

ASTEM97

**Based on the
IAPWS IF-97**

Water and Steam Properties for Industrial Use

Implementation by

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Appendix F

Validation

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The **ASTEM97** computed values are provided as validation of the program.

Region 1 Validation

Pressure	0.300000000E+07	0.800000000E+08	0.300000000E+07 Pa
Temperature	0.300000000E+03	0.300000000E+03	0.500000000E+03 K
Specific Volume	0.100215168E-02	0.971180894E-03	0.120241800E-02 m ³ /kg
Specific Enthalpy	0.115331273E+03	0.184142828E+03	0.975542239E+03 kJ/kg
Specific Internal Energy	0.112324818E+03	0.106448356E+03	0.971934985E+03 kJ/kg
Specific Entropy	0.392294792E+00	0.368563852E+00	0.258041912E+01 kJ/kg-K
Specific Heat At P=const	0.417301218E+01	0.401008987E+01	0.465580682E+01 kJ/kg-K
Sonic Velocity	0.150773921E+04	0.163469054E+04	0.124071337E+04 m/sec

Validation of ASTEM97 Backward Equations

Backward equation PHS97

Pressure	0.300000006E+07	0.800000000E+08	0.299999992E+07 Pa
Temperature	0.300000000E+03	0.300000000E+03	0.500000000E+03 K

Backward equation PVH97

Pressure	0.300000001E+07	0.800000000E+08	0.300000000E+07 Pa
Temperature	0.300000000E+03	0.300000000E+03	0.500000000E+03 K

Backward equation PVS97

Pressure	0.300000001E+07	0.800000000E+08	0.300000000E+07 Pa
Temperature	0.300000000E+03	0.300000000E+03	0.500000000E+03 K

Validation of IF-97 Backward Equations

Backward equation PHS97B

Pressure	0.300022490E+07	0.799939779E+08	0.301079497E+07 Pa
Temperature	0.300017776E+03	0.299982333E+03	0.499986066E+03 K

Backward equation TPH97B

Temperature	0.300017826E+03	0.299981027E+03	0.499986558E+03 K
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Backward equation TPS97B

Temperature	0.299998701E+03	0.299990340E+03	0.499991324E+03 K
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Region 2 Validation

Pressure	0.350000000E+04	0.350000000E+04	0.300000000E+08 Pa
Temperature	0.300000000E+03	0.700000000E+03	0.700000000E+03 K
Specific Volume	0.394913866E+02	0.923015898E+02	0.542946619E-02 m ³ /kg
Specific Enthalpy	0.254991145E+04	0.333568375E+04	0.263149474E+04 kJ/kg
Specific Internal Energy	0.241169160E+04	0.301262819E+04	0.246861076E+04 kJ/kg
Specific Entropy	0.852238967E+01	0.101749996E+02	0.517540298E+01 kJ/kg-K
Specific Heat At P=const	0.191300162E+01	0.208141274E+01	0.103505092E+02 kJ/kg-K
Sonic Velocity	0.427920172E+03	0.644289068E+03	0.480386523E+03 m/sec

Validation of ASTEM97 Backward Equations

Backward equation PHS97

Pressure	0.350000000E+04	0.350000000E+04	0.300000000E+08 Pa
Temperature	0.300000000E+03	0.700000000E+03	0.700000000E+03 K

Backward equation PVH97

Pressure	0.350000000E+04	0.350000000E+04	0.300000000E+08 Pa
Temperature	0.300000000E+03	0.700000000E+03	0.700000000E+03 K

Backward equation PVS97

Pressure	0.350000000E+04	0.350000000E+04	0.300000000E+08 Pa
Temperature	0.300000000E+03	0.700000000E+03	0.700000000E+03 K

Validation of IF-97 Backward Equations

Backward equation PHS97B

Pressure	0.350002566E+04	0.349995985E+04	0.300004138E+08 Pa
Temperature	0.299991787E+03	0.700002151E+03	0.700009886E+03 K

Backward equation TPH97B

Temperature	0.299991781E+03	0.700002151E+03	0.700008189E+03 K
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Backward equation TPS97B

Temperature	0.299995244E+03	0.700000191E+03	0.700014361E+03 K
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Metastable Region Validation

Pressure	0.100000000E+07	0.100000000E+07	0.150000000E+07	Pa
Temperature	0.450000000E+03	0.440000000E+03	0.450000000E+03	K
Specific Volume	0.192516540E+00	0.186212297E+00	0.121685206E+00	m ³ /kg
Specific Enthalpy	0.276881115E+04	0.274015123E+04	0.272134539E+04	kJ/kg
Specific Internal Energy	0.257629461E+04	0.255393894E+04	0.253881758E+04	kJ/kg
Specific Entropy	0.656660377E+01	0.650218759E+01	0.629170440E+01	kJ/kg-K
Specific Heat At P=const	0.276349265E+01	0.298166443E+01	0.362795578E+01	kJ/kg-K
Sonic Velocity	0.498408101E+03	0.489363295E+03	0.481941819E+03	m/sec

Region 3 Validation

Region 3 Validation given T,ρ

Temperature	0.650000000E+03	0.650000000E+03	0.750000000E+03	K
Density	0.500000000E+03	0.200000000E+03	0.500000000E+03	kg/m ³
Pressure	0.255837018E+08	0.222930643E+08	0.783095639E+08	Pa
Specific Volume	0.200000000E-02	0.500000000E-02	0.200000000E-02	m ³ /kg
Specific Enthalpy	0.186343019E+04	0.237512401E+04	0.225868845E+04	kJ/kg
Specific Internal Energy	0.181226279E+04	0.226365868E+04	0.210206932E+04	kJ/kg
Specific Entropy	0.405427273E+01	0.485438792E+01	0.446971906E+01	kJ/kg-K
Specific Heat At P=const	0.138935717E+02	0.446579342E+02	0.634165359E+01	kJ/kg-K
Sonic Velocity	0.502005554E+03	0.383444594E+03	0.760696041E+03	m/sec

Region 3 Validation given p,T

Pressure	0.255837018E+08	0.222930643E+08	0.783095639E+08	Pa
Temperature	0.650000000E+03	0.650000000E+03	0.750000000E+03	K
Specific Volume	0.200000000E-02	0.499999992E-02	0.200000000E-02	m ³ /kg
Specific Enthalpy	0.186343019E+04	0.237512400E+04	0.225868845E+04	kJ/kg
Specific Internal Energy	0.181226279E+04	0.226365868E+04	0.210206932E+04	kJ/kg
Specific Entropy	0.405427273E+01	0.485438790E+01	0.446971906E+01	kJ/kg-K
Specific Heat At P=const	0.138935718E+02	0.446579374E+02	0.634165360E+01	kJ/kg-K
Sonic Velocity	0.502005553E+03	0.383444592E+03	0.760696041E+03	m/sec

Validation of ASTEM97 Backward Equations

Backward equation PHS97

Pressure	0.255837018E+08	0.222930643E+08	0.783095639E+08	Pa
Temperature	0.650000000E+03	0.650000000E+03	0.750000000E+03	K

Backward equation PVH97

Pressure	0.255837018E+08	0.222930643E+08	0.783095639E+08	Pa
Temperature	0.650000000E+03	0.650000000E+03	0.750000000E+03	K

Backward equation PVS97

Pressure	0.255837018E+08	0.222930643E+08	0.783095639E+08	Pa
Temperature	0.650000000E+03	0.650000000E+03	0.750000000E+03	K

Region 5 Validation

Pressure	0.500000000E+06	0.800000000E+07	0.800000000E+07 Pa
Temperature	0.150000000E+04	0.150000000E+04	0.200000000E+04 K
Specific Volume	0.138455354E+01	0.865156616E-01	0.115743146E+00 m ³ /kg
Specific Enthalpy	0.521976332E+04	0.520609634E+04	0.658380291E+04 kJ/kg
Specific Internal Energy	0.452748654E+04	0.451397105E+04	0.565785774E+04 kJ/kg
Specific Entropy	0.965408431E+01	0.836546724E+01	0.915671044E+01 kJ/kg-K
Specific Heat At P=const	0.261610228E+01	0.264453866E+01	0.285306750E+01 kJ/kg-K
Sonic Velocity	0.917071933E+03	0.919708859E+03	0.105435806E+04 m/sec

Validation of ASTEM97 Backward Equations

Backward equation PHS97

Pressure	0.500000000E+06	0.800000000E+07	0.800000000E+07 Pa
Temperature	0.150000000E+04	0.150000000E+04	0.200000000E+04 K

Backward equation PVH97

Pressure	0.500000000E+06	0.800000000E+07	0.800000000E+07 Pa
Temperature	0.150000000E+04	0.150000000E+04	0.200000000E+04 K

Backward equation PVS97

Pressure	0.500000000E+06	0.800000000E+07	0.800000000E+07 Pa
Temperature	0.150000000E+04	0.150000000E+04	0.200000000E+04 K

Validation of Boundary Equations

Pressure / Temperature equations REGION 2-3 Boundary

FUNCTION P2397 : AT 0.165291643D+02 MPA T = 0.623150000D+03 K
FUNCTION T2397 : AT 0.623150000D+03 K P = 0.165291643D+02 MPA

Verification of PSAT97(T)

FUNCTION PSAT97: AT 0.300000000D+03 K P = 0.353658941D-02 MPA
FUNCTION PSAT97: AT 0.500000000D+03 K P = 0.263889776D+01 MPA
FUNCTION PSAT97: AT 0.600000000D+03 K P = 0.123443146D+02 MPA

Verification of TSAT97(P)

FUNCTION TSAT97: AT 0.100000000D+00 MPA T = 0.372755919D+03 K
FUNCTION TSAT97: AT 0.100000000D+01 MPA T = 0.453035632D+03 K
FUNCTION TSAT97: AT 0.100000000D+02 MPA T = 0.584149488D+03 K

Validation of IF-97 Backward Equations

VERIFICATION OF T(P,H)-REG 1			
Pressure	0.300000000E+07	0.800000000E+08	0.800000000E+08 Pa
Specific Enthalpy	0.500000000E+03	0.500000000E+03	0.150000000E+04 kJ/kg
Temperature	0.391798509E+03	0.378108626E+03	0.611041229E+03 K
VERIFICATION OF T(P,S) REG 1			
Pressure	0.300000000E+07	0.800000000E+08	0.800000000E+08 Pa
Specific Entropy	0.500000000E+00	0.500000000E+00	0.300000000E+01 kJ/kg-K
Temperature	0.307842258E+03	0.309979785E+03	0.565899909E+03 K
VERIFICATION OF T(P,H)-REG 2A			
Pressure	0.100000000E+04	0.300000000E+07	0.300000000E+07 Pa
Specific Enthalpy	0.300000000E+04	0.300000000E+04	0.400000000E+04 kJ/kg
Temperature	0.534433241E+03	0.575373370E+03	0.101077577E+04 K
VERIFICATION OF T(P,H)-REG 2B			
Pressure	0.500000000E+07	0.500000000E+07	0.250000000E+08 Pa
Specific Enthalpy	0.350000000E+04	0.400000000E+04	0.350000000E+04 kJ/kg
Temperature	0.801299102E+03	0.101531583E+04	0.875279054E+03 K
VERIFICATION OF T(P,H)-REG 2C			
Pressure	0.400000000E+08	0.600000000E+08	0.600000000E+08 Pa
Specific Enthalpy	0.270000000E+04	0.270000000E+04	0.320000000E+04 kJ/kg
Temperature	0.743056411E+03	0.791137067E+03	0.882756860E+03 K
VERIFICATION OF T(P,S)-REG 2A			
Pressure	0.100000000E+06	0.100000000E+06	0.250000000E+07 Pa
Specific Entropy	0.750000000E+01	0.800000000E+01	0.800000000E+01 kJ/kg-K
Temperature	0.399517097E+03	0.514127081E+03	0.103984917E+04 K
VERIFICATION OF T(P,S)-REG 2B			
Pressure	0.800000000E+07	0.800000000E+07	0.900000000E+08 Pa
Specific Entropy	0.600000000E+01	0.750000000E+01	0.600000000E+01 kJ/kg-K
Temperature	0.600484040E+03	0.106495556E+04	0.103801126E+04 K
VERIFICATION OF T(P,S)-REG 2C			
Pressure	0.200000000E+08	0.800000000E+08	0.800000000E+08 Pa
Specific Entropy	0.575000000E+01	0.525000000E+01	0.575000000E+01 kJ/kg-K
Temperature	0.697992849E+03	0.854011484E+03	0.949017998E+03 K
VERIFICATION OF P(H,S)-REG 1			
Specific Enthalpy	0.100000000E-02	0.900000000E+02	0.150000000E+04 kJ/kg
Specific Entropy	0.000000000E+00	0.000000000E+00	0.340000000E+01 kJ/kg-K
Pressure	0.980098061E+03	0.919295473E+08	0.586829442E+08 Pa
Temperature	-0.100000000E+01	0.273659064E+03	0.609683602E+03 K
	(0.273138542E+03)		
VERIFICATION OF P(H,S)-REG 2A			
Specific Enthalpy	0.280000000E+04	0.280000000E+04	0.410000000E+04 kJ/kg
Specific Entropy	0.650000000E+01	0.950000000E+01	0.950000000E+01 kJ/kg-K
Pressure	0.137101277E+07	0.187974384E+04	0.102478900E+06 Pa
Temperature	0.471359681E+03	0.431714869E+03	0.104735791E+04 K
VERIFICATION OF P(H,S)-REG 2B			
Specific Enthalpy	0.280000000E+04	0.360000000E+04	0.360000000E+04 kJ/kg
Specific Entropy	0.600000000E+01	0.600000000E+01	0.700000000E+01 kJ/kg-K
Pressure	0.479391144E+07	0.839551921E+08	0.752716144E+07 Pa
Temperature	0.535430628E+03	0.102284685E+04	0.853795490E+03 K
VERIFICATION OF P(H,S)-REG 2C			
Specific Enthalpy	0.280000000E+04	0.280000000E+04	0.340000000E+04 kJ/kg
Specific Entropy	0.510000000E+01	0.580000000E+01	0.580000000E+01 kJ/kg-K
Pressure	0.943920206E+08	0.841457412E+07	0.837690388E+08 Pa
Temperature	0.855235017E+03	0.580273512E+03	0.970064671E+03 K

VERIFICATION OF V(P,T)-REG 3A			
Pressure	0.170000000E+08	0.220000000E+08	0.230000000E+08 Pa
Temperature	0.624440000E+03	0.645860000E+03	0.630000000E+03 K
Specific Volume	0.175104070E-02	0.225318186E-02	0.169554160E-02 m ³ /kg
VERIFICATION OF V(P,T)-REG 3B			
Pressure	0.225000000E+08	0.230000000E+08	0.235000000E+08 Pa
Temperature	0.647720000E+03	0.649590000E+03	0.648000000E+03 K
Specific Volume	0.234556278E-02	0.245286789E-02	0.211183329E-02 m ³ /kg
VERIFICATION OF V(P,T)-REG 3C			
Pressure	0.225000000E+08	0.230000000E+08	0.235000000E+08 Pa
Temperature	0.649720000E+03	0.651590000E+03	0.668500000E+03 K
Specific Volume	0.440293561E-02	0.410603218E-02	0.666272701E-02 m ³ /kg
VERIFICATION OF V(P,T)-REG 3D			
Pressure	0.170000000E+08	0.220000000E+08	0.200000000E+08 Pa
Temperature	0.626440000E+03	0.647860000E+03	0.648780000E+03 K
Specific Volume	0.857356995E-02	0.475996451E-02	0.775012549E-02 m ³ /kg
VERIFICATION OF V(P,T)-REG 3E			
Pressure	0.250000000E+08	0.350000000E+08	0.390000000E+08 Pa
Temperature	0.630000000E+03	0.660000000E+03	0.709230000E+03 K
Specific Volume	0.166141166E-02	0.184317832E-02	0.319302583E-02 m ³ /kg
VERIFICATION OF V(P,T)-REG 3F			
Pressure	0.250000000E+08	0.350000000E+08	0.390000000E+08 Pa
Temperature	0.659040000E+03	0.696320000E+03	0.728410000E+03 K
Specific Volume	0.353914811E-02	0.330684904E-02	0.415717806E-02 m ³ /kg
VERIFICATION OF V(P,T)-REG 3G			
Pressure	0.410000000E+08	0.500000000E+08	0.100000000E+09 Pa
Temperature	0.630000000E+03	0.700000000E+03	0.862150000E+03 K
Specific Volume	0.151857341E-02	0.203558092E-02	0.257420572E-02 m ³ /kg

Validation of Additional Properties

VERIFICATION DYNAMIC VISCOSITY Bases on (ρ, T)

Density	0.999843633E+03	0.280459027E+00	0.528195286E+03	kg/m ³
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Dynamic Viscosity	0.179153095E+04	0.285746586E+02	0.660620605E+02	μ kg/m-sec

VERIFICATION DYNAMIC VISCOSITY Bases on (p,T)

Pressure	0.100000000E+06	0.100000000E+06	0.100000000E+09	Pa
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Dynamic Viscosity	0.179153095E+04	0.285746586E+02	0.660620604E+02	μ kg/m-sec

VERIFICATION OF SURFACE TENSION

Temperature	0.300000000E+03	0.500000000E+03	0.600000000E+03	K
Surface Tension	0.716859625E+02	0.314719761E+02	0.837561087E+01	milli N/m

VERIFICATION REFRACTIVE INDEX Bases on (ρ, T)

Density	0.999843633E+03	0.280459027E+00	0.528195286E+03	kg/m ³
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Refractive Index ($\lambda=0.2265$)	0.139452744E+01	0.100010083E+01	0.119828082E+01	---
Density	0.999843633E+03	0.280459027E+00	0.528195286E+03	kg/m ³
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Refractive Index ($\lambda=0.5890$)	0.133434461E+01	0.100008711E+01	0.117020512E+01	---

VERIFICATION REFRACTIVE INDEX Bases on (p,T)

Pressure	0.100000000E+06	0.100000000E+06	0.100000000E+09	Pa
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Refractive Index ($\lambda=0.2265$)	0.139452744E+01	0.100010083E+01	0.119828082E+01	---
Pressure	0.100000000E+06	0.100000000E+06	0.100000000E+09	Pa
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Refractive Index ($\lambda=0.5890$)	0.133434461E+01	0.100008711E+01	0.117020512E+01	---

VERIFICATION OF STATIC DIELECTRIC CONSTANT Bases on (ρ, T)

Density	0.100094934E+04	0.261720329E+02	0.378131821E+03	kg/m ³
Temperature	0.300000000E+03	0.870000000E+03	0.870000000E+03	K
Static Dielectric Constant	0.781122785E+02	0.112721058E+01	0.498289143E+01	---

VERIFICATION OF STATIC DIELECTRIC CONSTANT Bases on (p,T)

Pressure	0.100000000E+08	0.100000000E+08	0.100000000E+09	Pa
Temperature	0.300000000E+03	0.870000000E+03	0.870000000E+03	K
Static Dielectric Constant	0.781122784E+02	0.112721058E+01	0.498289143E+01	---

VERIFICATION OF INDUSTRIAL THERMAL CONDUCTIVITY

Bases on (ρ, T)

Density	0.999843633E+03	0.280459027E+00	0.528195286E+03	kg/m ³
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Thermal Conductivity (IND)	0.562030508E+00	0.668952959E-01	0.404846105D+00	W/m-K

Based on (p,T)

Pressure	0.100000000E+06	0.100000000E+06	0.100000000E+09	Pa
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Thermal Conductivity (IND)	0.562030508E+00	0.668952959E-01	0.404846105D+00	W/m-K

VERIFICATION OF GENERAL AND SCIENTIFIC THERMAL CONDUCTIVITY

Based on (ρ, T)

Density	0.999843633E+03	0.280459027E+00	0.528195286E+03	kg/m ³
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Thermal Conductivity (GSI)	0.561075931E+00	0.669788623E-01	0.394700444E+00	W/m-K

Based on (p,T)

Pressure	0.100000000E+06	0.100000000E+06	0.100000000E+09	Pa
Temperature	0.273150000E+03	0.773150000E+03	0.773150000E+03	K
Thermal Conductivity (GSI)	0.561075931E+00	0.669788623E-01	0.394700444E+00	W/m-K