NASA Technical Memorandum 81848

USER'S GUIDE FOR THE COMPUTER CODE 'COLTS' FOR CALCULATING THE COUPLED LAMINAR AND TURBULENT FLOWS OVER A JOVIAN ENTRY PROBE

Ajay Kumar and Randolph A. Graves, Jr.

JUNE 1980

National Aeronautics and Space Administration

Langley Research Center
Hampton, Virginia 23665

USER'S GUIDE FOR THE COMPUTER CODE 'COLTS' FOR CALCULATING THE COUPLED LAMINAR AND TURBULENT FLOWS OVER A JOVIAN ENTRY PROBE

Ajay Kumar* and Randolph A. Graves, Jr.**

SUMMARY

This report is a user's guide for a computer code 'COLTS' (Coupled Laminar and Turbulent Solutions) which calculates the laminar and turbulent hypersonic flows with radiation and coupled ablation injection past a Jovian entry probe. Time-dependent viscous-shock-layer equations are used to describe the flow field. These equations are solved by an explicit, two-step, time-asymptotic finite-difference method. Eddy viscosity in the turbulent flow is approximated by a two-layer model. In all, 19 chemical species are used to describe the injection of carbon-phenolic ablator in the hydrogen-helium gas mixture. The equilibrium composition of the mixture is determined by a free-energy minimization technique. A detailed frequency dependence of the absorption coefficient for various species is considered to obtain the radiative flux.

The code is written for a CDC-CYBER-203 computer and is capable of providing solutions for ablated probe shapes also. This report contains descriptions of the input and output quantities and a brief outline of how to use the code.

INTRODUCTION

The report is a user's guide for a computer code 'COLTS' which calculates the laminar and turbulent hypersonic flows with radiation and coupled ablation injection past a Jovian entry probe. Time-dependent viscous-shock-layer-type equations are used to describe the flow field bounded by the body, the shock wave, and the outflow boundary as shown in figure 1. A time-asymptotic, finite-difference method is used to solve the governing equations. The details of the governing equations and the method of solution are given in reference 1.

The code is written in Control Data CYBER-203 FORTRAN language 1.4 (an extension of ANSI FORTRAN for the Control Data CYBER-203 computer). The program listing is given in appendix A. It includes turbulence, nongray radiative transport, and coupled ablation injection of carbon phenolic into the H_2 - He gas mixture. In all, 19 chemical species are considered. These species are H_2, H, H^+, He, He^+, e^-, C, C_2, C_3, C^+, C_2H, C_3H, C_4H, C_2H_2, O, O_2, O^+, CO, and CO_2.

---

*Research Associate Professor, Department of Mechanical Engineering and Mechanics, Old Dominion University, Norfolk, Virginia 23508

**Research Leader, Aerothermodynamics Branch, Space Systems Division.

Page missing in original document.

Card Number	Symbolic Name	Description
12	LTURB	LTURB = 0 for turbulent flow and LTURB = 1 for laminar flow
13	NT	Number of mesh point along the body surface up to which the flow remains laminar. Flow becomes fully turbulent at NT + 1.
14	FTURB	The fraction of the difference of the new and old eddy viscosities which is added to the old eddy viscosity.
15	LR	The number of time steps after which the radiation package is called.
16	FMASS	After calculating the radiative fluxes, new surface mass fluxes are obtained. FMASS represents the fraction of the difference of the new and old mass fluxes which is added to the old mass fluxes.
17	LFI*	The number of permanent input file from which the solution of previous run is to be read to start the current run.
18	LFO*	The number of permanent output file on which the current solution is stored after LMAX time steps.
19	VF	Free-stream velocity in m/sec
20	ROF	Free-stream density in Kg/m^3
21	TF	Free-stream temperature in K
22	RN	Body nose radius in m
23	RE	Free-stream Reynolds number based on nose radius
24	THC	Half body angle in radians
25	TW	Body surface temperature in K

*Four permanent files are defined on the Program Card. These are: Unit 10 = Blunt 1, Unit 11 = Blunt 2, Unit 12 = Blunt 3, and Unit 13 = Blunt 4. LFI and LFO can be any unit number i.e. either 10, 11, 12, or 13.

Card Number	Symbolic Name	Description
26	N1	Number of mesh points in tangential direction
27	M1	Number of mesh points in normal direction
28	NJ	Number of mesh spacings between the stagnation point and sphere-cone juncture point
29	DY	Mesh spacing in tangential direction. This is obtained by dividing the distance between the stagnation point and the juncture point by NJ. Card 28 is set for a sphere-cone but for an ablated probe, DY has to be suitably defined.
30	YB	Distance of a mesh point on the probe's surface from the stagnation point
31-40	-	These cards calculate local body angle THE, local body curvature CUR, and local distance of a point on the body from the axis of symmetry R. The cards are set for a sphere cone but for an ablated probe, the values of THE, CUR, and R have to be suitably prescribed at all the mesh points on the probe's surface.
41	CURNJ1	Curvature at the juncture point when the juncture point is considered on the spherical cap.
42-47	CC	Artificial damping coefficient. It is described by card 42 for the laminar flow and by cards 44 to 47 for turbulent flow.
48-61	TMASS1	Arbitrary surface mass flux initially prescribed on the surface mesh points.

PROGRAM OUTPUT

This section describes the main quantities printed by the code. The code prints gross flow quantities after every 500 time steps. These quantities are:

(i) Distance along the body surface from the stagnation point nondimensionalized with nose radius, R_n

(ii) Shock standoff distance nondimensionalized with R_n

(iii) Shock speed nondimensionalized with free-stream velocity, V_∞

(iv) Heat transferred to the surface due to diffusion nondimensionalized with $\rho_\infty V_\infty^3/2$ where ρ_∞ is the free-stream density

(v) Heat transferred to the surface due to diffusion and conduction nondimensionalized with $\rho_\infty V_\infty^3/2$

(vi) Skin-friction coefficient nondimensionalized with $\rho_\infty V_\infty^2/2$

(vii) Surface pressure nondimensionalized with $\rho_\infty V_\infty^2$

(viii) Radiative heat transferred to the surface nondimensionalized with $\rho_\infty V_\infty^3/2$. This is the net radiative heat transfer. To calculate the radiative heat transfer toward the wall, the radiation emitted by the surface should be added to the net value.

The code prints detailed flow quantities at each grid point after every LW time step. These quantities are:

ZN Distance normal to body nondimensionalized with R_n

U Tangential velocity nondimensionalized with V_∞

V Normal velocity nondimensionalized with V_∞

P Pressure nondimensionalized with $\rho_\infty V_\infty^2$

RO Density nondimensionalized with ρ_∞

T Temperature nondimensionalized with T_∞

H Total enthalpy nondimensionalized with V_∞^2

SH Static enthalpy nondimensionalized with V_∞^2

HI Nondimensional static enthalpy as obtained from the chemistry package. It is equal to $\Sigma C_i h_i$ where C_i is the mass fraction of species i and h_i is the enthalpy of species i

PC Nondimensional chemical diffusion term $\Sigma h_i \frac{\partial C_i}{\partial n}$ where n is the normal distance

VIST Eddy viscosity nondimensionalized with laminar viscosity

QFXR Radiative flux nondimensionalized with $\rho_\infty V_\infty^3$

In addition, the radiation package prints some quantities including the net radiative flux in watts/cm^2 at every other grid point in the normal direction and at every grid point in the tangential direction. Whenever new radiative fluxes are obtained, calculations are also made for new surface mass fluxes. The code prints the sublimation temperature nondimensionalized with T_∞ and old and new surface mass fluxes nondimensionalized with $\rho_\infty V_\infty$.

For the turbulent flow, the eddy viscosity is updated after every 25 time steps. Each time the eddy viscosity is calculated, the code prints the boundary layer and displacement thicknesses at each grid point along the surface except the first grid point.

GENERAL REMARKS

The code COLTS has worked satisfactorily for various Jovian entry conditions and the results have been reported in reference 1. Since the current solution procedure is an explicit, time-asymptotic, finite-difference method which requires artificial numerical damping, it is possible that the solution may develop oscillations for certain free-stream conditions and the code may eventually fail. An adjustment in the value of the artificial damping coefficient, CC, may be necessary to damp these oscillations. For certain other conditions, a change in marching time step may be required which is achieved by changing the value of FDT. Since the code typically requires about 100 minutes to obtain the complete solution for a given entry condition, it is suggested that the solution procedure be progressed in pieces. After every few thousand iterations, the intermediate solution should be checked and necessary adjustments should be made before going further. There is no fixed convergence criterion prescribed in the code. Whenever the changes in the old and new surface mass fluxes are not significant, the solution is assumed to be converged.

As an example, the following solution procedure was used to obtain the coupled laminar and turbulent solutions for a given set of entry conditions. In all, nine runs were made with the code. In each run, LMAX, LW, and IPR were set equal to 4000, 2000, and 1, respectively. Other parameters were as follows:

(i) LTURB = 1 (for laminar flow), FDT = 1.0, FMASS = 0., LR = 2000, ILT = 0, LFI = 10, and LFO = 10

(ii) LTURB = 1, FDT = 1.0, FMASS = 0., LR = 2000, ILT = 1, LFI = 10, and LFO = 11

(iii) LTURB = 1, FDT = 1.0, FMASS = 0.1, LR = 2000, ILT = 2, LFI = 11, and LFO = 11

(iv) No change in parameters

(v) No change in parameters

(vi) LTURB = 0 (for turbulent flow), FDT = 0.75, FMASS = 1.0, LR =2000, ILT = 2, LFI = 11, LFO = 12, NT = 1, and FTURB = 0.01

(vii) LTURB = 0, FDT = 0.25, FMASS = 1.0, LR = 1000, ILT = 2, LFI = 12, LFO = 12, NT = 1, and FTURB = 0.01

(viii) No change in parameters

(iv) No change in parameters

After the last run, the changes in radiative heat fluxes and surface mass fluxes were found to be very small and the solution was assumed to be converged. In all, the solution was marched by 36,000 time steps with chemistry package called after every 200 time steps and radiation package called after every 1000 or 2000 time steps. The complete solution required about 6000 seconds on CDC-CYBER-203 computer.

REFERENCES

1. Kumar, Ajay; Graves, R. A., Jr.; Weilmuenster, K. J.; and Tiwari, S. N.: Laminar and Turbulent Flow Solutions with Radiation and Ablation Injection for Jovian Entry. AIAA Paper 80-288, Jan. 1980.

2. Kumar, Ajay; Graves, R. A., Jr.; and Weilmuenster, K. J.: User's Guide for the Vectorized Code 'EQUIL' for Calculating Equilibrium Chemistry on CDC-STAR-100 Computer. NASA TM 80193, 1980.

3. Nicolet, W. E.: User's Manual for the Generalized Radiation Transfer Code (RAD/EQIL). NASA CR-116353, 1969.

APPENDIX A

LISTING FOR CODE 'COLTS'

```
 PROGRAM COLTS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,UNIT10=BLUNT1,
1UNIT11=BLUNT2,UNIT12=BLUNT3,UNIT13=BLUNT4)
 DIMENSION CC(101,14)
 DIMENSION VIST1(101,14),DVIST(101,14)
 DIMENSION TI1(101,14),HI1(101,14),DTMASS(14)
 DIMENSION TCH(14),DHI(101,14),DTI(101,14),BIG(101,14)
 DIMENSION TE12(14),CHEK(14),CHDIF(14)
 DIMENSION YB(14),R(14),TEMP1(14),TEMP2(101),Z(101),
1TZ(101),TZ1(101),GM(7),DT(101,14),AU2(101,14,7)
  DIMENSION TAU(14,7),TAM(14,7),TAN1(14,7),TAN2(14,7),TAO(14,7),
1TAU1(14,7),CF(14),TE8(14),TE9(14),CR(14)
 COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
 COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
 COMMON/F3/B2,RE,TW,MM,XX,ZZ,FM,BETA,RN,EL,ELT,JJ,DY
 COMMON/F5/S(14),SS(14),G(14),CUR(14),US(14),DS(14),VN(14),VS(14)
 COMMON/F6/INT(14),THE(14),TIMP(14),TEMP(14),TF(14),TE1(14),TE2(14)
1,TE3(14),TE4(14),TE5(14),TE6(14),TE7(14)
 COMMON/F7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
 COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
1CL(101,14,5)
 COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
 COMMON/F8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
 COMMON/F9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
 COMMON/F10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
 COMMON/F11/DU(101,14),DSH(101,14),A6(101,14),A8(101,14)
 COMMON/F12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
 COMMON/F13/AU1(101,14,7),THE1(101,14),THE2(101,14),VAIR(101,14),DC
1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),AO(101,14,7)
 COMMON/F15/AMO(101,2,7)
 COMMON/F16/HINF,RE1,RE2,SIGT,VIST(101,14)
 COMMON/F17/XH2,XHE,ALH,ALHE,AMH,TF,ROF,VF,VISF,SHF,PF
 COMMON/F19/TE11(14),C12,PW(14),EQCONS,EQCH(101,14)
 COMMON/F21/A9(101,14),A10(101,14),A13(101,14),AA1(101,14),AA2(101,
114)
 COMMON/F23/QFXR(101,14)
 COMMON/CHEQN/NE,NS,NA,NN
 COMMON/CHEQD/FORT(101,14,19),Y(101,19),X(101,19),YBAR(101)
 COMMON/CHEQC/MW(19),SYMB(19),AA(19,5),MWEL(5),AAA(101,19,5)
 COMMON/CHEQF/YI1(101,14,19)
 COMMON/CHEQA2/EH(101,14,19),MOLEF(101,14,19)
 COMMON/CHEQH3/CPI2(101,14,19)
 COMMON/ITER/HI(101,14),WMIX1(101,14)
 COMMON/F30/TMASS1(14),TMASS(14)
 COMMON/F45/CH(14),TW1(14)
 BIT BIG
 REAL MW,MWEL,MOLEF
```

```
C     CONSTANTS AND FREESTREAM CONDITIONS
      MOLEF(1,1,1:26866)=0.
       CPI2(1,1,1:26866)=0.
         EH(1,1,1:26866)=0.
      VIST(1,1:1414)=0.
      QEXR(1,1:1414)=0.
      WMIX(1,1:1414)=0.
       SIG(1,1:1414)=0.
        HI(1,1:1414)=0.
        RO(1,1:1414)=0.
        PC(1,1:1414)=0.
         H(1,1:1414)=0.
      DCL(1,1,1:4242)=0.
      DVIST(1,1:1414)=0.
      TMASS1(1:14)=0.
       TMASS(1:14)=0.
      DTMASS(1:14)=0.
      CH(1:14)=0.
      TK(1:14)=0.
      PI=4.*ATAN(1.)
      GAMA=1.424
      RGAS=3616.9
      CPA=GAMA*RGAS/(GAMA-1.)
      FL=1.1                                                          (1)
      ELT=1.                                                          (2)
      SIGT=.9                                                         (3)
      XH2=.895                                                        (4)
      XHE=.105                                                        (5)
      BETA=1.05                                                       (6)
C     ILT=0,1, OR 2.  ILT=0 FOR FIRST RUN, ILT=1 FOR SECOND RUN, AND
C     ILT=2 FOR SUBSEQUENT RUNS.
      ILT=0                                                           (7)
C     FOR IPR=0, THE LAMINAR PRANDTL NUMBER VARIES AS CALCULATED BY THE
C     EQUILIBRIUM CHEMISTRY PACHAGE.  FOR IPR=1, IT IS SET EQUAL TO 0.64
      IPR=1                                                           (8)
      EDT=1.                                                          (9)
      LMAX=4000                                                      (10)
      LW=2000                                                        (11)
C     FOR LAMINAR FLOW, LTURB=1.   FOR TURBULENT FLOW, LTURB=0
      LTURB=1                                                        (12)
      NT=1                                                           (13)
      ETURB=.01                                                      (14)
      LR=2000                                                        (15)
      EMASS=0.                                                       (16)
      LFI=10                                                         (17)
      LFO=10                                                         (18)
```

```
      VF=33100.                                                          (19)
      ROF=9.17237E-4                                                     (20)
      TF=148.                                                            (21)
      RN=.344                                                            (22)
      RE=1.6023E6                                                        (23)
      THC=44.25*PI/180.                                                  (24)
      TW=4070.                                                           (25)
      PF=ROF*TF*RGAS
      FM=VF/(GAMA*RGAS*TF)**.5
      SHF=CPA*TF/VF/VF
      PF=PF/ROF/VF**2
      VISF=VF*ROF*RN/RE
      TW=TW/TF
      N1=14                                                              (26)
      M1=101                                                             (27)
      NJ=5                                                               (28)
      NJ1=NJ+1
      NJ2=NJ-1
      NJ3=NJ1+1
      A1=PI/2.-THC
      DY=A1/NJ                                                           (29)
      YB(1:N1)=Q8VINTL(0.,DY:YB(1:N1))                                   (30)
       DO 10 N=1,N1                                                      (31)
      IF(YB(N).GT.A1)GO TO 11                                            (32)
      THE(N)=PI/2.-YB(N)                                                 (33)
      CUR(N)=1.                                                          (34)
      R(N)=COS(THE(N))                                                   (35)
      GO TO 10                                                           (36)
 11   THE(N)=THC                                                         (37)
      CUR(N)=0.                                                          (38)
      R(N)=COS(THC)+(YB(N)-A1)*SIN(THC)                                  (39)
 10   CONTINUE                                                           (40)
      CURNJ1=CUR(NJ1)                                                    (41)
      CUR(NJ1)=0.
C     ARTIFICIAL DAMPING COEFFICIENT.
      CC(1,1:N1*M1)=.002                                                 (42)
      IF(LTURB.EQ.1)GO TO 13                                             (43)
      CC(1,1:M1)=.00015                                                  (44)
      DO 14 N=2,N1                                                       (45)
      NZY=N-1                                                            (46)
 14   CC(1,N:M1)=CC(1,NZY:M1)+.000025+NZY*.000015                        (47)
 13   CONTINUE
      IF(ILT.NE.1)GO TO 15
C     INITIAL SURFACE MASS FLUX ARBITRARILY PRESCRIBED ALONG THE SURFACE.
      TMASS1(1)=.55                                                      (48)
      TMASS1(2)=.525                                                     (49)
```

```
      TMASS1(3)=.465                                                    (50)
      TMASS1(4)=.378                                                    (51)
      TMASS1(5)=.250                                                    (52)
      TMASS1(6)=.162                                                    (53)
      TMASS1(7)=.120                                                    (54)
      TMASS1(8)=.090                                                    (55)
      TMASS1(9)=.085                                                    (56)
      TMASS1(10)=.078                                                   (57)
      TMASS1(11)=.075                                                   (58)
      TMASS1(12)=.071                                                   (59)
      TMASS1(13)=.069                                                   (60)
      TMASS1(14)=.067                                                   (61)
      DTMASS(1:N1)=TMASS1(1:N1)/LR
   15 CONTINUE
      ALH=2.*XH2
      ALHE=XHE
      AMH=1.008*ALH+4.003*ALHE
      C12=16.61962/ROF**.0258/VF**.048
      C13=4.595378E-04*ROF**.0222038*VF**1.362852/TF
      GM(1)=1.
      GM(2)=-1.
      GM(3)=1.
      GM(4)=1.
      GM(5)=1.
      GM(6)=1.
      GM(7)=1.
      GM3=CPA*TF/VF/VF
      HINF=0.995*(.5+GM3)
      RE1=SQRT(RE)
      RE2=.0168*RE
C     MESH SIZES AND VECTOR LENGTHS
      N14=N1-1
      N50=N1-2
      N52=N1-3
      M11=M1-1
      M50=M1-2
      M51=M1-3
      M52=M1-4
      NXM=N1*M1
      NXM1=NXM-M11
      NXM2=NXM-1
      NXM3=NXM-2
      NXM4=NXM-M1
      NXM5=NXM-M1-1
      NXM6=NXM-2*M1-2
      NXM7=NXM-3*M1+1
```

```
      NXM8=NXM-2*M1-1
      NXM9=NXM-4*M1+1
      NXM10=7*NXM
      NXMM=NXM-2*M1+1
      NXMM2=NXM-2*M1-4
      NXMM3=NXM-4*M1-2
      CALL READ
      EQCONS=8314.9*TF/VF/VF
      CONST=ROF*VF**2/1.01325E+05
      RTF=1./TF
      RCONST=1./CONST
      CVISF=.1/VISF
      CVF2=1./VF/VF
      CONST1=VF**2/4184.
      RCONST1=1./CONST1
C     STEP SIZES
      DZ=-1./M11
      YM=DY*N14
      XX=2.*DY
      ZZ=2.*DZ
      IF(ILT.NE.0)GO TO 795
C     INITIAL GUESS OF ELEMENTAL CONCENTRATIONS. ELEMENTS ARE IN THE
C     ORDER OF F,H,HE,C,O.
      CL(1,1,1:NXM)=1.E-10
      CL(1,1,3:NXM)=XHE*4.003/AMH
      CL(1,1,4:NXM)=5.E-6
      CL(1,1,5:NXM)=5.E-6
      CL(1,1,2:NXM)=1.-(CL(1,1,1:NXM)+CL(1,1,3:NXM)+CL(1,1,4:NXM)+
     1CL(1,1,5:NXM))
      S(1:N1)=.125
      SS(1:N1)=0.
      DS(1:N1)=0.
  795 CONTINUE
      IF(ILT.EQ.0)GO TO 865
      DO 800 N=1,N1
        READ(LFI,610)S(N),TMASS(N),DS(N),SS(N),CH(N)
        READ(LFI,690)(U(M,N),V(M,N),P(M,N),T(M,N),RO(M,N),SH(M,N),H(M,N),
     1VIS(M,N),VIST(M,N),M=1,M1)
        READ(LFI,660)(YI1(M,N,1),YI1(M,N,2),YI1(M,N,3),YI1(M,N,4),YI1(M,N
     1,5),YI1(M,N,6),WMIX(M,N),M=1,M1)
        READ(LFI,660)(YI1(M,N,7),YI1(M,N,8),YI1(M,N,9),YI1(M,N,10),YI1(M,
     1N,11),YI1(M,N,12),QFXR(M,N),M=1,M1)
        READ(LFI,660)(YI1(M,N,13),YI1(M,N,14),YI1(M,N,15),YI1(M,N,16),
     1YI1(M,N,17),YI1(M,N,18),YI1(M,N,19),M=1,M1)
        READ(LFI,660)(CL(M,N,1),CL(M,N,2),CL(M,N,3),CL(M,N,4),CL(M,N,5),
     1EQCH(M,N),PC(M,N),M=1,M1)
```

```
      WRITE(6,805)TMASS(N)
  800 CONTINUE
  805 FORMAT(/,10X,'MASS FLUX=',F15.4)
      WMIX1(1,1:NXM)=0.
      DO 850 I=1,NS
  850 WMIX1(1,1:NXM)=WMIX1(1,1:NXM)+YI1(1,1,I:NXM)
      DO 860 I=1,NS
  860 MOLEF(1,1,I:NXM)=YI1(1,1,I:NXM)/WMIX1(1,1:NXM)
  865 CONTINUE
      DO 20 N=1,N1
      VS(N)=COS(THE(N))
   20 VN(N)=-SIN(THE(N))
      Z(1:M1)=Q8VINTL(1.,DZ:Z(1:M1))
      DO 35 N=1,N1
      S1(1,N:M1)=S(N)
      DS1(1,N:M1)=DS(N)
      SS1(1,N:M1)=SS(N)
      CUR1(1,N:M1)=CUR(N)
      R1(1,N:M1)=R(N)
   35 THE1(1,N:M1)=THE(N)
      THEC(1,1:NXM)=VCOS(THE1(1,1:NXM):THEC(1,1:NXM))
      THES(1,1:NXM)=VSIN(THE1(1,1:NXM):THES(1,1:NXM))
      INT(1:N1)=Q8VINTL (1,M1:INT(1:N1))
C     BOUNDARY AND INITIAL CONDITIONS
      IF(ILT.NE.0)GO TO 55
      TE(1:N1)=VSIN(THE(1:N1):TE(1:N1))
      TE(1:N1)=VF*.001*TE(1:N1)*(1.+.7467*(1.-XH2))
      TE1(1:N1)=5.6611-.52661*TE(1:N1)+.020376*TE(1:N1)**2-.00037861*
     1TE(1:N1)**3+.0000034265*TE(1:N1)**4-.000000012206*TE(1:N1)**5
      TE1(1:N1)=TE1(1:N1)-.3167*(1.-XH2)
      TE2(1:N1)=-545.37+61.608*TE(1:N1)-2.2459*TE(1:N1)**2+.039922*TE(1:
     1N1)**3-.00035148*TE(1:N1)**4+.0000012361*TE(1:N1)**5
      TE2(1:N1)=TE2(1:N1)+61.2*(1.-XH2)
      TE11(1:N1)=TE1(1:N1)*C12
      TE12(1:N1)=TE2(1:N1)*C13
      DO 40 N=1,N1
   40 TEMP(N)=SIN(THE(N))**2*(.95+.05*(N-1)/N1)
      P(1,1:NXM)=Q8VSCATR(TEMP(1:N1 ),INT(1:N1 ):P(1,1:NXM))
      TEMP(1:N1)=0.
      U(1,1:NXM)=Q8VSCATR(TEMP(1:N1 ),INT(1:N1 ):U(1,1:NXM))
      V(1,1:NXM)=Q8VSCATR(TEMP(1:N1 ),INT(1:N1 ):V(1,1:NXM))
      TEMP(1:N1)=TW
      T(1,1:NXM)=Q8VSCATR(TEMP(1:N1 ),INT(1:N1 ):T(1,1:NXM))
      TEMP(1:N1)=VS(1:N1)
      U(M1,1:NXM1)=Q8VSCATR(TEMP(1:N1 ),INT(1:N1 ):U(M1,1:NXM1))
      TE1(1:N1)=.5-TE11(1:N1)
```

```
      TE2(1:N1)=TE11(1:N1)/VN(1:N1)*(PF+VN(1:N1)**2)
      TE3(1:N1)=-(.5*VN(1:N1)**2+SHF)
      TE4(1:N1)=TE2(1:N1)**2-4.*TE1(1:N1)*TE3(1:N1)
      TE4(1:N1)=VSQRT(TE4(1:N1):TE4(1:N1))
      TEMP1(1:N1)=(-TE2(1:N1)-TE4(1:N1))/2./TE1(1:N1)
      V(M1,1:NXM1)=Q8VSCATR(TEMP1(1:N1 ),INT(1:N1 ):V(M1,1:NXM1))
      TEMP(1:N1)=PF+VN(1:N1)**2-VN(1:N1)*TEMP1(1:N1)
      P(M1,1:NXM1)=Q8VSCATR(TEMP(1:N1 ),INT(1:N1 ):P(M1,1:NXM1))
      T(M1,1)=108.
      T(M1,2)=105.
      DO 45 N=3,N1
45    T(M1,N)=102.
      TEMP(1:N1)=-TE3(1:N1)-.5*TEMP1(1:N1)**2
      SH(M1,1:NXM1)=Q8VSCATR(TEMP(1:N1),INT(1:N1):SH(M1,1:NXM1))
      DO 50 N=1,N1
      DXU=(U(M1,N)-U(1,N))/M11
      DXV=(V(M1,N)-V(1,N))/M11
      DXP=(P(M1,N)-P(1,N))/M11
      DXT=(T(M1,N)-T(1,N))/M11
      U(1,N:M11)=Q8VINTL(U(1,N),DXU:U(1,N:M11))
      V(1,N:M11)=Q8VINTL(V(1,N),DXV:V(1,N:M11))
      P(1,N:M11)=Q8VINTL(P(1,N),DXP:P(1,N:M11))
50    T(1,N:M11)=Q8VINTL(T(1,N),DXT:T(1,N:M11))
      L=0
        PW(1:N1 )=Q8VGATHR(P(2,1:NXM1),INT(1:N1):PW(1:N1))
      P(1,1:NXM1)=Q8VSCATR(  PW(1:N1 ),INT(1:N1):P(1,1:NXM1))
      T(1,1:NXM)=T(1,1:NXM)*TF
      P(1,1:NXM)=P(1,1:NXM)*CONST
      CALL THERMO
      DO 51 N=1,N1
51    CALL CHEQ(0,N,M1,L)
      CALL CHEM(0)
      P(1,1:NXM)=P(1,1:NXM)*RCONST
      TI1(1,1:NXM)=T(1,1:NXM)
      T(1,1:NXM)=T(1,1:NXM)*RTF
      DO 52 N=1,N1
      SH(1,N)=HI(1,N)*RCONST1
      RO(1,N)=PW(N)*WMIX(1,N)/EQCONS/TW
      DXSH=(SH(M1,N)-SH(1,N))/M11
52    SH(1,N:M11)=Q8VINTL(SH(1,N),DXSH:SH(1,N:M11))
55    CONTINUE
      B1=(BETA+1.)/(BETA-1.)
      B2=2.*BETA/ALOG(B1)
      TZ(1:M1)=B1**(Z(1:M1))
      TZ1(1:M1)=BETA*(TZ(1:M1)-1.)/(TZ(1:M1)+1.)
      DO 30 N=1,N1
```

```
30    Z1(1,N:M1)=TZ1(1:M1)
      ZN(1,1:NXM)=S1(1,1:NXM)*(1.-Z1(1,1:NXM))
      EMDA(1,1:NXM)=1.+ZN(1,1:NXM)*CUR1(1,1:NXM)
      BT(1,1:NXM)=R1(1,1:NXM)+ZN(1,1:NXM)*THEC(1,1:NXM)
      TZ2(1,1:NXM)=BETA*BETA-Z1(1,1:NXM)*Z1(1,1:NXM)
      TZ3(1,1:NXM)=2.*Z1(1,1:NXM)/TZ2(1,1:NXM)
      TZ4(1,1:NXM)=R2/TZ2(1,1:NXM)
      AU1(1,1,1:NXM10)=1.
      AU2(1,1,1:NXM10)=1.
      TE8(1:N1)=1.
      TE9(1:N1)=0.
      WRITE (6,399) ALPHA,RE,FM
399   FORMAT(/,1X,'ALPHA',F8.5,5X,'REYN NO.',F15.3,5X,'MACH NO.',F8.3)
      L=1
      IF(L.EQ.1)GO TO 3
1     CONTINUE
      LL=L/200
      LL=LL*200
      IF(LL.NE.L)GO TO 2
3     CONTINUE
      SH(1,1:NXM)=SH(1,1:NXM)* CONST1
      T(1,1:NXM)=T(1,1:NXM)*TF
      P(1,1:NXM)=P(1,1:NXM)* CONST
      CALL THERMO
      CRIT=1.E-7
      KTEST=0
      DO 700 JF=1,N1
700   CALL CHEQ(KTEST,JF,M1,L,CRIT)
      CALL CHEM(KTEST)
      TI1(1,1:NXM)=T(1,1:NXM)
      HI1(1,1:NXM)=HI(1,1:NXM)
      T(1,1:NXM)=1.02*T(1,1:NXM)
      TWD=TW*TF
      T(1,1:NXM1)=QRVSCATR(TWD,INT(1:N1):T(1,1:NXM1))
      CALL THERMO
      DO 710 JF=1,N1
710   CALL CHEQ(1,JF,M1,L,CRIT)
      CALL CHEM(1)
      DO 711 N=1,N1
711   SH(1,N)=HI(1,N)
      TCH(1:N1)=0.
      LCHEM=0
715   CONTINUE
      LCHEM=LCHEM+1
      TV1(1,1:NXM)=(HI(1,1:NXM)-SH(1,1:NXM))/SH(1,1:NXM)
      TV1(1,1:NXM) =VABS(TV1(1,1:NXM):TV1(1,1:NXM))
```

```
      DO 725 N=1,N1
      IER=Q8SGE(TV1(1,N;M1),.01)
      IF(IER.NE.M1)GO TO 725
      TCH(N)=1.
  725 CONTINUE
      II=Q8SNF(TCH(1:N1),1.)
      IF(II.EQ.N1)GO TO 716
      DHI(1,1:NXM)=HI1(1,1:NXM)-HI(1,1:NXM)
      DTI(1,1:NXM)=TI1(1,1:NXM)-T(1,1:NXM)
      BIG(1,1:NXM)=TV1(1,1:NXM).LE..01
      DHI(1,1:NXM)=Q8VCTRL(1.,BIG(1,1:NXM):DHI(1,1:NXM))
      DTI(1,1:NXM)=Q8VCTRL(0.,BIG(1,1:NXM):DTI(1,1:NXM))
      TV1(1,1:NXM)=T(1,1:NXM)
      TV2(1,1:NXM)=HI(1,1:NXM)
      T(1,1:NXM)=T(1,1:NXM)+DTI(1,1:NXM)*(SH(1,1:NXM)-HI(1,1:NXM))/
     1DHI(1,1:NXM)
      TI1(1,1:NXM)=TV1(1,1:NXM)
      HI1(1,1:NXM)=TV2(1,1:NXM)
      CALL THERMO
      DO 720 JF=1,N1
      IF(TCH(JF).EQ.1.)GO TO 720
      CALL CHEQ(1,JF,M1,L,CRIT)
  720 CONTINUE
      CALL CHEM(1)
      IF(LCHEM.LE.50)GO TO 715
      WRITE(6,730)L
      STOP
  730 FORMAT(//,9X,'NO. OF ITERATIONS IN CHEMISTRY EXCEED 50 FOR L=',I4)
  716  CONTINUE
      DO 745 I=1,NS
C     FORT REPRESENTS MASS FRACTIONS
      FORT(1,1,I:NXM)=MOLEF(1,1,I:NXM)*MW(I)/WMIX(1,1:NXM)
  745 EH(1,1,I:NXM)=EH(1,1,I:NXM)*4184./MW(I)*CVF2
      TV1(1,1:NXM)=-ZZ*S1(1,1:NXM)*TZ2(1,1:NXM)/B2
      PC(1,1:NXM)=0.
      DO 2000 I=1,NS
      TV2(2,1:NXM3)=(FORT(3,1,I:NXM3)-FORT(1,1,I:NXM3))/TV1(2,1:NXM3)
      DO 2010 N=1,N1
      XX1=TV1(1,N)
      TV2(1,N)=(4.*FORT(2,N,I)-3.*FORT(1,N,I)-FORT(3,N,I))/XX1
      XX2=TV1(M1,N)
      TV2(M1,N)=-(4.*FORT(M11,N,I)-3.*FORT(M1,N,I)-FORT(M50,N,I))/XX2
 2010  CONTINUE
 2000 PC(1,1:NXM)=PC(1,1:NXM)+EH(1,1,I:NXM)*TV2(1,1:NXM)
      CALL TP
      SH(1,1:NXM)=SH(1,1:NXM)*RCONST1
```

```
      HI(1,1:NXM)=HI(1,1:NXM)*RCONST1
      T(1,1:NXM)=T(1,1:NXM)*RTF
      P(1,1:NXM)=P(1,1:NXM)*RCONST
      VIS(1,1:NXM)=VIS(1,1:NXM)*CVISF
      TK(1:N1)=418.4348*TK(1:N1)
      IF(ILT.EQ.0.AND.L.EQ.1)GO TO 24
      DHI(1,1:NXM)=EQCH(1,1:NXM)
      EQCH(1,1:NXM)=SH(1,1:NXM)*WMIX(1,1:NXM)/EQCONS/T(1,1:NXM)
      DTI(1,1:NXM)=(EQCH(1,1:NXM)-DHI(1,1:NXM))/200.
      EQCH(1,1:NXM)=DHI(1,1:NXM)
      GO TO 25
24    CONTINUE
      EQCH(1,1:NXM)=SH(1,1:NXM)*WMIX(1,1:NXM)/EQCONS/T(1,1:NXM)
      RO(1,1:NXM)=EQCH(1,1:NXM)*P(1,1:NXM)/SH(1,1:NXM)
      H(1,1:NXM)=SH(1,1:NXM)+(U(1,1:NXM)*U(1,1:NXM)+V(1,1:NXM)*V(1,1:NXM
     1))/2.
      DTI(1,1:NXM)=0.
25    CONTINUE
      IF(IPR.EQ.1)SIG(1,1:NXM)=0.64
2     CONTINUE
      EQCH(1,1:NXM)=EQCH(1,1:NXM)+DTI(1,1:NXM)
      IF(ILT.EQ.0)GO TO 8
      IF(LTURB.EQ.1)GO TO 9
      LL=L/25
      LL=LL*25
      IF(LL.NE.L)GO TO 4
      VIST1(1,1:NXM)=VIST(1,1:NXM)
      CALL DERV
      CALL EDDY(NT)
      DVIST(1,1:NXM)=FTURB*(VIST(1,1:NXM)-VIST1(1,1:NXM))/25.
      VIST(1,1:NXM)=VIST1(1,1:NXM)
4     CONTINUE
      VIST(1,1:NXM)= VIST(1,1:NXM)+DVIST(1,1:NXM)
9     CONTINUE
      IF(L.LT.LR.AND.ILT.EQ.1)GO TO 12
      IF(L.EQ.1)GO TO 5
      LL=L/LR
      LL=LL*LR
      IF(LL.NE.L)GO TO 6
5     CONTINUE
      P(1,1:NXM)=P(1,1:NXM)*CONST
      T(1,1:NXM)=T(1,1:NXM)*TF
      TV1(1,1:NXM)=ZN(1,1:NXM)/S1(1,1:NXM)
      S(1:N1)=S(1:N1)*RN*100.
      IF(L.EQ.1)GO TO 7
      DO 5000 JF=1,N1
```

```
      CALL ATRAD(JF)
5000  CONTINUE
      QRV3F=1.E4/(ROF*VF**3)
      QFXR(1,1:NXM)=-QFXR(1,1:NXM)*QRV3F
7      CONTINUE
      CALL SUBLIM(N1,NXM1,VF,ROF)
      DTMASS(1:N1)=FMASS*(TMASS1(1:N1)-TMASS(1:N1))/500.
      TW1(1:N1)=TW1(1:N1)*RTF
      WRITE(6,1500)(TW1(N),TMASS(N),TMASS1(N),N=1,N1)
1500   FORMAT(/,'WALL TEMP.=',F15.6,2X,'OLD MASS FLUX=',E15.6,2X,
     1'NEW MASS FLUX=',E15.6)
      P(1,1:NXM)=P(1,1:NXM)*RCONST
      T(1,1:NXM)=T(1,1:NXM)*RTF
      S(1:N1)=S(1:N1)/(100.*RN)
      LM=0
 6    CONTINUE
      LM=LM+1
      IF(LM.GT.500)GO TO 8
12    TMASS(1:N1)=DTMASS(1:N1)+TMASS(1:N1)
8     CONTINUE
      MM=1
      VAIR(1,1:NXM2)=GAMA*P(1,1:NXM2)/RO(1,1:NXM2)
      VAIR(1,1:NXM2)=VSQRT(VAIR(1,1:NXM2):VAIR(1,1:NXM2))
      DT(1,1:NXM2)=FDT*(ZN(2,1:NXM2)-ZN(1,1:NXM2))/(VABS(V(1,1:NXM2):
     1THE2(1,1:NXM2))+VAIR(1,1:NXM2))
      TIMP(1:N1 )=Q8VGATHR(DT(M11,1:NXM1),INT(1:N1 ):TIMP(1:N1 ))
      DT(M1,1:NXM1)=Q8VSCATR(TIMP(1:N1 ),INT(1:N1 ):DT(M1,1:NXM1))
      DO 70 N=1,N1
      DTM=Q8SMIN(DT(1,N:M1))
      DT(1,N:M1)=DTM
70    TIMP(N)=DTM
      CALL DERV
      CALL VEC1
      DDY=DY*(2.+CURNJ1*S(NJ1))
      DO 110 I=1,7
      AU1(2,2,I:NXM6)=AU(2,2,I:NXM6)-DT(2,2:NXM6)*((AM(2,3,I:NXM6)-AM(2,
     12,I:NXM6))/DY+(AN(3,2,I:NXM6)-AN(2,2,I:NXM6))/DZ+AQ(2,2,I:NXM6))
      AU1(2,N1,I:M50)=AU(2,N1,I:M50)-DT(2,N1:M50)*((AM(2,N1,I:M50)-AM(2,
     1N14,I:M50))/DY+(AN(3,N1,I:M50)-AN(2,N1,I:M50))/DZ+AQ(2,N1,I:M50))
      AU1(2,NJ1,I:M50)=AU(2,NJ1,I:M50)-DT(2,NJ1:M50)*((AM(2,NJ3,I:M50)-
     1AM(2,NJ,I:M50))/DDY+(AN(3,NJ1,I:M50)-AN(2,NJ1,I:M50))/DZ+
     2AQ(2,NJ1,I:M50))
      TAU(1,I:N1 )=Q8VGATHR(AU(M1,1,I:NXM1),INT(1:N1 ):TAU(1,I:N1 ))
      TAM(1,I:N1 )=Q8VGATHR(AM(M1,1,I:NXM1),INT(1:N1 ):TAM(1,I:N1 ))
      TAN1(1,I:N1 )=Q8VGATHR(AN(M1,1,I:NXM1),INT(1:N1 ):TAN1(1,I:N1 ))
      TAN2(1,I:N1 )=Q8VGATHR(AN(M11,1,I:NXM1),INT(1:N1 ):TAN2(1,I:N1 ))
```

```
      TAQ(1,I:N1 )=Q8VGATHR(AQ(M1,1,I:NXM1),INT(I:N1 ):TAQ(1,I:N1 ))
      TAU1(2,I:N50)=TAU(2,I:N50)-TIMP(2:N50)*((TAM(3,I:N50)-TAM(2,I:N50)
     1)/DY+(TAN1(2,I:N50)-TAN2(2,I:N50))/DZ+TAQ(2,I:N50))
      TAU1(N1,I)=TAU(N1,I)-TIMP(N1)*((TAM(N1,I)-TAM(N14,I))/DY+(TAN1(N1,
     11I)-TAN2(N1,I))/DZ+TAQ(N1,I))
      TAU1(NJ1,I)=TAU(NJ1,I)-TIMP(NJ1)*((TAM(NJ3,I)-TAM(NJ,I))/DDY+
     1(TAN1(NJ1,I)-TAN2(NJ1,I))/DZ+TAQ(NJ1,I))
110   AU1(M1,2,I:NXMM)=Q8VSCATR(TAU1(2,I:N14),INT(1:N14):AU1(M1,2,I:
     1NXMM))
      CALL VEC2
      DO 150 I=1,7
      AU1(2,1,I:M50)=AU(2,1,I:M50)-DT(2,1:M50)*((AMO(2,2,I:M50)-AMO(2,1,
     11I:M50))/DY+(AN(3,1,I:M50)-AN(2,1,I:M50))/DZ+AQ(2,1,I:M50))
150   AU1(M1,1,I)=AU(M1,1,I)-DT(M1,1)*((AMO(M1,2,I)-AMO(M1,1,I))/DY+(AN(
     1M1,1,I)-AN(M11,1,I))/DZ+AQ(M1,1,I))
      DO 120 I=1,7
      AU2(3,2,I:NXMM2)=AU(5,2,I:NXMM2)+AU(1,2,I:NXMM2)-4.*(AU(4,2,I:NXMM
     12)+AU(2,2,I:NXMM2))+6.*AU(3,2,I:NXMM2)
      TE1(1:N50)=Q8VGATHR(AU(1,2,I:NXM7),INT(1:N50):TE1(1:N50))
      TE2(1:N50)=Q8VGATHR(AU(2,2,I:NXM7),INT(1:N50):TE2(1:N50))
      TE3(1:N50)=Q8VGATHR(AU(3,2,I:NXM7),INT(1:N50):TE3(1:N50))
      TE4(1:N50)=Q8VGATHR(AU(4,2,I:NXM7),INT(1:N50):TE4(1:N50))
      TE5(1:N50)=TE4(1:N50)-TE1(1:N50)-3.*(TE3(1:N50)-TE2(1:N50))
      AU2(2,2,I:NXM7)=Q8VSCATR(TE5(1:N50),INT(1:N50):AU2(2,2,I:NXM7))
      TE1(1:N50)=Q8VGATHR(AU(M51,2,I:NXM7),INT(1:N50):TE1(1:N50))
      TE2(1:N50)=Q8VGATHR(AU(M50,2,I:NXM7),INT(1:N50):TE2(1:N50))
      TE3(1:N50)=Q8VGATHR(AU(M11,2,I:NXM7),INT(1:N50):TE3(1:N50))
      TE4(1:N50)=Q8VGATHR(AU(M1,2,I:NXM7),INT(1:N50):TE4(1:N50))
      TE5(1:N50)=TE1(1:N50)-TE4(1:N50)-3.*(TE2(1:N50)-TE3(1:N50))
      AU2(M11,2,I:NXM7)=Q8VSCATR(TE5(1:N50),INT(1:N50):AU2(M11,2,I:NXM7)
     1)
      AU2(3,1,I:M52)=AU(5,1,I:M52)+AU(1,1,I:M52)-4.*(AU(4,1,I:M52)+AU(2,
     11,I:M52))+6.*AU(3,1,I:M52)
      AU2(2,1,I)=AU(4,1,I)-AU(1,1,I)-3.*(AU(3,1,I)-AU(2,1,I))
      AU2(M11,1,I)=AU(M51,1,I)-AU(M1,1,I)-3.*(AU(M50,1,I)-AU(M11,1,I))
      AN(2,3,I:NXMM3)=AU1(2,3,I:NXMM3)-CC(2,3:NXMM3)*
     1(AU(2,5,I:NXMM3)+AU(2,1,I:NXM
     1M3)-4.*(AU(2,4,I:NXMM3)+AU(2,2,I:NXMM3))+6.*AU(2,3,I:NXMM3)+AU2(2,
     23,I:NXMM3))
      TE1(1:N52)=Q8VGATHR(AU1(M1,2,I:NXM9),INT(1:N52):TE1(1:N52))
      AN(M1,2,I:NXM9)=Q8VSCATR(TE1(1:N52),INT(1:N52):AN(M1,2,I:NXM9))
      AN(2,N14,I:M50)=AU1(2,N14,I:M50)-CC(2,N14:M50)*
     1(AU(2,N52,I:M50)-AU(2,N1,I:M
     150)-3.*(AU(2,N50,I:M50)-AU(2,N14,I:M50))+AU2(2,N14,I:M50))
      AN(2,2,I:M50)=AU1(2,2,I:M50)-CC(2,2:M50)*
     1(AU(2,4,I:M50)+GM(I)*AU(2,2,
```

```
     1I;M50)-4.*(AU(2,3,I:M50)+AU(2,1,I:M50))+6.*AU(2,2,I:M50)+AU2(2,2,I
     2:M50))
      AU1(2,2,I:NXM6)=AN(2,2,I:NXM6)
      IF(I.EQ.2)GO TO 120
      AU1(2,1,I:M50)=AU1(2,1,I:M50)-CC(2,1:M50)*
     1(2.*AU(2,3,I:M50)-8.*AU(2,2,I:M5
     10)+6.*AU(2,1,I:M50)+AU2(2,1,I:M50))
120   CONTINUE
      AU1(1,2,1:NXMM)=Q8VSCATR(TE8(1:N14),INT(1:N14):AU1(1,2,1:NXMM))
      AU1(1,2,2:NXMM)=Q8VSCATR(TE9(1:N14),INT(1:N14):AU1(1,2,2:NXMM))
      AU1(1,2,3:NXMM)=Q8VSCATR(TE9(1:N14),INT(1:N14):AU1(1,2,3:NXMM))
      AU1(1,2,4:NXMM)=Q8VSCATR(TE8 (1:N14),INT(1:N14):AU1(1,2,4:NXMM))
      IF(LTURB.EQ.1)GO TO 154
      CALL VEC4
      GO TO 155
154   CALL VEC3
155   CONTINUE
      SS(1)=0.
      DO 160 N=2,N14
160   SS(N)=(S(N+1)-S(N-1))/XX
      SS(NJ1)=(S(NJ1+1)-S(NJ))/DY/(2.+CURNJ1*S(NJ1))
      SS(N1)=-(4.*S(N14)-3.*S(N1)-S(N50))/XX
      CALL SHOCK
      AU2(1,1,1:NXM10)=AU(1,1,1:NXM10)+AU1(1,1,1:NXM10)
      MM=2
      DDY=DY*(2.+CURNJ1*S(NJ1))
      CALL DERV
      CALL VEC1
      DO 180 I=1,7
      AU1(2,2,I:NXM5)=0.5*(AU2(2,2,I:NXM5)-DT(2,2:NXM5)*((AM(2,2,I:NXM5)
     1-AM(2,1,I:NXM5))/DY+(AN(2,2,I:NXM5)-AN(1,2,I:NXM5))/DZ+AQ(2,2,I:
     2NXM5)))
180   AU1(2,NJ1,I:M11)=.5*(AU2(2,NJ1,I:M11)-DT(2,NJ1:M11)*((AM(2,NJ3,I:
     1M11)-AM(2,NJ,I:M11))/DDY+(AN(2,NJ1,I:M11)-AN(1,NJ1,I:M11))/DZ+
     2AQ(2,NJ1,I:M11)))
      U(1,2:M1)=-U(1,2:M1)
      CALL VEC2
      DO 190 I=1,7
190   AU1(2,1,I:M11)=.5*(AU2(2,1,I:M11)-DT(2,1:M11)*((AMQ(2,1,I:M11)-AMQ
     1(2,2,I:M11))/DY+(AN(2,1,I:M11)-AN(1,1,I:M11))/DZ+AQ(2,1,I:M11)))
      DO 200 I=1,7
      AU2(3,2,I:NXMM2)=AU(5,2,I:NXMM2)+AU(1,2,I:NXMM2)-4.*(AU(4,2,I:NXMM
     12)+AU(2,2,I:NXMM2))+6.*AU(3,2,I:NXMM2)
      TE1(1:N50)=Q8VGATHR(AU(1,2,I:NXM7),INT(1:N50):TE1(1:N50))
      TE2(1:N50)=Q8VGATHR(AU(2,2,I:NXM7),INT(1:N50):TE2(1:N50))
      TE3(1:N50)=Q8VGATHR(AU(3,2,I:NXM7),INT(1:N50):TE3(1:N50))
```

```
      TE4(1:N50)=Q8VGATHR(AU(4,2,I:NXM7),INT(1:N50):TE4(1:N50))
      TE5(1:N50)=TE4(1:N50)-TE1(1:N50)-3.*(TE3(1:N50)-TE2(1:N50))
      AU2(2,2,I:NXM7)=Q8VSCATR(TE5(1:N50),INT(1:N50):AU2(2,2,I:NXM7))
      TE1(1:N50)=Q8VGATHR(AU(M51,2,I:NXM7),INT(1:N50):TE1(1:N50))
      TE2(1:N50)=Q8VGATHR(AU(M50,2,I:NXM7),INT(1:N50):TE2(1:N50))
      TE3(1:N50)=Q8VGATHR(AU(M11,2,I:NXM7),INT(1:N50):TE3(1:N50))
      TE4(1:N50)=Q8VGATHR(AU(M1,2,I:NXM7),INT(1:N50):TE4(1:N50))
      TE5(1:N50)=TE1(1:N50)-TE4(1:N50)-3.*(TE2(1:N50)-TE3(1:N50))
      AU2(M11,2,I:NXM7)=Q8VSCATR(TE5(1:N50),INT(1:N50):AU2(M11,2,I:NXM7)
     1)
      AU2(3,1,I:M52)=AU(5,1,I:M52)+AU(1,1,I:M52)-4.*(AU(4,1,I:M52)+AU(2,
     11,I:M52))+6.*AU(3,1,I:M52)
      AU2(2,1,I)=AU(4,1,I)-AU(1,1,I)-3.*(AU(3,1,I)-AU(2,1,I))
      AU2(M11,1,I)=AU(M51,1,I)-AU(M1,1,I)-3.*(AU(M50,1,I)-AU(M11,1,I))
      AN(2,3,I:NXMM3)=AU1(2,3,I:NXMM3)-CC(2,3:NXMM3)*
     1(AU(2,5,I:NXMM3)+AU(2,1,I:NXM
     1M3)-4.*(AU(2,4,I:NXMM3)+AU(2,2,I:NXMM3))+6.*AU(2,3,I:NXMM3)+AU2(2,
     23,I:NXMM3))
      TE1(1:N52)=Q8VGATHR(AU1(M1,2,I:NXM9),INT(1:N52):TE1(1:N52))
      AN(M1,2,I:NXM9)=Q8VSCATR(TE1(1:N52),INT(1:N52):AN(M1,2,I:NXM9))
      AN(2,N14,I:M50)=AU1(2,N14,I:M50)-CC(2,N14:M50)*
     1(AU(2,N52,I:M50)-AU(2,N1,I:M
     150)-3.*(AU(2,N50,I:M50)-AU(2,N14,I:M50))+AU2(2,N14,I:M50))
      AN(2,2,I:M50)=AU1(2,2,I:M50)-CC(2,2:M50)*
     1(AU(2,4,I:M50)+GM(I)*AU(2,2,
     1I:M50)-4.*(AU(2,3,I:M50)+AU(2,1,I:M50))+6.*AU(2,2,I:M50)+AU2(2,2,I
     2:M50))
      AU1(2,2,I:NXM6)=AN(2,2,I:NXM6)
      IF(I.EQ.2)GO TO 200
      AU1(2,1,I:M50)=AU1(2,1,I:M50)-CC(2,1:M50)*
     1(2.*AU(2,3,I:M50)-8.*AU(2,2,I:M5
     10)+6.*AU(2,1,I:M50)+AU2(2,1,I:M50))
200   CONTINUE
      AU1(1,2,1:NXMM)=Q8VSCATR(TE8(1:N14),INT(1:N14):AU1(1,2,1:NXMM))
      AU1(1,2,2:NXMM)=Q8VSCATR(TE9(1:N14),INT(1:N14):AU1(1,2,2:NXMM))
      AU1(1,2,3:NXMM)=Q8VSCATR(TE9(1:N14),INT(1:N14):AU1(1,2,3:NXMM))
      AU1(1,2,4:NXMM)=Q8VSCATR(TE8 (1:N14),INT(1:N14):AU1(1,2,4:NXMM))
      IF(LTURB.EQ.1)GO TO 204
      CALL VEC4
      GO TO 205
204   CALL VEC3
205   CONTINUE
      SS(1)=0.
      DO 210 N=2,N14
210   SS(N)=(S(N+1)-S(N-1))/XX
      SS(NJ1)=(S(NJ1+1)-S(NJ))/DY/(2.+CURNJ1*S(NJ1))
```

```
      SS(N1)=-(4.*S(N14)-3.*S(N1)-S(N50))/XX
      CALL SHOCK
      LL=L/500
      LL=LL*500
      IF(LL.NE.L)GO TO 450
      WRITE(6,400) L
      WRITE(6,405)
      CON=2.*TF/(ROF*VF**3*RN)
      DO 250 N=1,N1
      TE(N)=-ZZ*TZ2(1,N)*S(N)/B2
      DT1=(4.*T(2,N)-3.*T(1,N)-T(3,N))/TE(N)
      CHFK=TK(N)*CON*DT1
      CHDIF(N)=2.*VIS(1,N)/SIG(1,N)/RE*EL*PC(1,N)
      CH(N)=CHFK(N)+CHDIF(N)
      CF(N)=2.*VIS(1,N)*(DU(1,N)-U(1,N)*CUR(N)/EMDA(1,N))/RE
      CR(N)=2.*QFXR(1,N)
250   WRITE(6,420) YB(N),S(N),US(N),CHDIF(N),CH(N),CF(N),PW(N),CR(N)
      LL=L/LW
      LL=LL*LW
      IF(LL.NE.L)GO TO 450
      DO 260 N=1,N1
      WRITE(6,265)N
      WRITE(6,431)
      WRITE(6,440)(ZN(M,N),U(M,N),V(M,N),P(M,N),RO(M,N),T(M,N),H(M,N),
     1SH(M,N),HI(M,N),PC(M,N),VIST(M,N),QFXR(M,N),M=1,M1)
260   CONTINUE
265   FORMAT(/,10X,'BODY STATION NO.=',I4,/)
275   FORMAT(15X,'E-',15X,'H',15X,'HE',14X,'C',14X,'O',13X,'WMIX')
280   FORMAT(7X,6E15.6)
400    FORMAT(/,10X,'NO.OF ITERATIONS=',I4)
405   FORMAT(/,1X,'DIST.ALONG BODY',3X,'SHOCK STANDOFF DIST.',3X,'SHOCK
     1SPEED',3X,'DIFFUSIVE CH',3X,'TOTAL CH',3X,'SKIN FRICTION',3X,
     1'WALL PRESSURE',3X,'RAD.HEATING')
420   FORMAT(3X,F10.5,8X,F10.5,8X,F10.5,4X,F11.7,4X,F11.7,4X,F11.7,4X,
     1F8.5,4X,F11.7)
440   FORMAT(1X,12F10.5)
431   FORMAT(/,6X,'ZN',9X,'U',9X,'V',8X,'P',8X,'RO',9X,'T',9X,'H',9X,
     1' SH',7X,' HI',7X,'PC',6X,'VIST',7X,'QFXR')
450   L=L+1
      IF(L.LE.LMAX)GO TO 1
      DO 270 N=1,N1
      WRITE(6,265)N
      WRITE(6,275)
270   WRITE(6,280)(CL(M,N,1),CL(M,N,2),CL(M,N,3),CL(M,N,4),CL(M,N,5),
     1WMIX(M,N),M=1,M1)
      REWIND LFO
```

```
      DO 550 N=1,N1
      WRITE(LFO,610)S(N),TMASS(N),DS(N),SS(N),CH(N)
      WRITE(LFO,690)(U(M,N),V(M,N),P(M,N),T(M,N),RO(M,N),SH(M,N),H(M,N),
     1VIS(M,N),VIST(M,N),M=1,M1)
      WRITE(LFO,660)(YI1(M,N,1),YI1(M,N,2),YI1(M,N,3),YI1(M,N,4),YI1(M,N
     1,5),YI1(M,N,6),WMIX(M,N),M=1,M1)
      WRITE(LFO,660)(YI1(M,N,7),YI1(M,N,8),YI1(M,N,9),YI1(M,N,10),YI1(M,
     1N,11),YI1(M,N,12),OFXR(M,N),M=1,M1)
      WRITE(LFO,660)(YI1(M,N,13),YI1(M,N,14),YI1(M,N,15),YI1(M,N,16),
     1YI1(M,N,17),YI1(M,N,18),YI1(M,N,19),M=1,M1)
      WRITE(LFO,660)(CL(M,N,1),CL(M,N,2),CL(M,N,3),CL(M,N,4),CL(M,N,5),
     1EQCH(M,N),PC(M,N),M=1,M1)
550   CONTINUE
610   FORMAT(10X,5F12.6)
660   FORMAT(1X,7E15.6)
690   FORMAT(1X,9E12.6)
      STOP
      END
```

```
      SUBROUTINE SHOCK
      DIMENSION A2(14),VNF(14)
      COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/F3/B2,RE,TW,MM,XX,ZZ,EM,BETA,RN,EL,ELT,JJ,DY
      COMMON/F5/S(14),SS(14),G(14),CUR(14),US(14),DS(14),VN(14),VS(14)
      COMMON/F6/INT(14),THE(14),TIMP(14),TEMP(14),TE(14),TE1(14),TE2(14)
     1,TE3(14),TE4(14),TE5(14),TE6(14),TE7(14)
      COMMON/F7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/F8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
      COMMON/F9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
      COMMON/F10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/F12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
      COMMON/F17/XH2,XHE,ALH,ALHE,AMH,TF,ROF,VF,VISF,SHF,PF
      COMMON/F19/TE11(14),C12,PW(14),EQCONS,EQCH(101,14)
      TE11(1:N1)=Q8VGATHR(EQCH(M1 ,1:NXM1),INT(1:N1):TE11(1:N1))
      A2(1:N1 )=SS(1:N1 )/(1.+S(1:N1 )*CUR(1:N1 ))
      G(1:N1)=1.+A2(1:N1)*A2(1:N1)
      G(1:N1 )=VSQRT(G(1:N1 ):G(1:N1 ))
      TEMP(1:N1 )=Q8VGATHR(P(M1,1:NXM1),INT(1:N1 ):TEMP(1:N1 ))
      TE5(1:N1)=TE11(1:N1)*TEMP(1:N1)
      TE6(1:N1)=(TEMP(1:N1)-PF)/2.
      TE(1:N1)=(TE5(1:N1)-TE6(1:N1))/(SHF+TE6(1:N1))
```

```
      VNF(1:N1)=(-A2(1:N1)*VS(1:N1)+VN(1:N1))/G(1:N1)
      TF1(1:N1)=TE(1:N1)*(TEMP(1:N1)-PE)/(TE(1:N1)-1.)
      TE1(1:N1)= VSQRT(TE1(1:N1):TF1(1:N1))
      US(1:N1)=VNF(1:N1)+TF1(1:N1)
      TF1(1:N1 )=(1.-1./TE(1:N1 ))*TF1(1:N1 )/G(1:N1 )
      TE2(1:N1 )=VS(1:N1 )-TE1(1:N1 )*A2(1:N1 )
      TE3(1:N1 )=VN(1:N1 )+TF1(1:N1 )
      TE6(1:N1)=TE11(1:N1)*TEMP(1:N1)/TE(1:N1)
      TE7(1:N1)=TE6(1:N1)+(TE2(1:N1)*TE2(1:N1)+TE3(1:N1)*TE3(1:N1))/2.
      RO(M1,1:NXM1)=08VSCATR(TE(1:N1 ),INT(1:N1 ):RO(M1,1:NXM1))
      U(M1,1:NXM1)=08VSCATR(TE2(1:N1 ),INT(1:N1 ):U(M1,1:NXM1))
      V(M1,1:NXM1)=08VSCATR(TE3(1:N1 ),INT(1:N1 ):V(M1,1:NXM1))
      SH(M1,1:NXM1)=08VSCATR(TE6(1:N1 ),INT(1:N1 ):SH(M1,1:NXM1))
      H(M1,1:NXM1)=08VSCATR(TE7(1:N1 ),INT(1:N1 ):H(M1,1:NXM1))
      IF(MM.EQ.2)GO TO 70
      DS(1:N1 )=US(1:N1 )*G(1:N1 )
      GO TO 71
   70 DS(1:N1 )=(DS(1:N1 )+US(1:N1 )*G(1:N1 ))/2.
   71 S(1:N1 )=S(1:N1 )+DS(1:N1 )*TIMP(1:N1 )
      DO 75 N=1,N1
      CL(M1,N,3)=XHE*4.003/AMH
      CL(M1,N,4)=5.E-6
      CL(M1,N,5)=5.E-6
      CL(M1,N,2)=1.-CL(M1,N,3)-1.E-10-1.E-5
      S1(1,N:M1)=S(N)
      SS1(1,N:M1)=SS(N)
   75 DS1(1,N:M1)=DS(N)
      ZN(1,1:NXM)=S1(1,1:NXM)*(1.-Z1(1,1:NXM))
      EMDA(1,1:NXM)=1.+ZN(1,1:NXM)*CUR1(1,1:NXM)
      BT(1,1:NXM)=R1(1,1:NXM)+ZN(1,1:NXM)*THEC(1,1:NXM)
      RETURN
      END
      END
      SUBROUTINE EDDY(NT)
      DIMENSION PE(14),DPE(14),BLD(14),BLE(14),UE(14),CUT2(101)
      COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/F3/B2,RE,TW,MM,XX,ZZ,EM,BETA,RN,EL,ELT,JJ,DY
      COMMON/F7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/F8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
      COMMON/F9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
      COMMON/F10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/F11/DU(101,14),DSH(101,14),A6(101,14),A8(101,14)
```

```
      COMMON/F12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
      COMMON/F16/HINF,RE1,RE2,SIGT,VIST(101,14)
      COMMON/F21/A9(101,14),A10(101,14),A13(101,14),AA1(101,14),AA2(101,
     114)
      NT1=NT-1
      NT2=NT+1
      TV1(1,1:NXM)=VIS(1,1:NXM)/SIG(1,1:NXM)
      TV2(1,1:NXM)=VIST(1,1:NXM)*SIG(1,1:NXM)/SIGT
      A9(1,1:NXM)=(1.+TV2(1,1:NXM))*(DSH(1,1:NXM)+U(1,1:NXM)*DU(1,1:NXM
     11))
      A10(1,1:NXM)=((SIG(1,1:NXM)-1.+TV2(1,1:NXM)*(SIGT-1.))*DU(1,1:NXM)
     1-U(1,1:NXM)*CUR1(1,1:NXM)*SIG(1,1:NXM)/EMDA(1,1:NXM))*U(1,1:NXM)
      A13(1,1:NXM)=(EL-1.+TV2(1,1:NXM)*(ELT-1.))*PC(1,1:NXM)
      AA1(1,1:NXM)=TV1(1,1:NXM)*(A9(1,1:NXM)+A10(1,1:NXM)+A13(1,1:NXM))
      TV1(1,1:NXM)=-ZZ*S1(1,1:NXM)*TZ2(1,1:NXM)/B2
      AA2(2,1:NXM3)=(AA1(3,1:NXM3)-AA1(1,1:NXM3))/TV1(2,1:NXM3)
      DO 70 N=1,N1
      XX1=1./TV1(1,N)
      AA2(1,N)=(4.*AA1(2,N)-3.*AA1(1,N)-AA1(3,N))*XX1
      XX1=1./TV1(M1,N)
      AA2(M1,N)=-(4.*AA1(M11,N)-3.*AA1(M1,N)-AA1(M50,N))*XX1
70    CONTINUE
      TV1(1,2:NXM4)=AA2(1,2:NXM4)+(CUR1(1,2:NXM4)/EMDA(1,2:NXM4)+THEC(
     11,2:NXM4)/BT(1,2:NXM4))*AA1(1,2:NXM4)
      TV1(1,1:M1)=AA2(1,1:M1)+2./EMDA(1,1:M1)*AA1(1,1:M1)
      TV2(1,1:NXM)=VABS(TV1(1,1:NXM):TV2(1,1:NXM))
      DO 71 N=1,N1
71    TV1(2,N:M11)=(TV2(2,N:M11)+TV2(1,N:M11))*.5*(ZN(2,N:M11)-ZN(1,N:
     1M11))
      DO 72 N=1,N1
      AA1(1,N)=0.
      DO 73 M=2,M1
      J=M-1
73    AA1(M,N)=TV1(M,N)+AA1(J,N)
72    CONTINUE
      DO 3075 N=2,N1
      DO 3070 M=15,M11
      CONS=AA1(M,N)/AA1(M1,N)
      IF(CONS.GE.0.95)GO TO 3072
3070  CONTINUE
3072  BLE(N)=ZN(M,N)
      UE(N)=U(M,N)
      PE(N)=P(M,N)
      BLD(N)=0.
      IF(N.EQ.1)GO TO 3075
      DO 3073 J=2,M
```

```
      J1=J-1
3073  BLD(N)=BLD(N)+(2.-(U(J1,N)+U(J,N))/UE(N))*(ZN(J,N)-ZN(J1,N))/2.
3075  CONTINUE
      WRITE(6,150)
150   FORMAT(/,10X,'BOUNDARY LAYER AND DISPLACEMENT THICKNESSES',/)
      WRITE(6,100)(BLE(N),BLD(N),N=2,N1)
100   FORMAT(10X,'B.L.THICKNESS=',F10.5,10X,'DISPLACEMENT THICKNESS=',
     1F10.6)
      DO 3110 N=NT2,N1
      CUT2(1:M1)=1./(1.+5.5*(ZN(1,N:M1)/BLE(N))**6)
      TV2(1,N:M1)=RE2*RO(1,N:M1)*UE(N)*BLD(N)*CUT2(1:M1)/VIS(1,N:M1)
      TV1(1,N)=0.
      CUT2(1:M1)=VABS(DU(1,N:M1):CUT2(1:M1))
      CUTT=SQRT(VIS(1,N)*CUT2(1))
      DO 3115 M=2,M1
      CUT=CUTT/SQRT(RO(M,N))
      UTAU=CUT/RE1
      VPLUS=V(1,N)/UTAU
      VPLUS=-VPLUS*5.9
      APLUS=26.*EXP(VPLUS)
      CNPLUS=ZN(M,N)*RO(M,N)*RE1/VIS(M,N)*CUT
      ANPLUS=CNPLUS/APLUS
      IF(ANPLUS.GT.12.)GO TO 3116
      VISTL=.4*ZN(M,N)*(1.-1./EXP(ANPLUS))
      GO TO 3115
3116  VISTL=.4*ZN(M,N)
3115  TV1(M,N)=RE*RO(M,N)*VISTL*VISTL/VIS(M,N)*CUT2(M)
3137  MB=M-1
      DO 3130 M=1,MB
      DVIS=TV2(M,N)-TV1(M,N)
      IF(DVIS.LE.0.)GO TO 3135
3130  VIST(M,N)=TV1(M,N)
      M=M+1
3135  MB1=M1-M+1
3110  VIST(M,N;MB1)=TV2(M,N:MB1)
      RETURN
      END
      SUBROUTINE SUBLIM(N1,NXM1,VF,ROF)
      COMMON/F6/INT(14),THE(14),TIMP(14),TEMP(14),TF(14),TF1(14),TF2(14)
     1,TF3(14),TF4(14),TF5(14),TF6(14),TF7(14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/F23/QFXR(101,14)
      COMMON/F30/TMASS1(14),TMASS(14)
      COMMON/F45/CH(14),TW1(14)
      TF(1:N1)=QSVGATHR(P(1,1;NXM1),INT(1:N1):TF(1:N1))
```

```
      TE(1:N1)=VALOG10(TE(1:N1):TE(1:N1))
      TE1(1:N1)=TE(1:N1)*TE(1:N1)
      TE2(1:N1)=Q8VGATHR(CL(1,1,4:NXM1),INT(1:N1):TE2(1:N1))
      TE2(1:N1)=TE2(1:N1)/.925
      TE3(1:N1)=TE2(1:N1)*TE2(1:N1)
      TE4(1:N1)=TE3(1:N1)*TE2(1:N1)
      TE5(1:N1)=TE4(1:N1)*TE2(1:N1)
      TE6(1:N1)=5552.-20184.*TE2(1:N1)+53058.*TE3(1:N1)-57933.*TE4(1:N1)
     1+23243.*TE5(1:N1)
      TE7(1:N1)=1798.-12049.*TE2(1:N1)+30145.*TE3(1:N1)-32045.*TE4(1:N1)
     1+12457.*TE5(1:N1)
      TEMP(1:N1)=322.-2208.*TE2(1:N1)+5270.*TE3(1:N1)-5450.*TE4(1:N1)+
     12092.*TE5(1:N1)
      TW1(1:N1)=TE6(1:N1)+TE7(1:N1)*TE(1:N1)+TEMP(1:N1)*TE1(1:N1)
      TE6(1:N1)=60.9-190.*TE2(1:N1)+482.*TE3(1:N1)-527.*TE4(1:N1)+199.*
     1TE5(1:N1)
      TE7(1:N1)=6.10-66.5*TE2(1:N1)+141.*TE3(1:N1)-141.*TE4(1:N1)+58.6*
     1TE5(1:N1)
      TEMP(1:N1)=-.4+10.7*TE2(1:N1)-20.6*TE3(1:N1)+17.3*TE4(1:N1)-6.7*
     1TE5(1:N1)
      TE6(1:N1)=TE6(1:N1)+TE7(1:N1)*TE(1:N1)+TEMP(1:N1)*TE1(1:N1)
      TE6(1:N1)=TE6(1:N1)*1.E6
C     TE6(1:N1) IS IN J/KG.
      TE7(1:N1)=Q8VGATHR(QEXR(1,1:NXM1),INT(1:N1):TE7(1:N1))
      TE7(1:N1)=(.5*CH(1:N1)-TE7(1:N1))*VE*VE
      TMASS1(1:N1)=TE7(1:N1)/TE6(1:N1)
      RETURN
      END
      SUBROUTINE DERV
      COMMON/E1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/E2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/E3/B2,RE,TW,MM,XX,ZZ,EM,BETA,RN,EL,ELT,JJ,DY
      COMMON/E7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/E8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
      COMMON/E9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
      COMMON/E10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/E11/DU(101,14),DSH(101,14),A6(101,14),A8(101,14)
      COMMON/E13/AU1(101,14,7),THE1(101,14),THE2(101,14),VAIR(101,14),DC
     1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),AO(101,14,7)
      COMMON/E12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
      COMMON/E16/HINF,RE1,RE2,SIGT,VIST(101,14)
      TV1(1,1:NXM)=-ZZ*S1(1,1:NXM)*TZ2(1,1:NXM)/B2
      DU(2,1:NXM3)=(U(3,1:NXM3)-U(1,1:NXM3))/TV1(2,1:NXM3)
```

```
      DSH(2,1:NXM3)=(SH(3,1:NXM3)-SH(1,1:NXM3))/TV1(2,1:NXM3)
      DO 10 I=1,3
      J=I+2
      DCL(2,1,I:NXM3)=(CL(3,1,J:NXM3)-CL(1,1,J:NXM3))/TV1(2,1:NXM3)
   10 CONTINUE
      TV2(1,1:NXM)=(EL+VIST(1,1:NXM)*SIG(1,1:NXM)*ELT/SIGT)*VIS(1,1:NXM)
     1/SIG(1,1:NXM)/RE
      DO 70 N=1,N1
      XX1=1./TV1(1,N)
      DU(1,N)=(4.*U(2,N)-3.*U(1,N)-U(3,N))*XX1
      DSH(1,N)=(4.*SH(2,N)-3.*SH(1,N)-SH(3,N))*XX1
      XX2=1./TV1(M1,N)
      DU(M1,N)=-(4.*U(M11,N)-3.*U(M1,N)-U(M50,N))*XX2
      DSH(M1,N)=-(4.*SH(M11,N)-3.*SH(M1,N)-SH(M50,N))*XX2
      DO 20 I=1,3
      J=I+2
      DCL(1,N,I)=(4.*CL(2,N,J)-3.*CL(1,N,J)-CL(3,N,J))*XX1
      DCL(M1,N,I)=-(4.*CL(M11,N,J)-3.*CL(M1,N,J)-CL(M50,N,J))*XX2
   20 CONTINUE
   70 CONTINUE
      DO 30 I=1,3
   30 DCL(1,1,I:NXM)=TV2(1,1:NXM)*DCL(1,1,I:NXM)
      A6(1,1:NXM)=VIS(1,1:NXM)/RE*(DU(1,1:NXM)-U(1,1:NXM)*CUR1(1,1:NXM)/
     1EMDA(1,1:NXM))
      A8(1,1:NXM)=(1.-Z1(1,1:NXM))/S1(1,1:NXM)
      RETURN
      END
      SUBROUTINE VEC1
      COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/F3/B2,RE,TW,MM,XX,ZZ,FM,BETA,RN,EL,ELT,JJ,DY
      COMMON/F7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
      COMMON/CHEOA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/F8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
      COMMON/F9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
      COMMON/F10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/F11/DU(101,14),DSH(101,14),A6(101,14),A8(101,14)
      COMMON/F12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
      COMMON/F13/AU1(101,14,7),THE1(101,14),THE2(101,14),VAIR(101,14),DC
     1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),AO(101,14,7)
      COMMON/F16/HINF,RE1,RE2,SIGT,VIST(101,14)
      COMMON/F21/A9(101,14),A10(101,14),A13(101,14),AA1(101,14),AA2(101,
     114)
      COMMON/F23/QFXR(101,14)
```

```
 A6(1,1:NXM)=(1.+VIST(1,1:NXM))*A6(1,1:NXM)
 TV1(1,1:NXM)=S1(1,1:NXM)*EMDA(1,1:NXM)*RO(1,1:NXM)
 AU(1,1,1:NXM)=TV1(1,1:NXM)
 AU(1,1,2:NXM)=TV1(1,1:NXM)*U(1,1:NXM)
 AU(1,1,3:NXM)=TV1(1,1:NXM)*V(1,1:NXM)
 AU(1,1,4:NXM)=TV1(1,1:NXM)*(H(1,1:NXM)-P(1,1:NXM)/RO(1,1:NXM))
 AU(1,1,5:NXM)=TV1(1,1:NXM)*CL(1,1,3:NXM)
 AU(1,1,6:NXM)=TV1(1,1:NXM)*CL(1,1,4:NXM)
 AU(1,1,7:NXM)=TV1(1,1:NXM)*CL(1,1,5:NXM)
 TV2(1,1:NXM)=S1(1,1:NXM)*RO(1,1:NXM)*U(1,1:NXM)
 AM(1,1,1:NXM)=TV2(1,1:NXM)
 AM(1,1,2:NXM)=TV2(1,1:NXM)*U(1,1:NXM)+S1(1,1:NXM)*P(1,1:NXM)
 AM(1,1,3:NXM)=TV2(1,1:NXM)*V(1,1:NXM)
 AM(1,1,4:NXM)=TV2(1,1:NXM)*H(1,1:NXM)
 AM(1,1,5:NXM)=TV2(1,1:NXM)*CL(1,1,3:NXM)
 AM(1,1,6:NXM)=TV2(1,1:NXM)*CL(1,1,4:NXM)
 AM(1,1,7:NXM)=TV2(1,1:NXM)*CL(1,1,5:NXM)
 A9(1,2:NXM4)=EMDA(1,2:NXM4)*THES(1,2:NXM4)/RT(1,2:NXM4)
 A10(1,2:NXM4)=S1(1,2:NXM4)*THEC(1,2:NXM4)/RT(1,2:NXM4)
 AA1(1,2:NXM4)=EMDA(1,2:NXM4)*RO(1,2:NXM4)*V(1,2:NXM4)
 A13(1,2:NXM4)=A8(1,2:NXM4)*(DS1(1,2:NXM4)*AU(1,2,1:NXM4)+SS1(1,2:
1NXM4)*AM(1,2,1:NXM4))-AA1(1,2:NXM4)
 AN(1,2,1:NXM4)=TZ4(1,2:NXM4)*A13(1,2:NXM4)
 AQ(1,2,1:NXM4)=A9(1,2:NXM4)*AM(1,2,1:NXM4)+A10(1,2:NXM4)*AA1(1,2:
1NXM4)-TZ3(1,2:NXM4)*A13(1,2:NXM4)
 AA2(1,2:NXM4)=AA1(1,2:NXM4)*U(1,2:NXM4)-EMDA(1,2:NXM4)*A6(1,2:NXM4
1)
 A13(1,2:NXM4)=A8(1,2:NXM4)*(DS1(1,2:NXM4)*AU(1,2,2:NXM4)+SS1(1,2:
1NXM4)*AM(1,2,2:NXM4))-AA2(1,2:NXM4)
 AN(1,2,2:NXM4)=TZ4(1,2:NXM4)*A13(1,2:NXM4)
 AQ(1,2,2:NXM4)=A9(1,2:NXM4)*AM(1,2,2:NXM4)+A10(1,2:NXM4)*AA2(1,2:
1NXM4)+TV2(1,2:NXM4)*CUR1(1,2:NXM4)*V(1,2:NXM4)-S1(1,2:NXM4)*CUR1(
21,2:NXM4)*A6(1,2:NXM4)-P(1,2:NXM4)*S1(1,2:NXM4)*A9(1,2:NXM4)-
3TZ3(1,2:NXM4)*A13(1,2:NXM4)
 AA2(1,2:NXM4)=AA1(1,2:NXM4)*V(1,2:NXM4)+EMDA(1,2:NXM4)*P(1,2:NXM4)
 A13(1,2:NXM4)=A8(1,2:NXM4)*(DS1(1,2:NXM4)*AU(1,2,3:NXM4)+SS1(1,2:
1NXM4)*AM(1,2,3:NXM4))-AA2(1,2:NXM4)
 AN(1,2,3:NXM4)=TZ4(1,2:NXM4)*A13(1,2:NXM4)
 TV1(1,2:NXM4)=A9(1,2:NXM4)*AM(1,2,3:NXM4)+A10(1,2:NXM4)*AA2(1,2:
1NXM4)-TV2(1,2:NXM4)*CUR1(1,2:NXM4)*U(1,2:NXM4)
   AQ(1,2,3:NXM4)=TV1(1,2:NXM4)  -P(1,2:NXM4)*(A10(1,2:NXM4)*EMDA(
31,2:NXM4)+S1(1,2:NXM4)*CUR1(1,2:NXM4))-TZ3(1,2:NXM4)*A13(1,2:NXM4)
 AA2(1,2:NXM4)=AA1(1,2:NXM4)*H(1,2:NXM4)-EMDA(1,2:NXM4)*(VIS(1,2:
1NXM4)/SIG(1,2:NXM4)/RE*((1.+VIST(1,2:NXM4)*SIG(1,2:NXM4)/SIGT)*(DS
2H(1,2:NXM4)-PC(1,2:NXM4))+(EL+ELT*VIST(1,2:NXM4)*SIG(1,2:NXM4)/SIG
4T)*PC(1,2:NXM4))+U(1,2:NXM4)*A6(1,2:NXM4)-QEXR(1,2:NXM4))
```

```
      A13(1,2:NXM4)=A8(1,2:NXM4)*(DS1(1,2:NXM4)*AU(1,2,4:NXM4)+SS1(1,2:
     1NXM4)*AM(1,2,4:NXM4))-AA2(1,2:NXM4)
      AN(1,2,4:NXM4)=TZ4(1,2:NXM4)*A13(1,2:NXM4)
      AQ(1,2,4:NXM4)=A9(1,2:NXM4)*AM(1,2,4:NXM4)+A10(1,2:NXM4)*AA2(1,2:
     1NXM4)-TZ3(1,2:NXM4)*A13(1,2:NXM4)
      DO 10 J=5,7
      I=J-2
      K=J-4
      AA2(1,2:NXM4)=AA1(1,2:NXM4)*CL(1,2,I:NXM4)-EMDA(1,2:NXM4)*DCL(1,2,
     1K:NXM4)
      A13(1,2:NXM4)=A8(1,2:NXM4)*(DS1(1,2:NXM)*AU(1,2,J:NXM4)+SS1(1,2:
     1NXM4)*AM(1,2,J:NXM4))-AA2(1,2:NXM4)
      AN(1,2,J:NXM4)=TZ4(1,2:NXM4)*A13(1,2:NXM4)
      AQ(1,2,J:NXM4)=A9(1,2:NXM4)*AM(1,2,J:NXM4)+A10(1,2:NXM4)*AA2(1,2:
     1NXM4)-TZ3(1,2:NXM4)*A13(1,2:NXM4)
10    CONTINUE
      RETURN
      END
      SUBROUTINE VEC2
      DIMENSION A20(101)
      COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/F3/B2,RE,TW,MM,XX,ZZ,FM,BETA,RN,EL,ELT,JJ,DY
      COMMON/F7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/F8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
      COMMON/F9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
      COMMON/F11/DU(101,14),DSH(101,14),A6(101,14),A8(101,14)
      COMMON/F12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
      COMMON/F13/AU1(101,14,7),THE1(101,14),THE2(101,14),VAIR(101,14),DC
     1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),AQ(101,14,7)
      COMMON/F15/AMO(101,2,7)
      COMMON/F16/HINF,RE1,RE2,SIGT,VIST(101,14)
      COMMON/F23/QFXR(101,14)
      DO 100 I=1,2
      A20(1:M1)=S1(1,I:M1)*RO(1,I:M1)
      AMO(1,I,1:M1)=2.*A20(1:M1)*U(1,I:M1)
      AMO(1,I,2:M1)=A20(1:M1)*(P(1,I:M1)/RO(1,I:M1)+2.*U(1,I:M1)**2)
      AMO(1,I,3:M1)=AMO(1,I,1:M1)*V(1,I:M1)
      AMO(1,I,5:M1)=AMO(1,I,1:M1)*CL(1,I,3:M1)
      AMO(1,I,6:M1)=AMO(1,I,1:M1)*CL(1,I,4:M1)
      AMO(1,I,7:M1)=AMO(1,I,1:M1)*CL(1,I,5:M1)
100   AMO(1,I,4:M1)=AMO(1,I,1:M1)*H(1,I:M1)
      A20(1:M1)=EMDA(1,1:M1)*RO(1,1:M1)
      AN(1,1,1:M1)=A20(1:M1)*V(1,1:M1)-A8(1,1:M1)*(DS1(1,1:M1)*AU(1,1,1:
```

```
1M1)+SS1(1,1:M1)*AMO(1,1,1:M1))
 AN(1,1,2:M1)=A20(1:M1)*(U(1,1:M1)*V(1,1:M1)-A6(1,1:M1)/RO(1,1:M1))
1-A8(1,1:M1)*(DS1(1,1:M1)*AU(1,1,2:M1)+SS1(1,1:M1)*AMO(1,1,2:M1))
 AN(1,1,3:M1)=A20(1:M1)*(V(1,1:M1)*V(1,1:M1)+P(1,1:M1)/RO(1,1:M1))-
1A8(1,1:M1)*(DS1(1,1:M1)*AU(1,1,3:M1)+SS1(1,1:M1)*AMO(1,1,3:M1))
 AN(1,1,4:M1)=A20(1:M1)*(V(1,1:M1)*H(1,1:M1)-VIS(1,1:M1)*(
1DSH(1,1:M1)+(EL-1.)*PC(1,1:M1))/SIG(1,1:M1)/RE/RO(1,1:M1)-
1(U(1,1:M1)*A6(1,1:M1)-QEXR(1,1:M1))/RO(1,1:M1))-A8(1,1
2:M1)*(DS1(1,1:M1)*AU(1,1,4:M1)+SS1(1,1:M1)*AMO(1,1,4:M1))
 A20(1:M1)=A20(1:M1)*V(1,1:M1)
 AN(1,1,5:M1)=A20(1:M1)*CL(1,1,3:M1)-DCL(1,1,1:M1)*EMDA(1,1:M1)-
1A8(1,1:M1)*(DS1(1,1:M1)*AU(1,1,5:M1)+SS1(1,1:M1)*AMO(1,1,5:M1))
 AN(1,1,6:M1)=A20(1:M1)*CL(1,1,4:M1)-DCL(1,1,2:M1)*EMDA(1,1:M1)-
1A8(1,1:M1)*(DS1(1,1:M1)*AU(1,1,6:M1)+SS1(1,1:M1)*AMO(1,1,6:M1))
 AN(1,1,7:M1)=A20(1:M1)*CL(1,1,5:M1)-DCL(1,1,3:M1)*EMDA(1,1:M1)-
1A8(1,1:M1)*(DS1(1,1:M1)*AU(1,1,7:M1)+SS1(1,1:M1)*AMO(1,1,7:M1))
 A30=CUR1(1,1)*S1(1,1)
 AQ(1,1,1:M1)=A30*RO(1,1:M1)*V(1,1:M1)+AN(1,1,1:M1)*TZ3(1,1:M1)
 AQ(1,1,2:M1)=2.*A30*(RO(1,1:M1)*U(1,1:M1)*V(1,1:M1)-A6(1,1:M1))+
1AN(1,1,2:M1)*TZ3(1,1:M1)
 AQ(1,1,3:M1)=A30*(-P(1,1:M1)+RO(1,1:M1)*(V(1,1:M1)*V(1,1:M1)-
1U(1,1:M1)*U(1,1:M1)))+AN(1,1,3:M1)*TZ3(1,1:M1)
 AQ(1,1,4:M1)=A30*(RO(1,1:M1)*V(1,1:M1)*H(1,1:M1)-VIS(1,1:M1)*
1(DSH(1,1:M1)+(EL-1.)*PC(1,1:M1))/RE/SIG(1,1:M1)-U(1,1:M1)*A6(1,1:
1M1)+QEXR(1,1:M1))+AN(1,1,4:M1)*TZ3(1,1:M1)
 AQ(1,1,5:M1)=A30*(RO(1,1:M1)*V(1,1:M1)*CL(1,1,3:M1)-DCL(1,1,1:M1))
1+AN(1,1,5:M1)*TZ3(1,1:M1)
 AQ(1,1,6:M1)=A30*(RO(1,1:M1)*V(1,1:M1)*CL(1,1,4:M1)-DCL(1,1,2:M1))
1+AN(1,1,6:M1)*TZ3(1,1:M1)
 AQ(1,1,7:M1)=A30*(RO(1,1:M1)*V(1,1:M1)*CL(1,1,5:M1)-DCL(1,1,3:M1))
1+AN(1,1,7:M1)*TZ3(1,1:M1)
 AN(1,1,1:M1)=-TZ4(1,1:M1)*AN(1,1,1:M1)
 AN(1,1,2:M1)=-TZ4(1,1:M1)*AN(1,1,2:M1)
 AN(1,1,3:M1)=-TZ4(1,1:M1)*AN(1,1,3:M1)
 AN(1,1,4:M1)=-TZ4(1,1:M1)*AN(1,1,4:M1)
 AN(1,1,5:M1)=-TZ4(1,1:M1)*AN(1,1,5:M1)
 AN(1,1,6:M1)=-TZ4(1,1:M1)*AN(1,1,6:M1)
 AN(1,1,7:M1)=-TZ4(1,1:M1)*AN(1,1,7:M1)
 RETURN
 END
 SUBROUTINE VEC3
 DIMENSION BCL(101,14)
 COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
 COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
 COMMON/F3/B2,RE,TW,MM,XX,ZZ,FM,BETA,RN,EL,ELT,JJ,DY
 COMMON/F6/INT(14),THF(14),TIMP(14),TEMP(14),TF(14),TF1(14),TF2(14)
```

```
     1,TF3(14),TF4(14),TF5(14),TF6(14),TF7(14)
      COMMON/F7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/F8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
      COMMON/F9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
      COMMON/F10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/F12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
      COMMON/F13/AUI(101,14,7),THE1(101,14),THE2(101,14),VAIR(101,14),DC
     1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),AO(101,14,7)
      COMMON/F17/XH2,XHE,ALH,ALHE,AMH,TE,ROE,VE,VISE,SHE,PE
      COMMON/F19/TE11(14),C12,PW(14),EQCONS,EQCH(101,14)
      COMMON/F30/TMASS1(14),TMASS(14)
      BIT BCL
      RO(2,1:NXM2)=AUI(2,1,1:NXM2)/S1(2,1:NXM2)/EMDA(2,1:NXM2)
      U(2,2:NXM5)=AUI(2,2,2:NXM5)/AUI(2,2,1:NXM5)
      V(2,1:NXM2)=AUI(2,1,3:NXM2)/AUI(2,1,1:NXM2)
      TV1(2,1:NXM2)=(U(2,1:NXM2)*U(2,1:NXM2)+V(2,1:NXM2)*V(2,1:NXM2))/2.
      TV2(2,1:NXM2)=AUI(2,1,4:NXM2)/AUI(2,1,1:NXM2)-TV1(2,1:NXM2)
      P(2,1:NXM2)=TV2(2,1:NXM2)*RO(2,1:NXM2)/(EQCH(2,1:NXM2)-1.)
      PW(1:N1)=GSVGATHR(P(2,1:NXM1),INT(1:N1):PW(1:N1))
      P(1,1:NXM1)=GSVSCATR(PW(1:N1),INT(1:N1):P(1,1:NXM1))
      TE(1:N1)=GSVGATHR(WMIX(1,1:NXM1),INT(1:N1):TE(1:N1))
      TE1(1:N1)=PW(1:N1)*TE(1:N1)/TW/EQCONS
      RO(1,1:NXM1)=GSVSCATR(TE1(1:N1),INT(1:N1):RO(1,1:NXM1))
      SH(1,1:NXM)=EQCH(1,1:NXM)*P(1,1:NXM)/RO(1,1:NXM)
      TE2(1:N1)=TMASS(1:N1)/TE1(1:N1)
      V(1,1:NXM1)=GSVSCATR(TE2(1:N1),INT(1:N1):V(1,1:NXM1))
      TE3(1)=(3.*RO(1,1)*V(1,1)+EMDA(3,1)*RO(3,1)*V(3,1)-RO(1,1)*V(1,1)*
     1ZN(2,1))/(4.*RO(2,1)*EMDA(2,1))
      DO 20 N=2,N1
      TE3(N)    =(3.*EMDA(1,N)*BT(1,N)*RO(1,N)*TE2(N)+EMDA(3,N)*BT(3,N)*
     1RO(3,N)*V(3,N))/(4.*EMDA(2,N)*BT(2,N)*RO(2,N))
20    CONTINUE
      V(2,1:NXM1)=GSVSCATR(TE3(1:N1),INT(1:N1):V(2,1:NXM1))
      H(1,1:NXM)=SH(1,1:NXM)+(U(1,1:NXM)*U(1,1:NXM)+V(1,1:NXM)*V(1,1:NXM
     1))/2.
      CL(2,1,3:NXM2)=AUI(2,1,5:NXM2)/AUI(2,1,1:NXM2)
      CL(2,1,4:NXM2)=AUI(2,1,6:NXM2)/AUI(2,1,1:NXM2)
      CL(2,1,5:NXM2)=AUI(2,1,7:NXM2)/AUI(2,1,1:NXM2)
      DO 10 N=1,N1
      ABC=-TMASS(N)*SIG(1,N)*RE/VIS(1,N)/EL/R2* S1(1,N)*TZ2(1,N)*ZZ/2.
      CL(1,N,3)=(CL(2,N,3)+ABC*5.E-6)/(1.+ABC)
      CL(1,N,4)=(CL(2,N,4)+ABC*.925)/(1.+ABC)
      CL(1,N,5)=(CL(2,N,5)+ABC*0.05)/(1.+ABC)
```

```
10    CONTINUE
          CLHEE=XHE*4.003/AMH
      BCL(1,1:NXM)=CL(1,1,3:NXM).GT.CLHEE
      CL(1,1,3:NXM)=QBVCTRL(      CLHEE,BCL(1,1:NXM):CL(1,1,3:NXM))
      BCL(1,1:NXM)=CL(1,1,4:NXM).GT..925
      CL(1,1,4:NXM)=QBVCTRL(0.925      ,BCL(1,1:NXM):CL(1,1,4:NXM))
      BCL(1,1:NXM)=CL(1,1,5:NXM).GT..05
      CL(1,1,5:NXM)=QBVCTRL(0.050      ,BCL(1,1:NXM):CL(1,1,5:NXM))
      BCL(1,1:NXM)=CL(1,1,3:NXM).LT.5.E-6
      CL(1,1,3:NXM)=QBVCTRL(5.E-6,BCL(1,1:NXM):CL(1,1,3:NXM))
      BCL(1,1:NXM)=CL(1,1,4:NXM).LT.5.E-6
      CL(1,1,4:NXM)=QBVCTRL(5.E-6,BCL(1,1:NXM):CL(1,1,4:NXM))
      BCL(1,1:NXM)=CL(1,1,5:NXM).LT.5.E-6
      CL(1,1,5:NXM)=QBVCTRL(5.E-6,BCL(1,1:NXM):CL(1,1,5:NXM))
      CL(1,1,2:NXM)=1.-CL(1,1,1:NXM)-CL(1,1,3:NXM)-CL(1,1,4:NXM)-
     1CL(1,1,5:NXM)
      RETURN
      END
      SUBROUTINE VEC4
      DIMENSION BCL(101,14)
      COMMON/E1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/E2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/E3/B2,RE,TW,MM,XX,ZZ,EM,BETA,RN,EL,ELT,JJ,DY
      COMMON/E6/INT(14),THE(14),TIMP(14),TEMP(14),TE(14),TE1(14),TE2(14)
     1,TE3(14),TE4(14),TE5(14),TE6(14),TE7(14)
      COMMON/E7/U(101,14),V(101,14),RO(101,14),H(101,14),PC(101,14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/E8/BT(101,14),EMDA(101,14),ZN(101,14),R1(101,14)
      COMMON/E9/S1(101,14),SS1(101,14),DS1(101,14),CUR1(101,14)
      COMMON/E10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/E12/TZ2(101,14),Z1(101,14),TZ3(101,14),TZ4(101,14)
      COMMON/E13/AU1(101,14,7),THE1(101,14),THE2(101,14),VAIR(101,14),DC
     1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),A0(101,14,7)
      COMMON/E17/XH2,XHE,ALH,ALHE,AMH,TF,ROF,VF,VISF,SHF,PF
      COMMON/E19/TF11(14),C12,PW(14),EQCONS,EQCH(101,14)
      COMMON/E30/TMASS1(14),TMASS(14)
      BIT BCL
      RO(2,1:NXM5)=AU1(2,1,1:NXM5)/S1(2,1:NXM5)/EMDA(2,1:NXM5)
      U(2,2:NXM8)=AU1(2,2,2:NXM8)/AU1(2,2,1:NXM8)
      V(2,1:NXM5)=AU1(2,1,3:NXM5)/AU1(2,1,1:NXM5)
      TV1(2,1:NXM5)=(U(2,1:NXM5)*U(2,1:NXM5)+V(2,1:NXM5)*V(2,1:NXM5))/2.
      TV2(2,1:NXM5)=AU1(2,1,4:NXM5)/AU1(2,1,1:NXM5)-TV1(2,1:NXM5)
      P(2,1:NXM5)=TV2(2,1:NXM5)*RO(2,1:NXM5)/(EQCH(2,1:NXM5)-1.)
      SH(2,1:NXM5)=EQCH(2,1:NXM5)*P(2,1:NXM5)/RO(2,1:NXM5)
```

```
      CL(2,1,3:NXM5)=AUX1(2,1,5:NXM5)/AUX1(2,1,1:NXM5)
      CL(2,1,4:NXM5)=AUX1(2,1,6:NXM5)/AUX1(2,1,1:NXM5)
      CL(2,1,5:NXM5)=AUX1(2,1,7:NXM5)/AUX1(2,1,1:NXM5)
      U(2,N1:M11)=2.5*U(2,N14:M11)-2.*U(2,N50:M11)+.5*U(2,N52:M11)
      V(2,N1:M11)=2.5*V(2,N14:M11)-2.*V(2,N50:M11)+.5*V(2,N52:M11)
      P(2,N1:M11)=2.5*P(2,N14:M11)-2.*P(2,N50:M11)+.5*P(2,N52:M11)
      SH(2,N1:M11)=SH(2,N14:M11)*2.5-2.*SH(2,N50:M11)+.5*SH(2,N52:M11)
      RO(2,N1:M11)=EOCH(2,N1:M11)*P(2,N1:M11)/SH(2,N1:M11)
      CL(2,N1,3:M11)=2.5*CL(2,N14,3:M11)-2.*CL(2,N50,3:M11)+.5*CL(2,N52,
     13:M11)
      CL(2,N1,4:M11)=2.5*CL(2,N14,4:M11)-2.*CL(2,N50,4:M11)+.5*CL(2,N52,
     14:M11)
      CL(2,N1,5:M11)=2.5*CL(2,N14,5:M11)-2.*CL(2,N50,5:M11)+.5*CL(2,N52,
     15:M11)
      TE3(1)=(3.*TMASS(1)       +EMDA(3,1)*RO(3,1)*V(3,1)-RO(1,1)*V(1,1)*
     1ZN(2,1))/(4.*RO(2,1)*EMDA(2,1))
      DO 20 N=2,N1
      TE3(N)    =(3.*EMDA(1,N)*BT(1,N)*TMASS(N)       +EMDA(3,N)*BT(3,N)*
     1RO(3,N)*V(3,N))/(4.*EMDA(2,N)*BT(2,N)*RO(2,N))
20    CONTINUE
      V(2,1:NXM1)=GSVSCATR(TE3(1:N1),INT(1:N1):V(2,1:NXM1))
      TE(1:N1)=GSVGATHR(WMIX(1,1:NXM1),INT(1:N1):TE(1:N1))
      TE1(1:N1)=GSVGATHR(P(2,1:NXM1),INT(1:N1):TE1(1:N1))
      TE2(1:N1)=GSVGATHR(P(3,1:NXM1),INT(1:N1):TE2(1:N1))
      TE4(1:N1)=GSVGATHR(V(3,1:NXM1),INT(1:N1):TE4(1:N1))
      TE5(1:N1)=(TMASS(1:N1)*(4.*TE3(1:N1)-TE4(1:N1))+4.*TE1(1:N1)-TE2(
     11:N1))/3.
      TE6(1:N1)=TE(1:N1)/TW/EOCONS
      TE7(1:N1)=TMASS(1:N1)*TMASS(1:N1)/TE6(1:N1)
      PW(1:N1)=TE5(1:N1)*TE5(1:N1)-4.*TE7(1:N1)
      PW(1:N1)=VSQRT(PW(1:N1):PW(1:N1))
      PW(1:N1)=(TE5(1:N1)+PW(1:N1))/2.
      TE1(1:N1)=PW(1:N1)*TE6(1:N1)
      TE2(1:N1)=TMASS(1:N1)/TE1(1:N1)
      P(1,1:NXM1)=GSVSCATR(PW(1:N1),INT(1:N1):P(1,1:NXM1))
      RO(1,1:NXM1)=GSVSCATR(TE1(1:N1),INT(1:N1):RO(1,1:NXM1))
      V(1,1:NXM1)=GSVSCATR(TE2(1:N1),INT(1:N1):V(1,1:NXM1))
      DO 10 N=1,N1
      SH(1,N)=EOCH(1,N)*PW(N)/TE1(N)
      ARC=-TMASS(N)*SIG(1,N)*RE/VIS(1,N)/EL/B2* S1(1,N)*TZ2(1,N)*Z7/2.
      CL(1,N,3)=(CL(2,N,3)+ARC*5.E-6)/(1.+ARC)
      CL(1,N,4)=(CL(2,N,4)+ARC*.925)/(1.+ARC)
      CL(1,N,5)=(CL(2,N,5)+ARC*0.05)/(1.+ARC)
10    CONTINUE
      H(1,1:NXM)=SH(1,1:NXM)+(U(1,1:NXM)*U(1,1:NXM)+V(1,1:NXM)*V(1,1:NXM
     1))/2.
```

```
      CLHEE=XHE*4.003/AMH
      BCL(1,1:NXM)=CL(1,1,3:NXM).GT.CLHEE
      CL(1,1,3:NXM)=OPVCTRL(      CLHEE,BCL(1,1:NXM):CL(1,1,3:NXM))
      BCL(1,1:NXM)=CL(1,1,4:NXM).GT..925
      CL(1,1,4:NXM)=OPVCTRL(0.925      ,BCL(1,1:NXM):CL(1,1,4:NXM))
      BCL(1,1:NXM)=CL(1,1,5:NXM).GT..05
      CL(1,1,5:NXM)=OPVCTRL(0.050      ,BCL(1,1:NXM):CL(1,1,5:NXM))
      BCL(1,1:NXM)=CL(1,1,3:NXM).LT.5.E-6
      CL(1,1,3:NXM)=OPVCTRL(5.E-6,BCL(1,1:NXM):CL(1,1,3:NXM))
      BCL(1,1:NXM)=CL(1,1,4:NXM).LT.5.E-6
      CL(1,1,4:NXM)=OPVCTRL(5.E-6,BCL(1,1:NXM):CL(1,1,4:NXM))
      BCL(1,1:NXM)=CL(1,1,5:NXM).LT.5.E-6
      CL(1,1,5:NXM)=OPVCTRL(5.E-6,BCL(1,1:NXM):CL(1,1,5:NXM))
      CL(1,1,2:NXM)=1.-CL(1,1,1:NXM)-CL(1,1,3:NXM)-CL(1,1,4:NXM)-
     1CL(1,1,5:NXM)
      RETURN
      END
      SUBROUTINE THERMO
C  FREE ENERGY, ENTHALPY, AND SPECIFIC HEAT BY APPROXIMATING POLYNOMIALSTHER0030
      REAL MOLEE
      DIMENSION CPI1(101,14,19),ENT(101,14,19)
      DIMENSION BG(101,14)
      COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/F10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/F13/AU1(101,14,7),THE1(101,14),THE2(101,14),VAIR(101,14),DC
     1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),AO(101,14,7)
      COMMON/F21/A9(101,14),A10(101,14),A13(101,14),AA1(101,14),AA2(101,
     114)
      COMMON/CHEON/NE,NS,NA,MM
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/CHEQA2/EH(101,14,19),MOLEE(101,14,19)
      COMMON/CHEQB/ AI(20,3),BI(20,3),CI(20,3),DI(20,3),EI(20,3),
     .              FI(20,3),GI(20,3)
      COMMON/CHEQD/EQRT(101,14,19),Y(101,19),X(101,19),YBAR(101)
      COMMON/CHEQH3/CPI2(101,14,19)
      EQUIVALENCE(CPI1(1,1,1),AU1(1,1,1)),(ENT(1,1,1),AM(1,1,1))
      DESCRIPTOR DA1,DA9
      BIT BG
C     COEFFICINTS ARE INPUT FOR THREE TEMPERATURE RANGES. (1) 300K TO
C     1000K, (2) 1000K TO 6000K, AND (3) 6000K TO 15000K. K AND L
C     DENOTES THE SET OF COEFFICIENTS THAT ARE BEING USED.  COMBINE TO
C     ASSURE SMOOTH TRANSITION BETWEEN EACH OF THE THREE TEMPERATURE
C     INTERVALS. T IS GENERALLY GREATER THAN 6500K.
      RR=1.987
      BG(1,1:NXM)=T(1,1:NXM).LE.6500.
```

```
      ASSIGN DA9,A9(1,1:NXM)
      DA9=O8VCMPRS(T(1,1:NXM),BG(1,1:NXM):DA9)
      L1=O8SLEN(DA9)
      BG(1,1:L1)=A9(1,1:L1).LE.5500.
      ASSIGN DA1,A10(1,1:NXM)
      DA1=O8VCMPRS(A9(1,1:L1),BG(1,1:L1):DA1)
      L2=O8SLEN(DA1)
      AA1(1,1:L2)=DA1*DA1
      AA2(1,1:L2)=DA1*AA1(1,1:L2)
      A13(1,1:L2)=AA1(1,1:L2)*AA1(1,1:L2)
      TV2 (1,1:L2)=VALOG(DA1:TV2 (1,1:L2))
      TV2 (1,1:L2)=1.-TV2 (1,1:L2)
      DO 10 I=1,NS
      CPI2(1,1,I:L2)=RR*(AI(I,2)+BI(I,2)*DA1+CI(I,2)*AA1(1,1:L2)+DI(I,2)
     1*AA2(1,1:L2)+FI(I,2)*A13(1,1:L2))
      FORT(1,1,I:L2)=AI(I,2)* TV2(1,1:L2)-.5*BI(I,2)*DA1-CI(I,2)*AA1(1,1
     1:L2)/6.-DI(I,2)*AA2(1,1:L2)/12.-FI(I,2)*0.05*A13(1,1:L2)+FI(I,2)/
     2DA1-GI(I,2)
      ENT(1,1,I:L2)=RR*DA1*(AI(I,2)+.5*BI(I,2)*DA1+CI(I,2)*AA1(1,1:L2)/3
     1.+DI(I,2)*AA2(1,1:L2)/4.+FI(I,2)*A13(1,1:L2)/5.+FI(I,2)/DA1)
10    CONTINUE
      BG(1,1:L1)=A9(1,1:L1).GT.5500.
      DA1=O8VCMPRS(A9(1,1:L1),BG(1,1:L1):DA1)
      L3=O8SLEN(DA1)
      AA1(1,1:L3)=DA1*DA1
      AA2(1,1:L3)=DA1*AA1(1,1:L3)
      A13(1,1:L3)=AA1(1,1:L3)*AA1(1,1:L3)
       TV2(1,1:L3)=VALOG(DA1: TV2(1,1:L3))
       TV2(1,1:L3)=1.- TV2(1,1:L3)
      DO 20 I=1,NS
       TV1(1,1:L3)=RR*((6.5-.001*DA1)*(AI(I,2)+BI(I,2)*DA1+CI(I,2)*AA1(1
     1,1:L3)+DI(I,2)*AA2(1,1:L3)+FI(I,2)*A13(1,1:L3))+(.001*DA1-5.5)*(AI
     2(I,3)+BI(I,3)*DA1+CI(I,3)*AA1(1,1:L3)+DI(I,3)*AA2(1,1:L3)+FI(I,3)*
     3A13(1,1:L3)))
      CPI1(1,1,I:L1)=O8VMERG( TV1(1,1:L3),CPI2(1,1,I:L2),BG(1,1:L1):
     1CPI1(1,1,I:L1))
       TV1(1,1:L3)=(6.5-.001*DA1)*(AI(I,2)* TV2(1,1:L3)-.5*BI(I,2)*DA1-
     1CI(I,2)*AA1(1,1:L3)/6.-DI(I,2)*AA2(1,1:L3)/12.-FI(I,2)*.05*A13(1,1
     2:L3)+FI(I,2)/DA1-GI(I,2))+(.001*DA1-5.5)*(AI(I,3)* TV2(1,1:L3)-0.5
     3*BI(I,3)*DA1-CI(I,3)*AA1(1,1:L3)/6.-DI(I,3)*AA2(1,1:L3)/12.-FI(I,3
     4)*.05*A13(1,1:L3)+FI(I,3)/DA1-GI(I,3))
      FH(1,1,I:L1)=O8VMERG( TV1(1,1:L3),FORT(1,1,I:L2),BG(1,1:L1):
     1FH(1,1,I:L1))
       TV1(1,1:L3)=RR*DA1*((6.5-.001*DA1)*(AI(I,2)+.5*BI(I,2)*DA1+CI(I,2
     1)*AA1(1,1:L3)/3.+DI(I,2)*AA2(1,1:L3)/4.+FI(I,2)*A13(1,1:L3)/5.+
     2FI(I,2)/DA1)+(.001*DA1-5.5)*(AI(I,3)+.5*BI(I,3)*DA1+CI(I,3)*AA1(1,
```

```
     31:L3)/3.+DI(I,3)*AA2(1,1:L3)/4.+FI(I,3)*A13(1,1:L3)/5.+FI(I,3)/
     4DA1))
      MOLFF(1,1,I:L1)=OSVMERG( TV1(1,1:L3),ENT(1,1,I:L2),BG(1,1:L1):
     1MOLFF(1,1,I:L1))
20    CONTINUE
      BG(1,1:NXM)=T(1,1:NXM).GT.6500.
      DA1=OSVCMPRS(T(1,1:NXM),BG(1,1:NXM):DA1)
      L2=OSSLEN(DA1)
      AA1(1,1:L2)=DA1*DA1
      AA2(1,1:L2)=DA1*AA1(1,1:L2)
      A13(1,1:L2)=AA1(1,1:L2)*AA1(1,1:L2)
       TV2(1,1:L2)=VALOG(DA1: TV2(1,1:L2))
       TV2(1,1:L2)=1.- TV2(1,1:L2)
      DO 30 I=1,NS
         TV1(1,1:L2)=RR*(AI(I,3)+BI(I,3)*DA1+CI(I,3)*AA1(1,1:L2)+DI(I,3)
     1*AA2(1,1:L2)+FI(I,3)*A13(1,1:L2))
      CPI2(1,1,I:NXM)=OSVMERG( TV1(1,1:L2),CPI1(1,1,I:L1),BG(1,1:NXM):
     1CPI2(1,1,I:NXM))
         TV1(1,1:L2)=AI(I,3)* TV2(1,1:L2)-.5*BI(I,3)*DA1-CI(I,3)*AA1(1,1
     1:L2)/6.-DI(I,3)*AA2(1,1:L2)/12.-FI(I,3)*0.05*A13(1,1:L2)+FI(I,3)/
     2DA1-GI(I,3)
      FORT(1,1,I:NXM)=OSVMERG( TV1(1,1:L2),FH(1,1,I:L1),BG(1,1:NXM):
     1FORT(1,1,I:NXM))
       TV1(1,1:L2)=RR*DA1*(AI(I,3)+.5*BI(I,3)*DA1+CI(I,3)*AA1(1,1:L2)/3.
     1+DI(I,3)*AA2(1,1:L2)/4.+FI(I,3)*A13(1,1:L2)/5.+FI(I,3)/DA1)
      ENT(1,1,I:NXM)=OSVMERG( TV1(1,1:L2),MOLFF(1,1,I:L1),BG(1,1:NXM):
     1ENT(1,1,I:NXM))
30    CONTINUE
       TV1(1,1:NXM)=VALOG(P(1,1:NXM): TV1(1,1:NXM))
      DO 50 I=1,NS
50    FORT(1,1,I:NXM)=FORT(1,1,I:NXM)+ TV1(1,1:NXM)
      FH(1,1,1:NS*NXM)=ENT(1,1,1:NS*NXM)
      RETURN                                                    THER0420
      END                                                       THER0430
      SUBROUTINE CHEM(KTEST)
      COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/CHE0A1/SH(101,14),T(101,14),P(101,14),MMIX(101,14),
     1CL(101,14,5)
      COMMON/F13/AU1(101,14,7),THE1(101,14),THE2(101,14),VATR(101,14),DC
     1L(101,14,3),AU(101,14,7),AM(101,14,7),AN(101,14,7),AO(101,14,7)
      COMMON/CHE0N/NE,NS,NA,NN
      COMMON/CHE0D/FORT(101,14,19),Y(101,19),X(101,19),YBAR(101)
      COMMON/CHE0A2/FH(101,14,19),MOLFF(101,14,19)
      COMMON/ITER/HI(101,14),MMIX1(101,14)
      COMMON/CHE0C/MW(19),SYMB(19),AA(19,5),MWEL(5),AAA(101,19,5)
      COMMON/CHE0F/YI1(101,14,19)
```

```
      REAL MW,MOLEF
      HI(1,1:NXM)=0.
      WMIX1(1,1:NXM)=0.
      THE2(1,1:NXM)=0.
      DO 10 I=1,NS
      WMIX1(1,1:NXM)=WMIX1(1,1:NXM)+  YI1(1,1,I:NXM)
   10  THE2(1,1:NXM)= THE2(1,1:NXM)+  YI1(1,1,I:NXM)*MW(I)
C    MOLECULAR WEIGHT OF EQUILIBRIUM MIXTURE                          CHE01760
      WMIX(1,1:NXM)=THE2(1,1:NXM)/WMIX1(1,1:NXM)
C      ENTHALPY OF EQUIL. MIXTURE IN CAL/MOL. DIVIDE BY MIXTURE MOL. WT.
C      TO GET IN CAL/GM.
C      1 CAL/GM = 4184 J/KG.
      DO 20 I=1,NS
      HI(1,1:NXM)=HI(1,1:NXM)+ EH(1,1,I:NXM)*YI1(1,1,I:NXM)
   20 MOLEF(1,1,I:NXM)=  YI1(1,1,I:NXM)/WMIX1(1,1:NXM)
      HI(1,1:NXM)=HI(1,1:NXM)/THE2(1,1:NXM)
      RETURN
      END
      SUBROUTINE CHEQ(KTEST,JF,M1,L,CRIT)
C    CHEMICAL EQUILIBRIUM OF MULTIPHASE SYSTEMS BASED ON THE PRINCIPLE  CHE00030
C    OF MINIMIZATION OF THE FREE ENERGY OF THE MIXTURE                  CHE00040
C   THE CONDENSED SPECIES OPTION IS NOT CURRENTLY IMPLEMENTED.          CHE00110
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/CHEQA2/EH(101,14,19),MOLEF(101,14,19)
      COMMON/CHEQH3/CPI2(101,14,19)
      COMMON/CHEQN/NF,NS,NA,NN
      COMMON/CHEQC/MW(19),SYMB(19),AA(19,5),MWEL(5),AAA(101,19,5)
      COMMON/CHEQD/FORT(101,14,19),Y(101,19),X(101,19),YBAR(101)
      COMMON/ITER/HI(101,14),WMIX1(101,14)
      COMMON/CHEQF/YI1(101,14,19)
      COMMON/CHEQS/SKIP(101)
      COMMON/CHEQT/ CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DFBAR(1
     101),HALL(101),DFDL(101)
      DIMENSION BIG(101)
      BIT BIG
      REAL MW,MWEL,MOLEF
      RCRIT=.1*CRIT
      MNS=M1*NS
      RR=1.987
      NT=0                                                             CHE00420
      SKIP(1:M1)=0.
C    IF KTEST EQ 1 USE MOLE NUMBERS COMPUTED PREVIOUSLLY FOR THIS
C   STATION AS INITIAL GUESS.
C   OTHERWISE,ESTIMATE SPECIES MOLE NUMBERS FROM ELEMENT
C   MASS FRACTIONS.
```

```
      IF(KTEST.EQ.1)GO TO 48
C  STARTING ASSUMPTION - ATOMS ONLY, NO COMPOUNDS
      Y(1,1:MNS)=1.E-7
      Y(1,1:M1)=CL(1,JF,1:M1)/MWEL(1)
      Y(1,2:M1)=CL(1,JF,2:M1)/MWEL(2)
      Y(1,5:M1)=CL(1,JF,3:M1)/MWEL(3)
      Y(1,7:M1)=CL(1,JF,4:M1)/MWEL(4)
      Y(1,15:M1)=CL(1,JF,5 :M1)/MWEL(5)
      GO TO 50
 48   CONTINUE
      DO 42 I=1,NS
 42   Y(1,I:M1)=YI1(1,JF,I:M1)
 50   CONTINUE
C  FREE ENERGY MINIMIZATION BY STEEPEST DESCENT
 60   CONTINUE
      NT=NT+1                                                          CHE00780
      CALL MINENG(NS,NF,JF,MNS,M1,L)
C  LAMBDA AND DIRECTIONAL DERIVATIVE (DELL), AND CONVERGENCE TEST      CHE00800
      XLAMBD(1:M1)=1.
      DELT(1,1:MNS)=X(1,1:MNS)-Y(1,1:MNS)
      DO 100 M=1,M1
      IF(SKIP(M).EQ.1.)GO TO 105
      IF(NT.LE.8)GO TO 107
      IF(NT.GE.17.AND.NT.LE.22)GO TO 107
      CALL TEST(M)
      GO TO 108
 107  CALL TEST1(M)
 108  CONTINUE
      GO TO 100
 105  DO 106 J=1,NS
 106  DELT(M,J)=0.
 100  CONTINUE
C  DERIVATIVE FOR GASEOUS SPECIES.
      F(1,1:MNS)=VABS(DELT(1,1:MNS):F(1,1:MNS))
      CONV(1:M1)=0.
      DEBAR(1:M1)=0.
      DO 110 I=1,NS
      CONV(1:M1)=F(1,I:M1)+CONV(1:M1)
 110  DEBAR(1:M1)=DELT(1,I:M1)+DEBAR(1:M1)
      NTRIES=0
 120  CONTINUE
      HALL(1:M1)=1./(YBAR(1:M1)+XLAMBD(1:M1)*DEBAR(1:M1))
      NTRIES=NTRIES+1
      DO 130 I=1,NS
 130  F(1,I:M1)=(Y(1,I:M1)+XLAMBD(1:M1)*DELT(1,I:M1))*HALL(1:M1)
      F(1,1:MNS)=VALOG(F(1,1:MNS):F(1,1:MNS))
```

```
      DFDL(1:M1)=0.
      DO 140 I=1,NS
      F(1,I:M1)=DELT(1,I:M1)*(FORT(1,JF,I:M1)+F(1,I:M1))
  140 DFDL(1:M1)=DFDL(1:M1)+F(1,I:M1)
C   IF DFDL < 0, WE ARE GOING THE RIGHT WAY ON FREE ENERGY SURFACE.      CHEQ1220
C   IF NOT, REDUCE LAMBDA AND TRY AGAIN...
      BIG(1:M1)=SKIP(1:M1).EQ.1.
      DFDL(1:M1)=Q8VCTRL(1.E-10,BIG(1:M1):DFDL(1:M1))
      BIG(1:M1)=DFDL(1:M1).GE.1.E-9
      HALL(1:M1)=.75*XLAMBD(1:M1)
      XLAMBD(1:M1)=Q8VCTRL(HALL(1:M1),BIG(1:M1):XLAMBD(1:M1))
      II=Q8SGE(DFDL(1:M1),1.E-9)
      IF(II.EQ.M1)GO TO 200
      IF(NTRIES.GT.16)GO TO 600
      GO TO 120                                                         CHEQ1290
  200 CONTINUE                                                          CHEQ1330
C   NEW MOLE FRACTIONS
      HALL(1:M1)=VABS(DFDL(1:M1):HALL(1:M1))
      BIG(1:M1)=HALL(1:M1).LT.1.E-9
      CONV(1:M1)=Q8VCTRL(RCRIT,BIG(1:M1):CONV(1:M1))
      BIG(1:M1)=CONV(1:M1).LE.CRIT
      XLAMBD(1:M1)=Q8VCTRL(0.,BIG(1:M1):XLAMBD(1:M1))
      SKIP(1:M1)=Q8VCTRL(1.,BIG(1:M1):SKIP(1:M1))
      II=Q8SGE(CONV(1:M1),CRIT)
      IF(II.EQ.M1)GO TO 600
      DO 220 I=1,NS
  220 Y(1,I:M1)=Y(1,I:M1)+XLAMBD(1:M1)*DELT(1,I:M1)
      IF(NT.LT.50)GO TO 500
      WRITE(6,231)
  231 FORMAT(/1X,'NO. OF ITERATIONS EXCEED  50'/)
      DO 350 M=1,M1
      IF(SKIP(M).EQ.1.)GO TO 350
      WRITE(6,300)L,JF,M,P(M,JF),T(M,JF),DFDL(M),CONV(M),XLAMBD(M)
  350 CONTINUE
  300 FORMAT(1X,I5,5X,I4,5X,I4,5X,'P=',F12.5,5X,'T=',F13.5,5X,'DFDL=',
     1E12.5,3X,'CONV=',E12.5,3X,'XLAMBD=',E11.5)
      GO TO 600
  500 GO TO 60
  600 CONTINUE                                                          CHEQ1680
      DO 620 I=1,NS
  620 YI1(1,JF,I:M1)=Y(1,I:M1)
      RETURN                                                            CHEQ2150
      END                                                               CHEQ2160
      SUBROUTINE TEST(M)
      COMMON/CHEQN/NF,NS,NA,NN
      COMMON/CHEQD/FORT(101,14,19),Y(101,19),X(101,19),YBAR(101)
```

```
      COMMON/CHEQT/ CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DFBAR(1
     101),HALL(101),DFDL(101)
      DO 107 I=1,NS
      IF(DELT(M,I).GE.0.)GO TO 107
      IF(Y(M,I)/YBAR(M).LT.1.E-7)GO TO 101
      XLAM=-Y(M,I)/DELT(M,I)
      IF(XLAM.GE.XLAMBD(M))GO TO 107
      XLAMBD(M)=0.9999999*XLAM
      GO TO 107
  101 DELT(M,I)=0.
  107 CONTINUE
      RETURN
      END
      SUBROUTINE TEST1(M)
      COMMON/CHEQN/NE,NS,NA,NN
      COMMON/CHEQD/FORT(101,14,19),Y(101,19),X(101,19),YBAR(101)
      COMMON/CHEQT/ CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DFBAR(1
     101),HALL(101),DFDL(101)
      DO 107 I=1,NS
      IF(DELT(M,I).GE.0.)GO TO 107
      XLAM=-Y(M,I)/DELT(M,I)
      IF(XLAM.GE.XLAMBD(M))GO TO 107
      XLAMBD(M)=0.9999999*XLAM
  107 CONTINUE
      RETURN
      END
      SUBROUTINE MINENG(NS,NE,JF,MNS,M1,L)
C  FIT N-DIMENSIONAL PARABOLA TO POINT IN FREE-ENERGY SPACE, WHERE      MINE0030
C  N IS NUMBER OF ELEMENTS IN SYSTEM.
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/CHEQA2/EH(101,14,19),MOLEF(101,14,19)
      COMMON/CHEQH3/CPI2(101,14,19)
      COMMON/CHEQC/MW(19),SYMB(19),AA(19,5),MWFL(5),AAA(101,19,5)
      COMMON/CHEQD/FORT(101,14,19),Y(101,19),X(101,19),YBAR(101)
      COMMON/CHEQG/A1(101,6,6),BB1(101,6)
      COMMON/CHEQS/SKIP(101)
      DIMENSION DELTA(101,19,5),F(101,19),DELT(101,19),BIM(101),XYBAR(
     1101),R1(101,6,6)
      MMM=NE+1
      MX=36*M1
      MNE=M1*NE
      MNE1=MMM*M1
      YBAR(1:M1)=0.
      DO 100 I=1,NS
  100 YBAR(1:M1)=YBAR(1:M1)+Y(1,I:M1)
```

```
C  SET UP AND SOLVE MATRIX
      BB1(1,1:606)=0.
      DO 110 J=1,NE
      DELTA(1,1,J:MNS)=AAA(1,1,J:MNS)*Y(1,1:MNS)
      DO 110 I=1,NS
  110 BB1(1,J:M1)=DELTA(1,I,J:M1)+BB1(1,J:M1)
C  (1) FREE ENERGY - GASEOUS SPECIES
      DO 170 I=1,NS
  170 F(1,I:M1)=Y(1,I:M1)/YBAR(1:M1)
      F(1,1:MNS)=VALOG(F(1,1:MNS):F(1,1:MNS))
      DO 180 I=1,NS
  180 F(1,I:M1)=Y(1,I:M1)*(FORT(1,JF,I:M1)+F(1,I:M1))
C  INITIALIZE MATRICES
      A1(1,1,1:MX)=0.
      R1(1,1,1:MX)=0.
      A1(1,1,1:MNE)=BB1(1,1:MNE)
      DO 270 J=1,NE                                              MINE0900
      DO 270 K=1,J
      DELT(1,1:MNS)=AAA(1,1,J:MNS)*DELTA(1,1,K:MNS)
      DO 275 I=1,NS
  275 R1(1,J,K:M1)=DELT(1,I:M1)+R1(1,J,K:M1)
  270 R1(1,K,J:M1)=R1(1,J,K:M1)
      DO 280 J=2,MMM
      K=J-1
  280 A1(1,1,J:MNE)=R1(1,1,K:MNE)
      DO 310 J=2,MMM
      K=J-1
  310 A1(1,MMM,J:M1)=A1(1,K,1:M1)
      DO 320 J=1,NE
      DELT(1,1:MNS)=AAA(1,1,J:MNS)*F(1,1:MNS)
      BUM(1:M1)=0.
      DO 330 I=1,NS
  330 BUM(1:M1)=DELT(1,I:M1)+BUM(1:M1)
  320 BB1(1,J:M1)=BB1(1,J:M1)+BUM(1:M1)
      BUM(1:M1)=0.
      DO 340 I=1,NS
  340 BUM(1:M1)=BUM(1:M1)+F(1,I:M1)
      BB1(1,MMM:M1)=BUM(1:M1)
      CALL EQSOL(MMM,NE,M1)
C  NEW MOLE FRACTIONS (X)
      XYBAR(1:M1)=BB1(1,1:M1)
      BB1(1,1:MNE)=BB1(1,2:MNE)
      DELT(1,1:MNS)=0.
      DO 390 J=1,NE
      DO 400 I=1,NS
  400 DELT(1,I:M1)=DELT(1,I:M1)+AAA(1,I,J:M1)*BB1(1,J:M1)
```

```
390   CONTINUE
      DO 410 I=1,NS
410   DELT(1,I:M1)=DELT(1,I:M1)+XYBAR(1:M1)
      X(1,1:MNS)=DELT(1,1:MNS)*Y(1,1:MNS)-F(1,1:MNS)
      RETURN                                                          MINF1730
      END
      SUBROUTINE EQSOL(MMM,NE,M1)
      COMMON/CHEOG/A1(101,6,6),BB1(101,6)
      DIMENSION U(101,6),S(101),TK2(101),UT(101)
      DO 200 K=1,NE
      J=K
      S(1:M1)=0.
      DO 20 I=K,MMM
20    S(1:M1)=S(1:M1)+A1(1,I,J:M1)*A1(1,I,J:M1)
      S(1:M1)=VSQRT(S(1:M1):S(1:M1))
      U(1,K:M1)=A1(1,K,J:M1)+VSIGN(S(1:M1),A1(1,K,J:M1):UT(1:M1))
      KP1=K+1
      KM1=M1*(MMM-K)
      U(1,KP1:KM1)=A1(1,KP1,J:KM1)
      A1(1,K,J:M1)=-VSIGN(S(1:M1),A1(1,K,J:M1):UT(1:M1))
      TK2(1:M1)=U(1,K:M1)*S(1:M1)
      TK2(1:M1)=VABS(TK2(1:M1):TK2(1:M1))
      JK=K+1
      DO 70 JJ=JK,MMM
      UT(1:M1)=0.
      DO 50 III=K,MMM
 50   UT(1:M1)=UT(1:M1)+U(1,III:M1)*A1(1,III,JJ:M1)
      UT(1:M1)=UT(1:M1)/TK2(1:M1)
      DO 40 II=K,MMM
40    A1(1,II,JJ:M1)=A1(1,II,JJ:M1)-U(1,II:M1)*UT(1:M1)
70    CONTINUE
      UT(1:M1)=0.
      DO 80 II=K,MMM
80    UT(1:M1)=UT(1:M1)+U(1,II:M1)*BB1(1,II:M1)
      UT(1:M1)=UT(1:M1)/TK2(1:M1)
      DO 60 II=K,MMM
60    BB1(1,II:M1)=BB1(1,II:M1)-U(1,II:M1)*UT(1:M1)
200   CONTINUE
      BB1(1,6:M1)=BB1(1,6:M1)/A1(1,6,6:M1)
      BB1(1,5:M1)=(BB1(1,5:M1)-A1(1,5,6:M1)*BB1(1,6:M1))/A1(1,5,5:M1)
      BB1(1,4:M1)=(BB1(1,4:M1)-A1(1,4,6:M1)*BB1(1,6:M1)-A1(1,4,5:M1)*
     1BB1(1,5:M1))/A1(1,4,4:M1)
      BB1(1,3:M1)=(BB1(1,3:M1)-A1(1,3,6:M1)*BB1(1,6:M1)-A1(1,3,5:M1)*
     1BB1(1,5:M1)-A1(1,3,4:M1)*BB1(1,4:M1))/A1(1,3,3:M1)
      BB1(1,2:M1)=(BB1(1,2:M1)-A1(1,2,6:M1)*BB1(1,6:M1)-A1(1,2,5:M1)*
     1BB1(1,5:M1)-A1(1,2,4:M1)*BB1(1,4:M1)-A1(1,2,3:M1)*BB1(1,3:M1))/
```

```
     1A1(1,2,2:M1)
      BB1(1,1:M1)=(BB1(1,1:M1)-A1(1,1,6:M1)*BB1(1,6:M1)-A1(1,1,5:M1)*
     1BB1(1,5:M1)-A1(1,1,4:M1)*BB1(1,4:M1)-A1(1,1,3:M1)*BB1(1,3:M1)-
     1A1(1,1,2:M1)*BB1(1,2:M1))/A1(1,1,1:M1)
      RETURN
      END
      SUBROUTINE READ
      REAL MW,MWEL
      COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/CHEQA2/EH(101,14,19),MOLEF(101,14,19)
      COMMON/CHEQH3/CPI2(101,14,19)
      COMMON/CHEQN/NE,NS,NA,NN
      COMMON/CHEQB/ AI(20,3),BI(20,3),CI(20,3),DI(20,3),EI(20,3),
     .              FI(20,3),GI(20,3)
      COMMON/CHEQC/MW(19),SYMB(19),AA(19,5),MWEL(5),AAA(101,19,5)
      COMMON/TP3/XMA(20),XMB(20),XMC(20),XKA(20),XKB(20)
      DIMENSION ILWP(6)
      DIMENSION ILW(9)
      DATA ILW/5H   SI,5H    F,5H    O,5H    N,5H    C,5H   HE,
     15H    H,5H   E-,5H    /
      NAMELIST/THERMO/       MW,MWEL,NA,NE,NS,NN
      NN=0
      NIT=0                                                          READ0910
      IUNIT=1
      XLEWIS = 0.0
      XPRAND=0.0
C  INPUT PROBLEM NAMELISTS
 20   READ(5,THERMO)                                                 READ1460
      WRITE(6,THERMO)
      DO 60 I=1,NS
      READ(5,901) SYMB(I),(AA(I,J),J=1,NE)                          READ1610
      DO 55 J= 1,3
 55   READ(5,902)AI(I,J),BI(I,J),CI(I,J),DI(I,J),EI(I,J),FI(I,J),GI(I,J)READ1630
      READ(5,902)XMA(I),XMB(I),XMC(I),XKA(I),XKB(I)                  READ1640
 60   CONTINUE                                                       READ1670
C  THERMOCHEMICAL PROPERTIES
      WRITE(6,919)                                                   READ2000
      DO 120 I=1,NS                                                  READ2010
      WRITE(6,920) SYMB(I),(AI(I,J),BI(I,J),CI(I,J),DI(I,J),EI(I,J),  READ2020
     .                      FI(I,J),GI(I,J),J= 1,3)
 120  CONTINUE                                                       READ2040
  122 WRITE(6,921)
      DO 130 I=1,NS                                                  READ2060
      WRITE(6,922) SYMB(I),XMA(I),XMB(I),XMC(I),XKA(I),XKB(I)        READ2070
```

```
                                                                      READ2080
 130  CONTINUE
C  SPECIES/ELEMENTAL COMPOSITION MATRIX
C  (THIS LOOP IS KEYED TO THE C-H-O-N-HE SYSTEM)
      DO 135 I=1,NE
      ILWP(I)=ILW(1)
      IF(MWEL(I).LT.27.) ILWP(I)=ILW(2)
      IF(MWEL(I).LT.17.) ILWP(I)=ILW(3)
      IF(MWEL(I).LT.15.) ILWP(I)=ILW(4)
      IF(MWEL(I).LT.13.) ILWP(I)=ILW(5)
      IF(MWEL(I).LT.4.1) ILWP(I)=ILW(6)
      IF(MWEL(I).LT.1.1) ILWP(I)=ILW(7)
      IF(MWEL(I).LT.0.1) ILWP(I)=ILW(8)
      IF(MWEL(I).EQ.0.0) ILWP(I)=ILW(9)
                                                                      READ2200
 135  CONTINUE                                                       READ2210
      WRITE(6,923) ILWP                                              READ2220
      DO 140 I=1,NS
      DO 137 J=1,NE
      IF(AA(I,J).EQ.0.) AA(I,J)=0.
 137  CONTINUE                                                       READ2230
      WRITE(6,924) SYMB(I),(AA(I,J),J=1,NE)                          READ2240
 140  CONTINUE                                                       READ3510
 901  FORMAT(A6,4X,6F5.0)                                            READ3520
 902  FORMAT(5F14.6)
 919  FORMAT(1H1,34X,'THERMOPHYSICAL PROPERTIES - CURVE FIT COEFFICIENTS
     .'//46X,'(1) THERMODYNAMIC PROPERTIES'//4X,'SPECIES',11X,'A',14X,
     .'B',14X,'C',14X,'D',14X,'E',14X,'F',14X,'G'/)
 920  FORMAT(1H0,5X,A6,3X,7E15.6,' T= 300K'/15X,7E15.6,' T=1000K'/15X,
     .  7E15.6,' T=6000K')
 921  FORMAT(1H0/4X,'SPECIES',30X,'VISCOSITY',28X,1H*,12X,'CONDUCTIVITY'READ38
                                                                      READ3850
     ./)                                                            READ3860
 922  FORMAT(1H ,4X,A6,4X,3E20.6,3X,1H*,E16.6,E20.6)
 923  FORMAT(1H0//49X,'ELEMENTAL PARTICLES TABLE'/42X,' SPECIES ',6A5)
                                                                      READ3880
 924  FORMAT(1H ,43X,A6,1X,6F5.0)
      NSNEM1=NS*NE*M1
      AAA(1,1,1:NSNEM1)=0.
      DO 110 I=1,M1
      DO 110 J=1,NS
      DO 110 K=1,NE
 110  AAA(I,J,K)=AA(J,K)
      RETURN                                                          READ3890
      END
      SUBROUTINE TP
      REAL MOLEF,MW
      COMMON/F1/N1,N14,N50,N52,M1,M11,M50,NJ,NJ1
      COMMON/F2/NXM,NXM1,NXM3,NXM4,NXM5,NXM8,NXM2,NXMM
      COMMON/F6/INT(14),THE(14),TIMP(14),TEMP(14),TF(14),TF1(14),TF2(14)
```

```
     1,TE3(14),TE4(14),TE5(14),TE6(14),TE7(14)
      COMMON/E21/A9(101,14),A10(101,14),A13(101,14),AA1(101,14),AA2(101,
     114)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/CHEQA2/EH(101,14,19),MOLEE(101,14,19)
      COMMON/CHEQH3/CPI2(101,14,19)
      COMMON/CHEQN/NE,NS,NA,NN
      COMMON/CHEQC/MW(19),SYMB(19),AA(19,5),MWEL(5),AAA(101,19,5)
      COMMON/CHEQD/EORT(101,14,19),Y(101,19),X(101,19),YBAR(101)
      COMMON/TRANS/VIS(101,14),TK(14),SIG(101,14)
      COMMON/TP3/XMA(20),XMB(20),XMC(20),XKA(20),XKB(20)                    TP  0290
      DIMENSION B1(101,14)
      BIT B1
C     HERE EH REPRESENTS VISCOSITY OF SPECIE I.
      DO 200 I=1,NS
      EH(1,1,I:NXM)=(XMA(I)+XMB(I)*T(1,1:NXM)+XMC(I)*T(1,1:NXM)*T(1,1:
     1NXM))/.0672
      B1(1,1:NXM)=EH(1,1,I:NXM).LE.0.
      EH(1,1,I:NXM)=Q8VCTRL(1.E-10,B1(1,1:NXM):EH(1,1,I:NXM))
  200 CONTINUE                                                          TP  0720
C     SPECIFIC HEAT OF MIXTURE
      A9(1,1:NXM)=0.
      DO 201 I=1,NS
      A9(1,1:NXM)=A9(1,1:NXM)+CPI2(1,1,I:NXM)*MOLEE(1,1,I:NXM)
  201 CONTINUE                                                          TP  0780
C    HERE EORT REPRESENTS THE THERMAL CONDUCTIVITY OF SPECIE I.
      DO 206 I=1,NS
      EORT(1,1,I:NXM)=(XKA(I)+XKB(I)*T(1,1:NXM))/.0672
  206 CONTINUE                                                          TP  0850
C     WILKE RELATION FOR MIX. VISCOSITY,THERMAL CONDUCTIVITY AND PRANDTL NO.
      VIS(1,1:NXM)=0.
      A10(1,1:NXM)=0.
      DO 204 I=1,NS
      A13(1,1:NXM)=0.
      DO 205 J=1,NS
      DENOM1=2.82*SQRT(1.0+MW(I)/MW(J))
      WJI=SQRT(MW(J)/MW(I))
      WJI=SQRT(WJI)
      AA1(1,1:NXM)=EH(1,1,I:NXM)/EH(1,1,J:NXM)
      AA1(1,1:NXM)=VSQRT(AA1(1,1:NXM):AA1(1,1:NXM))
      AA1(1,1:NXM)=1.+AA1(1,1:NXM)*WJI
      AA1(1,1:NXM)=AA1(1,1:NXM)*AA1(1,1:NXM)
      A13(1,1:NXM)=A13(1,1:NXM)+MOLEE(1,1,J:NXM)*AA1(1,1:NXM)/DENOM1
  205 CONTINUE                                                          TP  0980
      VIS(1,1:NXM)=MOLEE(1,1,I:NXM)*EH(1,1,I:NXM)/A13(1,1:NXM)+VIS(1,1:
```

```
     1NXM)
      A10(1,1:NXM)=MOLEF(1,1,I:NXM)*FORT(1,1,I:NXM)/A13(1,1:NXM)+A10(1,1
     1:NXM)
  204 CONTINUE                                                          TP  1010
      TK(1:N1)=OSVGATHR(A10(1,1:NXM1),INT(1:N1):TK(1:N1))
      SIG(1,1:NXM)=VIS(1,1:NXM)*A9(1,1:NXM)/A10(1,1:NXM)/WMIX(1,1:NXM)
      RETURN
      END                                                               TP  1200
      SUBROUTINE ATRAD(JF)
      REAL MW,MOLEF,MOLEF1,MWEL
      COMMON/F5/S(14),SS(14),G(14),CUR(14),US(14),DS(14),VN(14),VS(14)
      COMMON/F10/THEC(101,14),THES(101,14),TV1(101,14),TV2(101,14)
      COMMON/CHEQA1/SH(101,14),T(101,14),P(101,14),WMIX(101,14),
     1CL(101,14,5)
      COMMON/CHEQA2/EH(101,14,19),MOLEF(101,14,19)
      COMMON/CHEQC/MW(19),SYMB(19),AA(19,5),MWEL(5),AAA(101,19,5)
      COMMON/CHEQN/NE,NS,NA,NN
      COMMON/TRNV/P2(51),T2(51),SSO2(15),MOLEF1(51,21),P2S,T2S,PFAC,TFAC
      COMMON/NORD/DN(51)
      COMMON/PROB/ETA(51),E(51),BE1(51),BE2(51),TRC(51),TOTP(51),
     .CONTF1(51),CONTF2(51),P2P2(51)
      COMMON/CTRL/IE,IOUTPT,M,   NIT,NUMB,   OVLY,ROLY,NMP,TIMET,
     .NBODY,ITPO,MACE,IOPT,INDS,XLEWIS,XPRAND
      COMMON/CONT/IBNINJ,IDATAP,IDATAR,IDEBUG,IFLUXC,IRSKIP,ISUBLM,
     .ITRIGR,MEND,MSTART,   NC,NEREQ,NINT,NINT1,NTT,NT7
      COMMON/LRAD/IFZ,IRONLY,IMPON,LINES,MF,NETAX,NSR,ROF,UF,XOTIL,XMOL
      COMMON/SMALL/ DUMIT(40),IDGE(6)                                   RADIO160
      COMMON/GEOMER/ GDUM(14),RN
      COMMON/CHEQQ/QR1(51)
      COMMON/F23/QFXR(101,14)
      DATA P2S,T2S,PFAC,TFAC,LINES,XMOL/1.,1.,1.,1.,1,1./
      DATA(IDGE(J),J=1,6)/20,20,17,17,20,0/
      M=JF
      MOLEF1(1,1:51*21)=0.
      DO 10 I=1,101,2
      J=(I+1)/2
      P2(J)=P(I,M)
      T2(J)=T(I,M)
      ETA(J)=TV1(I,M)
      IE=J
      DO 10 K=1,NS
   10 MOLEF1(J,K)=MOLEF(I,M,K)
      IM=IE-1
      DN(1:IM)=ETA(2:IM)-ETA(1:IM)
      NETAX=25
      IDEBUG=0
```

```
      SSO2(M)=S(M)
      RN=1./30.48
      CALL AERD
      CALL ARADPO
      DO 20 N=1,101,2
      J=(N+1)/2
   20 QFXR(N,M)=QR1(J)
      DO 30 N=2,100,2
      N11=N-1
      N22=N+1
   30 QFXR(N,M)=QFXR(N11,M)+(QFXR(N22,M)-QFXR(N11,M))*(TV1(N,M)-TV1(N11,
     1M))/(TV1(N22,M)-TV1(N11,M))
      RETURN
      END
      SUBROUTINE AERD
      REAL MOLEF1
      COMMON/TRNV/P2(51),T2(51),SSO2(15),MOLEF1(51,21),P2S,T2S,PFAC,TFAC
      COMMON/NORD/DN(51)
      COMMON/PROB/ETA(51),F(51),BE1(51),BE2(51),TRC(51),TDTP(51),
     .CONTE1(51),CONTE2(51),P2P2(51)
      COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),FF(300),FHVC(50),FHV(25),
     .FHVM(25),FHVP(25),GAMP(300),GEE(56),GUP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XMOL(300),
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
     .FHVS(200),NSHC(25)
      COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
     .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
     .FMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
     .FRP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
     .SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
      COMMON/AERAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,      ARAD0190
     .         NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SF(5)
      COMMON/CHEQN/NE,NS,NA,NN
      COMMON/CTRL/IE,IOUTPT,M,    NIT,NUMB,    OVLY,RDLY,NMP,TIMET,
     .NBODY,ITPO,MACE,IOPT,INDS,XLEWIS,XPRAND
      COMMON/CONT/IBNINJ,IDATAP,IDATAR,IDEBUG,IFLUXC,IRSKIP,ISUBLM,
     .ITRIGR,MEND,MSTART,    NC,NFREQ,NINT,NINT1,NTT,NTZ
      COMMON/LRAD/IEZ,IRONLY,IMPON,LINES,MF,NETAX,NSR,ROE,UE,XDTIL,XMOL
      COMMON/SFLUX/QRI(3),DIFQRW,FP,FM
      COMMON/QCMX/ QCML                                                 ARAD0240
      COMMON/CHEQT/CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DEBAR(
     1101),HALL(101),DEDL(101)
      SFMIS=0.0                                                         ARAD0350
      NMP=51
   20 CALL RADIN
      CALL TRANSP
```

```
      QRTEMP=QRI(1)
      VX(1:NY)=FIMI(1:NY)-FIPI(1:NY)+TLCM(1:NY)-TLCP(1:NY)
      CALL CODIM(YY,VX,NY,ETA,QR,IE)
      CALL NDERIV(QR,BE2,IE,1,1,NMP)
      BE2(1:IE)=BE2(1:IE)/DELTA
      QR(1:IE)=-QR(1:IE)
      IM=IE-1
      IM1=IM-1
      CONV(1:IM1)=(ETA(2:IM1)-ETA(1:IM1))/(ETA(3:IM1)-ETA(2:IM1))
      XLAMBD(1:IM1)=1./CONV(1:IM1)
      DEDL(1:IM1)=1./(1.+CONV(1:IM1))
      HALL(1:IM1)=1./(1.+XLAMBD(1:IM1))
      BE2(1:IM1)=0.5*(DEDL(1:IM1)*BE2(1:IM1)+BE2(2:IM1)+HALL(1:IM1)*
     1BE2(3:IM1))
      QRI(1)=QR(1)                                                    ARAD0560
      QRI(2)=QR(IMPON)
      QRI(3)=QR(IE)                                                   ARAD0580
      DIFQRW=1.0-QRTEMP/QR(1)
      DIFQRW=ABS(DIFQRW)
      WRITE(6,40) QRTEMP,QRI(1),DIFQRW
   40 FORMAT(1X,'QRTEMP=',E12.5,'     QRI(1)=',E12.5,'     DIFQRW=',
     .     E12.5)
      IF(IDEBUG.EQ.0) GO TO 401
      WRITE(6,900)                                                    ARAD0630
  900 FORMAT(1H1//43X,'RADIATIVE FLUX VS. FREQUENCY - AEROTHERM MODEL'//
     . 4X,26(1H-),'CONTINUUM',54(1H-),'LINE GROUPS',25(1H-))
      WRITE(6,901) ETA(1),ETA(IMPON),ETA(IE),ETA(1),ETA(IMPON),ETA(IE)
  901 FORMAT(1H0,6X,'ETA =',F16.2,F21.2,F16.2,F29.2,F21.2,F16.2/6X,'FREQ
     ..',4X,'Q-MINUS',4X,'Q-PLUS',4X,'Q-MINUS',4X,'Q-PLUS',4X,'Q-MINUS',ARAD069
     .   9X,'FREQ.',4X,'Q-MINUS',4X,'Q-PLUS',4X,'Q-MINUS',4X,'Q-PLUS',
     .   4X,'Q-MINUS')
      NVMX=MAXO(NHV,NIHVC)                                            ARAD0720
      DO 400 I=1,NVMX                                                 ARAD0730
      WRITE(6,902)                                                    ARAD0740
  902 FORMAT(1H )                                                     ARAD0750
      IF(I.GT.NIHVC) GO TO 360                                        ARAD0760
      WRITE(6,903) I,FHVC(I),(FIMC(I,J),FIPC(I,J),J=1,2),FIMC(I,3)    ARAD0770
  360 IF(I.GT.NHV) GO TO 400                                          ARAD0780
      WRITE(6,904) FHV(I),(FIML(I,J),FIPL(I,J),J=1,2),FIML(I,3)       ARAD0790
  400 CONTINUE                                                        ARAD0800
      J=MIDPNT                                                        ARAD0810
      WRITE(6,905) FIMI(1),FIPI(1),FIMI(J),FIPI(J),FIMI(NY),
     .             TLCM(1),TLCP(1),TLCM(J),TLCP(J),TLCM(NY)
  401 CONTINUE
      FP=FIMI(1)+TLCM(1)
      FM=FIPI(1)+TLCP(1)
```

```
      WRITE(6,906) DELTA,QRI                                              ARAD0850
  903 FORMAT(1H+,I3,F8.3,E11.3,E10.3,E11.3,F10.3,E11.3)                   ARAD0910
  904 FORMAT(1H+,70X,F8.3,E11.3,E10.3,E11.3,E10.3,E11.3)                  ARAD0920
  905 FORMAT(1H0,' TOTAL FLUX',2(E11.3,E10.3),F11.3,14X,2(E11.3,E10.3),   ARAD
     . E11.3)                                                             ARAD0940
  906 FORMAT(1H0,'    DELTA='E15.6,' CM.      RADIATIVE FLUX ='3F15.6,.
     .'WATTS/CM--2'//4X,125(1H-))
      IF(IRONLY.GT.0) GO TO 20
      RETURN
      END                                                                 ARAD1020
      SUBROUTINE RADIN
      REAL MOLEF1,MW
      COMMON/TRNV/P2(51),T2(51),SSO2(15),MOLEF1(51,21),P2S,T2S,PFAC,TFAC
      COMMON/CHEQC/MW(19),SYMB(19),AA(19,5),MWEL(5),AAA(101,19,5)
      COMMON/CHEQN/NE,NS,NA,NN
      COMMON/CTRL/IE,IOUTPT,M,   NIT,NUMB,   QVLY,RDLY,NMP,TIMFT,
     .NBODY,ITPO,MACE,IOPT,INDS,XLEWIS,XPRAND
      COMMON/CONT/IBNINJ,IDATAP,IDATAR,IDEBUG,IFLUXC,IRSKIP,ISUBLM,
     .ITRIGR,MEND,MSTART,   NC,NFREQ,NINT,NINT1,NTT,NTZ
      COMMON/GEOMER/ GDUM(14),RN
      COMMON/LRAD/IEZ,IRONLY,IMPON,LINES,MF,NETAX,NSR,ROF,UF,XDTIL,XMOL
      COMMON/PROB/ETA(51),F(51),BE1(51),BE2(51),TRC(51),TDTP(51),
     .CONTF1(51),CONTF2(51),P2P2(51)
      COMMON/SMALL/ DUMIT(40),IDGE(6)
      COMMON/AERAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,        RADI0300
     .       NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SF(5)
      COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),FF(300),FHVC(50),FHV(25),
     .FHVM(25),FHVP(25),GAMP(300),GEE(56),GUP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
     .FHVS(200),NSHC(25)
      COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
     .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
     .EMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
     .FRP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
     .SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
      COMMON/CHEQT/CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DEBAR(
     1101),HALL(101),DEDL(101)
      DIMENSION EMSW(1),EMSWL(1)                                          RADI0340
      EQUIVALENCE (AHV,EMSW) , (AHVL,EMSWL)                               RADI0350
      EQUIVALENCE (EMSB,EMSBL) , (TMSB,TMSBL)                             RADI0360
      NAMELIST/ARAD/ AHV,AHVL,TMSW,TMSWL,NKK,TW,NCRC                      RADI0390
      IF(INREAD.GT.0) GO TO 250                                           RADI0470
      INREAD=INREAD+1                                                     RADI0480
      C1=0.
      C3=2.
```

```
      FL1=1.
      FLG=1.
      NERR=0
      TW=1.0                                                          RADI0540
      READ(5,ARAD,END=20)
10    WRITE(6,ARAD)                                                   RADI0570
      GO TO 30                                                        RADI0580
20    WRITE(6,975)                                                    RADI0590
975   FORMAT('1 AEROTHERM DATA PACKAGE NOT FOUND')
      GO TO 250
30    CONTINUE                                                        RADI0620
      READ(5,900)NHV,NAES,NXI
      READ(5,901) (GEE(I),I=1,NAES)                                   RADI0670
      READ(5,901) (EPS(I),I=1,NAES)                                   RADI0680
      READ(5,901) (FHVM(I),I=1,NHV)                                   RADI0690
      READ(5,901) (FHVP(I),I=1,NHV)                                   RADI0700
      READ(5,901) (FHV (I),I=1,NHV)                                   RADI0710
900   FORMAT(40I2)                                                    RADI0720
901   FORMAT(6E12.4)                                                  RADI0730
      IF(NXI.GT.0) READ(5,900) (IA(I),I=1,NXI)                        RADI0750
      READ(5,900) (NU(I),I=1,NHV)                                     RADI0760
      IS=0&SSUM(NU(1:NHV))
      READ(5,902) (ND(I),HVL(I),FF(I),GAMP(I),XNOL(I),GUP(I),I=1,IS)  RADI0810
902   FORMAT(I2,10X,2E12.1,3E12.2)                                    RADI0820
      XNOL(1:IS)=1.
      DO 140 I=2,IS                                                   RADI0870
      IF(HVL(I).GT.HVL(I-1)) GO TO 140                                RADI0880
      WRITE(6,950) HVL(I)                                             RADI0890
      NERR=1                                                          RADI0900
140   CONTINUE                                                        RADI0910
950   FORMAT(1H0,'---LINE CENTER FREQUENCY AT ',E9.3,' OUT OF SEQUENCE')RA
      READ(5,903) NIHVC                                               RADI0980
      READ(5,901) (FHVC(I),I=1,NIHVC)                                 RADI0990
903   FORMAT(24I3)                                                    RADI1000
      DO 160 I=2,NIHVC                                                RADI1020
      IF(FHVC(I).GT.FHVC(I-1)) GO TO 160                              RADI1030
      WRITE(6,951) FHVC(I)                                            RADI1040
      NERR=1                                                          RADI1050
160   CONTINUE                                                        RADI1060
951   FORMAT(1H0,'---CONTINUUM FREQUENCY AT ',F9.3,' OUT OF SEQUENCE')  RA
      WRITE(6,960)                                                    RADI1110
960   FORMAT(1H1,60X,8HTABLE II)                                      RADI1120
      WRITE(6,961)                                                    RADI1130
961   FORMAT(6H GROUP,8X,2HHV,12X,3HHV+,11X,3HHV-,10X,1HN,7X,4HK(I),6X, RADI1140
     . 5HHV(J),8X,4HF(I),9X,6HGAM(I),8X,6HNOL(I))                     RADI1150
962   FORMAT(I4,F12.3,F15.3,F14.3,I11,I9,F12.3,1P2E14.2,0PF14.3)      RADI1170
```

```
963   FORMAT(56X,I9,F12.3,1P2E14.3,0PF14.3)                              RADI1180
      IC1=0                                                              RADI1190
      DO 180 I=1,NHV                                                     RADI1200
      IC2=IC1+NU(I)                                                      RADI1210
      IC1=IC1+1                                                          RADI1220
      WRITE(6,962) I,FHV(I),FHVP(I),FHVM(I),NU(I),ND(IC1),HVL(IC1),      RADI1230
     .             FF(IC1),GAMP(IC1),XNOL(IC1)                         RADI1240
      IF(IC1.EQ.IC2) GO TO 180                                           RADI1250
      IC3=IC1+1                                                          RADI1270
      DO 170 J=IC3,IC2                                                   RADI1280
170   WRITE(6,963) ND(J),HVL(J),FF(J),GAMP(J),XNOL(J)                    RADI1290
180   IC1=IC2                                                            RADI1300
200   CONTINUE                                                           RADI1320
      WRITE(6,964) (I,I=1,20),(NCRC(I),I=1,20)                           RADI1340
964   FORMAT(1H1,51X,'RADIATION CONTROL NUMBERS'/(45X,20I2))             RADI1360
      WRITE(6,965)
965   FORMAT(50X,'RADIATIVE BOUNDARY CONDITIONS'/4X,26(1H-),'CONTINUUM',R
     .26(1H-),3X,25(1H-),'LINE GROUPS',25(1H-)/2(13X,'WAVE',9X,'EMITTANC
     .E',10X,'TRANSMITTANCE',3X)/2(5X,'FREQ.  LENGTH   WALL /OUTER BOUND
     .. WALL /OUTER BOUND.',2X)/5X,'(EN)   (A)',51X,'(FV)    (A)')
      NW=MAX0(NHV,NIHVC)                                                 RADI1410
      DO 220 I=1,NW                                                      RADI1420
      EMSB=0.0                                                           RADI1430
      TMSB=1.0                                                           RADI1440
      WRITE(6,967)                                                       RADI1450
967   FORMAT(1H )                                                        RADI1460
      IF(I.GT.NIHVC) GO TO 210                                           RADI1480
      V1=12400./FHVC(I)                                                  RADI1490
      WRITE(6,968) FHVC(I),V1,EMSW(I),EMSB,TMSW(I),TMSB                  RADI1500
      IF(I.GT.NHV) GO TO 220                                             RADI1520
210   V2=12400./FHV(I)                                                   RADI1530
      WRITE(6,969) FHV(I),V2,EMSWL(I),EMSBL,TMSWL(I),TMSBL               RADI1540
220   CONTINUE                                                           RADI1550
968   FORMAT(1H+,F9.3,E10.3,F8.3,F10.3,F11.3,F10.3)                      RADI1560
969   FORMAT(1H+,61X,F10.3,E10.3,F8.3,F10.3,F11.3,F10.3)                 RADI1570
      GO TO 260                                                          RADI1610
250   CONTINUE                                                           RADI1630
      IF(IRONLY.EQ.0) GO TO 260
      READ(5,ARAD,END=255)
      GO TO 260
255   IRONLY=-1
      RETURN                                                             RADI1680
260   CONTINUE
      DO 240 N=1,IE
      IF(ETA(N).GT.0.5)GO TO 240
      IMPON=N
```

```
240   CONTINUE
      IF(ETA(IMPON)-0.5.GT.0.5-ETA(IMPON-1))IMPON=IMPON-1
      NI=IF                                                          RADI1760
      NY=IF                                                          RADI1780
      MIDPNT=IMPON                                                   RADI1790
      PRES(1:IF)=P2S*PFAC*P2(1:IF)
       TEE(1:IF)=T2S*TFAC*T2(1:IF)
      YY(1:IF)=ETA(1:IF)
      DO 280 N=1,IF
280   NICN(N)=N
      IF(TW.NE.0.0) TW=TEE(1)                                        RADI1890
      DELTA=30.48*RN*SSQ2(M)                                         RADI1920
305   CONTINUE                                                       RADI1960
      C2=2.0*DELTA                                                   RADI1970
      DO 340 I=1,IF                                                  RADI1980
      TX=11606.0/TEE(I)                                              RADI1990
      IRK=0                                                          RADI2000
      NCES=0                                                         RADI2010
310   IRK=IRK+1                                                      RADI2030
      NICE=0                                                         RADI2040
      XQ(I,IRK)=0.0                                                  RADI2050
320   NCES=NCES+1                                                    RADI2070
      NICE=NICE+1                                                    RADI2080
      XQ(I,IRK)=XQ(I,IRK)+GEE(NCES)*EXP(-EPS(NCES)*TX)               RADI2090
      IF(NCES.EQ.NAES) GO TO 340                                     RADI2100
      IF(NICE-8) 320,310,310                                         RADI2110
340   CONTINUE                                                       RADI2120
      DO 440 I=1,21
      DO 360 J=1,NS
      IF(ALPHA(I).EQ.SYMB(J)) GO TO 400                              RADI2180
360   CONTINUE                                                       RADI2190
      XNN(1,I:IF)=0.
      GO TO 440                                                      RADI2240
400   JJ=J                                                           RADI2270
      XNN(1,I:IF)=7.3398E21*PRES(1:IF)*MOLEF1(1,JJ:IF)/TEE(1:IF)
440   CONTINUE                                                       RADI2300
      XLAMBD(1:IF)=VSQRT(TEE(1:IF):XLAMBD(1:IF))
      CONV(1:IF)=XNN(1,5:IF)/(4.83E15*TEE(1:IF)*XLAMBD(1:IF))
      XLAMBD(1:IF)=11606.0/TEE(1:IF)
      HALL(1:IF)=-2.8*XLAMBD(1:IF)
      HALL(1:IF)=VEXP(HALL(1:IF):HALL(1:IF))
      DEDL(1:IF)=10.*XNN(1,4:IF)*HALL(1:IF)/XQ(1,1:IF)
      HALL(1:IF)=1.22*XLAMBD(1:IF)
      HALL(1:IF)=VEXP(HALL(1:IF):HALL(1:IF))
      XNN(1,16:IF)=5.0*DEDL(1:IF)*CONV(1:IF)*HALL(1:IF)/XQ(1,1:IF)
      HALL(1:IF)=-.0353*XLAMBD(1:IF)
```

```
      HALL(1:IE)=VEXP(HALL(1:IE):HALL(1:IE))
      DEBAR(1:IE)=-1.48*XLAMBD(1:IE)
      DEBAR(1:IE)=VEXP(DEBAR(1:IE):DEBAR(1:IE))
      XNN(1,17:IE)=CONV(1:IE)*XNN(1,2:IE)*(4.+2.*HALL(1:IE))/(XQ(1,2:IE)
     1*DEBAR(1:IE))
      HALL(1:IE)=-.7540*XLAMBD(1:IE)
      HALL(1:IE)=VEXP(HALL(1:IE):HALL(1:IE))
      XNN(1,18:IE)=CONV(1:IE)*XNN(1,14:IE)/(XQ(1,4:IE)*HALL(1:IE))
      HALL(1:IE)=-1.250*XLAMBD(1:IE)
      HALL(1:IE)=VEXP(HALL(1:IE):HALL(1:IE))
      XNN(1,19:IE)=4.*CONV(1:IE)*XNN(1,12:IE)/(XQ(1,3:IE)*HALL(1:IE))
      HALL(1:IE)=-15.576*XLAMBD(1:IE)
      HALL(1:IE)=VEXP(HALL(1:IE):HALL(1:IE))
      XNN(1,20:IE)=HALL(1:IE)*XNN(1,7:IE)/CONV(1:IE)*(.458+5.1E-4*TEE(1:
     1IE)-1.438E-8*TEE(1:IE)*TEE(1:IE))
      DO 520 J=1,7
  520 XQ(1,J:IE)=1./XQ(1,J:IE)
      DEDL(1:IE)=1.E-4*TEE(1:IE)
      DEDL(1:IE)=VALOG(DEDL(1:IE):DEDL(1:IE))
      HALL(1:IE)=0.25*DEDL(1:IE)
      HALL(1:IE)=VEXP(HALL(1:IE):HALL(1:IE))
      XTX(1,1:IE)=XNN(1,5:IE)*HALL(1:IE)
      HALL(1:IE)=0.46*DEDL(1:IE)
      HALL(1:IE)=VEXP(HALL(1:IE):HALL(1:IE))
      XTX(1,2:IE)=XNN(1,5:IE)*HALL(1:IE)
      HALL(1:IE)=0.43*DEDL(1:IE)
      HALL(1:IE)=VEXP(HALL(1:IE):HALL(1:IE))
      XTX(1,3:IE)=XNN(1,5:IE)*HALL(1:IE)
      DEDL(1:IE)=VALOG(XNN(1,5:IE):DEDL(1:IE))
      DEDL(1:IE)=0.6667*DEDL(1:IE)
      VX(1:IE)=VEXP(DEDL(1:IE):VX(1:IE))
      IEZ=0
      IF(NETAX.LT.IE) IEZ=NETAX
      IF(IEZ.EQ.0) RETURN
      NCOL=23
      CALL RADGRD(XNN,FIMI,FIPI,TLCM,TLCP,FMU,BEE,ETA,TEE,BE2,
     .NICN,NA,NE,NETAX,NI,NMP,NCOL,IE,IMPON)
      NY=NETAX
      NI=NY
      IF(NE.EQ.NA) GO TO 560
      DO 550 I=1,NETAX
      IF(NICN(NI).LE.MIDPNT) GO TO 560
  550 NI=NI-1
  560 CONTINUE
      DO 600 I=1,NETAX
      L=NICN(I)
```

```
      YY(I)=ETA(L)
      PRES(I)=PRES(L)
      TEE(I)=TEE(L)
      VX(I)=VX(L)
      DO 570 J=1,NCOL
570   XNN(I,J)=XNN(L,J)
      DO 580 J=1,7
580   XQ(I,J)=XQ(L,J)
      DO 590 J=1,3
590   XTX(I,J)=XTX(L,J)
      IF(L.LE.IMPON) MIDPNT=I
600   CONTINUE                                                          RADI2760
      RETURN                                                            RADI2770
      END
      SUBROUTINE RADGRD(ND,NDN,SDN,BE2N,SWT,T2N,WTS,ETA,T2,BE2,Y,
     .                  NA,NE,NETAX,NI,NP,NR,IE,IMPON)
      COMMON/CHEQT/CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DEBAR(
     1101),HALL(101),DEDL(101)
      DIMENSION B(51)
      REAL ND(NP,NR),NDN(1),SDN(1),SWT(1),WTS(1)
      REAL T2(1),T2N(1),BE2(1),BE2N(1),ETA(1)
      INTEGER Y(1)
      BIT B
      SDN(1:IE)=0.
      DO 20 I=1,NR
      CALL NDERIV(ND(1,I),NDN,IE,1,1,NMP)
      DEDL(1:IE)=VABS(NDN(1:IE):DEDL(1:IE))
      SDN(1:IE)=SDN(1:IE)+DEDL(1:IE)
20    CONTINUE
      CALL NDERIV(BE2,WTS,IE,1,1,NMP)
      CALL NDERIV(WTS,BE2N,IE,1,1,NMP)
      CALL NDERIV(T2,T2N,IE,1,1,NMP)
      B(1:IE)=BE2(1:IE).GT.0.
      BE2N(1:IE)=OBVCTRL(0.,B(1:IE):BE2N(1:IE))
      WMAX=FLOAT(IE)/FLOAT(NETAX)
      IM=IE-1
      IM1=IM-1
      DMAX=OBSMAX(SDN(2:IM1))
      DEDL(2:IM1)=VABS(BE2N(2:IM1):DEDL(2:IM1))
      RMAX=OBSMAX(DEDL(2:IM1))
      HALL(2:IM1)=VABS(T2N(2:IM1):HALL(2:IM1))
      TMAX=OBSMAX(HALL(2:IM1))
      IF(RMAX.LT.1.E-10) RMAX=1.E100
      TWTS=1./TMAX
      RWTS=1./RMAX
      DWTS=1./DMAX
```

```
      WTS(1:IF)=1.
      WTS(2:IM1)=DWTS*SDN(2:IM1)+RWTS*DFDL(2:IM1)+TWTS*HALL(2:IM1)
      B(1:IM1)=WTS(2:IM1).LT.1.0
      WTS(2:IM1)=Q8VCTRL(1.,B(1:IM1):WTS(2:IM1))
      WSUM=Q8SSUM(WTS(2:IM1))
      SPWT=WSUM/FLOAT(NETAX)
      NW=NETAX/5
      B(1:NW)=WTS(1:NW).LT.SPWT
      WTS(1:NW)=Q8VCTRL(SPWT,B(1:NW):WTS(1:NW))
      IF(NA.EQ.NE) GO TO 70
      IF(NI.EQ.IF) GO TO 70
      N1=IMPON-NW/2
      N2=NW+1
      B(1:N2)=WTS(N1:N2).LT.SPWT
      WTS(N1:N2)=Q8VCTRL(SPWT,B(1:N2):WTS(N1:N2))
70    CONTINUE
      SWT(1)=WTS(1)
      DO 80 N=2,IF
      SWT(N)=SWT(N-1)+WTS(N)
80    CONTINUE
      W=SWT(IF)/FLOAT(NETAX)
      Y(1)=1
      Y(2)=2
      I=3
      Y(NETAX)=IF
      DO 90 N=3,IM
      IF(SWT(N)/FLOAT(I).LT.W) GO TO 90
      Y(I)=N
      I=I+1
90    CONTINUE
      Y(NETAX-1)=IM
      Y(NETAX)=IF
      RETURN
      END
      SUBROUTINE TRANSP                                                  TRAN0020
      CALL CONTN2                                                        TRAN0030
      CALL LINT2                                                         TRAN0040
      RETURN                                                             TRAN0050
      END
      BLOCK DATA AERORAD
      COMMON/AERAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,
     .      NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SE(5)
      COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),EE(300),EHVC(50),EHV(25),
     .EHVM(25),EHVP(25),GAMP(300),GEE(56),GUP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
```

```
.FHVS(200),NSHC(25)
 COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
.PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
.FMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
.FRP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
.SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
 COMMON/CONT/IBNINJ,IDATAP,IDATAR,IDEBUG,IFLUXC,IRSKIP,ISUBLM,
.ITRIGR,MEND,MSTART,   NC,NFREQ,NINT,NINT1,NTT,NTZ
 COMMON/LRAD/IEZ,IRONLY,IMPON,LINES,MF,NETAX,NSR,ROE,UE,XDTIL,XMOL
 DATA (ALPHA(J),J=1,20)/6H     O+,6H      O,6H     N+,6H      N,        EHV 0120
.     6H     E-,6H     O2,6H     N2,6H     CO,6H     H2,6H     C2,        EHV 0130
.     6H     CN,6H      C,6H     C+,6H      H,6H     NO,6H     N-,        EHV 0140
.     6H     O-,6H     H-,6H     C-,6H    N2+/                           EHV 0150
 DATA ALPHA(21)/6H     C3/
 DATA (BETA(J),J=1,7) / 6H      N,                                       EHV 0170
.     6H      O,6H      C,6H      H,6H     N+,6H     O+,6H     C+/        EHV 0180
 DATA AHV,AHVL,TMSW,TMSWL/75*1.0,75*0.0/                                 EHV 0200
 DATA NCRC,NKK/20*1,25*7/                                                EHV 0220
 DATA INREAD/0/                                                          EHV 0230
 DATA IRONLY,IEZ,IDEBUG/3*0/
 END                                                                     EHV 0240
 SUBROUTINE CONTN2                                                       CONT0010
 COMMON/AERAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,            CONT0160
.        NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SF(5)
 COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),FF(300),FHVC(50),FHV(25),
.FHVM(25),FHVP(25),GAMP(300),GEE(56),GUP(300),HVL(300),IA(9),
.NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
.ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
.FHVS(200),NSHC(25)
 COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
.PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
.FMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
.FRP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
.SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
 COMMON/CHEQT/CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DEBAR(
1101),HALL(101),DEDL(101)
 DIMENSION TAU(1)
 EQUIVALENCE (TAU,TAUT)                                                  CONT0200
 TW=TEE(1)                                                               CONT0210
 J=MIDPNT                                                                CONT0220
 DIM(1:NY)=0.
 DIP(1:NY)=0.
 FIMI(1:NY)=0.
 FIPI(1:NY)=0.
 DO 500 K=1,NIHVC                                                        CONT0310
 CALL MU(FHVC(K),NY,FMU)
```

```
      CALL TRANSA(FMII,NY)                                              CONT0350
      BEEW=0.0                                                          CONT0380
      IF(TW.EQ.0.0) GO TO 110                                           CONT0390
      BEEW=15833.7*FHVC(K)**3/(EXP(11606.0*FHVC(K)/TW)-1.0)             CONT0400
  110 CONTINUE                                                          CONT0410
      XJW=AHV(K)*BEEW+(1.0-AHV(K)-TMSW(K))*FIP(1)                       CONT0420
      DFDL(1:NY)=-TAU(1:NY)
      DFDL(1:NY)=VEXP(DFDL(1:NY):DFDL(1:NY))
      FIM(1:NY)=FIM(1:NY)+XJW*DFDL(1:NY)
      IF(K.GT.1) GO TO 210
      SF(1)=FIM(1)
      SF(2)=FIP(1)
      SF(3)=FIM(J)
      SF(4)=FIP(J)
      SF(5)=FIM(NY)
  210 CONTINUE
      IF(K.EQ.1)GO TO 350
      FHVAVG=0.5*(FHVC(K)-FHVC(K-1))
      DIM(1:NY)=(FIM(1:NY)+FRM(1:NY))*FHVAVG
      DIP(1:NY)=(FIP(1:NY)+FRP(1:NY))*FHVAVG
      FIMI(1:NY)=FIMI(1:NY)+DIM(1:NY)
      FIPI(1:NY)=FIPI(1:NY)+DIP(1:NY)
  350 FRM(1:NY)=FIM(1:NY)
      FRP(1:NY)=FIP(1:NY)
      FIMC(K,1)=DIM(1)                                                  CONT0630
      FIMC(K,2)=DIM(J)                                                  CONT0640
      FIMC(K,3)=DIM(NY)                                                 CONT0650
      FIPC(K,1)=DIP(1)                                                  CONT0660
      FIPC(K,2)=DIP(J)                                                  CONT0670
      FIPC(K,3)=DIP(NY)                                                 CONT0680
  500 CONTINUE                                                          CONT0690
      RETURN                                                            CONT0700
      END                                                               CONT0710
      SUBROUTINE ISLOV(N,X,Y,SR,R,SLR,YL,ND)
      DIMENSION X(1),Y(1),SR(1),R(1),XX(5),YY(5),SLR(1),YL(1)
      YL(1:N)=VALOG(Y(1:N):YL(1:N))
      CALL SLOPQ(N,X,YL,SLR,R)                                          ISLD0120
      SR(1:N)=Y(1:N)*SLR(1:N)
      DO 17 I=2,N                                                       ISLD0150
      XD=X(I)-X(I-1)                                                    ISLD0160
      XD2=.5*XD                                                         ISLD0170
      XD4=.25*XD                                                        ISLD0180
      YS=Y(I)+Y(I-1)                                                    ISLD0190
      SD=SR(I)-SR(I-1)                                                  ISLD0200
      YD=ABS(Y(I)-Y(I-1))                                               ISLD0210
      T3=ABS(SD*XD2)                                                    ISLD0220
```

```
      TS=ABS(Y(I-1))+YD                                                 ISLD0230
      IF(T3-.15*TS)3,3,4                                                ISLD0240
    3 R(I)=R(I-1)+XD2*(YS-XD/6.*SD)                                     ISLD0250
      GO TO 17                                                          ISLD0260
    4 YY(1)=YL(I-1)                                                     ISLD0270
      XX(1)=X(I-1)                                                      ISLD0280
      RR=0.                                                             ISLD0290
      DO 5 J=2,5                                                        ISLD0300
    5 XX(J)=XX(J-1)+XD4                                                 ISLD0310
      CALL OGLE (5,XX,YY,N,X,YL,SLR)                                    ISLD0320
      IF(ND-1)11,11,6                                                   ISLD0330
    6 YMAX=YY(1)                                                        ISLD0340
      YMIN=YY(5)                                                        ISLD0350
      IF(YY(5)-YY(1))7,7,8                                              ISLD0360
    7 YMAX=YY(5)                                                        ISLD0370
      YMIN=YY(1)                                                        ISLD0380
    8 DO 10 J=1,5                                                       ISLD0390
      IF(YY(J)-YMAX)9,9,13                                              ISLD0400
    9 IF(YY(J)-YMIN)13,10,10                                            ISLD0410
   10 CONTINUE                                                          ISLD0420
   11 DO 12 J=2,5                                                       ISLD0430
      SSR=(YY(J)-YY(J-1))/XD4                                           ISLD0440
   12 RR=RR+(EXP(YY(J))/SSR)*(1.-EXP(-SSR*XD4))                         ISLD0450
      GO TO 16                                                          ISLD0460
   13 SSR=(YY(5)-YY(1))/XD                                              ISLD0470
      TT=ABS(2.*SSR*XD)/(YY(5)+YY(1))                                   ISLD0480
      IF(TT-.00001)14,15,15                                             ISLD0490
   14 RR=XD2*(EXP(YY(5))+EXP(YY(1)))                                    ISLD0500
      GO TO 16                                                          ISLD0510
   15 RR=(EXP(YY(5))/SSR)*(1.-EXP(-SSR*XD))                             ISLD0520
   16 R(I)=R(I-1)+RR                                                    ISLD0530
   17 CONTINUE                                                          ISLD0540
      RETURN                                                            ISLD0550
      END                                                               ISLD0560
      SUBROUTINE CODIM (XI,YI,NI,T,ANS,NA)
      DIMENSION XI(1),YI(1),T(1),ANS(1)
      N = NI
      IF (N-2) 10,30,45
10    CONTINUE
      ANS(1:NA)=YI(1)
      RETURN
30    CONTINUE
      CANS    = (YI(2)-YI(1)) / (XI(2)-XI(1)) * (X-XI(1)) + YI(1)
      ANS(1:NA)=CANS
      RETURN
45    CONTINUE
```

```
      J = 1
      DO 210 IE=1,NA
      X = T(IE)
   50 CONTINUE
      IF (XI(J)-X) 70,60,80
   70 CONTINUE
      J = J+1
      IF (J-N) 50,50,120
   60 CONTINUE
      Y = YI(J)
      GO TO 200
   80 CONTINUE
      IF (J-2) 85,90,100
   85 CONTINUE
      Y = (YI(2)-YI(1)) / (XI(2)-XI(1)) * (X-XI(1)) + YI(1)
      GO TO 200
   90 CONTINUE
      JJ = 1
      K = 1
      M = 3
      XM2 = ABS((YI(J)-YI(M))/(XI(J)-XI(M)))
      GO TO 150
  100 CONTINUE
      IF (N-J) 120,110,140
  110 CONTINUE
      JJ = 1
      K = J-1
      M = K-1
      XM2 = ABS((YI(K)-YI(M))/(XI(K)-XI(M)))
      GO TO 150
  120 CONTINUE
      Y = (YI(N)-YI(N-1)) / (XI(N)-XI(N-1)) * (X-XI(N-1)) + YI(N-1)
      GO TO 200
  140 CONTINUE
      JJ = 0
      K = J-1
      M = K-1
      L = J+1
  150 CONTINUE
      A1 = X-XI(M)
      A2 = X-XI(K)
      A3 = X-XI(J)
      XJK = XI(J)-XI(K)
      XJM = XI(J)-XI(M)
      XKM = XI(K)-XI(M)
      AL = A2/XJK
```

```
      C1 = A3*A2/(XKM*XJM)
      C2 = -A1*A3/(XKM*XJK)
      C3 = A2*A1/(XJM*XJK)
      S = AL*YI(J)+(1.0-AL)*YI(K)
      P1 = C1*YI(M)+C2*YI(K)+C3*YI(J)
      IF (JJ.GT.0) GO TO 160
      A4 = X-XI(L)
      XJL = XI(J)-XI(L)
      XKL = XI(K)-XI(L)
      C4 = -A4*A3/(XJK*XKL)
      C5 = A2*A4/(XJK*XJL)
      C6 = A3*A2/(XKL*XJL)
      P2 = C4*YI(K)+C5*YI(J)+C6*YI(L)
      GO TO 170
  160 CONTINUE
      XM1 = ABS((YI(J)-YI(K))/XJK)
      IF (XM1+XM2.EQ.0) XM1 = 1.0
      XK = 1.0-ABS(XM1-XM2)/(XM1+XM2)
      P2 = S+XK*(P1-S)
      IF (M.LT.K) GO TO 170
      XK = P1
      P1 = P2
      P2 = XK
  170 CONTINUE
      E1 = ABS(P1-S)
      E2 = ABS(P2-S)
      IF (E1+E2.GT.0.0) GO TO 190
      Y = S
      GO TO 200
  190 CONTINUE
      XN = AL*E1*P2+(1.0-AL)*E2*P1
      DD = AL*E1+(1.0-AL)*E2
      Y = XN/DD
  200 CONTINUE
      ANS(IE) = Y
  210 CONTINUE
      RETURN
      END
      SUBROUTINE LINT2                                                  LINT0010
      COMMON/AERAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,      LINT0130
     .         NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SF(5)
      COMMON/QCMX/ QCML                                                 LINT0210
      COMMON/LRAD/IEZ,IRONLY,IMPON,LINES,MF,NETAX,NSR,ROF,UF,XDTIL,XMOL
      COMMON/CHFOR/AHV(50),AHVL(25),EPS(56),FF(300),FHVC(50),FHV(25),
     .FHVM(25),FHVP(25),GAMP(300),GEE(56),GUP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XMOL(300),
```

```
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
     .FHVS(200),NSHC(25)
      COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
     .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
     .EMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
     .FRP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
     .SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
      COMMON/CHEQT/CONV(101),XLAMBD(101),DELT(101,19),F(101,19),DFBAR(
     1101),HALL(101),DFDL(101)
      DIMENSION S(1),TAU(1),TMU(1),XIM(1),XIP(1),XIMD(1),XIPD(1)
      EQUIVALENCE (QR,S),(TAU,TAUT),(LMU,TMU),(FRM,XIMD),
     .            (FRP,XIPD),(FIM,XIM),(FIP,XIP)
      FIML(1,1:75)=0.
      FIPL(1,1:75)=0.
      FIM(1:NY)=0.
      FIP(1:NY)=0.
      FIIM(1:NY)=0.
      FIIP(1:NY)=0.
      DIM(1:NY)=0.
      DIP(1:NY)=0.
      XIM(1:NY)=0.
      XIP(1:NY)=0.
      FIMT(1:NY)=0.
      FIPT(1:NY)=0.
      TLCM(1:NY)=0.
      TLCP(1:NY)=0.
      XIMD(1:NY)=0.
      XIPD(1:NY)=0.
      IF(LINES.EQ.0) RETURN                                          LINT0490
      K2=0                                                           LINT0510
      IE=0                                                           LINT0520
      DO 500 K=1,NHV                                                 LINT0530
      K1=K2+1                                                        LINT0540
      K2=K2+NU(K)                                                    LINT0550
      NSL=NU(K)                                                      LINT0560
      IF(NKK(K).EQ.0) IE=IE+NSL                                      LINT0600
      IF(NKK(K).EQ.0) GO TO 500                                      LINT0610
      BEEW=0.0                                                       LINT0640
      IF(TW.EQ.0.0) GO TO 110                                        LINT0650
      TX=11606.0/TW                                                  LINT0660
      FHV3=FHV(K)**3                                                 LINT0670
      BEEW=15833.7*FHV3/(EXP(FHV(K)*TX)-1.0)                         LINT0680
  110 CONTINUE                                                       LINT0690
      XJW=BEEW*AHVL(K)                                               LINT0700
      CALL MU(FHV(K),NY,FMU)
      CALL TRANSA(FMU,NY)                                            LINT0740
```

```
      XJW=XJW+(1.-AHVL(K)-TMSWL(K))*FIP(1)                              LINT0770
      DFDL(1:NY)=-TAU(1:NY)
      DFDL(1:NY)=VEXP(DFDL(1:NY):DFDL(1:NY))
      FIM(1:NY)=FIM(1:NY)+XJW*DFDL(1:NY)
      DIM(1:NY)=FIM(1:NY)
      DIP(1:NY)=FIP(1:NY)
      NK=NKK(K)
      NSHC(1:NSL)=NK
      CALL FREQ(K,CFIL)                                                 LINT0940
      L=0                                                               LINT0970
      DO 360 JS=1,NSL                                                   LINT0980
      NPPL=NSHC(JS)                                                     LINT0990
      IE=IE+1                                                           LINT1000
      DO 250 LK=1,NPPL                                                  LINT1030
      L=L+1                                                             LINT1040
      CALL MULE(FHVS(L),S)                                              LINT1080
      TMU(1:NY)=FMU(1:NY)+S(1:NY)
      CALL TRANSA(TMU,NY)                                               LINT1130
      XJWL=XJW+(1.0-AHVL(K)-TMSWL(K))*XIP(1)                            LINT1160
      DFDL(1:NY)=-TAU(1:NY)
      DFDL(1:NY)=VEXP(DFDL(1:NY):DFDL(1:NY))
      XIM(1:NY)=XIM(1:NY)+XJWL*DFDL(1:NY)
      IF(LK.GT.1) DFHV=0.5*(FHVS(L)-FHVS(L-1))                          LINT1210
      IF(LK.EQ.1)GO TO 220
      FIMT(1:NY)=FIMT(1:NY)+DFHV*(XIM(1:NY)+XIMO(1:NY))
      FIPT(1:NY)=FIPT(1:NY)+DFHV*(XIP(1:NY)+XIPO(1:NY))
220   XIMO(1:NY)=XIM(1:NY)
      XIPO(1:NY)=XIP(1:NY)
250   CONTINUE
      FIIM(1:NY)=FIIM(1:NY)+XNOL(IE)*FIMT(1:NY)
      FIIP(1:NY)=FIIP(1:NY)+XNOL(IE)*FIPT(1:NY)
      FIMT(1:NY)=0.
      FIPT(1:NY)=0.
360   CONTINUE
      DIP(1:NY)=FIIP(1:NY)-CFIL*DIP(1:NY)
      DIM(1:NY)=FIIM(1:NY)-CFIL*DIM(1:NY)
      FIIP(1:NY)=0.
      FIIM(1:NY)=0.
      TLCP(1:NY)=TLCP(1:NY)+DIP(1:NY)
      TLCM(1:NY)=TLCM(1:NY)+DIM(1:NY)
      FIML(K,1)=DIM(1)                                                  LINT1530
      FIML(K,2)=DIM(MIDPNT)                                             LINT1540
      FIML(K,3)=DIM(NY)                                                 LINT1550
      FIPL(K,1)=DIP(1)                                                  LINT1560
      FIPL(K,2)=DIP(MIDPNT)                                             LINT1570
      FIPL(K,3)=DIP(NY)                                                 LINT1580
```

```
  500  CONTINUE                                                          LINT1600
       RETURN                                                            LINT1620
       END                                                               LINT1630
       SUBROUTINE MU(HV,NY,XAPNU)
       COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),FF(300),FHVC(50),FHV(25),
      .FHVM(25),FHVP(25),GAMP(300),GEE(56),GUP(300),HVL(300),IA(9),
      .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
      .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
      .FHVS(200),NSHC(25)
       COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
      .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
      .FMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
      .FRP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
      .SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
       DIMENSION XAPNU(1),XKT(1),T(1)
       EQUIVALENCE (XKT,QR),(T,TEE)
       ALOGT(Q)=ALOG10(Q)                                                MU  0040
       SQA=7.25E-16                                                      MU  0050
       XMOL=1.0                                                          MU  0060
       HV3=1./HV**3                                                      MU  0070
       XLAM=1.24/HV                                                      MU  0080
       DO 1000 I=1,NY                                                    MU  0130
       L=I                                                               MU  0140
       XKT(L)=8.62E-5*T(L)                                               MU  0160
       TX=11606.0/T(L)                                                   MU  0170
       BEE(I)=15833.7/(HV3*(EXP(HV*TX)-1.0))                             MU  0190
       AO=  XNN(I,2)                                                     MU  0240
       AN=  XNN(I,4)                                                     MU  0250
       AI=  XNN(I,5)                                                     MU  0260
       AO2=XNN(I,6)                                                      MU  0270
       AN2=XNN(I,7)                                                      MU  0280
       ACO=XNN(I,8)                                                      MU  0290
       AH2=XNN(I,9)                                                      MU  0300
       AC2=XNN(I,10)                                                     MU  0310
       ACN=XNN(I,11)                                                     MU  0320
       AC=  XNN(I,12)                                                    MU  0330
       ACP=XNN(I,13)                                                     MU  0340
       AH=  XNN(I,14)                                                    MU  0350
       ANO=XNN(I,15)                                                     MU  0360
       ANM=XNN(I,16)                                                     MU  0370
       AOM=XNN(I,17)                                                     MU  0380
       AHM=XNN(I,18)                                                     MU  0390
       AN2P=XNN(I,20)                                                    MU  0400
       DN=0.                                                             MU  0420
       DNO=0.                                                            MU  0430
       XOM=0.                                                            MU  0440
```

```
      XHM=0.                                                            MU  0450
      XNM=0.                                                            MU  0460
      DN2P=0.                                                           MU  0470
      XCM=0.                                                            MU  0480
      DOHS=0.                                                           MU  0490
      DNHS=0.                                                           MU  0500
      DI=0.
      XIN=1.492E+05*(1.-EXP(-HV/.431))/((XLAM**5)*(EXP(HV/.431)-1.))    MU  0550
   13 XN=14.3/XKT(L)                                                    MU  0560
      XO=13.4/XKT(L)                                                    MU  0570
      XI=25.5/XKT(L)                                                    MU  0580
      DNM=4.0+10.0*EXP(-2.38/XKT(L))+6.0*EXP(-3.57/XKT(L))              MU  0590
      DOM=9.0+5.0*EXP(-1.98/XKT(L))+EXP(-4.18/XKT(L))                   MU  0600
      DCM=9.0+5.0*EXP(-1.265/XKT(L))+EXP(-2.68/XKT(L))+5.0*EXP(-4.18/   MU  0610
     1XKT(L))                                                           MU  0620
      DCPM=6.0+12.0*EXP(-5.33/XKT(L))                                   MU  0630
      DHMA = 2. +8.*EXP(-10.2/XKT(L))                                   MU  0640
      CALL ZHV(HV,ZO,ZN,ZI,ZC)                                          MU  0650
      XX=HV/XKT(L)                                                      MU  0660
      FPC=1.0-EXP(-XX)                                                  MU  0670
      CETA=13.6/XKT(L)
      BEEI=5040.0*HV*HV*HV*EXP(-XX)
      IF(NCRC(1)) 600,2541,600                                          MU  0690
  600 CONTINUE
      IF(HV-0.85) 2540,2540,2541                                        MU  0720
 2540 E03=2.73E-09*AN*EXP(-14.54/XKT(L))*18.*((EXP(CETA/16.)-1.)/CETA-  MU
     10.0625)/(DNM*4.*CETA)
      DNHS=E03/(BEEI*1.42)                                              MU  0750
 2541 CONTINUE                                                          MU  0760
      IF(NCRC(2)) 601,2543,601                                          MU  0780
  601 IF(HV-0.85) 2542,2543,2543                                        MU  0790
 2542 E04=2.73E-09*AO*EXP(-CETA)*8.*((EXP(CETA/16.)-1.)/CETA-0.0625)/(DO
     1M*4.*CETA)
      DOHS=E04/(BEEI*1.77)                                              MU  0820
 2543 CONTINUE                                                          MU  0830
      IF(NCRC(3)) 602,3075,602                                          MU  0850
  602 IF(HV-2.23) 3075,3074,3074                                        MU  0860
 3074 IF(HV-4.46) 3073,3073,3075                                        MU  0870
 3073 IF(HV-3.35) 3084,3084,3083                                        MU  0880
 3084 DN2P=(AN2P*1.E-18)*10.**(-11.576+6.77*HV-0.91*HV**2)              MU  0890
      GO TO 3075                                                        MU  0900
 3083 DN2P=(AN2P*1.E-19)*10.**(-49.086+0.51623E-02*T(L)-0.23577E-06*T(L)MU  0910
     1**2+HV*(30.616-0.30289E-02*T(L)+0.13644E-06*T(L)**2)+(HV**2)*(-4.5MU  0920
     26684+0.43903E-03*T(L)-0.19543E-07*T(L)**2))                       MU  0930
 3075 CONTINUE                                                          MU  0940
      IF(NCRC(4)) 603,305,603                                           MU  0960
```

```
  603 IF(HV-1.22) 305,300,300                                                    MU  0970
  300 XNM=XNM+ANM*1.6E-16                                                        MU  0980
  305 CONTINUE                                                                   MU  0990
      IF(NCRC(20)) 6600,6600,6601                                                MU  1010
 6601 IF(HV-1.25) 6600,6602,6602                                                 MU  1020
 6602 XCM = XCM + 1.4E-17*AC*AI/(4.83E+15*T(L)**1.5*DCM*EXP(-1.25/XKT(L))MU  1030
     1)/(4.))                                                                    MU  1040
 6600 CONTINUE                                                                   MU  1050
      IF(NCRC(5)) 604,2502,604                                                   MU  1070
  604 IF(HV-13.6) 2500,2500,2502                                                 MU  1080
 2500 IF(HV-0.75) 2502,2501,2501                                                 MU  1090
 2501 IF(HV-1.3) 6500,6500,6501                                                  MU  1100
 6500 XHM = (AHM*1.E-17)*(-4.51+7.15*HV)                                         MU  1110
      GO TO 2502                                                                 MU  1120
 6501 IF(HV-6.) 6502,6502,6503                                                   MU  1130
 6502 XHM = (AHM*1.E-17)*(6.765-1.7*HV+0.1258*HV**2.)                            MU  1140
      GO TO 2502                                                                 MU  1150
 6503 XHM = (AHM*1.E-17)*(3.5-0.535*HV+0.0225*HV**2.)                            MU  1160
 2502 CONTINUE                                                                   MU  1170
      IF(NCRC(6)) 605,2510,605                                                   MU  1190
  605 IF(HV-11.) 2503,2503,2510                                                  MU  1200
 2503 IF(HV-1.5) 2510,2504,2504                                                  MU  1210
 2504 IF(HV-3.5) 2505,2506,2506                                                  MU  1220
 2505 XOM=AOM*6.2E-18                                                            MU  1230
      GO TO 2510                                                                 MU  1240
 2506 IF(HV-5.7) 2507,2507,2508                                                  MU  1250
 2507 XOM=AOM*1.E-18*(16.16-0.818*HV)                                            MU  1260
      GO TO 2510                                                                 MU  1270
 2508 XOM=AOM*1.E-18*(15.58-0.453*HV)                                            MU  1280
 2510 CONTINUE                                                                   MU  1290
      IF(NCRC(7)) 606,2525,606                                                   MU  1310
  606 IF(HV-13.5) 2511,2511,2525                                                 MU  1320
 2511 IF(HV-5.0) 2520,2520,2513                                                  MU  1330
 2513 IF(HV-6.65)2514,2515,2515                                                  MU  1340
 2514 ONO=(ANO*1.E-18)*10.0**(-4.2673+HV*0.68267)                                MU  1350
      GO TO 2525                                                                 MU  1360
 2515 IF(HV-10.) 2517,2517,2516                                                  MU  1370
 2517 ONO=ANO*1.9E-18                                                            MU  1380
      GO TO 2525                                                                 MU  1390
 2516 ONO=(ANO*1.E-18)*(89.75-19.125*HV+1.033*HV**2)                             MU  1400
      GO TO 2525                                                                 MU  1410
 2520 IF(HV-2.7) 2525,2521,2521                                                  MU  1430
 2521 ONO=(ANO*1.E-18)*10.**(-3.4820-0.11509E-02*T(L)+0.15999E-06*T(L)**MU  1440
     12+HV*(-2.3744+0.10952E-02*T(L)-0.10099E-06*T(L)**2)+(HV**2)*(0.575MU  1450
     249-0.17249E-03*T(L)+0.13874E-07*T(L)**2))                                  MU  1460
 2525 CONTINUE                                                                   MU  1470
```

```
      IF(NCRC(8))607, 15,607                                                    MU  1490
  607 DN=SQA*AN*XKT(L)*4.5*EXP(XX-XN)*ZN/HV**3                                  MU  1500
      IF(HV-4.22) 15,200,200                                                    MU  1510
  200 DN=DN*EXP(4.22/XKT(L)-XX)                                                 MU  1520
      IF(HV-10.8) 15,201,201                                                    MU  1530
  201 DN=DN+AN*5.16E-17*EXP(10.8/XKT(L)-XN)/DNM                                 MU  1540
      IF(HV-12.0) 15,202,202                                                    MU  1550
  202 DN=DN+AN*6.4E-17*EXP(12.0/XKT(L)-XN)/DNM                                  MU  1560
      IF(HV-14.3) 15,203,203                                                    MU  1570
  203 DN=DN+AN*3.16E-17/DNM                                                     MU  1580
   15 DZ=0.                                                                     MU  1600
      IF(NCRC(9))  608,609,608                                                  MU  1610
  608 DZ=SQA*AO*XKT(L)*(8.0/9.0)*EXP(XX-XO)*ZO/HV**3                            MU  1620
      IF(HV-4.22) 16,204,204                                                    MU  1630
  204 DZ=DZ*EXP(4.22/XKT(L)-XX)                                                 MU  1640
      DZ=DZ*(0.1415+0.4295*(T(L)/4000.))                                        MU  1650
      X3=HV-4.22                                                                MU  1660
      DZ=DZ+6.5E-18*AO*(8./DOM)*EXP(-9.28/XKT(L))*(1.-0.09375*X3+.00586*MU  1670
     1X3**2)                                                                    MU  1680
      IF(HV-13.4) 16,205,205                                                    MU  1690
  205 DZ=DZ+AO*3.6E-17/DOM                                                      MU  1700
  609 CONTINUE                                                                  MU  1710
   16 IF(T(L)-8000.) 5000,4975,4975                                             MU  1730
 4975 IF(HV-3.9) 4977,4977,5000                                                 MU  1740
 4977 IF(HV-.01) 5000 ,4978,4978                                                MU  1750
 4978 DZ=DZ*(0.1415+0.4295*(T(L)/4000.))                                        MU  1760
      DN=DN*(0.867+0.168*(T(L)/6000.))                                          MU  1770
 5000 CONTINUE                                                                  MU  1780
      IF(NCRC(10)) 611,17,611                                                   MU  1790
  611 DI=4.0*SQA*AI*1.33*XKT(L)*EXP(XX-XI)/HV**3                                MU  1800
      IF(HV-10.8) 17,206,206                                                    MU  1810
  206 DI=DI*EXP(11.2/XKT(L)-XX)                                                 MU  1820
   17 DO2=0.0                                                                   MU  1840
      IF(NCRC(11)) 613,18,613                                                   MU  1850
  613 IF(HV-3.) 18,1305,1305                                                    MU  1860
 1305 IF(HV-7.) 1301,207,207                                                    MU  1870
  207 IF(HV-9.2) 208,208,18                                                     MU  1880
  208 DO2=AO2*400.0*SQRT(TANH(0.0975/XKT(L)))*EXP(-TANH(0.195/(2.0*             MU  1890
     1XKT(L)))*((HV-8.56)/0.805)**2)/2.687E+19                                  MU  1900
      GO TO 18                                                                  MU  1910
 1301 DO2=(AO2*1.E-18)*10.**(-23.413+0.40509E-02*T(L)-0.24545E-06*T(L)**MU  1930
     12+HV*(6.2102-0.10559E-02*T(L)+0.66192E-07*T(L)**2)+(HV**2)*(-0.416MU  1940
     253+0.71490E-04*T(L)-0.47115E-08*T(L)**2))                                 MU  1950
   18 DN2=0.0                                                                   MU  1970
      IF(NCRC(12)) 614,2010,614                                                 MU  1980
  614 IF(HV-6.5) 2550,209,209                                                   MU  1990
```

```
  209 IF(HV-12.77)210,210,2010                                              MII  2000
  210 IF(HV-10.5)211,211,212                                                MII  2010
  211 DN2=(AN2/2.52E+19)*EXP(2.3026*(-14.871-0.39586E-03*T(L)+0.86911E-0MII  2040
     17*T(L)**2+HV*(-0.99225E-01+0.61168E-03*T(L)-0.41260E-07*T(L)**2)   MII  2050
     2+(HV**2)*(0.12305-0.48332E-04*T(L)+0.28353E-08*T(L)**2)))          MII  2060
      GO TO 2010                                                          MII  2070
  212 DN2=(AN2/2.52E+19)*EXP(2.3026*(-39.306+0.71761E-02*T(L)-0.46157E-0MII  2080
     16*T(L)**2+HV*(4.1032-0.76919E-03*T(L)+0.52442E-07*T(L)**2)+(HV**2)MII  2090
     2*(-0.56701E-01+0.16228E-04*T(L)-0.12761E-08*T(L)**2)))             MII  2100
      GO TO 2010                                                          MII  2110
 2550 IF(HV-4.5) 2551,2551,2010                                           MII  2130
 2551 IF(HV-0.75) 2010,2552,2552                                          MII  2140
 2552 DN2=8.E-20*AN2*10.**(-1.+2.78*HV-0.819*HV**2-2.696/XKT(L))+2.E-17 MII  2150
     1*AN2*10.**(-17.14+8.93*HV-1.132*HV**2-3.26/XKT(L))                 MII  2160
 2010 DCO=0.0                                                             MII  2190
      IF(NCRC(13).EQ.0.OR.HV.LT.4.27.OR.HV.GT.10.60) GOTO 118
      ARG =-245.36 + 4444.9 *XLAM - 31603.*XLAM**2
     .      +97915.7*XLAM**3 - 112317.*XLAM**4
      ARG = ARG*(2.1272 - 3.7609E-4*T(L) + 3.642E-8*T(L)**2
     .           -1.24E-12*T(L)**3)
      DCO = EXP(2.30259*ARG)/(1.492E5*EXP(-HV*11606./T(L))*1.0/
     .       (XLAM**5))
      DCO=DCO*ACO
  118 DH2=0.0                                                              MII  2320
      IF(NCRC(14))616,119,616                                             MII  2330
  616 IF(HV-3.65) 119,222,222                                             MII  2340
  222 IF(HV-25.0) 223,223,119                                             MII  2350
  223 IF(HV-15.50) 1023,124,124                                           MII  2360
 1023 IF(HV-10.) 2530,2531,2531                                           MII  2370
 2531 DH2=(AH2*1.E-18)*10.**(-120.73+0.17515E-01*T(L)-0.87076E-06*T(L)**MII  2380
     12+HV*(17.526-0.24654E-02*T(L)+0.12097E-06*T(L)**2)+(HV**2)*(-0.625MII  2390
     227+0.86154E-04*T(L)-0.41802E-08*T(L)**2))                          MII  2400
      IF(T(L)-3000.) 119,9125,9125                                        MII  2410
 9125 DH2=(AH2*1.E-19)*10.**(11.513+0.15839E-03*T(L)-0.11789E-06*T(L)**2MII  2420
     1+HV*(-1.2534-0.13165E-03*T(L)+0.31267E-07*T(L)**2)+(HV**2)*(0.3294MII  2430
     11E-01+0.89272E-05*T(L)-0.17775E-08*T(L)**2)) +DH2                  MII  2440
      GO TO 119                                                           MII  2450
 2530 IF(HV-6.2) 2532,2533,2533                                           MII  2460
 2533 DH2=AH2*2.5E-18                                                     MII  2470
      GO TO 119                                                           MII  2480
 2532 IF(HV-5.3) 2534,2534,2535                                           MII  2490
 2535 DH2=(AH2*1.E-18)*10.0**(-207.78+0.55206E-01*T(L)-0.44098E-05*T(L)*MII  2500
     1*2+HV*(66.917-0.17948E-01*T(L)+0.14473E-05*T(L)**2)+(HV**2)*(-5.37MII  2510
     267+0.14587E-02*T(L)-0.11872E-06*T(L)**2))                          MII  2520
      GO TO 119                                                           MII  2530
 2534 DH2=(AH2*1.E-18)*10.0**(-5.2820-0.27812E-02*T(L)+0.20715E-06*T(L)*MII  2540
```

```
     1*2+HV*(-5.1687+0.24948E-02*T(L)-0.16031E-06*T(L)**2)+(HV**2)*(0.96MU  2550
     2364-0.34072E-03*T(L)+0.21180E-07*T(L)**2))                          MU  2560
      GO TO 119                                                           MU  2570
  124 DH2=AH2*10.0**(-17.19+0.062*(HV-16.0))                              MU  2580
  119 DC2=0.0                                                             MU  2600
      IF(NCRC(15)) 617,120,617                                            MU  2610
617   CONTINUE
C.... C2 MOLECULAR BANDS FROM K.SUTTON, 5/78
      IF(HV.LT.0.1 .OR. HV.GT.6.6)  GO TO 470
      V = HV
      V2 = V*V
      V3 = V2*V
      V4 = V3*V
      U = T(L)
      IF(U.LT.2000.0) U = 2000.0
      IF(U.GT.14000.0)  U = 14000.0
      U2 = U*U
      U3 = U2*U
      IF(V.GT.1.9)  GO TO 410
C     C2 BALLIK-RAMSAY
      W = (-2.47556255E+1 +1.56675833E-3*U -1.49681021E-7*U2
     A      +4.76786134E-12*U3)  +(2.04675773E+1 -5.05326261E-3*U
     B      +4.57527045E-7*U2 -1.42849344E-11*U3)*V  +(-2.07591403E+1
     C      +5.28626421E-3*U -4.65253699E-7*U2 +1.42703647E-11*U3)*V2
     D      +(6.93314515E+0 -1.96130560E-3*U +1.62901846E-7*U2
     E      -4.82780698E-12*U3)*V3 +(-6.67009441E-1 +1.91144134E-4*U
     F      -1.33821102E-8*U2 +3.52119926E-13*U3)*V4
      DC2 = DC2 + AC2*(10.0**W)
  410 CONTINUE
      IF(V.GT.2.6)  GO TO 420
C     C2 PHILLIPS
      W = (-2.55010890E+1 +1.70584568E-3*U -1.65244165E-7*U2
     A      +5.32056661E-12*U3)  +(1.26249681E+1 -3.01906596E-3*U
     B      +2.75757647E-7*U2 -8.69708111E-12*U3)*V  +(-5.38213934E+0
     C      +1.07838911E-3*U -8.74715768E-8*U2 +2.60010262E-12*U3)*V2
     D      +(-5.10183000E-1 +3.11595820E-4*U -3.68018487E-8*U2
     E      +1.26878908E-12*U3)*V3  +(3.69027147E-1 -1.49010770E-4*U
     F      +1.51951958E-8*U2 -4.97888511E-13*U3)*V4
      DC2 = DC2 + AC2*(10.0**W)
  420 CONTINUE
      IF(V.LT.1.1)GO TO 470
      IF(V.GT.3.5)GO TO 430
C     C2 SWAN
      W = (+1.13973049E+1 -1.07516873E-2*U +8.91619111E-7*U2
     A      -2.48633789E-11*U3)  +(-8.63964298E+1 +2.63430298E-2*U
     B      -2.27779293E-6*U2 +6.57976986E-11*U3)*V  +(6.67733145E+1
```

```
     C      -1.96563652E-2*U +1.72196192E-6*U2 -5.00533984E-11*U3)*V2
     D      +(-1.95084525E+1 +5.89471406E-3*U -5.21078797E-7*U2
     E      +1.51363699E-11*U3)*V3  +(1.90859634E+0 -6.21306706E-4*U
     F      +5.55116345E-8*U2 -1.60805289E-12*U3)*V4
       DC2 = DC2 + AC2*(10.0**W)
  430 CONTINUE
       IF(V.LT.2.2)  GO TO 470
       IF(V.GT.4.2)  GO TO 440
C      C2 DESLANDRES-D'AZAMBUJA
       W = (+4.37104134E+2 -1.07172749E-1*U +9.13453174E-6*U2
     A      -2.69365071E-10*U3)  +(-6.40684147E+2 +1.51245196E-1*U
     B      -1.31009355E-5*U2 +3.90154018E-10*U3)*V  +(3.18696463E+2
     C      -7.60914126E-2*U +6.66707577E-6*U2 -1.99723467E-10*U3)*V2
     D      +(-6.77434932E+1 +1.64989333E-2*U -1.46097376E-6*U2
     E      +4.39700394E-11*U3)*V3  +(5.22243047E+0 -1.30860675E-3*U
     F      +1.17137751E-7*U2 -3.54019661E-12*U3)*V4
       DC2 = DC2 + AC2*(10.0**W)
  440 CONTINUE
       IF(V.LT.3.2)  GO TO 470
       IF(V.GT.6.0)  GO TO 450
C      C2 FOX-HERZBERG
       W = (-1.61270124E+1 -3.24205656E-3*U +1.65029202E-7*U2
     A      -2.52276490E-12*U3)  +(-2.18665136E+1 +7.64317879E-3*U
     B      -5.98228437E-7*U2 +1.67809358E-11*U3)*V  +(1.02710478E+1
     C      -3.18657710E-3*U +2.56604310E-7*U2 -7.39573553E-12*U3)*V2
     D      +(-1.64084342E+0 +4.83701438E-4*U -3.84919650E-8*U2
     E      +1.10330660E-12*U3)*V3  +(8.76186297E-2 -2.50488294E-5*U
     F      +1.92781533E-9*U2 -5.40620686E-14*U3)*V4
       DC2 = DC2 + AC2*(10.0**W)
  450 CONTINUE
       IF(V.LT.4.9)  GO TO 470
       IF(V.GT.5.8)  GO TO 460
C      C2 MULLIKEN
       W = (+1.30164627E+5 -4.97157720E-1*U +8.82595591E-5*U2
     A      -3.85774989E-9*U3)  +(-9.71235874E+4 +3.41272251E-1*U
     B      -6.33444218E-5*U2 +2.80550065E-9*U3)*V  +(2.71169027E+4
     C      -8.43582112E-2*U +1.67538464E-5*U2 -7.55974575E-10*U3)*V2
     D      +(-3.35819639E+3 +8.78863905E-3*U -1.93282716E-6*U2
     E      +8.94390272E-11*U3)*V3  +(1.55651193E+2 -3.17294480E-4*U
     F      +8.18680808E-8*U2 -3.91774199E-12*U3)*V4
       DC2 = DC2 + AC2*(10.0**W)
  460 CONTINUE
       IF(V.LT.5.0)  GO TO 470
C      C2 FREYMARK
       W = (+9.87635453E+3 -2.71103348E+0*U +2.54379768E-4*U2
     A      -8.00148084E-9*U3)  +(-6.91642388E+3 +1.90489949E+0*U
```

```
     A       -1.79377621E-4*U2 +5.65092977E-9*U3)*V  +(1.70929588E+3
     C       -4.99288490E-1*U +4.71907382E-5*U2 -1.48891798E-9*U3)*V2
     D       +(-2.06596603E+2 +5.79982162E-2*U -5.49394522E-6*U2
     E       +1.73612707E-10*U3)*V3  +(8.83615657E+0 -2.50699930E-3*U
     E       +2.38897981E-7*U2 -7.56183410E-12*U3)*V4
      DC2 = DC2 + AC2*(10.0**W)
  470 CONTINUE
  120 DCM=0.0                                                          MU  2790
      IF(NCRC(16)) 618,121,618                                         MU  2800
  618 IF(HV-0.8) 121,226,226                                           MU  2810
  226 IF(HV-6.)  1227,1227,121                                         MU  2820
 1227 DCM=(ACM*1.E-19)*10.**(-1.3962+0.19982E-03*T(L)-0.10678E-07*T(L)**MU  2830
     12+HV*(6.6871-0.10144E-02*T(L)+0.60781E-07*T(L)**2)+(HV**2)*(-2.909MU  2840
     27+0.43612E-03*T(L)-0.26433E-07*T(L)**2))                         MU  2850
      IF(HV-2.) 121,1228,1228                                          MU  2860
 1228 DCM=DCM+ACM*10.**(-41.46+13.76*HV-1.946*HV**2)                   MU  2870
  121 DC=0.                                                            MU  2880
      IF(NCRC(17)) 619,122,619                                         MU  2890
  619 IF (HV-3.78) 127,128,128                                         MU  2900
  127 DC=SQA*AC*1.33*XKT(L)*EXP((HV-11.26)/XKT(L))*7C/HV**3            MU  2910
      GO TO 122                                                        MU  2920
  128 DC=SQA*AC*1.33*XKT(L)*EXP(-7.58/XKT(L))*7C/HV**3                 MU  2930
      IF(HV-8.51) 122,228,228                                          MU  2940
  228 DC=DC+AC*2.2E-17*EXP(-2.75/XKT(L))/DCM                           MU  2950
      IF(HV-10.0) 122,229,229                                          MU  2960
  229 DC=DC+AC*8.5E-17*EXP(-1.26/XKT(L))/DCM                           MU  2970
      IF(HV-11.26) 122,230,230                                         MU  2980
  230 DC=DC+AC*9.9E-17/DCM                                             MU  2990
  122 DCP=0.                                                           MU  3000
      IF(NCRC(18)) 620,131,620                                         MU  3010
  620 IF (HV-15.08) 129,130,130                                        MU  3020
  129 DCP=8.34458E-20*ACP*T(L)*EXP((HV-24.4)/XKT(L))*7I/HV**3          MU  3030
      GO TO 131                                                        MU  3040
  130 DCP=8.34458E-20*ACP*T(L)*EXP(-9.32/XKT(L))*7I/HV**3              MU  3050
      IF(HV-19.03) 131,231,231                                         MU  3060
  231 DCP=DCP+6.84E-17*EXP(-5.37*XKT(L))*ACP/DCPM                      MU  3070
      IF(HV-24.4) 131,232,232                                          MU  3080
  232 DCP=DCP+1.32E-17*ACP/DCPM                                        MU  3090
  131 CONTINUE                                                         MU  3100
      XAPMU(L)=EPC*(DN+DZ+DI+XNM+XCM+DC+XMOL*(DCO+DH2+DC2+DCM          MU  3110
     1+DO2+DN2+DNO+DN2P)+XHM+XOM+DNHS+DOHS)                            MU  3120
      IF(HV-0.80)233,233,1405
  233 DH=6.26E-20*AH*T(L)*EXP((HV-13.6)/XKT(L))/HV**3                  MU  3130
      GO TO 1450                                                       MU  3140
 1405 DH=                                          6.26E-20*AH*T(L)    MU  3150
     1*EXP(-12.8/XKT(L))/HV**3                                         MU  3160
```

```
      IF(HV-1.60) 1450,234,234                                          MII  3220
  234 DH = DH+1.47E-15*AH*EXP(-12.0/XKT(L))/(DHMA*HV**3)                MII  3230
      IF(HV-3.40) 1450,235,235                                          MII  3240
  235 DH = DH+4.975E-15*AH*EXP(-10.2/XKT(L))/(DHMA*HV**3)               MII  3250
      IF(HV-13.38)1450,236,236                                          MII  3260
  236 DH=DH+3.98E-14*AH/(DHMA*HV**3)                                    MII  3270
 1450 CONTINUE                                                          MII  3280
      XAPMU(L)=XAPMU(L)+EPC*DH                                          MII  3290
      H=HV
      IF(H.LT.2.21.OR.H.GT.4.13) GO TO 1000
      ANG=XLAM*1.0E+4
      ANG2=ANG*ANG
      ANG3=ANG*ANG2
      IF(H.GT.3.1) DC3=1.31141E-16-1.06835E-19*ANG+2.87421E-23*
     1ANG2-2.49649E-27*ANG3
      IF(H.LE.3.1) DC3=1.984695E-16-1.07008E-19*ANG+1.90778E-23*
     1ANG2-1.11976E-27*ANG3
      XAPMU(L)=XAPMU(L)+DC3*XNN(I,21)
 1000 CONTINUE                                                          MII  3310
      RETURN                                                            MII  3320
      END                                                               MII  3330
      SUBROUTINE SLOPE(N,X,Y,S,Z)                                       SLOPE010
      DIMENSION X(1),Y(1),S(1),Z(1)                                     SLOPE020
      IF(N-1)9,9,1                                                      SLOPE040
    1 S(2)=(Y(2)-Y(1))/(X(2)-X(1))                                      SLOPE050
      S(1)=S(2)                                                         SLOPE060
      CC=S(2)                                                           SLOPE070
      DO 8 I=1,N                                                        SLOPE080
      IF(I+1-N)3,2,7                                                    SLOPE090
    2 AB=CC                                                             SLOPE100
      IF(I-2)8,7,6                                                      SLOPE110
    3 XDT=X(I)-X(I+1)                                                   SLOPE120
      XTT=X(I+1)-X(I+2)                                                 SLOPE130
      XTD=X(I+2)-X(I)                                                   SLOPE140
      AA=Y(I)/(XDT*XTD)                                                 SLOPE150
      AB=Y(I+1)/(XDT*XTT)                                               SLOPE160
      AC=Y(I+2)/(XTT*XTD)                                               SLOPE170
      AAA=AA*XTT                                                        SLOPE180
      ABB=AB*XTD                                                        SLOPE190
      ACC=AC*XDT                                                        SLOPE200
      CA=CC                                                             SLOPE210
      CB=S(I)                                                           SLOPE220
      CC=S(I+1)                                                         SLOPE230
      S(I)=AA*(XTD-XDT)+ABB-ACC                                         SLOPE240
      S(I+1)=AB*(XDT-XTT)+ACC-AAA                                       SLOPE250
      S(I+2)=AC*(XTT-XTD)+AAA-ABB                                       SLOPE260
```

```
      IF(I-2)9,6,5                                                      SLOP0270
    5 S(I)=.5*(S(I)+QA)                                                 SLOP0280
    6 S(I)=.5*(S(I)+QB)                                                 SLOP0290
    7 XD=X(I)-X(I-1)                                                    SLOP0300
      YS=Y(I)+Y(I-1)                                                    SLOP0310
      SD=S(I)-S(I-1)                                                    SLOP0320
      Z(I)=Z(I-1)+.5*XD*(YS-XD/6.*SD)                                   SLOP0330
    8 CONTINUE                                                          SLOP0340
    9 RETURN                                                            SLOP0350
      END                                                               SLOP0360
      SUBROUTINE TRANSA(TMU,NY)                                         TRAN0010
      COMMON/AERAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,      TRAN0140
     .     NSHV,NXI,NYCUM,TW,C2,MIDPNT,NTRANS,SF(5)
      COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),EE(300),EHVC(50),EHV(25),
     .EHVM(25),EHVP(25),GAMP(300),GEE(56),GIP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
     .EHVS(200),NSHC(25)
      COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
     .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),REE(51),
     .EMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
     .FRP(51),FLN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
     .SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
      DIMENSION TMU(1),DM(1),DP(1)
      EQUIVALENCE (DM,SK),(DP,DSK)
      NYP=NY+1                                                          TRAN0210
      NYM=NY-1                                                          TRAN0220
      FIM(1)=0.0                                                        TRAN0230
      FIP(NY)=0.0                                                       TRAN0240
      TAUT(1)=0.0                                                       TRAN0260
      DO 100 I=2,NY                                                     TRAN0290
      DYAL=C2*(YY(I)-YY(I-1))                                           TRAN0300
      V=TMU(I)/TMU(I-1)                                                 TRAN0310
      V1=V-1                                                            TRAN0320
      IF(ABS(V1).GT.0.01) GO TO 50                                      TRAN0330
      V1F=V1/24.0                                                       TRAN0350
      TAUT(I)=(1.0+V1*(0.5+V1F*(V1-2.0)))*DYAL*TMU(I-1)                 TRAN0360
      DM(I)=DYAL*(0.5-V1F*(4.0-3.0*V1))                                 TRAN0370
      DP(I-1)=DYAL*(0.5+V1F*(4.0-V1))                                   TRAN0380
      GO TO 100                                                         TRAN0390
   50 V3=1.0/ALOG(V)                                                    TRAN0410
      V3D=V3*V3                                                         TRAN0420
      TAUT(I)=V1*V3*DYAL*TMU(I-1)                                       TRAN0430
      DM(I)=DYAL*(V3-V1*V3D/V)                                          TRAN0440
      DP(I-1)=DYAL*(V1*V3D-V3)                                          TRAN0450
  100 CONTINUE                                                          TRAN0460
```

```
      I=NY                                                              TRAN0490
      DO 200 J=2,NY                                                     TRAN0500
      EXPT(I)=EXP(-TAUT(I))                                             TRAN0510
      ELN(I)=ALOG(REF(I)/REF(I-1))                                      TRAN0520
      DEN=TAUT(I)-ELN(I)                                                TRAN0530
      VIM=REF(I-1)-REF(I)*EXPT(I)                                       TRAN0540
      FIP(I-1)=FIP(I)*EXPT(I)+TAUT(I)*VIM/DEN                           TRAN0550
  200 I=I-1                                                             TRAN0560
      DO 300 I=2,NY                                                     TRAN0590
      DEN=ELN(I)+TAUT(I)                                                TRAN0600
      VIM=REF(I)-REF(I-1)*EXPT(I)                                       TRAN0610
      FIM(I)=FIM(I-1)*EXPT(I)+TAUT(I)*VIM/DEN                           TRAN0620
  300 CONTINUE                                                          TRAN0630
      TAUT(1)=0.0                                                       TRAN0650
      DO 400 I=2,NY                                                     TRAN0660
      DP(I)=TAUT(I)                                                     TRAN0670
      TAUT(I)=TAUT(I-1)+DP(I)                                           TRAN0680
  400 CONTINUE                                                          TRAN0690
      RETURN                                                            TRAN0700
      END                                                               TRAN0710
      SUBROUTINE ZHV(HV,ZO,ZN,ZI,ZC)                                    ZHV 0010
      X=HV                                                              ZHV 0020
      IF (HV-9.82) 1,1,2                                                ZHV 0030
    1 ZO=0.99997956-0.31554804*X +2.8245479E-02*X**2 +6.6773283E-03*X**3ZHV 0040
     1-3.6445854E-03*X**4 +8.0580698E-04*X**5 -7.7086374E-05*X**6 +2.   ZHV 0050
     2668133E-06*X**7                                                   ZHV 0060
      GO TO 3                                                           ZHV 0070
    2 ZO=(X/9.82)**3                                                    ZHV 0080
    3 IF (HV-8.35) 4,4,5                                                ZHV 0090
    4 ZN=1.0001488-0.41835346*X +0.16803591*X**2 -9.7794579E-02*X**3    ZHV 0100
     1+3.3546351E-02*X**4 -5.6093534E-03*X**5 +4.515535E-04*X**6 -1.4035ZHV 0110
     2945E-05*X**7                                                      ZHV 0120
      GO TO 6                                                           ZHV 0130
    5 ZN=(X/8.35)**3                                                    ZHV 0140
    6 X=HV/4.0                                                          ZHV 0150
      IF (X-6.6) 7,7,8                                                  ZHV 0160
    7 ZI=1.0003794-0.29547668*X +7.5052416E-02*X**2 -1.7029481E-02*X**3 ZHV 0170
     1+3.2795539E-03*X**4-2.1284692E-04*X**5                            ZHV 0180
      GO TO 9                                                           ZHV 0190
    8 ZI=(X/7.37)**3                                                    ZHV 0200
    9 X=HV                                                              ZHV 0210
      IF (X-7.37) 25,25,26                                              ZHV 0220
   25 ZC=0.99743674-0.43418122*X +8.5313141E-02*X**2 -1.3939168E-02*X**3ZHV 0230
     1+4.0385449E-03*X**4-5.4264246E-04*X**5+2.8121261E-05*X**6-3.88352 ZHV 0240
     298E-07*X**7                                                       ZHV 0250
      GO TO 20                                                          ZHV 0260
```

```
   26 ZC=(X/7.37)**3                                                    ZHV 0270
   20 RETURN                                                            ZHV 0280
      END                                                               ZHV 0290
      FUNCTION EXP3(X)
      IF(X.GT.0.7) GO TO 10
      XX = 0.5*X*X
      EXP3 = 0.5 - X + XX*(0.922784 - ALOG(X)) + 0.16666667*XX*X
      RETURN
   10 EXP3 = 0.4*EXP(-1.293*X)
      RETURN
      END
      FUNCTION GAMEX(N4,SUMN5)
      YMIN=0.625E-13*N4*X/(TT*TT)
      Y2=YMIN*YMIN
      Y3=Y2*YMIN
      E1=YMIN-0.25*Y2+0.05556*Y3-ALOG(YMIN)-0.577216
      GAMEX = 1.261E-21*X*SUMN5*E1/SQRT(TT)
      RETURN
      END
      FUNCTION HWING(L)
      EQUIVALENCE (WDH,ALPHA)
      REAL C(4) , WOT(4) , PON(4)
      DATA (C(I),I=1,4)/3.4E-6,1.78E-5,1.3E-3,3.57E-3/
      DATA (PON(I),I=1,4)/4.426E-9,3.151E-9,1.289E-7,7.072E-8/
      DATA (WOT(I),I=1,4)/.002567,.0008123,.03324,.01026/
      DLAMBDA = E0*ALPHA
      DLW = WOT(L)*TT
      TERM = 2.0
      IF(DLAMBDA.GT.DLW) GO TO 20
      DLP = PON(L)*SQRT(X)
      SQLAM = SQRT(DLAMBDA)
      TERM = 1.0+RNT*SQLAM
      IF(DLAMBDA.GT.DLP) TERM = (DLW-DLAMBDA)/(DLW-DLP)*TERM
      IF(TERM.GT.2.0) TERM = 2.0
   20 HWING = C(L)/ALPHA**2.5 * TERM
      RETURN
      END
      FUNCTION HYCORE(XA,YA,X,Y,DY,N)
      DIMENSION X(1),Y(1),DY(1)
      YA=Y(N)
      NM=N-1
      DO 10 I=1,NM
      IF(XA.LT.X(I+1)) GO TO 20
   10 CONTINUE
      GO TO 40
   20 DX=1.0/(X(I+1)-X(I))
```

```
      J=I
      DA=XA-X(I)
      G=(((Y(I+1)-Y(I))*DX)-DY(I))*DX
      F=(((DY(I+1)-DY(I))*DX)-2.0*G)*DX
      H=(F*(XA-X(I+1))+G)*DA
   30 YA=(H+DY(I))*(XA-X(I))+Y(I)
   40 HYCORE=EXP(2.303*YA)
      RETURN
      END
      SUBROUTINE NDERIV(W2,W2N,IE,I,K,NMP)
      COMMON/NORD/DN(51)
      DIMENSION W2(NMP,K),W2N(NMP,K)
      IM1=IE-2
      W2N(2,I:IM1)=(DN(1:IM1)*W2(3,I:IM1)/DN(2:IM1)-DN(2:IM1)*W2(1,I:IM1
     1)/DN(1:IM1))/(DN(2:IM1)+DN(1:IM1))+(DN(2:IM1)-DN(1:IM1))*W2(2,I:
     2IM1)/(DN(2:IM1)*DN(1:IM1))
      W2N(1,I)=-W2(1,I)*(DN(2)+2.0*DN(1))/(DN(1)*(DN(2)+DN(1)))          NDER0120
     1        +W2(2,I)*(DN(2)+DN(1))/(DN(2)*DN(1))                       NDER0130
     2        -W2(3,I)*DN(1)/(DN(2)*(DN(1)+DN(2)))                       NDER0140
      W2N(IE,I)=W2(IE,I)*(DN(IM-1)+2.0*DN(IM))/(DN(IM)*(DN(IM)+DN(IM-1))NDER0150
     1        )-W2(IE-1,I)*(DN(IM-1)+DN(IM))/(DN(IM)*DN(IM-1))           NDER0160
     2         +W2(IE-2,I)*DN(IM)/(DN(IM-1)*(DN(IM)+DN(IM-1)))           NDER0170
      RETURN                                                             NDER0180
      END                                                                NDER0190
      SUBROUTINE ARADPO
      COMMON/SFLUX/ORI(3),DIFORW,FP,FM
      COMMON/PROB/ETA(51),F(51),BE1(51),BE2(51),TRC(51),TOTP(51),
     .CONTE1(51),CONTE2(51),P2P2(51)
      COMMON/CTRL/IE,IOUTPT,M,   NIT,NUMB,   OVLY,RDLY,NMP,TIMET,
     .NBODY,ITPO,MACE,IOPT,INDS,XLEWIS,XPRAND
      COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),EE(300),EHVC(50),EHV(25),
     .EHVM(25),EHVP(25),GAMP(300),GEE(56),GIP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
     .EHVS(200),NSHC(25)
      COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
     .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
     .EMU(51),TAUT(51),DIM(51),DIP(51),EIM(51),EIP(51),ERM(51),
     .ERP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
     .SK(51),DSK(51),XE(51),EXPT(51),XTX(51,3),VX(51)
      COMMON/LRAD/IEZ,IRONLY,IMPON,LINES,ME,METAX,NSR,POE,UE,XOTIL,XMOL
      COMMON/ARAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,
     .         NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SE(5)
      COMMON/CHEQQ/QR1(51)
      IF(M.NE.1)GO TO 500
      WRITE(6,900)
```

```
900   FORMAT(1H1, 1X,'RADIATIVE FLUX VS. FREQUENCY - AEROTHERM MODEL'/
     .30X,'CONTINUUM',54X,'LINE GROUPS')
      WRITE(6,901) ETA(1),ETA(IMPON),ETA(IE),ETA(1),ETA(IMPON),ETA(IE)
 901  FORMAT(1H0,6X'ETA',F16.2,F21.2,F16.2,F29.2,F21.2,F16.2/6X,'FREQ.
     .  ',4X,'0-MINUS',4X,'0-PLUS',4X,'0-MINUS',4X,'0-PLUS',4X,'0-MINUS',
     .    9X,'FREQ.',4X,'0-MINUS',4X,'0-PLUS',4X,'0-MINUS',4X,'0-PLUS',
     .    4X,'0-MINUS')
      NVMX=MAX0(NHV,NIHVC)
      DO 400 I=1,NVMX
      WRITE(6,902)
 902  FORMAT(1H )
      IF(I.GT.NIHVC) GO TO 360
      WRITE(6,903) I,FHVC(I),(FIMC(I,J),FIPC(I,J),J=1,2),FIMC(I,3)        ARAD
 360  IF(I.GT.NHV) GO TO 400
      WRITE(6,904) FHV(I),(FIML(I,J),FIPL(I,J),J=1,2),FIML(I,3)           ARAD007
 400  CONTINUE
      J=MIDPNT
      WRITE(6,905) FIMI(1),FIPI(1),FIMI(J),FIPI(J),FIMI(NY),
     .             TLCM(1),TLCP(1),TLCM(J),TLCP(J),TLCM(NY)
      WRITE(6,906) DELTA,QRI
      WRITE(6,910)
 910  FORMAT(1H1,'CONTINUUM SPECTRAL FLUX VS. FREQUENCY'/)
      WRITE(6,901) ETA(1),ETA(IMPON),ETA(IE),ETA(1),ETA(IMPON),ETA(IE)
      SRF1=SF(1)
      SRF2=SF(2)
      SRF3=SF(3)
      SRF4=SF(4)
      SRF5=SF(5)
      DO 495 I=1,NVMX
      IF(I.EQ.1) GO TO 490
      SUM=2.0/(FHVC(I)-FHVC(I-1))
      SRF1=FIMC(I,1)*SUM-SRF1M
      SRF2=FIPC(I,1)*SUM-SRF2M
      SRF3=FIMC(I,2)*SUM-SRF3M
      SRF4=FIPC(I,2)*SUM-SRF4M
      SRF5=FIMC(I,3)*SUM-SRF5M
 490  CONTINUE
      SRF1M=SRF1
      SRF2M=SRF2
      SRF3M=SRF3
      SRF4M=SRF4
      SRF5M=SRF5
      WRITE(6,908) I,FHVC(I),SRF1,SRF2,SRF3,SRF4,SRF5
 908  FORMAT(1X,I3,F8.3,F11.3,F10.3,F11.3,F10.3,F11.3)
 495  CONTINUE
 500  CONTINUE
```

```
      WRITE(6,912)
  912 FORMAT(1H0,58X,'RADIATIVE FLUX, W/CM2',/)
      WRITE(6,913) (QR(N),N=1,IE)
  913 FORMAT(11(1X,10F13.4,/))
      WRITE(6,911)
  911 FORMAT(1H0,133(1H-))
  903 FORMAT(1H+,I3,F8.3,F11.3,F10.3,F11.3,F10.3,E11.3)
  904 FORMAT(1H+,70X,F8.3,F11.3,F10.3,F11.3,F10.3,E11.3)                    AR
  905 FORMAT(1H0,' TOTAL FLUX',2(F11.3,F10.3),F11.3,14X,2(F11.3,F10.3),
     . F11.3)
  906 FORMAT(1H0,'     DELTA='E15.6,' CM.       RADIATIVE FLUX ='3E15.6,
     .'WATTS/CM--2'//4X,125(1H-))
      QR1(1:IE)=QR(1:IE)
      RETURN
      END
      SUBROUTINE FREQ(K,CFIL)                                              FRE00010
      COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),EE(300),EHVC(50),EHV(25),
     .EHVM(25),EHVP(25),GAMP(300),GEE(56),GUP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
     .EHVS(200),NSHC(25)
      COMMON/CHEQR/XMN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
     .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
     .EMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),ERM(51),
     .ERP(51),ELN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
     .SK(51),DSK(51),XE(51),EXPT(51),XTX(51,3),VX(51)
      COMMON/AFRAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NTHVC,         FRE00180
     .       NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SE(5)
      DIMENSION AL(4)                                                      FRE00200
      DATA(AL(I),I=1,4)/1.5E-4,1.5E-3,1.5E-2,0.05/                         FRE00210
      N=6                                                                  FRE00230
      IRY=0                                                                FRE00240
      CFIL=0.                                                              FRE00250
      YNY=NY                                                               FRE00260
      IF(HVL(K1)-EHVM(K)) 30,30,31                                         FRE00280
   31 IF(HVL(K2)-EHVP(K)) 32,30,30                                         FRE00290
   30 WRITE(N,350)                                                         FRE00300
  350 FORMAT(49H ****LINE CENTER OUT OF GROUP FREQUENCY RANGE****)         FRE00310/
      CALL EXIT                                                            FRE00320
   32 CONTINUE                                                             FRE00330
      XMUM=1.E-08/(C2*YY(NY))                                              FRE00340
      XMIN=0.1*XMUM/YNY                                                    FRE00350
      IKK=0                                                                FRE00370
      DO 50 J=K1,K2                                                        FRE00380
      IKK=IKK+1                                                            FRE00410
      NK=NSHC(IKK)                                                         FRE00420
```

```
      XK=NK                                                          FRE00430
      NSHC(IKK)=2*NK+1                                               FRE00440
      IHT=1                                                          FRE00490
      JS=NY                                                          FRE00500
      IF(ND(J).GT.16) JS=NI                                          FRE00510
      CALL MULF(HVL(J),SK)                                           FRE00520
      DSK(1)=1.E-08/C2                                               FRE00530
      DO 500 I=1,NY                                                  FRE00540
      IF(SK(I)-XMUM) 501,500,500                                     FRE00550
  501 SK(I)=XMIN                                                     FRE00560
  500 CONTINUE                                                       FRE00570
      CALL ISLDV(JS,YY,SK,XF,DSK,PRES,DR,1)
      TAUC=DSK(JS)*C2                                                FRE00590
      IF(GAMP(J)) 400,401,400                                        FRE00610
  401 IHT=0                                                          FRE00620
      GIL=HVL(J)**2/(9.898E12 * XNN(NI,5)**0.333)                    FRE00630
      IF(K-IA(3)       ) 403,402,403                                 FRE00640
  402 GAMP(J)=AL(1)*GIL                                              FRE00650
      GO TO 400                                                      FRE00660
  403 IF(K-IA(4)       ) 405,404,405                                 FRE00670
  404 GAMP(J)=AL(2)*GIL                                              FRE00680
      GO TO 400                                                      FRE00690
  405 IF(K-IA(1) )      407,406,407                                  FRE00700
  406 GAMP(J)=AL(3)*GIL                                              FRE00710
      GO TO 400                                                      FRE00720
  407 IF(K-IA(2)       ) 400,408,400                                 FRE00730
  408 GAMP(J)=AL(4)*GIL                                              FRE00740
  400 CONTINUE                                                       FRE00750
      GAR=XNN(JS,5)*GAMP(J)*SQRT(1.0+TAUC)                           FRE00760
      GOR=0.5*GAR                                                    FRE00770
      GMAX=10.*GAR                                                   FRE00780
      IF(IHT.EQ.0) GAMP(J)=0.                                        FRE00790
      XF(1)=0.3                                                      FRE00800
      IF(J-K1) 1,20,1                                                FRE00860
   20 SM=HVL(K1)-FHVM(K)                                             FRE00870
      IF(SM-GMAX) 81,81,82                                           FRE00880
   82 SM=GMAX                                                        FRE00890
      GO TO 81                                                       FRE00900
    1 SM=0.5*(HVL(J)-HVL(J-1))                                       FRE00910
      IF(SM-GMAX)81,81,84                                            FRE00920
   84 SM=GMAX                                                        FRE00930
   81 IF(SM-GOR*XK) 80,80,2                                          FRE00940
   80 FHVS(IRY+1)=HVL(J)-SM                                          FRE00950
      DO 11 L=2,NK                                                   FRE00960
      LY=L+IRY                                                       FRE00970
   11 FHVS(LY)=FHVS(LY-1)+SM/XK                                      FRE00980
```

```
      GO TO 151                                                          FREQ0990
    2 DO 3 J1=1,19                                                       FREQ1010
   41 SK(J1)=((1.0+XF(J1))**NK-1.0)/XF(J1)                               FREQ1020
      DSK(J1)=(XF(J1)**2)/(XK*XF(J1)*(1.0+XF(J1))**(NK-1)-(1.0+XF(J1))**FREQ1030
     1NK+1.0)                                                            FREQ1040
      IF(SK(J1)*GOR/SM-20.) 42,42,40                                     FREQ1050
   40 IF(J1-1)44,44,43                                                   FREQ1060
   44 XF(J1)=XF(J1)/3.                                                   FREQ1070
      GO TO 41                                                           FREQ1080
   43 XF(J1)=XF(J1-1)+(XF(J1)-XF(J1-1))/5.                               FREQ1090
      GO TO 41                                                           FREQ1100
   42 XL=SM                                                              FREQ1110
      IF(ABS(SK(J1)*GOR/SM-1.0)-0.0001) 6,6,45                           FREQ1120
   45 XF(J1+1)=XF(J1)+DSK(J1)*(SM/GOR-SK(J1))                            FREQ1130
    3 CONTINUE                                                           FREQ1140
    4 WRITE(N,300)                                                       FREQ1150
  300 FORMAT(1H110X,10HERROR STOP// 4X,4HROOT, 8X,9HREMAINDER,15X,1HK,11FREQ1160
     1X,3HDHV,5X,13HMIN-INCREMENT,5X,2HSK,9X,3HDSK)                      FREQ1170
      DO 5 J2=1,20                                                       FREQ1180
      ERR=XL-SK(J2)*GOR                                                  FREQ1190
      WRITE(N,100) XF(J2),ERR,K,XL,GOR,SK(J2),DSK(J2)                    FREQ1200
  100 FORMAT(  2F13.6,11X,I3,6X, 4F12.4)                                 FREQ1210
    5 CONTINUE                                                           FREQ1220
      WRITE(N,200)                                                       FREQ1230
  200 FORMAT(42H FREQUENCY GRID ITERATION DID NOT CONVERGE)              FREQ1240
      CALL EXIT                                                          FREQ1250
    6 FX=XF(J1)                                                          FREQ1260
      XF(1)=0.3                                                          FREQ1270
      DO 150 L=1,NK                                                      FREQ1280
      LY=L+IRY                                                           FREQ1300
      FHVS(LY)=HVL(J)-GOR*(((1.+FX)**(NK+1-L)-1.)/FX)                    FREQ1310
  150 CONTINUE                                                           FREQ1320
  151 CONTINUE                                                           FREQ1330
      IF(J-K2) 7,21,7                                                    FREQ1340
   21 SP=FHVP(K)-HVL(J)                                                  FREQ1350
      IF(SP-GMAX) 12,12,90                                               FREQ1360
   90 SP=GMAX                                                            FREQ1370
      GO TO 12                                                           FREQ1380
    7 SP=.5*(HVL(J+1)-HVL(J))                                            FREQ1390
      IF(SP-GMAX) 12,12,91                                               FREQ1400
   91 SP=GMAX                                                            FREQ1410
   12 IF(SP-GOR*XK) 92,92,8                                              FREQ1420
   92 NIK=NK+1                                                           FREQ1430
      NFK=2*NK+1                                                         FREQ1440
      NIKP=NIK+1                                                         FREQ1450
      IR1=NIK+IRY                                                        FREQ1460
```

```
      FHVS(IR1)=HVL(J)                                                  FRE01470
      DO 13 L=NIKP,NFK                                                  FRE01480
      LY=L+IRY                                                          FRE01490
   13 FHVS(LY)=FHVS(LY-1)+SP/XK                                         FRE01500
      GO TO 251                                                         FRE01510
    9 DO 9 J1=1,19                                                      FRE01540
   61 SK(J1)=((1.0+XF(J1))**NK-1.0)/XF(J1)                              FRE01550
      DSK(J1)=(XF(J1)**2)/(XK*XF(J1)*(1.0+XF(J1))**(NK-1)-(1.0+XF(J1))**FRE01560
     1NK+1.0)                                                           FRE01570
      IF(SK(J1)*GOR/SP-20.) 62,62,60                                    FRE01580
   60 IF(J1-1) 64,64,63                                                 FRE01590
   64 XF(J1)=XF(J1)/3.                                                  FRE01600
      GO TO 61                                                          FRE01610
   63 XF(J1)=XF(J1-1)+(XF(J1)-XF(J1-1))/5.                              FRE01620
      GO TO 61                                                          FRE01630
   62 XL=SP                                                             FRE01640
      IF(ABS(SK(J1)*GOR/SP-1.0)-.0001) 10,10,65                         FRE01650
   65 XF(J1+1)=XF(J1)+DSK(J1)*(SP/GOR-SK(J1))                           FRE01660
      IF(ABS(SK(J1)*GOR/SP  -1.0)-.000101) 10,10,9                      FRE01670
    9 CONTINUE                                                          FRE01680
      XL=SP                                                             FRE01690
      GO TO 4                                                           FRE01700
   10 FX=XF(J1)                                                         FRE01710
      NIK=NK+1                                                          FRE01720
      NFK=2*NK +1                                                       FRE01730
      DO 250 L=NIK,NFK                                                  FRE01750
      LY=L+IRY                                                          FRE01760
      FHVS(LY)=HVL(J)+GOR*(((1.+FX)**(L-NIK)-1.)/FX)                    FRE01770
  250 CONTINUE                                                          FRE01780
  251 CONTINUE                                                          FRE01790
      I5=NFK+IRY                                                        FRE01800
      CFIL = CFIL + (FHVS(I5)-FHVS(IRY+1))*XNOL(J)                      FRE01810
      IRY=IRY+2*NK+1                                                    FRE01820
   50 CONTINUE                                                          FRE01830
      RETURN                                                            FRE01840
      END                                                               FRE01850
      SUBROUTINE MULF(FHVZ,S1)
      COMMON/CHEQR/AHV(50),AHVL(25),EPS(56),FF(300),FHVC(50),FHV(25),
     .FHVM(25),FHVP(25),GAMP(300),GEE(56),GIP(300),HVL(300),IA(9),
     .NCRC(20),ND(300),NKK(25),NU(25),TMSW(50),TMSWL(25),XNOL(300),
     .ALPHA(23),BETA(7),FIML(25,3),FIPL(25,3),FIMC(50,3),FIPC(50,3),
     .FHVS(200),NSHC(25)
      COMMON/CHEQR/XNN(51,23),XQ(51,7),NICN(51),YY(51),TEE(51),
     .PRES(51),QR(51),FIMI(51),FIPI(51),TLCM(51),TLCP(51),BEE(51),
     .EMU(51),TAUT(51),DIM(51),DIP(51),FIM(51),FIP(51),FRM(51),
     .FRP(51),FLN(51),FIIM(51),FIIP(51),FIMT(51),FIPT(51),LMU(51),
```

```
     .SK(51),DSK(51),XF(51),EXPT(51),XTX(51,3),VX(51)
      DIMENSION S1(1),XR(7)                                              MULE0220
      COMMON/AERAD/ DELTA,INREAD,K1,K2,NAES,NBLP,NHV,NI,NIC,NIHVC,       MULE0230
     .        NSHV,NXI,NY,TW,C2,MIDPNT,NTRANS,SF(5)
      DIMENSION ALPH(8),BETZ(8),DEL(8),XI(8),SLA(8),SLB(8),SHA(8),SHB(8)
     1,SLAS(8),SLBS(8),SHAS(8),SHBS(8)                                   MULE0260
      DIMENSION NILK(7)
      EQUIVALENCE (X,AI)
      DATA(ALPH(J),J=1,8)/0.,1.E-4,2.E-4,4.E-4,8.E-4,1.2E-3,1.6E-3,2.8E-MULE0270
     13/                                                                 MULE0280
      DATA(BETZ(J),J=1,8)/0.,5.E-4,1.E-3,2.E-3,3.E-3,5.E-3,7.E-3,1.E-2/
      DATA(DEL(J),J=1,8)/0.,.02,.04,.08,.12,.16,.2,.24/                  MULE0300
      DATA(XI(J),J=1,8)/0.,.025,.05,.1,.15,.2,.25,.3/                    MULE0310
      DATA(SLA(J),J=1,8)/3.362,3.114,2.748,2.301,2.000,1.778,1.580,1.146MULE0320
     1/                                                                  MULE0330
      DATA(SLB(J),J=1,8)/1.886,2.187,2.248,2.000,1.716,1.228,0.903,0.491MULE0340
     1/                                                                  MULE0350
      DATA(SHA(J),J=1,8)/1.231,.806,.512,.079,-.244,-.522,-.732,-.921/   MULE0360
      DATA(SHB(J),J=1,8)/.492,.7,.623,.267,-.06,-.337,-.537,-.721/       MULE0370
      DATA(SLAS(J),J=1,8)/-1.890E+03,-3.602E+03,-3.337E+03,-1.404E+03,   MULE0380
     1-4.141E+02,-5.086E+02,-4.633E+02,-2.616E+02/                       MULE0390
      DATA(SLBS(J),J=1,8)/8.419E+02,3.036E+02,-8.766E+01,-3.309E+02,     MULE0400
     1-2.820E+02,-1.990E+02,-1.370E+02,-1.222E+02/                       MULE0410
      DATA(SHAS(J),J=1,8)/-.245E+2,-.169E+2,-.126E+2,-.894E+1,-.738E+1,-MULE0420
     1.602E+1,-.469E+1,-.446E+1/                                         MULE0430
      DATA(SHBS(J),J=1,8)/.140E+2,.443E+00,-.626E+1,-.762E+1,-.615E+1,-.MULE0440
     1468E+1,-.353E+1,-.352E+1/                                          MULE0450
      DATA XR/0.207382E12,0.194044E12,0.223960E12,0.7730425E12,          MULE0460
     .        0.207382E12,0.194044E12,0.223960E12/                       MULE0470
      DATA PI/3.14159/,NILK/4,2,12,14,3,1,13/                            MULE0510
      POLY(A,B,C)=A + B*TT + C*TT*TT                                     MULE0560
      RLA(A,B,C,D,E,F)=POLY(A,B,C) + ALOGX*POLY(D,E,F)                   MULE0580
      GAMLY(A)=5.79E-21*A*AI/SQRT(TT) * (ALOG10(0.1875E6*TT)-0.5*ALOGX)  MULE0600
      BALMY(A,B,C,D,E) = A*(B*TT)**(-C) - ALOGX*D*(T3)**(-E)             MULE0620
      BLINE(A)=A*(1.+R*SQRT(WDH*F0))*WDH**(-2.5)                         MULE0640
      S069PI=SQRT(0.69315/PI)/8065.0                                     MULE0670
      DO 500 I=1,NY                                                      MULE0700
      X=XNN(I,5)                                                         MULE0710
      ALOGX=ALOG10(X)                                                    MULE0720
      S1(I)=0.0                                                          MULE0730
      TT=TEE(I)                                                          MULE0740
      TT2=TT*TT                                                          MULE0750
      T1=8.62E-5*TT                                                      MULE0760
      TX=1.0/T1                                                          MULE0770
      T2=1.38047E-16*TT                                                  MULE0780
      T3=1.0E-4*TT                                                       MULE0790
```

```
      V1=VX(I)                                                          MULF0800
      F0=12.528E-10*V1                                                  MULF0810
      WDHT=9.898E12/V1                                                  MULF0820
      T2S0=0.39276E-10*SQRT(T2)                                         MULF0830
      FHF0=1.5371/(FHVZ*FHVZ*F0)
      FHVT=1.0-EXP(-FHVZ*TX)                                            MULF0880
      DO 400 J=K1,K2                                                    MULF0980
      IK=MD(J)                                                          MULF0990
      IRK=0.125*FLOAT(IK-1) + 1.0001                                    MULF1000
      ILK=MILK(IRK)                                                     MULF1030
      XP=XMM(I,ILK)*GEF(IK)*XQ(I,IRK)*EXP(-EPS(IK)*TX)                  MULF1060
      SL=8.95397E-13*XP*FF(J)                                           MULF1100
      TEX=X                                                             MULF1110
      IF(IRK-4) 100,105,280                                             MULF1120
  100 TEX=XTX(I,IRK)                                                    MULF1130
      GO TO 280                                                         MULF1160
  105 MID=1000.0*(HVL(J)+0.0001)
      WDH=WDHT*ABS(1./FHVZ-1./HVL(J))                                   MULF1200
      IF(MID.NE.10196) GO TO 120                                        MULF1230
      IF(WDH.GE.0.0028) GO TO 110                                       MULF1240
      CALL OGLE(1,WDH,BL,8,ALPH,SLA,SLAS)                               MULF1250
      R=10.0**BL                                                        MULF1260
      GO TO 380                                                         MULF1270
  110 R=RLA(7.962,-5.128E-4,1.345E-8,-0.4127,2.907E-5,-7.65E-10)        MULF1280
      R=BLINE(3.4E-6)                                                   MULF1290
      GO TO 380                                                         MULF1320
  120 IF(MID.NE.12084) GO TO 140                                        MULF1330
      IF(WDH.GE.0.01) GO TO 130
      CALL OGLE(1,WDH,BL,8,BETZ,SLB,SLBS)                               MULF1350
      R=10.0**BL                                                        MULF1360
      GO TO 380                                                         MULF1370
  130 R=RLA(12.95,-8.07E-4,2.06E-8,-0.7175,4.7675E-5,-1.23E-9)          MULF1380
      R=BLINE(1.79E-5)                                                  MULF1390
      GO TO 380                                                         MULF1420
  140 IF(MID.NE.12745) GO TO 145                                        MULF1430
      GAM=GAMLY(1025.0)                                                 MULF1440
      GO TO 300                                                         MULF1470
  145 IF(MID.NE.1888) GO TO 160                                         MULF1490
      IF(WDH.GE.0.24) GO TO 150                                         MULF1500
      CALL OGLE(1,WDH,BL,8,DEL,SHA,SHAS)
      R=10.0**BL                                                        MULF1520
      GO TO 380                                                         MULF1530
  150 R=BALMY(1.5702,5.0E-5,0.52,0.1183,0.578)                          MULF1540
      R=BLINE(1.3E-3)                                                   MULF1550
      GO TO 380                                                         MULF1580
  160 IF(MID.NE.2549) GO TO 180
```

```
      IF(WDH.GE.0.3) GO TO 170                                          MULE1590
      CALL OGLE(1,WDH,BL,8,XI,SHB,SHBS)                                 MULE1600
      B=10.0**BL                                                        MULE1610
      GO TO 380                                                         MULE1620
  170 B=BALMY(2.17,1.0E-4,0.339,0.115,0.333)                            MULE1630
      B=BLINE(3.57E-3)                                                  MULE1640
      GO TO 380                                                         MULE1650
  180 IF(WID.NE.660) GO TO 280                                          MULE1680
      GAM=GAMLY(1267.0)                                                 MULE1690
      GO TO 300                                                         MULE1700
  280 GAM=GAMP(J)*TEX                                                   MULE1730
      IF(GUP(J).LT.1.0) GO TO 300                                       MULE1760
      A1R=0.175*GEE(IK)*FF(J)/HVL(J) * SQRT(GEE(IK)/GUP(J))             MULE1770
      GAM=GAM+0.37216E-19*A1R*XP                                        MULE1780
  300 WD=HVL(J)*T2SQ*XR(IRK)                                            MULE1810
      WD2=WD*WD                                                         MULE1870
      FHLS=FHVZ-HVL(J)
      FHLSQ=FHLS*FHLS                                                   MULE1890
      B=GAM/(25347.0*(FHLSQ+GAM*GAM))                                   MULE1900
      IF(GAM+GAM.GE.WD) GO TO 390                                       MULE1910
      BB=B                                                              MULE1980
      B=SQ69PI*EXP(-0.69315*FHLSQ/WD2)/WD                               MULE1990
      IF(FHLSQ.LE.WD2) GO TO 390                                        MULE2000
      B=AMAX1(B,BB)                                                     MULE2010
      GO TO 390                                                         MULE2020
  380 B=FHEQ*B                                                          MULE2040
  390 EMUS=SL*FHVT*B
  400 S1(I)=S1(I)+EMUS
  500 CONTINUE                                                          MULE2110
      RETURN                                                            MULE2120
      END                                                               MULE2130
      SUBROUTINE OGLE(N,XAM,PRM,NUMX,X,P,EM)                            OGLE0010
      DIMENSION XAM(1),X(1),P(1),EM(1),PRM(1)                           OGLE0020
      XDIF=X(NUMX)-X(1)                                                 OGLE0040
      IF(XDIF.EQ.0.)RETURN                                              OGLE0050
      IS=1                                                              OGLE0060
      DO 14 J=1,N                                                       OGLE0080
      XA=XAM(J)                                                         OGLE0090
      IO=1                                                              OGLE0100
      IT=1                                                              OGLE0110
    2 IF(XDIF*(XA-X(IS)))3,7,8                                          OGLE0120
    3 IF(IS-1)6,6,4                                                     OGLE0130
    4 IS=IS-1                                                           OGLE0140
      IT=2                                                              OGLE0150
      IF(IO-1)2,2,11                                                    OGLE0160
    5 IS=NUMX                                                           OGLE0170
```

```
    6 I=IS                                                                  OGLE0180
      H=0.                                                                  OGLE0190
      DPDI=EM(I)                                                            OGLE0200
      GO TO 12                                                              OGLE0210
    7 PR=P(IS)                                                              OGLE0220
      DPDI=EM(IS)                                                           OGLE0230
      GO TO 13                                                              OGLE0240
    8 IS=IS+1                                                               OGLE0250
      IF(IS-NUMX)9,9,5                                                      OGLE0260
    9 IT=2                                                                  OGLE0270
      IF(IT-1)2,2,10                                                        OGLE0280
   10 IS=IS-1                                                               OGLE0290
   11 I=IS                                                                  OGLE0300
      DX=1./(X(I+1)-X(I))                                                   OGLE0310
      DA=XA-X(I)                                                            OGLE0320
      EMI=EM(I)                                                             OGLE0330
      G=(((P(I+1)-P(I))*DX)-EMI)*DX                                         OGLE0340
      F=(((EM(I+1)-EMI)*DX)-2.*G)*DX                                        OGLE0350
      H= (F*(XA-X(I+1))+G)*DA                                               OGLE0360
      DPDI= (H+H+EMI+F*DA*DA)                                               OGLE0370
   12 PR=(H+EM(I))*(XA-X(I))+P(I)                                           OGLE0380
   13 CONTINUE                                                              OGLE0390
      PRM(J)=PR                                                             OGLE0400
   14 CONTINUE                                                              OGLE0410
      RETURN                                                                OGLE0420
      END                                                                   OGLE0430
```

```
$THERMO
 NS=19, NF=5, NA=3, NN=19,
MWFL(1)=5.486E-4,1.008,4.01,12.011,16.0,
MW(1)=5.486E-4,1.008,2.016,1.008,
 4.01,4.01,                          12.001,24.022,36.033,12.01,25.03,26.038,
  37.041,49.04,
                    16.,32.,16.,28.011,44.01,
&END
   E-        1
 0.2500000E+01 0.             0.             0.             0.                E       2
-0.7453750E+03-0.1173402E+02 GORDON AND MCBRIDE NASA SP-273                     E       3
 0.2500000E+01 0.             0.             0.             0.                E       4
-0.7453749E+03-0.1173402E+02 GORDON AND MCBRIDE NASA SP-273                     E       5
    0.2508E+01   -0.6332E-05    0.1364E-08   -0.1094E-12    0.2934E-17  E-          6
   -0.7450E+03   -0.1208E+02    ESCH ETAL NASA CR-111989                    E-      7
     0.0           .0500E-07    -.1000E-12    26.000E-05    0.0             E-    8
    H              1
 0.2500000E+01 0.             0.             0.             0.                H       2
 0.2547162E+05-0.4601176E+00 GORDON AND MCBRIDE NASA SP-273                     H       3
 0.2500000E+01 0.             0.             0.             0.                H       4
 0.2547162E+05-0.4601176E+00 GORDON AND MCBRIDE NASA SP-273                     H       5
  2.475164E+00  7.366387E-05 -2.537593E-08  2.386674E-12 -4.551431E-17  H          6
  2.523626E+04 -3.749137E-01 NICOLET NASA CR-132470                          H       7
    0.294E-05     .0889E-07    -.0811E-12     2.496E-05    5.1290E-08      H     8
   H2             2
 0.3057445E+01 0.2676520E-02-0.5809916E-05 0.5521039E-08-0.1812273E-11  H2      2
-0.9889047E+03-0.2299705E+01 GORDON AND MCBRIDE NASA SP-273                     H2      3
 0.3100190E+01 0.5111946E-03 0.5264421E-07-0.3490997E-10 0.3694534E-14  H2      4
-0.8773804E+03-0.1962942E+01 GORDON AND MCBRIDE NASA SP-273                     H2      5
    0.3363E+01    0.4656E-03   -0.5127E-07    0.2802E-11   -0.4905E-16  H2      6
   -0.1018E+04   -0.3716E+01    ESCH ETAL. NASA CR-111989                    H2      7
    -0.079E-05     .0791E-07    -.0886E-12     3.211E-05    5.3440E-08      H2    8
   H+       -1    1
 0.2500000E+01 0.             0.             0.             0.                H+      2
 0.1840334E+06-0.1153862E+01 GORDON AND MCBRIDE NASA SP-273                     H+      3
 0.2500000E+01 0.             0.             0.             0.                H+      4
 0.1840334E+06-0.1153862E+01 GORDON AND MCBRIDE NASA SP-273                     H+      5
 0.2500000E+01 0.             0.             0.             0.                H+      6
 0.1840334E+06-0.1153862E+01 GORDON AND MCBRIDE NASA SP-273                     H+      7
    0.0           .0500E-07    -.1000E-12    26.000E-05    0.0             H+    8
   HE                1
 0.2500000E+01 0.             0.             0.             0.                HE      2
-0.7453749E+03 0.9153488E+00 GORDON AND MCBRIDE NASA SP-273                     HE      3
 0.2500000E+01 0.             0.             0.             0.                HE      4
-0.7453749E+03 0.9153488E+00 GORDON AND MCBRIDE NASA SP-273                     HE      5
 0.2500000E+01 0.             0.             0.             0.                HE      6
```

```
-0.7453749E+03 0.9153488E+00 GORDON AND MCBRIDE NASA SP-273              HF      7
   -1.3451E-06  2.311919E-08 -4.735988E-13    2.0388E-05    3.2493E-08   HF      8
  HE+       -1          1
 0.2500000E+01 0.            0.            0.            0.              HE+     2
 0.2853426E+06 0.1608404E+01 GORDON AND MCBRIDE NASA SP-273              HE+     3
 0.2500000E+01 0.            0.            0.            0.              HE+     4
 0.2853426E+06 0.1608404E+01 GORDON AND MCBRIDE NASA SP-273              HE+     5
 0.2500000E+01 0.            0.            0.            0.              HE+     6
 0.2853426E+06 0.1608404E+01 GORDON AND MCBRIDE NASA SP-273              HE+     7
     0.0           .0500E-07    -.1000E-12    26.000E-05    0.0            HE+   8
     C                         1                                                 1
 0.2532870E+01-0.1588764E-03 0.3068208E-06-0.2677006E-09 0.8748882E-13   C       2
 0.8524042E+05 0.4606237E+01 GORDON AND MCBRIDE NASA SP-273              C       3
 0.2581066E+01-0.1469620E-03 0.7438808E-07-0.7948107E-11 0.5890097E-16   C       4
 0.8521629E+05 0.4312887E+01 GORDON AND MCBRIDE NASA SP-273              C       5
    0.2141E+01    0.3219E-03   -0.5498E-07    0.3604E-11   -0.5564E-16   C       6
    0.8542E+05    0.6874E+01    ESCH ETAL NASA CR-111989                 C       7
     1.997E-05     .1772E-07    -.3378E-12     2.506E-05     .7479E-08      C    8
   C2                        2                                                 1
 0.7451814E+01-0.1014468E-01 0.8587973E-05 0.8732110E-09-0.2442979E-11   C2      2
 0.9891198E+05-0.1584667E+02 GORDON AND MCBRIDE NASA SP-273              C2      3
 0.4043535E+01 0.2057365E-03 0.1090757E-06-0.3642787E-10 0.3412786E-14   C2      4
 0.9970948E+05 0.1277515E+01 GORDON AND MCBRIDE NASA SP-273              C2      5
    0.4026E+01    0.4857E-03   -0.7026E-07    0.4666E-11   -0.1142E-15   C2      6
    0.9787E+05    0.1090E+01 ESCH ETAL NASA CR-111989                    C2      7
     1.931E-05     .1393E-07    -.2575E-12      .859E-05     .6233E-08      C2   8
   C3                        3                                                 1
 0.5740846E+01-0.8428123E-02 0.1862019E-04-0.1451052E-07 0.3967697E-11   C3      2
 0.9715752E+05-0.2383737E+01 GORDON AND MCBRIDE NASA SP-273              C3      3
 0.3681536E+01 0.2416523E-02-0.8434811E-06 0.1450819E-09-0.9569730E-14   C3      4
 0.9741395E+05 0.6837780E+01 GORDON AND MCBRIDE NASA SP-273              C3      5
    0.2213E+02   -0.1759E-01    0.5565E-05   -0.6758E-09    0.2825E-13   C3      6
    0.9423E+05   -0.1021E+03 ESCH ETAL. NASA CR-111989                   C3      7
     2.019E-05     .1179E-07    -.1655E-12      .630E-05     .5804E-08      C3   8
   C+       -1                1                                                 1
 0.2595384E+01-0.4068664E-03 0.6892366E-06-0.5266487E-09 0.1508337E-12   C+      2
 0.2166628E+06 0.3895729E+01 GORDON AND MCBRIDE NASA SP-273              C+      3
 0.2511827E+01-0.1735978E-04 0.9504267E-08-0.2218851E-11 0.1862189E-15   C+      4
 0.2166772E+06 0.4286129E+01 GORDON AND MCBRIDE NASA SP-273              C+      5
    0.2528E+01    0.4869E-05   -0.7026E-08    0.1134E-11   -0.3476E-16   C+      6
    0.2168E+06    0.4139E+01 ESCH ETAL. NASA CR-111989                   C+      7
     0.0           .0500E-07    -.1000E-12    26.000E-05    0.0            C+    8
  C2H              1          2                                                 1
 0.2649940E+01 0.8491951E-02-0.9816537E-05 0.6537362E-08-0.1735627E-11   C2H     2
 0.5627575E+05 0.7689860E+01 GORDON AND MCBRIDE NASA SP-273              C2H     3
 0.4420765E+01 0.2211930E-02-0.5929494E-06 0.9419577E-10-0.6852759E-14   C2H     4
```

```
 0.5583544E+05-0.1158809E+01 GORDON AND MCBRIDE NASA SP-273
    0.5307E+01    0.9965E-03   -0.1378E-06    0.9251E-11   -0.2278E-15  C2H     6
    0.5809E+05   -0.5288E+01 ESCH ETAL. NASA CR-111989                   C2H     7
     2.404E-05     .1363E-07    -.2184E-12     1.126E-05     .7439E-08     C2H 8
 C2H2                2          2
 0.1410276E+01 0.1905727E-01-0.2450139E-04 0.1639087E-07-0.4134544E-11  C2H2    2
 0.2618820E+05 0.1139382E+02 GORDON AND MCBRIDE NASA SP-273             C2H2    3
 0.4575108E+01 0.5123835E-02-0.1745235E-05 0.2867306E-09-0.1795142E-13  C2H2    4
 0.2560742E+05-0.3573794E+01 GORDON AND MCBRIDE NASA SP-273             C2H2    5
    0.6789E+01    0.1503E-02   -0.2295E-06    0.1534E-10   -0.3763E-15  C2H2    6
    0.2590E+05   -0.1539E+02 ESCH ETAL. NASA CR-111989                   C2H2    7
     1.396E-05     .0842E-07    -.6939E-12     1.126E-05     .7439E-08     C2H2 8
 C3H                 1          3
 3.3446607E+00 1.0687605E-02-1.3312138E-05 1.3389601E-08-5.6987727E-12  C3H     2
 6.2581906E+04 6.0004184E+00 WAKELYN AND MCLAIN 72657                   C3H     3
 3.8776821E+00 6.7242969E-03-2.6055734E-06 4.4163330E-10-2.7082704E-14  C3H     4
 6.2564338E+04 3.8265297E+00 WAKELYN AND MCLAIN 72657                   C3H     5
 3.8776821E+00 6.7242969E-03-2.6055734E-06 4.4163330E-10-2.7082704E-14  C3H     6
 6.2564338E+04 3.8265297E+00 WAKELYN AND MCLAIN 72657                   C3H     7
     2.019E-05     .1179E-07    -.1655E-12      .630E-05     .5804E-08     C3H 8
  C4H                1          4
 4.9686610E+00 1.7278593E-02-2.9943171E-05 3.2461613E-08-1.3663978E-11  C4H     2
 7.5454605E+04-8.7699380E-01 WAKELYN AND MCLAIN 72657                   C4H     3
 6.5312534E+00 6.5064621E-03-2.2517411E-06 3.3295782E-10-1.7214711E-14  C4H     4
 7.5350412E+04-7.4467228E+00 WAKELYN AND MCLAIN 72657       214         C4H     5
 6.5312534E+00 6.5064621E-03-2.2517411E-06 3.3295782E-10-1.7214711E-14  C4H     6
 7.5350412E+04-7.4467228E+00 WAKELYN AND MCLAIN 72657       214         C4H     7
     2.019E-05     .1179E-07    -.1655E-12      .630E-05     .5804E-08     C4H 8
     0                        1                                         0       1
 0.2946428E+01-0.1638166E-02 0.2421031E-05-0.1602843E-08 0.3890696E-12  0       2
 0.2914764E+05 0.2963994E+01 GORDON AND MCBRIDE NASA SP-273             0       3
 0.2542059E+01-0.2755061E-04-0.3102803E-08 0.4551067E-11-0.4368051E-15  0       4
 0.2923080E+05 0.4920308E+01 GORDON AND MCBRIDE NASA SP-273             0       5
    0.2546E+01   -0.5952E-04    0.2701E-07   -0.2798E-11    0.9380E-16  0       6
    0.2915E+05    0.5049E+01 ESCH ETAL. NASA CR-111989                   0       7
     1.519E-05     .1875E-07    -.2228E-12     1.250E-05     .7092E-08     0     8
    02                        2                                         02      1
 0.3625598E+01-0.1878218E-02 0.7055454E-05-0.6763513E-08 0.2155599E-11  02      2
-0.1047522E+04 0.4305277E+01 GORDON AND MCBRIDE NASA SP-273             02      3
 0.3621953E+01 0.7361826E-03-0.1965222E-06 0.3620155E-10-0.2894562E-14  02      4
-0.1201982E+04 0.3615096E+01 GORDON AND MCBRIDE NASA SP-273             02      5
    0.3721E+01    0.4254E-03   -0.2835E-07    0.6050E-12   -0.5186E-17  02      6
   -0.1044E+04    0.3254E+01 ESCH ETAL. NASA CR-111989                   02      7
     1.693E-05     .1496E-07    -.2276E-12     1.019E-05     .4901E-08     02    8
    0+       -1                        1
 0.2498479E+01 0.1141097E-04-0.2976139E-07 0.3224653E-10-0.1237551E-13  0+      2
```

```
 0.1879490E+06 0.4386435E+01 GORDON AND MCBRIDE NASA SP-273                 O+      3
 0.2506048E+01-0.1446424E-04 0.1244604E-07-0.4685847E-11 0.6554887E-15  O+      4
 0.1879470E+06 0.4347974E+01 GORDON AND MCBRIDE NASA SP-273                 O+      5
    0.2944E+01   -0.4108E-03    0.9156E-07   -0.5848E-11    0.1190E-15  O+      6
    0.1879E+06    0.1750E+01 ESCH ETAL. NASA CR-111989                    O+      7
     0.0            .0500E-07    -.1000E-12    26.000E-05    0.0            0+   8
   CO                          1    1                                            1
 0.3710092E+01-0.1619096E-02 0.3692359E-05-0.2031967E-08 0.2395334E-12  CO      2
-0.1435631E+05 0.2955535E+01 GORDON AND MCBRIDE NASA SP-273                 CO      3
 0.2984069E+01 0.1489139E-02-0.5789968E-06 0.1036457E-09-0.6935355E-14  CO      4
-0.1424522E+05 0.6347915E+01 GORDON AND MCBRIDE NASA SP-273                 CO      5
    0.3366E+01    0.8027E-03   -0.1968E-06    0.1940E-10   -0.5549E-15  CO      6
   -0.1434E+05    0.4263E+01 ESCH ETAL. NASA CR-111989                    CO      7
     2.404E-05      .1363E-07    -.2184E-12      .859E-05     .6233E-08      CO   8
  CO2                          1    2                                            1
 0.2400779E+01 0.8735095E-02-0.6607087E-05 0.2002186E-08 0.6327403E-15  CO2     2
-0.4837752E+05 0.9695145E+01 GORDON AND MCBRIDE NASA SP-273                 CO2     3
 0.4460804E+01 0.3098171E-02-0.1239257E-05 0.2274132E-09-0.1552595E-13  CO2     4
-0.4896144E+05-0.9863598E+00 GORDON AND MCBRIDE NASA SP-273                 CO2     5
    0.4413E+01    0.3192E-02   -0.1298E-05    0.2415E-09   -0.1674E-13  CO2     6
   -0.4894E+05   -0.7288E+00 ESCH ETAL. NASA CR-111989                    CO2     7
     2.404E-05      .1363E-07    -.2184E-12      .859E-05     .6233E-08      CO   8
 &ARAD
  NKK(1)=25*5,
  NCRC(1)=0,1,2*0,2*1,2*0,1,0,1,0,3*1,0,4*1,
 AHV(1)=50*.8,
 AHVL(1)=25*.8,
 TMSW(1)=50*.2,
 TMSWL(1)=25*.2,
      TW=1.,
 &END
1956 4
   0.40  +01    0.10  +02    0.60  +01    0.18  +02    0.54  +02    0.90  +02
   0.00  +00    0.00  +00    0.90  +01    0.50  +01    0.10  +01    0.50  +01
   0.30  +01    1.50  +01    0.90  +01    0.40  +02    0.90  +01    0.50  +01
   0.10  +01    0.50  +01    0.12  +02    0.15  +02    0.36  +02    0.00  +00
   0.20  +01    0.80  +01    0.18  +02    0.32  +02    0.00  +00    0.00  +00
   0.00  +00    0.00  +00    0.90  +01    0.00  +00    0.00  +00    0.00  +00      0
   0.00  +00    0.00  +00    0.00  +00    0.00  +00    0.40  +01    0.00  +00
   0.00  +00    0.00  +00    0.00  +00    0.00  +00    0.00  +00    0.00  +00
   0.60  +01    0.00  +00    0.00  +00    0.00  +00    0.00  +00    0.00  +00
   0.00  +00    0.00  +00    0.00  +00    0.00  +00    0.00  +00    0.00  +00
   0.00  +00    0.2384+01    0.3576+01    0.1045+02    0.1188+02    0.1300+02
   0.00  +00    0.00  +00    0.96  -02    0.1967+01    0.4189+01    0.9144+01
   0.9519+01    0.1074+02    0.1099+02    0.1208+02    0.00  +00    1.2639+00
   2.6939+00    4.1825+00    7.5351+00    7.9461+00    8.6442+00    0.00  +00      0
```

```
   0.00  +00    0.1020+02    0.1208+02    0.1274+02    0.00  +00    0.00  +00

   0.10  +00    0.81  +00    0.95  +00    0.12  +01    0.14  +01    0.162 +01
   0.24  +01    0.35  +01    0.40  +01    0.62  +01    0.80  +01    0.90  +01
   0.97  +01    0.1045+02    0.1080+02    0.1170+02    0.1210+02    0.1280+02
   0.1340+02    0.0000+00    0.00  +00    0.00  +00    0.00  +00    0.00  +00
   0.80  +00    0.95  +00    0.12  +01    0.14  +01    0.16  +01    0.24  +01
   0.3500+01    0.40  +01    0.60  +01    0.80  +01    0.90  +01    0.97  +01
   0.1045+02    0.1080+02    0.1170+02    0.1210+02    0.1280+02    0.1340+02
   0.1380+02    0.0000+00    0.00  +00    0.00  +00    0.00  +00    0.00  +00
   0.69  +00    0.89  +00    0.1050+01    0.1290+01    0.1460+01    0.1850+01
   0.2850+01    0.3700+01    0.5000+01    0.7110+01    0.8400+01    0.94  +01
   0.1007+02    0.1062+02    0.1120+02    0.1190+02    0.1241+02    0.1304+02
   0.1358+02    0.0000+00     .     +      .     +      .     +      .     +
 6 71316
 7 3 8 3 3 4 5 1 1 7 8 9 8 2 6 4 6 3 1
29            .1662        1.231          14.80-20
29            .3060        1.038           8.34-20
28            .4722        .1793          12.20-20
27            .6611        .8421           3.64-20
16             0.685        0.196           110E-21 6.
22             0.6859       0.044           321E-21 3.
23             0.710        0.208           639E-18 4.
22             0.844        0.0808          412E-21 3.
21             0.852        0.0687          108E-21
15            0.8840       0.1570           367E-21
27            .9671        .1506           6.77-20
16             0.991        0.0805          309E-20 2.
23             1.019        0.0329          205E-19 4.
22             1.079        0.1008          320E-21 8.
15            1.0980       0.7490           344E-21
14            1.1320       0.2010           367E-21
27            1.1333       .05584          10.90-20
21             1.163        0.474           108E-21
22             1.224        0.0285          262E-21
21             1.326        0.206           138E-21 3.
14            1.3380       0.9130           342E-21
13            1.4670       0.9500           865E-22
21             1.487        0.0405          218E-21
12            1.594        1.0300           709E-22
15             1.767        0.0226          275E-20 3.
22             1.814        0.0039          350E-20 5.
```

26	1.888	0.6407		
14	2.015	0.0258	275E-20	3.
26	2.549	0.1193		
26	2.8559	.04467	6.35-20	
13	3.0	0.010	810E-21	2.
26	3.0221	.02209	10.60-20	
12	3.167	0.00826	520E-21	
12	3.7110	0.0143	110E-20	
19	5.002	0.0676	113E-21	
18	6.424	0.07290	113E-21	
19	7.013	0.01410	500E-21	
19	7.078	0.0748	262E-21	
17	7.481	0.105	873E-22	
19	7.717	0.00534	220E-20	
19	7.721	0.0367	109E-19	
17	7.947	0.283	208E-22	
19	8.030	0.00457	690E-19	
19	8.191	0.0116	130E-18	
19	8.203	0.00147	119E-19	
19	8.302	0.00831	538E-18	
18	8.368	0.011	214E-21	
19	8.377	0.00501	677E-18	
18	8.433	0.0142	500E-21	
18	8.474	0.0625	248E-21	
18	9.137	0.00526	220E-20	
18	9.141	0.0362	109E-19	
17	9.332	0.203	557E-23	
18	9.450	0.0218	690E-19	
09	9.5010	0.0471	548E-22	
18	9.611	0.0114	130E-18	
18	9.623	0.00143	119E-19	
17	9.697	0.01950	500E-21	
17	9.698	0.0038	235E-21	
17	9.709	0.0767	235E-21	
18	9.722	0.0081	538E-18	
18	9.797	0.00488	677E-18	
17	9.834	0.026	293E-21	
11	10.182	0.1510	653E-22	
25	10.196	0.4162		
17	10.401	0.00719	220E-20	
17	10.405	0.0495	109E-19	
17	10.714	0.0298	690E-19	
10	10.761	0.1200	653E-22	
18	10.873	0.705	630E-21	
17	10.875	0.0155	130E-18	
17	10.887	0.00195	119E-19	

17	10.986	0.011	253E-19
11	11.007	0.0185	367E-21
17	11.061	0.00659	677E-18
11	11.806	0.0049	145E-20
09	11.852	0.0199	367E-21
09	12.067	0.0218	344E-21
25	12.084	0.0791	
11	12.160	0.0019	128E-20
19	12.181	1.05	159E-22
10	12.404	0.0461	653E-22
09	12.521	0.0775	633E-22
09	12.651	0.00524	145E-20
25	12.746	.02899	2.95-20
25	13.052	.00780	6.29-20
17	13.119	0.379	101E-21
25	13.2182	.01394	10.50-20
18	13.601	0.295	159E-22

48

0.02	0.1	0.2	0.5	0.6	0.8
1.00	1.50	2.00	2.5	2.75	3.0
3.25	3.50	3.75	4.0	4.5	5.0
6.00	7.00	8.00	8.50	8.52	8.98
9.00	9.19	9.21	9.99	10.01	10.79
10.81	11.00	11.25	11.27	11.99	12.01
12.18	12.20	12.98	13.00	13.39	13.41
13.59	13.61	14.29	14.31	14.55	15.00

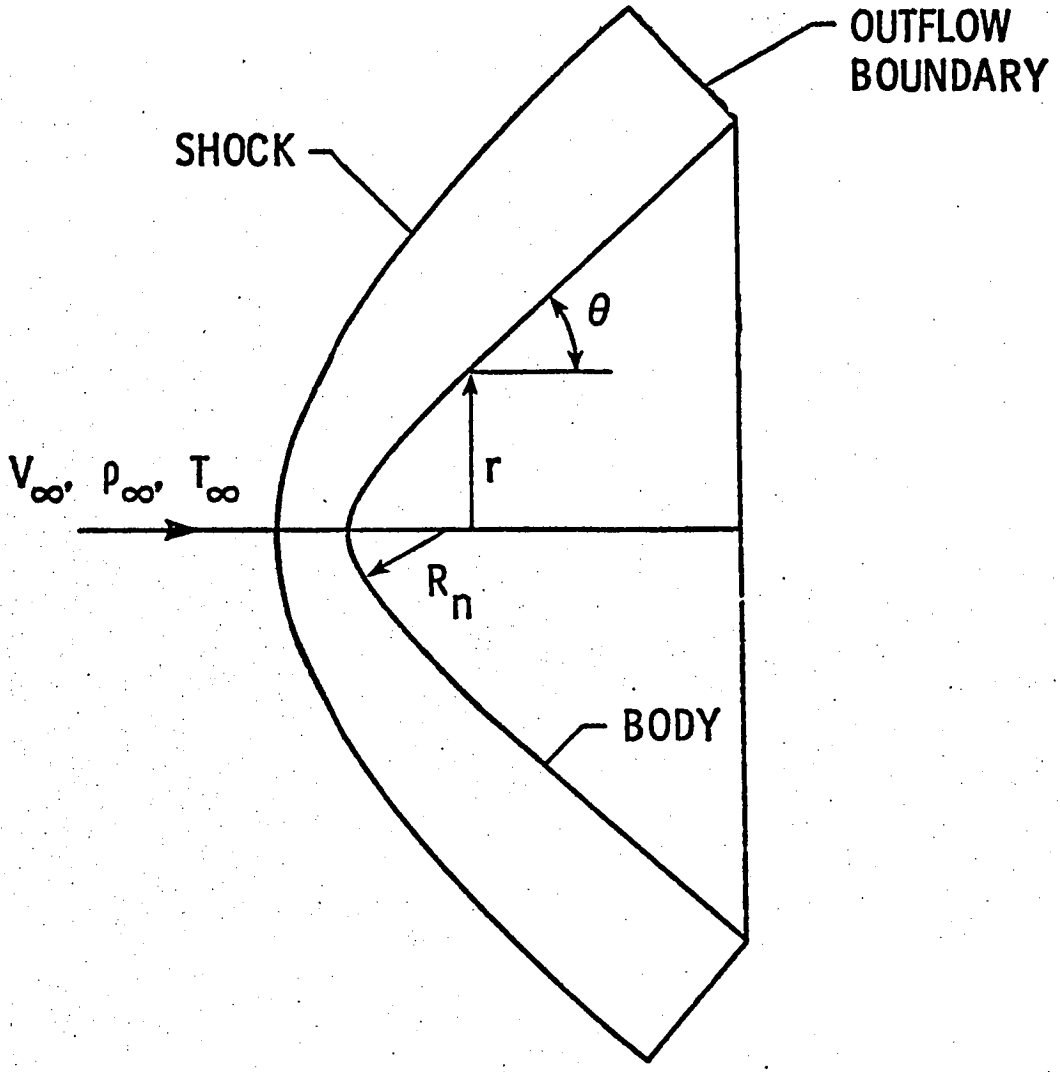

Figure 1.- Physical flow model.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-81848		

4. Title and Subtitle	5. Report Date
User's Guide for the Computer Code 'COLTS' for Calculating the Coupled Laminar and Turbulent Flows Over a Jovian Entry Probe	June 1980
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Ajay Kumar * and Randolph A. Graves, Jr.	
9. Performing Organization Name and Address	10. Work Unit No.
NASA Langley Research Center Hampton, VA 23665	506-51-23-01
	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Technical Memorandum
National Aeronautics and Space Administration Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

*Research Associate Professor, Department of Mechanical Engineering and Mechanics, Old Dominion University, Norfolk, Virginia 23508

16. Abstract

This report is a user's guide for a computer code 'COLTS' (Coupled Laminar and Turbulent Solutions) which calculates the laminar and turbulent hypersonic flows with radiation and coupled ablation injection past a Jovian entry probe. Time-dependent viscous-shock-layer equations are used to describe the flow field. These equations are solved by an explicit, two-step, time-asymptotic finite-difference method. Eddy viscosity in the turbulent flow is approximated by a two-layer model. In all, 19 chemical species are used to describe the injection of carbon-phenolic ablator in the hydrogen-helium gas mixture. The equilibrium composition of the mixture is determined by a free-energy minimization technique. A detailed frequency dependence of the absorption coefficient for various species is considered to obtain the radiative flux.

The code is written for a CDC-CYBER-203 computer and is capable of providing solutions for ablated probe shapes also. This report contains descriptions of the input and output quantities and a brief outline of how to use the code.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Computer Program Heat Transfer Fluid Mechanics	~~FEDD DISTRIBUTION~~ Subject Category 34

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	96	

N-305

Available: NASA's Industrial Applications Centers