

# **ASTEM97**

**Based on the  
IAPWS IF-97**

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

Implementation by

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Appendix A

## **Routine Summary**

Revision 1.2



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```
FUNCTION CPPT1(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 1
IAPWS 97 REGION 1 GIBBS EQUATION
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
IAPWS 97 REGION 2 GIBBS EQUATION
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
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
INPUT    PIN - PRESSURE PA
          TIN - TEMPERATURE K,
RETURN CPPT3 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
USES      ROOT3
ERROR  NONE
```

```
FUNCTION CPPT5(PIN,TIN)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 5
IAPWS 97 REGION 5 GIBBS EQUATION
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
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 SPECIFIC HEAT AT CONSTANT PRESSURE
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
USES      IREG97,CPPT1,CPPT2,CPPT3,CPPT5,CPPTM
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
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)
ROUTINE NUMBER 222
INPUT      PIN - PRESSURE PA
           XIN - QUALITY
RETURN CPPX97 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
USES      TSAT97,ROOT3MAX,CPPT1,CPPT2,CPTR3
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 AND IF XIN NE 1.0
           - -3 IF PIN LT PMIN
           - -4 IF PIN GT P6CRT

FUNCTION CPTR3(TIN,RHO)
SPECIFIC HEAT AT CONSTANT PRESSURE AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 10
IAPWS 97 REGION 3 HELMOLTZ
INPUT      TIN - TEMPERATURE K
           RHO - DENSITY KG/M^3
RETURN CPTR3 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
USES      CVTR3
ERROR NONE

```

```

FUNCTION CPTX97(TIN,XIN)
ROUTINE NUMBER 221
INPUT  TIN      - TEMPERATURE K
      XIN      - QUALITY
RETURN CPTX97 - SPECIFIC HEAT AT CONSTANT PRESSURE - KJ/KG-K
USES    PSAT97,ROOT3MAX,CPPT1,CPPT2,CPTR3
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 AND 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

```

IVAR	DESCRIPTION	SI UNITS	ENGLISH UNITS
1	Pressure	Pa	psia
2	Temperature	K	deg F
3	Specific Volume	m <sup>3</sup> /kg	ft <sup>3</sup> /lbm
4	Specific Internal Energy	kJ/kg	BTU/lbm
5	Specific Enthalpy	kJ/kg	BTU/lbm
6	Specific Entropy	kJ/kg-K	BTU/lbm-F
7	Quality	---	---
8	Specific Heat At P=const	kJ/kg-K	BTU/lbm-F
9	Specific Heat at v=const	kJ/kg-K	BTU/lbm-F
10	Sonic Velocity	m/sec	ft/sec
11	dv/dp at T=const	m <sup>3</sup> /kg-Pa	ft <sup>3</sup> /lbm-psi
12	dv/dt at p=const	m <sup>3</sup> /kg-K	ft <sup>3</sup> /lbm-F
13	dp/dv at T=const	Pa-kg/m <sup>3</sup>	psi-lbm/ft <sup>3</sup>
14	dp/dt at v=const	Pa/K	psi/F
15	Coef of Thermal Expansion	1/K	1/F
16	Isothermal Compressibility	1/Pa	1/psi
17	Isentropic Exponent	---	---
18	Dynamic Viscosity	micro kg/m-sec	lbm/ft-sec
19	Surface Tension	milli N/m	lbf/ft
20	Thermal Conductivity (IND)	W/m-K	BTU/hr-ft-F
21	Thermal Conductivity (GSI)	W/m-K	BTU/hr-ft-F
22	Refractive Index (Lamda=1)	---	---
23	Static Dielectric Constant	---	---
24	Gibbs Free Energy	kJ/kg	BTU/lbm
25	Helmholtz Free Energy	kJ/kg	BTU/lbm
26	Joule-Thomson Coef	K/Pa	F/psi
27	Isothermal Joule-Thom Coef	kJ/kg-Pa	BTU/lbm-psi
28	Kinematic Viscosity	micro m <sup>2</sup> /sec	ft <sup>2</sup> /sec
29	Compressibility Factor	---	---
30	Prandtl Number	---	---
31	Density	kg/m <sup>3</sup>	lbm/ft <sup>3</sup>

```
FUNCTION CVPT1(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 11
IAPWS 97 REGION 1 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN CVPT1 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      CPPT1
ERROR  NONE
```

```
FUNCTION CVPT2(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 12
IAPWS 97 REGION 2 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN CVPT2 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      CPPT2
ERROR  NONE
```

```
FUNCTION CVPT2I(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 13
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN CPPT2I - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      CPPT2I
ERROR  NONE
```

```
FUNCTION CVPT3(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 14
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K,
RETURN CVPT3 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      ROOT3,CVPT3
ERROR  NONE
```

```
FUNCTION CVPT5(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 15
IAPWS 97 REGION 5 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN CVPT5 - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      CPPT5
ERROR  NONE
```

```
FUNCTION CVPT5I(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 16
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN CVPT5I - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      CPPT5I
ERROR  NONE
```

```

FUNCTION CVPT97(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 17
IAPWS 97 SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
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
USES      IREG97,CVPT1,CVPT2,CVPT3,CVPT5,CVPTM
ERROR
    CALLS FUNCTION IREG97(PIN,TIN)
    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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN CVPTM - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      CPPTM
ERROR  NONE

FUNCTION CVPTMI(PIN,TIN)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 19
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN CVPTMI - SPECIFIC HEAT AT CONSTANT VOLUME - KJ/KG-K
USES      CPPTMI
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
USES      TSAT97,ROOT3MAX,CVPT1,CVPT2,CVTR3
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 AND IF XIN NE 1.0
            - -3 IF PIN LT PMIN
            - -4 IF PIN GT P6CRT

```

```

FUNCTION CVTR3(TIN,RHO)
SPECIFIC HEAT AT CONSTANT VOLUME AT PRESSURE,TEMPERATURE
ROUTINE NUMBER 20
IAPWS 97 REGION 3 HELMOLTZ
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
USES     PSAT97,ROOT3MAX,CVPT1,CVPT2,CVTR3
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 AND 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 FAILURES
ERROR
      RETURN -601 IF INVALID REQUEST

FUNCTION DPDTV1(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 22
IAPWS 97 REGION 1 GIBBS EQUATION
INPUT    PIN - PRESSURE PA
          TIN - TEMPERATURE K
RETURN DPDTV1 - DPDT AT V - PA/K
USES     DVDTP1,DVDPT1
ERROR NONE

```

```
FUNCTION DPDTV2(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 23
IAPWS 97 REGION 2 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDTV2 - DPDT AT V - PA/K
USES      CVPT2,DVDTP2,DVDPT2
ERROR  NONE
```

```
FUNCTION DPDTV2I(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 24
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDTV2I - DPDT AT V - PA/K
USES      DVDTP2I,VDPT2I
ERROR  NONE
```

```
FUNCTION DPDTV3(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 25
IAPWS 97 REGION 3 HELMOLTZ
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDTV3 - DPDT AT V - PA/K
USES      ROOT3,CPTR3
ERROR  NONE
```

```
FUNCTION DPDTV3R(TIN,RHO)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 26
IAPWS 97 REGION 3 HELMOLTZ
INPUT      TIN - TEMPERATURE K
           RHO - KG/M^3
RETURN DPDTV3R - DPDT AT V - PA/K
USES      CPTR3
ERROR  NONE
```

```
FUNCTION DPDTV5(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 27
IAPWS 97 REGION 5 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDTV5 - DPDT AT V - PA/K
USES      CVPT5,DVDTP5,DVDPT5
ERROR  NONE
```

```
FUNCTION DPDTV5I(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 28
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDTV5I - DPDT AT V - PA/K
USES      DVDTP5I,DVDPT5I
ERROR  NONE
```

```

FUNCTION DPDTV97(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 29
IAPWS 97 DPDT AT V - PA/K
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
USES      IREG97,DPDTV1,DPDTV2,DPDTV3,DPDPV5,DPDTVM
ERROR
        CALLS FUNCTION IREG97(PIN,TIN)
        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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN DPDTVM - DPDT AT V - PA/K
USES      CVPTM,DVDTPM,DVDPTM
ERROR  NONE

```

```

FUNCTION DPDTVMI(PIN,TIN)
DELTA-P/DELTA-T AT CONSTANT VOLUME
ROUTINE NUMBER 31
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT  PIN - PRESSURE PA (NOT USED)
        TIN - TEMPERATURE K
RETURN DPDTVMI - DPDT AT V - PA/K
USES      DVDTPMI,DVDPTMI
ERROR  NONE

```

```

FUNCTION DPDTV PX(TIN,XIN)
DP/DT AT V AT PRESSURE,QUAL=0 OR 1
ROUTINE NUMBER 228
INPUT  PIN      - PRESSURE PA
        XIN      - QUALITY
RETURN DPDTV PX - DP/DT AT V
USES      PSAT97,ROOT3MAX,DPDTV1,DPDTV2,DPDTV3R
ERROR
        RETURNS DPDTV PX = -1.0D0 IF PIN OR TIN OUTSIDE IF97 ENVELOPE
        RETRIEVE ERROR FLAG VALUE
                IERR = IERR97(1)
                - -5 IF XIN NE 0.0 AND IF XIN NE 1.0
                - -3 IF PIN LT PMIN
                - -4 IF PIN GT P6CRT

```

```

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
USES    PSAT97 , ROOT3MAX , DPDTV1 , DPDTV2 , DPDTV3R
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 AND 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
IAPWS 97 REGION 1 GIBBS EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN DPDVT1 - DPDV AT T - PA-KG/M^3
USES    DVDPT1
ERROR  NONE

```

```

FUNCTION DPDVT2(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 33
IAPWS 97 REGION 2 GIBBS EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN DPDVT2 - DPDV AT T - PA-KG/M^3
USES    CVPT2 , DVDPT2
ERROR  NONE

```

```

FUNCTION DPDVT2I(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 34
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
INPUT  PIN - PRESSURE PA (NOT USED)
        TIN - TEMPERATURE K
RETURN DPDVT2I - DPDV AT T - PA-KG/M^3
USES    DVDPT2I
ERROR  NONE

```

```

FUNCTION DPDVT3(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 35
IAPWS 97 REGION 3 HELMOLTZ
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN DPDVT3 - DPDV AT T - PA-KG/M^3
USES    ROOT3 , CPTR3
ERROR  NONE

```

```

FUNCTION DPDVT3R(TIN,RHO)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 36
IAPWS 97 REGION 3 HELMOLTZ
INPUT      TIN - TEMPERATURE K
           RHO - KG/M^3
RETURN DPDVT3R - DPDV AT T - PA-KG/M^3
USES      CPTR3
ERROR    NONE

FUNCTION DPDVT5(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 37
IAPWS 97 REGION 5 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDVT5 - DPDV AT T - PA-KG/M^3
USES      CVPT5,DVDPT5
ERROR    NONE

FUNCTION DPDVT5I(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 38
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDVT5I - DPDV AT T - PA-KG/M^3
USES      DVDPT5I
ERROR    NONE

FUNCTION DPDVT97(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 39
IAPWS 97 DPDV AT T - PA-KG/M^3
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
USES      IREG97,DPDVT1,DPDVT2,DPDTV3,DPDTV5,DPDVTM
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DPDVTM - DPDV AT T - PA-KG/M^3
USES      CVPTM,DVDPTM
ERROR    NONE

```

```

FUNCTION DPDVTMI(PIN,TIN)
DELTA-P/DELTA-V AT CONSTANT TEMPERATURE
ROUTINE NUMBER 41
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT      PIN - PRESSURE PA (NOT USED)
           TIN - TEMPERATURE K
RETURN DPDVTMI - DPDV AT T - PA-KG/M^3
USES      DVDPTMI
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
USES    TSAT97,ROOT3MAX,DPDVT1,DPDVT2,DPDVT3R
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 AND IF XIN NE 1.0
        - -3 IF PIN LT PMIN
        - -4 IF PIN GT P6CRT

```

```

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
USES    PSAT97,ROOT3MAX,DPDVT1,DPDVT2,DPDVT3R
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 AND 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
IAPWS 97 REGION 1 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDPT1 - DVDP AT T - M^3/PA-KG
USES      CVPT1
ERROR    NONE

```

```

FUNCTION DVDPT2(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 43
IAPWS 97 REGION 2 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDPT2 - DVDP AT T - M^3/PA-KG
USES      CVPT2
ERROR    NONE

```

```
FUNCTION DVDPT2I(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 44
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 REGION 3 HELMOLTZ
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDPT3 - DVDP AT T - M^3/PA-KG
USES      ROOT3,DPDVT3
ERROR  NONE
```

```
FUNCTION DVDPT3R(TIN,RHO)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 46
IAPWS 97 REGION 3 HELMOLTZ
INPUT      TIN - TEMPERATURE K
           RHO - KG/M^3
RETURN DVDPT3R - DVDP AT T - M^3/PA-KG
USES      DPDVT3R
ERROR  NONE
```

```
FUNCTION DVDPT5(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 47
IAPWS 97 REGION 5 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDPT5 - DVDP AT T - M^3/PA-KG
USES      CVPT5
ERROR  NONE
```

```
FUNCTION DVDPT5I(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 48
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 DVDP AT T - M^3/PA-KG
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
USES      IREG97,DVDPT1,DVDPT2,DVDPT3,DVDPT5,DVDPTM
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDPTM - DVDP AT T - M^3/PA-KG
USES      CVPTM
ERROR NONE

```

```

FUNCTION DVDPTMI(PIN,TIN)
DELTA-V/DELTA-P AT CONSTANT TEMPERATURE
ROUTINE NUMBER 51
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
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
USES      TSAT97,ROOT3MAX,DVDPT1,DVDPT2,DVDPT3R
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 AND IF XIN NE 1.0
           - -3 IF PIN LT PMIN
           - -4 IF PIN GT P6CRT

```

```

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
USES    PSAT97,ROOT3MAX,DVDPT1,DVDPT2,DVDPT3R
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 AND 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
IAPWS 97 REGION 1 GIBBS EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN DVDTP1 - DVDT AT P M^3/KG-K
USES    CVPT1
ERROR  NONE

```

```

FUNCTION DVDTP2(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 53
IAPWS 97 REGION 2 GIBBS EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN DVDTP2 - DVDT AT P M^3/KG-K
USES    CVPT2
ERROR  NONE

```

```

FUNCTION DVDTP2I(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 54
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 REGION 3 HELMOLTZ
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN DVDTP3 - DVDT AT P M^3/KG-K
USES    ROOT3,DPDTV3,DPDVT3
ERROR  NONE

```

```

FUNCTION DVDTP3R(TIN,RHO)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 56
IAPWS 97 REGION 3 HELMOLTZ
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDTP3R - DVDT AT P M^3/KG-K
USES      DPDTV3R,DPDVT3R
ERROR    NONE

```

```

FUNCTION DVDTP5(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 57
IAPWS 97 REGION 5 GIBBS EQUATION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDTP5 - DVDT AT P M^3/KG-K
USES      CVPT5
ERROR    NONE

```

```

FUNCTION DVDTP5I(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 58
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 DVDT AT P M^3/KG-K
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
USES      IREG97,DVDTP1,DVDTP2,DVDTP3,DVDTP5,DVDTPM
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN DVDTPM - DVDT AT P M^3/KG-K
USES      CVPTM
ERROR    NONE

```

```

FUNCTION DVDTPMI(PIN,TIN)
DELTA-V/DELTA-T AT CONSTANT PRESSURE
ROUTINE NUMBER 61
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
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
USES   TSAT97,ROOT3MAX,DVDTTP1,DVDTTP2,DVDTTP3R
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 AND IF XIN NE 1.0
       - -3 IF PIN LT PMIN
       - -4 IF PIN GT P6CRT

```

```

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
USES   PSAT97,ROOT3MAX,DVDTTP1,DVDTTP2,DVDTTP3R
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 AND 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)
USES   IREG97,VPT1,VPT2,VPT5,ROOT3,DYNVRHO
ERROR
CALLS FUNCTION IREG97(PIN,TIN)
RETURNS DVDTTP97 = -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
      RETRIEVE ERROR FLAG VALUE
      IERR = IERR97(1)
      - -5 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(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 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,G01)
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
USES PTR3
ERROR NONE

```

```

FUNCTION HPT1(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 75
IAPWS 97 REGION 1 GIBBS EQUATION
INPUT PIN - PRESSURE PA
TIN - TEMPERATURE K
RETURN HPT1 - ENTHAPLY - KJ/KG
ERROR NONE

```

```

FUNCTION HPT2(PIN,TIN)
ROUTINE NUMBER 76
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
IAPWS 97 REGION 2 GIBBS EQUATION
INPUT PIN - PRESSURE PA
TIN - TEMPERATURE K
RETURN HPT2 - ENTHAPLY - KJ/KG
ERROR NONE

```

```

FUNCTION HPT2I(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 77
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
INPUT   PIN - PRESSURE PA (NOT USED)
        TIN - TEMPERATURE K
RETURN HPT2I - ENTHAPLY - KJ/KG
ERROR  NONE

FUNCTION HPT3(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 78
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPT3 - ENTHAPLY - KJ/KG
USES   ROOT3,HTR3
ERROR  NONE

FUNCTION HPT5(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 79
IAPWS 97 REGION 5 GIBBS EQUATION
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPT5 - ENTHAPLY - KJ/KG
ERROR  NONE

FUNCTION HPT5I(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 80
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
INPUT   PIN - PRESSURE PA (NOT USED)
        TIN - TEMPERATURE K
RETURN HPT5I - ENTHAPLY - KJ/KG
ERROR  NONE

FUNCTION HPT97(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 81
IAPWS 97 ENTHALPY - KJ/KG
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT   PIN   - PRESSURE PA
        TIN   - TEMPERATURE K
RETURN HPT97 - ENTHALPY - KJ/KG
USES   IREG97,HPT1,HPT2,HPT3,HPT5,HPTM
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN HPTM - ENTHAPLY - KJ/KG

FUNCTION HPTMI(PIN,TIN)
ENTHALPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 83
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT  PIN - PRESSURE PA (NOT USED)
        TIN - TEMPERATURE K
RETURN HPTMI - ENTHAPLY - 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
USES   TSAT97,TWOFAZ
ERROR

        CALLS FUNCTION IREG97(PIN,TIN)
        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 HTR3(TIN,RHO)
ENTHALPY AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 85
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
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
USES   TWOFAZ
ERROR

        CALLS FUNCTION IREG97(PIN,TIN)
        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..          ..06.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)
USES    TSAT97,HPT1,SPT1,HPT2,SPT2,T2397
ERROR   RETRIEVE REGION IERR = IERR97(1)
        - -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 IERR97(INDEX)
ROUTINE NUMBER 88
USER CONTROL INTERFACE ROUTINE
RETURN IFLAG97(INDEX) VALUE
ERROR   OTHERWISE RETURN A "LARGE" NEGATIVE NUMBER FOR BAD INDEX
        = -99 IF INDEX <= 0, > 12

```

```

FUNCTION IGCALA97(IREG)
REPLACEMENT CODING FOR P97CALA,_1,_G1 AS FUNCTION
ROUTINE NUMBER 243
IAPWS 97 REGION 1,2,5 OR 7(METASTABLE) GIBBS EQUATION
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  0 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
IAPWS 97 REGION 1,2,5 OR 7(METASTABLE) GIBBS EQUATION
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   0 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
IAPWS 97 REGION 1,2,5 OR 7(METASTABLE) GIBBS EQUATION
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   0 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
IAPWS 97 REGION 3 HELM
INPUT   IREG =  3 REGION 3           (H97CALA  )
RETURN   0 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
IAPWS 97 REGION 3 HELM
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
IAPWS 97 REGION 3 HELM
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)
USES    TSAT97,VPT1,UPT1,HPT1,SPT1          ,VPT2,UPT2,HPT2,SPT2
        VPT5,UPT5,HPT5,SPT5,ROOT3MAX,VTR3,UTR3,HTR3,STR3
ERROR
      RETRIEVE REGION IERR = IERR97(1)
        - -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   O 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   O 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...      ..06.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
USES
ERROR
RETRIEVE REGION IERR = IERR97(1)
          - -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 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
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..        ..06.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)

```

```

USES  PSAT97,P2397 ,VPT1,UPT1,HPT1,SPT1,VPT2,UPT2,HPT2,SPT2
      ROOT3MAX,ROOT3,VTR3,UTR3,HTR3,STR3,VPT5,UPT5,HPT5,SPT5
      IFLAG97(2) TRACKS XREG TYPE (1=MM,2=PP,3=PM,4=MP)

```

```

ERROR  RETRIEVE REGION IERR = IERR97(1)
        - -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..      ..06.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
USES    PSAT97,HPT1
ERROR   RETRIEVE REGION IERR = IERR97(1)
        - -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)

```

```

-----
P623 -----
T          T          T
6          C          8
2          R          6
3          T          3
-----
PCRT I. . . .X.....+
      I      X      +
      I 3A(1)X      +
      I  X  3D(4)+
      I X      +
      IX++++ + + +
P024 I.....*.....+.....I
      I      " 3B*(2)      +
      I 3A(1) " * 3C(3) +
P040 I.....*.....+.....I
      I      " 3B*(2)      +
      I 3E(5)      * 3F(6) +
P623 -----
T          T          T
6          C          8
2          R          6
3          T          3
-----

```

```

RETURN  - IVPT97
        - 1 3A - 4 3D
        - 2 3B - 5 3E
        - 3 3C - 6 3F
        - 7 3G
USES    T2397
ERROR

```

```

RETRIEVE REGION 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 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 IXTAS97(PIN,TIN)
REPLACEMENT CODING FOR XTRAS97 AS FUNCTION
ROUTINE NUMBER 254
INPUT  IREG - 1 FOR P ,T CORRELATIONS
        2 FOR RHO,T CORRELATIONS
RETURN  O IF OKAY
CALLS XTRAS97
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
RETURNS EST OF TEMPERATURE K IF IFLAG97(11) = 1 IF 2-PHASE
          QUALITY          IF IFLAG97(11) = 0 IF 2-PHASE DEFAULT
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
USES VPT1,SPT1,HPT1,IPRS97
ERROR
PRET = -1.0 TRET          = -1.0  IFLAG97(1) = -9

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
      CALLS FUNCTION IREG97(PIN,TIN)
      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(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 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(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 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
USES THMETA,PTMETA97
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,SIN)
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    SIN  - ENTROPY KJ/KG-K
         HIN  - ENTHPLPY KJ/KG
RETURN   PHS97 - PRESSURE PA (AND TEMPERATURE IN PTMANS97(3))
IF IFLAG97 = 0 PRESSURE PA      QUALITY
IF IFLAG97 = 1 QUALITY          TEMPERATURE K
QUALITY SET TO 0 OR 1 IF +/- 1.0D-5
        S97(4) CONTAINS TEMPERATURE
        RETRIEVE PTMAN97(3)
USES   PSFIT97,SPT2,HPT2,SPT5,HPT5,STR3,HTR3,TSAT97,
        ROOT3MAX,IPRS97,TVAR97,HPT97
ERROR
IF SIN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
        PSH97      = -1.0
        S97(4)     = -1.0
        IFLAG97(1) = -3 SIN TO LOW
                    -4 SIN 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

FUNCTION PHS97B(HIN,SIN,IREG)
ROUTINE NUMBER 104
IAPWS 97 BACKWARD EQUATION P AS FUNCTION OF H AND S
INPUT  HIN    - ENTHALPY KJ/KG
        SIN    - ENTROPY  KJ/KG-K
RETURN PHS97B - PRESSURE PA
USES   PHSBK1,PHSBK2,IPRS97
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 ENTHALPY REGION IERR97(3)
                    RETRIEVE ENTROPY REGION IERR97(4)

FUNCTION PHSBK1(HIN,SIN)
ROUTINE NUMBER 105
BACKWARD EQUATION - NEW BACKWARD EQUATION REGION 1
INPUT    HIN - ENTHALPY KJ/KG
         SIN - KJ/KG-K
RETURN  PNSBK1 - PRESSURE PA
ERROR  NONE

```

```

FUNCTION PHSBK2(HIN,SIN)
ROUTINE NUMBER 106
BACKWARD EQUATION - NEW BACKWARD EQUATIONS REGION 2
INPUT      HIN - KJ/KG
           SIN - KJ/KG-K
RETURN PHSBK2 - PRESSURE PA
ERROR NONE

```

```

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

FUNCTION PTH97(TIN,VAR)
PRESSURE AS FUNCTION OF TEMPERATURE AND ENTHALPY
ROUTINE NUMBER 109
IAPWS 97 PRESSURE FROM TEMPERATURE AND ENTHALPY
INPUT  TIN      - TEMPERATURE K
      VAR      - 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)
USES      ITEM97,PVAR97
ERROR
  CALLS ITEM97
  PTH97 = -1.0D0
  RETRIEVE REGION IERR = IERR97(1)
    - -1 IF T LT TMIN
    - -2 IF T GT TMAX/TLAR
    - -3 IF V LT VMIN
    - -4 IF V GT VMAX

```

```

FUNCTION PTMANS97(INDEX)
ROUTINE NUMBER 110
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 3 | (XREG 3 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
USES  TPMETA,TSAT97
      VPTM,HPTM,SPTM,UPTM,CPPTM,CVPTM,SVPTM,DVDPTM,DVDTPM,DPDVTM,DPDTVM
      HTR3,STR3,UTR3,CPTR3,CVTR3,SVTR3,DVDPT3R,DVDTP3R,DPDVT3R,DPDTV3R
      DYNVRHO,TC85RHO,TC97PRS,RINDRHO,STDIRHO,SURTEN
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
USES  GIBB1,P97CALA,P97CALB,GIBB2,GIBB5,P97CAL1,P97CAL2
      ROOT3,HELM3,H97CALA,H97CALB,XTRAS97
ERROR
      RETURNS PIN IN P97(1),TIN IN P97(2), -1.0D0 FOR OTHERS
      RETRIEVE ERROR IERR = IERR97(1)
          - -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 PTR3(TIN,RHO)
PRESSURE AS FUNCTION OF TEMPERATURE AND DENSITY
ROUTINE NUMBER 113
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
INPUT  TIN - TEMPERATURE K
        RHO - DENSITY KG/M^3
RETURN PTR3 - PRESSURE PA
ERROR  NONE

FUNCTION PTS97(TIN,VAR)
PRESSURE AS FUNCTION OF TEMPERATURE AND ENTROPY
ROUTINE NUMBER 114
IAPWS 97 PRESSURE AS A FUNCTION OF TEMPERATURE AND ENTROPY
INPUT  TIN  - TEMPERATURE K
        VAR  - 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)
USES      ITEM97,PVAR97
ERROR
        CALLS FUNCTION ITEM97
        RETURNS PTS97 = -1.0D0 IF PIN OR VAR 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 PTU97(TIN,VAR)
PRESSURE AS FUNCTION OF TEMPERATURE AND INTERNAL ENERGY
ROUTINE NUMBER 115
IAPWS 97 PRESSURE AS A FUNCTION OF TEMPERATURE AND INTERNAL ENERGY
INPUT  TIN  - TEMPERATURE K
        VAR  - INTERNAL ENERGY KJ/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)
USES      ITEM97,PVAR97
ERROR
        CALLS FUNCTION ITEM97
        RETURNS PTU97 = -1.0D0 IF PIN OR VAR 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 PTV97(TIN,VAR)
PRESSURE AS FUNCTION OF TEMPERATURE AND SPECIFIC VOLUME
ROUTINE NUMBER 116
IAPWS 97 PRESSURE AS A FUNCTION OF TEMPERATURE AND SPECIFIC VOLUME
INPUT  TIN    - TEMPERATURE K
      VAR    - 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)
USES      ITEM97,PVAR97
ERROR
      CALLS FUNCTION ITEM97
      RETURNS PTV97 = -1.0D0 IF PIN OR VAR 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
IAPWS 97 PRESSURE AS FUNCTION OF TEMPERATURE AND VARIABLE
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
      - 5  GIBB5
      - 4  SAT GIBB1/GIBB2
      - 6  SAT HELM3 (ROOT3MAX)
      - 7  GIBB2 SUPPLEMENTAL SPECIAL CASE
RETURN  PRESSURE PA      IREG = 1,2,3,5 OR 7
RETURN  QUALITY          IREG = 4 OR 6
USES    PSAT97,P2397,ROOT3MAX,VPT1,UPT1,HPT1,SPT1
      VPT2,UPT2,HPT2,SPT2,VPT3,UPT3,HPT3,SPT3,VPT5,UPT5,HPT5,SPT5
      VPTM,UPTM,HPTM,SPTM
IVAR AND IREG NOT CHECKED LOCALLY
CALL TO ITEM97 FIRST TO SET IREG
NOTE ENTHAPLY 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

```

```

FUNCTION PVH97(VIN,HIN)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H OR S
ROUTINE NUMBER 237
INPUT   VIN   - SPECIFIC VOLUME (M^3/KG)
        HIN   - ENTHALPY KJ/KG   IF IVAR = 1
RETURN PVH97 - PRESSURE PA   (AND TEMPERATURE IN PTMANS97(3))
IF IFLAG97 = 0 PRESSURE PA   QUALITY
IF IFLAG97 = 1 QUALITY       TEMPERATURE K
QUALITY SET TO 0 OR 1 IF +/- 1.0D-5
        S97(4) CONTAINS TEMPERATURE
        RETRIEVE PTMAN97(3)
USES PVHS97
ERROR
IF SIN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
PVH97   = -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

```

```

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   (AND TEMPERATURE IN PTMANS97(3))
IF IFLAG97 = 0 PRESSURE PA   QUALITY
IF IFLAG97 = 1 QUALITY       TEMPERATURE K
QUALITY SET TO 0 OR 1 IF +/- 1.0D-5
        S97(4) CONTAINS TEMPERATURE
        RETRIEVE PTMAN97(3)
USES SPT2,HPT2,SPT5,HPT5,STR3,HTR3,TSAT97,
    ROOT3MAX,IPRS97,TVAR97,TPV97,HPT97,SPT97,VPT97
ERROR
IF SIN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
PVHS97  = -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

```

```

FUNCTION PVS97(VIN,SIN)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H OR S
ROUTINE NUMBER 238
INPUT    VIN  - SPECIFIC VOLUME (M^3/KG)
          SIN  - ENTROPY KJ/KG-K   IF IVAR = 2
RETURN PVS97 - PRESSURE PA (AND TEMPERATURE IN PTMANS97(3))
IF IFLAG97 = 0 PRESSURE PA      QUALITY
IF IFLAG97 = 1 QUALITY          TEMPERATURE K
QUALITY SET TO 0 OR 1 IF +/- 1.0D-5
          S97(4) CONTAINS TEMPERATURE
          RETRIEVE PTMAN97(3)
USES PVHS97
ERROR
IF SIN 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 VAR TOO LOW
            -2 VAR TOO HIGH

```

```

SUBROUTINE PXP97(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 ( 0 TO 1 )
CALLS GIBB1/GIBB2 OR HELM3/L/V AS APPROPRIATE
RETURN P97 ARRAY (1 - 6 and 17) RETRIEVE WITH PROP97
USES      TSAT97,TXPROP97
ERROR
RETURNS PIN IN P97(1),XIN IN P97(17), -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(PIN,TIN)
REPLACEMENT CODING FOR ROOT3 AS FUNCTION
UNLIKE ROOT3 INCLUDES TEMPERATURE 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
CALLS ROOT3MAX
TRACK TIN FOR EXPECTED MULTI-CALLS WITHOUT RECALLS
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
CALLS  IREG97, ROOT3
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
USES          IREG97,VPT1,VPT2,ROOT3,RINDRHO
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 RINDPRS = -ONE
RETRIEVE ERROR FLAG VALUE
IERR = IERR97(1)
      - -4 IF TIN GT 773.15

```

```

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
USES   VPTREG3, PTR3
ERROR  NONE

```

```

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
USES    PSAT97, PTR3
ERROR   NONE

```

```

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
ERROR DIFFERENCE BETWEEN F(1/R'' -1/R') AND HELM INTEGRAL
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
USES    ROOT3L, HELM312
ERROR   NONE

```

```

FUNCTION SPT1(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 124
IAPWS 97 REGION 1 GIBBS EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT1 - ENTROPY KJ/KG-K
USES    HPT1
ERROR   NONE

```

```

FUNCTION SPT2(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 125
IAPWS 97 REGION 2 GIBBS EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT2 - ENTROPY KJ/KG-K
USES    HPT2
ERROR   NONE

```

```

FUNCTION SPT2I(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 126
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT2I - ENTROPY KJ/KG-K
USES    HPT2I
ERROR   NONE

```

```

FUNCTION SPT3(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 127
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K,
RETURN SPT3 - ENTROPY KJ/KG-K
USES    ROOT3,STR3
ERROR NONE

FUNCTION SPT5(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 128
IAPWS 97 REGION 5 GIBBS EQUATION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT5 - ENTROPY KJ/KG-K
USES    HPT5
ERROR NONE

FUNCTION SPT5I(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 129
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPT5I - ENTROPY KJ/KG-K
USES    HPT5I
ERROR NONE

FUNCTION SPT97(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 130
IAPWS 97 ENTROPY KJ/KG-K
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN  - PRESSURE PA
        TIN  - TEMPERATURE K
RETURN SPT97 - ENTROPY KJ/KG-K
USES    IREG97,SPT1,SPT3,SPT3,SPT5,SPTM
ERROR
        CALLS FUNCTION IREG97(PIN,TIN)
        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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SPTM - ENTROPY KJ/KG-K
USES    HPTM
ERROR NONE

```

```

FUNCTION SPTMI(PIN,TIN)
ENTROPY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 132
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT      PIN - PRESSURE PA
           TIN - TEMPERATURE K
RETURN SPTMI - ENTROPY KJ/KG-K
USES      HPTMI
ERROR NONE

```

```

FUNCTION SPX97(PIN,XIN)
ENTROPY AS FUNCTION OF PRESSURE,QUALITY
ROUTINE NUMBER 133
IAPWS 97 ENTROPY AT PRESSURE AND QUALITY
INPUT  PIN   - PRESSURE PA
       XIN   - QUALITY
RETURN SPX97 - 2-PHASE ENTROPY KJ/KG-K
USES      TSAT97,TWOFAZ
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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
USES      IREG97,VPT1,VPT2,ROOT3,STDIRHO
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)
        - -4 IF TIN .GT. 873.

```

```

FUNCTION STR3(TIN,RHO)
ENTROPY AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 136
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
INPUT  TIN - TEMPERATURE K
        RHO - DENSITY KG/M^3
RETURN STR3 - ENTROPY KJ/KG-K
USES      UTR3
ERROR    NONE

```

```

FUNCTION STX97(TIN,XIN)
ENTROPY AS FUNCTION OF TEMPERATURE,QUALITY
ROUTINE NUMBER 137
IAPWS 97 ENTROPY AS A FUNCTION OF TEMPERATURE AND QUALITY
INPUT  TIN  - TEMPERATURE K
        XIN  - QUALITY
RETURN UTX97 - 2-PHASE ENTROPY KJ/KG-K
USES      TWOFAZ
ERROR

```

```

    CALLS FUNCTION IREG97(PIN,TIN)
    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  
IAPWS 97 REGION 1 GIBBS EQUATION  
INPUT     PIN - PRESSURE PA  
          TIN - TEMPERATURE K  
RETURN SVPT1 - SONIC VELOCITY - M/SEC  
USES       CVPT1  
ERROR    NONE

FUNCTION SVPT2(PIN,TIN)  
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 140  
IAPWS 97 REGION 2 GIBBS EQUATION  
INPUT     PIN - PRESSURE PA  
          TIN - TEMPERATURE K  
RETURN SVPT2 - SONIC VELOCITY - M/SEC  
USES       CVPT2  
ERROR    NONE

FUNCTION SVPT2I(PIN,TIN)  
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 141  
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART  
INPUT     PIN - PRESSURE PA  
          TIN - TEMPERATURE K  
RETURN SVPT2I - SONIC VELOCITY - M/SEC  
USES       CVPT2I  
ERROR    NONE

FUNCTION SVPT3(PIN,TIN)  
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 142  
IAPWS 97 REGION 3 HELMHOLTZ EQUATION  
INPUT     PIN - PRESSURE PA  
          TIN - TEMPERATURE K,  
RETURN SVPT3 - SONIC VELOCITY - M/SEC  
USES       ROOT3,SVTR3  
ERROR    NONE

FUNCTION SVPT5(PIN,TIN)  
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 143  
IAPWS 97 REGION 5 GIBBS EQUATION  
INPUT     PIN - PRESSURE PA  
          TIN - TEMPERATURE K  
RETURN SVPT5 - SONIC VELOCITY - M/SEC  
USES       CVPT5  
ERROR    NONE

FUNCTION SVPT5I(PIN,TIN)  
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 144  
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART  
INPUT     PIN - PRESSURE PA  
          TIN - TEMPERATURE K  
RETURN SVPT5I - SONIC VELOCITY - M/SEC  
USES       CVPT5I  
ERROR    NONE

```

FUNCTION SVPT97(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 145
IAPWS 97 SONIC VELOCOTY AS FUNCTION OF PRESSURE AND TEMPERATURE
INPUT  PIN      - PRESSURE PA
        TIN      - TEMPERATURE K
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
RETURN SPVT97 - SONIC VELOCITY M/SEC
USES          IREG97,SVPT1,SVPT2,SVPT3,SVPT5,SVPTM
ERROR
        CALLS FUNCTION IREG97(PIN,TIN)
        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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SVPTM - SONIC VELOCITY - M/SEC
USES          CVPTM
ERROR  NONE

```

```

FUNCTION SVPTMI(PIN,TIN)
SPEED OF SOUND AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 147
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN SVPTMI - SONIC VELOCITY - M/SEC
USES          SVPTMI
ERROR  NONE

```

```

FUNCTION SVTR3(TIN,RHO)
SPEED OF SOUND AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 148
IAPWS 97 REGION 3 HELMOLTZ
INPUT  TIN - TEMPERATURE K
        RHO - DENSITY KG/M^3
RETURN SVTR3 - SONIC VELOCITY - M/SEC
USES          CPTR3
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
USES    TSAT97,ROOT3MAX,SVPT1,SVPT2,SVTR3
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 AND IF XIN NE 1.0
            - -3 IF PIN LT PMIN
            - -4 IF PIN GT P6CRT

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
USES    PSAT97,ROOT3MAX,SVPT1,SVPT2,SVTR3
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 AND 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
USES      IREG97,VPT1,VPT2,ROOT3,TC85RHO
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)
        - -4 IF TIN GT TMAX

```

```

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
USES      PSAT97, IREG97, ZGIBB1, VPT1ZGIBB2, VPT2, ZHELM3,
           ROOT3, ROOT3MAX, DYNVRHO
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.
           PRANDTL NUMBER ~ DYNVIS*CP/TC
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)
USES      ITEM97, PTV97, 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
USES      TSAT97 ,HPT1 ,HPT2 ,ROOT3MAX ,HTR3 ,TVAR97 ,PVAR97
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 THS97(HIN,SIN)
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  SIN      - ENTROPY KJ/KG-K
        HIN      - ENTHPLPY KJ/KG
RETURN THS97 - TEMPERATURE K (AND PRESSURE IN PTMANS97(1))
    IF IFLAG97 = 0 TEMPERATURE K      QUALITY
    IF IFLAG97 = 1 QUALITY              PRESSURE PA
    QUALITY SET TO 0 OR 1 IF +/- 1.0D-5
        S97(6) CONTAINS PRESSURE IN PA
        RETRIEVE WITH PTMANS97(1)
USES PHS97
ERROR
IF SIN OUT OF RANGE RETURN OR ITYPE OUT OF RANGE
    PSH97      = -1.0
    IFLAG97(1) = -1 SIN OUT OF RANGE
                -2 COULD NOT CONVERGE ON SIN
                -3 HIN OUT OF RANGE
                -4 COULD NOT CONVERGE ON HIN

```

```

FUNCTION THS97B(HIN,SIN,IREG)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 155
IAPWS 97 BACKWARD EQUATION T AS FUNCTION OF H AND S
INPUT  HIN    - ENTHALPY KJ/KG
        SIN    - ENTROPY  KJ/KG-K
        IREG   - REGION 1 OR REGION 2
RETURN THS97B - TEMPERATURE K
USES      THSBK1,THSBK2,ITEM97,ITEM97A
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 THSBK1(HIN,SIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 156
BACKWARD EQUATION 2 NEW BACKWARD EQS REGION 1
INPUT  HIN - ENTHALPY KJ/KG
        SIN - ENTROPY KJ/KG-K
RETURN THSBK1 - TEMPERATURE K
USES      PHSBK1,TPHBK1
ERROR  NONE

```

```

FUNCTION THSBK2(HIN,SIN)
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
        SIN - ENTROPY KJ/KG-K
RETURN THSBK2 - TEMPERATURE K
USES      PHSBK2,TPHBK2
ERROR  NONE

```

```

FUNCTION TPH97(PIN,VAR)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 158
IAPWS 97 TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
INPUT  PIN    - PRESSURE PA
        VAR    - ENTHALPY KJ/KG
RETURN TPH97 - TEMPERATURE K
                IF 0 <= TPH97 <= 1, 2-PHASE QUALITY
USES      IPRS97,TVAR97
ERROR
    CHECK IF97 REGION IPRS97(PIN,VAR,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 VIN LT VMIN
                - -4 IF VIN GT VMAX

```

```

FUNCTION TPH97B(PIN,VAR)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 159
IAPWS 97 BACKWARD EQUATIONS T AS FUNC OF P AND H
INPUT  PIN      - PRESSURE PA
        VAR      - ENTHALPY KJ/KG
RETURN TPH97B - TEMPERATURE K
USES          IBAK97,TPHBK1,TPHBK2,IREG97
ERROR
    IREG = IBAK97( PIN,VAR,IVAR )
    IF IREG NOT 1 OR 2
    RETURN TPH97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
        - INPUT VALUE OF IREG (-IREG IF INPUT > 2)
    CHECK FOR VALID RETURN
    IREG = IREG97(PIN,TPH97B)
    IF IREG NOT 1 OR 2
    RETURN TPH97B = -1.0D0
    RETRIEVE IERR = IERR97(1)
        - INPUT VALUE OF IREG (-IREG IF INPUT > 2)
    SET S97(4) = TPH97B
        RETRIEVE TPH97B FROM FUNCTION PTMANS97(3)
        EG TCAL = 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  NONE

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  NONE

FUNCTION TPMETA(PIN)
ROUTINE NUMBER 162
COMPUTE METASTABLE TEMPERATURE AT PRESSURE
INPUT  PIN      - PRESSURE PA
RETURN TPMETA - MINIMUM METASTABLE TEMPERATURE K
USES          TSAT97,HPT1,HPT2,ROOT3MAX,HTR3,TVAPR97,PVAR97
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,VAR)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 163
IAPWS 97 TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
INPUT  PIN    - PRESSURE PA
        VAR    - ENTROPY KJ/KG-K
RETURN TPS97 - TEMPERATURE K
                IF 0 <= TPS97 <= 1, 2-PHASE QUALITY
USES
        IPRS97,TVAR97
ERROR
        CHECK IF97 REGION IPRS97(PIN,VAR,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 TPS97B(PIN,VAR)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTHALPY
ROUTINE NUMBER 164
IAPWS 97 BACKWARD EQUATION T AS FUNC OF P AND S
INPUT  PIN    - PRESSURE PA
        VAR    - ENTROPY KJ/KG-K
RETURN TPS97B - TEMPERATURE K
USES
        IBAK97,TPSBK1,TPSBK2,IREG97
ERROR
        IREG = IBAK97( PIN,VAR,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 TPSBK1(PIN,SIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 165
BACKWARD EQUATION 3.5 REGION 1
INPUT  PIN - PRESSURE PA
        SIN - ENTROPY KJ/KG-K
RETURN TPSBK1 - TEMPERATURE K
ERROR NONE

FUNCTION TPSBK2(PIN,SIN)
TEMPERATURE AS FUNCTION OF PRESSURE AND ENTROPY
ROUTINE NUMBER 166
BACKWARD EQUATION 3.18 TO 3.20 REGION 2
INPUT  PIN - PRESSURE PA
        SIN - ENTROPY KJ/KG-K
RETURN TPSBK2 - TEMPERATURE K
ERROR NONE

```

```

FUNCTION TPU97(PIN,VAR)
TEMPERATURE AS FUNCTION OF PRESSURE AND INTERNAL ENERGY
ROUTINE NUMBER 167
IAPWS 97 TEMPERATURE AS FUNCTION OF PRESSURE AND INTERNAL ENERGY
INPUT  PIN    - PRESSURE PA
      VAR    - INTERNAL ENERGY KJ/KG
RETURN TPU97 - TEMPERATURE K
          IF 0 <= TPU97 <= 1, 2-PHASE QUALITY
USES    IPRS97,TVAR97
ERROR
  CHECK IF97 REGION IPRS97(PIN,VAR,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 TPV97(PIN,VAR)
TEMPERATURE AS FUNCTION OF PRESSURE AND SPECIFIC VOLUME
ROUTINE NUMBER 168
IAPWS 97 TEMPERATURE AS FUNCTION OF PRESSURE AND SPECIFIC VOLUME
INPUT  PIN    - PRESSURE PA
      VAR    - SPECIFIC VOLUME M^3/KG
RETURN TPV97 - TEMPERATURE K
          IF 0 <= TPV97 <= 1, 2-PHASE QUALITY
USES    IPRS97,TVAR97
ERROR
  CHECK IF97 REGION IPRS97(PIN,VAR,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 TVAR97( PIN,VAR,IVAR,IREG)
TEMPERATURE AS FUNCTION OF PRESSURE AND VARIABLE
ROUTINE NUMBER 170
IAPWS 97 TEMPERATURE AS FUNCTION OF PRESSURE AND VARIABLE
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
      - 5  GIBB5
      - 4  SAT GIBB1/GIBB2
      - 6  SAT HELM3 (ROOT3MAX)
      - 7  GIBB2 SUPPLEMENTAL SPECIAL CASE
RETURN   TEMPERATURE K      IREG = 1,2,3,5 OR 7
RETURN   QUALITY            IREG = 4 OR 6
USES     VPT1,UPT1,HPT1,SPT1,TSAT97,T2397,VPT2,UPT2,HPT2,SPT2
          VTR3,UTR3,HTR3,STR3,ROOT3MAX,VPT3,UPT3,HPT3,SPT3
          VPT5,UPT5,HPT5,SPT5,VPTM,UPTM,HPTM,SPTM
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

```

```

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 (AND PRESSURE IN PTMANS97(1))
IF IFLAG97 = 0 TEMPERATURE K      QUALITY
IF IFLAG97 = 1 QUALITY            PRESSURE PA
QUALITY SET TO 0 OR 1 IF +/- 1.0D-5
      S97(6) CONTAINS PRESSURE IN PA
      RETRIEVE WITH PTMANS97(1)
USES PVHS97
ERROR
IF SIN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
      TVH97      = -1.0
      S97(6)     = -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

```

```

FUNCTION TVS97(VIN,SIN)
RETURNS ESTIMATE OF PRESSURE GIVEN V (M^3/KG) AND H OR S
ROUTINE NUMBER 240
INPUT   VIN   - SPECIFIC VOLUME (M^3/KG)
        SIN   - ENTROPY   KJ/KG-K   IF IVAR = 1
RETURN TVS97 - TEMPERATURE K (AND PRESSURE IN PTMANS97(1))
IF IFLAG97 = 0 TEMPERATURE K     QUALITY
IF IFLAG97 = 1 QUALITY           PRESSURE PA
QUALITY SET TO 0 OR 1 IF +/- 1.0D-5
        S97(6) CONTAINS PRESSURE IN PA
        RETRIEVE WITH PTMANS97(1)
USES PVHS97
ERROR
IF SIN OUT OF RANGE RETURN OR IYTPE OUT OF RANGE
TVS97      = -1.0
S97(6)    = -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

```

```

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 - ENTHAPLY
           4 - ENTROPY
RETURN VARL - FLUID COMPONENT
        VARG - VAPOR COMPONENT
USES VPT1,UPT1,HPT1,SPT1,VPT2,UPT2,HPT2,SPT2,PSAT97
        VTR3,UTR3,HTR3,STR3,ROOT3MAX
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 (1 - 6 and 17) RETRIEVE WITH PROP97
USES PSAT97,GIBB1,P97CALA,P97CALB,MOVE97,GIBB2,P97CAL1,P97CAL2
        ROOT3MAX,HELM3,H97CALA,H97CALB,XTRAS97
ERROR
RETURNS PIN IN P97(1),XIN IN P97(17), -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  
IAPWS 97 REGION 1 GIBBS EQUATION  
INPUT PIN - PRESSURE PA  
TIN - TEMPERATURE K  
RETURN UPT1 - INTERNAL ENERGY KJ/KG  
USES VPT1,HPT1  
ERROR NONE

FUNCTION UPT2(PIN,TIN)  
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 174  
IAPWS 97 REGION 2 GIBBS EQUATION  
INPUT PIN - PRESSURE PA  
TIN - TEMPERATURE K  
RETURN UPT2 - INTERNAL ENERGY KJ/KG  
USES VPT2,HPT2  
ERROR NONE

FUNCTION UPT2I(PIN,TIN)  
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 175  
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART  
INPUT PIN - PRESSURE PA  
TIN - TEMPERATURE K  
RETURN UPT2I - INTERNAL ENERGY KJ/KG  
USES HPT2I  
ERROR NONE

FUNCTION UPT3(PIN,TIN)  
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 176  
IAPWS 97 REGION 3 HELMHOLTZ EQUATION  
INPUT PIN - PRESSURE PA  
TIN - TEMPERATURE K,  
RETURN UPT3 - INTERNAL ENERGY KJ/KG  
USES ROOT3,UTR3  
ERROR NONE

FUNCTION UPT5(PIN,TIN)  
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 177  
IAPWS 97 REGION 5 GIBBS EQUATION  
INPUT PIN - PRESSURE PA  
TIN - TEMPERATURE K  
RETURN UPT5 - INTERNAL ENERGY KJ/KG  
USES VPT5,HPT5  
ERROR NONE

FUNCTION UPT5I(PIN,TIN)  
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE  
ROUTINE NUMBER 178  
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART  
INPUT PIN - PRESSURE PA  
TIN - TEMPERATURE K  
RETURN UPT5I - INTERNAL ENERGY KJ/KG  
USES HPT5I  
ERROR NONE

```

FUNCTION UPT97(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 179
IAPWS 97 INTERNAL ENERGY AS FUNCTION OF PRESSURE AND TEMPERATURE
SPECIAL FLAG SETTING
IF IFLAG97(5) = 1, THEN RETURN METASTABLE RESULTS
INPUT  PIN    - PRESSURE PA
        TIN    - TEMPERATURE K
RETURN UPT97 - INTERNAL ENERGY KJ/KG
USES      IREG97,UPT1,UPT2,UPT3,UPT5,UPTM
ERROR

```

```

    CALLS FUNCTION IREG97(PIN,TIN)
    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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN UPTM - INTERNAL ENERGY KJ/KG
USES      VPTM,HPTM
ERROR  NONE

```

```

FUNCTION UPTMI(PIN,TIN)
INTERNAL ENERGY AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 181
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
INPUT  PIN - PRESSURE PA
        TIN - TEMPERATURE K
RETURN UPTMI - INTERNAL ENERGY KJ/KG
USES      HPTMI
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
USES      TSAT97,TWOFAZ
ERROR
    CALLS FUNCTION IREG97(PIN,TIN)
    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
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
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
IAPWS97 2-PHASE INTERNAL ENERGY FUNCTION OF TEMPERATURE,QUALITY
INPUT   TIN   - TEMPERATURE K
        XIN   - QUALITY
RETURN  UTX97 - 2-PHASE INTERNAL ENERGY KJ/KG
USES    TWOFAZ
ERROR

CALLS FUNCTION IREG97(PIN,TIN)
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 VPT1(PIN,TIN)
SPECIFIC VOLUME AS FUNCTION OF PRESSURE,TEMPERATURE
ROUTINE NUMBER 185
IAPWS 97 REGION 1 GIBBS EQUATION
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
IAPWS 97 REGION 2 GIBBS EQUATION
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
IAPWS 97 REGION 2 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
INPUT   PIN - PRESSURE PA
        TIN - TEMPERATURE K,
RETURN VPT3 - SPECIFIC VOLUME M^3/KG
USES    TSAT97,TWOFAZ
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
IAPWS 97 REGION 5 GIBBS EQUATION
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
IAPWS 97 REGION 5 GIBBS EQUATION IDEAL GAS PART
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
IAPWS 97 SPECIFIC VOLUME AS FUNCTION OF PRESSURE AND TEMPERATURE
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
USES      IREG97,VPT1,VPT2,VPT3,VPT5,VPTM
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION
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
IAPWS 97 REGION 2 GIBBS EQUATION METASTABLE REGION IDEAL GAS PART
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
USES  IVPT97,VPT3A97,VPT3B97,VPT3C97,VPT3D97,VPT3E97,VPT3F97,VPT3G97
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
USES      TSAT97,TWOFAZ
ERROR
      CALLS FUNCTION IREG97(PIN,TIN)
      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 VTR3(TIN,RHO)
SPECIFIC VOLUME AS FUNCTION OF TEMPERATURE,DENSITY
ROUTINE NUMBER 203
IAPWS 97 REGION 3 HELMHOLTZ EQUATION
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
USES    TWOFAZ
ERROR

```

```

CALLS FUNCTION IREG97(PIN,TIN)
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

```

```

SUBROUTINE XPROP97(PIN,TIN)
ROUTINE NUMBER 205
INPUT PIN - PRESSURE PA
        QUALITY ( 0 TO 1 )
INPUT TIN - TEMPERATURE
        QUALITY ( 0 TO 1 )
RETURN    THERMODYNAMIC AND TRANSPORT PROPERTIES 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
USES  PSAT97,TSAT97,IREG97,ROOT3,ROOT3MAX
      VPT1,HPT1,SPT1,UPT1,CPPT1,CVPT1,SVPT1,DVDPT1,DVDTP1,DPDVT1,DPDTV1
      VPT2,HPT2,SPT2,UPT2,CPPT2,CVPT2,SVPT2,DVDPT2,DVDTP2,DPDVT2,DPDTV2
      VPT5,HPT5,SPT5,UPT5,CPPT5,CVPT5,SVPT5,DVDPT5,DVDTP5,DPDVT5,DPDTV5
      HTR3,STR3,UTR3,CPTR3,CVTR3,SVTR3,DVDPT3R,DVDTP3R,DPDVT3R,DPDTV3R
      DYNVPRS,TC85PRS,TC97PRS,RINDPRS,STDIPRS
      DYNVRHO,TC85RHO,          RINDRHO,STDIRHO,SURTEN
ERROR

```

```

CALLS FUNCTION IREG97(PVAL,TVAL)
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 REGION RETURN FROM IREG97
            - -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)
ROUTINE 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
USES    VPT1,UPT1,HPT1,SPT1
SAVE MIN,MAX, MID FOR POSSIBLE USE ELSEWHERE
        S97(1) = XPMIN
        S97(2) = XPMAX
        S97(3) = ZERO

ERROR
        IF VAR OUTSIDE RANGE
XREG1MM      = -1.0D0
IFLAG97(1) = -1 IF VAR TOO LOW
            -2 IF VAR TOO HIGH

```

```

FUNCTION XREG1PP(TIN,VAR,IVAR,PLIN,PHIN)
ROUTINE 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
USES    VPT1,UPT1,HPT1,SPT1
SAVE MIN,MAX, MID FOR POSSIBLE USE ELSEWHERE
        S97(1) = XPMIN
        S97(2) = XPMAX
        S97(3) = ZERO

ERROR
        IF VAR OUTSIDE RANGE
XREG1MM      = -1.0D0
IFLAG97(1) = -1 IF VAR TOO LOW
            -2 IF VAR TOO HIGH

```

```

FUNCTION XREG1PM(TIN,VAR,IVAR,PLIN,PHIN)
ROUTINE 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 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
  USES   VPT1,UPT1,HPT1,SPT1,DVDPT1,XREG1MM,XREG1PP
  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

```

```

FUNCTION XREG1MP(TIN,VAR,IVAR,PLIN,PHIN)
ROUTINE 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
  USES   VPT1,UPT1,HPT1,SPT1,DVDPT1,XREG1MM,XREG1PP
  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

```

```

SUBROUTINE XTRAS97(ITYPE)
  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(21)
  USES  DYNVPRS,TC85PRS,TC97PRS,RINDPRS,STDIPRS
        DYNVRHO,TC85RHO,          RINDRHO,STDIRHO,SURTEN
  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 CHARACTER*26 - PROPERTY NAME
        LABSIU CHARACTER*14 - SI UNITS NAME
        LABEGU CHARACTER*14 - 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
IVAR=      1    2    3    4    5    6    7    8    9
           T273,T623,T863,TMAX,TLAR,PMIN,P010,PMAX,P623
IVAR=     10   11   12   13   14   15   16   17   18   19
           RGAS,GASC,OMOL,TCRT,PCRT,P6CRT,RCRT,TTRP,Ptrp,TBOL
IVAR=     20   21   22   23   24   25   26   27
           PRS2E,HUS2E,CHS2E,VDS2E,TCS2E,SVS2E,DVS2E,STS2E
RETURN     ZUNIT97 - BUILT-IN VALUE
ERROR
      IF IVAR .LT. 1 OR .GT. 27 RETURN
      IFLAG97(1) = -1
      ZUNIT97     = -1.

SUBROUTINE ZZERR97(IVAR,LABNAM)
ROUTINE NUMBER 213
RETURNS BUILT-IN VALUES
INPUT      IVAR - INDEX
RETURN     LABNAM - CHARACTER*8 ROUTINE NAME
ERROR
      IF IVAR .LT. 1 OR .GT. 214 RETURN
      IFLAG97(1)   - 1
      LABNAM       - BLANKS

SUBROUTINE ZZZZZZ97(LABIAM)
ROUTINE NUMBER 214
RETURNS BUILT-IN VALUES
RETURN     LABIAM(5) - CHARACTER*40 PRGRAM ID
LABIAM(1) = '      IAPWS INDUSTRIAL FORMULATION      '
LABIAM(2) = '      (IF-97) FOR WATER AND STEAM      '
LABIAM(3) = '      Edward D. Throm (C) 2002      '
LABIAM(4) = '      E-mail : mistered@cox.rr.com      '
LABIAM(5) = ' http://members.tripod.com/~Mister_Ed '
ERROR     NONE

```

**Function/Subroutine 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	( INDEX_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 DPDTV PX ( PRES_IN , QUAL_IN ) DPDTV1 DPDTV2 DPDTV3R ROOT3MAX TSAT97
228 F DPDTV TX ( 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 DPDTVM
    IREG97
40 F DPDVTM ( PRES_IN , TEMP_IN ) CVPTM DVDPTM
41 F DPDVTMI ( PRES_IN , TEMP_IN ) DVDPTMI
229 F DPDVT PX ( PRES_IN , QUAL_IN ) DPDVT1 DPDVT2 DPDVT3R ROOT3MAX TSAT97
230 F DPDVT TX ( 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

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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 DVDT1 ( PRES\_IN , TEMP\_IN ) CVPT1  
53 F DVDT2 ( PRES\_IN , TEMP\_IN ) CVPT2  
54 F DVDT2I ( PRES\_IN , TEMP\_IN ) - - - -  
55 F DVDT3 ( PRES\_IN , TEMP\_IN ) DPDTV3 DPDVT3 ROOT3  
56 F DVDT3R ( TEMP\_IN , RHO\_IN ) DPDTV3R DPDVT3R  
57 F DVDT5 ( PRES\_IN , TEMP\_IN ) CVPT5  
58 F DVDT5I ( PRES\_IN , TEMP\_IN ) - - - -  
59 F DVDT97 ( PRES\_IN , TEMP\_IN ) DVDT1 DVDT2 DVDT3 DVDT5 DVDTM  
IREG97  
60 F DVDTM ( PRES\_IN , TEMP\_IN ) CVPTM  
61 F DVDTMI ( PRES\_IN , TEMP\_IN ) - - - -  
233 F DVDTTPX ( PRES\_IN , QUAL\_IN ) DVDT1 DVDT2 DVDT3R ROOT3MAX TSAT97  
234 F DVDTPTX ( TEMP\_IN , QUAL\_IN ) DVDT1 DVDT2 DVDT3R 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

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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
82 F HPTM     ( PRES_IN , TEMP_IN ) - - - -
83 F HPTMI    ( PRES_IN , TEMP_IN ) - - - -
84 F HPX97    ( PRES_IN , QUAL_IN ) TSAT97 TWOFAZ
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   ( INDEX_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

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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  
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 IXTAS97( IREG\_IN ) XTRAS97 |  
95 S MOVE97 ( INDEX\_IN ) - - - -  
241 S OVHS97 ( PRES\_IN , TEMP\_IN ,  
SPVL\_IN , VAR\_IN ,  
IVAR\_IN ) HPT1 IPRS97 SPT1 TVAR97 VPT1  
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 SPT9F  
STR3 T2397 TPS97 TSAT97 TVAR97 |  
104 F PHS97B ( ENTH\_IN , ENTO\_IN ,  
IREG\_IN ) IPRS97 PHSBK1 PHSBK2

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105 F PHSBK1 ( ENTH_IN , ENTO_IN ) - - - -
106 F PHSBK2 ( ENTH_IN , ENTO_IN ) - - - -
107 F PROP97 ( INDEX_IN          ) - - - -
108 F PSAT97 ( TEMP_IN           ) - - - -
215 F PSFIT97 ( ENTO_IN , ITYP_IN ) - - - -
109 F PTH97   ( TEMP_IN , ENTH_IN ) ITEM97  PVAR97
110 F PTMANS97( INDEX_IN          ) - - - -
111 S PTMETA97( PRES_IN , TEMP_IN ) CPPTM   CPTR3   CVPTM   CVTR3   DPDTV3R
DPDVTM   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

| 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

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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
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

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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           ) - - - -
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
| 235 F THS97  ( ENTH_IN , ENTO_IN ) PHS97 PSAT97
155 F THS97B  ( ENTH_IN , ENTO_IN ,
      IREG_IN           ) ITEM97 ITEM97A THSBK1 THSBK2
156 F THSBK1  ( ENTH_IN , ENTO_IN ) PHSBK1 TPHBK1
157 F THSBK2  ( ENTH_IN , ENTO_IN ) PHSBK2 TPHBK2
158 F TPH97   ( PRES_IN , ENTH_IN ) IPRS97 TVAR97
159 F TPH97B  ( PRES_IN , ENTH_IN ) IBAK97 IREG97 TPHBK1 TPHBK2
160 F TPHBK1  ( PRES_IN , ENTH_IN ) - - - -
161 F TPHBK2  ( PRES_IN , ENTH_IN ) - - - -
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
165 F TPSBK1  ( PRES_IN , ENTO_IN ) - - - -
166 F TPSBK2  ( PRES_IN , ENTO_IN ) - - - -
167 F TPU97   ( PRES_IN , ENGY_IN ) IPRS97 TVAR97
168 F TPV97   ( PRES_IN , SPVL_IN ) IPRS97 TVAR97
169 F TSAT97  ( PRES_IN ) - - - -

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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

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

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 ) - - - -

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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 ) - - - -
201 F VPTREG3  ( PRES_IN , TEMP_IN ) IVPT97  VPT3A97 VPT3B97 VPT3C97 VPT3D97
                VPT3E97 VPT3F97 VPT3G97
202 F VPX97   ( PRES_IN , QUAL_IN ) TSAT97 TWOFAZ
203 F VTR3    ( TEMP_IN , RHO_IN ) - - - -
204 F VTX97   ( TEMP_IN , QUAL_IN ) TWOFAZ
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

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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]

```

FUNCTION CPPT2I(PIN,TIN)
FUNCTION CPPT5I(PIN,TIN)
FUNCTION CPPTMI(PIN,TIN)
FUNCTION HPT2I(PIN,TIN)
FUNCTION HPT5I(PIN,TIN)
FUNCTION HPTMI(PIN,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]

```

FUNCTION VTR3(TIN,RHO)

```