SHOCK DYNAMICS LABORATORY

Department of Physics

Washington State University

INTERNAL REPORT

74-01

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Some Computer Programs

REVRB calculates pressure - volume - temperature states reached by reverberation in a material sandwiched between two identical anvils. Quadratic fits to pressure - particle velocity curves and a Zharkov and Kalinen equation of state were used. Program also computes resistivity values for each shot. Details of the analysis are available in my thesis and in papers to be published. Program is stored on CPS BASIC.

CALIB converts oscilloscope record x-y points to voltage-time points using horizontal and vertical calibration values for two-dimensional interpolation and conversion. That is, the photo is divided into a grid, with distinct calibration values for each grid section. This allows for nonlinearity of the trace calibration in both x and y directions. Program is stored on CPS BASIC.

HFLØ computes the temperature as a function of time in a three-slab sandwich geometry. Details of the analysis are given in my thesis and in a paper to be published by George Swan and myself. The difficult part of the computation is iterative solution of a transcendental equation for eigenvalues needed in the series solution for temperature. Care must be taken to make good first guesses for the first and succeeding eigenvalues. It helps to sketch a graph of the transcendental function. Deck copies of the FORTRAN program are available on request.

R E V R B

'H'   is Debye characteristic temperature

'X'   is V/V_0

```
1 REM PROGRAM PUNCHED   ON  4/01/74   AT 10:34:510
2 REM   FIND TEMPERATURE THROUGH THE SHOCK REVERBERATIONS
20 IMAGE
25 LET Q=5
30 LET VO=1/10.49
35 LET TR=.00024942
36 LET R=TR/3
38 LET AT=.00408
40 LET BT=-.16
42 LET AL=.005988
43 LET C2=-.110
80 PRINT 'PRESSURE',' REL VOL',' SPEED',' TEMP',' DELTA T'
100 DATA 3.33838,17.4485,4.44,1.36
110 DATA .31495,11.918,.33299
111 DATA .743,107.88
120 DATA .0464,296,.995,.039,295.7,.982,.0392,295.8,.99
121 DATA .027,296,.974,.0122,295.9,.977,.0517,295.7,1.031
122 DATA .0218,296.7,.995,.0232,296.4,.99,.0416,295.6,1.014
123 DATA .0395,296,1.05,.028,296,.987,.0401,298.2,1.039
124 DATA .0423,298.2,1.071,.0524,298.4,1.09,.053,297,1.045
200 READ A1,B1,A2,B2
205 READ A,B,K,DO,M
220 LET P(1)=0
222 LET U(1)=0
224 LET AA=B1-B2
230 LET X(1)=1
232 LET H0=225
233 LET T0=298
235 LET F(1)=3*VO*(A/B-K)
236 LET BA=BT/(AL*TO)
238 READ UP,T(1),RS
```

```
240 LET E(1)=F(1)+R/M*(5/8*HO+3*T(1)*DO)
255 PRINT  "UP=",UP
260 FOR N=2 TO Q
265 LET J=N
280 LET UR=-A1/(2*B1)+.5*SQR((A1/B1)**2+4*P(N-1)/B1)
298 REM   TEST IF N IS EVEN OR ODD
300 IF INT(N/2)-N/2>-.1 THEN 350
315 REM      N IS ODD
318 LET UU=U(N-1)+UR
320 LET BB=-A1-A2-2*B1*UU
330 LET CC=A1*UU+B1*UU**2
335 LET AG=BB**2-4*AA*CC
340 LET U(N)=(-BB-SQR(AG))/(2*AA)
345 LET P(N)=-A1*(U(N)-UU)+B1*(U(N)-UU)**2
348 GO TO 400
350
355 REM         N IS EVEN
358 LET UU=U(N-1)-UR
360 LET BB=A1+A2-2*B1*UU+2*B2*UP
365 LET CC=-A1*UU-A2*UP+B1*UU**2-B2*UP**2
380 LET U(N)=(-BB+SQR(BB**2-4*AA*CC))/(2*AA)
390 LET P(N)=A1*(U(N)-UU)+B1*(U(N)-UU)**2
400
440 LET X(N)=X(N-1)-1/VO*(U(N)-U(N-1))**2/(P(N)-P(N-1))
460 LET H(N)=4.04653*X(N)**2-10.5232*X(N)+7.476956
500 LET H=H(N)*HO
520 LET X=X(N)
548 REM    FIND POTENTIAL ENERGY, "EP"=F
550 LET F(N)=3*VO*(A/B*EXP(B*(1-X**(1/3)))-K/X**(1/3))
570 LET E(N)=E(N-1)+1/2*VO*(P(N)+P(N-1))*(X(N-1)-X(N))
600 LET BP=-M/TR*(E(N-1)+VO/2*(P(N)+P(N-1))*(X(N-1)-X(N))-F(N))
620 LET CP=H**2/20
640 LET T(N)=(-BP+SQR(BP**2-4*CP))/2
800 LET DT=T(N)-T(1)
900 PRINT USING 20, P(N),X(N),U(N),T(N),DT
950 NEXT N
960 LET AR=(1/X(1))+.64*(1/H(1))**2
965 LET DR=AR*(T(J)/TO-1)/(1+BA)
970 PRINT  "DR(T)=",DR
972 PRINT  "ALPHA REL=",AR
974 PRINT  "THETA REL=",H(J)
980 LET RR=RS*(1+AT*(T(1)-TO))
982 LET RI=RR-DR
983 LET RV=AR*(1+C2*H/298)/(1+C2*HO/298)
984 LET RD=RI-RV
986 PRINT  "RI=",RI,"RD=",RD,"RV=",RV
990 GO TO 238
999 END
```

4

'Y' and 'C' are arrays of vertical deflection and voltage values respectively
for vertical calibration traces.

'X' and 'M' are arrays of horizontal deflection and time values respectively
for horizontal calibration traces.

'D' and 'E' are arrays of X and Y coordinates respectively on the shot
record.

```
  1 REM PRØGRAM PUNCHED    ØN  4/01/74    AT 10:29:260
  2 REM PRØGRAM CØNVERTS SCØPE PHØTØ X-Y VALUES TØ VØLT@GE -TIME
  5 LET A=Q
 22 DIM Y(20,6),C(6)
 23 DIM X(20),M(20)
 24 DIM D(50),E(50),V(50),T(50)
 25
 30 IMAGE
-.---- , --.--- %
100 READ NT,NC,ND
105 FØR I=1 TØ NT-1
107 FØR J=1 TØ NC
109 READ Y(I,J)
110 NEXT J
112
113 NEXT I
114
116 FØR I=1 TØ NC
118 READ C(I)
120 NEXT I
121
122 FØR I=1 TØ NT
124 READ X(I),M(I)
126 NEXT I
127
128 FØR I=1 TØ ND
130 READ D(I),E(I)
132 NEXT I
133
```

```
158 REM BEGIN CALCULATION
160 FOR I=1 TO ND
180 FOR J=1 TO NT-1
198 REM FIND TIME VALUES
200 LET K=J
218 REM SPECIAL CASE:TRACE BEGINS TO LEFT OF FIRST TM.
220 IF X(1)-D(I)>0 THEN 320
238 REM SPECIAL CASE:TRACE GOES PAST LAST TM.
240 IF X(NT)-D(I)<0 THEN 360
260 IF X(J+1)-D(I)>=0 THEN 400
280 NEXT J
281
320 LET K=1
340 GO TO 400
360 LET K=NT-1
380 GO TO 400
400 LET F2=(D(I)-X(K))/(X(K+1)-X(K))
402 LET T(I)=M(K)+(M(K+1)-M(K))*F2
408 IF I>1 THEN 420
410 LET TS=T(1)
420 LET T(I)=T(I)-TS
498 REM   FIND VOLTAGE VALUES
500 FOR J=1 TO NC-1
520 LET L=J
538 REM SPECIAL CASE: TRACE BEGINS BELOW V=0.
540 IF Y(K,1)-E(I)>0 THEN 620
558 REM SPECIAL CASE: TRACE IS ABOVE HIGHEST VERTICAL CALIBRATION.
560 IF Y(K,NC)-E(I)<0 THEN 660
580 IF Y(K,J+1)-E(I)>=0 THEN 695
600 NEXT J
601
620 LET L=1
640 GO TO 695
660 LET L=NC-1
680 GO TO 695
695 LET F1=(E(I)-Y(K,L))/(Y(K,L+1)-Y(K,L))
700 LET V(I)=C(L)+(C(L+1)-C(L))*F1
706 IF I=1 THEN 720
710 LET VS=V(1)
720 LET V(I)=V(I)-VS
729 REM DROOP CORRECTION TO DELTA E
730 LET V(I)=V(I)+A*T(I)
740 NEXT I
890 PRINT "VOLTAGE","   TIME"
900 FOR I=1 TO ND
920 PRINT USING 30, V(I),T(I)
940 NEXT I
941
999 END
```

H F L 0

Flow Charts and Listing

OVERALL FLOW CHART FOR HFLØ

```
                    ┌──────────────┐
                    │    START     │
                    └──────────────┘
                           │
                    ┌──────────────┐
                    │     READ     │
                    │   CONTROL    │
                    │     CARD     │
                    └──────────────┘
                           │
                     ⬡ REPEAT ⬡
                     NSET TIMES
                     (DO 290III
                     =1,NSET)
                           │
            ┌───────────────────────────────┐
            │ READ & PRINT PARAMETERS        │
PART I      │ COMPUTE A1,A2,P,LL,PRL,        │
            │ RPL,HALF,SS,YN1,ZZ,N           │
            └───────────────────────────────┘
                           │
                    ┌──────────────┐
PART II             │   COMPUTE    │
                    │  AND PRINT   │
                    │ EIGENVALUES  │
                    └──────────────┘
                           │
                    ┌──────────────┐
PART III            │   COMPUTE    │
                    │  AND PRINT   │
                    │ TEMPERATURES │
                    └──────────────┘
                           │
                        ( 290 )
                           │
                    ┌──────────────┐
                    │     STOP     │
                    └──────────────┘
```
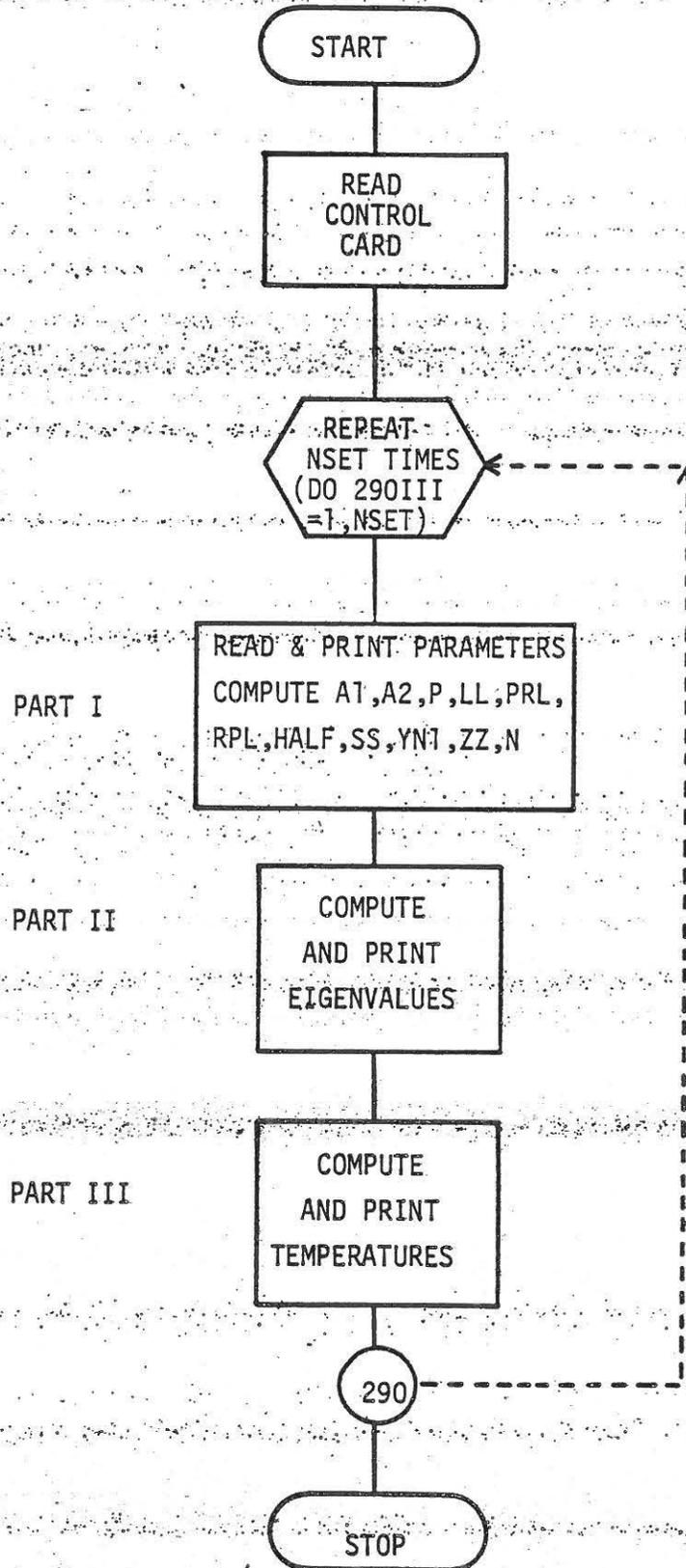
DO 210 M=1,L
(COMPUTE L
EIGENVALUES)

INITIALIZE
IK,ISW,YN1

70

INITIALIZE
ZJ1 = ZZ
COMPUTE ZR

DO 120 J = 1,99

CALCULATE
ZJ1

CHECK TO INSURE
ZJ1 DOES NOT EXCEED
THE BOUNDS. IF
NECESSARY MODIFY
ZJ1

DETAILED FLOW CHART FOR PART II

A B

C

D

E

(A) (B)   (C)   (D)   (E)

DOES ZJ1 CONVERGE? — NO → (120)   YES → (130)

(120): NO → IK=1?
- YES → YTEMP = YN1
- NO → (140)

(130): **IS ZJ1 A GOOD EIGENVALUE?**
- NO → IK > 1
  - YES → (140)
  - NO → TEMPORARILY STORE ZJ1, J → (140)
- YES → (160)

(160): PRINT ZJ1, J STORE ZJ1 IN Y INCREMENT N

N > L ?
- YES → GO TO 220 (PART III)
- NO → IK
  - =2 → SET ISW = 1 TO INDICATE 2ND ROOT WAS FOUND. GO TO 140 TO TRY TO FIND A 3RD ROOT
  - =3 → (190)
  - =1 → (200)

(140):

IK = 3 ?
- NO → IK = IK + 1
- YES → (SET ISW = 1 ...)

IK = IK + 1 → IK = 3 ?
- YES → (150)
- NO → COMPUTE BOUNDS: Z1, ZIP, ZIP1

(150) → ZZ = $\dfrac{Z1 + ZIP1}{2}$

COMPUTE BOUNDS → ZZ = $\dfrac{Z1 + ZIP}{2}$

(200): YES → YTEMP = YN1 ?
- (200) → ZZ = M * RPL + HALF * RPL → (210)

YTEMP = YN1 ?
- NO → RESTORE 1ST ZJ1, ZZ, J. SET IK = 1 GO BACK TO 160 TO PRINT & STORE ZJ1

(190)

(210)

```
          DOUBLE PRECISION ZJ1,Y(100),D,BA,PI,T1,T,A,XA,T2,TI,K1,C1,        HFLO  10
         1R1,K2,C2,R2,A1,A2,P,LL,SS,ZZ,ZL,F,FP,ZN,CL,SL,CN,SN,TM,NM,DM,ZJ,   HFLO  12
         2DSIN,DCOS,DABS,DEXP,DSQRT,DTAN,DCOTAN,YN1,RPL,PRL,DELT,            HFLO  14
         3YTEMP,ZTEMP,Z1,Z2,Z5,ZIP,ZIP1,ZR,FCOT,FTAN,HALF,DELZY             HFLO  16
C                                                                            HFLO  20
C       VARIABLES USED IN THIS PROGRAM:                                     HFLO  30
C                                                                            HFLO  40
C       A     DIMENSION OF REGION 1                                         HFLO  50
C       A1    REGION 1 DIFFUSIVITY                                          HFLO  60
C       A2    REGIONS 2 AND 3 DIFFUSIVITY                                   HFLO  70
C       BA    RATIO B/A, THE SLAB DIMENSIONS                                HFLO  80
C       C1    REGION 1 SPECIFIC HEAT                                        HFLO  90
C       C2    REGIONS 2 AND 3 SPECIFIC HEAT                                 HFLO 100
C       D     NUMERICAL ACCURACY REQUIRED OF THE ITERATION FOR EIGENVALUES  HFLO 110
C       F     EIGENVALUE FUNCTION, F=0                                      HFLO 120
C       FP    DERIVATIVE OF EIGENVALUE FUNCTION                             HFLO 130
C       HALF  HALF=0.5D0 IF LL<=1, HALF=0.D0 IF LL>1                        HFLO 140
C       K1    REGION 1 CONDUCTIVITY                                         HFLO 150
C       K2    REGIONS 2 AND 3  CONDUCTIVITY                                 HFLO 160
C       LL    GAMMA                                                         HFLO 170
C       L     NUMBER OF EIGENVALUES TO BE COMPUTED                          HFLO 180
C       NSET  NUMBER OF SETS OF DATA TO BE PROCESSED                        HFLO 190
C       PI    3.1415926536                                                  HFLO 200
C       PRL   PI IF LL>1, PI/LL IF LL<=1                                    HFLO 210
C       RPL   PI/LL IF LL>1, PI IF LL<=1                                    HFLO 220
C       R1    REGION 1 DENSITY                                              HFLO 230
C       R2    REGIONS 2 AND 3 DENSITY                                       HFLO 240
C       SS    SIGMA                                                         
C       T     COMPUTED TEMPERATURE                                          HFLO 260
C       TI    TIME                                                          HFLO 270
C       T1    INITIAL TEMPERATURE IN REGION 1                               HFLO 280
C       T2    INITIAL TEMPERATURE IN REGIONS 2 AND 3                        HFLO 290
C       XA    RATIO X/A                                                     HFLO 300
C       Y(J)  JTH COMPUTED EIGENVALUE                                       HFLO 310
C       ZIP   LOWER BOUND FOR FINDING EIGENVALUE WHEN IK=2                  HFLO 320
C       ZIP1  UPPER BOUND FOR FINDING EIGENVALUE WHEN IK=3                  HFLO 330
C       ZJ    CALCULATED EIGENVALUE IN THE PREVIOUS STEP                    HFLO 340
C       ZJ1   CALCULATED EIGENVALUE IN THE PRESENT STEP                     HFLO 350
C       ZN    NTH EIGENVALUE                                                HFLO 360
C       ZLFT  LOWER BOUND FOR FINDING EIGENVALUES WHEN IK=1                 
C       ZR    UPPER BOUND FOR FINDING THE EIGENVALUE WHEN IK=1              HFLO 370
C       ZZ    FIRST GUESS OF EIGENVALUE                                     HFLO 380
C       Z1    UPPER BOUND FOR FINDING EIGENVALUE WHEN IK=2 AND LOWER        HFLO 390
C             BOUND FOR FINDING THE EIGENVALUE WHEN IK=3. AN ASYMPTOTE      HFLO 400
C             OF THE SHORTER PERIOD FUNCTION                                HFLO 410
C                                                                            HFLO 420
C                                                                            HFLO 430
C       INPUT TO THE PROGRAM:                                              HFLO 440
C       1. D, PI, XA, L, NSET. USING FORMAT(4D20.5/2I5)                     
C       2. NSET SETS OF THE FOLLOWING:                                     HFLO 460
C          A, BA, T1, T2, K1, C1, R1, K2, C2, R2, TI. USING                
C          FORMAT(4D20.5)                                                  HFLO 480
C                                                                           HFLO 490
```

```
      READ (5,20)D,PI,XA,L,NSET
   20 FORMAT (3D20.5/2I5)
      DO 290 III=1,NSET                                          HFLO 520
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC HFLO 530
C                                                              C HFLO 540
C     PART I. READ AND PRINT PARAMETERS, COMPUTE A1,A2,P,LL,PRL,RPL, C HFLO 550
C             HALF,SS,LP1,INITIALIZE YN1,ZZ,N                  C HFLO 560
C                                                              C HFLO 570
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC HFLO 580
      READ (5,30) A,BA,T1,T2,K1,C1,R1,K2,C2,R2,TI
   30 FORMAT (4D20.5)                                            HFLO 600
      WRITE (6,40) A,BA,K1,C1,R1,K2,C2,R2                        HFLO 610
   40 FORMAT ('1A=',F15.7,8X,'BA=',F15.7/' K1=',F15.7,8X,'C1=',F15.7,8X,HFLO 620
     1'R1=',F15.7/' K2=',F15.7,5X,'C2=',F15.7,8X,'R2=',F15.7//  HFLO 625
     2'0EIGENVALUES')                                           HFLO 630
      A1=K1/(C1*R1)                                             HFLO 640
      A2=K2/(C2*R2)                                             HFLO 650
      P=DSQRT(A1/A2)                                            HFLO 660
      LL=P*(BA-1.D0)                                            HFLO 670
      IF (LL.GT.1.) GO TO 50                                    HFLO 680
C                                                               HFLO 690
C     COMPUTE VALUES OF PRL,RPL,HALF FOR LL LESS THAN OR EQUAL TO 1  HFLO 700
C                                                               HFLO 710
      PRL=PI/LL                                                 HFLO 720
      RPL=PI                                                    HFLO 730
      HALF=0.5D0                                                HFLO 740
      GO TO 60                                                  HFLO 750
C                                                               HFLO 760
C     COMPUTE VALUES OF PRL,RPL,HALF FOR LL GREATER THAN 1      HFLO 770
C                                                               HFLO 780
   50 PRL=PI                                                    HFLO 790
      RPL=PI/LL                                                 HFLO 800
      HALF=0.D0                                                 HFLO 810
   60 SS=K2/K1*P                                                HFLO 820
      YN1=0.D0                                                  HFLO 830
      ZZ=0.03D0
      ZTEMP=0.001D-8
      N=1                                                       HFLO 850
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC HFLO 860
C                                                              C HFLO 870
C     PART II. COMPUTE AND PRINT EIGENVALUES                   C HFLO 880
C                                                              C HFLO 890
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC HFLO 900
      DO 210 M=1,L                                              HFLO 910
      IK=1                                                      HFLO 920
      ISW=0                                                     HFLO 930
      IF (N.EQ.1) GO TO 70                                      HFLO 940
      YN1=Y(N-1)                                                HFLO 950
C                                                               HFLO 960
C     INITIALIZE ZJ1 TO ZZ, THE FIRST GUESS FOR EIGENVALUE     HFLO 970
C     COMPUTE THE UPPER AND LOWER BOUNDS FOR ZJ1 FOR IK=1
                                                                HFLO 990
```

```
   70 ZJ1=ZZ                                                             HFL01000
      ZR=ZTEMP+0.5D0*RPL
      ZLFT=ZTEMP-0.5D0*RPL
      IF (M.EQ.1) ZLFT=0.D0
      DO 120 J=1,99                                                      HFL01020
      ZJ=ZJ1                                                             HFL01030
      ZL=LL*ZJ                                                           HFL01040
      FCOT=-SS*DCOTAN(ZJ)                                                HFL01050
      FTAN=DTAN(ZL)                                                      HFL01060
      F=FCOT+FTAN                                                        HFL01070
      FP=SS/DSIN(ZJ)**2+LL/DCOS(ZL)**2                                  HFL01080
      ZJ1=ZJ-F/FP                                                        HFL01090
      IF (IK-2) 80,90,100                                               HFL01100
C     CHECK TO INSURE THAT THE VALUE OF ZJ1 STAYS BETWEEN THE BOUNDS
C     FOR IK=1
   80 IF (ZJ1.LE.ZR) GO TO 85
      ZJ1=(ZJ1+ZJ)*0.5D0                                                HFL01140
      GO TO 80                                                          HFL01150
   85 IF (ZJ1.GE.ZLFT) GO TO 110
      ZJ1=(ZJ1+ZJ)*0.5D0
      GO TO 85
C     CHECK TO INSURE THAT THE VALUE OF ZJ1 STAYS BETWEEN THE BOUNDS    HFL01160
C     FOR IK=2                                                          HFL01170
   90 IF (ZJ1.GE.ZIP.AND.ZJ1.LE.Z1) GO TO 110                          HFL01180
      IF (DABS(ZJ1-ZJ).LE.1.D-10) GO TO 110                            HFL01190
      ZJ1=(ZJ1+ZJ)*0.5D0                                                HFL01200
      GO TO 90                                                          HFL01210
C     CHECK TO INSURE THAT THE VALUE OF ZJ1 STAYS BETWEEN THE BOUNDS    HFL01220
C     FOR IK=3                                                          HFL01230
  100 IF (ZJ1.LE.ZIP1.AND.ZJ1.GE.Z1) GO TO 110                         HFL01240
      IF (DABS(ZJ1-ZJ).LE.1.D-10) GO TO 110                            HFL01250
      ZJ1=(ZJ1+ZJ)*0.5D0                                                HFL01260
      GO TO 100                                                         HFL01270
C     DOES ZJ1 CONVERGE?                                                HFL01280
  110 IF (DABS(ZJ1-ZJ).LT.D) GO TO 130                                 HFL01290
  120 CONTINUE                                                          HFL01300
      IF (IK.EQ.1) YTEMP=YN1                                            HFL01310
      GO TO 140                                                         HFL01320
  130 DELZY=DABS(ZJ1-YN1)                                               HFL01330
C     IF ZJ1 IS NOT EQUAL TO THE PREVIOUS EIGENVALUE AND NOT TOO LARGE  HFL01340
C     THEN PRINT OUT ZJ1 AND STORE IT IN Y(N)                           HFL01350
      IF (DELZY.GT.D.AND.DELZY.LT.RPL) GO TO 160                        HFL01360
C                                                                       HFL01370
C     SEARCH FOR MISSING EIGENVALUE BETWEEN YN1=Y(N-1) AND ZJ1          HFL01380
C                                                                       HFL01390
      IF (IK.GT.1) GO TO 140                                            HFL01400
C     TEMPORARILY STORE ZJ1, ZZ AND J. IF ZJ1 IS A GOOD EIGENVALUE,     HFL01410
C     PRINT IT OUT AND STORE IT AFTER THE "MISSING" EIGENVALUE IS FOUND HFL01420
      YTEMP=ZJ1                                                         HFL01430
      JTEMP=J                                                           HFL01450
  140 IF (IK.EQ.3) GO TO 190                                            HFL01460
      IK=IK+1                                                           HFL01470
      IF (IK.EQ.3) GO TO 150                                            HFL01480
```

```
C     COMPUTE THE UPPER AND LOWER BOUNDS                                    HFL01490
C     Z1 IS THE ASYMPTOTIC LINE OF THE SHORTER PERIOD FUNCTION. IT IS       HFL01500
C     THE UPPER BOUND FOR IK=2 AND THE LOWER BOUND FOR IK=3.                HFL01510
C     Z2 IS ASYMPTOTIC LINE OF LONGER PERIOD FUNCTION
C     ZIP IS THE LOWER BOUND FOR IK=2                                       HFL01520
C     ZIP1 IS THE UPPER BOUND FOR IK=3                                      HFL01530
      Z1=ZTEMP-0.500*RPL                                                    HFL01540
      IZ=Z1/PRL                                                             HFL01550
      Z2=(IZ+HALF)*PRL                                                      HFL01560
      ZIP=ZZ                                                                HFL01570
      IF (ZIP.GT.Z1) ZIP=ZIP-PRL                                           HFL01580
      ZIP1=ZIP+PRL                                                          HFL01590
      IF (ZIP.LT.YN1) ZIP=YN1                                              HFL01600
      IF (ZIP1.GT.ZTEMP) ZIP1=ZTEMP                                        HFL01610
C     IF IK=2, THEN SEARCH TO THE LEFT OF ASYMPTOTIC LINE OF               HFL01620
C     SHORTER PERIOD FUNCTION                                              HFL01630
C     START SEARCHING FOR SECOND ROOT FROM MID POINT BETWEEN Z1 AND ZIP    HFL01640
      ZZ=(Z1+ZIP)*0.5D0                                                    HFL01650
      GO TO 70                                                             HFL01660
C     START SEARCHING FOR THIRD ROOT FROM MID POINT BETWEEN Z1 AND ZIP1    HFL01670
  150 ZZ=(Z1+ZIP1)*0.5D0                                                   HFL01680
      GO TO 70                                                             HFL01690
C     AN EIGENVALUE HAS BEEN FOUND, PRINT OUT AND STORE ITS VALUE,         HFL01700
C     INCREMENT N.                                                         HFL01710
  160 WRITE (6,170) ZJ1,J,IK,M
  170 FORMAT (' Z=',D23.16,8X,'J=',I3,10X,'IK=',I2,10X,'M=',I3)
      Y(N)=ZJ1                                                             HFL01740
      N=N+1                                                                HFL01750
      IF (N.GT.L) GO TO 220
      IF (IK-2) 200,180,190                                               HFL01760
  180 ISW=1                                                                HFL01770
      GO TO 140                                                            HFL01780
  190 IF (DABS(YTEMP-YN1).LE.1.0-5) GO TO 200                             HFL01790
C     RESTORE THE EIGENVALUE OF FIRST ROOT FOUND (FOR IK=1), IF            HFL01800
C     DIFFERENT FROM EIGENVALUE OF IK=2 OR 3, THEN PRINT AND STORE IN Y    HFL01810
      ZJ1=YTEMP                                                            HFL01830
      J=JTEMP                                                              HFL01840
      IK=1                                                                 HFL01850
      GO TO 160                                                            HFL01860
  200 ZZ=M*RPL+HALF*RPL
      ZTEMP=M*RPL+HALF*RPL
  210 CONTINUE                                                             HFL01890
```

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```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC   HFL01900
C                                                                    C   HFL01910
C       PART III. COMPUTE AND PRINT TEMPERATURES                     C   HFL01920
C                                                                    C   HFL01930
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC   HFL01940
  220 WRITE (6,230) T1,T2                                                HFL01950
  230 FORMAT ('0T1=',F4.0,8X,'T2=',F6.0//)                              HFL01960
      DO 280 J=1,10                                                      HFL01970
      T=0.D0                                                             HFL01980
      DO 250 N=1,L                                                       HFL01990
      ZN=Y(N)                                                            HFL02000
      ZL=ZN*LL                                                           HFL02010
      CL=DCOS(ZL)                                                        HFL02020
      SL=DSIN(ZL)                                                        HFL02030
      CN=DCOS(ZN)                                                        HFL02040
      SN=DSIN(ZN)                                                        HFL02050
      NM=SN*SL*((T1-T2)*CL+T2)*DCOS(ZN*XA)                               HFL02060
      NM=NM*DEXP(-A1*(ZN/A)**2*TI)                                       HFL02070
      DM=SL*CL+LL*SN*CN                                                  HFL02080
      DELT=2.D0*NM/(ZN*DM)                                               HFL02090
      IF (DABS(DELT).LE..1D-40) GO TO 270                                HFL02100
      T=T+DELT                                                           HFL02110
      N1=N-1                                                             HFL02120
      IF (N1.NE.25) GO TO 250                                            HFL02130
      WRITE (6,240) T,N1                                                 HFL02140
  240 FORMAT (' T=',D23.16,8X,'N=',I3)                                   HFL02150
  250 CONTINUE                                                           HFL02160
  260 FORMAT (' T=',F7.2,8X,'TIME=',D12.4,10X,'N=',I3)                   HFL02170
      IF (N.GT.L) N=L                                                    HFL02130
  270 WRITE (6,260) T,TI,N                                               HFL02130
      TI=TI*10.D0                                                        HFL02130
  280 CONTINUE                                                           HFL02200
      WRITE (6,300) LL,SS,P,A1,A2                                        HFL02210
  290 CONTINUE                                                           HFL02220
  300 FORMAT ('0LL=',D23.16,8X,'SS=',D23.16,8X,'P=',D23.16/' A1=',D23.16HFL02230
     1,8X,'A2=',D23.16)                                                  HFL02240
      STOP                                                               HFL02250
      END                                                                HFL02260
```