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ABSTRACT

Three computer programs for calculating particle orbits with linearized vertical motion in general cyclotron magnetic fields are described in detail. The first program is used for finding properties of equilibrium orbits and small oscillations about them. The second program is a very flexible routine for determining the history of a particle under various conditions, including acceleration. Flexibility is achieved through the use of options such as a resonance-hunt routine, harmonic-bump routines, and an equilibrium-orbit-search routine. The third program, the deflector program, allows various combinations of electrostatic, magnetic, and regenerative extractors to be used.

THREE COMPUTER PROGRAMS FOR CALCULATING CYCLOTRON ORBITS[†]

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April 11, 1962

1. Introduction

This report concerns a system of IBM 704 orbit programs that has been found to be a very useful tool in the design and testing of the 88-inch cyclotron at Berkeley. The theory used in the equilibrium-orbit code¹⁾ was devised by Gordon^{††} and Welton²⁾; the program was written by Arnette^{††} and the author^{†††} at the Oak Ridge National Laboratory. The second program, for computing general cyclotron orbits, was designed by Welton³⁾. The third program, for designing deflector configurations, was designed by Garren⁴⁾. These latter two codes were programmed by the author.

Each of these programs requires a set of magnetic fields stored on a polar grid on magnetic tape in a format as described in detail in ref. ¹⁾.

2. The Equilibrium-Orbit Code

2-1 THE FUNCTIONS OF THE CODE

The equilibrium-orbit code will be mentioned only briefly, since it was reported in some detail at a previous conference⁵⁾.

The essential functions of the equilibrium-orbit code are to find the radius and radial momentum of the equilibrium orbit, and to compute the

† Work done under the auspices of the U. S. Atomic Energy Commission.

†† T. I. Arnette and M. M. Gordon are now at Michigan State University.

††† The author is now at the Lawrence Radiation Laboratory, Berkeley.

focusing frequencies and the time for the particle to make one revolution. Also, an essential byproduct of the equilibrium-orbit search is the information on small-amplitude radial and axial oscillations needed to enable one to conveniently determine nonlinear orbit properties. This last feature is used by the general orbit code to be discussed later.

The equilibrium-orbit code can be used to generate a table of equilibrium-orbit properties for determining the isochronization and focusing properties of various magnetic-field configurations. Tables of equilibrium-orbit properties are essential for orienting various other studies, such as deflection studies, which require the other two orbit codes.

2.2 OUTPUT

The table of equilibrium-orbit properties may be printed in equal increments of one of three independent variables: the magnitude of the particle momentum p , the total relativistic particle energy E , or velocity β . Any one of five different output formats is possible, each one being some variation of the example in fig. 1. The first three columns will contain p , E , and β , the order being determined by the choice for independent variable. The fourth column gives the time, normalized to one for convenience, for the particle to traverse one revolution. Columns six, seven, and eight give the axial frequency, radial frequency, and kinetic energy, respectively. The remaining columns give the radius, radial momentum, average radius, and radial amplitude of the equilibrium orbit.

2.3 TIMING

The equilibrium-orbit code takes approximately 7 sec to generate one line of output corresponding to one equilibrium orbit, if twenty integration steps per sector are used.

3. The General Orbit Code

3.1 INTRODUCTION

The general orbit code computes the orbit of a particle in a cyclotron magnetic field with allowances for several operating modes. In each of the operating modes the user has the option of tracing the particle outward from the starting point or inward toward the center.

The operating modes are numerous and are determined by the user's choice of routines available, as described in section C. below as well as his choice of equations to be integrated.

3.2 THE EQUATIONS INTEGRATED

The equations of motion—for a particle in a magnetic field in cylindrical coordinates r, θ, z —which are integrated by the Runge-Kutta method are:

$$r' = \frac{r p_r}{Q},$$

$$p_r' = Q - r B(r, \theta),$$

$$z' = \frac{r p_z}{Q},$$

$$p_z' = \left[r \frac{\partial B}{\partial r} - \frac{p_r}{Q} \frac{\partial B}{\partial \theta} \right] z,$$

$$r_e' = \frac{r_e p_{re}}{Q},$$

$$p_{re}' = Q_e - r_e B_e(r_e, \theta),$$

$$t' = \frac{r \sqrt{p^2 + 1}}{Q},$$

where

prime means $\frac{\partial}{\partial \theta}$

$r(\theta)$ = radius as a function of θ for the orbit to be calculated,

$p_r(\theta)$ = radial momentum as a function of θ ,

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

p = the magnitude of the particle momentum,

$z(\theta)$ = the axial displacement,

$p_z(\theta)$ = the axial momentum,

$t(\theta)$ = time from $\theta = 0$,

$r_e(\theta)$ = the value of $r(\theta)$ a particle will have if started on the equilibrium orbit and given acceleration,

$p_{re}(\theta)$ = the radial momentum associated with $r_e(\theta)$,

$Q_e(\theta) = (p^2 - p_{re}^2)^{1/2}$,

N = number of sectors,

$B(r, \theta)$ = magnitude of z component of magnetic field in the median plane.

The following units are used:

Speed in units of c , the velocity of light in a vacuum,

Momentum in units of $m_0 c$, where m_0 is the particle rest mass,

Energy in units of $m_0 c^2$,

Time in units of $a = c/\omega_0$,

Field in units of $b = m_0 c \omega_0 / e$.

It is convenient to take ω_0 to be the synchronous angular velocity, or $2\pi f$, where f is the rf frequency.

3.3 PRINCIPAL ROUTINES USED

A. Equilibrium-Orbit Routine. As mentioned earlier, the equilibrium-orbit code is incorporated in the general orbit code as a subroutine. It is entered to find equilibrium orbits to be used as operating points around which orbits of interest may be initiated. It is an integral part of the resonance-hunt routine, and is used to compute the details of small-amplitude oscillations by the ellipse initial conditions and curve-plotting routines.

B. Resonance-Hunt Routine. The resonance-hunt routine finds the momentum that will cause the operating point in the (ν_r, ν_z) plane to fall a given distance from a specified resonance line. By using a simple difference formula, an iterative procedure is followed to determine p so that the relationship $k = m\nu_r + n\nu_z$ is satisfied. Here ν_r and ν_z are the radial and axial focusing frequencies, respectively, m and n are integers specifying the resonance of interest, and k is a constant used in defining the resonance line.

C. Ellipse Routine. The ellipse routine computes the initial conditions, $x(\theta)$ and $p_x(\theta)$, using the formulas

$$x(\theta) = \sqrt{\frac{J_x}{\pi E}} (A \cos \psi_x + B \sin \psi_x),$$

$$p_x(\theta) = \sqrt{\frac{J_x}{\pi E}} (C \cos \psi_x + D \sin \psi_x),$$

where

θ = the starting angle,

x, p_x are the deviations from the equilibrium orbit of the radial coordinate and momentum,

J_x = an input number which determines the x -amplitude (Action).

ψ_x = an input number which determines the phase. $\int$

The coefficients A, B, C, D, and E are dependent on the details of the small-amplitude oscillations computed by the equilibrium-orbit code. The reader is referred to ref. ²) for explicit definitions of these coefficients. Exactly parallel equations are used to compute the $z(\theta)$, $p_z(\theta)$ initial conditions. It will be observed that, with these definitions, if the amplitude is sufficiently small to allow neglect of nonlinear effects, the ellipse defined is just an invariant ellipse.

D. Curve-Plotting Routines. With the curve-plotting routine the user can plot $x(\theta)$, $p_x(\theta)$ or $\sqrt{\frac{J_x}{\pi}} \cos \psi_x$ and $\sqrt{\frac{J_x}{\pi}} \sin \psi_x$ at a preset value of θ .

E. Harmonic-Field Bump Routines. Provision for three bump subroutines have been made, two of which have been written and checked out. The field component is computed as needed, and is used to modify the stored fields during the integration procedure. Both routines use the same form for the bump, i.e.,

$$B_R = A(r) \cos (n\theta + \gamma) + B(r) \sin (n\theta + \gamma),$$

where

B_R = the field bump to be added to the magnetic field,

θ = independent variable,

n = field harmonic desired,

γ determines the phase of the bump.

$A(r)$ and $B(r)$ determine the radial amplitude of the bump. The only difference in the two subroutines is that the radial coefficients, $A(r)$ and $B(r)$, are specified in tabular form in one and analytic form in the other. The analytic formula for both $A(r)$ and $B(r)$ is the cubic polynomial of the form

$$a(r) = a_0 + a_1 r + a_2 r^2 + a_3 r^3.$$

F. Acceleration Routine. The energy gain per gap crossing is computed by

$$\Delta E = \frac{\delta}{q} [(1 - \epsilon) \cos (\theta - \omega t) + \epsilon \cos 3(\theta - \omega t)] ,$$

where

δ = the energy gain per turn,

q = the number of acceleration gaps,

ωt = the phase angle with respect to the rf,

where t is time from $\theta = 0$ deg,

ϵ = an input constant.

The acceleration may be phase independent, i. e., $\Delta E = \frac{\delta}{q}$, if desired—in which case the equation for the time is not integrated.

If it is necessary to have a reference point for plotting or for other output, the equations of motion for a particle having the initial conditions of the equilibrium orbit are integrated. The same acceleration is given the reference particle that is given the orbital particle. If such a reference is not needed, the equations of motion are not integrated.

G. Modified Gap-Crossing Routine. This routine modifies the acceleration at the two gaps of a conventional dee structure so that

$$\Delta E_1 = F_1(r) \Delta E, \quad \Delta E_2 = F_2(r) \Delta E,$$

where ΔE_1 , ΔE_2 are the energies gained at the first and second gap crossings, respectively, $F_1(r)$, $F_2(r)$ are tabular input parameters computed independently, and ΔE is the energy gain described in subsec. F above. This modification is needed only in the central portion of the cyclotron, thus a cutoff radius is part of the input. It is used to take account of the larger intervals of time the particles spend crossing the acceleration gap at small radii, during which the E field changes, so that the particles see a different effective accelerating field.

3.4 OUTPUT

A. Printed Tables. Tables (see fig. 2) will be printed as a function of θ starting at any Runge-Kutta step, at equal intervals (divided by the Runge-Kutta step size) of θ .

B. Binary Output. If the main purpose of the run is for extended curve plotting, provision is made to write all of the information computed at each Runge-Kutta step in binary form on magnetic tape to be processed by a special curve-plotting routine. Such a curve-plotting routine is not now available.

C. C.R.T. Plots. Phase plots at a specified Runge-Kutta step may be made as described in subsec. 3.3-D.

3.5 TIMING

The time for one revolution is a function of the particular operating mode and the size of the integration step. It ranges from a minimum of 5 sec in the simplest case to a maximum of approximately 18 sec in the more extensive cases. These times are figured on the basis of twenty Runge-Kutta steps per sector.

4. The Deflector Code

4.1 INTRODUCTION

The deflector code was planned to facilitate the design of a cyclotron deflection system⁶). The code calculates particle orbits in the cyclotron with the magnetic field so modified as to simulate the action of electrostatic channels, and/or magnetic channels, and /or regenerative field bumps for resonant extraction. The program will simulate multiple channels in any combination of the above channels.

With the exception of the equations for r_e' and p_{re}' , the equations of motion are the same as in the general orbit code. The program first calculates and records the path that a particular orbit with given initial values of r and p_r .

called the reference ray, will take in the presence of the modified magnetic field. Using this it calculates the shape and position of the elements of the channels defined by the input parameters (fig. 3). It now shoots a barage of particles at the deflector and records what happens.

4.2 CALCULATION OF THE REFERENCE RAY AND CHANNEL WALLS

A. The Reference Ray. The reference ray particle is started (usually on or near an equilibrium orbit) at the angle θ_i and is integrated until the angle θ_f is reached (see fig.3). Outside the pie-shaped area where the deflector is located, determined by radial lines at θ_0 and θ_1 , the particle experiences the magnetic field

$$\tilde{b}(r, \theta) = b(r, \theta) + b_R(r, \theta),$$

whereas inside the angles θ_0 and θ_1 it sees a field

$$\tilde{b}(r, \theta) = b(r, \theta) + b_R(r, \theta) + b_M[x_c(\theta)] + b_E(\theta),$$

where

$b(r, \theta)$ = the cyclotron magnetic field without the deflector,

$b_R(r, \theta)$ = the component of field due to a harmonic bump; the code presently has the same two bump routines as described in the general orbit code,

$b_M[x_c(\theta)]$ = the component of field due to the influence of the magnetic channel; it is a function of the distance x_c of the particle from the channel,

$$b_E(\theta) = - \frac{\sqrt{1+p_c^2}}{p_c} \epsilon(\theta) = \text{the magnetic field equivalent to the electric}$$

field, where p_c is the magnitude of the particle momentum and $\epsilon(\theta) = [\mathcal{E}_0 + \mathcal{E}_1(\theta - \theta_0) + \mathcal{E}_2(\theta - \theta_0)^2] / B_0$, when $\mathcal{E}_0, \mathcal{E}_1, \mathcal{E}_2$ are input parameters specifying the electric field and B_0 is a normalizing constant—usually the value of the magnetic field at the center of the cyclotron.

B. Channel Walls.

(1). Computed. If $r_c(\theta)$ and $p_{rc}(\theta)$ denote the reference-ray radius and radial momentum, $d(\theta) = \frac{V}{|\epsilon(\theta)|}$ (where V is the voltage on the deflector) is the channel width, and σ_E , σ_M are the thicknesses of the electric and magnetic channel walls, respectively, then the radii of the channel walls (see fig. 3) are given by

$$T_+(\theta) = r_c(\theta) + [(1-u)d(\theta) + \sigma_E] p_c/q_c,$$

$$B_+(\theta) = r_c(\theta) + (1-u)d(\theta) p_c/q_c,$$

$$T_-(\theta) = r_c(\theta) - u d(\theta) p_c/q_c,$$

$$B_-(\theta) = r_c(\theta) - [u d(\theta) \sigma_E + \sigma_M] p_c/q_c,$$

where $q_c = \sqrt{p_c^2 - p_{rc}^2}$ and u is an input number specifying the fractional part of $d(\theta)$ that the wall $T_-(\theta)$ is from the reference ray. Thus, the parameter u allows the channel to be shifted with respect to the reference ray.

(2). Input Directly. The program has the option whereby the coordinates of the channel walls may be input directly. Provision is made so that the walls may be adjusted to different positions by changing four numbers, one at the end of each channel wall. This feature is only available for the electric channel.

(3). The Acceptance Test.

(a) Initial Conditions for barage. The program as now written requires that the initial conditions for each particle be punched on a separate card. A simple subroutine could be written to put the particles on a grid and save the card punching. Several different ways of specifying initial conditions are available, but as a rule they are set relative to the r , p_r coordinates of the equilibrium orbit of the same momentum, for which purpose the equilibrium-orbit code is used as a subroutine.

(b) Field Specifications. The particle will see the field component b_R as described in the general orbit-code descriptions of the harmonic-bump routine, during its entire history. It will see the magnetic equivalent of the electric field $b_E(r, \theta) = \frac{-\sqrt{p^2 + 1}}{p} \epsilon(\theta)$ only while it is inside the channel (see fig. 3). It is assumed that the fringe effects are negligible, and that the particle orbit is perpendicular to the electric field lines. The particle experiences the effect of the magnetic channel only when it is above or below the bar of iron defining the channel. The magnetic channel component b_M is a function of the distance of the particle from the channel $x(r, \theta) = u d(\theta) + \sigma_E + [r(\theta) - r_c(\theta)] q_c / p_c$.

For each iron shape this effect must be measured and fit to an analytic curve, such as $b_M[x(r, \theta)] = \frac{F_0}{x} + \frac{F_1}{x^2}$. With some difficulty the code could be modified to pick up this number from a table.

(c) Particle History. The particle is tracked and its history recorded from some initial starting position until one of several events takes place. If it hits a channel wall the integration stops, and its position and the wall encountered is recorded. If it passes through the channel it is stopped at the angle θ_f (see fig. 3), and the information for a restart is recorded. If it completes a specified number of revolutions and has not encountered a wall or entered the channel, it is stopped at θ_f and its coordinates recorded for a restart. If the run is a multichannel study, and all of the particles have been tracked, the information defining the next channel is called for and the surviving particles are continued from θ_f .

4.3 OUTPUT

A. Off-line. The input parameters for each run are output on tape 6. The detailed information about each particle is output at each integration step on tape 6 in decimal form (fig. 4), or on tape 4 in binary form for future

machine processing. The user has the choice of printing the detailed information starting at the initial point or delaying until the particle has entered the channel.

B. On-line. The same detailed information that is printed off-line on tape 6 is printed on-line at the angles θ_i , θ_0 , θ_1 , and θ_f (figs. 3 and 4), as well as information as to what part of the deflector structure, if any, has been hit.

4.4 TIMING

If 20 Runge-Kutta steps per sector are used, the deflector code takes about 15 sec/revolution with the abbreviated output and approx 25 sec/revolution with the extended output.

REFERENCES

- 1) M. M. Gordon, T. A. Welton, T. I. Arnette, and H. C. Owens, An IBM 704 Code for Determining Equilibrium Orbits and Properties of Small Amplitude Oscillations in Cyclotron Fields, Oak Ridge National Laboratory Report CF 59-11-2, Nov. 1959 (unpublished).
- 2) M. M. Gordon, and T. A. Welton, Computation Methods for AVF Cyclotron Design Studies, Oak Ridge National Laboratory Report ORNL-2765, Sept. 1959 (unpublished).
- 3) H. C. Owens and T. A. Welton, An IBM 704 Code for Studying Particle Orbits in Cyclotron Fields, Oak Ridge National Laboratories Report CF 59-11-3, Nov. 1959 (unpublished).
- 4) A. A. Garren and H. C. Owens, An IBM 704 Code for Studying Cyclotron Deflector Configuration and Efficiencies (to be published).
- 5) T. A. Welton, in Sector-Focused Cyclotrons, Proceedings of an Informal Conference, Sea Island, Georgia, Feb. 1959, Nuclear Science Series Report No. 26 (National Academy of Sciences-National Research Council, Washington, D. C., 1959) p. 48.
- 6) A. A. Garren, D. L. Judd, L. Smith, and H. A. Willax, Electrostatic Deflector Calculations for the Berkeley 88-Inch Cyclotron, Lawrence Radiation Laboratory Report UCRL-10067, May 1962, Nucl. Instr. and Meth. (to be published).

FIGURE CAPTIONS

Fig. 1. Equilibrium-orbit-code output format.

Fig. 2. General orbit-code output format.

Fig. 3. A channel configuration.

Fig. 4. Deflector-code output format.

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	-0.00000	02988	00055
0400	1.0008	0400	99596	9537	1459	1.0133	75	04072	-0.00000	03976	00095
0500	1.0012	0499	99521	9401	1660	1.0153	117	05100	-0.00000	04961	00137
0600	1.0018	0599	99469	9315	1778	1.0172	169	06127	-0.00000	05945	00180
0700	1.0024	0698	99427	9238	1838	1.0193	230	07153	-0.00000	06927	00224
0800	1.0032	0797	99389	9230	1886	1.0214	300	08176	-0.00000	07905	00268
0900	1.0040	0896	99349	9203	1919	1.0236	379	09197	-0.00000	08881	00312
1000	1.0050	0995	99307	9185	1940	1.0261	468	10215	-0.00000	09852	00358
1100	1.0060	1093	99263	9176	1952	1.0288	566	11230	-0.00000	10819	00405
1200	1.0072	1191	99216	9172	1957	1.0319	673	12242	-0.00000	11782	00454
1300	1.0084	1289	99166	9173	1956	1.0352	789	13250	-0.00000	12739	00504
1400	1.0098	1386	99112	9174	1954	1.0387	915	14255	-0.00000	13691	00556
1500	1.0112	1483	99056	9178	1949	1.0425	1050	15255	-0.00000	14637	00609
1600	1.0127	1580	98997	9183	1943	1.0466	1193	16251	-0.00000	15577	00664
1700	1.0143	1676	98935	9190	1935	1.0509	1346	17243	-0.00000	16510	00721
1800	1.0161	1772	98871	9198	1926	1.0554	1508	18229	-0.00000	17437	00780
1900	1.0179	1867	98804	9206	1915	1.0602	1678	19211	-0.00000	18356	00840
2000	1.0198	1961	98736	9216	1903	1.0652	1858	20187	-0.00000	19269	00902
2100	1.0218	2055	98666	9226	1891	1.0704	2046	21157	-0.00000	20174	00966
2200	1.0239	2149	98595	9238	1876	1.0759	2244	22121	-0.00000	21071	01032

UCRL-10083
Fig. 1

RUN NUMBER 61661

REV	THETA	KE	GAMMA	P	R	PR	X	PX	Z	PZ
	60.00	.091	-23.93	.00982950	.00751780	-.00237611	.00125240	-.00125240	.00000000	.00000000
	90.00	.091	-16.05	.00982950	.00681907	-.00113438	.00062537	-.00183798	.00000000	.00000000
	120.00	.091	-6.55	.00982950	.00663589	.00041405	-.00005371	-.00193114	.00000000	.00000000
	150.00	.091	2.36	.00982950	.00711640	.00185275	-.00081774	-.00150867	.00000000	.00000000
	180.00	.091	8.54	.00982950	.00810993	.00279241	-.00157539	-.00068186	.00000000	.00000000
	210.00	.091	10.35	.00982950	.00956568	.00298458	-.00198907	.00032706	.00000000	.00000000
	240.00	.160	9.19	.01305411	.01108213	.00274250	-.00174175	.00123823	.00000000	.00000000
	270.00	.160	11.37	.01305411	.01254310	.00312709	-.00104309	.00183857	.00000000	.00000000
	300.00	.160	9.84	.01305411	.01416806	.00264462	.00001667	.00196356	.00000000	.00000000
	330.00	.160	5.26	.01305411	.01542444	.00144502	.00111153	.00156663	.00000000	.00000000
	360.00	.160	-9.95	.01305411	.01586823	-.00005016	.00183502	.00077849	.00000000	.00000000
1	30.00	.160	-7.10	.01305411	.01536960	-.00151152	.00193797	-.00020602	.00000000	.00000000
1	60.00	.229	-10.41	.01560973	.01415833	-.00238830	.00144054	-.00116941	.00000000	.00000000
1	90.00	.229	-6.38	.01560973	.01321441	-.00158967	.00071242	-.00181726	.00000000	.00000000
1	120.00	.229	-1.83	.01560973	.01278547	-.00032055	-.00012623	-.00197346	.00000000	.00000000
1	150.00	.229	3.53	.01560973	.01294611	.00104290	-.00096757	-.00160915	.00000000	.00000000
1	180.00	.229	7.90	.01560973	.01366654	.00208560	-.00166399	-.00080562	.00000000	.00000000
1	210.00	.229	10.26	.01560973	.01481331	.00256027	-.00197767	.00021840	.00000000	.00000000
1	240.00	.297	10.89	.01780595	.01613034	.00266715	-.00173453	.00113834	.00000000	.00000000
1	270.00	.297	12.14	.01780595	.01759063	.00300656	-.00104450	.00175389	.00000000	.00000000
1	300.00	.297	10.80	.01780595	.01911323	.00241151	-.00002178	.00194136	.00000000	.00000000
1	330.00	.297	7.44	.01780595	.02015808	.00112901	.00103353	.00161298	.00000000	.00000000
1	360.00	.297	3.12	.01780595	.02042611	-.00020788	.00176462	.00090382	.00000000	.00000000
2	30.00	.297	-1.03	.01780595	.01993477	-.00143617	.00196494	-.00002357	.00000000	.00000000
2	60.00	.367	-3.29	.01978669	.01882379	-.00231159	.00159590	-.00101781	.00000000	.00000000
2	90.00	.367	-1.17	.01978669	.01779246	-.00180584	.00088000	-.00175082	.00000000	.00000000
2	120.00	.367	2.31	.01978669	.01719983	-.00066708	-.00000166	-.00199482	.00000000	.00000000
2	150.00	.367	6.30	.01978669	.01720517	.00067592	-.00089340	-.00171944	.00000000	.00000000
2	180.00	.367	9.79	.01978669	.01777615	.00170499	-.00162768	-.00096484	.00000000	.00000000
2	210.00	.367	11.99	.01978669	.01875342	.00224435	-.00197221	.00006054	.00000000	.00000000
2	240.00	.436	12.95	.02154913	.01995247	.00256947	-.00178751	.00098550	.00000000	.00000000
2	270.00	.436	13.94	.02154913	.02140443	.00300921	-.00116063	.00163629	.00000000	.00000000
2	300.00	.436	12.80	.02154913	.02291231	.00235620	-.00018654	.00192183	.00000000	.00000000
2	330.00	.436	10.04	.02154913	.02387216	.00097931	.00086783	.00169683	.00000000	.00000000

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Fig. 2

Electric channel,
Magnetic channel

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 Fig. 3

ORBIT 35, CHANNEL 1

REV	EV	THETA	KE	P	R	PR	X	PX	Z	PZ
6		90,000	64,3866	26420547	25876066	01482853	000000000	-00037147	000000000	000000000
6		96,000	64,3866	26420547	26031735	01526135	00041385	-00011560	000000000	000000000
6		102,000	64,3866	26420547	26189913	01520725	00040204	-00010948	000000000	000000000
6		108,000	64,3866	26420547	26347291	01495122	00039179	-00008511	000000000	000000000
6		114,000	64,3866	26420547	26502314	01459174	00038451	-00005063	000000000	000000000
6		120,000	64,3866	26420547	26654073	01416821	00038120	-00000815	000000000	000000000
6		126,000	64,3866	26420547	26801911	01369670	00038283	00004321	000000000	000000000
6		132,000	64,3866	26420547	26945314	01318874	00039038	00010302	000000000	000000000
6		138,000	64,3866	26420547	27084013	01272596	00040497	00017301	000000000	000000000
6		144,000	64,3866	26420547	27222301	01335675	00042787	00025610	000000000	000000000
6		150,000	64,3866	26420547	27385889	01735858	00046131	00036690	000000000	000000000
6		156,000	64,3866	26420547	27607544	02336023	00050847	00048990	000000000	000000000
6		162,000	64,3866	26420547	27901652	02987150	00056867	00058586	000000000	000000000
6		168,000	64,3866	26420547	28274221	03655719	00064101	00067953	000000000	000000000
6		174,000	64,3866	26420547	28731549	04353694	00072804	00079646	000000000	000000000
6		180,000	64,3866	26420547	29283902	05112246	00083506	00095240	000000000	000000000
6		186,000	64,3866	26420547	29948160	05973887	00097023	00116168	000000000	000000000
6		192,000	64,3866	26420547	30749864	06973795	00114515	00143463	000000000	000000000
6		198,000	64,3866	26420547	31723922	08133799	00137544	00177578	000000000	000000000
6		204,000	64,3866	26420547	32909485	09376399	00168430	00220466	000000000	000000000
6		210,000	64,3866	26420547	34368623	10880369	00210201	00267317	000000000	000000000
6		216,000	64,3866	26420547	36201308	12623344	00266452	00312304	000000000	000000000
6		222,000	64,3866	26420547	38547963	14555818	00342551	00351980	000000000	000000000
6		228,000	64,3866	26420547	41613425	16590971	00447138	00381336	000000000	000000000
6	C	228,000	64,3866	26420547	41613425	16590971	00593955	00392667	000000000	000000000

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Fig. 4