

## 2.16 Water (IFC 1967 Formulation for Industrial Use-ITS 1990)

Equations have been cited from reference [1] and [2].

### 2.16.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

### 2.16.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	Water, Light Water
Library File for UNIX:	libjh2oi90.a
Library File for DOS,Windows95/NT:	JH2OI90.LIB
Single Shot Program for UNIX:	h2oi90-ss
Single Shot Program for DOS,Windows95/NT:	H2OI90SS.EXE

### 2.16.3 Important Constants and Others

Molecular Formula:	H <sub>2</sub> O
Relative Molecular Mass:	18.0153
Gas Constant:	461.51 J/(kg·K)

Critical Constants:

Critical Pressure:	22.064×10 <sup>6</sup> Pa (220.64 bar)
Critical Temperature:	647.096 K (373.946°C)
Critical Specific Volume:	3.1055×10 <sup>-3</sup> m <sup>3</sup> /kg

Triple Point:

Pressure:	611.657 Pa (6.11657×10 <sup>-3</sup> bar)
Temperature:	273.16 K (0.01°C)

Reference State:

At the triple point, the internal energy and specific entropy of liquid have been set equal to 0 J/(kg·K) and 0 J/kg, respectively.

### 2.16.4 Formula

Vapor Pressure:

Equation (1) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equations (1) and (2) for specific volumes (densities) of saturated liquid and vapor, respectively. Equations (4) and (6) for specific enthalpy of saturated liquid, equations (4) and (7) for specific enthalpy of saturated vapor, equations (5) and (8) for specific entropy of saturated liquid, and equations (5) and (9) for specific entropy of saturated vapor. All these equations have been cited from reference [1].

Pressure and Temperature on Melting Curve:

Equations (1) to (5) in reference [2].

Pressure and Temperature on Sublimation Curve:

Equation (6) in reference [2].

## References

- [1] J.M.H.L.Sengers and B.Dooley, 'Revised Supplementary Release on Saturation Properties of Ordinary Water Substance', The international Association for the Properties of Water and Steam, St. Petersburg, Russia, (1992)
- [2] J.M.H.L.Sengers and B.Dooley, 'Revised Release on the Pressure along the Melting and Sublimation Curves of Ordinary Water Substance', The international Association for the Properties of Water and Steam, St. Petersburg, Russia, (1992)

Table II-2.16-1 Water(IFC 1967-ITS 1990) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 221.064$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		
21	CRP('A')	CRP: Critical Constants H: 'A'='H': $2.0866 \times 10^6$ [J/kg] Specific Enthalpy P*: 'A'='P': $22.064 \times 10^6$ [Pa], 220.64 [bar] Pressure S: 'A'='S': $4.410 \times 10^3$ [J/(kg·K)] Specific Entropy T*: 'A'='T': 647.096 [K], 373.946 [°C] Temperature V: 'A'='V': $3.1055 \times 10^{-3}$ [m <sup>3</sup> /kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7B	CVTD(T)		
78	CVTDD(T)		
22	EPSPT(P,T)		

Table II-2.16-1 Water(IFC 1967-ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 18.0153 Relative Molecular Mass R: 'A'='R': 461.51 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
71	HPS(P,S)		
25	HPT(P,T)		
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [-]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T*: Temperature [K], [°C] X: Dryness Fraction [-]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [-]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'H2O' Molecular Formula S: 'A'='S': 'WATER(IFC1967-ITS1990)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT*: Pressure on Melting Curve [Pa], [bar] T*: Temperature [K], [°C]	$251.165 \leq T \leq 273.16$ [K] $-21.985 \leq T \leq 0.01$ [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)	PSBT*: Pressure on Sublimation Curve [Pa], [bar] T*: Temperature [K], [°C]	$190 \leq T \leq 273.16$ [K] $-83.15 \leq T \leq 0.01$ [°C]
30	PST(T)	PST*: Saturation Pressure [Pa], [bar] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]

Table II-2.16-1 Water(IFC 1967-ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
35	SPT(P,T)		
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [-]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T*: Temperature [K], [°C] X: Dryness Fraction [-]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [-]
67	TLDP(P)		
69	TMLP(P)		
69	TMLP(P)	TMLP*: Temperature on Melting Curve [K], [°C] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 209.9 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 2099$ [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL*: Properties at Triple Point P*:'A'='P': $611.657$ [Pa], $6.11657 \times 10^{-3}$ [bar] Pressure T*:'A'='T': $273.16$ [K], $0.01$ [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)	TSBP*: Temperature on Sublimation Curve [K], [°C] P*: Pressure [Pa], [bar]	$41.532 \times 10^{-3} \leq P \leq 611.657$ [Pa] $0.41532 \times 10^{-6} \leq P \leq 6.11657 \times 10^{-3}$ [bar]
40	TSP(P)	TSP*: Saturation Temperature [K], [°C] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P*: Pressure [Pa], [bar]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar]
79	UPS(P,S)		
44	UPT(P,T)		
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	$611.657 \leq P \leq 22.064 \times 10^6$ [Pa] $6.11657 \times 10^{-3} \leq P \leq 220.64$ [bar] $0 \leq X \leq 1.0$ [-]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T*: Temperature [K], [°C]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T*: Temperature [K], [°C] X: Dryness Fraction [-]	$273.16 \leq T \leq 647.096$ [K] $0.01 \leq T \leq 373.946$ [°C] $0 \leq X \leq 1.0$ [-]

Table II-2.16-1 Water(IFC 1967-ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m <sup>3</sup> /kg] P*: Pressure [Pa], [bar]	611.657 ≤ P ≤ 22.064 × 10 <sup>6</sup> [Pa] 6.11657 × 10 <sup>-3</sup> ≤ P ≤ 220.64 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m <sup>3</sup> /kg] P*: Pressure [Pa], [bar]	611.657 ≤ P ≤ 22.064 × 10 <sup>6</sup> [Pa] 6.11657 × 10 <sup>-3</sup> ≤ P ≤ 220.64 [bar]
80	VPS(P,S)		
51	VPT(P,T)		
52	VPX(P,X)	VPX: Specific Volume of Mixture [m <sup>3</sup> /kg] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	611.657 ≤ P ≤ 22.064 × 10 <sup>6</sup> [Pa] 6.11657 × 10 <sup>-3</sup> ≤ P ≤ 220.64 [bar] 0 ≤ X ≤ 1.0 [-]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m <sup>3</sup> /kg] T*: Temperature [K], [°C]	273.16 ≤ T ≤ 647.096 [K] 0.01 ≤ T ≤ 373.946 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m <sup>3</sup> /kg] T*: Temperature [K], [°C]	273.16 ≤ T ≤ 647.096 [K] 0.01 ≤ T ≤ 373.946 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m <sup>3</sup> /kg] T*: Temperature [K], [°C] X: Dryness Fraction [-]	273.16 ≤ T ≤ 647.096 [K] 0.01 ≤ T ≤ 373.946 [°C] 0 ≤ X ≤ 1.0 [-]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [-] P*: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	611.657 ≤ P ≤ 22.064 × 10 <sup>6</sup> [Pa] 6.11657 × 10 <sup>-3</sup> ≤ P ≤ 220.64 [bar] HPD(P) ≤ H ≤ HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [-] P*: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	611.657 ≤ P ≤ 22.064 × 10 <sup>6</sup> [Pa] 6.11657 × 10 <sup>-3</sup> ≤ P ≤ 220.64 [bar] SPD(P) ≤ S ≤ SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [-] P*: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	611.657 ≤ P ≤ 22.064 × 10 <sup>6</sup> [Pa] 6.11657 × 10 <sup>-3</sup> ≤ P ≤ 220.64 [bar] UPD(P) ≤ U ≤ UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [-] P*: Pressure [Pa], [bar] V: Specific Volume of Mixture [m <sup>3</sup> /kg]	611.657 ≤ P ≤ 22.064 × 10 <sup>6</sup> [Pa] 6.11657 × 10 <sup>-3</sup> ≤ P ≤ 220.64 [bar] VPD(P) ≤ V ≤ VPDD(P) [m <sup>3</sup> /kg]
60	XTH(T,H)	XTH: Dryness Fraction [-] T*: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	273.16 ≤ T ≤ 647.096 [K] 0.01 ≤ T ≤ 373.946 [°C] HPD(T) ≤ H ≤ HPDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [-] T*: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	273.16 ≤ T ≤ 647.096 [K] 0.01 ≤ T ≤ 373.946 [°C] SPD(T) ≤ S ≤ SPDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [-] T*: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	273.16 ≤ T ≤ 647.096 [K] 0.01 ≤ T ≤ 373.946 [°C] UPD(T) ≤ U ≤ UPDD(P) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [-] T*: Temperature [K], [°C] V: Specific Volume of Mixture [m <sup>3</sup> /kg]	273.16 ≤ T ≤ 647.096 [K] 0.01 ≤ T ≤ 373.946 [°C] VPD(T) ≤ V ≤ VPDD(T) [m <sup>3</sup> /kg]