# ASTEM97

## Based on the IAPWS IF-97

## Water and Steam Properties for Industrial Use

Implementation by

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### Appendix A

# Routine Summary

### Version 2.0

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```
FUNCTION   CPPT1(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 1
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CPPT1 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR  NONE

FUNCTION   CPPT2(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 2
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CPPT2 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR  NONE

FUNCTION   CPPT2I(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 3
INPUT     PIN - PRESSURE PA (NOT USED)
          TIN - TEMPERATURE K
RETURN CPPT2I - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR NONE

FUNCTION   CPPT3(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
-----------------------------------------------------------
CP SHOWS MATHEMATICAL INSTABILITY GOING NEGATIVE NEAR THE
CRITICAL PRESSURE, TEMPERATURE POINT
A PRESSURE FIX (REDUCED BY 1.D-07 PA STEP) IS USED TO
ADJUST THE T,P POINT TO GIVE A POSITIVE RESULT
IFLAG97(6) ON/OFF OPTION 0 = NO, 1 = YES
LIMIT DELTA P TO 1.D-04 PA (EG 1000 ATTEMPTS)
-----------------------------------------------------------
ROUTINE NUMBER 4
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K,
RETURN CPPT3 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR  NONE

FUNCTION   CPPT5(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 5
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CPPT5 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR NONE

FUNCTION   CPPT5I(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 6
INPUT     PIN - PRESSURE PA (NOT USED)
          TIN - TEMPERATURE K
RETURN CPPT5I - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR  NONE
```

```
FUNCTION   CPPT97(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 7
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN CPPT97 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR
    RETURNS CPPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   CPPTM(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 8
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CPPTM - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR  NONE

FUNCTION   CPPTMI(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 9
INPUT     PIN - PRESSURE PA (NOT USED)
          TIN - TEMPERATURE K
RETURN CPPTMI - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR  NONE

FUNCTION   CPPX97(TIN,XIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 222
INPUT  PIN    - PRESSURE PA
       XIN    - QUALITY
RETURN CPPX97 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR
    RETURNS CPPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF PIN LT PMIN
                  - -4 IF PIN GT PCRT

FUNCTION   CPTR3(TIN,RHO)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 10
INPUT    TIN - TEMPERATURE K
         RHO - DENSITY KG/M^3
RETURN CPTR3 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR  NONE
```

```
FUNCTION   CPTX97(TIN,XIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT TEMPERATURE,QUAL=0 OR 1
ROUTINE NUMBER 221
INPUT  TIN    - TEMPERATURE K
       XIN    - QUALITY
RETURN CPTX97 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
ERROR
    RETURNS CPTX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   CSEU97(IVAR,VAR)
ROUTINE NUMBER 210
CONVERT FROM/TO SI/ENGLISH UNITS
INPUT  IVAR - VARIABLE INDEX
              IF IVAR + (POSITIVE) FROM SI TO ENGLISH
              IF IVAR - (NEGATIVE) FROM ENGLISH TO SI
       VAR - VARIABLE VALUE
RETURN CSEU97 - CONVERTED VALUE
ERROR
      IF IVAR = 0 OR IVAR <31 OR > 31
      IFLAG97(1) = -1
      CSEU97 = -1.0
TABLE FOR CONVERSION CONSTANTS           SI UNITS     US UNITS
                                         --------     --------
PROP97(1)  =                   PRESSURE  PA           PSIA
PROP97(2)  =                TEMPERATURE  K            DEG F
PROP97(3)  =             SPECIFIC VOLUME  M^3/KG       FT^3/LBM
PROP97(4)  =   SPECIFIC INTERNAL ENERGY  KJ/KG        BTU/LBM
PROP97(5)  =           SPECIFIC ENTHALPY  KJ/KG        BTU/LBM
PROP97(6)  =            SPECIFIC ENTROPY  KJ/(KG-K)    BTU/(LBM-F)
PROP97(7)  =                    QUALITY  ---           ---
PROP97(8)  =   SPECIFIC HEAT AT P=CONST  KJ/(KG-K)    BTU/(LBM-F)
PROP97(9)  =   SPECIFIC HEAT AT V=CONST  KJ/(KG-K)    BTU/(LBM-F)
PROP97(10) =              SONIC VELOCITY  M/SEC        FT/SEC
PROP97(11) =           DV/DP AT T=CONST  (M^3/KG)/PA  (FT^3/LBM)/PSI
PROP97(12) =           DV/DT AT P=CONST  (M^3/KG)/K   (FT^3/LBM)/K
PROP97(13) =           DP/DV AT T=CONST  PA/(M^3/KG)  PSI/(FT^3/LBM)
PROP97(14) =           DP/DT AT V=CONST  PA/K         PSI/F
PROP97(15) =  COEF OF THERMAL EXPANSION  1/K          1/F
PROP97(16) = ISOTHERMAL COMPRESSIBILITY  1/PA         1/PSI
PROP97(17) =        ISENTROPIC EXPONENT  ---          ---

DYNVPRS[18]-          DYNAMIC VISCOSITY  MICRO PA-SEC LBM/(FT-SEC)
SURTEN [19]-            SURFACE TENSION  MILLI N/M    LBF/FT
TC85PRS[20]-       THERMAL CONDUCTIVITY  W/M-K        BTU/(HR-FT-F)
TC97PRS[21]-       THERMAL CONDUCTIVITY  W/M-K        BTU/(HR-FT-F)
RINDPRS[22]-           REFRACTIVE INDEX  ---          ---
STDIPRS[23]- STATIC DIELECTRIC CONSTANT  ---          ---
GIBBFE [24]-          GIBBS FREE ENERGY  KJ/KG        BTU/LBM
HELMFE [25]-      HELMHOLTZ FREE ENERGY  KJ/KG        BTU/LBM
JTCOEF [26]-        JOULE-THOMPSON COEF  K/PA         F/PSIA
       [27]- ISOTHERMAL JOULE-THOM COEF  (KJ/KG)/PA   (BTU/LBM)/PSI
       [28]-        KINEMATIC VISCOSITY  M^2/SEC      FT^2/SEC
       [29]-     COMPRESSIBILITY FACTOR  ---          ---
       [30]-             PRANDTL NUMBER  ---          ---

1/SPVOL[31]-                    DENSITY  KG/M^3       LBM/FT^3
```

```
FUNCTION   CVPT1(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 11
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CVPT1 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE

FUNCTION   CVPT2(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 12
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CVPT2 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE

FUNCTION   CVPT2I(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 13
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN CPPT2I - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE

FUNCTION   CVPT3(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 14
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K,
RETURN CVPT3 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE

FUNCTION   CVPT5(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 15
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CVPT5 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE

FUNCTION   CVPT5I(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 16
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN CVPT5I - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE
```

```
FUNCTION   CVPT97(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 17
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN    - PRESSURE PA
       TIN    - TEMPERATURE K
RETURN CVPT97 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR
    RETURNS CPPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   CVPTM(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 18
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN CVPTM - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE

FUNCTION   CVPTMI(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 19
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN CVPTMI - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR  NONE

FUNCTION   CVPX97(TIN,XIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 224
INPUT  PIN    - PRESSURE PA
       XIN    - QUALITY
RETURN CVPX97 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR
    RETURNS CVPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF PIN LT PMIN
                  - -4 IF PIN GT PCRT

FUNCTION   CVTR3(TIN,RHO)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 20
INPUT    TIN - TEMPERATURE K
         RHO - DENSITY KG/M^3
RETURN CVTR3 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR NONE
```

```
FUNCTION   CVTX97(TIN,XIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT TEMPERATURE,QUAL=0 OR 1
ROUTINE NUMBER 223
INPUT  TIN    - TEMPERATURE K
       XIN    - QUALITY
RETURN CVTX97 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
ERROR
    RETURNS CVTX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   DERV97(INDEX)
ROUTINE NUMBER 21
USER CONTROL INTERFACE ROUTINE
RETURN G0(INDEX) IF INDEX IS POSITIVE (RANGE 1 TO 10)
FROM GIBBX CALL  (X IS 1, 2, 2I, M ,MI, 5 OR 5I)
     G0( 7) = PIN
     G0( 8) = TIN
     G0( 9) = PIE
     G0(10) = TAU
FROM HELM3 CALL
     G0( 7) = DEL
     G0( 8) = RHO
     G0( 9) = TIN
     G0(10) = TAU
RETURN GR(INDEX) IF INDEX IS NEGATIVE (RANGE 1 TO 6)
RETURN S97(6) IF INDEX = 0, SPECIAL CASE INTERNAL
ERROR
      RETURN -601 IF INVALID REQUEST

FUNCTION   DPDTV1(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 22
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDTV1 - DPDT AT V - PA/K
ERROR  NONE

FUNCTION   DPDTV2(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 23
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDTV2 - DPDT AT V - PA/K
ERROR  NONE

FUNCTION   DPDTV2I(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 24
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDTV2I - DPDT AT V - PA/K
ERROR  NONE
```

```
FUNCTION   DPDTV3(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 25
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDTV3 - DPDT AT V - PA/K
ERROR  NONE

FUNCTION   DPDTV3R(TIN,RHO)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 26
INPUT      TIN - TEMPERATURE K
           RHO - KG/M^3
RETURN DPDTV3R - DPDT AT V - PA/K
ERROR  NONE

FUNCTION   DPDTV5(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 27
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPCTV5 - DPDT AT V - PA/K
ERROR  NONE

FUNCTION   DPDTV5I(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 28
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDTV5I - DPDT AT V - PA/K
ERROR  NONE

FUNCTION   DPDTV97(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 29
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN     - PRESSURE PA
       TIN     - TEMPERATURE K
RETURN DPDTV97 - DPDT AT V - PA/K
ERROR
    RETURNS DPDTV97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   DPDTVM(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 30
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDYVM - DPDT AT V - PA/K
ERROR  NONE
```

```
FUNCTION   DPDTVMI(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 31
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDTVMI - DPDT AT V - PA/K
ERROR  NONE

FUNCTION   DPDTVPX(TIN,XIN)
DP/DT AT V AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 228
INPUT  PIN     - PRESSURE PA
       XIN     - QUALITY
RETURN DPDTVPX - DP/DT AT V
ERROR
    RETURNS DPDTVPX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF PIN LT PMIN
                  - -4 IF PIN GT PCRT

FUNCTION   DPDTVTX(TIN,XIN)
DP/DT AT V AT TEMPERATURE,QUAL=0 OR 1
ROUTINE NUMBER 227
INPUT  TIN     - TEMPERATURE K
       XIN     - QUALITY
RETURN DPDTVTX - DP/DT AT V
ERROR
    RETURNS DPDTVTX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   DPDVT1(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 32
INPUT    PIN  - PRESSURE PA
         TIN  - TEMPERATURE K
RETURN DPDVT1 - DPDV AT T - PA-KG/M^3
ERROR  NONE

FUNCTION   DPDVT2(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 33
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDVT2 - DPDV AT T - PA-KG/M^3
ERROR  NONE

FUNCTION   DPDVT2I(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 34
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDVT2I - DPDV AT T - PA-KG/M^3
ERROR  NONE
```

```
FUNCTION   DPDVT3(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 35
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDVT3 - DPDV AT T - PA-KG/M^3
ERROR  NONE

FUNCTION   DPDVT3R(TIN,RHO)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 36
INPUT      TIN - TEMPERATURE K
           RHO - KG/M^3
RETURN DPDVT3R - DPDV AT T - PA-KG/M^3
ERROR  NONE

FUNCTION   DPDVT5(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 37
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDVT5 - DPDV AT T - PA-KG/M^3
ERROR  NONE

FUNCTION   DPDVT5I(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 38
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDVT5I - DPDV AT T - PA-KG/M^3
ERROR  NONE

FUNCTION   DPDVT97(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 39
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDVT97 - DPDV AT T - PA-KG/M^3
ERROR
    RETURNS DPDVT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   DPDVTM(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 40
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDVTM - DPDV AT T - PA-KG/M^3
ERROR  NONE
```

```
FUNCTION   DPDVTMI(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 41
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDVTMI - DPDV AT T - PA-KG/M^3
ERROR  NONE

FUNCTION   DPDVTPX(TIN,XIN)
DP/DV AT T AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 230
INPUT  PIN     - PRESSURE PA
       XIN     - QUALITY
RETURN DPDVTPX - DP/DT AT V
ERROR
    RETURNS DPDVTPX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF PIN LT PMIN
                  - -4 IF PIN GT PCRT

FUNCTION   DPDVTTX(TIN,XIN)
DP/DV AT T AT TEMPERATURE,QUAL=0 OR 1
ROUTINE NUMBER 229
INPUT  TIN     - TEMPERATURE K
       XIN     - QUALITY
RETURN DPDVTTX - DP/DT AT V
ERROR
    RETURNS DPDVTTX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   DVDPT1(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 42
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDPT1 - DVDP AT T - M^3/PA-KG
ERROR  NONE

FUNCTION   DVDPT2(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 43
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDPT2 - DVDP AT T - M^3/PA-KG
ERROR  NONE

FUNCTION   DVDPT2I(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 44
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DVDPT2I - DVDP AT T - M^3/PA-KG
ERROR  NONE
```

```
FUNCTION   DVDPT3(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 45
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDPT3 - DVDP AT T - M^3/PA-KG
ERROR  NONE

FUNCTION   DVDPT3R(TIN,RHO)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 46
INPUT      TIN - TEMPERATURE K
           RHO - KG/M^3
RETURN DVDPT3R - DVDP AT T - M^3/PA-KG
ERROR  NONE

FUNCTION   DVDPT5(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 47
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDPT5 - DVDP AT T - M^3/PA-KG
ERROR  NONE

FUNCTION   DVDPT5I(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 48
INPUT      PIN - PRESSURE PA (NOT USED))
           TIN - TEMPERATURE K
RETURN DVDPT5I - DVDP AT T - M^3/PA-KG
ERROR  NONE

FUNCTION   DVDPT97(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 49
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDPT97 - DVDP AT T - M^3/PA-KG
ERROR
    RETURNS DVDPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   DVDPTM(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 50
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDPTM - DVDP AT T - M^3/PA-KG
ERROR  NONE
```

```
FUNCTION   DVDPTMI(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 51
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DVDPTMI - DVDP AT T - M^3/PA-KG
ERROR  NONE

FUNCTION   DVDPTPX(TIN,XIN)
DV/DP AT T AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 232
INPUT  PIN     - PRESSURE PA
       XIN     - QUALITY
RETURN DVDPTPX - DP/DT AT V
ERROR
    RETURNS DVDPTPX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF PIN LT PMIN
                  - -4 IF PIN GT PCRT

FUNCTION   DVDPTTX(TIN,XIN)
DV/DP AT T AT TEMPERATURE,QUAL=0 OR 1
ROUTINE NUMBER 231
INPUT  TIN     - TEMPERATURE K
       XIN     - QUALITY
RETURN DVDPTTX - DP/DT AT V
ERROR
    RETURNS DVDPTTX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   DVDTP1(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 52
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDTP1 - DVDT AT P M^3/KG-K
ERROR  NONE

FUNCTION   DVDTP2(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 53
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDTP2 - DVDT AT P M^3/KG-K
ERROR  NONE

FUNCTION   DVDTP2I(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 54
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDTP2I - DVDT AT P M^3/KG-K
ERROR  NONE
```

```
FUNCTION   DVDTP3(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 55
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDTP3 - DVDT AT P M^3/KG-K
ERROR  NONE

FUNCTION   DVDTP3R(TIN,RHO)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 56
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDTP3R - DVDT AT P M^3/KG-K
ERROR  NONE

FUNCTION   DVDTP5(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 57
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDTP5 - DVDT AT P M^3/KG-K
ERROR  NONE

FUNCTION   DVDTP5I(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 58
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDTP5I - DVDT AT P M^3/KG-K
ERROR  NONE

FUNCTION   DVDTP97(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 59
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN     - PRESSURE PA
       TIN     - TEMPERATURE K
RETURN DVDTP97 - DVDT AT P M^3/KG-K
ERROR
    RETURNS DVDTP97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   DVDTPM(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 60
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DVDTPM - DVDT AT P M^3/KG-K
ERROR  NONE
```

```
FUNCTION   DVDTPMI(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 61
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DVDTPMI - DVDT AT P M^3/KG-K
ERROR  NONE

FUNCTION   DVDTPPX(TIN,XIN)
DV/DT AT P AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 234
INPUT  PIN     - PRESSURE PA
       XIN     - QUALITY
RETURN DVDTPPX - DP/DT AT V
ERROR
    RETURNS DVDTPPX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF PIN LT PMIN
                  - -4 IF PIN GT PCRT

FUNCTION   DVDTPTX(TIN,XIN)
DV/DT AT P AT TEMPERATURE,QUAL=0 OR 1
ROUTINE NUMBER 233
INPUT  TIN     - TEMPERATURE K
       XIN     - QUALITY
RETURN DVDTPTX - DP/DT AT V
ERROR
    RETURNS DVDTPTX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   DYNVPRS(PIN,TIN)
ROUTINE NUMBER 62
COMPUTE DYNAMIC VISCOSITY OF WATER AT PIN,TIN
RANGE   273.15 <= T <=  423.15  P <= 500 MPA
        423.15 <  T <=  873.15  P <= 350 MPA
        873.15 <  T <= 1173.15  P <= 300 MPA
WITHIN IF-97 CONTEXT NO NEED TO VALIDATE PRESSURE (<= 100 MPA)
WOULD HAVE HAD TO PASS (P,T) SCREENING TO GET RHO
INPUT      PIN - PA
           TIN - K
RETURN DYNVPRS - MICRO PA-S (FROM FUNCTION DYNVRHO)
ERROR
    RETURNS DYNVPRS = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA
                  - -5 IF TIN GT 1173.15(REGION 5, P < 10 MPA)
```

```
FUNCTION   DYNVRHO(RHO,TIN)
ROUTINE NUMBER 63
COMPUTE DYNAMIC VISCOSITY OF WATER AT RHO,TIN
RANGE   273.15 <= T <=  423.15  P <= 500 MPA
        423.15 <  T <=  873.15  P <= 350 MPA
        873.15 <  T <= 1173.15  P <= 300 MPA
WITHIN IF-97 CONTEXT NO NEED TO VALIDATE PRESSURE (<= 100 MPA)
WOULD HAVE HAD TO PASS (P,T) SCREENING TO GET RHO
INPUT      TIN - K
           RHO - KG/M^3
RETURN DYNVRHO - MICRO PA-S
ERROR
     RETURNS DYNVRHO = -1.0D0 IF TIN > 1173.15 K OR TIN > 273.15 K
     RETRIEVE ERROR FLAG VALUE
              IERR = IERR97(1)
                   - -1 IF RHO<MIN 1/VPT2 (PMIN,TIN):VPT5(PMIN,TIN)
                   - -2 IF RHO>MAX 1/VPT97(PMAX,TIN):VPT5(P010,TIN)
                   - -3 IF TIN LT  273.15 K
                   - -4 IF TIN GT 1173.15 K

SUBROUTINE GIBB1(PIN,TIN)
ROUTINE NUMBER 64
GIBBS EQUATION REGION 1
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL P97CALA FOR FIRST ORDER
    CALL P97CALB FOR SECOND ORDER
ERROR NONE

SUBROUTINE GIBB2(PIN,TIN)
ROUTINE NUMBER 65
GIBBS EQUATION REGION 2
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL P97CAL1 FOR FIRST ORDER
    CALL P97CAL2 FOR SECOND ORDER
ERROR NONE

SUBROUTINE GIBB2I(PIN,TIN)
ROUTINE NUMBER 66
GIBBS EQUATION REGION 2 IDEAL GAS PART
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL P97CALG1 FOR FIRST ORDER
    CALL P97CALG2 FOR SECOND ORDER
ERROR NONE
```

```
SUBROUTINE GIBB5(PIN,TIN)
ROUTINE NUMBER 67
GIBBS EQUATION REGION 5
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL P97CAL1 FOR FIRST ORDER
    CALL P97CAL2 FOR SECOND ORDER
ERROR NONE

SUBROUTINE GIBB5I(PIN,TIN)
ROUTINE NUMBER 68
GIBBS EQUATION REGION 5 IDEAL GAS PART
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL P97CALG1 FOR FIRST ORDER
    CALL P97CALG2 FOR SECOND ORDER
ERROR NONE

SUBROUTINE GIBBM(PIN,TIN)
ROUTINE NUMBER 69
GIBBS EQUATION REGION 2 METASTABLE REGION
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL P97CAL1 FOR FIRST ORDER
    CALL P97CAL2 FOR SECOND ORDER
ERROR NONE

SUBROUTINE GIBBMI(PIN,TIN)
ROUTINE NUMBER 70
GIBBS EQUATION REGION 2 METASTABLE REGION IDEAL GAS PART
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL P97CALG1 FOR FIRST ORDER
    CALL P97CALG2 FOR SECOND ORDER
ERROR NONE

SUBROUTINE H97CALA
ROUTINE NUMBER 71
HELMHOLTZ EQUATION REGION 3 FIRST ORDER DERIVATIVES
MUST HAVE CALL HELM3 BEFORE CALL
RETURN STATE POINT IN P97(1) - P97(7), P97(24), P97(25)
P97(1)  = P -PA
P97(2)  = T - K
P97(3)  = V - M^3/KG
P97(31) = DENSITY - 1/P97(3) - KG/M^3
P97(4)  = U - KJ/KG
P97(5)  = H - KJ/KG-K
P97(6)  = S - KJ/KG
P97(7)  = QUALITY
P97(24) = GIBBS FREE ENERGY     = ENTHALPY - (TEMPERATURE*ENTROPY)
P97(25) = HELMHOLTZ FREE ENERGY = ENERGY   - (TEMPERATURE*ENTROPY)
ERROR     NONE
```

```
SUBROUTINE H97CALB
ROUTINE NUMBER 72
HELMHOLTZ EQUATION REGION 3 SECOND ORDER DERIVATIVES
MUST HAVE CALLED HELM3 BEFORE CALL
SPECIAL FLAG SETTING
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
RETURN STATE POINT IN P97(8) - P97(17), P97(26) , P97(27)
P97(8)  = CP - KJ/KG-K
P97(9)  = CV - KJ/KG-K
P97(10) = SV - M/SEC
P97(11) = DVDPT (-RT/P*P)
P97(12) = DVDTP (R /P  )
P97(13) = DPDVT = 1/DVDPT
P97(14) = DPDTV = -(DVDTP/DVDPT)
P97(15) = COEF OF THERMAL EXPANSION DVDTP/V K^-1   P97(12)/P97(3)
P97(16) = ISOTHERMAL EXPANSION     -DVDPT/V PA^-1 -P97(11)/P97(3)
P97(17) = ISENTROPIC EXPONENT     P97(10)*P97(10)/(P97(1)*P97(3))
P97(27) = ISOTHERMAL JOULE-THOM = V - T*DVDTP
P97(26) = JOULE-THOMPSON COEF   = (TIN*DVDTP-V)/CP
ERROR     NONE

SUBROUTINE HELM3(TIN,RHO)
ROUTINE NUMBER 73
HELMHOLTZ EQUATION REGION 3
INPUT  TIN - TEMPERATURE K
INPUT  RHO - DENSITY KG/M^3
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
TO COMPUTE ACTUAL PROPERTIES DO CALLS TO
    CALL H97CALA FOR FIRST ORDER
    CALL H97CALB FOR SECOND ORDER
ERROR NONE

SUBROUTINE HELM312(TIN,RIN,PCAL,GO1)
ROUTINE NUMBER 74
CALLED BY ROOT3MAX
AUXILIARY ROUTINE TO SOLVE MAXWELL CRITERION ON SAT LINE
NEED HELMHOLTZ EQUATION REGION 3
INPUT   TIN   - TEMPERATURE K
        RIN   - DENSITY KG/M^3
RETURN  PCAL  - PRESSURE PA
        G01   - REDUCED HELMHOLTZ VALUE
ERROR   NONE

FUNCTION   HPT1(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 75
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPT1 - ENTHALPY - KJ/KG
ERROR  NONE

FUNCTION   HPT2(PIN,TIN)
ROUTINE NUMBER 76
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPT2 - ENTHALPY - KJ/KG
ERROR  NONE
```

```
FUNCTION   HPT2I(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 77
INPUT    PIN - PRESSURE PA (NOT USED)
         TIN - TEMPERATURE K
RETURN HPT2I - ENTHALPY - KJ/KG
ERROR  NONE

FUNCTION   HPT3(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 78
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPT3 - ENTHALPY - KJ/KG
ERROR  NONE

FUNCTION   HPT5(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 79
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPT5 - ENTHALPY - KJ/KG
ERROR  NONE

FUNCTION   HPT5I(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 80
INPUT    PIN - PRESSURE PA (NOT USED)
         TIN - TEMPERATURE K
RETURN HPT5I - ENTHALPY - KJ/KG
ERROR  NONE

FUNCTION   HPT97(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 81
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN   - PRESSURE PA
       TIN   - TEMPERATURE K
RETURN HPT97 - ENTHALPY - KJ/KG
ERROR
    RETURNS HPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   HPTM(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 82
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPTM - ENTHALPY - KJ/KG
ERROR  NONE
```

```
FUNCTION   HPTMI(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 83
INPUT    PIN - PRESSURE PA (NOT USED)
         TIN - TEMPERATURE K
RETURN HPTMI - ENTHALPY - KJ/KG
ERROR  NONE

FUNCTION   HPX97(PIN,XIN)
ENTHALPY AS FUNCTION OF PRESSURE,QUALITY
ROUTINE NUMBER 84
INPUT  PIN   - PRESSURE PA
       XIN   - QUALITY
RETURN HPX97 - 2-PHASE ENTHALPY - KJ/KG
ERROR
    RETURNS HPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PCRT
                  - -3 IF XIN LT 0.0
                  - -4 IF XIN GT 1.0

FUNCTION   HSB1397B(SNN)
ROUTINE NUMBER 265
INPUT  SNN      - ENTROPY, KJ/KG-K
RETURN HSB1397B - ENTHALPY ON REG 1 TO 3 BOUNDARY, KJ/KG
ERROR             -1.0D0 IF OUT OF RANGE
                  IFLAG97(1) = -1 IF SNN TOO LOW
                  IFLAG97(1) = -2 IF SNN TOO HIGH

FUNCTION   HSMAX97(SNN)
ROUTINE NUMBER 270
INPUT  SNN      - ENTROPY, KJ/KG-K
RETURN HSMAX97 - FITTED ENTHALPY AT 100 MPA, KJ/KG
ERROR             -1.0D0 IF OUT OF RANGE
                  IFLAG97(1) = -1 IF SNN TOO LOW
                  IFLAG97(1) = -2 IF SNN TOO HIGH
RETURN HSMAX97 - FITTED ENTHALPY AT 100 MPA, KJ/KG
RETURN HSTMAX97 - FITTED ENTHALPY AT 1073.15 K, KJ/KG

FUNCTION   HSPMIN97(SNN)
ROUTINE NUMBER 269
INPUT  SNN      - ENTROPY, KJ/KG-K
RETURN HSPMIN97 - FITTED ENTHALPY AT 611.213 PA, KJ/KG
ERROR             -1.0D0 IF OUT OF RANGE
                  IFLAG97(1) = -1 IF SNN TOO LOW
                  IFLAG97(1) = -2 IF SNN TOO HIGH

FUNCTION   HSSAT97B(SNN)
ROUTINE NUMBER 264
INPUT  SNN      - ENTROPY, KJ/KG-K
RETURN HSSAT97B - SATURATION ENTHALPY (COMPOSITE), KJ/KG
ERROR            -1.0D0 IF OUT OF RANGE
                 IFLAG97(1) = -1 IF SNN TOO LOW
                 IFLAG97(1) = -2 IF SNN TOO HIGH
RETURN HS1L97B - SATURATION LIQUID ENTHALPY REG 1, KJ/KG
RETURN HS3L97B - SATURATION LIQUID ENTHALPY REG 3, KJ/KG
RETURN HS2VB97B - SATURATION VAPOR EHTHALPY REG 2B, KJ/KG
RETURN HS2VA97B - SATURATION VAPOR ENTHALPY REG 2A, KJ/KG
```

```
FUNCTION   HTR3(TIN,RHO)
ENTHALPY AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 85
INPUT   TIN - TEMPERATURE K
        RHO - DENSITY KG/M^3
RETURN HTR3 - ENTHALPY - KJ/KG
ERROR  NONE

FUNCTION   HTX97(TIN,XIN)
ENTHALPY AS FUNCTION OF TEMPERATURE,QUALITY
ROUTINE NUMBER 86
INPUT  TIN   - TEMPERATURE K
       XIN   - QUALITY
RETURN HTX97 - 2-PHASE ENTHALPY KJ/KG
ERROR
    RETURNS HTX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF XIN LT 0.0
                  - -2 IF XIN GT 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   IBAK97(PIN,VAR,IVAR)
ROUTINE NUMBER 87
GIVEN P,V FIND IF IF-97 BACKWARD EQUATIONS ARE VALID
INPUT  - PIN - PRESSURE PA
         VAR - H (KJ/KG)   IF IVAR = 1  P97 INDEX = 5
             - S (KJ/KG-K)    IVAR = 2  P97 INDEX = 6
    ------------------------------------------------------------
          PMAX  ---------------------------------------------------
                I             +      +        W              I
                I             +               W+             I
                I     1       +      3       W +  2         I
                I             +             W                I
          PCRT  I..          ..+     .6.   .W ..+           ..I
                I             + 8  6  9 W                     I
                I             +  6   +W                       I
          P623  I..          ..O6.WWW              2        ..I
                I             4+                              I
                I     1     4             2                   I
          P010  I..     .. 4           +        +           ..I-----I
                I       4                                     +     I
                I    44    2  +       +        +              +  5  I
          PMIN  ---------------------------------------------------
                T             T      T        T              T     T
                M             6      C        8              M     L
                I             2      R        6              A     A
                N             3      T        3              X     R
    ------------------------------------------------------------
RETURN       -    IF97 BACKWARD REGION (1 OR 2)
ERROR
    RETRIEVE REGION IERR = IBAK97
                         - -1 IF P LT PMIN
                         - -2 IF P GT PMAX
                         - -3 IF V LT TMIN
                         - -4 IF V GT TMAX
                         - -5 PERHAPS 2-PHASE OR REGION 3
                         - -6 IF CAN'T IDENTIFY IVAR
```

```
FUNCTION   IGCALA97(IREG)
REPLACEMENT CODING FOR P97CALA,_1,_G1 AS FUNCTION
ROUTINE NUMBER 243

INPUT    IREG =  1 REGION 1                (P97CALA   )
                 2 REGION 2                (P97CAL1   )
                -2 REGION 2 IDEAL GAS ONLY (P97CALG1  )
                 5 REGION 5                (P97CAL1   )
                -5 REGION 5 IDEAL GAS ONLY (P97CALG1  )
                 7 REGION 2 METASTABLE     (P97CAL1   )
                -7 REGION 2 METASTABLE IG  (P97CALC1  )
RETURN   O IF OKAY
CALLS THE APPROPRIATE FIRST ORDER CALCULATIONS
ERROR
IGCALA97 AND IFLAG97(1) RETURNED AS -1 IF INVALID IREG FLAG, ELSE 0

FUNCTION   IGCALB97(IREG)
REPLACEMENT CODING FOR P97CALB,_2,G2 AS FUNCTION
ROUTINE NUMBER 244

INPUT    IREG =  1 REGION 1                (P97CALB   )
                 2 REGION 2                (P97CAL2   )
                -2 REGION 2 IDEAL GAS ONLY (P97CALG2  )
                 5 REGION 5                (P97CAL2   )
                -5 REGION 5 IDEAL GAS ONLY (P97CALG2  )
                 7 REGION 2 METASTABLE     (P97CAL2   )
                -7 REGION 2 METASTABLE IG  (P97CALC2  )
RETURN   O IF OKAY
CALLS THE APPROPRIATE SECONDS ORDER CALCULATIONS
ERROR
IGCALB97 AND IFLAG97(1) RETURNED AS -1 IF INVALID IREG FLAG, ELSE 0

FUNCTION   IGIBB97(IREG,PIN,TIN)
REPLACEMENT CODING FOR GIBBNN AS FUNCTION
ROUTINE NUMBER 242

INPUT    IREG =  1 REGION 1                (GIBB1   )
                 2 REGION 2                (GIBB2   )
                -2 REGION 2 IDEAL GAS ONLY (GIBB2I  )
                 5 REGION 5                (GIBB5   )
                -5 REGION 5 IDEAL GAS ONLY (GIBB5M  )
                 7 REGION 2 METASTABLE     (GIBBM   )
                -7 REGION 2 METASTABLE IG  (GIBBMI  )
         PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN   O IF OKAY
CALLS APPROPRIATE GIBB REGION
ERROR
IGIBB97 AND IFLAG97(1) RETURNED AS -1 IF INVALID IREG FLAG, ELSE 0

FUNCTION   IHCALA97(IREG)
REPLACEMENT CODING FOR H97CALA AS FUNCTION
ROUTINE NUMBER 246
INPUT    IREG =  3 REGION 3                (H97CALA   )
RETURN   O IF OKAY
CALLS H97CALA
ERROR
IHCALA97 AND IFLAG97(1) RETURNED AS -1 IF INVALID IREG FLAG, ELSE 0
```

```
FUNCTION   IHCALB97(IREG)
REPLACEMENT CODING FOR H97CALB AS FUNCTION
ROUTINE NUMBER 247
INPUT    IREG =  3 REGION 3                (H97CALB   )
RETURN   0 IF OKAY
CALLS H97CALB
ERROR
IHCALB97 AND IFLAG97(1) RETURNED AS -1 IF INVALID IREG FLAG, ELSE 0

FUNCTION   IHELM97(IREG,TIN,RHO)
REPLACEMENT CODING FOR HELM3 AS FUNCTION
ROUTINE NUMBER 245
INPUT    IREG =  3 REGION 3                (HELM3   )
         TIN - TEMPERATURE K
         RHO - DENSITY KG/M^3
RETURN   0 IF OKAY
CALLS HELM3 REGION
ERROR
IHELM97 AND IFLAG97(1) RETURNED AS -1 IF INVALID IREG FLAG, ELSE 0

FUNCTION   IPHMET97(PIN,HIN)
REPLACEMENT CODING FOR PHMETA97 AS FUNCTION
ROUTINE NUMBER 252

INPUT    PIN - PRESSURE PA
         HIN - ENTHALPY KJ/KG
RETURN   0 IF OKAY
CALLS PHMETA97
ERROR
IPHMET97 AND IFLAG97(1) RETURNED FROM PHMETA97
```

```
FUNCTION   IPRS97(PIN,VAR,IVAR)
ROUTINE NUMBER 89
GIVEN P WITH V,U,H OR S FIND IF-97 REGION
INPUT  - PIN - PRESSURE PA
         VAR - V (M3/KG)   IF IVAR = 1  P97 INDEX = 3
             - U (KJ/KG)      IVAR = 2  P97 INDEX = 4
             - H (KJ/KG)      IVAR = 3  P97 INDEX = 5
             - S (KJ/KG-K)    IVAR = 4  P97 INDEX = 6
    ------------------------------------------------------------
          PMAX  ------------------------------------------------
                I             +      +        W              I
                I             +              W+              I
                I     1       +      3      W +  2          I
                I             +            W                 I
          PCRT  I..          ..+     .6.  .W ..+            ..I
                I             + 8  6  9 W                     I
                I             +  6   +W                       I
          P623  I..          ..O6.WWW             2         ..I
                I              4+                             I
                I     1     4            2                   I
          P010  I..    .. 4          +        +            ..I-----I
                I       4                                    +     I
                I    44    2  +      +        +              +  5  I
          PMIN  ------------------------------------------------
                T             T      T        T              T     T
                M             6      C        8              M     L
                I             2      R        6              A     A
                N             3      T        3              X     R
    ------------------------------------------------------------
RETURN       -  IPRS97
             -  1  GIBB1
             -  2  GIBB2
             -  3  HELM     (P<PCRT:8 IF TIN<TSAT, 9 IF TIN>TSAT )
             -  5  GIBB5
             -  4  SAT GIBB1/GIBB2
             -  6  SAT HELM3 (ROOT3MAX)
ERROR
    RETRIEVE REGION IERR = IPRS97
                         - -1 IF P LT PMIN
                         - -2 IF P GT PMAX
                         - -3 IF V LT VMIN
                         - -4 IF V GT VMAX
                         - -6 IF CAN'T IDENTIFY IVAR

FUNCTION   IPTCAL97(PIN,TIN)
REPLACEMENT CODING FOR PTPROP97 AS FUNCTION
ROUTINE NUMBER 249
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN   O IF OKAY
CALLS PTPROP97
ERROR
IPTCAL97 AND IFLAG97(1) RETURNED FROM PTPROP97
```

```
FUNCTION   IPTMET97(PIN,TIN)
REPLACEMENT CODING FOR PTMETA97 AS FUNCTION
ROUTINE NUMBER 253
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN   0 IF OKAY
CALLS PTMETA97
ERROR
IPTMET97 AND IFLAG97(1) RETURNED FROM PTMETA97

FUNCTION   IPXCAL97(PIN,XIN)
REPLACEMENT CODING FOR PXPROP97 AS FUNCTION
ROUTINE NUMBER 250
INPUT    PIN - PRESSURE PA
         XIN - QUALITY
RETURN   0 IF OKAY
CALLS TXPROP97
ERROR
IPXCAL97 AND IFLAG97(1) RETURNED FROM PXPROP97

FUNCTION   IREG97(PIN,TIN)
ROUTINE NUMBER 90
GIVEN P,T FIND THE IF-97 REGION FOR THE STATE POINT
INPUT  - PIN - PRESSURE PA
         TIN - TEMPERATURE
    ------------------------------------------------------------------
          PMAX  ----------------------------------------------------
                I             +      +        W              I
                I             +               W+             I
                I     1       +      3      W +  2          I
                I             +             W                I
          PCRT  I..          ..+     .6.   .W ..+           ..I
                I             + 8  6  9 W                     I
                I             +  6   +W                       I
          P623  I..          ..O6.WWW              2         ..I
                I            4+                               I
                I     1     4            2                    I
          P010  I..     .. 4          +        +             ..I-----I
                I       4                                     +     I
                I    44    2  +      +        +               +  5  I
          PMIN  ----------------------------------------------------
                T             T      T        T              T     T
                M             6      C        8              M     L
                I             2      R        6              A     A
                N             3      T        3              X     R
    ------------------------------------------------------------------
RETURN       -    IF97 SINGLE PHASE REGION : 1,2,3,OR 5)
                  IF97 2-PHASE REGION : 4  : NEW 6 IF P >P623)
                  NEW 8 IF IF97 REGION 3 BETWEEN P623/PCRT:<TSAT
                  NEW 9 IF IF97 REGION 3 BETWEEN P623/PCRT:>TSAT
ERROR
    RETRIEVE REGION IERR = IREG97
                         - -1 IF P LT PMIN
                         - -2 IF P GT PMAX OR P010 IF REGION 5
                         - -3 IF T LT TMIN
                         - -4 IF T GT TLAR OR TMAX IF P > 10 MPA
```

```
FUNCTION   IRGHS97(HIN,SNN)
ROUTINE NUMBER 271
GIVEN H,S DETERMINE THE IF97 BACKWARD EQUATION REGION
INPUT  HIN     - ENTHALPY KJ/KG
       SNN     - ENTROPY  KJ/KG-K
RETURN IRGHS97 - PRESSURE PA
ERROR
    IF IREG NOT 1, 2, 3 OR 4 (SATURATION)
    RETRIEVE IERR  = IRGHS97
             IERR  = -1 IF SNN TOO LOW
                   = -2 IF SNN TOO HIGH
                   = -3 IF HIN TOO LOW
                   = -4 IF HIN TOO HIGH
                   = -5 IF 4 BUT SNN LESS THAN S08
       ASTEM97 VALUE          IAPWS VALUE             REFERENCE
S01 = -8.58228709262202D-03                           AT PMAX TMIN
S02 = -1.54549591944324D-04  -1.545495919     D+00    AT PMIN TMIN
S03 =  4.75160915360271D-04                           PEAK TMIN BNDRY
S04 =  3.39778295470189D+00   3.397782955     D+00    REG 1/3 LOW BND
S05 =  3.77828133954429D+00   3.778281340     D+00    REG 1/3 UPP BND
S06 =  4.41202148223635D+00   4.41202148223476D+00    CRITICAL POINT
S07 =  5.04809682795210D+00   5.048096828     D+00    REG 2/3 LOW BND
S08 =  5.21088782493075D+00   5.210887825     D+00    AT T623 PSAT
S09 =  5.26057870689505D+00   5.260578707     D+00    REG 2/3 UPP BND
S10 =  5.85             D+00  5.85            D+00    BREAK POINT
S11 =  6.04048367171238D+00                           @ PMAX TMAX
S12 =  6.58426373060166D+00                           @ 4.0 MPA T623
S13 =  7.85234039987851D+00                           @ 4.0 MPA TMAX
S14 =  9.15575939522441D+00   9.155759395     D+00    @ PMIN TMIN+DELTA
S15 =  1.19210550686136D+01                           @ PMIN TMAX
H03 =  1.89900563906278D+01                           PEAK TMIN BNDRY
H07 =  2.56359200388842D+03   2.563592004     D+03    REG 2/3 LOW BND
H09 =  2.81294206060042D+03   2.812942061     D+03    REG 2/3 UPP BND
```

```
FUNCTION   IRPHS97(PIN,VAR,IVAR)
ROUTINE NUMBER 275
GIVEN P WITH H OR S FIND IF-97 REGION FOR BACKWARD FUNCTION
INPUT  - PIN - PRESSURE PA
         VAR - H (KJ/KG)      IVAR = 1  P97 INDEX = 1
             - S (KJ/KG-K)    IVAR = 2  P97 INDEX = 2
    ------------------------------------------------------------
          PMAX  ----------------------------------------------------
                I             +      +        W              I
                I             +               W+             I
                I     1       +      3      W +  2          I
                I             +            W                 I
          PCRT  I..          ..+     .6.  .W ..+            ..I
                I             + 8  6  9 W                     I
                I             +  6   +W                       I
          P623  I..          ..O6.WWW             2         ..I
                I            4+                              I
                I     1     4            2                   I
          P010  I..    .. 4          +        +            ..I-----I
                I       4                                    +     I
                I    44    2  +      +        +              +  5  I
          PMIN  ----------------------------------------------------
                T             T      T        T              T     T
                M             6      C        8              M     L
                I             2      R        6              A     A
                N             3      T        3              X     R
    ------------------------------------------------------------
RETURN       -  IRPHS97
             -  1   GIBB1
             -  2   GIBB2
             -  3   HELM  FROM PSHBK3 OR PSSBK3
             -  5   GIBB5 (INVALID HERE SET TO -5)
             -  4/6 SATURATION REGION (INVAID HERE SET TO -7)
ERROR
    RETRIEVE REGION IERR = IRPHS97
                         - -1 IF P LT PMIN
                         - -2 IF P GT PMAX
                         - -3 IF V LT VMIN
                         - -4 IF V GT VMAX
                         - -5 IF REGION 5
                         - -6 IF CAN'T IDENTIFY VAR (1 OR 2)
                         - -7 IF SATURATION REGION
```

```
FUNCTION   ISET97(INDEX,IVALUE)
ROUTINE NUMBER 91
USER CONTROL INTERFACE ROUTINE
SET IFLAG97(INDEX) TO IVALUE
ERROR
ISET97 =  0 IF VALID FLAG CHANGE
ISET97 = -1 IF NOTHING DONE
IFLAG97   1 INTERNAL REGION FLAG, IF NEGATIVE REGION ERROR
          2 INTERNAL USED SKIP 2ND ORDER CALCS IF 2-PHASE,XREG TRACK
          3 INTERNAL PHS97B   ENTHALPY REGION ERROR FLAG
          4 INTERNAL PHS97B   ENTROPY REGION ERROR FLAG
          5 USER              COMPUTE METASTABLE VALUES
          6 USER     CPPT3    COMPUTE POSITIVE CP (NEAR PCRT,TCRT)
          7 INTERNAL USED TO MODIFY FUNCTION RETURNS
          8 INTERNAL XREG1MM,-PP,-MP,-PM CHECK RANGE VALIDITY ONLY
          9 USER     ROOT3MAX APPLY RHOV CORRECTION
         10 USER     ROOT3MAX APPLY ASME-LIKE RHOL/RHOV CALCS
         11 USER     IF=0 RETURN X, ELSE RETURN P OR T 2-PHASE FUNCS
         12 INTERNAL ROUTINE IDENTIFIER
         13 USER     REGION 3 BCKWRD EQS SET TO 1 FOR VALIDATION ONLY
         14 USER     RTN P/T MIN/MAX FROM PHSBK1/2/3 OR TP H/S BK1/2
         15          NOT USED
   EXAMPLE SET IFLAG97(10) = 1 TO USE AMSE-LIKE REGION 3 RHO CALCS
   ALSO TO SET IT BACK TO 0 WHEN DONE
   IONASME  = ISET97(10,1)
   CALL ROOT3MAX(TIN,RHOL,RHOV)
   IOFFASME = ISET97(10,0)
```

```
FUNCTION   ITEM97(TIN,VAR,IVAR)
ROUTINE NUMBER 92
GIVEN T WITH V,U,H OR S FIND IF-97 REGION
INPUT  - TIN - TEMPERATURE K
         VAR - V (M3/KG)   IF IVAR = 1  P97 INDEX = 3
             - U (KJ/KG)      IVAR = 2  P97 INDEX = 4
             - H (KJ/KG)      IVAR = 3  P97 INDEX = 5
             - S (KJ/KG-K)    IVAR = 4  P97 INDEX = 6
    ------------------------------------------------------------
          PMAX  ------------------------------------------------
                I             +      +        W              I
                I             +              W+              I
                I     1       +      3      W +  2          I
                I             +            W                 I
          PCRT  I..          ..+     .6.  .W ..+            ..I
                I             + 8  6  9 W                     I
                I             +  6   +W                       I
          P623  I..          ..O6.WWW             2         ..I
                I              4+                             I
                I     1     4            2                   I
          P010  I..    .. 4          +        +            ..I-----I
                I       4                                    +     I
                I    44    2  +      +        +              +  5  I
          PMIN  ------------------------------------------------
                T             T      T        T              T     T
                M             6      C        8              M     L
                I             2      R        6              A     A
                N             3      T        3              X     R
    ------------------------------------------------------------

RETURN       -  ITEM97
             -  1  GIBB1
             -  2  GIBB2
             -  3  HELM     (P<PCRT:8 IF TIN<TSAT, 9 IF TIN>TSAT )
             -  5  GIBB5
             -  4  SAT GIBB1/GIBB2
             -  6  SAT HELM3 (ROOT3MAX)
             - 10  REGION 1 TWO ROOTS
             - 11  REGION 1 ONE ROOT  AND REGION 4
             - 12  REGION 1 TWO ROOTS AND REGION 4 (IN CASE)
       IFLAG97(2) TRACKS XREG TYPE (1=MM,2=PP,3=PM,4=MP)
ERROR
    RETRIEVE REGION IERR = ITEM97
                         - -1 IF T LT TMIN
                         - -2 IF T GT TMAX (OR TLAR IN REGION 5)
                         - -3 IF V LT VMIN
                         - -4 IF V GT VMAX
                         - -6 IF CAN'T IDENTIFY IVAR
```

```
FUNCTION   ITEM97A(TIN,VAR,IVAR)
ROUTINE NUMBER 93
SPECIAL CASE FOR REGION 1 CHECK ONLY
INPUT  - TIN - TEMPERATURE K
         VAR - V (M3/KG)   IF IVAR = 1  P97 INDEX = 3
             - U (KJ/KG)      IVAR = 2  P97 INDEX = 4
             - H (KJ/KG)      IVAR = 3  P97 INDEX = 5
             - S (KJ/KG-K)    IVAR = 4  P97 INDEX = 6
RETURN   ITEM97A - IF97 REGION
    ------------------------------------------------------------
          PMAX  ---------------------------------------------------
                I             +      +        W              I
                I             +              W+             I
                I     1       +      3      W +  2          I
                I             +            W                I
          PCRT  I..          ..+     .6.   .W ..+           ..I
                I             + 8  6  9 W                    I
                I             +  6   +W                      I
          P623  I..          ..O6.WWW             2         ..I
                I              4+                            I
                I     1     4            2                   I
          P010  I..     .. 4          +        +            ..I-----I
                I       4                                     +     I
                I    44    2  +      +        +              +  5  I
          PMIN  ---------------------------------------------------
                T             T      T        T              T     T
                M             6      C        8              M     L
                I             2      R        6              A     A
                N             3      T        3              X     R
    ------------------------------------------------------------

RETURN       -  ITEM97A
                1 OR 10 IF IN REGION 1
             -  1  GIBB1
ERROR
    RETRIEVE REGION IERR = ITEM97A
                         - -1 IF P LT PMIN
                         - -2 IF T GT T623
                         - -3 IF V LT TMIN
                         - -4 IF V GT TMAX
                         - -6 IF CAN'T IDENTIFY IVAR

FUNCTION   ITXCAL97(TIN,XIN)
REPLACEMENT CODING FOR TXPROP97 AS FUNCTION
ROUTINE NUMBER 251
INPUT    TIN - TEMPERATURE K
         XIN - QUALITY
RETURN   O IF OKAY
CALLS TXPROP97
ERROR
ITXCAL97 AND IFLAG97(1) RETURNED FROM TXPROP97
```

```
FUNCTION   IVPT97(PIN,TIN)
ROUTINE NUMBER 94
SPECIAL CASE TO FIND THE V(P,T) SUB-REGION
GIVEN P,T WITH  IF-97 REGION 3 SUB-REGION
INPUT  - PIN   - PRESSURE PA
         TIN   - TEMPERATURE K
RETURN   IVPT97 - IF97 REGION (3A TO 3G)
    ------------------------------------------------
          PMAX  ----------------------------------+----
                I          3G(7)                + I
                I                             +   I
          P040  I.............*...........+.....I
                I   3E(5)      *   3F(6)   +      I
          P024  I............*...........+.......I
                I        " 3B*(2)       +         I
                I  3A(1) " *   3C(3)  +           I
          PCRT  I. . . ..X.........+               I
                I       X         +               I
                I 3A(1)X        +                I
                I    X   3D(4)+                  I
                I  X        +                    I
                IX++++ + + +                     I
          P623 -----------------------------------
                T        T                       T
                6        C                       8
                2        R                       6
                3        T                       3
    ------------------------------------------------

RETURN       -  IVPT97
             -  1  3A
             -  2  3B
             -  3  3C
             -  4  3D
             -  5  3E
             -  6  3F
             -  7  3G
ERROR
      RETRIEVE REGION IERR = IVPT97
                           - -1 IF PIN .GT. PMAX
                           - -2 IF PIN .LT. P623
                           - -4 IF TIN .LT. T623
                           - -3 IF TIN .GT. T2397(PIN)

FUNCTION   IXPROP97(PIN,TIN)
REPLACEMENT CODING FOR XPROP97 AS FUNCTION
ROUTINE NUMBER 248
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN   O IF OKAY
CALLS XPROP97
ERROR
IXPROP97 AND IFLAG97(1) RETURNED FROM XPROP97
```

```
FUNCTION   IXTRAS97(IREG)
REPLACEMENT CODING FOR XTRAS97 AS FUNCTION
ROUTINE NUMBER 254

INPUT    IREG - 0 FOR LIQUID (FLUID)
                1 FOR VAPOR (GAS)
RETURN   O IF OKAY
ERROR
IXTRAS97 AND IFLAG97(1) -1 IF INVALID IREG FLAG

SUBROUTINE MOVE97(INDEX)
ROUTINE NUMBER 95
USER CONTROL INTERFACE ROUTINE
MOVE P97 ARRAY TO Q97 ARRAY IF INDEX ZERO
MOVE Q97 ARRAY TO P97 ARRAY IF INDEX NOT ZERO
MOVE97 =  INDEX VALUE
ERROR NONE

SUBROUTINE OVHS97(PRET,TRET,VIN,VAR,IVAR)
SPECIAL CASE TO HANDLE DOUBLE V ROOTS AT LOW P,T
RETURNS EST OF PRESSURE GIVEN V (M^3/KG) AND H OR S
              QUALITY       IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
RETURNS EST OF TEMPERATURE K IF IFLAG97(11) = 1 IF 2-PHASE
ROUTINE NUMBER 241
INPUT    VIN  - SPECIFIC VOLUME (M^3/KG)
         VAR  - ENTHALPY KJ/KG    IF IVAR = 1
              - ENTROPY  KJ/KG-K  IF IVAR = 2
RETURN   PRET - PRESSURE PA
         TRET - T OR X
ERROR
IF VAR OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
   PRET       = -1.0
   TRET       = -1.0
   IFLAG97(1) = -9
   SILENT ERROR IFLAG97(15) SET TO -101 IF ITERATION FAILURE

FUNCTION   P2397(TIN)
ROUTINE NUMBER 96
TEMPERATURE LINE BETWEEN REGION 2 AND 3
RANGE 623.15 K TO 863.15 K
INPUT  TIN   - TEMPERATURE K
RETURN P2397 - PRESSURE PA
ERROR
    RETURNS P2397 = -1.0D0 IF TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -3 IF TIN LT T623
                  - -4 IF TIN GT T863
```

```
SUBROUTINE P97CAL1
ROUTINE NUMBER 97
GIBBS EQUATION REGION 2/5 FIRST ORDER DERIVATIVES
MUST HAVE CALLED GIBB2, GIBBM OR GIBB5 BEFORE CALL
RETURN STATE POINT IN P97(1) - P97(7),P97(31), P97(24), P97(25)
P97(1)  = P -PA
P97(2)  = T - K
P97(3)  = V - M^3/KG
P97(31) = DENSITY - 1/P97(3) - KG/M^3
P97(4)  = U - KJ/KG
P97(5)  = H - KJ/KG-K
P97(6)  = S - KJ/KG
P97(7)  = QUALITY
P97(24) = GIBBS FREE ENERGY     = ENTHALPY - (TEMPERATURE*ENTROPY)
P97(25) = HELMHOLTZ FREE ENERGY = ENERGY   - (TEMPERATURE*ENTROPY)
ERROR     NONE

SUBROUTINE P97CAL2
ROUTINE NUMBER 98
GIBBS EQUATION REGION 2/5 SECOND ORDER DERIVATIVES
MUST HAVE CALLED GIBB1, GIBBM OR GIBB5 BEFORE CALL
SPECIAL FLAG SETTING
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
RETURN STATE POINT IN P97(8) - P97(17), P97(26), P97(27)
P97(8)  = CP - KJ/KG-K
P97(9)  = CV - KJ/KG-K
P97(10) = SV - M/SEC
P97(11) = DVDPT (-RT/P*P)
P97(12) = DVDTP (R /P  )
P97(13) = DPDVT = 1/DVDPT
P97(14) = DPDTV = -(DVDTP/DVDPT)
P97(15) = COEF OF THERMAL EXPANSION DVDTP/V K^-1   P97(12)/P97(3)
P97(16) = ISOTHERMAL EXPANSION     -DVDPT/V PA^-1 -P97(11)/P97(3)
P97(17) = ISENTROPIC EXPONENT     P97(10)*P97(10)/(P97(1)*P97(3))
P97(27) = ISOTHERMAL JOULE-THOM = V - T*DVDTP
P97(26) = JOULE-THOMPSON COEF   = (TIN*DVDTP-V)/CP
ERROR     NONE

SUBROUTINE P97CALA
ROUTINE NUMBER 99
GIBBS EQUATION REGION 1 FIRST ORDER DERIVATIVES
RETURN STATE POINT IN P97(1) - P97(7), P97(24), P97(25)
P97(1)  = P -PA
P97(2)  = T - K
P97(3)  = V - M^3/KG
P97(31) = DENSITY - 1/P97(3) - KG/M^3
P97(4)  = U - KJ/KG
P97(5)  = H - KJ/KG-K
P97(6)  = S - KJ/KG
P97(7)  = QUALITY
P97(24) = GIBBS FREE ENERGY     = ENTHALPY - (TEMPERATURE*ENTROPY)
P97(25) = HELMHOLTZ FREE ENERGY = ENERGY   - (TEMPERATURE*ENTROPY)
ERROR     NONE
```

```
SUBROUTINE P97CALB
ROUTINE NUMBER 100
GIBBS EQUATION REGION 1 SECOND ORDER DERIVATIVES
SPECIAL FLAG SETTING
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
RETURN STATE POINT IN P97(8) - P97(17), P97(26), P97(27)
P97(8)  = CP - KJ/KG-K
P97(9)  = CV - KJ/KG-K
P97(10) = SV - M/SEC
P97(11) = DVDPT (-RT/P*P)
P97(12) = DVDTP (R /P  )
P97(13) = DPDVT = 1/DVDPT
P97(14) = DPDTV = -(DVDTP/DVDPT)
P97(15) = COEF OF THERMAL EXPANSION DVDTP/V K^-1   P97(12)/P97(3)
P97(16) = ISOTHERMAL EXPANSION     -DVDPT/V PA^-1 -P97(11)/P97(3)
P97(17) = ISENTROPIC EXPONENT     P97(10)*P97(10)/(P97(1)*P97(3))
P97(27) = ISOTHERMAL JOULE-THOM = V - T*DVDTP
P97(26) = JOULE-THOMPSON COEF   = (TIN*DVDTP-V)/CP
ERROR     NONE

SUBROUTINE P97CALG1
ROUTINE NUMBER 101
GIBBS EQUATION REGION 2/5 FIRST ORDER DERIVATIVES IDEAL GAS PART
MUST HAVE CALLED GIBB2I, GIBBMI OR GIBB5I BEFORE CALL
RETURN STATE POINT IN P97(1) - P97(7), P97(24), P97(25)
P97(1)  = P -PA
P97(2)  = T - K
P97(3)  = V - M^3/KG
P97(31) = DENSITY - 1/P97(3) - KG/M^3
P97(4)  = U - KJ/KG
P97(5)  = H - KJ/KG-K
P97(6)  = S - KJ/KG
P97(7)  = QUALITY
P97(24) = GIBBS FREE ENERGY     = ENTHALPY - (TEMPERATURE*ENTROPY)
P97(25) = HELMHOLTZ FREE ENERGY = ENERGY   - (TEMPERATURE*ENTROPY)
ERROR     NONE

SUBROUTINE P97CALG2
ROUTINE NUMBER 102
GIBBS EQUATION REGION 2/5 SECOND ORDER DERIVATIVES IDEAL GAS PART
MUST HAVE CALLED GIBB2I, GIBBMI OR GIBB5I BEFORE CALL
SPECIAL FLAG SETTING
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
RETURN STATE POINT IN P97(8) - P97(17), P97(26), P97(27)
P97(8)  = CP - KJ/KG-K
P97(9)  = CV - KJ/KG-K
P97(10) = SV - M/SEC
P97(11) = DVDPT (-RT/P*P)
P97(12) = DVDTP (R /P  )
P97(13) = DPDVT = 1/DVDPT
P97(14) = DPDTV = -(DVDTP/DVDPT)
P97(15) = COEF OF THERMAL EXPANSION DVDTP/V K^-1   P97(12)/P97(3)
P97(16) = ISOTHERMAL EXPANSION     -DVDPT/V PA^-1 -P97(11)/P97(3)
P97(17) = ISENTROPIC EXPONENT     P97(10)*P97(10)/(P97(1)*P97(3))
P97(27) = ISOTHERMAL JOULE-THOM = V - T*DVDTP
P97(26) = JOULE-THOMPSON COEF   = (TIN*DVDTP-V)/CP
ERROR     NONE
```

```
SUBROUTINE PHMETA97(PIN,HIN)
ROUTINE NUMBER 103
COMPUTE METASTABLE PROPERTIES AT PRESSURE AND ENTHALPY
INPUT  PIN    - PRESSURE PA
       HIN    - ENTHALPY KJ/KG
RETURNS
       P97 ARRAY CONTAINS FULL RESULTS ACCESS WITH PROP97
ERROR
    RETURNS PIN IN P97(1),TMETA IN P97(2), -1.0D0 FOR OTHERS
    IF THMETA EVALUATES PMETA .GT. PCRT RETURNS IFLAG97(1) = -8
    RETRIEVE ERROR IERR = IERR97(1)
                        - -1 IF   PIN .LT. PMIN
                        - -2 IF   PIN .GT. PCRT
                        - -3 IF   HIN .LT. HM (0.05HL+0.95HG)
                        - -4 IF   HIN .GT. HG
                        - -8 IF PMETA .GT. PCRT (AT TMETA)

FUNCTION   PHS97(HIN,SNN)
RETURNS ESTIMATE OF PRESSURE GIVEN S (KJ/KG-K) AND H (KJ/LG)
ROUTINE NUMBER 216
PHS97K IS THE FUNCTIONAL EQUIVALENT FOR REGIONS 1 AND 2 ONLY
INPUT    SNN  - ENTROPY KJ/KG-K
         HIN  - ENTHPLPY KJ/KG
RETURN  PHS97 - PRESSURE PA IF IFLAG97(11) = 1 IF 2-PHASE
                QUALITY     IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
                            SET TO 0 OR 1 IF +/- 1.0D-5
       S97(4) - TEMPERATURE K
       RETRIEVE PTMAN97(3)
ERROR
IF SNN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
   PSH97      = -1.0
   S97(4)     = -1.0
   IFLAG97(1) = -3 SNN TO LOW
                -4 SNN TOO HIGH
                -1 HIN TO LOW
                   (ALLOW UP TO 1.0D-2 ON DELH - PMAX,TLAR)
                -2 HIN TO HIGH
                -5 CALLED AGAIN FAILED CALL
   SILENT ERROR IFLAG97(15) SET TO -102 IF ITERATION FAILURE

FUNCTION   PHS97B(HIN,SNN,IREG)
ROUTINE NUMBER 104
LEGACY FUNCTION VERSION 1 USE PHS97BK - FULL REGION CHECKING
INPUT  HIN    - ENTHALPY KJ/KG
       SNN    - ENTROPY  KJ/KG-K
RETURN PHS97B - PRESSURE PA
ERROR
    IF IREG NOT 1 OR 2
    RETURN PHS97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
                  - INPUT VALUE OF IREG (-IREG IF INPUT > 2)
DOES POST CHECK TO SEE IF (P,H), (P,S) IN REGION 1 OR 2
ERROR
    RETURN PHS97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
                  - - 6 IF NOT REGION 1 OR 2
                      RETRIEVE PHS97B FROM FUNCTION PTMANS97(1)
                      EG PCAL = PTMANS97(1)
                      RETRIEVE ENTHAPLPY REGION IERR97(3)
                      RETRIEVE ENTROPY REGION IERR97(4)
```

```
FUNCTION   PHS97BK(HIN,SNN)
ROUTINE NUMBER 272
INPUT  HIN     - ENTHALPY KJ/KG
       SNN     - ENTROPY  KJ/KG-K
RETURN PHS97BK - PRESSURE PA
FOR IREG = 4 GET PSAT FROM TSHS97B
ERROR
    IF IREG NOT 1, 2, 3 OR 4 (FROM IRGHS97)
    RETURN PHS97BK = -1.0D0
    RETRIEVE IERR  = IERR97(1)
             IERR  = -1 IF SNN TOO LOW
                   = -2 IF SNN TOO HIGH
                   = -3 IF HIN TOO LOW
                   = -4 IF HIN TOO HIGH
                   = -5 IF 4 BUT SNN LESS THAN S08
                   = -10 IF P OUT OF RANGE LOW GET PTMANS97(1)
                   = -20 IF P OUT OF RANGE HIGH GET PTMANS97(1)

FUNCTION   PHSBK1(HIN,SNN)
ROUTINE NUMBER 105
BACKWARD EQUATION - NEW BACKWARD EQUATION REGION 1
INPUT     HIN - ENTALPHY KJ/KG
          SNN - KJ/KG-K
RETURN PHSBK1 - PRESSURE PA
ERROR  PHSBK1 = -1.0
RETRIEVE IERR97(1)
              - 10 IF PCAL < PMIN
              - 20 IF PCAL > PMAX
       RETRIEVE CALC VALUE FROM PTMANS97(1) FROM S97(6)
       IF IFLAG97(14) = 1 THEN RETURN PMIN OR PMAX

FUNCTION   PHSBK2(HIN,SNN)
ROUTINE NUMBER 106
BACKWARD EQUATION - NEW BACKWARD EQUATIONS REGION 2
INPUT     HIN - KJ/KG
          SNN - KJ/KG-K
RETURN PHSBK2 - PRESSURE PA
ERROR  PHSBK2 = -1.0
RETRIEVE IERR97(1)
              - 10 IF PCAL < PMIN
              - 20 IF PCAL > PMAX
       RETRIEVE CALC VALUE FROM PTMANS97(1) FROM S97(6)
       IF IFLAG97(14) = 1 THEN RETURN PMIN OR PMAX

FUNCTION   PHSBK3(HIN,SNN)
ROUTINE NUMBER 263
INPUT  HIN    - ENTHALPY, KJ/KG
       SNN    - ENTROPY, KJ/KG-K
RETURN PHSBK3 - PRESSURE IN REGION 3A OR 3B, MPA
ERROR  PHSBK3 = -1.0
RETRIEVE IERR97(1)
              - 20 IF PCAL > PMAX
       RETRIEVE CALC VALUE FROM PTMANS97(1) FROM S97(6)
       IF IFLAG97(14) = 1 THEN RETURN PMAX
```

```
FUNCTION   PROP97(INDEX)
ROUTINE NUMBER 107
USER CONTROL INTERFACE ROUTINE
RETURN P97(INDEX) IF INDEX POSITIVE(+),USE AFTER CALL TO PCAL/HCAL
RETURN Q97(INDEX) IF INDEX NEGATIVE(-),USE AFTER CALL TO PCAL/HCAL
PROP97(1)  =  P     - PA
PROP97(2)  =  T     - K
PROP97(3)  =  V     - M^3/KG
PROP97(4)  =  U     - KJ/KG
PROP97(5)  =  H     - KJ/KG-K
PROP97(6)  =  S     - KJ/KG
PROP97(7)  =  QUAL  - ---
PROP97(8)  =  CP    - KJ/KG-K
PROP97(9)  =  CV    - KJ/KG-K
PROP97(10) =  SV    - M/SEC
PROP97(11) =  DVDPT - (M^3/KG)/PA
PROP97(12) =  DVDTP - (M^3/KG)/K
PROP97(13) =  DPDVT - PA/(M^3/KG)
PROP97(14) =  DPDTV - PA/K
PROP97(15) =  COEF OF THERMAL EXPANSION - /K
PROP97(16) =  ISOTHERMAL EXPANSION      - /PA
PROP97(17) =  ISENTROPIC EXPONENT       - ---
PROP97(18)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(19)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(20)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(21)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(22)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(23)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(24) =  GIBBS FREE ENERGY         - KJ/KG
PROP97(25) =  HELMHOLTZ FREE ENERGY     - KJ/KG
PRPO97(26) =  JOULE-THOMPSON COEF       - K/PA
PRPO97(27) =  ISOTHERMAL JOULE-THOM     - KJ/KG-PA
PROP97(28)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(29)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(30)    NOT DEFINED BY GIBB OR HELM CALL SEE XTRAS97
PROP97(31) =  DENSITY
ERROR
    RETURN -601.0 IF INVALID REQUEST

FUNCTION   PSAT97(TIN)
ROUTINE NUMBER 108
SATURATION LINE PRESSURE REGION 4 (AND MY REGION 6)
RANGE 273.15 K TO 647.096 K
INPUT  TIN    - K
RETURN PSAT97 - PRESSURE PA
IF TIN .GE. (TCRT-1.188D-9) RETURN PCRT 22064000 VS 22064000.0003206
          647.095999998812
ERROR
    RETURNS PSAT97 = -1.0D0 IF TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT
```

```
FUNCTION   PSFIT97(SNN,ITYPE)
RETURNS ESTIMATE OF PRESSURE (PA) GIVEN S (KJ/KG-K)
ROUTINE NUMBER 215
INPUT   SNN    - ENTROPY KJ/KG-K
      ITYPE    - SPECIFIC REGION FOR CALL
                 1 - SATURATED FLUID P/S BOUNDARY
                 2 - SATURATED VAPOR P/S BOUNDARY
                 3 - METASTABLE FLUID P/S BOUNDARY (NOT IN USE)
                 4 - 1073.15 P/S BOUNDARY
                 5 - 2273.15 P/S BOUNDARY
RETURN PSFIT97 - PRESSURE PA
ERROR
IF SNN OUT OF RANGE RETURN OR ITPE OUT OF RANGE
              PSFIT97    = -1.0
              IFLAG97(1) = -1 IF SNN TOO LOW
                           -2 IF SNN TOO HIGH
                           -3 IF ITYPE OUT OF RANGE (1-3)

FUNCTION   PSHBK3(HIN)
ROUTINE NUMBER 261
INPUT      HIN - ENTHALPY, KJ/KG
RETURN PSHBK3 - SATURATION PRESSURE REGION 3, MPA
ERROR            -1.0D0 IF OUT OF RANGE
                 IFLAG97(1) = -3 IF HIN TOO LOW
                 IFLAG97(1) = -4 IF HIN TOO HIGH

FUNCTION   PSSBK3(SNN)
ROUTINE NUMBER 262
INPUT      SNN - ENTROPY, KJ/KG-K
RETURN PSSBK3 - SATURATION PRESSURE REG 3, MPA
ERROR            -1.0D0 IF OUT OF RANGE
                 IFLAG97(1) = -1 IF SNN TOO LOW
                 IFLAG97(1) = -2 IF SNN TOO HIGH

FUNCTION   PTH97(TIN,HIN)
PRESSURE AS FUNCTION OF TEMPERATURE AND ENTHALPY
ROUTINE NUMBER 109
INPUT  TIN   - TEMPERATURE K
       HIN   - ENTHALPY KJ/KG
RETURN PTH97 - PRESSURE PA
RETURN S97(6)- PRESSURE PA
RETURN S97(5)- QUALITY OR PRESSURE (IFLAG97(11) = 1)
       IF 0 <= S97(5) <= 1, THEN 2-PHASE QUALITY
       RETRIEVE PTMANS97(1) = S97(6),PTMANS97(2) = S97(5)
ERROR
    CALLS ITEM97
    PTH97 = -1.0D0
    RETRIEVE REGION IERR = IERR97(1)
                         - -1 IF TIN LT TMIN
                         - -2 IF TIN GT TMAX/TLAR
                         - -3 IF HIN LT VMIN
                         - -4 IF HIN GT VMAX
```

```
FUNCTION   PTMANS97(INDEX)
ROUTINE NUMBER 110
RETURNS VALUE IN S97 ARRAY BASED ON INDEX
USED TO RETRIEVE MULTY ROOT PRESSURE OR ERROR STORAGE
EXAMPLE INDEX = 1 = 6 RETURNS 2-ND REGION 1 PRESSURE AND
              = 2 = 5 RETURNS TWO-PHASE QUALITY/PRESSURE
              = 3 = 4 RETURNS A TEMPERATURE | XREG PMID
              = 4 = 3 RETURNS XREG VMID  ??
              = 5 = 2 RETURNS XREG VMAX  ??
              = 6 = 1 RETURNS XREG VMIN  ??
INPUT  INDEX    - MUST BE 1 TO 6
RETURN PTMANS97 - S97(INDEX)
ERROR
    PTMANS97 = -1.0D0
    IF INDEX OUT OF RANGE

SUBROUTINE PTMETA97(PIN,TIN)
ROUTINE NUMBER 111
COMPUTE METASTABLE PROPERTIES AT PRESSURE AND TEMPERATURE
INPUT  PIN    - PRESSURE PA
       TIN    - TEMPERATURE K
RETURN    THERMODYNAMIC AND TRANSPORT PROPERITES IN P97 ARRAY
BASED ON USE OF LOW-LEVEL ROUTINES
ERROR
    RETURNS PIN IN P97(1),TMETA IN P97(2), -1.0D0 FOR OTHERS
    IF TPMETA EVALUATES PMETA .GT. PCRT RETURN IFLAG97(1) = -8
    RETRIEVE ERROR IERR = IERR97(1)
                        - -1 IF   PIN .LT. PMIN
                        - -2 IF   PIN .GT. PCRT
                        - -3 IF   TIN .LT. TMETA
                        - -4 IF   TIN .GT. TSAT
                        - -8 IF PMETA .GT. PCRT (AT TMETA)

SUBROUTINE PTPROP97(PIN,TIN)
ROUTINE NUMBER 112
COMPUTE PROPERTIES BASED ON PIN AND TIN
INPUT  PIN - PRESSURE PA
       TIN - TEMPERATURE
RETURN P97 ARRAY OF VALUES
CALLS IREG97 TO VALIDATE PIN,TIN
RETURN - FOR IF97 REGION 1,2,3, OR 5
         CALLS GIBB1,GIBB2,GIBB5 OR HELM3 AS APPROPRIATE
         P97 ARRAY CONTAINS FULL RESULTS ACCESS WITH PROP97
ERROR
    RETURNS PIN IN P97(1),TIN IN P97(2), -1.0D0 FOR OTHERS
    RETRIEVE ERROR IERR = IERR97(1)
                        - -1 IF PIN LT PMIN
                        - -2 IF PIN GT PMAX OR P010 IF REGION 5
                        - -3 IF TIN LT TMIN
                        - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   PTR3(TIN,RHO)
PRESSURE AS FUNCTION OF TEMPERATURE AND DENSITY
ROUTINE NUMBER 113
INPUT   TIN - TEMPERATURE K
        RHO - DENSITY KG/M^3
RETURN PTR3 - PRESSURE PA
ERROR  NONE
```

```
FUNCTION   PTS97(TIN,SNN)
PRESSURE AS FUNCTION OF TEMPERATURE AND ENTROPY
ROUTINE NUMBER 114
INPUT  TIN   - TEMPERATURE K
       SNN   - ENTROPY KJ/KG-K
RETURN PTS97 - PRESSURE PA
RETURN S97(6)- PRESSURE PA
RETURN S97(5)- QUALITY OR PRESSURE (IFLAG97(11) = 1)
       IF 0 <= S97(5) <= 1, THEN 2-PHASE QUALITY
       RETRIEVE PTMANS97(1) = S97(6),PTMANS97(2) = S97(5)
ERROR
    RETURNS PTS97 = -1.0D0 IF PIN OR SNN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF TIN LT TMIN
                  - -2 IF TIN GT TMAX
                  - -3 IF SNN LT VMIN
                  - -4 IF SNN GT VMAX

FUNCTION   PTU97(TIN,UIN)
PRESSURE AS FUNCTION OF TEMPERATURE AND INTERNAL ENERGY
ROUTINE NUMBER 115
INPUT  TIN   - TEMPERATURE K
       UIN   - INTERNAL ENERGY KJ/KG
RETURN PTU97 - PRESSURE PA
RETURN S97(6)- PRESSURE PA
RETURN S97(5)- QUALITY OR PRESSURE (IFLAG97(11) = 1)
       IF 0 <= S97(5) <= 1, THEN 2-PHASE QUALITY
       RETRIEVE PTMANS97(1) = S97(6),PTMANS97(2) = S97(5)
ERROR
    RETURNS PTU97 = -1.0D0 IF PIN OR UIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF TIN LT TMIN
                  - -2 IF TIN GT TMAX
                  - -3 IF UIN LT VMIN
                  - -4 IF UIN GT VMAX

FUNCTION   PTV97(TIN,VIN)
PRESSURE AS FUNCTION OF TEMPERATURE AND SPECIFIC VOLUME
ROUTINE NUMBER 116
INPUT  TIN   - TEMPERATURE K
       VIN   - SPECIFIC VOLUME M^3/KG
RETURN PTV97 - PRESSURE PA
RETURN S97(6)- PRESSURE PA
RETURN S97(5)- QUALITY OR PRESSURE (IFLAG97(11) = 1)
       IF 0 <= S97(5) <= 1, THEN 2-PHASE QUALITY
       RETRIEVE PTMANS97(1) = S97(6),PTMANS97(2) = S97(5)
ERROR
    RETURNS PTV97 = -1.0D0 IF PIN OR VIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF TIN LT TMIN
                  - -2 IF TIN GT TMAX
                  - -3 IF VIN LT VMIN
                  - -4 IF VIN GT VMAX
```

```
FUNCTION   PVAR97(TIN,VAR,IVAR,IREG)
PRESSURE AS FUNCTION OF TEMPERATURE AND VARIABLE
ROUTINE NUMBER 117
SPECIAL FLAG IFLAG97(11)
   = 0 THEN RETURN QUALITY ELSE RETURN PRESSURE IN REG 4/6
INPUT    TIN - TEMPERATURE K
         VAR - V (M3/KG)   IF IVAR = 1  P97 INDEX = 3
             - U (KJ/KG)      IVAR = 2  P97 INDEX = 4
             - H (KJ/KG)      IVAR = 3  P97 INDEX = 5
             - S (KJ/KG-K)    IVAR = 4  P97 INDEX = 6
        IREG - 1  GIBB1
             - 2  GIBB2
             - 3  HELM  (8,9)
             - 5  GIBB5
             - 4  SAT GIBB1/GIBB2
             - 6  SAT HELM3 (ROOT3MAX)
             - 7  GIBB2 SUPPLEMENTAL SPECIAL CASE
RETURN       PRESSURE PA    IREG = 1,2,3(8,9),5 OR 7
             PRESSURE PA    2-ND ROOT IN REG 1 IF IFLAG97(1) = 10
RETURN       QUALITY        IREG = 4 OR 6
IVAR AND IREG NOT CHECKED LOCALLY
CALL TO ITEM97 FIRST TO SET IREG
NOTE ENTHALPY IN REGION 1 REQUIRES SPECIAL HANDLING
ERROR CAN'T RESOLVE REG 3 BETWEEN SAT VALUES SHOULD USE REG 6
    IFLAG97(1) = -1
    PVAR97 = -1.0D0
    SILENT ERROR IFLAG97(15) SET TO -103 IF ITERATION FAILURE

FUNCTION   PVH97(VIN,HIN)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H
ROUTINE NUMBER 237
INPUT    VIN  - SPECIFIC VOLUME (M^3/KG)
         HIN  - ENTHALPY KJ/KG  IF IVAR = 1
RETURN PVH97  - PRESSURE PA IF IFLAG97(11) = 1 IF 2-PHASE
                QUALITY     IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
                            SET TO 0 OR 1 IF +/- 1.0D-5
       S97(4) - TEMPERATURE K
       RETRIEVE PTMAN97(3)
ERROR
IF HIN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
   PVH97      = -1.0
   S97(4)     = -1.0
   IFLAG97(1) = -3 VIN TOO LOW
                -4 VIN TOO HIGH
                -1 HIN TOO LOW
                -2 HIN TOO HIGH
```

```
FUNCTION   PVHS97(VIN,VAR,IVAR)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H OR S
ROUTINE NUMBER 236
INPUT    VIN  - SPECIFIC VOLUME (M^3/KG)
         VAR  - ENTHALPY KJ/KG  IF IVAR = 1
              - ENTROPY KJ/KG-K IF IVAR = 2
        IVAR  - 1 IF H 2 IF S
RETURN PVHS97 - PRESSURE PA IF IFLAG97(11) = 1 IF 2-PHASE
                QUALITY     IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
                            SET TO 0 OR 1 IF +/- 1.0D-5
       S97(4) - TEMPERATURE K
       RETRIEVE PTMAN97(3)
ERROR
IF SNN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
   PVHH97     = -1.0
   S97(4)     = -1.0
   IFLAG97(1) = -6 IVAR OUT OF RANGE (1 OR 2)
                -3 VIN TOO LOW
                -4 VIN TOO HIGH
                -1 VAR TOO LOW
                -2 VAR TOO HIGH
                -5 SAME CALL SAME ERROR
    SILENT ERROR IFLAG97(15) SET TO -104 IF ITERATION FAILURE

FUNCTION   PVS97(VIN,SNN)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H OR S
ROUTINE NUMBER 238
INPUT    VIN  - SPECIFIC VOLUME (M^3/KG)
         SNN  - ENTROPY  KJ/KG-K  IF IVAR = 2
RETURN PVS97  - PRESSURE PA IF IFLAG97(11) = 1 IF 2-PHASE
                QUALITY     IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
                            SET TO 0 OR 1 IF +/- 1.0D-5
       S97(4) - TEMPERATURE K
       RETRIEVE PTMAN97(3)
ERROR
IF SNN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
   PVS97      = -1.0
   S97(4)     = -1.0
   IFLAG97(1) = -6 IVAR OUT OF RANGE (1 OR 2)
                -3 VIN TOO LOW
                -4 VIN TOO HIGH
                -1 SNN TOO LOW
                -2 SNN TOO HIGH

SUBROUTINE PXPROP97(PIN,XIN)
ROUTINE NUMBER 118
COMPUTE 2-PHASE PROPERTY VALUES BASED ON TIN AND XIN
AT PIN COMPUTE TSAT THEN CALL TXPROPS
INPUT  PIN - PRESSURE PA
       XIN - QUALITY ( O TO 1 )
CALLS GIBB1/GIBB2 OR HELM3/L/V AS APPROPRIATE
RETURN P97 ARRAY (1 - 6 AND 17) RETRIEVE WITH PROP97
ERROR
    RETURNS PIN IN P97(1),XIN IN P97(7), -1.0D0 FOR OTHERS
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF XIN  .LT. ZERO
                  - -2 IF XIN  .GT. ONE
                  - -3 IF PIN  .LT. PMIN
                  - -4 IF PIN  .GT. PCRT
```

```
FUNCTION   RHO3LG97(TIN,IREG)
REPLACEMENT CODING FOR ROOT3 AS FUNCTION
UNLIKE ROOT3 INCLUDES TEMERATURE ERROR CHECKING
ROUTINE NUMBER 256

INPUT          TIN - TEMPERATURE K
               IREG - 0 FOR SATURATED LIQUID
                      1 FOR SATURATED VAPOR
RETURN   RHO3LG97 - DENSITY KG/M^3 IF OKAY ELSE -1.0
TRACK TIN FOR EXPECTED MULTI-CALLS WITHOUT RECALS
ERROR
RHO3LG97 AND IFLAG97(1) SET TO -1 IF IREG NOT VALID
                               -2 IF TIN NOT VALID

FUNCTION   RHO3PT97(PIN,TIN)
REPLACEMENT CODING FOR ROOT3 AS FUNCTION
UNLIKE ROOT3 INCLUDES REGION ERROR CHECKING
ROUTINE NUMBER 255

INPUT         PIN - PRESSURE PA
              TIN - TEMPERATURE K
RETURN   RHO3PT97 - DENSITY KG/M^3 IF OKAY
ERROR
RHO3PT97 AND IFLAG97(1) SET TO -1

FUNCTION   RINDPRS(PIN,TIN,RIN)
ROUTINE NUMBER 119
REFRACTIVE INDEX EQUATION FUNCTION PRESSURE AND TEMPERATURE
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K (MAX IS 773.15 K)
           RIN - WAVELENGTH MICRO-METERS (0.2 TO 1.9 MICRO-M)
                 (IF < 0.2 SET TO 0.2 IF > 1.9 SET TO 1.9)
RETURN RINDPRS - N (FROM RINDRHO) DIMENSIONLESS
ERROR
    CHECK TIN FIRST
    IF( TIN .GT. 773.15 ) IREG = -4
    CHECK FOR VALID REGION IREG97(PIN,TIN)
    CHECK IF97 REGION IF IREG = 5, TREAT AS TIN .GT. 773.15
    IF( IREG .LT. 0 ) IFLAG97(1) = IREG
    RETURN RINDPRS = -ONE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA
```

```
FUNCTION   RINDRHO(RHO,TIN,RIN)
ROUTINE NUMBER 120
REFRACTIVE INDEX EQUATION FUNCTION OF DENSITY AND TEMPERATURE
INPUT      RHO - DENSITY KG/M^3
           TIN - TEMPERATURE K  (MAX IS 773.15 K)
           RIN - WAVELENGTH MICRO-METERS (0.2 TO 1.9 MICRO-M)
                 (IF < 0.2 SET TO 0.2 IF > 1.9 SET TO 1.9)
RETURN RINDRHO - N (DIMENSIONLESS)
ERROR
    CHECK TIN FIRST
    IF( TIN .GT. 773.15 ) IREG = -4
    RETURN RINDRHO = -ONE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF RHO<MIN 1/VPT2(PMIN,TIN)
                  - -2 IF RHO>MAX 1/VPT97(PMAX,TIN)
                  - -3 IF TIN LT 273.15 K
                  - -4 IF TIN GT 773.15 K

SUBROUTINE ROOT3(PCOMP,TIN,RHO)
ROUTINE NUMBER 121
GIVEN P AND T FIND RHO IN HELMHOLTZ REGION 3
HELMHOLTZ EQUATION REGION 3
INPUT   TIN   - TEMPERATURE K
        PCOMP - PRESSURE PA
RETURN  RHO   - DENSITY KG/M^3
ERROR   IF NOT IN REGION 3 CHECKED BY VPTREG3(PCOMP,TIN)
        RHO        = -1.0D0
        IFLAG97(1) = -1
        SILENT ERROR IFLAG97(15) SET TO -105 IF ITERATION FAILURE

SUBROUTINE ROOT3L(PCOMP,TIN,RHO)
ROUTINE NUMBER 122
AUXILIARY ROUTINE TO SOLVE MAXWELL CRITERION ON SAT LINE
HELMHOLTZ EQUATION REGION 3
CALCULATE STARTING VALUE FOR USE IN ROOT3MAX
INPUT   TIN   - TEMPERATURE K
        PCOMP - = ZERO FOR LIQUID RHO
                = ONE  FOR VAPOR  RHO
                = SET TO SATURATION PRESSURE PA AT TIN K
                  FOR ITERATION ON RHO
RETURN  RHO   - DENSITY KG/M^3
ERROR
        SILENT ERROR IFLAG97(15) SET TO -106 IF ITERATION FAILURE
```

```
SUBROUTINE ROOT3MAX(TIN,RHOL,RHOV)
ROUTINE NUMBER 123
AUXILIARY ROUTINE TO SOLVE MAXWELL CRITERION ON SAT LINE
LINEAR INTERPOLATION ON RHOL/RHOV ABOVE 647.09599 K
DOES A NUMERICAL CORRECTION TO RHOG TO MINIMIZE MAXWELL
C ERROR DIFFRENCE BETWEEN F(1/R'' -1/R') AND HELM INTEGRAL
C   CHECK FOR VALUES LEADING TO MATH ERROR DIVIDE BY 0
C   CURRENT VALUE EQUAL TO PREVIOUS VALUE
C   RETURN LAST COMPUTED SET OF VALUES - AS GOOD AS IT GETS
C NEED HELMHOLTZ EQUATION REGION 1 FIRST ORDER DERIVATIVES
SPECIAL FLAG SEETINGS
(1) ASME-LIKE SOLUTION WITHOUT MAXWELL CHECK
    SET IFLAG97(10) = 1 EG. JDUM = ISET97(10,1)
(2) IMPLEMENT RHOV CORRECTION
    SET IFLAG97( 9) = 1 EG. JDUM = ISET97( 9,1)
INPUT   TIN   - TEMPERATURE K
RETURN  RHOL  - LIQUID DENSITY KG/M^3
        RHOV  - VAPOR  DENSITY KG/M^3
ERROR   T < 623.15 K,  IFLAG97(1) = -3, RHOL,RHOG = -1.0
        T > 647.096 K, IFLAG97(1) = -4, RHOL,RHOG = -1.0
        SILENT ERROR IFLAG97(15) SET TO -107 IF ITERATION FAILURE

FUNCTION   SHTMIN97(HIN)
ROUTINE NUMBER 268
INPUT  HIN      - ENTHALPY, KJ/KG
RETURN SHTMIN97 - FITTED ENTROPY AT 273.15 K, KJ/KG-K
ERROR             -1.0D0 IF OUT OF RANGE
                  IFLAG97(1) = -3 IF HIN TOO LOW
                  IFLAG97(1) = -4 IF HIN TOO HIGH

FUNCTION   SPT1(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 124
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT1 - ENTROPY KJ/KG-K
ERROR NONE

FUNCTION   SPT2(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 125
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT2 - ENTROPY KJ/KG-K
ERROR NONE

FUNCTION   SPT2I(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 126
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN SPT2I - ENTROPY KJ/KG-K
ERROR NONE

FUNCTION   SPT3(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 127
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K,
RETURN SPT3 - ENTROPY KJ/KG-K
ERROR NONE
```

```
FUNCTION   SPT5(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 128
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT5 - ENTROPY KJ/KG-K
ERROR NONE

FUNCTION   SPT5I(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 129
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN SPT5I - ENTROPY KJ/KG-K
ERROR NONE

FUNCTION   SPT97(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 130
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN   - PRESSURE PA
       TIN   - TEMPERATURE K
RETURN SPT97 - ENTROPY KJ/KG-K
ERROR
    RETURNS SPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   SPTM(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 131
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPTM - ENTROPY KJ/KG-K
ERROR NONE

FUNCTION   SPTMI(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 132
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN SPTMI - ENTROPY KJ/KG-K
ERROR NONE
```

```
FUNCTION   SPX97(PIN,XIN)
ENTROPY AS FUNCTION OF PRESSURE,QUALITY
ROUTINE NUMBER 133
INPUT  PIN   - PRESSURE PA
       XIN   - QUALITY
RETURN SPX97 - 2-PHASE ENTROPY KJ/KG-K
ERROR
    RETURNS SPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PCRT
                  - -3 IF XIN LT 0.0
                  - -4 IF XIN GT 1.0

FUNCTION   STDIPRS(PIN,TIN)
ROUTINE NUMBER 134
STATIC DIELECTRIC CONSTANT FUNCTION OF PRESSURE,TEMPERATURE
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE - K
RETURN STDIPRS - STATIC DIELECTRIC CONSTANT - DIMENSIONLESS
ERROR
    CHECK TIN FIRST
    IF( TIN .GT. 873. ) IREG = -4
    CHECK FOR VALID REGION IREG97(PIN,TIN)
    CHECK IF97 REGION IF IREG = 5, TREAT AS TIN .GT. 873.
    IF( IREG .LT. 0 ) IFLAG97(1) = IREG
    RETURN STDIPRS = -ONE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   STDIRHO(RHO,TIN)
ROUTINE NUMBER 135
STATIC DIELECTRIC CONSTANT FUNCTION OF DENSITY,TEMPERATURE
INPUT  RHO     - DENSITY KG/M^3
       TIN     -  TEMPERATURE - K
RETURN STDIRHO - STATIC DIELECTRIC CONSTANT - DIMENSIONLESS
ERROR
      CHECK TIN
      IF TIN .GT. 873.
      RETURN STDIRHO = -1.0
      RETRIEVE ERROR FLAG VALUE
               IERR = IERR97(1)
                    - -1 IF RHO<MIN 1/VPT2(PMIN,TIN)
                    - -2 IF RHO>MAX 1/VPT97(PMAX,TIN)
                    - -3 IF TIN .LT. T273
                    - -4 IF TIN .GT. 873.

FUNCTION   STR3(TIN,RHO)
ENTROPY AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 136
INPUT   TIN - TEMPERATURE K
        RHO - DENSITY KG/M^3
RETURN STR3 - ENTROPY KJ/KG-K
ERROR  NONE
```

```
FUNCTION   STX97(TIN,XIN)
ENTROPY AS FUNCTION OF TEMPERATURE,QUALITY
ROUTINE NUMBER 137
INPUT  TIN   - TEMPERATURE K
       XIN   - QUALITY
RETURN UTX97 - 2-PHASE ENTROPY KJ/KG-K
ERROR
    RETURNS STX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF XIN LT 0.0
                  - -2 IF XIN GT 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   SURTEN(TIN)
ROUTINE NUMBER 138
SURFACE TENSION EQUATION FUNCTION OF TEMPERATURE
INPUT  - TEMPERATURE - K
RETURN - SURFACE TENSION MILLI-N/M
ERROR
    IF( (TIN. LT. TTRP) .OR. (TIN .GT. TCRT) ) THEN
    RETURN SURTEN = -1.0D0
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -7 TIN OUT OF RANGE

FUNCTION   SVPT1(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 139
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN SVPT1 - SONIC VELOCITY - M/SEC
ERROR  NONE

FUNCTION   SVPT2(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 140
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN SVPT2 - SONIC VELOCITY - M/SEC
ERROR  NONE

FUNCTION   SVPT2I(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 141
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN SVPT2I - SONIC VELOCITY - M/SEC
ERROR  NONE

FUNCTION   SVPT3(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 142
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K,
RETURN SVPT3 - SONIC VELOCITY - M/SEC
ERROR  NONE
```

```
FUNCTION   SVPT5(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 143
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN SVPT5 - SONIC VELOCITY - M/SEC
ERROR  NONE

FUNCTION   SVPT5I(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 144
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN SVPT5I - SONIC VELOCITY - M/SEC
ERROR  NONE

FUNCTION   SVPT97(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 145
INPUT  PIN    - PRESSURE PA
       TIN    - TEMPERATURE K
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
RETURN SPVT97 - SONIC VELOCITY M/SEC
ERROR
    RETURNS SVPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   SVPTM(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 146
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN SVPTM - SONIC VELOCITY - M/SEC
ERROR  NONE

FUNCTION   SVPTMI(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 147
INPUT     PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN SVPTMI - SONIC VELOCITY - M/SEC
ERROR  NONE
```

```
FUNCTION   SVPX97(TIN,XIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 226
INPUT  PIN    - PRESSURE PA
       XIN    - QUALITY
RETURN SVPX97 - SONIC VELOCITY M/SEC
ERROR
    RETURNS SVPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF PIN LT PMIN
                  - -4 IF PIN GT PCRT

FUNCTION   SVTR3(TIN,RHO)
SPEED OF SOUND AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 148
INPUT    TIN - TEMPERATURE K
         RHO - DENSITY KG/M^3
RETURN SVTR3 - SONIC VELOCITY - M/SEC
ERROR  NONE

FUNCTION   SVTX97(TIN,XIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT TEMPERATURE,QUAL=0 OR 1
ROUTINE NUMBER 225
INPUT  TIN    - TEMPERATURE K
       XIN    - QUALITY
RETURN SVTX97 - SONIC VELOCITY M/SEC
ERROR
    RETURNS SVTX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -5 IF XIN NE 0.0 OR IF XIN NE 1.0
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TCRT

FUNCTION   T2397(PIN)
ROUTINE NUMBER 149
TEMPERATURE LINE BETWEEN REGION 2 AND 3
RANGE 16.5292 MPA TO 100 MPA
INPUT  PIN   - PRESSURE PA
RETURN T2397 - TEMPERATURE K
ERROR
    IF PRESSURE OUT OF RANGE
    RETURN T2397 = -1.0
    RETRIEVE ERROR FLAG
             IERR = IERR97(1)
                  - -1 IF PIN .LT. P2397(T623)
                  - -2 IF PIN .GT. PMAX
```

```
FUNCTION   TC85PRS(PIN,TIN)
ROUTINE NUMBER 150
THERMAL CONDUCTIVITY EQUATION FOR INDUSTRIAL USE IAPS 85
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE
RETURN TC85PRS - (FROM TC85RHO) THERMAL CONDUCTIVITY - W/M-K
ERROR
    CHECK FOR VALID REGION IREG97(PIN,TIN)
    CHECK IF97 REGION IF IREG = 5, TREAT AS TIN .GT. 1073.15
    IF( IREG .LT. 0 ) IFLAG97(1) = IREG
    CHECK TIN TREAT AS TIN TOO HIGH (IREG = -4)
    IF PIN .GT. 40 MPA TIN .LE. 923.15 K
    IF PIN .GT. 70 MPA TIN .LE. 773.15 K
    RETURN RINDPRS = -ONE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA
                       OR TIN TOO LARGE FOR PRESSURE RANGE

FUNCTION   TC85RHO(RHO,TIN)
ROUTINE NUMBER 151
THERMAL CONDUCTIVITY EQUATION FOR INDUSTRIAL USE IAPS 85
INPUT      RHO - DENSITY KG/M^3
           TIN - TEMPERATURE
RETURN TC85RHO - THERMAL CONDUCTIVITY  - W/M-K
ERROR
      CHECK IF TIN .GT. TMAX
      RETURN TC85RHO = -1.0
      RETRIEVE ERROR FLAG VALUE
               IERR = IERR97(1)
                   - -1 IF RHO<MIN 1/VPT2 (PMIN,TIN)
                   - -2 IF RHO>MAX 1/VPT97(PVAR,TIN)[100:70:40,TIN]
                   - -3 IF TIN LT  273.15 K
                   - -4 IF TIN GT 1073.15 K
```

```
FUNCTION   TC97PRS(PIN,TIN)
ROUTINE NUMBER 152
THERMAL CONDUCTIVITY EQUATION SCIENTIFIC/GENERAL USE
INPUT      PIN - PRESSURE PA
                 = 0 THEN SATURATED LIQUID VALUE
                 = 1 THEN SATURATED VAPOR VALUE
           TIN - TEMPERATURE K
RETURN TC97PRS - CONDUCTIVITY - W/M-K
NEAR CRITICAL POINT
WAS  RETURN TC = 8.024147528E+8 (SET INTERM A1 = 1.4673617D-20)
NOW  RETURN TC = 31.6391021364  (SET INTERM A1 = 1.0D-4       )
            CP = 19657519.86000 (WITH CPPT3 CORRECTION TO POSITIVE)
            PRANDTL NUMBER ~ DYNVIS*CP/TC SIMILAR TO TC85 RESULT
 MPA       K          CP       DV   T97   T85     PR97       PR85
22.064 647.0959999  4185482. 39.49 30.61 0.8106  5400197.5 203929235.
22.064 647.0960000 19657519. 39.43 31.63 0.8105 24498316.1 956228889.
22.064 647.0960001  4355950. 39.36 31.20 0.8104  5495683.5 211575276.
ERROR
    CHECK FOR VALID REGION IREG97(PIN,TIN)
    CHECK IF97 REGION IF IREG = 5, TREAT AS TIN TOO HIGH
    IF( IREG .LT. 0 ) IFLAG97(1) = IREG
    RETURN TC97PRS = -ONE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA
                       OR TIN TOO LARGE (>1073.15)
                  - -7 IF PIN = 0,1 AND TIN < T273
                  - -8 IF PIN = 0,1 AND TIN > TCRT

FUNCTION   TC97RHO(RHO,TIN)
ROUTINE NUMBER 152
THERMAL CONDUCTIVITY EQUATION SCIENTIFIC/GENERAL USE
INPUT      RHO - DENSITY KG/M^3
           TIN - TEMPERATURE K
RETURN TC97RHO - CONDUCTIVITY - W/M-K (FROM TC97PRS)
ERROR
    CHECK FOR VALID REGION ITEM97(TIN,RHO,IRHO)
    IF IREG .LT. 0 .OR. .GT. 3
    RETURN TC97RHO = -ONE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -4 IF REGION 4
                  - -5 IF REGION 5
```

```
FUNCTION   THMETA(PIN,HIN)
ROUTINE NUMBER 154
COMPUTE METASTABLE TEMPERATURE AT PRESSURE
INPUT  PIN    - PRESSURE PA
       HIN    - ENTHALPY KJ/KG
RETURN THMETA - MINIMUM METASTABLE TEMPERATURE K
ERROR
    CHECK PRESSURE RANGE PIN (PMIN TO PCRT)
    CHECK ENTHALPY RANGE HIN (HMETA TO HG)
    IF EQUIVALENT PMETA AT TSAT,HG .GT. PCRT IREG = -8
    NOTE PMETA ON THE ORDER OF 21.098 MPA AT HG
                      (VS ASME 21.2   MPA)
    THMETA = -1.0 AND SET S97(4) = TM AS COMPUTED
              RETRIEVE TM FROM FUNCTION PTMANS97(3)
              EG TMCAL = PTMANS97(3)
              RETRIEVE ERROR FLAG
              IERR = IERR97(1)
                   - -1 IF   PIN .LT. PMIN
                   - -2 IF   PIN .GT. PCRT
                   - -3 IF   HIN .LT. HMETA
                   - -4 IF   HIN .GT. HG
                   - -8 IF PMETA .GT. PCRT

FUNCTION   THS2397B(HIN,SNN)
ROUTINE NUMBER 266
INPUT  HIN      - ENTHALPY, KJ/KG-K
       SNN      - ENTROPY, KJ/KG-K
RETURN THS2397B - TEMPERATURE ON REG 2-3 BOUNDARY , K
ERROR             -1.0D0
                  IFLAG97(1) = -1 IF SNN TOO LOW
                  IFLAG97(1) = -2 IF SNN TOO HIGH
                  IFLAG97(1) = -3 IF HIN TOO LOW
                  IFLAG97(1) = -4 IF HIN TOO HIGH

FUNCTION   THS97(HIN,SNN)
RETURNS ESTIMATE OF TEMPERATURE GIVEN S (KJ/KG-K) AND H (KJ/LG)
ROUTINE NUMBER 235
THS97K IS THE FUNCTIONAL EQUIVALENT FOR REGIONS 1 AND 2 ONLY
INPUT    SNN  - ENTROPY KJ/KG-K
         HIN  - ENTHPLPY KJ/KG
RETURN THS97  - TEMPERATURE K OR QUALITY BASED ON IFLAG97(11)
                TEMPERATURE K IF IFLAG97(11) = 1 IF 2-PHASE
                QUALITY       IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
                              SET TO 0 OR 1 IF +/- 1.0D-5
                S97(6) CONTAINS PRESSURE IN PA
                RETRIEVE WITH PTMANS97(1)
ERROR
IF SNN OUT OF RANGE RETURN OR ITYPE OUT OF RANGE
   PSH97      = -1.0
   IFLAG97(1) = -1 SNN OUT OF RANGE
                -2 COULD NOT CONVERGE ON SNN
                -3 HIN OUT OF RANGE
                -4 COULD NOT CONVERGE ON HIN
```

```
FUNCTION   THS97B(HIN,SNN,IREG)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 155
LEGACY FUNCTION VERSION 1 USE THS97BK - FULL REGION CHECKING
INPUT  HIN    - ENTHALPY KJ/KG
       SNN    - ENTROPY  KJ/KG-K
       IREG   - REGION 1 OR REGION 2
RETURN THS97B - TEMPERATURE K
ERROR
    IF IREG NOT 1 OR 2
    RETURN THS97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
                  - INPUT VALUE OF IREG (-IREG IF INPUT > 2)
DOES POST CHECK TO SEE IF (T,H), (T,S) IN REGION 1 OR 2
ERROR
    RETURN THS97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
                  - - 6 IF NOT REGION 1 OR 2
                      RETRIEVE THS97B FROM FUNCTION PTMANS97(3)
                      EG TCAL = PTMANS97(3)

FUNCTION   THS97BK(HIN,SNN)
ROUTINE NUMBER 273
INPUT  HIN     - ENTHALPY KJ/KG
       SNN     - ENTROPY  KJ/KG-K
RETURN THS97BK - TEMPERTURE K
FOR IREG = 4 GET TSHS97B
ERROR
    IF IREG NOT 1, 2, 3 OR 4 (FROM IRGHS97)
    RETURN THS97BK = -1.0D0
    RETRIEVE IERR  = IERR97(1)
             IERR  = -1 IF SNN TOO LOW
                   = -2 IF SNN TOO HIGH
                   = -3 IF HIN TOO LOW
                   = -4 IF HIN TOO HIGH
                   = -5 IF 4 BUT SNN LESS THAN S08
                   = -10 IF T OUT OF RANGE LOW GET PTMANS97(3)
                   = -20 IF T OUT OF RANGE HIGH GET PTMANS97(3)

FUNCTION   THSBK1(HIN,SNN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 156
BACKWARD EQUATION 2 NEW BACKWARD EQS REGION 1
INPUT     HIN - ENTHALPY KJ/KG
          SNN - ENTROPY KJ/KG-K
RETURN THSBK1 - TEMPERATURE K
RETURN THSBK1 - TEMPERATURE K
ERROR  RETURN THSBK1 = -1.0
       FROM PHSBK1 IF P <> P IF97, IERR -11, -21
                   IF IFLAG97(14) = 1 RETURN PMIN OR PMAX
       FROM TPHBK1 IF T <> T IF97, IERR -10, -20
                   IF IFLAG97(14) = 1 RETURN TMIN OR TMAX
```

```
FUNCTION   THSBK2(HIN,SNN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 157
BACKWARD EQUATION NEW EQ 4-5-6 FOR ENTHALPY BOUNDARY REGION 2
INPUT     HIN - ENTHALPY KJ/KG
          SNN - ENTROPY KJ/KG-K
RETURN THSBK2 - TEMPERATURE K
ERROR  RETURN THSBK2 = -1.0
       FROM PHSBK2 IF P <> P IF97, IERR -11, -21
                   IF IFLAG97(14) = 1 RETURN PMIN OR PMAX
       FROM TPHBK2 IF T <> T IF97, IERR -10, -20
                   IF IFLAG97(14) = 1 RETURN TMIN OR TMAX

FUNCTION   THSBK3(HIN,SNN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 279
BACKWARD EQUATION 3 NEW BACKWARD EQS REGION 3
INPUT     HIN - ENTHALPY KJ/KG
          SNN - ENTROPY KJ/KG-K
RETURN THSBK3 - TEMPERATURE K
ERROR  RETURN THSBK3 = -1.0
       FROM PHSBK3 IF P <> P IF97, IERR -11, -21
                   IF IFLAG97(14) = 1 RETURN PMIN OR PMAX
       FROM TPHBK3
       PIN TOO LOW  -1
       PIN TOO HIGH -2
       HIN TOO LOW  -3
       HIN TOO HIGH -4
       NOT VALID    -5

FUNCTION   TPH97(PIN,HIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 158
INPUT  PIN   - PRESSURE PA
       HIN   - ENTHALPY KJ/KG
RETURN TPH97 - TEMPERATURE K
               IF 0 <= TPH97 <= 1, 2-PHASE QUALITY
ERROR
    CHECK IF97 REGION IPRS97(PIN,HIN,IVAR)
    IF IREG .LT. 0
    RETURN TPH97 = -1.0D0
    RETRIEVE ERROR FLAG
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX
                  - -3 IF HIN LT VMIN
                  - -4 IF HIN GT VMAX

FUNCTION   TPH97B(PIN,HIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 159
LEGACY FUNCTION VERSION 1 USE TPH97BK - FULL REGION CHECKING
INPUT  PIN    - PRESSURE PA
       HIN    - ENTHALPY KJ/KG
RETURN TPH97B - TEMPERATURE K
ERROR
```

```
FUNCTION   TPH97BK(PIN,HIN)
ROUTINE NUMBER 276
INPUT  PIN     - PRESSURE , MPA
       HIN     - ENTHALPY , KJ/KG
RETURN TPH97BK - TEMPERTURE K
ERROR
    IF IREG NOT 1, 2, OR 3 (FROM IRGHS97)
    RETURN TPH97BK = -1.0D0
    RETRIEVE IERR  = IERR97(1)
             IERR  = -1 IF PIN TOO LOW
                   = -2 IF PIN TOO HIGH
                   = -3 IF HIN TOO LOW
                   = -4 IF HIN TOO HIGH
                   = -5 IF REGION 4
                   = -10 IF T OUT OF RANGE LOW GET PTMANS97(3)
                   = -20 IF T OUT OF RANGE HIGH GET PTMANS97(3)

FUNCTION   TPHBK1(PIN,HIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 160
BACKWARD EQUATION 3.4 REGION 1
INPUT     PIN - PRESSURE PA
          HIN - ENTHALPY KJ/KG
RETURN TPHBK1 - TEMPERATURE K
ERROR  TPHBK1 = -1.0
RETRIEVE IERR97(1)
              - 10 IF PCAL < T273
              - 20 IF PCAL > TMAX
       RETRIEVE CALC VALUE FROM PTMANS97(3) FROM S97(4)
       IF IFLAG97(14) = 1 THEN RETURN T273 OR TMAX

FUNCTION   TPHBK2(PIN,HIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 161
BACKWARD EQUATION 3.15 TO 3.17 REGION 2
INPUT     PIN - PRESSURE PA
          HIN - ENTHALPY KJ/KG
RETURN TPHBK2 - TEMPERATURE K
ERROR  TPHBK2 = -1.0
RETRIEVE IERR97(1)
              - 10 IF PCAL < T273
              - 20 IF PCAL > TMAX
       RETRIEVE CALC VALUE FROM PTMANS97(3) FROM S97(4)
       IF IFLAG97(14) = 1 THEN RETURN T273 OR TMAX

FUNCTION   TPHBK3(PIN,HIN)
ROUTINE NUMBER 257
INPUT  PIN    - PRESSURE PA
       HIN    - ENTHALPY KJ/KG
RETURN TPHBK3 - TEMPERATURE K
SET IFLAG97(13) TO 1 FOR VALIDATION ONLY
ERROR RETURN TPHBK3 = -1.0
    PIN TOO LOW  -1
    PIN TOO HIGH -2
    HIN TOO LOW  -3
    HIN TOO HIGH -4
    NOT VALID    -5
```

```
FUNCTION   TPMETA(PIN)
ROUTINE NUMBER 162
COMPUTE METASTABLE TEMPERATURE AT PRESSURE
INPUT  PIN    - PRESSURE PA
RETURN TPMETA - MINIMUM METASTABLE TEMPERATURE K
ERROR
    CHECK PRESSURE RANGE PIN (PMIN TO PCRT)
    IF EQUIVALENT PMETA AT TSAT,HG .GT. PCRT IREG = -8
    NOTE PMETA ON THE ORDER OF 21.098 MPA AT HG
                      (VS ASME 21.2   MPA)
    TPMETA = -1.0 AND SET S97(4) = TM AS COMPUTED
              RETRIEVE TM FROM FUNCTION PTMANS97(3)
              EG TCAL = PTMANS97(3)
              RETRIEVE ERROR FLAG
              IERR = IERR97(1)
                   - -1 IF   PIN .LT. PMIN
                   - -2 IF   PIN .GT. PCRT
                   - -8 IF PMETA .GT. PCRT

FUNCTION   TPS97(PIN,SNN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 163
INPUT  PIN   - PRESSURE PA
       SNN   - ENTROPY KJ/KG-K
RETURN TPS97 - TEMPERATURE K
               IF 0 <= TPS97 <= 1, 2-PHASE QUALITY
ERROR
    CHECK IF97 REGION IPRS97(PIN,SNN,IVAR)
    IF IREG .LT. 0  GO TO 100
    RETURN TPH97 = -1.0D0
    RETRIEVE ERROR FLAG
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX
                  - -3 IF SNN LT VMIN
                  - -4 IF SNN GT VMAX

FUNCTION   TPS97B(PIN,SNN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 164
LEGACY FUNCTION VERSION 1 USE TPS97BK - FULL REGION CHECKING
INPUT  PIN   - PRESSURE PA
       SNN   - ENTROPY KJ/KG-K
RETURN TPS97B - TEMPERATURE K
ERROR
    IREG = IBAK97( PIN,SNN,IVAR )
    IF IREG NOT 1 OR 2
    RETURN TPS97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
                  - INPUT VALUE OF IREG (-IREG IF INPUT > 2)
    CHECK FOR VALID RETURN
    IREG = IREG97(PIN,TPS97B)
    IF IREG NOT 1 OR 2
    RETURN TPS97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
                  - INPUT VALUE OF IREG (-IREG IF INPUT > 2)
    SET S97(4) = TPS97B
                 RETRIEVE TPS97B FROM FUNCTION PTMANS97(3)
                      EG TCAL = PTMANS97(3)
```

```
FUNCTION   TPS97BK(PIN,SNN)
ROUTINE NUMBER 277
INPUT  PIN     - PRESSURE , MPA
       SNN     - ENTROPY  , KJ/KG-K
RETURN TPS97BK - TEMPERTURE K
ERROR
    IF IREG NOT 1, 2, OR 3 (FROM IRGHS97)
    RETURN TPS97BK = -1.0D0
    RETRIEVE IERR  = IERR97(1)
             IERR  = -1 IF PIN TOO LOW
                   = -2 IF PIN TOO HIGH
                   = -3 IF SNN TOO LOW
                   = -4 IF SNN TOO HIGH
                   = -5 IF REGION 4
                   = -10 IF T OUT OF RANGE LOW GET PTMANS97(3)
                   = -20 IF T OUT OF RANGE HIGH GET PTMANS97(3)

FUNCTION   TPSBK1(PIN,SNN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 165
BACKWARD EQUATION 3.5 REGION 1
INPUT     PIN - PRESSURE PA
          SNN - ENTROPY KJ/KG-K
RETURN TPSBK1 - TEMPERATURE K
ERROR  RETURN TPSBK1 = -1.0
RETRIEVE IERR97(1)
              - 10 IF PCAL < T273
              - 20 IF PCAL > TMAX
       RETRIEVE CALC VALUE FROM PTMANS97(3) FROM S97(4)
       IF IFLAG97(14) = 1 THEN RETURN T273 OR TMAX

FUNCTION   TPSBK2(PIN,SNN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 166
BACKWARD EQUATION 3.18 TO 3.20 REGION 2
INPUT     PIN - PRESSURE PA
          SNN - ENTROPY KJ/KG-K
RETURN TPSBK2 - TEMPERATURE K
ERROR  RETURN TPSBK2 = -1.0
RETRIEVE IERR97(1)
              - 10 IF PCAL < T273
              - 20 IF PCAL > TMAX
       RETRIEVE CALC VALUE FROM PTMANS97(3) FROM S97(4)
       IF IFLAG97(14) = 1 THEN RETURN T273 OR TMAX

FUNCTION   TPSBK3(PIN,SNN)
ROUTINE NUMBER 258
INPUT  PIN    - PRESSURE PA
       SNN    - ENTROPY KJ/KG-K
RETURN TPSBK3 - TEMPERATURE K
SET IFLAG97(13) TO 1 FOR VALIDATION ONLY
ERROR  RETURN TPSBK3 = -1.0
RETRIEVE IERR97(1)
    PIN TOO LOW  -1
    PIN TOO HIGH -2
    SNN TOO LOW  -3
    SNN TOO HIGH -4
    NOT VALID    -5
```

```
FUNCTION   TPU97(PIN,UIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND INTERNAL ENERGY
ROUTINE NUMBER 167
INPUT  PIN   - PRESSURE PA
       UIN   - INTERNAL ENERGY KJ/KG
RETURN TPU97 - TEMPERATURE K
               IF 0 <= TPU97 <= 1, 2-PHASE QUALITY
ERROR
    CHECK IF97 REGION IPRS97(PIN,UIN,IVAR)
    IF IREG .LT. 0  GO TO 100
    RETURN TPH97 = -1.0D0
    RETRIEVE ERROR FLAG
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX
                  - -3 IF UIN LT VMIN
                  - -4 IF UIN GT VMAX

FUNCTION   TPV97(PIN,VIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND SPECIFIC VOLUME
ROUTINE NUMBER 168
INPUT  PIN   - PRESSURE PA
       VIN   - SPECIFIC VOLUME M^3/KG
RETURN TPV97 - TEMPERATURE K
               IF 0 <= TPV97 <= 1, 2-PHASE QUALITY
ERROR
   CHECK IF97 REGION IPRS97(PIN,VIN,IVAR)
    IF IREG .LT. 0  GO TO 100
    RETURN TPH97 = -1.0D0
    RETRIEVE ERROR FLAG
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX
                  - -3 IF VIN LT VMIN
                  - -4 IF VIN GT VMAX

FUNCTION   TSAT97(PIN)
ROUTINE NUMBER 169
SATURATION LINE TEMPERATURE REGION 4 (AND MY REGION 6)
RANGE 611.213 PA TO 22.064 MPA
INPUT  PIN    - PRESSURE PA
RETURN TSAT97 - K
IF PIN .GE. (PCRT-1.7D-7) RETURN TCRT (647.096 VS 647.095999998812 )
ERROR
    RETURNS TSAT97 = -1.0D0 IF TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN .LT. PMIN
                  - -2 IF PIN .GT. PCRT
```

```
FUNCTION   TR3PT97B(PIN,IREG)
TEMPERATURE AS A FUNCTION OF PRESSURE ON V(P,T) BOUNDARIES
ROUTINE NUMBER 280
IAPWS 97 TEMPERATURE BOUNDARIES FOR V(P,T) IN REGION 3
INPUT      PIN  - PRESSURE PA
           IREG - TEMPERATURE EQUATION ID
           IREG =  1 FOR AB
           IREG =  2 FOR CD
           IREG =  3 FOR EF
           IREG =  4 FOR GH
           IREG =  5 FOR IJ
           IREG =  6 FOR JK
           IREG =  7 FOR MN
           IREG =  8 FOR OP
           IREG =  9 FOR QU
           IREG = 10 FOR RX
           IREG = 11 FOR UV
           IREG = 12 FOR WX
RETURN TR3PT97B - TEMPERATURE K
ERROR  IF IREG < 0 OR > 12 IERR = -1
       TR3PT97B =                -1.0D0


FUNCTION   TSHS97B(HIN,SNN)
ROUTINE NUMBER 267
INPUT  HIN     - ENTHALPY, KJ/KG-K
       SNN     - ENTROPY, KJ/KG-K
RETURN TSHS97B - SATURATION TEMPERATURE ,K
ERROR  TSHS97B     = -1.0D0
    RETRIEVE IERR  = IERR97(1)
             IERR  = -1 IF SNN TOO LOW
                   = -2 IF SNN TOO HIGH
                   = -3 IF HIN TOO LOW
                   = -4 IF HIN TOO HIGH
                   = -5 IF 4 BUT SNN LESS THAN S08
                   = -6 IF NOT REGION 4

FUNCTION   TVAR97(PIN,VAR,IVAR,IREG)
TEMPERATURE AS FUNCTION OF PRESSURE AND VARIABLE
ROUTINE NUMBER 170
SPECIAL FLAG IFLAG97(11)
        = 0 THEN RETURN QUALITY ELSE RETURN TEMPERATURE IN REG 4/6
INPUT    PIN - PRESSURE PA
         VAR - V (M3/KG)   IF IVAR = 1  P97 INDEX = 3
             - U (KJ/KG)      IVAR = 2  P97 INDEX = 4
             - H (KJ/KG)      IVAR = 3  P97 INDEX = 5
             - S (KJ/KG-K)    IVAR = 4  P97 INDEX = 6
        IREG - 1  GIBB1
             - 2  GIBB2
             - 3  HELM   (8,9)
             - 5  GIBB5
             - 4  SAT GIBB1/GIBB2
             - 6  SAT HELM3 (ROOT3MAX)
             - 7  GIBB2 SUPPLEMENTAL SPECIAL CASE
RETURN       TEMPERATURE K    IREG = 1,2,3 (8,9),5 OR 7
RETURN       QUALITY          IREG = 4 OR 6
IVAR AND IREG NOT CHECKED LOCALLY
CALL TO IPRS97 FIRST TO SET IREG
ERROR CAN'T RESOLVE REG 3 BETWEEN SAT VALUES SHOULD USE REG 6
    IFLAG97(1) = -1       TVAR97 = -1.0D0
    SILENT ERROR IFLAG97(15) SET TO -108 IF ITERATION FAILURE
```

```
FUNCTION   TVH97(VIN,HIN)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H OR S
ROUTINE NUMBER 239
INPUT    VIN  - SPECIFIC VOLUME (M^3/KG)
         HIN  - ENTHALPY KJ/KG  IF IVAR = 1
RETURN TVH97  - TEMPERATURE K OR QUALITY BASED ON IFLAG97(11)
                TEMPERATURE K IF IFLAG97(11) = 1 IF 2-PHASE
                QUALITY       IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
                              SET TO 0 OR 1 IF +/- 1.0D-5
                S97(6) CONTAINS PRESSURE IN PA
       RETRIEVE PTMAN97(1)
ERROR
IF HIN OUT OF RANGE RETURN
   TVH97      = -1.0
   S97(6)     = -1.0
   IFLAG97(1) = -3 VIN TOO LOW
                -4 VIN TOO HIGH
                -1 HIN TOO LOW
                -2 NIN TOO HIGH

FUNCTION   TVS97(VIN,SNN)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H OR S
ROUTINE NUMBER 240
INPUT    VIN  - SPECIFIC VOLUME (M^3/KG)
         SNN  - ENTROPY  KJ/KG-K  IF IVAR = 1
RETURN TVS97  - TEMPERATURE K OR QUALITY BASED ON IFLAG97(11)
                TEMPERATURE K IF IFLAG97(11) = 1 IF 2-PHASE
                QUALITY       IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
                              SET TO 0 OR 1 IF +/- 1.0D-5
                S97(6) CONTAINS PRESSURE IN PA
       RETRIEVE PTMAN97(1)
ERROR
IF SNN OUT OF RANGE RETURN
   TVS97      = -1.0
   S97(6)     = -1.0
   IFLAG97(1) = -3 VIN TOO LOW
                -4 VIN TOO HIGH
                -1 SNN TOO LOW
                -2 SNN TOO HIGH

SUBROUTINE TWOFAZ(TIN,IVAR,VARL,VARG)
ROUTINE NUMBER 171
COMPUTE FLUID AND VAPOR COMPONENTS AT T
INPUT  TIN  - TEMPERAURE K
       IVAR - VARIABLE
              1 - SPECIFIC VOLUME
              2 - INTERNAL ENERGY
              3 - ENTHALPY
              4 - ENTROPY
RETURN VARL - FLUID COMPONENT
       VARG - VAPOR COMPONENT
ERROR
    CHECK TIN RANGE (T273 TO TCRT)
    RETURN  VARL = -1.0D0
            VARG = VARL
    RETRIEVE ERROR FLAG IERR = IERR97(1)
                             - -3 IF TIN .LT. T273
                             - -4 IF TIN .GT. TCRT
```

```
SUBROUTINE TXPROP97(TIN,XIN)
ROUTINE NUMBER 172
COMPUTE 2-PHASE VALUES BASED ON TIN AND XIN
INPUT  TIN - TEMPERATURE K
       XIN - QUALITY ( 0 TO 1 )
CALLS GIBB1/GIBB2 OR HELM3/L/V AS APPROPRIATE
RETURN P97 ARRAY RETRIEVE WITH PROP97
ERROR
    RETURNS PIN IN P97(1),XIN IN P97(7), -1.0D0 FOR OTHERS
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF XIN  .LT. ZERO
                  - -2 IF XIN  .GT. ONE
                  - -3 IF TIN  .LT. T273
                  - -4 IF TIN  .GT. TCRT

FUNCTION   UPT1(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 173
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN UPT1 - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UPT2(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 174
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN UPT2 - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UPT2I(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 175
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN UPT2I - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UPT3(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 176
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K,
RETURN UPT3 - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UPT5(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 177
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN UPT5 - INTERNAL ENERGY KJ/KG
ERROR  NONE
```

```
FUNCTION   UPT5I(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 178
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN UPT5I - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UPT97(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 179
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN   - PRESSURE PA
       TIN   - TEMPERATURE K
RETURN UPT97 - INTERNAL ENERGY KJ/KG
ERROR
    RETURNS UPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   UPTM(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 180
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN UPTM - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UPTMI(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 181
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN UPTMI - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UPX97(PIN,XIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,QUALITY
ROUTINE NUMBER 182
INPUT  PIN   - PRESSURE PA
       XIN   - QUALITY
RETURN UPX97 - 2-PHASE INTERNAL ENERGY KJ/KG
ERROR
    RETURNS HPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PCRT
                  - -3 IF XIN LT 0.0
                  - -4 IF XIN GT 1.0
```

```
FUNCTION   UTR3(TIN,RHO)
INTERNAL ENERGY AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 183
INPUT   TIN - TEMPERATURE K
        RHO - DENSITY KG/M^3
RETURN UTR3 - INTERNAL ENERGY KJ/KG
ERROR  NONE

FUNCTION   UTX97(TIN,XIN)
INTERNAL ENERGY AS FUNCTION OF TEMPERATURE,QUALITY
ROUTINE NUMBER 184
INPUT  TIN   - TEMPERATURE K
       XIN   - QUALITY
RETURN UTX97 - 2-PHASE INTERNAL ENERGY KJ/KG
ERROR
    RETURNS UPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PCRT
                  - -3 IF XIN LT 0.0
                  - -4 IF XIN GT 1.0

FUNCTION   V3APT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 281
IAPWS 97 REGION 3 BACKWARD 3A
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3APT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3BPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 282
IAPWS 97 REGION 3 BACKWARD 3B
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3BPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3CPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 283
IAPWS 97 REGION 3 BACKWARD 3C
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3CPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3DPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 284
IAPWS 97 REGION 3 BACKWARD 3D
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3DPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE
```

```
FUNCTION   V3EPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 285
IAPWS 97 REGION 3 BACKWARD 3E
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3EPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3FPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 286
IAPWS 97 REGION 3 BACKWARD 3F
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3FPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3GPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 287
IAPWS 97 REGION 3 BACKWARD 3G
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3GPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3HPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 288
IAPWS 97 REGION 3 BACKWARD 3H
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3HPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3IPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 289
IAPWS 97 REGION 3 BACKWARD 3I
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3IPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3JPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 290
IAPWS 97 REGION 3 BACKWARD 3J
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3JPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE
```

```
FUNCTION   V3KPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 291
IAPWS 97 REGION 3 BACKWARD 3K
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3KPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3LPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 292
IAPWS 97 REGION 3 BACKWARD 3L
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3LPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3MPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 293
IAPWS 97 REGION 3 BACKWARD 3M
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3MPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3NPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 294
IAPWS 97 REGION 3 BACKWARD 3N
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3NPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3OPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 295
IAPWS 97 REGION 3 BACKWARD 3O
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3OPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3PPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 296
IAPWS 97 REGION 3 BACKWARD 3P
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3PPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE
```

```
FUNCTION   V3QPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 297
IAPWS 97 REGION 3 BACKWARD 3Q
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3QPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3RPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 298
IAPWS 97 REGION 3 BACKWARD 3R
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3RPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3SPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 299
IAPWS 97 REGION 3 BACKWARD 3S
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3SPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3TPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 300
IAPWS 97 REGION 3 BACKWARD 3T
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3TPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3UPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 301
IAPWS 97 REGION 3 BACKWARD 3U
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3UPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3VPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 302
IAPWS 97 REGION 3 BACKWARD 3V
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3VPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE
```

```
FUNCTION   V3WPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 303
IAPWS 97 REGION 3 BACKWARD 3W
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3WPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3XPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 304
IAPWS 97 REGION 3 BACKWARD 3W
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3XPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3YPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 305
IAPWS 97 REGION 3 BACKWARD 3W
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3YPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   V3ZPT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 306
IAPWS 97 REGION 3 BACKWARD 3W
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN V3ZPT97B - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   VHSBK3(HIN,SNN)
ROUTINE NUMBER 274
INPUT  HIN     - ENTHALPY KJ/KG
       SNN     - ENTROPY  KJ/KG-K
RETURN VHSBK3 - SPECIFIC VOLUME  M^3/KG
FOR IREG = 4 GET TSAT FROM TSHS97B AND GET P FROM PSAT97(TSAT)
ERROR
    IF IREG NOT 3 (FROM IRGHS97)
    RETURN VHSBK3 = -1.0D0
    RETRIEVE IERR  = IERR97(1)
             IERR  = -1 IF SNN TOO LOW
                   = -2 IF SNN TOO HIGH
                   = -3 IF HIN TOO LOW
                   = -4 IF HIN TOO HIGH
                   = -5 IF 4 BUT SNN LESS THAN S08
                   = -6 IF NOT REGION 3
```

```
FUNCTION   VPHBK3(PIN,HIN)
ROUTINE NUMBER 259
INPUT  PIN    - PRESSURE PA
       HIN    - ENTHALPY KJ/KG
RETURN VPHBK3 - TEMPERATURE K
SET IFLAG97(13) TO 1 FOR VALIDATION ONLY
ERROR
    PIN TOO LOW  -1
    PIN TOO HIGH -2
    HIN TOO LOW  -3
    HIN TOO HIGH -4
    NOT VALID    -5
    RETURN VPHBK3 = -1.0D0

FUNCTION   VPSBK3(PIN,SNN)
ROUTINE NUMBER 260
INPUT  PIN    - PRESSURE PA
       SNN    - ENTROPY KJ/KG-K
RETURN VPSBK3 - SPECIFIC VOLUME M^3/KG
SET IFLAG97(13) TO 1 FOR VALIDATION ONLY
ERROR
    PIN TOO LOW  -1
    PIN TOO HIGH -2
    SNN TOO LOW  -3
    SNN TOO HIGH -4
    NOT VALID    -5
    RETURN VPSBK3 = -1.0D0

FUNCTION   VPT1(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 185
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN VPT1 - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   VPT2(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 186
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN VPT2 - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   VPT2I(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 187
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN VPT2I - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   VPT3(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 188
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K,
RETURN VPT3 - SPECIFIC VOLUME M^3/KG
ERROR  NONE
```

```
FUNCTION   VPT3A97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 189
NEW V(P,T) EQUATION SUBREGION 3A V(P,T)
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN VPT3A97 - SPECIFIC VOLUME M^3/KG
ERROR  NONE

FUNCTION   VPT3B97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 190
NEW V(P,T) EQUATION SUBREGION 3B V(P,T)
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN VPT3B97 - SPECIFIC VOLUME M^3/KG
ERROR  NONE

FUNCTION   VPT3C97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 191
NEW V(P,T) EQUATION SUBREGION 3C V(P,T)
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN VPT3C97 - SPECIFIC VOLUME M^3/KG
ERROR NONE

FUNCTION   VPT3D97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 192
NEW V(P,T) EQUATION SUBREGION 3D V(P,T)
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN VPT3D97 - SPECIFIC VOLUME M^3/KG
ERROR NONE

FUNCTION   VPT3E97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 193
NEW V(P,T) EQUATION SUBREGION 3E V(P,T)
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN VPT3E97 - SPECIFIC VOLUME M^3/KG
ERROR NONE

FUNCTION   VPT3F97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 194
NEW V(P,T) EQUATION SUBREGION 3F V(P,T)
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN VPT3F97 - SPECIFIC VOLUME M^3/KG
ERROR NONE
```

```
FUNCTION   VPT3G97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 195
NEW V(P,T) EQUATION SUBREGION 3G V(P,T)
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN VPT3G97 - SPECIFIC VOLUME M^3/KG
ERROR NONE

FUNCTION   VPT5(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 196
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN VPT5 - SPECIFIC VOLUME - M^3/KG
ERROR NONE

FUNCTION   VPT5I(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 197
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN VPT5I - SPECIFIC VOLUME - M^3/KG
ERROR  NONE

FUNCTION   VPT97(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 198
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN   - PRESSURE PA
       TIN   - TEMPERATURE K
RETURN VPT97 - SPECIFIC VOLUME M^3/KG
ERROR
    RETURNS VPT97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA

FUNCTION   VPTM(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 199
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN VPTM - SPECIFIC VOLUME - M^3/KG
ERROR NONE

FUNCTION   VPTMI(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 200
INPUT    PIN - PRESSURE PA
         TIN - TEMPERATURE K
RETURN VPTMI - SPECIFIC VOLUME - M^3/KG
ERROR NONE
```

```
FUNCTION   VPTREG3(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 201
NEW V(P,T) EQUATION
GIVEN P,T FIND IF-97 REGION 3 SUB-REGION FROM IVPT97
INPUT  PIN     - PRESSURE PA
       TIN     - TEMPERATURE K
RETURN VPTREG3 - DENSITY KG/M^3
ERROR
    CALLS IVPT97
    IF CAN'T LOCATE REGION 1 THROUGH 7 (A THRU G) THEN
    RETURN VPTREG3 = -1.0D0
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN .GT. PMAX
                  - -2 IF PIN .LT. P623
                  - -4 IF TIN .LT. T623
                  - -3 IF TIN .GT. T2397(PIN)

FUNCTION   VPX97(PIN,XIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,QUALITY
ROUTINE NUMBER 202
SPECIFIC VOLUME AS FUNCTION OF PRESSURE AND QUALITY
INPUT  PIN   - PRESSURE PA
       XIN   - QUALITY
RETURN VPX97 - 2-PHASE SPECIFIC VOLUME M^3/KG
ERROR
    RETURNS HPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PCRT
                  - -3 IF XIN LT 0.0
                  - -4 IF XIN GT 1.0

FUNCTION   VR3PT97B(PIN,TIN)
SPECIFIC VOLUME AT PRESSURE,TEMPERATURE NEW REGION 3 FORMULATIONS
ROUTINE NUMBER 307
IAPWS 97 REGION 3 BACKWARD EQUATION
INPUT       PIN - PRESSURE PA
            TIN - TEMPERATURE K
RETURN VR3PT97B - SPECIFIC VOLUME - M^3/KG
     IFLAG97(1) - REGION NUMBER 1-26 (A-Z)
         IF TIN = TSAT(PIN) RETURN
                  IFLAG97(1) - 30 (SPECIAL VALUE)
                  VR3PT97B   = V-LIQUID
                  PTMANS97(4)= V-VAPOR
ERROR  PIN < PSAT(623.15), IFLAG97(1) = -1 , VR3PT97B = -1.0
           >      100 MPA, IFLAG97(1) = -2 , VR3PT97B = -1.0
       TIN <=    623.15 K, IFLAG97(1) = -3 , VR3PT97B = -1.0
           >=  T2397(PIN), IFLAG97(1) = -4 , VR3PT97B = -1.0

FUNCTION   VTR3(TIN,RHO)
SPECIFIC VOLUME AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 203
INPUT   TIN - TEMPERATURE K (NOT USED HERE, MUST BE REGION 3)
        RHO - DENSITY KG/M^3
RETURN VTR3 - SPECIFIC VOLUME - M^3/KG
ERROR  NONE
```

```
FUNCTION   VTX97(TIN,XIN)
SPECIFIC VOLUME AS FUNCTION OF TEMPERATURE,QUALITY
ROUTINE NUMBER 204
SPECIFIC VOLUME AS FUNCTION OF TEMPERATURE AND QUALITY
INPUT  TIN   - TEMPERATURE K
       XIN   - QUALITY
RETURN VTX97 - 2-PHASE SPECIFIC VOLUME M^3/KG
ERROR
    RETURNS VPX97 = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN
                  - -2 IF PIN GT PCRT
                  - -3 IF XIN LT 0.0
                  - -4 IF XIN GT 1.0

FUNCTION   XHSBK4(HIN,SNN)
ROUTINE NUMBER 278
INPUT  HIN     - ENTHALPY KJ/KG
       SNN     - ENTROPY  KJ/KG-K
RETURN XHSBK4  - QUALITY IN (LIMITED) REGION 4
FOR IREG = 4 GET TSAT FROM TSHS97B AND GET P FROM PSAT97(TSAT)
ERROR
    IF IREG NOT 4 (FROM IRGHS97)
    RETURN XHSBK4 = -1.0D0
    RETRIEVE IERR  = IERR97(1)
             IERR  = -1 IF SNN TOO LOW
                   = -2 IF SNN TOO HIGH
                   = -3 IF HIN TOO LOW
                   = -4 IF HIN TOO HIGH
                   = -5 IF 4 BUT SNN LESS THAN S08
                   = -6 IF NOT REGION 4

SUBROUTINE XPROP97
ROUTINE NUMBER 205
INPUT PIN - PRESSURE PA
            QUALITY ( 0 OR 1 )
INPUT TIN - TEMPERATURE
            QUALITY ( 0 OR 1 )
RETURN      THERMODYNAMIC AND TRANSPORT PROPERITES IN P97 ARRAY
BASED ON USE OF LOW-LEVEL ROUTINES
IF PIN IS QUALITY, TIN MUST BE VALID IN SATURATION RANGE
IF TIN IS QUALITY, PIN MUST BE VALID IN SATURATION RANGE
ERROR
    RETRIEVE ERROR FLAG VALUE
             IERR = IERR97(1)
                  - -1 IF PIN LT PMIN (IF GT 1 IF TIN IS QUALITY)
                  - -2 IF PIN GT PMAX OR P010 IF REGION 5
                  - -3 IF TIN LT TMIN
                  - -4 IF TIN GT TLAR OR TMAX IF P > 10 MPA
    INTERNAL      - -5 GOT A BAD QUALITY REQUEST
                  - -8 CANNOT HAVE BOTH PIN,TIN AS QUALITY
    RETURN P97(1) = PIN , P97(2) = TIN , P97(3)-P97(30)=-1.0
```

```
FUNCTION   XREG1MM(TIN,VAR,IVAR,PLIN,PHIN)
ROUINE NUMBER 217
CALCULATE PRESSURE AT T AND VAR IN IF97 REGION 1
GIVEN DVAR/DP|T IS - AT PLIN, AND - AT PHIH
SPECIAL FLAG
IF IFLAG97(8) = 1 THEN CHECK RANGE VALIDITY ONLY
 INPUT   TIN     - TEMPERATURE (K)
         VAR     - VARIABLE VALUE
         IVAR    - VARIABLE TYPE   1=V,2=U,3=H,4=S
         PLIN    - MINIMUM PRESSURE (PA)
         PHIN    - MAXIMUM PRESSURE (PA)
 RETURN  XREG1MM - PRESSURE IN PA
      IFLAG97(1) -  1 ONE ROOT
 SAVE MIN,MAX, MID FOR POSSIBLE USE ELSEWHERE
        S97(1) = XPMIN
        S97(2) = XPMAX
        S97(3) = ZERO
        S97(4) = -1.0 EG NOT A PM/MP CALL
 ERROR
         IF VAR OUTSIDE RANGE
         XREG1MM    = -1.0D0
         IFLAG97(1) = -1 IF VAR TOO LOW
                      -2 IF VAR TOO HIGH
         SILENT ERROR IFLAG97(15) SET TO -109 IF ITERATION FAILURE

FUNCTION   XREG1MP(TIN,VAR,IVAR,PLIN,PHIN)
ROUINE NUMBER 220
CALCULATE PRESSURE AT T AND VAR IN IF97 REGION 1
GIVEN DVAR/DP|T IS - AT PLIN, AND + AT PHIH
SPECIAL FLAG
IF IFLAG97(8) = 1 THEN CHECK RANGE VALIDITY ONLY
 INPUT   TIN     - TEMPERATURE (K)
         VAR     - VARIABLE VALUE
         IVAR    - VARIABLE TYPE   1=V,2=U,3=H,4=S
         PLIN    - MINIMUM PRESSURE (PA)
         PHIN    - MAXIMUM PRESSURE (PA)
 RETURN  XREG1MM - PRESSURE IN PA
         S97(6)  - PRESSURE IN PA, IF 2-ND ROOT FOUND
      IFLAG97(1) -  1 IF ONE ROOT
                 - 10 IF 2-ND ROOT EXISTS
 SAVE MIN,MAX, MID FOR POSSIBLE USE ELSEWHERE
          S97(1) = VMIN
          S97(2) = VMAX
          S97(3) = VMID
          S97(4) = PMID
 ERROR
         IF VAR OUTSIDE RANGE
         XREG1MM    =  -1.0D0
         IFLAG97(1) =  -1 IF VAR TOO LOW
                       -2 IF VAR TOO HIGH
         SILENT ERROR IFLAG97(15) SET TO -110 IF ITERATION FAILURE
```

```
FUNCTION   XREG1PM(TIN,VAR,IVAR,PLIN,PHIN)
ROUINE NUMBER 219
CALCULATE PRESSURE AT T AND VAR IN IF97 REGION 1
GIVEN DVAR/DP|T IS + AT PLIN, AND - AT PHIH
SPECIAL FLAG
IF IFLAG97(8) = 1 THEN CHECK RANGE VALIDITY ONLY
 INPUT   TIN     - TEMPERATURE (K)
         VAR     - VARIABLE VALUE
         IVAR    - VARIABLE TYPE   1=V,2=U,3=H,4=S
         PLIN    - MINIMUM PRESSURE (PA)
         PHIN    - MAXIMUM PRESSURE (PA)
 RETURN  XREG1PM - PRESSURE IN PA
         S97(6)  - PRESSURE IN PA, IF 2-ND ROOT FOUND
      IFLAG97(1) -  1 IF ONE ROOT
                 - 10 IF 2-ND ROOT EXISTS
 SAVE MIN,MAX, MID FOR POSSIBLE USE ELSEWHERE
          S97(1) = VMIN
          S97(2) = VMAX
          S97(3) = VMID
          S97(4) = PMID
 ERROR
         IF VAR OUTSIDE RANGE
         XREG1MM    =  -1.0D0
         IFLAG97(1) =  -1 IF VAR TOO LOW
                       -2 IF VAR TOO HIGH
         SILENT ERROR IFLAG97(15) SET TO -111 IF ITERATION FAILURE

FUNCTION   XREG1PP(TIN,VAR,IVAR,PLIN,PHIN)
ROUINE NUMBER 218
CALCULATE PRESSURE AT T AND VAR IN IF97 REGION 1
GIVEN DVAR/DP|T IS + AT PLIN, AND + AT PHIH
SPECIAL FLAG
IF IFLAG97(8) = 1 THEN CHECK RANGE VALIDITY ONLY
 INPUT   TIN     - TEMPERATURE (K)
         VAR     - VARIABLE VALUE
         IVAR    - VARIABLE TYPE   1=V,2=U,3=H,4=S
         PLIN    - MINIMUM PRESSURE (PA)
         PHIN    - MAXIMUM PRESSURE (PA)
 RETURN  XREG1MM - PRESSURE IN PA
      IFLAG97(1) -  1 ONE ROOT
 SAVE MIN,MAX, MID FOR POSSIBLE USE ELSEWHERE
        S97(1) = XPMIN
        S97(2) = XPMAX
        S97(3) = ZERO
        S97(4) = -1.0 EG NOT A PM/MP CALL
 ERROR
         IF VAR OUTSIDE RANGE
         XREG1MM    = -1.0D0
         IFLAG97(1) = -1 IF VAR TOO LOW
                      -2 IF VAR TOO HIGH
         SILENT ERROR IFLAG97(15) SET TO -112 IF ITERATION FAILURE
```

```
SUBROUTINE XTRAS97
COMPUTE EXTRA PARAMETERS (18 THRU 23 AND 28 THRU 30)
ASSUMES GIBBXX OR HELM3 CALLED WITH P97CALX/H97CALX CALLED AS WELL
ROUTINE NUMBER 206
INPUT ITYPE - 1 USE PRESSURE,TEMPERATURE CORRELATIONS
                (SUPCOOLED SUPERHEATED)
              2 USE TEMPERATURE, DENSITY CORRELATIONS
                (SATURATED)
P97(18) = DYNVPRS(PIN,TIN)      P97(18) = DYNVRHO(RHO,TIN)
P97(19) = SURTEN(TIN)           P97(19) = SURTEN(TIN)
P97(20) = TC85PRS(PIN,TIN)      P97(20) = TC85RHO(RHO,TIN)
P97(21) = TC97PRS(PIN,TIN)      P97(21) = TC97PRS(P97(7),TIN)
                                          P97(7)=QUALITY 0,1
REFRACTIVE INDEX RETURNED WITH A LAMDA OF 1.0
P97(22) = RINDPRS(PIN,TIN,ONE)  P97(22) = RINDRHO(RHO,TIN,ONE)
P97(23) = STDIPRS(PIN,TIN)      P97(23) = STDIRHO(RHO,TIN)
P97(28) = P97(18)*P97(3)
P97(29) = P97( 1)*P97(3)*OMOL*1.D-3/(GASC*P97(2))
P97(30) = P97(18)*P97(8)*1.D-3/P97(20)
ERROR
      IFLAG97(1)   = -1 IF ITYPE NOT 1 OR 2
      VALUES SET TO  -1.0

SUBROUTINE ZGIBB1(PIN,TIN)
OBTAIN G0(2),(4),(6) FOR GIBB REGION 1 FOR TC97PRS
ROUTINE NUMBER 207
GIBBS EQUATION REGION 1
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
ERROR NONE

SUBROUTINE ZGIBB2(PIN,TIN)
ROUTINE NUMBER 208
OBTAIN G0(2),(4),(6); GR(2),(4),(6) FOR GIBB REGION 2 FOR TC97PRS
INPUT  PIN - PRESSURE    PA
INPUT  TIN - TEMPERATURE K
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
ERROR NONE

SUBROUTINE ZHELM3(TIN,RHO)
ROUTINE NUMBER 209
OBTAIN G0(2),(4),(6) FOR HELM REGION 3 FOR TC97PRS
INPUT  TIN - TEMPERATURE K
INPUT  RHO - DENSITY KG/M^3
IF IFLAG97(2) = 1 THEN SKIP SECOND ORDER DERIVATIVES (2-PHASE USE)
ERROR NONE

SUBROUTINE ZTITL97(IVAR,LABTIL,LABSIU,LABEGU)
ROUTINE NUMBER 211
RETURNS BUILT-IN VALUES
INPUT   IVAR   - INDEX
RETURN  LABTIL - PROPERTY NAME
        LABSIU - SI UNITS NAME
        LABEGU - ENGLISH UNIT NAME
ERROR
    IF IVAR .LT. 1 OR .GT. 31 RETURN
    IFLAG97(1)    - 1
    LABTIL,LABSIU,LABEGU - BLANKS
```

```
FUNCTION   ZUNIT97(IVAR)
ROUTINE NUMBER 212
RETURNS BUILT-IN VALUES
INPUT       IVAR - INDEX
RETURN   ZUNIT97 - BUILT-IN VALUE
ERROR
    IF IVAR .LT. 1 OR .GT. 27 RETURN
    IFLAG97(1) = -1
    ZUNIT97    = -1.
     1    2    3    4    5    6    7    8    9
    T273,T623,T863,TMAX,TLAR,PMIN,P010,PMAX,P623
     10   11   12   13   14   15    16   17   18   19
    RGAS,GASC,OMOL,TCRT,PXCRT,PCRT,RCRT,TTRP,PTRP,TBOL
     20    21    22    23    24    25    26    27
    PRS2E,HUS2E,CHS2E,VDS2E,TCS2E,SVS2E,DVS2E,STS2E

SUBROUTINE ZZERR97(IVAR,LABNAM)
ROUTINE NUMBER 213
RETURNS BUILT-IN VALUES
INPUT   IVAR - INDEX
RETURN  LABNAM - ROUTINE NAME
ERROR
    IF IVAR .LT. 1 OR .GT. 279 RETURN
    IFLAG97(1)    - 1
    LABNAM        - BLANKS

SUBROUTINE ZZZZZZ97(LABIAM)
ROUTINE NUMBER 214
RETURNS BUILT-IN VALUES
RETURN  LABIAM - PROGRAM ID
SUBROUTINE ZZZZZZ97(LABIAM)
ROUTINE NUMBER 214
RETURNS BUILT-IN VALUES
RETURN  LABIAM - PROGRAM ID
        LABIAM(1) = ' ASTEM97 IAPWS INDUSTRIAL FORMULATION '
        LABIAM(2) = '      FOR WATER AND STEAM IF-97       '
        LABIAM(3) = ' Edward D. Throm (C) 2005 Version 2.0 '
        LABIAM(4) = '     E-mail :  mister-ed@cox.net      '
        LABIAM(5) = '   http://members.cox.net/mister_ed   '
ERROR   NONE
```

**F**unction/**S**ubroutine Cross Reference

```
 NO. T NAME      PARAMETERS          USES F OR CALLS S

 1   F CPPT1   ( PRES_IN , TEMP_IN ) ...
 2   F CPPT2   ( PRES_IN , TEMP_IN ) ...
 3   F CPPT2I  ( PRES_IN , TEMP_IN ) ...
 4   F CPPT3   ( PRES_IN , TEMP_IN ) CPTR3   ROOT3
 5   F CPPT5   ( PRES_IN , TEMP_IN ) ...
 6   F CPPT5I  ( PRES_IN , TEMP_IN ) ...
 7   F CPPT97  ( PRES_IN , TEMP_IN ) CPPT1   CPPT2   CPPT3  CPPT5     CPPTM
                                     IREG97
 8   F CPPTM   ( PRES_IN , TEMP_IN ) ...
 9   F CPPTMI  ( PRES_IN , TEMP_IN ) ...
 222 F CPPX97  ( PRES_IN , QUAL_IN ) CPPT1   CPPT2   CPTR3  ROOT3MAX  TSAT97
 10  F CPTR3   ( TEMP_IN , RHO_IN  ) CVTR3
 221 F CPTX97  ( TEMP_IN , QUAL_IN ) CPPT1   CPPT2   CPTR3  PSAT97    ROOT3MAX

 210 F CSEU97  ( IVAR_IN , VAR_IN  ) ...

 11  F CVPT1   ( PRES_IN , TEMP_IN ) CPPT1
 12  F CVPT2   ( PRES_IN , TEMP_IN ) CPPT2
 13  F CVPT2I  ( PRES_IN , TEMP_IN ) CPPT2I
 14  F CVPT3   ( PRES_IN , TEMP_IN ) CVTR3   ROOT3
 15  F CVPT5   ( PRES_IN , TEMP_IN ) CPPT5
 16  F CVPT5I  ( PRES_IN , TEMP_IN ) CPPT5I
 17  F CVPT97  ( PRES_IN , TEMP_IN ) CVPT1   CVPT2    CVPT3  CVPT5  CVPTM
                                     IREG97
 18  F CVPTM   ( PRES_IN , TEMP_IN ) CPPTM
 19  F CVPTMI  ( PRES_IN , TEMP_IN ) CPPTMI
 224 F CVPX97  ( PRES_IN , QUAL_IN ) CVPT1   CVPT2    CVTR3  ROOT3MAX TSAT97
 20  F CVTR3   ( TEMP_IN , RHO_IN  ) ...

 223 F CVTX97  ( TEMP_IN , QUAL_IN ) CVPT1   CVPT2    CVTR3  PSAT97   ROOT3MAX

 21  F DERV97  ( INDX_IN           ) ...

 22  F DPDTV1  ( PRES_IN , TEMP_IN ) DVDPT1  DVDTP1
 23  F DPDTV2  ( PRES_IN , TEMP_IN ) CVPT2   DVDPT2  DVDTP2
 24  F DPDTV2I ( PRES_IN , TEMP_IN ) DVDPT2I DVDTP2I
 25  F DPDTV3  ( PRES_IN , TEMP_IN ) CPTR3   ROOT3
 26  F DPDTV3R ( TEMP_IN , RHO_IN  ) CPTR3
 27  F DPDTV5  ( PRES_IN , TEMP_IN ) CVPT5   DVDPT5  DVDTP5
 28  F DPDTV5I ( PRES_IN , TEMP_IN ) DVDPT5I DVDTP5I
 29  F DPDTV97 ( PRES_IN , TEMP_IN ) DPDTV1  DPDTV2  DPDTV3  DPDTV5  DPDTVM
                                     IREG97
 30  F DPDTVM  ( PRES_IN , TEMP_IN ) CVPTM   DVDPTM  DVDTPM
 31  F DPDTVMI ( PRES_IN , TEMP_IN ) DVDPTMI DVDTPMI
 227 F DPDTVPX ( PRES_IN , QUAL_IN ) DPDTV1  DPDTV2  DPDTV3R ROOT3MAX TSAT97
 228 F DPDTVTX ( TEMP_IN , QUAL_IN ) DPDTV1  DPDTV2  DPDTV3R PSAT97   ROOT3MAX

 32  F DPDVT1  ( PRES_IN , TEMP_IN ) DVDPT1
 33  F DPDVT2  ( PRES_IN , TEMP_IN ) CVPT2   DVDPT2
 34  F DPDVT2I ( PRES_IN , TEMP_IN ) DVDPT2I
 35  F DPDVT3  ( PRES_IN , TEMP_IN ) CPTR3   ROOT3
 36  F DPDVT3R ( TEMP_IN , RHO_IN  ) CPTR3
 37  F DPDVT5  ( PRES_IN , TEMP_IN ) CVPT5   DVDPT5
 38  F DPDVT5I ( PRES_IN , TEMP_IN ) DVDPT5I
 39  F DPDVT97 ( PRES_IN , TEMP_IN ) DPDVT1  DPDVT2 DPDVT3  DPDVT5  DPDVTM
                                     IREG97
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40  F DPDVTM  ( PRES_IN , TEMP_IN ) CVPTM   DVDPTM
41  F DPDVTMI ( PRES_IN , TEMP_IN ) DVDPTMI
229 F DPDVTPX ( PRES_IN , QUAL_IN ) DPDVT1  DPDVT2 DPDVT3R ROOT3MAX TSAT97
230 F DPDVTTX ( TEMP_IN , QUAL_IN ) DPDVT1  DPDVT2 DPDVT3R PSAT97   ROOT3MAX

42  F DVDPT1  ( PRES_IN , TEMP_IN ) CVPT1
43  F DVDPT2  ( PRES_IN , TEMP_IN ) CVPT2
44  F DVDPT2I ( PRES_IN , TEMP_IN ) ...
45  F DVDPT3  ( PRES_IN , TEMP_IN ) DPDVT3  ROOT3
46  F DVDPT3R ( TEMP_IN , RHO_IN  ) DPDVT3R
47  F DVDPT5  ( PRES_IN , TEMP_IN ) CVPT5
48  F DVDPT5I ( PRES_IN , TEMP_IN ) ...
49  F DVDPT97 ( PRES_IN , TEMP_IN ) DVDPT1  DVDPT2  DVDPT3  DVDPT5   DVDPTM
                                    IREG97
50  F DVDPTM  ( PRES_IN , TEMP_IN ) CVPTM
51  F DVDPTMI ( PRES_IN , TEMP_IN ) ...
231 F DVDPTPX ( PRES_IN , QUAL_IN ) DVDPT1 DVDPT2  DVDPT3R ROOT3MAX TSAT97
232 F DVDPTTX ( TEMP_IN , QUAL_IN ) DVDPT1 DVDPT2  DVDPT3R PSAT97   ROOT3MAX

52  F DVDTP1  ( PRES_IN , TEMP_IN ) CVPT1
53  F DVDTP2  ( PRES_IN , TEMP_IN ) CVPT2
54  F DVDTP2I ( PRES_IN , TEMP_IN ) ...
55  F DVDTP3  ( PRES_IN , TEMP_IN ) DPDTV3  DPDVT3  ROOT3
56  F DVDTP3R ( TEMP_IN , RHO_IN  ) DPDTV3R DPDVT3R
57  F DVDTP5  ( PRES_IN , TEMP_IN ) CVPT5
58  F DVDTP5I ( PRES_IN , TEMP_IN ) ...
59  F DVDTP97 ( PRES_IN , TEMP_IN ) DVDTP1  DVDTP2  DVDTP3   DVDTP5   DVDTPM
                                    IREG97
60  F DVDTPM  ( PRES_IN , TEMP_IN ) CVPTM
61  F DVDTPMI ( PRES_IN , TEMP_IN ) ...
233 F DVDTPPX ( PRES_IN , QUAL_IN ) DVDTP1  DVDTP2  DVDTP3R ROOT3MAX TSAT97
234 F DVDTPTX ( TEMP_IN , QUAL_IN ) DVDTP1  DVDTP2  DVDTP3R PSAT97   ROOT3MAX

62  F DYNVPRS ( PRES_IN , TEMP_IN ) DYNVRHO IREG97  ROOT3   VPT1     VPT2
                                    VPT5
63  F DYNVRHO ( RHO_IN  , TEMP_IN ) ...

64  S GIBB1   ( PRES_IN , TEMP_IN ) ...
65  S GIBB2   ( PRES_IN , TEMP_IN ) ...
66  S GIBB2I  ( PRES_IN , TEMP_IN ) ...
67  S GIBB5   ( PRES_IN , TEMP_IN ) ...
68  S GIBB5I  ( PRES_IN , TEMP_IN ) ...
69  S GIBBM   ( PRES_IN , TEMP_IN ) ...
70  S GIBBMI  ( PRES_IN , TEMP_IN ) ...

71  S H97CALA                       TSAT97
72  S H97CALB                       ...

73  S HELM3   ( TEMP_IN , RHO_IN  ) ...
74  S HELM312 ( TEMP_IN , RHO_IN  ,
                PRS_OUT , VAL_OUT ) PTR3

75  F HPT1    ( PRES_IN , TEMP_IN ) ...
76  F HPT2    ( PRES_IN , TEMP_IN ) ...
77  F HPT2I   ( PRES_IN , TEMP_IN ) ...
78  F HPT3    ( PRES_IN , TEMP_IN ) HTR3  ROOT3
79  F HPT5    ( PRES_IN , TEMP_IN ) ...
80  F HPT5I   ( PRES_IN , TEMP_IN ) ...
81  F HPT97   ( PRES_IN , TEMP_IN ) HPT1  HPT2  HPT3  HPT5  HPTM  IREG97
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82  F HPTM    ( PRES_IN , TEMP_IN ) ...
83  F HPTMI   ( PRES_IN , TEMP_IN ) ...
84  F HPX97   ( PRES_IN , QUAL_IN ) TSAT97  TWOFAZ

265 F HSB1397B( ENTO_IN           ) PSAT97  SPT1
270 F HSMAX97 ( ENTO_IN           ) PSAT97  SPT1  SPT2
269 F HSPMIN97( ENTO_IN           ) SPT1    SPT2
264 F HSSAT97B( ENTO_IN           ) PSAT97  SPT1  SPT3
85  F HTR3    ( TEMP_IN , RHO_IN  ) UTR3
86  F HTX97   ( TEMP_IN , QUAL_IN ) TWOFAZ

87  F IBAK97  ( PRES_IN , VAR_IN ,
                IVAR_IN           ) HPT1  HPT2  SPT1  SPT2  T2397  TSAT97
88  F IERR97  ( INDX_IN           ) ...
243 F IGCALA97( IREG_IN           ) P97CAL1  P97CALA  P97CALG1
244 F IGCALB97( IREG_IN           ) P97CAL1  P97CALA  P97CALG1
242 F IGIBB97 ( IREG_IN , PRES_IN ,
                TEMP_IN           ) GIBB1  GIBB2  GIBB2I  GIBB5  GIBB5I
                                    GIBBM  GIBBMI
246 F IHCALA97( IREG_IN           ) H97CALA
247 F IHCALB97( IREG_IN)          ) H97CALB
245 F IHELM97 ( IREG_IN , TEMP_IN ,
                RHO_IN            ) HELM3
252 F IPHMET97( PRES_IN , ENTH_IN ) PTHMETA97
89  F IPRS97  ( PRES_IN , VAR_IN  ,
                IVAR_IN           ) HPT1  HPT2  HPT5  HTR3   ROOT3MAX  SPT1
                                    SPT2  SPT5  STR3  T2397  TSAT97    UPT1
                                    UPT2  UPT5  UTR3  VPT1   VPT2      VPT5
                                    VTR3
249 F IPTCAL97( PRES_IN , TEMP_IN ) PTPROP97
253 F IPTMET97( PRES_IN , TEMP_IN ) PTMETA97
250 F IPXCAL97( PRES_IN , TEMP_IN ) PXPROP97
90  F IREG97  ( PRES_IN , TEMP_IN ) T2397    TSAT97
271 F IRGHS97 ( ENTH_IN , ENTO_IN ) HPT1     HPT2     HSB1397B  HSMAX97
                                    HSPMIN97 HSSAT97B P2397     PHSBK2
                                    PSAT97   SPT1     SPT2      SHTMIN97
                                    THS2397B
275 F IRPHS97 ( PRES_IN , VAR_IN  ,
                IVAR_IN           ) HPT1  HPT2  PSAT97  PSHBK3  PSSBK3
                                    SPT1  SPT2  T2397   TSAT97   VPT2
91  F ISET97  ( INDX_IN , IVAL_IN ) ...
92  F ITEM97  ( TEMP_IN , VAR_IN  ,
                IVAR_IN           ) DVDPT1 DVDTP1  HPT1  HPT2     HPT5 HTR3
                                    P2397  PSAT97  ROOT3 ROOT3MAX SPT1 SPT2
                                    SPT5   STR3    UPT1  UPT2     UPT5 UTR3
                                    VPT1   VPT2    VPT5  VTR3
                                    XREG1MM XREG1MP XREG1PM XREG1PP
93  F ITEM97A ( TEMP_IN , VAR_IN ,
                IVAR_IN           ) DVDPT1  DVDTP1  PSAT97 VPT1
                                    XREG1MM XREG1MP XREG1PM XREG1PP
251 F ITXCAL97( TEMP_IN , QUAL_IN ) TXPROP97
94  F IVPT97  ( PRES_IN , TEMP_IN ) T2397   TSAT97
248 F IXPROP97( PRES_IN , TEMP_IN ) XPROP97
254 F IXTRAS97( IREG_IN           ) XTRAS97

95  S MOVE97  ( INDX_IN           ) ...
241 S OVHS97  ( PRES_IN , TEMP_IN ,
                SPVL_IN , VAR_IN  ,
                IVAR_IN           ) HPT1   IPRS97  SPT1 TVAR97 VPT1
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96  F P2397   ( TEMP_IN           ) ...

97  S P97CAL1                     ...
98  S P97CAL2                     ...
99  S P97CALA                     ...
100 S P97CALB                     ...
101 S P97CALG1                    ...
102 S P97CALG2                    ...

103 S PHMETA97( PRES_IN , ENTH_IN ) PTMETA97 THMETA

216 F PHS97   ( ENTH_IN , ENTO_IN ) HPT1     HPT2   HPT5    HPT97   HTR3
                                    IPRS97   IREG97 PSAT97  PSFIT97 ROOT3
                                    ROOT3MAX SPT1   SPT2    SPT5    SPT97
                                    STR3     T2397  TPS97   TSAT97  TVAR97
104 F PHS97B  ( ENTH_IN , ENTO_IN ,
                IREG_IN           ) IPRS97 PHSBK1  PHSBK2
272 F PHS97BK ( ENTH_IN , ENTO_IN ,
                IREG_IN           ) IRGHS97 PHSBK1  PHSBK2 PHSBK3 PSAT96
                                    TSHS97B
105 F PHSBK1  ( ENTH_IN , ENTO_IN ) ...
106 F PHSBK2  ( ENTH_IN , ENTO_IN ) ...
263 F PHSBK3  ( ENTH_IN , ENTO_IN ) SPT3

107 F PROP97  ( INDX_IN           ) ...

108 F PSAT97  ( TEMP_IN           ) ...
215 F PSFIT97 ( ENTO_IN , ITYP_IN ) SPT1   SPT2  SPT2I  SPT3  TPMETA

261 F PSHBK3  ( ENTH_IN           ) HPT1   HPT2  PSAT97
262 F PSSBK3  ( ENTO_IN           ) PSAT97 SPT1  SPT2

109 F PTH97   ( TEMP_IN , ENTH_IN ) ITEM97 PVAR97

110 F PTMANS97( INDX_IN           ) ...

111 S PTMETA97( PRES_IN , TEMP_IN ) CPPTM   CPTR3   CVPTM   CVTR3   DPDTV3R
                                    DPDTVM  DPDVT3R DPDVTM  DVDPT3R DVDPTM
                                    DVDTP3R DVDTPM  DYNVRHO HPTM    HTR3
                                    RINDRHO ROOT3   SPTM    STDIRHO STR3
                                    SURTEN  SVPTM   SVTR3   TC85RHO TC97PRS
                                    TPMETA TSAT97   UPTM    UTR3    VPTM

112 S PTPROP97( PRES_IN , TEMP_IN ) GIBB1   GIBB2   GIBB5   H97CALA H97CALB
                                    HELM3   IREG97  P97CAL1 P97CAL2 P97CALA
                                    P97CALB ROOT3   XTRAS97
113 F PTR3    ( TEMP_IN , RHO_IN  ) ...

114 F PTS97   ( TEMP_IN , ENTO_IN ) ITEM97  PVAR97
115 F PTU97   ( TEMP_IN , ENGY_IN ) ITEM97  PVAR97
116 F PTV97   ( TEMP_IN , SPVL_IN ) ITEM97  PVAR97
117 F PVAR97  ( TEMP_IN , VAR_IN ,
                IVAR_IN , IREG_IN ) DVDPT1   DVDTP1  HPT1    HPT2   HPT5
                                    HPTM     HTR3    P2397   PSAT97 ROOT3
                                    ROOT3MAX SPT1    SPT2    SPT5   SPTM
                                    STR3     T2397   UPT1    UPT2   UPT5
                                    UPTM     UTR3    VPT1    VPT2   VPT5
                                    VPTM     VTR3    XREG1MM XREG1MP
                                    XREG1PM  XREG1PP
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237 F PVH97   ( SPVL_IN , ENTH_IN ) PSAT97   PVHS97  TVH97
236 F PVHS97  ( SPVL_IN , VAR_IN ,
                IVAR_IN           ) HPT1   HPT2   HPT5   HPT97    HTR3
                                    OVHS97 PSAT97 ROOT3  ROOT3MAX SPT1
                                    SPT2   SPT5   SPT97  STR3     T2397
                                    TPV97  TSAT97 TVAR97 VPT1     VPT2
                                    VPT5   VPT97  VTR3
238 F PVS97   ( SPVL_IN , ENTO_IN ) PSAT97 PVHS97 TVS97
118 S PXPROP97( PRES_IN , QUAL_IN ) TSAT97 TXPROP97

256 F RHO3LG97( TEMP_IN , IREG_IN ) ROOT3MAX
255 F RHO3PT97( PRES_IN , TEMP_IN ) ROOT3

119 F RINDPRS ( PRES_IN , TEMP_IN ,
                WVLN_IN           ) IREG97  RINDRHO ROOT3 VPT1 VPT2
120 F RINDRHO ( RHO_IN  , TEMP_IN ,
                WVLN_IN           ) ...

121 S ROOT3   ( PRES_IN , TEMP_IN ,
                RHO_OUT           ) PTR3    VPTREG3
122 S ROOT3L  ( PRES_IN , TEMP_IN ,
                RHO_OUT           ) PSAT97  PTR3
123 S ROOT3MAX( TEMP_IN , RF_OUT ,
                RG_OUT            ) HELM312 ROOT3L

268 F SHTMIN97( ENTH_IN           ) HPT1    HPT2

124 F SPT1    ( PRES_IN , TEMP_IN ) HPT1
125 F SPT2    ( PRES_IN , TEMP_IN ) HPT2
126 F SPT2I   ( PRES_IN , TEMP_IN ) HPT2I
127 F SPT3    ( PRES_IN , TEMP_IN ) ROOT3   STR3
128 F SPT5    ( PRES_IN , TEMP_IN ) HPT5
129 F SPT5I   ( PRES_IN , TEMP_IN ) HPT5I
130 F SPT97   ( PRES_IN , TEMP_IN ) IREG97  SPT1 SPT2 SPT3 SPT5 SPTM
131 F SPTM    ( PRES_IN , TEMP_IN ) HPTM
132 F SPTMI   ( PRES_IN , TEMP_IN ) HPTMI
133 F SPX97   ( PRES_IN , QUAL_IN ) TSAT97  TWOFAZ

134 F STDIPRS ( PRES_IN , TEMP_IN ) IREG97  ROOT3 STDIRHO VPT1 VPT2
135 F STDIRHO ( RHO_IN  , TEMP_IN ) ...

136 F STR3    ( TEMP_IN , RHO_IN  ) UTR3
137 F STX97   ( TEMP_IN , QUAL_IN ) TWOFAZ

138 F SURTEN  ( TEMP_IN           ) ...

139 F SVPT1   ( PRES_IN , TEMP_IN ) CVPT1
140 F SVPT2   ( PRES_IN , TEMP_IN ) CVPT2
141 F SVPT2I  ( PRES_IN , TEMP_IN ) CVPT2I
142 F SVPT3   ( PRES_IN , TEMP_IN ) ROOT3   SVTR3
143 F SVPT5   ( PRES_IN , TEMP_IN ) CVPT5
144 F SVPT5I  ( PRES_IN , TEMP_IN ) CVPT5I
145 F SVPT97  ( PRES_IN , TEMP_IN ) IREG97  SVPT1 SVPT2 SVPT3 SVPT5 SVPTM
146 F SVPTM   ( PRES_IN , TEMP_IN ) CVPTM
147 F SVPTMI  ( PRES_IN , TEMP_IN ) CVPTMI
148 F SVPX97  ( PRES_IN , QUAL_IN ) ROOT3MAX SVPT1    SVPT2   SVTR3 TSAT97
225 F SVTR3   ( TEMP_IN , RHO_IN  ) CPTR3
226 F SVTX97  ( TEMP_IN , QUAL_IN ) PSAT97  ROOT3MAX SVPT1   SVPT2 SVTR3

149 F T2397   ( PRES_IN           ) ...
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150 F TC85PRS ( PRES_IN , TEMP_IN ) IREG97  ROOT3    TC85RHO VPT1  VPT2
151 F TC85RHO ( RHO_IN  , TEMP_IN ) ...

152 F TC97PRS ( PRES_IN , TEMP_IN ) DYNVRHO IREG97   PSAT97  ROOT3  ROOT3MAX
                                    VPT1    VPT2     ZGIBB1  ZGIBB2 ZHELM3
152 F TC97RHO ( RHO_IN  , TEMP_IN ) ITEM97  PTV97    TC97PRS

154 F THMETA  ( PRES_IN , ENTH_IN ) HPT1    HPT2     HTR3    PVAR97 ROOT3MAX
                                    TSAT97  TVAR97

266 F THS2397B( ENTH_IN , ENTO_IN ) HPT2    PSAT97

235 F THS97   ( ENTH_IN , ENTO_IN ) PHS97   PSAT97
155 F THS97B  ( ENTH_IN , ENTO_IN ,
                IREG_IN           ) ITEM97  ITEM97A THSBK1 THSBK2
273 F THS97BK ( ENTH_IN , ENTO_IN ) IRGHS97 PHSBK3  THSBK1 THSBK2 TPHBK3
                                    TSHS97B
156 F THSBK1  ( ENTH_IN , ENTO_IN ) PHSBK1  TPHBK1
157 F THSBK2  ( ENTH_IN , ENTO_IN ) PHSBK2  TPHBK2
279 F THSBK3  ( ENTH_IN , ENTO_IN ) PHSBK3  SPT3    TPHBK3
158 F TPH97   ( PRES_IN , ENTH_IN ) IPRS97  TVAR97
159 F TPH97B  ( PRES_IN , ENTH_IN ) IBAK97  IREG97  TPHBK1  TPHBK2
276 F TPH97BK ( PRES_IN , ENTH_IN ) IRPHS97 TPHBK1  TPHBK2  TPHBK3
160 F TPHBK1  ( PRES_IN , ENTH_IN ) ...
161 F TPHBK2  ( PRES_IN , ENTH_IN ) ...
257 F TPHBK3  ( PRES_IN , ENTH_IN ) IRPHS97
162 F TPMETA  ( PRES_IN           ) HPT1    HPT2    HTR3   PVAR97 ROOT3MAX
                                    TSAT97  TVAR97
163 F TPS97   ( PRES_IN , ENTO_IN ) IPRS97  TVAR97
164 F TPS97B  ( PRES_IN , ENTO_IN ) IBAK97  IREG97  TPSBK1 TPSBK2
277 F TPS97BK ( PRES_IN , ENTO_IN ) IRPHS97 TPSBK1  TPSBK2 TPSBK3
165 F TPSBK1  ( PRES_IN , ENTO_IN ) ...
166 F TPSBK2  ( PRES_IN , ENTO_IN ) ...
258 F TPSBK3  ( PRES_IN , ENTO_IN ) IRPHS97
167 F TPU97   ( PRES_IN , ENGY_IN ) IPRS97  TVAR97
168 F TPV97   ( PRES_IN , SPVL_IN ) IPRS97  TVAR97

280 F TR3PT97B( PRES_IN , TEMP_IN ) ...

169 F TSAT97  ( PRES_IN           ) ...

267 F TSHS97B ( ENTH_IN , ENTO_IN ) IRPHS97

170 F TVAR97  ( PRES_IN , VAR_IN ,
                IVAR_IN , IREG_IN ) HPT1 HPT2 HPT3  HPT5   HPTM HTR3 ROOT3
                                    ROOT3MAX  SPT1  SPT2   SPT3 SPT5 SPTM
                                    STR3      T2397 TSAT97 UPT1 UPT2 UPT3
                                    UPT5 UPTM UTR3  VPT1   VPT2 VPT3 VPT5
                                    VPTM VTR3
239 F TVH97   ( SPVL_IN , ENTH_IN ) PSAT97    PVHS97
240 F TVS97   ( SPVL_IN , ENTO_IN ) PSAT97    PVHS97
171 S TWOFAZ  ( TEMP_IN , IVAR_IN ,
                VF_OUT  , VG_OUT  ) HPT1 HPT2 HTR3 PSAT97 ROOT3MAX SPT1 SPT2
                                    STR3 UPT1 UPT2 UTR3   VPT1     VPT2 VTR3

172 S TXPROP97( TEMP_IN , QUAL_IN ) GIBB1   GIBB2    H97CALA H97CALB HELM3
                                    MOVE97  P97CAL1  P97CAL2 P97CALA P97CALB
                                    PSAT97  ROOT3MAX XTRAS97

173 F UPT1    ( PRES_IN , TEMP_IN ) HPT1    VPT1
174 F UPT2    ( PRES_IN , TEMP_IN ) HPT2    VPT2
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175 F UPT2I   ( PRES_IN , TEMP_IN ) HPT2I
176 F UPT3    ( PRES_IN , TEMP_IN ) ROOT3   UTR3
177 F UPT5    ( PRES_IN , TEMP_IN ) HPT5    VPT5
178 F UPT5I   ( PRES_IN , TEMP_IN ) HPT5I
179 F UPT97   ( PRES_IN , TEMP_IN ) IREG97  UPT1   UPT2  UPT3  UPT5  UPTM
180 F UPTM    ( PRES_IN , TEMP_IN ) HPTM    VPTM
181 F UPTMI   ( PRES_IN , TEMP_IN ) HPTMI
182 F UPX97   ( PRES_IN , QUAL_IN ) TSAT97  TWOFAZ
183 F UTR3    ( TEMP_IN , RHO_IN  ) ...
184 F UTX97   ( TEMP_IN , QUAL_IN ) TWOFAZ

281 F V3APT97B( PRES_IN , TEMP_IN ) ...
282 F V3BPT97B( PRES_IN , TEMP_IN ) ...
283 F V3CPT97B( PRES_IN , TEMP_IN ) ...
284 F V3DPT97B( PRES_IN , TEMP_IN ) ...
285 F V3EPT97B( PRES_IN , TEMP_IN ) ...
286 F V3FPT97B( PRES_IN , TEMP_IN ) ...
287 F V3GPT97B( PRES_IN , TEMP_IN ) ...
288 F V3HPT97B( PRES_IN , TEMP_IN ) ...
289 F V3IPT97B( PRES_IN , TEMP_IN ) ...
290 F V3JPT97B( PRES_IN , TEMP_IN ) ...
291 F V3KPT97B( PRES_IN , TEMP_IN ) ...
292 F V3LPT97B( PRES_IN , TEMP_IN ) ...
293 F V3MPT97B( PRES_IN , TEMP_IN ) ...
294 F V3NPT97B( PRES_IN , TEMP_IN ) ...
295 F V3OPT97B( PRES_IN , TEMP_IN ) ...
296 F V3PPT97B( PRES_IN , TEMP_IN ) ...
297 F V3QPT97B( PRES_IN , TEMP_IN ) ...
298 F V3RPT97B( PRES_IN , TEMP_IN ) ...
299 F V3SPT97B( PRES_IN , TEMP_IN ) ...
300 F V3TPT97B( PRES_IN , TEMP_IN ) ...
301 F V3UPT97B( PRES_IN , TEMP_IN ) ...
302 F V3VPT97B( PRES_IN , TEMP_IN ) ...
303 F V3WPT97B( PRES_IN , TEMP_IN ) ...
304 F V3XPT97B( PRES_IN , TEMP_IN ) ...
305 F V3YPT97B( PRES_IN , TEMP_IN ) ...
306 F V3ZPT97B( PRES_IN , TEMP_IN ) ...

274 F VHSBK3  ( ENTH_IN , ENTO_IN ) IRGHS97 PHSBK3  VPHBK3
259 F VPHBK3  ( PRES_IN , ENTH_IN ) IRPHS97
260 F VPSBK3  ( PRES_IN , ENTO_IN ) IRPHS97 SPT3

185 F VPT1    ( PRES_IN , TEMP_IN ) ...
186 F VPT2    ( PRES_IN , TEMP_IN ) ...
187 F VPT2I   ( PRES_IN , TEMP_IN ) ...
188 F VPT3    ( PRES_IN , TEMP_IN ) ROOT3

189 F VPT3A97 ( PRES_IN , TEMP_IN ) ...
190 F VPT3B97 ( PRES_IN , TEMP_IN ) ...
191 F VPT3C97 ( PRES_IN , TEMP_IN ) ...
192 F VPT3D97 ( PRES_IN , TEMP_IN ) ...
193 F VPT3E97 ( PRES_IN , TEMP_IN ) ...
194 F VPT3F97 ( PRES_IN , TEMP_IN ) ...
195 F VPT3G97 ( PRES_IN , TEMP_IN ) ...

196 F VPT5    ( PRES_IN , TEMP_IN ) ...
197 F VPT5I   ( PRES_IN , TEMP_IN ) ...
198 F VPT97   ( PRES_IN , TEMP_IN ) IREG97 VPT1 VPT2 VPT3 VPT5 VPTM
199 F VPTM    ( PRES_IN , TEMP_IN ) ...
200 F VPTMI   ( PRES_IN , TEMP_IN ) ...
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201 F VPTREG3 ( PRES_IN , TEMP_IN ) IVPT97  VPT3A97 VPT3B97 VPT3C97 VPT3D97
                                    VPT3E97 VPT3F97 VPT3G97

202 F VPX97   ( PRES_IN , QUAL_IN ) TSAT97 TWOFAZ

307 F VR3PT97B( PRES_IN , TEMP_IN ) TSAT97   T2397    TR3PT97B
                                    V3APT97B V3BPT97B V3CPT97B V3DPT97B
                                    V3EPT97B V3FPT97B V3GPT97B V3HPT97B
                                    V3IPT97B V3JPT97B V3KPT97B V3LPT97B
                                    V3MPT97B V3NPT97B V3OPT97B V3PPT97B
                                    V3QPT97B V3RPT97B V3SPT97B V3TPT97B
                                    V3UPT97B V3VPT97B V3WPT97B V3XPT97B
                                    V3YPT97B V3ZPT97B

203 F VTR3    ( TEMP_IN , RHO_IN  ) ...
204 F VTX97   ( TEMP_IN , QUAL_IN ) TWOFAZ

278 F XHSBK4  ( ENTH_IN , ENTO_IN ) HPT1    HPT2    IRGHS97 PSAT97  TSHS97B

205 S XPROP97 ( PRES_IN , TEMP_IN ) CPPT1   CPPT2   CPPT5   CPTR3   CVPT1
                                    CVPT2   CVPT5   CVTR3   DPDTV1  DPDTV2
                                    DPDTV3R DPDTV5  DPDVT1  DPDVT2  DPDVT3R
                                    DPDVT5  DVDPT1  DVDPT2  DVDPT3R DVDPT5
                                    DVDTP1  DVDTP2  DVDTP3R DVDTP5  DYNVPRS
                                    DYNVRHO HPT1    HPT2    HPT5    HTR3
                                    IREG97  PSAT97  RINDPRS RINDRHO ROOT3
                                    ROOT3MAX        SPT1    SPT2    SPT5
                                    STDIPRS STDIRHO STR3    SURTEN  SVPT1
                                    SVPT2   SVPT5   SVTR3   TC85PRS TC85RHO
                                    TC97PRS TSAT97  UPT1    UPT2    UPT5
                                    UTR3    VPT1    VPT2    VPT5
217 F XREG1MM ( TEMP_IN , VAR_IN  ,
                IVAR_IN , PRSL_IN ,
                PRSH_IN           ) HPT1 SPT1 UPT1 VPT1

218 F XREG1MP ( TEMP_IN , VAR_IN  ,
                IVAR_IN , PRSL_IN ,
                PRSH_IN           ) DVDPT1  DVDTP1  HPT1 SPT1 UPT1 VPT1
                                    XREG1MM XREG1PP
219 F XREG1PM ( TEMP_IN , VAR_IN  ,
                IVAR_IN , PRSL_IN ,
                PRSH_IN           ) DVDPT1  DVDTP1  HPT1 SPT1 UPT1 VPT1
                                    XREG1MM XREG1PP
220 F XREG1PP ( TEMP_IN , VAR_IN  ,
                IVAR_IN , PRSL_IN ,
                PRSH_IN           ) HPT1    SPT1    UPT1    VPT1
206 S XTRAS97 ( ITYPE_IN          ) DYNVPRS DYNVRHO RINDPRS RINDRHO STDIPRS
                                    STDIRHO SURTEN  TC85PRS TC85RHO TC97PRS

207 S ZGIBB1  ( PRES_IN , TEMP_IN ) ...
208 S ZGIBB2  ( PRES_IN , TEMP_IN ) ...
209 S ZHELM3  ( TEMP_IN , RHO_IN  ) ...

211 S ZTITL97 ( IVAR_IN ,
                LABTIL_OUT ,
                LABSIU_OUT ,
                LABEGU_OUT        ) ...
212 F ZUNIT97 ( IVAR_IN           ) ...
213 S ZZERR97 ( IVAR_IN ,
                LABNAM_OUT        ) ...
214 S ZZZZZZ97( LABIAM_OUT        ) ...
```

Functions with Dummy Arguments

Some routines contain dummy variables in their calls. This was done to preserve similarity in function use. The following call to functions for the ideal gas part of the Gibbs equations do not use the pressure (PIN).

```
Warning: This variable has not been used.   [PIN]
CPPT2I  : Variables declared but never referenced: PIN
CPPT5I  : Variables declared but never referenced: PIN
CPPTMI  : Variables declared but never referenced: PIN
HPT2I   : Variables declared but never referenced: PIN
HPT5I   : Variables declared but never referenced: PIN
HPTMI   : Variables declared but never referenced: PIN
```

The following call to functions for the ideal gas part of the Gibbs equations do not use the temperature (TIN).

```
Warning: This variable has not been used.   [TIN]
DVDTP2I : Variables declared but never referenced: TIN
DVDTP5I : Variables declared but never referenced: TIN
DVDTPMI : Variables declared but never referenced: TIN
```

A function to return the Region 3 specific volume given the temperature and density is included, however since the density must be specified, the temperature (TIN) is not used.

```
Warning: This variable has not been used.   [TIN]
VTR3    : Variables declared but never referenced: TIN
```