

# **ASTEM97**

**Based on the  
IAPWS IF-97**

## **Water and Steam Properties for Industrial Use**

Implementation by

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**Appendix F**

## **Validation**

**Version 2.0**



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V2.0 VALIDATION RUN GIBB1

REF 1: TABLE 5

Validate High Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| 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 <sup>3</sup> /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              |

REF 1: TABLE 5

Validate Low Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| 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 <sup>3</sup> /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              |

ASTEM97 BACKWARD EQUATIONS

|                        |                 |                 |                   |
|------------------------|-----------------|-----------------|-------------------|
| Temperature from TPV97 | 0.300000000E+03 | 0.300000000E+03 | 0.500000000E+03 K |
| Temperature from TPU97 | 0.300000000E+03 | 0.300000000E+03 | 0.500000000E+03 K |
| Temperature from TPH97 | 0.300000000E+03 | 0.300000000E+03 | 0.500000000E+03 K |
| Temperature from TPS97 | 0.300000000E+03 | 0.300000000E+03 | 0.500000000E+03 K |

|                     |                 |                 |                    |
|---------------------|-----------------|-----------------|--------------------|
| Pressure from PTV97 | 0.299999998E+07 | 0.800000000E+08 | 0.300000000E+07 Pa |
| Pressure from PTU97 | 0.300000000E+07 | 0.800000000E+08 | 0.300000000E+07 Pa |
| Pressure from PTH97 | 0.300000000E+07 | 0.800000000E+08 | 0.300000000E+07 Pa |
| Pressure from PTS97 | 0.300000003E+07 | 0.800000000E+08 | 0.300000000E+07 Pa |

|             |                 |                 |                    |
|-------------|-----------------|-----------------|--------------------|
| PHS97       | THS97           |                 |                    |
| Pressure    | 0.300000006E+07 | 0.800000000E+08 | 0.299999992E+07 Pa |
| Temperature | 0.300000000E+03 | 0.300000000E+03 | 0.500000000E+03 K  |

|             |                 |                 |                    |
|-------------|-----------------|-----------------|--------------------|
| PVH97       | TVH97           |                 |                    |
| Pressure    | 0.300000001E+07 | 0.800000000E+08 | 0.300000000E+07 Pa |
| Temperature | 0.300000000E+03 | 0.300000000E+03 | 0.500000000E+03 K  |

|             |                 |                 |                    |
|-------------|-----------------|-----------------|--------------------|
| PVS97       | TVS97           |                 |                    |
| Pressure    | 0.300000001E+07 | 0.800000000E+08 | 0.300000000E+07 Pa |
| Temperature | 0.300000000E+03 | 0.300000000E+03 | 0.500000000E+03 K  |

IF97 BACKWARD EQUATIONS

|             |                 |                 |                    |
|-------------|-----------------|-----------------|--------------------|
| PHSBK1      | THSBK1          |                 |                    |
| Pressure    | 0.300022490E+07 | 0.799939779E+08 | 0.301079497E+07 Pa |
| Temperature | 0.300017776E+03 | 0.299982333E+03 | 0.499986066E+03 K  |
| TPHBK1      |                 |                 |                    |
| Temperature | 0.300017826E+03 | 0.299981027E+03 | 0.499986558E+03 K  |
| TPSBK1      |                 |                 |                    |
| Temperature | 0.299998701E+03 | 0.299990340E+03 | 0.499991324E+03 K  |

VALIDATE IF97 BACKWARD EQS

```

REF 1: TABLE 7 FOR H, TABLE 9 FOR S
TPHBK1  TPSBK1
    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
    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

REF 2: TABLE 3
PHSBK1  THSBK1
    IFLAG97(14) = 0 , DEFAULT VALUE
    Specific Enthalpy 1.000000000E-03 9.000000000E+01 1.500000000E+03 kJ/kg
    Specific Entropy 0.000000000E+00 0.000000000E+00 3.400000000E+00 kJ/kg-K
    Pressure 9.800980612E+02 9.192954727E+07 5.868294423E+07 Pa
    Temperature -1.000000000E+00 2.736590640E+02 6.096836021E+02 K

    POINT 1 RETURNS T < TMIN, IERR97(1) = -10
    PTMANS97(3) 2.731385417E+02 K

    IFLAG97(14) = 1 , SET P,T BOUND
PHSBK1  THSBK1
    Specific Enthalpy 1.000000000E-03 9.000000000E+01 1.500000000E+03 kJ/kg
    Specific Entropy 0.000000000E+00 0.000000000E+00 3.400000000E+00 kJ/kg-K
    Pressure 9.800980612E+02 9.192954727E+07 5.868294423E+07 Pa
    Temperature 2.731500000E+02 2.736590640E+02 6.096836021E+02 K
    IFLAG97(14) = 0 , RESET DEFAULT

```

V2.0 VALIDATION RUN GIBB2

REF 1: TABLE 15

Validate High Level Calls

|                          |                 |                 |                 |                    |
|--------------------------|-----------------|-----------------|-----------------|--------------------|
| 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 <sup>3</sup> /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              |

REF 1: TABLE 15

Validate Low Level Calls

|                          |                 |                 |                 |                    |
|--------------------------|-----------------|-----------------|-----------------|--------------------|
| 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 <sup>3</sup> /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              |

ASTEM97 BACKWARD EQUATIONS

|                        |                 |                 |                 |    |
|------------------------|-----------------|-----------------|-----------------|----|
| Temperature from TPV97 | 0.300000000E+03 | 0.700000000E+03 | 0.700000000E+03 | K  |
| Temperature from TPU97 | 0.300000000E+03 | 0.700000000E+03 | 0.700000000E+03 | K  |
| Temperature from TPH97 | 0.300000000E+03 | 0.700000000E+03 | 0.700000000E+03 | K  |
| Temperature from TPS97 | 0.300000000E+03 | 0.700000000E+03 | 0.700000000E+03 | K  |
| Pressure from PTV97    | 0.350000000E+04 | 0.350000000E+04 | 0.300000000E+08 | Pa |
| Pressure from PTU97    | 0.350000001E+04 | 0.349999986E+04 | 0.300000000E+08 | Pa |
| Pressure from PTH97    | 0.350000009E+04 | 0.350000341E+04 | 0.300000000E+08 | Pa |
| Pressure from PTS97    | 0.350000000E+04 | 0.350000000E+04 | 0.300000000E+08 | Pa |

PHS97

THS97

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

PVH97

TVH97

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

PVS97

TVS97

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

IF97 BACKWARD EQUATIONS

PHS97B

THS97B

|             |                 |                 |                 |    |
|-------------|-----------------|-----------------|-----------------|----|
| Pressure    | 0.350002566E+04 | 0.349995985E+04 | 0.300004138E+08 | Pa |
| Temperature | 0.299991787E+03 | 0.700002151E+03 | 0.700009886E+03 | K  |
| Temperature | 0.299991781E+03 | 0.700002151E+03 | 0.700008189E+03 | K  |
| Temperature | 0.299995244E+03 | 0.700000191E+03 | 0.700014361E+03 | K  |

VALIDATE IF97 BACKWARD EQS

REF 1: TABLE 24 FOR H, TABLE 29 FOR S

|           |                   |                 |                 |                         |
|-----------|-------------------|-----------------|-----------------|-------------------------|
| TPHBK2(A) | TPSBK2(A)         |                 |                 |                         |
|           | 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       |
|           | 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       |
| TPHBK2(B) | TPSBK2(B)         |                 |                 |                         |
|           | 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       |
|           | 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       |
| TPHBK2(C) | TPSBK2(C)         |                 |                 |                         |
|           | 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       |
|           | 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       |

REF 2: TABLE 9

|           |                   |                 |                 |                         |
|-----------|-------------------|-----------------|-----------------|-------------------------|
| PHSBK2(A) | THSBK2(A)         |                 |                 |                         |
|           | Specific Enthalpy | 2.800000000E+03 | 2.800000000E+03 | 4.100000000E+03 kJ/kg   |
|           | Specific Entropy  | 6.500000000E+00 | 9.500000000E+00 | 9.500000000E+00 kJ/kg-K |
|           | Pressure          | 1.371012767E+06 | 1.879743844E+03 | 1.024788997E+05 Pa      |
|           | Temperature       | 4.713596812E+02 | 4.317148691E+02 | 1.047357911E+03 K       |
| PHSBK2(B) | THSBK2(B)         |                 |                 |                         |
|           | Specific Enthalpy | 2.800000000E+03 | 3.600000000E+03 | 3.600000000E+03 kJ/kg   |
|           | Specific Entropy  | 6.000000000E+00 | 6.000000000E+00 | 7.000000000E+00 kJ/kg-K |
|           | Pressure          | 4.793911442E+06 | 8.395519209E+07 | 7.527161441E+06 Pa      |
|           | Temperature       | 5.354306277E+02 | 1.022846849E+03 | 8.537954902E+02 K       |
| PHSBK2(C) | THSBK2(C)         |                 |                 |                         |
|           | Specific Enthalpy | 2.800000000E+03 | 2.800000000E+03 | 3.400000000E+03 kJ/kg   |
|           | Specific Entropy  | 5.100000000E+00 | 5.800000000E+00 | 5.800000000E+00 kJ/kg-K |
|           | Pressure          | 9.439202060E+07 | 8.414574124E+06 | 8.376903879E+07 Pa      |
|           | Temperature       | 8.552350175E+02 | 5.802735117E+02 | 9.700646705E+02 K       |

V2.0 VALIDATION RUN GIBB2M

REF 1: TABLE 18

Validate High Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| 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 <sup>3</sup> /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              |

REF 1: TABLE 18

Validate Low Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| 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 <sup>3</sup> /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              |

V2.0 VALIDATION RUN HELM3

REF 1: TABLE 33

Validate High Level Calls

|                          |                 |                 |                 |                    |
|--------------------------|-----------------|-----------------|-----------------|--------------------|
| Temperature              | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K                  |
| Density                  | 0.500000000E+03 | 0.200000000E+03 | 0.500000000E+03 | kg/m <sup>3</sup>  |
| Pressure                 | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa                 |
| Specific Volume          | 0.200000000E-02 | 0.500000000E-02 | 0.200000000E-02 | m <sup>3</sup> /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              |

REF 1: TABLE 33

Validate Low Level Calls

|                          |                 |                 |                 |                    |
|--------------------------|-----------------|-----------------|-----------------|--------------------|
| Temperature              | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K                  |
| Density                  | 0.500000000E+03 | 0.200000000E+03 | 0.500000000E+03 | kg/m <sup>3</sup>  |
| Pressure                 | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa                 |
| Specific Volume          | 0.200000000E-02 | 0.500000000E-02 | 0.200000000E-02 | m <sup>3</sup> /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              |

ASTEM97 BACKWARD EQUATIONS

|                        |                 |                 |                 |    |
|------------------------|-----------------|-----------------|-----------------|----|
| Temperature from TPV97 | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K  |
| Temperature from TPU97 | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K  |
| Temperature from TPH97 | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K  |
| Temperature from TPS97 | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K  |
| Pressure from PTV97    | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa |
| Pressure from PTU97    | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa |
| Pressure from PTH97    | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa |
| Pressure from PTS97    | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa |

PHS97

|             |                 |                 |                 |    |
|-------------|-----------------|-----------------|-----------------|----|
| THS97       |                 |                 |                 |    |
| Pressure    | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa |
| Temperature | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K  |

PVH97

|             |                 |                 |                 |    |
|-------------|-----------------|-----------------|-----------------|----|
| TVH97       |                 |                 |                 |    |
| Pressure    | 0.255837018E+08 | 0.222930643E+08 | 0.783095639E+08 | Pa |
| Temperature | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K  |

PVS97

|             |                 |                 |                 |    |
|-------------|-----------------|-----------------|-----------------|----|
| TVS97       |                 |                 |                 |    |
| Pressure    | 0.255837018E+08 | 0.222930642E+08 | 0.783095639E+08 | Pa |
| Temperature | 0.650000000E+03 | 0.650000000E+03 | 0.750000000E+03 | K  |

IAPWS BACKWARD EQUATIONS

PHSBK3

|          |                 |                 |                 |    |
|----------|-----------------|-----------------|-----------------|----|
| Pressure | 0.255845523E+08 | 0.222931817E+08 | 0.783081570E+08 | Pa |
|----------|-----------------|-----------------|-----------------|----|

TPHBK3

|             |                 |                 |                 |   |
|-------------|-----------------|-----------------|-----------------|---|
| TPSBK3      |                 |                 |                 |   |
| Temperature | 0.650011460E+03 | 0.649987135E+03 | 0.750009754E+03 | K |
| Temperature | 0.650016201E+03 | 0.649983405E+03 | 0.750001002E+03 | K |

VPHBK3

|                 |                 |                 |                 |                    |
|-----------------|-----------------|-----------------|-----------------|--------------------|
| VPSBK3          |                 |                 |                 |                    |
| Specific Volume | 0.200002172E-02 | 0.500046364E-02 | 0.200005265E-02 | m <sup>3</sup> /kg |
| Specific Volume | 0.200000419E-02 | 0.500031070E-02 | 0.199998078E-02 | m <sup>3</sup> /kg |

VALIDATE IF97 BACKWARD EQS

```

REF 4: TABLE 5
PHSBK3(A)  PHSBK3(B)
Specific Enthalpy 1.700000000E+03 2.000000000E+03 2.100000000E+03 kJ/kg
Specific Entropy 3.800000000E+00 4.200000000E+00 4.300000000E+00 kJ/kg-K
Pressure 2.555703246E+07 4.540873468E+07 6.078123340E+07 Pa
Specific Enthalpy 2.500000000E+03 2.400000000E+03 2.400000000E+03 kJ/kg
Specific Entropy 5.100000000E+00 4.700000000E+00 5.100000000E+00 kJ/kg-K
Pressure 1.720612413E+07 6.363924887E+07 6.031680428E+07 Pa

PHS97BK
Pressure -1.000000000E+00 6.363924887E+07 6.032043066E+07 Pa
POINT 1 IS OUTSIDE REG 3 IERR97(1) = -5
CALL ASTEM97 PHS97
Quality 9.526896456E-01 ---
Temperature 6.264603809E+02 K
Pressure 1.721234978E+07 Pa

REF 3: TABLE 5 FOR H, TABLE 12 FOR S
TPHBK3(A)  TPSBK3(B)
IFLAG97(13) = 0 , CHECK FOR REGION 3
Pressure 2.000000000E+07 5.000000000E+07 1.000000000E+08 Pa
Specific Enthalpy 1.700000000E+03 2.000000000E+03 2.100000000E+03 kJ/kg
Temperature 6.293083892E+02 6.905718338E+02 7.336163014E+02 K
Specific Entropy 3.700000000E+00 3.500000000E+00 4.000000000E+00 kJ/kg-K
Temperature -1.000000000E+00 -1.000000000E+00 7.056880237E+02 K
POINTS 1/2 IN REG 1 IERR97(1) = 1 1
Pressure 2.000000000E+07 5.000000000E+07 1.000000000E+08 Pa
Specific Enthalpy 2.500000000E+03 2.400000000E+03 2.700000000E+03 kJ/kg
Temperature 6.418418053E+02 7.351848618E+02 8.420460876E+02 K
Specific Entropy 5.000000000E+00 4.500000000E+00 5.000000000E+00 kJ/kg-K
Temperature 6.401176443E+02 7.163687517E+02 8.474332825E+02 K

REF 3: TABLE 8 FOR H, TABLE 15 FOR S
VPHBK3(A)  VPSBK3(B)
Pressure 2.000000000E+07 5.000000000E+07 1.000000000E+08 Pa
Specific Enthalpy 1.700000000E+03 2.000000000E+03 2.100000000E+03 kJ/kg
Specific Volume 1.749903962E-03 1.908139035E-03 1.676229776E-03 m^3/kg
Specific Entropy 3.700000000E+00 3.500000000E+00 4.000000000E+00 kJ/kg-K
Specific Volume -1.000000000E+00 -1.000000000E+00 1.555893131E-03 m^3/kg
POINTS 1/2 IN REG 1 IERR97(1) = 1 1
Pressure 2.000000000E+07 5.000000000E+07 1.000000000E+08 Pa
Specific Enthalpy 2.500000000E+03 2.400000000E+03 2.700000000E+03 kJ/kg
Specific Volume 6.670547043E-03 2.801244590E-03 2.404234998E-03 m^3/kg
Specific Entropy 5.000000000E+00 4.500000000E+00 5.000000000E+00 kJ/kg-K
Specific Volume 6.262101987E-03 2.332634294E-03 3.401506024E-03 m^3/kg

IFLAG97(13) = 1 , SET FOR VALIDATION ONLY
REF 3: TABLE 5 FOR H, TABLE 12 FOR S
TPHBK3(A)  TPSBK3(B)
Pressure 2.000000000E+07 5.000000000E+07 1.000000000E+08 Pa
Specific Enthalpy 1.700000000E+03 2.000000000E+03 2.100000000E+03 kJ/kg
Temperature 6.293083892E+02 6.905718338E+02 7.336163014E+02 K
Specific Entropy 3.700000000E+00 3.500000000E+00 4.000000000E+00 kJ/kg-K
Temperature 6.208841563E+02 6.181549029E+02 7.056880237E+02 K
Pressure 2.000000000E+07 5.000000000E+07 1.000000000E+08 Pa
Specific Enthalpy 2.500000000E+03 2.400000000E+03 2.700000000E+03 kJ/kg
Temperature 6.418418053E+02 7.351848618E+02 8.420460876E+02 K
Specific Entropy 5.000000000E+00 4.500000000E+00 5.000000000E+00 kJ/kg-K
Temperature 6.401176443E+02 7.163687517E+02 8.474332825E+02 K

```

REF 3: TABLE 8 FOR H, TABLE 15 FOR S

|           |                   |                 |                 |                                    |
|-----------|-------------------|-----------------|-----------------|------------------------------------|
| VPHBK3(A) | VPSBK3(B)         |                 |                 |                                    |
|           | Pressure          | 2.000000000E+07 | 5.000000000E+07 | 1.000000000E+08 Pa                 |
|           | Specific Enthalpy | 1.700000000E+03 | 2.000000000E+03 | 2.100000000E+03 kJ/kg              |
|           | Specific Volume   | 1.749903962E-03 | 1.908139035E-03 | 1.676229776E-03 m <sup>3</sup> /kg |
|           | Specific Entropy  | 3.700000000E+00 | 3.500000000E+00 | 4.000000000E+00 kJ/kg-K            |
|           | Specific Volume   | 1.639890984E-03 | 1.423030205E-03 | 1.555893131E-03 m <sup>3</sup> /kg |
|           | Pressure          | 2.000000000E+07 | 5.000000000E+07 | 1.000000000E+08 Pa                 |
|           | Specific Enthalpy | 2.500000000E+03 | 2.400000000E+03 | 2.700000000E+03 kJ/kg              |
|           | Specific Volume   | 6.670547043E-03 | 2.801244590E-03 | 2.404234998E-03 m <sup>3</sup> /kg |
|           | Specific Entropy  | 5.000000000E+00 | 4.500000000E+00 | 5.000000000E+00 kJ/kg-K            |
|           | Specific Volume   | 6.262101987E-03 | 2.332634294E-03 | 2.449610757E-03 m <sup>3</sup> /kg |

RESET IFLAG97(13) = 0 , DEFAULT

|         |                   |                 |                 |                         |
|---------|-------------------|-----------------|-----------------|-------------------------|
| TPH97BK | TPS97BK           |                 |                 |                         |
|         | Pressure          | 2.000000000E+07 | 5.000000000E+07 | 1.000000000E+08 Pa      |
|         | Specific Enthalpy | 1.700000000E+03 | 2.000000000E+03 | 2.100000000E+03 kJ/kg   |
|         | Temperature       | 6.293083892E+02 | 6.905718338E+02 | 7.336163014E+02 K       |
|         | Specific Entropy  | 3.700000000E+00 | 3.500000000E+00 | 4.000000000E+00 kJ/kg-K |
|         | Temperature       | 6.208665832E+02 | 6.181256564E+02 | 7.056880237E+02 K       |
|         | Pressure          | 2.000000000E+07 | 5.000000000E+07 | 1.000000000E+08 Pa      |
|         | Specific Enthalpy | 2.500000000E+03 | 2.400000000E+03 | 2.700000000E+03 kJ/kg   |
|         | Temperature       | 6.418418053E+02 | 7.351848618E+02 | 8.420460876E+02 K       |
|         | Specific Entropy  | 5.000000000E+00 | 4.500000000E+00 | 5.000000000E+00 kJ/kg-K |
|         | Temperature       | 6.401176443E+02 | 7.163687517E+02 | 8.474332825E+02 K       |

V2.0 VALIDATION RUN GIBB5

REF 1: TABLE 42

Validate High Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| 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 <sup>3</sup> /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              |

REF 1: TABLE 42

Validate Low Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| 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 <sup>3</sup> /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              |

ASTEM97 BACKWARD EQUATIONS

|                        |                 |                 |                   |
|------------------------|-----------------|-----------------|-------------------|
| Temperature from TPV97 | 0.150000000E+04 | 0.150000000E+04 | 0.200000000E+04 K |
| Temperature from TPU97 | 0.150000000E+04 | 0.150000000E+04 | 0.200000000E+04 K |
| Temperature from TPH97 | 0.150000000E+04 | 0.150000000E+04 | 0.200000000E+04 K |
| Temperature from TPS97 | 0.150000000E+04 | 0.150000000E+04 | 0.200000000E+04 K |

|                     |                 |                 |                    |
|---------------------|-----------------|-----------------|--------------------|
| Pressure from PTV97 | 0.500000000E+06 | 0.800000000E+07 | 0.800000000E+07 Pa |
| Pressure from PTU97 | 0.499999997E+06 | 0.800000000E+07 | 0.799999999E+07 Pa |
| Pressure from PTH97 | 0.499999959E+06 | 0.800000003E+07 | 0.799999988E+07 Pa |
| Pressure from PTS97 | 0.500000000E+06 | 0.800000000E+07 | 0.800000000E+07 Pa |

|             |                 |                 |                    |
|-------------|-----------------|-----------------|--------------------|
| PHS97       | THS97           |                 |                    |
| Pressure    | 0.500000000E+06 | 0.800000000E+07 | 0.800000000E+07 Pa |
| Temperature | 0.150000000E+04 | 0.150000000E+04 | 0.200000000E+04 K  |

|             |                 |                 |                    |
|-------------|-----------------|-----------------|--------------------|
| PVH97       | TVH97           |                 |                    |
| Pressure    | 0.500000000E+06 | 0.800000000E+07 | 0.800000000E+07 Pa |
| Temperature | 0.150000000E+04 | 0.150000000E+04 | 0.200000000E+04 K  |

|             |                 |                 |                    |
|-------------|-----------------|-----------------|--------------------|
| PVS97       | TVS97           |                 |                    |
| Pressure    | 0.500000000E+06 | 0.800000000E+07 | 0.800000000E+07 Pa |
| Temperature | 0.150000000E+04 | 0.150000000E+04 | 0.200000000E+04 K  |

V2.0 VALIDATION RUN GIBB2I

Validate High Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| Pressure                 | 0.611657000E+03 | 0.611657000E+03 | 0.611657000E+03 Pa                 |
| Temperature              | 0.273150000E+03 | 0.473150000E+03 | 0.127315000E+04 K                  |
| Specific Volume          | 0.206105427E+03 | 0.357015495E+03 | 0.960655771E+03 m <sup>3</sup> /kg |
| Specific Enthalpy        | 0.250141909E+04 | 0.288004094E+04 | 0.464352714E+04 kJ/kg              |
| Specific Internal Energy | 0.237535326E+04 | 0.266166992E+04 | 0.405593532E+04 kJ/kg              |
| Specific Entropy         | 0.915710601E+01 | 0.101951369E+02 | 0.123329626E+02 kJ/kg-K            |
| Specific Heat at P=const | 0.185890588E+01 | 0.194016597E+01 | 0.248967200E+01 kJ/kg-K            |
| Sonic Velocity           | 0.409515313E+03 | 0.535285808E+03 | 0.849296497E+03 m/sec              |

Validate Low Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| Pressure                 | 0.611657000E+03 | 0.611657000E+03 | 0.611657000E+03 Pa                 |
| Temperature              | 0.273150000E+03 | 0.473150000E+03 | 0.127315000E+04 K                  |
| Specific Volume          | 0.206105427E+03 | 0.357015495E+03 | 0.960655771E+03 m <sup>3</sup> /kg |
| Specific Enthalpy        | 0.250141909E+04 | 0.288004094E+04 | 0.464352714E+04 kJ/kg              |
| Specific Internal Energy | 0.237535326E+04 | 0.266166992E+04 | 0.405593532E+04 kJ/kg              |
| Specific Entropy         | 0.915710601E+01 | 0.101951369E+02 | 0.123329626E+02 kJ/kg-K            |
| Specific Heat at P=const | 0.185890588E+01 | 0.194016597E+01 | 0.248967200E+01 kJ/kg-K            |
| Sonic Velocity           | 0.409515313E+03 | 0.535285808E+03 | 0.849296497E+03 m/sec              |

V2.0 VALIDATION RUN GIBB5I

Validate High Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| Pressure                 | 0.611657000E+03 | 0.611657000E+03 | 0.611657000E+03 Pa                 |
| Temperature              | 0.127315000E+04 | 0.167315000E+04 | 0.227315000E+04 K                  |
| Specific Volume          | 0.960655771E+03 | 0.126247591E+04 | 0.171520612E+04 m <sup>3</sup> /kg |
| Specific Enthalpy        | 0.464282647E+04 | 0.568129960E+04 | 0.737698042E+04 kJ/kg              |
| Specific Internal Energy | 0.405523464E+04 | 0.490909737E+04 | 0.632786259E+04 kJ/kg              |
| Specific Entropy         | 0.123323953E+02 | 0.130402914E+02 | 0.139046209E+02 kJ/kg-K            |
| Specific Heat at P=const | 0.247688954E+01 | 0.270408570E+01 | 0.293071712E+01 kJ/kg-K            |
| Sonic Velocity           | 0.849795631E+03 | 0.964947630E+03 | 0.111589089E+04 m/sec              |

Validate Low Level Calls

|                          |                 |                 |                                    |
|--------------------------|-----------------|-----------------|------------------------------------|
| Pressure                 | 0.611657000E+03 | 0.611657000E+03 | 0.611657000E+03 Pa                 |
| Temperature              | 0.127315000E+04 | 0.167315000E+04 | 0.227315000E+04 K                  |
| Specific Volume          | 0.960655771E+03 | 0.126247591E+04 | 0.171520612E+04 m <sup>3</sup> /kg |
| Specific Enthalpy        | 0.464282647E+04 | 0.568129960E+04 | 0.737698042E+04 kJ/kg              |
| Specific Internal Energy | 0.405523464E+04 | 0.490909737E+04 | 0.632786259E+04 kJ/kg              |
| Specific Entropy         | 0.123323953E+02 | 0.130402914E+02 | 0.139046209E+02 kJ/kg-K            |
| Specific Heat at P=const | 0.247688954E+01 | 0.270408570E+01 | 0.293071712E+01 kJ/kg-K            |
| Sonic Velocity           | 0.849795631E+03 | 0.964947630E+03 | 0.111589089E+04 m/sec              |

V2.0 VALIDATION RUN V(P,T) REGION 3

REF: 5, TABLE 9

|                            |                |                |                                   |
|----------------------------|----------------|----------------|-----------------------------------|
| VPTREG3(A)                 |                |                |                                   |
| Pressure                   | 1.70000000E+07 | 2.20000000E+07 | 2.30000000E+07 Pa                 |
| Temperature                | 6.24440000E+02 | 6.45860000E+02 | 6.30000000E+02 K                  |
| Specific Volume            | 1.75104070E-03 | 2.25318186E-03 | 1.69554160E-03 m <sup>3</sup> /kg |
| SPECIFIC VOLUME FROM ROOT3 | 1.74974723E-03 | 2.25424423E-03 | 1.69450021E-03 m <sup>3</sup> /kg |
| PERCENT DIFFERENCE         | -0.0739        | 0.0471         | -0.0615                           |
| VPTREG3(B)                 |                |                |                                   |
| Pressure                   | 2.25000000E+07 | 2.30000000E+07 | 2.35000000E+07 Pa                 |
| Temperature                | 6.47720000E+02 | 6.49860000E+02 | 6.48000000E+02 K                  |
| Specific Volume            | 2.34556278E-03 | 2.54496724E-03 | 2.11183329E-03 m <sup>3</sup> /kg |
| SPECIFIC VOLUME FROM ROOT3 | 2.34622629E-03 | 2.54551311E-03 | 2.11175183E-03 m <sup>3</sup> /kg |
| PERCENT DIFFERENCE         | 0.0283         | 0.0214         | -0.0039                           |
| VPTREG3(C)                 |                |                |                                   |
| Pressure                   | 2.25000000E+07 | 2.30000000E+07 | 2.35000000E+07 Pa                 |
| Temperature                | 6.49720000E+02 | 6.51900000E+02 | 6.68500000E+02 K                  |
| Specific Volume            | 4.40293561E-03 | 4.10603218E-03 | 6.66272701E-03 m <sup>3</sup> /kg |
| SPECIFIC VOLUME FROM ROOT3 | 4.40648231E-03 | 4.10769820E-03 | 6.66547815E-03 m <sup>3</sup> /kg |
| PERCENT DIFFERENCE         | 0.0805         | 0.0406         | 0.0413                            |
| VPTREG3(D)                 |                |                |                                   |
| Pressure                   | 1.70000000E+07 | 2.20000000E+07 | 2.00000000E+07 Pa                 |
| Temperature                | 6.26440000E+02 | 6.47860000E+02 | 6.48780000E+02 K                  |
| Temperature                | 8.57356995E-03 | 4.75996451E-03 | 7.75012549E-03 m <sup>3</sup> /kg |
| SPECIFIC VOLUME FROM ROOT3 | 8.56908080E-03 | 4.76333432E-03 | 7.75549266E-03 m <sup>3</sup> /kg |
| PERCENT DIFFERENCE         | -0.0524        | 0.0707         | 0.0692                            |
| VPTREG3(E)                 |                |                |                                   |
| Pressure                   | 2.50000000E+07 | 3.50000000E+07 | 3.90000000E+07 Pa                 |
| Temperature                | 6.30000000E+02 | 6.60000000E+02 | 7.09230000E+02 K                  |
| Temperature                | 1.66141166E-03 | 1.84317832E-03 | 3.19302583E-03 m <sup>3</sup> /kg |
| SPECIFIC VOLUME FROM ROOT3 | 1.66213467E-03 | 1.84375197E-03 | 3.19467658E-03 m <sup>3</sup> /kg |
| PERCENT DIFFERENCE         | 0.0435         | 0.0311         | 0.0517                            |
| VPTREG3(F)                 |                |                |                                   |
| Pressure                   | 2.50000000E+07 | 3.50000000E+07 | 3.90000000E+07 Pa                 |
| Temperature                | 6.59040000E+02 | 6.96320000E+02 | 7.28410000E+02 K                  |
| Temperature                | 3.53914811E-03 | 3.30684904E-03 | 4.15717806E-03 m <sup>3</sup> /kg |
| SPECIFIC VOLUME FROM ROOT3 | 3.53840717E-03 | 3.30543543E-03 | 4.15637281E-03 m <sup>3</sup> /kg |
| PERCENT DIFFERENCE         | -0.0209        | -0.0428        | -0.0194                           |
| VPTREG3(G)                 |                |                |                                   |
| Pressure                   | 4.10000000E+07 | 5.00000000E+07 | 1.00000000E+08 Pa                 |
| Temperature                | 6.30000000E+02 | 7.00000000E+02 | 8.62150000E+02 K                  |
| Temperature                | 1.51857341E-03 | 2.03558092E-03 | 2.57420572E-03 m <sup>3</sup> /kg |
| SPECIFIC VOLUME FROM ROOT3 | 1.51772037E-03 | 2.03587754E-03 | 2.57600900E-03 m <sup>3</sup> /kg |
| PERCENT DIFFERENCE         | -0.0562        | 0.0146         | 0.0700                            |

V2.0 VALIDATION RUN (P,T)

|  |                            |                 |                 |                            |
|--|----------------------------|-----------------|-----------------|----------------------------|
|  | Dynamic Viscosity          |                 |                 | from Ref 6 Table 4.3       |
|  | Thermal Conductivity       |                 |                 | from Ref 6 Table 4.6       |
|  | Surface Tension            |                 |                 | from Ref 6 Table 4.7       |
|  | Static Dielectric Constant |                 |                 | from Ref 6 Table 4.10      |
|  | Refractive Index           |                 |                 | from Ref 6 Table 4.12      |
|  | Pressure                   | 0.100000000E+06 | 0.100000000E+06 | 0.100000000E+09 Pa         |
|  | Temperature                | 0.273150000E+03 | 0.773150000E+03 | 0.773150000E+03 K          |
|  | Density                    | 0.999843633E+03 | 0.280459027E+00 | 0.528195286E+03 kg/m^3     |
|  | DYNVPRS                    |                 |                 |                            |
|  | Dynamic Viscosity          | 0.179153095E+04 | 0.285746586E+02 | 0.660620604E+02 μ kg/m-sec |
|  | TC97PRS                    |                 |                 |                            |
|  | Thermal Conductivity (GSI) | 0.561075931E+00 | 0.669788623E-01 | 0.394700444E+00 W/m-K      |
|  | TC85PRS                    |                 |                 |                            |
|  | Thermal Conductivity (IND) | 0.562030508E+00 | 0.668952959E-01 | 0.404846105E+00 W/m-K      |
|  | RINDPRS LAMBDA = 0.2265    |                 |                 |                            |
|  | Refractive Index           | 0.139452744E+01 | 0.100010083E+01 | 0.119828082E+01 ---        |
|  | RINDPRS LAMBDA = 0.5890    |                 |                 |                            |
|  | Refractive Index           | 0.133434461E+01 | 0.100008711E+01 | 0.117020512E+01 ---        |
|  | STDIPRS                    |                 |                 |                            |
|  | 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 ---        |
|  | SURTEN                     |                 |                 |                            |
|  | 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  |
|  | V2.0 VALIDATION RUN (R,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          |
|  | DYNVRHO                    |                 |                 |                            |
|  | Dynamic Viscosity          | 0.179153095E+04 | 0.285746586E+02 | 0.660620604E+02 μ kg/m-sec |
|  | TC97RHO                    |                 |                 |                            |
|  | Thermal Conductivity (GSI) | 0.561075931E+00 | 0.669788623E-01 | 0.394700444E+00 W/m-K      |
|  | TC85RHO                    |                 |                 |                            |
|  | Thermal Conductivity (IND) | 0.562030508E+00 | 0.668952959E-01 | 0.404846105E+00 W/m-K      |
|  | RINDRHO LAMBDA = 0.2265    |                 |                 |                            |
|  | Refractive Index           | 0.139452744E+01 | 0.100010083E+01 | 0.119828082E+01 ---        |
|  | RINDRHO LAMBDA = 0.5890    |                 |                 |                            |
|  | Refractive Index           | 0.133434461E+01 | 0.100008711E+01 | 0.117020512E+01 ---        |
|  | STDIPRS                    |                 |                 |                            |
|  | 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 | 0.781122784E+02 | 0.112721058E+01 | 0.498289143E+01 ---        |

V2.0 VALIDATION RUN IF97 BACKWARD EQS FOR H,S

|          |                   |                 |                 |                 |         |
|----------|-------------------|-----------------|-----------------|-----------------|---------|
| PSHBK3   |                   | REF 3: TABLE 18 |                 |                 |         |
|          | Specific Enthalpy | 1.700000000E+03 | 2.000000000E+03 | 2.400000000E+03 | kJ/kg   |
|          | Pressure          | 1.724175718E+07 | 2.193442957E+07 | 2.018090839E+07 | Pa      |
| PSSBK3   |                   | REF 3: TABLE 20 |                 |                 |         |
|          | Specific Entropy  | 3.800000000E+00 | 4.200000000E+00 | 5.200000000E+00 | kJ/kg-K |
|          | Pressure          | 1.687755057E+07 | 2.164451789E+07 | 1.668968482E+07 | Pa      |
| HSSAT97B |                   | REF 4: TABLE 11 | EQ.3            |                 |         |
|          | Specific Entropy  | 1.000000000E+00 | 2.000000000E+00 | 3.000000000E+00 | kJ/kg-K |
|          | Specific Enthalpy | 3.085509647E+02 | 7.006304472E+02 | 1.198359754E+03 | kJ/kg   |
| HSSAT97B |                   | REF 4: TABLE 11 | EQ.4            |                 |         |
|          | Specific Entropy  | 3.800000000E+00 | 4.000000000E+00 | 4.200000000E+00 | kJ/kg-K |
|          | Specific Enthalpy | 1.685025565E+03 | 1.816891476E+03 | 1.949352563E+03 | kJ/kg   |
| HSSAT97B |                   | REF 4: TABLE 18 | EQ.5            |                 |         |
|          | Specific Entropy  | 7.000000000E+00 | 8.000000000E+00 | 9.000000000E+00 | kJ/kg-K |
|          | Specific Enthalpy | 2.723729985E+03 | 2.599047210E+03 | 2.511861477E+03 | kJ/kg   |
| HSSAT97B |                   | REF 4: TABLE 18 | EQ.8            |                 |         |
|          | Specific Entropy  | 5.500000000E+00 | 5.000000000E+00 | 4.500000000E+00 | kJ/kg-K |
|          | Specific Enthalpy | 2.687693850E+03 | 2.451623609E+03 | 2.144360448E+03 | kJ/kg   |
| HSB1397B |                   | REF 4: TABLE 24 | EQ.6            |                 |         |
|          | Specific Entropy  | 3.700000000E+00 | 3.600000000E+00 | 3.500000000E+00 | kJ/kg-K |
|          | Specific Enthalpy | 1.632525047E+03 | 1.593027214E+03 | 1.566104611E+03 | kJ/kg   |
| THS2397B |                   | REF 4: TABLE 26 | EQ.8            |                 |         |
|          | Specific Enthalpy | 2.600000000E+03 | 2.700000000E+03 | 2.800000000E+03 | kJ/kg   |
|          | Specific Entropy  | 5.100000000E+00 | 5.150000000E+00 | 5.200000000E+00 | kJ/kg-K |
|          | Temperature       | 7.135259364E+02 | 7.685345532E+02 | 8.176202120E+02 | K       |
| TSHS97B  |                   | REF 4: TABLE 29 | EQ.9            |                 |         |
|          | Specific Enthalpy | 1.800000000E+03 | 2.400000000E+03 | 2.500000000E+03 | kJ/kg   |
|          | Specific Entropy  | 5.300000000E+00 | 6.000000000E+00 | 5.500000000E+00 | kJ/kg-K |
|          | Temperature       | 3.468475498E+02 | 4.251373305E+02 | 5.225579013E+02 | K       |
| XHSBK4   |                   |                 |                 |                 |         |
|          | Specific Enthalpy | 1.800000000E+03 | 2.400000000E+03 | 2.500000000E+03 | kJ/kg   |
|          | Specific Entropy  | 5.300000000E+00 | 6.000000000E+00 | 5.500000000E+00 | kJ/kg-K |
|          | Quality           | 6.418081200E-01 | 8.347355316E-01 | 8.247218454E-01 | ---     |

V2.0 VALIDATION OF V(P,T) TEMPERATURE BOUNDARIES

|      | REF 7: TABLE 3  |                 |
|------|-----------------|-----------------|
| Eq.  | Pressure (Pa)   | Temperature (K) |
| T3AB | 4.000000000E+07 | 6.930341408E+02 |
| T3CD | 2.500000000E+07 | 6.493659208E+02 |
| T3EF | 4.000000000E+07 | 7.139593992E+02 |
| T3GH | 2.300000000E+07 | 6.498873759E+02 |
| T3IJ | 2.300000000E+07 | 6.515778091E+02 |
| T3KL | 2.300000000E+07 | 6.558338344E+02 |
| T3MN | 2.280000000E+07 | 6.496054133E+02 |
| T3OP | 2.280000000E+07 | 6.500106943E+02 |
| T3QU | 2.200000000E+07 | 6.456355027E+02 |
| T3RX | 2.200000000E+07 | 6.482622754E+02 |

|      | REF 7: TABLE 3  |                 |
|------|-----------------|-----------------|
| Eq.  | Pressure (Pa)   | Temperature (K) |
| T3UV | 2.230000000E+07 | 6.477996121E+02 |
| T3WX | 2.230000000E+07 | 6.482049480E+02 |

V2.0 VALIDATION OF V(P,T) FOR REGION 3

REF 7: TABLE 5

| Reg | Pressure (Pa)   | Temperature (K) | V-VALIDATE(m <sup>3</sup> /kg) | V-VR3PT97B(m <sup>3</sup> /kg) | IREG |
|-----|-----------------|-----------------|--------------------------------|--------------------------------|------|
| A   | 5.000000000E+07 | 6.300000000E+02 | 1.470853100E-03                | 1.470853100E-03                | 1    |
| A   | 8.000000000E+07 | 6.700000000E+02 | 1.503831359E-03                | 1.503831359E-03                | 1    |
| B   | 5.000000000E+07 | 7.100000000E+02 | 2.204728587E-03                | 2.204728587E-03                | 2    |
| B   | 8.000000000E+07 | 7.500000000E+02 | 1.973692940E-03                | 1.973692940E-03                | 2    |
| C   | 2.000000000E+07 | 6.300000000E+02 | 1.761696406E-03                | 1.761696406E-03                | 3    |
| C   | 3.000000000E+07 | 6.500000000E+02 | 1.819560617E-03                | 1.819560617E-03                | 3    |
| D   | 2.500000000E+07 | 6.500000000E+02 | 2.045506581E-03                | 2.045512417E-03                | 7    |
| D   | 3.000000000E+07 | 6.700000000E+02 | 2.506897702E-03                | 2.506897702E-03                | 4    |
| E   | 2.500000000E+07 | 6.600000000E+02 | 4.363203554E-03                | 3.867495940E-03                | 9    |
| E   | 3.000000000E+07 | 6.750000000E+02 | 3.004627086E-03                | 3.004627086E-03                | 5    |
| F   | 2.500000000E+07 | 6.700000000E+02 | 5.660294977E-03                | 5.660319363E-03                | 11   |
| F   | 3.000000000E+07 | 6.900000000E+02 | 4.656470142E-03                | 4.656470142E-03                | 6    |
| G   | 2.350000000E+07 | 6.500000000E+02 | 2.280228192E-03                | 2.280224774E-03                | 12   |
| G   | 2.400000000E+07 | 6.500000000E+02 | 2.166044161E-03                | 2.166044161E-03                | 7    |
| H   | 2.350000000E+07 | 6.500000000E+02 | 2.292633862E-03                | 2.280224774E-03                | 12   |
| H   | 2.400000000E+07 | 6.540000000E+02 | 2.967802335E-03                | 2.967802335E-03                | 8    |
| I   | 2.350000000E+07 | 6.520000000E+02 | 2.742598602E-03                | 2.813485797E-03                | 8    |
| I   | 2.400000000E+07 | 6.550000000E+02 | 3.550329864E-03                | 3.550329864E-03                | 9    |
| J   | 2.350000000E+07 | 6.550000000E+02 | 4.545001142E-03                | 4.545001142E-03                | 10   |
| J   | 2.400000000E+07 | 6.600000000E+02 | 5.100267704E-03                | 5.100267704E-03                | 10   |
| K   | 2.300000000E+07 | 6.600000000E+02 | 6.109525997E-03                | 6.109525997E-03                | 11   |
| K   | 2.400000000E+07 | 6.700000000E+02 | 6.427325645E-03                | 6.427325645E-03                | 11   |
| L   | 2.250000000E+07 | 6.440000000E+02 | 2.017533009E-03                | 2.017530677E-03                | 17   |
| L   | 2.300000000E+07 | 6.460000000E+02 | 2.062374674E-03                | 2.062374674E-03                | 12   |
| M   | 2.250000000E+07 | 6.483000000E+02 | 2.537710212E-03                | 2.535375749E-03                | 21   |
| M   | 2.280000000E+07 | 6.493000000E+02 | 2.572971781E-03                | 2.572971781E-03                | 13   |
| N   | 2.250000000E+07 | 6.486000000E+02 | 2.832219262E-03                | 2.832373260E-03                | 22   |
| N   | 2.280000000E+07 | 6.497000000E+02 | 2.913311494E-03                | 2.913311494E-03                | 14   |
| O   | 2.250000000E+07 | 6.488000000E+02 | 3.333305691E-03                | 3.333523111E-03                | 23   |
| O   | 2.280000000E+07 | 6.499000000E+02 | 3.221160278E-03                | 3.221160278E-03                | 15   |
| P   | 2.250000000E+07 | 6.492000000E+02 | 4.004583293E-03                | 4.003752014E-03                | 24   |
| P   | 2.280000000E+07 | 6.502000000E+02 | 3.664754790E-03                | 3.664754790E-03                | 16   |
| Q   | 2.110000000E+07 | 6.400000000E+02 | 1.970999272E-03                | 1.970999272E-03                | 17   |
| Q   | 2.180000000E+07 | 6.430000000E+02 | 2.043919161E-03                | 2.043919161E-03                | 17   |
| R   | 2.110000000E+07 | 6.440000000E+02 | 5.251009921E-03                | 5.251009921E-03                | 18   |
| R   | 2.180000000E+07 | 6.480000000E+02 | 5.256844741E-03                | 5.256844741E-03                | 18   |
| S   | 1.910000000E+07 | 6.350000000E+02 | 1.932829079E-03                | 1.932829079E-03                | 19   |
| S   | 2.000000000E+07 | 6.380000000E+02 | 1.985387227E-03                | 1.985387227E-03                | 19   |
| T   | 1.700000000E+07 | 6.260000000E+02 | 8.483262001E-03                | 8.483262001E-03                | 20   |
| T   | 2.000000000E+07 | 6.400000000E+02 | 6.227528101E-03                | 6.227528101E-03                | 20   |

REF 7: TABLE 13

| Reg | Pressure (Pa)   | Temperature (K) | V-VALIDATE(m <sup>3</sup> /kg) | V-VR3PT97B(m <sup>3</sup> /kg) | IREG |
|-----|-----------------|-----------------|--------------------------------|--------------------------------|------|
| U   | 2.110000000E+07 | 6.435000000E+02 | 2.300279389E-03                | 4.980308856E-03                | 18   |
| U   | 2.200000000E+07 | 6.461000000E+02 | 2.296350553E-03                | 2.296350553E-03                | 21   |
| V   | 2.250000000E+07 | 6.486000000E+02 | 2.832373260E-03                | 2.832373260E-03                | 22   |
| V   | 2.230000000E+07 | 6.479000000E+02 | 2.811424405E-03                | 2.811424405E-03                | 22   |
| W   | 2.211000000E+07 | 6.473000000E+02 | 3.534933908E-03                | 3.560726351E-03                | 26   |
| W   | 2.230000000E+07 | 6.481000000E+02 | 3.622226305E-03                | 3.622226305E-03                | 23   |
| X   | 2.211000000E+07 | 6.480000000E+02 | 4.528072649E-03                | 4.528072649E-03                | 24   |
| X   | 2.230000000E+07 | 6.490000000E+02 | 4.556905799E-03                | 4.556905799E-03                | 24   |
| Y   | 2.200000000E+07 | 6.468400000E+02 | 2.698354719E-03                | 2.698354719E-03                | 25   |
| Y   | 2.206400000E+07 | 6.470500000E+02 | 2.717655648E-03                | 2.717655648E-03                | 25   |
| Z   | 2.200000000E+07 | 6.468900000E+02 | 3.798732962E-03                | 3.798732962E-03                | 26   |
| Z   | 2.206400000E+07 | 6.471500000E+02 | 3.701940009E-03                | 3.701940009E-03                | 26   |

Note: V-VALIDATE values from direct call to V3?PT97B, with ?=A TO Z  
 V-VR3PT97B values from direct call to VR3PT97B, and IREG=IERR97(1)

MISC FUNCTIONS

|                           |                   |                       |                 |                    |
|---------------------------|-------------------|-----------------------|-----------------|--------------------|
| P2397                     |                   | REF 1: TABLE 1 CHECK  |                 |                    |
|                           | Temperature       | 0.623150000E+03       | K               |                    |
|                           | Pressure          | 0.165291643E+08       | Pa              |                    |
| T2397                     |                   | REF 1: TABLE 1 CHECK  |                 |                    |
|                           | Pressure          | 0.165291643E+08       | Pa              |                    |
|                           | Temperature       | 0.623150000E+03       | K               |                    |
| PSAT97                    |                   | REF 1: TABLE 35       |                 |                    |
|                           | Temperature       | 0.300000000E+03       | 0.500000000E+03 | 0.600000000E+03 K  |
|                           | Pressure          | 0.353658941E+04       | 0.263889776E+07 | 0.123443146E+08 Pa |
| TSAT97                    |                   | REF 1: TABLE 36       |                 |                    |
|                           | Pressure          | 0.100000000E+06       | 0.100000000E+07 | 0.100000000E+08 Pa |
|                           | Temperature       | 0.372755919E+03       | 0.453035632E+03 | 0.584149488E+03 K  |
| NO FUNCTION-INTERNAL CODE |                   | REF 1: TABLE 19 CHECK |                 |                    |
|                           | Pressure          | 0.100000000E+09       | Pa              |                    |
|                           | Specific Enthalpy | 0.351600432E+04       | kJ/kg           |                    |
| NO FUNCTION-INTERNAL CODE |                   | REF 2: TABLE 5 CHECK  |                 |                    |
|                           | Specific Entropy  | 7.000000000E+00       | kJ/kg-K         |                    |
|                           | Specific Enthalpy | 3.376437884E+03       | kJ/kg           |                    |
| NO FUNCTION-INTERNAL CODE |                   | REF 3: TABLE 2 CHECK  |                 |                    |
|                           | Pressure          | 2.500000000E+07       | Pa              |                    |
|                           | Specific Enthalpy | 2.095936454E+03       | kJ/kg           |                    |

References:

R1

Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (September 1997) (This release replaces the corresponding release of 1967)

R2

Supplementary Release on Backward Equations for Pressure as a Function of Enthalpy and Entropy  $p(h,s)$  to the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (September 2001)

R3

Revised Supplementary Release on Backward Equations for the Functions  $T(p,h)$ ,  $v(p,h)$ , and  $T(p,s)$ ,  $v(p,s)$  for Region 3 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (September 2004)

R4

Supplementary Release on Backward Equations  $p(h,s)$  for Region 3, Equations as a Function of  $h$  and  $s$  for the Region Boundaries, and an Equation  $T_{sat}(h,s)$  for Region 4 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (September 2004)

R5

Kretzschmar, H.-J.; Stöcker, I.; Knobloch, K.; Willkommen, Th.; Trübenbach, J.; Dittmann A.: Supplementary Backward Equations  $p(h,s)$  and Equations  $v(p,T)$  for the Critical Region to the New Industrial Formulation IAPWS-IF97 for Water and Steam. 13th International Conference on the Properties of Water and Steam, Toronto 1999

R6

Wagner, W., A. Kruse, 'Properties of Water and Steam. The Industrial Standard IAPWS-IF97 for the Thermodynamic Properties and Supplementary Equations for Other Properties,' Springer, Berlin, 1998. ISBN 3-540-64339-7

R7

Supplementary Release on Backward Equations for Specific Volume as a Function of Pressure and Temperature  $v(p,T)$  for Region 3 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (July 2005)