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Property Library for Seawater Calculated from the IAPWS Industrial Formulation 2013

**FluidEXL *Graphics*
with LibSeaWa
for Excel®**

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0. Package Contents

0.1 Zip files for 32-bit Excel®

The following zip files are delivered for your computer running a 32-bit version of Excel®.

English zip file "CD_FluidEXL_Graphics_LibSeaWa_Eng.zip" including the following files:

FluidEXL_Graphics_Eng_Setup.exe	- Self-extracting and self-installing program for FluidEXL <i>Graphics</i>
FluidEXL_Graphics_Eng.xla	- FluidEXL <i>Graphics</i> Add-In
LibSeaWa.hlp	- Help file for the LibSeaWa property library
LibSeaWa.dll	- Dynamic link library with functions for seawater
FluidEXL_Graphics_LibSeaWa_Docu_Eng.pdf	- User's Guide

German zip file "CD_FluidEXL_Graphics_LibSeaWa.zip" including the following files:

FluidEXL_Graphics_Setup.exe	- Self-extracting and self-installing program for FluidEXL <i>Graphics</i>
FluidEXL_Graphics.xla	- German Add-In for FluidEXL <i>Graphics</i>
LibSeaWa.hlp	- Help file for the LibSeaWa property library
LibSeaWa.dll	- Dynamic link library with functions for seawater
FluidEXL_Graphics_LibSeaWa_Docu_Eng.pdf	- User's Guide

0.2 Zip files for 64-bit Excel®

The following zip files are delivered for your computer running a 64-bit version of Excel®.

English zip file "CD_FluidEXL_Graphics_LibSeaWa_x64_Eng.zip" including the following files and folders:

Files:

Setup.exe	- Self-extracting and self-installing program for FluidEXL ^{Graphics}
FluidEXL_Graphics_Eng_64_Setup.msi	- Self-extracting and self-installing program
FluidEXL_Graphics_Eng.xla	- FluidEXL ^{Graphics} Add-In
FluidEXL_Graphics_LibSeaWa_Docu_Eng.pdf	- User's Guide
LibSeaWa.dll	- Dynamic link library with functions for seawater
LibSeaWa.hlp	- Help file for the LibSeaWa property library

Folders:

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

German zip file "CD_FluidEXL_Graphics_LibSeaWa_x64.zip" including the following files and folders:

Files:

Setup.exe	- Self-extracting and self-installing program for FluidEXL ^{Graphics}
FluidEXL_Graphics_64_Setup.msi	- Self-extracting and self-installing program
FluidEXL_Graphics.xla	- German FluidEXL ^{Graphics} Add-In
FluidEXL_Graphics_LibSeaWa_Docu_Eng.pdf	- User's Guide
LibSeaWa.dll	- Dynamic link library for use in Windows® programs
LibSeaWa.hlp	- Help file for the LibSeaWa property library

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
$a = f(p, t, \xi)$	a_ptXI_SeaWa	= A_PTXI_SEAWA(P,T,XI)	Thermal diffusivity	m ² /s	[1], [2]	3/2
$a_l = f(t, \xi)$	al_tXI_SeaWa	= AL_TXI_SEAWA(T,XI)	Thermal diffusivity of subcooled liquid	m ² /s	[1], [2]	3/3
$a_{sl} = f(p_s, t_s, \xi_{sl})$	asl_pstsXisl_SeaWa	= ASL_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal diffusivity of saturated liquid	m ² /s	[1], [2]	3/4
$a_{sv} = f(p_s, t_s, \xi_{sl})$	asv_pstsXisl_SeaWa	= ASV_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal diffusivity of saturated vapor	m ² /s	[1], [2]	3/5
$\alpha_l = f(p, t, \xi)$	alphan_ptXi_SeaWa	= ALPHAL_PTXI_SEAWA(P,T,XI)	Thermal expansion coefficient of subcooled liquid	1/K	[1]	3/6
$\alpha_{sl} = f(p_s, t_s, \xi_{sl})$	alphasl_pstsXisl_SeaWa	= ALPHASL_PSTSXISL_SEAWA(PS,TS,XISL)	Thermal expansion coefficient of saturated liquid	1/K	[1]	3/7
$\beta_l = f(p, t, \xi)$	betan_ptXi_SeaWa	= BETAL_PTXI_SEAWA(P,T,XI)	Haline contraction coefficient of subcooled liquid	kg/kg	[1]	3/8
$\beta_{sl} = f(p, t, \xi_{sl})$	betasl_pstsXisl_SeaWa	= BETASL_PSTSXISL_SEAWA(PS,TS,XISL)	Haline contraction coefficient of saturated liquid	kg/kg	[1]	3/9
$\beta_{sl} = f(p, t, \xi)$	betasl_ptXi_SeaWa	= BETAISL_PTXI_SEAWA(P,T,XI)	Isentropic temperature-pressure coefficient of subcooled liquid	K/kPa	[1]	3/10
$\beta_{ssl} = f(p, t, \xi_{sl})$	betassl_pstsXisl_SeaWa	= BETAISL_PSTSXISL_SEAWA(PS,TS,XISL)	Isentropic temperature-pressure coefficient of saturated liquid	K/kPa	[1]	3/11
$c_p = f(p, t, \xi)$	cp_ptXI_SeaWa	= CP_PTXI_SEAWA(P,T,XI)	Specific isobaric heat capacity	kJ/(kg·K)	[1], [2]	3/12
$c_{p,l} = f(p, t, \xi)$	cpl_ptXI_SeaWa	= CPL_PTXI_SEAWA(P,T,XI)	Specific isobaric heat capacity of subcooled liquid	kJ/(kg·K)	[1], [2]	3/13
$c_{p,sl} = f(p_s, t_s, \xi_{sl})$	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
$c_{p_{sv}} = f(p_s, t_s, \xi_{sl})$	cpsv_pstsXisl_SeaWa	= CPSV_PSTSXISL_SEAWA(P,S,XISL)	Specific isobaric heat capacity of saturated vapor	kJ/(kg·K)	[1], [2]	3/15
$\eta = f(p, t, \xi)$	eta_ptXI_SeaWa	= ETA_PTXI_SEAWA(P,T,XI)	Dynamic viscosity	Pa·s	[1], [2]	3/16
$\eta_l = f(t, \xi)$	etal_tXI_SeaWa	= ETAL_TXI_SEAWA(T,XI)	Dynamic viscosity of subcooled liquid	Pa·s	[1], [2]	3/17
$\eta_{sl} = f(p_s, t_s, \xi_{sl})$	etasl_pstsXisl_SeaWa	= ETASL_PSTSXISL_SEAWA(P,S,XISL)	Dynamic viscosity of saturated liquid	Pa·s	[1], [2]	3/18
$\eta_{sv} = f(p_s, t_s, \xi_{sl})$	etasv_pstsXisl_SeaWa	= ETASV_PSTSXISL_SEAWA(P,S,XISL)	Dynamic viscosity of saturated vapor	Pa·s	[1], [2]	3/19
$f_l = f(p, t, \xi)$	fl_ptXI_SeaWa	= FL_PTXI_SEAWA(P,T,XI)	Specific Helmholtz energy of subcooled liquid	kJ/kg	[1]	3/20
$f_{sl} = f(p_s, t_s, \xi_{sl})$	fsl_pstsXisl_SeaWa	= FSL_PSTSXISL_SEAWA(P,S,XISL)	Specific Helmholtz energy of saturated liquid	kJ/kg	[1]	3/21
$\phi = f(p, t, \xi)$	phil_ptXI_SeaWa	= PHIL_PTXI_SEAWA(P,T,XI)	Osmotic coefficient of subcooled liquid	[-]	[1]	3/22
$\phi_{sl} = f(p_s, t_s, \xi_{sl})$	phisl_pstsXisl_SeaWa	= PHISL_PSTSXISL_SEAWA(P,S,XISL)	Osmotic coefficient of saturated liquid	[-]	[1]	3/23
$h = f(p, t, \xi)$	h_ptXI_SeaWa	= H_PTXI_SEAWA(P,T,XI)	Specific enthalpy	kJ/kg	[1], [2]	3/24
$h_l = f(p, t, \xi)$	hl_ptXI_SeaWa	= HL_PTXI_SEAWA(P,T,XI)	Specific enthalpy of subcooled liquid	kJ/kg	[1], [2]	3/25
$h_{sl} = f(p_s, t_s, \xi_{sl})$	hsl_pstsXisl_SeaWa	= HSL_PSTSXISL_SEAWA(P,S,XISL)	Specific enthalpy of saturated liquid	kJ/kg	[1], [2]	3/26
$h_{sv} = f(p_s, t_s, \xi_{sl})$	hsv_pstsXisl_SeaWa	= HSV_PSTSXISL_SEAWA(P,S,XISL)	Specific enthalpy of saturated steam	kJ/kg	[1], [2]	3/27
$\kappa = f(p, t, \xi)$	kappa_ptXI_SeaWa	= KAPPA_PTXI_SEAWA(P,T,XI)	Isentropic exponent	[-]	[1]	3/28
$\kappa_l = f(p, t, \xi)$	kappal_ptXI_SeaWa	= KAPPAL_PTXI_SEAWA(P,T,XI)	Isentropic exponent of subcooled liquid	[-]	[1]	3/29
$\kappa_{sl} = f(p_s, t_s, \xi_{sl})$	kappasl_pstsXisl_SeaWa	= KAPPASL_PSTSXISL_SEAWA(P,S,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(P,TS,XISL)	Isentropic exponent of saturated vapor	[-]	[1]	3/31
$\kappa_{T_l} = f(p, t, \xi)$	kappaTI_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(P,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(P,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	= LAMBDA_L_PTXI_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	= LAMBDA_SL_PSTSXISL_SEAWA(P,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	= LAMBDA_SV_PSTSXISL_SEAWA(P,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(P,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 ₂ O of subcooled liquid	kJ/kg	[1]	3/42
$\mu_{w_sl} = f(p_s, t_s, \xi_{sl})$	mywsl_pstsXisl_SeaWa	= MYWSL_PSTSXISL_SEAWA(P,TS,XISL)	Relative chem. potential of H ₂ O of saturated liquid	kJ/kg	[1]	3/43
$\mu_{salt_l} = f(p, t, \xi)$	mySaltl_ptXI_SeaWa	= MYSALT_L_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	= MYSALT_SL_PSTSXISL_SEAWA(P,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
$\nu = f(p, t, \xi)$	ny_ptXI_SeaWa	= NY_PT XI_SEAWA(P,T,XI)	Kinematic viscosity	m ² /s	[1], [2]	3/46
$\nu_l = f(t, \xi)$	nyl_tXI_SeaWa	= NYL_TXI_SEAWA(T,XI)	Kinematic viscosity of subcooled liquid	m ² /s	[1], [2]	3/47
$\nu_{sl} = f(p_s, t_s, \xi_{sl})$	nysl_pstsXisl_SeaWa	= NYSL_PST SXISL_SEAWA(PS,TS,XISL)	Kinematic viscosity of saturated liquid	m ² /s	[1], [2]	3/48
$\nu_{sv} = f(p_s, t_s, \xi_{sl})$	nysv_pstsXisl_SeaWa	= NYSV_PST SXISL_SEAWA(PS,TS,XISL)	Kinematic viscosity of saturated vapor	m ² /s	[1], [2]	3/49
$p_s = f(t_s, \xi_{sl})$	ps_tsXisl_SeaWa	= PS_TSXISL_SEAWA(TS,XISL)	Boiling pressure	bar	[1] ,[2] ,[4]	3/50
$p_{mel} = f(t, \xi)$	pmel_tXi_SeaWa	= PMEL_TXI_SEAWA(T,XI)	Freezing pressure	bar	[1] ,[4], [5]	3/51
$p_{tr} = f(\xi)$	ptr_Xi_SeaWa	= PTR_XI_SEAWA(T,XI)	Triple point pressure	bar	[1] ,[4], [5]	3/52
$Pr = f(p, t, \xi)$	Pr_ptXI_SeaWa	= PR_PT XI_SEAWA(P,T,XI)	Prandtl Number	[-]	[1], [2], [3]	3/53
$Pr_l = f(t, \xi)$	Prl_tXI_SeaWa	= PRL_TXI_SEAWA(T,XI)	Prandtl Number of subcooled liquid	[-]	[1], [2], [3]	3/54
$Pr_{sl} = f(p_s, t_s, \xi_{sl})$	Prsl_pstsXisl_SeaWa	= PRSL_PST SXISL_SEAWA(PS,TS,XISL)	Prandtl Number of saturated liquid	[-]	[1], [2], [3]	3/55
$Pr_{sv} = f(p_s, t_s, \xi_{sl})$	Prsv_pstsXisl_SeaWa	= PRSV_PST SXISL_SEAWA(PS,TS,XISL)	Prandtl Number of saturated vapor	[-]	[1], [2], [3]	3/56
$\rho = f(p, t, \xi)$	rho_ptXI_SeaWa	= RHO_PT XI_SEAWA(P,T,XI)	Density	kg/m ³	[1], [2]	3/57
$\rho_l = f(p, t, \xi)$	rho_l_ptXI_SeaWa	= RHOL_PT XI_SEAWA(P,T,XI)	Density of subcooled liquid	kg/m ³	[1], [2]	3/58
$\rho_{sl} = f(p_s, t_s, \xi_{sl})$	rhosl_pstsXisl_SeaWa	= RHOSL_PST SXISL_SEAWA(PS,TS,XISL)	Density of saturated liquid	kg/m ³	[1], [2]	3/59
$\rho_{sv} = f(p_s, t_s, \xi_{sl})$	rhosv_pstsXisl_SeaWa	= RHOSV_PST SXISL_SEAWA(PS,TS,XISL)	Density of saturated vapor	kg/m ³	[1], [2]	3/60
$s = f(p, t, \xi)$	s_ptXI_SeaWa	= S_PT XI_SEAWA(P,T,XI)	Specific entropy	kJ/(kg*K)	[1], [2]	3/61
$s_l = f(p, t, \xi)$	sl_ptXI_SeaWa	= SL_PT XI_SEAWA(P,T,XI)	Specific entropy of subcooled liquid	kJ/(kg*K)	[1], [2]	3/62
$s_{sl} = f(p_s, t_s, \xi_{sl})$	ssl_pstsXisl_SeaWa	= SSL_PST SXISL_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
Region = $f(p, t, \xi)$	Region_ptXi_SeaWa	= REGION_PTXI_SEAWA(P,T,XI)	Region	[-]	[1], [2], [4]	3/68
Region = $f(p, h, \xi)$	Region_phXi_SeaWa	= REGION_PHXI_SEAWA(P,H,XI)	Region	[-]	[1], [2], [4]	3/69
Region = $f(p, s, \xi)$	Region_psXi_SeaWa	= REGION_P SXI_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_P SXI_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
$v = f(p, t, \xi)$	v_ptXi_SeaWa	= V_PTXI_SEAWA(P,T,XI)	Specific volume	m³/kg	[1], [2]	3/77
$v_l = f(p, t, \xi)$	vl_ptXi_SeaWa	= VL_PTXI_SEAWA(P,T,XI)	Specific internal energy of subcooled liquid	m³/kg	[1], [2]	3/78
$v_{sl} = f(p_s, t_s, \xi_{sl})$	vsl_pstsXisl_SeaWa	= VSL_PSTSXISL_SEAWA(PS,TS,XISL)	Specific volume of saturated liquid	m³/kg	[1], [2]	3/79
$v_{sv} = f(p_s, t_s, \xi_{sl})$	vsv_pstsXisl_SeaWa	= VSV_PSTSXISL_SEAWA(PS,TS,XISL)	Specific volume of saturated vapor	m³/kg	[1], [2]	3/80

Functional Dependence	Function Name in Excel®	Call as Fortran Program	Property or Function	Unit of the Result	Reference	Page
$w = f(p, t, \xi)$	w_ptXI_SeaWa	= W_PTXI_SEAWA(P,T,XI)	Speed of sound	m/s	[1]	3/81
$w_l = f(p, t, \xi)$	wl_ptXI_SeaWa	= WL_PTXI_SEAWA(P,T,XI)	Speed of sound of liquid	m/s	[1]	3/82
$w_{sl} = f(p_s, t_s, \xi_{sl})$	wsl_pstsXisl_SeaWa	= WSL_PSTSXISL_SEAWA(PS,TS,XISL)	Speed of sound of saturated liquid	m/s	[1]	3/83
$w_{sv} = f(p_s, t_s, \xi_{sv})$	wsv_pstsXisl_SeaWa	= WSV_PSTSXISL_SEAWA(PS,TS,XISL)	Speed of sound of saturated vapor	m/s	[1]	3/84
$x = f(p, t, \xi)$	x_ptXI_SeaWa	= X_PTXI_SEAWA(P,T,XI)	Vapor fraction	kg/kg	[1]	3/85
$\xi_{sl} = f(p_s, t_s)$	Xisl_psts_SeaWa	= XISL_PSTS_SEAWA(PS,TS)	Mass fraction of sea salt in saturated liquid	kg/kg	[1]	3/86
$\xi_{sv} = f(p_s, t_s)$	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	$\leq$	p	$\leq$	1000	bar
Temperature:	0	$\leq$	t	$\leq$	220	°C
Salinity:	0	$\leq$	ξ	$\leq$	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
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Property functions with deviation to the range of validity (cp. Chapter. 3)

2. Application of FluidEXL^{Graphics} in Excel[®]

The FluidEXL^{Graphics} Add-In has been developed to calculate thermodynamic properties in Excel more conveniently. Within Excel[®], it enables the direct call of functions relating to seawater from the LibSeaWa property library.

2.1 Installing FluidEXL^{Graphics}

If FluidEXL^{Graphics} has not yet been installed or if there is a version installed which has been delivered before June 2010, please complete the initial installation procedure described below.

If FluidEXL^{Graphics} has already been installed in a version which has been delivered after June 2010, you simply need to copy the files which belong to the LibSeaWa library. In this case, follow the subsection "Adding the LibSeaWa Library" on page 2/11.

Installing FluidEXL^{Graphics} for 32-bit Excel[®]

Complete the following steps for initial installation of FluidEXL^{Graphics}.

Before you begin, it is best to uninstall any trial version or full version of FluidEXL^{Graphics} delivered before June 2010.

After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibSeaWa_Eng.zip" (for English version of Windows)

"CD_FluidEXL_Graphics_LibSeaWa.zip" (for German version of Windows)
you will see the folder

CD_FluidEXL_Graphics_LibSeaWa_Eng (for English version of Windows)

CD_FluidEXL_Graphics_LibSeaWa (for German version of Windows)

in your Windows Explorer, Norton Commander etc.

Now, open this folder by double-clicking on it.

Within this folder you will see the following files:

FluidEXL_Graphics_Eng_Setup.exe (for English version of Windows)

FluidEXL_Graphics_Setup.exe (for German version of Windows)

FluidEXL_Graphics_Eng.xla (for English version of Windows)

FluidEXL_Graphics.xla (for German version of Windows)

FluidEXL_Graphics_LibSeaWa_Docu_Eng.pdf

LibSeaWa.dll

LibSeaWa.hlp.

In order to run the installation of FluidEXL^{Graphics} double-click the file

FluidEXL_Graphics_Eng_Setup.exe (for English version of Windows)

FluidEXL_Graphics_Setup.exe (for German version of Windows).

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 "Continue" button.

In the following dialog box, "Choose Destination Location", the default path offered automatically for the installation of FluidEXL^{Graphics} is

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
 C:\Programme\FluidEXL_Graphics (for German version of Windows).

By clicking the "Browse..." button, you can change the installation directory before installation (see figure below).

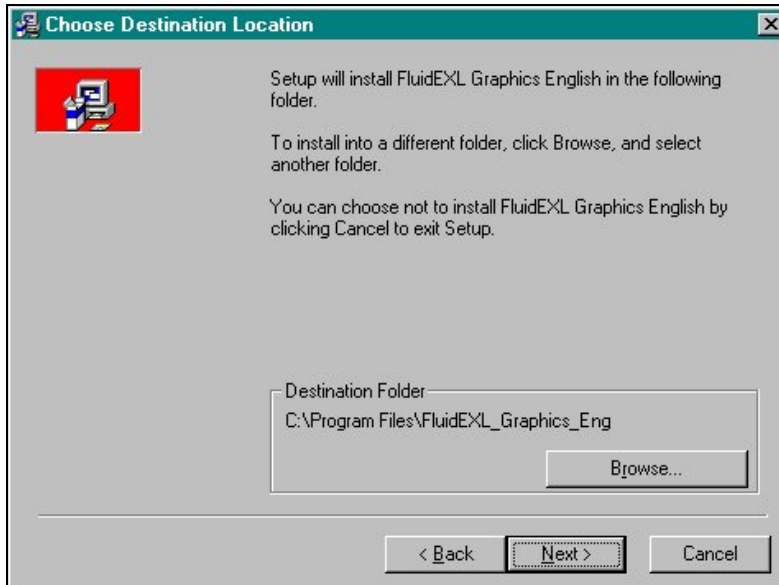


Figure 2.1: Choose Destination Location

Finally, click on "Next" to continue installation; click "Next" again in the "Start Installation" window which follows in order to start the installation of FluidEXL *Graphics*.

After FluidEXL *Graphics* has been installed, the sentence

"FluidEXL Graphics English has been successfully installed."

will be shown. Confirm this by clicking the "Finish" button.

During the installation process the following files

Advapi32.dll	LC.dll
DFORMD.dll	Msvcp60.dll
Dforrt.dll	Msvcrt.dll
UNWISE.EXE	UNWISE.INI
INSTALL_EXL.LOG	

have been copied into the chosen destination folder, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
 C:\Programme\FluidEXL_Graphics (for German version of Windows).

In addition, the two subdirectories \FORMULATION97 and \FLuft have been compiled in the destination folder.

In the next step, the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibSeaWa.dll	
LibSeaWa.hlp	

from the extracted folder

CD_FluidEXL_Graphics_LibSeaWa_Eng (for English version of Windows)

CD_FluidEXL_Graphics_LibSeaWa (for German version of Windows)

must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)

C:\Programme\FluidEXL_Graphics (for German version of Windows),

using an appropriate program such as Explorer or Norton Commander.

Installing FluidEXL *Graphics* for 64-bit Excel®

Complete the following steps for initial installation of FluidEXL *Graphics* for a 64-bit version of Excel.

Before you begin, it is best to uninstall any trial version or full version of FluidEXL *Graphics* delivered before June 2010.

After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibSeaWa_x64_Eng.zip" (for English version of Windows)

"CD_FluidEXL_Graphics_LibSeaWa_x64.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibSeaWa_Eng (for English version of Windows)

CD_FluidEXL_Graphics_LibSeaWa (for German version of Windows)

in your Windows Explorer, Norton Commander etc.

Now, open this folder by double-clicking on it.

Within this folder you will see the following files

FluidEXL_Graphics_LibSeaWa_Docu_Eng

FluidEXL_Graphics_Eng.xla (for English version of Windows)

FluidEXL_Graphics.xla (for German version of Windows)

FluidEXL_Graphics_Eng_Setup_64.msi (for English version of Windows)

FluidEXL_Graphics_Setup_64.msi (for German version of Windows)

LibSeaWa.dll

LibSeaWa.hlp

Setup.exe

and the folders

vcredist_x64

WindowsInstaller3_1.

In order to run the installation of FluidEXL *Graphics* double-click the file

Setup.exe.

If the "Microsoft Visual C++ 2010 x64 Redistributable Pack" is not running on your computer yet, installation will start with a window noting that the "Visual C++ 2010 runtime library (x64)" will be installed on your machine (see figure below).

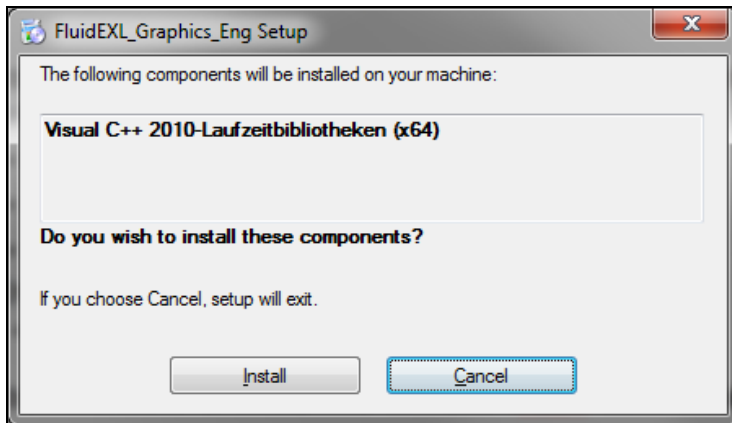


Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

Click on "Install" to continue.

In the following window you are required to accept the Microsoft® license terms to install the "Microsoft Visual C++ 2010 x64 Redistributable Pack" by ticking the box next to "I have read and accept the license terms" (see figure below).

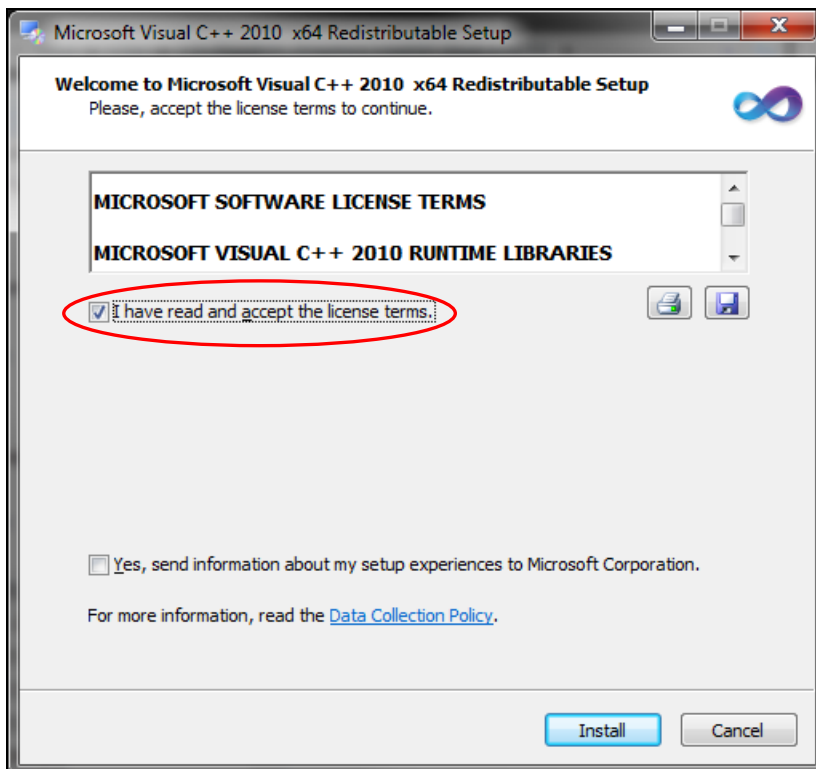


Figure 2.3: Accepting the license terms

Now click on "Install" to continue installation.

After the "Microsoft Visual C++ 2010 x64 Redistributable Pack" has been installed, you will see the sentence "Microsoft Visual C++ 2010 x64 Redistributable has been installed." Confirm this by clicking "Finish."

Now the installation of FluidEXL_Graphics_Eng_64 starts with a window noting that the installer will guide you through the installation. Click the "Next >" button to continue.

In the following dialog box, "Select Installation Folder," the default path offered automatically for the installation of FluidEXL *Graphics* is

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows).

C:\Programme\FluidEXL_Graphics (for German version of Windows).

By clicking the "Browse..." button, you can change the installation directory before installation (see Figure 2.4).

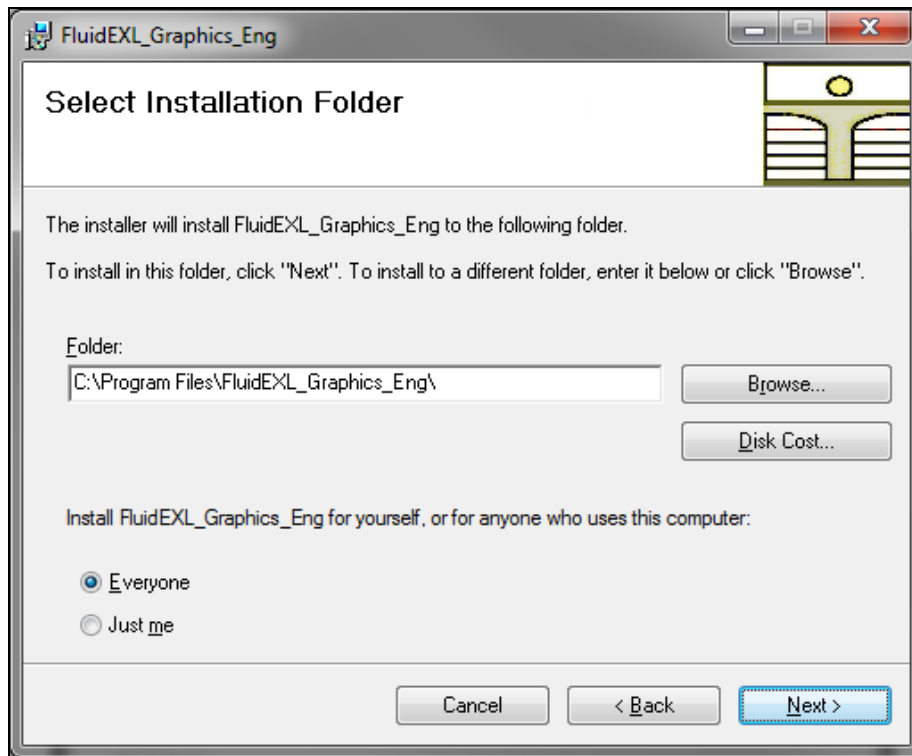


Figure 2.4: Choosing the Installation Folder of FluidEXL *Graphics*

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

After FluidEXL *Graphics* has been installed, you will see the sentence "FluidEXL_Graphics_Eng has been successfully installed." Confirm this by clicking the "Close" button.

During the installation process the following files will have been copied into the destination folder chosen, the standard being C:\Program Files\FluidEXL_Graphics_Eng:

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

In addition, the two subdirectories \FORMULATION97 and \FLuft were created in the destination folder.

In the next step, the files below,

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibSeaWa.dll	
LibSeaWa.hlp	

found in your CD folder, must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)

C:\Programme\FluidEXL_Graphics (for German version of Windows))

using an appropriate program such as Explorer or Norton Commander.

2.2 Registering FluidEXL^{Graphics} as Add-In in Excel[®]

Registering FluidEXL^{Graphics} as Add-In in Excel[®], versions 2003 or earlier

After the installation of FluidEXL^{Graphics}, the program must be registered as an Add-In in Excel[®]. In order to do so, start Excel[®] and carry out the following steps:

- Click "Tools" in the upper menu bar of Excel[®].
- Here, click the "Add-Ins..." menu item.
After a short delay the "Add-Ins" dialog box will appear.
- Click "Browse...."
- In the following dialog box, choose your chosen destination folder (the standard being
 - C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
 - C:\Programme\FluidEXL_Graphics (for German version of Windows))
 here select
 - "FluidEXL_Graphics_Eng.xla" (for English version of Windows)
 - "FluidEXL_Graphics.xla" (for German version of Windows)
 and afterwards click "OK".
- Now, the entry
 - "FluidEXL Graphics Eng" (for English version of Windows)
 - "FluidEXL Graphics" (for German version of Windows)
 will appear in the Add-Ins list.

Note:

As long as the check box next to the file name "FluidEXL Graphics Eng" is checked, this Add-In will be loaded automatically every time you start Excel[®] until you unmark the box by clicking on it again.

In order to register FluidEXL^{Graphics} as an Add-In, click "OK" in the "Add-Ins" dialog box. Now, the new FluidEXL^{Graphics} menu bar will appear in the upper menu area of your Excel[®] screen, marked with a red circle in Figure 2.5.

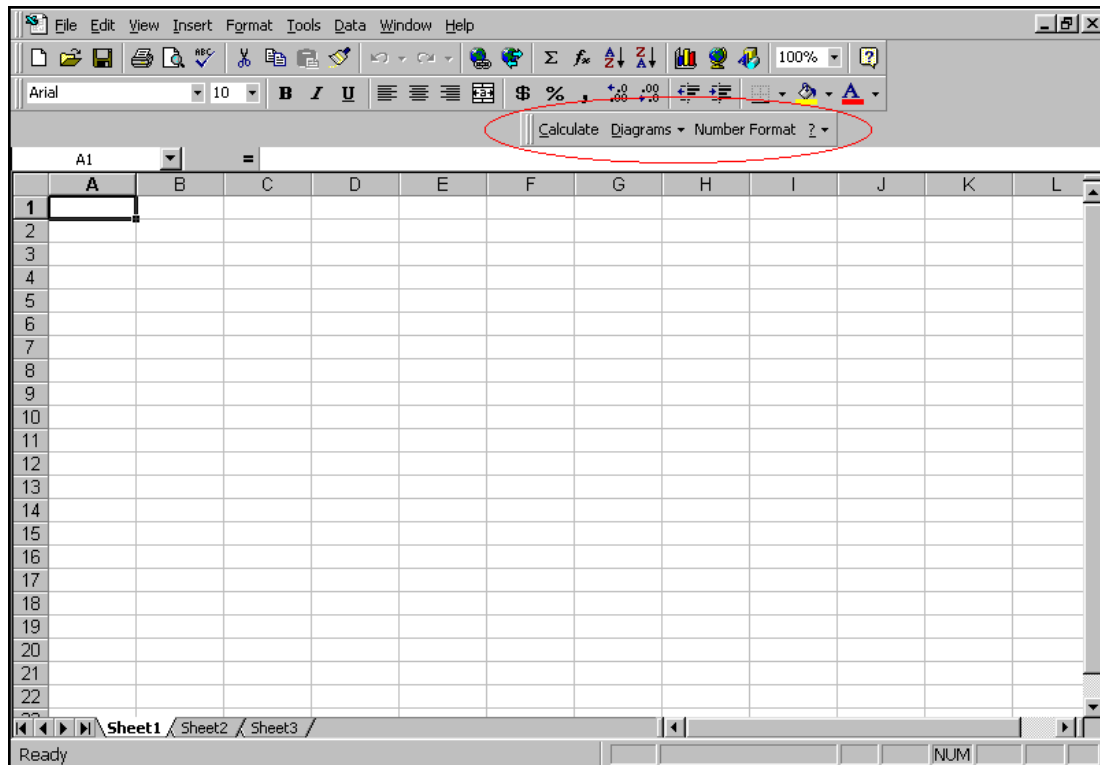


Figure 2.5: Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "Seawater LibSeaWa" DLL library property functions via this menu bar (see part 2.5 on page 2/19).

Registering FluidEXL *Graphics* as Add-In in Excel® 2007 (or later versions)

After installation in Windows®, FluidEXL *Graphics* must be registered in Excel® versions 2007 and later as an Add-In. To do this, start Excel® and carry out the following steps:

- Click the Windows Office® button in the upper left hand corner of Excel®
- Click on the "Excel Options" button in the menu which appears (see Figure 2.6)

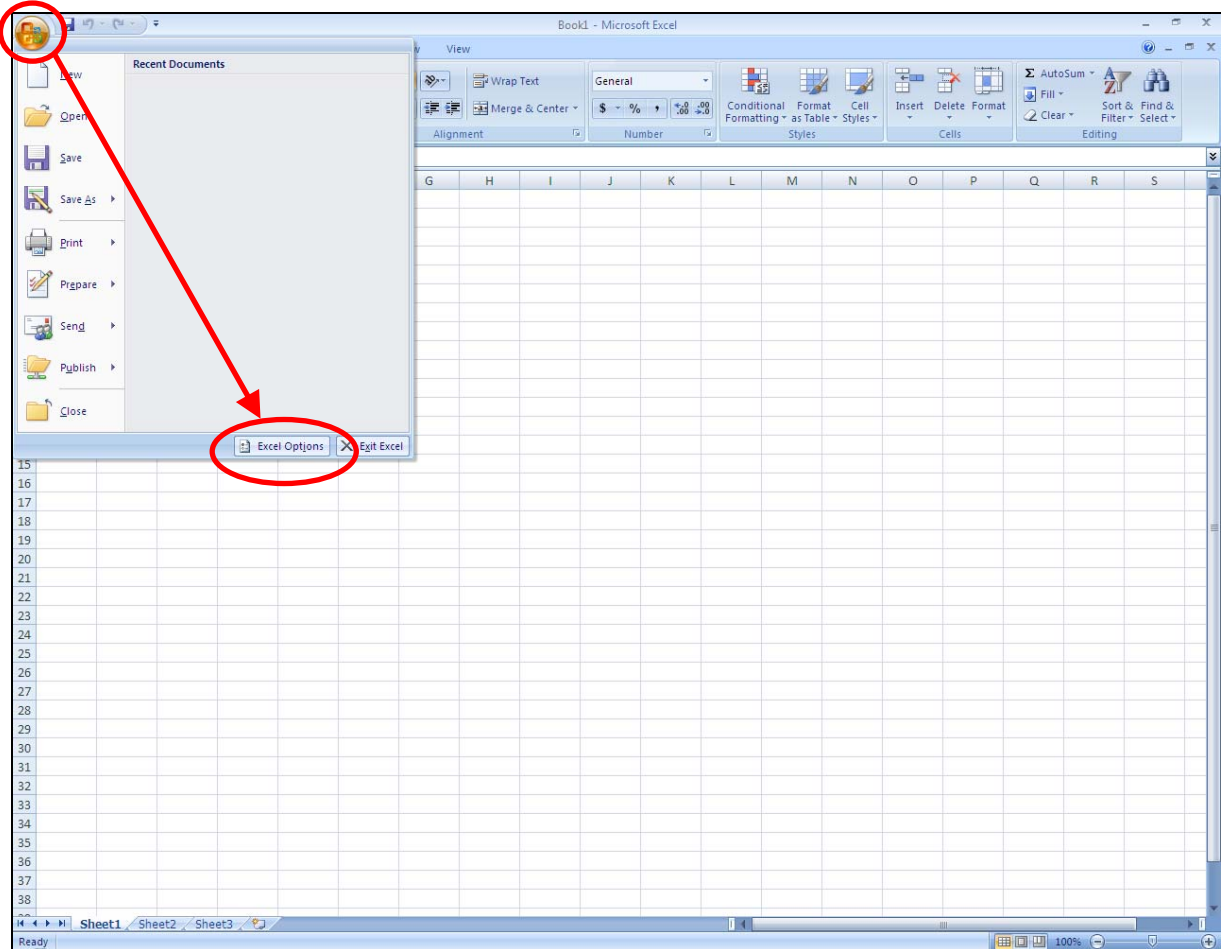


Figure 2.6: Registering FluidEXL *Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

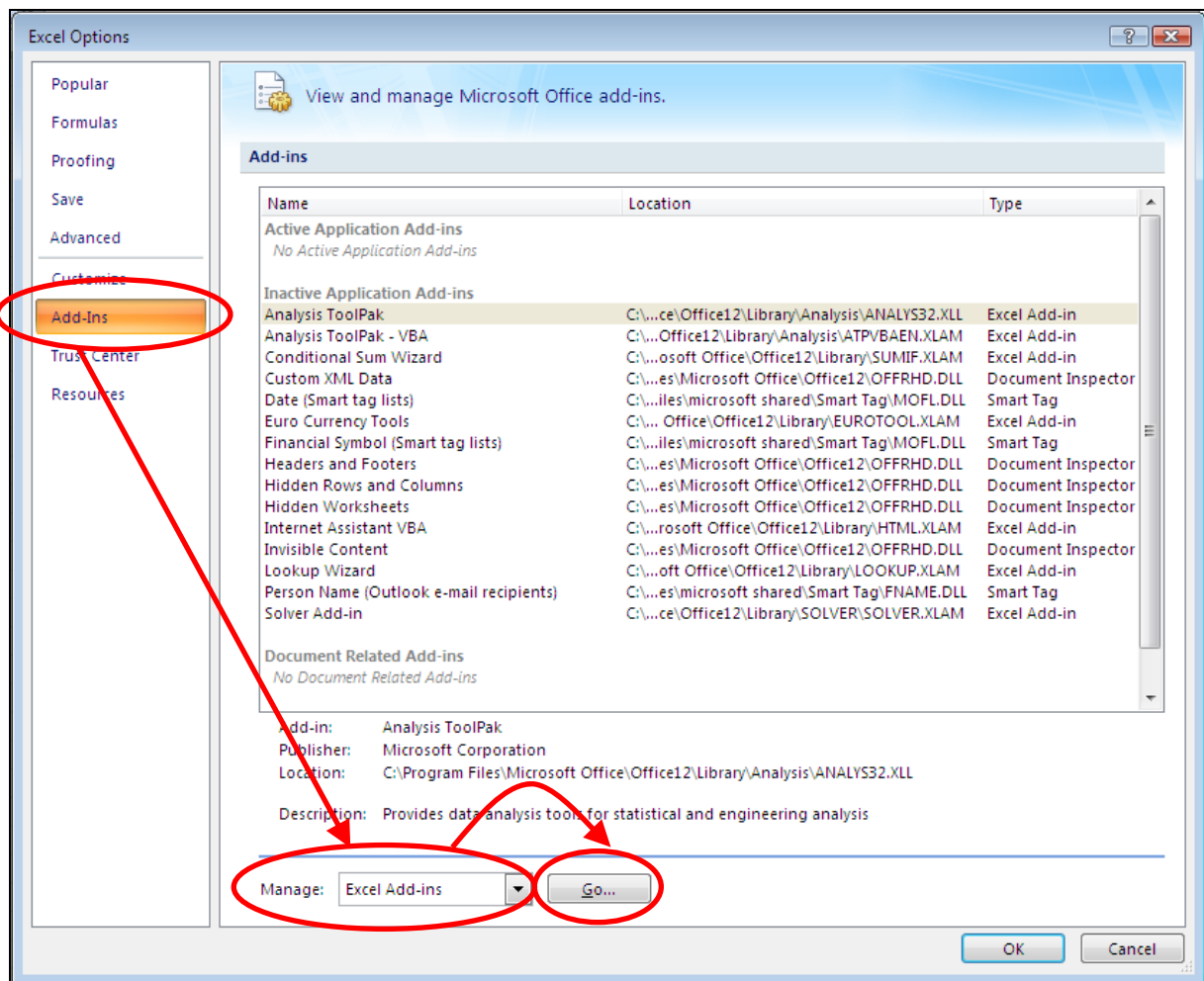


Figure 2.7: Dialog window "Excel Options"

- Should it not be shown in the list automatically, select "Excel Add-ins" (found next to "Manage:" in the lower area of the menu)
- Then click the "Go..." button
- Click "Browse" in the following window and locate the destination folder, generally
 C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
 C:\Programme\FluidEXL_Graphics (for German version of Windows);
 within that folder click on the file named
 "FluidEXL_Graphics_Eng.xla" (for English version of Windows)
 "FluidEXL_Graphics.xla" (for German version of Windows)
 and then hit "OK."

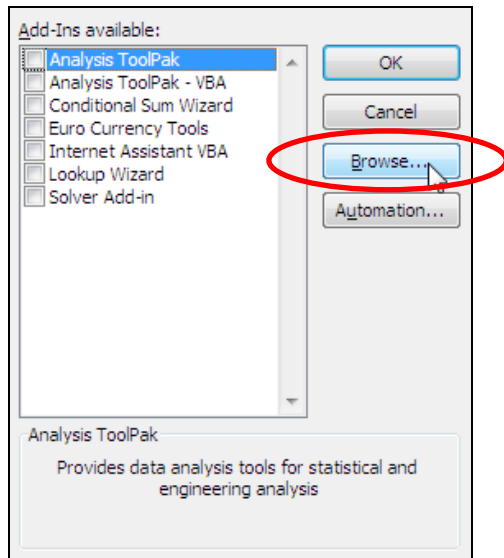


Figure 2.8: Dialog window "Add-Ins available"

- Now, "FluidEXL Graphics Eng" will be shown in your list of Add-Ins.
(If a check-mark is situated in the box next to the name "FluidEXL Graphics Eng," this Add-In will automatically be loaded whenever Excel® starts. This will continue to occur unless the check-mark is removed from the box by clicking on it.)

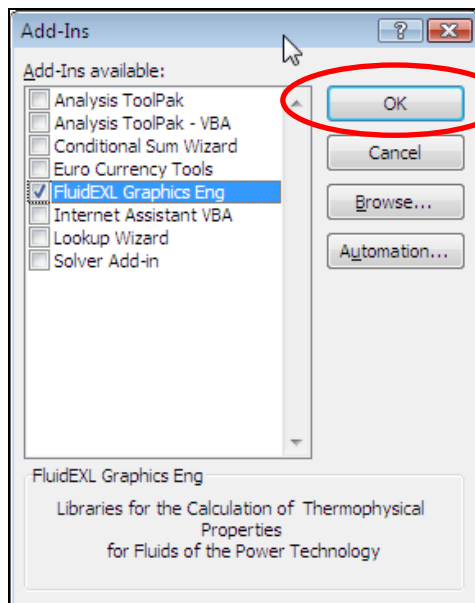


Figure 2.9: Dialog window "Add-Ins"

- In order to register the Add-In click the "OK" button in the "Add-Ins" window.

In order to use FluidEXL *Graphics* in the following example, click on the menu item "Add-Ins" shown in Figure 2.10.

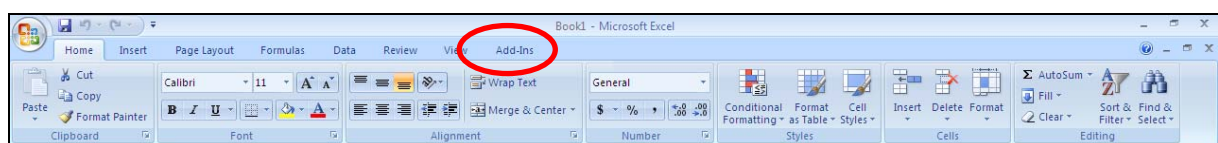


Figure 2.10: Menu item "Add-Ins"

In the upper menu region of Excel, the FluidEXL^{Graphics} menu bar will appear as marked with the red circle in the next figure.

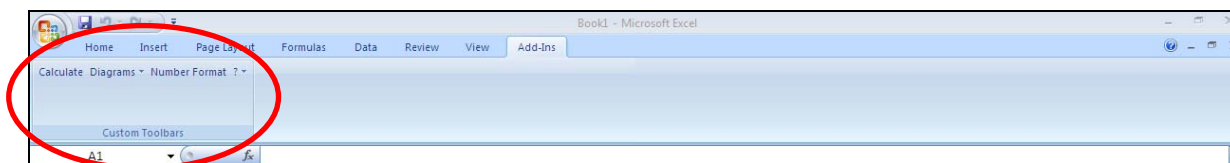


Figure 2.11: FluidEXL^{Graphics} menu bar

Installation of FluidEXL^{Graphics} in Excel® (versions 2007 and later) is now finished. FluidEXL^{Graphics} can be used analogous to the description for using with earlier Excel® versions.

Adding the LibSeaWa Library (FluidEXL^{Graphics} is already installed)

If FluidEXL^{Graphics} has already been installed in the June 2010 version, you only have to copy the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibSeaWa.dll	
LibSeaWa.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibSeaWa_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibSeaWa	(for German version of Windows)

into the folder you have chosen for the installation of FluidEXL^{Graphics} (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)

using an appropriate program such as Explorer® or Norton Commander.

From within Excel you can now select the "SeaWater LibSeaWa" DLL library property functions for seawater via this menu bar (the example calculation can be found in chapter 2.5 on page 2/19).

2.3 The FluidEXL^{Graphics} Help System

As mentioned earlier, FluidEXL^{Graphics} also provides detailed online help functions.

If you are running Windows Vista or Windows 7, please note the paragraph

"Using the FluidEXL^{Graphics} Online-Help in Windows Vista or Windows 7."

For general information in Excel®

- Click on "?" and then "Help" in the FluidEXL^{Graphics} menu bar.

Information on individual property functions may be accessed via the following steps:

- Click "Calculate" in the FluidEXL^{Graphics} menu bar.
- Click on the "Seawater LibSeaWa" library under "Or select a category:" in the "Insert Function" window which will appear.
- Click the "Help on this function" button in the lower left-hand edge of the "Insert Function" window.
- If the "Office Assistant" is active, first double-click "Help on this feature" and in the next menu click "Help on selected function".

If the LibSeaWa.hlp function help cannot be found, confirm the question whether you want to

look for it yourself with "Yes". Select the LibSeaWa.hlp file in the installation folder of FluidEXL^{Graphics} in the window which is opened, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)

C:\Programme\FluidEXL_Graphics (for German version of Windows)

and click "Yes" in order to complete the search.

Using the FluidEXL^{Graphics} Online Help in Windows Vista or Windows 7

If you are running Windows Vista or Windows 7 on your computer, you might not be able to open Help files. To view these files you have to install the Microsoft® Windows Help program which is provided by Microsoft®. Please carry out the following steps in order to download and install the Windows Help program.

Open Microsoft Internet Explorer® and go to the following address:

<http://support.microsoft.com/kb/917607/>

You will see the following web page:



Figure 2.12: Microsoft® Support web page

Scroll down until you see the headline "Resolution." Here you can see the bold hint:

"Download the appropriate version of Windows Help program (WinHlp32.exe), depending on the operating system that you are using:"

The following description relates to Windows® 7. The procedure is analogous for Windows® Vista.

Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.13).

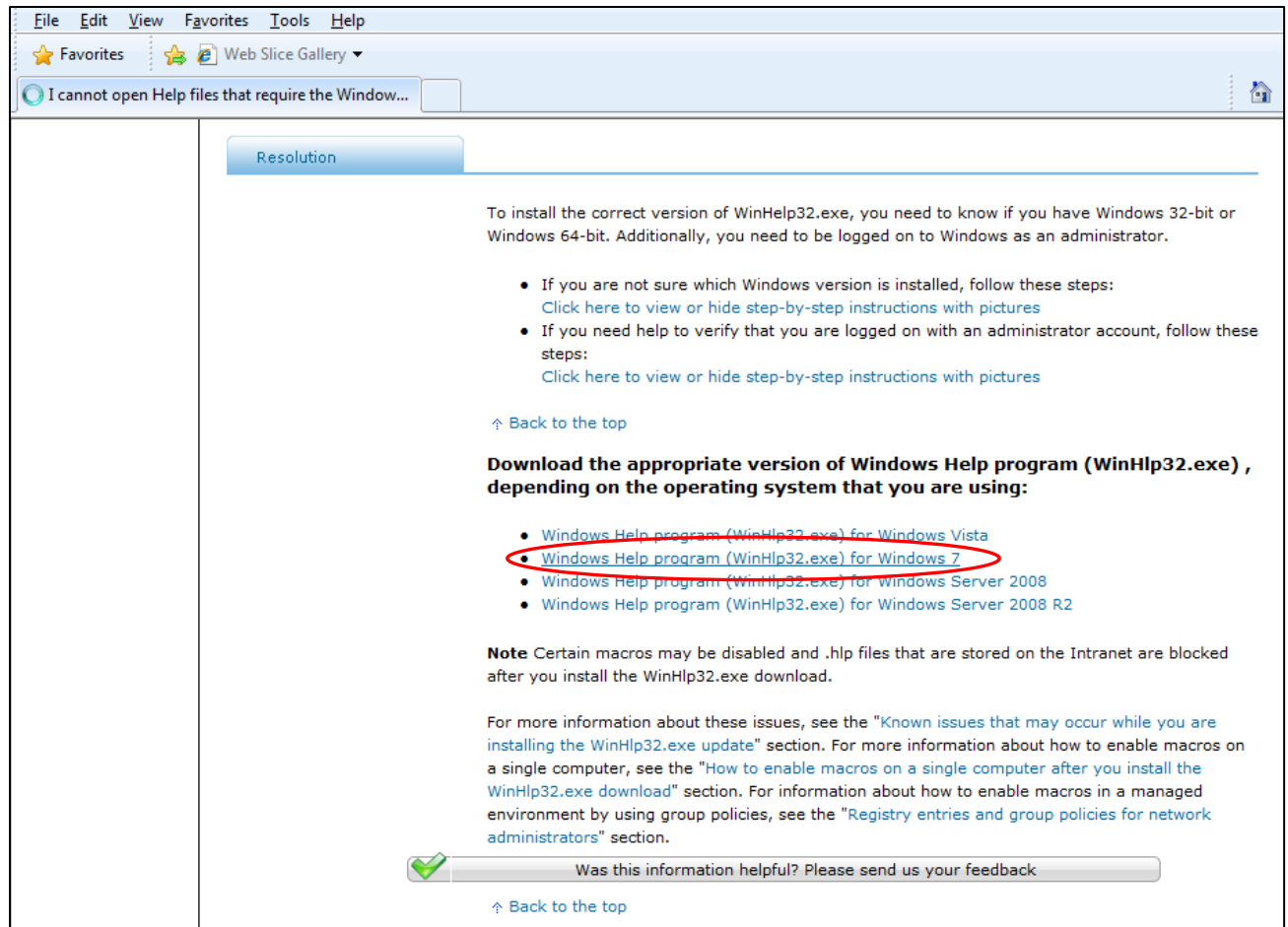


Figure 2.13: Selecting your Windows version

You will be forwarded to the Microsoft Download Center where you can download the Microsoft Windows Help program.

First, a validation of your Windows License is required.

To do this click on the "Continue" button (see Figure 2.14).

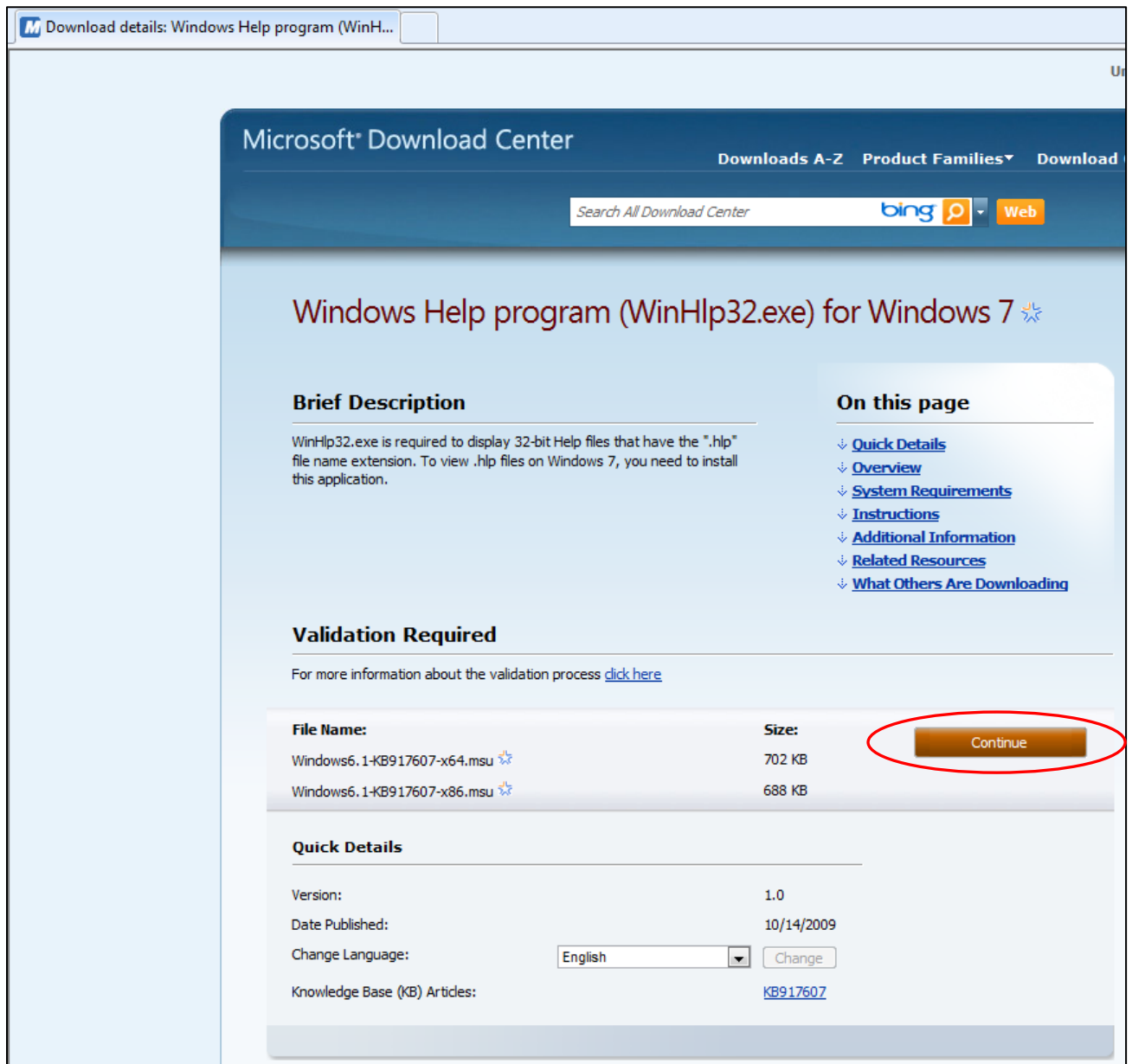


Figure 2.14: Microsoft® Download Center

You will be forwarded to a web page with instructions on how to install the Genuine Windows Validation Component.

At the top of your Windows Internet Explorer you will see a yellow information bar. Right-click this bar and select "Install ActiveX Control" in the context menu (see Figure 2.15).

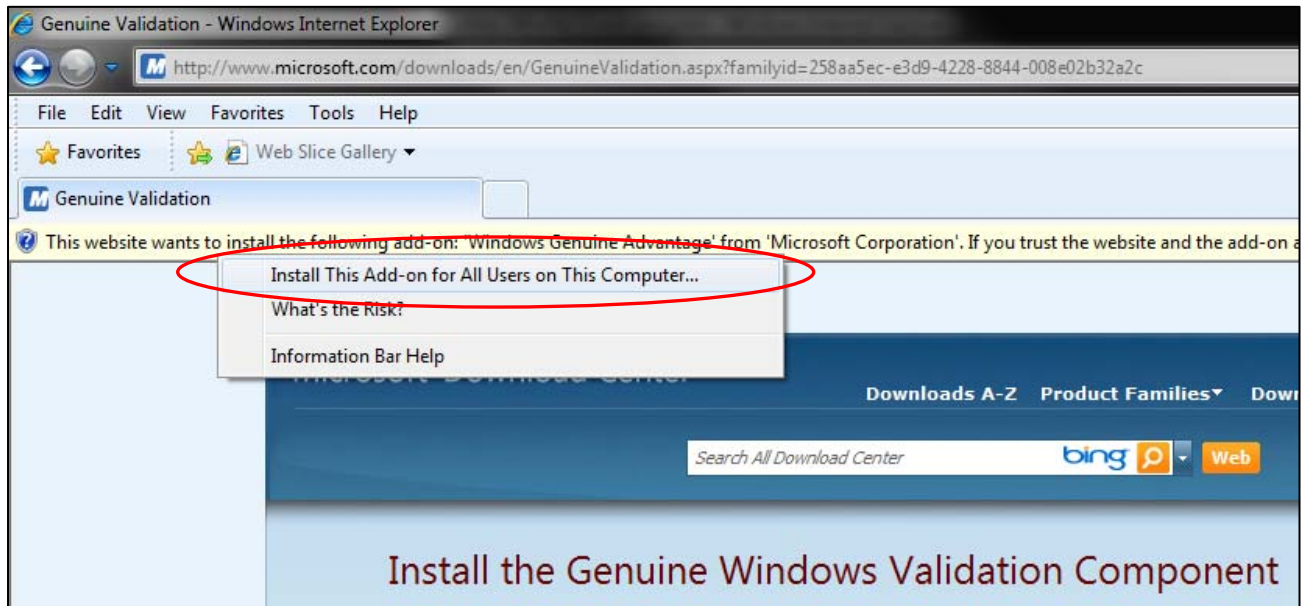


Figure 2.15: Installing the Genuine Windows Validation Component

A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue (see Figure 2.16).



Figure 2.16: Internet Explorer – Security Warning

After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.17).

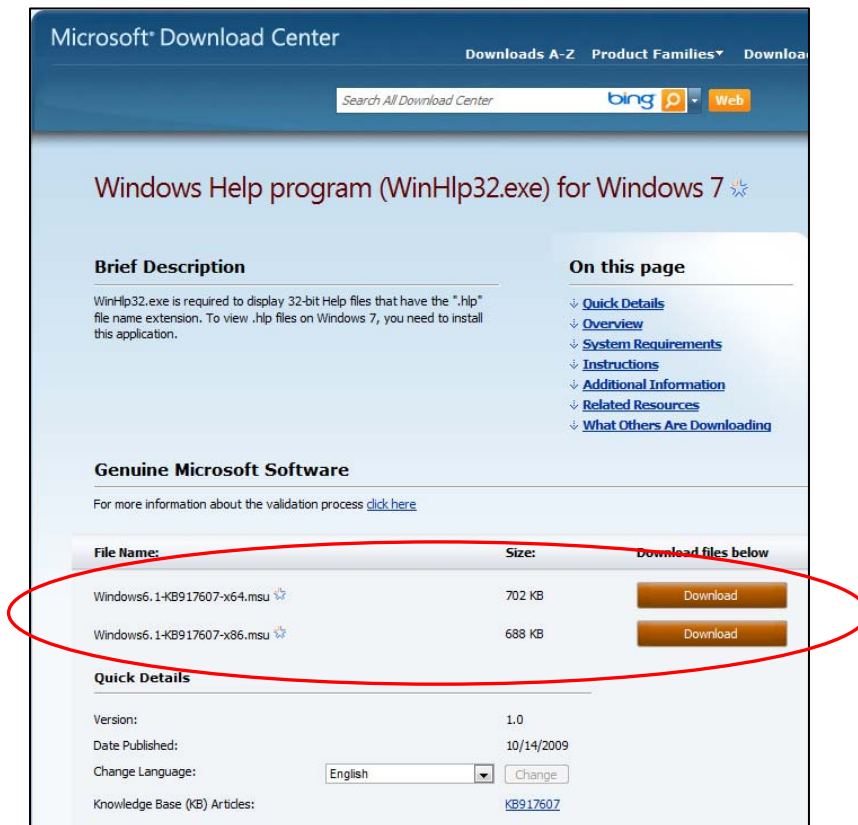


Figure 2.17: Downloading the Windows Help program

To download and install the correct file you need to know which Windows version (32-bit or 64-bit) you are running on your computer.

If you are running a 64-bit operating system, please download the file
 Windows6.1-KB917607-x64.msu.

If you are running a 32-bit operating system, please download the file
 Windows6.1-KB917607-x86.msu.

In order to run the installation of the Windows Help program double-click the file you have just downloaded on your computer:

Windows6.1-KB917607-x64.msu (for 64-bit operating system)

Windows6.1-KB917607-x86.msu. (for 32-bit operating system).

Installation starts with a window searching for updates on your computer. After the program has finished searching you may see the following window.

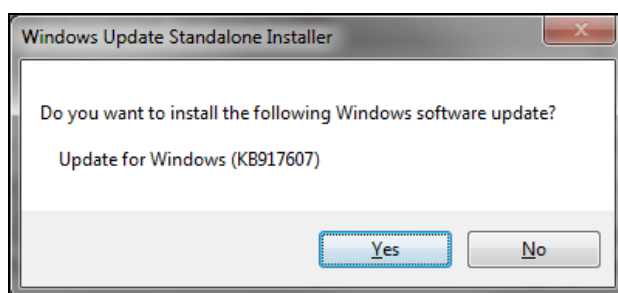


Figure 2.18: Windows Update Standalone Installer

In this case, the installation can be continued by clicking the "Yes" button.

(If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.")

In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept" (see Figure 2.19)

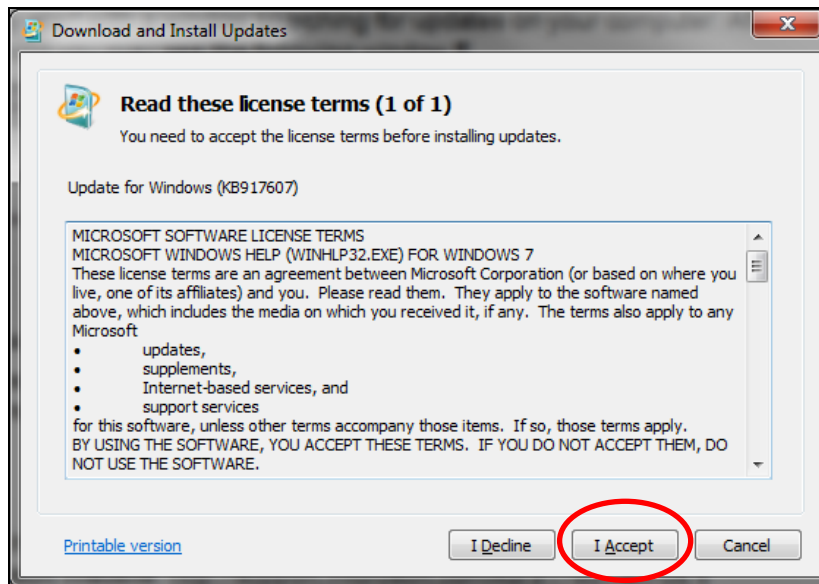


Figure 2.19: Windows License Terms

Installation starts once you have clicked the "I Accept" button (see Figure 2.20).

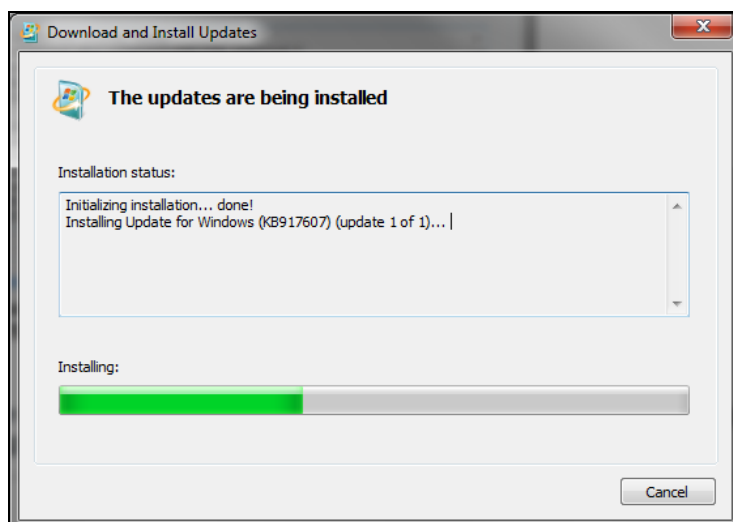


Figure 2.20: Installation process

After the Windows Help program has been installed, the notification "Installation complete" will appear. Confirm this by clicking the "Close" button.

The installation of the Windows Help program has been completed and you will now be able to open the Help files.

2.4 Licensing the LibSeaWa Property Library

The licensing procedure has to be carried out when Excel[®] starts up and a FluidEXL^{Graphics} prompt message appears. In this case, you will see the "License Information" window (see figure below).

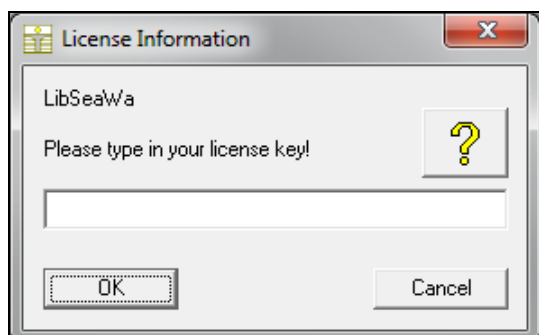


Figure 2.21: "License Information" window

Here you will have to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. You can 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:

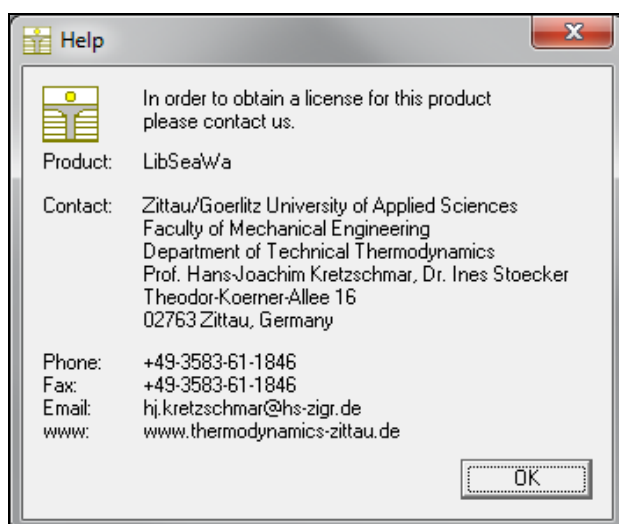


Figure 2.22: "Help" window

If you do not enter a valid license it is still possible to start Excel 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 start Excel unless you uninstall FluidEXL^{Graphics} according to the description in section 2.5 of this User's Guide.

Should you not wish to license the LibSeaWa property library, you have to delete the files
LibSeaWa.dll
LibSeaWa.hlp

in the installation folder of FluidEXL^{Graphics} (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows)

using an appropriate program such as Explorer[®] or Norton Commander.

2.5 Example: Calculation of $h = f(p, t, \xi)$

We will now calculate, step by step, the specific enthalpy h of seawater as a function of mixture pressure p , temperature t and mass fraction of sea salt in mixture ξ , using FluidEXL *Graphics*.

Please carry out the following steps:

- Start Excel
- Enter the value for p in bar into a cell
(Range of validity: $p = 0.01 \dots 800$ bar)
⇒ e.g.: Enter the value 1 into cell A2
- Enter the value for t in °C into a cell
(Range of validity: $t = -6.0 \text{ °C} \dots 220 \text{ °C}$)
⇒ e.g.: Enter the value 100 into cell B2
- Enter the value for ξ in kg/kg (*kg sea salt per kg mixture*) into a cell
(Range of validity: $\xi = 0 \dots 0.2$ kg/kg)
⇒ e.g.: Enter the value 0.01 into cell C2
- Click the cell, in which the calculated air-specific enthalpy h in kJ/kg is to be displayed
⇒ e.g.: Click on the cell D2
- Click "Calculate" in the FluidEXL *Graphics* menu bar
The "Insert Function" window appears as shown in Figure 2.23.

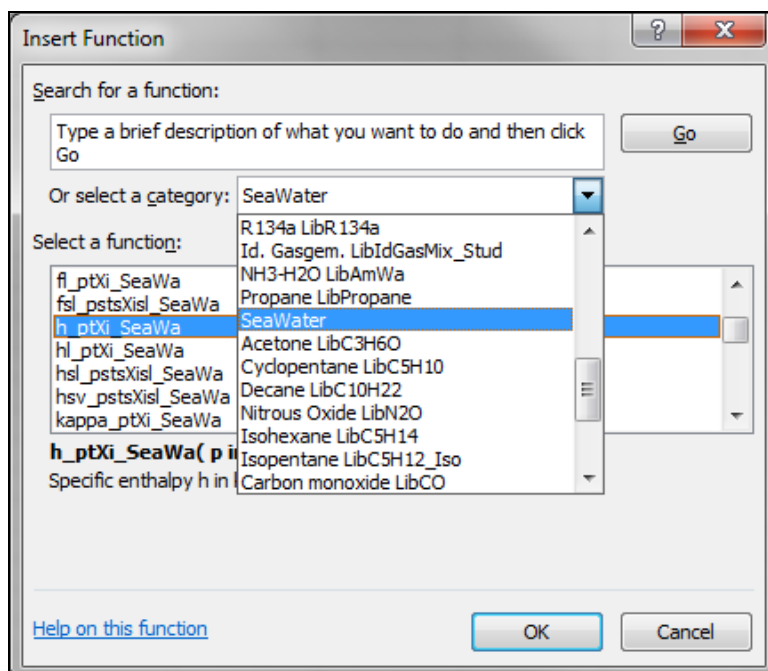


Figure 2.23: Choice of library and function name

- Search and click the "SeaWater" library under "Or select a category:" in the upper part of the window

- Search and click the "h_ptXi_SeaWa" function under "Select a function:" right below
- Click the "OK" button
The "Function Arguments" menu for the function "h_ptXi_SeaWa" in Figure 2.24 will now appear

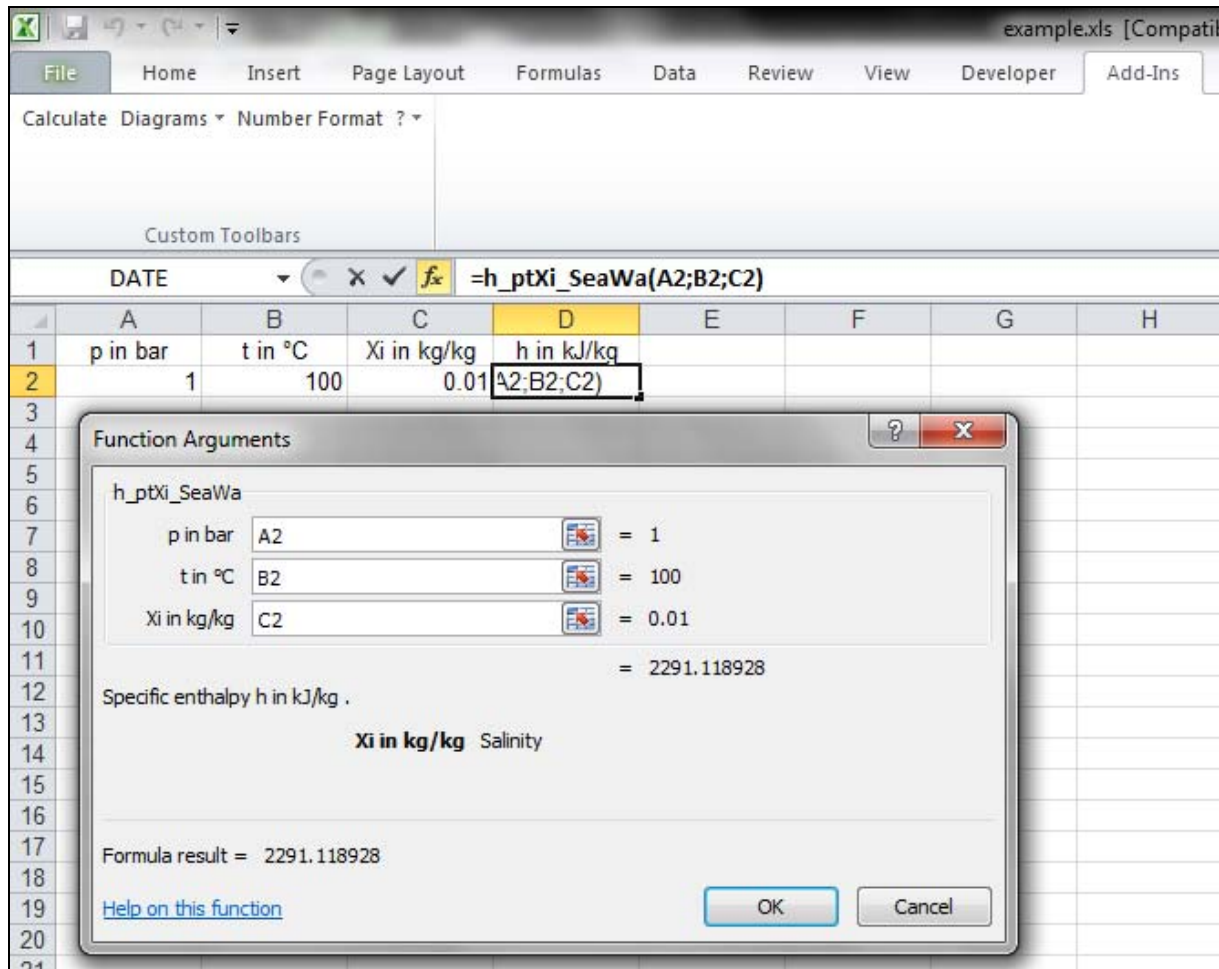


Figure 2.24: Input menu for the function

- The cursor is now situated on the line next to "p in bar". You can now enter the value for the mixture pressure p either by clicking the cell with the value for p , by entering the name of the cell, or by entering the value for p directly into the line next to "p in bar".
⇒ e. g.: Click the cell A2
- Situate the cursor on the line next to "t in °C" and enter the value for t either by clicking the cell with the value for t , by entering the name of the cell, or by entering the value for t directly into the line next to "t in °C".
⇒ e. g.: Type B2 into the line next to "t in °C"
- Situate the cursor on the line next to "Xi in kg/kg" and enter the value for the mass fraction of sea salt ζ either by clicking the cell with the value for ζ , by entering the name of the cell, or by entering the value for ζ directly into the line next to "Xi in kg/kg".
⇒ e. g.: Click on the cell C2

- Click the "OK" button

The result for h in kJ/kg appears in the cell selected above.

⇒ The cell D2 now contains the value 2291.118928.

The calculation of $h = f(p, t, \xi)$ has thus been completed.

You can now arbitrarily change the values for p , t or ξ in the appropriate cells. The specific enthalpy h are recalculated and updated every time you change the data. This shows that the Excel data flow and the DLL calculations are working together successfully

Note:

If the calculation results in -1000, this indicates that the values entered are located outside the range of validity of humid air. More detailed information on each function and its range of validity is available in Chapter 3.

For further property functions calculable in FluidEXL^{Graphics} see the function table in Chapter 1.

Number Formats

When using FluidEXL^{Graphics} you have the option of choosing special number formats in advance.

Changes can be made as follows:

- Click the cell or select and click on the cells you wish to format.
(In empty cells the new format will be applied once a value has been entered.)
- Click "Number Format" in the FluidEXL^{Graphics} menu bar.
- Select the desired number format in the dialog box which appears:
 - "STD – Standard": Insignificant zeros behind the decimal point are not shown.
 - "FIX – Fixed Number of Digits": All set decimal places are shown, including insignificant zeros.
 - "SCI – Scientific Format": Numbers are always shown in the exponential form with the set number of decimal places.
- Set the "Number of decimal places" by entering the number into the appropriate window.
- Confirm this by clicking the "OK" button.

As an example, the table below shows the three formats for the number 1.230 adjusted for three decimal places:

STD	1.23
FIX	1.230
SCI	1.230E+00

This formatting can also be applied to cells which have already been calculated.

2.6 Removing FluidEXL *Graphics*

Should you wish to remove only the LibSeaWa library, delete the files

LibSeaWa.dll
LibSeaWa.hlp

in the directory selected for the installation of FluidEXL *Graphics* (in the standard case

C:\Program Files\FuildEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FuildEXL_Graphics (for German version of Windows)

by using an appropriate program such as Explorer®, Windows, or Norton Commander.

Unregistering FluidEXL *Graphics* as Add-In in Excel®, versions 2003 or earlier

To remove FluidEXL *Graphics* completely, proceed as follows: First the registration of

FluidEXL_Graphics_Eng.xla (for English version of Windows)
FluidEXL_Graphics.xla (for German version of Windows)

has to be cancelled in Excel®.

In order to do that, click "Tools" in the upper menu bar of Excel and here "Add-Ins...". Untick the box on the left-hand side of

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

in the window that appears and click the "OK" button. The additional menu bar of FluidEXL *Graphics* disappears from the upper part of the Excel window. Afterwards, we recommend closing Excel.

If the FluidEXL *Graphics* menu bar does not disappear, take the following steps:

Click "View" in the upper menu bar of Excel, then "Toolbars" and then "Customize..." in the list box which appears.

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

is situated at the bottom of the "Toolbars" entries, which must be selected by clicking on it. Delete the entry by clicking "Delete". You will be asked whether you really want to delete the toolbar – click "OK".

Within the next step delete the files

LibSeaWa.dll
LibSeaWa.hlp

in the directory selected for the installation of FluidEXL *Graphics* (in the standard case

C:\Program Files\FuildEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FuildEXL_Graphics (for German version of Windows),

using an appropriate program such as Explorer® or Norton Commander.

In order to remove FluidEXL *Graphics* from Windows and the hard disk drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel". Now double-click on "Add or Remove Programs". In the list box of the "Add/Remove Programs" window that appears select

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

by clicking on it and click the "Add/Remove..." button. In the following dialog box click "Automatic" and thereafter "Next >". Click "Finish" in the "Perform Uninstall" window. Answer the question whether all shared components shall be removed with "Yes to All". Finally, close the "Add/Remove Programs" and "Control Panel" windows.

Now FluidEXL *Graphics* has been removed.

Unregistering FluidEXL *Graphics* as Add-In in Excel® 2007 (or later versions)

In order to unregister the FluidEXL *Graphics* Add-In in Excel® 2007 start Excel and carry out the following commands:

- Click the Windows Office® button in the upper left corner of Excel
- Click on the "Excel Options" button in the menu which appears

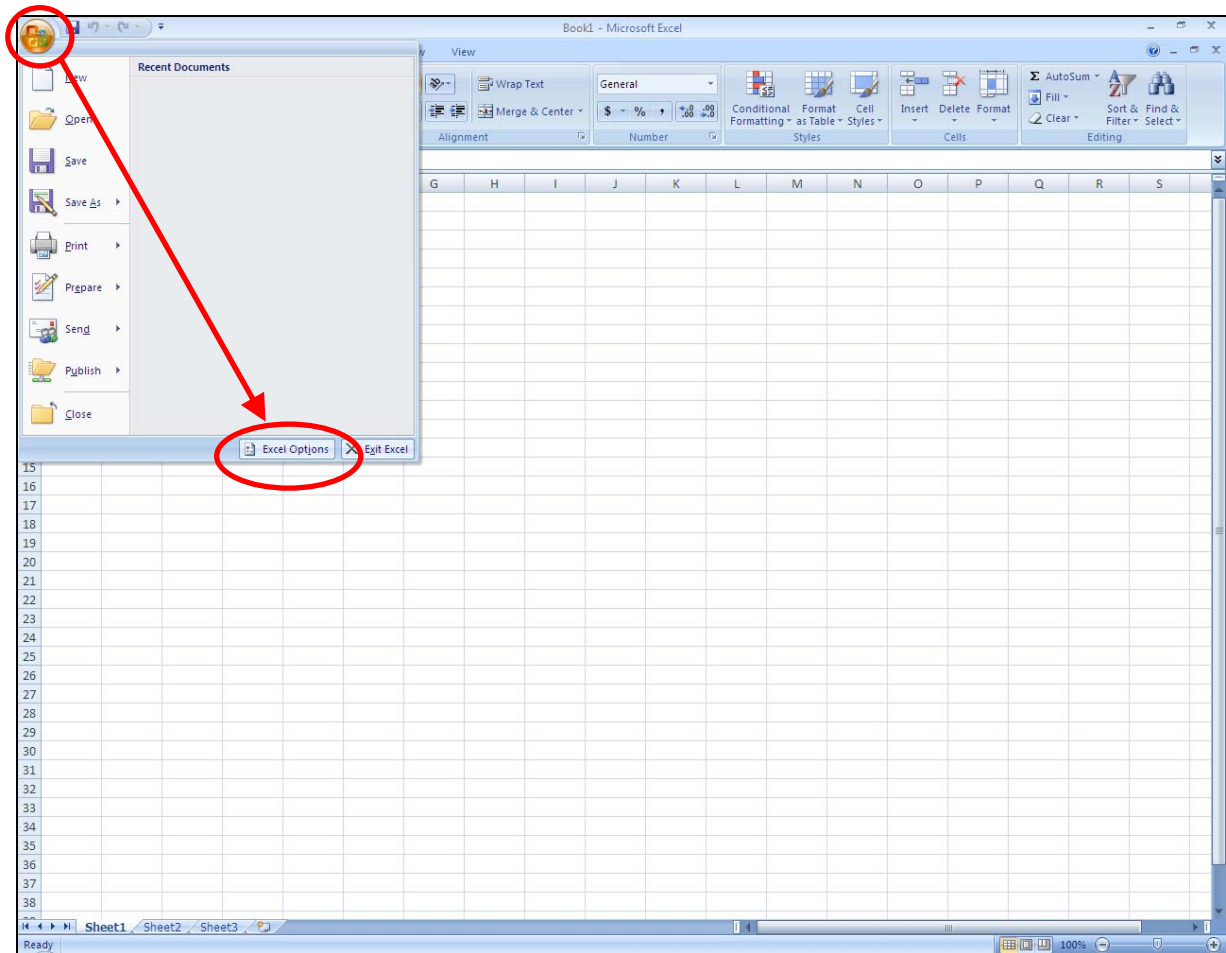


Figure 2.25: Unregistering FluidEXL *Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

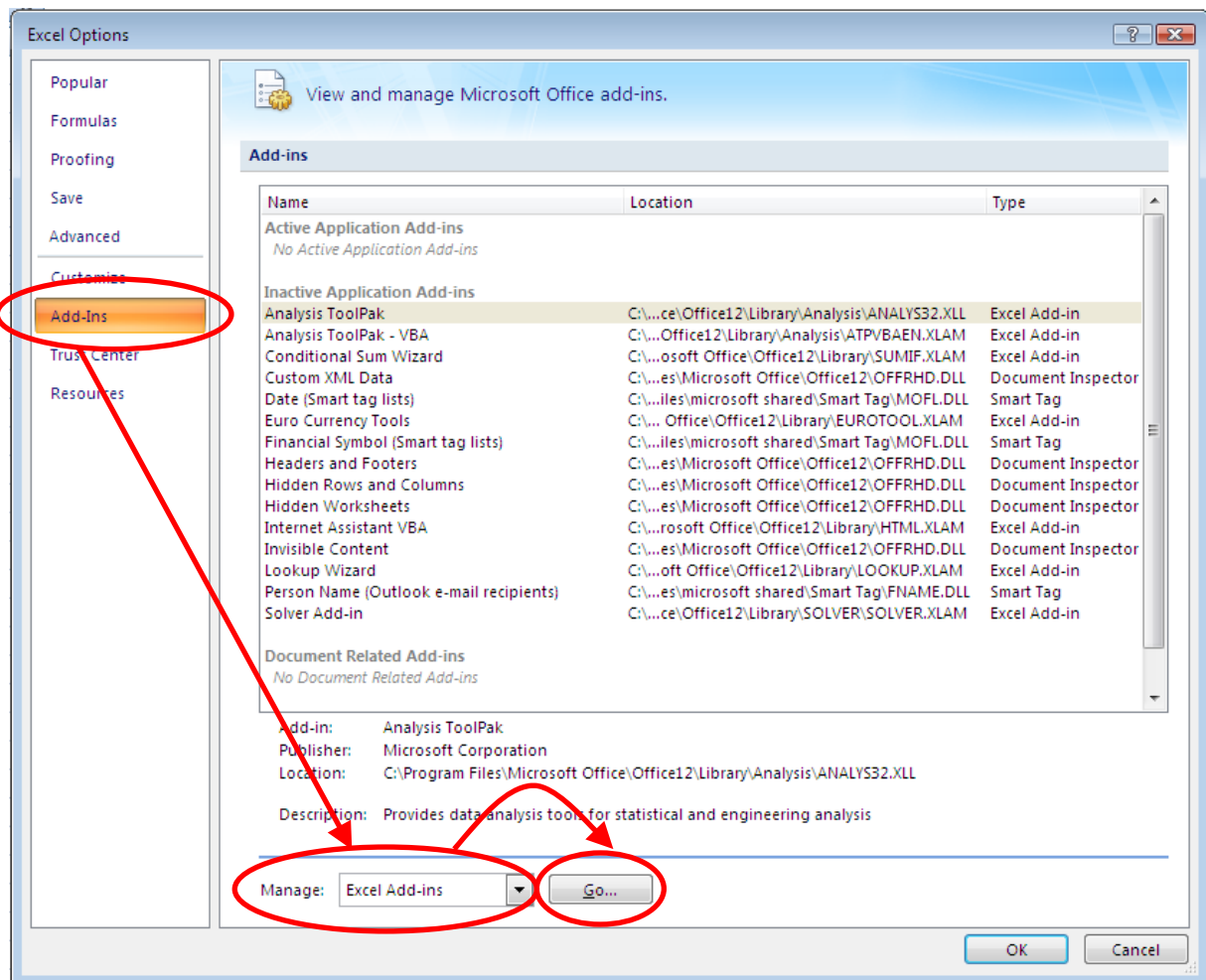


Figure 2.26: Dialog window "Add-Ins"

- If it is not shown in the list automatically, chose and click "Excel Add-ins" next to "Manage:" in the lower area of the menu
- Afterwards click the "Go..." button
- Remove the checkmark in front of
 - "FluidEXL Graphics Eng" (for English version of Windows)
 - "FluidEXL Graphics" (for German version of Windows)
 in the window which now appears. Click the "OK" button to confirm your entry.

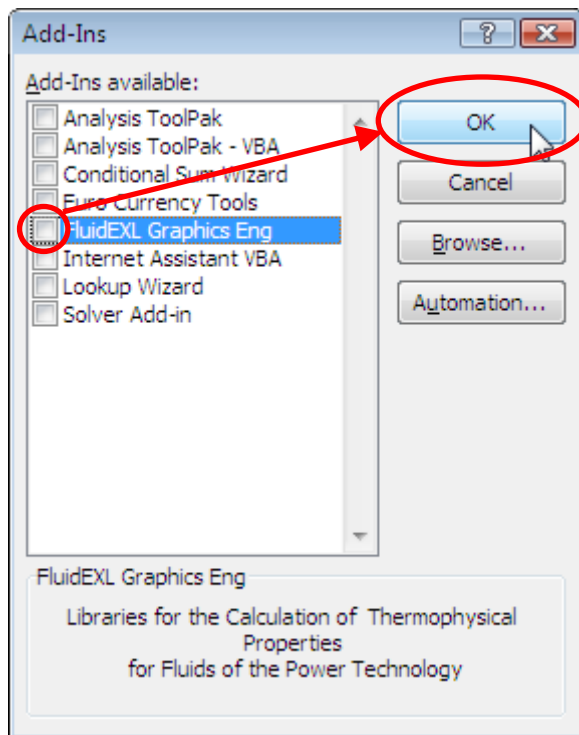


Figure 2.27: Dialog window "Add-Ins"

In order to remove FluidEXL *Graphics* from Windows and the hard drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel."

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

In the list box of the "Add or Remove Programs" window that appears, select

"FluidEXL Graphics Eng" (for English version of Windows)

"FluidEXL Graphics" (for German version of Windows)

by clicking on it and then clicking the "Add/Remove..." button.

Click "Automatic" in the following dialog box and then the "Next >" button.

Click "Finish" in the "Perform Uninstall" window.

Answer the question of whether all shared components should be removed with "Yes to All."

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

Now FluidEXL *Graphics* has been completely removed from your computer.

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

Comments:

- Thermal diffusivity $a = \frac{\lambda}{\rho * c_p}$
- This function is not 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

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

Result:

al_tXi_SeaWa, a_l - 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 $a = \frac{\lambda}{\rho * c_p}$

Result for Wrong Input Values:

al_tXi_SeaWa, $a_l = -1000$

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_PSTXISL_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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

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

Possible input variants:

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

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

$$a^{sl} = f(p_s, t_s, -1000)$$

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

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 $p_s(t = 0\text{ °C}, \xi = 0.2)$ to $p_s(t = 220\text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

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

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:

alpha_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
 X_i - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

alpha_ptXi_SeaWa, alpha - Thermal expansion of liquid seawater in 1/K

Range of Validity:

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

Result for Wrong Input Values:

alpha_ptXi_SeaWa, alpha = -1000

References:

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

Thermal Expansion Coefficient of Saturated Liquid $\alpha_{sl} = f(p_s, t_s, \xi^{sl})$
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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to $p_s(t = 80\text{ °C}, \xi = 0)$
Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

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

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

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

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

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
 ξ - 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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ bar to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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_PSTXISL_SEAWA(PS, TS, XISL),
REAL*8 PS, TS, XISL
```

Input Values:

p_s - Pressure p in bar
 t_s - 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 $p_s (t = 0 \text{ °C}, \xi = 0.12)$ to $p_s (t = 80 \text{ °C}, \xi = 0)$
Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}\beta^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \beta^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \beta^{sl} &= f(p_s, t_s, -1000) \\ \beta^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

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 $\beta_{\text{sl}} = f(p, t, \xi)$

Function Name:

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

Result:

betalsl_ptXi_SeaWa, betalsl - adiabatic lapse rate in K/kPa

Range of Validity:

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

Result for Wrong Input Values:

betalsl_ptXi_SeaWa, betalsl = -1000

References:

$\beta_{\text{sl}}(p, t, \xi)$ [1]

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

Function Name:

betalssl_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION BETAISL_PSTSL_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:

betalssl_pstsXisl_SeaWa, betalssl - Adiabatic lapse rate of saturated seawater in K/kPa

Range of Validity:

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

Possible input variants:

$$\begin{aligned}\beta_{ls}^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \beta_{ls}^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \beta_{ls}^{sl} &= f(p_s, t_s, -1000) \\ \beta_{ls}^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

Result for Wrong Input Values:

betalssl_pstsXisl_SeaWa, betalssl = -1000

References:

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

Specific Isobaric Heat Capacity $c_p = f(p, t, \xi)$
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
 ξ - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

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

Range of Validity:

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

Comments:

- This function is not defined in the wet steam region.

Result for Wrong Input Values:

cp_ptXi_SeaWa, $c_p = -1000$

References:

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

Specific Isobaric Heat Capacity of Liquid Seawater $c_{pI} = f(p, t, \xi)$
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
 ξ - 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ bar to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $c_{p_{sl}} = f(p_s, t_s, \xi^{sl})$

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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

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

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

$$c_p^{sl} = f(p_s, t_s, -1000)$$

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

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:

p_s - Pressure p in bar
 t_s - 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
Mass fraction ξ : $0 \leq \xi \leq 0.2$ 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 $\eta = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 100 bar and $p \geq p_{\text{mel}}(t, \xi)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- This function is not 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:

$\eta(\rho, t, \xi)$ [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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}\eta^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \eta^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \eta^{sl} &= f(p_s, t_s, -1000) \\ \eta^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

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_PSTSEXISL_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 $p_s(t = 0\text{ °C}, \xi = 0.2)$ to $p_s(t = 220\text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ 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
 X_i - 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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to $p_s(t = 80\text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

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

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

$$f^{sl} = f(p_s, t_s, -1000)$$

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

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
 X_i - 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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 Coefficient in [-]

Range of Validity:

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

Possible input variants:

$$\begin{aligned}\phi^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \phi^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \phi^{sl} &= f(p_s, t_s, -1000) \\ \phi^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 Enthalpy of saturated seawater in kJ/kg

Range of Validity:

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

Possible input variants:

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

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

$$h^{sl} = f(p_s, t_s, -1000)$$

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

Result for Wrong Input Values:

hsl_pstsXisl_SeaWa, hsl = -1000

References:

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

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

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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Result for Wrong Input Values:

hsv_pstsXisl_SeaWa, hsv = -1000

References:

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

Isentropic Exponent $\kappa = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- Isentropic Exponent $\kappa = \frac{w^2}{p * v}$
- This function is not 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 $\kappa_i = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

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

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_PSTSL_XISL_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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to $p_s(t = 80 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

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

Possible input variants:

$$\begin{aligned}\kappa^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \kappa^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \kappa^{sl} &= f(p_s, t_s, -1000) \\ \kappa^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

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:

p_s - Pressure p in bar
 t_s - 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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to $p_s(t = 80 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Comments:

- Isentropic Exponent $\kappa = \frac{w^2}{p \cdot v}$

Result for Wrong Input Values:

kappasv_pstsXisl_SeaWa, kappasv = -1000

References:

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

Isothermal Compressibility of Liquid Seawater $\kappa_{\text{TI}} = f(p, t, \xi)$
Function Name:

kappaTI_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:

kappaTI_ptXi_SeaWa, kappaTI - Isothermal Compressibility of liquid seawater in [1/kPa]

Range of Validity:

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

Result for Wrong Input Values:

kappaTI_ptXi_SeaWa, kappaTI = -1000

References:

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

Isothermal Compressibility of Saturated Fluid $\kappa_{T\text{sl}} = f(p_s, t_s, \xi^{\text{sl}})$
Function Name:

kappaTsl_pstsXisl_SeaWa

Fortran Programs:

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

Input Values:

p_s - Pressure p in bar
 t_s - 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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to $p_s(t = 80\text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}\kappa_T^{\text{sl}} &= f(-1000, t_s, \xi^{\text{sl}}) \\ \kappa_T^{\text{sl}} &= f(p_s, -1000, \xi^{\text{sl}}) \\ \kappa_T^{\text{sl}} &= f(p_s, t_s, -1000) \\ \kappa_T^{\text{sl}} &= f(p_s, t_s, \xi^{\text{sl}})\end{aligned}$$

Result for Wrong Input Values:

kappaTsl_pstsXisl_SeaWa, kappaTsl = -1000

References:

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

Isothermal Compressibility of Liquid Seawater $\kappa_{\text{ISL}} = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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:
 $\kappa_{\text{IS}}(p, t, \xi)$ [1]

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

kappalssl_pstsXisl_SeaWa

Fortran Programs:

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

Input Values:

p_s - Pressure p in bar
 t_s - Temperature t in °C
 $Xisl$ - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

kappalssl_pstsXisl_SeaWa, kappalssl - Isentropic Compressibility of saturated seawater in [1/kPa]

Range of Validity:

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

Possible input variants:

$$\begin{aligned}\kappa_{Is}^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \kappa_{Is}^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \kappa_{Is}^{sl} &= f(p_s, t_s, -1000) \\ \kappa_{Is}^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

Result for Wrong Input Values:

kappalssl_pstsXisl_SeaWa, kappalssl = -1000

References:

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

Thermal Conductivity $\lambda = f(p, t, \xi)$
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
 ξ - 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 100 bar and $p \geq p_{\text{mel}}(t, \xi)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- This function is not 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:

$\lambda(\rho, t, \xi)$ [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  LAMBDA_SL_PSTSL_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  $\xi$  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 $p_s(t = 0\text{ °C}, \xi = 0.2)$ to $p_s(t = 220\text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}\lambda^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \lambda^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \lambda^{sl} &= f(p_s, t_s, -1000) \\ \lambda^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

Result for Wrong Input Values:

lambdasl_pstsXisl_SeaWa, lambdasl = -1000

References:

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

Thermal Conductivity of Saturated Vapor $\lambda_{sv} = f(p_s, t_s, \xi^{sl})$
Function Name:

lambdasv_pstsXisl_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION  LAMBDA SV_PST SXISL_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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
Mass fraction ξ : $0 \leq \xi \leq 0.2$ 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 $\mu_l = f(p, t, \xi)$
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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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_PSTXISL_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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to $p_s(t = 80 \text{ °C}, \xi = 0)$
Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}\mu^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \mu^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \mu^{sl} &= f(p_s, t_s, -1000) \\ \mu^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

Result for Wrong Input Values:

mysl_pstsXisl_SeaWa, mysl = -1000

References:

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

Chemical Potential of H₂O 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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 H₂O 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 $p_s(t = 0\text{ °C}, \xi = 0.12)$ to $p_s(t = 80\text{ °C}, \xi = 0)$
Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}\mu_w^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \mu_w^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \mu_w^{sl} &= f(p_s, t_s, -1000) \\ \mu_w^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

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 $\mu_{\text{Salt I}} = f(p, t, \xi)$
Function Name:

mySaltI_ptXi_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION MYSALTPTXI_SEAWA(P, T, XI), REAL*8 P, T, XI
```

Input Values:

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

Result:

mySaltI_ptXi_SeaWa, mySaltI - 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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Result for Wrong Input Values:

mySaltI_ptXi_SeaWa, mySaltI = -1000

References:

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

Chemical Potential of Sea Salt of Saturated Liquid $\mu_{\text{Salt sl}} = f(p_s, t_s, \xi^{\text{sl}})$
Function Name:

mySaltsI_pstsXisl_SeaWa

Fortran Programs:

```

      REAL*8 FUNCTION  MYSALTSL_PSTSLXISL_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  $\xi$  in kg sea salt/kg mixture
  
```

Result:

mySaltsI_pstsXisl_SeaWa, mySaltsI - 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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to $p_s(t = 80 \text{ °C}, \xi = 0)$

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

Possible input variants:

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

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

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

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

Result for Wrong Input Values:

mySaltsI_pstsXisl_SeaWa, mySaltsI = -1000

References:

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

Kinematic Viscosity $\nu = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 100 bar and $p \geq p_{\text{mel}}(t, \xi)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Kinematic Viscosity $\nu = \frac{\eta}{\rho}$
- This function is not defined in the wet steam region.

Result for Wrong Input Values:

ny_ptXi_SeaWa, ny = -1000

References:

$\nu(p, t, \xi)$ [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

 X_i - 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 $\nu = \frac{\eta}{\rho}$
Result for Wrong Input Values:

nyl_tXi_SeaWa, nyl = -1000

References:
 $\nu(\rho, t, \xi)$ [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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

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

Possible input variants:

$$\begin{aligned}\nu^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \nu^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \nu^{sl} &= f(p_s, t_s, -1000) \\ \nu^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

Result for Wrong Input Values:

nysl_pstsXisl_SeaWa, nysl = -1000

References:

$\nu(p, t, \xi)$ [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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

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

Result for Wrong Input Values:

nysv_pstsXisl_SeaWa, nysv = -1000

References:

$\nu(p, t, \xi)$ [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:

t_s - Saturated Temperature t_s in °C

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

Result for Wrong Input Values:

pmel_tXi_SeaWa, pmel = -1000

References:

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

Triple Point Pressure $p_{tr} = f(\xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 100 bar and $p \geq p_{\text{mel}}(t, \xi)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

- Prandtl Number $Pr = \frac{V}{a}$
- This function is not 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
 ξ - 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

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

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

$$Pr^{sl} = f(p_s, t_s, -1000)$$

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

Comments:

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

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_PSTXISL_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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Comments:

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

Result for Wrong Input Values:

Prsv_pstsXisl_SeaWa, Prsv = -1000

References:

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

Density $\rho = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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:

rhoI_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
 X_i - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

rhoI_ptXi_SeaWa, rhoI - Density of liquid seawater in kg/m³

Range of Validity:

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

Result for Wrong Input Values:

rhoI_ptXi_SeaWa, rhoI = -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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}\rho^{sl} &= f(-1000, t_s, \xi^{sl}) \\ \rho^{sl} &= f(p_s, -1000, \xi^{sl}) \\ \rho^{sl} &= f(p_s, t_s, -1000) \\ \rho^{sl} &= f(p_s, t_s, \xi^{sl})\end{aligned}$$

Result for Wrong Input Values:

rhosl_pstsXisl_SeaWa, rhosl = -1000

References:

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

Density of Saturated Vapor $\rho_{sv} = f(p_s, t_s, \xi^{sl})$
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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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:

$s(p, t, \xi)$ [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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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:

$s(p, t, \xi)$ [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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

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

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

$$s^{sl} = f(p_s, t_s, -1000)$$

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

Result for Wrong Input Values:

ssl_pstsXi_SeaWa, ssl = -1000

References:

$s(p, t, \xi)$ [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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ 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 $p_s(t = 0\text{ °C}, \xi = 0.2)$ to $p_s(t = 220\text{ °C}, \xi = 0)$

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 $t_{\text{mel}} = f(p, \xi)$
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

ξ - 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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to 1000 bar

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

Comments:

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

Result for Wrong Input Values:

tmel_pXi_SeaWa, tmel = -1000

References:

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

Triple Point Temperature $t_{tr} = f(\xi)$
Function Name:

ttr_Xi_SeaWa

Fortran Programs:

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

Input Values:

ξ - 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 $Region = f(p, t, \xi)$
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
 ξ - 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $Region = f(p, h, \xi)$
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
 ξ - Mass fraction of sea salt ξ in kg sea salt/kg mixture

Result:

Region_phXi_SeaWa, Region - Region in [-]

Range of Validity:

Pressure p : from $p_s(t = 0\text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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:

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

Region *Region* = $f(p, s, \xi)$
Function Name:

Region_psXi_SeaWa

Fortran Programs:

```
REAL*8 FUNCTION REGION_PSI_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 $p_s(t = 0\text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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:

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

Backward Function: Temperature $t = f(p, h, \xi)$
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
 ξ - 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 $p_s(t = 0\text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $t = f(p, s, \xi)$
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)
 ξ - 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 $p_s(t = 0\text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $u = f(p, t, \xi)$
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
 ξ - 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

$$\begin{aligned}
 u^{sl} &= f(-1000, t_s, \xi^{sl}) \\
 u^{sl} &= f(p_s, -1000, \xi^{sl}) \\
 u^{sl} &= f(p_s, t_s, -1000) \\
 u^{sl} &= f(p_s, t_s, \xi^{sl})
 \end{aligned}$$

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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 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:

usv_pstsXisl_SeaWa, usv = -1000

References:

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

Specific Volume $v = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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_PSTXISL_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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.2$ kg sea salt/kg mixture

Possible input variants:

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

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

$$v^{sl} = f(p_s, t_s, -1000)$$

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

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

Comments:

- This function is not 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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to $p_s(t = 80 \text{ °C}, \xi = 0)$
 Mass fraction ξ : $0 \leq \xi \leq 0.12$ kg sea salt/kg mixture

Possible input variants:

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

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

$$w^{sl} = f(p_s, t_s, -1000)$$

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

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 $p_s(t = 0 \text{ °C}, \xi = 0.12)$ to $p_s(t = 80 \text{ °C}, \xi = 0)$
 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:

wsv_pstsXisl_SeaWa, wsv = –1000

References:

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

Vapor Fraction $x = f(p, t, \xi)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to 1000 bar and $p \geq p_{\text{mel}}(t, \xi)$
 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 $\xi_{sl} = f(p_s, t_s)$
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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$

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 $p_s(t = 0 \text{ °C}, \xi = 0.2)$ to $p_s(t = 220 \text{ °C}, \xi = 0)$

Result for Wrong Input Values:

Xisv_psts_SeaWa, Xisv = -1000

References:

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



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)

Humid Combustion Gas Mixtures

Library LibHuGas

- Model: Ideal mixture of the real fluids:
- CO₂ - Span and Wagner O₂ - Schmidt and Wagner
H₂O - IAPWS-95 Ar - Tegeler et al.
N₂ - Span et al.
- and of the ideal gases:
- SO₂, CO, Ne (Scientific Formulation of Bückner et al.)
- Consideration of:
- Dissociation from VDI 4670 and 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 the VDI 4670
 - Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

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 ₂ O | F ₂ | Propane |
| N ₂ | SO ₂ | NH ₃ | Iso-Butane |
| O ₂ | H ₂ | Methane | n-Butane |
| CO | H ₂ S | 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

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bückner et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bückner et al. (2003)

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 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 ₂ H ₆ O ₂	Ethylene glycol
C ₃ H ₈ O ₂	Propylene glycol
C ₂ H ₅ OH	Ethyl alcohol
CH ₃ OH	Methyl alcohol
C ₃ H ₈ O ₃	Glycerol
K ₂ CO ₃	Potassium carbonate
CaCl ₂	Calcium chloride
MgCl ₂	Magnesium chloride
NaCl	Sodium chloride
C ₂ H ₃ KO ₂	Potassium acetate

Formulation of the International Institute of Refrigeration (1997)

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 $C_{14}H_{42}O_6Si_6$ **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)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

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**

Dinitrogen monoxide 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:

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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

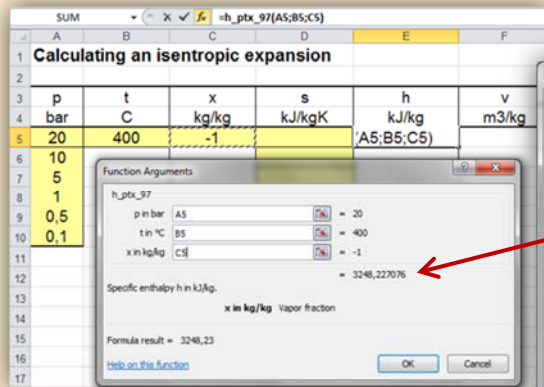
- Partial derivatives can be calculated.

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



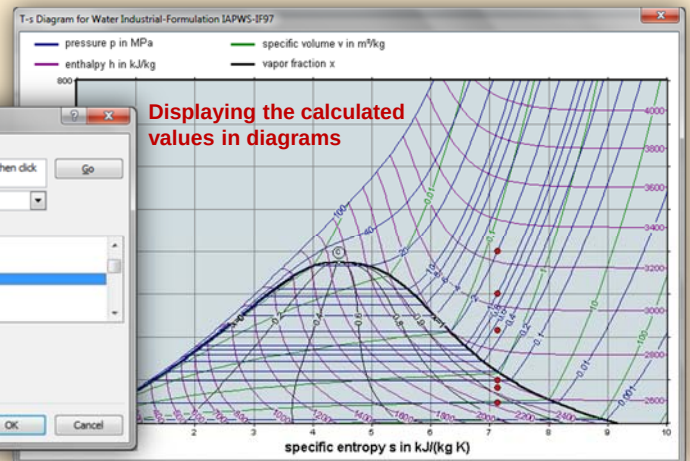
Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function

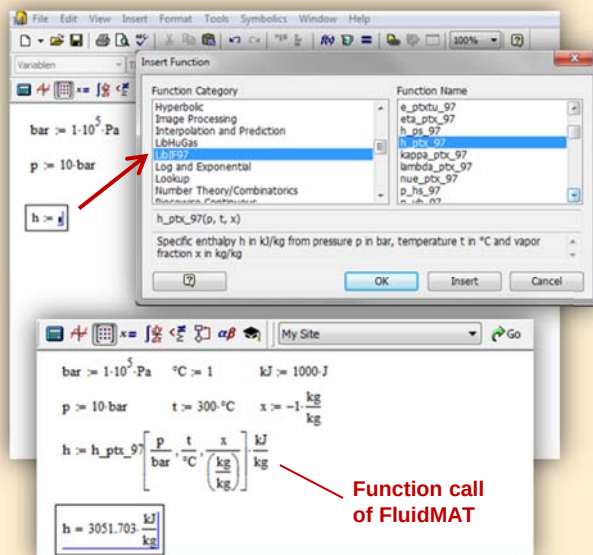
Displaying the calculated values in diagrams



Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

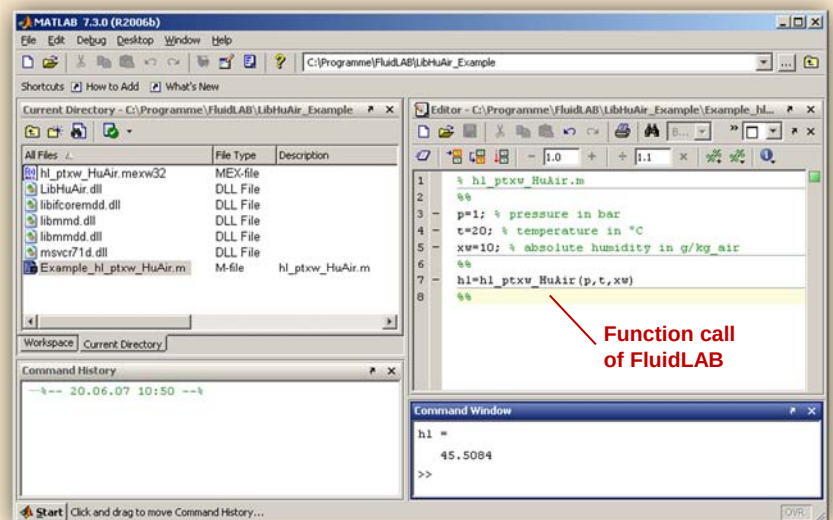
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

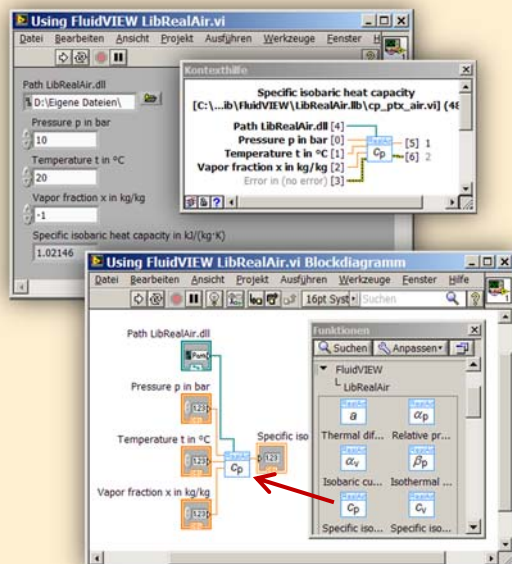
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

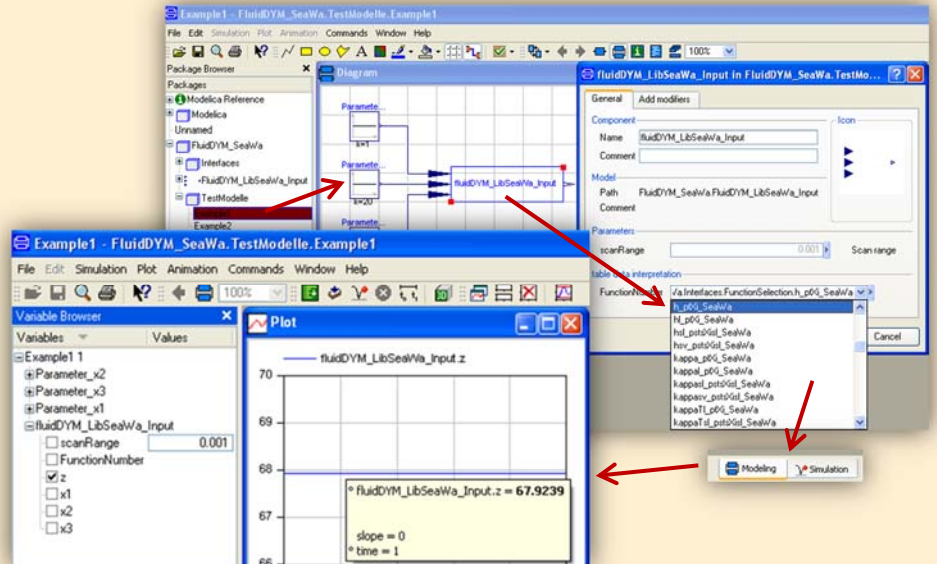
Add-On FluidVIEW for LabVIEW[®]

The property functions can be calculated in LabVIEW[®].

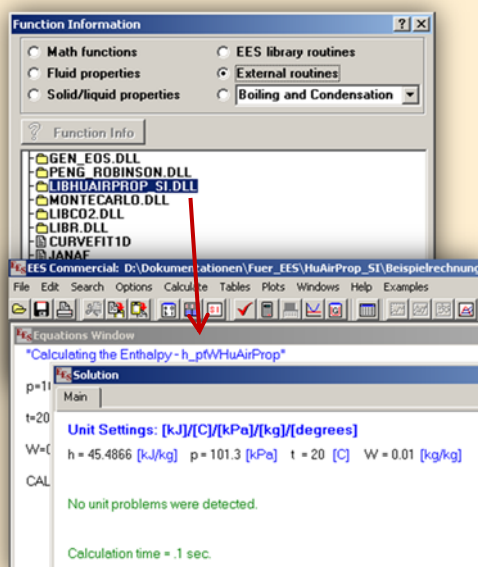


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

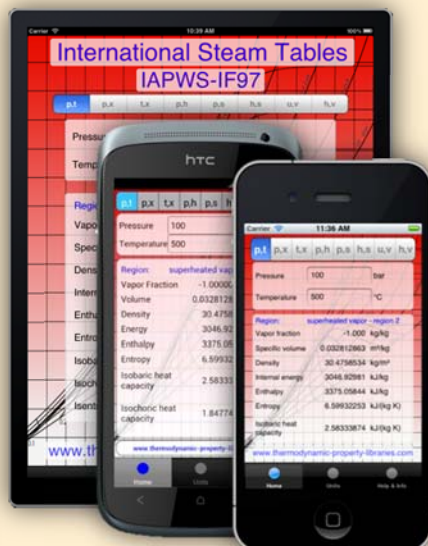
The property functions can be called in DYMOLA[®] and SimulationX[®].



Add-In FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android smart phones and tablets



Online Property Calculator at www.thermodynamics-zittau.de

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

Enter given values: [Range of validity](#)

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = 3097.38 kJ/kg

For further information on property libraries available for EXCEL®, MATLAB®, Mathcad®, Engineering Equation Solver®, DYMOLA® (Modelica), SimulationX®, and LabView® click [here](#)

An App for calculating steam properties on iPhone, iPad, and iPod touch can be found [here](#)

PDF with the description

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Faculty of Mechanical Engineering
Department of Technical Thermodynamics
Prof. Hans-Joachim Kretzschmar
Dr. Ines Stoecker
Programmer: Joachim Posselt

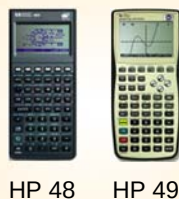
Tel.: +49-3583-61-1846 or -1881
Fax: +49-3583-61-1845
E-mail: info@thermodynamics-zittau.de
www.thermodynamics-zittau.de
www.thermodynamic-property-libraries.com
www.international-steam-tables.com
www.thermodynamic-formelsammlung.de

Property Software for Pocket Calculators

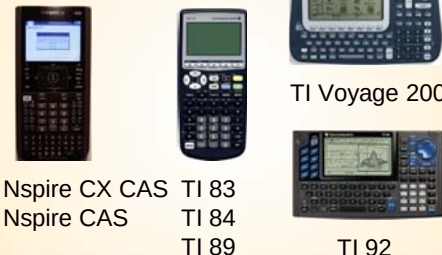
FluidCasio



FluidHP



FluidTI



For more information please contact:

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Professor Hans-Joachim Kretzschmar
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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.

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 an 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 H₂O 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 CO₂-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: 10/2011

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)
- FluidVIEW for LabVIEW[®]:

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
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Stadtwerke Leipzig	12/2010
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Shanghai New Energy Resources Science & Technology, China	11/2010
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Steinmueller, Berlin	11/2010
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Vaillant, Remscheid	10/2010

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MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
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Fischer-Uhrig Consulting Engineers, Berlin	01/2010

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Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
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VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Pettersson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
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TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	06/2003
University of Cali, Colombia	07/2003
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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
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Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

2002

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G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
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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 Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
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SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
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DVO Data Processing Service, Oberhausen	05/2000
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VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
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Steinhaus Informationssysteme, Datteln (general license for process data software)	12/2000

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Bayernwerk, Munich	01/1999
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Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
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

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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SCA Hygiene Products, Munich	10/1998
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Gerb, Dresden	06/1997
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