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SUBJECT: AN IBM-704 CODE FOR DETERMINING EQUILIBRIUM ORBITS AND PROPERTIES OF SMALL-AMPLITUDE OSCILLATIONS IN CYCLOTRON FIELDS

TO: Distribution

FROM: M. M. Gordon, T. A. Welton, T. I. Arnette, and H. C. Owens

Abstract

A 704 code is described in detail for calculating properties of equilibrium orbits and small oscillations in general cyclotron magnetic fields. The code is very flexible, accurate, and economical to operate.

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An IBM-704 Code for Determining Equilibrium Orbits and Properties of Small-Amplitude Oscillations in Cyclotron Fields

M. M. Gordon,* T. A. Welton, T. I. Arnette, and H. C. Owens

I. INTRODUCTION AND GENERAL DESCRIPTION

This is a preliminary description of a cyclotron orbit code** (the local designation is No. 1482) for the IBM-704 (8192 word memory), which has proved to be extremely useful for the calculation of the following quantities, as functions of particle energy:

1. radius and radial momentum of the equilibrium orbit, at any desired azimuth
2. time for one revolution
3. ν_r and ν_z.

The required input is a set of median plane field values $B(r,\theta)$ and azimuthal derivatives $\partial B/\partial \theta$. These must be provided as stored values on magnetic tape, at uniform intervals of r and θ, in a manner to be described in detail in a later section. The equations to be integrated are:

$$p_r' = Q - rB(r,\theta) \tag{1}$$

$$r' = (r/Q)\, p_r \tag{2}$$

$$p_{x1}' = -(p_r/Q)\, p_{x1} - \partial/\partial r \left[rB(r,\theta)\right] x_1 \tag{3}$$

$$x_1' = (p_r/Q)\, x_1 + (p^2\, r/Q^3)\, p_{x1} \tag{4}$$

$$p_{x2}' = -(p_r/Q)\, p_{x2} - \partial/\partial r \left[rB(r,\theta)\right] x_2 \tag{5}$$

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**Sets of binary program cards can be obtained by writing to T. A. Welton, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tennessee

$$x_2' = (p_r/Q)\, x_2 + (p^2\, r/Q^3)\, p_{x2} \tag{6}$$

$$p_{z1}' = \left[r\, \partial B/\partial r - (p_r/Q)\ \ \partial B/\partial \theta\right]\ z_1 \tag{7}$$

$$z_1' = (r/Q)\, p_{z1} \tag{8}$$

$$p_{z2}' = \left[r\, \partial B/\partial r - (p_r/Q)\ \ \partial B/\partial \theta\right]\ z_2 \tag{9}$$

$$z_2' = (r/Q) p_{z2} \tag{10}$$

$$\tau' = (N/2\pi)\, E\, r/Q \tag{11}$$

$$\langle r' \rangle = (N/2\pi)\, r \tag{12}$$

where:

prime means $d/d\theta$

$r(\theta)$ = radius as a function of θ for an arbitrary reference orbit in the median plane

$p_r(\theta)$ = radial momentum as a function of θ for an arbitrary reference orbit in the median plane

$Q(\theta)$ = $(p^2 - p_r^2)^{1/2}$

p = magnitude of particle momentum

$x_1(\theta)$ = radial displacement from $r(\theta)$ of a disturbed orbit with $x_1(0) = \delta x$, $p_{x1}(0) = 0$.

$p_{x1}(\theta)$ = radial momentum displacement from $p_r(\theta)$ of a disturbed orbit

$x_2(\theta)$ = radial displacement with $x_2(0) = 0$, $p_{x2}(0) = \delta p_x$

$p_{x2}(\theta)$ = radial momentum with $x_2(0) = 0$, $p_{x2}(0) = \delta p_x$

$z_1(\theta)$ = axial displacement from reference orbit with $z_1(0) = \delta z$, $p_{z1}(0) = 0$

$p_{z1}(\theta)$ = axial momentum from reference orbit with $z_1(0) = \delta z$, $p_{z1}(0) = 0$

$z_2(\theta)$ = axial displacement from reference orbit with $z_2(0) = 0$, $p_{z2}(0) = \delta p_z$

$p_{z2}(\theta)$ = axial momentum from reference orbit with $z_2(0) = 0$, $p_{z2}(0) = \delta p_z$

$\tau(\theta)$ = $N/2\pi$ x time from $\theta = 0$

$r(\theta)$ = mean radius of reference orbit from $\theta = 0$

N = number of sectors

E = total relativistic energy.

The following units are used:

speed in units of c, so that velocity and β are identical

momentum in units of $m_o c$, where m_o is the particle rest mass

energy in units of $m_o c^2$

time in units of ω_o^{-1}, where ω_o is an arbitrarily chosen mean orbital angular speed

length in units of $a = c/\omega_o$

field in units of $b = m_o c\, \omega_o/e$.

If b is measured in units of 10^4 gauss, and the particles have charge number Z and mass number A (not necessarily integral), then:

a = 313.0A/bZ cm. = 123.21A/bZ inches

$\omega_o/2\pi$ = Z/A (15.246 b) Mc/sec.

The code is designed to work most efficiently if the field unit b is taken to be the actual central magnetic field, assuming a reasonable degree of isochronism, but has performed without error and without noticeable loss of speed even when this condition was not satisfied.

The computational procedure is as follows:

1. The independent variable for the desired output (p, E, or β) is set equal to the first value desired.

2. The field storage core locations are loaded from magnetic tape, to provide the anticipated required field information for the orbit integrations.

3. Guesses are prepared for the r and p_r values for the equilibrium orbit at $\theta = 0$. This guess increases in complexity and accuracy as the calculation proceeds.

4. Using these guessed initial conditions, equations (1), (2), (3), (4), (5), and (6) are integrated simultaneously through one sector ($2\pi/N > \theta > 0$).

5. From the results at $\theta = 2\pi/N$, an approximate correction can be calculated to $r(0)$ and $p_r(0)$ to make $r(2\pi/N)$ and $p_r(2\pi/N)$ on the next try more nearly equal to their starting values.

6. This process is repeated until

$$\left| r\left(\frac{2\pi}{N}\right) - r(0) \right| + \left| p_r\left(\frac{2\pi}{N}\right) - p_r(0) \right| < \epsilon \ .$$

At this point the improved values for $r(0)$ and $p_r(0)$ are again calculated.

7. The integration scheme is now changed and equations (1) through (12) are integrated through one sector. From the results can be calculated the quantities:

$$\nu_r, \ \nu_z, \ \langle r \rangle, \ \tau\left(\frac{2\pi}{N}\right) = \frac{1}{\omega} \ .$$

These are printed, together with quantities like cos σ_z, (which will vary smoothly with momentum, even if axial defocusing occurs. In the event that ν_z becomes imaginary, cos σ_z will be printed in the ν_z column, in addition), $r(0)$ (= R), $p_r(0)$ (= P_r), $\frac{r_{max} - r_{min}}{2}$ (= AMP in the notation of the code. This is the the amplitude of oscillation of the equilibrium orbit about the median circle), the kinetic energy of the particle in Mev.

8. The independent variable is advanced by the desired step and the complete sequence gone through again. This continues until the last specified value of the independent variable has been used, or until no more fields are available.

It is believed that this code is foolproof, in that if a starting momentum value is specified for which fields are not available, the initial p value will be advanced in steps until fields are available for the orbit integrations. If the field values in core storage are not adequate to complete the orbit integrations specified, a fresh loading of field values from tape will be performed and the orbit integration resumed. If no more field values are available on tape, the calculation will stop. A complete flow chart is appended.

The integration of the orbit equations is done by the Runge-Kutta procedure. This requires provision of field values every half of a Runge-Kutta step. We have run the code with 15, 16, 20, 32, and 45 Runge-Kutta steps per sector, with the conclusion that the smallest number would have been adequate in every case tested. If N_{RK} is the number of steps per sector, B and $\partial B/\partial \theta$ must be supplied at 2 N_{RK} equally spaced Q-values per sector. The code does not perform any interpolation or differentiation in the θ-direction.

It is necessary, on the other hand, for the code to obtain B, $\partial B/\partial \theta$, and $\partial B/\partial r$ at arbitrary r-values. This is done by four-point central Lagrangian interpolation, which has proven to be adequate in many tests. Two words of caution are in order. If r_o is the minimum value of r represented in the table of field-values, and Δr is the tabular interval, then any orbit which involves an r-value less than $r_o + \Delta r$ will cause an automatic stop. A simple way to avoid such stops is to let $r_o = -\Delta r$, and supply the required field values at a single negative value of r by an obvious symmetry relation:

$$B(-r, \theta) = B(r, \theta + \pi). \tag{13}$$

The other point of caution concerns the required Δr. In general, the ν_r and ν_z values will have roughly the accuracy of $\partial B/\partial r$. If the error level in B is known, then Δr should be so adjusted as to roughly minimize the total error in $\partial B/\partial r$. Too large a Δr will cause the four-point formula to be inaccurate, while too small a Δr will exaggerate the effect on $\partial B/\partial r$ of random errors in B.

II. INSTRUCTIONS FOR LOADING PARAMETERS

Input parameters are fed into the program by means of NY INP1. The control word is set up for one word per card which is to be stored in the decimal address punched in columns 1 - 6 on each card. The last card must be a transfer to the main routine (TRA 89). This card has been included as the last card in the binary deck. Thus the parameter cards must be inserted immediately in front of this final transfer card. The parameters can be given in either decimal or octal with the proper pseudo-operation DEC or OCT. The decimal or octal data is then punched starting in column 12.

The following table lists the required input parameters. The code designation of the parameter is first given, followed by its decimal location and mode of input. A description of the role of the parameter is attached together with the designation used in the preceding part of the description, if any, in parentheses.

III. INSTRUCTIONS FOR PROVIDING STORED FIELDS AND DERIVATIVES ON TAPE

Two tapes, written in the binary mode, containing the magnetic fields (logical tape one) and the derivatives of those fields with respect to theta (logical tape two), must be furnished the code. The field values must be given at equal intervals on a polar grid and are stored on magnetic tape in blocks, each block containing fields for all θ-values and a single r-value. Successive blocks refer to successive r-values. Thus one file of information must contain all of the field values needed to compute the desired table of momentum values and each record of that file, beginning with the second record, must contain all of the field values at one radius. More explicitly, the second record

Parameters	Decimal Location	Mode of Input	Description
AMORT	1240	Fl. Pt.	Atomic mass number of ions being accelerated. Used to compute the kinetic energy in Mev. (= A)
NFL	1241	Fl. Pt.	Number of sectors in cyclotron. (N)
P	1242	Fl. Pt.	Initial momentum value for table (used with INKEY = 1). (p_o)
KFX	1243	Integer	Number of Runge-Kutta steps per sector. (N_{RK})
NSTAR	1244	Integer	Number of sectors per angular field cycle (= 1 for normal operation). This parameter can be used to combine one or more sectors into one larger sector. Thus, if NSTAR is set equal to 2 and NFL is 8, the orbits will be calculated as though the machine had only 4 sectors.
DELTAE	1245	Fl. Pt.	E-increment for table (used with INKEY = 2). (ΔE)
DELBET	1246	Fl. Pt.	β-increment for table (used with INKEY = 3). ($\Delta\beta$)
DELTAR	1247	Fl. Pt.	Radial increment for which fields are stored on tape. (Δr)
INKEY	1248	Integer (1,2, or 3)	Tells code whether table is to be in equal increments of p, E, or β according as INKEY is 1, 2, or 3, respectively. If INKEY = 1, p_o and Δp must be furnished code; if 2, E_o and ΔE must be furnished; or if 3, β_o and -β must be furnished.
OUTKEY	1249	Integer (1,2,3,4, or 5)	Gives choice of output. 1, 2, and 3 give extended output with either p, E, or β in left-hand column, respectively. Extended output includes p, E, β, time, cos σ_z, ν_z, ν_r, KE, R, P_r, $\langle r \rangle$, and orbit amplitude. Outkey = 4 or 5 gives abbreviated output, with p or E, respectively, as left-hand column. Abbreviated output consists of p, E, time, ν_z, ν_r, R, and P_r.

cont'd.

Parameters	Decimal Location	Mode of Input	Description
TSIZ	1250	Integer	Number of values of independent variable to be used for table.
KEYB	1251	Integer	Identifies fields -- must be same number as first word on first record of field data as stored on tape. Note: Keyword on tape must be in decrement position like a Fortran integer, whereas BKEY in code must be in address position of word.
RIN	1252	Fl. Pt.	Minimum value of r for which fields are stored on tape. (r_o)
MROT	1253	Fl. Pt.	Maximum value of r for which fields are stored on tape. Both RIN and RMOT are checked against corresponding values stored on 1st record of fields.
DELTAP	1254	Fl. Pt.	p-increment for table (used with INKEY = 1). (Δp)
EPS	1264	Fl. Pt.	Accuracy to which equilibrium orbit is specified. (Actually this code makes the final improvement to r and pr after this condition is met.) Epsilon is now set at 1 x 10^{-3} and gives the equilibrium orbit to approximately 10^{-5}. We think this accuracy will suffice, but in a pathological field it may be necessary to reduce EPS. This is likely to increase the running time. (ϵ)
EPS2	1268	Fl. Pt.	The amount the α and β determinants may vary from 1 is governed by EPS2. EPS2 is now set to 0.001. This is simply an overall check on the solutions of the equations of motion (area preservation) and can probably be set smaller without loss of speed.
E	1282	Fl. Pt.	Initial E value for table (must be supplied when INKEY = 2). (E_o)
BETA	1283	Fl. Pt.	Initial β value for table (must be furnished when INKEY = 3). (β_o)

must contain $B(r,\theta)$ for $r = r_o$, $\theta = \frac{2\pi}{N} - \Delta\theta, \frac{2\pi}{N} - 2\Delta\theta, 2\Delta\theta, \Delta\theta, 0$ in that order. The third record has $r = r_o + \Delta r$, and so on. The integer N is the number of sectors in the magnetic field. The Runge-Kutta process requires that the functions be evaluated at one-half intervals, thus at each radius twice as many field values as the number of Runge-Kutta steps to be integrated must be furnished.*

The first record on the field tape contains four words* used for identification and checking purposes. The first word must be an integer, < 32768, written in the decrement of the word (as Fortran would write an integer) and is used to identify the field set. The second word must be the value of the smallest radius at which the fields are stored and is checked against the input parameter RIN. The third word must be the maximum value of the radius at which field values are stored and is checked against the input parameter MROT. The fourth word must be the radial increment at which field measurements are taken and is checked against the input parameter DELTAR.

The derivative tape must be written in the same format as the field tape except for the first record. The first record of the derivative tape is the identification record and must contain one word* which is the negative of the identification word (first word of first record) used on the field tape.

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*NOTE: Because Fortran writes a nonsense word as the first word of each record on magnetic tape, this code was written assuming the first word of each record to be meaningless. If Fortran is used in storing the fields, the nonsense word will be automatically supplied, but if not then an extra word must be written as the first word of each record.

IV. OPERATING INSTRUCTIONS

Operate with sense switch 1 down (used in Input Routine only). The board must be SHARE-2. The normal stop for program is in FX1 or Octal 02363. Other stops in code are identifiable from the attached SAP listing.

If fields are needed for an r-value which is too small, the program increases p (or E or β, as the case may be) and goes on to the next desired entry. When r becomes too large for the available fields the program stops. (Octal 1152.)

The code as written supposedly writes all 13 computed quantities on the drum at each R-K step. We have, however, made no use as yet of this data and consequently have not checked this part of the program. A later description of the code will contain instructions on the use of this part.

V. OUTPUT FORMAT

The principal output is by line printer, directly following computation. A number of output formats can be chosen by selection of the parameter OUTKEY. For OUTKEY = 1, the column headings will be:

P, E, BETA, TIME, COS, NU Z, NU R, KE, R, PR, R, R AVE, AMP.

For OUTKEY = 2, E and P are interchanged, the left-hand column always being the independent variable, which is advanced in uniform increments. For OUTKEY = 3, the first three headings are BETA, P, E, the others being left the same. OUTKEY = 4 leads to the headings P, E, TIME, NU Z, NU R, R, PR, and OUTKEY = 5 simply interchanges P and E.

The following table gives the equivalence between code symbols and the symbols used in the algebraic work at the beginning.

Code Symbol	Algebraic Symbol
P	p
E	E $(= \sqrt{p^2 + 1})$
BETA	β (= p/E)
TIME	$\tau(2\pi/N)$ = orbit period/2π
NU Z	ν_z
NU R	ν_r
COS	cos σ_z
KE	kinetic energy in Mev = 938.23A (E - 1)
R	R = r(0)
PR	$P_r = p_r(0)$
R AVE	$\langle r\ (2\pi/N)\rangle$
AMP	orbit amplitude = 1/2 $(r_{max} - r_{min})$

VI. ILLUSTRATIVE EXAMPLE AND TEST FOR CORRECT OPERATION

In order to obtain operating experience with this code, in the absence of a wide variety of experimentally measured fields, a FORTRAN code was written to supply magnetic fields on tape, in the required format, from an analytical specification. This auxiliary code also allows the introduction of random errors and a great variety of diagnostic studies can be made with its help, some of which will be described in a later report. For present purposes, its utility is as the generator of a typical magnetic field which can be used in getting into reliable operation the main orbit code. A deck of cards for this auxiliary field-generating code will be supplied to all potential users of the main orbit code. If the following instructions are obeyed, there should then result an output from the main orbit code which can be compared with the attached sample output. Any failure should then be more easily traceable to mis-operation, mis-arrangement of field input, etc.

The Fortran program No. 1636 calculates B-values (code No. 1645 described in the following calculates $\partial B/\partial \theta$) by the formulas given below and stores them on magnetic tape Drive 1. The first record is an identification record containing the following four words:

1.) KEYB = Identification number

2.) RIN = Smallest radial value for which fields are calculated

3.) RMOT = Largest radial value for which fields are calculated

4.) DELR = Increment in radius.

After this identification record, each succeeding record contains fields for a constant r, varying θ. The records are in ascending order of r-values, but within each record the fields are stored in descending θ-values. In other words, the $\Theta = 0$ value is the last value on each record.

The fields are calculated according to:

$$B(r,\Theta) = \sum_{n=0}^{5} F_n(r) \cos n N \left[\Theta - \mathcal{S}_n(r)\right]$$

where: $$F_o(r) = \frac{1}{\sqrt{1 - \frac{r^2}{A^2}}} \quad \frac{a_o + b_o r^2}{1 + c_o r^2}$$

$$F_1(r) = \frac{r^N}{(r^2 + B^2)^{N/2}} \quad \frac{a_1 + b_1 r^2}{1 + c_1 r^2}$$

$$F_2(r) = \frac{r^{2N}}{(r^2 + B^2)^{2N/2}} \quad \frac{a_2 + b_2 r^2}{1 + c_2 r^2}, \text{ etc.}$$

and $$\mathcal{S}_n(r) = \frac{d_n + e_n r^2}{1 + f_n r^2} \quad .$$

The input parameters are inserted by the following READ statement:

```
    READ 2,  NRK, KEYB, S, N, AFIRST, BE, AO, BO, CO, RIN, DELTAR,
             RMOT, (A(I), B(I), C(I), D(I), E(I), F(I), I = 1, N)

  2 FORMAT,  (2I5/E 4.1/I1/2E 11.5/3E 11.5/3E 9.5/(6E 11.5))
```

where NRK = twice the number of Runge-Kutta steps/sector asked for in the main orbit code.

KEYB = Identification number. Program No. 1482 searches for this number

S = N in equations = number of sectors in machine

N = n in equations

AFIRST = A in equations

BE = B in equations

AO = a_o

BO = b_o

CO = c_o

A(I) = a_n, etc.

<u>Note</u>: This code re-winds tape when finishing.

The parameter cards sent are:

card	parameter	value
card 1	NRK	= 32
	KEYB	= 103
2	S	= 3.0
3	N	= 1
4	A	= 1.0
	B	= .02258
5	AO	= 1.0
	BO	= 0
	CO	= 0
6	RIN	= .01129
	DELTAR	= .01129
	RMOT	= .41773
7	A(1)	= .28780
	B(1)	= 3.92441
	C(1)	= 2.83841

All parameters not listed above are zero, and thus the field for this test case has a sinusoidal flutter with no spiral. Approximate isochronism will be maintained.

Program No. 1645 takes the fields as calculated from 1636, interpolates for θ- derivatives and stores them on Drive 2. There is no input for this code, but octal location 230 must be changed by a binary correction card if NRK is other than 32. Change this number to agree with the No. 1636 NRK. This code also re-winds tape when finishing. The fields from No. 1636 must be on Drive 1 ready for use when starting this program.

The sequence of codes 1636, 1645, and 1482 can be followed one after the other by only clearing core and loading cards after each program. Successful operation of the sequence will yield an output exactly the same as the attached page.

```
                  00125           ORG 85
                                      EQUILIBRIUM ORBIT 1 1482 OWENS AND ARNETTE
00125  0 07400 4 10321  LOAD  TSX INP1,4           A1
00126  0 00001 0 00001            1,0,1
00127  0 42000 0 00000        HPR
00130  0 02000 0 00125        TRA LOAD
00131  0 53400 1 02366        LXA FX4,1                 HUNTING FIELDS ON TAPE
00132  0 76200 0 00221        RTB 1                     READ IDENTIFICATION RECORD
00133  0 70000 0 14521        CPY COMMON
00134  0 70000 1 14525  CAPY  CPY COMMON+4,1
00135  2 00001 1 00134        TIX CAPY,1,1              COPY 4 IDENT. WORDS
00136 -0 76000 0 00011        ETT                       END OF TAPE TEST
00137  0 02000 0 02300        TRA ETT+3                 END OF TAPE - TRANSFER TO REWIND
00140  0 76600 0 00333        IOD
00141 -0 76000 0 00012        RTT                       REDUNDANCY TAPE TEST
00142  0 42000 0 00000        HPR                       STOP, TAPE ERROR-IN-KEYWORDS
00143  0 50000 0 14521        CLA COMMON
00144  0 77100 0 00022        ARS 18
00145  0 40200 0 02343        SUB BKEY
00146  0 10000 0 00154        TZE CAPY+16          CORRECT SET OF FIELDS FOUND
00147  0 76200 0 00221        RTB 1
00150  0 70000 0 14521        CPY COMMON
00151  0 02000 0 02275        TRA ETT
00152  0 02000 0 00131        TRA CAPY-3                END OF FILE TRANSFER
00153  0 02000 0 02275        TRA ETT                   END OF RECORD TRANSFER
00154  0 50000 0 14522        CLA COMMON+1              CHECK MINIMUM R VALUE
00155  0 40200 0 02344        SUB RIN
00156  0 76000 0 00003        SSP
00157  0 40200 0 02302        SUB ETT+5
00160 -0 12000 0 00162        TMI CAPY+22
00161  0 42000 0 00000        HPR
00162  0 50000 0 14523        CLA COMMON+2              CHECK MAXIMUM R VALUE
00163  0 40200 0 02345        SUB MROT
00164  0 76000 0 00003        SSP
00165  0 40200 0 02302        SUB ETT+5
00166 -0 12000 0 00170        TMI CAPY+28
00167  0 42000 0 00000        HPR
00170  0 50000 0 14524        CLA COMMON+3              CHECH DELTA R VALUE
00171  0 40200 0 02337        SUB DELTAR
00172  0 76000 0 00003        SSP
00173  0 40200 0 02302        SUB ETT+5
00174 -0 12000 0 00176        TMI CAPY+34
00175  0 42000 0 00000        HPR
```

```
00176  0 76200 0 00222         RTB 2               HUNT CORRECT FIELD DERIVATIVES ON 2
00177  0 70000 0 14521         CPY COMMON
00200  0 70000 0 14521  CBPY   CPY COMMON
00201 -0 76000 0 00011         ETT
00202  0 02000 0 02303         TRA ETT+6
00203  0 76600 0 00333         IOD
00204 -0 76000 0 00012         RTT
00205  0 42000 0 00000         HPR
00206  0 50000 0 14521         CLA COMMON
00207  0 77100 0 00022         ARS 18
00210  0 40000 0 02343         ADD BKEY
00211  0 10000 0 00217         TZE SETIN           CORRECT SET OF DERIVATIVES FOUND
00212  0 76200 0 00222         RTB 2
00213  0 70000 0 14521         CPY COMMON
00214  0 02000 0 02305         TRA ETT+8
00215  0 02000 0 00177         TRA CBPY-1          END OF FILE TRANSFER
00216  0 02000 0 02305         TRA ETT+8           END OF RECORD TRANSFER
00217  0 50000 0 02371  SETIN  CLA FX2
00220  0 34000 0 02340         CAS INKEY
00221  0 02000 0 00230         TRA SETIN+9         SET UP FOR INPUT 1 (P VARIABLE)
00222  0 02000 0 00235         TRA SETIN+14        SET UP FOR INPUT 2 (E VARIABLE)
00223  0 50000 0 02424         CLA SETAD+2         SET UP FOR INPUT 3 (BETA VARIABLE)
00224  0 62100 0 02012         STA Z12
00225  0 40000 0 02372         ADD FX3
00226  0 62100 0 00323         STA VARTRA
00227  0 02000 0 00242         TRA FXK
00230  0 50000 0 02422         CLA SETAD
00231  0 62100 0 02012         STA Z12
00232  0 40000 0 02372         ADD FX3
00233  0 62100 0 00323         STA VARTRA
00234  0 02000 0 00242         TRA FXK
00235  0 50000 0 02423         CLA SETAD+1
00236  0 62100 0 02012         STA Z12
00237  0 40000 0 02372         ADD FX3
00240  0 62100 0 00323         STA VARTRA
00241  0 02000 0 00242         TRA FXK
00242  0 50000 0 02333  FXK    CLA KFX             FLOAT K FIX
00243  0 07400 4 03233         TSX FXFLO,4         ENTER FIX-FLOAT ROUTINE
00244  0 00000 0 00043         PZE 35
00245  0 42000 0 00000         HPR
00246  0 60100 0 02410         STO KFL
00247  0 50000 0 02371         CLA FX2
00250  0 34000 0 02341         CAS OUTKEY
```

```
00251  0 02000 0 00260        TRA SETH1
00252  0 02000 0 00265        TRA SETH2
00253  0 50000 0 02366        CLA FX4
00254  0 34000 0 02341        CAS OUTKEY
00255  0 02000 0 00272        TRA SETH3
00256  0 02000 0 00277        TRA SETH4
00257  0 02000 0 00304        TRA SETH5
00260  0 50000 0 00363  SETH1 CLA PTH1
00261  0 60100 0 00312        STO PTH
00262  0 50000 0 02425        CLA TRALA
00263  0 62100 0 01664        STA OUT1-1
00264  0 02000 0 00310        TRA PTH-2
00265  0 50000 0 00364  SETH2 CLA PTH2
00266  0 60100 0 00312        STO PTH
00267  0 50000 0 02426        CLA TRALA+1
00270  0 62100 0 01664        STA OUT1-1
00271  0 02000 0 00310        TRA PTH-2
00272  0 50000 0 00365  SETH3 CLA PTH3
00273  0 60100 0 00312        STO PTH
00274  0 50000 0 02427        CLA TRALA+2
00275  0 62100 0 01664        STA OUT1-1
00276  0 02000 0 00310        TRA PTH-2
00277  0 50000 0 00366  SETH4 CLA PTH4
00300  0 60100 0 00312        STO PTH
00301  0 50000 0 02430        CLA TRALA+3
00302  0 62100 0 01664        STA OUT1-1
00303  0 02000 0 00310        TRA PTH-2
00304  0 50000 0 00367  SETH5 CLA PTH5
00305  0 60100 0 00312        STO PTH
00306  0 50000 0 02431        CLA TRALA+4
00307  0 62100 0 01664        STA OUT1-1
00310  0 07400 4 03271        TSX OUT,4                  ENTER OUTPUT ROUTINE FOR HEADING
00311  0 00000 0 00000        HTR
00312  3 47230 0 00370  PTH   PTH HEAD1,0,20120
00313 -1 00363 0 00364        FVE 244,0,243
00314  0 56000 0 02410        LDQ KFL               A2
00315  0 26000 0 02331        FMP NFL
00316  0 60100 0 14521        STO COMMON                 KNFL TO COMMON
00317  0 50000 0 02352        CLA 2PI
00320  0 24000 0 14521        FDH COMMON
00321 -0 60000 0 00773        STQ H1                     STORE H FOR RK1
00322 -0 60000 0 01511        STQ H2                     STORE H FOR RK2
00323  0 07400 4 00000 VARTRA TSX 0,4               A3   TRANSFER DEPENDS ON INPUT
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00324  0 56000 0 02403         LDQ BETA
00325 -0 60000 0 02414         STQ INITR                        BETA TO INITIAL R
00326 -0 60000 0 02544         STQ YRKY3-7                      BETA TO R.K
00327 -0 60000 0 02527         STQ R                            BETA TO R.K
00330 -0 60000 0 02403         STQ BETA                         BETA=P/E
00331  0 50000 0 02331         CLA NFL                    A6
00332  0 24000 0 02352         FDH 2PI
00333 -0 60000 0 02405         STQ NO2PI                        STORE N/2 PI
00334  0 60000 0 02530         STZ PR                     A6.5  INITIALIZE PR
00335  0 60000 0 02545         STZ YRKY3-6
00336  0 60000 0 02415         STZ INITPR
00337  0 50000 0 02350         CLA NURKY4
00340  0 60100 0 02347         STO NURKY3                       NO. OF EQUATIONS TO RK1
00341  0 56000 0 02333         LDQ KFX                    A7
00342  0 20000 0 02334         MPY NSTAR
00343  0 76300 0 00001         LLS 1
00344 -0 60000 0 02407         STQ BEER                         BEER=(2KN*)*=NO. OF WORDS/RECORD
00345  0 60000 0 02406         STZ BEERT                        ZERO TO BEERT
00346  0 53400 1 02407         LXA BEER,1                 A7.5  BEER TO IR1
00347 -0 63400 1 00474         SXD TW,1
00350 -0 63400 1 01127         SXD TIXN,1                       BEER TO DECREMENT
00351  0 60000 0 01533         STZ COUNT                        INITIALIZE DRUM RK COUNTER
00352  0 60000 0 01532         STZ DRADD                        0 TO DRUM ADDRESS
00353  0 50000 0 02344         CLA RIN                          SET FRIA INITIALLY WITH RIN
00354  0 60100 0 02434         STO FRIA
00355  0 60000 0 02433         STZ RHO1
00356  0 60000 0 02435         STZ RHO2
00357  0 60000 0 02442         STZ PRHO1
00360  0 60000 0 02443         STZ PRHO2
00361  0 60000 0 02475         STZ TCOUNT                       ZERO COUNTER OF TABLE ENTRIES
00362  0 02000 0 00475         TRA FAD1-7
00363  3 37340 0 00370   PTH1  PTH HEAD1,0,16096
00364  3 37340 0 00410   PTH2  PTH HEAD2,0,16096
00365  3 37340 0 00430   PTH3  PTH HEAD3,0,16096
00366  3 23514 0 00450   PTH4  PTH HEAD4,0,10060
00367  3 23514 0 00462   PTH5  PTH HEAD5,0,10060
00370  606047606060      HEAD1 BCD    P        E     BETA      TIME       COS       NU Z     NU R
00371  606060602560
00372  606060222563
00373  216060606060
00374  633144256060
00375  606060602346
00376  626060606060
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00377   456460716060
00400   606045646051
00401   606060606060
00402   604225606060          BCD 6 KE       R          PR     R AVE    AMP
00403   606060516060
00404   606060606060
00405   475160606060
00406   516021652560
00407   606060214447
00410   606025606060    HEAD2 BCD     E         P     BETA      TIME        COS       NU Z      NU R
00411   606060604760
00412   606060222563
00413   216060606060
00414   633144256060
00415   606060602346
00416   626060606060
00417   456460716060
00420   606045646051
00421   606060606060
00422   604225606060          BCD 6 KE       R          PR     R AVE    AMP
00423   606060516060
00424   606060606060
00425   475160606060
00426   516021652560
00427   606060214447
00430   222563216060    HEAD3 BCD  BETA      P        E         TIME        COS       NU Z      NU R
00431   606060476060
00432   606060606025
00433   606060606060
00434   633144256060
00435   606060602346
00436   626060606060
00437   456460716060
00440   606045646051
00441   606060606060
00442   604225606060          BCD 6 KE       R          PR     R AVE    AMP
00443   606060516060
00444   606060606060
00445   475160606060
00446   516021652560
00447   606060214447
00450   606047606060    HEAD4 BCD     P        E       TIME      NU Z      NU R      R          PR
00451   606060602560
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00452  606060606063
00453  314425606060
00454  606045646071
00455  606060606045
00456  646051606060
00457  606051606060
00460  606060606047
00461  516060606060
00462  606025606060     HEAD5 BCD    E          P        TIME      NU Z      NU R      R        PR
00463  606060604760
00464  606060606063
00465  314425606060
00466  606045646071
00467  606060606045
00470  646051606060
00471  606051606060
00472  606060606047
00473  516060606060
00474   1 00000 1 01124  TW     TXI CLAP,1,0
00475 -0 75400 0 00000          PXD                       A8   ZERO ACCUMULATOR
00476   0 56000 0 02355         LDQ MAXSTO
00477   0 22000 0 02407         DVH BEER
00500 -0 60000 0 02411          STQ RAP                        NO. OF R VALUES IN APIARY=RAP
00501   0 60000 0 02440         STZ RSPAN                 A8.5
00502   0 53400 2 02411         LXA RAP,2
00503   0 50000 0 02440         CLA RSPAN
00504   0 30000 0 02337  FAD1   FAD DELTAR
00505   0 60100 0 02440         STO RSPAN
00506   2 00001 2 00504         TIX FAD1,2,1                   R INCREMENT IN APIARY=R SPAN (FLPT)
00507   0 56000 0 02331         LDQ NFL                   A9
00510   0 26000 0 02331         FMP NFL
00511   0 60100 0 14521         STO COMMON                     N SQ TO COMMON
00512   0 50000 0 02353         CLA 1FL                        MAYBE CHANGED TO 2FL
00513   0 24000 0 14521         FDH COMMON
00514 -0 60000 0 02441          STQ 1ONSQ                      1/NSQ TO PERM. STORAGE
00515   0 26000 0 02403         FMP BETA                  A10
00516   0 60100 0 02404         STO RAMP                       RAMP=R AMPLITUDE FOR P
00517   0 50000 0 02403         CLA BETA                  A11
00520   0 30200 0 02404         FSB RAMP
00521   0 30200 0 02337         FSB DELTAR
00522   0 30200 0 02337         FSB DELTAR
00523   0 60100 0 02413         STO RMIN                       ESTIMATED R MIN. FOR P
00524   0 30200 0 02344         FSB RIN                   A12
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00525  0 24000 0 02337         FDH DELTAR
00526 -0 60000 0 14521         STQ COMMON                   FL. PT. TAPE LOCATION
00527  0 50000 0 14521         CLA COMMON
00530  0 07400 4 03213         TSX FLOFX,4                  ENTER FLOATING TO FIX ROUTINE
00531  0 00000 0 00043         PZE 35
00532  0 42000 0 00000         HPR
00533  0 60100 0 02432         STO MTLOC               A13
00534  0 10000 0 00550         TZE A135
00535 -0 12000 0 00550         TMI A135
00536  0 53400 2 02432         LXA MTLOC,2             A14
00537  0 50000 0 02434         CLA FRIA                     INITIALLY FRIA CONTAINS RIN
00540  0 30000 0 02337  FAD2   FAD DELTAR
00541  0 60100 0 02434         STO FRIA
00542  2 00001 2 00540         TIX FAD2,2,1                 FRIA=FIRST R IN APIARY
00543  0 53400 2 02432         LXA MTLOC,2
00544  0 76200 0 00221  SKIP   RTB 1                        SKIP TO INITIAL RECORD
00545  0 76200 0 00222         RTB 2
00546  2 00001 2 00544         TIX SKIP,2,1
00547  0 02000 0 00553         TRA A15
00550  0 60000 0 02432  A135   STZ MTLOC               A13.5
00551  0 50000 0 02344         CLA RIN
00552  0 60100 0 02434         STO FRIA
00553  0 53400 1 02411  A15    LXA RAP,1               A15  IR1 CONTAINS NUMBER OF RECORDS IN APIARY
00554  0 53400 2 02407  LXA1   LXA BEER,2                   IR2 CONTAINS NUMBER OF FIELDS/R VALUE
00555  0 50000 0 02356         CLA MAP                      COPY LOOP FOR READING FIELDS
00556  0 40200 0 02406         SUB BEERT
00557  0 62100 0 00565         STA CPY
00560  0 60000 0 02262         STZ RETRY+9                  ZEROCOUNTER
00561  0 76200 0 00221         RTB 1
00562  0 70000 0 14521         CPY COMMON
00563  0 02000 0 00565         TRA CPY
00564  0 02000 0 00575         TRA READER
00565  0 70000 2 00000  CPY    CPY 0,2
00566  2 00001 2 00565         TIX CPY,2,1
00567 -0 76000 0 00012         RTT                          REDUNDANCY TAPE CHECK
00570  0 07400 4 02251         TSX RETRY,4                  FAILED, TRY AGAIN
00571  0 50000 0 02406         CLA BEERT
00572  0 40000 0 02407         ADD BEER
00573  0 60100 0 02406         STO BEERT
00574  2 00001 1 00554         TIX LXA1,1,1                 INITIAL HIVE OF BEES IN APIARY
00575  0 76100 0 00000 READER  NOP
00576  0 60000 0 02406         STZ BEERT                    LOAD IRS FOR READING DERIVATIVES
00577  0 53400 1 02411         LXA RAP,1
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00600   0 53400 2 02407  LXA2   LXA BEER,2
00601   0 50000 0 02357         CLA MAD
00602   0 40200 0 02406         SUB BEERT
00603   0 62100 0 00611         STA CPYCAT
00604   0 60000 0 02274         STZ RETRY2+9                ZERO COUNTER FOR TRYING TO REREAD.
00605   0 76200 0 00222         RTB 2
00606   0 70000 0 14521         CPY COMMON
00607   0 02000 0 00611         TRA CPYCAT
00610   0 02000 0 00627         TRA A154+6
00611   0 70000 2 00000 CPYCAT  CPY 0,2                     COPY LOOP FOR DERIVATIVES
00612   2 00001 2 00611         TIX CPYCAT,2,1
00613  -0 76000 0 00012         RTT                         REDUNDANCY TAPE CHECK
00614   0 07400 4 02263         TSX RETRY2,4                FAILED, TRY AGAIN
00615   0 50000 0 02406         CLA BEERT
00616   0 40000 0 02407         ADD BEER
00617   0 60100 0 02406         STO BEERT
00620   2 00001 1 00600         TIX LXA2,1,1                INITIAL BAND OF DER. IN MEMORY
00621   0 50000 0 02434  A154   CLA FRIA               A15.4
00622   0 76600 0 00333         IOD 219                     I-O DELAY
00623   0 30000 0 02440         FAD RSPAN
00624   0 60100 0 02436         STO MARIA                   MARIA=MAX R IN APIARY
00625   0 76100 0 00000         NOP
00626   0 02000 0 00635         TRA A154+12
00627   0 50000 0 02162         CLA Z28+7
00630   0 60100 0 00623         STO A154+2
00631   0 02000 0 00621         TRA A154
00632   0 76100 0 00000         NOP
00633   0 76100 0 00000         NOP
00634   0 76100 0 00000         NOP
00635   0 07400 4 00730         TSX OROUT,4            A16
00636   0 56000 0 02403         LDQ BETA               R1   CALCULATE AND STORE NEW R GUESS FOR NEW P
00637   0 26000 0 02433         FMP RHO1                    WHERE R=BETA(1+RHO)
00640   0 30000 0 02403         FAD BETA
00641   0 60100 0 02414         STO INITR
00642   0 60100 0 02527         STO R
00643   0 60100 0 02544         STO YRKY3-7
00644   0 56000 0 02332         LDQ P                  R2   CALCULATE AND STORE NEW PR GUESS FOR NEW P
00645   0 26000 0 02442         FMP PRHO1                   PR=P(PRHO1)
00646   0 60100 0 02415         STO INITPR
00647   0 60100 0 02545         STO YRKY3-6
00650   0 60100 0 02530         STO PR
00651   0 07400 4 00730         TSX OROUT,4            R3
00652   0 50000 0 02433         CLA RHO1               R4
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00653  0 30000 0 02433          FAD RHO1
00654  0 30200 0 02435          FSB RHO2
00655  0 60100 0 02421          STO RHO                      RHO=2RHO1-RHO2
00656  0 50000 0 02442          CLA PRHO1
00657  0 30000 0 02442          FAD PRHO1
00660  0 30200 0 02443          FSB PRHO2
00661  0 60100 0 02445          STO PRHO                     PRHO=2PRHO1-PRHO2
00662  0 56000 0 02403          LDQ BETA              R5
00663  0 26000 0 02421          FMP RHO
00664  0 30000 0 02403          FAD BETA
00665  0 60100 0 02527          STO R
00666  0 60100 0 02414          STO INITR
00667  0 60100 0 02544          STO YRKY3-7                  R=BETA(1+RHO)=INITIAL R GUESS
00670  0 56000 0 02332          LDQ P                 R6
00671  0 26000 0 02445          FMP PRHO
00672  0 60100 0 02530          STO PR
00673  0 60100 0 02415          STO INITPR
00674  0 60100 0 02545          STO YRKY3-6                  PR=PXPRHO=INITIAL GUESS
00675  0 07400 4 00730   ENTER  TSX OROUT,4           R7     TRANSFER TO O-ROUTINE
00676  0 50000 0 02433          CLA RHO1              R8
00677  0 30200 0 02435          FSB RHO2
00700  0 60100 0 14521          STO COMMON
00701  0 56000 0 14521          LDQ COMMON
00702  0 26000 0 02361          FMP 3FL
00703  0 30000 0 02437          FAD RHO3
00704  0 60100 0 02421          STO RHO                      RHO=3RHO1-3RHO2+RHO3
00705  0 50000 0 02442          CLA PRHO1             R10
00706  0 30200 0 02443          FSB PRHO2
00707  0 60100 0 14521          STO COMMON
00710  0 56000 0 14521          LDQ COMMON
00711  0 26000 0 02361          FMP 3FL
00712  0 30000 0 02444          FAD PRHO3
00713  0 60100 0 02445          STO PRHO                     PRHO=3(PRHO1-PRHO2)+PRHO3
00714  0 56000 0 02403          LDQ BETA              R9
00715  0 26000 0 02421          FMP RHO
00716  0 30000 0 02403          FAD BETA
00717  0 60100 0 02527          STO R
00720  0 60100 0 02414          STO INITR
00721  0 60100 0 02544          STO YRKY3-7                  R=BETA(1+RHO) (3 PTS USED)
00722  0 56000 0 02445          LDQ PRHO              R11
00723  0 26000 0 02332          FMP P
00724  0 60100 0 02530          STO PR
00725  0 60100 0 02415          STO INITPR
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00726  0 60100 0 02545         STO YRKY3-6              PR=P(PRHO) (3PTSUSED)
00727  0 02000 0 00675         TRA ENTER
00730 -0 63400 4 02654  OROUT  SXD JUNK,4          0.05
00731  0 60000 0 02417         STZ TEMP2           01
00732  0 60000 0 02535  RENT   STZ THETA           02   INITIALIZE R.K.1+RK2
00733  0 60000 0 02532         STZ PX1
00734  0 60000 0 02533         STZ X2
00735  0 60000 0 02552         STZ YRKY3-1
00736  0 60000 0 02550         STZ YRKY3-3
00737  0 60000 0 02547         STZ YRKY3-4
00740  0 50000 0 02353         CLA 1FL             03
00741  0 60100 0 02531         STO X1
00742  0 60100 0 02534         STO PX2
00743  0 60100 0 02551         STO YRKY3-2
00744  0 60100 0 02546         STO YRKY3-5
00745  0 60000 0 02451         STZ TC              04.5 ZERO TEST COUNTER
00746  0 50000 0 02451         CLA TC                   ZERO TXI DECREMENT
00747  0 62200 0 01123         STD TXI
00750  0 50000 0 02407         CLA BEER            04
00751  0 77100 0 00001         ARS 1
00752  0 73400 1 00000         PAX 0,1                  BEER/2 TO IR1
00753  0 50000 0 02417         CLA TEMP2           05
00754  0 12000 0 00763         TPL 056
00755  0 50000 0 01140         CLA FORSU           05.5  SET UP ORDERS FOR Z-EQUATIONS
00756  0 62200 0 01126         STD CLAP+2
00757  0 50000 0 00762         CLA NOP
00760  0 62200 0 01406         STD K23
00761  0 02000 0 01464         TRA ZROUT
00762  0 76100 0 00000  NOP    NOP                      USED FOR SETTING ORDERS
00763  0 50000 0 00762  056    CLA NOP             05.6
00764  0 62200 0 01126         STD CLAP+2
00765  0 53400 2 02350         LXA NURKY4,2        06   SET UP TO REENTER R.K.1
00766  0 60000 2 02654  STZ1   STZ QRKY3,2
00767  2 00001 2 00766         TIX STZ1,2,1
00770  0 50000 0 01140         CLA FORSU           07
00771  0 62200 0 01406         STD K23
00772  0 07400 4 03000  RK1    TSX RKY3,4          08   ENTER RUNGA-KUTTA WITH BEER/2 IN I.R.1
00773  0 42000 0 00000  H1     HPR
00774  2 00001 1 00772         TIX RK1,1,1         09
00775  0 50000 0 02527         CLA R               010
00776  0 30200 0 02414         FSB INITR
00777  0 60100 0 14521         STO COMMON               EPSILON R IN COMMON
01000  0 50000 0 02530         CLA PR
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01001  0 30200 0 02415          FSB INITPR
01002  0 60100 0 14522          STO COMMON+1          EPSILON PR IN COMMON+1
01003  0 76000 0 00003          SSP
01004  0 60100 0 14523          STO COMMON+2
01005  0 50000 0 14521          CLA COMMON
01006  0 76000 0 00003          SSP
01007  0 30000 0 14523          FAD COMMON+2
01010  0 30200 0 02360          FSB EPS
01011  0 60100 0 02417          STO TEMP2             TO TEST FOR EQUI. ORBIT
01012  0 50000 0 02534          CLA PX2               NEWR,PRGUESS
01013  0 30200 0 02353          FSB 1FL
01014  0 24000 0 02533          FDH X2
01015 -0 60000 0 14523          STQ COMMON+2          (ALPHA22-1)/(ALPHA21) IN COMMON+2
01016  0 26000 0 14521          FMP COMMON
01017  0 30200 0 14522          FSB COMMON+1
01020  0 60100 0 14524          STO COMMON+3          NUMERATOR OF A
01021  0 56000 0 14523          LDQ COMMON+2
01022  0 26000 0 02531          FMP X1
01023  0 30200 0 14523          FSB COMMON+2
01024  0 30200 0 02532          FSB PX1
01025  0 60100 0 14525          STO COMMON+4          DENOMINATOR OF A
01026  0 50000 0 14524          CLA COMMON+3
01027  0 24000 0 14525          FDH COMMON+4
01030 -0 60000 0 14522          STQ COMMON+1          A IN COMMON+1
01031  0 50000 0 02414          CLA INITR
01032  0 30200 0 14522          FSB COMMON+1
01033  0 60100 0 02414          STO INITR
01034  0 60100 0 02527          STO R
01035  0 60100 0 02544          STO YRKY3-7           NEW R
01036  0 56000 0 14522          LDQ COMMON+1
01037  0 26000 0 02531          FMP X1
01040  0 30200 0 14522          FSB COMMON+1
01041  0 76000 0 00002          CHS
01042  0 30000 0 14521          FAD COMMON
01043  0 24000 0 02533          FDH X2
01044 -0 60000 0 14523          STQ COMMON+2          B IN COMMON+2
01045  0 50000 0 02415          CLA INITPR
01046  0 30200 0 14523          FSB COMMON+2
01047  0 60100 0 02415          STO INITPR
01050  0 60100 0 02530          STO PR
01051  0 60100 0 02545          STO YRKY3-6           NEW PR GUESS STORED
01052  0 02000 0 00732          TRA RENT
01053  0 50000 0 02527    BEEP  CLA R          B1
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01054  0 30200 0 02434         FSB FRIA
01055  0 24000 0 02337         FDH DELTAR
01056 -0 60000 0 14521         STQ COMMON
01057  0 50000 0 14521         CLA COMMON           B2    FIX=NO. OF R VALUES R IS FROM APIARY
01060  0 07400 4 03213         TSX FLOFX,4
01061  0 00000 0 00043         PZE 35
01062  0 42000 0 00000         HPR                  B3    FLT=FIX FLOATED
01063  0 60100 0 02453         STO FIX
01064  0 10000 0 02012         TZE Z12
01065  0 07400 4 03233         TSX FXFLO,4
01066  0 00000 0 00043         PZE 35
01067  0 42000 0 00000         HPR
01070  0 60100 0 02454         STO FLT
01071  0 56000 0 02454         LDQ FLT              B4    CALCULATE R2 FOR INTERPOLATION
01072  0 26000 0 02337         FMP DELTAR
01073  0 30000 0 02434         FAD FRIA
01074  0 60100 0 02502         STO R2
01075  0 56000 0 02453         LDQ FIX              B5    INT=RELATIVE ADDRESS OF R2 FROM APIARY
01076  0 20000 0 02407         MPY BEER
01077 -0 60000 0 02452         STQ INT
01100  0 50000 0 02452         CLA INT              B6
01101  0 40000 0 02407         ADD BEER
01102  0 40000 0 02407         ADD BEER
01103  0 40000 0 02363         ADD FX1
01104  0 73400 1 00000         PAX 0,1                    LOAD IR1 WITH REL. ADDRESS OF R4
01105  0 53400 2 02366         LXA FX4,2            B7    4 IN IR2
01106  0 50000 0 02451         CLA TC               B8
01107  0 76000 0 00001         LBT
01110  0 02000 0 01120         TRA INCTC                  WHEN C(AC)35=0
01111  0 50000 0 01123         CLA TXI                    WHEN C(AC)35=1
01112  0 40000 0 02400         ADD BIT
01113  0 62200 0 01123         STD TXI
01114  0 34000 0 00474         CAS TW
01115  0 00000 0 01115  TOFAR  HTR TOFAR                  STOP  THETA TOO LARGE
01116  0 02000 0 01133         TRA SETDC                  WHEN THETA=2 PI/N
01117  0 76100 0 00000         NOP
01120  0 50000 0 02451  INCTC  CLA TC                     INCREASE TEST COUNTER
01121  0 40000 0 02363         ADD FX1
01122  0 60100 0 02451         STO TC
01123  1 00000 1 01124  TXI    TXI CLAP,1,0               ADVANCES THETA PICK-UP
01124  0 50000 1 10321  CLAP   CLA APIARY,1
01125  0 60100 2 02465         STO B5,2                   FIELDS FOR INTERPOLATION STORED
01126  0 76100 0 01136         NOP BFORZ                  NOP TO TRA TO PICK UP DTHETA
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01127  2 00000 1 01131  TIXN   TIX NEXT,1,0                 DECREMENT IR1 BY BEER
01130  0 76100 0 00000         NOP
01131  2 00001 2 01124  NEXT   TIX CLAP,2,1
01132  0 02000 0 01154         TRA RIGHT+1                  ALL 4 FIELDS FOR INTER. STORED
01133 -0 75400 0 00000  SETDC  PXD
01134  0 62200 0 01123         STD TXI                      SET UP INCREMENT FOR THETA=2 PI/N
01135  0 02000 0 01120         TRA INCTC
01136  0 50000 1 14521  BFORZ  CLA BTHETA,1
01137  0 60100 2 02472         STO DB5,2                    B DERIVATIVES STORED TO INTERPOLATE
01140  0 02000 0 01127  FORSU  TRA TIXN
01141 -0 63400 1 02655  WRKY3  SXD JUNK+1,1          K1     STORE ALL I.R.S
01142 -0 63400 2 02656         SXD JUNK+2,2
01143 -0 63400 4 02657         SXD JUNK+3,4
01144  0 50000 0 02527         CLA R                 K2     TEST ON SUFFICIENT FIELDS FOR INTERPOLATION
01145  0 30000 0 02337         FAD DELTAR
01146  0 60100 0 14521         STO COMMON
01147  0 56000 0 14521         LDQ COMMON
01150  0 50000 0 02436         CLA MARIA
01151  0 04000 0 01153         TLQ RIGHT             K3
01152  0 42000 0 00000         HPR                          STOP NEED MORE FIELDS
01153  0 02000 0 01053  RIGHT  TRA BEEP              K5     TO PICK UP BEES AND DERIVATIVES
01154  0 50000 0 02527         CLA R                 K6
01155  0 30200 0 02502         FSB R2
01156  0 24000 0 02337         FDH DELTAR
01157 -0 60000 0 02450         STQ X                        X=(R-R2)/DELTA R
01160  0 26000 0 02450         FMP X                        X USED IN INTER. POLY.
01161  0 60100 0 02447         STO XSQ                      X SQUARED=XSQ
01162  0 56000 0 02447         LDQ XSQ
01163  0 26000 0 02450         FMP X
01164  0 60100 0 02446         STO XCUB                     X CUBED=XCUB
01165  0 30200 0 02450         FSB X                 K8     CALCULATE INTER. COEFF.=
01166  0 60100 0 14521         STO COMMON                   A1,A2,A3,ANDA4
01167  0 24000 0 02370         FDH 6FL
01170 -0 60000 0 02455         STQ A4                       A4=1/6(X CUBED-X)
01171  0 56000 0 14521         LDQ COMMON
01172  0 26000 0 02373         FMP HALF
01173  0 30200 0 02447         FSB XSQ
01174  0 30000 0 02353         FAD 1FL
01175  0 60100 0 02457         STO A2                       A2=(X CUBE-2X SQ-X+2)/2
01176  0 50000 0 14521         CLA COMMON
01177  0 30200 0 02450         FSB X
01200  0 30200 0 02447         FSB XSQ
01201  0 76000 0 00002         CHS
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01202   0 24000 0 02354     FDH 2FL
01203  -0 60000 0 02456     STQ A3                    A3=-(X CUBE-X SQ-2X)/2
01204   0 50000 0 02447     CLA XSQ
01205   0 30200 0 02450     FSB X
01206   0 24000 0 02354     FDH 2FL
01207  -0 60000 0 14521     STQ COMMON                (X SQ-X)/2 IN COMMON
01210   0 50000 0 14521     CLA COMMON
01211   0 30200 0 02455     FSB A4
01212   0 60100 0 02460     STO A1                    A1=-(X CUBE-3X SQ+2X)/6
01213   0 56000 0 02447     LDQ XSQ              K9   CALCULATE COEFFICIENTS FOR R DERIVATIVES
01214   0 26000 0 02373     FMP HALF
01215   0 60100 0 14521     STO COMMON                1/2 X SQUARE IN COMMON
01216   0 30200 0 02374     FSB SIXTH
01217   0 60100 0 14525     STO COMMON+4              A4*=1/2X SQ-1/6
01220   0 50000 0 02450     CLA X
01221   0 30200 0 14521     FSB COMMON
01222   0 30200 0 02375     FSB THIRD
01223   0 60100 0 14522     STO COMMON+1              A1*=-X SQ/2+X-1/3
01224   0 56000 0 14521     LDQ COMMON
01225   0 26000 0 02361     FMP 3FL
01226   0 60100 0 14521     STO COMMON
01227   0 30200 0 02450     FSB X
01230   0 30200 0 02353     FSB 1FL
01231   0 76000 0 00002     CHS
01232   0 60100 0 14524     STO COMMON+3              A3*=-3X SQ/2+X+1
01233   0 50000 0 14521     CLA COMMON
01234   0 30200 0 02450     FSB X
01235   0 30200 0 02450     FSB X
01236   0 30200 0 02373     FSB HALF
01237   0 60100 0 14523     STO COMMON+2              A2*=3X SQ/2-2X-1/2
01240   0 56000 0 14522     LDQ COMMON+1         K10  DBDR=A1*B1+A2*B2+A3*B3+A4*B4
01241   0 26000 0 02464     FMP B1
01242   0 60100 0 14522     STO COMMON+1              A1*B1 IN COMMON+1
01243   0 56000 0 14523     LDQ COMMON+2
01244   0 26000 0 02463     FMP B2
01245   0 30000 0 14522     FAD COMMON+1
01246   0 60100 0 14522     STO COMMON+1
01247   0 56000 0 14524     LDQ COMMON+3
01250   0 26000 0 02462     FMP B3
01251   0 30000 0 14522     FAD COMMON+1
01252   0 60100 0 14522     STO COMMON+1
01253   0 56000 0 14525     LDQ COMMON+4
01254   0 26000 0 02461     FMP B4
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01255  0 30000 0 14522        FAD COMMON+1
01256  0 24000 0 02337        FDH DELTAR
01257 -0 60000 0 02476        STQ DBDR
01260  0 56000 0 02460        LDQ A1               K11  B=A1B1+A2B2+A3B3+A4B4
01261  0 26000 0 02464        FMP B1
01262  0 60100 0 14522        STO COMMON+1
01263  0 56000 0 02457        LDQ A2
01264  0 26000 0 02463        FMP B2
01265  0 30000 0 14522        FAD COMMON+1
01266  0 60100 0 14522        STO COMMON+1
01267  0 56000 0 02456        LDQ A3
01270  0 26000 0 02462        FMP B3
01271  0 30000 0 14522        FAD COMMON+1
01272  0 60100 0 14522        STO COMMON+1
01273  0 56000 0 02455        LDQ A4
01274  0 26000 0 02461        FMP B4
01275  0 30000 0 14522        FAD COMMON+1
01276  0 60100 0 02477        STO B
01277  0 56000 0 02530        LDQ PR               K12
01300  0 26000 0 02530        FMP PR
01301  0 60100 0 14521        STO COMMON                PR SQUARED IN COMMON
01302  0 50000 0 02401        CLA PSQ
01303  0 30200 0 14521        FSB COMMON
01304  0 60100 0 14521        STO COMMON                P SQ-PR SQ IN COMMON
01305  0 07400 4 03162        TSX SQRT,4           K13  ENTER SQUARE ROOT ROUTINE
01306  0 42000 0 01306  SQRTQ HPR SQRTQ
01307  0 60100 0 02474        STO QINV             K14  SQ RT(P SQ-PR SQ)=Q INVERSE
01310  0 50000 0 02353        CLA 1FL
01311  0 24000 0 02474        FDH QINV
01312 -0 60000 0 02500        STQ QBALL                 Q BALL=1/SQRT(PSQ-PRSQ)
01313  0 26000 0 02530        FMP PR               K15
01314  0 60100 0 14521        STO COMMON                QPR IN COMMON
01315  0 56000 0 14521        LDQ COMMON
01316  0 26000 0 02527        FMP R
01317  0 60100 0 02630        STO VRKY3-7
01320  0 56000 0 02527        LDQ R                K16
01321  0 26000 0 02477        FMP B
01322  0 30200 0 02474        FSB QINV
01323  0 76000 0 00002        CHS
01324  0 60100 0 02631        STO VRKY3-6               F(PR)=Q INV-RB
01325  0 56000 0 02527        LDQ R                K17
01326  0 26000 0 02476        FMP DBDR
01327  0 60100 0 14526        STO COMMON+5              R(DBDR) IN COMMON+5
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01330  0 30000 0 02477       FAD B
01331  0 60100 0 14523       STO COMMON+2                 B+R(DBDR) IN COMMON+2
01332  0 56000 0 02500       LDQ QBALL
01333  0 26000 0 02527       FMP R
01334  0 60100 0 14524       STO COMMON+3                 RQ IN COMMON+3
01335  0 56000 0 02500       LDQ QBALL
01336  0 26000 0 02500       FMP QBALL
01337  0 60100 0 14522       STO COMMON+1
01340  0 56000 0 14522       LDQ COMMON+1
01341  0 26000 0 02401       FMP PSQ
01342  0 60100 0 14522       STO COMMON+1                 (P SQUARED)(Q SQUARED) IN COMMON+1
01343  0 56000 0 14522       LDQ COMMON+1
01344  0 26000 0 14524       FMP COMMON+3
01345  0 60100 0 14525       STO COMMON+4                 P SQ R Q CUBED IN COMMON+4
01346  0 56000 0 02531       LDQ X1               K18
01347  0 26000 0 14521       FMP COMMON
01350  0 60100 0 14522       STO COMMON+1
01351  0 56000 0 02532       LDQ PX1
01352  0 26000 0 14525       FMP COMMON+4
01353  0 30000 0 14522       FAD COMMON+1
01354  0 60100 0 02632       STO VRKY3-5                  F(X1)=(Q PR)X1+(P SQ R Q CUBED)PX1
01355  0 56000 0 02533       LDQ X2               K19
01356  0 26000 0 14521       FMP COMMON
01357  0 60100 0 14522       STO COMMON+1
01360  0 56000 0 02534       LDQ PX2
01361  0 26000 0 14525       FMP COMMON+4
01362  0 30000 0 14522       FAD COMMON+1
01363  0 60100 0 02634       STO VRKY3-3                  F(X2)=(QR)X2+(P SQ R Q CUBED)PX2
01364  0 56000 0 14521       LDQ COMMON           K20
01365  0 26000 0 02532       FMP PX1
01366  0 60100 0 14522       STO COMMON+1
01367  0 56000 0 02531       LDQ X1
01370  0 26000 0 14523       FMP COMMON+2
01371  0 30000 0 14522       FAD COMMON+1
01372  0 76000 0 00002       CHS
01373  0 60100 0 02633       STO VRKY3-4                  F(PX1)=(-QPR)PX1-(B+RDBDR)X1
01374  0 56000 0 14521       LDQ COMMON           K21
01375  0 26000 0 02534       FMP PX2
01376  0 60100 0 14522       STO COMMON+1
01377  0 56000 0 02533       LDQ X2
01400  0 26000 0 14523       FMP COMMON+2
01401  0 30000 0 14522       FAD COMMON+1
01402  0 76000 0 00002       CHS
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01403  0 60100 0 02635          STO VRKY3-2                F(PX2) STORED
01404  0 50000 0 02353          CLA 1FL              K22
01405  0 60100 0 02636          STO VRKY3-1                F(THETA)
01406  0 02000 0 01460   K23    TRA KEXIT            K23
01407  0 56000 0 02460          LDQ A1               K24   THETA DERIVATIVE=A1 DB1+A2 DB2+A3 DB3+A4 DB4
01410  0 26000 0 02471          FMP DB1
01411  0 60100 0 14522          STO COMMON+1
01412  0 56000 0 02457          LDQ A2
01413  0 26000 0 02470          FMP DB2
01414  0 30000 0 14522          FAD COMMON+1
01415  0 60100 0 14522          STO COMMON+1
01416  0 56000 0 02456          LDQ A3
01417  0 26000 0 02467          FMP DB3
01420  0 30000 0 14522          FAD COMMON+1
01421  0 60100 0 14522          STO COMMON+1
01422  0 56000 0 02455          LDQ A4
01423  0 26000 0 02466          FMP DB4
01424  0 30000 0 14522          FAD COMMON+1
01425  0 60100 0 02501          STO DTHETA
01426  0 56000 0 14524          LDQ COMMON+3         K25
01427  0 26000 0 02402          FMP E
01430  0 60100 0 14522          STO COMMON+1
01431  0 56000 0 14522          LDQ COMMON+1
01432  0 26000 0 02405          FMP NO2PI
01433  0 60100 0 02627          STO VRKY3-8                F(T)=ERQN/2PI
01434  0 56000 0 02527          LDQ R                K26
01435  0 26000 0 02405          FMP NO2PI
01436  0 60100 0 02622          STO VRKY3-13               F(R AVE)=RN/2PI
01437  0 56000 0 14524          LDQ COMMON+3         K27
01440  0 26000 0 02523          FMP PZ1
01441  0 60100 0 02623          STO VRKY3-12               F(Z1)=(RQ)PZ1
01442  0 56000 0 14524          LDQ COMMON+3         K28
01443  0 26000 0 02525          FMP PZ2
01444  0 60100 0 02625          STO VRKY3-10               F(Z2)=(RQ)PZ2
01445  0 56000 0 14521          LDQ COMMON           K29
01446  0 26000 0 02501          FMP DTHETA
01447  0 30200 0 14526          FSB COMMON+5
01450  0 76000 0 00002          CHS
01451  0 60100 0 14527          STO COMMON+6
01452  0 56000 0 14527          LDQ COMMON+6
01453  0 26000 0 02522          FMP Z1
01454  0 60100 0 02624          STO VRKY3-11               F(PZ1)=(R DBDR-Q PR DTHETA)Z1
01455  0 56000 0 14527          LDQ COMMON+6         K30
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01456  0 26000 0 02524         FMP Z2
01457  0 60100 0 02626         STO VRKY3-9                 F(PZ2)
01460 -0 53400 1 02655  KEXIT  LXD JUNK+1,1
01461 -0 53400 2 02656         LXD JUNK+2,2
01462 -0 53400 4 02657         LXD JUNK+3,4
01463  0 02000 4 00001         TRA 1,4
01464  0 50000 0 02351  ZROUT  CLA NURKY5             Z ROUT   13 EQUATIONS TO BE SOLVED R.K.2
01465  0 60100 0 02347         STO NURKY3                  13 EQUATIONS TO BE SOLVED RK2
01466  0 53400 2 02347         LXA NURKY3,2
01467  0 60000 2 02654  STZ2   STZ QRKY3,2
01470  2 00001 2 01467         TIX STZ2,2,1                Q BANK ZEROED
01471  0 60000 0 02524         STZ Z2                 Z2   INITIALIZE RK2
01472  0 60000 0 02523         STZ PZ1
01473  0 60000 0 02541         STZ YRKY3-10
01474  0 60000 0 02540         STZ YRKY3-11
01475  0 60000 0 02526         STZ TIME
01476  0 60000 0 02521         STZ RAVE
01477  0 60000 0 02536         STZ YRKY3-13
01500  0 60000 0 02543         STZ YRKY3-8
01501  0 50000 0 02353         CLA 1FL                Z3
01502  0 60100 0 02522         STO Z1
01503  0 60100 0 02525         STO PZ2
01504  0 60100 0 02542         STO YRKY3-9
01505  0 60100 0 02537         STO YRKY3-12
01506  0 60100 0 02506         STO MINA                    1FL IN CELL TO LOCATE MINIMUM R
01507  0 60000 0 02507         STZ MAXA                    0 IN CELL TO LOCATE MAXIMUM R
01510  0 07400 4 03000  RK2    TSX RKY3,4             Z4   ENTER RUNGA-KUTTA 2
01511  0 42000 0 00000  H2     HPR
01512 -0 63400 1 02660         SXD JUNK+4,1                STORE I.R.1
01513  0 76100 0 01541         NOP NUGOON             Z5   STORE JUNK ON DRUMS
01514  0 53400 1 02351         LXA NURKY5,1                PUT 13 IN I.R.1
01515  0 76600 0 00301  WDR1   WDR 193                     SELECT DRUM
01516  0 46000 0 01532         LDA DRADD                   LOCATE DRUM ADDRESS
01517  0 70000 1 02536  COPY   CPY THETA+1,1               COPY 13 WORDS ON DRUM
01520  2 00001 1 01517         TIX COPY,1,1
01521  0 50000 0 01533         CLA COUNT
01522  0 40000 0 02363         ADD FX1
01523  0 60100 0 01533         STO COUNT                   INCREASE DRUM COUNTER
01524  0 40200 0 02365         SUB ST157                   IS COUNTER=157
01525  0 12000 0 01534         TPL REDRUM                  YES, GO TO REDRUM
01526  0 50000 0 01532         CLA DRADD                   NO,
01527  0 40000 0 02351         ADD NURKY5
01530  0 60100 0 01532         STO DRADD                   INCREASE DRUM ADDRESS BY 13
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01531  0 02000 0 01541         TRA NUGOON
01532  0 00000 0 00000  DRADD  HTR                           DRUM ADDRESS COUNTER
01533  0 00000 0 00000  COUNT  HTR                           NO. OF RK STEPS PER DRUM
01534  0 60000 0 01532 REDRUM  STZ DRADD                     SET DRUM ADDRESS ZERO
01535  0 60000 0 01533         STZ COUNT                     SET COUNTER=0
01536  0 50000 0 01515         CLA WDR1
01537  0 40000 0 02363         ADD FX1
01540  0 60100 0 01515         STO WDR1
01541  0 50000 0 02527 NUGOON  CLA R                Z5.5
01542  0 56000 0 02506         LDQ MINA
01543  0 04000 0 01545         TLQ NUGOON+4
01544  0 60100 0 02506         STO MINA
01545  0 56000 0 02507         LDQ MAXA
01546  0 04000 0 01550         TLQ NUGOON+7
01547  0 02000 0 01551         TRA GOON
01550  0 60100 0 02507         STO MAXA
01551 -0 53400 1 02660  GOON   LXD JUNK+4,1         Z6
01552  2 00001 1 01510         TIX RK2,1,1                   FINAL PASS THRU ORBIT COMPLETED
01553  0 56000 0 02533         LDQ X2               Z7
01554  0 26000 0 02532         FMP PX1
01555  0 60100 0 14521         STO COMMON                    ALPHA 12 X ALPHA 21 IN COMMON
01556  0 56000 0 02531         LDQ X1                        ALPHA 11 X ALPHA 22
01557  0 26000 0 02534         FMP PX2
01560  0 30200 0 14521         FSB COMMON                    ALPHA DETERMINANT - 1
01561  0 30200 0 02353         FSB 1FL
01562  0 76000 0 00003         SSP
01563  0 30200 0 02364         FSB EPS2                      ABSOLUTE VALUE OF (ALPHADET.-1)
01564 -0 12000 0 01566         TMI PAT                       -EPSILON2
01565  0 00000 0 00000         HTR                           FLUNKED
01566  0 56000 0 02524  PAT    LDQ Z2                        PASSED ALPHA TEST
01567  0 26000 0 02523         FMP PZ1
01570  0 60100 0 14521         STO COMMON                    BETA 12 X BETA 21
01571  0 56000 0 02522         LDQ Z1
01572  0 26000 0 02525         FMP PZ2
01573  0 30200 0 14521         FSB COMMON
01574  0 30200 0 02353         FSB 1FL
01575  0 76000 0 00003         SSP
01576  0 30200 0 02364         FSB EPS2
01577 -0 12000 0 01601         TMI PBT
01600  0 00000 0 00000         HTR                           FLUNKED BETA TEST
01601  0 50000 0 02531  PBT    CLA X1               Z8
01602  0 30000 0 02534         FAD PX2
01603  0 24000 0 02354         FDH 2FL                       COS SIGMA R
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01604 -0 60000 0 02416         STQ CSR                    IN CSR
01605  0 50000 0 02522         CLA Z1
01606  0 30000 0 02525         FAD PZ2
01607  0 24000 0 02354         FDH 2FL
01610 -0 60000 0 02420         STQ CSZ                    COS SIGMA Z IN CSZ
01611  0 50000 0 02527         CLA R              Z8.3
01612  0 30200 0 02414         FSB INITR
01613  0 76000 0 00003         SSP
01614  0 60100 0 14521         STO COMMON
01615  0 50000 0 02530         CLA PR
01616  0 30200 0 02415         FSB INITPR
01617  0 76000 0 00003         SSP
01620  0 30000 0 14521         FAD COMMON
01621  0 60100 0 02473         STO EPI
01622  0 50000 0 02416         CLA CSR            Z8.35
01623  0 07400 4 02664         TSX ARCOS,4
01624  0 02000 0 01641         TRA CSRO
01625  0 60100 0 14521         STO COMMON
01626  0 56000 0 14521         LDQ COMMON
01627  0 26000 0 02405         FMP NO2PI
01630  0 60100 0 02503         STO NUR                    NUR=N/2PI ARC COS(SIGMA R)
01631  0 50000 0 02420  CALNU  CLA CSZ
01632  0 07400 4 02664         TSX ARCOS,4
01633  0 02000 0 01645         TRA CSRO+4
01634  0 60100 0 14521         STO COMMON
01635  0 56000 0 14521         LDQ COMMON
01636  0 26000 0 02405         FMP NO2PI
01637  0 60100 0 02504         STO NUZ                    NUZ=N/2PI ARC COS(SIGMA Z)
01640  0 02000 0 01651         TRA Z84
01641  0 50000 0 02416  CSRO   CLA CSR
01642  0 30000 0 02377         FAD FL90
01643  0 60100 0 02503         STO NUR                    COS R OVER ONE. 90+COS R OUTPUT
01644  0 02000 0 01631         TRA CALNU
01645  0 50000 0 02420         CLA CSZ
01646  0 30000 0 02377         FAD FL90
01647  0 60100 0 02504         STO NUZ                    COS Z OVER ONE, 90+COS Z OUTPUT
01650  0 02000 0 01651         TRA Z84
01651  0 50000 0 02507  Z84    CLA MAXA           Z8.4
01652  0 30200 0 02506         FSB MINA
01653  0 24000 0 02354         FDH 2FL
01654 -0 60000 0 02510         STQ AMP                    AMP=(MAX R-MIN R)/2
01655  0 56000 0 02402         LDQ E
01656  0 26000 0 02376         FMP FL938
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01657  0 30200 0 02376          FSB FL938
01660  0 60100 0 14521          STO COMMON                  (E-1)938.23 IN COMMON
01661  0 56000 0 14521          LDQ COMMON
01662  0 26000 0 02330          FMP AMORT
01663  0 60100 0 02505          STO KE                      KE=(E-1)938.23A
01664  0 02000 0 00000          TRA                         TO BE FILLED IN BY CODE
01665  0 07400 4 03271   OUT1   TSX OUT,4               Z8.5 OUTPUT ROUTINE 1
01666  0 00000 0 01665          HTR OUT1                    OUTPUT ERROR RETURN
01667 -3 07646 0 02332          SVN P,0,4006                P OUT
01670 -3 07656 0 02402          SVN E,0,4014                E OUT
01671 -3 07665 0 02403          SVN BETA,0,4021             BETA OUT
01672 -3 11646 0 02526          SVN TIME,0,5030             TIME OUT
01673 -3 07707 0 02420          SVN CSZ,0,4039              COSINE(SIGMA Z) OUT
01674 -3 07720 0 02504          SVN NUZ,0,4048              NU Z OUT
01675 -3 07730 0 02503          SVN NUR,0,4056              NU R OUT
01676 -3 04020 0 02505          SVN KE,0,2064               KE OUT
01677 -3 11720 0 02527          SVN R,0,5072                R OUT
01700 -3 11731 0 02530          SVN PR,0,5081               PR OUT
01701 -3 11741 0 02521          SVN RAVE,0,5089             R AVE. OUT
01702 -3 11751 0 02510          SVN AMP,0,5097              AMPLITUDE OUT
01703 -1 00000 0 00364          FVE 244
01704  0 02000 0 01773          TRA Z9
01705  0 07400 4 03271   OUT2   TSX OUT,4                   OUTPUT ROUTINE 2
01706  0 00000 0 01705          HTR OUT2                    OUTPUT ERROR RETURN
01707 -3 07646 0 02402          SVN E,0,4006                E OUT
01710 -3 07656 0 02332          SVN P,0,4014                P OUT
01711 -3 07665 0 02403          SVN BETA,0,4021             BETA OUT
01712 -3 11646 0 02526          SVN TIME,0,5030             TIME OUT
01713 -3 07707 0 02420          SVN CSZ,0,4039              COSINE(SIGMA Z) OUT
01714 -3 07720 0 02504          SVN NUZ,0,4048              NU Z OUT
01715 -3 07730 0 02503          SVN NUR,0,4056              NU R OUT
01716 -3 04020 0 02505          SVN KE,0,2064               KE OUT
01717 -3 11720 0 02527          SVN R,0,5072                R OUT
01720 -3 11731 0 02530          SVN PR,0,5081               PR OUT
01721 -3 11741 0 02521          SVN RAVE,0,5089             R AVERAGE OUT
01722 -3 11751 0 02510          SVN AMP,0,5097              AMPLITUDE OUT
01723 -1 00000 0 00364          FVE 244
01724  0 02000 0 01773          TRA Z9
01725  0 07400 4 03271   OUT3   TSX OUT,4                   OUTPUT ROUTINE 3
01726  0 00000 0 01725          HTR OUT3                    OUTPUT ERROR RERURN
01727 -3 07645 0 02403          SVN BETA,0,4005             BETA OUT
01730 -3 07655 0 02332          SVN P,0,4013                P OUT
01731 -3 07665 0 02402          SVN E,0,4021                E OUT
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01732 -3 11646 0 02526          SVN TIME,0,5030            TIME OUT
01733 -3 07707 0 02420          SVN CSZ,0,4039             COSINE(SIGMA Z) OUT
01734 -3 07720 0 02504          SVN NUZ,0,4048             NU Z OUT
01735 -3 07730 0 02503          SVN NUR,0,4056             NU R OUT
01736 -3 04020 0 02505          SVN KE,0,2064              KE OUT
01737 -3 11720 0 02527          SVN R,0,5072               R OUT
01740 -3 11731 0 02530          SVN PR,0,5081              PR OUT
01741 -3 11741 0 02521          SVN RAVE,0,5089            R AVERAGE OUT
01742 -3 11751 0 02510          SVN AMP,0,5097             AMPLITUDE OUT
01743 -1 00000 0 00364          FVE 244
01744  0 02000 0 01773          TRA Z9
01745  0 07400 4 03271   OUT4   TSX OUT,4                  OUTPUT ROUTINE 4
01746  0 00000 0 01745          HTR OUT4                   OUTPUT ERROR RETURN
01747 -3 07646 0 02332          SVN P,0,4006               P OUT
01750 -3 07656 0 02402          SVN E,0,4014               E OUT
01751 -3 11637 0 02526          SVN TIME,0,5023            TIME OUT
01752 -3 07700 0 02504          SVN NUZ,0,4032             NU Z OUT
01753 -3 07710 0 02503          SVN NUR,0,4040             NU R OUT
01754 -3 11670 0 02527          SVN R,0,5048               R OUT
01755 -3 11701 0 02530          SVN PR,0,5057              PR OUT
01756 -1 00000 0 00364          FVE 244
01757  0 02000 0 01773          TRA Z9
01760  0 07400 4 03271   OUT5   TSX OUT,4                  OUTPUT ROUTINE 5
01761  0 00000 0 01760          HTR OUT5                   OUTPUT ERROR RETURN
01762 -3 07646 0 02402          SVN E,0,4006
01763 -3 07656 0 02332          SVN P,0,4014
01764 -3 11637 0 02526          SVN TIME,0,5023
01765 -3 07700 0 02504          SVN NUZ,0,4032
01766 -3 07710 0 02503          SVN NUR,0,4040
01767 -3 11670 0 02527          SVN R,0,5048
01770 -3 11701 0 02530          SVN PR,0,5057
01771 -1 00000 0 00364          FVE 244
01772  0 02000 0 01773          TRA Z9
01773  0 50000 0 02435   Z9     CLA RHO2              Z9   ALL RHOS AND PRHOS
01774  0 60100 0 02437          STO RHO3              MOVED BACK ONE CELL
01775  0 50000 0 02433          CLA RHO1
01776  0 60100 0 02435          STO RHO2
01777  0 50000 0 02443          CLA PRHO2
02000  0 60100 0 02444          STO PRHO3
02001  0 50000 0 02442          CLA PRHO1
02002  0 60100 0 02443          STO PRHO2
02003  0 50000 0 02527          CLA R                 Z10  RHO1=(R-BETA)/BETA
02004  0 30200 0 02403          FSB BETA
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02005  0 24000 0 02403          FDH BETA
02006 -0 60000 0 02433          STQ RHO1
02007  0 50000 0 02530          CLA PR                Z11  PRHO1=PR/P
02010  0 24000 0 02332          FDH P
02011 -0 60000 0 02442          STQ PRHO1                  PRHO1 STORED
02012  0 07400 4 00000   Z12    TSX 0,4               Z12  VARIABLE TRANSFER TO CALCULATE P,E,BETA
02013  0 50000 0 02350          CLA NURKY4            Z14
02014  0 60100 0 02347          STO NURKY3                 NO. OF EQUATIONS=7
02015  0 50000 0 02475          CLA TCOUNT            Z15  TEST TO SEE IF THRU TABLE
02016  0 40000 0 02363          ADD FX1                    INCREASE T COUNTER
02017  0 60100 0 02475          STO TCOUNT
02020  0 56000 0 02342          LDQ TSIZ
02021  0 04000 0 02363          TLQ FX1                    IF THROUGH, GO TO CONSTANT, FX1
02022  0 56000 0 02403          LDQ BETA              Z16
02023  0 26000 0 02441          FMP 1ONSQ
02024  0 60100 0 02404          STO RAMP                   BETA/NSQ=R AMPLITUDE
02025  0 30000 0 02403          FAD BETA              Z17
02026  0 30000 0 02337          FAD DELTAR
02027  0 30000 0 02337          FAD DELTAR
02030  0 60100 0 02412          STO RMAX                   R MAX=BETA+R AMP+2 DELTA R
02031  0 50000 0 02434          CLA FRIA              Z19
02032  0 30000 0 02440          FAD RSPAN
02033  0 56000 0 02412          LDQ RMAX              Z18
02034  0 04000 0 02153          TLQ Z28               Z20  IF BEES IN MEMORY EXIT O-ROUT
02035  0 50000 0 02403          CLA BETA              Z21
02036  0 30200 0 02404          FSB RAMP
02037  0 30200 0 02337          FSB DELTAR
02040  0 30200 0 02337          FSB DELTAR
02041  0 60100 0 02413          STO RMIN                   R MIN=BETA-(R AMP+2 DELTA R)
02042  0 30200 0 02344          FSB RIN               Z22
02043  0 24000 0 02337          FDH DELTAR
02044 -0 60000 0 14521          STQ COMMON
02045  0 50000 0 14521          CLA COMMON
02046  0 07400 4 03213          TSX FLOFX,4
02047  0 00000 0 00043          PZE 35
02050  0 42000 0 00000          HPR
02051  0 60100 0 14521          STO COMMON
02052  0 50000 0 02432          CLA MTLOC             Z23
02053  0 40000 0 02411          ADD RAP
02054  0 40200 0 14521          SUB COMMON
02055 -0 12000 0 02362          TMI FX6               Z24  STOP IN FX6 IF FIELDS DO NOT OVERLAP
02056  0 10000 0 02065          TZE Z27               Z25  TAPE LOCATED RIGHT
02057  0 60100 0 14522          STO COMMON+1          Z26
```

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02060 -0 63400 2 02662          SXD JUNK+6,2
02061  0 53400 2 14522          LXA COMMON+1,2
02062  0 76400 0 00201   BST    BST 1
02063  0 76400 0 00202          BST 2
02064  2 00001 2 02062          TIX BST,2,1                  TAPE POSITIONED TO READ BEES
02065 -0 63400 1 02663   Z27    SXD JUNK+7,1
02066  0 53400 1 02411          LXA RAP,1
02067  0 60000 0 02406          STZ BEERT
02070  0 53400 2 02407   LXA5   LXA BEER,2
02071  0 50000 0 02356          CLA MAP
02072  0 40200 0 02406          SUB BEERT
02073  0 62100 0 02101          STA YPC
02074  0 60000 0 02262          STZ RETRY+9                  ZERO COUNTER FOR TRIALS OF M.T. READING
02075  0 76200 0 00221          RTB 1
02076  0 70000 0 14522          CPY COMMON+1
02077  0 02000 0 02101          TRA YPC
02100  0 02000 0 02111          TRA REREAD
02101  0 70000 2 00000   YPC    CPY 0,2
02102  2 00001 2 02101          TIX YPC,2,1
02103 -0 76000 0 00012          RTT                          REDUNDANCY TAPE CHECK
02104  0 07400 4 02251          TSX RETRY,4                  FAILED, TRY AGAIN
02105  0 50000 0 02406          CLA BEERT
02106  0 40000 0 02407          ADD BEER
02107  0 60100 0 02406          STO BEERT
02110  2 00001 1 02070          TIX LXA5,1,1
02111  0 76100 0 00000 REREAD   NOP
02112  0 76000 0 00144          SLN 4
02113  0 60000 0 02406          STZ BEERT
02114  0 53400 1 02411          LXA RAP,1
02115  0 53400 2 02407   LXA6   LXA BEER,2
02116  0 50000 0 02357          CLA MAD
02117  0 40200 0 02406          SUB BEERT
02120  0 62100 0 02126          STA TACYPC
02121  0 60000 0 02274          STZ RETRY2+9                 ZERO COUNTER FOR TRYING TO REREAD
02122  0 76200 0 00222          RTB 2
02123  0 70000 0 14522          CPY COMMON+1
02124  0 02000 0 02126          TRA TACYPC
02125  0 02000 0 02157          TRA Z28+4
02126  0 70000 2 00000 TACYPC   CPY 0,2
02127  2 00001 2 02126          TIX TACYPC,2,1
02130 -0 76000 0 00012          RTT                          REDUNDANCY TAPE CHECK
02131  0 07400 4 02263          TSX RETRY2,4                 FAILED, TRY AGAIN
02132  0 50000 0 02406          CLA BEERT
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02133  0 40000 0 02407         ADD BEER
02134  0 60100 0 02406         STC BEERT
02135  2 00001 1 02115         TIX LXA6,1,1
02136  0 50000 0 14521  Z275   CLA COMMON              Z27.5
02137  0 60100 0 02432         STO MTLOC                    MAGNETIC TAPE LOCATION STORED
02140  0 53400 1 02432         LXA MTLOC,1
02141  0 60000 0 02434         STZ FRIA
02142  0 76600 0 00333         IOD 219                      I-O DELAY
02143  0 50000 0 02434  THERE  CLA FRIA
02144  0 30000 0 02337         FAD DELTAR
02145  0 60100 0 02434         STO FRIA                     MTLOC(DELTA R) COMPUTED
02146  2 00001 1 02144         TIX THERE+1,1,1
02147  0 30000 0 02344         FAD RIN
02150  0 60100 0 02434         STO FRIA                     FRIA=RIN+(MTLOC)(DELTAR)
02151  0 30000 0 02440         FAD RSPAN
02152  0 60100 0 02436         STO MARIA                    MARIA=FRIA+R SPAN
02153 -0 53400 2 02662  Z28    LXD JUNK+6,2            Z28  REPLACING INDEX REG.
02154 -0 53400 1 02663         LXD JUNK+7,1
02155 -0 53400 4 02654         LXD JUNK,4
02156  0 02000 4 00001         TRA 1,4                      EXIT Z,O ROUTINES
02157  0 50000 0 02162         CLA Z28+7
02160  0 60100 0 02151         STO THERE+6
02161  0 02000 0 02136         TRA Z275
02162  0 50000 0 02345         CLA MROT
02163  0 50000 0 02332  SELP   CLA P                        INCREMENT P
02164  0 30000 0 02346         FAD DELTAP
02165  0 60100 0 02332         STO P
02166 -0 63400 4 14532         SXD COMMON+9,4               SAVE I.R.4
02167  0 56000 0 02332         LDQ P
02170  0 26000 0 02332         FMP P
02171  0 60100 0 02401         STO PSQ                      P SQUARED IN PERMANENT STORAGE
02172  0 30000 0 02353         FAD 1FL
02173  0 07400 4 03162         TSX SQRT,4                   ENTER SQUARE ROOT ROUTINE
02174  0 42000 0 00000         HPR                          SQ.RT. ERROR RETURN
02175  0 60100 0 02402         STO E                        E=SQ.RT.(PSQ+1)
02176  0 50000 0 02332         CLA P
02177  0 24000 0 02402         FDH E
02200 -0 60000 0 02403         STQ BETA                     BETA=P/E
02201 -0 53400 4 14532         LXD COMMON+9,4               RESTORE I.R.4
02202  0 02000 4 00001         TRA 1,4
02203  0 50000 0 02402  SELE   CLA E                        WHEN E INPUT
02204  0 30000 0 02335         FAD DELTAE                   INCREMENT E
02205  0 60100 0 02402         STO E
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02206 -0 63400 4 14532          SXD COMMON+9,4          SAVE I.R.4
02207  0 56000 0 02402          LDQ E
02210  0 26000 0 02402          FMP E
02211  0 30200 0 02353          FSB 1FL
02212  0 60100 0 02401          STO PSQ                 P SQUARED IN PERMANENT STORAGE
02213  0 07400 4 03162          TSX SQRT,4
02214  0 42000 0 00000          HPR                     SQ.RT. ERROR RETURN
02215  0 60100 0 02332          STO P                   P=SQ.RT.(ESQ-1)
02216  0 24000 0 02402          FDH E
02217 -0 60000 0 02403          STQ BETA                BETA=P/E
02220 -0 53400 4 14532          LXD COMMON+9,4          RESTORE I.R.4
02221  0 02000 4 00001          TRA 1,4
02222  0 50000 0 02403   SELB   CLA BETA                WHEN BETA INPUT
02223  0 30000 0 02336          FAD DELBET              INCREMENT BETA
02224  0 60100 0 02403          STO BETA
02225 -0 63400 4 14532          SXD COMMON+9,4          SAVE I.R.4
02226  0 56000 0 02403          LDQ BETA
02227  0 26000 0 02403          FMP BETA
02230  0 60100 0 14521          STO COMMON              BETA SQUARED IN COMMON
02231  0 50000 0 02353          CLA 1FL
02232  0 30200 0 14521          FSB COMMON              1-(BETA SQ.) IN ACCUMULATOR
02233  0 07400 4 03162          TSX SQRT,4              ENTER SQ.RT. ROUTINE
02234  0 42000 0 00000          HPR                     SQ.RT. ERROR RETURN
02235  0 60100 0 14521          STO COMMON              SQ.RT.(1-BETA SQ.)IN COMMON
02236  0 50000 0 02403          CLA BETA
02237  0 24000 0 14521          FDH COMMON
02240 -0 60000 0 02332          STQ P                   P=BETA/SQ.RT.(1-BETA SQ.)
02241  0 26000 0 02332          FMP P
02242  0 60100 0 02401          STO PSQ
02243  0 30000 0 02353          FAD 1FL                 (P SQ+1)IN ACCUMULATOR
02244  0 07400 4 03162          TSX SQRT,4              ENTER SQ.RT ROUTINE
02245  0 42000 0 00000          HPR                     SQ.RT. ERROR RETURN
02246  0 60100 0 02402          STO E                   E=SQ.RT.(P SQ+1)
02247 -0 53400 4 14532          LXD COMMON+9,4          RESTORE I.R.4
02250  0 02000 4 00001          TRA 1,4
02251  0 50000 0 02262   RETRY  CLA RETRY+9             SET UP TO REREAD DRIVE 1
02252  0 40000 0 02363          ADD FX1
02253  0 60100 0 02262          STO RETRY+9
02254  0 40200 0 02367          SUB FX5                 DO NOT TRY MORE THAN 5 TIMES
02255 -0 12000 0 02257          TMI RETRY+6
02256  0 02000 0 02320          TRA WHICH1
02257  0 53400 2 02407          LXA BEER,2
02260  0 76400 0 00201          BST 1
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02261   0 02000 4 77771        TRA -7,4         END OF REREAD TAPE 1 LOOP
02262   0 00000 0 00000        HTR              COUNTER FOR NUMBER OF TRIES AT READING
02263   0 50000 0 02274 RETRY2 CLA RETRY2+9     SET UP TO TRY TO REREAD DRIVE 2
02264   0 40000 0 02363        ADD FX1
02265   0 60100 0 02274        STO RETRY2+9
02266   0 40200 0 02367        SUB FX5
02267  -0 12000 0 02271        TMI RETRY2+6
02270   0 02000 0 02310        TRA WHICH
02271   0 53400 2 02407        LXA BEER,2
02272   0 76400 0 00202        BST 2
02273   0 02000 4 77771        TRA -7,4         END OF REREAD TAPE 2 LOOP
02274   0 00000 0 00000        HTR              COUNTER FOR REREADING DRIVE 2
02275  -0 76000 0 00011  ETT   ETT
02276   0 02000 0 02300        TRA ETT+3
02277   0 02000 0 00145        TRA CAPY+9
02300   0 77200 0 00201        REW 1            REWIND AND STOP
02301   0 00000 0 00000        HTR              STOP, END OF TAPE 1 AND REWOUND
02302  +000000000010           OCT 000000000010 EPSILON FOR CONVERSION
02303   0 77200 0 00202        REW 2            REWIND 2 AND
02304   0 00000 0 00000        HTR              STOP
02305  -0 76000 0 00011        ETT
02306   0 02000 0 02303        TRA ETT+6
02307   0 02000 0 00212        TRA CBPY+10
02310   0 53400 2 02407  WHICH LXA BEER,2
02311   0 76400 0 00202        BST 2
02312   0 76200 0 00222        RTB 2
02313   0 70000 0 14521        CPY COMMON
02314   0 70000 0 14521        CPY COMMON
02315   2 00001 2 02314        TIX *-1,2,1
02316   0 00000 0 00000        HTR              STOP-TRIED TO READ RECORD FROM TAPE 2 5 TIME
02317   0 00000 0 00000        HTR              STOP-BEER NOT = NUMBER OF DERIV. PER RECORD
02320   0 53400 2 02407 WHICH1 LXA BEER,2
02321   0 76400 0 00201        BST 1
02322   0 76200 0 00221        RTB 1
02323   0 70000 0 14521        CPY COMMON
02324   0 70000 0 14521        CPY COMMON
02325   2 00001 2 02324        TIX *-1,2,1
02326   0 00000 0 00000        HTR              STOP-TRIED TO READ RECORD FROM TAPE 1 5 TIME
02327   0 00000 0 00000        HTR              STOP-BEER NOT = NUMBER OF FIELDS PER RECORD
02330  +204700000000    AMORT  DEC 14.00     FACTOR USED IN CALCULATING KE
02331  +202600000000    NFL    DEC 3.00      NUMBER OF SECTORS PER REVOLUTION
02332  +173507534121    P      DEC .02       MOMENTUM
02333  +000000000020    KFX    DEC 16        SAME AS KFL EXCEPT FIXED
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02334 +000000000001     NSTAR DEC 1               NUMBER OF SECTORS PER FIELD CYCLE
02335 +000000000000    DELTAE DEC
02336 +000000000000    DELBET DEC
02337 +167406111564    DELTAR DEC .001            DELTA R=INCREMENT IN R FOR STORED FIELDS
02340 +000000000001     INKEY DEC 1                    KEYWORD FOR VARIABLE INPUT
02341 +000000000001    OUTKEY DEC 1                    KEYWORD FOR VARIABLE OUTPUT
02342 +000000000000     TSIZ  DEC                      NUMBER OF ENTRIES IN TABLE
02343 +000000000001     BKEY  DEC 1                    FIELD IDENTIFICATION WORD
02344 +000000000000     RIN   DEC 0               INITIAL R FOR FIELDS ON TAPE
02345 +175631463146     MROT  DEC .10             MAXIMUM R FOR WHICH FIELDS ARE ON TAPE
02346 +172507534121    DELTAP DEC .01             INCREMENT IN P
02347 +000000000015    NURKY3 DEC 13              TEMPORARY USED BY RUNGA-KUTTA
02350 +000000000007    NURKY4 DEC 7               NUMBER OF EQUATIONS USED TO FIND EQUILIBRIUM ORBIT
02351 +000000000015    NURKY5 DEC 13              MAXIMUM NUMBER OF EQUATIONS USED
02352 +203622077323     2PI   DEC 6.2831852       FLOATING POINT 2 PI
02353 +201400000000     1FL   DEC 1.000
02354 +202400000000     2FL   DEC 2.000
02355 +000000004200    MAXSTO DEC 2176            MAXIMUM STORAGE IN APIARY (FIXED POINT)
02356  0 00000 0 10321  MAP   HTR APIARY          MEMORY LOCATION OF APIARY
02357  0 00000 0 14521  MAD   HTR BTHETA          MEMORY LOCATION OF DERIVATIVES(BTHETA)
02360 +167406111564     EPS   DEC .001            EPSILON FOR ORBIT TEST(FL. PT.)
02361 +202600000000     3FL   DEC 3.000
02362 +000000000006     FX6   DEC 6               USED AS A STOP FROM Z24
02363 +000000000001     FX1   DEC 1
02364 +167406111564     EPS2  DEC .001            EPSILON FOR ALPHA AND BETA DETERMINANTS
02365 +000000000235     ST157 DEC 157
02366 +000000000004     FX4   DEC 4
02367 +000000000005     FX5   DEC 5
02370 +203600000000     6FL   DEC 6.00
02371 +000000000002     FX2   DEC 2
02372 +000000000003     FX3   DEC 3
02373 +200400000000     HALF  DEC .500
02374 +176525252527     SIXTH DEC .16666667
02375 +177525252524     THIRD DEC .33333333
02376 +212725072702     FL938 DEC 938.23          938.23(FL. PT.)
02377 +207550000000     FL90  DEC 90.00
02400 +000001000000     BIT   OCT 000001000000    1 IN 17TH BIT
02401  0 00000 0 00000  PSQ                       P-SQUARED
02402  0 00000 0 00000  E                         SQ RT(P SQUARED+1)
02403  0 00000 0 00000  BETA                      P/SQ RT(P SQUARED+1)
02404  0 00000 0 00000  RAMP                      BETA/N SQ (FLT. PT.)
02405  0 00000 0 00000  NO2PI                     FACTOR USED IN NU ROUTINE
02406  0 00000 0 00000  BEERT                     TEMPORARY TO AVOID SUBROUTINE TEMPS
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02407   0 00000 0 00000   BEER                     NUMBER OF FIELDS PER R-VALUE=2KN*(FIXED INT.)
02410   0 00000 0 00000   KFL                      NUMBER OF RUNGA-KUTTA STEPS PER SECTOR(FL. PT)
02411   0 00000 0 00000   RAP                      NUMBER OF RECORDS IN APIARY(FIXED PT)
02412   0 00000 0 00000   RMAX                     MAXIMUM R FOR P(BY FORMULA)
02413   0 00000 0 00000   RMIN                     MINIMUM R FOR P(BY FORMULA)
02414   0 00000 0 00000   INITR                    INITIAL R FOR GIVEN ORBIT
02415   0 00000 0 00000  INITPR                    INITIAL PR FOR GIVEN ORBIT
02416   0 00000 0 00000   CSR                      COSINE SIGMA R
02417   0 00000 0 00000   TEMP2                    TEMPORARY USED IN O-ROUTINE
02420   0 00000 0 00000   CSZ                      COSINE SIGMA Z
02421   0 00000 0 00000   RHO                      USED IN GUESS FOR INITR
02422   0 50000 0 02163   SETAD  CLA SELP
02423   0 50000 0 02203          CLA SELE
02424   0 50000 0 02222          CLA SELB
02425   0 02000 0 01665   TRALA  TRA OUT1
02426   0 02000 0 01705          TRA OUT2
02427   0 02000 0 01725          TRA OUT3
02430   0 02000 0 01745          TRA OUT4
02431   0 02000 0 01760          TRA OUT5
02432   0 00000 0 00000   MTLOC                    NUMBER OF BLOCKS HUNTED FORWARD FOR FIELDS
02433   0 00000 0 00000   RHO1
02434   0 00000 0 00000   FRIA                     FIRST R IN APIARY
02435   0 00000 0 00000   RHO2
02436   0 00000 0 00000   MARIA                    MAXIMUM R IN APIARY
02437   0 00000 0 00000   RHO3
02440   0 00000 0 00000   RSPAN                    INCREMENT OF R IN APIARY=MARIA-FRIA
02441   0 00000 0 00000   1ONSQ                    1/N SQUARED(FL. PT.)
02442   0 00000 0 00000   PRHO1
02443   0 00000 0 00000   PRHO2
02444   0 00000 0 00000   PRHO3
02445   0 00000 0 00000   PRHO                     USED IN GUESS FOR INITPR
02446   0 00000 0 00000   XCUB                     X CUBED
02447   0 00000 0 00000   XSQ                      X SQUARED
02450   0 00000 0 00000   X                        X=(R-R2)/DELTA R
02451   0 00000 0 00000   TC                       TEST COUNTER-EITHER 0 OR 1
02452   0 00000 0 00000   INT                      RELATIVE ADDRESS OF R2 FROM APIARY
02453   0 00000 0 00000   FIX                      NUMBER OF R VALUES BETWEEN R AND APIARY
02454   0 00000 0 00000   FLT                      FIX FLOATED
02455   0 00000 0 00000   A4                       A S ARE COEFFICIENTS
02456   0 00000 0 00000   A3                       FOR INTERPOLATION WITH
02457   0 00000 0 00000   A2                       CORRESPONDING B S AND DB S.
02460   0 00000 0 00000   A1
02461   0 00000 0 00000   B4                       B VALUES FOR INTERPOLATION
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02462  0 00000 0 00000  B3                     WITH B GREATER THAN B2
02463  0 00000 0 00000  B2                     AND LESS THAN B3
02464  0 00000 0 00000  B1
02465  0 00000 0 00000  B5
02466  0 00000 0 00000  DB4                    THETA DERIVATIVE VALUES
02467  0 00000 0 00000  DB3                    FOR INTERPOLATION-SAME
02470  0 00000 0 00000  DB2                    ORDER AS FIELDS
02471  0 00000 0 00000  DB1
02472  0 00000 0 00000  DB5
02473  0 00000 0 00000  EPI                    EPSILON=ERROR IN EQUILIBRIUM ORBIT
02474  0 00000 0 00000  QINV                   =SQ. RT.(P SQ-PR SQ)
02475  0 00000 0 00000 TCOUNT                      COUNTER FOR NUMBER OF ENTRIES IN TABLE
02476  0 00000 0 00000  DBDR                   RADIAL DERIVATIVE OF B
02477  0 00000 0 00000  B                      MAGNETIC FIELD OBTAINED BY INTERPOLATION
02500  0 00000 0 00000  QBALL                  1/SQ. RT(P SQ-PR SQ)
02501  0 00000 0 00000 DTHETA                  THETA DERIVATIVE OF B
02502  0 00000 0 00000  R2
02503  0 00000 0 00000  NUR
02504  0 00000 0 00000  NUZ
02505  0 00000 0 00000  KE                     KE=938.23(E-1)A
02506  0 00000 0 00000  MINA                   ACTUAL MINIMUM R IN ORBIT
02507  0 00000 0 00000  MAXA                   ACTUAL MAXIMUM R FOUND IN ORBIT
02510  0 00000 0 00000  AMP                    (MAXIMUM R-MINIMUM R)/2 FOR EACH ORBIT
                02511  TURKY3 BSS 8
                02536  XRKY3  BES 13
                02553  YRKY3  BES 13
                02570  RRKY3  BES 13
                02605  SRKY3  BES 13
                02622  URKY3  BES 13
                02637  VRKY3  BES 13
                02654  QRKY3  BES 13
                02654  JUNK   BSS 8
                02664  ARCOS  BSS 76
                              RKY3 MURA FLOATING POINT RUNGE-KUTTA                MURKY3
03000  0 50000 4 00001  RKY3  CLA 1,4            H TO AC                          RKY30001
03001  0 60100 0 02515        STO TURKY3+4       SAVE H                           RKY30002
03002 -0 63400 1 02516        SXD TURKY3+5,1     SAVE IR1                         RKY30003
03003 -0 63400 2 02517        SXD TURKY3+6,2     SAVE IR2                         RKY30004
03004 -0 63400 4 02520        SXD TURKY3+7,4     SAVE IR4                         RKY30005
03005 -0 53400 2 03156        LXD RKY3+110,2     SET IR2=4                        RKY30006
03006  0 50000 2 03162        CLA RKY3+114,2     SET SWITCH                       RKY30007
03007  0 62100 0 03017        STA RKY3+15                                         RKY30008
03010  0 53400 1 02347        LXA NURKY3,1
```

```
03011  0 07400 4 01141      TSX WRKY3,4          COMPUTE F(I)                                   RKY30010
03012  0 56000 1 02637      LDQ VRKY3,1          F(I)                                           RKY30011
03013  0 26000 0 02515      FMP TURKY3+4         FORM K(IJ)=H F(I)                              RKY30012
03014  0 10000 0 03016      TZE RKY3+14          IF ZERO,DO NOT ROUND                           RKY30013
03015 -0 50100 0 03143      ORA RKY3+99          ROUND                                          RKY30014
03016  0 76500 0 00043      LRS 35               K(IJ) TO MQ                                    RKY30015
03017  0 02000 0 00000      TRA 0                SWITCH(TO EVALUATE EACH EQ.)                   RKY30016
03020  0 50000 1 02654      CLA QRKY3,1          EPSILON(I) TERM                                RKY30017
03021  0 56000 0 03145      LDQ RKY3+101         CLEAR MQ                                       RKY30018
03022  0 07400 4 03102      TSX RKY3+66,4        TO DOUBLE PRECISION FLOATING PT. ADD.          RKY30019
03023  0 30000 1 02553      FAD YRKY3,1          +Y(I)                                          RKY30020
03024  0 60100 1 02536      STO XRKY3,1          FOR NEXT EQUATION                              RKY30021
03025 -3 00001 2 03034      TXL RKY3+28,2,1      TO PREPARE FOR NEXT STEP                       RKY30022
03026  2 00001 1 03012      TIX RKY3+10,1,1      LOOP,DONE AFTER N PASSES                       RKY30023
03027  2 00001 2 03006      TIX RKY3+6,2,1       LOOP,DONE AFTER 4 PASSES                       RKY30024
03030 -0 53400 1 02516      LXD TURKY3+5,1       RESTORE IR1                                    RKY30025
03031 -0 53400 2 02517      LXD TURKY3+6,2       RESTORE IR2                                    RKY30026
03032 -0 53400 4 02520      LXD TURKY3+7,4       RESTORE IR4                                    RKY30027
03033  0 02000 4 00002      TRA 2,4              OUT                                            RKY30028
03034  0 60100 1 02553      STO YRKY3,1          Y(I)                                           RKY30029
03035 -0 60000 1 02654      STQ QRKY3,1          SAVE EPSILON(I)TERM FOR NEXT STEP              RKY30030
03036  0 02000 0 03026      TRA RKY3+22                                                         RKY30031
03037 -0 60000 1 02570      STQ RRKY3,1          K(I0)                                          RKY30032
03040  0 26000 0 03146      FMP RKY3+102         1/2 K(I0)                                      RKY30033
03041  0 60100 0 02511      STO TURKY3           STORE FOR DP FLOATING PT. ADD.                 RKY30034
03042 -0 60000 0 02512      STQ TURKY3+1                                                        RKY30035
03043  0 02000 0 03020      TRA RKY3+16          TO MAIN                                        RKY30036
03044 -0 60000 1 02605      STQ SRKY3,1          K(I1)                                          RKY30037
03045  0 26000 0 03147      FMP RKY3+103         (1-SQ.RT.1/2)K(I1)                             RKY30038
03046  0 60100 0 02511      STO TURKY3           STORE FOR DP FLOATING PT. ADD.                 RKY30039
03047 -0 60000 0 02512      STQ TURKY3+1                                                        RKY30040
03050  0 56000 1 02570      LDQ RRKY3,1          K(I0)                                          RKY30041
03051  0 26000 0 03150      FMP RKY3+104         (-1/2+SQ.RT.1/2)K(I0)                          RKY30042
03052  0 07400 4 03102      TSX RKY3+66,4        TO DOUBLE PRECISION FLOATING PT. ADD.          RKY30043
03053  0 02000 0 03020      TRA RKY3+16          TO MAIN                                        RKY30044
03054 -0 60000 1 02622      STQ URKY3,1          K(I2)                                          RKY30045
03055  0 26000 0 03151      FMP RKY3+105         (1+SQ.RT.1/2)K(I2)                             RKY30046
03056  0 60100 0 02511      STO TURKY3           STORE FOR DP FLOATING PT. ADD.                 RKY30047
03057 -0 60000 0 02512      STQ TURKY3+1                                                        RKY30048
03060  0 56000 1 02605      LDQ SRKY3,1          K(I1)                                          RKY30049
03061  0 26000 0 03152      FMP RKY3+106         (-SQ.RT.1/2)K(I1)                              RKY30050
03062  0 07400 4 03102      TSX RKY3+66,4        TO DOUBLE PRECISION FLOATING PT. ADD.          RKY30051
03063  0 02000 0 03020      TRA RKY3+16          TO MAIN                                        RKY30052
```

```
03064 -0 60000 1 02637    STQ VRKY3,1       K(I3)                                     RKY30053
03065  0 26000 0 03153    FMP RKY3+107      (1/6)K(I3)                                RKY30054
03066  0 60100 0 02511    STO TURKY3        STORE FOR DP FLOATING PT. ADD.            RKY30055
03067 -0 60000 0 02512    STQ TURKY3+1                                                RKY30056
03070  0 56000 1 02622    LDQ URKY3,1       K(I2)                                     RKY30057
03071  0 26000 0 03154    FMP RKY3+108      1/3(1+SQ.RT.1/2)K(I2)                     RKY30058
03072  0 07400 4 03102    TSX RKY3+66,4     TO DOUBLE PRECISION FLOATING PT. ADD.     RKY30059
03073  0 56000 1 02605    LDQ SRKY3,1       K(I1)                                     RKY30060
03074  0 26000 0 03155    FMP RKY3+109      1/3(1-SQ.RT.1/2)K(I1)                     RKY30061
03075  0 07400 4 03102    TSX RKY3+66,4     TO DOUBLE PRECISION FLOATING PT. ADD.     RKY30062
03076  0 56000 1 02570    LDQ RRKY3,1       K(I0)                                     RKY30063
03077  0 26000 0 03153    FMP RKY3+107      (1/6)K(I0)                                RKY30064
03100  0 07400 4 03102    TSX RKY3+66,4     TO DOUBLE PRECISION FLOATING PT. ADD.     RKY30065
03101  0 02000 0 03020    TRA RKY3+16       TO MAIN                                   RKY30066
03102 -0 60000 0 02513    STQ TURKY3+2      DP FLOATING PT. ADD, STORE A(2)           RKY30067
03103  0 30000 0 02511    FAD TURKY3        A(1)+B(1)                                 RKY30068
03104  0 60100 0 02514    STO TURKY3+3      STORE MSP                                 RKY30069
03105 -0 75400 0 00000    PXD               CLEAR AC                                  RKY30070
03106  0 76300 0 00043    LLS 35            LSP TO AC                                 RKY30071
03107  0 30000 0 02513    FAD TURKY3+2      +A(2)                                     RKY30072
03110  0 30000 0 02512    FAD TURKY3+1      +B(2)                                     RKY30073
03111  0 30000 0 02514    FAD TURKY3+3      +MSP OF A(1)+B(1)                         RKY30074
03112  0 60100 0 02511    STO TURKY3        STORE MSP OF SUM                          RKY30075
03113  0 16200 0 03134    TQP RKY3+92                                                 RKY30076
03114 -0 12000 0 03131    TMI RKY3+89       HERE IF MQ-, OUT IF AC-                   RKY30077
03115  0 40200 0 03143    SUB RKY3+99       HERE IF MQ-,AC+,-1 IN 35TH BIT            RKY30078
03116  0 60100 0 02514    STO TURKY3+3                                                RKY30079
03117  0 76000 0 00000    CLM               CLEAR MAGNITUDE AC                        RKY30080
03120 -0 77300 0 00011    RQL 9             SEPERATE CHARACTERISTIC                   RKY30081
03121 -0 76300 0 00033    LGL 27            FROM FRACTION OF LSP                      RKY30082
03122  0 10000 0 03137    TZE RKY3+95       IF ZERO,TRANSFER                          RKY30083
03123 -0 76000 0 00003    SSM               -FRACTION OF LSP                          RKY30084
03124  0 40000 0 03142    ADD RKY3+98       1-FRACTION                                RKY30085
03125 -0 60000 0 02512    STQ TURKY3+1                                                RKY30086
03126 -0 60200 0 02512    ORS TURKY3+1      COMBINE CHARACTERISTIC AND FRACTION       RKY30087
03127  0 50200 0 02512    CLS TURKY3+1      -LSP                                      RKY30088
03130  0 30000 0 02514    FAD TURKY3+3      +MSP                                      RKY30089
03131  0 60100 0 02511    STO TURKY3        MSP                                       RKY30090
03132 -0 60000 0 02512    STQ TURKY3+1      LSP                                       RKY30091
03133  0 02000 4 00001    TRA 1,4           OUT                                       RKY30092
03134  0 12000 0 03131    TPL RKY3+89       HERE IF MQ+,OUT IF AC+                    RKY30093
03135  0 40000 0 03143    ADD RKY3+99       HERE IF MQ+,AC-,+1 IN 35TH BIT            RKY30094
03136  0 02000 0 03116    TRA RKY3+78                                                 RKY30095
```

```
3137   0 50000 0 02511              CLA TURKY3         HERE IF LSP=0, REPLACE MSP
3140   0 76500 0 00000              LRS                SIGN OF MSP REPLACES SIGN OF LSP
3141   0 02000 0 03131              TRA RKY3+89
3142  +001000000000                 OCT 001000000000   1 IN 8TH BIT
3143   0 00000 0 00001              HTR 1              1 IN 35TH BIT
3144   0 00000 0 02347              HTR NURKY3         NUMBER OF EQUATIONS
3145   0 00000 0 00000              HTR                ZERO
3146  +200400000000                 OCT 200400000000   1/2
3147  +177453730315                 OCT 177453730315   1-SQ.RT.(1/2)
3150  +176650117146                 OCT 176650117146   -1/2+SQ.RT.(1/2)
3151  +201665011715                 OCT 201665011715   1+SQ.RT.(1/2)
03152 -200552023632                 OCT 600552023632   -SQ.RT.(1/2)
03153 +176525252525                 OCT 176525252525   1/6
03154 +200443261211                 OCT 200443261211   1/3(1+SQ.RT.1/2)
03155 +175617713146                 OCT 175617713146   1/3(1-SQ.RT.1/2)
03156  0 00004 0 03037              HTR RKY3+31,0,4    SWITCH CONSTANTS
03157  0 00000 0 03044              HTR RKY3+36
03160  0 00000 0 03054              HTR RKY3+44
03161  0 00000 0 03064              HTR RKY3+52
                03162  SQRT   BSS 25
                03213  FLOFX  BSS 16
                03233  FXFLO  BSS 30
                03271  OUT    BSS 408
                10321 APIARY  BES 2176
                14521 BTHETA  BES 2176
                10321  INP1   SYN APIARY
                14521 COMMON  BSS 10
                02535  THETA  SYN XRKY3-1
                02534  PX2    SYN XRKY3-2
                02533  X2     SYN XRKY3-3
                02532  PX1    SYN XRKY3-4
                02531  X1     SYN XRKY3-5
                02530  PR     SYN XRKY3-6
                02527  R      SYN XRKY3-7
                02526  TIME   SYN XRKY3-8
                02525  PZ2    SYN XRKY3-9
                02524  Z2     SYN XRKY3-10
                02523  PZ1    SYN XRKY3-11
                02522  Z1     SYN XRKY3-12
                02521  RAVE   SYN XRKY3-13
                00125         END LOAD

ASSEMBLER STATISTICS
```

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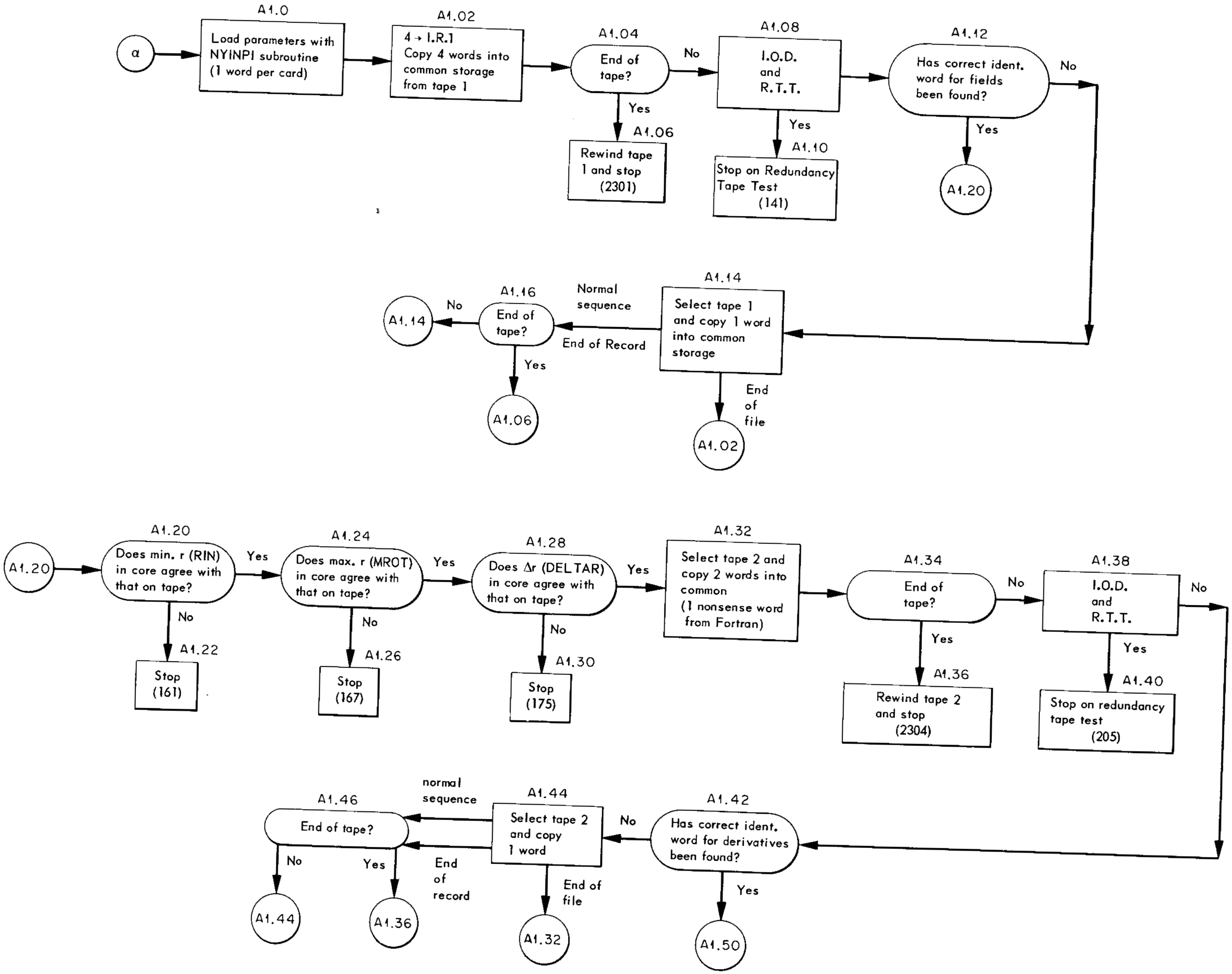
Equilibrium Orbit Code No. 1482



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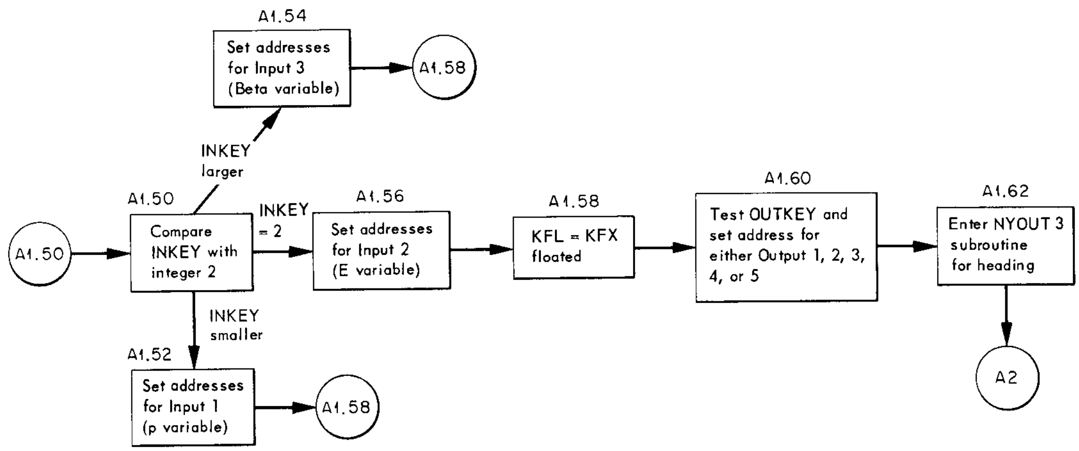

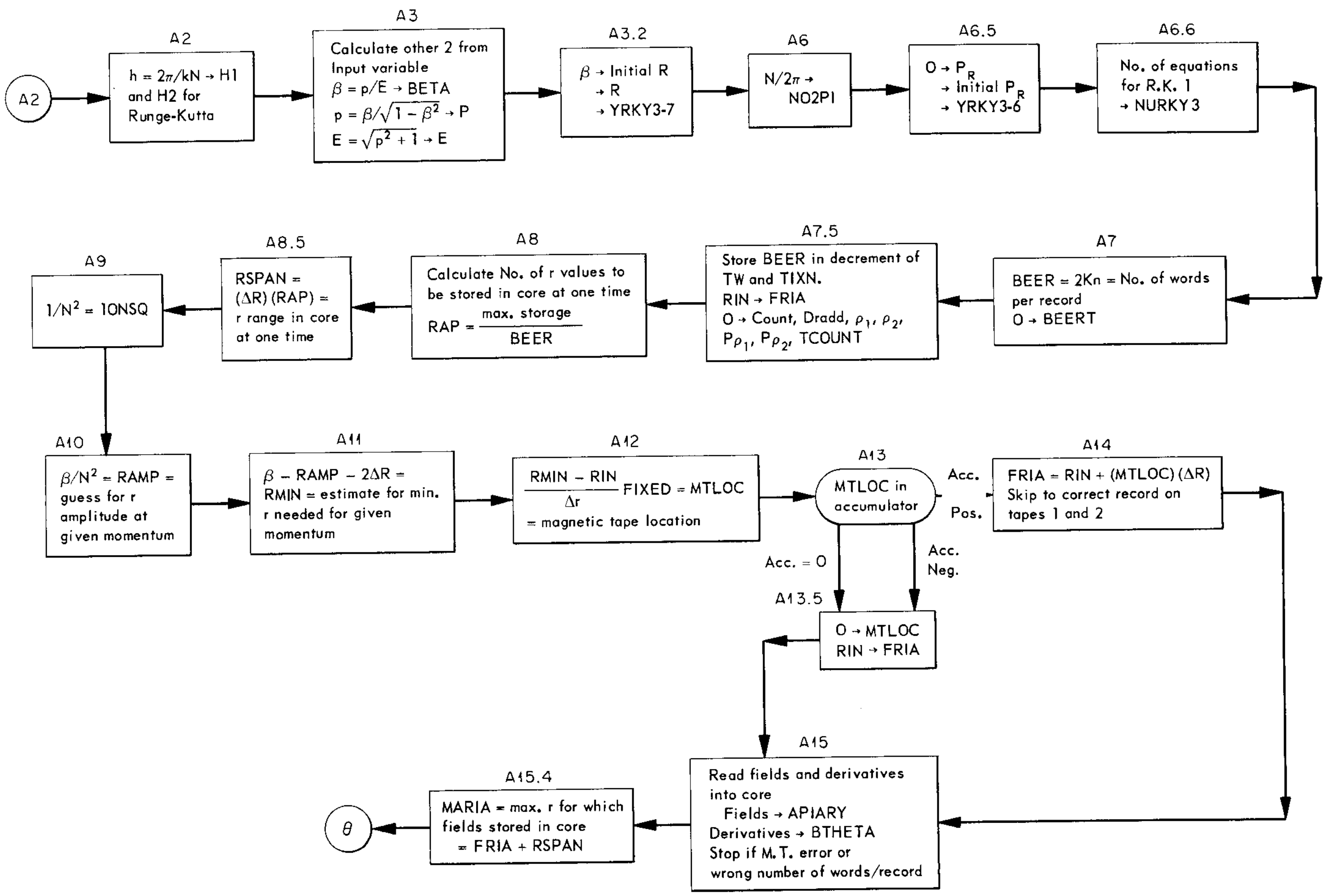

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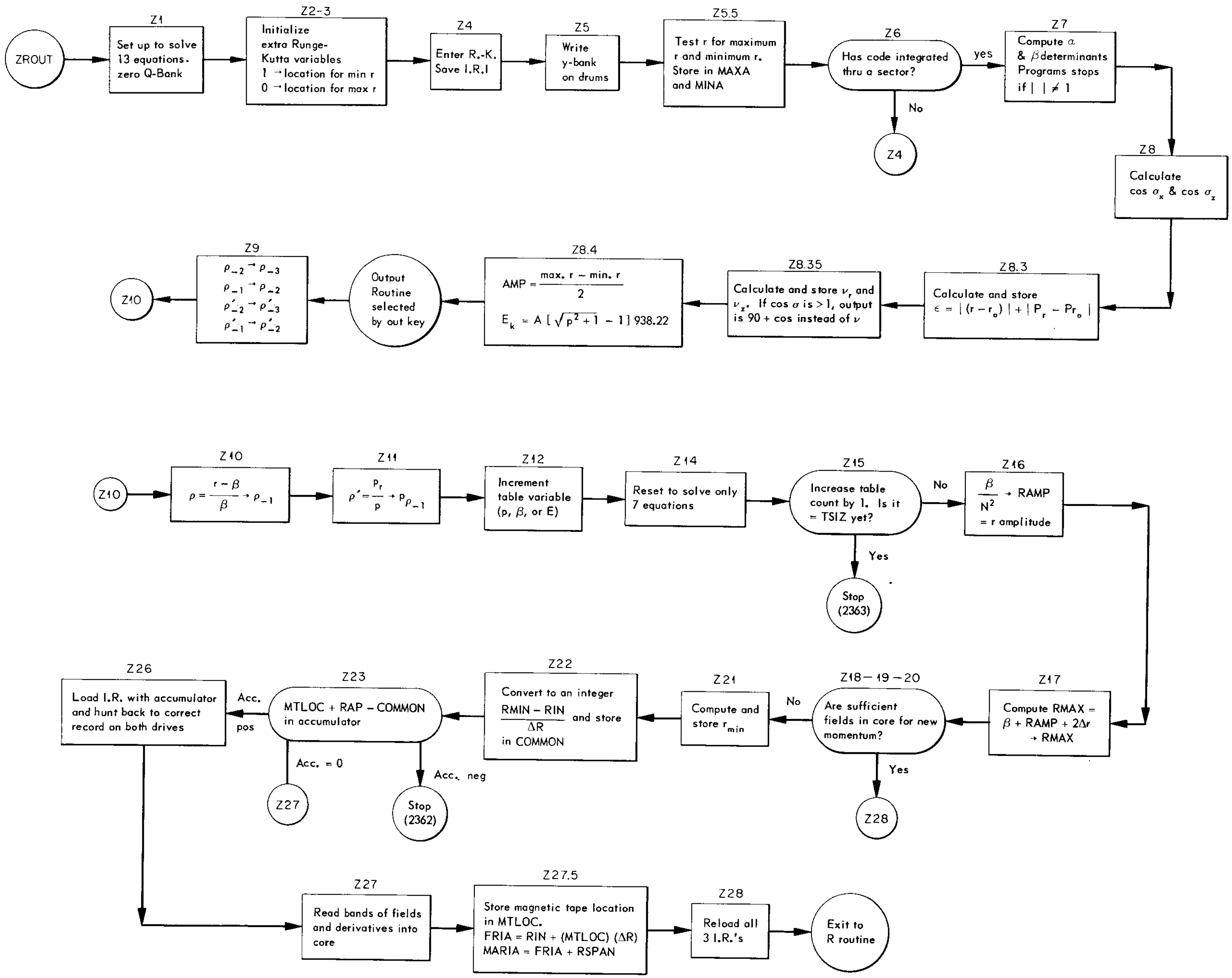

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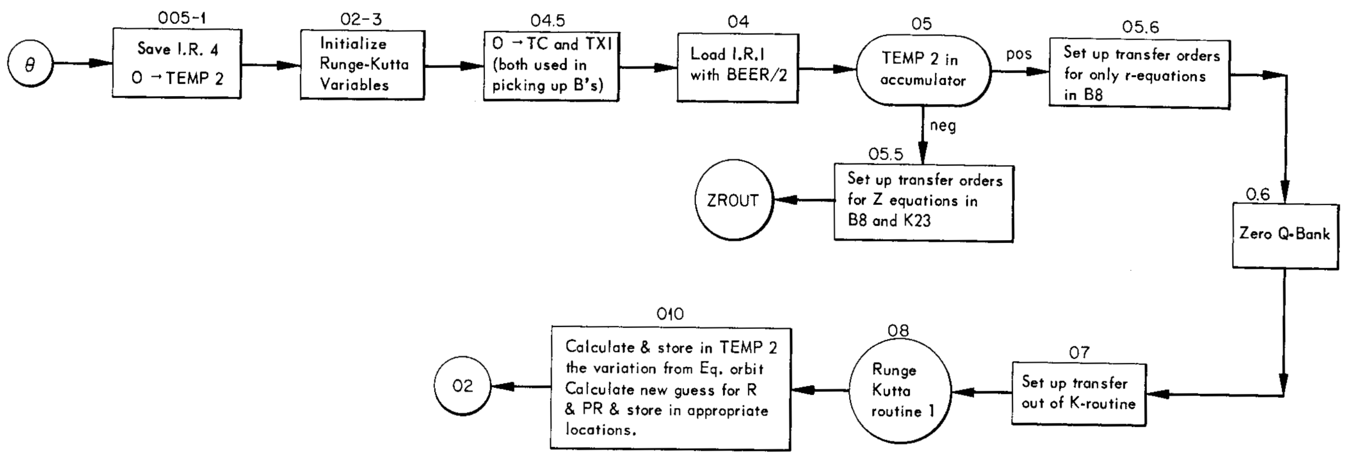
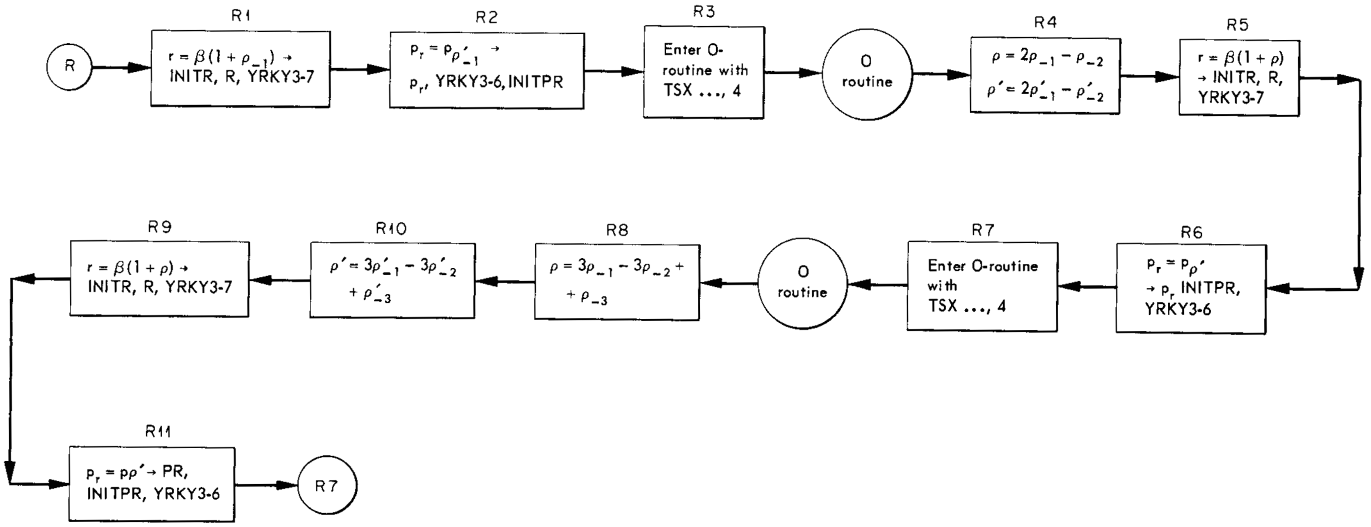
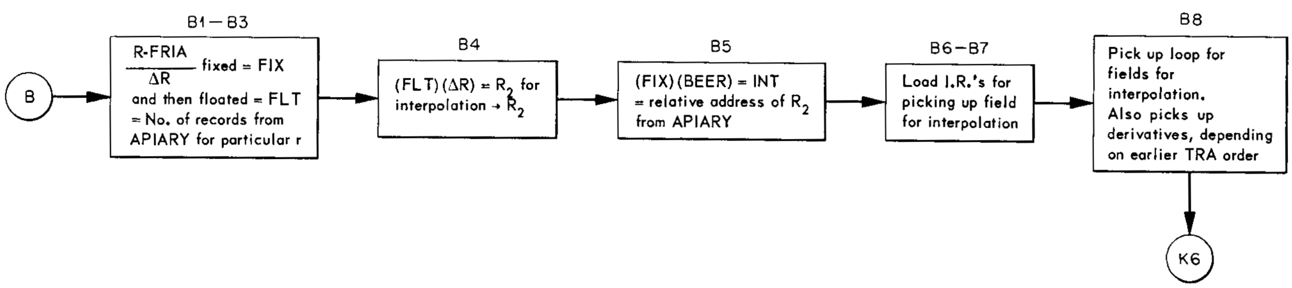
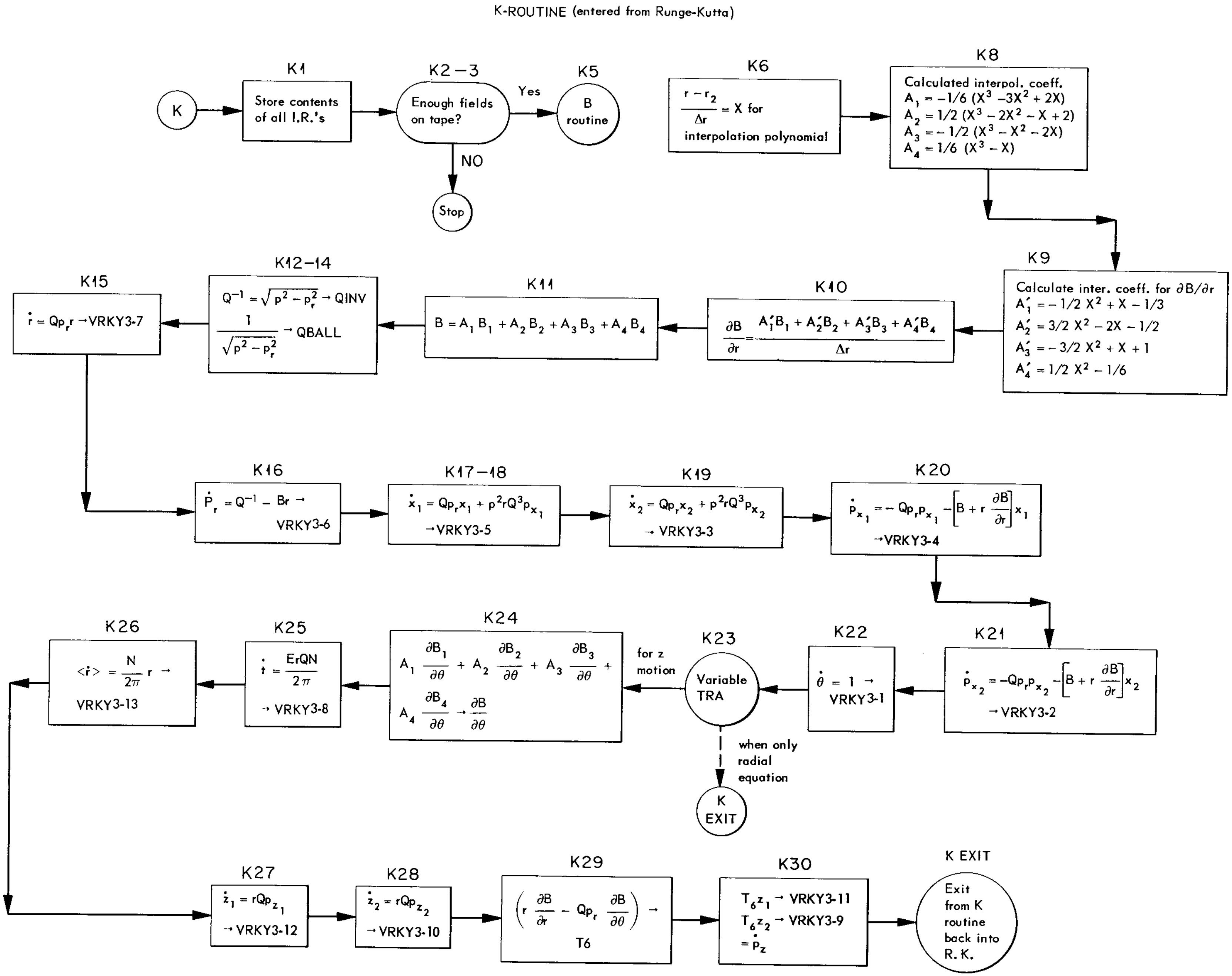




B-routine




K-ROUTINE (entered from Runge-Kutta)
K
K1
Store contents of all I.R.'s
K2-3
Enough fields on tape?
Yes
NO
Stop
K5
B routine
K6
(r − r2)/Δr = X for interpolation polynomial
K8
Calculated interpol. coeff.
A1 = −1/6 (X³ −3X² + 2X)
A2 = 1/2 (X³ − 2X² − X + 2)
A3 = − 1/2 (X³ − X² − 2X)
A4 = 1/6 (X³ − X)
K9
Calculate inter. coeff. for ∂B/∂r
A′1 = − 1/2 X² + X − 1/3
A′2 = 3/2 X² − 2X − 1/2
A′3 = − 3/2 X² + X + 1
A′4 = 1/2 X² − 1/6
K10
∂B/∂r = (A′1B1 + A′2B2 + A′3B3 + A′4B4)/Δr
K11
B = A1 B1 + A2 B2 + A3 B3 + A4 B4
K12-14
Q⁻¹ = √(p² − pr²) → QINV
1/√(p² − pr²) → QBALL
K15
ṙ = Qpr r → VRKY3-7
K16
Ṗr = Q⁻¹ − Br → VRKY3-6
K17-18
ẋ1 = Qpr x1 + p²rQ³px1 → VRKY3-5
K19
ẋ2 = Qpr x2 + p²rQ³px2 → VRKY3-3
K20
ṗx1 = − Qpr px1 − [B + r ∂B/∂r] x1 → VRKY3-4
K21
ṗx2 = −Qpr px2 − [B + r ∂B/∂r] x2 → VRKY3-2
K22
θ̇ = 1 → VRKY3-1
K23
Variable TRA
for z motion
when only radial equation
K EXIT
K24
A1 ∂B1/∂θ + A2 ∂B2/∂θ + A3 ∂B3/∂θ + A4 ∂B4/∂θ → ∂B/∂θ
K25
ṫ = ErQN/2π → VRKY3-8
K26
<ṙ> = N/2π r → VRKY3-13
K27
ż1 = rQpz1 → VRKY3-12
K28
ż2 = rQpz2 → VRKY3-10
K29
(r ∂B/∂r − Qpr ∂B/∂θ) → T6
K30
T6z1 → VRKY3-11
T6z2 → VRKY3-9
= ṗz
K EXIT
Exit from K routine back into R. K.

SAMPLE OUTPUT FROM TEST CASE

P	E	BETA	TIME	COS	NU Z	NU R	KE	R	PR	R AVE	AMP
.0300	1.0004	.0300	.99713	.9730	.1112	1.0106	.42	.03043	-.00000	.02988	.00055
.0400	1.0008	.0400	.99596	.9537	.1459	1.0133	.75	.04072	-.00000	.03976	.00095
.0500	1.0012	.0499	.99521	.9401	.1660	1.0153	1.17	.05100	-.00000	.04961	.00137
.0600	1.0018	.0599	.99469	.9315	.1778	1.0172	1.69	.06127	-.00000	.05945	.00180
.0700	1.0024	.0698	.99427	.9268	.1838	1.0193	2.30	.07153	-.00000	.06927	.00224
.0800	1.0032	.0797	.99389	.9230	.1886	1.0214	3.00	.08176	-.00000	.07905	.00268
.0900	1.0040	.0896	.99349	.9203	.1919	1.0236	3.79	.09197	-.00000	.08881	.00312
.1000	1.0050	.0995	.99307	.9185	.1940	1.0261	4.68	.10215	-.00000	.09852	.00358
.1100	1.0060	.1093	.99263	.9176	.1952	1.0288	5.66	.11230	-.00000	.10819	.00405
.1200	1.0072	.1191	.99216	.9172	.1957	1.0319	6.73	.12242	-.00000	.11782	.00454
.1300	1.0084	.1289	.99166	.9173	.1956	1.0352	7.89	.13250	-.00000	.12739	.00504
.1400	1.0098	.1386	.99112	.9174	.1954	1.0387	9.15	.14255	-.00000	.13691	.00556
.1500	1.0112	.1483	.99056	.9178	.1949	1.0425	10.50	.15255	-.00000	.14637	.00609
.1600	1.0127	.1580	.98997	.9183	.1943	1.0466	11.93	.16251	-.00000	.15577	.00664
.1700	1.0143	.1676	.98935	.9190	.1935	1.0509	13.46	.17243	-.00000	.16510	.00721
.1800	1.0161	.1772	.98871	.9198	.1926	1.0554	15.08	.18229	-.00000	.17437	.00780
.1900	1.0179	.1867	.98804	.9206	.1915	1.0602	16.78	.19211	-.00000	.18356	.00840
.2000	1.0198	.1961	.98736	.9216	.1903	1.0652	18.58	.20187	-.00000	.19269	.00902
.2100	1.0218	.2055	.98666	.9226	.1891	1.0704	20.46	.21157	-.00000	.20174	.00966
.2200	1.0239	.2149	.98595	.9238	.1876	1.0759	22.44	.22121	-.00000	.21071	.01032

Internal:

1. R. H. Bassel
2. R. S. Bender
3. J. L. Fowler
4. F. T. Howard
5. R. S. Livingston
6. J. A. Martin

7-11. H. C. Owens

12. A. Simon

13-22. T. A. Welton

23-42. Laboratory Records

External:

43. J. S. Allen, U. of Illinois
44. H. L. Anderson, U. of Chicago
45. T. I. Arnette, Michigan State U.
46. H. G. Blosser, Michigan State U.
47. K. Boyer, LASL
48. F. T. Cole, MURA
49. B. L. Cohen, U. of Pittsburgh
50. J. H. Cook, UCLA
51. E. D. Courant, BNL
52. A. A. Garren, LRL, Berkeley
53. W. Gentner, CERN, Geneva
54. M. M. Gordon, Michigan State U.
55. K. G. Green, BNL
56. H. A. Howe, U.S. Naval Radiological Defense Lab.
57. D. L. Judd, LRL, Berkeley
58. F. A. Heyn, Tech. U., Delft, The Netherlands
59. E. L. Kelly, LRL, Berkeley
60. N. M. King, AERE, Harwell
61. L. M. Lederman, Columbia U.
62. D. A. Lind, U. of Colorado
63. F. E. Mills, MURA
64. G. Parzen, MURA
65. J. M. Peterson, LRL, Livermore
66. T. G. Pickavance, AERE, Harwell
67. J. Rainwater, Columbia U.
68. J. R. Richardson, UCLA
69. A. Roberts, U. of Rochester
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83. R. Wilson, Harvard U.

84-98. TISE, AEC