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TIME VARYING SOLAR CYCLE PROTONS PROGRAM MANUAL

BY
R. A. DEVANEY
R. C. BLANCHARD
J. ANDARY

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NASA

GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

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PROGRAM MANUAL

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R. A. Devaney
R. C. Blanchard
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Theoretical Division
National Aeronautics and Space Administration
GODDARD SPACE FLIGHT CENTER

Greenbelt, Maryland

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TIME VARYING SOLAR CYCLE PROTONS PROGRAM MANUAL

INTRODUCTION

The purpose of this manual is to provide a detailed description of the programs employed in calculating the variation of the proton population in the earth's radiation belt due to solar cycle atmospheric and source changes. This report makes no attempt to make detail explanations of the theory involved in the calculations. An adequate list of references is provided for those interested in the explanation of the methods and the results to be expected. The entire process involves several interdependent steps. For example, the diurnal averaged atmosphere and the rings output from the B-L search routine are input to the longitudinal averaging processor. The output from this program is then used as input to the "bounce" average program and so forth. Each program description includes the equations used, a flow chart and Fortran listing of the program, input and output specifications, card descriptions, sample input and output data and running time. The code is written in Fortran II language and assembled under GSFC-NASA Theoretical Division monitor system on the IBM-7094 computer.

I. DIURNAL AVERAGED ATMOSPHERE

Contained here are tables of number density vs. altitude and solar flux number. Separate tables of He, O, O_2, N_2 and H are contained in Tables 1-5. The models are those generated by Harris and Priester.[2] Each model refers to a given solar radiation flux in units of 10^{-22} watts/m^2/cycle/sec. The link between solar flux, S, and time is given by Figure 1 (reproduced from reference 2 with the permission of Harris and Priester). This data is included for continuity and is used as input for the longitudinal averaging processor. The Harris and Priester atmosphere and solar flux vs. time curve is the data used and is subject to change as soon as better data becomes available. Such changes can be performed without effecting the logic of the following programs.

Table 1
Diurnal Averaged Number Densities of He as a Function of Altitude for Five Solar Flux Numbers.

S / h(km.)	250	200	150	100	70
120	2.500E07	2.500E07	2.500E07	2.500E07	2.500E07
200	4.413E06	4.872E06	5.484E06	6.319E06	6.982E06
300	2.642E06	2.843E06	3.050E06	3.205E06	3.212E06
400	1.945E06	2.007E06	2.012E06	1.885E06	1.689E06
500	1.499E06	1.477E06	1.390E06	1.154E06	9.272E05
600	1.176E06	1.107E06	9.646E05	7.236E05	5.231E05
700	9.327E05	8.387E05	6.842E05	4.607E05	3.021E05
800	7.461E05	6.422E05	4.916E05	3.004E05	1.783E05
900	6.016E05	4.964E05	3.574E05	1.984E05	1.074E05
1000	4.886E05	3.871E05	2.628E05	1.331E05	6.593E04
1100	3.995E05	3.044E05	1.953E05	9.050E04	4.119E04
1200	3.287E05	2.411E05	1.466E05	6.238E04	2.616E04
1300	2.721E05	1.925E05	1.110E05	4.353E04	1.687E04
1400	2.265E05	1.547E05	8.482E04	3.074E04	1.104E04
1500	1.895E05	1.251E05	6.537E04	2.195E04	7.328E03
1600	1.595E05	1.019E05	5.078E04	1.584E04	4.925E03
1700	1.348E05	8.346E04	3.974E04	1.155E04	3.351E03
1800	1.145E05	6.875E04	3.133E04	8.497E03	2.306E03
1900	9.774E04	5.696E04	2.487E04	6.308E03	1.605E03
2000	8.378E04	4.743E04	1.988E04	4.724E03	1.128E04

Table 2
Diurnal Averaged Number Densities of O as a Function of Altitude for Five Solar Flux Numbers.

h(km.) \ S	250	200	150	100	70
120	7.600E10	7.600E10	7.600E10	7.600E10	7.600E10
200	3.600E09	3.457E09	3.209E09	2.795E09	2.416E09
300	8.870E08	7.134E08	5.124E08	2.809E08	1.564E08
400	3.054E08	2.054E08	1.112E08	4.025E07	1.471E07
500	1.168E08	6.616E07	2.788E07	6.771E06	1.675E06
600	4.749E07	2.287E07	7.708E06	1.273E06	2.183E05
700	2.024E07	8.364E06	2.232E06	2.611E05	3.153E04
800	8.983E06	3.207E06	6.918E05	5.747E04	4.946E03
900	4.130E06	1.282E06	2.252E05	1.342E04	8.320E02
1000	1.960E06	5.312E05	7.645E04	3.301E03	1.488E02
1100	9.567E05	2.275E05	2.696E04	8.502E02	2.810E01
1200	4.791E05	1.003E05	9.834E03	2.284E02	5.381E00
1300	2.456E05	4.538E04	3.701E03	6.379E01	1.162E00
1400	1.287E05	2.106E04	1.434E03	1.848E01	2.527E-1
1500	6.878E04	9.997E03	5.706E02	5.541E00	5.729E-2
1600	3.746E04	4.849E03	2.330E02	1.717E00	1.352E-2
1700	2.077E04	2.399E03	9.744E01	5.486E-1	3.312E-3
1800	1.170E04	1.210E03	4.170E01	1.806E-1	8.412E-4
1900	6.700E03	6.216E02	1.824E01	6.079E-2	2.212E-4
2000	3.893E03	3.247E02	8.149E00	2.128E-2	6.010E-5

Table 3
Diurnal Averaged Number Densities of O_2 as a Function of Altitude for Five Solar Flux Numbers.

h(km.) \ S	250	200	150	100	70
120	1.200E11	1.200E11	1.200E11	1.200E11	1.200E11
200	9.900E08	7.910E08	5.699E08	3.438E08	2.151E08
300	7.683E07	4.269E07	1.791E07	4.503E06	1.188E06
400	1.020E07	4.069E06	1.048E06	1.191E05	1.427E04
500	1.217E06	4.886E05	7.983E04	4.808E03	2.444E02
600	3.142E05	6.758E04	7.106E03	1.857E02	5.155E00
700	6.428E04	1.033E03	7.062E02	9.135E00	1.265E-1
800	1.364E04	1.714E03	7.688E01	5.002E-1	3.528E-3
900	3.242E03	3.031E02	8.962E00	3.010E-2	1.102E-4
1000	7.981E02	5.682E01	1.122E00	1.975E-3	3.821E-6
1100	2.056E02	1.122E01	1.493E-1	1.403E-4	1.459E-7
1200	5.526E01	2.322E00	2.106E-2	1.074E-5	5.274E-9
1300	1.544E01	5.028E-1	3.139E-3	8.835E-7	2.788E-10
1400	4.474E00	1.136E-1	4.927E-4	7.772E-8	1.382E-11
1500	1.342E00	2.778E-2	8.124E-5	7.292E-9	7.412E-13
1600	4.157E-1	6.520E-3	1.405E-5	7.277E-10	4.288E-14
1700	1.328E-1	1.653E-3	2.541E-6	7.702E-11	2.667E-15
1800	4.370E-2	4.342E-4	4.800E-7	8.627E-12	1.777E-16
1900	1.478E-2	1.177E-4	9.452E-8	1.200E-12	1.267E-17
2000	5.142E-3	2.906E-5	1.937E-8	1.270E-13	9.626E-19

Table 4
Diurnal Averaged Number Densities of N_2 as a Function of Altitude for Five Solar Flux Numbers.

h(km.) \ S	250	200	150	100	70
120	5.800E11	5.800E11	5.800E11	5.800E11	5.800E11
200	7.393E09	6.180E09	4.743E09	3.136E09	2.124E09
300	7.630E08	4.639E08	2.210E08	6.739E07	2.113E07
400	1.278E08	5.777E07	2.151E07	2.682E06	4.225E05
500	2.562E07	8.798E06	1.810E06	1.407E05	1.156E04
600	5.730E06	1.521E06	3.239E05	8.800E03	3.844E02
700	1.403E06	2.884E05	2.763E04	6.190E02	1.471E01
800	3.664E05	5.883E04	3.899E03	4.802E01	6.320E-1
900	1.012E05	1.276E04	5.894E02	4.057E00	3.006E-2
1000	2.932E04	2.918E03	9.470E01	3.702E-1	1.570E-3
1100	8.862E03	6.994E02	1.609E01	3.627E-2	8.936E-5
1200	2.783E03	1.725E02	2.878E00	3.798E-3	1.016E-5
1300	9.053E02	4.558E01	5.404E-1	4.237E-4	3.674E-7
1400	3.041E02	1.233E01	1.063E-1	5.017E-5	2.633E-8
1500	1.075E02	3.456E00	2.183E-2	6.287E-6	2.023E-9
1600	3.768E01	1.002E00	4.677E-3	8.321E-7	1.661E-10
1700	1.380E01	3.001E-1	1.042E-3	1.160E-7	1.454E-11
1800	5.211E00	9.268E-2	2.313E-4	1.699E-8	1.353E-12
1900	2.005E00	2.949E-2	5.746E-5	2.612E-9	1.334E-13
2000	7.927E-1	9.654E-3	1.431E-5	4.619E-10	1.393E-14

Table 5
Diurnal Averaged Number Densities of H as a Function of Altitude for Five Solar Flux Numbers.

h(km.) \ S	250	200	150	100	70
120	4.356E04	4.356E04	4.356E04	4.356E04	4.356E04
200	1.071E04	1.224E04	1.447E04	1.790E04	2.104E04
300	8.035E03	9.323E03	1.114E04	1.380E04	1.611E04
400	7.205E03	8.328E03	9.837E03	1.189E04	1.352E04
500	6.690E03	7.660E03	8.898E03	1.046E04	1.157E04
600	6.272E03	7.102E03	8.107E03	9.263E03	9.974E03
700	5.904E03	6.609E03	7.415E03	8.214E03	8.638E03
800	5.573E03	6.168E03	6.803E03	7.360E03	7.518E03
900	5.272E03	5.769E03	6.260E03	6.597E03	6.571E03
1000	4.996E03	5.408E03	5.774E03	5.933E03	5.768E03
1100	4.742E03	5.079E03	5.339E03	5.352E03	5.083E03
1200	4.502E03	4.778E03	4.947E03	4.843E03	4.495E03
1300	4.291E03	4.503E03	4.594E03	4.395E03	3.989E03
1400	4.090E03	4.250E03	4.275E03	3.998E03	3.552E03
1500	3.903E03	4.018E03	3.986E03	3.647E03	3.173E03
1600	3.730E03	3.804E03	3.723E03	3.335E03	2.843E03
1700	3.568E03	3.606E03	3.484E03	3.057E03	2.555E03
1800	3.417E03	3.424E03	3.266E03	2.809E03	2.303E03
1900	3.276E03	3.255E03	3.066E03	2.587E03	2.081E03
2000	3.144E03	3.098E03	2.884E03	2.387E03	1.886E03

II. B-L SEARCH

A. Introduction

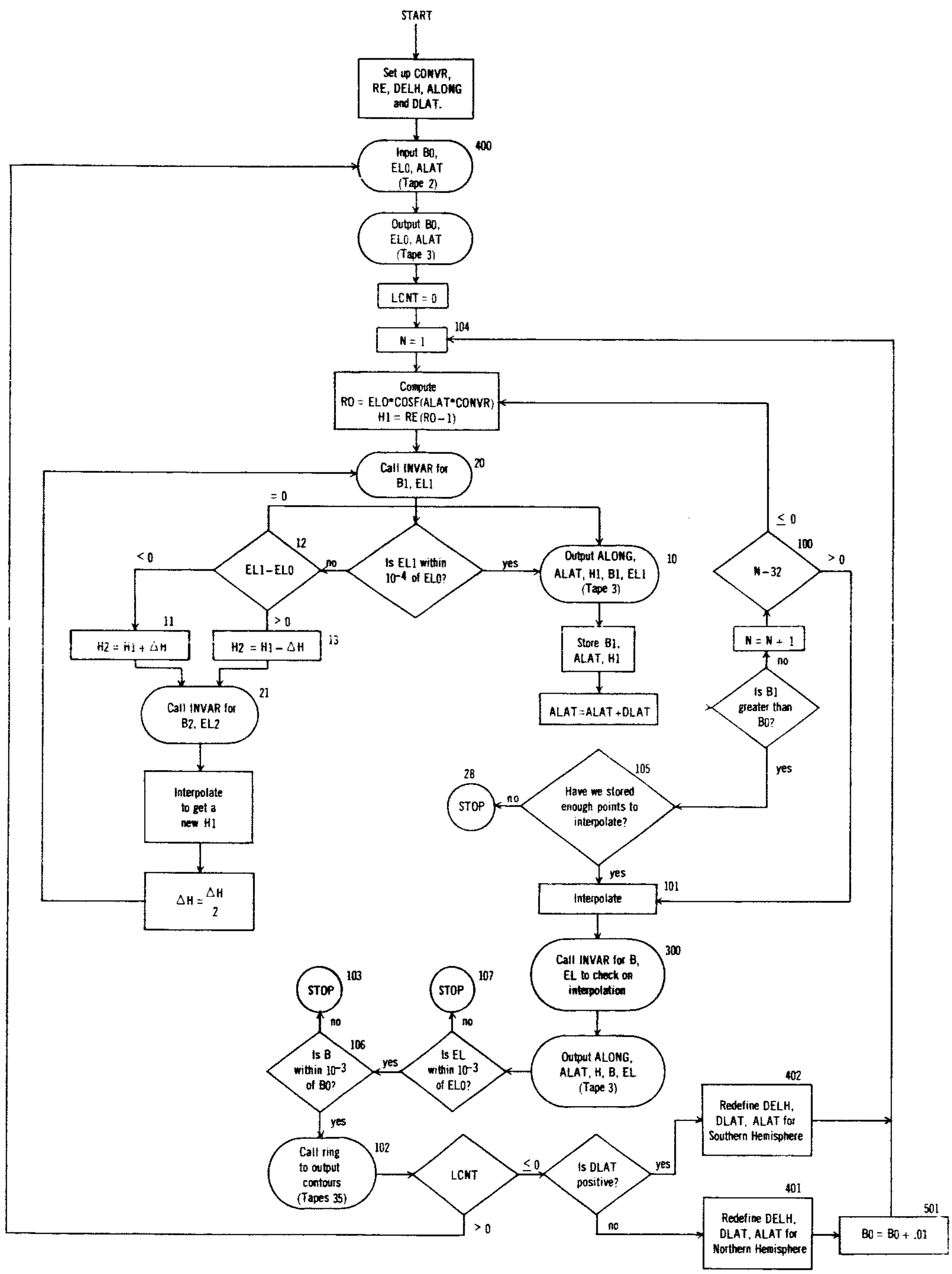
This program produces contours of constant B and L as a function of longitude, latitude and altitude in both the northern and southern hemispheres. The desired initial values of B and L are read into the program along with an approximate corresponding latitude, λ, which can easily be obtained by the use of Figure 2. The dipole equation $r_0 = L_0 \cos^2 \lambda$ relating the initial L and the geocentric distance r_0 is used with the radius of the earth, r_e, and the equation $h_1 = r_e (r_0 - 1)$ to provide an approximation of the altitude. This is fed, together with a longitude of 18C degrees and latitude λ, into subroutine INVAR which calculates B and L for a given longitude, latitude and altitude. This subroutine makes use of the transformation developed by McIlwain (3) using the 48 spherical harmonic coefficients of Jenson and Cain (4). INVAR numerically integrates the longitudinal invariant I using a series expansion for the magnetic field. Then L is calculated as a function of both B and I by using a dipole representation of the earth. The B and L obtained in this manner are returned to the main program. Here the accuracy of the initial approximation is checked. If the computed L is found to be within an accuracy of 10^{-4} of the initial L the program will enter into a search routine with linear interpolation in latitude and altitude in order to arrive at a correct B. The search parameters Δh (increment in altitude) and $\Delta\lambda$ (increment in latitude) are prefixed and must remain small in order that interpolation may hold. Once B is found, it is checked, together with the value of L, to insure an accuracy of 10^{-3} in comparison with the initial values. If the accuracy is sufficient the subroutine RING will be called for the northern hemisphere. This subroutine takes a given latitude and altitude and computes the B and L contour map for longitudes of 10 degree increment for the full 360 degrees. The program then computes the contour map for the southern hemisphere at the same B and L, increments B by .01 gauss and returns to the northern hemisphere. It will continue in this manner until the altitude drops below 100 kilometers, at which point the next initial B, L and λ will be read until input data is exhausted. The entire process prepares input for the longitudinal averaging processor.

B. Mnemonics

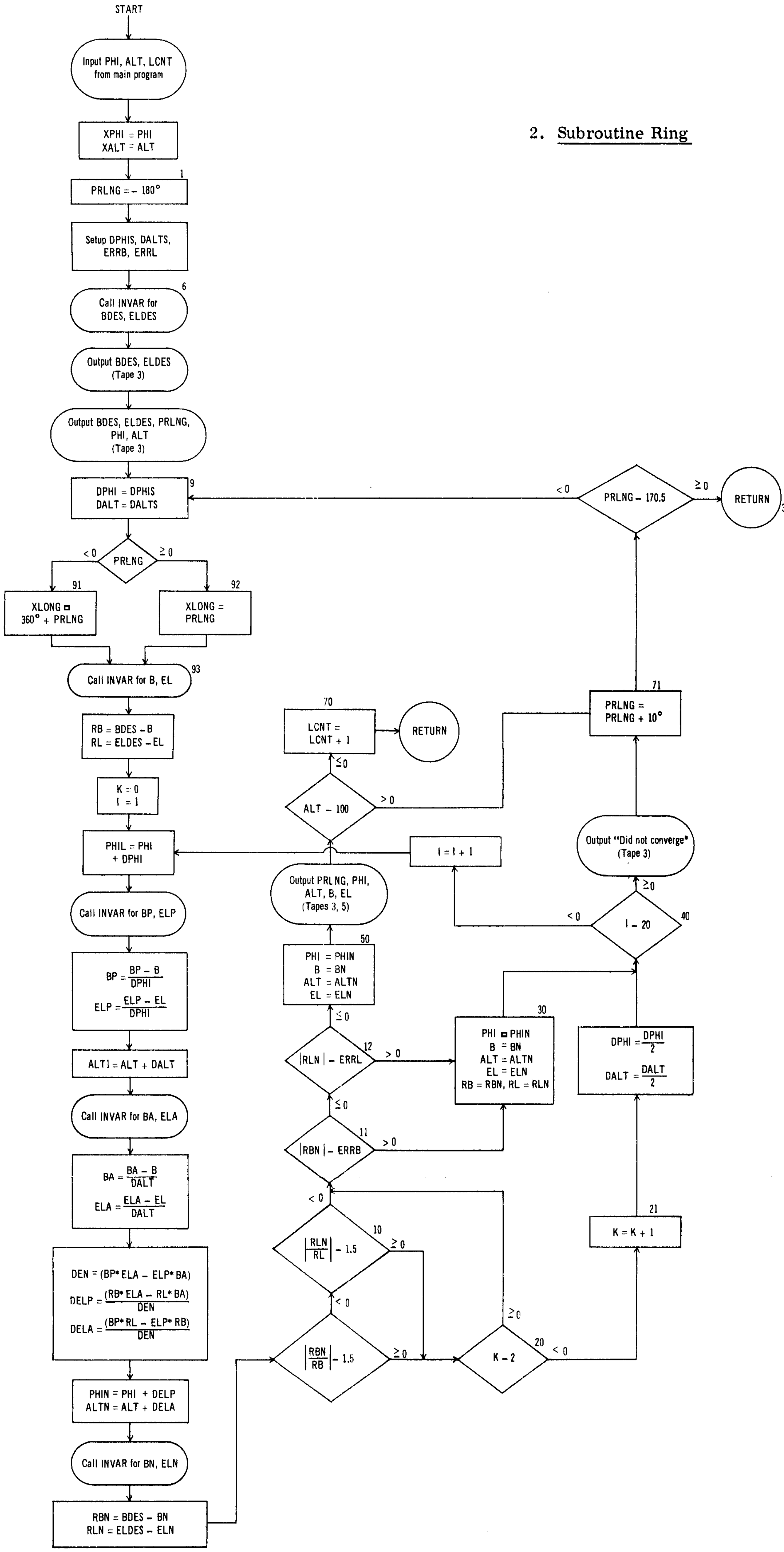
Quantity	Description	Units
CONVR	conversion factor – degrees to radians	- -
RE	radius of the earth	km.
DELH	delta altitude	km.
ALONG	geocentric longitude	degrees
DLAT	delta latitude	"
ALAT	geocentric latitude	"
B	magnetic induction	gauss
EL	magnetic field line	earth radii
R	geocentric distance	"
H	altitude	km.
SAVB	temporary storage of B	gauss
SAVH	temporary storage of H	km.
SAVLAT	temporary storage of ALAT	degrees
LCNT	an indicator used to indicate when the altitude has dropped below 100 km.	- -

C. Flow Charts

1. Main Program



2. Subroutine Ring



D. Fortran Listing

```
C      B-L SEARCH
       DIMENSION SAVB(32),SAVLAT(32),SAVH(32)
     1 FORMAT(2F12.5,F8.5)
     2 FORMAT(5F12.5)
     3 FORMAT (5X,42H INTERMEDIATE RESULTS--NORTHERN HEMISPHERE)
     4 FORMAT (8X,4HLONG,8X,3HLAT,9X,3HALT,10X,1HB,11X,1HL)
     5 FORMAT (4H1B0=1F8.5,4X,4H L0=1F8.5,4X,13H INITIAL LAT=1F8.5)
     6 FORMAT (1H1,5X,42H INTERMEDIATE RESULTS--SOUTHERN HEMISPHERE)
     7 FORMAT (1H1,5X,42H INTERMEDIATE RESULTS--NORTHERN HEMISPHERE)
     8 FORMAT (36H0VALUE OF B IS NOT WITHIN .001 OF B0)
     9 FORMAT (60H0INTERPOLATION CANNOT PROCEED--MAKE INITIAL LATITUDE SM
      1ALLER)
    10 FORMAT (37H0VALUE OF L IS NOT WITHIN .001 OF EL0)
  400  READ INPUT TAPE 2,1,B0,EL0,ALAT
       WRITE OUTPUT TAPE 3,5,B0,EL0,ALAT
       WRITE OUTPUT TAPE 3,3
       WRITE OUTPUT TAPE 3,4
       CONVR=.01745333
       RE=6378.2
       DELH=100.
       ALONG=180.
       DLAT=2.
       ALAT0=ALAT
       LCNT=0
   104 DO 100 N=1,32
       R0=EL0*COSF(ALAT*CONVR)**2
       H1=RE*(R0-1.)
    20 CALL INVAR(ALAT,ALONG,H1,.01,B1,EL1)
       CKEL=EL1-EL0
       IF(ABSF(CKEL)-1.E-4)14,14,12
    12 IF(CKEL)  11,14,13
    13 H2=H1-DELH
    21 CALL INVAR(ALAT,ALONG,H2,.01,B2,EL2)
       H1=H1-(EL1-EL0)*(H1-H2)/(EL1-EL2)
       DELH=DELH/2.
       GO TO 20
    11 H2=H1+DELH
       GO TO 21
    14 WRITE OUTPUT TAPE 3,2,ALONG,ALAT,H1,B1,EL1
       SAVB(N)=B1
       SAVLAT(N)=ALAT
       SAVH(N)=H1
       ALAT=ALAT+DLAT
       IF(B1-B0) 100,100,105
   100 CONTINUE
   105 IF (N-1) 28,28,101
    28 WRITE OUTPUT TAPE 3,9
       CALL EXIT
  101  DO 200 I=1,32
       IF(SAVB(I)-B0) 200,30,31
    31 AL2=SAVLAT(I)
       B2=SAVB(I)
       H2=SAVH(I)
       AL1=SAVLAT(I-1)
       B1=SAVB(I-1)
```

```
      H1=SAVH(I-1)
      ALAT=AL2-(AL2-AL1)*(B2-BO)/(B2-B1)
      H=H1-(BO-B1)*(H1-H2)/(B2-B1)
      GO TO 300
   30 B=SAVB(I)
      ALAT=SAVLAT(I)
      H=SAVH(I)
      GO TO 300
  200 CONTINUE
  300 CALL INVAR(ALAT,ALONG,H,.01,B,EL)
      WRITE OUTPUT TAPE 3,2,ALONG,ALAT,H,B,EL
      CKL=EL-ELO
      IF (ABSF(CKL)-1.E-3) 106,106,107
  107 WRITE OUTPUT TAPE 3,10
      CALL EXIT
  106 CKB=B-BO
      IF (ABSF(CKB)-1.E-3) 102,102,103
  103 WRITE OUTPUT TAPE 3,8
      CALL EXIT
  102 CALL RING(ALAT,H,LCNT)
      IF (LCNT) 403,403,400
  403 IF(DLAT) 401,401,402
 402  DELH=100.
      DLAT=-2.
      IF (ALATO-11.) 500,501,501
  500 ALAT=-1.
      GO TO 502
  501 ALAT=-ALATO+11.
  502 WRITE OUTPUT TAPE 3,6
      WRITE OUTPUT TAPE 3,4
      GO TO 104
 401  DLAT=2.
      DELH=100.
      ALAT=ALATO+1.
      ALATO=ALAT
      BO=BO+.01
      WRITE OUTPUT TAPE 3,7
      WRITE OUTPUT TAPE 3,4
      GO TO 104
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                                   STORAGE NOT USED BY PROGRAM

        DEC   OCT              DEC   OCT
        624 01160            32561 77461

                  STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

        DEC   OCT              DEC   OCT               DEC   OCT              DEC   OCT              DEC   OCT
 SAVB   623 01157     SAVH     559 01057     SAVLAT    591 01117

               STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

        DEC   OCT              DEC   OCT               DEC   OCT              DEC   OCT              DEC   OCT
  AL1   527 01017       AL2    526 01016      ALATO    525 01015     ALAT     524 01014     ALONG    523 01013
   BO   522 01012        B1    521 01011         H2    520 01010        B     519 01007       CKB    518 01006
 CKEL   517 01005       CKL    516 01004      CONVR    515 01003     DELH     514 01002      DLAT    513 01001
  LLO   512 01000       LL1    511 00777        LL2    510 00776       EL     509 00775        H1    508 00774
   H2   507 00773         H    506 00772          I    505 00771     LCNT     504 00770         N    503 00767
   RO   502 00766        RE    501 00765

                        SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

        EFN   LOC              EFN   LOC               EFN   LOC              EFN   LOC              EFN   LOC
  8)1     1 00757       8)2      2 00754        8)3      3 00752      8)4       4 00741      8)5       5 00731
  8)6     6 00720       8)7      7 00706        8)8      8 00674      8)9       9 00665      8)A      10 00652

                       LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

        DEC   OCT              DEC   OCT               DEC   OCT              DEC   OCT              DEC   OCT
   1)   496 00760        2)    399 00617         3)    403 00623       4)   32767 77777        6)    413 00635
 C)GO   499 00763      C)G1    500 00764      D)1CF    204 00314     D)20L    266 00412     D)401     15 00017
 D)40B  189 00275     D)601     14 00016        E)5    110 00156       E)8    145 00221       E)9    150 00226
  E)C   188 00274       E)F    202 00312        E)H    211 00323       E)J    263 00407       E)N    311 00467
  E)P   330 00512       E)R    345 00531      E)101     17 00021

                                   LOCATIONS OF NAMES IN TRANSFER VECTOR

        DEC   OCT              DEC   OCT               DEC   OCT              DEC   OCT              DEC   OCT
  COS     5 00005      EXIT      7 00007      INVAR      6 00006     RING       8 00010     (FIL)      4 00004
 (FPT)    0 00000     (RTN)      2 00002      (STH)      3 00003     (TSH)      1 00001

                           ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

 COS          EXIT         INVAR        RING         (FIL)        (FPT)        (RTN)        (STH)        (TSH)

               EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

  EFN   IFN   LOC        EFN   IFN   LOC         EFN   IFN   LOC        EFN   IFN   LOC        EFN   IFN   LOC
  400    13 00023        104    26 00111          20    29 00134         12    33 00160         13    34 00164
   21    35 00167         11    40 00222          14    42 00227        100    49 00272        105    50 00276
   28    51 00302        101    53 00315          31    55 00325         30    64 00376        200    68 00410
  300    59 00413        107    75 00457         106    77 00471        103    79 00502        102    81 00514
  403    84 00525        402    85 00533         500    88 00543        501    90 00546        502    91 00551
  401    94 00566
```

```
      SUBROUTINE RING(PHI,ALT,LCNT)
  101 FORMAT (25X,14H FINAL RESULTS)
  102  FORMAT(17H DID NOT CONVERGE)
  103  FORMAT(3F12.2,2F12.5)
  107 FORMAT (3H B=1F8.5,4X,3H L=1F8.5)
       DPHIS=4.0
       DALTS=5.0
       ERRB=1.0E-4
       ERRL=1.0E-3
      XPHI = PHI
      XALT = ALT
    1  PRLNG=-180.0
      CALL INVAR(PHI,180.,ALT,0.01,BDES,ELDES)
    6  WRITE OUTPUT TAPE 3,107,BDES,ELDES
       WRITE OUTPUT TAPE 3,101
      WRITE OUTPUT TAPE 3,103,PRLNG,PHI,ALT,BDES,ELDES
    9  DPHI=DPHIS
       DALT=DALTS
      IF (PRLNG) 91,92,92
   91 XLONG = 360. + PRLNG
      GO TO 93
   92 XLONG = PRLNG
   93 CONTINUE
C      COMPUTE B AND L
      CALL INVAR(PHI,XLONG,ALT,0.01,B,EL)
       RB=BDES-B
       RL=ELDES-EL
C      COMPUTE  PARTIALS
       K=0
      DO 40 I=1,20
       PHI1=PHI+DPHI
      CALL INVAR(PHI1,XLONG,ALT,0.01,BP,ELP)
       BP=(BP-B)/DPHI
       ELP=(ELP-EL)/DPHI
       ALT1=ALT+DALT
      CALL INVAR(PHI,XLONG,ALT1,0.01,BA,ELA)
       BA=(BA-B)/DALT
       ELA=(ELA-EL)/DALT
C      COMPUTE CORRECTIONS
       DEN=BP*ELA-ELP*BA
       DELP=(RB*ELA-RL*BA)/DEN
       DELA=(BP*RL-ELP*RB)/DEN
       PHIN=PHI+DELP
       ALTN=ALT+DELA
      CALL INVAR(PHIN,XLONG,ALTN,0.01,BN,ELN)
       RBN=BDES-BN
       RLN=ELDES-ELN
       IF(ABSF(RBN/RB)-1.5) 10,20,20
   20  IF(K-2) 21,11,11
   21  K=K+1
       DPHI=DPHI/2.
       DALT=DALT/2.
       GO TO 40
   10  IF(ABSF(RLN/RL)-1.5) 11,20,20
   11  IF(ABSF(RBN)-ERRB) 12,12,30
```

```
12   IF(ABSF(RLN)-ERRL) 50,50,30
30   PHI=PHIN
     B=BN
     ALT=ALTN
     EL=ELN
     RB=RBN
     RL=RLN
40   CONTINUE
     WRITE OUTPUT TAPE 3,102
    PRLNG=PRLNG+10.
     IF(PRLNG-180.5) 9,3,3
50   PHI=PHIN
     B=BN
     ALT=ALTN
     EL=ELN
    WRITE OUTPUT TAPE 3,103,PRLNG,PHI,ALT,B,EL
    WRITE OUTPUT TAPE 5,103,PRLNG,PHI,ALT,B,EL
    IF(ALT-100.) 70,70,71
71   PRLNG=PRLNG+10.
    IF(PRLNG-170.5) 9,3,3
   3 RETURN
70  LCNT=LCNT+1
    RETURN
    END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                                   STORAGE NOT USED BY PROGRAM

           DEC   OCT                DEC   OCT
           423 00647              32561 77461

              STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

           DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
   ALT1    422 00646       ALTN     421 00645        RA      420 00644      BDES      419 00643        BN      418 00642
     BP    417 00641          B     416 00640      DALT      415 00637      DALTS     414 00636      DELA      413 00635
   DELP    412 00634        DEN     411 00633      DPHI      410 00632      DPHIS     409 00631       ELA      408 00630
  ELDES    407 00627        ELN     406 00626       ELP      405 00625         EL     404 00624      ERRB      403 00623
   ERRL    402 00622          T     401 00621         K      400 00620       PHI1     399 00617      PHIN      398 00616
  PRLNG    397 00615        RBN     396 00614        RB      395 00613        RLN     394 00612        RL      393 00611
   XALT    392 00610      XLONG     391 00607      XPHI      390 00606

                         SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

           EFN   LOC                EFN   LOC                EFN   LOC                EFN   LOC                EFN   LOC
   8)35    101 00602       8)36     102 00576      8)37      103 00572      8)38      107 00567

                         LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

           DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
     1)    387 00603         2)     347 00533        3)      352 00540         6)     365 00555     C)2CC     389 00605
  C)201     88 00130      D)401     335 00517       E)9      231 00347        E)B     243 00363       E)D     250 00372
    E)H    326 00506

                                   LOCATIONS OF NAMES IN TRANSFER VECTOR

           DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
  INVAR      0 00000      (FIL)       2 00002     (STH)        1 00001

                            ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

 INVAR        (FIL)        (STH)

          EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

   EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC
     1    13 00064            6    16 00075            9    21 00131           91    24 00140           92    26 00144
    93    27 00146           20    54 00322           21    55 00326           10    59 00340           11    60 00350
    12    61 00355           30    62 00373           40    68 00407           50    72 00425           71    81 00507
     3    83 00520           70    85 00524
```

```
      SUBROUTINE INVAR(FLAT,FLONG,ALT,ERR,BB,FL)                        INVAR000
C         NOTE   ERROR IN L IS TYPICALLY LESS THAN 0.1*ERR               INVARA01
C        FLAT=LATITUDE IN DEGREES   , FLONG=LONGITUDE IN DEGREES         INVARB01
C       ALT=ALTITUDE=DISTANCE FROM SURFACE OF EARTH IN KILOMETERS        INVARC01
      DIMENSION V(3,3),B(200),ARC(200),VN(3),VP(3),BEG(200),BEND(200),  INVAR001
     1BLOG(200),ECO(200),R1(3),R2(3),R3(3)                               INVAR002
      V(1,2)=ALT/6371.2                                                 INVAR003
      V(2,2)=(90.-FLAT)/57.2957795                                      INVAR004
      V(3,2)=FLONG/57.2957795                                           INVAR005
      ARC(1)=0.                                                         INVAR006
      ARC(2)=(1.0+V(1,2))*SQRTF(ERR)*0.3                                INVAR007
      DCLT=1.5708-0.2007*COSF(V(3,2)+1.239)                             INVAR008
      IF(V(2,2)-DCLT)10,10,11                                           INVAR009
   11 ARC(2)=-ARC(2)                                                    INVAR010
   10 CALL START (R1,R2,R3,B,ARC,ERR,V)                                 INVAR011
      DO 12 I=1,3                                                       INVAR012
      VP(I)=V(I,2)                                                      INVAR013
   12 VN(I)=V(I,3)                                                      INVAR014
      CALL LINES (R1,R2,R3,B,ARC,ERR,J,VP,VN)                           INVAR015
      IF(J-200)16,17,17                                                 INVARA15
   17 FL=-1.0                                                           INVARB15
      GO TO 18                                                          INVARC15
   16 JUP=J                                                             INVAR016
      DO 40 J=1,JUP                                                     INVAR017
      ARC(J)=ABSF(ARC(J))                                               INVAR018
   40 BLOG(J)=LOGF(B(J))                                                INVAR019
      JEP=JUP-1                                                         INVAR020
      DO 21 J=2,JEP                                                     INVAR021
      ASUM=ARC(J)+ARC(J+1)                                              INVAR022
      DX=BLOG(J-1)-BLOG(J)                                              INVAR023
      DN=ASUM*ARC(J)*ARC(J+1)                                           INVAR024
      BCO    =((BLOG(J-1)-BLOG(J+1))*ARC(J)**2-DX*ASUM**2)/DN           INVAR025
      CCO    -(DX*ARC(J+1)-(BLOG(J)-BLOG(J+1))*ARC(J))/DN               INVAR026
      SA=.75*ARC(J)                                                     INVAR027
      SC=SA+.25*ASUM                                                    INVAR028
      DCO=BLOG(J-1)-CCO    *SA*SC                                       INVAR029
      ECO(J)=BCO    +CCO    *(SA+SC)                                    INVAR030
      BEG(J)=EXPF(DCO+ECO(J)*.5*ARC(J))                                 INVAR031
   21 BEND(J)=EXPF(DCO+ECO(J)*.5*(ASUM+ARC(J)))                         INVAR032
      BEG(JUP)=BEND(JEP)                                                INVAR033
      BEND(JUP)=B(JUP)                                                  INVAR034
      ECO(JUP)=(2.0/ARC(JUP))*LOGF(BEND(JUP)/BEG(JUP))                  INVAR035
      CALL INTEG (ARC,BEG,BEND,B,JEP,ECO,FLINT)                         INVAR036
   27 CALL CARMEL (B(2),FLINT,FL)                                       INVAR037
   18 BB=B(2)                                                           INVAR038
      RETURN                                                            INVAR039
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

STORAGE NOT USED BY PROGRAM

DEC	OCT	DEC	OCT
1507	02743	32561	77461

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
ARC	1306	02432	BEG	1100	02114	BEND	900	01604	BLOG	700	01274	B	1506	02742
ECO	500	00764	R1	300	00454	R2	297	00451	R3	294	00446	VN	1106	02122
VP	1103	02117	V	291	00443									

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
ASUM	282	00432	BCC	281	00431	CCO	280	00430	DCLT	279	00427	DCC	278	00426
DN	277	00425	DX	276	00424	FLINT	275	00423	JEP	274	00422	J	273	00421
JUP	272	00420	SA	271	00417	SC	270	00416						

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
1)	264	00410	2)	242	00362	3)	245	00365	6)	258	00402	C)G3	268	00414
C)G4	269	00415												

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
CARMEL	7	00007	COS	1	00001	EXP	5	00005	INTEG	6	00006	LINES	3	00003
LOG	4	00004	SQRT	0	00000	START	2	00002						

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

CARMEL COS EXP INTEG LINES LOG SQRT START

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
11	11	00105	10	12	00107	12	16	00123	17	20	00147	16	22	00152
40	25	00164	21	38	00303	27	44	00350	18	46	00354			

```
      SUBROUTINE LINES (R1,R2,R3,B,ARC,ERR,J,VP,VN)                     LINES000
      DIMENSION B(200),ARC(200),R1(3),R2(3),R3(3),VN(3),VP(3),RA(3)     LINES001
      CRE=0.25                                                          LINES002
      IF(ERR-0.15625)74,75,75                                           LINES003
   74 CRE=     (ERR**0.333333333)                                       LINES004
   75 A3=ARC(3)                                                         LINES005
      AAB=ABSF(A3)                                                      LINES006
      SNA=A3/AAB                                                        LINES007
      A1=ARC(1)                                                         LINES008
      A2=ARC(2)                                                         LINES009
      A06=A3*A3/6.0                                                     LINES010
      J=3                                                               LINES011
      ILP=1                                                             LINES012
      IS=1                                                              LINES013
      GO TO 87                                                          LINES014
   66 IS=1                                                              LINES015
      J=J+1                                                             LINES016
      A06=A3*A3/6.0                                                     LINES017
      ARCJ=A1+A2+A3                                                     LINES018
      AD=(ASUM+A1)/AA                                                   LINES019
      BD=ASUM/BB                                                        LINES020
      CD=A1/CC                                                          LINES021
   36 DO 5 I=1,3                                                        LINES022
      DD=R1(I)/AA-R2(I)/BB+R3(I)/CC                                     LINES023
      GO TO(6,8),IS                                                     LINES024
    6 RT=R1(I)-(AD*R1(I)-BD*R2(I)+CD*R3(I)-DD*ARCJ)*ARCJ                LINES025
      RA(I)=R1(I)                                                       LINES026
      R1(I)=R2(I)                                                       LINES027
      R2(I)=R3(I)                                                       LINES028
      R3(I)=RT                                                          LINES029
      VP(I)=VN(I)                                                       LINES030
    8 RBAR=(R2(I)+R3(I))/2.-DD*A06                                      LINES031
    5 VN(I)=VP(I)+A3*RBAR                                               LINES032
   87 IF(VN(2))76,77,77                                                 LINES033
   76 VN(2)=-VN(2)                                                      LINES034
   77 IF(VN(2)-3.141592653)78,78,79                                     LINES035
   79 VN(2)=6.283185307-VN(2)                                           LINES036
      GO TO 77                                                          LINES037
   78 IF(VN(3))80,81,81                                                 LINES038
   80 VN(3)=VN(3)+6.283185307                                           LINES039
      GO TO 78                                                          LINESA39
   81  IF(VN(3)-6.283185307)82,82,83                                    LINES040
   83 VN(3)=VN(3)-6.283185307                                           LINES041
      GO TO 81                                                          LINES042
   82 GO TO (9,10),IS                                                   LINES043
    9 SIT=ABSF(SINF(VN(2)))                                             LINES044
      PRE1=VN(1)                                                        LINES045
      PRE2=PRE1*VN(2)                                                   LINES046
      PRE3=PRE1*SIT*VN(3)                                               LINES047
      SSQ=SIT*SIT                                                       LINES048
      OER=(6356.912+SSQ*(21.3677+.108*SSQ))/6371.2                      LINES049
      AER=VN(1)-OER                                                     LINES050
      CALL MAGNET(AER,SIT,VN(3),BR,BT,BP,B(J),VN(2))                    LINES051
      R3(1)=BR/B(J)                                                     LINES052
      DN=B(J)*VN(1)                                                     LINES053
```

```
      R3(2)=BT/DN                                                       LINES054
      R3(3)=BP/(DN*SIT)                                                 LINES055
      ASUM=A3+A2                                                        LINES056
      AA=ASUM*A2                                                        LINES057
      BB=A3*A2                                                          LINES058
      CC=ASUM*A3                                                        LINES059
      IS=2                                                              LINES060
      GO TO 36                                                          LINES061
   10 SIT=ABSF(SINF(VN(2)))                                             LINES062
      B(J)=B(J)*((PRE1/VN(1))**3)                                       LINES063
   59 QRT=.5*ABSF(R3(1))/(.1+ABSF(R3(2)*VN(1)))                         LINES064
      X=(ABSF(VN(1)-PRE1)+QRT*ABSF(VN(1)*VN(2)-PRE2)+ABSF(VN(1)*SIT*VN(3LINES065
     1)-PRE3))/(AAB*ERR*SQRTF(1.+QRT*QRT))                              LINES066
      GO TO (90,93,90),ILP                                              LINES067
   93 IF(X-3.3)90,89,89                                                 LINES068
   89 A3=A3*0.2*(8.0+X)/(0.8+X)                                         LINES069
      J=J-1                                                             LINES070
      ILP=3                                                             LINES071
      ASUM=A2+A1                                                        LINES072
      AA=ASUM*A1                                                        LINES073
      BB=A2*A1                                                          LINES074
      CC=ASUM*A2                                                        LINES075
      DO 91 I=1,3                                                       LINES076
      VN(I)=VP(I)                                                       LINES077
      R3(I)=R2(I)                                                       LINES078
      R2(I)=R1(I)                                                       LINES079
   91 R1(I)=RA(I)                                                       LINES080
      GO TO 73                                                          LINES081
   90 IF(J-200)67,60,60                                                 LINES082
   67 A1=A2                                                             LINES083
      IF(B(J)-B(2))49,49,60                                             LINES084
   49 ILP=2                                                             LINES085
      A2=A3                                                             LINES086
      A3=A3*.2*(8.+X)/(.8+X)                                            LINES087
      AM=(2.-R3(2)*VN(1))*VN(1)*CRE                                     LINES088
      IF(ABSF(A3)-AM)84,84,72                                           LINES089
   72 A3=SNA*AM                                                         LINES090
   84 IF(SNA*R3(1)+.5)85,85,73                                          LINES091
   85 AM=-.5*SNA*VN(1)/R3(1)                                            LINES092
      IF(ABSF(A3)-AM)73,73,86                                           LINES093
   86 A3=SNA*AM                                                         LINES094
   73 ARC(J+1)=A3                                                       LINES095
      AAB=ABSF(A3)                                                      LINES096
      GO TO 66                                                          LINES097
   60 RETURN                                                            LINES098
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

STORAGE NOT USED BY PROGRAM

DEC	OCT	DEC	OCT
650	01212	32561	77461

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
RA	649	01211												

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
A1	646	01206	A2	645	01205	A3	644	01204	AAB	643	01203	AA	642	01202
AD	641	01201	AER	640	01200	AM	639	01177	AC6	638	01176	ARCJ	637	01175
ASUM	636	01174	BB	635	01173	PD	634	01172	BP	633	01171	BR	632	01170
BT	631	01167	CC	630	01166	CD	629	01165	CRE	628	01164	DC	627	01163
DN	626	01162	ILP	625	01161	IS	624	01160	OER	623	01157	PRE1	622	01156
PRE2	621	01155	PRE3	620	01154	ORT	619	01153	RBAR	618	01152	RT	617	01151
SIT	616	01150	SNA	615	01147	SSG	614	01146	X	613	01145			

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
1)	604	01134	2)	572	01074	3)	576	01100	6)	594	01122	9)	600	01130
C)G2	610	01142	C)G3	611	01143	C)G4	612	01144	E)1	155	00233	E)A	277	00425
E)E	292	00444	E)K	444	00674	E)G	493	00755	E)P	498	00762			

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
EXP(3	0	00000	MAGNET	2	00002	SIN	1	00001	SQRT	3	00003			

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

EXP(3 MAGNET SIN SQRT

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
74	6	00234	75	7	00240	66	17	00274	36	24	00327	6	27	00346
8	33	00403	5	34	00414	87	35	00422	76	36	00426	77	37	00430
79	38	00435	78	40	00441	80	41	00445	81	43	00451	83	44	00456
82	46	00462	9	47	00464	10	66	00574	59	68	00614	93	71	00675
89	72	00702	91	83	00750	90	85	00756	67	86	00764	49	88	00772
72	93	01033	84	94	01036	85	95	01043	86	97	01057	73	98	01062
60	101	01070												

```
      SUBROUTINE START (R1,R2,R3,B,ARC,ERR,V)                           START000
      DIMENSION B(200),ARC(200),V(3,3),R1(3),R2(3),R3(3)                START001
      SIT=ABSF(SINF(V(2,2)))                                            START002
      AER=V(1,2)                                                        START003
      SSQ=SIT*SIT                                                       START004
      OER=(6356.912+SSQ*(21.3677+.108*SSQ))/6371.2                      START005
      V(1,2)=AER+OER                                                    START006
   10 IF(V(3,2))11,12,12                                                STARTA06
   11 V(3,2)=V(3,2)+6.283185307                                         STARTB06
      GO TO 10                                                          START006
   12 CALL MAGNET(AER,SIT,V(3,2),BR,BT,BP,B(2),V(2,2))                  START007
      R2(1)=BR/B(2)                                                     START008
      DN=B(2)*V(1,2)                                                    START009
      R2(2)=BT/DN                                                       START010
      R2(3)=BP/(DN*SIT)                                                 START011
      IS=0                                                              START012
    1  DO 2 I=1,3                                                       START013
    2 V(I,1)=V(I,2)-ARC(2)*R2(I)                                        START014
      SIT=ABSF(SINF(V(2,1)))                                            START015
    3  SSQ=SIT*SIT                                                      START016
      OER=(6356.912+SSQ*(21.3677+.108*SSQ))/6371.2                      START017
      AER=V(1,1)-OER                                                    START018
      CALL MAGNET(AER,SIT,V(3,1),BR,BT,BP,B(1),V(2,1))                  START019
      IF(B(1)-B(2))4,5,5                                                START020
    4  ARC(2)=-ARC(2)                                                   START021
      GO TO 1                                                           START022
    5 R1(1)=BR/B(1)                                                     START023
      ARC(3)=ARC(2)                                                     START024
      DN=B(1)*V(1,1)                                                    START025
      R1(2)=BT/DN                                                       START026
      R1(3)=BP/(DN*SIT)                                                 START027
      DO 6 I=1,3                                                        START028
    6 V(I,1)=V(I,2)-ARC(2)*(R1(I)+R2(I))/2.                             START029
      SIT=ABSF(SINF(V(2,1)))                                            START030
      IS=IS+1                                                           START031
      GO TO (3,7),IS                                                    START032
    7  DO 8 I=1,3                                                       START033
    8 V(I,3)=V(I,2)+ARC(3)*((1.5)*R2(I)-.5*R1(I))                       START034
      RETURN                                                            START035
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

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                                        STORAGE NOT USED BY PROGRAM

        DEC   OCT                   DEC   OCT
        293 C0445                 32561 77461

           STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

        DEC   OCT                 DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT
 AER    292 C0444          BP     291 C0443         BR     290 00442         BT    289 C0441        DN     288 CC440
 IS     287 C0437          UER    286 C0436         SIT    285 00435         SSQ   284 C0434

                        LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

        DEC   OCT                 DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT
   1)   280 C0430          2)     257 C0401         3)     259 00403         6)    267 C0413        9)     273 C0421
 C)G2   283 C0433          E)8    193 C0301

                                 LOCATIONS OF NAMES IN TRANSFER VECTOR

        DEC   OCT                 DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT
MAGNET    1 CC001          SIN      0 0CC00

                             ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

MAGNET      SIN

           EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

  EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC
   10     9 00164           11    10 00167           12    12 00173            1    19 C0227            2    20 00231
    3    22 C0245            4    28 C0302            5    30 00305            6    36 00330            7    40 C0355
    8    41 00357
```

```
      SUBROUTINE MAGNET (R,S,PHI,PR,BTHET,BPHI,BB,THET)                      MAGNT000
      DIMENSION DP(49),P(49),G(49),H(49),CONST(49),ACR(7),SP(7),CP(7)        MAGNT001
      IF(KIP)151,150,150                                                     MAGNT002
  150 KIP=-1                                                                 MAGNT003
      DO 152 N=1,49                                                          MAGNT004
      G(N)=0.0                                                               MAGNT005
  152 H(N)=0.0                                                               MAGNT006
C     JENSEN AND CAIN COEFFICIENTS FOR 1960 (JUNE 1962)                      MAGNT007
C     G(I) = G(N,M) AND H(I) = H(N,M) WHERE I = N+7*(M-1)                    MAGNT008
      G( 2)= 3.04112050E-01                                                  MAGNT009
      G( 9)= 2.14736858E-02                                                  MAGNT010
      G( 3)= 2.40353671E-02                                                  MAGNT011
      G(10)=-5.12533379E-02                                                  MAGNT012
      G(17)=-1.33811969E-02                                                  MAGNT013
      G( 4)=-3.15178651E-02                                                  MAGNT014
      G(11)= 6.21300906E-02                                                  MAGNT015
      G(18)=-2.48981333E-02                                                  MAGNT016
      G(25)=-6.49565905E-03                                                  MAGNT017
      G( 5)=-4.17943639E-02                                                  MAGNT018
      G(12)=-4.52983660E-02                                                  MAGNT019
      G(19)=-2.17947447E-02                                                  MAGNT020
      G(26)= 7.00825405E-03                                                  MAGNT021
      G(33)=-2.04395562E-03                                                  MAGNT022
      G( 6)= 1.62556271E-02                                                  MAGNT023
      G(13)=-3.44067606E-02                                                  MAGNT024
      G(20)=-1.94470026E-02                                                  MAGNT025
      G(27)=-6.08211374E-04                                                  MAGNT026
      G(34)= 2.77533549E-03                                                  MAGNT027
      G(41)= 6.96802467E-04                                                  MAGNT028
      G( 7)=-1.95231736E-02                                                  MAGNT029
      G(14)=-4.85326147E-03                                                  MAGNT030
      G(21)= 3.21172428E-03                                                  MAGNT031
      G(28)= 2.14128828E-02                                                  MAGNT032
      G(35)= 1.05051275E-03                                                  MAGNT033
      G(42)= 2.26829448E-04                                                  MAGNT034
      G(49)= 1.11471358E-03                                                  MAGNT035
      H( 9)=-5.79890501E-02                                                  MAGNT036
      H(10)= 3.31240714E-02                                                  MAGNT037
      H(17)=-1.57893822E-03                                                  MAGNT038
      H(11)= 1.48696943E-02                                                  MAGNT039
      H(18)=-4.07490158E-03                                                  MAGNT040
      H(25)= 2.10318235E-04                                                  MAGNT041
      H(12)=-1.18245456E-02                                                  MAGNT042
      H(19)= 1.00057732E-02                                                  MAGNT043
      H(26)= 4.30380863E-04                                                  MAGNT044
      H(33)= 1.38503490E-03                                                  MAGNT045
      H(13)=-7.95897466E-04                                                  MAGNT046
      H(20)=-2.00044021E-03                                                  MAGNT047
      H(27)= 4.59718859E-03                                                  MAGNT048
      H(34)= 2.42063078E-03                                                  MAGNT049
      H(41)=-1.21806522E-03                                                  MAGNT050
      H(14)=-5.75830293E-03                                                  MAGNT051
      H(21)=-8.73461401E-03                                                  MAGNT052
      H(28)=-3.40604073E-03                                                  MAGNT053
      H(35)=-1.18162456E-04                                                  MAGNT054
```

```
      H(42)=-1.11623013E-03                                             MAGNT055
      H(49)=-3.24831891E-04                                             MAGNT056
      P(1)=1.0                                                          MAGNT057
      DP(1)=0.0                                                         MAGNT058
      SP(1)=0.0                                                         MAGNT059
      CP(1)=1.0                                                         MAGNT060
      CONST(9)=0.0                                                      MAGNT061
      CONST(16)=0.0                                                     MAGNT062
      DO 80 N=3,7                                                       MAGNT063
      FN=N                                                              MAGNT064
      DO 80 M=1,N                                                       MAGNT065
      FM=M                                                              MAGNT066
      I=N+7*(M-1)                                                       MAGNT067
   80 CONST(I)=((FN-2.0)**2-(FM-1.0)**2)/((FN+FN-3.0)*(FN+FN-5.0))     MAGNT068
  151 C=SQRTF(ABSF(1.0-S*S))                                            MAGNT069
      IF(THET-1.570796327) 154,154,156                                  MAGNT070
  156 C=-C                                                              MAGNT071
  154 AR=1./(1.+R)                                                      MAGNT072
  155 SP(2)=SINF(PHI)                                                   MAGNT073
      CP(2)=COSF(PHI)                                                   MAGNT074
      AOR(1)=AR*AR                                                      MAGNT075
      AOR(2)=AR*AOR(1)                                                  MAGNT076
      DO 90 M=3,7                                                       MAGNT077
      N=M-1                                                             MAGNT078
      SP(M)=SP(2)*CP(N)+CP(2)*SP(N)                                     MAGNT079
      CP(M)=CP(2)*CP(N)-SP(2)*SP(N)                                     MAGNT080
   90 AOR(M)=AR*AOR(N)                                                  MAGNT081
      BR=0.0                                                            MAGNT082
      BTHET=0.0                                                         MAGNT083
      BPHI=0.0                                                          MAGNT084
      DO 32 N=2,7                                                       MAGNT085
      FN=N                                                              MAGNT086
      SUMR=0.0                                                          MAGNT087
      SUMT=0.0                                                          MAGNT088
      SUMP=0.0                                                          MAGNT089
      DO 33 M=1,N                                                       MAGNT090
      IF(N-M)87,88,87                                                   MAGNT091
   88 I=8*N-7                                                           MAGNT092
      L=I-8                                                             MAGNT093
      P(I)=S*P(L)                                                       MAGNT094
      DP(I)=S*DP(L)+C*P(L)                                              MAGNT095
      GO TO 89                                                          MAGNT096
   87 I=N+7*(M-1)                                                       MAGNT097
      J=I-1                                                             MAGNT098
      K=I-2                                                             MAGNT099
      P(I)=C*P(J)-CONST(I)*P(K)                                         MAGNT100
      DP(I)=C*DP(J)-S*P(J)-CONST(I)*DP(K)                               MAGNT101
   89 FM=M-1                                                            MAGNT102
      TS=G(I)*CP(M)+H(I)*SP(M)                                          MAGNT103
      SUMR=SUMR+P(I)*TS                                                 MAGNT104
      SUMT=SUMT+DP(I)*TS                                                MAGNT105
   33 SUMP=SUMP+FM*P(I)*(-G(I)*SP(M)+H(I)*CP(M))                        MAGNT106
      BR=BR+AOR(N)*FN*SUMR                                              MAGNT107
      BTHET=BTHET-AOR(N)*SUMT                                           MAGNT108
   32 BPHI=BPHI-AOR(N)*SUMP                                             MAGNT109
      BPHI=BPHI/S                                                       MAGNT110
```

```
      BB=SQRTF(BR**2+BTHET**2+BPHI**2)                                  MAGNT111
      RETURN                                                            MAGNT112
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

STORAGE NOT USED BY PROGRAM

	DEC	OCT		DEC	OCT
	830	01476		32561	77461

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
AOR	584	01110	CONST	633	01171	CP	570	01072	DP	829	01475	G	731	01333
H	682	01252	P	780	01414	SP	577	01101						

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
AR	563	01063	C	562	01062	FM	561	01061	FN	560	01060	I	559	01057
J	558	01056	KIP	557	01055	K	556	01054	L	555	01053	M	554	01052
N	553	01051	SUMP	552	01050	SUMR	551	01047	SUMT	550	01046	TS	549	01045

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
1)	537	01031	2)	472	00730	3)	477	00735	6)	531	01023	C)G0	542	01036
C)G2	543	01037	C)G3	544	01040	C)G4	545	01041	C)G5	546	01042	C)G6	547	01043
C)201	548	01044	D)20D	307	00463	D)404	173	00255	C)408	230	00346			

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
COS	2	00002	SIN	1	00001	SQRT	0	00000						

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

COS SIN SQRT

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
150	5	00064	152	8	00071	80	68	00307	151	69	00347	156	71	00365
154	72	00367	155	73	00375	90	81	00443	88	92	00512	87	97	00541
89	102	00607	33	106	00635	32	109	00672						

```
      SUBROUTINE INTEG (ARC,BEG,BEND,B,JEP,ECC,FI)                       INTEG001
      DIMENSION ARC(200),BEG(200),BEND(200),B(200),ECC(200)              INTEG002
    4 KK=JEP                                                             INTEG003
    6 IF(KK-4)14,11,20                                                   INTEG004
   11 KK=KK-1                                                            INTEG005
   14 A=B(KK-1)/B(2)                                                     INTEG006
      X2=B(KK)/B(2)                                                      INTEG007
      X3=B(KK+1)/B(2)                                                    INTEG008
      ASUM=ARC(KK)+ARC(KK+1)                                             INTEG009
      DN=ARC(KK)*ARC(KK+1)*ASUM                                          INTEG010
      BB=(-A*ARC(KK+1)*(ARC(KK)+ASUM)+X2*ASUM**2-X3*ARC(KK)**2)/DN       INTEG011
      C=(A*ARC(KK+1)-X2*ASUM+X3*ARC(KK))/DN                              INTEG012
      FI=1.570796326*(1.-A+BB*BB/(4.*C))/SQRTF(ABSF(C))                  INTEG013
      RETURN                                                             INTEG014
   20 T=SQRTF(1.-BEND(2)/B(2))                                           INTEG015
      FI=(2.*T-LOGF((1.+T)/(1.-T)))/ECC(2)                               INTEG016
      IF(B(2)-BEND(KK))21,21,25                                          INTEG017
   25 KK=KK+1                                                            INTEG018
   21 T=SQRTF(ABSF(1.0-BEG(KK)/B(2)))                                    INTEG019
      FI=FI-(2.*T-LOGF((1.+T)/(1.-T)))/ECC(KK)                           INTEG020
      KK=KK-1                                                            INTEG021
   22 DO 5 I=3,KK                                                        INTEG022
      ARG1=1.-BEND(I)/B(2)                                               INTEG023
      IF(ARG1)26,26,27                                                   INTEG024
   26 TE=1.E-5                                                           INTEG025
      GO TO 28                                                           INTEG026
   27 TE=SQRTF(ARG1)                                                     INTEG027
   28 ARG1=1.-BEG(I)/B(2)                                                INTEG028
      IF(ARG1)29,29,31                                                   INTEG029
   31 TB=SQRTF(ARG1)                                                     INTEG030
      GO TO 32                                                           INTEG031
   29 TB=1.E-5                                                           INTEG032
   32 IF(ABSF(ECC(I))-2.E-5) 23,23,24                                    INTEG033
   23 FI=FI+((TE+TB)*(ARC(I)+ARC(I+1)))/4.                               INTEG034
      GO TO 5                                                            INTEG035
   24 FI=FI+(2.*(TE-TB)-LOGF((1.+TE)*(1.-TB)/((1.-TE)*(1.+TB))))/ECC(I) INTEG036
    5 CONTINUE                                                           INTEG037
   30 RETURN                                                             INTEG038
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                                   STORAGE NOT USED BY PROGRAM

        DEC   OCT                 DEC   OCT
        371 00563               32561 77461

          STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

        DEC   OCT                 DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
   ARG1 370 00562            A    369 00561       ASUM    368 00560       BB    367 00557        C    366 00556
     DN 365 00555           KK    364 00554         TB    363 00553       TC    362 00552        T    361 00551
     X2 360 00550           X3    359 00547

                        LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

        DEC   OCT                 DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
     1) 350 00536           2)    329 00511         3)    333 00515       6)    339 00523       9)    345 00531
   C)GO 358 00546          E)2     92 00134        E)5    202 00312

                                LOCATIONS OF NAMES IN TRANSFER VECTOR

        DEC   OCT                 DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
    LOG   1 00001         SQRT      0 00000

                            ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

  LOG         SQRT

           EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

   EFN   IFN   LOC          EFN   IFN   LOC         EFN   IFN   LOC         EFN   IFN   LOC         EFN   IFN   LOC
     4     4 00117            6     5 00122          11     6 00127          14     7 00135          20    17 00246
    25    20 00305           21    21 00313          22    24 00355          26    27 00371          27    29 00374
    28    30 00401           31    32 00413          29    34 00421          32    35 00423          23    36 00430
    24    38 00445            5    39 00503          30    40 00505
```

```
      SUBROUTINE CARMEL (B,XI,VL)                                       CARMLC00
C     COMPUTE L                                                         CARMLC01
      XX=LOG F(((XI**3)*B)/0.311653)                                    CARMLC02
      IF(XX+22.)1,1,8                                                   CARMLC03
    8 IF(XX+3.)2,2,9                                                    CARMLC04
    9 IF(XX-3.)3,3,10                                                   CARMLC05
   10 IF(XX-12.)4,4,11                                                  CARMLC06
   11 IF(XX-23.)5,5,6                                                   CARMLC07
    1 GG=.333338*XX+.30062102                                           CARMLC08
      GO TO 7                                                           CARMLC09
    2 GG=((((((((-8.1537735E-14*XX+8.3232531E-13)*XX+1.0066362E-9)*XX+  CARML010
     18.1046663E-8)*XX+3.2916354E-6)*XX+8.2711096E-5)*XX+1.3714667E-3)* CARML011
     2XX+.01501724 5)*XX+.43432642)*XX+.62337691                        CARML012
      GO TO 7                                                           CARML013
    3 GG=((((((((2.6047023E-10*XX+2.3028767E-9)*XX-2.1997983E-8)*XX-    CARML014
     15.3977642E-7)*XX-3.3408822E-6)*XX+3.8379917E-5)*XX+1.1784234E-3)* CARML015
     2XX+1.4492441E-2)*XX+.43352788)*XX+.6228644                        CARML016
      GO TO 7                                                           CARML017
    4 GG=((((((((6.3271665E-10*XX-3.9583066E-8)*XX+9.9766148E-07)*XX-   CARML018
     11.2531932E-5)*XX+7.9451313E-5)*XX-3.2077032E-4)*XX+2.1680398E-3)* CARML019
     2XX+1.2817956E-2)*XX+.43510529)*XX+.6222355                        CARML020
      GO TO 7                                                           CARML021
    5 GG=(((((2.8217095E-8*XX-3.8049276E-6)*XX+2.1702246E-4)*XX-6.7310339CARML022
     1E-3)*XX+.12038224)*XX-.18461796)*XX+2.0007187                     CARML023
      GO TO 7                                                           CARML024
    6 GG=XX-3.0460681                                                   CARML025
    7 VL=(((1.0+EXP F(GG))*0.311653)/B)**(1./3.)                        CARML026
C     END COMPUTE L                                                     CARML027
      RETURN                                                            CARML028
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                                   STORAGE NOT USED BY PROGRAM

     DEC   OCT              DEC   OCT
     250 00372            32561 77461

    STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

     DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
 GG  249 00371         XX   248 00370

                    LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

     DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
 1)  244 00364         2)   191 00277         3)   192 00300         6)   238 00356

                              LOCATIONS OF NAMES IN TRANSFER VECTOR

     DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
 EXP   1 00001      EXP(3     2 00002      LOG      0 00000

                           ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

EXP         EXP(3       LOG

          EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

 EFN   IFN   LOC        EFN   IFN   LOC        EFN   IFN   LOC        EFN   IFN   LOC        EFN   IFN   LOC
   8     5 00045          9     6 00052         10     7 00057         11     8 00064          1     9 00071
   2    11 00076          3    13 00134          4    15 00171          5    17 00226          6    19 00252
   7    20 00255
```

E. Restrictions

ALAT must be remotely close to the correct latitude corresponding to the initial B in order to save machine time and to insure the accuracy of the answers. ALAT must always be positive and greater than the geomagnetic equator at geocentric longitude of 180°. This means that ALAT must be greater than 4°.

F. Input

Cards containing the initial values of B, L and λ are all the data necessary for the execution of this program. This data is entered on logical tape number two. Each card represents a single case.

1. Card Description

Columns	Mode	Quantity	Units	Description
1-12	F	BO	gauss	initial magnetic induction
13-24	F	ELO	earth radii	initial magnetic field line
25-32	F	ALAT	degrees	initial latitude

2. Sample

GENERAL PURPOSE DATA SHEET

Problem INPUT B-L SEARCH (INITIAL B, L, λ)

Sponsor TAPE 2 | Date SAMPLE | Page of

.11	1.75	26.
.2	1.188	10.
.17	1.25	10.
.159	1.4	15.

GSFC FORM 541-1 (July - 60)

G. Output

Output from this program appears on logical tapes 3 and 5. Both tapes contain the same information with the exception that tape 3 also contains the intermediate results of the search routine. Tape 5 is the output to be used in the longitudinal averaging processor. This tape is punched onto cards which can be combined with similar output from other runs. All this data can then be used as input to the longitudinal averaging processor, but it is important that a blank card follow the last of the data cards. This arrangement is discussed in the next section.

1. Tape 3 Sample

```
B0= 0.11000        L0= 1.75000        INITIAL LAT=26.00000
      INTERMEDIATE RESULTS--NORTHERN HEMISPHERE
        LONG          LAT          ALT          B          L
    180.00000     26.00000   3533.22839     0.10159     1.75000
    180.00000     28.00000   3257.93344     0.11298     1.75000
    180.00000     27.47628   3330.02185     0.10985     1.74955
B= 0.10985        L= 1.74955
                              FINAL RESULTS
     -180.00        27.48       3330.02     0.10985     1.74955
     -180.00        27.48       3330.02     0.10985     1.74955
     -170.00        25.79       3309.07     0.10987     1.75027
     -160.00        23.86       3298.23     0.10987     1.75043
     -150.00        21.82       3293.89     0.10987     1.75049
     -140.00        19.74       3290.96     0.10986     1.74966
     -130.00        17.71       3287.41     0.10986     1.74966
     -120.00        15.73       3279.11     0.10986     1.74966
     -110.00        13.83       3263.27     0.10987     1.75054
     -100.00        11.97       3234.47     0.10987     1.75049
      -90.00        10.27       3190.87     0.10987     1.75052
      -80.00         8.93       3132.92     0.10986     1.75014
      -70.00         8.27       3067.73     0.10986     1.74978
      -60.00         8.66       3009.01     0.10985     1.74947
      -50.00        10.36       2972.82     0.10985     1.74926
      -40.00        13.12       2964.85     0.10985     1.74926
      -30.00        16.35       2979.89     0.10985     1.74933
      -20.00        19.48       3011.16     0.10985     1.74939
      -10.00        22.19       3052.95     0.10985     1.74927
       -0.          24.34       3101.34     0.10985     1.74913
       10.00        25.90       3153.89     0.10985     1.74914
       20.00        26.92       3210.03     0.10985     1.74922
       30.00        27.49       3269.30     0.10985     1.74940
       40.00        27.80       3331.19     0.10986     1.74874
       50.00        28.10       3397.64     0.10987     1.74857
       60.00        28.53       3466.52     0.10985     1.74941
       70.00        29.03       3528.77     0.10985     1.74939
       80.00        29.55       3579.90     0.10985     1.74936
       90.00        29.99       3614.76     0.10985     1.74941
      100.00        30.27       3629.99     0.10985     1.74857
      110.00        30.48       3626.67     0.10985     1.74880
      120.00        30.63       3605.07     0.10986     1.74932
      130.00        30.67       3566.43     0.10987     1.74938
      140.00        30.64       3517.70     0.10987     1.74968
      150.00        30.42       3464.00     0.10988     1.75053
      160.00        29.83       3410.37     0.10986     1.74985
      170.00        28.87       3364.67     0.10986     1.75002
```

2. Tape 5

INTERMEDIATE RESULTS--SOUTHERN HEMISPHERE

LONG	LAT	ALT	B	L
180.00000	-15.00000	3695.08514	0.10030	1.74998
180.00000	-17.00000	3433.09256	0.11171	1.74995
180.00000	-16.70013	3472.37378	0.10990	1.74989

B= 0.10990 L= 1.74989

FINAL RESULTS

-180.00	-16.70	3472.37	0.10990	1.74989
-180.00	-16.70	3472.37	0.10990	1.74989
-170.00	-18.67	3441.67	0.10990	1.75006
-160.00	-20.70	3407.85	0.10990	1.75001
-150.00	-22.78	3370.58	0.10990	1.75002
-140.00	-24.86	3327.75	0.10990	1.75005
-130.00	-26.87	3277.04	0.10988	1.74890
-120.00	-28.92	3219.97	0.10987	1.74896
-110.00	-30.96	3153.88	0.10987	1.74892
-100.00	-32.95	3077.77	0.10987	1.74908
-90.00	-34.76	2990.94	0.10987	1.74901
-80.00	-36.23	2895.15	0.10988	1.74917
-70.00	-37.17	2794.22	0.10989	1.74943
-60.00	-37.39	2694.25	0.10990	1.74975
-50.00	-36.73	2603.75	0.10991	1.75009
-40.00	-35.09	2533.92	0.10991	1.75021
-30.00	-32.47	2497.69	0.10991	1.75013
-20.00	-29.06	2503.03	0.10987	1.74902
-10.00	-25.47	2545.84	0.10990	1.74915
-0.	-22.21	2615.13	0.10990	1.74996
10.00	-19.60	2695.72	0.10990	1.75003
20.00	-17.80	2780.87	0.10990	1.75013
30.00	-16.70	2870.66	0.10990	1.75012
40.00	-15.98	2969.88	0.10990	1.75012
50.00	-15.29	3079.53	0.11000	1.74901
60.00	-14.53	3205.88	0.10990	1.75006
70.00	-13.64	3328.53	0.10990	1.75010
80.00	-12.77	3437.57	0.10990	1.75010
90.00	-12.08	3524.42	0.10990	1.75011
100.00	-11.65	3585.00	0.10990	1.75007
110.00	-11.42	3618.98	0.10990	1.74908
120.00	-11.44	3631.77	0.10990	1.74995
130.00	-11.60	3624.71	0.10991	1.75053
140.00	-11.89	3601.71	0.10990	1.74967
150.00	-12.51	3570.65	0.10989	1.74957
160.00	-13.51	3536.55	0.10989	1.74939
170.00	-14.92	3503.21	0.10988	1.74915

a. Card Description

Columns	Mode	Quantity	Units	Description
1-12	F	PRLNG	degrees	geocentric longitude
13-24	F	PHI	degrees	geocentric latitude
25-36	F	ALT	km.	altitude
37-48	F	B	gauss	magnetic induction
49-60	F	EL	earth radii	magnetic field line

b. Sample

GENERAL PURPOSE DATA SHEET

Problem: OUTPUT – B-L SEARCH (B-L CONTOURS)

Sponsor: TAPE 5 | Date: SAMPLE | Page ___ of ___

-180.00	25.63	3580.68	0.09974	1.74968
-170.00	23.94	3558.77	0.09975	1.75047
-160.00	22.01	3546.12	0.09976	1.75060
-150.00	19.99	3539.24	0.09976	1.75062
-140.00	17.91	3533.42	0.09974	1.74979
-130.00	15.93	3527.48	0.09976	1.75057
-120.00	13.95	3515.46	0.09976	1.75058
-110.00	12.02	3494.90	0.09976	1.75056
-100.00	10.16	3462.34	0.09976	1.75047
-90.00	8.47	3415.35	0.09975	1.75031
-80.00	7.12	3354.42	0.09974	1.74971
-70.00	6.46	3287.59	0.09974	1.74983
-60.00	6.81	3226.16	0.09976	1.74898
-50.00	8.45	3190.38	0.09974	1.74949
-40.00	11.14	3182.49	0.09974	1.74945
-30.00	14.35	3199.33	0.09974	1.74949
-20.00	17.50	3232.51	0.09974	1.74945
-10.00	20.24	3276.20	0.09974	1.74937
-0.00	22.42	3326.28	0.09973	1.74929
10.00	24.01	3380.07	0.09974	1.74941
20.00	25.05	3437.11	0.09974	1.74942
30.00	25.67	3497.81	0.09974	1.74947
40.00	26.05	3562.57	0.09974	1.74932
50.00	26.39	3631.12	0.09974	1.74957

GSFC FORM 541-1 (July - 60)

H. Running Time

This program takes about ten minutes for each 100 kilometers in altitude. The initial minimum altitude is required in order to estimate the number of kilometers for a particular run. Use Figure 2 and the initial values of B, L and λ to arrive at an estimate of the initial altitude h. Subtracting 800 kilometers from this value will give the approximate initial minimum altitude of the first ring. This is the altitude used in figuring the running time.

III. LONGITUDINAL AVERAGING PROCESSOR

A. Introduction

Input to this program are the five diurnal average number density tables (Tables 1-5) and the B-L contour rings output from the B-L search routine. The tables are interpolated (extrapolated) in order to obtain a density value for every ten degrees of longitude in the B-L contours. The densities are then added together for each of the five flux models, and the resulting sum is divided by 36 to arrive at the longitudinally averaged number density. This is done for the northern and southern hemispheres separately and then these values are added together and divided by two in order to obtain one number density for each B and L and each of the five flux models. These final values are used as input to the lambda punch program.

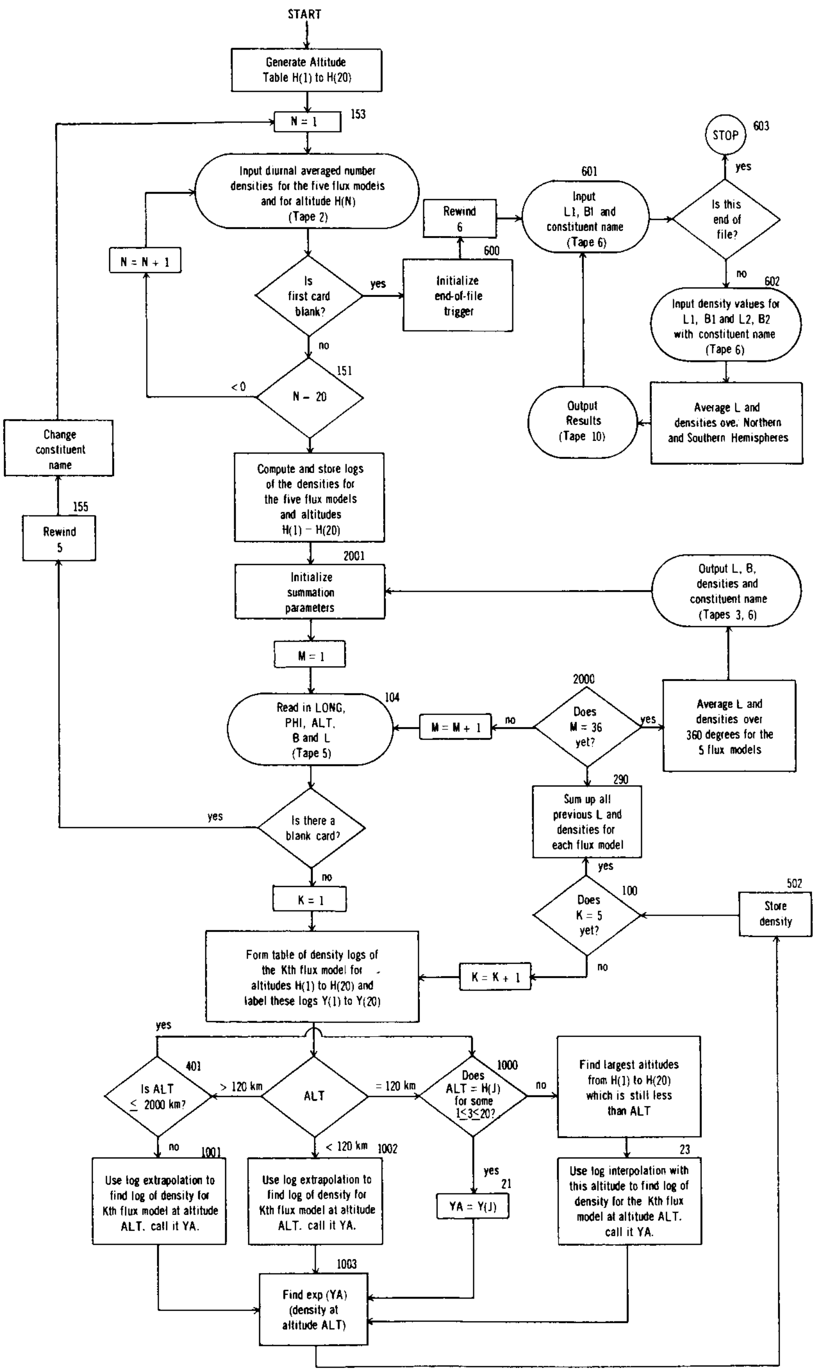
B. Mnemonics

Quantity	Description	Units
H(J)	J^{th} altitude from the diurnal averaged atmosphere tables, Tables 1-5	km.
S1(J), . . ., S5(J)	diurnal averaged atmosphere densities for the J^{th} altitude and fluxes of 250, 200, 150, 100 and 70×10^{-22} watts/m^2/cycle/sec from Tables 1-5	atoms/cm^3
A1,. . ., A5	temporary storage of S1(J), . . ., S5(J)	"
SS1(J), . . ., SS5(J)	natural logarithms of S1(J), . . ., S5(J)	- -
AVHA	sum of EL	earth radii
AVBN1, . . ., AVBN5	density summation for the five flux models	atoms/cm^3
LONG	geocentric longitude	degrees
PHI	geocentric latitude	degrees

Quantity	Description	Units
ALT	altitude	km.
B	magnetic induction	gauss
EL	magnetic field line	earth radii
Y(I)	temporary storage of SSK(J) at altitude I = J depending on whether K = 1, 2, 3, 4 or 5	- -
HA	temporary storage of altitude	km.
YA	natural logarithm of density at altitude ALT	- -
BARN	density at altitude ALT	atoms/cm^3
BARNAV(K)	temporary storage of BARN for flux model K	"
JUNK	temporary storage of K	- -
AVERH1	average longitudinal value of EL for only one hemisphere	earth radii
AVERN1,...,AVERN5	averaged densities for the five flux models and one hemisphere	atoms/cm^3
FINI	end of file trigger for tape 6	- -
EL1	EL for northern hemisphere	earth radii
EL2	EL for southern hemisphere	"
B1	B for northern hemisphere	gauss
B2	B for southern hemisphere	"

Quantity	Description	Units
EN1, . . ., EN5	the first time this designation appears it represents the northern hemisphere densities for the five flux models. The second time it appears it represents the densities for the north and south averaged together.	atoms/cm^3
EN12, . . ., EN52	averaged southern hemisphere densities for the five flux models	"
ITT	counter to keep track of which hemisphere is being considered	- -
ITTI	counter to keep track of which atmospheric constituent is being considered	- -
XLA(ITTI)	first six letters of the constituent name designated by ITTI	- -
XLB(ITTI)	last two letters of the constituent name designated by ITTI	- -
TSA	first six letters of constituent name	- -
TSB	last two letters of constituent name	- -

C. Flow Chart


START
Generate Altitude Table H(1) to H(20)
N = 1
153
Input diurnal averaged number densities for the five flux models and for altitude H(N) (Tape 2)
N = N + 1
Is first card blank?
yes
no
Initialize end-of-file trigger
600
Rewind 6
601
Input L1, B1 and constituent name (Tape 6)
Is this end of file?
yes
STOP
603
no
602
Input density values for L1, B1 and L2, B2 with constituent name (Tape 6)
Average L and densities over Northern and Southern Hemispheres
Output Results (Tape 10)
151
<0
N − 20
Change constituent name
155
Rewind 5
Compute and store logs of the densities for the five flux models and altitudes H(1) − H(20)
2001
Initialize summation parameters
Output L, B, densities and constituent name (Tapes 3, 6)
M = 1
104
Read in LONG, PHI, ALT, B and L (Tape 5)
M = M + 1
2000
Does M = 36 yet?
Average L and densities over 360 degrees for the 5 flux models
290
Sum up all previous L and densities for each flux model
Is there a blank card?
K = 1
100
Does K = 5 yet?
502
Store density
Form table of density logs of the Kth flux model for altitudes H(1) to H(20) and label these logs Y(1) to Y(20)
K = K + 1
401
Is ALT ≤ 2000 km?
> 120 km
ALT
= 120 km
1000
Does ALT = H(J) for some 1≤J≤20?
Find largest altitudes from H(1) to H(20) which is still less than ALT
< 120 km
1001
1002
21
23
Use log extrapolation to find log of density for Kth flux model at altitude ALT. call it YA.
Use log extrapolation to find log of density for Kth flux model at altitude ALT. call it YA.
YA = Y(J)
Use log interpolation with this altitude to find log of density for the Kth flux model at altitude ALT. call it YA.
1003
Find exp (YA) (density at altitude ALT)

D. Fortran Listing

```
C     LONGITUDINAL AVERAGING PROCESSOR
      DIMENSION S1(20),S2(20),S3(20),S4(20),S5(20),H(20),SS1(20),SS2(20)
     1,SS3(20),SS4(20),SS5(20),Y(20),BARNAV(5),XLA(5),XLB(5)
    1 FORMAT(8X,35HAVERAGE NUMBER DENSITIES FOR DIFF S / 11X,
     119HSOUTHERN HEMISPHERE)
    2 FORMAT(8X,12HAVERAGE    L=1F6.3,3X,2HB=1F6.5)
    3 FORMAT(8X,35HAVERAGE NUMBER DENSITIES FOR DIFF S / 11X,
     119HNORTHERN HEMISPHERE)
    4 FORMAT(5E12.4,12X,A6,A2)
    5 FORMAT(1H1,8X,25HATMOSPHERIC CONSTITUENT--,A6,A2////)
    6 FORMAT(1H0)
    7 FORMAT(2F8.5,56X,A6,A2)
    8 FORMAT(5E12.4)
  103 FORMAT(3F12.2,2F12.5)
  152 FORMAT(5E12.6)
      XLA(1)=6HHELIUM
      XLA(2)=6HOXYGEN
      XLA(3)=6H    O 2
      XLA(4)=6HNITROG
      XLA(5)=6HHYDROG
      XLB(1)=2H
      XLB(2)=2H
      XLB(3)=2H
      XLB(4)=2HEN
      XLB(5)=2HEN
      ITT=1
      ITTI=1
      WRITE OUTPUT TAPE 3,5,XLA(ITTI),XLB(ITTI)
      H(1)=120.
      H(2)=200.
      DO 150 N=2,19
      H(N+1)=H(N)+100.
  150 CONTINUE
  153 DO 151 N=1,20
      READ INPUT TAPE 2,152,S1(N),S2(N),S3(N),S4(N),S5(N)
      IF(S1(1)) 151,600,151
  151 CONTINUE
      DO 10 I=1,20
      A1=S1(I)
      A2=S2(I)
      A3=S3(I)
      A4=S4(I)
      A5=S5(I)
      SS1(I) = LOGF(A1)
      SS2(I) = LOGF(A2)
      SS3(I) = LOGF(A3)
      SS4(I) = LOGF(A4)
      SS5(I) = LOGF(A5)
   10 CONTINUE
 2001 AVHA=0.
      AVBN1=0.
      AVBN2=0.
      AVBN3=0.
      AVBN4=0.
      AVBN5=0.
```

```
      DO 2000 M=1,36
104   READ INPUT TAPE 5, 103,LONG,PHI,ALT,B,EL
      IF (B) 155,155,505
155   REWIND 5
      ITTI=ITTI+1
      IF (ITTI-5) 157,157,153
 157  WRITE OUTPUT TAPE 3,5,XLA(ITTI),XLB(ITTI)
      GO TO 153
505   DO 100 K=1,5
      GO TO   (200,201,202,203,204),K
 200  DO 300 I=1,20
      Y(I) =SS1(I)
300   CONTINUE
      GO TO 400
 201  DO 301 I=1,20
      Y(I) =SS2(I)
301   CONTINUE
      GO TO 400
 202  DO 302 I=1,20
      Y(I) =SS3(I)
302   CONTINUE
      GO TO 400
 203  DO 303 I=1,20
      Y(I) =SS4(I)
303   CONTINUE
      GO TO 400
 204  DO 304 I=1,20
      Y(I) =SS5(I)
304   CONTINUE
400   HA=ALT
      IF(HA-120.) 1002,1000,401
401   IF(HA-2000.) 1000,1000,1001
1000  DO 20 J=1,20
      IF( H(J)-HA ) 20,21,22
21    YA=Y(J)
      GO TO 30
22    H1=H(J)
      Y1=Y(J)
      H0=H(J-1)
      Y0=Y(J-1)
      GO TO 23
20    CONTINUE
23    YA=Y1-(Y1-Y0)*(H1-HA)/(H1-H0)
30    GO TO 1003
1001  YA=Y(20)+(HA-H(20))*(Y(20)-Y(19))/(H(20)-H(19))
      GO TO 1003
1002  YA=Y(2)-(H(2)-HA)*(Y(2)-Y(1))/(H(2)-H(1))
1003  BARN=EXPF(YA)
502   BARNAV(K)=BARN
      JUNK=K
      IF(JUNK-5) 100,290,100
290   AVHA=EL+AVHA
      AVBN1 = BARNAV(1)+AVBN1
      AVBN2 = BARNAV(2)+AVBN2
      AVBN3 = BARNAV(3)+AVBN3
      AVBN4 = BARNAV(4)+AVBN4
```

```
      AVBN5 = BARNAV(5)+AVBN5
100   CONTINUE
2000  CONTINUE
      AVERH1=AVHA/36.
      AVERN1 = AVBN1/36.
      AVERN2 = AVBN2/36.
      AVERN3 = AVBN3/36.
      AVERN4 = AVBN4/36.
      AVERN5 = AVBN5/36.
      WRITE OUTPUT TAPE 3,2,AVERH1,B
      IF (ITT-1) 36,35,36
35    WRITE OUTPUT TAPE 3,3
      ITT=ITT+1
      GO TO 37
36    WRITE OUTPUT TAPE 3,1
      ITT=1
37    WRITE OUTPUT TAPE 3,8,AVERN1,AVERN2,AVERN3,AVERN4,AVERN5
      WRITE OUTPUT TAPE 6,7,AVERH1,B,XLA(ITTI),XLB(ITTI)
      WRITE OUTPUT TAPE 6,4,AVERN1,AVERN2,AVERN3,AVERN4,AVERN5,XLA(ITTI)
     1,XLB(ITTI)
      WRITE OUTPUT TAPE 3,6
      GO TO 2001
600   FINI=0.
      WRITE OUTPUT TAPE 6,7,FINI,FINI
      REWIND 6
601   READ INPUT TAPE 6,7,EL1,B1,TSA,TSB
      IF(EL1) 602,603,602
602   READ INPUT TAPE 6,4,EN1,EN2,EN3,EN4,EN5,TSA,TSB
      READ INPUT TAPE 6,7,EL2,B2,TSA,TSB
      READ INPUT TAPE 6,4,EN12,EN22,EN32,EN42,EN52,TSA,TSB
      EL=(EL1+EL2)/2.
      B=(B1+B2)/2.
      EN1=(EN1+EN12)/2.
      EN2=(EN2+EN22)/2.
      EN3=(EN3+EN32)/2.
      EN4=(EN4+EN42)/2.
      EN5=(EN5+EN52)/2.
      WRITE OUTPUT TAPE 10,7,EL,B,TSA,TSB
      WRITE OUTPUT TAPE 10,4,EN1,EN2,EN3,EN4,EN5,TSA,TSB
      GO TO 601
603   CALL EXIT
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

STORAGE NOT USED BY PROGRAM

```
 DEC   OCT           DEC   OCT
 1041 02021         32561 77461
```

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

```
        DEC   OCT          DEC   OCT          DEC   OCT          DEC   OCT          DEC   OCT
BARNAV  800 01440     H    940 01654    S1   1040 02020    S2   1020 01774    S3   1000 01750
    S4  980 01724    S5    960 01700   SS1    920 01630   SS2    900 01604   SS3    880 01560
   SS4  860 01534   SS5    840 01510   XLA    795 01433   XLB    790 01426     Y    820 01464
```

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

```
        DEC   OCT          DEC   OCT          DEC   OCT          DEC   OCT          DEC   OCT
    A1  785 01421     A2   784 01420    A3    783 01417    A4    782 01416    A5    781 01415
   ALT  780 01414  AVDN1   779 01413  AVBN2   778 01412  AVBN3   777 01411  AVBN4   776 01410
 AVBN5  775 01407  AVERH1  774 01406  AVERN1  773 01405  AVERN2  772 01404  AVERN3  771 01403
AVERN4  770 01402  AVERN5  769 01401  AVHA    768 01400    B1    767 01377    B2    766 01376
  BARN  765 01375      B   764 01374   EL1    763 01373   EL2    762 01372    EL    761 01371
  EN12  760 01370    EN1   759 01367  EN22    758 01366   EN2    757 01365  EN32    756 01364
   EN3  755 01363   EN42   754 01362   EN4    753 01361  EN52    752 01360   EN5    751 01357
  FIN1  750 01356     H0   749 01355    H1    748 01354    HA    747 01353  ITTI    746 01352
   ITT  745 01351      J   744 01350  JUNK    743 01347     K    742 01346  LONG    741 01345
     M  740 01344      N   739 01343   PHI    738 01342   TSA    737 01341   TSB    736 01340
    Y0  735 01337     Y1   734 01336    YA    733 01335
```

SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

```
       EFN   LOC         EFN   LOC         EFN   LOC         EFN   LOC         EFN   LOC
 8)1     1 01324   8)2     2 01306   8)3     3 01277   8)4     4 01261   8)5     5 01256
 8)6     6 01246   8)7     7 01245   8)8     8 01242   8)37  103 01240   8)40  152 01235
```

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

```
        DEC   OCT          DEC   OCT          DEC   OCT            DEC   OCT          DEC   OCT
    1)  725 01325     2)   627 01165    3)    655 01217    4)   32767 77777    6)    662 01226
    B)  635 01173   C)G1   728 01330  C)G3    729 01331  C)G4     730 01332  C)G5    731 01333
 C)200  732 01334  D)215   265 00411  D)219   293 00445  E)40B    143 00217  D)50B   142 00216
   E)7   85 00125    E)8    88 00130   E)B    141 00215   E)C     178 00262   E)F    205 00315
   E)K  212 00324    E)N   219 00333   E)G    226 00342  E)14     257 00401  E)15    264 00410
 E)112  250 00372
```

LOCATIONS OF NAMES IN TRANSFER VECTOR

```
       DEC   OCT          DEC   OCT          DEC   OCT          DEC   OCT          DEC   OCT
 EXIT    8 00010    EXP     7 00007    LOG     5 00005   (FIL)    2 00002   (FPT)    0 00000
(RTN)    4 00004   (RWT)    6 00006   (STH)    1 00001   (TSH)    3 00003
```

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

```
EXIT      EXP      LOG      (FIL)      (FPT)      (RTN)      (RWT)      (STH)      (TSH)
```

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
150	31	00067	153	32	00071	151	36	00123	10	48	00174	2001	49	00176
104	56	00220	155	59	00245	157	62	00266	505	65	00305	200	67	00316
300	69	00321	201	71	00325	301	73	00330	202	75	00334	302	77	00337
203	79	00343	303	81	00346	204	83	00351	304	85	00354	400	86	00356
401	88	00365	1000	89	00373	21	91	00403	22	93	00412	20	98	00425
23	99	00427	30	100	00446	1001	101	00447	1002	103	00464	1003	104	00501
502	105	00506	290	108	00517	100	114	00541	2000	115	00544	35	125	00606
36	128	00616	37	130	00624	600	138	00706	601	142	00730	602	145	00752
603	163	01151												

E. Restrictions

Input tables must have densities for altitudes starting at 120 kilometers and followed by each 100-kilometer level up to 2000 kilometers. If the tables are changed then the program must be modified. The tables must be input in the following order:

(1) helium,

(2) oxygen,

(3) molecular oxygen,

(4) nitrogen,

(5) hydrogen.

F. Input

Input to this program is handled by two tapes. On tape 2 are entered the diurnal averaged atmosphere tables (Tables 1-5). These tables are punched on cards and placed one behind the other at the end of the Fortran deck. These tables must be input in the following order: helium, oxygen, molecular oxygen, nitrogen and hydrogen. This is necessary in order that the constitutuent names may be correctly punched on the output. It is also important that a blank card follow the last table in order to notify the program when it has reached the end of the file.

On tape 5 are placed the B-L contours which were produced by the B-L search program. As with the tables, the last card must be blank in order to designate an end of file.

1. Tape 2

a. Input Card Description

ATMOSPHERE TABLES

Columns	Mode	Quantity	Units	Description				
1-12	E	S1(N)	atoms/cm^3	density	for flux	model	1,	altitude N
13-24	E	S2(N)	"	"	"		2,	"
25-36	E	S3(N)	"	"	"		3,	"
37-48	E	S4(N)	"	"	"		4,	"
49-60	E	S5(N)	"	"	"		5,	"

b. Sample

GENERAL PURPOSE DATA SHEET

Problem: INPUT – LONGITUDINAL AVERAGING PROCESSOR (DENSITY TABLES)

Sponsor: TAPE 2 | Date: SAMPLE | Page: (TABLES 1-5) of

5.800E+11	5.800E+11	5.800E+11	5.800E+11	5.800E+11
7.393E+69	6.180E+09	4.743E+09	3.136E+09	2.124E+09
7.630E+08	4.639E+08	2.210E+08	6.739E+07	2.113E+07
1.278E+08	5.777E+07	2.151E+07	2.682E+06	4.225E+05
2.562E+07	8.798E+06	1.810E+06	1.407E+05	1.156E+04
5.730E+06	1.521E+06	3.239E+05	8.800E+03	3.844E+02
1.403E+06	2.884E+05	2.763E+04	6.190E+02	1.471E+01
3.664E+05	5.883E+04	3.899E+03	4.802E+01	6.320E-01
1.012E+05	1.276E+04	5.894E+02	4.057E+00	3.006E-02
2.932E+04	2.918E+03	9.470E+01	3.702E-01	1.570E-03
8.862E+03	6.994E+02	1.609E+01	3.627E-02	8.936E-05
2.783E+03	1.752E+02	2.878E+00	3.798E-03	1.016E-05
9.053E+02	4.558E+01	5.404E-01	4.237E-04	3.674E-07
3.041E+02	1.233E+01	1.063E-01	5.017E-05	2.633E-08
1.075E+02	3.456E+00	2.183E-02	6.287E-06	2.023E-09
3.768E+01	1.002E+00	4.677E-03	8.321E-07	1.661E-10
1.380E+01	3.001E-01	1.042E-03	1.160E-07	1.454E-11
5.211E+00	9.268E-02	2.414E-04	1.699E-08	1.353E-12
2.005E+00	2.949E-02	5.746E-05	2.612E-09	1.334E-13
7.927E-01	9.654E-03	1.431E-05	4.619E-10	1.393E-14
7.600E+10	7.600E+10	7.600E+10	7.600E+10	7.600E+10
3.600E+09	3.457E+09	3.209E+09	2.795E+09	2.416E+09
8.870E+08	7.134E+08	5.124E+08	2.809E+08	1.564E+08
3.054E+08	2.054E+08	1.112E+08	4.025E+07	1.471E+07

GSFC FORM 541-1 (July - 60)

2. Tape 5

a. Input Card Description

B-L CONTOURS

Columns	Mode	Quantity	Units	Description
1-12	F	LONG	degrees	geocentric longitude
13-24	F	PHI	degrees	geocentric latitude
25-36	F	ALT	km	altitude
37-48	F	B	gauss	magnetic induction
49-60	F	EL	earth radii	magnetic field line

b. Sample

GENERAL PURPOSE DATA SHEET

Problem: INPUT – LONGITUDINAL AVERAGING PROCESSOR (B-L CONTOURS)

Sponsor: TAPE 5 | Date: SAMPLE | Page ___ of ___

-180.00	25.63	3580.68	0.09974	1.74968
-170.00	23.94	3558.77	0.09975	1.75047
-160.00	22.01	3546.12	0.09976	1.75060
-150.00	19.99	3539.24	0.09976	1.75062
-140.00	17.91	3533.42	0.09974	1.74979
-130.00	15.93	3527.48	0.09976	1.75057
-120.00	13.95	3515.46	0.09976	1.75058
-110.00	12.02	3494.90	0.09976	1.75056
-100.00	10.16	3462.34	0.09976	1.75047
-90.00	8.47	3415.35	0.09975	1.75031
-80.00	7.12	3354.42	0.09974	1.74971
-70.00	6.46	3287.59	0.09974	1.74983
-60.00	6.81	3226.16	0.09976	1.74898
-50.00	8.45	3190.38	0.09974	1.74949
-40.00	11.14	3182.49	0.09974	1.74945
-30.00	14.35	3199.33	0.09974	1.74949
-20.00	17.50	3232.51	0.09974	1.74945
-10.00	20.24	3276.20	0.09974	1.74937
-0.00	22.42	3326.28	0.09973	1.74929
10.00	24.01	3380.07	0.09974	1.74941
20.00	25.05	3437.11	0.09974	1.74942
30.00	25.67	3497.81	0.09974	1.74947
40.00	26.05	3562.57	0.09974	1.74932
50.00	26.39	3631.12	0.09974	1.74957

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G. Output

Output for this program appears on logical tapes 3 and 10. Tape 3 will contain the averaged densities for each of the five flux models at a particular B and L for both northern and southern hemispheres and for each of the five constituents. The constituents (He, O, O_2, N_2, H) follow each other in the same order as they exist in the tables which are input on tape 2. Tape 3 is printed with appropriate headings.

Tape 10 also contains densities for the five flux models at each B and L but here the northern and southern hemispheres are averaged together to give one final value for each B and L. Tape 10 contains no headings but each card is labeled with the appropriate constituent name. This tape is punched in order to be used as input to the lambda punch.

A scratch tape must be set up on logical tape unit 6. Although no data appears on this tape at the completion of the program it is used in intermediate steps to store data.

1. <u>Tape 3 Sample</u>

```
             ATMOSPHERIC CONSTITUENT--HELIUM


         AVERAGE    L= 1.142    B=.23891
         AVERAGE NUMBER DENSITIES FOR DIFF S
            NORTHERN HEMISPHERE
0.8300E 06  0.7508E 06  0.6289E 06  0.4600E 06  0.3382E 06


         AVERAGE    L= 1.142    B=.23890
         AVERAGE NUMBER DENSITIES FOR DIFF S
            SOUTHERN HEMISPHERE
0.1346E 08  0.1210E 08  0.1064E 08  0.9134E 07  0.8207E 07


         AVERAGE    L= 1.142    B=.22741
         AVERAGE NUMBER DENSITIES FOR DIFF S
            NORTHERN HEMISPHERE
0.7137E 06  0.6282E 06  0.5063E 06  0.3493E 06  0.2433E 06


         AVERAGE    L= 1.142    B=.22736
         AVERAGE NUMBER DENSITIES FOR DIFF S
            SOUTHERN HEMISPHERE
0.1428E 07  0.1402E 07  0.1357E 07  0.1293E 07  0.1250E 07


         AVERAGE    L= 1.142    B=.23465
         AVERAGE NUMBER DENSITIES FOR DIFF S
            NORTHERN HEMISPHERE
0.7842E 06  0.7021E 06  0.5795E 06  0.4145E 06  0.2984E 06


         AVERAGE    L= 1.142    B=.23466
         AVERAGE NUMBER DENSITIES FOR DIFF S
            SOUTHERN HEMISPHERE
0.5205E 07  0.4932E 07  0.4608E 07  0.4235E 07  0.3986E 07


         AVERAGE    L= 1.142    B=.21968
         AVERAGE NUMBER DENSITIES FOR DIFF S
            NORTHERN HEMISPHERE
0.6485E 06  0.5615E 06  0.4423E 06  0.2952E 06  0.1996E 06


         AVERAGE    L= 1.142    B=.21968
         AVERAGE NUMBER DENSITIES FOR DIFF S
            SOUTHERN HEMISPHERE
0.8665E 06  0.8125E 06  0.7325E 06  0.6253E 06  0.5477E 06


         AVERAGE    L= 1.170    B=.23992
         AVERAGE NUMBER DENSITIES FOR DIFF S
            NORTHERN HEMISPHERE
0.7300E 06  0.6415E 06  0.5134E 06  0.3472E 06  0.2351E 06


         AVERAGE    L= 1.170    B=.23991
         AVERAGE NUMBER DENSITIES FOR DIFF S
            SOUTHERN HEMISPHERE
0.1571E 08  0.1399E 08  0.1217E 08  0.1032E 08  0.9197E 07
```

AVERAGE L= 1.170 B=.23468
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.6785E 06 0.5881E 06 0.4614E 06 0.3026E 06 0.1990E 06

AVERAGE L= 1.170 B=.23467
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.5025E 07 0.4766E 07 0.4459E 07 0.4106E 07 0.3874E 07

AVERAGE L= 1.170 B=.22957
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.6319E 06 0.5403E 06 0.4158E 06 0.2647E 06 0.1693E 06

AVERAGE L= 1.170 B=.22956
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.1975E 07 0.1940E 07 0.1885E 07 0.1810E 07 0.1758E 07

AVERAGE L= 1.170 B=.21976
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.5513E 06 0.4595E 06 0.3410E 06 0.2052E 06 0.1246E 06

AVERAGE L= 1.170 B=.21977
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.8559E 06 0.8062E 06 0.7343E 06 0.6406E 06 0.5740E 06

AVERAGE L= 1.170 B=.20975
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.4812E 06 0.3913E 06 0.2804E 06 0.1600E 06 0.9249E 05

AVERAGE L= 1.170 B=.20972
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.6456E 06 0.5736E 06 0.4764E 06 0.3555E 06 0.2730E 06

AVERAGE L= 1.170 B=.20474
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.4513E 06 0.3629E 06 0.2560E 06 0.1428E 06 0.8090E 05

AVERAGE L= 1.170 B=.20475
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.5692E 06 0.4911E 06 0.3896E 06 0.2688E 06 0.1907E 06

AVERAGE L= 1.170 B=.20141
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.4332E 06 0.3460E 06 0.2419E 06 0.1333E 06 0.7469E 05

AVERAGE L= 1.170 B=.20134
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.5207E 06 0.4399E 06 0.3375E 06 0.2199E 06 0.1474E 06

AVERAGE L= 1.188 B=.23382
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.6179E 06 0.5248E 06 0.3992E 06 0.2485E 06 0.1550E 06

AVERAGE L= 1.188 B=.23383
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.3782E 07 0.3632E 07 0.3447E 07 0.3229E 07 0.3084E 07

AVERAGE L= 1.188 B=.21177
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.4507E 06 0.3605E 06 0.2517E 06 0.1373E 06 0.7561E 05

AVERAGE L= 1.188 B=.21175
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.6639E 06 0.5964E 06 0.5050E 06 0.3904E 06 0.3108E 06

AVERAGE L= 1.188 B=.25851
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.8776E 06 0.7972E 06 0.6687E 06 0.4846E 06 0.3495E 06

AVERAGE L= 1.188 B=.25853
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.8554E 09 0.6005E 09 0.3943E 09 0.2397E 09 0.1695E 09

AVERAGE L= 1.188 B=.24959
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.7733E 06 0.6856E 06 0.5550E 06 0.3807E 06 0.2603E 06

AVERAGE L= 1.188 B=.24954
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.1175E 09 0.9275E 08 0.7004E 08 0.5030E 08 0.3995E 08

AVERAGE L= 1.188 B=.23938
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.6690E 06 0.5769E 06 0.4486E 06 0.2890E 06 0.1862E 06

AVERAGE L= 1.188 B=.23934
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.1212E 08 0.1095E 08 0.9695E 07 0.8383E 07 0.7571E 07

AVERAGE L= 1.188 B=.21981
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.5056E 06 0.4133E 06 0.2976E 06 0.1702E 06 0.9799E 05

AVERAGE L= 1.188 B=.21981
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.8335E 06 0.7838E 06 0.7133E 06 0.6223E 06 0.5579E 06

AVERAGE L= 1.188 B=.20482
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.4087E 06 0.3211E 06 0.2185E 06 0.1146E 06 0.6086E 05

AVERAGE L= 1.188 B=.20481
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.5597E 06 0.4837E 06 0.3855E 06 0.2689E 06 0.1932E 06

AVERAGE L= 1.200 B=.24991
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.7400E 06 0.6498E 06 0.5184E 06 0.3469E 06 0.2312E 06

AVERAGE L= 1.200 B=.24992
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.1125E 09 0.8896E 08 0.6733E 08 0.4849E 08 0.3861E 08

AVERAGE L= 1.200 B=.23952
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.6373E 06 0.5438E 06 0.4160E 06 0.2608E 06 0.1634E 06

AVERAGE L= 1.200 B=.23948
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.1122E 08 0.1018E 08 0.9049E 07 0.7866E 07 0.7131E 07

AVERAGE L= 1.200 B=.22940
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.5508E 06 0.4569E 06 0.3357E 06 0.1976E 06 0.1166E 06

AVERAGE L= 1.200 B=.22938
AVERAGE NUMBER DENSITIES FOR DIFF S
SOUTHERN HEMISPHERE
0.1666E 07 0.1638E 07 0.1594E 07 0.1536E 07 0.1496E 07

AVERAGE L= 1.200 B=.21979
AVERAGE NUMBER DENSITIES FOR DIFF S
NORTHERN HEMISPHERE
0.4790E 06 0.3869E 06 0.2735E 06 0.1516E 06 0.8459E 05

```
        AVERAGE   L= 1.200   B=.21980
        AVERAGE NUMBER DENSITIES FOR DIFF S
           SOUTHERN HEMISPHERE
0.8144E 06  0.7642E 06  0.6936E 06  0.6031E 06  0.5390E 06

        AVERAGE   L= 1.200   B=.20970
        AVERAGE NUMBER DENSITIES FOR DIFF S
           NORTHERN HEMISPHERE
0.4136E 06  0.3249E 06  0.2207E 06  0.1151E 06  0.6061E 05

        AVERAGE   L= 1.200   B=.20971
        AVERAGE NUMBER DENSITIES FOR DIFF S
           SOUTHERN HEMISPHERE
0.6189E 06  0.5489E 06  0.4559E 06  0.3416E 06  0.2637E 06

        AVERAGE   L= 1.200   B=.18974
        AVERAGE NUMBER DENSITIES FOR DIFF S
           NORTHERN HEMISPHERE
0.3116E 06  0.2325E 06  0.1468E 06  0.6859E 05  0.3260E 05

        AVERAGE   L= 1.200   B=.18975
        AVERAGE NUMBER DENSITIES FOR DIFF S
           SOUTHERN HEMISPHERE
0.3818E 06  0.3026E 06  0.2112E 06  0.1179E 06  0.6790E 05
```

2. Tape 10

a. Output card description

	Columns	Mode	Quantity	Units	Description
B, L Card	1-8	F	EL	earth radii	averaged magnetic field line
	9-16	F	B	gauss	magnetic induction
	72-80	-	-	-	constituent name
Density Card	1-12	E	EN1	atoms/cm^3	density for flux model 1
	13-24	E	EN2	atoms/cm^3	den " 2
	25-36	E	EN3	"	" " 3
	37-48	E	EN4	"	" " 4
	49-60	E	EN5	"	" " 5
	72-80	-	-	-	constituent name

b. Sample

GENERAL PURPOSE DATA SHEET

Problem: OUTPUT – LONGITUDINAL AVERAGING PROCESSOR (NORTH-SOUTH AVERAGE)

Sponsor: TAPE 10 | Date: SAMPLE | Page ___ of ___

1.14196	0.23890									NITROGEN
0.3881E	13	0.4914E	13	0.6975E	13	0.1209E	14	0.2036E	14	NITROGEN
1.14197	0.22738									NITROGEN
0.2430E	10	0.2258E	10	0.2038E	10	0.1748E	10	0.1521E	10	NITROGEN
1.14198	0.23465									NITROGEN
0.2745E	12	0.3119E	12	0.3771E	12	0.5095E	12	0.6780E	12	NITROGEN
1.14200	0.21968									NITROGEN
0.6784E	08	0.4488E	08	0.2533E	08	0.1057E	08	0.4720E	07	NITROGEN
1.17001	0.23991									NITROGEN
0.5180E	13	0.6565E	13	0.9330E	13	0.1615E	14	0.2711E	14	NITROGEN
1.17000	0.23467									NITROGEN
0.2258E	12	0.2519E	12	0.2962E	12	0.3819E	12	0.4858E	12	NITROGEN
1.16994	0.22956									NITROGEN
0.9956E	10	0.9755E	10	0.9490E	10	0.9110E	10	0.8785E	10	NITROGEN
1.17002	0.21976									NITROGEN
0.8742E	08	0.6089E	08	0.3662E	08	0.1667E	08	0.8015E	07	NITROGEN
1.17006	0.20973									NITROGEN
0.7853E	07	0.3602E	07	0.1343E	07	0.2060E	06	0.3886E	05	NITROGEN
1.17000	0.20474									NITROGEN
0.2687E	07	0.9987E	06	0.2702E	06	0.2615E	05	0.3099E	04	NITROGEN
1.17005	0.20137									NITROGEN
0.1281E	07	0.4079E	06	0.8558E	05	0.5995E	04	0.5059E	03	NITROGEN
1.18795	0.23382									NITROGEN
0.9725E	11	0.1047E	12	0.1166E	12	0.1382E	12	0.1623E	12	NITROGEN

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H. Running Time

An allowance of 8 seconds for each B-L line will give a close estimate of the running time for this program.

IV. LAMBDA PUNCH

A. Introduction

This program takes the cards from the longitudinal averaging processor and punches the latitude in degrees on every B-L card. This value is necessary in the execution of the "bounce" average calculation.

Computing the latitude is done by the method of false position using the equation.

$$B = \frac{M}{r_e^3} \frac{\sqrt{4 - 3\cos^2\lambda}}{L^3 \cos^6\lambda} \tag{1}$$

where M is the earth's magnetic dipole moment, r_e is the radius of the earth and λ is the latitude. B is traded to the right hand side of equation (1) and the resulting function is evaluated for zero at a fixed B and L:

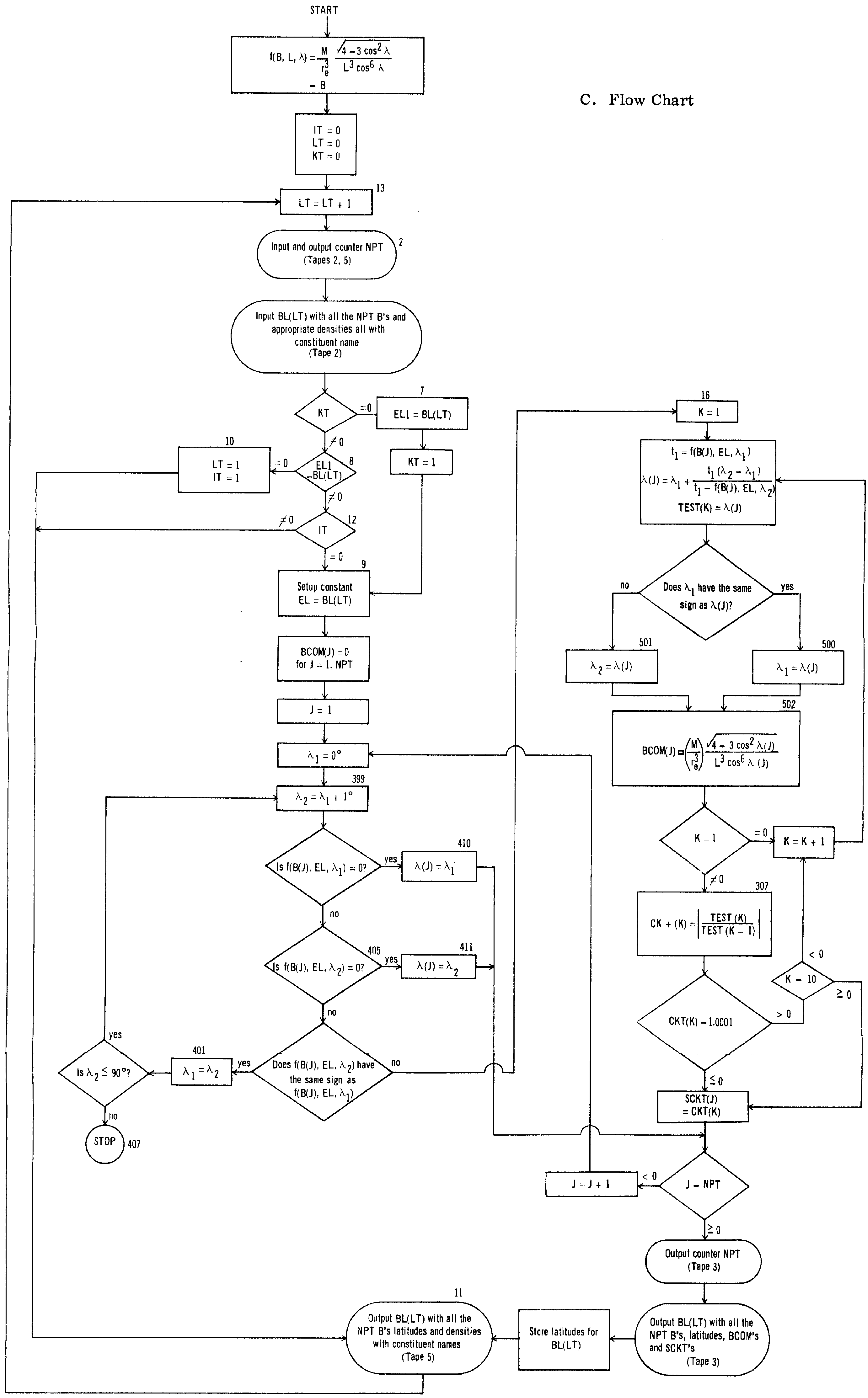
$$BFUNF(B, L, \lambda) = \frac{M}{r_e^3} \frac{\sqrt{4 - 3\cos^2\lambda}}{L^3 \cos^6\lambda} - B$$

B. Mnemonics

Quantity	Description	Units
IT	counter to eliminate repetition in computation	-
LT	L counter	-
KT	counter to determine whether a particular L is the first L considered	-
RTD	conversion factor - radians to degrees	-
DTR	" " - degrees to radians	-

Quantity	Description	Units
RE	radius of the earth (6378.16×10^5)	cm
EM	the earth's magnetic dipole moment (8.1×10^{25} gauss cm^3) divided by the radius of the earth cubed	gauss
NPT	count of the number of B's to a given L	-
BL(J)	J^{th} magnetic field line	earth radii
B(I)	I^{th} magnetic induction for a given L	gauss
SS1(I),..., SS5(I)	longitudinally averaged number densities for the five flux models and the I^{th} B.	$atoms/cm^3$
RATIO(I)	ratio of the upper limit on the latitude XLW2 to the lower limit on the latitude XLW1 for the I^{th} B.	-
BCOM(I)	B computed for the final latitude XLAMP(I) at B(I)	gauss
XLW1	lower limit on the latitude	radians
XLW2	upper limit on the latitude	"
FXLW1	BFUNF computed for XLW1	-
FXLW2	" " " XLW2	-
XLAMP(I)	final selected latitude for B(I)	radians/ degrees
TERM 1	BFUNF computed for XLW1	-
TBLAM(J, I)	latitude for the I^{th} B of the J^{th} L	degrees
TEST(K)	temporary storage of XLAMP(J)	radians
CKT(K)	the absolute value of TEST(K)/TEST(K-1)	-
SCKT(J)	temporary storage of final CKT(K)	-

C. Flow Chart


START
f(B, L, λ) = M/r_e^3 √(4 − 3 cos² λ)/(L³ cos⁶ λ) − B
IT = 0
LT = 0
KT = 0
13
LT = LT + 1
2
Input and output counter NPT (Tapes 2, 5)
Input BL(LT) with all the NPT B's and appropriate densities all with constituent name (Tape 2)
KT
= 0
≠ 0
7
EL1 = BL(LT)
KT = 1
10
LT = 1
IT = 1
= 0
8
EL1 −BL(LT)
≠ 0
12
IT
≠ 0
= 0
9
Setup constant EL = BL(LT)
BCOM(J) = 0 for J = 1, NPT
J = 1
λ1 = 0°
399
λ2 = λ1 + 1°
Is f(B(J), EL, λ1) = 0?
yes
410
λ(J) = λ1
no
405
Is f(B(J), EL, λ2) = 0?
yes
411
λ(J) = λ2
no
Does f(B(J), EL, λ2) have the same sign as f(B(J), EL, λ1)
yes
no
401
λ1 = λ2
Is λ2 ≤ 90°?
yes
no
STOP
407
16
K = 1
t1 = f(B(J), EL, λ1)
λ(J) = λ1 + t1(λ2 − λ1)/(t1 − f(B(J), EL, λ2))
TEST(K) = λ(J)
Does λ1 have the same sign as λ(J)?
no
yes
501
λ2 = λ(J)
500
λ1 = λ(J)
502
BCOM(J) = (M/r_e^3) √(4 − 3 cos² λ(J))/(L³ cos⁶ λ(J))
K − 1
= 0
K = K + 1
≠ 0
307
CK + (K) = |TEST (K)/TEST (K − 1)|
K − 10
< 0
≥ 0
CKT(K) − 1.0001
> 0
≤ 0
SCKT(J) = CKT(K)
J − NPT
< 0
J = J + 1
≥ 0
Output counter NPT (Tape 3)
Output BL(LT) with all the NPT B's, latitudes, BCOM's and SCKT's (Tape 3)
Store latitudes for BL(LT)
11
Output BL(LT) with all the NPT B's latitudes and densities with constituent names (Tape 5)

D. Fortran Listing

LAMPUN

```
C     LAMBDA PUNCH
      DIMENSION B(25),TBLAM(25,25),SS1(25),SS2(25),SS3(25),SS4(25),
     1SS5(25),BCOM(25),BL(25),TEST(20),CKT(20),SCKT(25),XLAMP(25)
      BFUNF(B,EM,EL,XLAM)=EM*SQRTF(4.0-3.0*COSF(XLAM)**2)/((EL**3)*
     1COSF(XLAM)**6)-B
C   ERROR 1 = LAMBDA GREATER THAN 90.0 DEG.
C     FORMATS
  100 FORMAT(I2)
  101 FORMAT(2F8.5,56X,A6,A2)
  102 FORMAT(5E12.4,12X,A6,A2)
  103 FORMAT(6H ERROR,I2)
  104 FORMAT(5H1 NPT,5X,1HL,9X,1HB,6X,6HLAMBDA,4X,9HB COMP.   ,10X,5HRATI
     1O)
  105 FORMAT(I4)
  106 FORMAT(4X,2F10.5,F10.3,2E15.7)
  107 FORMAT(2F8.5,F8.3,48X,A6,A2/5E12.4,12X,A6,A2)
      IT=0
      LT=0
      KT=0
   13 LT=LT+1
    2 READ INPUT TAPE 2,100,NPT
      WRITE OUTPUT TAPE 5,100,NPT
      DO 18 I=1,NPT
      READ INPUT TAPE 2,101,BL(LT),B(I),XLA,XLB
   18 READ INPUT TAPE 2,102,SS1(I),SS2(I),SS3(I),SS4(I),SS5(I),XLA,XLB
      IF(KT) 8,7,8
    7 EL1=BL(LT)
      KT=1
      GO TO 9
    8 IF (EL1-BL(LT)) 12,10,12
   12 IF (IT) 11,9,11
C     SOLVE FOR LAMBDA BY METHOD OF FALSE POSITION
C     DETERMINE APPROX. SOLN. USING  1  DEG. INCREMENTS
    9 RTD=57.29578
      DTR=0.01745329
      RE=6378.165E5
      EM=8.1E25/RE**3
      EL=BL(LT)
      DO 199 II=1,NPT
  199 BCOM(II)=0.0
      DO 200 J=1,NPT
      XLW1=0.0
  399 XLW2=XLW1+DTR
      FXLW1=BFUNF(B(J),EM,EL,XLW1)
      FXLW2=BFUNF(B(J),EM,EL,XLW2)
      IF(FXLW1) 405,410,405
  405 IF(FXLW2) 406,411,406
  406 IF(FXLW1-SIGNF(FXLW1,FXLW2)) 16,401,16
  401 XLW1=XLW2
      IF(XLW2-1.5707961) 399,399,407
  407 IERR=1
      WRITE OUTPUT TAPE 3,103,IERR
      CALL EXIT
  410 XLAMP(J)=XLW1
      GO TO 200
```

```
  411 XLAMP(J)=XLW2
      GO TO 200
C     METHOD OF FALSE POSITION
   16 DO 150 K=1,10
      TERM1=BFUNF(B(J),EM,EL,XLW1)
      XLAMP(J)=XLW1+TERM1/((TERM1-BFUNF(B(J),EM,EL,XLW2))
     1*(XLW2-XLW1)
      TEST(K)=XLAMP(J)
      IF(XLAMP(J)-SIGNF(XLAMP(J),XLW1)) 501,500,501
  500 XLW1=XLAMP(J)
  502 BCOM(J)=EM*SQRTF(4.0-3.0*COSF(XLAMP(J))**2)/((EL**3)*
     1COSF(XLAMP(J))**6)
      IF (K-2) 307,150,307
  307 CKT(K)=ABSF(TEST(K)/TEST(K-1))
      IF (CKT(K)-1.0001) 309,309,150
  501 XLW2=XLAMP(J)
      GO TO 502
  150 CONTINUE
  309 SCKT(J)=CKT(K)
  200 CONTINUE
      WRITE OUTPUT TAPE 3,104
      WRITE OUTPUT TAPE 3,105,NPT
      DO 201 L=1,NPT
      XLAMP(L)=XLAMP(L)*RTD
  201 WRITE OUTPUT TAPE 3,106,BL(LT),B(L),XLAMP(L),BCOM(L),SCKT(L)
      DO 15 J=1,NPT
   15 TBLAM(LT,J)=XLAMP(J)
      GO TO 11
   10 LT=1
      IT=1
   11 DO 17 L=1,NPT
   17 WRITE OUTPUT TAPE 5,107,BL(LT),B(L),TBLAM(LT,L),XLA,XLB,SS1(L),
     1SS2(L),SS3(L),SS4(L),SS5(L),XLA,XLB
      GO TO 13
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                              STORAGE NOT USED BY PROGRAM

       DEC   OCT               DEC   OCT
       1446 02646            32561 77461

               STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

       DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
 BCOM  1295 02417        BL    1270 02366        B     1445 02545      CKT   1225 02311     SCKT   1205 02265
  SS1  1420 02614       SS2    1395 02563      SS3     1370 02532      SS4   1345 02501      SS5   1320 02450
TBLAM  1155 02203      TEST    1245 02335    XLAMP     1180 02234

            STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

       DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
  DTR   530 01022       EL1     529 01021       EL      528 01020       EM     527 01017    FXLW1    526 01016
FXLW2   525 01015      IERR     524 01014       IT      523 01013        K     522 01012       KT    521 01011
   LT   520 01010       NPT     519 01007       RE      518 01006      RTC     517 01005    TERM1    516 01004
  XLA   515 01003       XLB     514 01002     XLW1      513 01001     XLW2     512 01000

                        SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

       EFN   LOC               EFN   LOC               EFN   LOC               EFN   LOC               EFN   LOC
 8)34   100 00754      8)35     101 00753     8)36      102 00750     8)37     103 00745     8)38    104 00742
 8)39   105 00727      8)3A     106 00726     8)3B      107 00722

                       LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

       DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
   1)   493 00755       1)1     499 00763       2)      439 00667       3)     445 00675       4) 32767 77777
  4)1   504 00770        6)     454 00706       7)      508 00774     C)G0     509 00775     C)G3    510 00776
 C)G4   511 00777     D)40A     116 00164    D)40C      297 00451      E)4      76 00114      E)E     85 00125
  E)F   158 00236       E)H     183 00267      E)K      234 00352      E)C     291 00443      E)P    296 00450
  I)S   302 00456

                              LOCATIONS OF NAMES IN TRANSFER VECTOR

       DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
  COS     1 00001      EXIT       7 00007     SQRT        2 00002    (FIL)       6 00006    (FPT)      0 00000
(RTN)     4 00004     (STH)       5 00005    (TSH)        3 00003

                          ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

COS         EXIT         SQRT        (FIL)       (FPT)       (RTN)       (STH)       (TSH)

                          NAMES AND LOCATIONS OF ARITHMETIC STATEMENT FUNCTIONS

       DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
 BFUN   401 00621

          EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS
```

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
13	15	00025	2	16	00031	18	23	00064	7	26	00115	8	29	00122
12	39	00126	9	31	00132	199	37	00155	399	40	00167	405	44	00224
406	45	00226	401	46	00240	407	48	00247	410	52	00264	411	54	00270
16	56	00273	500	61	00354	502	62	00356	307	64	00426	501	66	00440
150	67	00445	309	69	00452	200	70	00454	201	76	00505	15	79	00535
10	81	00543	11	83	00551	17	84	00555						

E. Restrictions

Before the first card of a new L line section a counter card must be inserted in order to inform the computer of the number of B's connected with that L.

F. Input

There are three different cards in the input deck for this program. A counter card is followed by the designated number of card pairs for each L line of every constituent. The card pairs consist of a B-L card and a density card in that order. These are the cards output from the longitudinal averaging processor.

1. (Tape 2)

CARD DESCRIPTION

	Columns	Mode	Quantity	Units	Description
Counter Card	1-2	I	NPT	-	B-L, density card pair counter
B-L Card	1-8	F	EL	earth radii	magnetic field line
	9-16	F	B	gauss	magnetic induction
	73-80	-	-	-	constituent name
Density Card	1-12	E	SS1	atoms/cm^3	density for flux model 1
	13-24	E	SS2	"	" " " " 2
	25-36	E	SS3	"	" " " " 3
	37-48	E	SS4	"	" " " " 4
	49-60	E	SS5	"	" " " " 5
	73-80	-	-	-	constituent name

2. Sample

GENERAL PURPOSE DATA SHEET

Problem: INPUT – LAMBDA PUNCH

Sponsor: TAPE 2 | Date: SAMPLE | Page ___ of ___

4						
1.14196	0.23890					NITROGEN
0.3881E 13	0.4914E 13	0.6975E 13	0.1209E 14	0.2036E 14		NITROGEN
1.14196	0.22738					NITROGEN
0.2430E 10	0.2258E 10	0.2038E 10	0.1748E 10	0.1521E 10		NITROGEN
1.14198	0.23465					NITROGEN
0.2745E 12	0.3119E 12	0.3771E 12	0.5095E 12	0.6780E 12		NITROGEN
1.14200	0.21968					NITROGEN
0.6784E 08	0.4488E 08	0.2533E 08	0.1057E 08	0.4720E 07		NITROGEN
7						
1.17001	0.23991					NITROGEN
0.5180E 13	0.6565E 13	0.9330E 13	0.1615E 14	0.2711E 14		NITROGEN
1.17000	0.23467					NITROGEN
0.2258E 12	0.2519E 12	0.2962E 12	0.3819E 12	0.4858E 12		NITROGEN
1.16994	0.22956					NITROGEN
0.9956E 10	0.9755E 10	0.9490E 10	0.9110E 10	0.8785E 10		NITROGEN
1.17002	0.21976					NITROGEN
0.8742E 08	0.6089E 08	0.3662E 08	0.1667E 08	0.8015E 07		NITROGEN
1.17006	0.20973					NITROGEN
0.7853E 07	0.3602E 07	0.1343E 07	0.2060E 06	0.3886E 05		NITROGEN
1.17000	0.20474					NITROGEN
0.2687E 07	0.9987E 06	0.2702E 06	0.2615E 05	0.3099E 04		NITROGEN
1.17005	0.20137					NITROGEN
0.1281E 07	0.4079E 06	0.8558E 05	0.5995E 04	0.5059E 03		NITROGEN

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G. Output

Output for this program occurs on logical tapes 3 and 5. Tape 3 contains the results of the latitude calculation. The counter NPT is printed along with L, B, λ, BCOMP and the ratio RATIO. BCOMP is the new B computed by inserting the values of L and λ into equation (1). It should compare with the initial B. RATIO is the ratio of λ to a former value of the latitude computed in the intermediate steps. It is the same as SCKT (refer to the mnemonics listing). RATIO should be within .0001 of unity.

Tape 5 contains the same data that was input on tape 2 with the exception that latitudes were added. This tape is punched and used as input for the "bounce" average calculation.

1. Tape 3 Sample

NPT	L	B	LAMBDA	B COMP.	RATIO
4					
	1.14200	0.23890	9.836	0.2389000E-00	0.1000009E 01
	1.14200	0.22738	7.740	0.2273800E-00	0.1000034E 01
	1.14200	0.23465	9.129	0.2346499E-00	0.1000039E 01
	1.14200	0.21968	5.867	0.2196800E-00	0.1000023E 01

NPT	L	B	LAMBDA	B COMP.	RATIO
7					
	1.17005	0.23991	12.444	0.2399099E-00	0.1000030E 01
	1.17005	0.23467	11.752	0.2346700E-00	0.1000012E 01
	1.17005	0.22956	11.022	0.2295600E-00	0.1000005E 01
	1.17005	0.21976	9.420	0.2197599E-00	0.1000056E 01
	1.17005	0.20973	7.346	0.2097300E-00	0.1000005E 01
	1.17005	0.20474	6.014	0.2047400E-00	0.1000015E 01
	1.17005	0.20137	4.894	0.2013700E-00	0.1000025E 01

2. Tape 5

a. Output card description

	Columns	Mode	Quantity	Units	Description
Counter Card	1-2	I	NPT	-	B-L-λ and density card pair counter
B-L-λ Card	1-8	F	EL	earth radii	magnetic field line
	9-16	F	B	gauss	magnetic induction
	17-24	F	XLAM	degrees	latitude
	73-80	-	-	-	constituent name
Density Card	1-12	E	SS1	atoms/cm^3	density for flux model 1
	13-24	E	SS2	"	" " " " 2
	25-36	E	SS3	"	" " " " 3
	37-48	E	SS4	"	" " " " 4
	49-60	E	SS5	"	" " " " 5
	73-80	-	-	-	constituent name

b. Sample

GENERAL PURPOSE DATA SHEET

Problem: OUTPUT – LAMBDA PUNCH

Sponsor: TAPE 5 | Date: SAMPLE | Page ___ of ___

4						
1.14200	0.23890	9.836				NITROGEN
0.3881E 13	0.4914E 13	0.6975E 13	0.1209E 14	0.2036E 14		NITROGEN
1.14200	0.22738	7.740				NITROGEN
0.2430E 10	0.2258E 10	0.2038E 10	0.1748E 10	0.1521E 10		NITROGEN
1.14200	0.23465	9.129				NITROGEN
0.2745E 12	0.3119E 12	0.3771E 12	0.5095E 12	0.6780E 12		NITROGEN
1.14200	0.21968	5.867				NITROGEN
0.6784E 08	0.4488E 08	0.2533E 08	0.1057E 08	0.4720E 07		NITROGEN
7						
1.17005	0.23991	12.444				NITROGEN
0.5180E 13	0.6565E 13	0.9330E 13	0.1615E 14	0.2711E 14		NITROGEN
1.17005	0.23467	11.752				NITROGEN
0.2258E 12	0.2519E 12	0.2962E 12	0.3819E 12	0.4858E 12		NITROGEN
1.17005	0.22956	11.022				NITROGEN
0.9956E 10	0.9755E 10	0.9490E 10	0.9110E 10	0.8785E 10		NITROGEN
1.17005	0.21976	9.420				NITROGEN
0.8742E 08	0.6089E 08	0.3662E 08	0.1667E 08	0.8015E 07		NITROGEN
1.17005	0.20973	7.346				NITROGEN
0.7853E 07	0.3602E 07	0.1343E 07	0.2060E 06	0.3886E 05		NITROGEN
1.17005	0.20474	6.014				NITROGEN
0.2687E 07	0.9987E 06	0.2702E 06	0.2615E 05	0.3099E 04		NITROGEN
1.17005	0.20137	4.894				NITROGEN
0.1281E 07	0.4079E 06	0.8558E 05	0.5995E 04	0.5059E 03		NITROGEN

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H. Running Time

This program will take close to a minute for every two L lines evaluated.

V. "BOUNCE" AVERAGE CALCULATION

A. Introduction

The "bounce" average of the number density is defined[5] by the equation

$$\overline{\rho} = \frac{\int_{\lambda_s}^{\lambda_n} \rho(B, L)\, ds}{\int_{\lambda_s}^{\lambda_n} ds} \tag{1}$$

In other words, for a given mirror point λ_0 and a given field line L, the "bounce" average of the number density is the average number of atoms/cm^3 that a particle encounters while spiraling about a field line from the northern to the southern mirror points (see Figure 5). The earth is assumed to be a dipole. This gives symmetry to the magnetic field, permitting the integrals in equation (1) to be evaluated over a fourth of a complete oscillation (see page 189, reference 1, for a discussion of the motion of trapped particles in a magnetic field.)

The output from the lambda punch becomes input to this program. Results are printed and punched for use in later programs. Subroutine TABLE is included to interpolate (extrapolate) the density table to supply the appropriate density at any latitude specified by the main program.

B. Equations

To calculate equation (1) we project the element of arc length ds onto the field line L. Next we eliminate L from the equation and use the dipole representation

$$B = \frac{M}{r^3}(1 + 3\sin^2\lambda)^{1/2} \tag{2}$$

to express B in terms of λ. This gives the "bounce" average $\overline{\rho}$ weighted over latitude for a given field line as

$$\text{RHOAV} = \frac{\int_0^{\lambda_0} \rho(\lambda)\, A(\lambda)\, d\lambda}{\int_0^{\lambda_0} A(\lambda)\, d\lambda} \tag{3}$$

where the "weighing" factor is

$$A(\lambda) = \frac{\cos^4\lambda \sqrt{4 - 3\cos^2\lambda}}{\sqrt{\cos^6\lambda \sqrt{4 - 3\cos^2\lambda_0} - \cos^6\lambda_0 \sqrt{4 - 3\cos^2\lambda}}}$$

This factor allows for the fact that particles spiraling about the field line stay longer at the mirror latitudes λ_0 (see page 189, reference 1, for a complete treatment of the derivation). Figure 6 is a plot of $A(\lambda)$ versus λ for different mirror latitudes. Since $A(\lambda)$ becomes undefined at λ_0 we divided equation (3) into two cases:

$$\text{RHOAV} = \frac{\int_0^{\lambda_0 - 2h} \rho(\lambda)A(\lambda)d\lambda + \int_{\lambda_0 - 2h}^{\lambda_0} \rho(\lambda)A(\lambda)d\lambda}{\int_0^{\lambda_0 - 2h} A(\lambda)d\lambda + \int_{\lambda_0 - 2h}^{\lambda_0} A(\lambda)d\lambda}$$

Next we designate the square of the denominator of $A(\lambda)$ by $q(\lambda)$. Expanding about λ_0 by Taylor's series gives us

$$g(\lambda) = (\lambda - \lambda_0) \sum_{i=1}^{\infty} \frac{q^{(i)}(\lambda_0)}{i!} (\lambda - \lambda_0)^{i-1}$$

where $q^{(i)}(\lambda_0)$ is the i^{th} derivative of q evaluated at λ_0. To approximate the infinite series we define

$$S(\lambda) = \text{SLAMF}(\lambda, \lambda_0) = -\sum_{i=1}^{3} \frac{q^{(i)}(\lambda_0)}{i!} (\lambda - \lambda_0)^{i-1}$$

where the minus sign is inserted in order to avoid the square root of a negative number. In the program we let S1LAMF(λ, λ_0), S2LAMF(λ, λ_0) and S3LAMF (λ, λ_0) represent the first, second and third terms of SLAMF(λ, λ_0) respectively and we define

$$\text{WLAMF}(\lambda, \lambda_0) = \frac{\cos^4\lambda \sqrt{4 - 3\cos^2\lambda}}{\sqrt{\text{SLAMF}(\lambda, \lambda_0)}}$$

This gives

$$\int_{\lambda_0 - 2h}^{\lambda_0} \rho(\lambda) A(\lambda) d\lambda = \int_{\lambda_0 - 2h}^{\lambda_0} \frac{\rho(\lambda)\text{WLAMF}(\lambda, \lambda_0)}{\sqrt{\lambda_0 - \lambda}} d\lambda \tag{4}$$

and

$$\int_{\lambda_0 - 2h}^{\lambda_0} A(\lambda) d\lambda = \int_{\lambda_0 - 2h}^{\lambda_0} \frac{\text{WLAMF}(\lambda, \lambda_0)}{\sqrt{\lambda_0 - \lambda}} d\lambda \tag{5}$$

which are linearly approximated by the equations

$$\text{ADDNUM} = \sqrt{2h}\left[\frac{4}{5}\rho(\lambda_0)\text{WLAMF}(\lambda_0, \lambda_0) + \frac{16}{15}\rho(\lambda_0 - h)\text{WLAMF}(\lambda_0 - h, \lambda_0) + \frac{2}{15}\rho(\lambda_0 - 2h)\text{WLAMF}(\lambda_0 - 2h, \lambda_0)\right]$$

and

$$\text{ADDDEN} = \sqrt{2h}\left[\frac{4}{5}\text{WLAMF}(\lambda_0, \lambda_0) + \frac{16}{15}\text{WLAMF}(\lambda_0 - h, \lambda_0) + \frac{2}{15}\text{WLAMF}(\lambda_0 - 2h, \lambda_0)\right]$$

respectively. The final step is to integrate by Simpson's rule[6] and add on ADDNUM and ADDDEN to get the correct density $\bar{\rho}$.

Additional equations used in this program are listed below:

$\text{AAAF}(\lambda) = \sqrt{4 - 3\cos^2\lambda}$

$\text{BBBF}(\lambda) = \cos^6\lambda$

$\text{MONEF}(\lambda) = 3\cos^4\lambda \sin 2\lambda$ — the first derivative of BBBF(λ) used in computing S1LAMF(λ, λ_0)

$\text{MTWOF}(\lambda) = \frac{15}{2}(\cos\lambda \sin 2\lambda)^2 - 6\cos^6\lambda$ — the second derivative of BBBF(λ) used in computing S2LAMF(λ, λ_0)

$\text{MTHRF}(\lambda) = 48\cos^4\lambda \sin 2\lambda - 15\sin^3 2\lambda$ — the third derivative of BBBF(λ), used in computing S3LAMF(λ, λ_0)

$\text{ETAF}(\lambda) = 10\cos 2\lambda - 3\sin^2 2\lambda - 6\cos^2 2\lambda$ — a factor which appears in the second and third derivatives of AAAF(λ)

$\text{NONEF}(\lambda) = \frac{3\sin 2\lambda}{2\text{AAAF}(\lambda)}$ — the first derivative of AAAF(λ) used in computing S1LAMF(λ, λ_0).

$\text{NTWOF}(\lambda) = \frac{3\,\text{ETAF}(\lambda)}{4(4 - 3\cos^2\lambda)^{3/2}}$ — the second derivative of AAAF(λ) used in computing S2LAMF(λ, λ_0).

$\text{NTHRF}(\lambda) = \frac{3}{4}\,\frac{-20\sin\lambda - 6\sin 4\lambda - \frac{9\,\text{ETAF}(\lambda)\sin 2\lambda}{4 - 3\cos^2\lambda}}{(4 - 3\cos^2\lambda)^{3/2}}$ — the third derivative of AAAF(λ), used in computing S3LAMF (λ, λ_0)

WGTF(λ, λ_0) the designation for A(λ) when integrating by Simpson's rule

ALAM the value of the denominator in equation (3) but without equation (5)

RHOAS the value of the numerator in equation (3) but without equation (4)

BSUBO B_0 computed by equation (2) for λ_0.

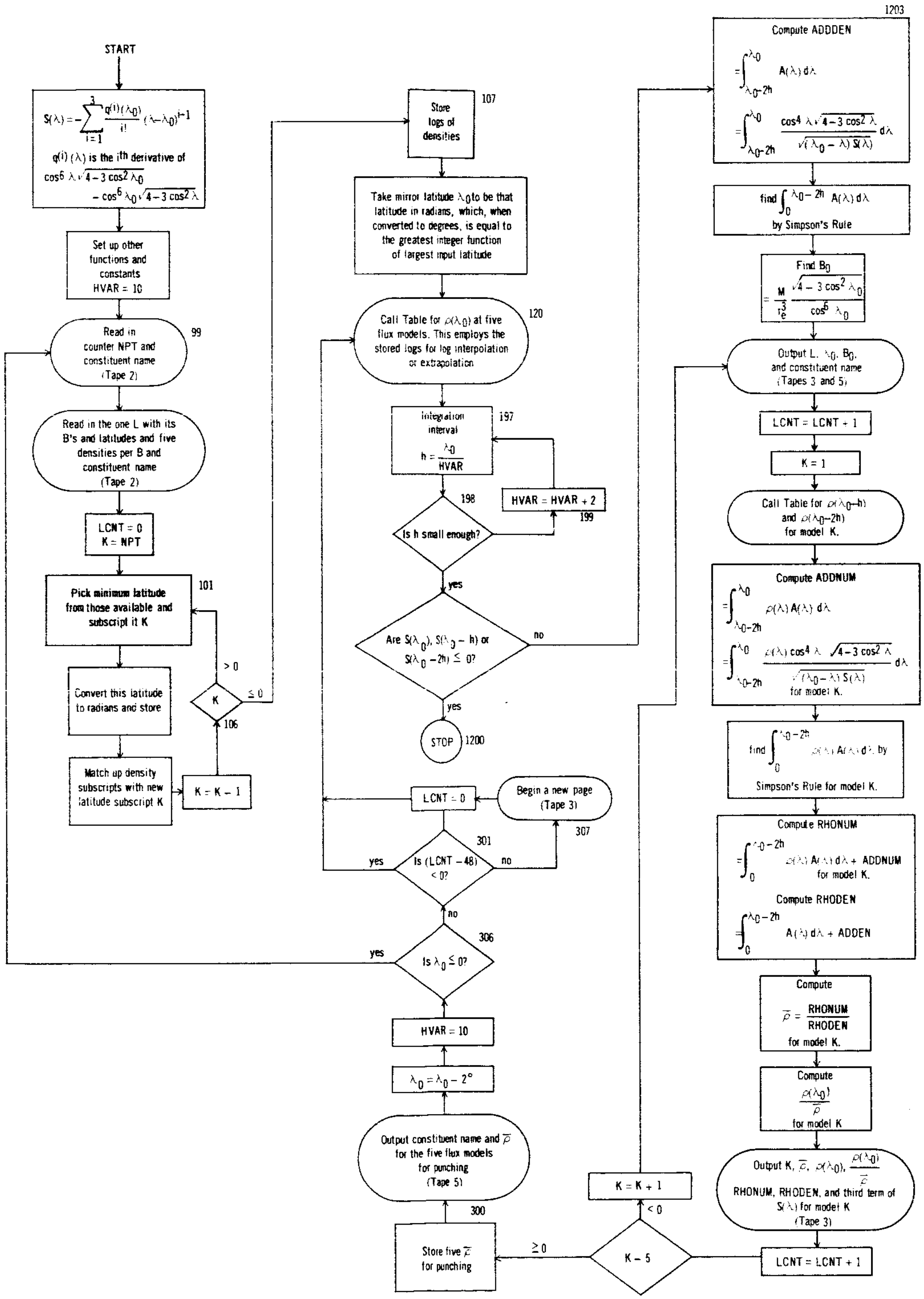
C. Mnemonics

Quantity	Description	Units
DTR	Conversion factor - degrees to radians	-
RTD	Conversion factor - radians to degrees	-
RE	radius of the earth, 6378.165×10^5 cm.	cm.
EM	earth's magnetic dipole moment, 8.1×10^{25} gauss cm^3, divided by the radius of the earth cubed.	gauss
HVAR	number of partitions in Simpson's rule	-
NPT	counter of the B's for a given L	-
XLAB1	first six letters of constituent identification name	-
XLAB2	remaining two letters of constituent identification name	-
EL	magnetic field line L	earth radii
B(I)	I^{th} magnetic induction for a given L	gauss
SS(I,J)	(a) the first time this designation is used it represents the longitudinally averaged density for the I^{th} solar flux model and the J^{th} magnetic induction	$atoms/cm^3$
	(b) the second time this designation is used it represents the log of the densities in (a)	-
LCNT	line counter for output on tape 3	-
XMIN	storage of the smallest available latitude	degrees
XLAMW(K)	latitude in radians, sorted in decreasing order	radians
XLAMRF	storage of maximum value of the latitude	radians

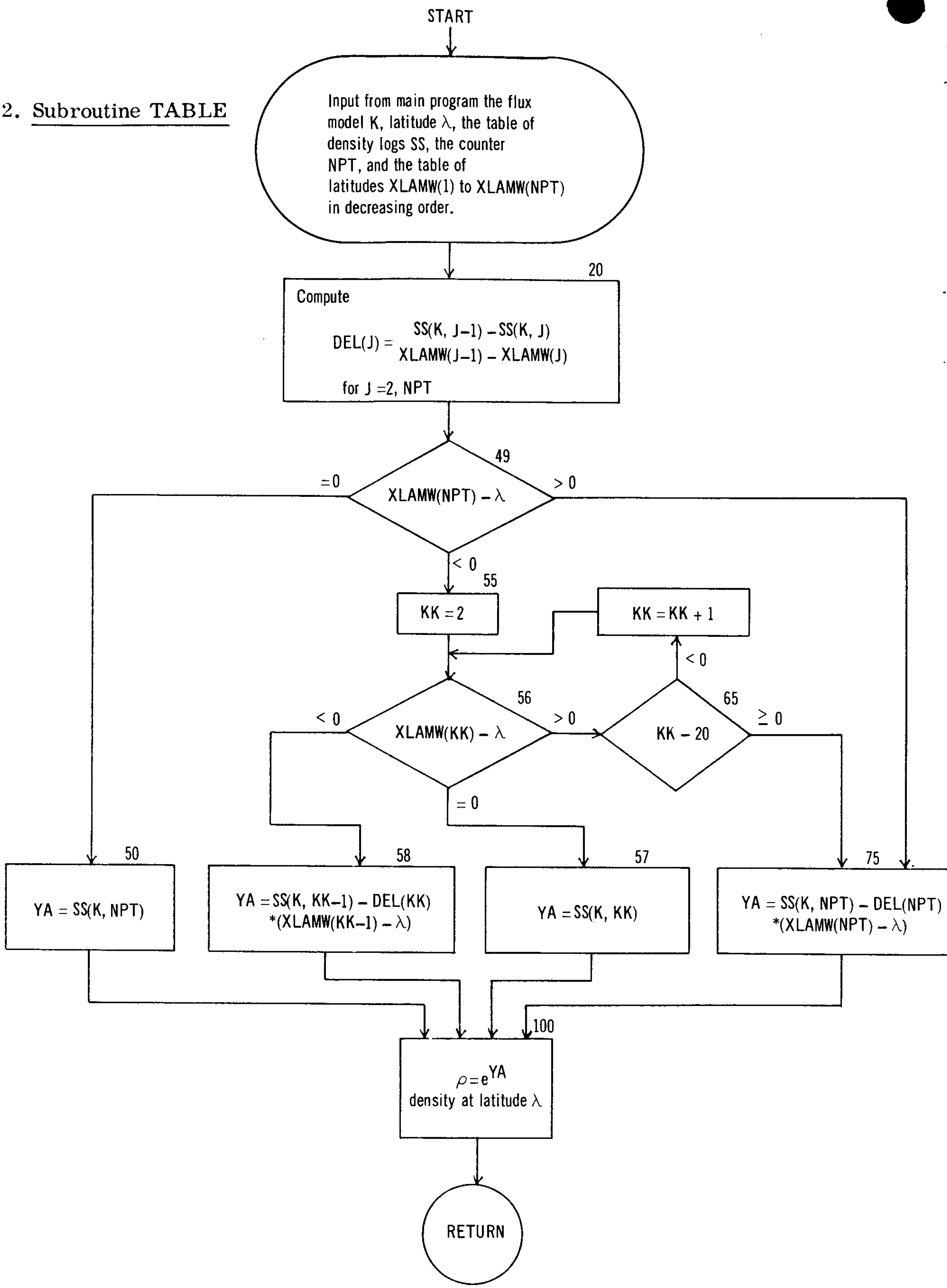
Quantity	Description	Units
XLAMO	mirror latitude λ_0	radians
RHOLO(I)	density for I^{th} flux model at mirror latitude	atoms/cm^3
HS	integration interval h for Simpson's rule	radians
RHOAV	"bounce" average density	atoms/cm^3
RATRHO	ratio of density at mirror latitude to density RHOAV	-
RHOLOP	density at mirror latitude	atoms/cm^3
DENB(K)	temporary storage of "bounce" average density at K^{th} flux model for tape 5 punch	atoms/cm^3

D. Flow Chart

1. Main Program



2. Subroutine TABLE



E. Fortran Listing

BOUNCE

```
C      BOUNCE AVERAGE CALCULATION
C      PROGRAM TO COMPUTE RHO TRIPLE BAR AS FUNCTION OF L,LAMBDA AND FLUX
       DIMENSION B(20),XLM(20),SS(5,20),
      1XLAMW(20),S(5,20),DENB(20),RHOLC(5),DEL(5)
       FREQUENCY 102(10),106(0,1,10),107(10),103(5,0,5),198(1,0,100)
      1,301(5,1,0 ),306(1,0,10),120(10,0,5),209(100),211(99),259(100),
      2261(99),1199(0,1,10),1201(0,1,10),1202(0,1,10)
C FORMATS
    1 FORMAT(I2,70X,A6,A2)
    2 FORMAT(2F8.5,F8.3,48X,A6,A2)
    3 FORMAT(5E12.4,12X,A6,A2)
    4 FORMAT(16H1CONSTITUENT   L,5X,11HMIRROR    B,4X,86HFLUX  AVERAGE R
     1HO  RHO AT MIRROR  RHO/AV. RHO   INTEGRAL OF   INTEGRAL OF  S3 (LA
     2M.) FOR/22X,4HLAT.,31X,8HLATITUDE,19X,21HRHO*A  DLAM   A  DLAM,6X,
     313HINT. INTERVAL//)
    5 FORMAT(3X,A6,A2,F6.4,F8.3,F8.4)
    6 FORMAT(36X,I2,1P6E14.4)
    7 FORMAT(32HO ERROR - S(LAM) IS NEG. OR ZERO/6H SL1 =E15.5,
     16H SL2 =E15.5,6H SL3 =E15.5,8H XLAMO =E15.5,5H HS =E15.5)
    8 FORMAT (25H1DIVIDE CHECK HAS OCCURED)
    9 FORMAT (30H1QUOTIENT OVERFLOW HAS OCCURED)
C ARITHMETIC FUNCTIONS
       AAAF(XL)=SQRTF(4.0-3.0*(COSF(XL)**2))
       BBBF(XL)= COSF(XL)**6
       ETAF(XL)=10.0*(COSF(2.0*XL))-3.0*(SINF(2.0*XL)**2)
      1-6.0*((COSF(2.0*XL))**2)
       MONEF(XL)=-3.0*(COSF(XL)**4)*SINF(2.0*XL)
       MTWOF(XL)=7.5*(COSF(XL)*SINF(2.0*XL))**2-6.0*(COSF(XL)**6)
       MTHRF(XL)=48.0*(COSF(XL)**4)*(SINF(2.0*XL))
      1-15.0*((SINF(2.0*XL))**3)
       NONEF(XL)=1.5*SINF(2.0*XL)/AAAF(XL)
       NTWOF(XL)=0.75*ETAF(XL)/((4.0-3.0*(COSF(XL)**2))**1.5)
       NTHRF(XL)=(0.75*(-20.0*(SINF(2.0*XL))-6.0*(SINF(4.0*XL))
      1-(9.0*ETAF(XL)*(SINF(2.0*XL)))/(4.0-3.0*(COSF(XL))**2)))
      2/((4.0-3.0*(COSF(XL)**2))**1.5)
       S1LAMF(XL,XLO)=-1.0*(AAAF(XLO)*MONEF(XLO)-BBBF(XLO)*NONEF(XLO))
       S2LAMF(XL,XLO)=(AAAF(XLO)*MTWOF(XLO)-BBBF(XLO)*NTWOF(XLO))
      2*(XL-XLO)/(-2.0)
       S3LAMF(XL,XLO)=(AAAF(XLO)*MTHRF(XLO)-BBBF(XLO)*NTHRF(XLO))
      2*((XL-XLO)**2)/(-6.0)
       SLAMF(XL,XLO)=S1LAMF(XL,XLO)+S2LAMF(XL,XLO)+S3LAMF(XL,XLO)
       WLAMF(XL,XLO)=(COSF(XL)**4)*AAAF(XL)/SQRTF(SLAMF(XL,
      1XLO))
       WOTF(XL,XLO)=(COSF(XL)**4)*AAAF(XL)/SQRTF(
      1AAAF(XLO)*BBBF(XL)-BBBF(XLO)*AAAF(XL))
C TURN OFF DIVIDE CHECK LIGHT
C AND QUOTIENT OVERFLOW LIGHT
       IF DIVIDE CHECK 30,30
   30 IF QUOTIENT OVERFLOW 31,31
C   PROGRAM CONSTANTS
   31 DTR=1.7453293E-2
       RTD=57.295779
       RE=6378.165E5
       EM=8.1E25/RE**3
       FVAR=10.0
```

```
   99 IF DIVIDE CHECK 33,98
   98 IF QUOTIENT OVERFLOW 34,32
   33 WRITE OUTPUT TAPE 3,8
      CALL EXIT
   34 WRITE OUTPUT TAPE 3,9
      CALL EXIT
C   READ IN TABLES OF DENSITY FOR GIVEN L AND VARIOUS LAMBDA-S
C   DENSITY - FIRST SUBSCRIPT = FLUX NO. , SECOND SUBS. = LATITUDE NO.
   32 READ INPUT TAPE 2,1,NPT,XLAB1,XLAB2
      DO 100 I=1,NPT
      READ INPUT TAPE 2,2,EL,B(I),XL M(I),XLAB1,XLAB2
  100 READ INPUT TAPE 2,3,(SS(IF,I),IF=1,5),XLAB1,XLAB2
      WRITE OUTPUT TAPE 3,4
      LCNT=0
      EL3=EL*EL*EL
C   SORT LAMBDA-S IN DECREASING ORDER
C   SUBSCRIPT = 1 = MAX VALUE UP TO SUBSCRIPT = NPT = MIN VALUE
      K=NPT
  101 XMIN=90.0
  102 DO 105 I=1,NPT
  103 IF(XMIN-XL M(I)) 105,105,104
  104 XMIN=XL M(I)
      JJ=I
  105 CONTINUE
C   XLAMW(K)=WORKING VALUE OF LAMBDA (IN RAD.) SORTED IN DECREASING ORDER
C   DENSITY SUBSCRIPTS MATCHED UP WITH SORTED LAMBDA-S
      XLAMW(K)=XMIN*DTR
      DO 1105 KF=1,5
 1105 S(KF,K)=SS(KF,JJ)
      XL M(JJ)=90.0
      K=K-1
  106 IF(K) 107,107,101
C   STORE LOG OF DENSITIES
  107 DO 108 I=1,NPT
      DO 1108 IL=1,5
 1108 SS(IL,I)=LOGF(S(IL,I))
  108 CONTINUE
C   MIRROR LATITUDE
      XLAMRF=XLAMW(1)
      XLAMO=0.0174
 1300 IF(XLAMO-XLAMRF) 1301,120,1302
 1301 XLAMO=XLAMO+0.0174
      GO TO 1300
 1302 XLAMO=XLAMO-0.0174
C   LINEAR INTERP. (EXTRAP.) TO FIND DENSITY (FROM TABLE) ASSOCIATED WITH
C   MIRROR LATITUDE
  120 DO 1140 KI=1,5
      CALL TABLE (KI,XLAMO,SS,RHOS,NPT,XLAMW)
 1140 RHOLO(KI)=RHOS
C   FIND INTEGRATION INTERVAL FOR SIMPSON-S RULE (HS)
  197 HS=XLAMO/HVAR
      TWOH=2.0*HS
      S3FUN=S3LAMF(XLAMO+TWOH,XLAMO)
  198 IF(ABSF(S3FUN)-1.0E-7) 200,200,199
  199 HVAR=HVAR+2.0
      GO TO 197
```

```
C   COMPUTE ADDEND FUNCTION FOR FINAL INTEGRATION STEPS
  200 SQ2H=SQRTF(TWCH)
      HA=HS
      TWHA=TWCH
      HS03=HS/3.0
C   TEST IF SLAMF NEG.
      SL1=SLAMF(XLAMO,XLAMO)
      SL2=SLAMF(XLAMO-HS,XLAMO)
      SL3=SLAMF(XLAMO-TWCH,XLAMO)
 1199 IF(SL1) 1200,1200,1201
 1200 WRITE OUTPUT TAPE 3,7,SL1,SL2,SL3,XLAMO,HS
      CALL EXIT
 1201 IF(SL2) 1200,1200,1202
 1202 IF(SL3) 1200,1200,1203
 1203 ADDDEN=SQ2H*(0.8*WLAMF(XLAMO,XLAMO)+1.0666667*
     1WLAMF(XLAMO-HA,XLAMO)+0.13333333*WLAMF(XLAMO-TWHA,
     2XLAMO))
C   INTEGRATE DENOMINATOR BY SIMPSON-S RULE   (A(LAM) FUNCTION)
      XLIMIT=XLAMO-TWHA
      XN=(XLIMIT/TWCH)+0.1
      N=XN
      NM1=N
      NM2=N-1
      A4=0.0
      A2=0.0
      XLAM=-HS
  209 DO 210 IS=1,NM1
      XLAM=XLAM+TWCH
  210 A4=A4+WGTF(XLAM,XLAMO)
      XLAM=0.0
  211 DO 212 ISS=1,NM2
      XLAM=XLAM+TWCH
  212 A2=A2+WGTF(XLAM,XLAMO)
      ALAM=HS03     *(WGTF(0.0,XLAMO)+4.0*A4+2.0*A2+WGTF(XLIMIT,
     1XLAMO))
C   END SIMPSON-S RULE FOR A(LAMBDA)
      BSUBC=EM*AAAF(XLAMO)/(EL3*BBBF(XLAMO))
      XLAMP=XLAMO*RTD
      WRITE OUTPUT TAPE 3,5,XLAB1,XLAB2,EL,XLAMP,BSUBC
      WRITE OUTPUT TAPE 5,2,EL,BSUBC,XLAMP,XLAB1,XLAB2
      LCNT=LCNT+1
C   INTEGRATE FIVE DENSITY MODELS
      DO 300 K=1,5
C   ADDEND FUNCTION FOR NUMERATOR
      RHOW1=RHOLO(K)
      CALL TABLE (K,XLAMO-HA,SS,RHOW2,NPT,XLAMW)
      CALL TABLE (K,XLAMO-TWHA,SS,RHOW3,NPT,XLAMW)
      ADDNUM=SQ2H*(0.8*RHOW1*WLAMF(XLAMO,XLAMO)+1.0666667*
     1RHOW2*WLAMF(XLAMO-HA,XLAMO)+0.13333333*RHOW3*
     2WLAMF(XLAMO-TWHA,XLAMO))
C   INTEGRATE NUMERATOR BY SIMPSON-S RULE    RHO(LAM).A(LAM)
      RHOA4=0.0
      RHOA2=0.0
      XLAM=-HS
  259 DO 260 KS=1,NM1
      XLAM=XLAM+TWCH
```

```
      CALL TABLE (K,XLAM,SS,RHCTAB,NPT,XLAMW)
  250 RHOA4=RHOA4+RHOTAB*WGTF(XLAM,XLAMO)
      XLAM=0.0
  261 DO 262 KSS=1,NM2
      XLAM=XLAM+TWOH
      CALL TABLE (K,XLAM,SS,RHCTAB,NPT,XLAMW)
  262 RHOA2=RHOA2+RHOTAB*WGTF(XLAM,XLAMO)
      CALL TABLE (K,0.0,SS,RHOASO,NPT,XLAMW)
      CALL TABLE (K,XLIMIT,SS,RHOASN,NPT,XLAMW)
      RHOAS=HSU3     *(RHOASO*WGTF(0.0,XLAMO)+4.0*RHOA4+2.0*RHOA2
     1+RHOASN*WGTF(XLIMIT,XLAMO))
C  END SIMPSON-S RULE FOR RHO*A (LAMBDA)
C  COMPUTE BOUNCE AVERAGE
      RHONUM=RHOAS+ADDNUM
      RHODEN=ALAM+ADDDEN
      RHOAV=RHONUM/RHODEN
C  COMPUTE RATIO OF BOUNCE DENSITY TO INITIAL
      RATRHO=RHOLO(K)/RHOAV
      RHOLCP=RHOLO(K)
      WRITE OUTPUT TAPE 3,6,K,RHOAV,RHOLCP,RATRHO,RHONUM,RHODEN,S3FUN
      LCNT=LCNT+1
C  STORE BOUNCE AVERAGE DENSITIES FOR A-5 PUNCH
  300 DENB(K)=RHOAV
      WRITE OUTPUT TAPE 5,3,DENB(1),DENB(2),DENB(3),DENB(4),DENB(5),
     1XLAB1,XLAB2
C  DECREMENT MIRROR LATITUDE BY 2 DEGREES
      XLAMO=XLAMO-0.03490653
      HVAR=10.0
  306 IF(XLAMO) 99,99,301
  301 IF(LCNT-40) 120,307,307
  307 WRITE OUTPUT TAPE 3,4
      LCNT=0
      GO TO 120
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

STORAGE NOT USED BY PROGRAM

DEC	OCT	DEC	OCT
1733	03305	32561	77461

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
B	1732	03304	DEL	1647	03157	DENB	1672	03210	RHOLD	1652	03164	S	1542	03006
SS	1642	03152	XLAMW	1692	03234	XLM	1712	03260						

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
A2	1442	02642	A4	1441	02641	ADDDEN	1440	02640	ADDNUM	1439	02637	ALAM	1438	02636
BSUBC	1437	02635	DTR	1436	02634	DL3	1435	02633	EL	1434	02632	EM	1433	02631
HA	1432	02630	HSD3	1431	02627	HS	1430	02626	HVAR	1429	02625	I	1428	02624
JJ	1427	02623	KI	1426	02622	K	1425	02621	LCNT	1424	02620	NM1	1423	02617
NM2	1422	02616	NPT	1421	02615	N	1420	02614	RATRHO	1419	02613	RE	1418	02612
RHOA2	1417	02611	RHOA4	1416	02610	RHOASN	1415	02607	RFCASD	1414	02606	RFCAS	1413	02605
RHOAV	1412	02604	RHODEN	1411	02603	RHODCP	1410	02602	RHONUM	1409	02601	RFOS	1408	02600
RFCTAB	1407	02577	RHOW1	1406	02576	RHOW2	1405	02575	RHOW3	1404	02574	RTD	1403	02573
S3FUN	1402	02572	SL1	1401	02571	SL2	1400	02570	SL3	1399	02567	SQ2H	1398	02566
TWHA	1397	02565	TWOH	1396	02564	XLAB1	1395	02563	XLAB2	1394	02562	XLAMC	1393	02561
XLAMP	1392	02560	XLAMRF	1391	02557	XLAM	1390	02556	XLIMIT	1389	02555	XMIN	1388	02554
XN	1387	02553												

SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

	EFN	LOC		EFN	LOC		EFN	LOC		EFN	LOC		EFN	LOC
8)1	1	02467	8)2	2	02464	8)3	3	02460	8)4	4	02455	8)5	5	02411
8)6	6	02404	8)7	7	02401	8)8	8	02355	8)9	9	02347			

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
1)	1336	02470	1)1	1343	02477	1)2	1349	02505	1)3	1358	02516	1)4	1364	02524
1)5	1366	02526	2)	1209	02271	3)	1217	02301	4)	32767	77777	4)1	1368	02530
4)2	1369	02531	4)3	1371	02533	4)4	1373	02535	4)5	1375	02537	6)	1244	02334
7)	1377	02541	7)1	1378	02542	7)2	1379	02543	7)3	1380	02544	7)4	1381	02545
C)G1	1382	02546	C)G2	1383	02547	C)1C1	1384	02550	C)102	1385	02551	C)2CC	1386	02552
C)10C	119	00167	D)20R	223	00337	C)30R	222	00336	C)400	127	00177	D)40H	168	00250
C)50H	167	00247	E)C	118	00166	E)P	212	00324	E)G	217	00331	E)12	313	00471

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
COS	1	00001	EXIT	7	00007	EXP(3	4	00004	LOG	10	00012	SIN	3	00003
SQRT	2	00002	TABLE	11	00013	(FIL)	6	00006	(FPT)	0	00000	(RIN)	9	00011
(STH)	5	00005	(TSH)	8	00010									

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

COS (STH)	EXIT (TSH)	EXP(3	LOG	SIN	SQRT	TABLE	(FIL)	(FPT)	(RTN)

NAMES AND LOCATIONS OF ARITHMETIC STATEMENT FUNCTIONS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
AAA	748	01354	BBB	764	01374	ETA	780	01414	MONE	810	01452	MTHR	870	01546
MTWO	834	01502	NONE	903	01607	NTHR	942	01656	NTWO	917	01625	SILAM	998	01746
S2LAM	1031	02007	S3LAM	1067	02053	SLAM	1106	02122	WCT	1163	02213	WLAM	1132	02154

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
30	29	00023	31	31	00026	99	36	00046	98	37	00050	33	39	00054
34	41	00061	32	43	00066	100	48	00124	101	57	00170	102	58	00172
103	59	00200	104	60	00205	105	62	00213	1105	65	00251	106	68	00266
107	69	00271	1108	71	00300	108	72	00310	1300	75	00320	1301	76	00325
1302	78	00332	120	79	00340	1140	82	00354	197	83	00361	198	86	00376
199	87	00404	200	89	00410	1199	96	00446	1200	97	00451	1201	100	00472
1202	101	00476	1203	102	00502	209	111	00576	210	113	00604	211	115	00621
212	117	00627	259	136	01061	260	140	01100	261	142	01120	262	146	01141
300	160	01300	306	165	01334	301	166	01340	307	167	01345			

```
C      SUBROUTINE TABLE
C      SUBROUTINE TO INTERP. (EXTRAP.) IN DENSITY TABLE FOR GIVEN S
       SUBROUTINE TABLE (K,XLAM,SS,RHOS,NPT,XLAMW)
       DIMENSION SS(5,20),Y(20),DEL(20),XLAMW(20)
       FREQUENCY15(10),49(10,0,5),56(5,0,5)
   15  DO 20 J=2,NPT
   20  DEL(J)=(SS(K,J-1)-SS(K,J))/(XLAMW(J-1)-XLAMW(J))
   49  IF(XLAMW(NPT)-XLAM) 55,50,75
   50  YA=SS(K,NPT)
       GO TO 100
   55  DO 65 KK=2,20
   56  IF(XLAMW(KK)-XLAM) 58,57,65
   57  YA=SS(K,KK)
       GO TO 100
   58  YA=SS(K,KK-1)-DEL(KK)*(XLAMW(KK-1)-XLAM)
       GO TO 100
   65  CONTINUE
C   EXTRAPOLATE
   75  YA=SS(K,NPT)-DEL(NPT)*(XLAMW(NPT)-XLAM)
  100  RHOS=EXPF(YA)
       RETURN
       END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

STORAGE NOT USED BY PROGRAM

DEC	OCT	DEC	OCT
204	00314	32561	77461

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
DEL	183	00267	Y	203	00313									

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
KK	163	00243	YA	162	00242									

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
1)	154	00232	2)	142	00216	6)	144	00220	9)	150	00226	A)101	129	00201
C)01	158	00236	C)02	159	00237	C)101	160	00240	C)102	161	00241	D)103	73	00111
E)106	121	00171	E)13	72	00110	E)14	77	00115						

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
EXP	0	00000												

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

EXP

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
15	5	00062	20	6	00071	49	7	00103	50	8	00112	55	10	00116
56	11	00125	57	12	00132	58	14	00137	65	16	00152	75	17	00157
100	18	00172												

F. Input

The input to this program are simply the cards output from the lambda punch. Each constituent can be run separately or they can all be run at the same time. Any number of L lines may be run also. A counter card must state the number of points to each L line which is run. Counter cards are included in the output from the lambda punch but they must be corrected if the number of points per L line are changed before running this program. Input occurs on tape 2.

1. Input card description

	Columns	Mode	Quantity	Units	Description
Counter Card	1-2	I	NPT	-	B-L-λ, density card pair counter
B-L-λ Card	1-8	F	EL	earth radii	magnetic field line
	9-16	F	B(I)	gauss	magnetic induction
	17-24	F	XLAM(I)	degrees	latitude
	73-80	-	-	-	constituent name
Density Card	1-12	E	SS(1,I)	atoms/cm^3	density for flux model 1
	13-24	E	SS(2,I)	"	" " 2
	25-36	E	SS(3,I)	"	" " 3
	37-48	E	SS(4,I)	"	" " 4
	49-60	E	SS(5,I)	"	" " 5
	73-80	-	-	-	constituent name

2. Sample

GENERAL PURPOSE DATA SHEET

Problem: INPUT – "BOUNCE" AVERAGE CALCULATION

Sponsor: TAPE 2 | Date: SAMPLE | Page: | of:

4						
1.14200	0.23890	9.836				OXYGEN
0.9347E 11	0.9836E 11		0.1081E 12	0.1288E 12	0.1551E 12	OXYGEN
1.14200	0.22738	7.740				OXYGEN
0.5882E 09	0.5626E 09		0.5318E 09	0.4901E 09	0.4558E 09	OXYGEN
1.14200	0.23465	9.129				OXYGEN
0.1471E 11	0.1508E 11		0.1582E 11	0.1733E 11	0.1910E 11	OXYGEN
1.14200	0.21968	5.867				OXYGEN
0.7599E 08	0.5826E 08		0.4130E 08	0.2470E 08	0.1572E 08	OXYGEN
7						
1.17005	0.23991	12.444				OXYGEN
0.1205E 12	0.1270E 12		0.1400E 12	0.1677E 12	0.2031E 12	OXYGEN
1.17005	0.23467	11.752				OXYGEN
0.1349E 11	0.1380E 11		0.1441E 11	0.1562E 11	0.1703E 11	OXYGEN
1.17005	0.22956	11.022				OXYGEN
0.1563E 10	0.1541E 10		0.1513E 10	0.1476E 10	0.1443E 10	OXYGEN
1.17005	0.21976	9.420				OXYGEN
0.8147E 08	0.6556E 08		0.4948E 08	0.3218E 08	0.2184E 08	OXYGEN
1.17005	0.20973	7.346				OXYGEN
0.2206E 08	0.1353E 08		0.6905E 07	0.2469E 07	0.9461E 06	OXYGEN
1.17005	0.20474	6.014				OXYGEN
0.1256E 08	0.6731E 07		0.2815E 07	0.7430E 06	0.2128E 06	OXYGEN
1.17005	0.20137	4.894				OXYGEN
0.8589E 07	0.4184E 07		0.1520E 07	0.3201E 06	0.7391E 05	OXYGEN

GSFC FORM 541-1 (July - 60)

G. Output

Output from this program appears on logical tapes 3 and 5. Tape 3 gives results which are to be printed. Each page is devoted to a single L line for a specific constituent. Of the eleven columns which cross the page, the first contains the constituent name. This is followed by the value of L, the mirror latitude λ_0, the corresponding value of B, the flux model number, the "bounce" average number density, the longitudinally averaged number density, the ratio of the longitudinally averaged number density to the "bounce" averaged number density, the value of $\int_0^{\lambda_0} \rho(\lambda)A(\lambda)\, d\lambda$, the value of $\int_0^{\lambda_0} A(\lambda)d\lambda$ and the third term of SLAMF($\lambda_0 + 2h, \lambda_0$). All these additional values are included as an intermediate check on the process.

Tape 5 contains the data to be punched. The counter card has been eliminated and all that remains are the B-L-λ card and the "bounce" average density card with constituent names punched to the right of each card.

1. Tape 3 Sample

CONSTITUENT	L	MIRROR LAT.	B	FLUX	AVERAGE RHO	RHO AT MIRROR LATITUDE	RHO/AV. RHO	INTEGRAL OF RHO*A DLAM	INTEGRAL OF A DLAM	S3 (LAM.) FOR INT. INTERVAL
HELIUM	1.1420	8.973	0.2338							
				1	1.0923E 06	2.6674E 06	2.4419E 00	8.2198E 05	7.5248E-01	-9.9948E-08
				2	1.0098E 06	2.5110E 06	2.4866E 00	7.5985E 05	7.5248E-01	-9.9948E-08
				3	8.9910E 05	2.3114E 06	2.5707E 00	6.7656E 05	7.5248E-01	-9.9948E-08
				4	7.6346E 05	2.0678E 06	2.7084E 00	5.7449E 05	7.5248E-01	-9.9948E-08
				5	6.7422E 05	1.9022E 06	2.8213E 00	5.0734E 05	7.5248E-01	-9.9948E-08
HELIUM	1.1420	6.973	0.2239							
				1	6.2564E 05	9.2931E 05	1.4654E 00	4.6787E 05	7.4783E-01	-9.9891E-08
				2	5.5698E 05	8.6498E 05	1.5474E 00	4.1802E 05	7.4783E-01	-9.9891E-08
				3	4.6831E 05	7.7118E 05	1.6467E 00	3.5022E 05	7.4783E-01	-9.9891E-08
				4	3.5807E 05	6.4768E 05	1.8088E 00	2.6778E 05	7.4783E-01	-9.9891E-08
				5	2.8677E 05	5.6219E 05	1.9604E 00	2.1446E 05	7.4783E-01	-9.9891E-08
HELIUM	1.1420	4.973	0.2168							
				1	4.7748E 05	6.4203E 05	1.3446E 00	3.5538E 05	7.4428E-01	-9.9846E-08
				2	4.1045E 05	5.7017E 05	1.3891E 00	3.0549E 05	7.4428E-01	-9.9846E-08
				3	3.2262E 05	4.7128E 05	1.4608E 00	2.4012E 05	7.4428E-01	-9.9846E-08
				4	2.2101E 05	3.4903E 05	1.5793E 00	1.6449E 05	7.4428E-01	-9.9846E-08
				5	1.5864E 05	2.6842E 05	1.6920E 00	1.1807E 05	7.4428E-01	-9.9846E-08
HELIUM	1.1420	2.973	0.2122							
				1	3.6833E 05	4.4356E 05	1.2042E 00	2.7325E 05	7.4185E-01	-9.9703E-08
				2	3.0540E 05	3.7584E 05	1.2306E 00	2.2656E 05	7.4185E-01	-9.9703E-08
				3	2.2619E 05	2.8801E 05	1.2733E 00	1.6780E 05	7.4185E-01	-9.9703E-08
				4	1.3990E 05	1.8809E 05	1.3445E 00	1.0378E 05	7.4185E-01	-9.9703E-08
				5	9.0697E 04	1.2816E 05	1.4130E 00	6.7283E 04	7.4185E-01	-9.9703E-08
HELIUM	1.1420	0.973	0.2099							
				1	2.8749E 05	3.0644E 05	1.0659E 00	2.1293E 05	7.4064E-01	-9.5809E-08
				2	2.3060E 05	2.4774E 05	1.0743E 00	1.7079E 05	7.4064E-01	-9.5809E-08
				3	1.6177E 05	1.7601E 05	1.0880E 00	1.1981E 05	7.4064E-01	-9.5809E-08
				4	9.1254E 04	1.0136E 05	1.1107E 00	6.7586E 04	7.4064E-0	-9.5809E-08
				5	5.4019E 04	6.1189E 04	1.1327E 00	4.0009E 04	7.4064E-0	-9.5809E-08

CONSTITUENT	L	MIRROR LAT.	B	FLUX	AVERAGE RHO	RHO AT MIRROR LATITUDE	RHO/AV. RHO	INTEGRAL OF RHO*A DLAM	INTEGRAL OF A DLAM	S3 (LAM.) FOR INT. INTERVAL
HELIUM	1.1700	11.963	0.2362							
				1	1.1605E 06	3.9406E 06	3.3955E 00	8.8337E 05	7.6118E-01	-9.9974E-08
				2	1.0554E 06	3.6392E 06	3.4480E 00	8.0338E 05	7.6118E-01	-9.9974E-08
				3	9.2413E 05	3.2852E 06	3.5549E 00	7.0342E 05	7.6118E-01	-9.9974E-08
				4	7.7353E 05	2.8870E 06	3.7323E 00	5.8879E 05	7.6118E-01	-9.9974E-08
				5	6.7968E 05	2.6315E 06	3.8716E 00	5.1736E 05	7.6118E-01	-9.9974E-08
HELIUM	1.1700	9.963	0.2229							
				1	5.7759E 05	8.6715E 05	1.5013E 00	4.3617E 05	7.5516E-01	-9.9922E-08
				2	4.9857E 05	7.9498E 05	1.5945E 00	3.7650E 05	7.5516E-01	-9.9922E-08
				3	3.9851E 05	6.9577E 05	1.7460E 00	3.0093E 05	7.5516E-01	-9.9922E-08
				4	2.8489E 05	5.7327E 05	2.0123E 00	2.1513E 05	7.5516E-01	-9.9922E-08
				5	2.1614E 05	4.9280E 05	2.2800E 00	1.6322E 05	7.5516E-01	-9.9922E-08
HELIUM	1.1700	7.963	0.2124							
				1	4.9387E 05	6.0193E 05	1.2188E 00	3.7041E 05	7.5001E-01	-9.9847E-08
				2	4.1153E 05	5.2299E 05	1.2708E 00	3.0865E 05	7.5001E-01	-9.9847E-08
				3	3.0989E 05	4.2009E 05	1.3556E 00	2.3242E 05	7.5001E-01	-9.9847E-08
				4	1.9767E 05	2.9864E 05	1.5108E 00	1.4826E 05	7.5001E-01	-9.9847E-08
				5	1.3185E 05	2.2157E 05	1.6805E 00	9.8892E 04	7.5001E-01	-9.9847E-08
HELIUM	1.1700	5.963	0.2046							
				1	4.4908E 05	5.0865E 05	1.1326E 00	3.3497E 05	7.4590E-01	-9.9979E-08
				2	3.6544E 05	4.2540E 05	1.1641E 00	2.7259E 05	7.4590E-01	-9.9979E-08
				3	2.6457E 05	3.2122E 05	1.2142E 00	1.9734E 05	7.4590E-01	-9.9979E-08
				4	1.5665E 05	2.0438E 05	1.3047E 00	1.1684E 05	7.4590E-01	-9.9979E-08
				5	9.5889E 04	1.3457E 05	1.4034E 00	7.1524E 04	7.4590E-01	-9.9979E-08
HELIUM	1.1700	3.963	0.1991							
				1	4.1452E 05	4.5089E 05	1.0878E 00	3.0794E 05	7.4290E-01	-9.9457E-08
				2	3.3077E 05	3.6665E 05	1.1085E 00	2.4573E 05	7.4290E-01	-9.9457E-08
				3	2.3198E 05	2.6479E 05	1.1414E 00	1.7234E 05	7.4290E-01	-9.9457E-08
				4	1.2947E 05	1.5551E 05	1.2011E 00	9.6186E 04	7.4290E-01	-9.9457E-08
				5	7.4132E 04	9.3876E 04	1.2663E 00	5.5073E 04	7.4290E-01	-9.9457E-08
HELIUM	1.1700	1.963	0.1959							
				1	3.8312E 05	3.9969E 05	1.0432E 00	2.8393E 05	7.4110E-01	-9.9592E-08
				2	2.9999E 05	3.1601E 05	1.0534E 00	2.2233E 05	7.4110E-01	-9.9592E-08
				3	2.0408E 05	2.1828E 05	1.0695E 00	1.5125E 05	7.4110E-01	-9.9592E-08
				4	1.0770E 05	1.1833E 05	1.0987E 00	7.9820E 04	7.4110E-01	-9.9592E-08
				5	5.7930E 04	6.5489E 04	1.1305E 00	4.2932E 04	7.4110E-01	-9.9592E-08

2. Tape 5

a. Output card description

	Columns	Mode	Quantity	Units	Description
B-L-\ Card	1-8	F	EL	earth radii	magnetic field line
	9-16	F	BSUBO	gauss	magnetic induction
	17-24	F	XLAMP	degrees	latitude
	73-80	-	-	-	constituent name
Density Card	1-12	E	DENB(1)	atoms/cm^3	density for flux model 1
	13-24	E	DENB(2)	"	" " 2
	25-36	E	DENB(3)	"	" " 3
	37-48	E	DENB(4)	"	" " 4
	49-60	E	DENB(5)	"	" " 5
	73-80	-	-	-	constituent name

b. Sample

GENERAL PURPOSE DATA SHEET

Problem: OUTPUT – "BOUNCE" AVERAGE CALCULATION

Sponsor: TAPE 5 | Date: SAMPLE | Page ___ of ___

1.14200	0.23376	8.973			OXYGEN
0.1833E 10	0.1838E 10	0.1870E 10	0.1952E 10	0.2058E 10	OXYGEN
1.14200	0.22394	6.973			OXYGEN
0.7484E 08	0.6200E 08	0.4898E 08	0.3489E 08	0.2613E 08	OXYGEN
1.14200	0.21680	4.973			OXYGEN
0.1003E 08	0.6560E 07	0.3809E 07	0.1709E 07	0.8531E 06	OXYGEN
1.14200	0.21215	2.973			OXYGEN
0.1468E 07	0.7595E 06	0.3248E 06	0.9186E 05	0.3057E 05	OXYGEN
1.14200	0.20988	0.973			OXYGEN
0.2584E 06	0.1078E 06	0.3466E 05	0.6337E 04	0.1430E 04	OXYGEN
1.17005	0.23623	11.963			OXYGEN
0.3511E 10	0.3588E 10	0.3751E 10	0.4089E 10	0.4494E 10	OXYGEN
1.17005	0.22287	9.963			OXYGEN
0.5199E 08	0.4121E 08	0.3109E 08	0.2097E 08	0.1500E 08	OXYGEN
1.17005	0.21242	7.963			OXYGEN
0.1389E 08	0.8186E 07	0.4068E 07	0.1470E 07	0.5909E 06	OXYGEN
1.17005	0.20457	5.963			OXYGEN
0.7013E 07	0.3388E 07	0.1243E 07	0.2772E 06	0.6986E 05	OXYGEN
1.17005	0.19912	3.963			OXYGEN
0.4157E 07	0.1725E 07	0.5010E 06	0.7570E 05	0.1305E 05	OXYGEN
1.17005	0.19592	1.963			OXYGEN
0.2545E 07	0.9191E 06	0.2156E 06	0.2271E 05	0.2735E 04	OXYGEN

GSFC FORM 541-1 (July - 60)

H. Running Time

This program will take about twenty minutes for every two L lines if five constituents are run together.

VI. R, Σ CALCULATION AND FLUX ELIMINATION

A. Introduction

This program computes the atmospheric scale factor R and the atmospheric loss parameter Σ. The scale factor is used in the next program in order to relate the energy loss of the atmosphere with the measured energy loss data.[7] The atmospheric loss parameter appears in the calculation of the proton loss term of the conservation equation in the next section. Solar flux S is eliminated from both R and Σ by subroutine ELIM. This subroutine logrithmically interpolates Figure 9 to yield R and Σ as functions of time rather than solar flux S. B, L, and λ and the "bounce" averaged number densities are input to this program. B, L, λ, R and Σ are output for use in the conservation equation calculation.

B. Equations

For a given B and solar flux model, the "bounce" average number densities of the five constituents are put together to form an average number of equivalent oxygen atoms/cm^3 by the equation OXY = RHO/8 where

$$\text{RHO} = 14\bar{\bar{\bar{n}}}^{(N_2)} + 8\bar{\bar{\bar{n}}}^{(O)} + 2\bar{\bar{\bar{n}}}^{(He)} + 16\bar{\bar{\bar{n}}}^{(O_2)} + \bar{\bar{\bar{n}}}^{(H)}$$

and $\bar{\bar{\bar{n}}}^{(J)}$ is the "bounce" average number density for the J^{th} constituent.

The scale factor R is given by the equation

$$R(L, B, t) = \frac{(\text{OXYGEN ATOMS/CM}^3)\text{ATMOS}}{(\text{OXYGEN ATOMS/CM}^3)\text{NTP}}$$

where (oxygen atoms/cm^3) ATMOS is OXY and (oxygen atoms/cm^3) NTP comes from the following relationship of an ideal gas:

$$22414\ \text{cm}^3/\text{Kmole} = .60249 \times 10^{24}\ \text{atoms/Kmole}$$

or (oxygen atoms/cm^3)$_{NTP}$ $= 2.69 \times 10^{19}$. Figure 7 is an example of the output from this program. It shows the time dependence of the atmosphere in terms of the scale factor R .

Sigma is given by the equation

$$\sum = \frac{\bar{\bar{n}}^{(He)}}{2} \sigma(He) + \left[\frac{\bar{\bar{n}}^{(0)} + 2\bar{\bar{n}}^{(0_2)}}{8} + \frac{2\bar{\bar{n}}^{(N_2)}}{7}\right] \sigma(0) \text{ atoms/cm.}$$

where σ(He) and σ(0) are the interaction cross sections of helium and oxygen respectively. Figure 8 again illustrates output from this program. It shows $\log_e \Sigma$ as a function of time for various values of B at an L of 1.25 earth radii.

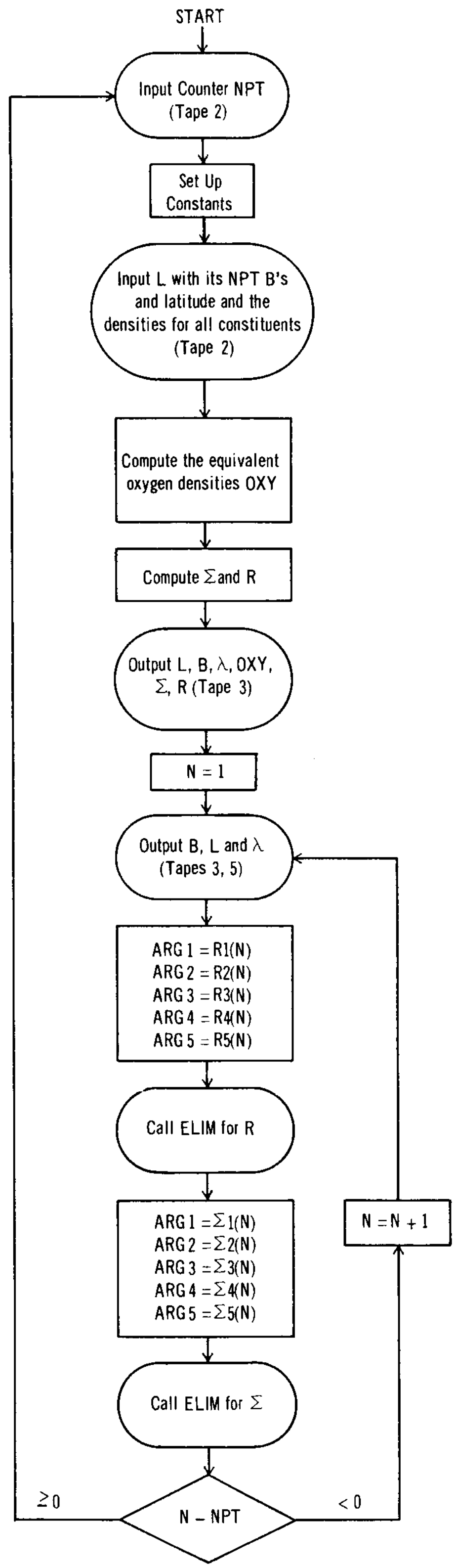
C. Mnemonics

Quantity	Description	Units
NPT	counter of the number of B's to a given L	-
C	(oxygen atoms/cm^3) NTP = 2.69×10^{19}	atoms/cm^3
SIGHE	σ(He) = $.143 \times 10^{-24}$	cm^2
SIGO	σ(0) = $.36 \times 10^{-24}$	"
EL	magnetic field line L	earth radii
B(N)	Nth magnetic induction B for a given L line	gauss
ALATO(N)	latitude corresponding to B(N)	degrees
HE1(N),..., HE5(N)	helium "bounce" averaged densities for B(N) and the five flux models	atoms/cm^3
01(N), ..., 05(N)	oxygen "bounce" averaged densities for B(N) and the five flux models	atoms/cm^3
021(N), ..., 025(N)	molecular oxygen "bounce" averaged densities for B(N) and the five flux models	atoms/cm^3
AN21(N), ..., AN25(N)	nitrogen "bounce" averaged densities for B(N) and the five flux models	atoms/cm^3

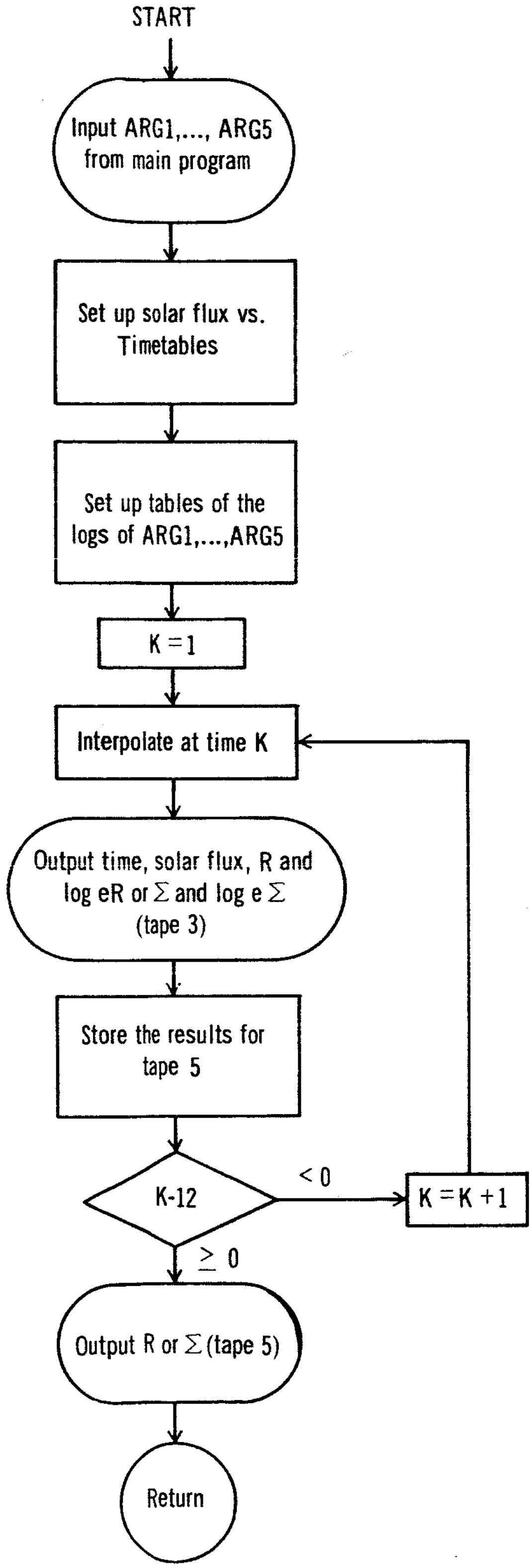
Quantity	Description	Units
H1(N), . . ., H5(N)	hydrogen "bounce" averaged densities for B(N) and the five flux models	atoms/cm^3
RHO1(N), . . .,RHO5(N)	RHO for B(N) and the five flux models (see equation on page 105)	atoms/cm^3
OXY1(N), . . ., OXY5(N)	OXY for B(N) and the five flux models (see equation on page 105)	atoms/cm^3
SIG1(N), . . ., SIG5(N)	atmospheric loss parameter Σ for B(N) and the five flux models	atoms/cm
RAT1(N), . . ., RAT5(N)	scale factor R for B(N) and the five flux models	-
LCNT	counter to notify subroutine whether it is working with R or Σ	-
ARG1	temporary storage of RAT1 or SIG1 depending on LCNT	depends on LCNT
ARG2	temporary storage of RAT2 or SIG2 depending on LCNT	depends on LCNT
ARG3	temporary storage of RAT3 or SIG3 depending on LCNT	depends on LCNT
ARG4	temporary storage of RAT4 or SIG4 depending on LCNT	depends on LCNT
ARG5	temporary storage of RAT5 or SIG5 depending on LCNT	depends on LCNT

D. Flow Charts

1. Main program



2. Subroutine Elim.



E. Fortran Listing

```
RATIO

C      RATIO,SIGMA CALCULATION AND FLUX ELIMINATION
       DIMENSION  B(12),RHO1(12),RHO2(12),RHO3(12),RHO4(12),RHO5(12),OXY1
      1(12),OXY2(12),OXY3(12),OXY4(12),OXY5(12),RAT1(12),RAT2(12),RAT3(12
      2),RAT4(12),RAT5(12),ALATO(12)
       DIMENSION ST(12),R(5),Y(5),S(5)
       DIMENSION AN21(12),AN22(12),AN23(12),AN24(12),AN25(12)
       DIMENSION C1(12),C2(12),C3(12),C4(12),C5(12)
       DIMENSION HE1(12),HE2(12),HE3(12),HE4(12),HE5(12)
       DIMENSION O21(12),O22(12),O23(12),O24(12),O25(12)
       DIMENSION H1(12),H2(12),H3(12),H4(12),H5(12),XS(12)
       DIMENSION SIG1(12),SIG2(12),SIG3(12),SIG4(12),SIG5(12)
       COMMON LONT,ARG1,ARG2,ARG3,ARG4,ARG5
     1 FORMAT (2F8.5,F8.3)
     2 FORMAT (4H OXY,6X,5E12.4)
     3 FORMAT (1H1)
     4 FORMAT (5E12.6)
     5 FORMAT (12X,2HL=F8.5,4X,2HB=F8.5,4X,4HLAT=F6.3)
     6 FORMAT (6H RATIO,4X,5E12.4)
     7 FORMAT (6H SIGMA,4X,5E12.4////)
     8 FORMAT (5E12.4)
     9 FORMAT (I2)
    10 FORMAT (14X,5HS=250,7X,5HS=200,7X,5HS=150,7X,5HS=100,7X,4HS=70)
    11 FORMAT (5HOLAT=F8.4,4X,2HL=F8.4,4X,2HB=F8.4)
    12 FORMAT (3F8.4)
    13 FORMAT (//)
   100 READ INPUT TAPE 2,9,NPT
       WRITE OUTPUT TAPE 3,3
       WRITE OUTPUT TAPE 3,10
       C=2.69E19
       SIGHE=.143E-24
       SIGO=.36E-24
       DO 16 N=1,NPT
       READ INPUT TAPE 2,1,EL,B(N),ALATO(N)
       READ INPUT TAPE 2,8,HE1(N),HE2(N),HE3(N),HE4(N),HE5(N)
    16 CONTINUE
       DO 17 N=1,NPT
       READ INPUT TAPE 2,1,EL,B(N),ALATO(N)
       READ INPUT TAPE 2,8,O1(N),O2(N),O3(N),O4(N),O5(N)
    17 CONTINUE
       DO 18 N=1,NPT
       READ INPUT TAPE 2,1,EL,B(N),ALATO(N)
       READ INPUT TAPE 2,8,O21(N),O22(N),O23(N),O24(N),O25(N)
    18 CONTINUE
       DO 19 N=1,NPT
       READ INPUT TAPE 2,1,EL,B(N),ALATO(N)
       READ INPUT TAPE 2,8,AN21(N),AN22(N),AN23(N),AN24(N),AN25(N)
    19 CONTINUE
       DO 14 N=1,NPT
       READ INPUT TAPE 2,1,EL,B(N),ALATO(N)
       READ INPUT TAPE 2,8,H1(N),H2(N),H3(N),H4(N),H5(N)
    14 CONTINUE
       DO 15 N=1,NPT
       RHO1(N)=14.*AN21(N)+8.*C1(N)+2.*HE1(N)+16.*O21(N)+H1(N)
       RHO2(N)=14.*AN22(N)+8.*O2(N)+2.*HE2(N)+16.*O22(N)+H2(N)
       RHO3(N)=14.*AN23(N)+8.*O3(N)+2.*HE3(N)+16.*O23(N)+H3(N)
```

```
      RHO4(N)=14.*AN24(N)+8.*O4(N)+2.*FE4(N)+16.*C24(N)+H4(N)
      RHO5(N)=14.*AN25(N)+8.*O5(N)+2.*FE5(N)+16.*C25(N)+H5(N)
 15   CONTINUE
      DO 20 N=1,NPT
      OXY1(N)=RHO1(N)/8.
      OXY2(N)=RHO2(N)/8.
      OXY3(N)=RHO3(N)/8.
      OXY4(N)=RHO4(N)/8.
      OXY5(N)=RHO5(N)/8.
 20   CONTINUE
      DO 25 J=1,NPT
      SIG1(J)=FE1(J)*SIGFE/2.+((O1(J)+2.*C21(J))/8.+2.*AN21(J)/7.)*SIGC
      SIG2(J)=FE2(J)*SIGFE/2.+((O2(J)+2.*C22(J))/8.+2.*AN22(J)/7.)*SIGC
      SIG3(J)=FE3(J)*SIGFE/2.+((O3(J)+2.*C23(J))/8.+2.*AN23(J)/7.)*SIGC
      SIG4(J)=FE4(J)*SIGFE/2.+((O4(J)+2.*C24(J))/8.+2.*AN24(J)/7.)*SIGC
      SIG5(J)=FE5(J)*SIGFE/2.+((O5(J)+2.*C25(J))/8.+2.*AN25(J)/7.)*SIGC
 25   CONTINUE
      DO 30 N=1,NPT
      RAT1(N)=OXY1(N)/C
      RAT2(N)=OXY2(N)/C
      RAT3(N)=OXY3(N)/C
      RAT4(N)=OXY4(N)/C
      RAT5(N)=OXY5(N)/C
 30   CONTINUE
      DO 40 N=1,NPT
      WRITE OUTPUT TAPE 3,5,EL,B(N),ALATO(N)
      WRITE OUTPUT TAPE 3,2,OXY1(N),OXY2(N),OXY3(N),OXY4(N),OXY5(N)
      WRITE OUTPUT TAPE 3,6,RAT1(N),RAT2(N),RAT3(N),RAT4(N),RAT5(N)
      WRITE OUTPUT TAPE 3,7,SIG1(N),SIG2(N),SIG3(N),SIG4(N),SIG5(N)
 40   CONTINUE
      WRITE OUTPUT TAPE 3,3
      DO 50 N=1,NPT
      LCNT=0
      WRITE OUTPUT TAPE 3,11,ALATO(N),EL,B(N)
      WRITE OUTPUT TAPE 5,12,ALATO(N),EL,B(N)
      ARG1=RAT1(N)
      ARG2=RAT2(N)
      ARG3=RAT3(N)
      ARG4=RAT4(N)
      ARG5=RAT5(N)
      CALL ELIM
      LCNT=1
      WRITE OUTPUT TAPE 3,13
      ARG1=SIG1(N)
      ARG2=SIG2(N)
      ARG3=SIG3(N)
      ARG4=SIG4(N)
      ARG5=SIG5(N)
      CALL ELIM
 50   CONTINUE
      GO TO 100
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                                  STORAGE NOT USED BY PROGRAM

        DEC   OCT                DEC   OCT
       1194 02252              32555 77453

                    STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
ARG1  32560 77460       ARG2  32559 77457       ARG3  32558 77456       ARG4  32557 77455       ARG5  32556 77454
LCNT  32561 77461

              STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
ALATO  1001 01751       AN21   962 01702       AN22   950 01666       AN23   938 01652       AN24   926 01636
AN25    914 01622          B  1193 02251         H1   722 01322         H2   710 01306         H3   698 01272
  H4    686 01256         H5   674 01242        HE1   842 01512        HE2   830 01476        HE3   818 01462
 HE4    806 01446        HE5   794 01432         C1   902 01606        O21   782 01416        O22   770 01402
 O23    758 01366        O24   746 01352        C25   734 01336         C2   850 01572         C3   878 01556
  O4    866 01542         C5   854 01526       OXY1  1121 02141       OXY2  1109 02125       OXY3  1097 02111
OXY4   1085 02075       OXY5  1073 02061       RAT1  1061 02045       RAT2  1049 02031       RAT3  1037 02015
RAT4   1025 02001       RAT5  1013 01765       RHO1  1181 02235       RHO2  1169 02221       RHO3  1157 02205
RHO4   1145 02171       RHO5  1133 02155          R   977 01721       SIG1   650 01212       SIG2   638 01176
SIG3    626 01162       SIG4   614 01146       SIG5   602 01132          S   967 01707         ST   989 01735
  XS    662 01226          Y   972 01714

          STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
   C    590 01116         EL   589 01115        NPT   588 01114      SIGHE   587 01113       SIGO   586 01112

                   SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

        EFN   LOC                EFN   LOC                EFN   LOC                EFN   LOC                EFN   LOC
 8)1      1 01104        8)2      2 01101        8)3      3 01075        8)4      4 01074        8)5      5 01072
 8)6      6 01063        8)7      7 01057        8)8      8 01052        8)9      9 01050        8)A     10 01047
 8)B     11 01035        8)C     12 01026        8)D     13 01024

                   LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
  1)    581 01105          2)   513 01001         3)   518 01006         4) 32767 77777         6)   526 01016

                               LOCATIONS OF NAMES IN TRANSFER VECTOR

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
ELIM      5 00005       (FIL)      4 00004      (FPT)      0 00000      (RTN)      2 00002      (STH)      3 00003
(TSH)     1 00001

                       ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

ELIM       (FIL)      (FPT)      (RTN)      (STH)      (TSH)
```

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
100	24	00013	16	36	00072	17	42	00127	18	48	00164	19	54	00221
14	60	00256	15	67	00403	20	74	00427	25	81	00566	30	88	00612
40	98	00703	50	120	00776									

```
C     SUBROUTINE TO ELIMINATE SOLAR FLUX
      SUBROUTINE ELIM
      DIMENSION ST(12),R(5),Y(5),S(5),XS(12)
      COMMON LCNT,ARG1,ARG2,ARG3,ARG4,ARG5
    1 FORMAT (//////)
    2 FORMAT(5E12.6)
    3 FORMAT(I3,4X,1F10.2,2E20.5)
    4 FORMAT (5H TIME,7X,5HSOLAR,12X,6HLOG OF,15X,5HRATIO/6H (YRS),6X,4H
     1FLUX,13X,5HRATIO)
    5 FORMAT (5H TIME,7X,5HSOLAR,12X,6HLOG OF,15X,5HSIGMA/6H (YRS),6X,4H
     1FLUX,13X,5HSIGMA)
    6 FORMAT(6E10.4)
      R(1) = ARG1
      R(2) = ARG2
      R(3) = ARG3
      R(4) = ARG4
      R(5) = ARG5
      ST(1)= 70.
      ST(2)= 75.
      ST(3)= 130.
      ST(4)= 230.
      ST(5)= 250.
      ST(6)= 220.
      ST(7)= 165.
      ST(8)= 140.
      ST(9)= 105.
      ST(10)=90.
      ST(11)= 75.
      ST(12)= 70.
      S(1)=250.
      S(2)=200.
      S(3)=150.
      S(4)=100.
      S(5)=70.
      IF (LCNT) 14,14,17
   14 WRITE OUTPUT TAPE 3,4
      GO TO 18
   17 WRITE OUTPUT TAPE 3,5
   18 DO 20 J=1,5
      A=R(J)
      Y(J)=LOGF(A)
   20 CONTINUE
      DO 30 K=1,12
      HA=ST(K)
      IF(HA-250.)40,41,41
   40 IF(HA-70.)42,42,43
   41 ANS=Y(1)
      GO TO 1000
   42 ANS=Y(5)
      GO TO 1000
   43 DO 50 J=1,5
      IF(HA-S(J))50,51,52
   51 ANS=Y(J)
      GO TO 1000
   52 H1=S(J)
```

```
      Y1=Y(J)
      H0=S(J-1)
      Y0=Y(J-1)
      ANS=Y1-(Y1-Y0)*(H1-HA)/(H1-H0)
      GO TO 1000
50    CONTINUE
1000  X=EXPF(ANS)
      ITIME=K-1
      WRITE OUTPUT TAPE 3,3,ITIME,HA,ANS,X
      XS(K)=X
30    CONTINUE
      WRITE OUTPUT TAPE 3,1
      WRITE OUTPUT TAPE 5,6,XS(1),XS(2),XS(3),XS(4),XS(5),XS(6)
      WRITE OUTPUT TAPE 5,6,XS(7),XS(8),XS(9),XS(10),XS(11),XS(12)
      RETURN
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                                   STORAGE NOT USED BY PROGRAM

       DEC    OCT                  DEC    OCT
       324  00504                32555  77453

                     STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

       DEC    OCT                  DEC    OCT                DEC    OCT                DEC    OCT                DEC    OCT
  ARG1 32560 77460            ARG2 32559 77457          ARG3 32558 77456          ARG4 32557 77455          ARG5 32556 77454
  LCNT 32561 77461

                STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

       DEC    OCT                  DEC    OCT                DEC    OCT                DEC    OCT                DEC    OCT
     R  311 00467              S   301 00455           ST   323 00503           XS   296 00450            Y   306 00462

          STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

       DEC    OCT                  DEC    OCT                DEC    OCT                DEC    OCT                DEC    OCT
   ANS  284 00434              A   283 00433           F0   282 00432           H1   281 00431           HA   280 00430
 ITIME  279 00427              J   278 00426            K   277 00425            X   276 00424           YC   275 00423
    Y1  274 00422

                      SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

       EFN    LOC                  EFN    LOC                EFN    LOC                EFN    LOC                EFN    LOC
   8)1    1 00414            8)2    2 00412           8)3    3 00410           8)4    4 00404           8)5    5 00367
   8)6    6 00352

                     LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

       DEC    OCT                  DEC    OCT                DEC    OCT                DEC    OCT                DEC    OCT
    1)  269 00415             2)   211 00323           3)   214 00326           6)   227 00343         C)G1   272 00420
  C)G2  273 00421          D)206    82 00122        D)200   141 00215          E)C   107 00153          E)E   137 00211

                              LOCATIONS OF NAMES IN TRANSFER VECTOR

       DEC    OCT                  DEC    OCT                DEC    OCT                DEC    OCT                DEC    OCT
   EXP    3 00003            LOG     2 00002        (FIL)     1 00001        (STH)     0 00000

                          ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

 EXP         LOG          (FIL)       (STH)

           EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

  EFN    IFN   LOC          EFN    IFN   LOC          EFN    IFN   LOC          EFN    IFN   LOC          EFN    IFN   LOC
   14     34 00074           17     36 00101           18     37 00105           20     40 00115           40     44 00131
   41     45 00136           42     47 00141           43     49 00144           51     51 00154           52     53 00161
   50     59 00212         1000     60 00216           30     65 00250
```

F. Input

Input to this program are the "bounce" average density cards together with the B-L-λ cards output from the last program. The cards are rearranged by L line rather than by constituent as they have been arranged in previous programs. A counter card must again be inserted in order to inform the computer of the number of card pairs per constituent for a given L-line. All input is on tape 2. For a given L-line the constituents must be in the following order:

(1) helium,

(2) oxygen,

(3) molecular oxygen,

(4) nitrogen,

(5) hydrogen.

1. Input Card Description

	Columns	Mode	Quantity	Units	Description
Counter Card	1-2	I	NPT	-	B-L-λ and density card pair counter
B-L-λ Card	1-8	F	EL	earth radii	magnetic field line
	9-16	F	B	gauss	magnetic induction
	17-24	F	ALATO	degrees	latitude
	73-80	-	-	-	constituent name
Density Card	1-12	E	*	atoms/cm^3	density for flux model 1
	13-24	E	*	"	density for flux model 2
	25-36	E	*	"	density for flux model 3
	37-48	E	*	"	density for flux model 4
	49-60	E	*	"	density for flux model 5
	73-80	-	-	-	constituent name

*All of the five constituents use the same card format here. Therefore the quantity on a given density card (HE, 0, 02 N2 or H) will depend on the constituent name listed in columns 73-80 of that same card.

2. Sample

GENERAL PURPOSE DATA SHEET

Problem: INPUT – R, Σ CALCULATION AND FLUX ELIMINATION

Sponsor: TAPE 2 | Date: SAMPLE | Page | of

5					
1.14200	0.23376	8.973			HELIUM
0.1092E 07	0.1010E 07	0.8991E 06	0.7635E 06	0.6742E 06	HELIUM
1.14200	0.22394	6.973			HELIUM
0.6256E 06	0.5590E 06	0.4683E 06	0.3581E 06	0.2868E 06	HELIUM
1.14200	0.21680	4.973			HELIUM
0.4775E 06	0.4105E 06	0.3226E 06	0.2210E 06	0.1586E 06	HELIUM
1.14200	0.21215	2.973			HELIUM
0.3683E 06	0.3054E 06	0.2262E 06	0.1399E 06	0.9070E 05	HELIUM
1.14200	0.20988	0.973			HELIUM
0.2875E 06	0.2306E 06	0.1618E 06	0.9125E 05	0.5402E 05	HELIUM
1.14200	0.23376	8.973			OXYGEN
0.1833E 10	0.1838E 10	0.1870E 10	0.1952E 10	0.2058E 10	OXYGEN
1.14200	0.22394	6.973			OXYGEN
0.7484E 08	0.6200E 08	0.4898E 08	0.3489E 08	0.2613E 08	OXYGEN
1.14200	0.21680	4.973			OXYGEN
0.1003E 08	0.6560E 07	0.3809E 07	0.1709E 07	0.8531E 06	OXYGEN
1.14200	0.21215	2.973			OXYGEN
0.1468E 07	0.7595E 06	0.3248E 06	0.9186E 05	0.3057E 05	OXYGEN
1.14200	0.20988	0.973			OXYGEN
0.2584E 06	0.1078E 06	0.3466E 05	0.6337E 04	0.1430E 04	OXYGEN
1.14200	0.23376	8.973			O 2
0.5968E 10	0.6665E 10	0.7872E 10	0.1026E 11	0.1320E 11	O 2
1.14200	0.22394	6.973			O 2

GSFC FORM 541-1 (July - 60)

G. Output

Output for this program occurs on tapes 3 and 5. Tape 3 contains two groups of data for each L. The first group lists the values of R, Σ and OXY as functions of position and flux model. The second group contains R, $\log_e R$, Σ, $\log_e \Sigma$ and solar flux as functions of position and time.

On tape 5 is the data to be punched for use in the conservation equation calculation. Each B-L-λ card is followed by two R cards which are followed in turn by two Σ cards.

1. Tape 3 Sample

	S=250	S=200	S=150	S=100	S=70
	L= 1.14200	B= 0.23376	LAT= 8.973		
OXY	0.5479E 11	0.5975E 11	0.6824E 11	0.8475E 11	0.1046E 12
RATIO	0.2037E-08	0.2221E-08	0.2537E-08	0.3151E-08	0.3889E-08
SIGMA	0.3031E-14	0.3303E-14	0.3768E-14	0.4672E-14	0.5757E-14
	L= 1.14200	B= 0.22394	LAT= 6.973		
OXY	0.3230E 09	0.2545E 09	0.1835E 09	0.1138E 09	0.7492E 08
RATIO	0.1208E-10	0.9452E-11	0.6822E-11	0.4231E-11	0.2765E-11
SIGMA	0.1765E-15	0.1379E-16	0.9906E-17	0.6101E-17	0.3984E-17
	L= 1.14200	B= 0.21680	LAT= 4.973		
OXY	0.1631E 08	0.9954E 07	0.5278E 07	0.2141E 07	0.1007E 07
RATIO	0.6965E-12	0.3700E-12	0.1962E-12	0.7958E-13	0.3744E-13
SIGMA	0.8406E-18	0.5144E-18	0.2747E-18	0.1145E-18	0.5633E-19
	L= 1.14200	B= 0.21215	LAT= 2.973		
OXY	0.1731E 07	0.8997E 06	0.3982E 06	0.1296E 06	0.5424E 05
RATIO	0.6435E-13	0.3345E-13	0.1480E-13	0.4816E-14	0.2016E-14
SIGMA	0.1023E-18	0.5969E-19	0.3173E-19	0.1425E-19	0.7878E-20
	L= 1.14200	B= 0.20988	LAT= 0.973		
OXY	0.3371E 06	0.1677E 06	0.7598E 05	0.2981E 05	0.1557E 05
RATIO	0.1253E-13	0.6232E-14	0.2824E-14	0.1108E-14	0.5789E-15
SIGMA	0.3255E-19	0.2143E-19	0.1314E-19	0.6810E-20	0.3927E-20

LAT= 8.9730 L= 1.1420 B= 0.2338

TIME (YRS)	SOLAR FLUX	LOG OF RATIO	RATIO
0	70.00	-0.19365E 02	0.38892E-08
1	75.00	-0.19400E 02	0.37550E-08
2	130.00	-0.19706E 02	0.27666E-08
3	230.00	-0.19977E 02	0.21087E-08
4	250.00	-0.20012E 02	0.20368E-08
5	220.00	-0.19960E 02	0.21457E-08
6	185.00	-0.19885E 02	0.23118E-08
7	140.00	-0.19749E 02	0.26492E-08
8	105.00	-0.19597E 02	0.30832E-08
9	90.00	-0.19505E 02	0.33798E-08
10	75.00	-0.19400E 02	0.37550E-08
11	70.00	-0.19365E 02	0.38892E-08

TIME (YRS)	SOLAR FLUX	LOG OF SIGMA	SIGMA
0	70.00	-0.32788E 02	0.57570E-14
1	75.00	-0.32823E 02	0.55601E-14
2	130.00	-0.33126E 02	0.41067E-14
3	230.00	-0.33396E 02	0.31370E-14
4	250.00	-0.33430E 02	0.30307E-14
5	220.00	-0.33378E 02	0.31915E-14
6	185.00	-0.33304E 02	0.34365E-14
7	140.00	-0.33169E 02	0.39339E-14
8	105.00	-0.33019E 02	0.45726E-14
9	90.00	-0.32928E 02	0.50088E-14
10	75.00	-0.32823E 02	0.55601E-14
11	70.00	-0.32788E 02	0.57570E-14

LAT= 6.9730 L= 1.1420 B= 0.2239

TIME (YRS)	SOLAR FLUX	LOG OF RATIO	RATIO
0	70.00	-0.26607E 02	0.27852E-11
1	75.00	-0.26537E 02	0.29862E-11
2	130.00	-0.25902E 02	0.56356E-11
3	230.00	-0.25237E 02	0.10957E-10
4	250.00	-0.25139E 02	0.12083E-10
5	220.00	-0.25286E 02	0.10434E-10
6	185.00	-0.25482E 02	0.85774E-11
7	140.00	-0.25806E 02	0.62006E-11
8	105.00	-0.26141E 02	0.44381E-11
9	90.00	-0.26328E 02	0.36806E-11
10	75.00	-0.26537E 02	0.29862E-11
11	70.00	-0.26607E 02	0.27852E-11

TIME YRS)	SOLAR FLUX	LOG OF SIGMA	SIGMA
0	70.00	-0.40064E 02	0.39844E-17
1	75.00	-0.39993E 02	0.42776E-17
2	130.00	-0.39347E 02	0.81603E-17
3	230.00	-0.38675E 02	0.15991E-16
4	250.00	-0.38576E 02	0.17648E-16
5	220.00	-0.38724E 02	0.15221E-16
6	185.00	-0.38922E 02	0.12488E-16
7	140.00	-0.39250E 02	0.89911E-17
8	105.00	-0.39590E 02	0.64039E-17
9	90.00	-0.39780E 02	0.52931E-17
10	75.00	-0.39993E 02	0.42776E-17
11	70.00	-0.40064E 02	0.39844E-17

LAT= 4.9730 L= 1.1420 B= 0.2168

TIME (YRS)	SOLAR FLUX	LOG OF RATIO	RATIO
0	70.00	-0.30916E 02	0.37441E-13
1	75.00	-0.30790E 02	0.42455E-13
2	130.00	-0.29620E 02	0.13677E-12
3	230.00	-0.28329E 02	0.49772E-12
4	250.00	-0.28131E 02	0.60649E-12
5	220.00	-0.28428E 02	0.45089E-12
6	185.00	-0.28815E 02	0.30591E-12
7	140.00	-0.29440E 02	0.16382E-12
8	105.00	-0.30072E 02	0.87100E-13
9	90.00	-0.30413E 02	0.61897E-13
10	75.00	-0.30790E 02	0.42455E-13
11	70.00	-0.30916E 02	0.37441E-13

TIME (YRS)	SOLAR FLUX	LOG OF SIGMA	SIGMA
0	70.00	-0.44323E 02	0.56327E-19
1	75.00	-0.44205E 02	0.63395E-19
2	130.00	-0.43089E 02	0.19356E-18
3	230.00	-0.41817E 02	0.69067E-18
4	250.00	-0.41620E 02	0.84064E-18
5	220.00	-0.41915E 02	0.62604E-18
6	185.00	-0.42300E 02	0.42613E-18
7	140.00	-0.42914E 02	0.23059E-18
8	105.00	-0.43526E 02	0.12495E-18
9	90.00	-0.43850E 02	0.90378E-19
10	75.00	-0.44205E 02	0.63395E-19
11	70.00	-0.44323E 02	0.56327E-19

LAT= 2.9730 L= 1.1420 B= 0.2121

TIME (YRS)	SOLAR FLUX	LOG OF RATIO	RATIO
0	70.00	-0.33838E 02	0.20163E-14
1	75.00	-0.33692E 02	0.23311E-14
2	130.00	-0.32293E 02	0.94462E-14
3	230.00	-0.30636E 02	0.49528E-13
4	250.00	-0.30374E 02	0.64346E-13
5	220.00	-0.30767E 02	0.43452E-13
6	185.00	-0.31273E 02	0.26189E-13
7	140.00	-0.32069E 02	0.11824E-13
8	105.00	-0.32855E 02	0.53884E-14
9	90.00	-0.33257E 02	0.36028E-14
10	75.00	-0.33692E 02	0.23311E-14
11	70.00	-0.33838E 02	0.20163E-14

TIME (YRS)	SOLAR FLUX	LOG OF SIGMA	SIGMA
0	70.00	-0.46290E 02	0.78783E-20
1	75.00	-0.46191E 02	0.86967E-20
2	130.00	-0.45217E 02	0.23039E-19
3	230.00	-0.43942E 02	0.82457E-19
4	250.00	-0.43727E 02	0.10228E-18
5	220.00	-0.44050E 02	0.74037E-19
6	185.00	-0.44455E 02	0.49381E-19
7	140.00	-0.45057E 02	0.27037E-19
8	105.00	-0.45617E 02	0.15442E-19
9	90.00	-0.45895E 02	0.11698E-19
10	75.00	-0.46191E 02	0.86967E-20
11	70.00	-0.46290E 02	0.78783E-20

LAT= 0.9730 L= 1.1420 B= 0.2099

TIME (YRS)	SOLAR FLUX	LOG OF RATIO	RATIO
0	70.00	-0.35085E 02	0.57888E-15
1	75.00	-0.34977E 02	0.64504E-15
2	130.00	-0.33875E 02	0.19426E-14
3	230.00	-0.32290E 02	0.94762E-14
4	250.00	-0.32011E 02	0.12530E-13
5	220.00	-0.32430E 02	0.82409E-14
6	185.00	-0.32946E 02	0.49151E-14
7	140.00	-0.33688E 02	0.23424E-14
8	105.00	-0.34343E 02	0.12167E-14
9	90.00	-0.34653E 02	0.89241E-15
10	75.00	-0.34977E 02	0.64504E-15
11	70.00	-0.35085E 02	0.57888E-15

TIME (YRS)	SOLAR FLUX	LOG OF SIGMA	SIGMA
0	70.00	-0.46986E 02	0.39268E-20
1	75.00	-0.46895E 02	0.43043E-20
2	130.00	-0.46041E 02	0.10104E-19
3	230.00	-0.45039E 02	0.27541E-19
4	250.00	-0.44872E 02	0.32550E-19
5	220.00	-0.45122E 02	0.25333E-19
6	185.00	-0.45436E 02	0.18509E-19
7	140.00	-0.45910E 02	0.11524E-19
8	105.00	-0.46370E 02	0.72732E-20
9	90.00	-0.46619E 02	0.56685E-20
10	75.00	-0.46895E 02	0.43043E-20
11	70.00	-0.46986E 02	0.39268E-20

2. Tape 5

a. Output Card Description

	Columns	Mode	Quantity	Units	Description
B-L-λ	1-8	F	ALATO	degrees	latitude
	9-16	F	EL	earth radii	magnetic field line
	17-24	F	B	gauss	magnetic induction
1st R Card	1-10	E	XS(1)	-	R for time 0
	11-20	E	XS(2)	-	R for time 1
	21-30	E	XS(3)	-	R for time 2
	31-40	E	XS(4)	-	R for time 3
	41-50	E	XS(5)	-	R for time 4
	51-60	E	XS(6)	-	R for time 5
2nd R Card	1-10	E	XS(7)	-	R for time 6
	11-20	E	XS(8)	-	R for time 7
	21-30	E	XS(9)	-	R for time 8
	31-40	E	XS(10)	-	R for time 9
	41-50	E	XS(11)	-	R for time 10
	51-60	E	XS(12)	-	R for time 11
1st Σ Card	1-10	E	XS(1)	atoms/cm	Σ for time 0
	11-20	E	XS(2)	"	Σ for time 1
	21-30	E	XS(3)	"	Σ for time 2
	31-40	E	XS(4)	"	Σ for time 3
	41-50	E	XS(5)	"	Σ for time 4
	51-60	E	XS(6)	"	Σ for time 5

	Columns	Mode	Quantity	Units	Description
2nd Σ Card	1-10	E	XS(7)	atoms/cm	Σ for time 6
	11-20	E	XS(8)	"	Σ for time 7
	21-30	E	XS(9)	"	Σ for time 8
	31-40	E	XS(10)	"	Σ for time 9
	41-50	E	XS(11)	"	Σ for time 10
	51-60	E	XS(12)	"	Σ for time 11

This five card group is repeated for each new B and L.

b. Sample

GENERAL PURPOSE DATA SHEET

Problem: OUTPUT – R, Σ CALCULATION AND FLUX ELIMINATION

Sponsor: TAPE 5 | Date: SAMPLE | Page ___ of ___

Columns 1–10	Columns 11–20	Columns 21–30	Columns 31–40	Columns 41–50	Columns 51–60
8.9730	1.1420	0.2338			
0.3889E–08	0.3755E–08	0.2767E–08	0.2109E–08	0.2037E–08	0.2146E–08
0.2312E–08	0.2649E–08	0.3083E–08	0.3380E–08	0.3755E–08	0.3889E–08
0.5757E–14	0.5560E–14	0.4107E–14	0.3137E–14	0.3031E–14	0.3191E–14
0.3437E–14	0.3934E–14	0.4573E–14	0.5009E–14	0.5560E–14	0.5757E–14
6.9730	1.1420	0.2239			
0.2785E–11	0.2986E–11	0.5636E–11	0.1096E–10	0.1208E–10	0.1043E–10
0.8577E–11	0.6201E–11	0.4438E–11	0.3681E–11	0.2986E–11	0.2785E–11
0.3984E–17	0.4278E–17	0.8160E–17	0.1599E–16	0.1765E–16	0.1522E–16
0.1249E–16	0.8991E–17	0.6404E–17	0.5293E–17	0.4278E–17	0.3984E–17
4.9730	1.1420	0.2168			
0.3744E–13	0.4245E–13	0.1368E–12	0.4977E–12	0.6065E–12	0.4509E–12
0.3059E–12	0.1638E–12	0.8710E–13	0.6190E–13	0.4245E–13	0.3744E–13
0.5633E–19	0.6339E–19	0.1936E–18	0.6907E–18	0.8406E–18	0.6260E–18
0.4261E–18	0.2306E–18	0.1250E–18	0.9038E–19	0.6339E–19	0.5633E–19
2.9730	1.1420	0.2121			
0.2016E–14	0.2331E–14	0.9446E–14	0.4953E–13	0.6435E–13	0.4345E–13
0.2619E–13	0.1182E–13	0.5388E–14	0.3603E–14	0.2331E–14	0.2016E–14
0.7878E–20	0.8697E–20	0.2304E–19	0.8246E–19	0.1023E–18	0.7404E–19
0.4938E–19	0.2704E–19	0.1544E–19	0.1170E–19	0.8697E–20	0.7878E–20
0.9730	1.1420	0.2099			
0.5789E–15	0.6450E–15	0.1943E–14	0.9476E–14	0.1253E–13	0.8241E–14
0.4915E–14	0.2342E–14	0.1217E–14	0.8924E–15	0.6450E–15	0.5789E–15
0.3927E–20	0.4304E–20	0.1010E–19	0.2754E–19	0.3255E–19	0.2533E–19

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H. Running Time

The running time for this program will be about three minutes for every L line.

VII. CONSERVATION EQUATION CALCULATION

A. Introduction

This program studies the build-up of proton density by use of the conservation equation (see equation (1)). Several lines of action are available. Either a transient or a time-averaged steady state solution can be calculated for any of 15 desired energy levels without altering the program.

In the transient steady-state solution the conservation equation is integrated as a function of time for a particular energy level until maximum and minimum values of the densities start repeating from one solar cycle to another. At this point the cycle number is recorded together with the time of the maximum and minimum densities. These values are printed with the maximum and minimum density and flux values as well as with the ratio of the maximum flux to the minimum flux. In addition, when calculating the transient steady-state solution, one may have the time history of any one of the energy levels printed on tape 5 with as many points as desired.

In the time-averaged steady-state solution the condition $dN_p/dt = 0$ yields a density equation for density N_p which is solved using the relative neutron source strength Φ together with Σ and R from the last program. All these values are averaged over time for this solution of the conservation equation.

Three subroutines assist the main program: subroutine RUNGE is used in integrating by the Runge Kutta technique, subroutine DERIV is used to evaluate dN_p/dt for a given t and N_p and subroutine TABLE interpolates any given table either logarithmically or linearly.

B. Equations

The form of the particle conservation equation used for the study of the proton population as a function of time is given by

$$\frac{dN_p}{dt} = C_0\Phi - C_1 N_p \left(\frac{dE}{dx}\right) - C_2 N_p \frac{d}{dE}\left(\frac{dE}{dx}\right) - C_2 N_p \Sigma \tag{1}$$

where $\frac{dE}{dx}$, $\frac{d}{dE}\left(\frac{dE}{dx}\right)$, Φ and Σ are the quantities to be supplied and where:

N_p = density

$C_0 = A_0/L^2E^{B_0} \cos^4 \lambda_0$

$C_1 = A_1/E^{B_1}$

$C_2 = A_2E^{B_2}$

E = Energy

$A_0, \ldots, A_2$ = high or low energy conservation equation coefficients depending on whether E > 80 Mev. or E $\leq$ 80 Mev. respectively

$B_0, \ldots, B_2$ = " " " " " " " " " " " " "

λ_0 = mirror latitude

The condition dNp/dt = 0 yields the equation for the time averaged steady state proton density:

$$N_p = \frac{A_0\Phi}{L^2E^{B_0}\left[\frac{A_1}{E^{B_1}}\left(\frac{dE}{dX}\right) + A_2E^{B_2}\frac{d}{dE}\left(\frac{dE}{dX}\right) + A_2E^{B_2}\Sigma\right]\cos^4\lambda_0}$$

where Φ, Σ and the scale factor R used in calculating dE/dx and d/dE (dE/dx) are all averaged over time.

The density N_p gives a flux by the equation:

$$\text{Flux} = 2C_2N_p = N_pv$$

where v is the neutron velocity factor.

C. Mnemonics

Quantity	Description	Units
TIME(J)	Abscissa of time in increments of years for 12 years	years
ELOSS(J)	dE/dk corresponding to E(J) (see Figure 11)	Mev/cm.
E(J)	energy corresponding to ELOSS(J) "	Mev.
CONVM	conversion factor – months to seconds	-
ALO	A_0 for $E \leq 80$ Mev. (see page 130)	$\frac{\text{\# protons}}{\text{cm. sec. Mev.}}$
AL1	A_1 " " "	cm./sec.
AL2	A_2 " " "	cm./Mev ^{2}/sec.
AH0	A_0 for $E > 80$ Mev. (see page 130)	$\frac{\text{\# protons}}{\text{cm. sec. Mev.}}$
AH1	A_1 " " "	cm./sec.
AH2	A_2 " " "	cm./Mev ^{2}/sec.
BL0	B_0 for $E \leq 80$ Mev. (see page 130)	-
BL1	B_1 " " "	-
BL2	B_2 " " "	-
BH0	B_0 for $E > 80$ Mev. (see page 130)	-
BH1	B_1 " " "	-
BH2	B_2 " " "	-
DELOSS(J)	d(dE/dx)/dE corresponding to DE(J) (see Figure 12)	cm. $^{-1}$
DE(J)	energy corresponding to DELOSS(J) (see Figure 12)	Mev.

Quantity	Description	Units
PREL(J)	ϕ for TIME(J) (see page 130 and Figure 11)	-
AVPRL	simple average of PREL(1), ..., PREL(12)	-
ALAT	mirror latitude λ_0	degrees
EL	magnetic field line L	earth radii
B	magnetic induction B	gauss
CONVR	conversion factor – degrees to radians	-
ALATO	ALAT in radians	radians
CSLAT4	$\cos^4$(ALATO)	-
ELEL	L^2	(earth radii)^2
R(I)	atmospheric scale factor R for TIME(I)	-
SIG(I)	atmospheric loss parameter Σ for TIME(I)	atoms/cm.
ENO	initial density N_{p_o} for integration	# protons/cm^3
TSUBO	initial time t_o for integration	months
DT1	integration interval for ICSUBO	months
DT2	integration interval for all other cycles	months
TEND	end limit on integration	months
IEST	initial energy level subscript	-
IEDEL	increment for energy level subscript	-
IEEND	final energy level subscript	-
IEPR	subscript of energy level whose time history is desired	-

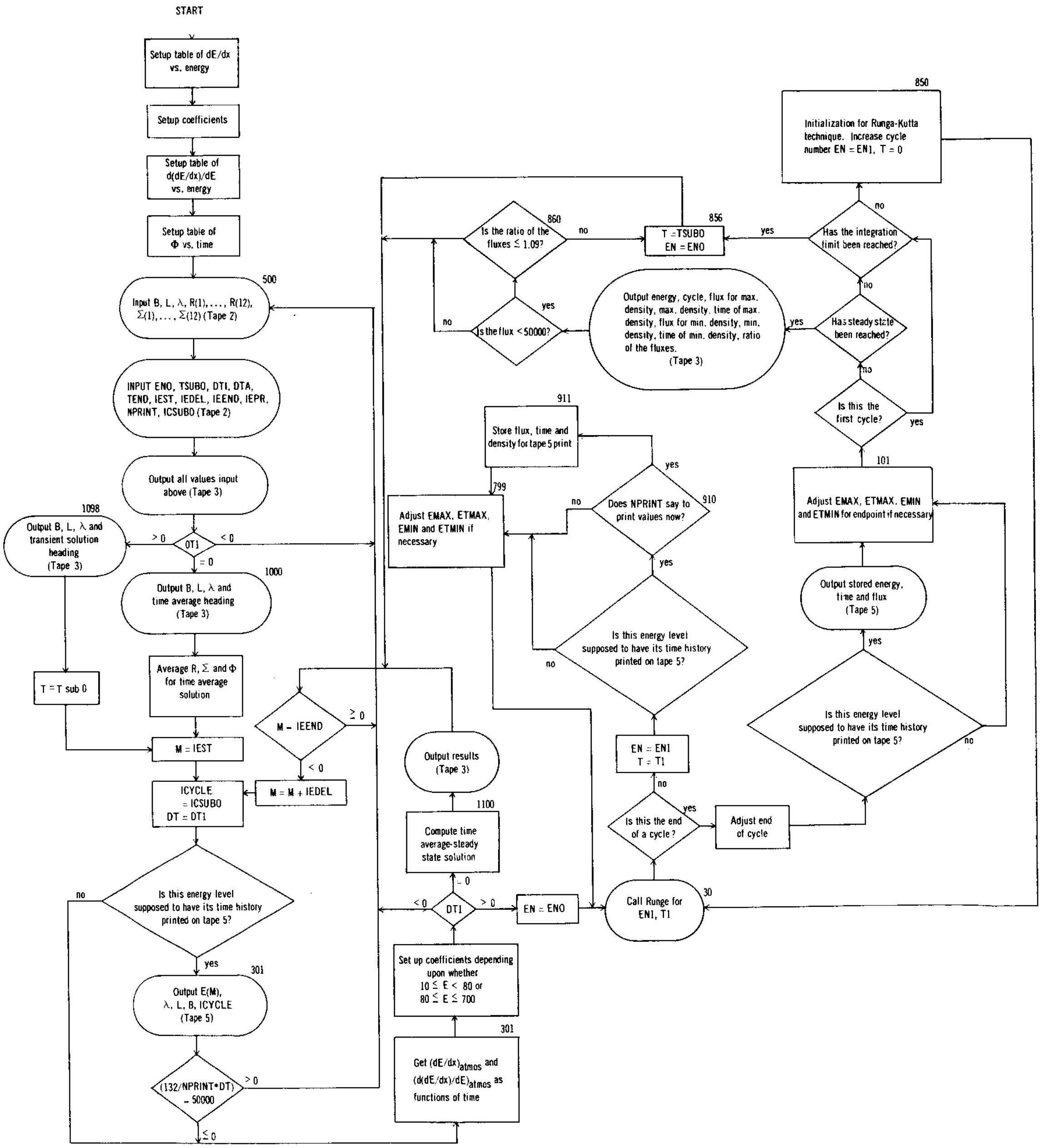
Quantity	Description	Units
NPRINT	a control factor for the time history print on tape 5. Density and flux are given for every NPRINT increments in time. (See Restriction (1)).	-
ICSUBO	initial cycle number corresponding to ENO and TSUBO	-
SUMR	sum of R(1), ..., R(12)	-
AVR	simple average of R(1), ..., R(12)	-
SUMSIG	sum of SIG(1), ..., SIG(12)	atoms/cm
AVSIG	simple average of SIG(1), ..., SIG(12)	atoms/cm
T	time	months
TMAX	time of an eleven year cycle – 132 months	months
TCK	time check to see if TEND has been reached	months
DT	increment in time	months
ICYCLE	cycle number	-
EMAX(J)	maximum density for cycle J	atoms/cm ^{3}
EMIN(J)	minimum density for cycle J	atoms/cm^3
ETMAX(J)	time at EMAX(J)	months
ETMIN(J)	time at EMIN(J)	months
M	subscript to indicate the energy level which is under consideration	-
ENER	energy level M under consideration	Mev.
ITEST3	test value to see if the energy level under consideration is to have its time history printed on tape 5	-

Quantity	Description	Units
ALOSS	temporary storage of ELOSS(M)	Mev./cm.
X(1), ..., X(15)	temporary storage of DE(1), ..., DE(15)	Mev
Y(1), ..., Y(15)	temporary storage of DELOSS(1), ..., DELOSS(15)	cm^{-1}
ALOSSA(J)	(dE/dx) × R(J) for energy ENER	Mev./cm.
DLOSSA(J)	(d(dE/dx)/dE) × R(J) for energy ENER	cm^{-1}
A0	temporary storage of ALO or AHO	$\frac{\#\ \text{protons}}{\text{cm. sec. Mev.}}$
A1	temporary storage of AL1 or AH1	cm/sec
A2	temporary storage of AL2 or AH2	cm/Mev^2sec
B0	temporary storage of BL0 or BH0	-
B1	temporary storage of BL1 or BH1	-
B2	temporary storage of BL2 or BH2	-
C0	conservation equation coefficient (see page 129)	# $protons/cm^3$ sec Mev.
C1	conservation equation coefficient (see page 129)	cm/sec. Mev.
C2	conservation equation coefficient (see page 129)	cm/sec. Mev.
DEDX	temporary storage of ALOSSA(J)	Mev./cm.
DDEDX	temporary storage of DLOSSA(J)	cm^{-1}

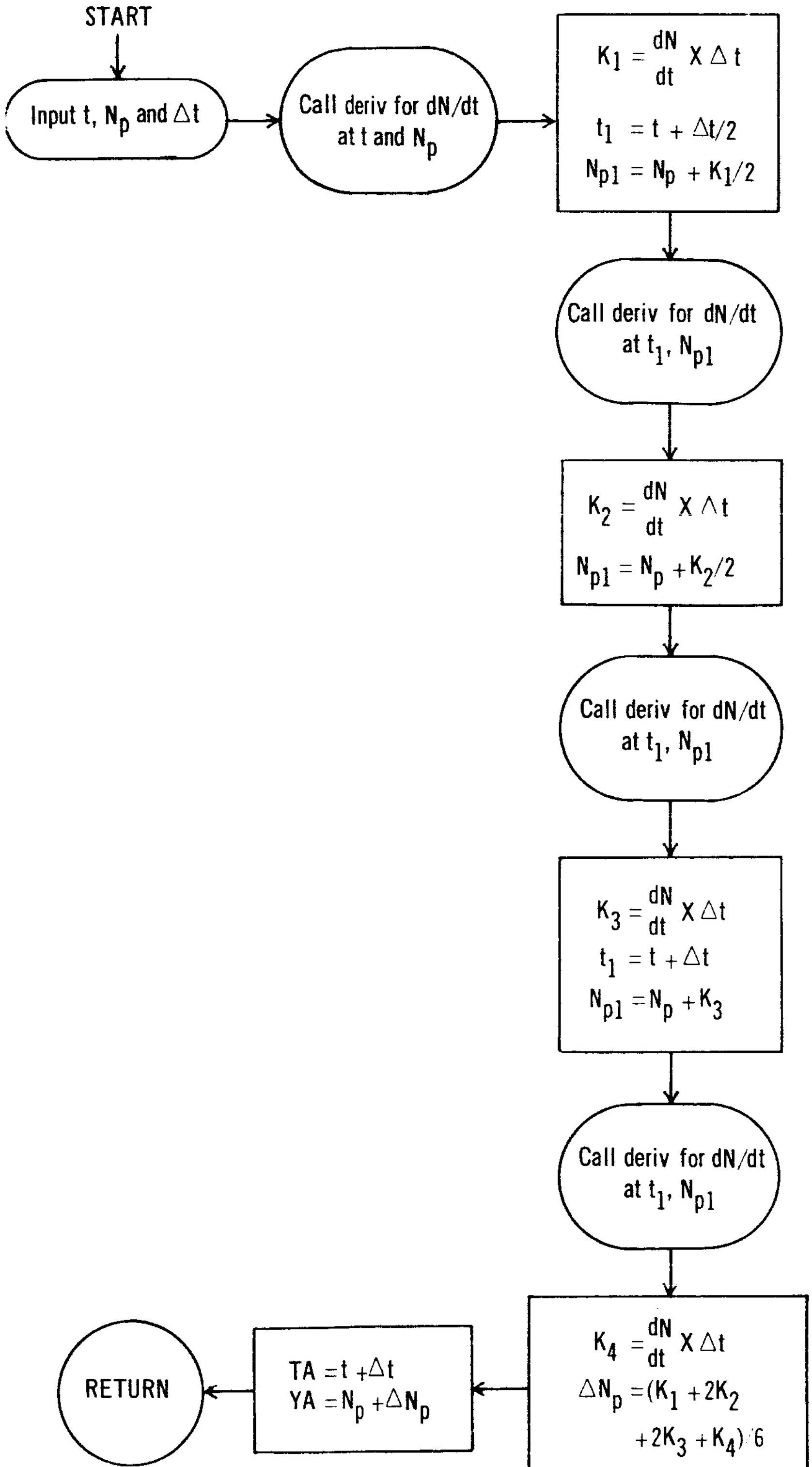
Quantity	Description	Units
DENS	proton density N_p	# protons/cm^3 Mev.
FLUX	proton flux	# protons/cm^2 sec. Mev.
NP	counter of the increments in time; used as a check for NPRINT	-
N5	counter of the number of prints on tape 5	-
EN	proton density N_p	atoms/cm^{3}Mev
ICYM1	the value ICYCLE-1 used in testing for steady-state	-
TEST1	test to see if steady state has been reached	-
TEST2	test to see if steady state has been reached	-
EPR1	minimum density in cycle ICYM1	# protons/cm^3 Mev.
FLPR1	flux for EPR1	# protons/cm^2 sec. Mev.
TPR1	time of EPR1	months
EPR2	maximum density in cycle ICYM1	# protons/cm^3 Mev.
FLPR2	flux for EPR2	# protons/cm^2 sec. Mev.
TPR2	time of EPR2	months
RATIO	ratio of FLPR2 to FLPR1	-

D. Flow Chart

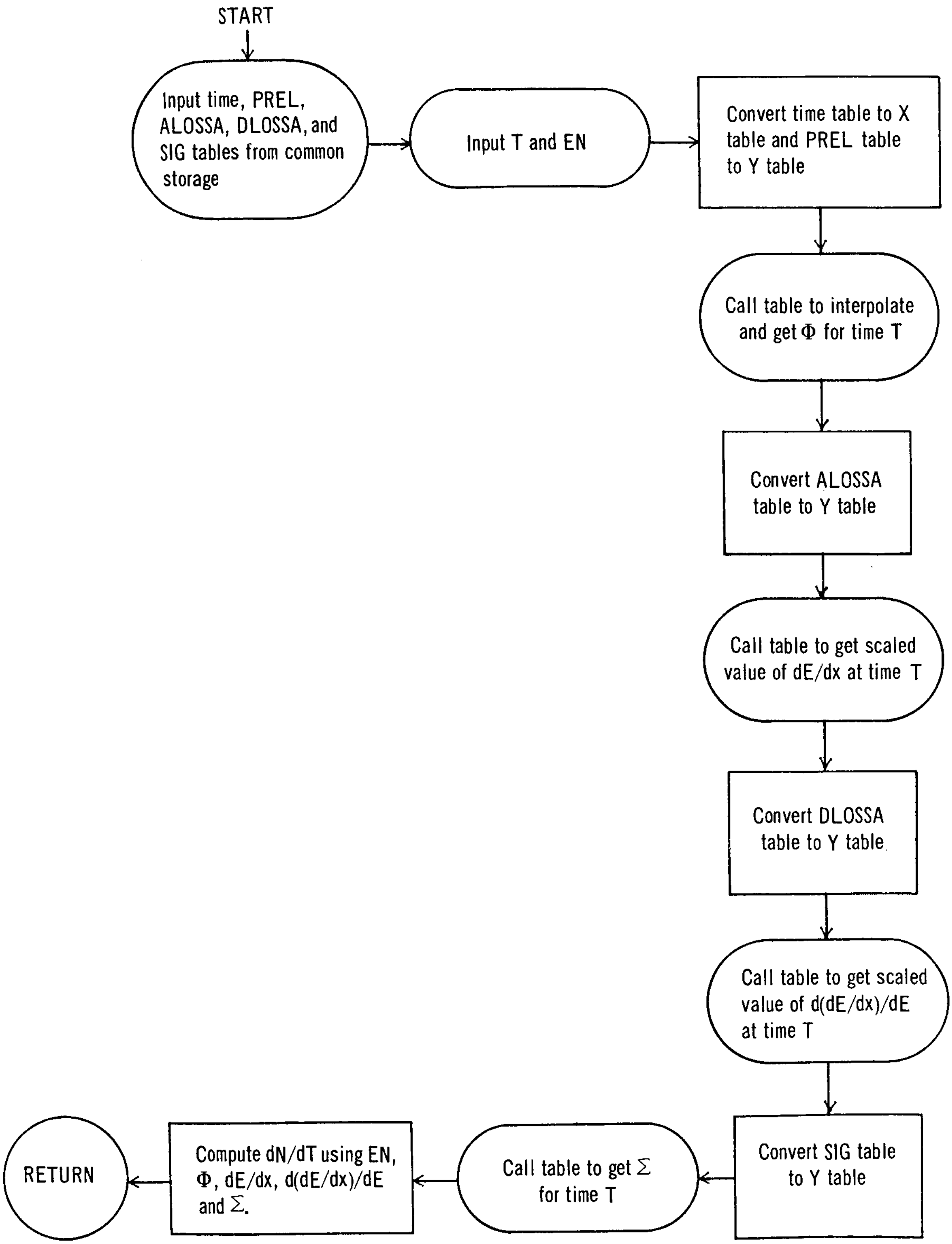
1. Main Program



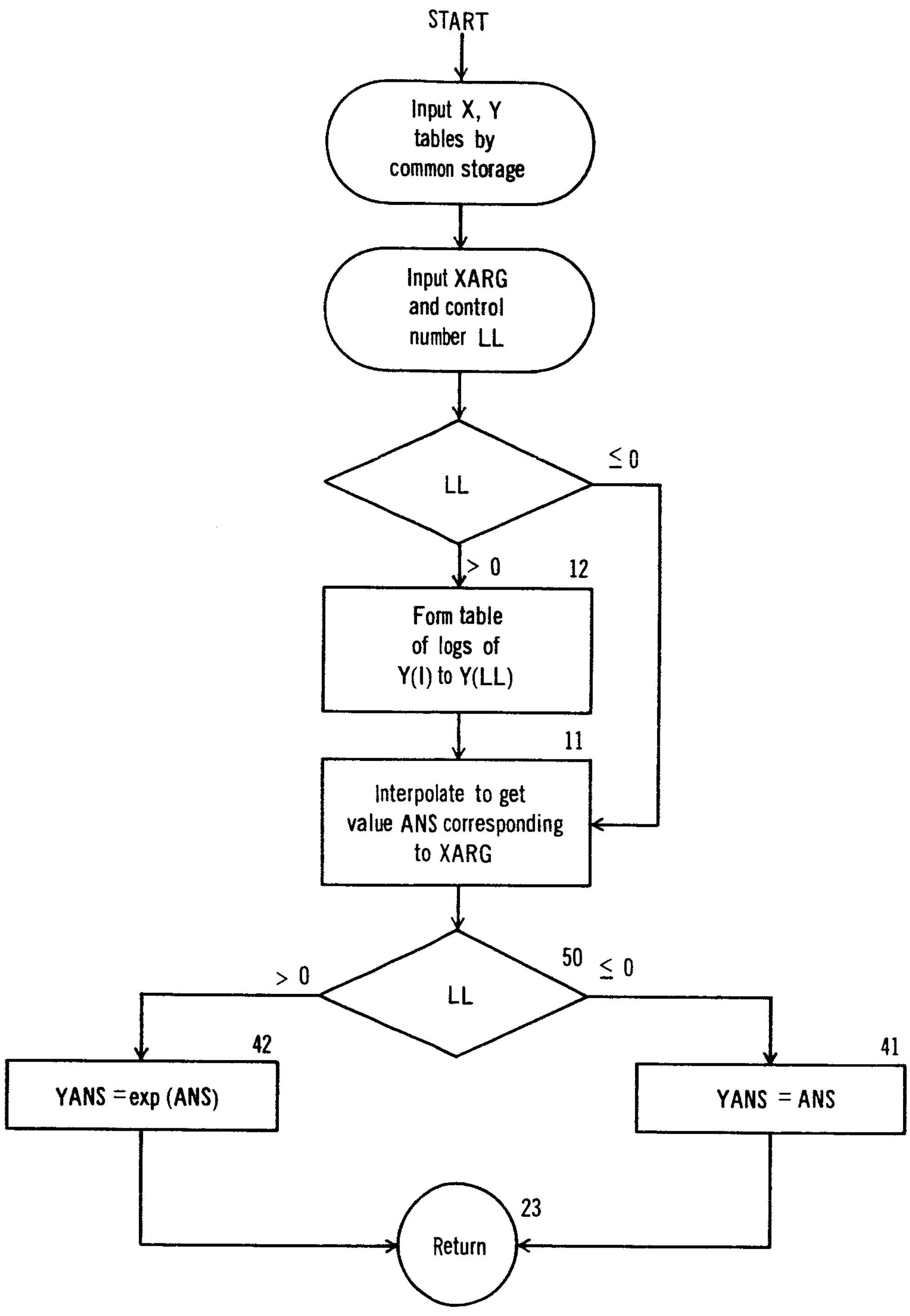
2. Subroutine RUNGE



3. Subroutine DERIV



4. Subroutine TABLE



E. Fortran Listing

```
CONSER                                                                      10/01/64

C     CONSERVATION EQUATION CALCULATION
C   IF DT1=0.0 THEN BRANCH TO TIME AVERAGE STEADY STATE SOLUTION.
C   OTHERWISE,INTEGRATE STEADY STATE SOLUTION AVERAGED OVER TIME.
      DIMENSION E(15),ELOSS(15),TIME(12),R(12),DELOSS(15),DE(15),PREL(12
     1),ALOSSA(12),CLOSSA(12),X(15),Y(15),SIG(12),
     1EMAX(200),ETMAX(200),EMIN(200),ETMIN(200),T5(5000),E5(5000),
     1FL5(5000)
      COMMON C0,C1,C2,X,Y,TIME,PREL,ALOSSA,CLOSSA,SIG
      FREQUENCY 710(5,0,10)
    1 FORMAT(3F8.4)
    2 FORMAT(6E10.4)
    3 FORMAT(1F15.3,1E20.4,F20.3)
  720 FORMAT(2E10.4/3F8.4/3I3/3I5)
      TIME(1)=0.0
      DO 11 J=1,11
   11 TIME(J+1)=TIME(J)+12.0
      ELOSS(1)=5.3985E-2
      ELOSS(2)=2.5732E-2
      ELOSS(3)=1.4755E-2
      ELOSS(4)=1.0754E-2
      ELOSS(5)=8.6553E-3
      ELOSS(6)=7.3567E-3
      ELOSS(7)=6.4720E-3
      ELOSS(8)=5.3435E-3
      ELOSS(9)=4.6543E-3
      ELOSS(10)=4.1914E-3
      ELOSS(11)=3.8602E-3
      ELOSS(12)=3.6127E-3
      ELOSS(13)=3.2701E-3
      ELOSS(14)=3.0476E-3
      ELOSS(15)=2.8942E-3
      E(1)=10.
      E(2)=25.
      E(3)=50.
      E(4)=75.
      E(5)=100.
      E(6)=125.
      E(7)=150.
      E(8)=200.
      E(9)=250.
      E(10)=300.
      E(11)=350.
      E(12)=400.
      E(13)=500.
      E(14)=600.
      E(15)=700.
C     CONVERT 1MO.= 3600*24*30 SEC
      CONVM=     2.592E6
C     10-E-80 MEV
      ALO=CONVM* 2.964E-13
      AL1=CONVM*3.463E+8
      AL2=CONVM*7.255E+8
      BL0=2.509
      BL1=.923
      BL2=.477
```

```
C       80-E-700 MEV
        AHO=CONVM*3.4792E-13
        AH1=CONVM*4.617E+8
        AH2=CONVM*1.343E+9
        BHO=2.549
        BH1=.656
        BH2=.344
        DE(1)=10.
        DE(2)=10.5
        DE(3)=16.5
        DE(4)=27.5
        DE(5)=52.5
        DE(6)=72.5
        DE(7)=92.5
        DE(8)=137.5
        DE(9)=212.5
        DE(10)=262.5
        DE(11)=312.5
        DE(12)=412.5
        DE(13)=525.5
        DE(14)=625.5
        DE(15)=700.
        DELOSS(1)=-.400E-2
        DELOSS(2)=-.3985E-2
        DELOSS(3)=-.1770E-2
        DELOSS(4)=-.7051E-3
        DELOSS(5)=-.2173E-3
        DELOSS(6)=-.1172E-3
        DELOSS(7)=-.743E-4
        DELOSS(8)=-.354E-4
        DELOSS(9)=-.153E-4
        DELOSS(10)=-.101E-4
        DELOSS(11)=-.713E-5
        DELOSS(12)=-.410E-5
        DELOSS(13)=-.244E-5
        DELOSS(14)=-.166E-5
        DELOSS(15)=-.131E-5
        PREL(1)=1.25
        PREL(2)=1.245
        PREL(3)=1.22
        PREL(4)=1.13
        PREL(5)=1.0
        PREL(6)=1.02
        PREL(7)=1.05
        PREL(8)=1.08
        PREL(9)=1.15
        PREL(10)=1.16
        PREL(11)=1.20
        PREL(12)=1.25
        AVPRL=1.14625
  500   READ INPUT TAPE 2,1,ALAT,EL,B
        CONVR=0.17453292E-1
        ALATO=ALAT*CONVR
        CSLAT4=COSF(ALATO)**4
        ELEL=EL*EL
        READ INPUT TAPE 2,2,((R(I),I=1,12),(SIG(J),J=1,12))
```

```
  400 READ INPUT TAPE 2,720,ENC,TSUBO,DT1,DT2,TENC,IEST,IEDEL,IEEND,
     1IEPR,NPRINT,ICSUBC
C  INPUT PRINTOUT
      WRITE OUTPUT TAPE 3,700
  700 FORMAT(26H1   ***** PROGRAM INPUT *****///)
      WRITE OUTPUT TAPE 3,701,ALAT,EL,B,ENC,TSUBO,DT1,DT2,
     1TEND,IEST,IEDEL,IEEND,IEPR,ICSUBO,NPRINT
  701 FORMAT(13H   LATO *** =F8.4/13H   L ****** =F8.4/13H   B ****** =
     1F8.4/13H   NP SUB C =E12.4/13H   T  SUB C =E12.4/
     113H   DELTA T1 =F8.4/13H   DELTA T2 =F8.4
     2                                                /13H   T END ** =
     2F8.1//23H   ENERGY LEVEL START =I3,/23H   DELTA ENERGY LEVEL =I3/
     323H   ENERGY LEVEL END   =I3//30H   ENERGY LEVEL TIME HISTORY =I3,
     47X,92HINDICATES ENERGY LEVEL AT WHICH TIME HISTORY OF DENSITY AND
     5FLUX WILL BE PRINTED ON TAPE  5. /40X,43HZERO INDICATES NO TIME HI
     6STORY ON TAPE  5 .//30H   CYCLE AT T SUB ZERO ***** =I5//35H   PRI
     7NTING ON TAPE  5  AFTER EVERY,I6,9H DELTA T.//)
      WRITE OUTPUT TAPE 3,702,(R(I),SIG(I),I=1,12)
  702 FORMAT(6X,4HR(I),10X,6HSIG(I)/(2E14.4))
C  HEADING
C  HEADING AND R,SIG,PREL, AVERAGED FOR TIME AVERAGE ST.ST. SOLUTION
      IF(DT1) 500,1000,1098
 1000 WRITE OUTPUT TAPE 3,1001,ALAT,EL,B
 1001 FORMAT(48H1  TIME AVERAGE STEADY STATE SOLUTION FOR LATO =F8.4,
     16H , L =F7.4,6H , B =F7.4////
     288H   ENERGY      PROTON-        PROTON-       PHI BAR       SIG BAR
     3  (DE/DX)      D(DE/DX)/DE/
     434H     (MEV)       FLUX           DENSITY/)
      SUMR=0.0
      DO 1002 NN=1,12
 1002 SUMR=SUMR+R(NN)
      AVR=SUMR/12.0
      DO 1003 NN=1,12
 1003 R(NN)=AVR
      SUMSIG=0.0
      DO 1005 NN=1,12
 1005 SUMSIG=SUMSIG+SIG(NN)
      AVSIG=SUMSIG/12.0
      DO 1006 NN=1,12
 1006 SIG(NN)=AVSIG
      DO 1008 NN=1,12
 1008 PREL(NN)=AVPRL
      GO TO 1099
 1098 WRITE OUTPUT TAPE 3,705,ALAT,EL,B
  705 FORMAT(45H1  TRANSIENT STEADY STATE SOLUTION FOR LATO =F8.4,
     16H , L =F7.4,6H , B =F7.4////
     240H   ENERGY   CYCLE I MINIMUM -     PROTON-,6X,22HPROTON-    I  MAX
     3IMUM -,5X, 7HPROTON-,6X,7HPROTON-,3X,13HI  FLUX RATIO/
     3                                           4X,33H(MEV)     NO.  I TIME (MC)
     4   FLUX,9X,31HDENSITY    I  TIME (MC)      FLUX,9X,7HDENSITY,
     53X,13HI    (MAX/MIN)/
     518X,1HI,37X,1HI,39X,1HI)
      T=TSUBO
      TMAX=132.
      TCK=0.0
C  IEEND MUST BE LESS THAN OR EQUAL TO 15 , BUT GREATER THAN 0
```

```
 1099 DO 300 M=IEST,IEEND,IEDEL
      DT=DT1
      ICYCLE=ICSUBC
      EMAX(1)=ENC
      ETMAX(1)=0.0
      EMIN(1)=ENO
      ETMIN(1)=0.0
      ENER=E(M)
C   TIME HISTORY HEADING ON TAPE  5
      ITEST3=M-IEPR
      IF(ITEST3) 310,301,310
  301 WRITE OUTPUT TAPE 5,302,ENER,ALAT,EL,B
  302 FORMAT(46H1  TIME HISTORY OF DENSITY AND FLUX FOR ENERGY =F6.1,
     1 9H , LA10 =F8.4, 6H , L =F7.4,6H , B =F7.4//24X,95HTIME       FLUX
     2       DENSITY  I     TIME       FLUX       DENSITY  I     TIME       FL
     3UX       DENSITY)
      WRITE OUTPUT TAPE 5,900,ICYCLE
  900 FORMAT(14H    CYCLE NO. =I4,35X,1H1,33X,1H1)
      IF(132.0/(FLOATF(NPRINT)*DT)-5000.0) 310,310,901
  901 WRITE OUTPUT TAPE 3,902
  902 FORMAT(61HONPRINT WILL CAUSE T5,E5,AND FL5 TO EXCEED DIMENSION OF
     15000.)
      GO TO 500
  310 ALOSS=ELOSS(M)
      DO 201 K=1,15
      X(K)=DL(K)
  201 Y(K)=DELOSS(K)
      CALL TABLE(ENER,EANS,15)
      DO 20 J=1,12
      ALOSSA(J)=R(J)*ALOSS
   20 DLOSSA(J)=R(J)*EANS
C     NOW HAVE (DE/DX)ATMOS AND (D(DE/DX)/DE)ATMOS AS FUNCTIONS
C     OF TIME FOR A GIVEN ENERGY AND L
  710 IF(ENER-80.) 21,21,22
   21 A0=AL0
      A1=AL1
      A2=AL2
      B0=BL0
      B1=BL1
      B2=BL2
      GO TO 23
   22 A0=AH0
      A1=AH1
      A2=AH2
      B0=BH0
      B1=BH1
      B2=BH2
   23 C0=A0/(ELEL*ENER**B0*CSLAT4)
      C1=A1/(ENER**B1)
      C2=A2*ENER**B2
C   COMPUTE TIME AVERAGE STEADY STATE SOLUTION
      IF(DT1) 500,1100,1999
 1100 DEDX=ALOSSA(1)
      DDEDX=DLOSSA(1)
      DENS=A0*AVPRL/((A0/C0)*(C1*DEDX+C2*(DDEDX+AVSIG)))
      FLUX=2.0*DENS*C2/CONVM
```

```
      WRITE OUTPUT TAPE 3,1101,ENER,FLUX,DENS,AVPRL,AVSIG,
     1DEDX,CDEDX
 1101 FORMAT(1H0,F8.2,1P6E13.4)
      GO TO 300
C  BEGIN RUNGE KUTTA TECHNIQUE
 1999 NP=0
      N5=0
      EN=EN0
   30 CALL RUNGE(T,EN,DT,DEN,T1,EN1)
      IF(T1-TMAX) 31,100,100
   31 EN=EN1
      T=T1
C  TEST/STORE TIME HISTORY
      IF(ITEST3) 799,910,799
  910 NP=NP+1
      IF(NP-NPRINT) 799,911,911
  911 N5=N5+1
      NP=0
      T5(N5)=T1
      E5(N5)=EN1
      FL5(N5)=EN1*2.0*C2/CONVM
C  TEST AND STORE MIN-MAX
  799 IF(EMAX(ICYCLE)-EN1) 800, 30,801
  800 EMAX(ICYCLE)=EN1
      ETMAX(ICYCLE)=T1
      GO TO 30
  801 IF(EMIN(ICYCLE)-EN1) 30,30,802
  802 EMIN(ICYCLE)=EN1
      ETMIN(ICYCLE)=T1
      GO TO 30
C  ADJUST END OF 11 YEAR CYCLE
  100 EN1=EN+((TMAX-T)/DT)*DEN
      IF(ITEST3) 101,915,101
C  PRINT TIME HISTORY ON 5
  915 N5=N5+1
      T5(N5)=TMAX
      E5(N5)=EN1
      FL5(N5)=EN1*2.0*C2/CONVM
      WRITE OUTPUT TAPE 5,916,(T5(I),FL5(I),E5(I),I=1,N5)
  916 FORMAT(20X,0PF9.3,0PF11.4,1PE12.4,2H I,0PF9.3,0PF11.4,1PE12.4,
     12H I,0PF9.3,0PF11.4,1PE12.4)
      ICY5=ICYCLE+1
      WRITE OUTPUT TAPE 5,900,ICY5
      N5=0
      NP=0
C  CHECK END POINT FOR MIN-MAX
  101 IF(EMAX(ICYCLE)-EN1) 810,815,811
  810 EMAX(ICYCLE)=EN1
      ETMAX(ICYCLE)=TMAX
      GO TO 815
  811 IF(EMIN(ICYCLE)-EN1) 815,815,812
  812 EMIN(ICYCLE)=EN1
      ETMIN(ICYCLE)=TMAX
C  TEST STEADY STATE SOLUTION
  815 TCK=TCK+132.0
      IF(ICYCLE-ICSLBC) 819,849,820
```

```
 819 STOP 77777
 820 ICYM1=ICYCLE-1
     TEST1=EMAX(ICYCLE)/EMAX(ICYM1    )-1.0
     TEST2=EMIN(ICYCLE)/EMIN(ICYM1    )-1.0
     IF(ABSF(TEST1)-1.0E-4) 821,821,849
 821 IF(ABSF(TEST2)-1.0E-4) 822,822,849
 822 TPR1=ETMIN(ICYM1)
     EPR1=EMIN(ICYM1)
     FLPR1=EPR1*2.0*C2/CONVM
     TPR2=ETMAX(ICYM1)
     EPR2=EMAX(ICYM1)
     FLPR2=EPR2*2.0*C2/CONVM
     RATIO=FLPR2/FLPR1
     WRITE OUTPUT TAPE 3,823,ENER,ICYM1 ,TPR1,FLPR1,EPR1,TPR2,FLPR2
    1,EPR2,RATIO
 823 FORMAT(0PF9.2,3X,I3,4H    I,0PF9.4,0PF13.4,1PE13.4,3H  I,0PF10.4,
    10PF14.4,1PE13.4,3H  I,0PF10.4)
     IF(ABSF(FLPR1)-50000.) 860,831,831
 860 IF(RATIO-1.090) 861,861,830
 861 WRITE OUTPUT TAPE 3,862
 862 FORMAT(////96H    ALL HIGHER ENERGY LEVELS ARE BEING NEGLECTED SINC
    1E THE FLUX RATIO HAS BECOME LESS THAN 1.090.)
     GO TO 500
 831 WRITE OUTPUT TAPE 3,832
 832 FORMAT(//// 52H    I BLEW UP.  RERUN THIS CASE WITH SMALLER DELTA T
    1.)
     GO TO 500
 830 WRITE OUTPUT TAPE 3,824
 824 FORMAT(18X,1HI,37X,1HI,39X,1HI)
     GO TO 856
 849 IF(TCK-TEND) 850,855,855
 850 T=0.0
     EN=EN1
     DT=DT2
     ICYCLE=ICYCLE+1
     EMAX(ICYCLE)=EN1
     EMIN(ICYCLE)=EN1
     ETMAX(ICYCLE)=0.0
     ETMIN(ICYCLE)=0.0
     GO TO 30
C   NO TRANSIENT STEADY STATE SOLUTION AS YET
 855 TPR1=ETMIN(ICYCLE)
     EPR1=EMIN(ICYCLE)
     FLPR1=EPR1*2.0*C2/CONVM
     TPR2=ETMAX(ICYCLE)
     EPR2=EMAX(ICYCLE)
     FLPR2=EPR2*2.0*C2/CONVM
     RATIO=FLPR2/FLPR1
     WRITE OUTPUT TAPE 3,857,ENER,ICYCLE,TPR1,FLPR1,EPR1,TPR2,FLPR2,
    1EPR2,RATIO
 857 FORMAT(0PF9.2,3X,I3,4H    I,0PF9.4,0PF13.4,1PE13.4,3H  I,0PF10.4,
    10PF14.4,1PE13.4,3H  I,0PF10.4,
    122HNO T.S.S. SOLN. AS YET)
     WRITE OUTPUT TAPE 3,824
 856 T=TSUBO
     TCK=0.0
```

```
      EN=ENO
  3CO CONTINUE
      GO TO 5CO
      END(1,1,0,C,C,0,0,1,0,0,0,0,C,0,0)
```

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
COS	3	00003	EXP(3	7	00007	RUNGE	8	00010	TABLE	6	00006	(FIL)	5	00005
(FPT)	0	00000	(RTN)	2	00002	(STH)	4	00004	(TSH)	1	00001			

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

COS EXP(3 RUNGE TABLE (FIL) (FPT) (RTN) (STH) (TSH)

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
11	26	00021	500	113	00315	400	130	00401	1000	141	00534	1002	145	00555
1003	148	00566	1005	151	00575	1006	154	00606	1008	156	00613	1098	158	00622
1099	163	00646	301	173	00705	901	178	00755	310	180	00764	201	183	00771
20	188	01007	710	189	01014	21	190	01020	22	197	01037	23	203	01053
1100	207	01120	1999	214	01204	30	217	01213	31	220	01231	910	223	01241
911	225	01251	799	230	01271	800	231	01275	801	234	01302	802	235	01307
100	238	01314	915	240	01326	101	254	01414	810	255	01420	811	258	01425
812	259	01432	815	261	01436	819	263	01445	820	264	01447	821	268	01473
822	269	01500	860	279	01564	861	280	01570	831	282	01577	830	284	01606
849	286	01616	850	287	01622	855	296	01646	856	306	01735	300	309	01743

STORAGE NOT USED BY PROGRAM

DEC	OCT	DEC	OCT
17467	42073	32468	77324

STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
ALOSSA	32504	77370	C0	32561	77461	C1	32560	77460	C2	32559	77457	DLOSSA	32492	77354
PREL	32516	77404	SIG	32480	77340	TIME	32528	77420	X	32558	77456	Y	32543	77437

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
DELOSS	17424	42020	DE	17409	42001	E5	11594	26512	ELOSS	17451	42053	EMAX	17394	41762
EMIN	16994	41142	E	17466	42072	ETMAX	17194	41452	ETMIN	16794	40632	FL5	6594	14702
R	17436	42034	T5	16594	40322									

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
A0	1594	03072	A1	1593	03071	A2	1592	03070	AH0	1591	03067	AH1	1590	03066
AH2	1589	03065	AL0	1588	03064	AL1	1587	03063	AL2	1586	03062	ALATC	1585	03061
ALAT	1584	03060	ALOSS	1583	03057	AVPRL	1582	03056	AVR	1581	03055	AVSIG	1580	03054
B0	1579	03053	B1	1578	03052	B2	1577	03051	BH0	1576	03050	BH1	1575	03047
BH2	1574	03046	BL0	1573	03045	BL1	1572	03044	BL2	1571	03043	B	1570	03042
CONVM	1569	03041	CONVR	1568	03040	CSLAT4	1567	03037	DDEDX	1566	03036	DEDX	1565	03035
DEN	1564	03034	DENS	1563	03033	DT1	1562	03032	DT2	1561	03031	DT	1560	03030
EANS	1559	03027	ELEL	1558	03026	EL	1557	03025	EN0	1556	03024	EN1	1555	03023
ENER	1554	03022	EN	1553	03021	EPR1	1552	03020	EPR2	1551	03017	FLPR1	1550	03016
FLPR2	1549	03015	FLUX	1548	03014	ICSUB0	1547	03013	ICY5	1546	03012	ICYCLE	1545	03011
ICYM1	1544	03010	IEDEL	1543	03007	IEEND	1542	03006	IEPR	1541	03005	IEST	1540	03004
ITEST3	1539	03003	M	1538	03002	N5	1537	03001	NPRINT	1536	03000	NP	1535	02777
RATIO	1534	02776	SUMR	1533	02775	SUMSIG	1532	02774	T1	1531	02773	TCK	1530	02772
TEND	1529	02771	TEST1	1528	02770	TEST2	1527	02767	TMAX	1526	02766	TPR1	1525	02765
TPR2	1524	02764	T	1523	02763	TSUB0	1522	02762						

SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

	EFN	LOC		EFN	LOC		EFN	LOC		EFN	LOC		EFN	LOC
8)1	1	02750	8)2	2	02746	8)3	3	02744	8)9E	302	02344	8)LS	700	02734
8)LT	701	02726	8)LU	702	02554	8)M1	705	02464	8)MG	720	02740	8)PN	823	02234
8)P0	824	02160	8)Q0	832	02173	8)QP	857	02153	8)QU	862	02215	8)S4	900	02301
8)S6	902	02272	8)SK	916	02253	8)V9	1001	02546	8)12C	1101	02257			

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
1)	1513	02751	2)	1000	01750	3)	1007	01757	4)	32767	77777	6)	1100	02114
0)G4	1518	02756	0)G6	1519	02757	0)G7	1520	02760	0)G8	1521	02761	D)203	201	00311
0)21T	909	01615	D)220	988	01734	D)603	200	00310	E)L	400	00620	E)C	451	00703
E)10	541	01035	E)12	591	01117	E)13	642	01202	E)15	664	01230	E)1G	779	01413
E)503	203	00313												

```
C     SUBROUTINE FOR RUNGE KUTTA TECHNIQUE
      SUBROUTINE RUNGE(TO,YO,H,DELY,TA,YA)
      COMMON CO,C1,C2,X,Y,TIME,PREL,ALOSSA,DLOSSA,SIG
      CALL DERIV(TO,YO,DER)
      CONT1= DER*H
      T1 = TO+H/2.
      Y1 = YO+CONT1/2.
      CALL DERIV(T1,Y1,DER)
      CONT2=DER*H
      Y1 = YO+CONT2/2.
      CALL DERIV(T1,Y1,DER)
      CONT3=DER*H
      T1=TO+H
      Y1=YO+CONT3
      CALL DERIV(T1,Y1,DER)
      CONT4=DER*H
      DELY=(CONT1+2.*CONT2+2.*CONT3+CONT4)/6.
      TA= TO+H
      YA= YO+DELY
      RETURN
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
FLAGE                                                                    10/01/64

                                     STORAGE NOT USED BY PROGRAM

         DEC   OCT                DEC   OCT
         125 00175              32551 77447

                        STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

         DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT                 DEC   OCT
ALOSSA 32554 77452          CO 32561 77461        C1 32560 77460        C2 32559 77457       DLOSSA 32553 77451
  PREL 32555 77453         SIG 32552 77450      TIME 32556 77454         X 32558 77456            Y 32557 77455

          STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

         DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT                 DEC   OCT
COUNT1   124 00174      COUNT2    123 00173     COUNT3    122 00172     COUNT4    121 00171         DER     120 00170
    T1   119 00167          Y1    118 00166

                        LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

         DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT                 DEC   OCT
    1)   116 00164          3)    108 00154         6)    110 00156

                                LOCATIONS OF NAMES IN TRANSFER VECTOR

         DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT                 DEC   OCT
DERIV      0 00000

                         ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

DERIV
```

```
C     SUBROUTINE TO EVALUATE (DN/DT) FOR A GIVEN T AND EN
      SUBROUTINE DERIV(T,EN,DER)
      DIMENSION TIME(12),PREL(12),ALOSSA(12),DLOSSA(12),X(15),Y(15),SIG(
     112)
      COMMON C0,C1,C2,X,Y,TIME,PREL,ALOSSA,DLOSSA,SIG
      DO 1 K=1,12
      X(K)=TIME(K)
    1 CONTINUE
      DO 2 K=1,12
      Y(K)=PREL(K)
    2 CONTINUE
      CALL TABLE(T,TANS,0)
      P=TANS
      DO 3 K=1,12
      Y(K)=ALOSSA(K)
    3 CONTINUE
      CALL TABLE(T,ANS,12)
      EX=ANS
      DO 4 K=1,12
      Y(K)=DLOSSA(K)
    4 CONTINUE
      CALL TABLE(T,ANS,12)
      EXX=ANS
      DO 5 K=1,12
      Y(K)=SIG(K)
    5 CONTINUE
      CALL TABLE(T,ANS,12)
      SIGMA=ANS
C     EVALUATE(DN/DT)C
      DER    =C0*P-C1*EN*EX-C2*EN*EXX-SIGMA*EN*C2
      RETURN
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                                   STORAGE NOT USED BY PROGRAM

       DEC   OCT            DEC   OCT
       114 00162          32468 77324

                     STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

       DEC   OCT            DEC   OCT            DEC   OCT            DEC   OCT             DEC   OCT
ALOSSA 32504 77370     C0 32561 77461     C1 32560 77460     C2 32559 77457     DLOSSA 32492 77354
  PREL 32516 77404    SIG 32480 77340   TIME 32528 77420      X 32558 77456          Y 32543 77437

            STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

       DEC   OCT            DEC   OCT            DEC   OCT            DEC   OCT             DEC   OCT
  ANS    113 00161     EX   112 00160    EXX   111 00157      P   110 00156     SIGMA   109 00155
 TANS    108 00154

                     LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

       DEC   OCT            DEC   OCT            DEC   OCT            DEC   OCT             DEC   OCT
   1)    104 00150     2)    95 00137     6)    98 00142

                              LOCATIONS OF NAMES IN TRANSFER VECTOR

       DEC   OCT            DEC   OCT            DEC   OCT            DEC   OCT             DEC   OCT
 TABLE     0 00000

                         ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

TABLE

            EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

 EFN   IFN   LOC     EFN   IFN   LOC     EFN   IFN   LOC     EFN   IFN   LOC     EFN   IFN   LOC
   1     7 00030       2    10 00035       3    16 00050       4    22 00063       5    28 00076
```

```
C     SUBROUTINE TO INTERPOLATE A GIVEN TABLE
      SUBROUTINE TABLE(XARG,YANS,LL)
      DIMENSION X(15),Y(15)
      COMMON C0,C1,C2,X,Y,TIME,PREL,ALOSSA,BLOSSA,SIG
      IF(LL)11,11,12
   12 DO 10 K=1,LL
      A=Y(K)
      Y(K)=LOGF(A)
   10 CONTINUE
   11 DO 20 J=1,15
      IF(X(J)-XARG)20,21,22
   21 ANS=Y(J)
      GO TO 50
   22 H1=X(J)
      Y1=Y(J)
      H0=X(J-1)
      Y0=Y(J-1)
      ANS=Y1-(Y1-Y0)*(H1-XARG)/(H1-H0)
      GO TO 50
   20 CONTINUE
   50 IF(LL)41,41,42
   41 YANS=ANS
      GO TO 23
   42 YANS=EXPF(ANS)
   23 RETURN
      END(1,1,0,0,0,0,0,1,0,0,0,0,0,0,0)
```

```
                              STORAGE NOT USED BY PROGRAM

   DEC   OCT            DEC   OCT
   110 00156          32523 77413

                STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

       DEC   OCT             DEC   OCT            DEC   OCT            DEC   OCT              DEC   OCT
ALCSSA 32526 77416      CO 32561 77461     C1 32560 77460     C2 32559 77457     DLCSSA 32525 77415
  PREL 32527 77417     SIG 32524 77414   TIME 32528 77420      X 32558 77456          Y 32543 77437

     STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

       DEC   OCT             DEC   OCT            DEC   OCT            DEC   OCT              DEC   OCT
ANS    109 00155       A    108 00154     F0    107 00153     H1    106 00152      J      105 00151
Y0     104 00150       Y1   103 00147

                LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

       DEC   OCT             DEC   OCT            DEC   OCT            DEC   OCT              DEC   OCT
1)      99 00143       2)    92 00134     6)     93 00135     C)G1  102 00146      D)4CA   75 00113
E)7     48 00060       E)C   82 00122

                         LOCATIONS OF NAMES IN TRANSFER VECTOR

       DEC   OCT             DEC   OCT            DEC   OCT            DEC   OCT              DEC   OCT
EXP      1 00001       LOG    0 00000

                    ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

EXP          LOG

      EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN   IFN   LOC       EFN   IFN   LOC      EFN   IFN   LOC      EFN   IFN   LOC      EFN   IFN   LOC
 12     6 00031        10     9 00043       11    10 00045       21    12 00053       22    14 00061
 20    20 00111        50    21 00114       41    22 00117       42    24 00123       23    25 00130
```

F. Restrictions

(1) 132/(NPRINT × DT1) must be less than 5000 in order that T5, E5 and FL5 subscripts do not exceed their dimension specifications.

(2) IEEND cannot exceed 15 since the table of energy levels contains only 15 values (see energy level table below)

G. Input

Input to this program consists of five data cards and four control cards for every B-L line considered. The data cards are those output by the preceeding program. The control cards are those that handle the selection of the many available calculations in this program. The first control card contains the initial density (END) and the initial time (TSUBO) for integration. The second card contains the integration interval for the first cycle (DT1), the integration interval for all other cycles (DT2) and the end limit of integration (TEND). Setting DT1 equal to zero will give a time averaged steady state solution of the equation. The next control card defines the energy level(s) to be used. It gives the initial energy level subscript (IEST), the increment in energy level subscripts (IEDEL) and the final energy level subscript (IEEND). Energy levels are as follows:

E(1) = 10 Mev	E(6) = 125 Mev	E(11) = 350 Mev.
E(2) = 25 Mev	E(8) = 150 Mev	E(12) = 400 Mev.
E(3) = 50 Mev	E(8) = 200 Mev	E(13) = 500 Mev.
E(4) = 75 Mev	E(9) = 250 Mev	E(14) = 600 Mev.
E(5) = 100 Mev	E(10) = 300 Mev	E(15) = 700 Mev.

Note that IEST, IEEND and IEDEL must be greater than zero and that IEND cannot be greater than 15. The fourth control card contains three numbers (1) IEPR is the subscript of that energy level whose time history is to be printed on tape 5. If IEPR = 0 then no time history will be printed. (2) NPRINT tells the computer how often to print density, flux and time values on tape 5 if IEPR ≠ 0. Values will be given for every NPRINT increments in time. However, if 132/(NPRINT × DT1) is greater than 5000 the computer will print an error message and go on to the next case. This is done in order to prevent time, energy and flux subscripts from exceeding their dimension statement capacities. (3) ICSUBO is the cycle number at initial density (ENO) and initial time (TSUBO). ICSUBO is always greater than or equal to 1. All input occurs on tape 2.

1. Input Card Description

	Columns	Mode	Quantity	Units	Description
Card 1	1-8	F	ALAT	degrees	latitude
	9-16	F	EL	earth radii	magnetic field line
	17-24	F	B	gauss	magnetic induction
Card 2	1-10	E	R(1)	-	scale factor R for TIME(1)
	11-20	E	R(2)	-	scale factor R for TIME(2)
	21-30	E	R(3)	-	scale factor R for TIME(3)
	31-40	E	R(4)	-	scale factor R for TIME(4)
	41-50	E	R(5)	-	scale factor R for TIME(5)
	51-60	E	R(6)	-	scale factor R for TIME(6)
Card 3	1-10	E	R(7)	-	scale factor R for TIME(7)
	11-20	E	R(8)	-	scale factor R for TIME(8)
	21-30	E	R(9)	-	scale factor R for TIME(9)
	31-40	E	R(10)	-	scale factor R for TIME(10)
	41-50	E	R(11)	-	scale factor R for TIME(11)
	51-60	E	R(12)	-	scale factor R for TIME(12)
Card 4	1-10	E	SIG(1)	atoms/cm	atmospheric loss parameter Σ for TIME(1)
	11-20	E	SIG(2)	atoms/cm	atmospheric loss parameter Σ for TIME(2)
	21-30	E	SIG(3)	atoms/cm	atmospheric loss parameter Σ for TIME(3)
	31-40	E	SIG(4)	atoms/cm	atmospheric loss parameter Σ for TIME(4)
	41-50	E	SIG(5)	atoms/cm	atmospheric loss parameter Σ for TIME(5)
	51-60	E	SIG(6)	atoms/cm	atmospheric loss parameter Σ for TIME(6)

	Columns	Mode	Quantity	Units	Description
Card 5	1-10	E	SIG(7)	atoms/cm	atmospheric loss parameter Σ for TIME(7)
	11-20	E	SIG(8)	atoms/cm	atmospheric loss parameter Σ for TIME(8)
	21-30	E	SIG(9)	atoms/cm	atmospheric loss parameter Σ for TIME(9)
	31-40	E	SIG(10)	atoms/cm	atmospheric loss parameter Σ for TIME(10)
	41-50	E	SIG(11)	atoms/cm	atmospheric loss parameter Σ for TIME(11)
	51-60	E	SIG(12)	atoms/cm	atmospheric loss parameter Σ for TIME(12)
Card 6	1-10	E	ENO	# protons/ cm^3	initial proton density
	11-20	E	TSUBO	months	initial time
Card 7	1-8	F	DT1	months	first cycle integration interval
	9-16	F	DT2	months	remaining cycle integration interval
	17-24	F	TEND	months	limit of integration
Card 8	1-3	I	IEST	-	initial energy level subscript*
	4-6	I	IEDEL	-	energy level subscript increment*
	7-9	I	IEEND	-	final energy level subscript*
Card 9	1-5	I	IEPR	-	subscript of energy level to be printed on tape 5
	6-10	I	NPRINT	-	print on tape 5 after so many increments in time
	11-15	I	ICSUBO		cycle corresponding to ENO and TSUBO

*see table of energy levels in INPUT.

2. Sample

GENERAL PURPOSE DATA SHEET

Problem: INPUT – CONSERVATION EQUATION CALCULATION

Sponsor: TAPE 2 | Date: SAMPLE | Page | of

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

 28.9050  1.6000  0.2208
0.1679E-150.2078E-150.1628E-140.1674E-130.2370E-130.1407E-13
0.7046E-140.2267E-140.7116E-150.3938E-150.2078E-150.1679E-15
0.7208E-210.8309E-210.3571E-200.2518E-190.3479E-190.2142E-19
0.1159E-190.4581E-200.1915E-200.1273E-200.8309E-210.7208E-21
     0.0E0     0.0E0
  0.1000  0.50001320000.0
  2  2 14
    0    0    1
 15.9450  1.2500  0.2240
0.3529E-120.3880E-120.9239E-120.2289E-110.2617E-110.2141E-11
0.1639E-110.1054E-110.6653E-120.5155E-120.3880E-120.3529E-12
0.4902E-180.5401E-180.1311E-170.3299E-170.3780E-170.3082E-17
0.2350E-170.1499E-170.9377E-180.7224E-180.5401E-180.4902E-18
     0.0E0     0.0E0
  0.0100  0.1000 13200.0
  2  2 14
    4   10    1
```

GSFC FORM 541-1 (July - 60)

H. Output

Output from this program exists in several forms. First of all there is the output from the transient steady-state solution. In this solution there are two pages of printout for each case (each B-L line considered). The first page merely lists the input with explanatory headings. The second page lists each energy level and the cycle number at which steady-state was reached for that energy level. It also gives the maximum and minimum density and flux for that cycle with the times at which they appear within the cycle. Finally it lists the ratio of the maximum to the minimum flux. If, for any energy level, the absolute value of the minimum flux becomes greater than 50,000 protons/cm^2 sec. mev. then the program will ask that a smaller integration interval be used and go on to the next case. On the other hand, if the ratio of the maximum to the minimum flux becomes less than 1.09 for any energy level the program will neglect all higher energy levels and pass on to the next case since there will be no solar cycle variations in higher energy levels. This output occurs on tape 3.

The time-averaged steady-state solution has the same output with the exception that on the second page for a given B-L line $\bar{\Phi}$, $\bar{\Sigma}$, dE/dx and d/dE (dE/dx) are printed along with the flux and density for each energy level.

Time histories for energy levels are printed on tape 5 if requested during the steady-state solution. Here time, flux and density are printed for each cycle at the intervals indicated by NPRINT. See figure 13 for an idea of the results to be expected from the transient steady-state solution. Figure 15 shows output from several time history runs.

1. Transient Steady-State Sample

```
***** PROGRAM INPUT *****

LATO *** = 15.9450
L ****** =  1.2500
B ****** =  0.2240
NP SUB 0 =  0.
T  SUB 0 =  0.
DELTA T1 =  0.
DELTA T2 =  0.1000
T END ** = 13200.0

ENERGY LEVEL START =  2
DELTA ENERGY LEVEL =  2
ENERGY LEVEL END   = 14

ENERGY LEVEL TIME HISTORY =  0       INDICATES ENERGY LEVEL AT WHICH TIME HISTORY OF DENSITY AND FLUX WILL BE PRINTED ON TAPE A5.
                                     ZERO INDICATES NO TIME HISTORY ON TAPE A-5.

CYCLE AT T SUB ZERO ***** =    1

PRINTING ON TAPE A-5 AFTER EVERY    10 DELTA T.

   R(I)          SIG(I)
 0.3529E-12    0.4902E-18
 0.3880E-12    0.5401E-18
 0.9239E-12    0.1311E-17
 0.2289E-11    0.3299E-17
 0.2617E-11    0.3780E-17
 0.2141E-11    0.3082E-17
 0.1639E-11    0.2350E-17
 0.1054E-11    0.1499E-17
 0.6653E-12    0.9377E-18
 0.5155E-12    0.7224E-18
 0.3880E-12    0.5401E-18
 0.3529E-12    0.4902E-18
```

TIME AVERAGE STEADY STATE SOLUTION FOR LATD = 15.9450 , L = 1.2500 , B = 0.2240

ENERGY (MEV)	PROTON-FLUX	PROTON-DENSITY	PHI BAR	SIG BAR	(DE/DX)	D(DE/DX)/DE
25.00	1.0457E-01	1.5521E-11	1.1462E 00	1.5868E-18	2.8576E-14	9.6523E-16
75.00	5.0094E-02	4.4027E-12	1.1462E 00	1.5868E-18	1.1943E-14	1.2295E-16
125.00	3.7291E-02	2.6373E-12	1.1462E 00	1.5868E-18	8.1699E-15	4.8304E-17
200.00	2.5994E-02	1.5639E-12	1.1462E 00	1.5868E-18	5.9342E-15	1.9541E-17
300.00	1.8619E-02	9.7436E-13	1.1462E 00	1.5868E-18	4.6547E-15	8.6384E-18
400.00	1.4035E-02	6.6527E-13	1.1462E 00	1.5868E-18	4.0121E-15	4.8793E-18
600.00	8.9035E-03	3.6709E-13	1.1462E 00	1.5868E-18	3.3845E-15	2.0338E-18

2. Tape 5 Time History Sample

```
***** PROGRAM INPUT *****


LATO *** = 28.0050
L ****** =  1.5000
B ****** =  0.2208
NP SUB 0 =  0.
DELTA T1 =  0.1000
DELTA T2 =  0.5000
T END ** =132000.0

ENERGY LEVEL START =  2
DELTA ENERGY LEVEL =  2
ENERGY LEVEL END   = 14

ENERGY LEVEL TIME HISTORY =  0      INDICATES ENERGY LEVEL AT WHICH TIME HISTORY OF DENSITY AND FLUX WILL BE PRINTED ON TAPE A5.
                                    ZERO INDICATES NO TIME HISTORY ON TAPE A-5.

PRINTING ON TAPE A-5 AFTER EVERY    0 DELTA T.


   R(I)          SIG(I)
 0.1679E-15    0.7208E-21
 0.2078E-15    0.8309E-21
 0.1629E-14    0.3571E-20
 0.1674E-13    0.2518E-19
 0.2370E-13    0.3470E-19
 0.1407E-13    0.2142E-19
 0.7046E-14    0.1159E-19
 0.2267E-14    0.4581E-20
 0.7116E-15    0.1915E-20
 0.3938E-15    0.1273E-20
 0.2078E-15    0.8309E-21
 0.1679E-15    0.7208E-21
```

TRANSIENT STEADY STATE SOLUTION FOR LATD = 28.9050 , L = 1.6000 , B = 0.2208

ENERGY (MEV)	CYCLE NO.	MINIMUM - TIME (MO)	PROTON-FLUX	PROTON-DENSITY	MAXIMUM - TIME (MO)	PROTON-FLUX	PROTON-DENSITY	FLUX RATIO (MAX/MIN)
25.00	2	54.0000	4.9453	7.3402E-10	22.5000	87.7865	1.3030E-08	17.7515
75.00	6	68.5000	5.2627	4.6253E-10	28.0000	15.0626	1.3238E-09	2.8621
125.00	11	72.5000	5.0683	3.5847E-10	29.5000	8.3303	5.8914E-10	1.6435
200.00	19	74.0000	3.9392	2.3700E-10	30.0000	5.0901	3.0624E-10	1.2922
300.00	31	74.5000	2.9496	1.5436E-10	30.0000	3.4172	1.7883E-10	1.1585
400.00	41	74.5000	2.2517	1.0673E-10	30.0000	2.4980	1.1841E-10	1.1094
600.00	59	75.0000	1.4299	5.8954E-11	30.0000	1.5293	6.3054E-11	1.0695

3. Time Averaged Steady State Sample

```
***** PROGRAM INPUT *****

LAIO *** = 28.9050
L ****** =  1.6000
B ****** =  0.2208
NP SUB 0 =  0.
T  SUB 0 =  0.
DELTA T1 =  0.1000
DELTA T2 =  0.1000
T END ** = 13200.0

ENERGY LEVEL START =  8
DELTA ENERGY LEVEL =  8
ENERGY LEVEL END   =  8

ENERGY LEVEL TIME HISTORY =  8       INDICATES ENERGY LEVEL AT WHICH TIME HISTORY OF DENSITY AND FLUX WILL BE PRINTED ON TAPE A5.
                                     ZERO INDICATES NO TIME HISTORY ON TAPE A-5.

CYCLE AT T SUB ZERO ***** =    1

PRINTING ON TAPE A-5 AFTER EVERY    50 DELTA T.
```

R(I)	SIG(I)
0.1679E-15	0.7208E-21
0.2078E-15	0.8309E-21
0.1628E-14	0.3571E-20
0.1674E-13	0.2518E-19
0.2370E-13	0.3479E-19
0.1407E-13	0.2142E-19
0.7046E-14	0.1159E-19
0.2267E-14	0.4581E-20
0.7116E-15	0.1915E-20
0.3938E-15	0.1273E-20
0.2078E-15	0.8309E-21
0.1679E-15	0.7208E-21

TIME HISTORY OF DENSITY AND FLUX FOR ENERGY = 200.0 , LATO = 28.9050 , L = 1.6000 , B = 0.2208

	TIME	FLUX	DENSITY	TIME	FLUX	DENSITY	TIME	FLUX	DENSITY
CYCLE NO. = 1									
	5.000	0.0849	5.1058E-12	10.000	0.1695	1.0200E-11	15.000	0.2539	1.5273E-11
	20.000	0.3372	2.0286E-11	25.000	0.4187	2.5191E-11	30.000	0.4951	2.9784E-11
	35.000	0.5592	3.3645E-11	40.000	0.6042	3.6354E-11	45.000	0.6379	3.8381E-11
	50.000	0.6617	3.9811E-11	55.000	0.6901	4.1517E-11	60.000	0.7253	4.3635E-11
	65.000	0.7672	4.6161E-11	70.000	0.8157	4.9078E-11	75.000	0.8700	5.2344E-11
	80.000	0.9306	5.5990E-11	85.000	0.9960	5.9921E-11	90.000	1.0655	6.4106E-11
	95.000	1.1388	6.8516E-11	100.000	1.2145	7.3072E-11	105.000	1.2910	7.7672E-11
	110.000	1.3681	8.2313E-11	115.000	1.4466	8.7032E-11	120.000	1.5264	9.1835E-11
	125.000	1.6076	9.6723E-11	130.000	1.6903	1.0170E-10	132.000	1.7238	1.0371E-10
CYCLE NO. = 2									
	5.000	1.8077	1.0876E-10	10.000	1.8912	1.1379E-10	15.000	1.9742	1.1878E-10
	20.000	2.0545	1.2361E-10	25.000	2.1290	1.2809E-10	30.000	2.1878	1.3163E-10
	35.000	2.2068	1.3277E-10	40.000	2.1675	1.3041E-10	45.000	2.1079	1.2682E-10
	50.000	2.0335	1.2234E-10	55.000	1.9827	1.1929E-10	60.000	1.9574	1.1777E-10
	65.000	1.9543	1.1758E-10	70.000	1.9700	1.1852E-10	75.000	2.0010	1.2039E-10
	80.000	2.0469	1.2315E-10	85.000	2.1032	1.2654E-10	90.000	2.1671	1.3038E-10
	95.000	2.2369	1.3458E-10	100.000	2.3103	1.3900E-10	105.000	2.3850	1.4349E-10
	110.000	2.4607	1.4805E-10	115.000	2.5380	1.5270E-10	120.000	2.6170	1.5745E-10
	125.000	2.6975	1.6229E-10	130.000	2.7795	1.6723E-10	132.000	2.8128	1.6923E-10
CYCLE NO. = 3									
	5.000	2.8960	1.7424E-10	10.000	2.9789	1.7922E-10	15.000	3.0609	1.8416E-10
	20.000	3.1393	1.8887E-10	25.000	3.2094	1.9309E-10	30.000	3.2571	1.9596E-10
	35.000	3.2476	1.9539E-10	40.000	3.1551	1.8982E-10	45.000	3.0364	1.8268E-10
	50.000	2.9001	1.7448E-10	55.000	2.7992	1.6842E-10	60.000	2.7358	1.6460E-10
	65.000	2.7042	1.6270E-10	70.000	2.6992	1.6240E-10	75.000	2.7154	1.6337E-10
	80.000	2.7521	1.6558E-10	85.000	2.8027	1.6862E-10	90.000	2.8630	1.7225E-10
	95.000	2.9306	1.7632E-10	100.000	3.0026	1.8065E-10	105.000	3.0761	1.8507E-10
	110.000	3.1509	1.8957E-10	115.000	3.2275	1.9418E-10	120.000	3.3059	1.9890E-10
	125.000	3.3860	2.0372E-10	130.000	3.4676	2.0863E-10	132.000	3.5007	2.1062E-10
CYCLE NO. = 4									
	5.000	3.5835	2.1560E-10	10.000	3.6659	2.2056E-10	15.000	3.7475	2.2546E-10
	20.000	3.8246	2.3011E-10	25.000	3.8919	2.3416E-10	30.000	3.9326	2.3660E-10
	35.000	3.9051	2.3495E-10	40.000	3.7789	2.2736E-10	45.000	3.6230	2.1798E-10
	50.000	3.4476	2.0742E-10	55.000	3.3151	1.9945E-10	60.000	3.2276	1.9418E-10
	65.000	3.1779	1.9120E-10	70.000	3.1598	1.9011E-10	75.000	3.1667	1.9052E-10
	80.000	3.1976	1.9238E-10	85.000	3.2445	1.9521E-10	90.000	3.3027	1.9870E-10
	95.000	3.3689	2.0269E-10	100.000	3.4399	2.0696E-10	105.000	3.5126	2.1134E-10
	110.000	3.5869	2.1580E-10	115.000	3.6631	2.2039E-10	120.000	3.7412	2.2509E-10
	125.000	3.8209	2.2988E-10	130.000	3.9023	2.3478E-10	132.000	3.9353	2.3676E-10
CYCLE NO. = 5									
	5.000	4.0178	2.4173E-10	10.000	4.1000	2.4667E-10	15.000	4.1811	2.5156E-10
	20.000	4.2575	2.5615E-10	25.000	4.3231	2.6010E-10	30.000	4.3593	2.6227E-10
	35.000	4.3204	2.5994E-10	40.000	4.1730	2.5107E-10	45.000	3.9936	2.4027E-10
	50.000	3.7934	2.2823E-10	55.000	3.6410	2.1906E-10	60.000	3.5382	2.1287E-10
	65.000	3.4772	2.0920E-10	70.000	3.4508	2.0762E-10	75.000	3.4518	2.0768E-10
	80.000	3.4790	2.0931E-10	85.000	3.5237	2.1200E-10	90.000	3.5804	2.1541E-10
	95.000	3.6457	2.1934E-10	100.000	3.7161	2.2358E-10	105.000	3.7884	2.2793E-10
	110.000	3.8623	2.3237E-10	115.000	3.9382	2.3694E-10	120.000	4.0161	2.4163E-10
	125.000	4.0957	2.4641E-10	130.000	4.1769	2.5130E-10	132.000	4.2098	2.5328E-10
CYCLE NO. = 6									
	5.000	4.2922	2.5824E-10	10.000	4.3742	2.6317E-10	15.000	4.4551	2.6804E-10
	20.000	4.5310	2.7261E-10	25.000	4.5954	2.7648E-10	30.000	4.6289	2.7849E-10
	35.000	4.5828	2.7572E-10	40.000	4.4220	2.6605E-10	45.000	4.2277	2.5436E-10
	50.000	4.0118	2.4137E-10	55.000	3.8468	2.3144E-10	60.000	3.7344	2.2468E-10
	65.000	3.6662	2.2058E-10	70.000	3.6346	2.1868E-10	75.000	3.6319	2.1851E-10
	80.000	3.6568	2.2001E-10	85.000	3.7000	2.2261E-10	90.000	3.7558	2.2597E-10
	95.000	3.8206	2.2986E-10	100.000	3.8906	2.3406E-10	105.000	3.9626	2.3841E-10
	110.000	4.0363	2.4284E-10	115.000	4.1120	2.4740E-10	120.000	4.1898	2.5208E-10
	125.000	4.2693	2.5686E-10	130.000	4.3503	2.6173E-10	132.000	4.3832	2.6371E-10
CYCLE NO. = 7									

I. Running Time

Transient steady-state solutions where DT1 = .5 and DT2 = 1.0 will cover eleven cycles per minute. See figure 14 for an idea of how many cycles are necessary to reach steady-state for various B's at an L of 1.25 earth radii.

Runs requesting a time history print on tape 5 take about twice as long.

Time averaged steady state solutions take about a quarter of a minute for each B-L line.

VIII. STEADY-STATE CALCULATION

A. Introduction

This program evaluates the solar maximum and solar minimum steady state conditions of the conservation equation. That is, with dN_p/dt set equal to zero, the flux and density are studied at solar minimum (time = 0.0 years, see Figure 1) and solar maximum (time = 4.0 years). The mean lifetimes of the protons are also calculated as well as dE/dx, d/dE(dE/dx), the three coefficients of the conservation equation C_0, C_1 and C_2 and the source and loss terms. This is all printed together with the appropriate Σ for a given B, L, λ and energy level. All 15 energy levels of the preceeding program are evaluated for each B and L.

B. Equations

The equations used in this program are listed below:

$$\text{SOURCE} = \text{XX} = A_0 \Phi / L^2 E^{B_0} \cos^4 \lambda_0$$

$$\text{LOSS} = \text{YY} = \frac{A_1 N_p}{E^{B_1}} \left(\frac{dE}{dX}\right) + A_2 N_p E^{B_2} \frac{d}{dE} \left(\frac{dE}{dX}\right) + A_2 N_p E^{B_2} \Sigma$$

$$\text{MEAN LIFETIME} = \text{TAU} = N_p/\text{XX}$$

$$\text{FLUX} = \text{FLUXP} = N_p(\text{EXT})E^{B_2} C = N_p \beta C = N_p v$$

$$\text{DENSITY} = \text{EN1} = \frac{A_0 \Phi}{L^2 E^{B_0} \cos^4 \lambda_0 \left[\frac{A_1}{E^{B_1}} \left(\frac{dE}{dX}\right) + A_2 E^{B_2} \left(\frac{d}{dE} \left(\frac{dE}{dX}\right) + \Sigma\right)\right]}$$

where C = speed of light

Φ = PREL = relative neutron source strength

Σ = SIG = atmospheric loss parameter

$A_0, \ldots, A_2$ = high or low energy conservation equation coefficients depending upon whether E > 80 Mev. or E $\leq$ 80 Mev respectively

$B_0, \ldots, B_2$ = high or low energy conservation equation coefficients depending upon whether E > 80 Mev. or E $\leq$ 80 Mev. respectively

λ_0 = Mirror latitude

N_p = proton number density

v = neutron velocity

β = v/C

$EXT = \beta / E^{B_2}$

C. Mnemonics

Quantity	Description	Units
TIME(J)	abscissa of time in increments of years for 12 years	years
ELOSS(J)	dE/dX corresponding to E(J) (see Figure 11)	Mev./cm.
E(J)	energy corresponding to ELOSS(J) (see Figure 11)	Mev
ALO	A_0 for E $\leq$ 80 Mev. (see preceeding page)	# protons / cm. sec. Mev.
AL1	A_1 " " "	cm/sec
AL2	A_2 " " "	cm./Mev^2 sec.
AH0	A_0 for E > 80 Mev. (see preceeding page)	# protons / cm. sec. Mev.
AH1	A_1 " " "	cm. sec.
AH2	A_2 " " "	cm/Mev^2 sec.

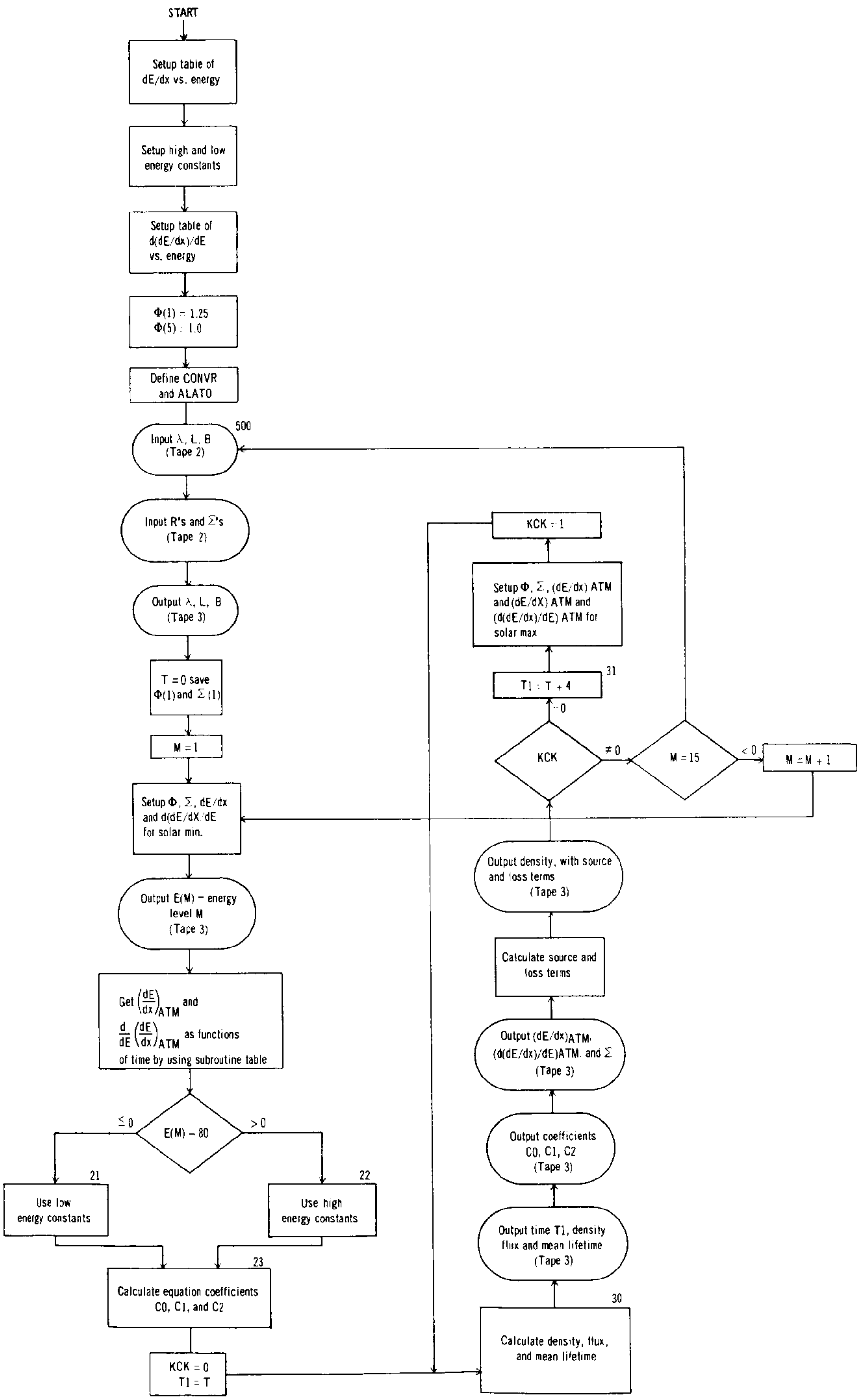
Quantity	Description	Units
BL0	B_0 for E $\geq$ 80 Mev. (see preceeding page)	-
BL1	B_1 " " "	-
BL2	B_2 " " "	-
BH0	B_0 for E > 80 Mev. (see preceeding page)	-
BH1	B_1 " " "	-
BH2	B_2 " " "	-
DELOSS(J)	d(dE/dX)/dE corresponding to DE(J) (see Figure 12)	$cm.^{-1}$
DE(J)	energy corresponding to DELOSS(J) (see Figure 12)	Mev.
PREL(J)	Φ for TIME(J) (see Figure 11 and page 167)	-
CONVR	conversion factor – degrees to radians	-
ALAT	mirror latitude λ_0	degrees
EL	magnetic field line L	earth radii
B	magnetic induction B	gauss
R(J)	atmospheric scale factor R for TIME(J)	-
SIG(J)	atmospheric loss parameter Σ for TIME(J)	atoms/cm
ALATO	ALAT in radians	radians
SVPR	temporary storage of PREL(1)	-
SVSG	temporary storage of SIG(1)	atoms/cm
t	time	years

Quantity	Description	Units
M	energy level subscript	-
ENER	energy level E(M)	Mev.
ALOSS	dE/dX for E(M)	Mev/cm
X(k)	temporary storage of DE(k)	Mev.
Y(k)	temporary storage of DELOSS(k)	cm^{-1}
EANS	d(dE/dX)/dE for E(M)	cm^{-1}
ALOSSA(J)	(dE/dX) X R(J) for E(M)	Mev/cm
DLOSSA(J)	(d(dE/dX)/dE) X R(J) for E(M)	cm^{-1}
A0	temporary storage of AL0 or AH0	$\frac{\text{\# protons}}{\text{cm. sec. Mev.}}$
A1	temporary storage of AL1 or AH1	cm./sec.
A2	temporary storage of AL2 or AH2	cm/Mev^2 sec.
B0	temporary storage of BL0 or BH0	-
B1	temporary storage of BL1 or BH1	-
B2	temporary storage of BL2 or BH2	-
EXT	(see page 168)	-
C0	conservation equation coefficient c_0 where $C_0 = A_0/L^2 E^{B_0} \cos^4 \lambda_0$	$\frac{\text{\# protons}}{\text{cm}^2\text{ sec. Mev.}}$
C1	conservation equation coefficient C_1 where $C = A_1/E^{B_1}$	cm/sec. Mev.
C2	conservation equation coefficient C_2 where $C_2 = A_2 E^{B_2}$	cm/sec. Mev.

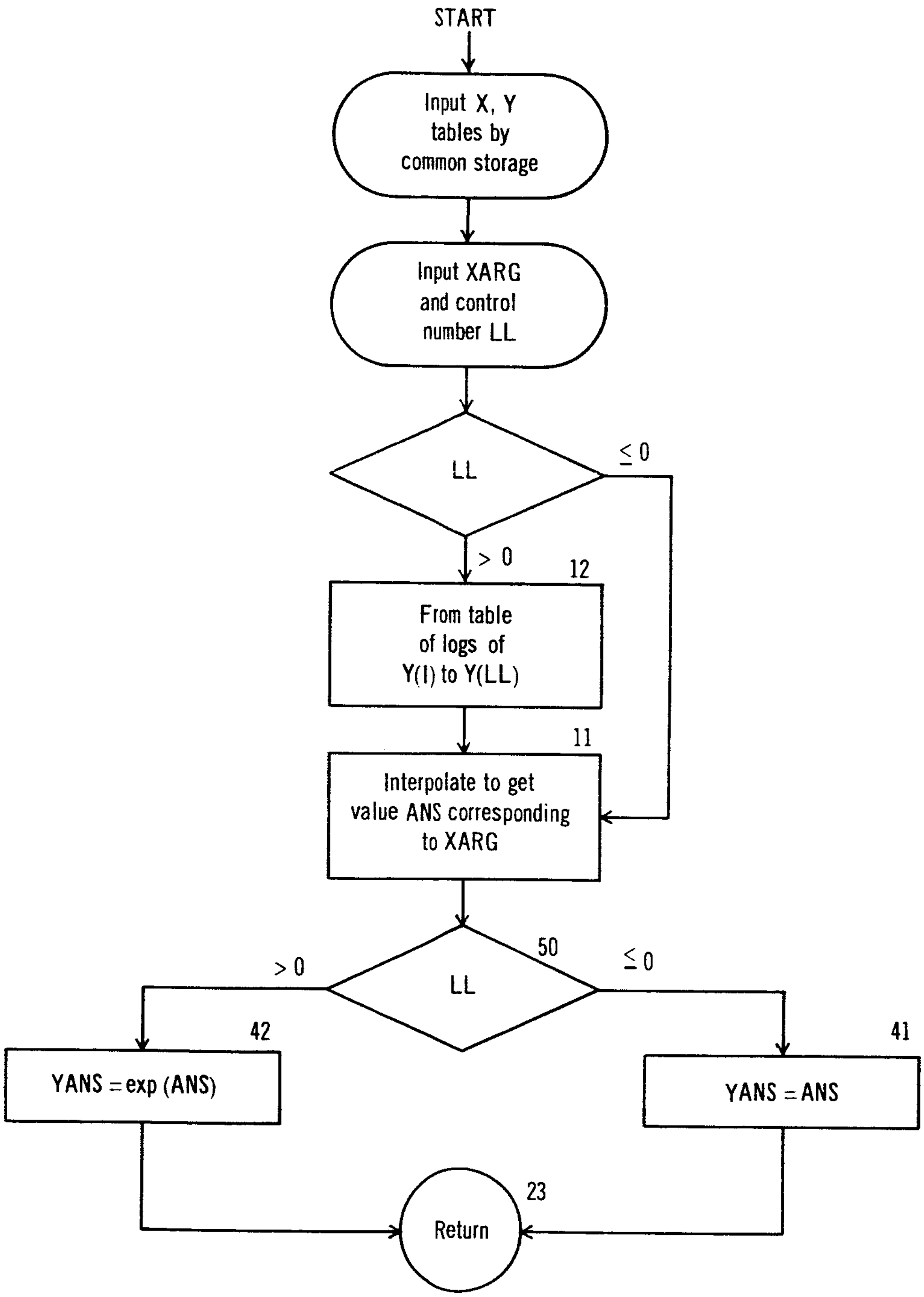
Quantity	Description	Units
KCK	counter to determine if solar maximum or solar minimum is being evaluated	-
T1	particular time under consideration	years
EN1	proton density	$\frac{\text{\# protons}}{\text{Mev. cm}}$
FLUXP	proton flux	$\frac{\text{\# protons}}{\text{cm}^2\text{ sec. Mev.}}$
TAU	mean proton lifetime	sec
XX	conservation equation source term (see page 167)	$\frac{\text{\# protons}}{\text{cm}^2\text{sec.}}$
YY	conservation equation loss term (see page 167)	$\frac{\text{\# protons}}{\text{cm}^2\text{sec.}}$

D. Flow Charts

1. Main Program



2. Subroutine Table



E. Fortran Listing

```
STEADY                                                                10/01/64

C      STEADY STATE
       DIMENSION E(15),ELOSS(15),TIME(12),R(12),DELOSS(15),DE(15),PREL(5)
      1,ALOSSA(12),CLOSSA(12),X(15),Y(15),SIG(12)
       COMMON X,Y
     1 FORMAT(3F8.4)
     2 FORMAT(6E10.4)
     3 FORMAT(1F15.3,1E20.4,1F20.5,1E20.5)
     4 FORMAT(1H1,2X,5HLATO=1F8.3,2X,2HL=1F6.3,3X,2HB=F7.4)
     5 FORMAT(10X,7HENERGY=1F8.2,3HMEV)
     6 FORMAT(9X,4HTIME,15X,4HN(E),17X,4HFLUX,10X,13HMEAN LIFETIME)
     7 FORMAT(5X,3HC0=E12.5,5X,3HC1=E12.5,5X,3HC2=E12.5)
     8 FORMAT(1X,7HALOSSA=E12.5,1X,7HCLOSSA=E12.5,4X,4HSIG=E12.5)
     9 FORMAT(3X,5HN(E)=E12.5,1X,7HSOURCE=E12.5,3X,5HLOSS=E12.5)
       TIME(1)=0.0
       DO 11 J=1,11
       TIME(J+1)=TIME(J)+12.0
    11 CONTINUE
       ELOSS(1)=5.3985E-2
       ELOSS(2)=2.5732E-2
       ELOSS(3)=1.4755E-2
       ELOSS(4)=1.0754E-2
       ELOSS(5)=8.6553E-3
       ELOSS(6)=7.3567E-3
       ELOSS(7)=6.4720E-3
       ELOSS(8)=5.3435E-3
       ELOSS(9)=4.6543E-3
       ELOSS(10)=4.1914E-3
       ELOSS(11)=3.8602E-3
       ELOSS(12)=3.6127E-3
       ELOSS(13)=3.2701E-3
       ELOSS(14)=3.0476E-3
       ELOSS(15)=2.8942E-3
       E(1)=10.
       E(2)=25.
       E(3)=50.
       E(4)=75.
       E(5)=100.
       E(6)=125.
       E(7)=150.
       E(8)=200.
       E(9)=250.
       E(10)=300.
       E(11)=350.
       E(12)=400.
       E(13)=500.
       E(14)=600.
       E(15)=700.
C      10-E-80 MEV
       AL0=       2.964E-13
       AL1=      3.463E+8
       AL2=      7.255E+8
       BL0=2.509
       BL1=.523
       BL2=.477
C      80-E-700 MEV
```

```
      AH0=        3.4792E-13
      AH1=        4.617E+8
      AH2=        1.343E+9
      BH0=2.549
      BH1=.656
      BH2=.344
      DE(1)=10.
      DE(2)=10.5
      DE(3)=16.5
      DE(4)=27.5
      DE(5)=52.5
      DE(6)=72.5
      DE(7)=92.5
      DE(8)=137.5
      DE(9)=212.5
      DE(10)=262.5
      DE(11)=312.5
      DE(12)=412.5
      DE(13)=525.5
      DE(14)=625.5
      DE(15)=700.
      DELOSS(1)=-.40E-2
      DELOSS(2)=-.3985E-2
      DELOSS(3)=-.1770E-2
      DELOSS(4)=-.7051E-3
      DELOSS(5)=-.2173E-3
      DELOSS(6)=-.1172E-3
      DELOSS(7)=-.743E-4
      DELOSS(8)=-.354E-4
      DELOSS(9)=-.153E-4
      DELOSS(10)=-.101E-4
      DELOSS(11)=-.713E-5
      DELOSS(12)=-.410E-5
      DELOSS(13)=-.244E-5
      DELOSS(14)=-.166E-5
      DELOSS(15)=-.131E-5
      PREL(1)=1.25
      PREL(5)=1.0
      CONVR=1./57.29577
  500 READ INPUT TAPE 2,1,ALAT,EL,B
      READ INPUT TAPE 2,2,R(1),R(2),R(3),R(4),R(5),R(6)
      READ INPUT TAPE 2,2,R(7),R(8),R(9),R(10),R(11),R(12)
      READ INPUT TAPE 2,2,SIG(1),SIG(2),SIG(3),SIG(4),SIG(5),SIG(6)
      READ INPUT TAPE 2,2,SIG(7),SIG(8),SIG(9),SIG(10),SIG(11),SIG(12)
      WRITE OUTPUT TAPE 3,4,ALAT,EL,B
      ALATO=ALAT*CONVR
      SVPR=PREL(1)
      SVSG=SIG(1)
      T=0.0
      DO 300 M=1,15
      ENER=E(M)
      WRITE OUTPUT TAPE 3,5,ENER
      WRITE OUTPUT TAPE 3,6
      ALOSS=ELOSS(M)
      DO 201 K=1,15
      X(K)=DE(K)
```

```
      Y(K)=ELLOSS(K)
 201  CONTINUE
      CALL TABLE(ENER,EANS,15)
      DO 20 J=1,12
      ALOSSA(J)=R(J)*ALOSS
      DLOSSA(J)=R(J)*EANS
   20 CONTINUE
C     NOW HAVE (DE/DX)ATMOS AND (D(DE/DX)/DE)ATMOS AS FUNCTIONS
C     OF TIME FOR A GIVEN ENERGY AND L
      IF(ENER-80.) 21,21,22
   21 A0=AL0
      A1=AL1
      A2=AL2
      B0=BL0
      B1=BL1
      B2=BL2
      EXT=.0484
      GO TO 23
   22 A0=AH0
      A1=AH1
      A2=AH2
      B0=BH0
      B1=BH1
      B2=BH2
      EXT=.0896
   23 C0=A0/(EL**2.*ENER**B0*COSF(ALATO)**4)
      C1=A1/(ENER**B1)
      C2=A2*ENER**B2
      KCK=0
      T1=T
 30   EN1=C0*PREL(1)/(C1*ALOSSA(1)+C2*DLOSSA(1)+C2*SIG(1))
      FLUXP=EN1*EXT*ENER**B2*2.9979E10
      TAU=EN1/(C0*PREL(1)*2.592E6)
      WRITE OUTPUT TAPE 3,3,T1,EN1,FLUXP,TAU
      WRITE OUTPUT TAPE 3,7,C0,C1,C2
      WRITE OUTPUT TAPE 3,8,ALOSSA(1),DLOSSA(1),SIG(1)
      XX=C0*PREL(1)
      YY=C1*ALOSSA(1)+C2*DLOSSA(1)+C2*SIG(1)
      WRITE OUTPUT TAPE 3,9,EN1,XX,YY
      IF(KCK) 301,31,301
 31   T1=T+4.
      ALOSSA(1)=ALOSSA(5)
      DLOSSA(1)=DLOSSA(5)
      PREL(1)=PREL(5)
      SIG(1)=SIG(5)
      KCK=1
      WRITE OUTPUT TAPE 3,6
      GO TO 30
 301  PREL(1)=SVPR
      SIG(1)=SVSG
 300  CONTINUE
      GO TO 500
      END(1,0,0,0,0,0,0,0,0,0,0,0,0,0,0)
```

```
STEADY                                                                    10/01/64

                                   STORAGE NOT USED BY PROGRAM

          DEC   OCT                DEC   OCT
          817 01461              32531 77423

                    STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

          DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
      X 32561 77461            Y 32546 77442

             STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

          DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
ALOSSA    727 01327      DELOSS    762 01372       DE      747 01353    DLOSSA     715 01313    ELOSS      801 01441
     E    816 01460        PREL    732 01334        R      774 01406       SIG     703 01277     TIME      786 01422

         STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

          DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
    A0    691 01263          A1    690 01262       A2      689 01261       AH0     688 01260      AH1      687 01257
   AH2    686 01256         AL0    685 01255      AL1      684 01254       AL2     683 01253    ALATC      682 01252
  ALAT    681 01251       ALOSS    680 01250       B0      679 01247        B1     678 01246       B2      677 01245
   BH0    676 01244         BH1    675 01243      BH2      674 01242       BL0     673 01241      BL1      672 01240
   BL2    671 01237           B    670 01236       C0      669 01235        C1     668 01234       C2      667 01233
 CONVR    666 01232        EANS    665 01231       EL      664 01230       EN1     663 01227     ENER      662 01226
   EXT    661 01225       FLUXP    660 01224      KCK      659 01223      SVPR     658 01222     SVSG      657 01221
    T1    656 01220         TAU    655 01217        T      654 01216        XX     653 01215       YY      652 01214

                        SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

          EFN   LOC                EFN   LOC               EFN   LOC               EFN   LOC               EFN   LOC
   811      1 01206         812      2 01204      813        3 01202       814       4 01175      815        5 01165
   816      6 01160         817      7 01147      818        8 01137       819       9 01126

                       LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

          DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
    1)    647 01207          2)    496 00760       3)      502 00766        4)   32767 77777       6)      584 01110

                                  LOCATIONS OF NAMES IN TRANSFER VECTOR

          DEC   OCT                DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
   COS      6 00006        EXP(3     7 00007    TABLE        5 00005     (FIL)       4 00004    (FPT)        0 00000
 (RTN)      2 00002        (STH)     3 00003    (TSH)        1 00001

                            ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

COS          EXP(3        TABLE        (FIL)        (FPT)        (RTN)        (STH)        (TSH)

          EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

   EFN    IFN   LOC         EFN    IFN   LOC        EFN    IFN   LOC         EFN    IFN   LOC        EFN    IFN   LOC
    11     16 00023         500     92 00254        201    117 00435          20    123 00452         21    125 00460
    22    133 00477          23    140 00515         30    145 00571          31    155 00727        301    167 00751
   300    169 00755
```

```
C     SUBRCUTINE TC INTERPOLATE A GIVEN TABLE
      SUBROUTINE TABLE(XARG,YANS,LL)
      CIMENSICN X(15),Y(15)
      COMMON X,Y
      IF(LL)11,11,12
   12 DC 10 K=1,LL
      A=Y(K)
      Y(K)=LOGF(A)
   10 CONTINUE
   11 DO 20 J=1,15
      IF(X(J)-XARG)20,21,22
   21 ANS=Y(J)
      GO TO 50
   22 H1=X(J)
      Y1=Y(J)
      HO=X(J-1)
      YO=Y(J-1)
      ANS=Y1-(Y1-YC)*(H1-XARG)/(H1-HO)
      GC TO 50
   20 CONTINUE
   50 IF(LL) 41,41,42
   41 YANS=ANS
      GO TO 23
   42 YANS=EXPF(ANS)
   23 RETURN
      END(1,0,0,0,0,0,0,C,0,0,C,C,C,C,0)
```

```
                               STORAGE NOT USED BY PROGRAM

     DEC   OCT              DEC   OCT
     110 00156            32531 77423

                  STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

     DEC   OCT              DEC   OCT             DEC   OCT             DEC   OCT             DEC   OCT
  X 32561 77461           Y 32546 77442

           STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

     DEC   OCT              DEC   OCT             DEC   OCT             DEC   OCT             DEC   OCT
 ANS 109 00155           A  108 00154       F0    107 00153       H1    106 00152       J     105 00151
  Y0 104 00150           Y1 103 00147

                  LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

     DEC   OCT              DEC   OCT             DEC   OCT             DEC   OCT             DEC   OCT
  1)  99 00143           2)  92 00134       6)     93 00135       C/C   102 00146       D)4CA  75 00113
 E)7  48 00060          E)C  82 00122

                             LOCATIONS OF NAMES IN TRANSFER VECTOR

     DEC   OCT              DEC   OCT             DEC   OCT             DEC   OCT             DEC   OCT
 EXP   1 00001          LOG   0 00000

                        ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

EXP          LOG

            EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

 EFN   IFN   LOC        EFN   IFN   LOC       EFN   IFN   LOC       EFN   IFN   LOC       EFN   IFN   LOC
  12     6 00031         10     9 00043        11    10 00045        21    12 00053        22    14 00061
  20    20 00111         50    21 00114        41    22 00117        42    24 00123        23    25 00130
```

F. Input

Input to this program occurs on logical tape 2 and consists of B, L, λ, R(1), ..., R(12) Σ (1), ..., Σ (12) for each case under consideration. As with the conservation equation calculation the B-L-λ card is followed by two R cards which are followed in turn by two Σ cards. The control cards are left out of this program since there is only one method of computation available here.

1. Input Card Description

	Columns	Mode	Quantity	Units	Description
B-L-λ	1-8	F	ALAT	degrees	latitude
Card	9-16	F	EL	earth radii	magnetic field line
	17-24	F	B	gauss	magnetic induction
First R Card	1-10	E	R(1)	-	scale factor R for TIME(1)
	11-20	E	R(2)	-	scale factor R for TIME(2)
	21-30	E	R(3)	-	scale factor R for TIME(3)
	31-40	E	R(4)	-	scale factor R for TIME(4)
	41-50	E	R(5)	-	scale factor R for TIME(5)
	51-60	E	R(6)	-	scale factor R for TIME(6)
Second R Card	1-10	E	R(7)	-	scale factor R for TIME(7)
	11-20	E	R(8)	-	scale factor R for TIME(8)
	21-30	E	R(9)	-	scale factor R for TIME(9)
	31-40	E	R(10)	-	scale factor R for TIME(10)
	41-50	E	R(11)	-	scale factor R for TIME(11)
	51-60	E	R(12)	-	scale factor R for TIME(12)
First Σ Card	1-10	E	SIG(1)	atoms/cm	atmospheric loss parameter Σ for TIME(1)
	11-20	E	SIG(2)	atoms/cm	atmospheric loss parameter Σ for TIME(2)
	21-30	E	SIG(3)	atoms/cm	atmospheric loss parameter Σ for TIME(3)
	31-40	E	SIG(4)	atoms/cm	atmospheric loss parameter Σ for TIME(4)

	Columns	Mode	Quantity	Units	Description
	41-50	E	SIG(5)	atoms/cm	atmospheric loss parameter Σ for TIME(5)
	51-60	E	SIG(6)	atoms/cm	atmospheric loss parameter Σ for TIME(6)
Second Σ Card	1-10	E	SIG(7)	atoms/cm	atmospheric loss parameter Σ for TIME(7)
	11-20	E	SIG(8)	atoms/cm	atmospheric loss parameter Σ for TIME(8)
	21-30	E	SIG(9)	atoms/cm	atmospheric loss parameter Σ for TIME(9)
	31-40	E	SIG(10)	atoms/cm	atmospheric loss parameter Σ for TIME(10)
	41-50	E	SIG(11)	atoms/cm	atmospheric loss parameter Σ for TIME(11)
	51-60	E	SIG(12)	atoms/cm	atmospheric loss parameter Σ for TIME(12)

2. Sample

GENERAL PURPOSE DATA SHEET

Problem: INPUT – STEADY STATE

Sponsor: TAPE 2 | Date: SAMPLE | Page ___ of ___

```
  6.9730  1.1420  0.2239
0.2785E-110.2986E-110.5636E-110.1096E-100.1208E-100.1043E-10
0.8577E-110.6201E-110.4438E-110.3681E-110.2986E-110.2785E-11
0.3984E-170.4278E-170.8160E-170.1599E-160.1765E-160.1522E-16
0.1249E-160.8991E-170.6404E-170.5293E-170.4278E-170.3984E-17
  4.9730  1.1420  0.2168
0.3744E-130.4245E-130.1368E-120.4977E-120.6065E-120.4509E-12
0.3059E-120.1638E-120.8710E-130.6190E-130.4245E-130.3744E-13
0.5633E-190.6339E-190.1936E-180.6907E-180.8406E-180.6260E-18
0.4261E-180.2306E-180.1250E-180.9038E-190.6339E-190.5633E-19
  2.9730  1.1420  0.2121
0.2016E-140.2331E-140.9446E-140.4953E-130.6435E-130.4345E-13
0.2619E-130.1182E-130.5388E-140.3603E-140.2331E-140.2016E-14
0.7878E-200.8697E-200.2304E-190.8246E-190.1023E-180.7404E-19
0.4938E-190.2704E-190.1544E-190.1170E-190.8697E-200.7878E-20
  0.9730  1.1420  0.2099
0.5789E-150.6450E-150.1943E-140.9476E-140.1253E-130.8241E-14
0.4915E-140.2342E-140.1217E-140.8924E-150.6450E-150.5789E-15
0.3927E-200.4304E-200.1010E-190.2754E-190.3255E-190.2533E-19
0.1851E-190.1152E-190.7273E-200.5668E-200.4304E-200.3927E-20
```

GSFC FORM 541-1 (July - 60)

G. Output

Output for this program occurs on tape 3. Time, density, flux, mean lifetime, dE/dX, d(dE/dX)/dE, Σ, source and loss are all printed for each energy level at a given B, L and latitude. The headings are listed below with explanations and dimensions:

TIME – time – years

N(E) – density – # protons/cm^3 Mev.

FLUX – flux – # protons/cm^2 sec. Mev.

MEAN LIFETIME – proton mean lifetime – sec.

C0 - C_0 (see MNEMONICS) – # protons/cm^3 sec. Mev.

C1 - C_1 (see MNEMONICS) – cm/sec. Mev.

C2 - C_2 (see MNEMONICS) – cm/sec. Mev.

ALOSSA – (dE/dX) ATMOS – Mev./cm.

DLOSSA – (d(dE/dX)/dE) ATMOS – cm^{-1}

SIG – Σ – atoms/cm

SOURCE – conservation equation source term – # protons/cm^3 Mev.

LOSS – conservation equation loss term – # protons/cm^3 Mev.

ENERGY – energy – Mev.

LATO – latitude – degrees

L – magnetic field line – earth radii

B – magnetic induction – gauss

```
LATO=  12.954  L= 1.188   B= 0.2331
        ENERGY=    10.00MEV
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         0.                0.7172E-13                 0.00031           0.30695E-04
    C0= 0.72115E-15     C1= 0.10386E 09         C2= 0.21759E 10
ALOSSA= 0.47404E-10 DLOSSA= 0.35124E-11         SIG= 0.13080E-14
  N(E)= 0.71720E-13 SOURCE= 0.90144E-15        LOSS= 0.12569E-01
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         4.000             0.7083E-13                 0.00031           0.37893E-04
    C0= 0.72115E-15     C1= 0.10386E 09         C2= 0.21759E 10
ALOSSA= 0.38400E-10 DLOSSA= 0.28452E-11         SIG= 0.10610E-14
  N(E)= 0.70831E-13 SOURCE= 0.72115E-15        LOSS= 0.10181E-01
        ENERGY=    25.00MEV
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         0.                0.2246E-13                 0.00015           0.95765E-04
    C0= 0.72376E-16     C1= 0.64318E 08         C2= 0.33686E 10
ALOSSA= 0.22595E-10 DLOSSA= 0.76320E-12         SIG= 0.13080E-14
  N(E)= 0.22457E-13 SOURCE= 0.90470E-16        LOSS= 0.40286E-02
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         4.000             0.2218E-13                 0.00015           0.11822E-03
    C0= 0.72376E-16     C1= 0.64318E 08         C2= 0.33686E 10
ALOSSA= 0.18303E-10 DLOSSA= 0.61823E-12         SIG= 0.10610E-14
  N(E)= 0.22178E-13 SOURCE= 0.72376E-16        LOSS= 0.32634E-02
        ENERGY=    50.00MEV
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         0.                0.9981E-14                 0.00009           0.24227E-03
    C0= 0.12715E-16     C1= 0.44760E 08         C2= 0.46886E 10
ALOSSA= 0.12956E-10 DLOSSA= 0.21465E-12         SIG= 0.13080E-14
  N(E)= 0.99806E-14 SOURCE= 0.15894E-16        LOSS= 0.15925E-02
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         4.000             0.9857E-14                 0.00009           0.29908E-03
    C0= 0.12715E-16     C1= 0.44760E 08         C2= 0.46886E 10
ALOSSA= 0.10495E-10 DLOSSA= 0.17387E-12         SIG= 0.10610E-14
  N(E)= 0.98567E-14 SOURCE= 0.12715E-16        LOSS= 0.12900E-02
        ENERGY=    75.00MEV
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         0.                0.6368E-14                 0.00007           0.42753E-03
    C0= 0.45973E-17     C1= 0.36207E 08         C2= 0.56891E 10
ALOSSA= 0.94431E-11 DLOSSA= 0.97214E-13         SIG= 0.13080E-14
  N(E)= 0.63681E-14 SOURCE= 0.57466E-17        LOSS= 0.90241E-03
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         4.000             0.6289E-14                 0.00007           0.52777E-03
    C0= 0.45973E-17     C1= 0.36207E 08         C2= 0.56891E 10
ALOSSA= 0.76493E-11 DLOSSA= 0.78748E-13         SIG= 0.10610E-14
  N(E)= 0.62890E-14 SOURCE= 0.45973E-17        LOSS= 0.73100E-03
        ENERGY=   100.00MEV
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         0.                0.4893E-14                 0.00006           0.69244E-03
    C0= 0.21809E-17     C1= 0.22509E 08         C2= 0.65475E 10
ALOSSA= 0.76002E-11 DLOSSA= 0.57659E-13         SIG= 0.13080E-14
  N(E)= 0.48928E-14 SOURCE= 0.27261E-17        LOSS= 0.55716E-03
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         4.000             0.4832E-14                 0.00006           0.85460E-03
    C0= 0.21809E-17     C1= 0.22509E 08         C2= 0.65475E 10
ALOSSA= 0.61565E-11 DLOSSA= 0.46707E-13         SIG= 0.10610E-14
  N(E)= 0.48320E-14 SOURCE= 0.21809E-17        LOSS= 0.45134E-03
        ENERGY=   125.00MEV
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         0.                0.3812E-14                 0.00005           0.95289E-03
    C0= 0.12348E-17     C1= 0.19444E 08         C2= 0.70699E 10
ALOSSA= 0.64599E-11 DLOSSA= 0.38193E-13         SIG= 0.13080E-14
  N(E)= 0.38123E-14 SOURCE= 0.15435E-17        LOSS= 0.40488E-03
        TIME                 N(E)                       FLUX            MEAN LIFETIME
         4.000             0.3765E-14                 0.00005           0.11763E-02
```

```
      C0= 0.12348E-17      C1= 0.19444E 08      C2= 0.70699E 10
  ALOSSA= 0.52328E-11  DLOSSA= 0.30938E-13     SIG= 0.10610E-14
    N(E)= 0.37650E-14  SOURCE= 0.12348E-17    LOSS= 0.32798E-03
         ENERGY=  150.00MEV
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         0.                0.3115E-14             0.00005             0.12391E-02
      C0= 0.77584E-18      C1= 0.17252E 08      C2= 0.75275E 10
  A    SSA= 0.56831E-11  DLOSSA= 0.27029E-13     SIG= 0.13080E-14
    N(E)= 0.31148E-14  SOURCE= 0.96980E-18    LOSS= 0.31135E-03
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         4.000             0.3076E-14             0.00005             0.15296E-02
      C0= 0.77584E-18      C1= 0.17252E 08      C2= 0.75275E 10
  ALOSSA= 0.46035E-11  DLOSSA= 0.21895E-13     SIG= 0.10610E-14
    N(E)= 0.30761E-14  SOURCE= 0.77584E-18    LOSS= 0.25222E-03
         ENERGY=  200.00MEV
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         0.                0.2258E-14             0.00004             0.18701E-02
      C0= 0.37265E-18      C1= 0.14285E 08      C2= 0.83106E 10
  ALOSSA= 0.46921E-11  DLOSSA= 0.15451E-13     SIG= 0.13080E-14
    N(E)= 0.22579E-14  SOURCE= 0.46582E-18    LOSS= 0.20630E-03
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         4.000             0.2230E-14             0.00004             0.23084E-02
      C0= 0.37265E-18      C1= 0.14285E 08      C2= 0.83106E 10
  ALOSSA= 0.38008E-11  DLOSSA= 0.12516E-13     SIG= 0.10610E-14
    N(E)= 0.22298E-14  SOURCE= 0.37265E-18    LOSS= 0.16713E-03
         ENERGY=  250.00MEV
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         0.                0.1753E-14             0.00003             0.25641E-02
      C0= 0.21100E-18      C1= 0.12340E 08      C2= 0.89736E 10
  ALOSSA= 0.40869E-11  DLOSSA= 0.98392E-14     SIG= 0.13080E-14
    N(E)= 0.17529E-14  SOURCE= 0.26375E-18    LOSS= 0.15046E-03
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         4.000             0.1731E-14             0.00003             0.31651E-02
      C0= 0.21100E-18      C1= 0.12340E 08      C2= 0.89736E 10
  ALOSSA= 0.33106E-11  DLOSSA= 0.79702E-14     SIG= 0.10610E-14
    N(E)= 0.17310E-14  SOURCE= 0.21100E-18    LOSS= 0.12189E-03
         ENERGY=  300.00MEV
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         0.                0.1404E-14             0.00003             0.32680E-02
      C0= 0.13257E-18      C1= 0.10949E 08      C2= 0.95545E 10
  ALOSSA= 0.36805E-11  DLOSSA= 0.68303E-14     SIG= 0.13080E-14
    N(E)= 0.14037E-14  SOURCE= 0.16571E-18    LOSS= 0.11805E-03
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         4.000             0.1386E-14             0.00003             0.40338E-02
      C0= 0.13257E-18      C1= 0.10949E 08      C2= 0.95545E 10
  ALOSSA= 0.29813E-11  DLOSSA= 0.55329E-14     SIG= 0.10610E-14
    N(E)= 0.13861E-14  SOURCE= 0.13257E-18    LOSS= 0.95643E-04
         ENERGY=  350.00MEV
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         0.                0.1142E-14             0.00002             0.39376E-02
      C0= 0.89495E-19      C1= 0.98958E 07      C2= 0.10075E 11
  ALOSSA= 0.33896E-11  DLOSSA= 0.50877E-14     SIG= 0.13080E-14
    N(E)= 0.11418E-14  SOURCE= 0.11187E-18    LOSS= 0.97978E-04
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         4.000             0.1127E-14             0.00002             0.48601E-02
      C0= 0.89495E-19      C1= 0.98958E 07      C2= 0.10075E 11
  ALOSSA= 0.27458E-11  DLOSSA= 0.41212E-14     SIG= 0.10610E-14
    N(E)= 0.11274E-14  SOURCE= 0.89495E-19    LOSS= 0.79381E-04
         ENERGY=  400.00MEV
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         0.                0.9561E-15             0.00002             0.46341E-02
      C0= 0.63676E-19      C1= 0.90659E 07      C2= 0.10548E 11
  ALOSSA= 0.31723E-11  DLOSSA= 0.38580E-14     SIG= 0.13080E-14
    N(E)= 0.95607E-15  SOURCE= 0.79596E-19    LOSS= 0.83253E-04
        TIME                  N(E)                  FLUX            MEAN LIFETIME
         4.000             0.9440E-15             0.00002             0.57195E-02
```

```
    CO= 0.63676E-19      C1= 0.90659E 07      C2= 0.10548E 11
ALOSSA= 0.25697E-11 DLOSSA= 0.31252E-14      SIG= 0.10610E-14
  N(E)= 0.94400E-15 SOURCE= 0.63676E-19     LOSS= 0.67454E-04
       ENERGY=  500.00MEV
      TIME               N(E)                 FLUX           MEAN LIFETIME
       0.              0.6953E-15            0.00002          0.59518E-02
    CO= 0.36054E-19      C1= 0.78313E 07      C2= 0.11390E 11
   SSA= 0.28715E-11 DLOSSA= 0.24088E-14      SIG= 0.13080E-14
  N(E)= 0.69526E-15 SOURCE= 0.45068E-19     LOSS= 0.64821E-04
      TIME               N(E)                 FLUX           MEAN LIFETIME
       4.000           0.6864E-15            0.00002          0.73451E-02
    CO= 0.36054E-19      C1= 0.78313E 07      C2= 0.11390E 11
ALOSSA= 0.23260E-11 DLOSSA= 0.19512E-14      SIG= 0.10610E-14
  N(E)= 0.68642E-15 SOURCE= 0.36054E-19     LOSS= 0.52525E-04
       ENERGY=  600.00MEV
      TIME               N(E)                 FLUX           MEAN LIFETIME
       0.              0.5248E-15            0.00001          0.71499E-02
    CO= 0.22653E-19      C1= 0.69485E 07      C2= 0.12127E 11
ALOSSA= 0.26761E-11 DLOSSA= 0.16081E-14      SIG= 0.13080E-14
  N(E)= 0.52477E-15 SOURCE= 0.28316E-19     LOSS= 0.53959E-04
      TIME               N(E)                 FLUX           MEAN LIFETIME
       4.000           0.5181E-15            0.00001          0.88230E-02
    CO= 0.22653E-19      C1= 0.69485E 07      C2= 0.12127E 11
ALOSSA= 0.21678E-11 DLOSSA= 0.13026E-14      SIG= 0.10610E-14
  N(E)= 0.51805E-15 SOURCE= 0.22653E-19     LOSS= 0.43727E-04
       ENERGY=  700.00MEV
      TIME               N(E)                 FLUX           MEAN LIFETIME
       0.              0.4033E-15            0.00001          0.81399E-02
    CO= 0.15292E-19      C1= 0.62802E 07      C2= 0.12788E 11
ALOSSA= 0.25414E-11 DLOSSA= 0.11503E-14      SIG= 0.13080E-14
  N(E)= 0.40331E-15 SOURCE= 0.19115E-19     LOSS= 0.47397E-04
      TIME               N(E)                 FLUX           MEAN LIFETIME
       4.000           0.3981E-15            0.00001          0.10044E-01
    CO= 0.15292E-19      C1= 0.62802E 07      C2= 0.12788E 11
ALOSSA= 0.20586E-11 DLOSSA= 0.93180E-15      SIG= 0.10610E-14
  N(E)= 0.39811E-15 SOURCE= 0.15292E-19     LOSS= 0.38412E-04
```

H. Running Time

This program will do eleven cases in a minute and a half.

IX. REFERENCES

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2. Harris, I., and Priester, W., "Theoretical Models for the Solar-Cycle Variation of the Upper Atmosphere," NASA, GSFC publ. X-640-62-70, June 1962.

3. McIlwain, C.E., "Coordinates for Mapping the Distribution of Magnetically Trapped Particles," Journal of Geophysical Research, vol. 66, (1961), pp. 3681-3691.

4. Jensen, D.C., and Cain, J.C., unpublished, presented at April, 1962, meeting of the American Geophysical Union, Washington, D.C.

5. Ray, Ernest, C., "On the Theory of Protons Trapped in the Earth's Magnetic Field," Journal of Geophysical Research, vol. 65, no. 4, April, 1960, pp. 1125-1133.

6. Scarborough, J.B., Numerical Mathematical Analysis, 3rd Edition, Oxford University Press, copyright, 1955.

7. Aron, W.A., Hoffman, B.C., Williams, F.C., "Range-Energy Curves" (2nd Rev. 1949) U.S.A.E.C., Univ. of Calif. Rad. Lab.

X. ILLUSTRATIONS

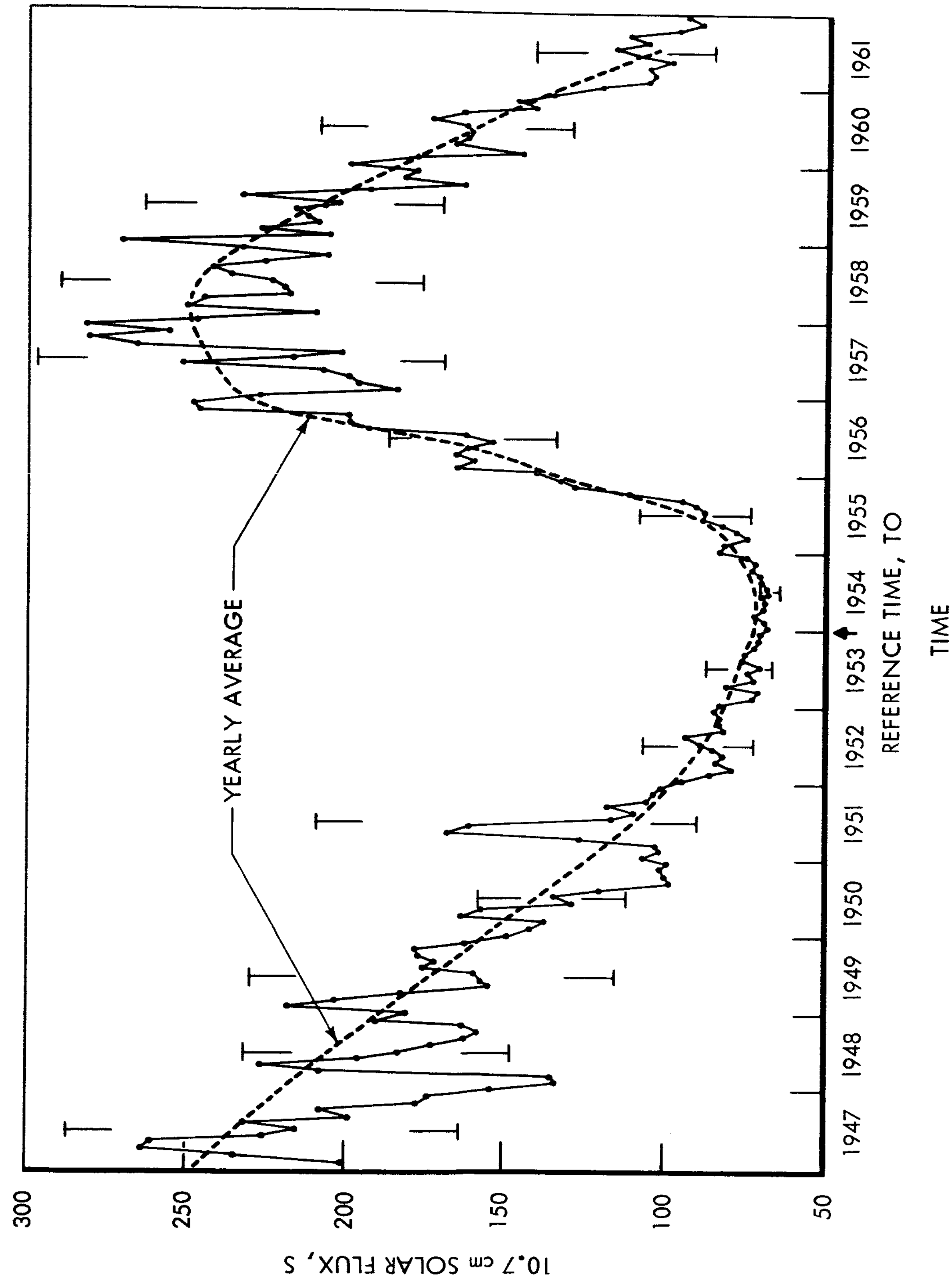


Figure 1–A time history of the 10.7 cm solar flux according to the measurements of the National Research Council of Canada for the recent past. The heavy dotted line indicates the approximate yearly average.

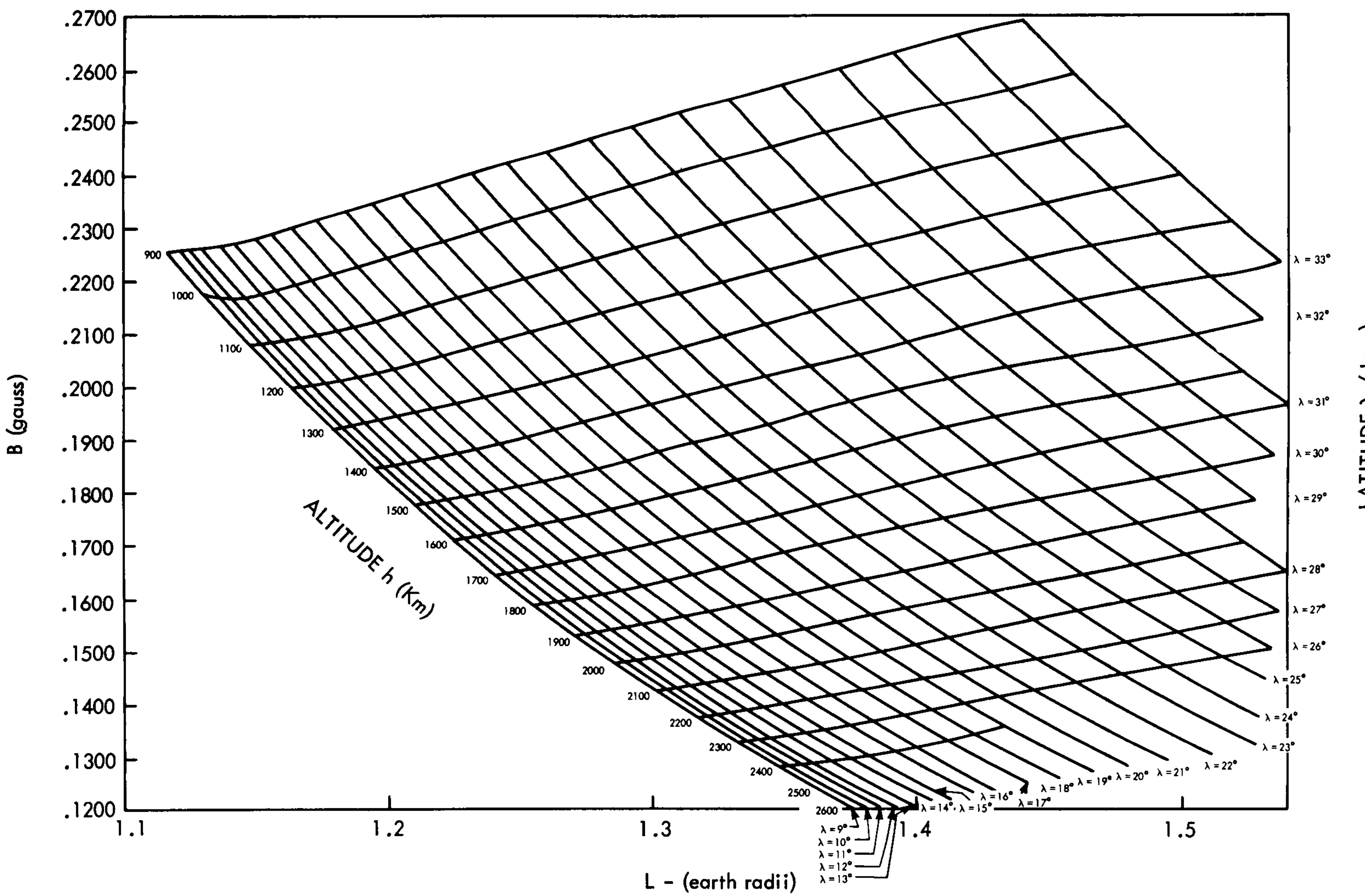


Figure 2-A mapping of the polar coordinates R and λ onto the B-L plane where R = (h + 6378.2)

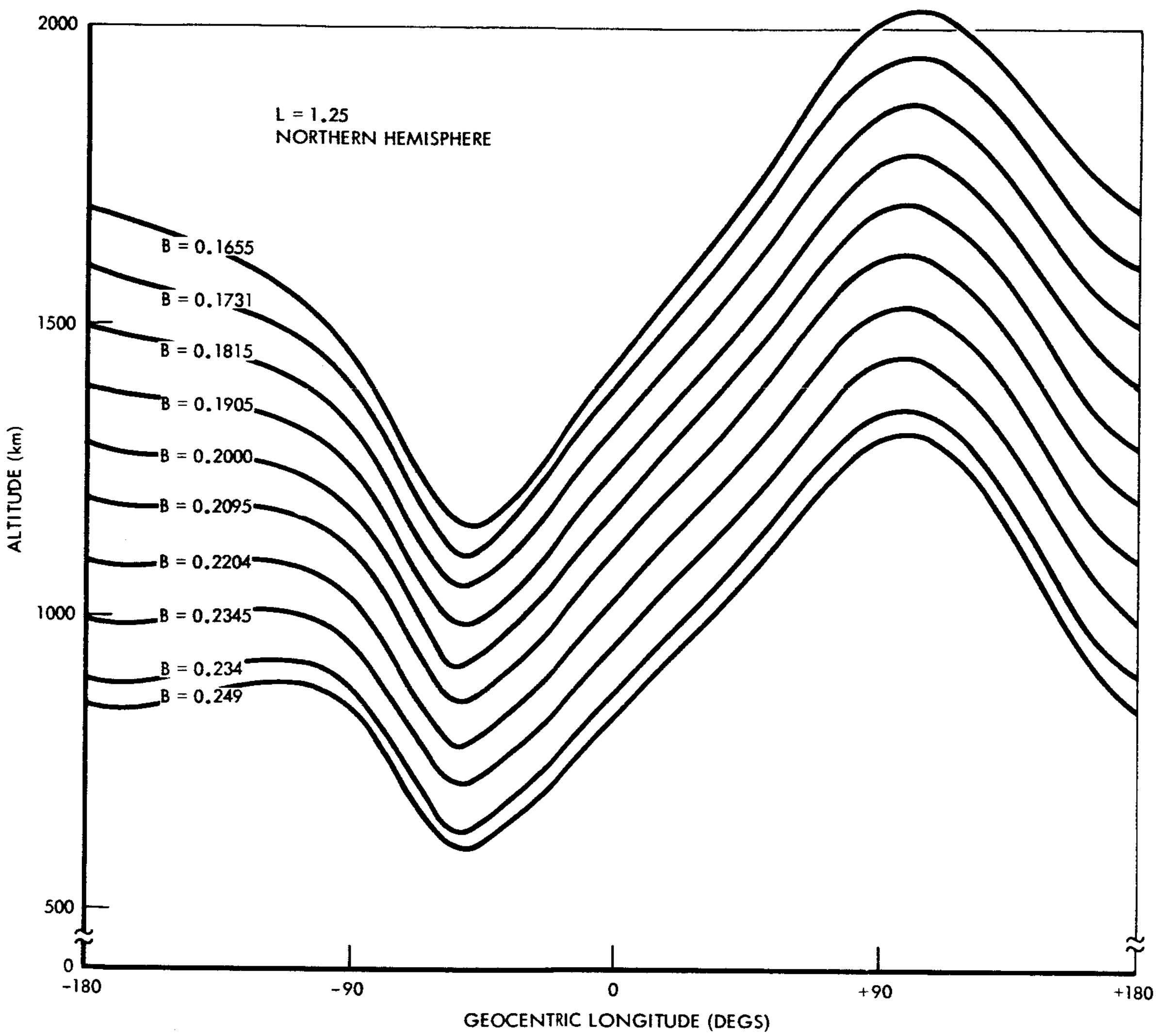


Figure 3-B-L contours for the northern hemisphere at an L of 1.25 earth radii

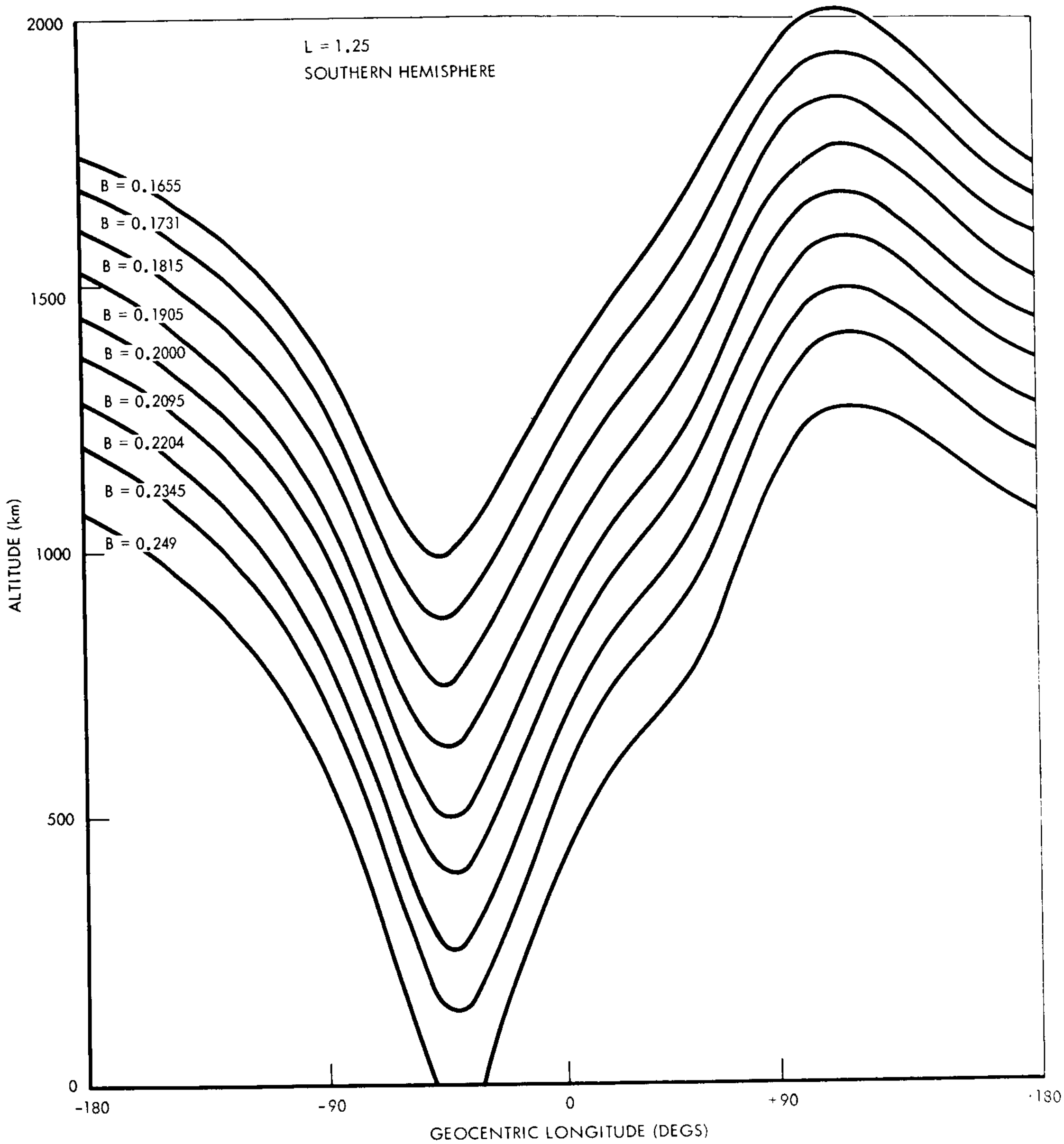
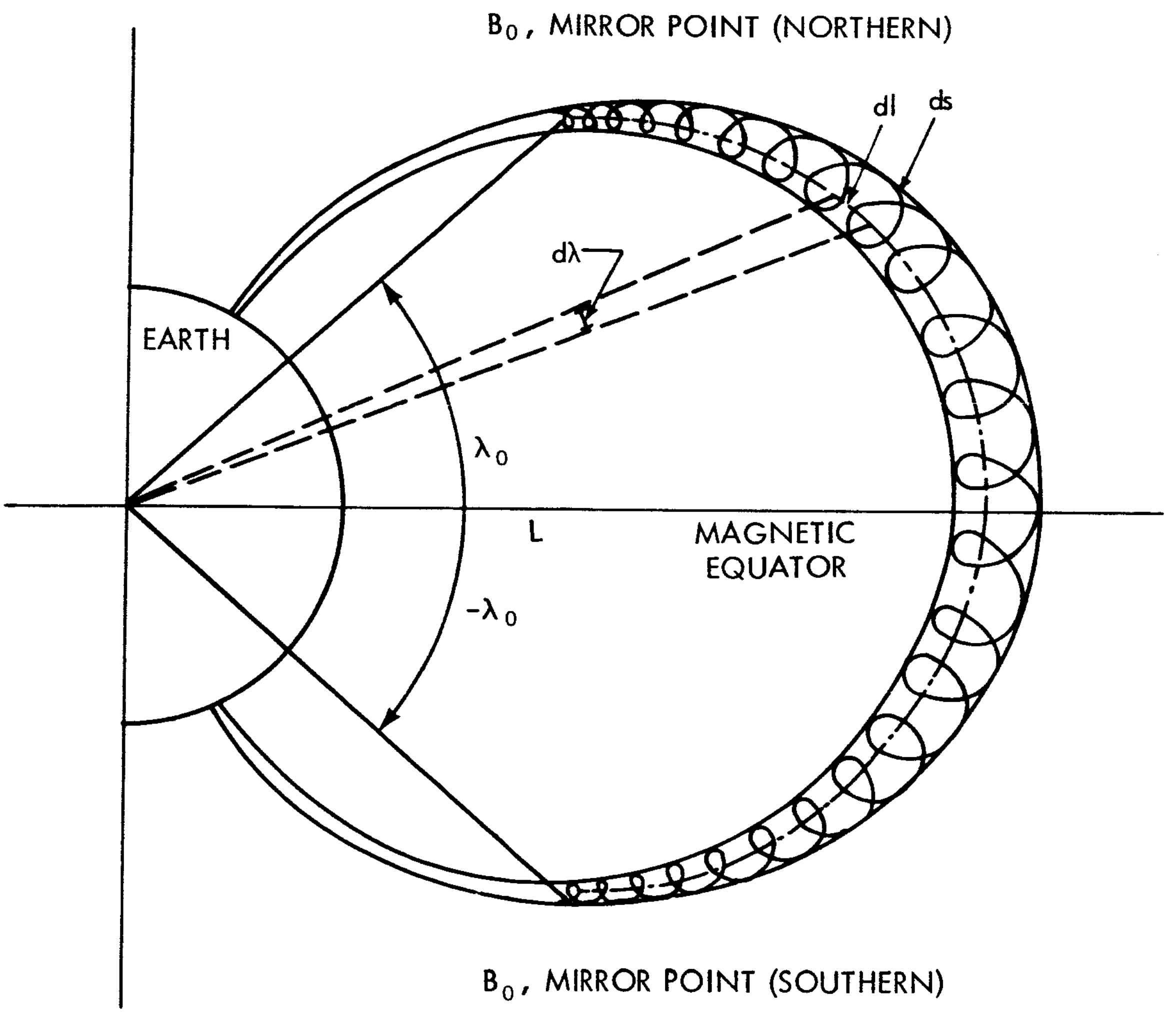


Figure 4-B-L contours for the southern hemisphere at an L of 1.25 earth radii



WHERE:

ds – Element of Arc along the particle's helical trajectory

dl – Element of Arc along the field line

Figure 5-Schematic of a trapped particle's north-south motion

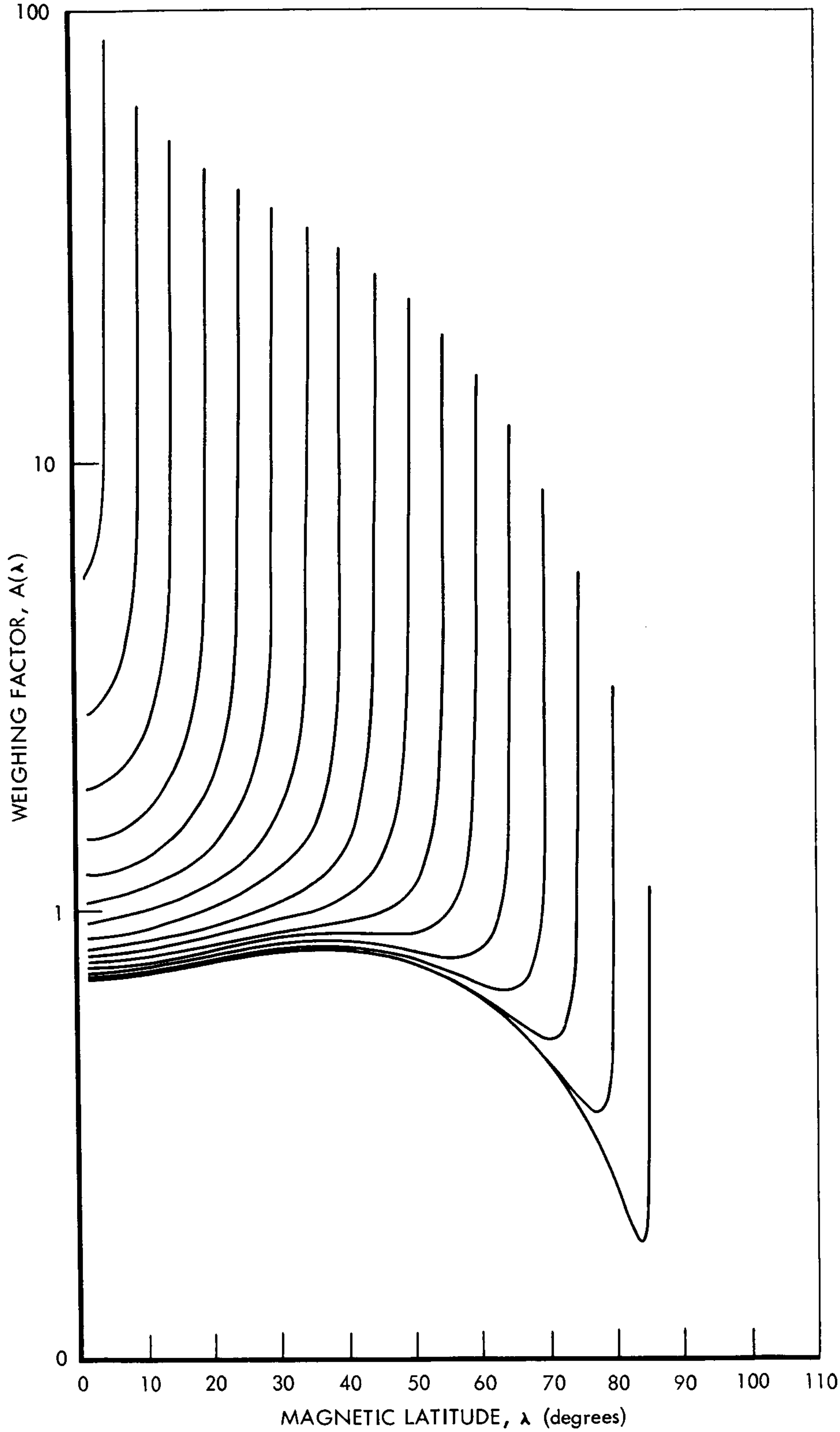


Figure 6-The weighing factor, $A(\lambda)$, versus latitude for various mirror latitudes, λ_o, where λ_o are the asymptotes of each curve

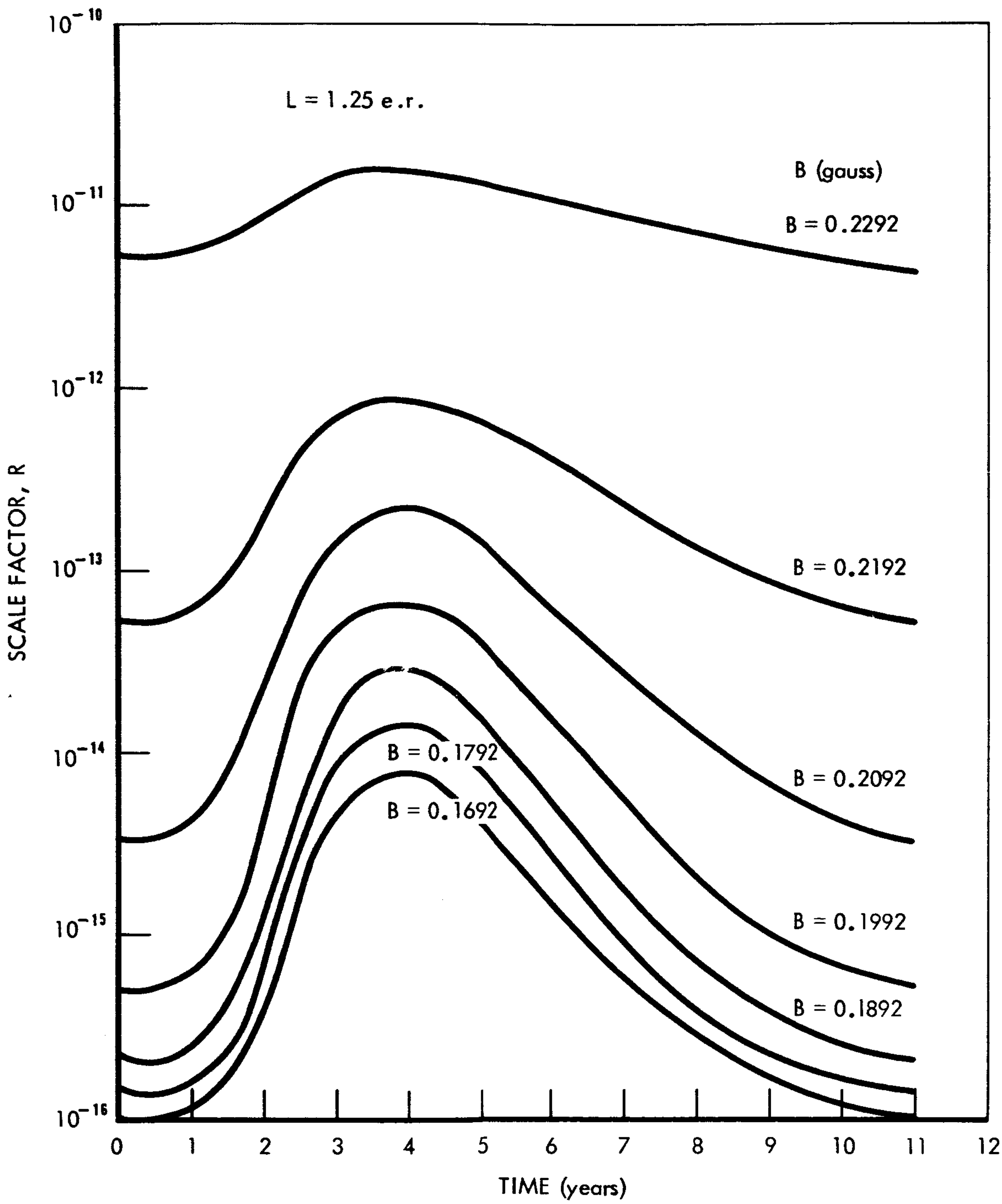


Figure 7-A time history of the atmosphere scale factor, R, as a function of B at L = 1.25 e.r.

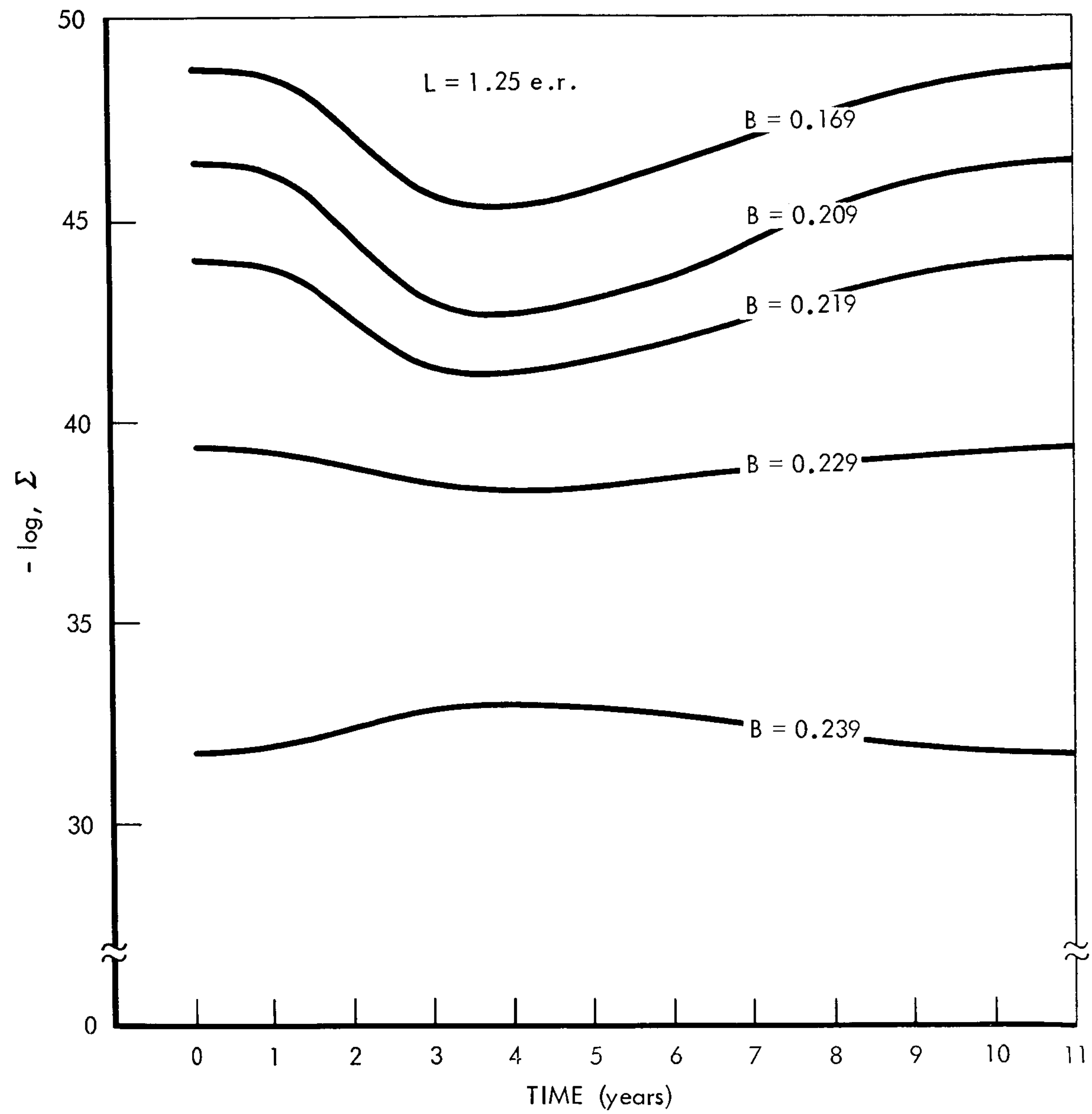


Figure 8-A time history of the atmospheric loss parameter Σ, as a function of B at L = 1.25 e.r.

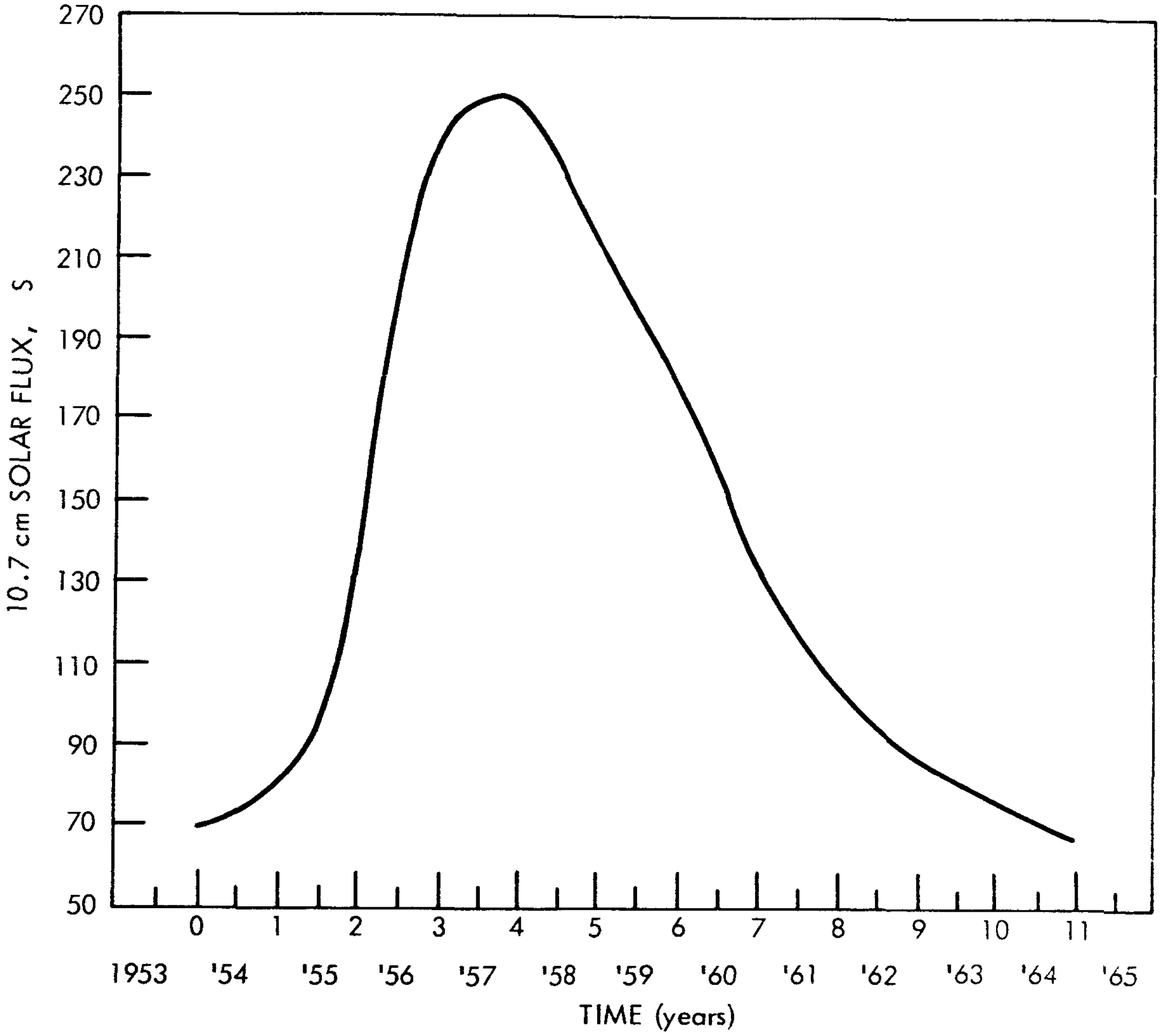


Figure 9–A time history of the constructed mean solar cycle variation of the 10.7 cm. solar flux with reference time t_o of Jan., 1954

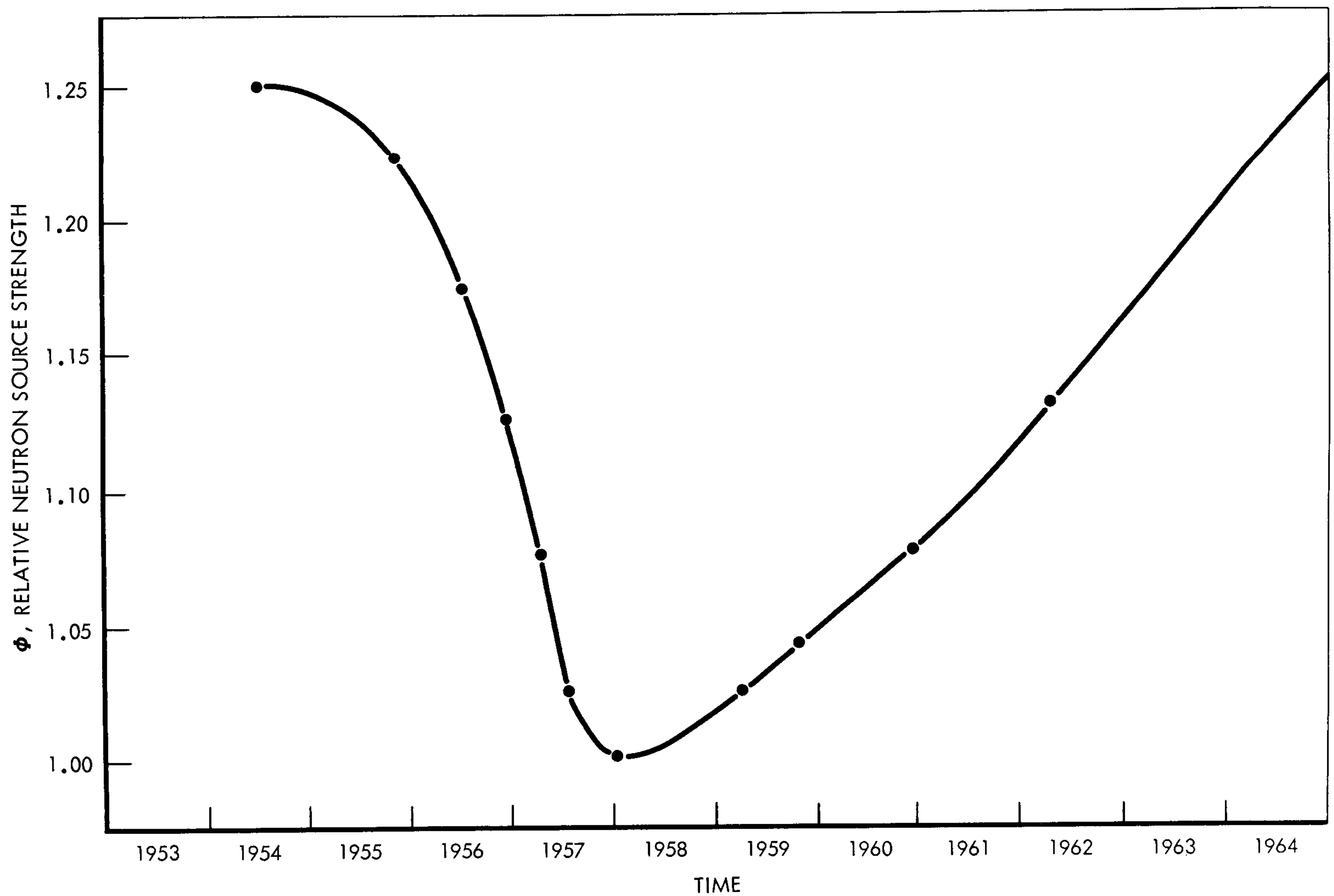


Figure 10-A time history of the relative inner belt source strength

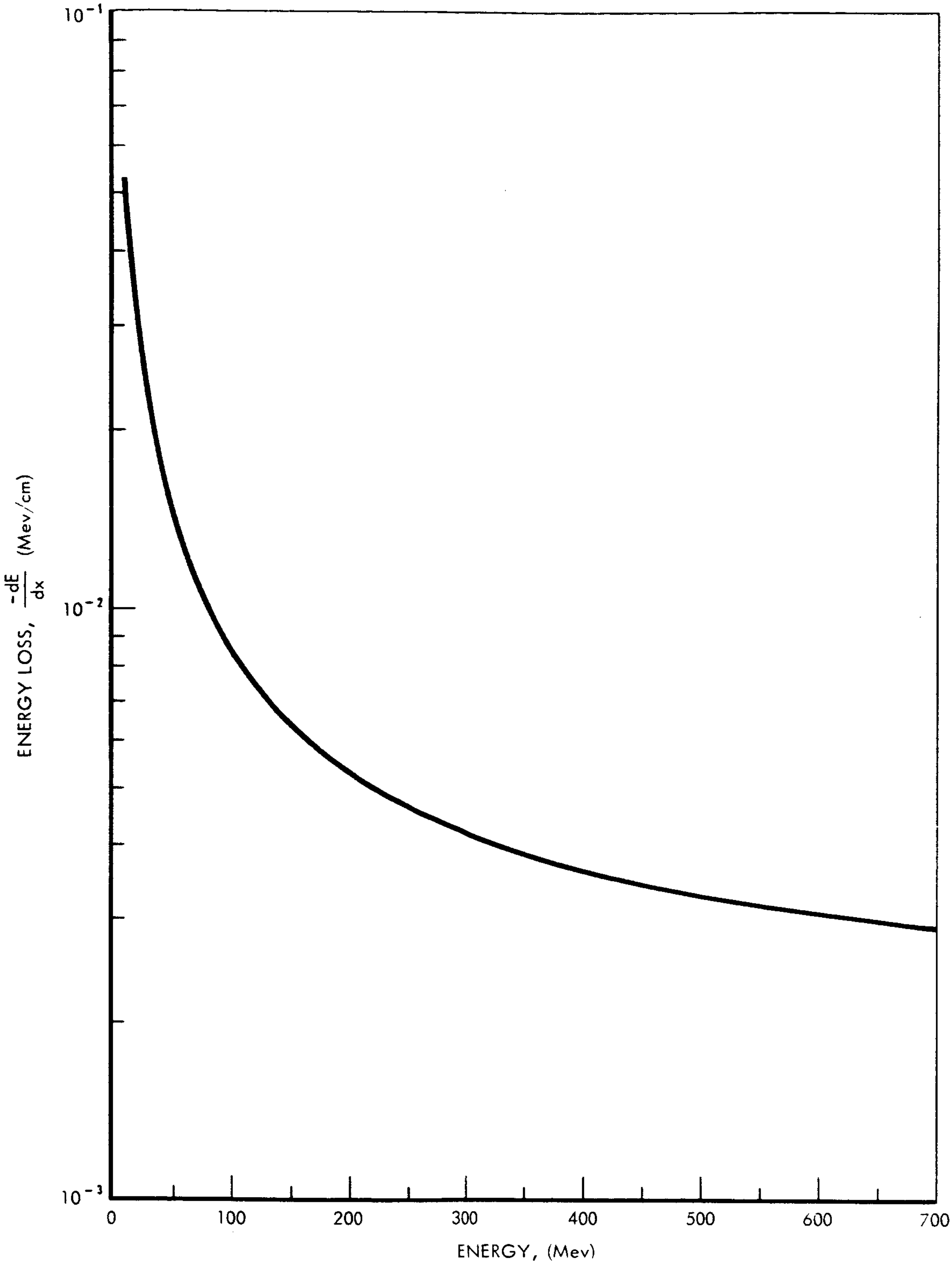


Figure 11-The proton energy loss spectrum for an oxygen target

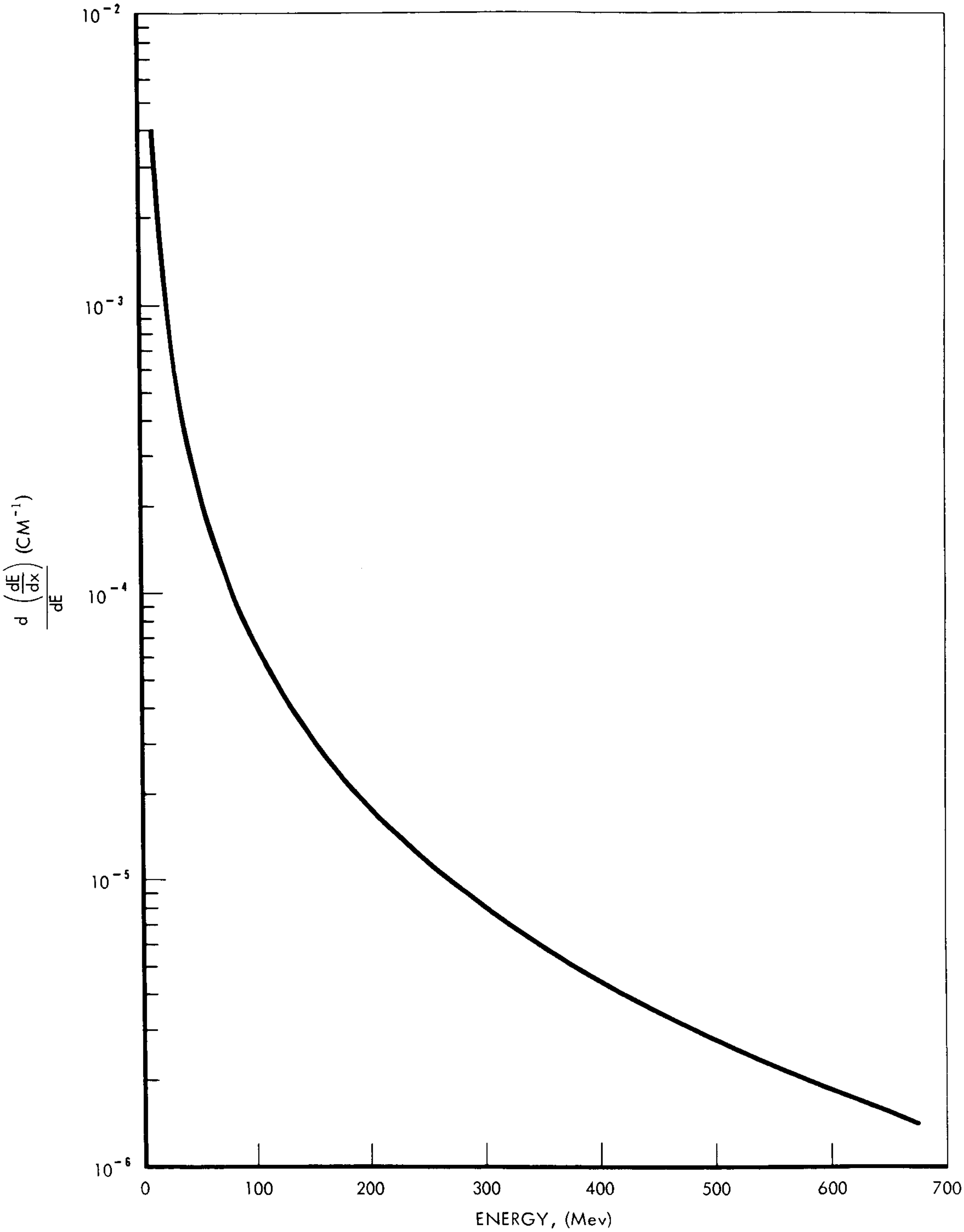


Figure 12-The slope of proton energy loss versus energy for an oxygen target

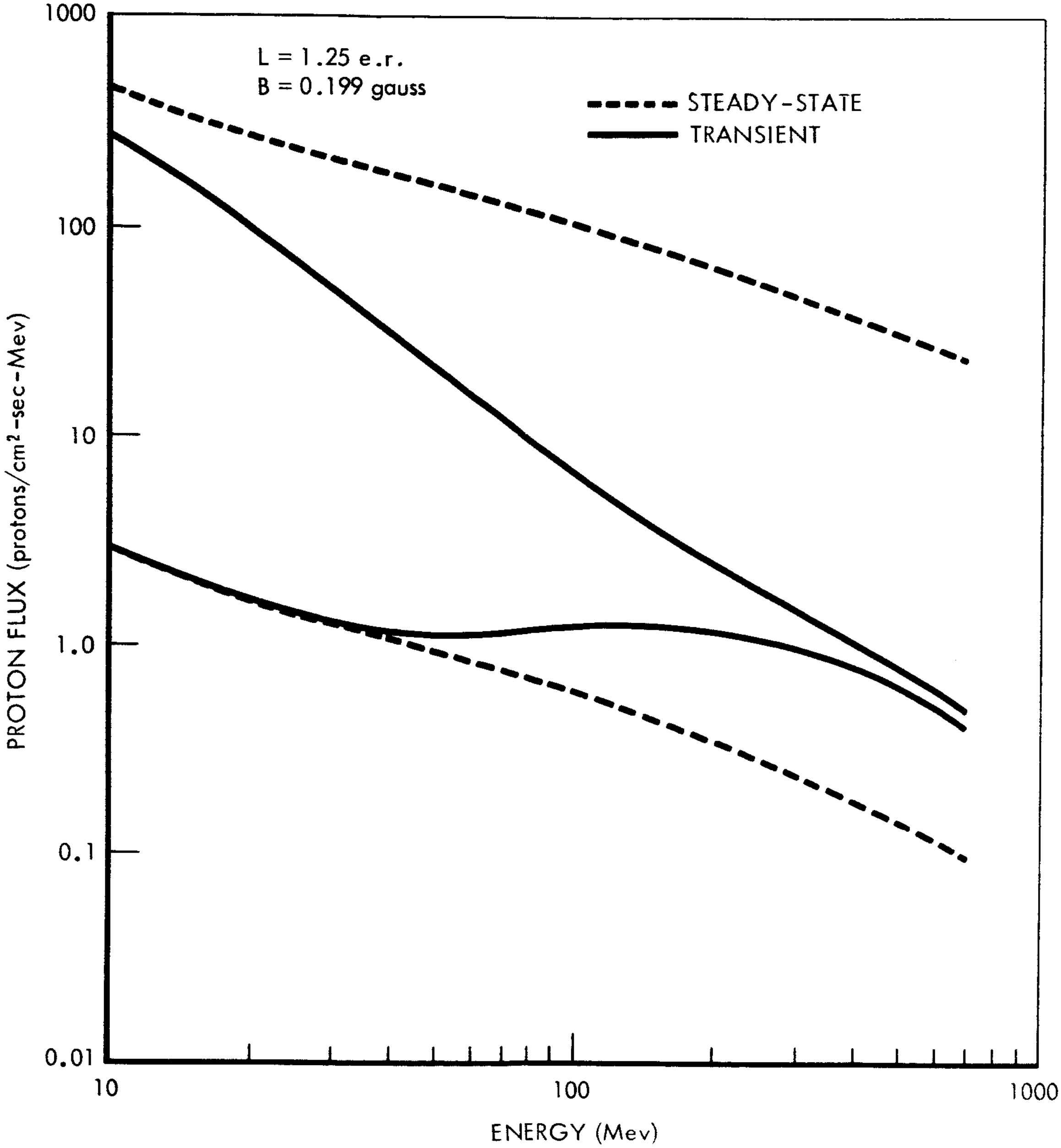


Figure 13–A comparison of the steady-state and transient proton flux energy spectrums for L = 1.25, B = .199 at solar minimum and solar maximum

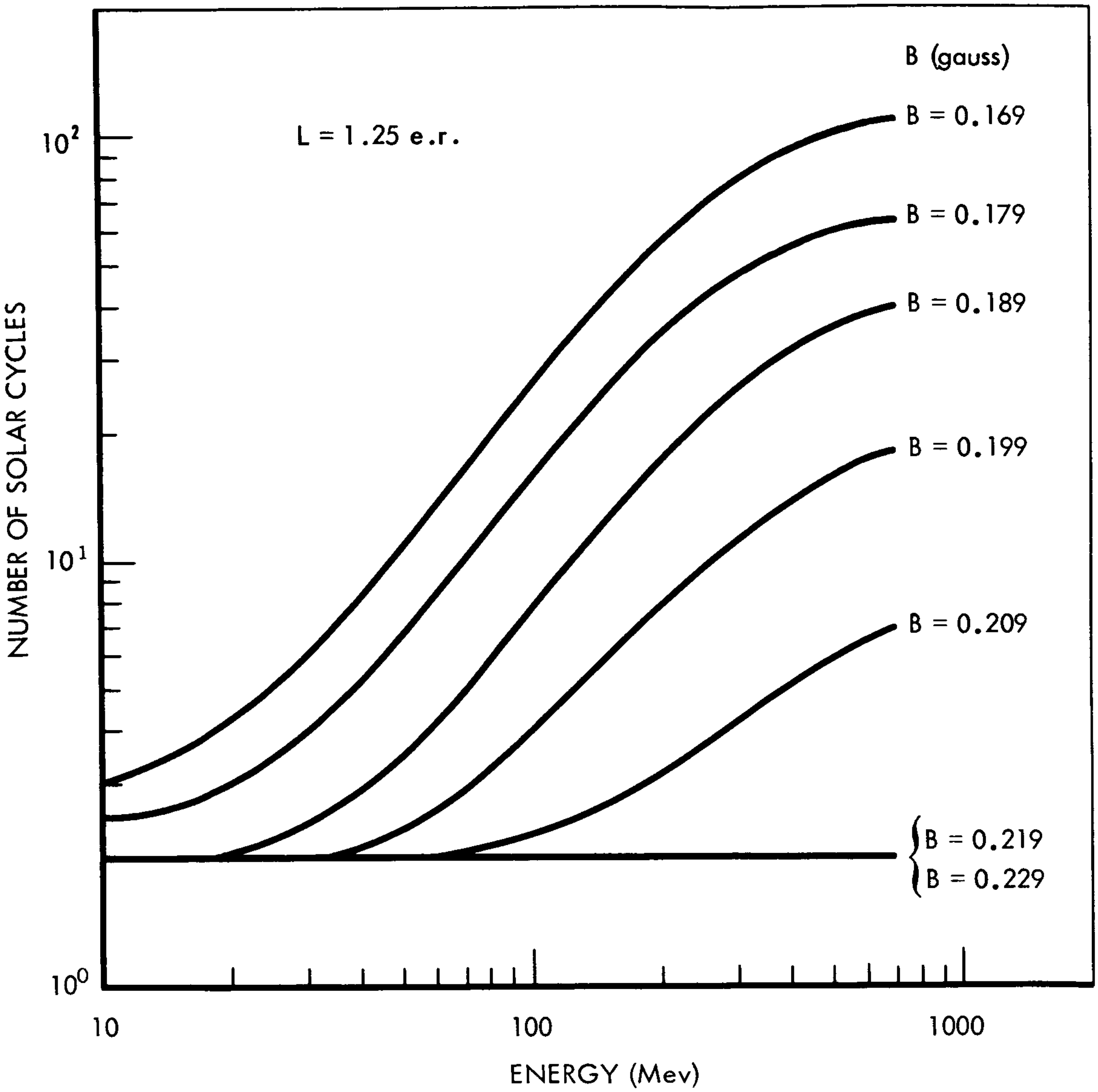


Figure 14–The time required in terms of solar cycles to build steady state conditions versus energy as a function of B

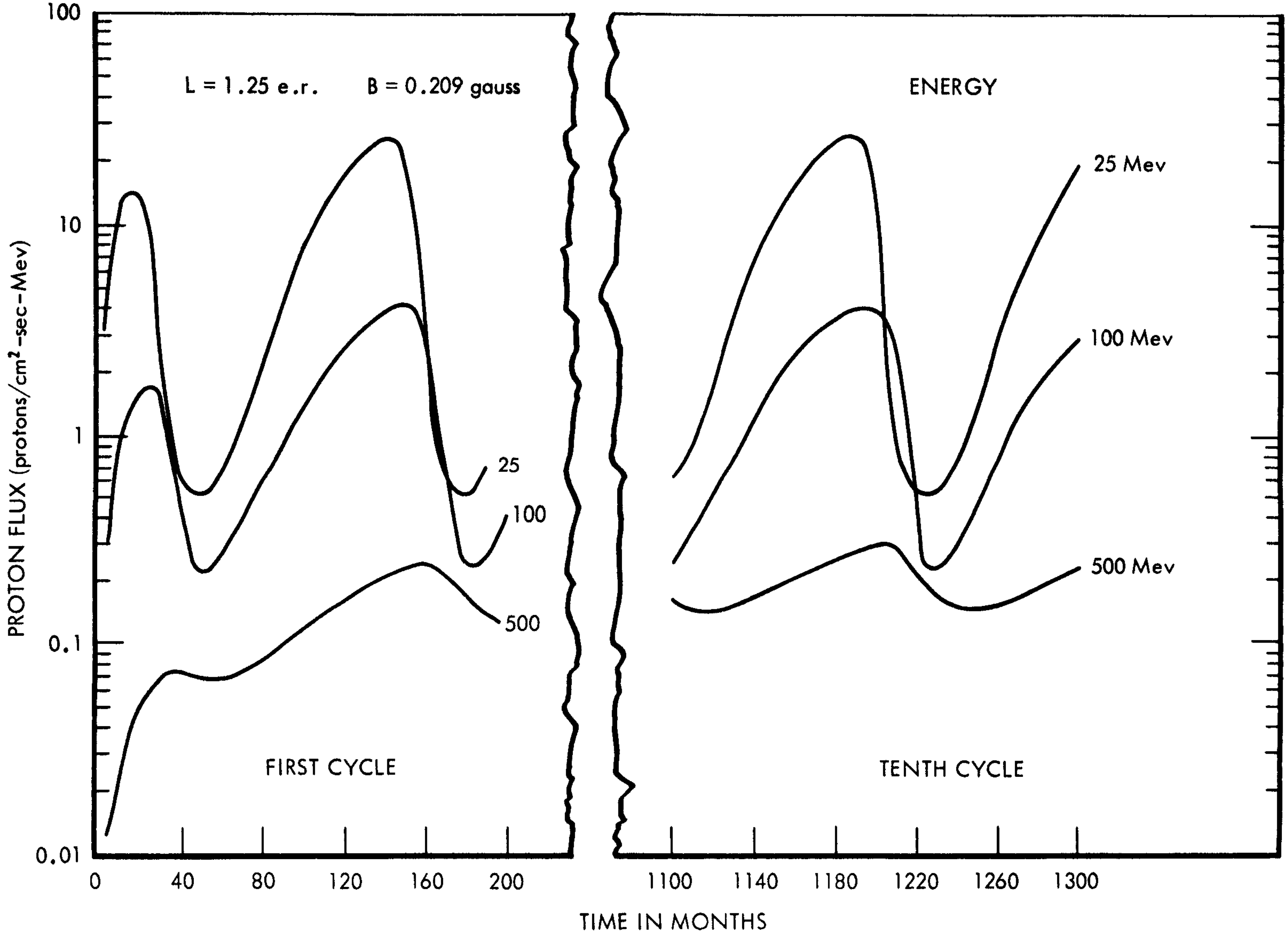


Figure 15-A time history of proton flux as a function of energy at L = 1.25, B = .209 for the first and tenth solar cycles