Sound $w = f(p,t,\xi)$

Function Name:

w_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION W_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

w_ptXi_SeaWa, w - Speed of Sound in m/s

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- This function is <u>not</u> defined in the wet steam region.
- If the input values are outside the range of validity of [1] the result is –1000 (for high salinity, high pressures and temperatures above 65 °C)

Result for Wrong Input Values:

w_ptXi_SeaWa, w= –1000

References:

$w(p,t,\xi)$ [1]

Speed of Sound of Liquid $w_l = f(p,t,\xi)$

Function Name:

wl_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION WL_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

wl_ptXi_SeaWa, wl - Speed of Sound of liquid in m/s

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.12\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- If the input values are outside the range of validity of [1] the result is –1000 (for high salinity, high pressures and temperatures above 65 °C)

Result for Wrong Input Values:

wl_ptXi_SeaWa, wl = –1000

References:

$w(p,t,\xi)$ [1]

Speed of Sound of Saturated Liquid $w_{sl} = f(p_s, t_s, \xi^{sl})$

Function Name:

wsl_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION WSL_PSTSXISL_SEAWA(PS, TS, XISL), REAL*8 PS, TS, XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

wsl_pstsXisl_SeaWa, wsl - Sound speed of saturated seawater in m/s

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Mixture pressure *p*:	from $p_s\left(t = 0\ °C, \xi = 0.12\right)$ to $p_s\left(t = 80\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.12$ kg sea salt/kg mixture

Possible input variants:

$$w^{sl} = f\left(-1000, t_s, \xi^{sl}\right)$$
$$w^{sl} = f\left(p_s, -1000, \xi^{sl}\right)$$
$$w^{sl} = f\left(p_s, t_s, -1000\right)$$
$$w^{sl} = f\left(p_s, t_s, \xi^{sl}\right)$$

Comments:

- If the input values are outside the range of validity of [1] the result is –1000 (for high salinity, high pressures and temperatures above 65 °C)

Result for Wrong Input Values:

wsl_pstsXisl_SeaWa, wsl = –1000

References:

$w(p,t,\xi)$ [1]

Speed of Sound of Saturated Vapor $w_{sv} = f(p_S, t_S, \xi^{sl})$

Function Name:

wsv_pstsXisl_SeaWa

Fortran Programs:

REAL*8 FUNCTION WSV_PSTSXISL_SEAWA(PS,TS,XISL), REAL*8 PS,TS,XISL

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C
Xisl - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

wsv_pstsXisl_SeaWa, wsv - Specific volume of saturated seawater in m³/kg

Range of Validity:

Temperature *t*:	from 0 °C to 80 °C
Mixture pressure *p*:	from $p_S\left(t = 0\ °C, \xi = 0.12\right)$ to $p_S\left(t = 80\ °C, \xi = 0\right)$
Mass fraction ξ:	$0 \le \xi \le 0.12$ kg sea salt/kg mixture

Comments:

- If the input values are outside the range of validity of [1] the result is –1000 (for high salinity, high pressures and temperatures above 65 °C)

Result for Wrong Input Values:

wsv_pstsXisl_SeaWa, wsv = –1000

References:

$w(p,t,\xi)$ [1]

Vapor Fraction x = f(p,t,ξ)

Function Name:

x_ptXi_SeaWa

Fortran Programs:

REAL*8 FUNCTION X_PTXI_SEAWA(P, T, XI), REAL*8 P, T, XI

Input Values:

p - Pressure *p* in bar
t - Temperature *t* in °C
Xi - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

x_ptXi_SeaWa, x - Vapor Fraction in kg/kg

Range of Validity:

Temperature *t*:	from 0 °C to 220 °C
Pressure *p*:	from $p_s\left(t = 0\ °\text{C}, \xi = 0.2\right)$ to 1000 bar and $p \geq p_{\text{mel}}\left(t, \xi\right)$
Mass fraction ξ:	$0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- This function is defined in the wet steam region.

Result for Wrong Input Values:

x_ptXi_SeaWa, x= –1000

References:

$x(p,t,\xi)$ [1]

Mass Fraction of Sea Salt of Saturated Liquid ξ_{sl} = f(p_s,t_s)

Function Name:

Xisl_psts_SeaWa

Fortran Programs:

REAL*8 FUNCTION XISL_PSTS_SEAWA(PS, TS), REAL*8 PS, TS

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C

Result:

Xisl_psts_SeaWa, Xisl - Mass fraction of sea salt of saturated liquid in kg sea salt/kg mixture

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$

Result for Wrong Input Values:

Xisl_psts_SeaWa, Xisl = –1000

References:

$\xi_{sl}(p_s,t_s)$ [1]

Mass Fraction of Sea Salt of Saturated Vapor $\xi_{sv} = f(p_s, t_s)$

Function Name:

Xisv_psts_SeaWa

Fortran Programs:

REAL*8 FUNCTION XISV_PSTS_SEAWA(PS, TS), REAL*8 PS, TS

Input Values:

ps - Pressure *p* in bar
ts - Temperature *t* in °C

Result:

Xisv_psts_SeaWa, Xisv - Mass fraction of sea salt of saturated steam in kg sea salt/kg mixture

Range of Validity:

Temperature *t*: from 0 °C to 220 °C

Mixture pressure *p*: from $p_s\left(t = 0\ °C, \xi = 0.2\right)$ to $p_s\left(t = 220\ °C, \xi = 0\right)$

Result for Wrong Input Values:

Xisv_psts_SeaWa, Xisv = –1000

References:

$\xi_{sv}(p_s, t_s)$ [1]

KCE

KCE-ThermoFluidProperties
www.thermofluidprop.com

Property Libraries for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Water and Steam

Library LibIF97

- Industrial Formulation IAPWS-IF97 (Revision 2007)
- Supplementary Standards
  - IAPWS-IF97-S01
  - IAPWS-IF97-S03rev
  - IAPWS-IF97-S04
  - IAPWS-IF97-S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)

Library LibSBTL_IF97
Library LibSBTL_95

Extremely fast property calculations according to the IAPWS Guideline 2015
Spline-based Table Look-up Method (SBTL)
applied to the
Industrial Formulation IAPWS-IF97
and to the
Scientific Formulation IAPWS-95
for Computational Fluid Dynamics and simulating non-stationary processes

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

CO_2 - Span, Wagner H_2O - IAPWS-95
O_2 - Schmidt, Wagner N_2 - Span et al.
Ar - Tegeler et al.

and of the ideal gases:
SO_2, CO, Ne
(Scientific Formulation of Bücker et al.)

Consideration of:
- Dissociation from VDI 4670
- Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:
- Dry air from Lemmon et al.
- Steam, water and ice from IAPWS-IF97 and IAPWS-06

Consideration of:
- Condensation and freezing of steam
- Dissociation from VDI 4670
- Poynting effect from ASHRAE RP-1485

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

Ice from IAPWS-06, Melting and sublimation pressures from IAPWS-08, Water from IAPWS-IF97, Steam from IAPWS-95 and -IF97

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

Ar	NO	He	Propylene
Ne	H_2O	F_2	Propane
N_2	SO_2	NH_3	Iso-Butane
O_2	H_2	Methane	n-Butane
CO	H_2S	Ethane	Benzene
CO_2	OH	Ethylene	Methanol
Air			

Consideration of:
- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:
- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

Model: Virial equation from ASHRAE Report RP-1485 for real mixture of the real fluids:
- Dry air
- Steam

Consideration of:
- Enhancement of the partial saturation pressure of water vapor at elevated total pressures

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bücker and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

IAPWS Guideline 2001
of Tillner-Roth and Friend (1998)

Helmholtz energy equation for the mixing term

(also useable for calculating the Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

$C_2H_6O_2$	Ethylene glycol
$C_3H_8O_2$	Propylene glycol
C_2H_5OH	Ethanol
CH_3OH	Methanol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate
$CHKO_2$	Potassium formate
LiCl	Lithium chloride
NH_3	Ammonia

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol
Library LibC2H5OH
Formulation of Schroeder (2012)

Methanol
Library LibCH3OH
Formulation of de Reuck and Craven (1993)

Propane
Library LibPropane
Formulation of Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $C_8H_{24}O_4Si_4$ **Library LibD4**

Decamethylcyclopentasiloxane $C_{10}H_{30}O_5Si_5$ **Library LibD5**

Tetradecamethylhexasiloxane $C_{14}H_{42}O_5Si_6$ **Library LibMD4M**

Hexamethyldisiloxane $C_6H_{18}OSi_2$ **Library LibMM**

Formulation of Colonna et al. (2006)

Dodecamethylcyclohexasiloxane $C_{12}H_{36}O_6Si_6$ **Library LibD6**

Decamethyltetrasiloxane $C_{10}H_{30}O_3Si_4$ **Library LibMD2M**

Dodecamethylpentasiloxane $C_{12}H_{36}O_4Si_5$ **Library LibMD3M**

Octamethyltrisiloxane $C_8H_{24}O_2Si_3$ **Library LibMDM**

Formulation of Colonna et al. (2008)

Nitrogen and Oxygen
Libraries LibN2 and LibO2
Formulations of Span et al. (2000) and Schmidt and Wagner (1985)

Hydrogen
Library LibH2
Formulation of Leachman et al. (2009)

Helium
Library LibHe
Formulation of Arp et al. (1998)

Hydrocarbons

Decane $C_{10}H_{22}$ **Library LibC10H22**
Isopentane C_5H_{12} **Library LibC5H12_ISO**
Neopentane C_5H_{12} **Library LibC5H12_NEO**
Isohexane C_6H_{14} **Library LibC6H14**
Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**
Carbonyl sulfide **COS** **Library LibCOS**
Hydrogen sulfide H_2S **Library LibH2S**
Nitrous oxide N_2O **Library LibN2O**
Sulfur dioxide SO_2 **Library LibSO2**
Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

KCE-ThermoFluidProperties UG (limited liability) & Co. KG
Professor Hans-Joachim Kretzschmar

Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
E-mail: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-4262250

The following thermodynamic and transport properties can be calculated[a]:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl number Pr

Backward Functions

- T, v, s (p,h)
- T, v, h (p,s)
- p, T, v (h,s)
- p, T (v,h)
- p, T (v,u)

Thermodynamic Derivatives

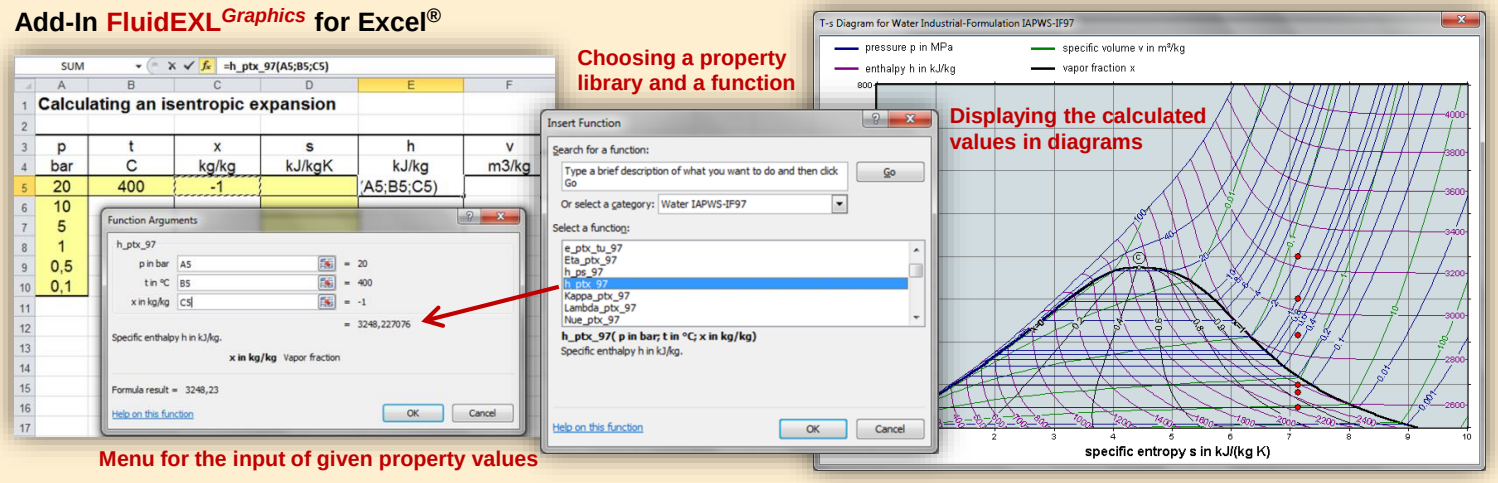
- Partial derivatives can be calculated.

[a] Not all of these property functions are available in all property libraries.

KCE-ThermoFluidProperties
www.thermofluidprop.com

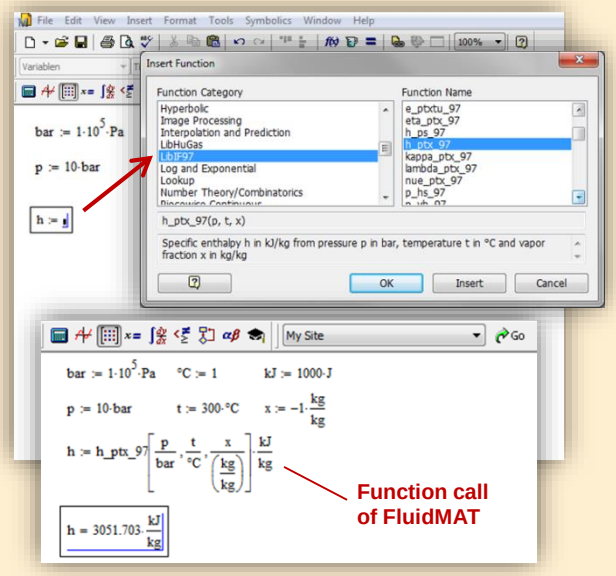
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



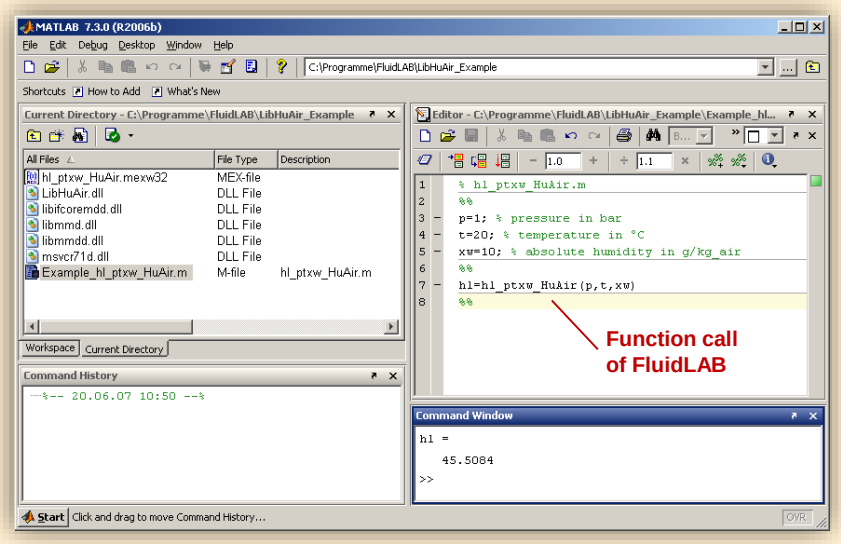
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



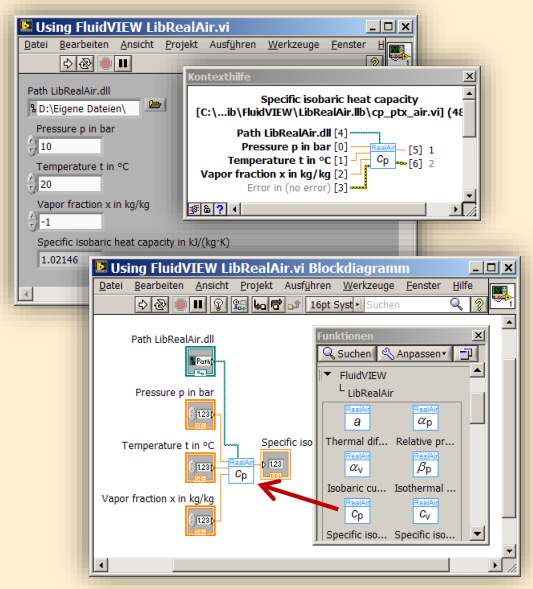
Add-In FluidLAB for MATLAB®

Using the Add-In FluidLAB the property functions can be called in MATLAB®.



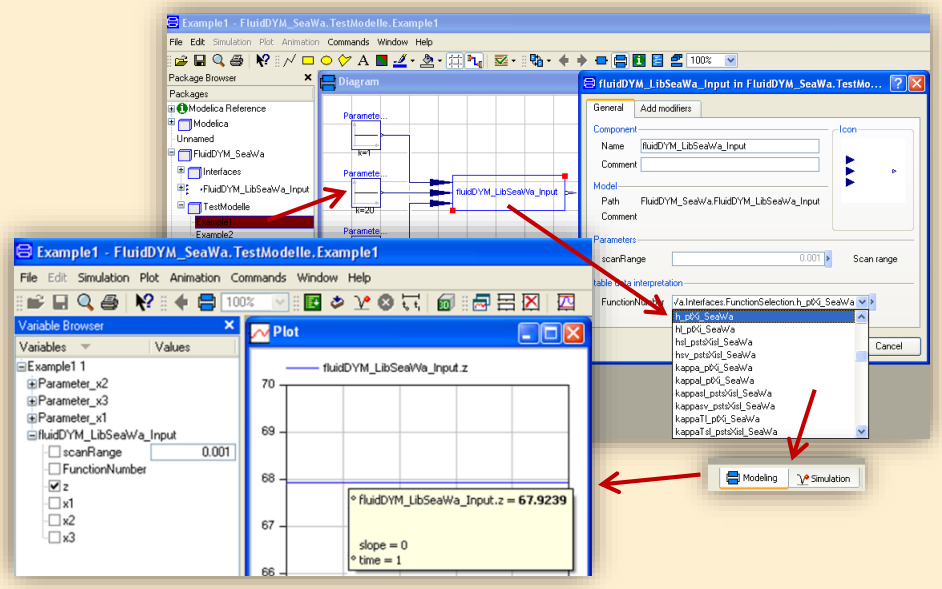
Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

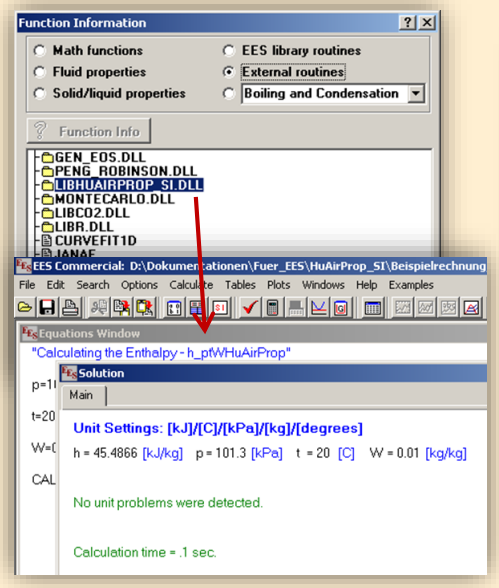


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

The property functions can be called in DYMOLA® and SimulationX®.

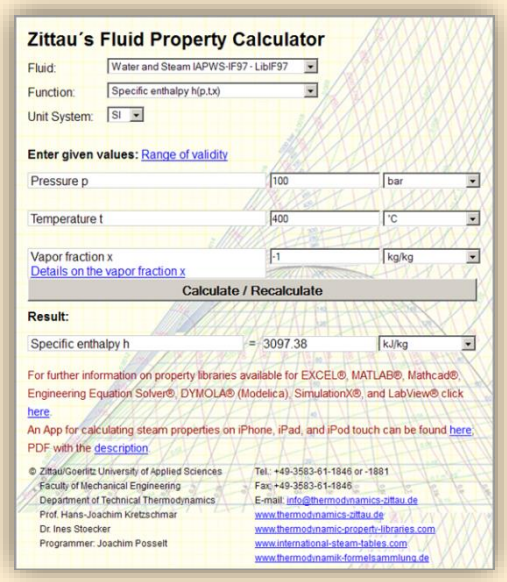


Add-In FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android Smartphones and Tablets

Online Property Calculator at www.thermofluidprop.com



Property Software for Pocket Calculators

FluidCasio

fx 9750 G II | CFX 9850 fx-GG20 | CFX 9860 G Graph 85 | ALGEBRA FX 2.0

FluidHP

HP 48 | HP 49

FluidTI

TI Nspire CX CAS
TI Nspire CAS

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

For more information please contact:

KCE-ThermoFluidProperties UG (limited liability) & Co. KG
Professor Hans-Joachim Kretzschmar

Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
E-mail: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-4262250

The following thermodynamic and transport properties[a] can be calculated in Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® (EES), DYMOLA® (Modelica), SimulationX® and LabVIEW™:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl number Pr

Backward Functions

- T, v, s (p,h)
- T, v, h (p,s)
- p, T, v (h,s)
- p, T (v,h)
- p, T (v,u)

Thermodynamic Derivatives

- Partial derivatives can be calculated.

[a] Not all of these property functions are available in all property libraries.

www.thermofluidprop.com

5. References

[1] IAPWS. Advisory Note No. 5: Industrial Calculation of the Thermodynamic Properties of Seawater.
Available at http://www.iapws.org (2013)

[2] Hömig, H.E:
Seawater and Seawater Distillation. Fichtner-Handbook,
Vulkan-Verlag, Essen (1978)

[3] Jamieson, D.T; Tudhope, J. S.:
Physical Properties of Sea Water Solutions: Thermal Conductivity
Desalination 8, 393-401 (1970)

[4] Feistel, R.:
A Gibbs Function for Seawater Thermodynamics for –6 to 80 °C and Salinity up to 120 g kg^{-1}. Deep-Sea Research I 55, 1639-1671 (2008)

[5] IAPWS. Revised Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substances for General and Scientific Use.
Available at http://www.iapws.org (2009)

[6] IAPWS. Revised Release on the Equation of State 2006 for H_2O Ice Ih.
Available at http://www.iapws.org (2009)

[7] IAPWS. Release on Revised Advisory Note No.3, Thermodynamic Derivatives from IAPWS Formulations.
Available at http://www.iapws.org (2008)

[8] IAPWS. Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam IAPWS-IF97.
Available at http://www.iapws.org (2007)

[9] Wagner, W.; Kretzschmar, H.-J.:
International Steam Tables. 2nd edition. Springer-Verlag, Berlin and Heidelberg (2008)

[10] Hellriegel, T.:
ITERA_PRO Iterationsroutine.
Fachgebiet Technische Thermodynamik, Hochschule Zittau/Görlitz (2008)

[11] Miyagawa, K.:
IAPWS-IF97 for the Water Part of the EOS of SeaWater. (2008)

[12] Kretzschmar, H.-J.; Stöcker, I.; Jähne, I.: Programm FluidEXL Graphics für Excel® Hochschule Zittau/Görlitz (FH), Fachbereich Maschinenwesen (1998 - 2008)

[13] Salomo, B.:
Berechnung der thermodynamischen Stoffeigenschaften von Kohlendioxid/Wasser-Gemischen für die Modellierung von Energie-umwandlungsprozessen mit CO_2-Abscheidung Anbindung an MATLAB.
Diplomarbeit, Zittau (2007)

[14] IAPWS. Revised Release on the Pressure along the Melting and Sublimation Curves of Ordinary Water Substance. Available at http://www.iapws.org (2008)

[15] IAPWS. Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance. Available at http://www.iapws.org (2011)

6. Satisfied Customers

Date: 05/2018

The following companies and institutions use the property libraries

- FluidEXL*Graphics* for Excel®
- FluidLAB for MATLAB®
- FluidMAT for Mathcad®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica) and SimulationX®
- FluidVIEW for LabVIEW™.

2018

Universität Madrid, Madrid, Spanien	05/2018
HS Zittau/ Görlitz, Fakultät Wirtschaft, Zittau	05/2018
HS Niederrhein, Krefeld	05/2018
GRS, Köln	03/2018
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	02/2018
AIXPROCESS, Aachen	02/2018
KRONES, Neutraubling	02/2018
Doosan Lentjes, Ratingen	01/2018

2017

Compact Kältetechnik, Dresden	12/2017
Endress + Hauser Messtechnik GmbH +Co. KG, Hannover	12/2017
TH Mittelhessen, Gießen	11/2017
Haarslev Industries, Søndersø, Denmark	11/2017
Hochschule Zittau/Görlitz, Fachgebiet Energiesystemtechnik	11/2017
ATESTEO, Alsdorf	10/2017
Wijbenga, PC Geldermalsen, Netherlands	10/2017
Fels-Werke GmbH, Elbingerode	10/2017
KIT Karlsruhe, Institute für Neutronenphysik und Reaktortechnik	09/2017
Air-Consult, Jena	09/2017
Papierfabrik Koehler, Oberkirch	09/2017
ZWILAG, Würenlingen, Switzerland	09/2017
TLK-Thermo Universität Braunschweig, Braunschweig	08/2017
Fichtner IT Consulting AG, Stuttgart	07/2017
Hochschule Ansbach, Ansbach	06/2017
RONAL, Härkingen, Switzerland	06/2017
BORSIG Service, Berlin	06/2017

BOGE Kompressoren, Bielefeld	06/2017
STEAG Energy Services, Zwingenberg	06/2017
CES clean energy solutions, Wien, Austria	04/2017
Princeton University, Princeton, USA	04/2017
B2P Bio-to-Power, Wadersloh	04/2017
TU Dresden, Institute for Energy Engineering, Dresden	04/2017
SAINT-GOBAIN, Vaujours, France	03/2017
TU Bergakademie Freiberg, Chair of Thermodynamics, Freiberg	03/2017
SCHMIDT + PARTNER, Therwil, Switzerland	03/2017
KAESER Kompressoren, Gera	03/2017
F&R, Praha, Czech Republic	03/2017
ULT Umwelt-Lufttechnik, Löbau	02/2017
JS Energie & Beratung, Erding	02/2017
Kelvion Brazed PHE, Nobitz-Wilchwitz	02/2017
MTU Aero Engines, München	02/2017
Hochschule Zittau/Görlitz, IPM	01/2017
CombTec ProCE, Zittau	01/2017
SHELL Deutschland Oil, Wesseling	01/2017
MARTEC Education Center, Frederikshaven, Denmark	01/2017
SynErgy Thermal Management, Krefeld	01/2017

2016

BOGE Druckluftsysteme, Bielefeld	12/2016
BFT Planung, Aachen	11/2016
Midiplan, Bietigheim-Bissingen	11/2016
BBE Barnich IB	11/2016
Wenisch IB,	11/2016
INL, Idaho Falls	11/2016
TU Kältetechnik, Dresden	11/2016
Kopf SynGas, Sulz	11/2016
INTVEN, Bellevne (USA)	11/2016
DREWAG Dresden, Dresden	10/2016
AGO AG Energie+Anlagen, Kulmbach	10/2016
Universität Stuttgart, ITW, Stuttgart	09/2016
Pöyry Deutschland GmbH, Dresden	09/2016
Siemens AG, Erlangen	09/2016
BASF über Fichtner IT Consulting AG	09/2016
B+B Engineering GmbH, Magdeburg	09/2016
Wilhelm Büchner Hochschule, Pfungstadt	08/2016

Webasto Thermo & Comfort SE, Gliching	08/2016
TU Dresden, Dresden	08/2016
Endress+Hauser Messtechnik GmbH+Co. KG, Hannover	08/2016
D + B Kältetechnik, Althausen	07/2016
Fichtner IT Consulting AG, Stuttgart	07/2016
AB Electrolux, Krakow, Poland	07/2016
ENEXIO Germany GmbH, Herne	07/2016
VPC GmbH, Vetschau/Spreewald	07/2016
INWAT, Lodz, Poland	07/2016
E.ON SE, Düsseldorf	07/2016
Planungsbüro Waidhas GmbH, Chemnitz	07/2016
EEB Enerko, Aldershoven	07/2016
IHEBA Naturenergie GmbH & Co. KG, Pfaffenhofen	07/2016
SSP Kälteplaner AG, Wolfertschwenden	07/2016
EEB ENERKO Energiewirtschaftliche Beratung GmbH, Berlin	07/2016
BOGE Kompressoren Otto BOGE GmbH & Co KG, Bielefeld	06/2016
Universidad Carlos III de Madrid, Madrid, Spain	04/2016
INWAT, Lodzi, Poland	04/2016
Planungsbüro WAIDHAS GmbH, Chemnitz	04/2016
STEAG Energy Services GmbH, Laszlo Küppers, Zwingenberg	03/2016
WULFF & UMAG Energy Solutions GmbH, Husum	03/2016
FH Bielefeld, Bielefeld	03/2016
EWT Eckert Wassertechnik GmbH, Celle	03/2016
ILK Institut für Luft- und Kältetechnik GmbH, Dresden	02/2016, 06/2016 (2x)
IEV KEMA - DNV GV – Energie, Dresden	02/2016
Allborg University, Department of Energie, Aalborg, Denmark	02/2016
G.A.M. Heat GmbH, Gräfenhainichen	02/2016
Institut für Luft- und Kältetechnik, Dresden	02/2016, 05/2016, 06/2016
Bosch, Stuttgart	02/2016
INL Idaho National Laboratory, Idaho, USA	11/2016, 01/2016
Friedl ID, Wien, Austria	01/2016
Technical University of Dresden, Dresden	01/2016

2015

EES Enerko, Aachen	12/2015
Ruldolf IB, Strau, Austria	12/2015
Allborg University, Department of Energie, Aalborg, Denmark	12/2015
University of Lyubljana, Slovenia	12/2015
Steinbrecht IB, Berlin	11/2015
Universidad Carlos III de Madrid, Madrid, Spain	11/2015
STEAK, Essen	11/2015

Bosch, Lohmar	10/2015
Team Turbo Machines, Rouen, France	09/2015
BTC – Business Technology Consulting AG, Oldenburg	07/2015
KIT Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen	07/2015
ILK, Dresden	07/2015
Schniewindt GmbH & Co. KG, Neuenwalde	08/2015

2014

PROJEKTPLAN, Dohna	04/2014
Technical University of Vienna, Austria	04/2014
MTU Aero Engines AG, Munich	04/2014
GKS, Schweinfurt	03/2014
Technical University of Nuremberg	03/2014
EP-E, Niederstetten	03/2014
Rückert NatUrgas GmbH, Lauf	03/2014
YESS-World, South Korea	03/2014
ZAB, Dessau	02/2014
KIT-TVT, Karlsruhe	02/2014
Stadtwerke Neuburg	02/2014
COMPAREX, Leipzig for RWE Essen	02/2014
Technical University of Prague, Czech Republic	02/2014
HS Augsburg	02/2014
Envi-con, Nuremberg	01/2014
DLR, Stuttgart	01/2014
Doosan Lentjes, Ratingen	01/2014
Technical University of Berlin	01/2014
Technical University of Munich	01/2014
Technical University of Braunschweig	01/2014
M&M Turbinentechnik, Bielefeld	01/2014

2013

TRANTER-GmbH, Artern	12/2013
SATAKE, Shanghai, China	12/2013
VOITH, Kunshan, China	12/2013
ULT, Löbau	12/2013
MAN, Copenhagen, Dänemark	11/2013
DREWAG, Dresden	11/2013
Haarslev Industries, Herlev, Dänemark	11/2013
STEAG, Herne	11/2013, 12/2013
Ingersoll-Rand, Oberhausen	11/2013
Wilhelm-Büchner HS, Darmstadt	10/2013

IAV, Chemnitz	10/2013
Technical University of Regensburg	10/2013
PD-Energy, Bitterfeld	09/2013
Thermofin, Heinsdorfergrund	09/2013
SHI, New Jersey, USA	09/2013
M&M Turbinentechnik, Bielefeld	08/2013
BEG-BHV, Bremerhaven	08/2013
TIG-Group, Husum	08/2013
COMPAREX, Leipzig	08/2013, 11/2013
for RWE Essen	12/2013
University of Budapest, Hungary	08/2013
Siemens, Frankenthal	08/2013, 10/2013
	11/2013
VGB, Essen	07/2013, 11/2013
Brunner Energieberatung, Zurich, Switzerland	07/2013
Technical University of Deggendorf	07/2013
University of Maryland, USA	07/2013, 08/2013
University of Princeton, USA	07/2013
NIST, Boulder, USA	06/2013
IGUS GmbH, Dresden	06/2013
BHR Bilfinger, Essen	06/2013
SÜDSALZ, Bad Friedrichshall	06/2013, 12/2013
Technician School of Berlin	05/2013
KIER, Gajeong-ro, Südkorea	05/2013
Schwing/Stetter GmbH, Memmingen	05/2013
Vattenfall, Berlin	05/2013
AUTARK, Kleinmachnow	05/2013
STEAG, Zwingenberg	05/2013
Hochtief, Düsseldorf	05/2013
University of Stuttgart	04/2013
Technical University -Bundeswehr, Munich	04/2013
Rerum Cognitio Forschungszentrum, Frankfurt	04/2013
Kältetechnik Dresen + Bremen, Alfhausen	04/2013
University Auckland, New Zealand	04/2013
MASDAR Institut, Abu Dhabi, United Arab Emirates	03/2013
Simpelkamp, Dresden	02/2013
VEO, Eisenhüttenstadt	02/2013
ENTEC, Auerbach	02/2013
Caterpillar, Kiel	02/2013
Technical University of Wismar	02/2013
Technical University of Dusseldorf	02/2013

ILK, Dresden	01/2013, 08/2013
Fichtner IT, Stuttgart	01/2013, 11/2013
Schnepf Ingeniuerbüro, Nagold	01/2013
Schütz Engineering, Wadgassen	01/2013
Endress & Hauser, Reinach, Switzerland	01/2013
Oschatz GmbH, Essen	01/2013
frischli Milchwerke, Rehburg-Loccum	01/2013

2012

Voith, Bayreuth	12/2012
Technical University of Munich	12/2012
Dillinger Huette	12/2012
University of Stuttgart	11/2012
Siemens, Muehlheim	11/2012
Sennheiser, Hannover	11/2012
Oschatz GmbH, Essen	10/2012
Fichtner IT, Stuttgart	10/2012, 11/2012
Helbling Technik AG, Zurich, Switzerland	10/2012
University of Duisburg	10/2012
Rerum Cognitio Forschungszentrum, Frankfurt	09/2012
Pöyry Deutschland GmbH, Dresden	08/2012
Extracciones, Guatemala	08/2012
RWE, Essen	08/2012
Weghaus Consulting Engineers, Wuerzburg	08/2012
GKS, Schweinfurt	07/2012
COMPAREX, Leipzig for RWE Essen	07/2012
GEA, Nobitz	07/2012
Meyer Werft, Papenburg	07/2012
STEAG, Herne	07/2012
GRS, Cologne	06/2012
Fichtner IT Consult, Chennai, India	06/2012
Siemens, Freiburg	06/2012
Nikon Research of America, Belmont, USA	06/2012
Niederrhein University of Applied Sciences, Krefeld	06/2012
STEAG, Zwingenberg	06/2012
Mainova, Frankfurt on Main via Fichtner IT Consult	05/2012
Endress & Hauser	05/2012
PEU, Espenheim	05/2012
Luzern University of Applied Sciences, Switzerland	05/2012

BASF, Ludwigshafen (general license) via Fichtner IT Consult	05/2012
SPX Balcke-Dürr, Ratingen	05/2012, 07/2012
Gruber-Schmidt, Wien, Austria	04/2012
Vattenfall, Berlin	04/2012
ALSTOM, Baden	04/2012
SKW, Piesteritz	04/2012
TERA Ingegneria, Trento, Italy	04/2012
Siemens, Erlangen	04/2012, 05/2012
LAWI Power, Dresden	04/2012
Stadtwerke Leipzig	04/2012
SEITZ, Wetzikon, Switzerland	03/2012, 07/2012
M & M, Bielefeld	03/2012
Sennheiser, Wedemark	03/2012
SPG, Montreuil Cedex, France	02/2012
German Destilation, Sprendlingen	02/2012
Lopez, Munguia, Spain	02/2012
Endress & Hauser, Hannover	02/2012
Palo Alto Research Center, USA	02/2012
WIPAK, Walsrode	02/2012
Freudenberg, Weinheim	01/2012
Fichtner, Stuttgart	01/2012
airinotec, Bayreuth	01/2012, 07/2012
University Auckland, New Zealand	01/2012
VPC, Vetschau	01/2012
Franken Guss, Kitzingen	01/2012

2011

XRG-Simulation, Hamburg	12/2011
Smurfit Kappa PPT, AX Roermond, Netherlands	12/2011
AWTEC, Zurich, Switzerland	12/2011
eins-energie, Bad Elster	12/2011
BeNow, Rodenbach	11/2011
Luzern University of Applied Sciences, Switzerland	11/2011
GMVA, Oberhausen	11/2011
CCI, Karlsruhe	10/2011
W.-Büchner University of Applied Sciences, Pfungstadt	10/2011
PLANAIR, La Sagne, Switzerland	10/2011
LAWI, Dresden	10/2011
Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011

Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011
Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010

University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010
Vaillant, Remscheid	10/2010
PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
Saacke, Bremen	09/2010
WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	08/2010
ERGION, Mannheim	07/2010
Fichtner IT Consulting, Stuttgart	07/2010
TF Design, Matieland, South Africa	07/2010
MCE, Berlin	07/2010, 12/2010
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	06/2010
RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010
Universitaet der Bundeswehr, Munich	04/2010

Technical University of Hamburg-Harburg	04/2010
Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
VER, Dresden	04/2010
CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
Technical University of Dresden	02/2010
Siemens Energy, Nuremberg	02/2010
Augsburg University of Applied Sciences	02/2010
ALSTOM Power, Baden, Switzerland	02/2010, 05/2010
MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	01/2010, 12/2010
Technical University of Freiberg	01/2010
ILK, Dresden	01/2010, 12/2010
Fischer-Uhrig Consulting Engineers, Berlin	01/2010

2009

ALSTOM Power, Baden, Schweiz	01/2009, 03/2009 05/2009
Nordostschweizerische Kraftwerke AG, Doettingen, Switzerland	02/2009
RWE, Neurath	02/2009
Brandenburg University of Technology, Cottbus	02/2009
Hamburg University of Applied Sciences	02/2009
Kehrein, Moers	03/2009
EPP Software, Marburg	03/2009
Bernd Münstermann, Telgte	03/2009
Suedzucker, Zeitz	03/2009
CPP, Marburg	03/2009
Gelsenkirchen University of Applied Sciences	04/2009
Regensburg University of Applied Sciences	05/2009
Gatley & Associates, Atlanta, USA	05/2009
BOSCH, Stuttgart	06/2009, 07/2009
Dr. Nickolay, Consulting Engineers, Gommersheim	06/2009
Ferrostal Power, Saarlouis	06/2009
BHR Bilfinger, Essen	06/2009
Intraserv, Wiesbaden	06/2009
Lausitz University of Applied Sciences, Senftenberg	06/2009
Nuernberg University of Applied Sciences	06/2009

Technical University of Berlin	06/2009
Fraunhofer Institut UMSICHT, Oberhausen	07/2009
Bischoff, Aurich	07/2009
Fichtner IT Consulting, Stuttgart	07/2009
Techsoft, Linz, Austria	08/2009
DLR, Stuttgart	08/2009
Wienstrom, Vienna, Austria	08/2009
RWTH Aachen University	09/2009
Vattenfall, Hamburg	10/2009
AIC, Chemnitz	10/2009
Midiplan, Bietigheim-Bissingen	11/2009
Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
FZD, Rossendorf	11/2009
Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
EC, Heidelberg	11/2009
MCI, Innsbruck, Austria	12/2009
Saacke, Bremen	12/2009
ENERKO, Aldenhoven	12/2009

2008

Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	01/2008
University of Karlsruhe	01/2008
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	02/2008
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008
WEBASTO, Neubrandenburg	04/2008
CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008

Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008
Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
VER, Dresden	02/2007
Technical University of Dresden, Chair in Jet Propulsion Systems	02/2007
Redacom, Nidau, Switzerland	02/2007
Universität der Bundeswehr, Munich	02/2007
Maxxtec, Sinsheim	03/2007
University of Rostock, Chair in Technical Thermodynamics	03/2007
AGO, Kulmbach	03/2007
University of Stuttgart, Chair in Aviation Propulsions	03/2007
Siemens Power Generation, Duisburg	03/2007
ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
Technical University of Cottbus, Chair in Power Plant Engineering	06/2007
Voith Paper Air Systems, Bayreuth	06/2007
Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
National Energy Technology Laboratory, Pittsburg, USA	10/2007
Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007

Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006
Technical University of Munich, Chair in Apparatus and Plant Engineering	02/2006
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Department of USET Merseburg incorporated society	05/2006
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	05/2006
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
Suedzucker, Ochsenfurt	06/2006
M&M Turbine Technology, Bielefeld	06/2006
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006

Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden Professorship of Thermic Energy Machines and Plants	04/2005
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005
Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005

Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	01/2004
University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004
Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003

Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
Ingenieurbuero Ostendorf, Gummersbach	05/2003
TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	06/2003
University of Cali, Colombia	07/2003
Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003
Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002

FZR Forschungszentrum, Rossendorf/Dresden	03/2002
CompAir, Simmern	03/2002
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
ALSTOM Power Baden, Switzerland (group licenses)	05/2002
InfraServ, Gendorf	05/2002
SoftSolutions, Muehlhausen (company license)	05/2002
DREWAG, Dresden (company license)	05/2002
SOFBID, Zwingenberg	06/2002
(general EBSILON program license)	
Kleemann Engineering, Dresden	06/2002
Caliqua, Basel, Switzerland (company license)	07/2002
PCK Raffinerie, Schwedt (group license)	07/2002
Fischer-Uhrig Engineering, Berlin	08/2002
Fichtner Consulting & IT, Stuttgart	08/2002
(company licenses and distribution)	
Stadtwerke Duisburg	08/2002
Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel	12/2002
(general license and training test benches)	
VEAG, Berlin (group license)	12/2002

2001

ALSTOM Power, Baden, Switzerland	01/2001, 06/2001
	12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of	02/2001
Power Machinery and Plants	
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart	04/2001
(company licenses and distribution)	
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe	08/2001
(general license for the WinIS information system)	
Neusiedler AG, Ulmerfeld, Austria	09/2001

h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

2000

SOFBID, Zwingenberg	01/2000
(general EBSILON program license)	
AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000
IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
UMAG W. UDE, Husum	03/2000
VEAG, Berlin (group license)	03/2000
Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
G.U.N.T. Geraetebau, Barsbuettel	11/2000
(general license for training test benches)	
Steinhaus Informationssysteme, Datteln	12/2000
(general license for process data software)	

1999

Bayernwerk, Munich	01/1999
DREWAG, Dresden (company license)	02/1999
KEMA IEV, Dresden	03/1999
Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart	07/1999
(company licenses and distribution)	
Technical University of Cottbus, Chair in Power Plant Engineering	07/1999
Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
M&M Turbine Technology Bielefeld	06/1998
B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998
SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

1997

Gerb, Dresden	06/1997
Siemens Power Generation, Goerlitz	07/1997