#448

PG-18A

[redacted]

PFITZERS B-L RETRIEVAL

PACKAGE

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1. INTRODUCTION:

The documentation for this data set was originally on paper, kept in NSSDC's Data Set Catalogs (DSCs). The paper documentation in the Data Set Catalogs have been made into digital images, and then collected into a single PDF file for each Data Set Catalog. The inventory information in these DSCs is current as of July 1, 2004. This inventory information is now no longer maintained in the DSCs, but is now managed in the inventory part of the NSSDC information system. The information existing in the DSCs is now not needed for locating the data files, but we did not remove that inventory information.

The offline tape datasets have now been migrated from the original magnetic tape to Archival Information Packages (AIP's).

A prior restoration may have been done on data sets, if a requestor of this data set has questions; they should send an inquiry to the request office to see if additional information exists.

2. ERRATA/CHANGE LOG:

NOTE: Changes are made in a text box, and will show up that way when displayed on screen with a PDF reader.

When printing, special settings may be required to make the text box appear on the printed output.

Version	Date	Person	Page	Description of Change
01				
02				

3 LINKS TO RELEVANT INFORMATION IN THE ONLINE NSSDC INFORMATION SYSTEM:

http://nssdc.gsfc.nasa.gov/nmc/

[NOTE: This link will take you to the main page of the NSSDC Master Catalog. There you will be able to perform searches to find additional information]

4. CATALOG MATERIALS:

a. Associated Documents — To find associated documents you will need to know the document ID number and then click here.
http://nssdcftp.gsfc.nasa.gov/miscellaneous/documents/

b. Core Catalog Materials

REQ. AGENT	RAND NO.	ACQ. AGENT
DEW RSH	RD3215	DWS

PFITZER'S B-L RETRIEVAL PACKAGE

PG-18A SPMS-00789

This data set consists of 1 tape. The original tape was 800 BPI, 7 TRK, BCD and was created on an IBM 360. The tape now being used 1600 BPI, 9 TRK, ASCII. This new tape is not an updated version, it was only converted from the original 800 BPI BCD to 1600 BPI ASCII. The D and C numbers are as follows:

D#	C#
D-35171	C-20798

```
      PROGRAM INVTST(OUTPUT,TAPE6=OUTPUT)
C
C     (SUBROUTINE SECOND USED BY THIS TEST PROGRAM IS A SYSTEM ROUTINE
C     WHICH GIVES THE CURRENT COMPUTER CLOCK TIME IN SECONDS)
      DIMENSION IAR(3)
      DATA IAR/6H INT  ,6H IN+EX,6H L AVE/
      LN=100
      DO 6 ID=1,90,89
      DA=ID
      DO 5 IU=1,19,6
      UT=IU-1
      LN=100
      DO 4 IL=1,31,30
      FLAT=IL-1
      DO 3 ILG=1,181,90
      XLONG=ILG-1
      DO 2 IR=2,8,3
      R=IR
      DO 1 IC=1,3
      CALL SECOND(TA)
      CALL FLDINT(FLAT,XLONG,R,1975.,DA,UT,IC-2,EL,BLOC,BM,XMLONG,XMLAT)
      CALL SECOND(TB)
      TC=TB-TA
      LN=LN+1
      IF (LN.LT.58) GO TO 10
      LN=0
      WRITE (6,11)
   11 FORMAT(1H1,11X,115HLAT          LONG          R          DAYOFYR          TIM
     *E          L          BLOCAL          BMIN          MAGLONG          MAGLAT          CPTI
     *ME,//)
   12 FORMAT(A6,11F11.5)
   10 WRITE(6,12) IAR(IC),FLAT,XLONG,R,DA,UT,EL,BLOC,BM,XMLONG,XMLAT,TC
    1 CONTINUE
    2 CONTINUE
    3 CONTINUE
    4 CONTINUE
    5 CONTINUE
    6 CONTINUE
      END
      SUBROUTINE FLDINT(XLAT,XLONG,R,YR,DAY,TIME,JSWTCH,EL,BLOCAL,BMIN,
     *XMLONG,XMLAT)
C
C     PURPOSE
C         EVALUATE THE MAGNETIC L SHELL PARAMETER AT A SPECIFIED POINT.
C         THE L SHELL IS A SHELL ON WHICH LOW ENERGY (CONSERVE THE
C         FIRST TWO ADIABATIC INVARIANTS) CHARGED PARTICLES
C         MOVE.  THE SHELL IS LABELED BY THE APPROXIMATE RADIAL DISTANCE
C         WHERE IT CROSSES THE GEOMAGNETIC EQUATOR (IN UNITS OF EARTH
C         RADII).  IN A PURE DIPOLE FIELD THE SHELL FOLLOWS A MAGNETIC
C         FIELD LINE ROTATED ABOUT THE EARTH.  IN A REAL FIELD SOME
C         DISTORTION FROM THIS ROTATIONALLY SYMMETRIC SHELL OCCURS.
C
C     METHOD
C         INTEGRATE ALONG THE MAGNETIC FIELD LINE WHICH PASSES THROUGH
C         THE POINT.  THE INTEGRATION IS PERFORMED BETWEEN THE MIRROR
C         POINT MAGNETIC FIELD VALUES.  THE MIRROR POINT VALUES ARE
C         EITHER THE LOCAL VALUE OR A MODIFIED VALUE OF THE FIELD
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```
C        WHICH IS CHOSEN BY THE PROGRAM TO MORE ACCURATELY REPRESENT
C        DRIFT SHELLS OF ISOTROPIC PARTICLE DISTRIBUTIONS IN THE DRIFT
C        LINE IS COMPLETED THE SECOND ADIABATIC INVARIANT IS EVALUATED
C        AND HILTONS EXPANSION OF L IN TERMS OF BMAX AND THE SECOND
C        INVARIANT IS USED TO EVALUATE L (SEE SUBROUTINE HILTEL)
C
C     INPUT -- ARGUMENT LIST
C        XLAT   GEOCENTRIC GEOGRAPHIC LATITUDE IN DEGREES (+ IS NORTH)
C        XLONG  GEOCENTRIC GEOGRAPHIC LONGITUDE EAST OF GREENWHICH IN
C               DEGREES
C        R      GEOCENTRIC DISTANCE FROM THE EARTHS CENTER IN UNITS
C               EARTH RADII, RE.  RE=6371.2 KM
C        YR     THE YEAR - USED BY THE INTERNAL MAGNETIC FIELD ROUTINE
C               TO TAKE INTO ACCOUNT THE SECULAR VARIATIONS
C               (E.G. JULY 15,1964 = 1964.54)
C               NOTE*** YR SHOULD BE CHANGED ONLY EVERY FEW DAYS OR
C               MONTHS. NEW FIELD COEFFICIENTS MUST BE COMPUTED FOR
C               EVERY CHANGE IN YR, THIS COULD CAUSE A LARGE INCREASE IN
C               COMPUTER TIME. THE EARTHS FIELD CHANGES ONLY ABOUT
C               .001 GAUSS/YEAR AT THE EARTHS SURFACE.
C        DAY    THE DAY OF YEAR (1.-366.).  THE DAY IS USED BY THE
C               MAGNETIC FIELD ROUTINE TO CALCULATE THE TILT OF THE
C               DIPOLE AXIS FOR THE EXTERNAL FIELD ROUTINE
C               DAY MUST BE A WHOLE NUMBER AND DAY 1 IS JANUARY 1
C        TIME   UNIVERSAL TIME IN HOURS (0.000-24.0000)
C        JSWTCH A FLOW CONTROL VARIABLE
C               JSWTCH =-1 COMPUTE L USING INTERNAL FIELD ONLY
C                      = 0 COMPUTE L USING INTERNAL + EXTERNAL FIELD
C                      =+1 COMPUTE AVERAGE L USING INTERNAL + EXTERNAL
C                          FIELD
C     OUTPUT PARAMETERS
C        EL     THE L VALUE DETERMINED AS REQUESTED BY FLOW CONTROL
C               VARIABLE JSWTCH
C               *****NOTE****
C               SINCE THIS ROUTINE USES AN ACTUAL MAGNETOSPHERIC
C               MAGNETIC FIELD, THE FIELD LINES ARE NOT ALL CLOSED.
C               THUS L IS DEFINED ONLY IN THE INNER MAGNETOSPHERE (IN
C               THE REGION OF CLOSED DRIFT SHELLS).  AN ATTEMPT
C               TO CALCULATE L OUTSIDE OF THIS REGION WILL SET EL TO
C               100 (EL=100), SET BMIN TO THE LOCAL FIELD VALUE
C               AND SET XMLONG TO ZERO UNLESS MINIMUM B WAS PASSED PRIOR
C               TO THE DETECTION OF THE ERROR
C        BLOCAL THE VALUE OF THE MAGNETIC FIELD AT THE INPUT POSITION
C               (IN GAUSS)
C        BMIN   THE MINIMUM VALUE OF B ALONG THE FIELD LINE IN GAUSS
C        XMLONG THE MAGNETIC LONGITUDE OF THE MAGNETIC FIELD MINIMUM
C               MEASURED EAST OF THE PRIME MAGNETIC MERIDIAN
C               (IN DEGREES).
C               A PRESET CONSTANT IN SUBROUTINE MGLONG ALLOWS THE USER
C               TO SELECT EITHER A CENTERED DIPOLE MAGNETIC COORDINATE
C               SYSTEM WITH ZERO AT 69 DEG W. GEOGRAPHIC, OR AN OFFSET
C               DIPOLE COORDINATE SYSTEM WITH ZERO THROUGH GREENWHICH.
C        XMLAT  THE MAGNETIC LATITUDE IN DEGREES OF THE CURRENT POSITION
C
C     CONSTANTS
C        ERR    = 0.0005  SCALES THE ERROR LIMITS FOR THE INTEGRATION
C               THE ERROR IN L IS APPROXIMATELY L*ERR
```

```
C
C     SUBROUTINES REQUIRED
C         SUBROUTINE BMNEXT
C         SUBROUTINE FILTEL
C         SUBROUTINE INTERP
C         SUBROUTINE INTGRT
C         SUBROUTINE INVR
C         SUBROUTINE MAXFIX
C         SUBROUTINE MGLONG
C
C     VARIABLES
C         BINTL  A REAL ARRAY THAT SAVES THE VALUE OF THE MAGNETIC FIELD
C                AT THE INPUT POSITION
C         B      A REAL ARRAY THAT HOLDS THE INSTANTANEOUS MAGNETIC FIELD
C                VECTOR AT EACH INTEGRATION STEP
C         BB     A 2 DIMENSIONED REAL ARRAY THAT HOLDS ALL OF THE
C                MAGNETIC FIELD MAGNITUDES CALCULATED AT ALL OF THE
C                INTEGRATION STEPS
C         BL     A REAL ARRAY THAT SAVES THE MAGNETIC FIELD VECTOR
C                FROM THE PREVIOUS INTEGRATION STEP
C         BMAX   THE MAGNETIC FIELD AT THE PARTICLE MIRROR POINT
C         COSINE THE COSINE OF THE GEOGRAPHIC LATITUDE
C         DAYYR  THE DAY OF THE YEAR
C         DDS    THE ESTIMATED STEP SIZE NECESSARY TO COMPLETE THE
C                INTEGRATION.  IF NO ESTIMATE IS YET POSSIBLE IT IS
C                SET TO 100.
C         DEL    SCALES THE INTEGRATION STEP SIZE.  IT IS PROPORTIONAL
C                TO THE FOURTH ROOT OF THE ERROR LIMITS.  IF IT IS
C                POSITIVE INTEGRATION WILL BE PARALLEL TO THE FIELD, IF
C                NEGATIVE IT IS ANTIPARALLEL
C         DS     THE CURRENT VALUE OF THE INTEGRATION STEP SIZE IN
C                EARTH RADII. POSITIVE IS FOR PARALLEL TO FIELD.
C                NEGATIVE FOR ANTIPARALLEL
C         IERFLG AN ERROR FLAG SET BY SUBROUTINE INTGRT.  IF NON-ZERO
C                THE INTEGRATION HAS GONE BEYOND THE SET LIMITS AND
C                MUST BE TERMINATED
C         JSW    A FLOW CONTROL PARAMETER USED BY THE MAGNETIC FIELD
C                SUBROUTINE
C         KODE   SET EQUAL TO ONE TO INDICATE TO SUBROUTINE BMNEXT
C                THAT CARESIAN COORDINATES ARE TO BE USED
C         KS     A VARIABLE TRANSMITTED TO SUBROUTINE INTERP.  IT IS
C                USED TO DETERMINE WHICH SOLUTION APPLIES TO THE
C                PARTICULAR INTERPOLATION
C         MINFLG INITIALLY SET TO ZERO.  IT IS SET TO ONE WHEN THE FIELD
C                MINIMUM HAS BEEN PASSED
C         N      THE CURRENT INTEGRATION STEP NUMBER
C         PICON  PI / 180.
C         Q, QL  REAL ARRAYS CONTAINING THE CURRENT AND PREVIOUS ERROR
C                ESTIMATES.  USED BY GILLS METHOD INTEGRATION ROUTINE TO
C                CONTROL ROUND OFF ERROR
C         SER    ERROR CONTROL VARIABLE.  THE INTEGRATION STOPS IF
C                THE CURRENT POSITION POINT IS WITHIN DISTANCE SER OF
C                BMAX
C         SF     OUTPUT OF THE INTERPOLATION SUBROUTINE INTERP.  IT
C                INDICATES THE SCALAR DISTANCE ALONG THE FIELD WHERE
C                B IS EQUAL TO BMAX
C         SXJ    A REAL ARRAY WHICH SAVES THE INTEGRATION STEP VALUES
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```
C                     OF THE SECOND ADIABATIC INVARIANT
C           UT        UNIVERSAL TIME
C                     OF INTEGRATION
C           XJ        FINAL VALUE OF THE SECOND ADIABATIC INVARIANT
C           XL        A REAL ARRAY HOLDING THE PREVIOUS VALUE OF THE POSITION
C                     VECTOR
C           XSV       A 2 DIMENSIONED REAL ARRAY HOLDING ALL OF THE POSITION
C                     VECTORS ALONG THE INTEGRATION PATH
C           XXJ       INTERPOLATED VALUE OF THE SECOND ADIABATIC INVARIANT
C           YEAR      THE YEAR
C           ZP        THE Z COMPONENT OF THE POSITION VECTOR IN CENTERED
C                     DIPOLE COORDINATES
C
C     VERSION 10/25/77
C     FOR MORE INFORMATION CALL OR WRITE K. A. PFITZER AT MCDONNELL
C     DOUGLAS ASTRONAUTICS CO. 5301 BOLSA AVE, HUNTINGTON BEACH CALIF.
C     PHONE (714) 896-3231.
C
      COMMON/BXYZCM/YEAR,DAYYR,UT,KODE,JSW
      COMMON /INTPAR/DS,DEL,N,IERFLG,XL(3),X(3),XSV(100,3),
     *BB(100,4),S(100),GL(3),G(3),BL(3),B(3),SXJ(100),DDS
      DIMENSION XX(3),BINTL(3)
      DATA PICON/.01745329252/
      DATA ERR/.0005/
C
C     OBTAIN THE CARTESIAN COMPONENTS OF THE POSITION VECTOR
C
      COSINE=COS(XLAT*PICON)
      XX(1)=R*COSINE*COS(XLONG*PICON)
      XX(2)=R*COSINE*SIN(XLONG*PICON)
      XX(3)=R*SIN(XLAT*PICON)
C
C     ROTATE TO DIPOLE COORDINATES (FIRST ROTATE ABOUT Z 291 DEGREES
C     THEN ABOUT THE NEW Y 11.7 DEGREES TO THE DIPOLE AXIS)
C
      ZP=(XX(1)*.3583679495-XX(2)*.9335804265)*.2027872954
     *+XX(3)*.9792228106
C
C     EVALUATE THE MAGNETIC LATITUDE
      XMLAT=90.-ACOS(ZP/R)/PICON
C
C     SET THE MAGNETIC LONGITUDE TO ZERO.  IF MINIMUM B IS REACHED
C     PRIOR TO AN ERROR BEING DETECTED XMLONG IS UPDATED TO REFLECT
C     MAGNETIC LONGITUDE AT MINIMUM B
      XMLONG=0.
C
C     SET UP THE COMMON BLOCK INPUT VARIABLES FOR THE MAGNETIC FIELD
C     SUBROUTINE
      YEAR=YR
      UT=TIME
      DAYYR=DAY
      JSW=JSWTCH
      KODE=1
C
C     EVALUATE THE MAGNETIC FIELD AT THE STARTING POINT
      CALL BMNEXT(XX,B,BB(2,1))
      BLOCAL = BB(2,1)
```

```
C
C      SAVE THE INITIAL POSITION AND MAGNETIC FIELD VECTORS

       BINIT(I)=B(I)
       X(I)=XX(I)
       XSV(2,I)=XX(I)
       Q(I)=0
   10  CONTINUE
C
C      EXIT THE ROUTINE IF POSITION IS OVER THE POLAR CAP OR DISTANCE
C      IS TOO LARGE OR MAGNETIC FIELD IS TOO WEAK
       IF(ABS(XMLAT).GT.75..OR.R.GT.12..OR.BB(2,1).LT..00025) GO TO 330
C
C      SET UP THE INITIAL VALUES FOR THE VARIABLES
       N=2
       S(2)=0.
       DDS=100.
       MINFLG=0
       BMAX=BB(2,1)
C
C      SET BMIN TO LOCAL FIELD VALUE.  IF MINIMUM B IS REACHED PRIOR
C      TO ERROR DETECTION BMIN IS UPDATED TO MINIMUM B.
       BMIN=BB(2,1)
C
C      SET UP THE ERROR LIMITS FOR THE INTEGRATION
       SER=2.*SQRT(ERR)
C      STEP SIZE GOES AS ERROR TO THE .25 POWER
       DEL=-2.5*ERR**.25
       DS=SER
C
C      STEP ONCE IN THE INCREASING FIELD DIRECTION AND SET STEP
C      PARAMETERS TO INTEGRATE IN THE DECREASING FIELD DRECTION
       IF(XMLAT.GT.0.)GO TO 30
   20  DEL=-DEL
       DS=-DS
   30  DO 35 I=1,3
       XL(I)=X(I)+DS*B(I)/BB(2,1)
   35  CONTINUE
       CALL BMNEXT(XL,BL,BB(1,1))
C
C      IF THE PREVIOUS STEP WAS IN THE DECREASING FIELD DIRECTION TRY
C      AGAIN
       IF(BB(1,1).LT.BB(2,1)) GO TO 20
       S(1)=DS
       DO 36 I=1,3
       XSV(1,I)=XL(I)
   36  CONTINUE
C
C
C      BEGIN THE FIELD LINE INTEGRATION.  THE INTEGRATION USES A VARIABLE
C      STEPSIZE WHICH IS DEPENDENT ON THE CURVATURE OF THE FIELD LINE
C      AND ON THE DISTANCE EACH POINT IS FROM EARTH CENTER (A MEASURE
C      OF THE MAGNETIC FIELD STRENGTH).  THE INITIAL INTEGRATION IS A
C      LINE INTEGRAL OF THE MAGNETIC FIELD UNIT VECTOR.  THIS INTEGRATION
C      LOOP ALSO SAVES ALL OF THE VARIABLES WHICH ARE LATER NEEDED TO
C      EVALUATE THE SECOND INTEGRAL INVARIANT.
C
   40  CALL STEPSZ
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      CALL INTGRT
C
C     MAXIMUM NUMBER OF STEPS HAVE OCCURED THE ERROR EXIT IS TAKEN
C
      IF(IERFLG.NE.0) GO TO 330
C
C     IF FIELD IS STILL DECREASING RELOOP
      IF(BB(N,1).LT.BB(N-1,1)) GO TO 40
C
C     IF MINIMUM VALUES HAVE BEEN CALCULATED, JUMP OVER MINIMUM ROUTINES
      IF(MINFLG.NE.0) GO TO 50
C
C     WHEN THE CURRENT VALUE OF B EXCEEDS THE LAST, FIND THE
C     INTERPOLATED MINIMUM MAGNETIC FIELD VALUE AND USE THIS VALUE TO
C     UPDATE THE VALUE OF BMAX TO REFLECT THE AVERAGE DRIFT SHELL (IF
C     AVERAGE SHELLS ARE REQUIRED)
      CALL INTERP(BB(N-2,1),S(N-2),BMIN,SF,-1)
C
C     UPDATE BMAX IF JSW IS GREATER THAN ZERO
      IF(JSW.GT.0) CALL MAXFIX(BMAX,BMIN)
C
C     USE THE DISTANCE, SF, TO THE FIELD MINIMUM TO DETERMINE THE
C     MAGNETIC LONGITUDE OF THE FIELD MINIMUM
C
      CALL MGLONG(XSV(N-2,1),S(N-2),SF,XMLONG)
      MINFLG=1
C
C     CONTINUE STEPPING ALONG THE FIELD LINE AS LONG AS B IS LESS THAN
C     BMAX AND THE INTEGRATION IS MORE THAN A DISTANCE SER FROM BMAX
C
C
C     IF BMAX HAS BEEN EXCEEDED, EXIT TO INTERPOLATION SCHEME
 50   IF(BB(N,1).GE.BMAX) GO TO 70
      CALL INTERP (BB(N-2,1),S(N-2),BMAX,SF,3)
      DDS=100.
C
C     IF S DOES NOT INCREASE MONOTONICALLY, IGNORE INTERPOLATION
C     AND RELOOP
      IF(ABS(SF).LE.ABS(S(N))) GO TO 40
      XDS=SF-S(N)
C
C     IF WITHIN SER OF BMAX STOP INTEGRATION GO GET VALUE OF INVARIANT
      IF(ABS(XDS).LT.SER) GO TO 100
      DDS=.97*XDS
C     RELOOP
      GO TO 40
C
C
C     THE FUNCTION SQRT(1-B/BMAX) DOES NOT EXIST FOR B GREATER THAN BMAX
C     IF PREVIOUS STEP IS NOT WITHIN SER OF BMAX INTERPOLATE TO FIND
C     A STEP SIZE THAT WILL GET CLOSE TO BUT NOT EXCEED BMAX
C
 70   CALL INTERP(BB(N-2,1),S(N-2),BMAX,SF,3)
      N=N-1
C
C     SET UP THE STEP SIZE AND RESET INTEGRATION VALUES TO THE PREVIOUS
C     STEP
```

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C
      DS=.97*(SF-S(N))

      X(I)=XL(I)
      Q(I)=QL(I)
      B(I)=BL(I)
   80 CONTINUE
C     IF THE STEP SIZE IS LESS THAN SER, THE PREVIOUS STEP IS CLOSE
C     ENOUGH EXIT TO INVARIANT CALCULATION
      IF(ABS(SF-S(N)).LT.SER) GO TO 100
      CALL INTGRT
C
C     IF LAST STEP IS STILL PAST BMAX TRY THE INTERPOLATION SCHEME AGAIN
   90 IF(BB(N,1).GT.BMAX) GO TO 70
C
C     INTERPOLATE TO SEE IF THE INTERPOLATION STEP IS CLOSE ENOUGH
C     TO BMAX. IF IT IS NOT, INTERPOLATE AGAIN AND TRY TO COME CLOSER
C
      CALL INTERP(BB(N-2,1),S(N-2),BMAX,SF,3)
C
C     IF WE ARE CLOSE ENOUGH EXIT THE INTEGRATION LOOP
      IF(ABS(SF-S(N)).LT.SER) GO TO 100
      DS=.97*(SF-S(N))
      CALL INTGRT
      IF(IERFLG.NE.0) GO TO 330
      GO TO 90
C
C     THE FIELD MAXIMUM HAS NOW BEEN REACHED.  THE STORED VALUES
C     OF THE MAGNETIC FIELD AND THE PATH LENGTH VALUES CAN NOW BE
C     USED TO EVALUATE THE SECOND INVARIANT.
C
  100 KS=3
C     IF N IS LESS THAN THREE THE FIELD LINE LENGTH IS LESS THAN SER,
C     L CAN BE EVALUATED DIRECTLY
      IF(N.LT.3) GO TO 230
C     IF N IS GREATER THAN THREE ENOUGH POINTS EXIST FOR INTERPOLATION,
C     IF N EQUALS THREE AN INTERMEDIATE POINT MUST BE FOUND
      IF(N.GT.3) GO TO 110
      DS=.5*(S(N-1)-S(N))
      CALL INTGRT
      KS=2
C
C     CALL THE ROUTINE WHICH DETERMINES THE SECOND INVARIANT FROM
C     FROM THE STORED VALUES
C
  110 CALL INVR(BMAX)
C
C     INTERPOLATE TO GET THE BEST FIT
C
      CALL INTERP(BB(N-2,1),SXJ(N-2),BMAX,XXJ,KS)
C
C     SAVE THE ABSOLUTE VALUE OF THE SECOND INVARIANT
      XJ=ABS(XXJ)
C
C
C     THE INTEGRAL HAS NOW BEEN EVALUATED FROM THE STARTING POINT
C     THROUGH THE MINIMUM VALUE OF B TO BMAX.  BMAX, HOWEVER, WAS
C     UPDATED AND MAY NOW BE DIFFERENT FROM THE INITIAL VALUE OF
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```
C      B AND THUS THE INTEGRAL MUST BE TURNED AROUND AND THE SECTION
C      OF THE FIELD LINE BETWEEN THE INITIAL LOCATION AND BMAX AT THE
C
C      CHECK TO SEE IF BMAX IS SUFFICIENTLY DIFFERENT TO REQUIRE
C      THIS INTEGRATION.  IF NOT, GO DIRECTLY TO THE L EVALUATION.
C
       IF(ABS(BB(2,1)-BMAX)/BMAX.LT.ERR) GO TO 210
       CALL INTERP(BB(2,1),S(2),BMAX,SF,1)
       IF(ABS(SF).LT.SER) GO TO 220
C
C      WE MUST INTEGRATE THE REST OF THE LINE --- TURN THE STARTING
C      POINTS AROUND AND RESET THE INITIAL VALUES.
C
       SXJ(1)=SXJ(3)
       BB(1,1)=BB(3,1)
       S(1)=S(3)
       DEL=-DEL
       DS=S(2)-S(3)
       IF(ABS(SF).LT.ABS(DS)) DS=.97*SF
       DO 120 I=1,3
       X(I)=XX(I)
       Q(I)=0.
       B(I)=BINTL(I)
  120  CONTINUE
       N=2
       GO TO 140
C
C      BEGIN INTEGRATING THE SECOND PART
  130  CALL STEPSZ
  140  CALL INTGRT
       IF(IERFLG.NE.0) GO TO 330
       DDS=100.
C
C      STOP INTEGRATION IF BMAX HAS BEEN PASSED
       IF(BB(N,1).GE.BMAX) GO TO 150
       CALL INTERP (BB(N-2,1),S(N-2),BMAX,SF,3)
C
C      IGNORE INTERPOLATION IF RESULT IS NOT MONOTONIC
       IF(ABS(SF).LE.ABS(S(N))) GO TO 130
       XDS=SF-S(N)
C
C      STOP INTEGRATION IF WITHIN SER OF BMAX
       IF(ABS(XDS).LT.SER) GO TO 200
       DDS=.97*XDS
       GO TO 130
C
C      BMAX HAS BEEN PASSED, BEGIN INTERPOLATION SCHEME TO FIND A POINT
C      CLOSE TO BMAX BUT LESS THAN IT.
C
  150  CALL INTERP(BB(N-2,1),S(N-2),BMAX,SF,3)
       N=N-1
       IF(ABS(SF-S(N)).LE.SER) GO TO 200
       DS=.97*(SF-S(N))
       DO 160 I=1,3
       X(I)=XL(I)
       Q(I)=QL(I)
       B(I)=BL(I)
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  160 CONTINUE
      CALL INTGRT
C
C     IF THE POINT IS LESS THAN BMAX MAKE SURE IT IS CLOSE ENOUGH. IF
C     NOT, TRY TO GET CLOSER
C
      CALL INTERP(BB(N-2,1),S(N-2),BMAX,SF,3)
      IF(ABS(SF-S(N)).LT.SER) GO TO 200
      DS=.97*(SF-S(N))
      CALL INTGRT
      IF(IERFLG.NE.0) GO TO 330
      GO TO 170
C
C     INTEGRAL IS COMPLETE USE STORED VALUES TO GET INVARIANT
  200 CALL INVR(BMAX)
      CALL INTERP(BB(N-2,1),SXJ(N-2),BMAX,XXJ,3)
C
C     ADD IN REMAINING CONTRIBUTION OF SECOND INVARIANT
  215 XJ=XJ+ABS(XXJ)
C
C     CALL THE L VALUE ROUTINE
  210 CALL HILTEL(BMAX,XJ,EL)
      RETURN
C
C     NEW BMAX IS VERY CLOSE TO INITIAL B.  NO ADDITIONAL POINTS ARE
C     REQUIRED TO INTERPOLATE INVARIANT VALUE FOR SECOND PART OF LINE
  220 CALL INTERP(BB(2,1),SXJ(2),BMAX,XXJ,1)
      GO TO 215
C
C     FIELD LINE IS TOO SHORT TO DETERMINE 2ND INVARIANT, USE BMIN
  230 CALL HILTEL(BMIN,0.,EL)
      RETURN
C
C     IF EL CANNOT BE CALCULATED SET EL TO 100.
  330 EL=100.
      RETURN
      END
      SUBROUTINE STEPSZ
C
C     PURPOSE
C        DETERMINE THE STEP SIZE FOR THE NEXT INTEGRATRION STEP
C
C     METHOD
C        THE STEP SIZE OF THE RUNGE KUTTA INTEGRATION IS A FUNCTION
C        OF THE ERROR LIMITS, THE CURVATURE OF THE FIELD LINE, THE
C        GRADIENT IN THE MAGNETIC FIELD, AND THE ESTIMATED DISTANCE
C        TO THE END OF THE INTEGRATION.
C
C     INPUT -- COMMON BLOCK INTPAR
C        DEL     A PARAMETER SET UP BY THE CALLING PROGRAM TO SCALE THE
C                STEP SIZE.  IT DEPENDS ON THE ERROR LIMITS OF THE
C                INTEGRATION.
C        B       A REAL ARRAY WHICH CONTAINS THE MAGNETIC FIELD VECTOR
C                AT THE CURRENT STEP
C        BL      A REAL ARRAY WHICH CONTAINS THE MAGNETIC FIELD VECTOR
C                AT THE PREVIOUS STEP
C        BB      A 2 DIMENSIONED REAL ARRAY
```

```
C                  BB(N,1) IS THE MAGNETIC FIELD MAGNITUDE AT THE CURRENT
C                  STEP
C                  PREVIOUS STEP
C            DDS   THE ESTIMATED STEP SIZE REQUIRED TO COMPLETE THE
C                  INTEGRATION
C
C     INPUT/OUTPUT -- COMMON BLOCK INTPAR
C        DS        ON ENTRY TO THE ROUTINE DS CONTAINS THE SIZE OF THE
C                  LAST STEP.  THE ROUTINE RESETS THE VALUE TO THE BEST
C                  STEP SIZE FOR THE NEXT INTEGRATION STEP.
C
C     CALLING SUBROUTINES
C        FLDINT
C
C     TEMPORARY VARIABLES
C        CURVMN THE MINIMUM ACCEPABLE CURVATURE.  THIS LIMITS THE STEP
C                  SIZE IN THE VICINITY OF THE EARTH WHERE THE FIELD
C                  CHANGES RAPIDLY
C        CURV   THE CURVATURE OF THE FIELD LINE
C
      COMMON /INTPAR/DS,DEL,N,IERFLG,XL(3),X(3),XSV(100,3),
     *BB(100,4),S(100),QL(3),Q(3),BL(3),B(3),SXJ(100),DDS
C
C     DETERMINE THE MINIMUM CURVATURE
C
      CURVMN=1.6667/(X(1)**2+X(2)**2+X(3)**2)**(.75)
C
C     DETERMINE THE CURVATURE OF THE FIELD BY USING THE RATE OF CHANGE
C     OF THE UNIT FIELD VECTOR OVER THE LAST STEP
C
      CURV=0.
      DO 50 I=1,3
      CURV=CURV+((B(I)/BB(N,1)-BL(I)/BB(N-1,1))/DS)**2
   50 CONTINUE
      CURV=SQRT(CURV)
      CURV=AMAX1(CURV,CURVMN)
C
C     SET UP THE NEW STEP SIZE AND LIMIT THE STEP SIZE TO LESS THAN 2.8
C     EARTH RADDII TO PREVENT THE INTEGRATION FROM STEPPING OUT OF THE
C     VALID FIELD REGION
C
      DS=DEL/CURV
      DS=SIGN(AMIN1(ABS(DS),2.8),DS)
C
C     IF THE DISTANCE TO THE END OF THE INTEGRATION IS SMALLER THAN THE
C     NEW STEP SIZE, SET THE STEP SIZE TO THE SMALLER VALUE.
C
      IF(ABS(DDS).LT.ABS(DS)) DS=DDS
      RETURN
      END
      SUBROUTINE INTGRT
C
C     PURPOSE
C        THIS SUB MODULE PERFORMS A SINGLE RUNGE-KUTTA INTEGRATION
C        STEP AND UPDATES ALL OF THE VARIABLES IN THE INTEGRATION LOOP
C
C     METHOD
```

```
C        PERFORM A SINGLE FOURTH ORDER INTEGRATION STEP USING GILLS
C        METHOD OF INTEGRATION (REF. S. GILL CAMBRIDGE PHILOSOPHICAL

C
C     INPUT -- COMMON BLOCK INTPAR
C        DS      THE INTEGRATION STEP SIZE IN UNITS OF EARTH RADII.
C                THE INTEGRATION MOVES THE SPACE COORDINATE A DISTANCE
C                DS ALONG THE MAGNETIC FIELD LINE. IF DS IS POSITIVE,
C                MOTION IS IN THE DIRECTION OF THE FIELD. IF DS IS
C                NEGATIVE MOTION IS ANTI-PARALLEL TO THE FIELD.
C
C     INPUT/OUTPUT -- COMMON BLOCK INTPAR
C        N       THE INTEGRATION STEP NUMBER. IT IS INCREMENTED BY
C                ONE AT THE END OF THIS ROUTINE. (NOTE N=2 IS THE
C                BEGINNING OF THE INTEGRATION)
C        X       A REAL ARRAY GIVING THE VECTOR LOCATION OF THE
C                INTEGRATION VARIABLE.
C                INPUT - THE INITIAL POSITION PRIOR TO THE INTEGRATION
C                        STEP
C                OUTPUT- THE FINAL VALUE AFTER THE INTEGRATION STEP
C        B       A REAL ARRAY CONTAINING THE VECTOR MAGNETIC FIELD
C                IN GAUSS
C                INPUT - THE VECTOR FIELD BEFOR THE INTEGRATION STEP
C                OUTPUT- THE VECTOR FIELD AFTER THE STEP
C        G       A REAL ARRAY CONTAINING AN ERROR CONTROL VARIABLE
C                USED BY GILLS INTEGRATION METHOD
C                INPUT - ERROR FROM PREVIOUS STEP
C                OUTPUT- ERROR AFTER PRESENT STEP FOR INPUT TO SUBSEQUENT
C                        STEPS
C
C     OUTPUT -- COMMON BLOCK INPTAR
C        S       A REAL ARRAY WHICH SAVES EACH OF THE DISTANCES (SINCE
C                THE START OF THE INTEGRATION) ALONG THE MAGNETIC FIELD
C                LINE.
C                S(2)=0
C                S(N+1)=S(N)+DS ETC.
C        XSV     A REAL 2 DIMENSIONED ARRAY WHICH SAVES THE VECTOR
C                POSITION IN EARTH RADII FOR EACH OF THE INTEGRATION
C                STEPS.  XSV(N,1), XSV(N,2), XSV(N,3) ARE VECTOR
C                CARTESIAN POSITION COORDINATES CORESPONDING TO POSITION
C                S(N) ON THE FIELD LINE
C        BB      A REAL 2 DIMENSIONED ARRAY WHCIH SAVES THE MAGNITUDE
C                OF THE MAGNETIC FIELD FORM EACH INTEGRATION STEP.
C                BB(N,1) IS MAGNETIC FIELD VALUE AT DISTANCE S(N).
C                BB(N-1,2), BB(N-1,3), BB(N-1,4) ARE THE INTERMEDIATE
C                VALUES OF THE FIELD USED BY GILLS METHOD TO GET FROM
C                BB(N-1,1) TO BB(N,1).
C        XL      A REAL ARRAY WHICH SAVES THE INITIAL POSITION VALUES
C                PRIOR TO STARTING THE INTEGRATION STEP
C        BL      A REAL ARRAY WHICH SAVES THE VECTOR MAGNETIC FIELD
C                VALUES PRIOR TO STARTING THE INTEGRATION STEP
C        GL      A REAL ARRAY WHICH SAVES THE INITIAL VALUES OF THE
C                ERROR CONTROL VARIABLE
C        IERFLG  AN ERROR CONTROL INDICATOR WHICH IS USED BY THE CALLING
C                PROGRAM TO CONTROL THE PROGRAM FLOW
C                IERFLG = 0 NO ERROR
C                IERFLG = 1 INTEGRATION IS OUTSIDE VALID FIELD LIMITS
C                           OR THE MAXIMUM STEP NUMBER (100) HAS BEEN
```

```
C                             REACHED.
C
C          P29     1.0-SQRT(0.5)
C          CP7     1.0+SQRT(0.5)
C
C     VARIABLES
C          F5DS    .5 * STEP SIZE
C          F29DS   (1.0-SQRT(0.5)) * STEP SIZE
C          OP7DS   (1.0-SQRT(0.5)) * STEP SIZE
C          RR,SS   REAL ARRAYS USED BY GILLS METHOD TO MINIMIZE COMPUTER
C                  TIME AND MINIMIZE ROUNDOFF ERROR
C
C     CALLING SUBROUTINES
C          SUBROUTINE FLDINT
C
C     SUBROUTINES REQUIRED
C          SUBROUTINE BMNEXT
C
      COMMON /INTPAR/DS,DEL,N,IERFLG,XL(3),X(3),XSV(100,3),
     *BB(100,4),S(100),QL(3),Q(3),BL(3),B(3),SXJ(100),DDS
      DIMENSION SS(3),RR(3)
      DATA P29,OP7/.29289322,1.70710678/
      IERFLG=0
C     SAVE THE INITIAL VALUES.  THESE INITIAL VALUES MAY BE NEEDED IF
C     IF THE INTEGRATION STEP IS UNSUCCESSFUL (GOES TOO FAR) AND THE
C     STEP MUST BE REPEATED.
C
      DO 65 I=1,3
      XL(I)=X(I)
      QL(I)=Q(I)
      BL(I)=B(I)
   65 CONTINUE
C
C     SET UP THE CONSTANST NEEDED BY THE INTEGRATION LOOP
C
      P5DS=.5*DS
      P29DS=P29*DS
      OP7DS=OP7*DS
C
C     BEGIN GILLS METHOD (GILL 1951) OF FOURTH ORDER INTEGRATION
C
      DO 70 I=1,3
      SS(I)=P5DS*B(I)/BB(N,1)
      RR(I)=SS(I)-Q(I)
      X(I)=X(I)+RR(I)
      Q(I)=Q(I)+3.*RR(I)-SS(I)
   70 CONTINUE
      CALL BMNEXT(X,B,BB(N,2))
      DO 71 I=1,3
      SS(I)=P29DS*B(I)/BB(N,2)
      RR(I)=SS(I)-P29*Q(I)
      X(I)=X(I)+RR(I)
      Q(I)=Q(I)+3.*RR(I)-SS(I)
   71 CONTINUE
      CALL BMNEXT(X,B,BB(N,3))
      DO 72 I=1,3
      SS(I)=OP7DS*B(I)/BB(N,3)
```

```
      RR(I)=SS(I)-OP7*Q(I)
      X(I)=X(I)+RR(I)
   72 CONTINUE
      CALL BMNEXT(X,B,BB(N,4))
      DO 73 I=1,3
      SS(I)=F5DS*B(I)/BB(N,4)
      RR(I)=(SS(I)-Q(I))/3.
      X(I)=X(I)+RR(I)
      Q(I)=Q(I)+3.*RR(I)-SS(I)
   73 CONTINUE
      N=N+1
C
C     SAVE THE CURRENT DISTANCE ALONG THE FIELD LINE
C
      S(N)=S(N-1)+DS
      DO 80 I=1,3
      XSV(N,I)=X(I)
   80 CONTINUE
C
C     OBTAIN THE CURRENT VALUES OF THE MAGNETIC FIELD
C
      CALL BMNEXT(X,B,BB(N,1))
C
C     IF N IS TOO BIG, SET ERROR FLAG
C
      IF(N.GE.100) IERFLG=1
C
C     IF OUTSIDE INTEGRATION LIMITS SET ERROR FLAG
      IF(X(1)**2+X(2)**2+X(3)**2.GT.144..OR.BB(N,1).LT.0.00025)IERFLG=1
      RETURN
      END
      SUBROUTINE INVR(BMAX)
C
C     PURPOSE
C        TO CALCULATE THE VALUE OF THE SECOND INVARIANT
C
C     METHOD
C        USE THE VALUES STORED IN THE S AND BB ARRAYS TO EVALUATE THE
C        INTEGRAL  SQRT(1-BB/BMAX) ALONG THE FIELD LINE.  USE THE
C        SAME INTERGRATION METHOD (GILLS METHOD) USED IN INTEGRATING
C        THE FIELD LINE
C
C     INPUT -- COMMON BLOCK INTPAR
C        N       THE NUMBER OF INTEGRATION STEPS
C        BMAX    THE VALUE OF THE MAXIMUM MAGNETIC FIELD (THE POINT
C                WHERE THE PARTICLE HAS ITS MIRROR POINT)
C        BB      A REAL 2 DIMENSIONED ARRAY CONTAINING ALL OF THE
C                MAGNETIC FIELD MAGNITUDES CALCULATED IN THE FIELD LINE
C                INTEGRATION
C        S       A REAL ARRAY CONTAINING ALL THE DISTANCE VALUES CAL-
C                CULATED IN THE FIELD LINE INTEGRATION
C                S(N) IS THE DISTANCE FROM THE INTEGRATION START TO
C                THE POINT WHERE THE FIELD HAS VALUE BB(N,1)
C
C     OUTPUT -- COMMON BLOCK INTPAR
C        SXJ     THE VALUES OF THE SECOND INVARIANT INTEGRATION AT
C                EACH INTEGRATION STEP.  SXJ(N) CONTAINS THE BEST
```

```
C                 APPROXIMATION TO THE VALUE OF THE SECOND INVARIANT.
C                 THE SAVING OF THE STEPS PERMITS THE USE OF INTERPOLATION
C
C      CALLING SUBROUTINES
C         SUBROUTINE FLDINT
C
C      CONSTANTS
C         P29     1.0-SQRT(.5)
C         OP7     1.0+SQRT(.5)
C
       COMMON /INTPAR/DS,DEL,N,IERFLG,XL(3),X(3),XSV(100,3),
      *BB(100,4),S(100),QL(3),Q(3),BL(3),B(3),SXJ(100),DDS
       DATA P29,OP7/.29289322,1.70710678/
       SXJ(2)=0.
C
C      START THE INTEGRATION LOOP.
C      THIS IS GILLS METHOD MADE SIMPLE IF ALL THE POINTS ARE GIVEN
       NN=N-1
       DO 210 K=2,NN
       TEMP=0
       IF(BB(K,1).LT.BMAX)TEMP=TEMP+.5*SQRT(1.-BB(K,1)/BMAX)
       IF(BB(K,2).LT.BMAX)TEMP=TEMP+P29*SQRT(1.-BB(K,2)/BMAX)
       IF(BB(K,3).LT.BMAX)TEMP=TEMP+OP7*SQRT(1.-BB(K,3)/BMAX)
       IF(BB(K,4).LT.BMAX)TEMP=TEMP+.5*SQRT(1.-BB(K,4)/BMAX)
C
C      SAVE THE INTEGRATION VALUES
C
       SXJ(K+1)=SXJ(K)+TEMP*(S(K+1)-S(K))/3.
  210  CONTINUE
       RETURN
       END
       SUBROUTINE INTERP(BB,CC,D,E,J)
C
C      PURPOSE
C         INTERPOLATION ROUTINE
C
C      METHOD
C         GIVEN A SET OF THREE X,Y POINT PAIRS, INTERP FINDS THE SOLUTION
C         TO THE THREE LINEAR EQUATIONS EXPRESSING THE LOGARITHM OF THE
C         DEPENDENT VARIABLE Y AS A SECOND ORDER POLYNOMIAL OF THE
C         INDEPENDENT VARIABLE X. (LOG Y = A*X**2 +B*X +C)
C         USING THE BINOMIAL FORMULA, X CAN THEN BE EVALUATED AT A
C         SPECIFIED VALUE OF Y1
C         X = (-B +- SQRT(B**2-4*A*(C-LOG(Y1))))/(2*A)
C
C      INPUT -- ARGUMENT LIST
C         BB      A REAL ARRAY CONTAINING THE THREE VALUES OF THE
C                 DEPENDENT VARIABLE
C         CC      A REAL ARRAY CONTAINING THE THREE CORESPONDING VALUES
C                 OF THE INDEPENDENT VARIABLE
C         J       A FLOW CONTROL VARIABLE
C                 IF J IS LESS THAN 0
C                 FIT THE POLYNOMIAL TO CC AND BB AND FIND THE MINIMUM
C                 VALUE OF THE DEPENDENT VARIABLE
C                 IF J IS GRATER THAN 0
C                 USE THE BINOMIAL FORMULA TO TO FIND THE VALUE OF
C                 THE INDEPENDENT VARIABLE WHEN THE DEPENDENT VARIABLE
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```
C                   HAS THE VALUE D.CHOOSE THE ROOT THAT IS CLOSEST TO CC(J)
C          D        WHEN J IS GREATER THAN ZERO, D IS USED FOR INPUT.
                    SOLUTION TO THE DEPENDENT VARIABLE IS WANTED
C
C     OUTPUT -- ARGUMENT LIST
C          D        WHEN J IS LESS THAN 0, D OUTPUTS THE VALUE OF THE
C                   DEPENDENT VARIABLE WHERE THE FUNCTION IS A MINIMUM
C          E        WHEN J IS LESS THAN 0, E OUTPUTS THE VALUE OF THE
C                   INDEPENDENT VARIABLE WHERE THE FUNCTION IS A MINIMUM
C                   WHEN J IS GREATER THAN 0, E OUPUTS THE VALUE OF THE
C                   INDEPENDENT VARIABLE WHERE THE FUNCTION HAS THE VALUE D
C
C     CALLING SUBROUTINES
C        SUBROUTINE FLDINT
C
C     VARIABLES
C        X2,X3,Y1,Y2,Y3,DD  ARE USED BY THE LINEAR EQUATION SOLUTION
C                   TO MINIMIZE COMPUTER TIME
C        A,B,C      THE THREE POLYNOMIAL COOEFICIENTS
C        DIS        B**2-4*A*C
C        SA,SB      THE TWO ROOTS OF THE POLYNOMIAL
C
      DIMENSION BB(3),CC(3)
C
C     SET UP THE INITIAL VARIABLES, MOVE THE ORIGIN OF THE INDEPENDENT
C     VARIABLE TO CC(1)
C
      Y1=ALOG(BB(1))
      Y2=ALOG(BB(2))
      Y3=ALOG(BB(3))
      X2=CC(2)-CC(1)
      X3=CC(3)-CC(1)
C
C     SOLVE THE LINEAR EQUATIONS
      DD=(X3-X2)*X2*X3
      A=(X3*(Y1-Y2)+X2*(Y3-Y1))/DD
      B=(X3**2*(Y2-Y1)-X2**2*(Y3-Y1))/DD
C
C     IF J THE FLOW CONTROL VARIABLE IS LESS THAN ZERO BRANCH TO
C     MINIMUM EVALUATION ROUTINE
      IF(J.LT.0)GO TO 100
      C=Y1-ALOG(D)
      DIS=B**2-4.*A*C
C
C     IF DIS IS NEGATIVE NO SOLUTION EXIST, EXCHANGE DEPENDENT AND
C     INDEPENDENT VARIABLE ROLES AND TRY ANOTHER SOLUTION
      IF(DIS.LE.0.) GO TO 200
      DIS=SQRT(DIS)
C
C     OBTAIN THE TWO ROOTS
      SA=(-B+DIS)/(2.*A)+CC(1)
      SB=(-B-DIS)/(2.*A)+CC(1)
      E=SA
C
C     FIND THE ROOT CLOSEST TO CC(J)
      IF(ABS(SB-CC(J)).LT.ABS(SA-CC(J)))E=SB
      RETURN
```

```
C
C      FIND THE VALUES AT THE MINIMUM

       E=X
       D=EXP(A*X**2+B*X+Y1)
       RETURN
C
C      ALTERNATE INTERPOLATION SCHEME PLACED HERE AS A SAFEGUARD
C      AGAINST A STRANGE FIELD CONFIGURATION CAUSING AN IMAGINARY
C      SOLUTION (EXCHANGE THE ROLES OF DEPENDENT AND INDEPENDENT
C      VARIABLES)
C
  200  Y1=CC(1)
       Y2=CC(2)
       Y3=CC(3)
       X2=BB(2)-BB(1)
       X3=BB(3)-BB(1)
       DD=(X3-X2)*X2*X3
       A=(X3*(Y1-Y2)+X2*(Y3-Y1))/DD
       B=(X3**2*(Y2-Y1)-X2**2*(Y3-Y1))/DD
       E=(A*D+B)*D+Y1
       RETURN
       END
       SUBROUTINE MAXFIX(BMAX,BMIN)
C
C      PURPOSE
C         THIS ROUTINE MODIFIES THE VALUE OF BMAX SUCH THAT THE COMPUTED
C         L GIVES A BETTER FIT TO THE DRIFT SHELLS FOR ISOTROPIC PARTICLE
C         DISTRIBUTIONS IN THE REGION WHERE DRIFT SHELL SPLITTING OCCURS
C
C      METHOD
C         USE BMIN TO OBTAIN AN APPROXIMATE VALUE FOR L AND IF L IS
C         IN THE DRIFT SHELL SPLITTING REGION MODIFY THE MIRROR POINT
C         FIELD, BMAX, TO REPRESENT THE DRIFT SHELL OF AN AVERAGE
C         PITCH ANGLE PARTICLE
C
C      INPUT -- ARGUMENT LIST
C         BMIN   THE MINIMUM VALUE OF THE MAGNETIC FIELD ON THE FIELD
C                LINE
C
C      INPUT/OUTPUT -- ARGUMENT LIST
C         BMAX   THE MIRROR POINT FIELD.  ON INPUT IT CONTAINS THE
C                MAGNETIC FIELD AT THE START OF THE INTEGRATION.  ON
C                OUTPUT IT HAS THE MIRROR POINT FIELD DESCRIBING THE
C                AVERAGE DRIFT SHELL
C
C      CALLING SUBROUTINE
C         SUBROUTINE FLDINT
C
C      VARIABLES
C         EL     THE APPROXIMATE L VALUE
C         CON    THE L DEPENDENT MULTIPLIER THAT MODIFIES BMAX
C
C
C      IF BMAX IS GREATER THAN 3 TIMES BMIN, FURTHER DRIFT SHELL
C      SPLITTING DOES NOT TAKE PLACE FOR LARGER VALUES OF BMAX
       IF(BMAX.GT.3.*BMIN) RETURN
C
```

```
C     CALCULATE THE APPROXIMATE L VALUE
      EL=(0.311653/BMIN)**(1./3.)

C     IF L IS LESS THAN 3, NO DRIFT SHELL SPLITTING TAKES PLACE
      IF(EL.LT.3.) RETURN
      CON=1.3
C
C     BETWEEN L 3 AND 5, TURN ON THE DRIFT SHELL SPLITTING FUNCTION
      IF(EL.LT.5.) CON=1.+0.15*(EL-3.)
C
C     MODIFY BMAX BY A MAXIMUM OF 1.3, TO BETTER REPRESENT THE AVERAGE
C     DRIFT SHELL (1.3 REPRESENTS A PARTICLE HAVING A PITCH ANGLE OF
C     ABOUT 60 DEGREES)
      BMAX=AMIN1(3.*BMIN,CON*BMAX)
      RETURN
      END
      SUBROUTINE MGLONG(X,S,SF,XMLONG)
C
C     PURPOSE
C        TO DETERMINE THE MAGNETIC LONGITUDE OF THE MINIMUM B LOCATION
C        OF THE MAGNETIC FIELD LINE
C
C     METHOD
C        GIVEN A LOCUS OF POSITIONS ALONG A FIELD LINE AS A FUNCTION
C        OF THE SCALAR DISTANCE ALONG THE FIELD LINE AND GIVEN THE
C        SCALAR DISTANCE WHERE THE FIELD IS A MINIMUM, THE ROUTINE
C        FINDS THE VECTOR POSITION OF THE MINIMUM.  IT THEN TRANSFORMS
C        THIS MINIMUM TO OFFSET DIPOLE COORDINATES AND CALCULATES
C        THE MAGNETIC LONGITUDE OF THE MINIMUM
C        NOTE*******THE CONSTANT ISWTCH IS SET BY A DATA STATEMENT,
C        IF IT IS SET TO ZERO XMLONG IS CALCULATED USING A CENTERED
C        DIPOLE COORDINATE SYSTEM WITH ZERO LONGITUDE AT 69 DEGREES
C        WEST GEOGRAPHIC.  IF ISWTCH IS SET NON-ZERO, AN OFFSET DIPOLE
C        COORDINATE SYSTEM IS USED WITH XMLONG=0 GOING THROUGH
C        GREENWHICH
C
C     INPUT -- ARGUMENT LIST
C        X       A REAL 2 DIMENSIONED ARRAY CONTAINING THE LOCUS OF
C                POINTS ALONG A FIELD LINE
C                X(1,1), X(1,2) AND X(1,3) ARE THE X, Y, Z VALUES
C                (RIGHT HANDED CARTESIAN COORDINATES) AT THE FIRST
C                POINT, X(2,1), X(2,2) AND X(2,3) THE SECOND LOCATION
C                AND X(3,1), X(3,2) AND X(3,3) ARE AT THE THIRD LOCATION
C                THE FIRST DIMENSION OF X MUST BE THE SAME AS THE
C                CALLING PROGRAMS DIMENSION - IN THIS CASE IT IS 100
C        S       A REAL ARRAY CONTAINING THE SCALAR DISTANCE ALONG THE
C                FIELD LINE IN EARTH RADII. S(1) IS THE SCALAR DISTANCE
C                TO THE X(1,1), X(1,2), X(1,3) POINT FROM THE START
C                OF THE INTEGRATION, S(2) IS THE DISTANCE TO X(2,1),...
C        SF      THE SCALAR DISTANCE TO THE MAGNETIC MINIMUM
C
C     OUTPUT -- ARGUMENT LIST
C        XMLONG THE MAGNETIC LONGITUDE (IN DEGREES) OF THE MINIMUM
C                OF THE MAGNETIC LINE OF FORCE
C                IF ISWTCH IS ZERO, THE ZERO OF MAGNETIC LONGITUDE IS
C                ALONG 69 DEG WEST GEOGRAPHIC
C                IF ISWTCH IS NOT ZERO, THE ZERO OF MAGNETIC LONGITUDE
C                IS THROUGH GREENWHICH
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```
C
C      CONSTANTS
C                   DIPOLE IN EARTH RADII (GEOGRAPHIC CARTESIAN COORDS)
C         A22-A34 TRANSFORMATION MATRIX TO OFFSET DIPOLE COORDS. FIRST
C                 ROTATE ABOUT THE GEOGRAPHIC Z AXIS, TO THE MERIDIAN
C                 CONTAINING THE OFFSET DIPOLE,  THEN ABOUT THE NEW Y AXIS
C                 TO THE LATITUDE CONTAINING THE OFFSET DIPOLE AND THEN
C                 ABOUT THE NEW Z AXIS SUCH THAT THE ZERO OF LONGITUDE
C                 PASSES THROUGH GREENWHICH
C         ISWTCH  A FLOW CONTROL CONSTANT
C                 IF SET TO ZERO BY THE DATA STATEMENT USE CENTERED DIPOLE
C                 COORDINATES
C                 IF SET NON-ZERO USE OFFSET DIPOLE COORDINATES
C         SIN D   SINE OF THE COLATITUDE OF THE CENTERED DIPOLE AXIS
C         COS D   COSINE OF THE COLATITUDE OF THE CENTERED DIPOLE AXIS
C         S69     SINE OF 69 DEGREES
C         C69     COSINE OF 69 DEGREES
C
C      TEMPORARY VARIABLES
C         XF,X1,X2,Y1,Y2,Y3,A,B,DD  THESE VARIABLE ARE USED IN THE
C                 INTERPOLATION LOOP TO MINIMIZE THE NUMBER OF MEMORY
C                 REFERENCES AND TO MINIMIZE THE NUMBER OF MULTIPIES
C         XT      A REAL ARRAY HOLDING THE LOCATION OF THE MINIMUM AND
C                 LATER THE OFFSET MINIMUM OF THE FIELD LINE
C         XP,YP   THE POSITION OF THE MINIMUM IN OFFSET MAGNETIC CORDS.
       DIMENSION X(100,3),S(100),DX(3),XT(3)
       DATA DX(1),DX(2),DX(3)/0.0576,-0.0321,-0.0184/
       DATA A22,A23,A24,A32,A33,A34/0.97056,0.23948,-0.02556,
      *-0.22969,0.95232,0.20082/
       DATA SIND,COSD,S69,C69/.2027872954,.9792228106,.9335804265,
      *.3583679495/
C
C
C      ********SET UP THE FLOW CONTROL SWITCH**********
C      COORDINATE SYSTEM DEFINITION USED. (SEE METHOD)
       DATA ISWTCH/1/
C
C      BEGIN GUADRATIC INTERPOLATION
       XF=SF-S(1)
       X2=S(2)-S(1)
       X3=S(3)-S(1)
       DD=(X3-X2)*X2*X3
C
C      INTERPOLATE EACH COMPONENT SEPERATELY
       DO 10 I=1,3
       Y1=X(1,I)
       Y2=X(2,I)
       Y3=X(3,I)
       A=(X3*(Y1-Y2)+X2*(Y3-Y1))/DD
       B=(X3**2*(Y2-Y1)-X2**2*(Y3-Y1))/DD
C
C      EVALUATE THE POSITION OF THE MINIMUM
   10  XT(I)=(A*XF+B)*XF+Y1
C
C      IF ISWTCH IS ZERO GO TO CENTERED DIPOLE DEFINITION
       IF (ISWTCH.EQ.0) GO TO 30
C
```

```
C      ADD IN THE DIPOLE OFFSET
       DO 20 I=1,3

C
C      TRANSFORM TO OFFSET DIPOLE COORDINATES AND EVALUATE THE LONGITUDE
       XP=A22*XT(1)+A23*XT(2)+A24*XT(3)
       YP=A32*XT(1)+A33*XT(2)+A34*XT(3)
       GO TO 40
C
C      TRANSFORM TO CENTERED DIPOLE COORDINATES
   30  XP=(XT(1)*C69-XT(2)*S69)*COSD-XT(3)*SIND
       YP=XT(1)*S69+XT(2)*C69
C
C      CALCULATE MAGNETIC LONGITUDE
   40  XMLONG=ATAN2(YP,XP)*57.2957795
       IF(XMLONG.LT.0.) XMLONG=XMLONG+360.
       RETURN
       END
       SUBROUTINE HILTEL (B,XI,VL)
C      PURPOSE
C         CALCULATE THE L VALUE
C         THE ORIGINAL MCILWAIN L EXPANSION GIVEN BY THE OLD
C         SUBROUTINE CARMEL HAS BEEN REPLACED BY HILTONS SIMPLER
C         EXPANSION.  DIFFERENCES BETWEEN HILTONS AND MCILWAINS
C         EXPANSION ARE TYPICALLY LESS THAN .01 PERCENT.
C
C      METHOD
C         SEE J. HILTON, J. GEOPHYS. RES. 76, 6952 (1971)
C
C      INPUT -- CALLING SEQUENCE
C         B         THE MAGNETIC FIELD AT THE PARTICLE MIRROR POINT
C         XI        THE SECOND INVARIANT EVALUATED BETWEEN MIRROR POINTS
C                   EXPRESSED IN UNITS OF EARTH RADII
C
C      OUTPUT -- CALLING SEQUENCE
C         VL        THE L VALUE
C
       DATA XM/.311653/
       IF(XI.GT.1.0E-36) GO TO 10
       VL=(XM/B)**(1./3.)
       RETURN
   10  X=XI*(B/XM)**(1./3.)
       V=1.+X*(1.35047+X*(.465376+.0475455*X))
       VL=(V*XM/B)**(1./3.)
C      END COMPUTE L
       RETURN
       END
       SUBROUTINE BMNEXT(XX,B,BMAG)
C
C      PURPOSE
C         TO DETERMINE THE MAIN MAGNETIC FIELD PLUS THE EXTERNAL
C         FIELD
C
C      METHOD
C         DETERMINES THE VECTOR MAGNETIC FIELD IN GEOGRAPHIC
C         COORDINATES USING A SPHERICAL COORDINATE EXPANSION OF THE
C         EARTHS INTERNAL FIELD AND A CARTESIAN COORDINATE EXPANSION
C         OF THE BOUNDARY, TAIL AND RING CURRENT FIELDS IN SOLAR
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```
C        MAGNETIC COORDINATES
C
C                  COORDINATES
C                  IF KODE = 1
C                  XX(1)=X, XX(2)=Y, XX(3)=Z, WHERE X, Y, Z ARE IN EARTH
C                  RADII.  THE DIRECTION OF Z IS ALONG THE EARTHS ROTATION
C                  AXIS TOWARDS THE GEOGRAPHIC NORTH POLE.  THE DIRECTION
C                  OF X IS TO THE GREENWHICH MERIDIAN IN THE EQUATORIAL
C                  PLANE.  THE Y AXIS IS IN THE EQUATORIAL PLANE NORMAL
C                  TO X AND Z IN A RIGHT HANDED SENSE.
C                  IF KODE = 2
C                  XX(1)=R, GEOCENTRIC RADIUS IN EARTH RADII,
C                  XX(2)=THETAG, COLATITUDE IN DEGREES,
C                  XX(3)=PHIG, LONGITUDE IN DEGREES
C
C     INPUT -- COMMON BLOCK BXYZCM
C        UT        THE CURRENT UNIVERSAL TIME IN HOURS
C        KODE      A FLOW CONTROL VARIABLE.  KODE EQUAL TO ONE MEANS THAT
C                  INPUT AND OUTPUT ARE IN CARTESIAN COORDINATES.  KODE
C                  EQUAL TO TWO MEANS THAT INPUT AND OUTPUT ARE SPHERICAL
C                  COORDINATES.
C        DAYYR     THE NUMBER OF THE DAY OF YEAR
C        JSW       A FLOW CONTROL VARIABLE. IF JSW IS LESS THAN ZERO, THE
C                  THE FIELD IS COMPUTED USING THE INTERNAL FIELD ONLY.
C                  IF JSW IS GREATER THAN OR EQUAL TO ZERO THE FIELD
C                  WILL BE COMPUTED USING THE INTERNAL PLUS EXTERNAL
C                  FIELD.
C        YEAR      THE YEAR USED BY THE INTERNAL MAGNETIC FIELD ROUTINE
C                  TO TAKE INTO ACCOUNT THE SECULAR VARIATIONS
C                  (E.G. JULY 15, 1964 = 1964.54)
C                  NOTE**** YEAR SHOULD BE CHANGED ONLY EVERY FEW DAYS OR
C                  MONTHS.  NEW FIELD COEFFICIENTS MUST BE COMPUTED FOR
C                  EVERY CHANGE IN YEAR.  THIS COULD CAUSE A LARGE INCREASE
C                  IN COMPUTER TIME.  THE EARTHS FIELD CHANGES ONLY ABOUT
C                  .001 GAUSS/YEAR AT THE EARTHS SURFACE.
C
C     OUTPUT -- ARGUMENT LIST
C        B         A REAL ARRAY CONTAINING THE COMPONENTS OF THE MAGNETIC
C                  FIELD IN GAUSS AT THE CURRENT POSITION AND TIME
C                  IF KODE = 1
C                  B(1)=BX, B(2)=BY, B(3)=BZ  THE CARTESIAN COMPONENTS
C                  OF THE MAGNETIC FIELD IN GEOGRAPHIC COORDINATES
C                  IF KODE = 2
C                  B(1)=BR, RADIAL COMPONENT OF THE FIELD, POSITIVE IN THE
C                  DIRECTION OF INCREASING RADIUS.
C                  B(2)=BTHETA, COMPONENT IN LATITUDE, POSITIVE IN THE
C                  DIRECTION OF INCREASING COLATITUDE
C                  B(3)=BPHI, COMPONENT IN LONGITUDE, POSITIVE IN THE
C                  DIRECTION OF INCREASING LONGITUDE.
C        BMAG      THE MAGNITUDE OF THE MAGNETIC FIELD VECTOR IN UNITS OF
C                  GAUSS.
C
C     OUTPUT -- COMMON BLOCK BXYZCM
C        XMLAT     THE MAGNETIC LATITUDE AT THE CURRENT POSITION IN RADIANS
C
C     SUBROUTINE CONSTANTS
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C         PICON  THE NUMBER OF DEGREES PER RADIAN
C         SIN D  THE SINE OF THE COLATITUDE OF THE DIPOLE AXIS
C
C      CALLING SUBROUTINES
C         SUBROUTINE FLDINT
C
C      SUBROUTINES REQUIRED
C         SUBROUTINE BXYZMU
C         SUBROUTINE ANGLE
C         SUBROUTINE SPHRCM
C
C      VARIABLES
C         AOR     INVERSE OF RADIUS VECTOR (AOR=1./R)
C         BGMX,BGMY,BGMZ  INTERMEDIATE VALUES OF THE MAGNETIC FIELD
C                 VECTOR DURING COORDINATE TRANSFORMATION
C         BMX,BMY,BMZ  EXTERNAL MAGNETIC FIELD IN GEOMAGNETIC COORDINATES
C         BP,BR,BT  COMPONENTS OF INTERNAL FIELD IN SPHERICAL COORDINATES
C                 BP IS LONGITUDINAL COMPONENT
C                 BR IS RADIAL COMPONENT
C                 BT IS LATITUDINAL COMPONENT
C         BX,BY,BZ  CARTESIAN COMPONENT OF EXTERNAL FIELD IN GEOGRAPHIC
C                 COORDINATES
C         CP      COSINE OF COLATITUDE
C         CPS     COSINE OF HOUR ANGLE TO GET FROM SOLAR MAGNETIC TO
C                 GEOMAGNETIC COORDINATES
C         CT      COSINE OF GEOGRAPHIC LONGITUDE
C         DAYLST LAST DAY FOR WHICH TILT AND HOUR ANGLE WERE UPDATED
C         NMAX    MAXIMUM NUMBER OF TERMS USED BY INTERNAL FIELD ROUTINE
C                 SET UP BY INTERNAL FIELD ROUTINE
C         PHIG    GEOGRAPHIC COLATITUDE
C         R       RADIUS VECTOR TO POSITION POINT
C         R2      R**2
C         SP      SINE OF COLATITUDE
C         SPS     SINE OF HOUR ANGLE TO GET FROM SOLAR MAGNETIC TO
C                 GEOMAGNETIC COORDINATES
C         ST      SINE OF LONGITUDE
C         THETAG GEOGRAPHIC LONGITUDE
C         TILT    TILT OF THE DIPOLE AXIS
C         UTLST  LAST UNIVERSAL TIME FOR WHICH TILT AND HOUR ANGLE WERE
C                 UPDATED
C         X       A REAL ARRAY HOLDING THE POSITION VECTOR IN SOLAR
C                 MAGNETIC COORDINATES
C         XP,YP,ZP  POSITION VECTOR IN GEOMAGNETIC COORDINATES
C         XPP,YPP INTERMEDIATE POSITION COMPONENT DURING COORDINATE
C                 TRANSFORMATION
C         YEARI  TRANSMITS THE YEAR TO THE INTERNAL FIELD ROUTINE
C
C      VERSION 10/25/77
C      FOR MORE INFORMATION CALL OR WRITE K. A. PFITZER AT MCDONNELL
C      DOUGLAS ASTRONAUTICS CO. 5301 BOLSA AVE, HUNTINGTON BEACH CALIF.
C      PHONE (714) 896-3231.
C
       DIMENSION X(3),B(3),XX(3)
       COMMON/BXYZCM/YEAR,DAYYR,UT,KODE,USW
       COMMON /GCOM/ ST,CT,SP,CP,AOR,BT,BP,BR,NMAX,YEARI
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      DATA PICON/57.29577951/,SIND,COSD/.2027872954,.9792228106/,
     *S69,C69/.9335804265,.3583679495/,UTLST,DAYLST/2*123456./

C
      IF(UT.EQ.UTLST.AND.DAYYR.EQ.DAYLST) GO TO 1
      UTLST=UT
      DAYLST=DAYYR
      CALL ANGLE (TILT,SPS,CPS)
    1 IF(KODE.GT.1) GO TO 3
C
C     DETERMINE THE SPHERICAL COORDINATES OF POSITION IF CARTESIAN
C     COORDINATES WERE ENTERED
C
      X(1)=XX(1)
      X(2)=XX(2)
      X(3)=XX(3)
      R2=X(1)**2+X(2)**2
      R=SQRT(X(3)**2+R2)
      R2=SQRT(R2)
      CT=X(3)/R
      ST=R2/R
      CF=X(1)/R2
      SF=X(2)/R2
      GO TO 5
C
C     DETERMINE THE CARTESIAN COORDINATES OF POSITION IF SPHERICAL
C     COORDINATES WERE ENTERED
C
    3 R=XX(1)
      THETAG=XX(2)/PICON
      PHIG=XX(3)/PICON
      CT=COS(THETAG)
      ST=SIN(THETAG)
      CP=COS(PHIG)
      SP=SIN(PHIG)
      X(1)=R*ST*CP
      X(2)=R*ST*SP
      X(3)=R*CT
    5 BX=0.
      BY=0.
      BZ=0.
C
C     IF THE EXTERNAL MAGNETIC FIELD IS TO BE USED IN THE COMPUTATION,
C     COMPUTE THE SOLAR MAGNETIC COORDINATES
C
      IF(JSW.LT.0) GO TO 9
C
C     FIRST ROTATION IS ABOUT THE Z-AXIS TROUGH AN ANGLE OF 291 DEGREES
C     (THE LONGITUDE OF THE MAGNETIC NORTH POLE)
C
      XPP=X(1)*C69-X(2)*S69
      YPP= X(1)*S69+X(2)*C69
C
C     SECOND ROTATION IS ABOUT THE NEW Y-AXIS THROUGH AN ANGLE OF 11.7
C     DEGREES (THE COLATITUDE OF THE MAGNETIC NORTH POLE)
C
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      ZP=XPP*SIND+X(3)*COSD
      XP=XPP*COSD-X(3)*SIND

C     ROTATION IS ABOUT THE MAGNETIC Z-AXIS THROUGH THE HOUR ANGLE OF
C     THE SUN FROM THE PRIME MAGNETIC MERIDIAN (NEGATIVE ROTATION)
C
      X(1)=XP*CPS-YP*SPS
      X(2)=XP*SPS+YP*CPS
      X(3)=ZP
C
C     DETERMINE THE EXTERNAL MAGNETIC FIELD USING A TILT DEPENDENT
C     MAGNETIC FIELD
C
      CALL BXYZMU(X,B,TILT)
C
C     THE CARTESIAN COMPONENTS OF THE FIELD ARE IN SOLAR MAGNETIC
C     COORDINATES. THE COMPONENTS ARE NEEDED IN THE GEOGRAPHIC
C     COORDINATE SYSTEM
C
C     FIRST ROTATION IS ABOUT THE MAGNETIC Z-AXIS THROUGH THE HOUR
C     ANGLE OF THE SUN TO THE PRIME MAGNETIC MERIDIAN
C     (POSITIVE ROTATION) PUTS RESULTS INTO GEOMAGNETIC COORDINATES
C
      BMX=B(1)*CPS+B(2)*SPS
      BMY=-B(1)*SPS+B(2)*CPS
      BMZ=B(3)
C
C     SECOND ROTATION IS ABOUT THE MAGNETIC Y-AXIS THOUGH -11.7 DEGREES
C     COLATITUDE
C
      BGMX=BMX*COSD+BMZ*SIND
      BGMY=BMY
      BGMZ=-BMX*SIND+BMZ*COSD
C
C     THIRD ROTATION IS ABOUT THE NEW Z-AXIS THROUGH -291 DEGREES
C
      BX=BGMX*C69+BGMY*S69
      BY=-BGMX*S69+BGMY*C69
      BZ=BGMZ
C
C     DETERMINE THE MAIN FIELD
C
    9 CONTINUE
      AOR=1./R
      YEARI=YEAR
      CALL SPHRCM
      IF(KODE.GT.1) GO TO 10
C
C     IF THE OUTPUT IS TO BE IN CARTESIAN GEOGRAPHIC COORDINATES CONVERT
C     THE MAIN MAGNETIC FIELD AND ADD
C
      B(1)=(BX+CP*(ST*BR+CT*BT)-SP*BP)*0.00001
      B(2)=(BY+SP*(ST*BR+CT*BT)+CP*BP)*0.00001
      B(3)=(BZ+CT*BR-ST*BT)*0.00001
      GO TO 20
C
C     IF OUTPUT IS TO BE IN SPHERICAL GEOGRAPHIC CONVERT THE EXTERNAL
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C      FIELD AND ADD
C
 10    B(1)=(BR+(BX*CP+BY*SP)*ST+BZ*CT)*0.00001
       B(2)=(BT+(BX*CP+BY*SP)*CT-BZ*ST)*0.00001
       B(3)=(BP+BY*CP-BX*SP)*0.00001
C
C      DETERMINE THE MAGNITUDE OF THE FIELD VECTOR
C
 20    BMAG=SQRT(B(1)**2+B(2)**2+B(3)**2)
       RETURN
       END
       SUBROUTINE ANGLE(TILT,SINPHE,COSPHE)
C
C      PURPOSE
C         THIS ROUTINE CALCULATES THE ANGLE BETWEEN THE MAGNETIC DIPOLE
C         AXIS AND THE SUN-EARTH LINE AS WELL AS THE ROTATION SINES
C         AND COSINES TO CONVERT FROM GEOMAGNETIC TO SOLAR MAGNETIC
C         COORDINATES
C
C      METHOD
C         MAGNETIC COORDINATES HAVE THEIR ORIGIN AT THE CENTER OF THE
C         EARTH WITH THE Z AXIS ALLIGNED THROUGH THE GEOMAGNETIC NORTH
C         POLE.  IN GEOMAGNETIC COORDINATES THE X AXIS IS IN THE
C         PLANE PASSING THROUGH THE DIPOLE AXIS AND THE GEOGRAPHIC
C         AXIS (ABOUT 69 DEGREES WEST LONG.).  IN SOLAR MAGNETIC
C         COORDINATES X AXIS LIES IN THE PLANE CONTAINING THE SUN
C         EARTH LINE AND THE Z AXIS (POSITIVE X AXIS HAS A LARGE
C         COMPONENT IN THE SOLAR DIRECTION). THE Y AXIS IS ORTHOGONAL
C         TO THE X AND Z AXIS SUCH THAT X, Y AND Z FORM A RIGHT
C         HANDED SYSTEM.  THE ECCLIPTIC COORDINATE SYSTEM HAS ITS
C         Z AXIS ALONG THE ECCLIPTIC NORTH POLE (THROUGH THE CENTER
C         OF THE EARTH AND PERPENDICULAR TO THE EARTHS ORBITAL PLANE)
C         THE X AXIS POINTS TOWARD THE SUN AND Y FORMS A RIGHT HANDED
C         COORDINATE SYSTEM.  IN THIS ROUTINE IN ORDER TO REDUCE
C         COMPUTER TIME THE APPROXIMATION OF A CIRCULAR EARTH ORBIT
C         AROUND THE SUN IS MADE.
C
C      INPUT -- COMMON BLOCK BXYZCM
C         DAYYR  IS THE DAY OF YEAR (1.-366.).  IT MUST BE A WHOLE
C                NUMBER.  DAY 1 IS JANUARY 1.
C         UT     THE UNIVERSAL TIME IN HOURS (0.0000-24.00000)
C
C      OUTPUT -- PARAMETER LIST
C         TILT   THE TILT OF THE DIPOLE AXIS IN DEGREES.
C                TILT = 90. - PSI, WHERE PSI IS THE ANGLE BETWEEN
C                THE MAGNETIC DIPOLE AXIS AND THE SOLAR DIRECTION.
C         SINPHE THE SINE OF THE ROTATION ANGLE ABOUT THE MAGNETIC
C                Z AXIS TO CONVERT FROM GEOMAGNETIC TO SOLAR MAGNETIC
C                COORDINATES
C         COSPHE THE COSINE OF THE ROTATION ANGLE ABOUT THE MAGNETIC
C                Z AXIS TO CONVERT FROM GEOMAGNETIC TO SOLAR MAGNETIC
C                COORDINATES
C
C      CONSTANTS
C         PI2    PI / 2.
C         CON    180. / PI CONVERTS RADIANS TO DEGREES
C         SALF   SINE (11.7)  INCLINATION OF MAGNETIC Z TO GEOGRAPHIC Z
C         CALF   COSINE (11.7)
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C        SGAM   SIN (23.5) INCLINATION OF ROTATION AXIS TO ECLIPTIC Z
C        CGAM   COSINE (23.5)

C        CASG   CALF * SGAM
C        CACG   CALF * CGAM
C        W      EARTHS ANGULAR ROTATION FREQUENCY CORRECTED FOR ITS
C               ONCE A YEAR ROTATION ABOUT THE SUN (UNITS ARE 1/HOURS)
C
C     CALLING SUBROUTINES
C        SUBROUTINE BMNEXT
C
C     VARIABLES
C        WT      INSTANTANEOUS ROTATION ANGLE AT THE SPECIFIED UNIVERSAL
C                TIME AND DAY OF YEAR
C        CWT    WT/365.256
C        XX,XY,XZ COMPONENTS OF THE GEOMAGNEITIC X AXIS IN ECCLIPTIC
C                COORDINATES
C        ZX,ZY,ZZ COMPONENTS OF THE DIPOLE AXIS IN ECCLIPTIC COORDINATES
C        OSP,SSMLT,CSMLT,SBWT,CBWT,SMLSWT,SMLCWT,CMLSWT,CMLCWT ARE
C                SINES AND COSINES AND THEIR PRODUCTS AND ARE SET UP
C                TO MINIMIZE COMPUTER TIME
C
      COMMON/BXYZCM/YEAR,DAYYR,UT,KODE,JSW
      DATA  IFIRST/0/
C
C     THE FIRST TIME TROUGH THE SUBROUTINE SET UP THE FIXED CONSTANTS
      IF(IFIRST.NE.0) GO TO 10
      IFIRST=1
      PI2=ATAN2(0.,-1.)/2.
      CON=90./PI2
      SALF=SIN(11.7/CON)
      CALF=COS(11.7/CON)
      SGAM=SIN(23.5/CON)
      CGAM=COS(23.5/CON)
      SASG=SALF*SGAM
      SACG=SALF*CGAM
      CASG=CALF*SGAM
      CACG=CALF*CGAM
      W=PI2/6.*(1.+1./365.256)
C
C     MAIN ENTRY POINT.  SET UP THE THE SINES AND COSINES REQUIRED
C     BY THE TRANSFORMATIONS.
   10 WT=(UT-16.6+(DAYYR-172.)*24.)*W
      CWT=-WT/365.256
      SSMLT=SIN(WT)
      CSMLT=COS(WT)
      SBWT=SIN(CWT)
      CBWT=COS(CWT)
      SMLSWT=SSMLT*SBWT
      SMLCWT=SSMLT*CBWT
      CMLSWT=CSMLT*SBWT
      CMLCWT=CSMLT*CBWT
C
C     DETERMINE THE COMPONENTS OF THE DIPOLE AXIS IN ECCLIPTIC
C     COORDINATES
      ZX=CASG*CBWT+SACG*CMLCWT-SALF*SMLSWT
      ZY=CASG*SBWT+SACG*CMLSWT+SALF*SMLCWT
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      ZZ=CACG-SASG*CSMLT
C

      CSP=1./(SIN(PSI))
      TILT=CCN*(PI2-PSI)
C
C     DETEMINE THE COMPONENTS OF THE GEOMAGNETIC X AXIS IN ECCLIPTIC
C     COORDINATES
      XX=CACG*CMLCWT-SASG*CBWT-CALF*SMLSWT
      XY=CACG*CMLSWT-SASG*SBWT+CALF*SMLCWT
      XZ=-CASG*CSMLT-SACG
C
C     OBTAIN THE ROTATION SINES AND COSINES
      SINPHE=(XY*ZZ-XZ*ZY)*CSP
      COSPHE=(XX*(ZZ*ZZ+ZY*ZY)-ZX*(XY*ZY+XZ*ZZ))*CSP
      RETURN
      END
      SUBROUTINE BXYZMU(XX,BF,TILT)
C
C  VERSION 11/01/76
C
C     PURPOSE
C       TO CALCULATE THE CONTRIBUTION TO THE EARTHS MAGNETIC FIELD BY
C       SOURCES EXTERNAL TO THE EARTH.  NO INTERNAL FIELD IS INCLUDED
C       IN THIS ROUTINE.
C
C     METHOD
C        THE ROUTINE INCLUDES THE FIELD CONTRIBUTIONS FROM THE
C        MAGNETOPAUSE CURRENTS, AND CURRENTS DISTRIBUTED THROUGHOUT
C        THE MAGNETOSPHERE (THE TAIL AND RING CURRENTS).  IT IS VALID
C        FOR ALL TILTS OF THE EARTHS DIPOLE AXIS AND IS VALID DURING
C        QUIET MAGNETIC CONDITIONS.
C        A GENERALIZED ORTHONORMAL LEAST SQUARES PROGRAM WAS USED
C        TO FIT THE COEFFICIENTS OF A POWER SERIES (INCLUDING
C        EXPONENTIAL TERMS) THROUGH FOURTH ORDER IN SPACE AND
C        THIRD ORDER IN TILT.  THIS EXPANSION HAS BEEN OPTIMIZED
C        FOR THE NEAR EARTH REGION AND IS VALID TO 15 EARTH RADII.
C        OUTSIDE OF THIS REGION THE FIELD DIVERGES RAPIDLY AND A
C        TEMPLATE SETS THE FIELD TO ZERO.  IN ORDER TO IMPROVE
C        COMPUTATIONAL SPEED THE FIELD IS SET TO ZERO BELOW 2 EARTH
C        RADII.  (IN THIS REGION THE EARTHS INTERNAL FIELD DOMINATES
C        AND THE VARIATIONS EXCPRESSED BY THIS EXPANSION IS NOT
C        SUFFICIENTLY ACCURATE THE PREDICT VARIATIONS ON THE EARTHS
C        SURFACE)
C
C        THE POWER SERIES REPRESENTING THE MAGNETIC FIELD IS
C        BX=SUM OVER I,J,K OF ( A(I,J,K)*X**(I-1)*Y**(2*J-2)*Z**(K-1)
C                + B(I,J,K)*X**(I-1)*Y**(2*J-2)*Z**(K-1)*EXP(-.06*R**2))
C            I GOES FROM 1 TO 5,J FROM 1 TO 3, K FROM 1 TO 5
C            THE SUM OF I + 2*J + K IS LESS THAN OR EQUAL TO 9
C        BY=SUM OVER I,J,K OF ( C(I,J,K)*X**(I-1)*Y**(2*J-1)*Z**(K-1)
C                + D(I,J,K)*X**(I-1)*Y**(2*J-1)*Z**(K-1)*EXP(-.06*R**2))
C            I GOES FROM 1 TO 5, J FROM 1 TO 3, K FROM 1 TO 5
C            THE SUM OF I + 2*J+1 + K IS LESS THAN OR EQUAL TO 9
C        BZ=SUM OVER I,J,K OF ( E(I,J,K)*X**(I-1)*Y**(2*J-2)*Z**(K-1)
C                + F(I,J,K)*X**(I-1)*Y**(2*J-2)*Z**(K-1)*EXP(-.06*R**2))
C            I GOES FROM 1 TO 5, J FROM 1 TO 3, K FROM 1 TO 5
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C             THE SUM OF I + 2*J + K IS LESS THAN OR EQUAL TO 9
C         THE COEFFICIENTS A-F ARE DEPENDENT ONLY ON POSITION AND
C         CONSTANTS AA-FF BY THE FOLLOWING EXPRESSIONS
C         A(I,J,K)=AA(I,J,K,1)*TILT**(K-1-(K-1)/2*2)
C                  +AA(I,J,K,2)*TILT**(K+1-(K-1)/2*2)
C         B(I,J,K)=BB......
C         C(I,J,K)=CC......
C         D(I,J,K)=DD......
C         E(I,J,K)=EE(I,J,K,1)*TILT**(K-(K)/2*2)
C                  +EE(I,J,K,2)*TILT**(K+2-(K)/2*2)
C         F(I,J,K)=FF......
C
C      INPUT -- CALLING SEQUENCE
C         XX      A REAL ARRAY GIVING THE POSITION WHERE THE MAGNETIC
C                 FIELD IS TO BE EVALUATED.  XX(1), XX(2), XX(3) ARE
C                 RESPECTIVELY THE X, Y, AND Z SOLAR MAGNETIC
C                 COORDINATES IN EARTH RADII. Z IS ALONG THE EARTHS
C                 NORTH DIPOLE AXIS, X IS PERPENDICULAR TO Z AND IN THE
C                 PLANE CONTAINING THE Z AXIS AND THE SUN-EARTH LINE,
C                 Y IS PERPENDICULAR TO X AND Z FORMING A RIGHT HANDED
C                 COORDINATE SYSTEM. X IS POSITIVE IN THE SOLAR DIRECTION.
C         TILT    IS THE TILT OF THE DIPOLE AXIS IN DEGREES.  IT IS
C                 THE COMPLEMENT OF THE ANGLE BETWEEEN THE NORTH DIPOLE
C                 AXIS AND THE SOLAR DIRECTION (PSI). TILT=90-PSI.
C
C      OUTPUT -- CALLING SEQUENCE
C         BF      A REAL ARRAY CONTAING THE X, Y, AND Z COMPONENTS OF
C                 THE MAGNETOSPHERIC MAGNETIC FIELD IN GAMMA. BF(1),
C                 BF(2) AND BF(3) ARE THE BX, BY, BZ COMPONENTS.
C
C      CONSTANTS
C         AA,BB,CC,DD,EE,FF ARE REAL ARRAYS CONTAING THE TILT DEPENDED
C                 COEFFICIENTS.
C                 AA(I,J,K,L) ARE STORED SUCH THAT L VARIES MOST RAPIDLY
C                 FOLLOWED IN ORDER BY K, J AND I.  I VARIES THE SLOWEST.
C                 THE ARRAY IS CLOSE PACKED AND ALL COEFFICIENTS THAT
C                 ARE ZERO BECAUSE OF SYMMETRY OR BECAUSE THE CROSS TERM
C                 POWER IS TOO LARGE ARE DELETED.
C
C      VARIABLES
C         A,B,C,D,E,F  THE TILT INDEPENDENT COEFFICIENTS.  THEIR USE
C                 IS DESCRIBED UNDER METHOD.
C         ITA     A REAL ARRAY WHICH CONTAINS THE SYMMETRY OF THE TILT
C                 DEPENDENCE FOR EACH OF THE A AND B COEFFICIENTS
C                 ITA(1) HAS THE SYMMETRY INFORMATION FOR A(1,1,1,1)
C                         AND A(1,1,1,2)
C                 ITA(2) HAS THE SYMMETRY INFORMATION FOR A(1,1,2,1)
C                         AND A(1,1,2,2)  ETC.
C                 IF ITA = 1 TILT SYMMETRY IS EVEN WITH RESPECT TO Z SYM.
C                 IF ITA = 2 TILT SYMMETRY IS ODD WITH RESPECT TO Z SYM.
C         ITB     SYMMETRY POINTER FOR C AND D ARRAYS
C         ITC     SYMMETRY POINTER FOR E AND F ARRAYS
C         X       X COMPONENT OF POSITION
C         Y       Y COMPONENT OF POSITION
C         Z       Z COMPONENT OF POSITION
C         Y2      Y**2
```

```
C          Z2      Z**2
C          R2      X**2 + Y**2 + Z**2


C                  REPRESENTS THE POWER TO WHICH X IS CURRENTLY RAISED
C                  I.E. X**(I-1)
C          J       DO LOOP VARIABLE.  ALSO Y**(2*J-2)
C          K       DO LOOP VARIABLE.  ALSO Z**(K-1)
C          XB      X**(I-1)
C          YEXB    X**(I-1)*Y**(2*J-2)
C          ZEYEXB  X**(I-1)*Y**(2*J-2)*Z**(K-1)
C          IJK     I + 2*J + K
C          II      POINTS TO THE ARRAY LOCATION WHERE THE CURRENT POWER
C                  SERIES COEFFICIENT FOR BX IS LOCATED
C          JJ      BY COEFFICIENT LOCATION POINTER
C          KK      BZ COEFFICIENT LOCATION POINTER
C          BX,BY,BZ ARE USED TO CONSTRUCT THE MAGNETIC FIELD WITHIN THE
C                  POWER SERIES LOOP.
C          EXPR    EXP(-.06*R2)
C          TILTL   HOLDS THE LAST VALUE OF THE TILT FOR WHICH THE TILT
C                  INDEPENDENT COEFFICIENTS A-F WERE CALCULATED
C          TT      A REAL ARRAY HOLDING THE POWERS OF THE TILT.
C                  TT(1)=TILT**0, TT(2)=TILT**1, ETC.
C          CON     =0 FOR R LESS THAN 2
C                  =1 FOR R GREATER THAN 2.5
C                  GOES FROM 0 TO 1 IN THE REGION 2 TO 2.5
C
C     FOR MORE INFORMATION CALL OR WRITE K. A. PFITZER OR W. P. OLSON
C     AT MCDONNEL DOUGLAS ASTRONAUTICS CO. 5301 BOLSA AVE, HUNTINGTON
C     CALIF., PHONE (714) 896-3231.
C
      DIMENSION BF(3),XX(3),AA(64),BB(64),CC(44),DD(44),EE(64),FF(64),
     *A(32),B(32),C(22),D(22),E(32),F(32),TT(4),ITA(32),ITB(22),ITC(32)
      DATA (ITA(I),I=1,32) /2,1,2,1,2,2,1,2,1,2,1,2,1,2,1,2,2,1,2,2,2,1,
     *2,1,2,1,2,1,2,2,2,1/
      DATA (ITB(I),I=1,22) /2,1,2,1,2,2,1,2,2,2,1,2,1,2,1,2,1,2,2,2,1,2/
      DATA (ITC(I),I=1,32) /1,2,1,2,1,1,2,1,2,1,2,1,2,1,2,1,1,2,1,1,1,2,
     *1,2,1,2,1,2,1,1,1,2/
      DATA (AA(I),I=1,64)/-2.26836E-02,-1.01863E-04, 3.42986E+00,        TOTAL
     *-3.12195E-04, 9.50629E-03,-2.91512E-06,-1.57317E-03, 8.62856E-08, TOTAL
     *-4.26478E-05, 1.62924E-08,-1.27549E-04, 1.90732E-06,-1.65983E-02, TOTAL
     * 8.46680E-09,-5.55850E-05, 1.37404E-08, 9.91815E-05, 1.59296E-08, TOTAL
     * 4.52864E-07,-7.17669E-09, 4.98627E-05, 3.33662E-10,-5.97620E-02, TOTAL
     * 1.60669E-05,-2.29457E-01,-1.43777E-04, 1.09403E-03,-9.15606E-07, TOTAL
     * 1.60658E-03,-4.01198E-07,-3.15064E-06, 2.03125E-09, 4.92887E-04, TOTAL
     *-1.80676E-07,-1.12022E-03, 5.98568E-07,-5.90009E-06, 5.16504E-09, TOTAL
     *-1.48737E-06, 4.83477E-10,-7.44379E-04, 3.82472E-06, 7.41737E-04, TOTAL
     *-1.31468E-05,-1.24729E-04, 1.92930E-08,-1.91764E-04,-5.30371E-08, TOTAL
     * 1.38186E-05,-2.81594E-08, 7.46386E-06, 2.64404E-08, 2.45049E-04, TOTAL
     *-1.81802E-07,-1.00278E-03, 1.98742E-06,-1.16425E-05, 1.17556E-08, TOTAL
     *-2.46079E-06,-3.45831E-10, 1.02440E-05,-1.90716E-08,-4.00855E-05, TOTAL
     * 1.25818E-07/
      DATA (BB(I),I=1,64)/ 9.47753E-02, 1.45981E-04,-1.82933E+00,        TOTAL
     * 5.54882E-04, 5.03665E-03,-2.07698E-06, 1.10959E-01,-3.45837E-05, TOTAL
     *-4.40075E-05, 5.06464E-07,-1.20112E-03, 3.64911E-06, 1.49849E-01, TOTAL
     *-7.44929E-05, 2.46382E-04, 9.65870E-07,-9.54881E-04, 2.43647E-07, TOTAL
     * 3.06520E-04, 3.07836E-07, 6.48301E-03, 1.26251E-06,-7.09548E-03, TOTAL
     *-1.55596E-05, 3.06465E+00,-7.84893E-05, 4.95145E-03, 3.71921E-06, TOTAL
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      *-1.52002E-01, 6.81988E-06,-8.55686E-05,-9.01230E-08,-3.71458E-04, TOTAL
      * 1.30476E-07,-1.82971E-01, 1.51390E-05,-1.45912E-04,-2.22778E-07, TOTAL
      * 3.17837E-04, 1.78959E-07,-8.93794E-03, 6.37549E-06, 1.27887E-03, TOTAL
      *-2.45878E-07,-1.93210E-01, 6.91233E-06,-2.80637E-04,-2.57073E-07, TOTAL
      * 5.78343E-05, 4.52128E-10, 1.89621E-04,-4.84911E-08,-1.50058E-02, TOTAL
      * 6.21772E-06/
       DATA (CC(I),I=1,44)/-1.88177E-02,-1.92493E-06,-2.89064E-01,        TOTAL
      *-8.49439E-05,-4.76380E-04,-4.52998E-08, 1.61086E-03, 3.18728E-07, TOTAL
      * 1.29159E-06, 5.52259E-10, 3.95543E-05, 5.61209E-09, 1.38287E-03, TOTAL
      * 5.74237E-07, 1.86489E-06, 7.10175E-10, 1.45243E-07,-2.97591E-10, TOTAL
      *-2.43029E-03,-6.70000E-07,-2.30624E-02,-6.22193E-06,-2.40815E-05, TOTAL
      * 2.01689E-08, 1.76721E-04, 3.78689E-08, 9.88496E-06, 7.33820E-09, TOTAL
      * 7.32126E-05, 8.43986E-08, 8.82449E-06,-6.11708E-08, 1.78881E-04, TOTAL
      * 8.62589E-07, 3.43724E-06, 2.53783E-09,-2.04239E-07, 8.16641E-10, TOTAL
      * 1.68075E-05, 7.62815E-09, 2.26026E-04, 3.66341E-08, 3.44637E-07, TOTAL
      * 2.25531E-10/
       DATA (DD(I),I=1,44)/ 2.50143E-03, 1.01200E-06, 3.23821E+00,        TOTAL
      * 1.08589E-05,-3.39199E-05,-5.27052E-07,-9.46161E-02,-1.95413E-09, TOTAL
      *-4.23614E-06, 1.43153E-08,-2.62948E-04, 1.05138E-07,-2.15784E-01, TOTAL
      *-2.20717E-07,-2.65687E-05, 1.26370E-08, 5.88917E-07,-1.13658E-08, TOTAL
      * 1.64385E-03, 1.44263E-06,-1.66045E-01,-1.46096E-05, 1.22811E-04, TOTAL
      * 3.43922E-08, 9.66760E-05,-6.32150E-07,-4.97400E-05,-2.78578E-08, TOTAL
      * 1.77366E-02, 2.05401E-07,-1.91756E-03,-9.49392E-07,-1.99488E-01, TOTAL
      *-2.07170E-06,-5.40443E-05, 1.59289E-08, 7.30914E-05, 3.38786E-08, TOTAL
      *-1.59537E-04,-1.65504E-07, 1.90940E-02, 2.03238E-06, 1.01148E-04, TOTAL
      * 5.20815E-08/
       DATA (EE(I),I=1,64)/-2.77924E+01,-1.01457E-03, 9.21436E-02,        TOTAL
      *-8.52177E-06, 5.19106E-01, 8.28881E-05,-5.59651E-04, 1.16736E-07, TOTAL
      *-2.11206E-03,-5.35469E-07, 4.41990E-01,-1.33679E-05,-7.18642E-04, TOTAL
      * 6.17358E-08,-3.51990E-03,-5.29070E-07, 1.88443E-06,-6.60696E-10, TOTAL
      *-1.34708E-03, 1.02160E-07, 1.58219E-06, 2.05040E-10, 1.18039E+00, TOTAL
      * 1.58903E-04, 1.86944E-02,-4.46477E-06, 5.49869E-02, 4.94690E-06, TOTAL
      *-1.18335E-04, 6.95684E-09,-2.73839E-04,-9.17883E-08, 2.79126E-02, TOTAL
      *-1.02567E-05,-1.25427E-04, 3.07143E-08,-5.31826E-04,-2.98476E-08, TOTAL
      *-4.89899E-05, 4.91480E-08, 3.85563E-01, 4.16966E-05, 6.74744E-04, TOTAL
      *-2.08736E-07,-3.42654E-03,-3.13957E-06,-6.31361E-06,-2.92981E-09, TOTAL
      *-2.63883E-03,-1.32235E-07,-6.19406E-06, 3.54334E-09, 6.65986E-03, TOTAL
      *-5.81949E-06,-1.88809E-04, 3.62055E-08,-4.64380E-04,-2.21159E-07, TOTAL
      *-1.77496E-04, 4.95560E-08,-3.18867E-04,-3.17697E-07,-1.05815E-05, TOTAL
      * 2.22220E-09/
       DATA (FF(I),I=1,64)/-5.07092E+00, 4.71960E-03,-3.79551E-03,        TOTAL
      *-3.67309E-06,-6.02439E-01, 1.08490E-04, 5.09287E-04, 5.62210E-07, TOTAL
      * 7.05718E-02, 5.13160E-06,-2.85571E+00,-4.31728E-05, 1.03185E-03, TOTAL
      * 1.05332E-07, 1.04106E-02, 1.60749E-05, 4.18031E-05, 3.32759E-08, TOTAL
      * 1.20113E-01, 1.40486E-05,-3.37993E-05, 5.48340E-09, 9.10815E-02, TOTAL
      *-4.00608E-04, 3.75393E-03,-4.69939E-07,-2.48561E-02, 1.31836E-04, TOTAL
      *-2.67755E-04,-7.60285E-08, 3.04443E-03,-3.28956E-06, 5.82367E-01, TOTAL
      * 5.39496E-06,-6.15261E-04, 4.05316E-08, 1.13546E-02,-4.26493E-06, TOTAL
      *-2.72007E-02, 5.72523E-08,-2.98576E+00, 3.07325E-05, 1.51645E-03, TOTAL
      * 1.25098E-06, 4.07213E-02, 1.05964E-05, 1.04232E-04, 1.77381E-08, TOTAL
      * 1.92781E-01, 2.15734E-05,-1.65741E-05,-1.88683E-09, 2.44803E-01, TOTAL
      * 1.51316E-05,-3.01157E-04, 8.47006E-08, 1.86971E-02,-6.94074E-06, TOTAL
      * 9.13198E-03,-2.38052E-07, 1.28552E-01, 6.92595E-06,-8.36792E-05, TOTAL
      *-6.10021E-08/
       DATA TILTL/99./
 C
```

```
C      SET UP SOME OF THE INITIAL POSITION VARIABLES
       X=XX(1)
       Y2=Y**2
       Z2=Z**2
       R2=X**2+Y2+Z2
C
C      SET MAGNETIC FIELD VARIABLES TO ZERO
       BX=0.
       BY=0.
       BZ=0.
C
C      CHECK TO SEE IF POSITION IS WITHIN REGION OF VALIDITY
       CON=1.
C      IF DISTANCE TOO LARGE TAKE ERROR EXIT
       IF(R2.GT.225.) GO TO 50
C      IF DISTANCE TOO SMALL SET FIELD TO ZERO AND EXIT
       IF(R2.LT.4.)GO TO 40
       IF(R2.LT.6.25) CON=CON*(R2-4.0)/2.25
C
C      IF TILT HAS NOT CHANGED, GO DRECTLY TO FIELD CALCULATION
       IF(TILTL.EQ.TILT)GO TO 6
C      SET UP POWERS OF TILT
       TILTL=TILT
       TT(1)=1
       TT(2)=TILTL
       TT(3)=TILTL**2
       TT(4)=TILT*TT(3)
C
C      SET UP THE X AND Z COMPONENT TILT INDEPENDENT COEFFICIENTS
       DO  1 I=1,32
       J=(I-1)*2+1
       K=ITA(I)
       A(I)=AA(J)*TT(K)+AA(J+1)*TT(K+2)
       B(I)=BB(J)*TT(K)+BB(J+1)*TT(K+2)
       K=ITC(I)
       E(I)=EE(J)*TT(K)+EE(J+1)*TT(K+2)
       F(I)=FF(J)*TT(K)+FF(J+1)*TT(K+2)
  1    CONTINUE
C
C      SET UP THE Y COMPONENT TILT INDEPENDENT COEFFICIENTS
       DO  2 I=1,22
       J=(I-1)*2+1
       K=ITB(I)
       C(I)=CC(J)*TT(K)+CC(J+1)*TT(K+2)
       D(I)=DD(J)*TT(K)+DD(J+1)*TT(K+2)
  2    CONTINUE
  6    EXPR=EXP(-0.06*R2)
C
C      INITIALIZE THE POINTERS
       II=1
       JJ=1
       KK=1
       XB=1.
C
C      BEGIN SUM OVER X
       DO 30 I=1,5
```

```
            YEXB=XB
      C
            IF(I+2*J.GT. 8) GO TO 25
            ZEYEXB=YEXB
            IJK=I+2*J+1
            K=1
      C
      C     Z LOOP STARTS HERE
   10       BZ=BZ+(E(KK)+F(KK)*EXPR)*ZEYEXB
            KK=KK+1
            BX=BX+(A(II)+B(II)*EXPR )*ZEYEXB
            II=II+1
            IF(IJK .GT. 8) GO TO 15
            BY=BY+(C(JJ)+D(JJ)*EXPR )*ZEYEXB*Y
            JJ=JJ+1
            ZEYEXB=ZEYEXB*Z
            IJK=IJK+1
            K=K+1
            IF(IJK.LE.9.AND.K.LE.5) GO TO 10
   15       YEXB=YEXB*Y2
   20       CONTINUE
   25       XB=XB*X
   30       CONTINUE
      C
      C     SET UP THE OUTPUT ARRAY, MULTIPLY BY CON. CON IS NORMALY ONE
      C     BUT INSIDE OF R=2.5 IT GOES TO ZERO. INSIDE R=2 IT IS ZERO.
   40       BF(1)=BX*CON
            BF(2)=BY*CON
            BF(3)=BZ*CON
            RETURN
      C
      C     ERROR EXIT IF OUTSIDE OF R = 15.
   50       WRITE(6,60) XX
   60       FORMAT(4H X= ,E10.3,4H Y= ,E10.3,4H Z= ,E10.3,76H  IS OUTSIDE THE
           *VALID REGION--POWER SERIES DIVERGES BFIELD IS SET TO ZERO  )
            GO TO 40
            END
            SUBROUTINE SPHRCM
      C
      C     MODIFIED BY K.A. PFITZER
      C     SPHRCM IS A MODIFIED VERSION OF J.C. CAIN:S 14 TERM FAST SPHRC
      C     ROUTINE.
      C     IT HAS BEEN SHORTENED TO 10 TERMS.
      C     IT HAS A TRUNCATION FOR LARGE R - THE TRUNCATION BETWEEN TERMS
      C     IS SMOOTH.
      C     IT IS SELF CONTAINED AND SET UP TO USE GAUSS NORMALIZED
      C     COEFFICIENTS.
      C
      C     THE IGS75 GAUSS NORMALIZED COEFFICIENTS THRU N=10 ARE INCLUDED
      C     WITH THIS DECK  (BARRACLOUGH,ET AL GEOPHYSICAL JOURNAL OF THE
      C     ROYAL ASTRONOMICAL SOCIETY, 43, 645, (1975))
      C     THEY ARE VALID FROM 1945. TO 1975. THEY MAY BE USED FOR LATER
      C     PERIODS WITH CAUTION (I.E. THEY HAVE NOT BEEN VERIFIED)
      C
      C     INPUT -- COMMON BLOCK GCOM
      C        YEARI   IS THE YEAR, IF YEARI CHANGES THE COEFFICIENTS ARE
```

```
C                 UPDATED.
C         ST      SINE OF THE GEOGRAPHIC CO-LATITUDE.

C         CPH     COSINE OF THE GEOGRAPHIC LONGITUDE.
C         AOR     6371.2/R, WHERE R IS THE GEOCENTRIC DISTANCE IN KM FROM
C                 THE CENTER OF THE EARTH.
C         NMAX    MAXIMUM NUMBER OF TERMS TO BE USED  (MUST BE LESS OR
C                 EQUAL TO 10). THIS ROUTINE PRESETS IT TO 10
C      OUTPUT -- COMMON BLOCK GCOM
C         BR      RADIAL COMPONENT OF FIELD IN GAUSS.
C         BT      THETA COMPONENT (SOUTH POINTING) COMPONENT.
C         BP      PHI COMPONENT (EAST)
C
       DIMENSION G(10,10),CONST(10,10),FM(10),FN(10)
       DIMENSION GO(10,10),GT(10,10),GTT(10,10)
       COMMON /GCOM/ ST,CT,SPH,CPH,AOR,BT,BP,BR,NMAX,YEARI
       DIMENSION CONA(10)
       DATA YRLAST,TF,TL,TZERO,NMAX/-12345.,1945.,1975.,1975.,10/
       DATA IFIRST/0/
       DATA CONA/0.,12.0,6.5,4.5,3.5,2.9,2.6,2.3,2.1,2.0/
C
C      COEFFICIENTS FOR BASE YEAR (1975.)
       DATA GO /0.,30103.6,2860.05,-3195.5,-4142.69,1737.23,-636.69,-1917
      *.09,-553.01,-883.14,-5682.6,2016.5,-5213.3,6558.51,-4385.68,-3572.
      *54,-1321.33,1890.53,-341.86,-1274.03,3576.17,50.32,-1414.22,-2425.
      *72,-1736.64,-2015.83,-413.96,-66.61,145.81,-173.84,1009.8,-514.91,
      *179.46,-656.96,844.82,300.26,1935.78,-274.41,521.89,946.,-1070.27,
      *1040.11,-110.86,210.91,-157.15,349.42,4.91,79.03,368.96,-597.58,-2
      *49.08,-1140.49,759.11,185.03,-64.75,28.2,-8.84,-19.76,1.48,-20.21,
      *211.71,-1500.4,-773.11,219.91,18.38,-10.48,73.01,-41.17,16.+8,3.48
      *,2716.97,715.33,92.15,-86.44,-151.27,52.8,8.35,3.82,-30.83,-4.52,-
      *328.45,779.54,-207.1,481.25,-84.53,-99.55,27.83,10.47,-3.07,-1.25,
      *2497.11,-1705.81,-406.52,174.76,141.5,-168.76,-91.91,.52,-.18,-.3/
C      FIRST TIME DERIVATIVES OF THE COEFFICIENTS
       DATA GT /0.,-26.82,37.56,9.43,3.85,-1.58,-9.38,10.19,-22.12,0.,10.
      *1,-10.,-.45,32.03,12.23,10.37,-17.58,6.74,-21.45,0.,4.88,16.37,-4.
      *75,5.12,15.73,-9.91,-34.82,14.77,2.24,0.,-22.01,-5.48,5.06,3.72,4.
      *43,9.84,-35.27,-5.32,-17.4,0.,-29.77,-2.66,-5.35,.5,3.39,1.35,-.05
      *,-10.37,6.15,0.,-9.35,-20.37,12.52,-2.97,-.79,-.91,-1.88,-3.46,5.4
      *9,0.,6.24,3.25,-2.29,8.51,-.91,-1.34,.27,-1.16,-4.26,0.,43.27,5.79
      *,-1.02,-3.83,3.89,.1,-.78,.49,.68,0.,12.07,19.07,12.01,8.56,-7.27,
      *3.43,1.4,-.31,.01,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0./
C      SECOND TIME DERIVATIVES OF THE COEFFICIENTS
       DATA GTT/0.,-.35,.15,.35,0.,.51,-.51,0.,0.,0.,.25,0.,0.,0.,.47,.71
      *,-.38,0.,0.,0.,-.59,0.,-.07,.31,0.,.54,-.9,0.,0.,0.,-.2,0.,0.,0.,.
      *15,.24,-.55,0.,0.,0.,-.83,0.,0.,-.06,.06,0.,0.,0.,0.,0.,.71,-.38,0
      *.,0.,-.04,0.,-.1,0.,0.,0.,0.,0.,.5,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0
      *.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0
      *.,0.,0.,0.,0./
C      SET UP INITIAL CONSTANTS DURING FIRST CALL
       IF(IFIRST.NE.0) GO TO 199
       IFIRST=1
       FM(1)=0
       DO 6 N=2,10
       FM(N)=N-1
       FN(N)=N
       DO 6 M=1,N
```

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  6     CONST(N,M)=FLOAT((N-2)**2-(M-1)**2)/FLOAT((2*N-3)*(2*N-5))
C       SET UP THE COEFFICIENTS
        IF(YEARI.GE.TF.AND.YEARI.LE.TL) GO TO 210
        WRITE(6,200) YEARI
  200   FORMAT(10H0**WARNING,F7.1,34H IS OUTSIDE MAIN FIELD TIME LIMITS)
  210   T=YEARI-TZERO
        DO 220 N=1,NMAX
        DO 220 M=1,NMAX
  220   G(N,M)=GO(N,M)+T*(GT(N,M)+T*GTT(N,M))
        YRLAST=YEARI
C
  230   AR=ACR*ACR*ACR
        AR=AOR*AOR*AOR                                                  1-00006
        C2=G(2,2)*CPH+G(1,2)*SPH                                        1-00007
        BR=-(AR+AR)*(G(2,1)*CT+C2*ST)                                   1-00008
        BT=AR*(C2*CT-G(2,1)*ST)                                         1-00009
        BP=AR*(G(1,2)*CPH-G(2,2)*SPH)                                   1-00010
        IF (NMAX.LE.2) RETURN                                           1-00011
        R=1./ACR
        IF(R.GT.CONA(2)) RETURN
        CON=0.
        SP2=SPH                                                         1-00012
        CP2=CPH                                                         1-00013
        P21=CT                                                          1-00014
        P22=ST                                                          1-00015
        DP21=-ST                                                        1-00016
        DP22=CT                                                         1-00017
        N=3
        SP3=(SP2+SP2)*CP2                                               1-00019
        CP3=(CP2+SP2)*(CP2-SP2)                                         1-00020
        P31=CT*P21-CONST(3,1)                                           1-00021
        P32=CT*P22                                                      1-00022
        P33=ST*P22                                                      1-00023
        DP31=-P32-P32                                                   1-00024
        DP32=CT*DP22-P33                                                1-00025
        DP33=-DP31                                                      1-00026
        C2=G(3,2)*CP2+G(1,3)*SP2                                        1-00027
        C3=G(3,3)*CP3+G(2,3)*SP3                                        1-00028
        AR=ACR*AR                                                       1-00029
        XR=BR-FN(3)*AR*(G(3,1)*P31+C2*P32+C3*P33)                       1-00030
        XT=BT+AR*(G(3,1)*DP31+C2*DP32+C3*DP33)                          1-00031
        XP=BP-AR*(FM(2)*(G(3,2)*SP2-G(1,3)*CP2)*P21+FM(3)*(G(3,3)*SP3-G(2,1-00032
       +3)*CP3)*P22)                                                    1-00033
        BP=BP*ST                                                        1-00035
        XP=XP*ST                                                        1-00035
        IF(NMAX.LE.3) GO TO 21
        IF(R.GT.CONA(3)) GO TO 20
        N=4
        SP4=SPH*CP3+CPH*SP3                                             1-00037
        CP4=CPH*CP3-SPH*SP3                                             1-00038
        P41=CT*P31-CONST(4,1)*P21                                       1-00039
        DP41=CT*DP31-ST*P31-CONST(4,1)*DP21                             1-00040
        P42=CT*P32-CONST(4,2)*P22                                       1-00041
        DP42=CT*DP32-ST*P32-CONST(4,2)*DP22                             1-00042
        P43=CT*P33                                                      1-00043
        DP43=CT*DP33-ST*P33                                             1-00044
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```
      P44=ST*P33                                                        1-00045
      DP44=FM(4)*P43                                                    1-00046
      C4=G(4,4)*CP4+G(3,4)*SP4                                          1-00049
      AR=AOR*AR                                                         1-00050
      BR=XR-FN(4)*AR*(G(4,1)*P41+C2*P42+C3*P43+C4*P44)                  1-00051
      BT=XT+AR*(G(4,1)*DP41+C2*DP42+C3*DP43+C4*DP44)                    1-00052
      BP=XP-AR*(FM(2)*(G(4,2)*SP2-G(1,4)*CP2)*P42+FM(3)*(G(4,3)*SP3-G(2,1-00053
     +4)*CP3)*P43+FM(4)*(G(4,4)*SP4-G(3,4)*CP4)*P44)                    1-00054
      IF(NMAX.LE.4) GO TO 11
      IF(R.GT.CONA(4)) GO TO 10
      N=5
      SP5=(SP3+SP3)*CP3                                                 1-00057
      CP5=(CP3+SP3)*(CP3-SP3)                                           1-00058
      P51=CT*P41-CONST(5,1)*P31                                         1-00059
      DP51=CT*DP41-ST*P41-CONST(5,1)*DP31                               1-00060
      P52=CT*P42-CONST(5,2)*P32                                         1-00061
      DP52=CT*DP42-ST*P42-CONST(5,2)*DP32                               1-00062
      P53=CT*P43-CONST(5,3)*P33                                         1-00063
      DP53=CT*DP43-ST*P43-CONST(5,3)*DP33                               1-00064
      P54=CT*P44                                                        1-00065
      DP54=CT*DP44-ST*P44                                               1-00066
      P55=ST*P44                                                        1-00067
      DP55=FM(5)*P54                                                    1-00068
      C2=G(5,2)*CP2+G(1,5)*SP2                                          1-00069
      C3=G(5,3)*CP3+G(2,5)*SP3                                          1-00070
      C4=G(5,4)*CP4+G(3,5)*SP4                                          1-00071
      C5=G(5,5)*CP5+G(4,5)*SP5                                          1-00072
      AR=AOR*AR                                                         1-00073
      XR=BR-FN(5)*AR*(G(5,1)*P51+C2*P52+C3*P53+C4*P54+C5*P55)           1-00074
      XT=BT+AR*(G(5,1)*DP51+C2*DP52+C3*DP53+C4*DP54+C5*DP55)            1-00075
      XP=BP-AR*(FM(2)*(G(5,2)*SP2-G(1,5)*CP2)*P52+FM(3)*(G(5,3)*SP3-G(2,1-00076
     +5)*CP3)*P53+FM(4)*(G(5,4)*SP4-G(3,5)*CP4)*P54+FM(5)*(G(5,5)*SP5-G(1-00077
     +4,5)*CP5)*P55)                                                    1-00078
      IF(NMAX.LE.5) GO TO 21
      IF(R.GT.CONA(5)) GO TO 20
      N=6
      SP6=SPH*CP5+CPH*SP5                                               1-00081
      CP6=CPH*CP5-SPH*SP5                                               1-00082
      P61=CT*P51-CONST(6,1)*P41                                         1-00083
      DP61=CT*DP51-ST*P51-CONST(6,1)*DP41                               1-00084
      P62=CT*P52-CONST(6,2)*P42                                         1-00085
      DP62=CT*DP52-ST*P52-CONST(6,2)*DP42                               1-00086
      P63=CT*P53-CONST(6,3)*P43                                         1-00087
      DP63=CT*DP53-ST*P53-CONST(6,3)*DP43                               1-00088
      P64=CT*P54-CONST(6,4)*P44                                         1-00089
      DP64=CT*DP54-ST*P54-CONST(6,4)*DP44                               1-00090
      P65=CT*P55                                                        1-00091
      DP65=CT*DP55-ST*P55                                               1-00092
      P66=ST*P55                                                        1-00093
      DP66=FM(6)*P65                                                    1-00094
      C2=G(6,2)*CP2+G(1,6)*SP2                                          1-00095
      C3=G(6,3)*CP3+G(2,6)*SP3                                          1-00096
      C4=G(6,4)*CP4+G(3,6)*SP4                                          1-00097
      C5=G(6,5)*CP5+G(4,6)*SP5                                          1-00098
      C6=G(6,6)*CP6+G(5,6)*SP6                                          1-00099
      AR=AOR*AR                                                         1-00100
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      BR=XR-FN(6)*AR*(G(6,1)*P61+C2*P62+C3*P63+C4*P64+C5*P65+C6*P66)       1-00101
      BT=XT+AR*(G(6,1)*DP61+C2*DP62+C3*DP63+C4*DP64+C5*DP65+C6*DP66)       1-00102

     +4,6)*CP5)*P65+FM(6)*(G(6,6)*SP6-G(5,6)*CP6)*P66)                     1-00105
      IF(NMAX.LE.6) GO TO 11
      IF(R.GT.CONA(6)) GO TO 10
      N=7
      SP7=(SP4+SP4)*CP4                                                    1-00108
      CP7=(CP4+SP4)*(CP4-SP4)                                              1-00109
      P71=CT*P61-CONST(7,1)*P51                                            1-00110
      DP71=CT*DP61-ST*P61-CONST(7,1)*DP51                                  1-00111
      P72=CT*P62-CONST(7,2)*P52                                            1-00112
      DP72=CT*DP62-ST*P62-CONST(7,2)*DP52                                  1-00113
      P73=CT*P63-CONST(7,3)*P53                                            1-00114
      DP73=CT*DP63-ST*P63-CONST(7,3)*DP53                                  1-00115
      P74=CT*P64-CONST(7,4)*P54                                            1-00116
      DP74=CT*DP64-ST*P64-CONST(7,4)*DP54                                  1-00117
      P75=CT*P65-CONST(7,5)*P55                                            1-00118
      DP75=CT*DP65-ST*P65-CONST(7,5)*DP55                                  1-00119
      P76=CT*P66                                                           1-00120
      DP76=CT*DP66-ST*P66                                                  1-00121
      P77=ST*P66                                                           1-00122
      DP77=FM(7)*P76                                                       1-00123
      C2=G(7,2)*CP2+G(1,7)*SP2                                             1-00124
      C3=G(7,3)*CP3+G(2,7)*SP3                                             1-00125
      C4=G(7,4)*CP4+G(3,7)*SP4                                             1-00126
      C5=G(7,5)*CP5+G(4,7)*SP5                                             1-00127
      C6=G(7,6)*CP6+G(5,7)*SP6                                             1-00128
      C7=G(7,7)*CP7+G(6,7)*SP7                                             1-00129
      AR=ACR*AR                                                            1-00130
      XR=BR-FN(7)*AR*(G(7,1)*P71+C2*P72+C3*P73+C4*P74+C5*P75+C6*P76+C7*P1-00131
     +77)                                                                  1-00132
      XT=BT+AR*(G(7,1)*DP71+C2*DP72+C3*DP73+C4*DP74+C5*DP75+C6*DP76+C7*D1-00133
     +P77)                                                                 1-00134
      XP=BP-AR*(FM(2)*(G(7,2)*SP2-G(1,7)*CP2)*P72+FM(3)*(G(7,3)*SP3-G(2,1-00135
     +7)*CP3)*P73+FM(4)*(G(7,4)*SP4-G(3,7)*CP4)*P74+FM(5)*(G(7,5)*SP5-G(1-00136
     +4,7)*CP5)*P75+FM(6)*(G(7,6)*SP6-G(5,7)*CP6)*P76+FM(7)*(G(7,7)*SP7-1-00137
     +G(6,7)*CP7)*P77)                                                     1-00138
      IF(NMAX.LE.7) GO TO 21
      IF(R.GT.CONA(7)) GO TO 20
      N=8
      SP8=SPH*CP7+CPH*SP7                                                  1-00141
      CP8=CPH*CP7-SPH*SP7                                                  1-00142
      P81=CT*P71-CONST(8,1)*P61                                            1-00143
      DP81=CT*DP71-ST*P71-CONST(8,1)*DP61                                  1-00144
      P82=CT*P72-CONST(8,2)*P62                                            1-00145
      DP82=CT*DP72-ST*P72-CONST(8,2)*DP62                                  1-00146
      P83=CT*P73-CONST(8,3)*P63                                            1-00147
      DP83=CT*DP73-ST*P73-CONST(8,3)*DP63                                  1-00148
      P84=CT*P74-CONST(8,4)*P64                                            1-00149
      DP84=CT*DP74-ST*P74-CONST(8,4)*DP64                                  1-00150
      P85=CT*P75-CONST(8,5)*P65                                            1-00151
      DP85=CT*DP75-ST*P75-CONST(8,5)*DP65                                  1-00152
      P86=CT*P76-CONST(8,6)*P66                                            1-00153
      DP86=CT*DP76-ST*P76-CONST(8,6)*DP66                                  1-00154
      P87=CT*P77                                                           1-00155
      DP87=CT*DP77-ST*P77                                                  1-00156
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      P88=ST*P77                                                        1-00157
      DP88=FM(8)*P87                                                    1-00158

      C4=G(8,4)*CP4+G(3,8)*SP4                                          1-00161
      C5=G(8,5)*CP5+G(4,8)*SP5                                          1-00162
      C6=G(8,6)*CP6+G(5,8)*SP6                                          1-00163
      C7=G(8,7)*CP7+G(6,8)*SP7                                          1-00164
      C8=G(8,8)*CP8+G(7,8)*SP8                                          1-00165
      AR=AOR*AR                                                         1-00166
      BR=XR-FN(8)*AR*(G(8,1)*P81+C2*P82+C3*P83+C4*P84+C5*P85+C6*P86+C7*P1-00167
     +87+C8*P88)                                                        1-00168
      BT=XT+AR*(G(8,1)*DP81+C2*DP82+C3*DP83+C4*DP84+C5*DP85+C6*DP86+C7*D1-00169
     +P87+C8*DP88)                                                      1-00170
      BP=XP-AR*(FM(2)*(G(8,2)*SP2-G(1,8)*CP2)*P82+FM(3)*(G(8,3)*SP3-G(2,1-00171
     +8)*CP3)*P83+FM(4)*(G(8,4)*SP4-G(3,8)*CP4)*P84+FM(5)*(G(8,5)*SP5-G(1-00172
     +4,8)*CP5)*P85+FM(6)*(G(8,6)*SP6-G(5,8)*CP6)*P86+FM(7)*(G(8,7)*SP7-1-00173
     +G(6,8)*CP7)*P87+FM(8)*(G(8,8)*SP8-G(7,8)*CP8)*P88)                1-00174
      IF(NMAX.LE.8) GO TO 11
      IF(R.GT.CONA(8)) GO TO 10
      N=9
      SP9=(SP5+SP5)*CP5                                                 1-00177
      CP9=(CP5+SP5)*(CP5-SP5)                                           1-00178
      P91=CT*P81-CONST(9,1)*P71                                         1-00179
      DP91=CT*DP81-ST*P81-CONST(9,1)*DP71                               1-00180
      P92=CT*P82-CONST(9,2)*P72                                         1-00181
      DP92=CT*DP82-ST*P82-CONST(9,2)*DP72                               1-00182
      P93=CT*P83-CONST(9,3)*P73                                         1-00183
      DP93=CT*DP83-ST*P83-CONST(9,3)*DP73                               1-00184
      P94=CT*P84-CONST(9,4)*P74                                         1-00185
      DP94=CT*DP84-ST*P84-CONST(9,4)*DP74                               1-00186
      P95=CT*P85-CONST(9,5)*P75                                         1-00187
      DP95=CT*DP85-ST*P85-CONST(9,5)*DP75                               1-00188
      P96=CT*P86-CONST(9,6)*P76                                         1-00189
      DP96=CT*DP86-ST*P86-CONST(9,6)*DP76                               1-00190
      P97=CT*P87-CONST(9,7)*P77                                         1-00191
      DP97=CT*DP87-ST*P87-CONST(9,7)*DP77                               1-00192
      P98=CT*P88                                                        1-00193
      DP98=CT*DP88-ST*P88                                               1-00194
      P99=ST*P88                                                        1-00195
      DP99=FM(9)*P98                                                    1-00196
      C2=G(9,2)*CP2+G(1,9)*SP2                                          1-00197
      C3=G(9,3)*CP3+G(2,9)*SP3                                          1-00198
      C4=G(9,4)*CP4+G(3,9)*SP4                                          1-00199
      C5=G(9,5)*CP5+G(4,9)*SP5                                          1-00200
      C6=G(9,6)*CP6+G(5,9)*SP6                                          1-00201
      C7=G(9,7)*CP7+G(6,9)*SP7                                          1-00202
      C8=G(9,8)*CP8+G(7,9)*SP8                                          1-00203
      C9=G(9,9)*CP9+G(8,9)*SP9                                          1-00204
      AR=AOR*AR                                                         1-00205
      XR=BR-FN(9)*AR*(G(9,1)*P91+C2*P92+C3*P93+C4*P94+C5*P95+C6*P96+C7*P1-00206
     +97+C8*P98+C9*P99)                                                 1-00207
      XT=BT+AR*(G(9,1)*DP91+C2*DP92+C3*DP93+C4*DP94+C5*DP95+C6*DP96+C7*D1-00208
     +P97+C8*DP98+C9*DP99)                                              1-00209
      XP=BP-AR*(FM(2)*(G(9,2)*SP2-G(1,9)*CP2)*P92+FM(3)*(G(9,3)*SP3-G(2,1-00210
     +9)*CP3)*P93+FM(4)*(G(9,4)*SP4-G(3,9)*CP4)*P94+FM(5)*(G(9,5)*SP5-G(1-00211
     +4,9)*CP5)*P95+FM(6)*(G(9,6)*SP6-G(5,9)*CP6)*P96+FM(7)*(G(9,7)*SP7-1-00212
     +G(6,9)*CP7)*P97+FM(8)*(G(9,8)*SP8-G(7,9)*CP8)*P98+FM(9)*(G(9,9)*SP1-00213
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     +9-G(8,9)*CP9)*P99)                                                1-00214
      IF(NMAX.LE.9) GO TO 21
      IF(R.GT.CONA(9)) GO TO 20
      N=10
      SP10=SPH*CP9+CPH*SP9                                              1-00217
      CP10=CPH*CP9-SPH*SP9                                              1-00218
      P101=CT*P91-CONST(10,1)*P81                                       1-00219
      DP101=CT*DP91-ST*P91-CONST(10,1)*DP81                             1-00220
      P102=CT*P92-CONST(10,2)*P82                                       1-00221
      DP102=CT*DP92-ST*P92-CONST(10,2)*DP82                             1-00222
      P103=CT*P93-CONST(10,3)*P83                                       1-00223
      DP103=CT*DP93-ST*P93-CONST(10,3)*DP83                             1-00224
      P104=CT*P94-CONST(10,4)*P84                                       1-00225
      DP104=CT*DP94-ST*P94-CONST(10,4)*DP84                             1-00226
      P105=CT*P95-CONST(10,5)*P85                                       1-00227
      DP105=CT*DP95-ST*P95-CONST(10,5)*DP85                             1-00228
      P106=CT*P96-CONST(10,6)*P86                                       1-00229
      DP106=CT*DP96-ST*P96-CONST(10,6)*DP86                             1-00230
      P107=CT*P97-CONST(10,7)*P87                                       1-00231
      DP107=CT*DP97-ST*P97-CONST(10,7)*DP87                             1-00232
      P108=CT*P98-CONST(10,8)*P88                                       1-00233
      DP108=CT*DP98-ST*P98-CONST(10,8)*DP88                             1-00234
      P109=CT*P99                                                       1-00235
      DP109=CT*DP99-ST*P99                                              1-00236
      P1010=ST*P99                                                      1-00237
      DP1010=FM(10)*P109                                                1-00238
      C2=G(10,2)*CP2+G(1,10)*SP2                                        1-00239
      C3=G(10,3)*CP3+G(2,10)*SP3                                        1-00240
      C4=G(10,4)*CP4+G(3,10)*SP4                                        1-00241
      C5=G(10,5)*CP5+G(4,10)*SP5                                        1-00242
      C6=G(10,6)*CP6+G(5,10)*SP6                                        1-00243
      C7=G(10,7)*CP7+G(6,10)*SP7                                        1-00244
      C8=G(10,8)*CP8+G(7,10)*SP8                                        1-00245
      C9=G(10,9)*CP9+G(8,10)*SP9                                        1-00246
      C10=G(10,10)*CP10+G(9,10)*SP10                                    1-00247
      AR=AOR*AR                                                         1-00248
      BR=XR-FN(10)*AR*(G(10,1)*P101+C2*P102+C3*P103+C4*P104+C5*P105+C6*P1-00249
     +106+C7*P107+C8*P108+C9*P109+C10*P1010)                            1-00250
      BT=XT+AR*(G(10,1)*DP101+C2*DP102+C3*DP103+C4*DP104+C5*DP105+C6*DP11-00251
     +06+C7*DP107+C8*DP108+C9*DP109+C10*DP1010)                         1-00252
      BP=XP-AR*(FM(2)*(G(10,2)*SP2-G(1,10)*CP2)*P102+FM(3)*(G(10,3)*SP3-1-00253
     +G(2,10)*CP3)*P103+FM(4)*(G(10,4)*SP4-G(3,10)*CP4)*P104+FM(5)*(G(101-00254
     +,5)*SP5-G(4,10)*CP5)*P105+FM(6)*(G(10,6)*SP6-G(5,10)*CP6)*P106+FM(1-00255
     +7)*(G(10,7)*SP7-G(6,10)*CP7)*P107+FM(8)*(G(10,8)*SP8-G(7,10)*CP8)*1-00256
     +P108+FM(9)*(G(10,9)*SP9-G(8,10)*CP9)*P109+FM(10)*(G(10,10)*SP10-G(1-00257
     +9,10)*CP10)*P1010)                                                1-00258
      BP=BP/ST                                                          1-00474
      IF(NMAX.LE.10) RETURN
      WRITE (6,2) NMAX                                                  1-00476
      STOP                                                              1-00477
C
    2 FORMAT(57HC ERROR, THIS SPHRC ONLY FOR NMAX=J10, CALL WAS FOR NMAX
     *=,I5)
C     MAKE A SMOOTH FIT BETWEEN TRUNCATED TERMS.
   10 CON=(R-CONA(N))/(CONA(N-1)-CONA(N))
   11 BR=BR+(XR-BR)*CON
      BT=BT+(XT-BT)*CON
      BP=(BP+(XP-BP)*CON)/ST
```

```
      RETURN
 20   CON=(R-CONA(N))/(CONA(N-1)-CCNA(N))

      BF=(XP+(BP-XF)*CON)/ST
      RETURN
      END                                                        1-00480
 00
//
//
//
//YZRWPDE2 JOB (K10102404C,P,KA0001,003004),601,MSGLEVEL=1
//TEST1 EXEC PGM=PATRICK,PARM=:STN,001,088,001:,REGION=200K
//IN1 DD UNIT=2400-9,LABEL=(,BLP,,IN),DCB=(,RECFM=U,EROPT=ACC,DEN=4,
//              BLKSIZE=32000),
//          VOL=SER=JJ0157
//OUT1 DD UNIT=2400-9,DCB=(,RECFM=U,EROPT=ACC,DEN=3,BLKSIZE=32000),
//          LABEL=(,BLP,,OUT),
//          VOL=SER=JJ0167
//OUT2 DD SYSOUT=A,DCB=(RECFM=FB,LRECL=132,BLKSIZE=3000)
EXI
$WEO LPS
```

```
$$
$ASS IN MT4 OUT TLO
```