' water97\_v13: A collection of Visual Basic functions

' for calculating properties of water and steam.

'

' Source: IAPWS-IF97. For details see

' http://www.cheresources.com/iapwsif97.shtml

'

' Version 1.3, 02/10/02: documentation updated

'

' Version 1.2, 02/06/01: starting value for iteration in densreg3 for

' supercritical temperatures changed from 500 to 600

'

'

' Version 1.1, 01/29/01: mistake in calculation of partial derivatives

' for thermal conductivity corrected

'

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'

'

Public Const rgas\_water As Double = 461.526 'gas constant in J/(kg K)

Public Const tc\_water As Double = 647.096 'critical temperature in K

Public Const pc\_water As Double = 220.64 'critical pressure in bar

Public Const dc\_water As Double = 322# 'critical density in kg/m\*\*3

Private ireg1(1 To 34) As Integer

Private jreg1(1 To 34) As Integer

Private nreg1(1 To 34) As Double

Private j0reg2(1 To 9) As Integer

Private n0reg2(1 To 9) As Double

Private ireg2(1 To 43) As Integer

Private jreg2(1 To 43) As Integer

Private nreg2(1 To 43) As Double

Private ireg3(1 To 40) As Integer

Private jreg3(1 To 40) As Integer

Private nreg3(1 To 40) As Double

Private nreg4(1 To 10) As Double

Private nbound(1 To 5) As Double

Private n0visc(0 To 3) As Double

Private ivisc(1 To 19) As Integer

Private jvisc(1 To 19) As Integer

Private nvisc(1 To 19) As Double

Private n0thcon(0 To 3) As Double

Private nthcon(0 To 4, 0 To 5) As Double

'

'

'

Sub InitFieldsreg1()

'

' Initialize coefficients and exponents for region 1

'

 ireg1(1) = 0

 ireg1(2) = 0

 ireg1(3) = 0

 ireg1(4) = 0

 ireg1(5) = 0

 ireg1(6) = 0

 ireg1(7) = 0

 ireg1(8) = 0

 ireg1(9) = 1

 ireg1(10) = 1

 ireg1(11) = 1

 ireg1(12) = 1

 ireg1(13) = 1

 ireg1(14) = 1

 ireg1(15) = 2

 ireg1(16) = 2

 ireg1(17) = 2

 ireg1(18) = 2

 ireg1(19) = 2

 ireg1(20) = 3

 ireg1(21) = 3

 ireg1(22) = 3

 ireg1(23) = 4

 ireg1(24) = 4

 ireg1(25) = 4

 ireg1(26) = 5

 ireg1(27) = 8

 ireg1(28) = 8

 ireg1(29) = 21

 ireg1(30) = 23

 ireg1(31) = 29

 ireg1(32) = 30

 ireg1(33) = 31

 ireg1(34) = 32

'

 jreg1(1) = -2

 jreg1(2) = -1

 jreg1(3) = 0

 jreg1(4) = 1

 jreg1(5) = 2

 jreg1(6) = 3

 jreg1(7) = 4

 jreg1(8) = 5

 jreg1(9) = -9

 jreg1(10) = -7

 jreg1(11) = -1

 jreg1(12) = 0

 jreg1(13) = 1

 jreg1(14) = 3

 jreg1(15) = -3

 jreg1(16) = 0

 jreg1(17) = 1

 jreg1(18) = 3

 jreg1(19) = 17

 jreg1(20) = -4

 jreg1(21) = 0

 jreg1(22) = 6

 jreg1(23) = -5

 jreg1(24) = -2

 jreg1(25) = 10

 jreg1(26) = -8

 jreg1(27) = -11

 jreg1(28) = -6

 jreg1(29) = -29

 jreg1(30) = -31

 jreg1(31) = -38

 jreg1(32) = -39

 jreg1(33) = -40

 jreg1(34) = -41

'

 nreg1(1) = 0.14632971213167

 nreg1(2) = -0.84548187169114

 nreg1(3) = -3.756360367204

 nreg1(4) = 3.3855169168385

 nreg1(5) = -0.95791963387872

 nreg1(6) = 0.15772038513228

 nreg1(7) = -0.016616417199501

 nreg1(8) = 8.1214629983568E-04

 nreg1(9) = 2.8319080123804E-04

 nreg1(10) = -6.0706301565874E-04

 nreg1(11) = -0.018990068218419

 nreg1(12) = -0.032529748770505

 nreg1(13) = -0.021841717175414

 nreg1(14) = -5.283835796993E-05

 nreg1(15) = -4.7184321073267E-04

 nreg1(16) = -3.0001780793026E-04

 nreg1(17) = 4.7661393906987E-05

 nreg1(18) = -4.4141845330846E-06

 nreg1(19) = -7.2694996297594E-16

 nreg1(20) = -3.1679644845054E-05

 nreg1(21) = -2.8270797985312E-06

 nreg1(22) = -8.5205128120103E-10

 nreg1(23) = -2.2425281908E-06

 nreg1(24) = -6.5171222895601E-07

 nreg1(25) = -1.4341729937924E-13

 nreg1(26) = -4.0516996860117E-07

 nreg1(27) = -1.2734301741641E-09

 nreg1(28) = -1.7424871230634E-10

 nreg1(29) = -6.8762131295531E-19

 nreg1(30) = 1.4478307828521E-20

 nreg1(31) = 2.6335781662795E-23

 nreg1(32) = -1.1947622640071E-23

 nreg1(33) = 1.8228094581404E-24

 nreg1(34) = -9.3537087292458E-26

'

End Sub

'

'

'

Sub InitFieldsreg2()

'

' Initialize coefficients and exponents for region 2

'

 j0reg2(1) = 0

 j0reg2(2) = 1

 j0reg2(3) = -5

 j0reg2(4) = -4

 j0reg2(5) = -3

 j0reg2(6) = -2

 j0reg2(7) = -1

 j0reg2(8) = 2

 j0reg2(9) = 3

'

 n0reg2(1) = -9.6927686500217

 n0reg2(2) = 10.086655968018

 n0reg2(3) = -0.005608791128302

 n0reg2(4) = 0.071452738081455

 n0reg2(5) = -0.40710498223928

 n0reg2(6) = 1.4240819171444

 n0reg2(7) = -4.383951131945

 n0reg2(8) = -0.28408632460772

 n0reg2(9) = 0.021268463753307

'

 ireg2(1) = 1

 ireg2(2) = 1

 ireg2(3) = 1

 ireg2(4) = 1

 ireg2(5) = 1

 ireg2(6) = 2

 ireg2(7) = 2

 ireg2(8) = 2

 ireg2(9) = 2

 ireg2(10) = 2

 ireg2(11) = 3

 ireg2(12) = 3

 ireg2(13) = 3

 ireg2(14) = 3

 ireg2(15) = 3

 ireg2(16) = 4

 ireg2(17) = 4

 ireg2(18) = 4

 ireg2(19) = 5

 ireg2(20) = 6

 ireg2(21) = 6

 ireg2(22) = 6

 ireg2(23) = 7

 ireg2(24) = 7

 ireg2(25) = 7

 ireg2(26) = 8

 ireg2(27) = 8

 ireg2(28) = 9

 ireg2(29) = 10

 ireg2(30) = 10

 ireg2(31) = 10

 ireg2(32) = 16

 ireg2(33) = 16

 ireg2(34) = 18

 ireg2(35) = 20

 ireg2(36) = 20

 ireg2(37) = 20

 ireg2(38) = 21

 ireg2(39) = 22

 ireg2(40) = 23

 ireg2(41) = 24

 ireg2(42) = 24

 ireg2(43) = 24

'

 jreg2(1) = 0

 jreg2(2) = 1

 jreg2(3) = 2

 jreg2(4) = 3

 jreg2(5) = 6

 jreg2(6) = 1

 jreg2(7) = 2

 jreg2(8) = 4

 jreg2(9) = 7

 jreg2(10) = 36

 jreg2(11) = 0

 jreg2(12) = 1

 jreg2(13) = 3

 jreg2(14) = 6

 jreg2(15) = 35

 jreg2(16) = 1

 jreg2(17) = 2

 jreg2(18) = 3

 jreg2(19) = 7

 jreg2(20) = 3

 jreg2(21) = 16

 jreg2(22) = 35

 jreg2(23) = 0

 jreg2(24) = 11

 jreg2(25) = 25

 jreg2(26) = 8

 jreg2(27) = 36

 jreg2(28) = 13

 jreg2(29) = 4

 jreg2(30) = 10

 jreg2(31) = 14

 jreg2(32) = 29

 jreg2(33) = 50

 jreg2(34) = 57

 jreg2(35) = 20

 jreg2(36) = 35

 jreg2(37) = 48

 jreg2(38) = 21

 jreg2(39) = 53

 jreg2(40) = 39

 jreg2(41) = 26

 jreg2(42) = 40

 jreg2(43) = 58

'

 nreg2(1) = -1.7731742473213E-03

 nreg2(2) = -0.017834862292358

 nreg2(3) = -0.045996013696365

 nreg2(4) = -0.057581259083432

 nreg2(5) = -0.05032527872793

 nreg2(6) = -3.3032641670203E-05

 nreg2(7) = -1.8948987516315E-04

 nreg2(8) = -3.9392777243355E-03

 nreg2(9) = -0.043797295650573

 nreg2(10) = -2.6674547914087E-05

 nreg2(11) = 2.0481737692309E-08

 nreg2(12) = 4.3870667284435E-07

 nreg2(13) = -3.227767723857E-05

 nreg2(14) = -1.5033924542148E-03

 nreg2(15) = -0.040668253562649

 nreg2(16) = -7.8847309559367E-10

 nreg2(17) = 1.2790717852285E-08

 nreg2(18) = 4.8225372718507E-07

 nreg2(19) = 2.2922076337661E-06

 nreg2(20) = -1.6714766451061E-11

 nreg2(21) = -2.1171472321355E-03

 nreg2(22) = -23.895741934104

 nreg2(23) = -5.905956432427E-18

 nreg2(24) = -1.2621808899101E-06

 nreg2(25) = -0.038946842435739

 nreg2(26) = 1.1256211360459E-11

 nreg2(27) = -8.2311340897998

 nreg2(28) = 1.9809712802088E-08

 nreg2(29) = 1.0406965210174E-19

 nreg2(30) = -1.0234747095929E-13

 nreg2(31) = -1.0018179379511E-09

 nreg2(32) = -8.0882908646985E-11

 nreg2(33) = 0.10693031879409

 nreg2(34) = -0.33662250574171

 nreg2(35) = 8.9185845355421E-25

 nreg2(36) = 3.0629316876232E-13

 nreg2(37) = -4.2002467698208E-06

 nreg2(38) = -5.9056029685639E-26

 nreg2(39) = 3.7826947613457E-06

 nreg2(40) = -1.2768608934681E-15

 nreg2(41) = 7.3087610595061E-29

 nreg2(42) = 5.5414715350778E-17

 nreg2(43) = -9.436970724121E-07

'

End Sub

'

'

'

Sub InitFieldsreg3()

'

' Initialize coefficients and exponents for region 3

'

 ireg3(1) = 0

 ireg3(2) = 0

 ireg3(3) = 0

 ireg3(4) = 0

 ireg3(5) = 0

 ireg3(6) = 0

 ireg3(7) = 0

 ireg3(8) = 0

 ireg3(9) = 1

 ireg3(10) = 1

 ireg3(11) = 1

 ireg3(12) = 1

 ireg3(13) = 2

 ireg3(14) = 2

 ireg3(15) = 2

 ireg3(16) = 2

 ireg3(17) = 2

 ireg3(18) = 2

 ireg3(19) = 3

 ireg3(20) = 3

 ireg3(21) = 3

 ireg3(22) = 3

 ireg3(23) = 3

 ireg3(24) = 4

 ireg3(25) = 4

 ireg3(26) = 4

 ireg3(27) = 4

 ireg3(28) = 5

 ireg3(29) = 5

 ireg3(30) = 5

 ireg3(31) = 6

 ireg3(32) = 6

 ireg3(33) = 6

 ireg3(34) = 7

 ireg3(35) = 8

 ireg3(36) = 9

 ireg3(37) = 9

 ireg3(38) = 10

 ireg3(39) = 10

 ireg3(40) = 11

'

 jreg3(1) = 0

 jreg3(2) = 0

 jreg3(3) = 1

 jreg3(4) = 2

 jreg3(5) = 7

 jreg3(6) = 10

 jreg3(7) = 12

 jreg3(8) = 23

 jreg3(9) = 2

 jreg3(10) = 6

 jreg3(11) = 15

 jreg3(12) = 17

 jreg3(13) = 0

 jreg3(14) = 2

 jreg3(15) = 6

 jreg3(16) = 7

 jreg3(17) = 22

 jreg3(18) = 26

 jreg3(19) = 0

 jreg3(20) = 2

 jreg3(21) = 4

 jreg3(22) = 16

 jreg3(23) = 26

 jreg3(24) = 0

 jreg3(25) = 2

 jreg3(26) = 4

 jreg3(27) = 26

 jreg3(28) = 1

 jreg3(29) = 3

 jreg3(30) = 26

 jreg3(31) = 0

 jreg3(32) = 2

 jreg3(33) = 26

 jreg3(34) = 2

 jreg3(35) = 26

 jreg3(36) = 2

 jreg3(37) = 26

 jreg3(38) = 0

 jreg3(39) = 1

 jreg3(40) = 26

'

 nreg3(1) = 1.0658070028513

 nreg3(2) = -15.732845290239

 nreg3(3) = 20.944396974307

 nreg3(4) = -7.6867707878716

 nreg3(5) = 2.6185947787954

 nreg3(6) = -2.808078114862

 nreg3(7) = 1.2053369696517

 nreg3(8) = -8.4566812812502E-03

 nreg3(9) = -1.2654315477714

 nreg3(10) = -1.1524407806681

 nreg3(11) = 0.88521043984318

 nreg3(12) = -0.64207765181607

 nreg3(13) = 0.38493460186671

 nreg3(14) = -0.85214708824206

 nreg3(15) = 4.8972281541877

 nreg3(16) = -3.0502617256965

 nreg3(17) = 0.039420536879154

 nreg3(18) = 0.12558408424308

 nreg3(19) = -0.2799932969871

 nreg3(20) = 1.389979956946

 nreg3(21) = -2.018991502357

 nreg3(22) = -8.2147637173963E-03

 nreg3(23) = -0.47596035734923

 nreg3(24) = 0.0439840744735

 nreg3(25) = -0.44476435428739

 nreg3(26) = 0.90572070719733

 nreg3(27) = 0.70522450087967

 nreg3(28) = 0.10770512626332

 nreg3(29) = -0.32913623258954

 nreg3(30) = -0.50871062041158

 nreg3(31) = -0.022175400873096

 nreg3(32) = 0.094260751665092

 nreg3(33) = 0.16436278447961

 nreg3(34) = -0.013503372241348

 nreg3(35) = -0.014834345352472

 nreg3(36) = 5.7922953628084E-04

 nreg3(37) = 3.2308904703711E-03

 nreg3(38) = 8.0964802996215E-05

 nreg3(39) = -1.6557679795037E-04

 nreg3(40) = -4.4923899061815E-05

'

End Sub

'

'

'

Sub InitFieldsreg4()

'

' Initialize coefficients for region 4

'

 nreg4(1) = 1167.0521452767

 nreg4(2) = -724213.16703206

 nreg4(3) = -17.073846940092

 nreg4(4) = 12020.82470247

 nreg4(5) = -3232555.0322333

 nreg4(6) = 14.91510861353

 nreg4(7) = -4823.2657361591

 nreg4(8) = 405113.40542057

 nreg4(9) = -0.23855557567849

 nreg4(10) = 650.17534844798

'

End Sub

'

'

'

Sub InitFieldsbound()

'

' Initialize coefficients for boundary equation

'

 nbound(1) = 348.05185628969

 nbound(2) = -1.1671859879975

 nbound(3) = 1.0192970039326E-03

 nbound(4) = 572.54459862746

 nbound(5) = 13.91883977887

'

End Sub

'

'

'

Sub InitFieldsvisc()

'

' Initialize coefficients and exponents for viscosity

'

 n0visc(0) = 1#

 n0visc(1) = 0.978197

 n0visc(2) = 0.579829

 n0visc(3) = -0.202354

'

 ivisc(1) = 0

 ivisc(2) = 0

 ivisc(3) = 0

 ivisc(4) = 0

 ivisc(5) = 1

 ivisc(6) = 1

 ivisc(7) = 1

 ivisc(8) = 1

 ivisc(9) = 2

 ivisc(10) = 2

 ivisc(11) = 2

 ivisc(12) = 3

 ivisc(13) = 3

 ivisc(14) = 3

 ivisc(15) = 3

 ivisc(16) = 4

 ivisc(17) = 4

 ivisc(18) = 5

 ivisc(19) = 6

'

 jvisc(1) = 0

 jvisc(2) = 1

 jvisc(3) = 4

 jvisc(4) = 5

 jvisc(5) = 0

 jvisc(6) = 1

 jvisc(7) = 2

 jvisc(8) = 3

 jvisc(9) = 0

 jvisc(10) = 1

 jvisc(11) = 2

 jvisc(12) = 0

 jvisc(13) = 1

 jvisc(14) = 2

 jvisc(15) = 3

 jvisc(16) = 0

 jvisc(17) = 3

 jvisc(18) = 1

 jvisc(19) = 3

'

 nvisc(1) = 0.5132047

 nvisc(2) = 0.3205656

 nvisc(3) = -0.7782567

 nvisc(4) = 0.1885447

 nvisc(5) = 0.2151778

 nvisc(6) = 0.7317883

 nvisc(7) = 1.241044

 nvisc(8) = 1.476783

 nvisc(9) = -0.2818107

 nvisc(10) = -1.070786

 nvisc(11) = -1.263184

 nvisc(12) = 0.1778064

 nvisc(13) = 0.460504

 nvisc(14) = 0.2340379

 nvisc(15) = -0.4924179

 nvisc(16) = -0.0417661

 nvisc(17) = 0.1600435

 nvisc(18) = -0.01578386

 nvisc(19) = -0.003629481

'

End Sub

'

'

'

Sub InitFieldsthcon()

'

' Initialize coefficients and exponents for thermal conductivity

'

 n0thcon(0) = 1#

 n0thcon(1) = 6.978267

 n0thcon(2) = 2.599096

 n0thcon(3) = -0.998254

'

 nthcon(0, 0) = 1.3293046

 nthcon(0, 1) = -0.40452437

 nthcon(0, 2) = 0.2440949

 nthcon(0, 3) = 0.018660751

 nthcon(0, 4) = -0.12961068

 nthcon(0, 5) = 0.044809953

 nthcon(1, 0) = 1.7018363

 nthcon(1, 1) = -2.2156845

 nthcon(1, 2) = 1.6511057

 nthcon(1, 3) = -0.76736002

 nthcon(1, 4) = 0.37283344

 nthcon(1, 5) = -0.1120316

 nthcon(2, 0) = 5.2246158

 nthcon(2, 1) = -10.124111

 nthcon(2, 2) = 4.9874687

 nthcon(2, 3) = -0.27297694

 nthcon(2, 4) = -0.43083393

 nthcon(2, 5) = 0.13333849

 nthcon(3, 0) = 8.7127675

 nthcon(3, 1) = -9.5000611

 nthcon(3, 2) = 4.3786606

 nthcon(3, 3) = -0.91783782

 nthcon(3, 4) = 0#

 nthcon(3, 5) = 0#

 nthcon(4, 0) = -1.8525999

 nthcon(4, 1) = 0.9340469

 nthcon(4, 2) = 0#

 nthcon(4, 3) = 0#

 nthcon(4, 4) = 0#

 nthcon(4, 5) = 0#

'

End Sub

'

'

'

Private Function gammareg1(tau, pi)

'

' Fundamental equation for region 1

'

 Call InitFieldsreg1

 gammareg1 = 0

 For i = 1 To 34

 gammareg1 = gammareg1 + nreg1(i) \* (7.1 - pi) ^ ireg1(i) \* (tau - 1.222) ^ jreg1(i)

 Next i

'

End Function

'

'

'

Private Function gammapireg1(tau, pi)

'

' First derivative of fundamental equation in pi for region 1

'

 Call InitFieldsreg1

 gammapireg1 = 0

 For i = 1 To 34

 gammapireg1 = gammapireg1 - nreg1(i) \* ireg1(i) \* (7.1 - pi) ^ (ireg1(i) - 1) \* (tau - 1.222) ^ jreg1(i)

 Next i

'

End Function

'

'

'

Private Function gammapipireg1(tau, pi)

'

' Second derivative of fundamental equation in pi for region 1

'

 Call InitFieldsreg1

 gammapipireg1 = 0

 For i = 1 To 34

 gammapipireg1 = gammapipireg1 + nreg1(i) \* ireg1(i) \* (ireg1(i) - 1) \* (7.1 - pi) ^ (ireg1(i) - 2) \* (tau - 1.222) ^ jreg1(i)

 Next i

'

End Function

'

'

'

Private Function gammataureg1(tau, pi)

'

' First derivative of fundamental equation in tau for region 1

'

 Call InitFieldsreg1

 gammataureg1 = 0

 For i = 1 To 34

 gammataureg1 = gammataureg1 + nreg1(i) \* (7.1 - pi) ^ ireg1(i) \* jreg1(i) \* (tau - 1.222) ^ (jreg1(i) - 1)

 Next i

'

End Function

'

'

'

Private Function gammatautaureg1(tau, pi)

'

' Second derivative of fundamental equation in tau for region 1

'

 Call InitFieldsreg1

 gammatautaureg1 = 0

 For i = 1 To 34

 gammatautaureg1 = gammatautaureg1 + nreg1(i) \* (7.1 - pi) ^ ireg1(i) \* jreg1(i) \* (jreg1(i) - 1) \* (tau - 1.222) ^ (jreg1(i) - 2)

 Next i

'

End Function '

'

'

'

Private Function gammapitaureg1(tau, pi)

'

' Second derivative of fundamental equation in pi and tau for region 1

'

 Call InitFieldsreg1

 gammapitaureg1 = 0

 For i = 1 To 34

 gammapitaureg1 = gammapitaureg1 - nreg1(i) \* ireg1(i) \* (7.1 - pi) ^ (ireg1(i) - 1) \* jreg1(i) \* (tau - 1.222) ^ (jreg1(i) - 1)

 Next i

'

End Function

'

'

'

Private Function gamma0reg2(tau, pi)

'

' Ideal-gas part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gamma0reg2 = Log(pi)

 For i = 1 To 9

 gamma0reg2 = gamma0reg2 + n0reg2(i) \* tau ^ j0reg2(i)

 Next i

'

End Function

'

'

'

Private Function gamma0pireg2(tau, pi)

'

' First derivative in pi of ideal-gas part of fundamental equation for region 2

'

 gamma0pireg2 = 1 / pi

'

End Function

'

'

'

Private Function gamma0pipireg2(tau, pi)

'

' Second derivative in pi of ideal-gas part of fundamental equation for region 2

'

 gamma0pipireg2 = -1 / pi ^ 2

'

End Function

'

'

'

Private Function gamma0taureg2(tau, pi)

'

' First derivative in tau of ideal-gas part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gamma0taureg2 = 0

 For i = 1 To 9

 gamma0taureg2 = gamma0taureg2 + n0reg2(i) \* j0reg2(i) \* tau ^ (j0reg2(i) - 1)

 Next i

'

End Function

'

'

'

Private Function gamma0tautaureg2(tau, pi)

'

' Second derivative in tau of ideal-gas part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gamma0tautaureg2 = 0

 For i = 1 To 9

 gamma0tautaureg2 = gamma0tautaureg2 + n0reg2(i) \* j0reg2(i) \* (j0reg2(i) - 1) \* tau ^ (j0reg2(i) - 2)

 Next i

'

End Function

'

'

'

Private Function gamma0pitaureg2(tau, pi)

'

' Second derivative in pi and tau of ideal-gas part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gamma0pitaureg2 = 0

'

End Function

'

'

'

Private Function gammarreg2(tau, pi)

'

' Residual part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gammarreg2 = 0

 For i = 1 To 43

 gammarreg2 = gammarreg2 + nreg2(i) \* pi ^ ireg2(i) \* (tau - 0.5) ^ jreg2(i)

 Next i

'

End Function

'

'

'

Private Function gammarpireg2(tau, pi)

'

' First derivative in pi of residual part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gammarpireg2 = 0

 For i = 1 To 43

 gammarpireg2 = gammarpireg2 + nreg2(i) \* ireg2(i) \* pi ^ (ireg2(i) - 1) \* (tau - 0.5) ^ jreg2(i)

 Next i

'

End Function

'

'

'

Private Function gammarpipireg2(tau, pi)

'

' Second derivative in pi of residual part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gammarpipireg2 = 0

 For i = 1 To 43

 gammarpipireg2 = gammarpipireg2 + nreg2(i) \* ireg2(i) \* (ireg2(i) - 1) \* pi ^ (ireg2(i) - 2) \* (tau - 0.5) ^ jreg2(i)

 Next i

'

End Function

'

'

'

Private Function gammartaureg2(tau, pi)

'

' First derivative in tau of residual part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gammartaureg2 = 0

 For i = 1 To 43

 gammartaureg2 = gammartaureg2 + nreg2(i) \* pi ^ ireg2(i) \* jreg2(i) \* (tau - 0.5) ^ (jreg2(i) - 1)

 Next i

'

End Function

'

'

'

Private Function gammartautaureg2(tau, pi)

'

' Second derivative in tau of residual part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gammartautaureg2 = 0

 For i = 1 To 43

 gammartautaureg2 = gammartautaureg2 + nreg2(i) \* pi ^ ireg2(i) \* jreg2(i) \* (jreg2(i) - 1) \* (tau - 0.5) ^ (jreg2(i) - 2)

 Next i

'

End Function

'

'

'

Private Function gammarpitaureg2(tau, pi)

'

' Second derivative in pi and tau of residual part of fundamental equation for region 2

'

 Call InitFieldsreg2

 gammarpitaureg2 = 0

 For i = 1 To 43

 gammarpitaureg2 = gammarpitaureg2 + nreg2(i) \* ireg2(i) \* pi ^ (ireg2(i) - 1) \* jreg2(i) \* (tau - 0.5) ^ (jreg2(i) - 1)

 Next i

'

End Function

'

'

'

Private Function fireg3(tau, delta)

'

' Fundamental equation for region 3

'

 Call InitFieldsreg3

 fireg3 = nreg3(1) \* Log(delta)

 For i = 2 To 40

 fireg3 = fireg3 + nreg3(i) \* delta ^ ireg3(i) \* tau ^ jreg3(i)

 Next i

'

End Function

'

'

'

Private Function fideltareg3(tau, delta)

'

' First derivative in delta of fundamental equation for region 3

'

 Call InitFieldsreg3

 fideltareg3 = nreg3(1) / delta

 For i = 2 To 40

 fideltareg3 = fideltareg3 + nreg3(i) \* ireg3(i) \* delta ^ (ireg3(i) - 1) \* tau ^ jreg3(i)

 Next i

'

End Function

'

'

'

Private Function fideltadeltareg3(tau, delta)

'

' Second derivative in delta of fundamental equation for region 3

'

 Call InitFieldsreg3

 fideltadeltareg3 = -nreg3(1) / delta ^ 2

 For i = 2 To 40

 fideltadeltareg3 = fideltadeltareg3 + nreg3(i) \* ireg3(i) \* (ireg3(i) - 1) \* delta ^ (ireg3(i) - 2) \* tau ^ jreg3(i)

 Next i

'

End Function

'

'

'

Private Function fitaureg3(tau, delta)

'

' First derivative in tau of fundamental equation for region 3

'

 Call InitFieldsreg3

 fitaureg3 = 0

 For i = 2 To 40

 fitaureg3 = fitaureg3 + nreg3(i) \* delta ^ ireg3(i) \* jreg3(i) \* tau ^ (jreg3(i) - 1)

 Next i

'

End Function

'

'

'

Private Function fitautaureg3(tau, delta)

'

' Second derivative in tau of fundamental equation for region 3

'

 Call InitFieldsreg3

 fitautaureg3 = 0

 For i = 2 To 40

 fitautaureg3 = fitautaureg3 + nreg3(i) \* delta ^ ireg3(i) \* jreg3(i) \* (jreg3(i) - 1) \* tau ^ (jreg3(i) - 2)

 Next i

'

End Function

'

'

'

Private Function fideltataureg3(tau, delta)

'

' Second derivative in delta and tau of fundamental equation for region 3

'

 Call InitFieldsreg3

 fideltataureg3 = 0

 For i = 2 To 40

 fideltataureg3 = fideltataureg3 + nreg3(i) \* ireg3(i) \* delta ^ (ireg3(i) - 1) \* jreg3(i) \* tau ^ (jreg3(i) - 1)

 Next i

'

End Function

'

'

'

Private Function psivisc(tau, delta)

'

' Reduced dynamic viscosity

'

 Call InitFieldsvisc

 psi0 = 0

 psi1 = 0

 For i = 0 To 3

 psi0 = psi0 + n0visc(i) \* tau ^ i

 Next i

 psi0 = 1 / (tau ^ 0.5 \* psi0)

 For i = 1 To 19

 psi1 = psi1 + nvisc(i) \* (delta - 1#) ^ ivisc(i) \* (tau - 1#) ^ jvisc(i)

 Next i

 psi1 = Exp(delta \* psi1)

 psivisc = psi0 \* psi1

'

End Function

'

'

'

Private Function lambthcon(temperature, pressure, tau, delta)

'

' Reduced thermal conductivity

'

 Call InitFieldsthcon

 lamb0 = 0

 lamb1 = 0

 For i = 0 To 3

 lamb0 = lamb0 + n0thcon(i) \* tau ^ i

 Next i

 lamb0 = 1 / (tau ^ 0.5 \* lamb0)

 For i = 0 To 4

 For j = 0 To 5

 lamb1 = lamb1 + nthcon(i, j) \* (tau - 1#) ^ i \* (delta - 1#) ^ j

 Next j

 Next i

 lamb1 = Exp(delta \* lamb1)

'

' v1.1: calculation of lamb2 corrected

'

 If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

 taus = 1386# / temperature

 pis = pressure / 165.3

 dpidtau = (647.226 \* 165.3 \* (gammapitaureg1(taus, pis) \* 1386# - gammapireg1(taus, pis) \* temperature)) / (221.15 \* temperature ^ 2 \* gammapipireg1(taus, pis))

 ddeltadpi = -(22115000# \* gammapipireg1(taus, pis)) / (317.763 \* rgas\_water \* temperature \* gammapireg1(taus, pis) ^ 2)

 ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

 taus = 540# / temperature

 pis = pressure / 10#

 dpidtau = (647.226 \* 10# \* ((gamma0pitaureg2(taus, pis) + gammarpitaureg2(taus, pis)) \* 540# - (gamma0pireg2(taus, pis) + gammarpireg2(taus, pis)) \* temperature)) / (221.15 \* temperature ^ 2 \* (gamma0pipireg2(taus, pis) + gammarpipireg2(taus, pis)))

 ddeltadpi = -(22115000# \* (gamma0pipireg2(taus, pis) + gammarpipireg2(taus, pis))) / (317.763 \* rgas\_water \* temperature \* (gamma0pireg2(taus, pis) + gammarpireg2(taus, pis)) ^ 2)

 ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

 taus = 647.096 / temperature

 deltas = delta \* 317.763 / 322#

 dpidtau = (647.226 \* rgas\_water \* (delta \* 317.763) ^ 2 \* (fideltareg3(taus, deltas) - (647.096 / temperature) \* fideltataureg3(taus, deltas))) / (22115000# \* 322#)

 ddeltadpi = (22115000# \* 322#) / (317.763 \* delta \* 317.763 \* rgas\_water \* temperature \* (2 \* fideltareg3(taus, deltas) + (delta \* 317.763 / 322#) \* fideltadeltareg3(taus, deltas)))

 Else

' outside range

 dpidtau = 0

 ddeltadpi = 0

 End If

 lamb2 = 0.0013848 / psivisc(tau, delta) \* (tau \* delta) ^ (-2) \* dpidtau ^ 2 \* (delta \* ddeltadpi) ^ 0.4678 \* delta ^ 0.5 \* Exp(-18.66 \* (1 / tau - 1) ^ 2 - (delta - 1) ^ 4)

 lambthcon = lamb0 \* lamb1 + lamb2

'

End Function

'

'

'

Public Function pSatW(temperature)

'

' saturation pressure of water

' pSatW in bar

' temperature in K

'

' pSatW = -1: temperature outside range

'

'

 If temperature < 273.15 Or temperature > 647.096 Then

 pSatW = -1#

 Else

 Call InitFieldsreg4

 del = temperature + nreg4(9) / (temperature - nreg4(10))

 aco = del ^ 2 + nreg4(1) \* del + nreg4(2)

 bco = nreg4(3) \* del ^ 2 + nreg4(4) \* del + nreg4(5)

 cco = nreg4(6) \* del ^ 2 + nreg4(7) \* del + nreg4(8)

 pSatW = (2 \* cco / (-bco + (bco ^ 2 - 4 \* aco \* cco) ^ 0.5)) ^ 4 \* 10

 End If

'

End Function

'

'

'

Public Function tSatW(pressure)

'

' saturation temperature of water

' tSatW in K

' pressure in bar

'

' tSatW = -1: pressure outside range

'

'

 If pressure < 0.00611213 Or pressure > 220.64 Then

 tSatW = -1#

 Else

 Call InitFieldsreg4

 bet = (0.1 \* pressure) ^ 0.25

 eco = bet ^ 2 + nreg4(3) \* bet + nreg4(6)

 fco = nreg4(1) \* bet ^ 2 + nreg4(4) \* bet + nreg4(7)

 gco = nreg4(2) \* bet ^ 2 + nreg4(5) \* bet + nreg4(8)

 dco = 2 \* gco / (-fco - (fco ^ 2 - 4 \* eco \* gco) ^ 0.5)

 tSatW = 0.5 \* (nreg4(10) + dco - ((nreg4(10) + dco) ^ 2 - 4 \* (nreg4(9) + nreg4(10) \* dco)) ^ 0.5)

 End If

'

End Function

'

'

'

Private Function pBound(temperature)

'

' boundary pressure between regions 2 and 3

' pBound in bar

' temperature in K

'

' pBound = -1: temperature outside range

'

'

 If temperature < 623.15 Or temperature > 863.15 Then

 pBound = -1#

 Else

 Call InitFieldsbound

 pBound = (nbound(1) + nbound(2) \* temperature + nbound(3) \* temperature ^ 2) \* 10#

 End If

'

End Function

'

'

'

Private Function tBound(pressure)

'

' boundary temperature between regions 2 and 3

' tBound in K

' pressure in bar

'

' tBound = -1: pressure outside range

'

'

 If pressure < 165.292 Or pressure > 1000# Then

 tBound = -1#

 Else

 Call InitFieldsbound

 tBound = nbound(4) + ((0.1 \* pressure - nbound(5)) / nbound(3)) ^ 0.5

 End If

'

End Function

'

'

'

Private Function volreg1(temperature, pressure)

'

' specific volume in region 1

' volreg1 in m^3/kg

' temperature in K

' pressure in bar

'

 tau = 1386# / temperature

 pi = 0.1 \* pressure / 16.53

 volreg1 = rgas\_water \* temperature \* pi \* gammapireg1(tau, pi) / (pressure \* 100000#)

'

End Function

'

'

'

Private Function energyreg1(temperature, pressure)

'

' specific internal energy in region 1

' energyreg1 in kJ/kg

' temperature in K

' pressure in bar

'

 tau = 1386# / temperature

 pi = 0.1 \* pressure / 16.53

 energyreg1 = 0.001 \* rgas\_water \* temperature \* (tau \* gammataureg1(tau, pi) - pi \* gammapireg1(tau, pi))

'

End Function

'

'

'

Private Function entropyreg1(temperature, pressure)

'

' specific entropy in region 1

' entropyreg1 in kJ/(kg K)

' temperature in K

' pressure in bar

'

 tau = 1386# / temperature

 pi = 0.1 \* pressure / 16.53

 entropyreg1 = 0.001 \* rgas\_water \* (tau \* gammataureg1(tau, pi) - gammareg1(tau, pi))

'

End Function

'

'

'

Private Function enthalpyreg1(temperature, pressure)

'

' specific enthalpy in region 1

' enthalpyreg1 in kJ/kg

' temperature in K

' pressure in bar

'

 tau = 1386# / temperature

 pi = 0.1 \* pressure / 16.53

 enthalpyreg1 = 0.001 \* rgas\_water \* temperature \* tau \* gammataureg1(tau, pi)

'

End Function

'

'

'

Private Function cpreg1(temperature, pressure)

'

' specific isobaric heat capacity in region 1

' cpreg1 in kJ/(kg K)

' temperature in K

' pressure in bar

'

 tau = 1386# / temperature

 pi = 0.1 \* pressure / 16.53

 cpreg1 = -0.001 \* rgas\_water \* tau ^ 2 \* gammatautaureg1(tau, pi)

'

End Function

'

'

'

Private Function cvreg1(temperature, pressure)

'

' specific isochoric heat capacity in region 1

' cvreg1 in kJ/(kg K)

' temperature in K

' pressure in bar

'

 tau = 1386# / temperature

 pi = 0.1 \* pressure / 16.53

 cvreg1 = 0.001 \* rgas\_water \* (-tau ^ 2 \* gammatautaureg1(tau, pi) + (gammapireg1(tau, pi) - tau \* gammapitaureg1(tau, pi)) ^ 2 / gammapipireg1(tau, pi))

'

End Function

'

'

'

' Private Function spsoundreg1(temperature, pressure)

'

' speed of sound in region 1

' spsoundreg1 in m/s

' temperature in K

' pressure in bar

'

' tau = 540# / temperature

' pi = 0.1 \* pressure / 16.53

' spsoundreg1 = (rgas\_water \* temperature \* (gammapireg1(tau, pi) ^ 2 / ((gammapireg1(tau, pi) - tau \* gammapitaureg1(tau, pi)) ^ 2 / (tau ^ 2 \* gammatautaureg1(tau, pi)) - gammapipireg1(tau, pi)))) ^ 0.5

'

' End Function

'

'

'

Private Function volreg2(temperature, pressure)

'

' specific volume in region 2

' volreg2 in m^3/kg

' temperature in K

' pressure in bar

'

 tau = 540# / temperature

 pi = 0.1 \* pressure

 volreg2 = rgas\_water \* temperature \* pi \* (gamma0pireg2(tau, pi) + gammarpireg2(tau, pi)) / (pressure \* 100000#)

'

End Function

'

'

'

Private Function energyreg2(temperature, pressure)

'

' specific internal energy in region 2

' energyreg2 in kJ/kg

' temperature in K

' pressure in bar

'

 tau = 540# / temperature

 pi = 0.1 \* pressure

 energyreg2 = 0.001 \* rgas\_water \* temperature \* (tau \* (gamma0taureg2(tau, pi) + gammartaureg2(tau, pi)) - pi \* (gamma0pireg2(tau, pi) + gammarpireg2(tau, pi)))

'

End Function

'

'

'

Private Function entropyreg2(temperature, pressure)

'

' specific entropy in region 2

' entropyreg2 in kJ/(kg K)

' temperature in K

' pressure in bar

'

 tau = 540# / temperature

 pi = 0.1 \* pressure

 entropyreg2 = 0.001 \* rgas\_water \* (tau \* (gamma0taureg2(tau, pi) + gammartaureg2(tau, pi)) - (gamma0reg2(tau, pi) + gammarreg2(tau, pi)))

'

End Function

'

'

'

Private Function enthalpyreg2(temperature, pressure)

'

' specific enthalpy in region 2

' enthalpyreg2 in kJ/kg

' temperature in K

' pressure in bar

'

 tau = 540# / temperature

 pi = 0.1 \* pressure

 enthalpyreg2 = 0.001 \* rgas\_water \* temperature \* tau \* (gamma0taureg2(tau, pi) + gammartaureg2(tau, pi))

'

End Function

'

'

'

Private Function cpreg2(temperature, pressure)

'

' specific isobaric heat capacity in region 2

' cpreg2 in kJ/(kg K)

' temperature in K

' pressure in bar

'

 tau = 540# / temperature

 pi = 0.1 \* pressure

 cpreg2 = -0.001 \* rgas\_water \* tau ^ 2 \* (gamma0tautaureg2(tau, pi) + gammartautaureg2(tau, pi))

'

End Function

'

'

'

Private Function cvreg2(temperature, pressure)

'

' specific isochoric heat capacity in region 2

' cvreg2 in kJ/(kg K)

' temperature in K

' pressure in bar

'

 tau = 540# / temperature

 pi = 0.1 \* pressure

 cvreg2 = 0.001 \* rgas\_water \* (-tau ^ 2 \* (gamma0tautaureg2(tau, pi) + gammartautaureg2(tau, pi)) - (1 + pi \* gammarpireg2(tau, pi) - tau \* pi \* gammarpitaureg2(tau, pi)) ^ 2 / (1 - pi ^ 2 \* gammarpipireg2(tau, pi)))

'

End Function

'

'

'

' Private Function spsoundreg2(temperature, pressure)

'

' speed of sound in region 2

' spsoundreg2 in m/s

' temperature in K

' pressure in bar

'

' tau = 540# / temperature

' pi = 0.1 \* pressure

' spsoundreg2 = (rgas\_water \* temperature \* (1 + 2 \* pi \* gammarpireg2(tau, pi) + pi ^ 2 \* gammarpireg2(tau, pi) ^ 2) / ((1 - pi ^ 2 \* gammarpipireg2(tau, pi)) + (1 + pi \* gammarpireg2(tau, pi) - tau \* pi \* gammarpitaureg2(tau, pi)) ^ 2 / (tau ^ 2 \* (gamma0tautaureg2(tau, pi) + gammartautaureg2(tau, pi))))) ^ 0.5

'

' End Function

'

'

'

Private Function pressreg3(temperature, density)

'

' pressure in region 3

' pressreg3 in bar

' temperature in K

' density in kg/m^3

'

 tau = tc\_water / temperature

 delta = density / dc\_water

 pressreg3 = density \* rgas\_water \* temperature \* delta \* fideltareg3(tau, delta) / 100000#

'

End Function

'

'

'

Private Function energyreg3(temperature, density)

'

' specific internal energy in region 3

' energyreg3 in kJ/kg

' temperature in K

' density in kg/m^3

'

 tau = tc\_water / temperature

 delta = density / dc\_water

 energyreg3 = 0.001 \* rgas\_water \* temperature \* tau \* fitaureg3(tau, delta)

'

End Function

'

'

'

Private Function entropyreg3(temperature, density)

'

' specific entropy in region 3

' entropyreg3 in kJ/(kg K)

' temperature in K

' density in kg/m^3

'

 tau = tc\_water / temperature

 delta = density / dc\_water

 entropyreg3 = 0.001 \* rgas\_water \* (tau \* fitaureg3(tau, delta) - fireg3(tau, delta))

'

End Function

'

'

'

Private Function enthalpyreg3(temperature, density)

'

' specific enthalpy in region 3

' enthalpyreg3 in kJ/kg

' temperature in K

' density in kg/m^3

'

 tau = tc\_water / temperature

 delta = density / dc\_water

 enthalpyreg3 = 0.001 \* rgas\_water \* temperature \* (tau \* fitaureg3(tau, delta) + delta \* fideltareg3(tau, delta))

'

End Function

'

'

'

Private Function cpreg3(temperature, density)

'

' specific isobaric heat capacity in region 3

' cpreg3 in kJ/(kg K)

' temperature in K

' density in kg/m^3

'

 tau = tc\_water / temperature

 delta = density / dc\_water

 cpreg3 = 0.001 \* rgas\_water \* (-tau ^ 2 \* fitautaureg3(tau, delta) + (delta \* fideltareg3(tau, delta) - delta \* tau \* fideltataureg3(tau, delta)) ^ 2 / (2 \* delta \* fideltareg3(tau, delta) + delta ^ 2 \* fideltadeltareg3(tau, delta)))

'

End Function

'

'

'

Private Function cvreg3(temperature, density)

'

' specific isochoric heat capacity in region 3

' cvreg3 in kJ/(kg K)

' temperature in K

' density in kg/m^3

'

 tau = tc\_water / temperature

 delta = density / dc\_water

 cvreg3 = 0.001 \* rgas\_water \* (-tau ^ 2 \* fitautaureg3(tau, delta))

'

End Function

'

'

'

' Private Function spsoundreg3(temperature, density)

'

' speed of sound in region 3

' spsoundreg3 in m/s

' temperature in K

' density in kg/m^3

'

' tau = tc\_water / temperature

' delta = density / dc\_water

' spsoundreg3 = (rgas\_water \* temperature \* (2 \* delta \* fideltareg3(tau, delta) + delta ^ 2 \* fideltadeltareg3(tau, delta) - (delta \* fideltareg3(tau, delta) - delta \* tau \* fideltataureg3(tau, delta)) ^ 2 / (tau ^ 2 \* fitautaureg3(tau, delta)))) ^ 0.5

'

' End Function

'

'

'

Private Function densreg3(temperature, pressure)

'

' Determine density in region 3 iteratively using Newton method

' densreg3 in kg/m^3

' temperature in K

' pressure in bar

'

' densreg3 = -2: not converged

'

 If temperature < tc\_water And pressure < pSatW(temperature) Then

 densold = 100#

 Else

 densold = 600#

 End If

 tau = tc\_water / temperature

'

 For j = 1 To 1000

 delta = densold / dc\_water

 derivprho = rgas\_water \* temperature / dc\_water \* (2 \* densold \* fideltareg3(tau, delta) + densold ^ 2 / dc\_water \* fideltadeltareg3(tau, delta))

 densnew = densold + (pressure \* 100000# - rgas\_water \* temperature \* densold ^ 2 / dc\_water \* fideltareg3(tau, delta)) / derivprho

 diffdens = Abs(densnew - densold)

 If diffdens < 0.000005 Then

 densreg3 = densnew

 Exit Function

 End If

 densold = densnew

 Next j

 densreg3 = -2#

'

End Function

'

'

'

Public Function densW(temperature, pressure)

'

' density of water or steam

' densW in kg/m^3

' temperature in K

' pressure in bar

'

' densW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

 densW = 1 / volreg1(temperature, pressure)

 ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

 densW = 1 / volreg2(temperature, pressure)

 ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

 densW = densreg3(temperature, pressure)

 Else

' outside range

 densW = -1#

 End If

'

End Function

'

'

'

Public Function energyW(temperature, pressure)

'

' specific internal energy of water or steam

' energyW in kJ/kg

' temperature in K

' pressure in bar

'

' energyW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

 energyW = energyreg1(temperature, pressure)

 ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

 energyW = energyreg2(temperature, pressure)

 ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

 density = densreg3(temperature, pressure)

 energyW = energyreg3(temperature, density)

 Else

' outside range

 energyW = -1#

 End If

'

End Function

'

'

'

Public Function entropyW(temperature, pressure)

'

' specific entropy of water or steam

' entropyW in kJ/(kg K)

' temperature in K

' pressure in bar

'

' entropyW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

 entropyW = entropyreg1(temperature, pressure)

 ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

 entropyW = entropyreg2(temperature, pressure)

 ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

 density = densreg3(temperature, pressure)

 entropyW = entropyreg3(temperature, density)

 Else

' outside range

 entropyW = -1#

 End If

'

End Function

'

'

'

Public Function enthalpyW(temperature, pressure)

'

' specific enthalpy of water or steam

' enthalpyW in kJ/kg

' temperature in K

' pressure in bar

'

' enthalpyW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

 enthalpyW = enthalpyreg1(temperature, pressure)

 ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

 enthalpyW = enthalpyreg2(temperature, pressure)

 ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

 density = densreg3(temperature, pressure)

 enthalpyW = enthalpyreg3(temperature, density)

 Else

' outside range

 enthalpyW = -1#

 End If

'

End Function

'

'

'

Public Function cpW(temperature, pressure)

'

' specific isobaric heat capacity of water or steam

' cpW in kJ/(kg K)

' temperature in K

' pressure in bar

'

' cpW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

 cpW = cpreg1(temperature, pressure)

 ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

 cpW = cpreg2(temperature, pressure)

 ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

 density = densreg3(temperature, pressure)

 cpW = cpreg3(temperature, density)

 Else

' outside range

 cpW = -1#

 End If

'

End Function

'

'

'

Public Function cvW(temperature, pressure)

'

' specific isochoric heat capacity of water or steam

' cvW in kJ/(kg K)

' temperature in K

' pressure in bar

'

' cvW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

 cvW = cvreg1(temperature, pressure)

 ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

 cvW = cvreg2(temperature, pressure)

 ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

 density = densreg3(temperature, pressure)

 cvW = cvreg3(temperature, density)

 Else

' outside range

 cvW = -1#

 End If

'

End Function

'

'

'

' Public Function spsoundW(temperature, pressure)

'

' speed of sound in water or steam

' spsoundW in m/s

' temperature in K

' pressure in bar

'

' spsoundW = -1: temperature and/or pressure outside range

'

' If temperature >= 273.15 And temperature <= 623.15 And pressure >= pSatW(temperature) And pressure <= 1000# Then

' region 1

' spsoundW = spsoundreg1(temperature, pressure)

' ElseIf (temperature >= 273.15 And temperature <= 623.15 And pressure > 0 And pressure <= pSatW(temperature)) Or (temperature >= 623.15 And temperature <= 863.15 And pressure > 0 And pressure <= pBound(temperature)) Or (temperature >= 863.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000#) Then

' region 2

' spsoundW = spsoundreg2(temperature, pressure)

' ElseIf temperature >= 623.15 And temperature <= tBound(pressure) And pressure >= pBound(temperature) And pressure <= 1000# Then

' region 3

' density = densreg3(temperature, pressure)

' spsoundW = spsoundreg3(temperature, density)

' Else

' outside range

' spsoundW = -1#

' End If

'

' End Function

'

'

'

Public Function viscW(temperature, pressure)

'

' dynamic viscosity of water or steam

' viscW in Pa s

' temperature in K

' pressure in bar

'

' viscW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000# Then

 density = densW(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscW = 0.000055071 \* psivisc(tau, delta)

 Else

' outside range

 viscW = -1#

 End If

'

End Function

'

'

'

Public Function thconW(temperature, pressure)

'

' thermal conductivity of water or steam

' thconW in W/(m K)

' temperature in K

' pressure in bar

'

' thconW = -1: temperature and/or pressure outside range

'

 If temperature >= 273.15 And temperature <= 1073.15 And pressure > 0 And pressure <= 1000# Then

 density = densW(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 thconW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 Else

' outside range

 thconW = -1#

 End If

'

End Function

'

'

'

Public Function densSatLiqTW(temperature)

'

' density of saturated liquid water as a function of temperature

' densSatLiqTW in kg/m^3

' temperature in K

'

' densSatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 densSatLiqTW = 1 / volreg1(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 densSatLiqTW = densreg3(temperature, pressure)

 Else

' outside range

 densSatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function densSatVapTW(temperature)

'

' density of saturated steam as a function of temperature

' densSatVapTW in kg/m^3

' temperature in K

'

' densSatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 densSatVapTW = 1 / volreg2(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 densSatVapTW = densreg3(temperature, pressure)

 Else

' outside range

 densSatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function densSatLiqPW(pressure)

'

' density of saturated liquid water as a function of pressure

' densSatLiqPW in kg/m^3

' pressure in bar

'

' densSatLiqPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

 temperature = tSatW(pressure)

 densSatLiqPW = 1 / volreg1(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 densSatLiqPW = densreg3(temperature, pressure)

 Else

' outside range

 densSatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function densSatVapPW(pressure)

'

' density of saturated steam as a function of pressure

' densSatVapPW in kg/m^3

' pressure in bar

'

' densSatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 densSatVapPW = 1 / volreg2(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure - 0.00001

 densSatVapPW = densreg3(temperature, pressure)

 Else

' outside range

 densSatVapPW = -1#

 End If

'

End Function

'

'

'

Public Function energySatLiqTW(temperature)

'

' specific internal energy of saturated liquid water as a function of temperature

' energySatLiqTW in kJ/kg

' temperature in K

'

' energySatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 energySatLiqTW = energyreg1(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 density = densreg3(temperature, pressure)

 energySatLiqTW = energyreg3(temperature, density)

 Else

' outside range

 energySatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function energySatVapTW(temperature)

'

' specific internal energy of saturated steam as a function of temperature

' energySatVapTW in kJ/kg

' temperature in K

'

' energySatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 energySatVapTW = energyreg2(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 density = densreg3(temperature, pressure)

 energySatVapTW = energyreg3(temperature, density)

 Else

' outside range

 energySatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function energySatLiqPW(pressure)

'

' specific internal energy of saturated liquid water as a function of pressure

' energySatLiqPW in kJ/kg

' pressure in bar

'

' energySatLiqPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

 temperature = tSatW(pressure)

 energySatLiqPW = energyreg1(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 density = densreg3(temperature, pressure)

 energySatLiqPW = energyreg3(temperature, density)

 Else

' outside range

 energySatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function energySatVapPW(pressure)

'

' specific internal energy of saturated steam as a function of pressure

' energySatVapPW in kJ/kg

' pressure in bar

'

' energySatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 energySatVapPW = energyreg2(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure - 0.00001

 density = densreg3(temperature, pressure)

 energySatVapPW = energyreg3(temperature, density)

 Else

' outside range

 energySatVapPW = -1#

 End If

'

End Function

'

'

'

Public Function entropySatLiqTW(temperature)

'

' specific entropy of saturated liquid water as a function of temperature

' entropySatLiqTW in kJ/(kg K)

' temperature in K

'

' entropySatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 entropySatLiqTW = entropyreg1(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 density = densreg3(temperature, pressure)

 entropySatLiqTW = entropyreg3(temperature, density)

 Else

' outside range

 entropySatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function entropySatVapTW(temperature)

'

' specific entropy of saturated steam as a function of temperature

' entropySatVapTW in kJ/(kg K)

' temperature in K

'

' entropySatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 entropySatVapTW = entropyreg2(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 density = densreg3(temperature, pressure)

 entropySatVapTW = entropyreg3(temperature, density)

 Else

' outside range

 entropySatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function entropySatLiqPW(pressure)

'

' specific entropy of saturated liquid water as a function of pressure

' entropySatLiqPW in kJ/(kg K)

' pressure in bar

'

' entropySatLiqPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

 temperature = tSatW(pressure)

 entropySatLiqPW = entropyreg1(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 density = densreg3(temperature, pressure)

 entropySatLiqPW = entropyreg3(temperature, density)

 Else

' outside range

 entropySatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function entropySatVapPW(pressure)

'

' specific entropy of saturated steam as a function of pressure

' entropySatVapPW in kJ/(kg K)

' pressure in bar

'

' entropySatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 entropySatVapPW = entropyreg2(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure - 0.00001

 density = densreg3(temperature, pressure)

 entropySatVapPW = entropyreg3(temperature, density)

 Else

' outside range

 entropySatVapPW = -1#

 End If

'

End Function

'

'

'

Public Function enthalpySatLiqTW(temperature)

'

' specific enthalpy of saturated liquid water as a function of temperature

' enthalpySatLiqTW in kJ/kg

' temperature in K

'

' enthalpySatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 enthalpySatLiqTW = enthalpyreg1(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 density = densreg3(temperature, pressure)

 enthalpySatLiqTW = enthalpyreg3(temperature, density)

 Else

' outside range

 enthalpySatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function enthalpySatVapTW(temperature)

'

' specific enthalpy of saturated steam as a function of temperature

' enthalpySatVapTW in kJ/kg

' temperature in K

'

' enthalpySatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 enthalpySatVapTW = enthalpyreg2(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 density = densreg3(temperature, pressure)

 enthalpySatVapTW = enthalpyreg3(temperature, density)

 Else

' outside range

 enthalpySatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function enthalpySatLiqPW(pressure)

'

' specific enthalpy of saturated liquid water as a function of pressure

' enthalpySatLiqPW in kJ/kg

' pressure in bar

'

' enthalpySatLiqPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

 temperature = tSatW(pressure)

 enthalpySatLiqPW = enthalpyreg1(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 density = densreg3(temperature, pressure)

 enthalpySatLiqPW = enthalpyreg3(temperature, density)

 Else

' outside range

 enthalpySatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function enthalpySatVapPW(pressure)

'

' specific enthalpy of saturated steam as a function of pressure

' enthalpySatVapPW in kJ/kg

' pressure in bar

'

' enthalpySatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 enthalpySatVapPW = enthalpyreg2(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure - 0.00001

 density = densreg3(temperature, pressure)

 enthalpySatVapPW = enthalpyreg3(temperature, density)

 Else

' outside range

 enthalpySatVapPW = -1#

 End If

'

End Function

'

'

'

Public Function cpSatLiqTW(temperature)

'

' specific isobaric heat capacity of saturated liquid water as a function of temperature

' cpSatLiqTW in kJ/(kg K)

' temperature in K

'

' cpSatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 cpSatLiqTW = cpreg1(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 density = densreg3(temperature, pressure)

 cpSatLiqTW = cpreg3(temperature, density)

 Else

' outside range

 cpSatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function cpSatVapTW(temperature)

'

' specific isobaric heat capacity of saturated steam as a function of temperature

' cpSatVapTW in kJ/(kg K)

' temperature in K

'

' cpSatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 cpSatVapTW = cpreg2(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 density = densreg3(temperature, pressure)

 cpSatVapTW = cpreg3(temperature, density)

 Else

' outside range

 cpSatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function cpSatLiqPW(pressure)

'

' specific isobaric heat capacity of saturated liquid water as a function of pressure

' cpSatLiqPW in kJ/(kg K)

' pressure in bar

'

' cpSatLiqPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

 temperature = tSatW(pressure)

 cpSatLiqPW = cpreg1(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 density = densreg3(temperature, pressure)

 cpSatLiqPW = cpreg3(temperature, density)

 Else

' outside range

 cpSatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function cpSatVapPW(pressure)

'

' specific isobaric heat capacity of saturated steam as a function of pressure

' cpSatVapPW in kJ/(kg K)

' pressure in bar

'

' cpSatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 cpSatVapPW = cpreg2(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure - 0.00001

 density = densreg3(temperature, pressure)

 cpSatVapPW = cpreg3(temperature, density)

 Else

' outside range

 cpSatVapPW = -1#

 End If

'

End Function

'

'

'

Public Function cvSatLiqTW(temperature)

'

' specific isochoric heat capacity of saturated liquid water as a function of temperature

' cvSatLiqTW in kJ/(kg K)

' temperature in K

'

' cvSatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 cvSatLiqTW = cvreg1(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 density = densreg3(temperature, pressure)

 cvSatLiqTW = cvreg3(temperature, density)

 Else

' outside range

 cvSatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function cvSatVapTW(temperature)

'

' specific isochoric heat capacity of saturated steam as a function of temperature

' cvSatVapTW in kJ/(kg K)

' temperature in K

'

' cvSatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 cvSatVapTW = cvreg2(temperature, pressure)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 density = densreg3(temperature, pressure)

 cvSatVapTW = cvreg3(temperature, density)

 Else

' outside range

 cvSatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function cvSatLiqPW(pressure)

'

' specific isochoric heat capacity of saturated liquid water as a function of pressure

' cvSatLiqPW in kJ/(kg K)

' pressure in bar

'

' cvSatLiqPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

 temperature = tSatW(pressure)

 cvSatLiqPW = cvreg1(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 density = densreg3(temperature, pressure)

 cvSatLiqPW = cvreg3(temperature, density)

 Else

' outside range

 cvSatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function cvSatVapPW(pressure)

'

' specific isochoric heat capacity of saturated steam as a function of pressure

' cvSatVapPW in kJ/(kg K)

' pressure in bar

'

' cvSatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 cvSatVapPW = cvreg2(temperature, pressure)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure - 0.00001

 density = densreg3(temperature, pressure)

 cvSatVapPW = cvreg3(temperature, density)

 Else

' outside range

 cvSatVapPW = -1#

 End If

'

End Function

'

'

'

' Public Function spsoundSatLiqTW(temperature)

'

' speed of sound in saturated liquid water as a function of temperature

' spsoundSatLiqTW in m/s

' temperature in K

'

' spsoundSatLiqTW = -1: temperature outside range

'

' If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

' pressure = pSatW(temperature)

' spsoundSatLiqTW = spsoundreg1(temperature, pressure)

' ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

' pressure = pSatW(temperature)

' density = densreg3(temperature, pressure)

' spsoundSatLiqTW = spsoundreg3(temperature, density)

' Else

' outside range

' spsoundSatLiqTW = -1#

' End If

'

' End Function

'

'

'

' Public Function spsoundSatVapTW(temperature)

'

' speed of sound in saturated steam as a function of temperature

' spsoundSatVapTW in m/s

' temperature in K

'

' spsoundSatVapTW = -1: temperature outside range

'

' If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

' pressure = pSatW(temperature)

' spsoundSatVapTW = spsoundreg2(temperature, pressure)

' ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

' pressure = pSatW(temperature) - 0.00001

' density = densreg3(temperature, pressure)

' spsoundSatVapTW = spsoundreg3(temperature, density)

' Else

' outside range

' spsoundSatVapTW = -1#

' End If

'

' End Function

'

'

'

' Public Function spsoundSatLiqPW(pressure)

'

' speed of sound in saturated liquid water as a function of pressure

' spsoundSatLiqPW in m/s

' pressure in bar

'

' spsoundSatLiqPW = -1: pressure outside range

'

' If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

' temperature = tSatW(pressure)

' spsoundSatLiqPW = spsoundreg1(temperature, pressure)

' ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

' temperature = tSatW(pressure)

' pressure = pressure + 0.00001

' density = densreg3(temperature, pressure)

' spsoundSatLiqPW = spsoundreg3(temperature, density)

' Else

' outside range

' spsoundSatLiqPW = -1#

' End If

'

' End Function

'

'

'

' Public Function spsoundSatVapPW(pressure)

'

' speed of sound in saturated steam as a function of pressure

' spsoundSatVapPW in m/s

' pressure in bar

'

' spsoundSatVapPW = -1: pressure outside range

'

' If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

' temperature = tSatW(pressure)

' spsoundSatVapPW = spsoundreg2(temperature, pressure)

' ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

' temperature = tSatW(pressure)

' pressure = pressure - 0.00001

' density = densreg3(temperature, pressure)

' spsoundSatVapPW = spsoundreg3(temperature, density)

' Else

' outside range

' spsoundSatVapPW = -1#

' End If

'

' End Function

'

'

'

Public Function viscSatLiqTW(temperature)

'

' dynamic viscosity of saturated liquid water as a function of temperature

' viscSatLiqTW in Pa s

' temperature in K

'

' viscSatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 density = 1 / volreg1(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscSatLiqTW = 0.000055071 \* psivisc(tau, delta)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 density = densreg3(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscSatLiqTW = 0.000055071 \* psivisc(tau, delta)

 Else

' outside range

 viscSatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function viscSatVapTW(temperature)

'

' dynamic viscosity of saturated steam as a function of temperature

' viscSatVapTW in Pa s

' temperature in K

'

' viscSatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 density = 1 / volreg2(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscSatVapTW = 0.000055071 \* psivisc(tau, delta)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 density = densreg3(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscSatVapTW = 0.000055071 \* psivisc(tau, delta)

 Else

' outside range

 viscSatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function viscSatLiqPW(pressure)

'

' dynamic viscosity of saturated liquid water as a function of pressure

' viscSatLiqPW in Pa s

' pressure in bar

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' viscSatLiqPW = -1: pressure outside range

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 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 1

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 viscSatLiqPW = 0.000055071 \* psivisc(tau, delta)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 density = densreg3(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscSatLiqPW = 0.000055071 \* psivisc(tau, delta)

 Else

' outside range

 viscSatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function viscSatVapPW(pressure)

'

' dynamic viscosity of saturated steam as a function of pressure

' viscSatVapPW in Pa s

' pressure in bar

'

' viscSatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 density = 1 / volreg2(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscSatVapPW = 0.000055071 \* psivisc(tau, delta)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure - 0.00001

 density = densreg3(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 viscSatVapPW = 0.000055071 \* psivisc(tau, delta)

 Else

' outside range

 viscSatVapPW = -1#

 End If

'

End Function

'

'

'

Public Function thconSatLiqTW(temperature)

'

' thermal conductivity of saturated liquid water as a function of temperature

' thconSatLiqTW in W /(m K)

' temperature in K

'

' thconSatLiqTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 1

 pressure = pSatW(temperature)

 density = 1 / volreg1(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 thconSatLiqTW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature)

 density = densreg3(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 thconSatLiqTW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 Else

' outside range

 thconSatLiqTW = -1#

 End If

'

End Function

'

'

'

Public Function thconSatVapTW(temperature)

'

' thermal conductivity of saturated steam as a function of temperature

' thconSatVapTW in W /(m K)

' temperature in K

'

' thconSatVapTW = -1: temperature outside range

'

 If temperature >= 273.15 And temperature <= 623.15 Then

' region 2

 pressure = pSatW(temperature)

 density = 1 / volreg2(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 pressure = pressure - 0.0001 \* pressure

 thconSatVapTW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 ElseIf temperature > 623.15 And temperature <= tc\_water Then

' region 3

 pressure = pSatW(temperature) - 0.00001

 density = densreg3(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 thconSatVapTW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 Else

' outside range

 thconSatVapTW = -1#

 End If

'

End Function

'

'

'

Public Function thconSatLiqPW(pressure)

'

' thermal conductivity of saturated liquid water as a function of pressure

' thconSatLiqPW in W /(m K)

' pressure in bar

'

' thconSatLiqPW = -1: pressure outside range

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' region 1

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 thconSatLiqPW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

 temperature = tSatW(pressure)

 pressure = pressure + 0.00001

 density = densreg3(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 thconSatLiqPW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 Else

' outside range

 thconSatLiqPW = -1#

 End If

'

End Function

'

'

'

Public Function thconSatVapPW(pressure)

'

' thermal conductivity of saturated steam as a function of pressure

' thconSatVapPW in W /(m K)

' pressure in bar

'

' thconSatVapPW = -1: pressure outside range

'

 If pressure >= pSatW(273.15) And pressure <= pSatW(623.15) Then

' region 2

 temperature = tSatW(pressure)

 density = 1 / volreg2(temperature, pressure)

 delta = density / 317.763

 tau = 647.226 / temperature

 pressure = pressure - 0.0001 \* pressure

 thconSatVapPW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 ElseIf pressure > pSatW(623.15) And pressure <= pc\_water Then

' region 3

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 thconSatVapPW = 0.4945 \* lambthcon(temperature, pressure, tau, delta)

 Else

' outside range

 thconSatVapPW = -1#

 End If

'

End Function