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# RESEARCH SUPPORT FOR PLASMA DIAGNOSTICS ON ELMO BUMPY TORUS - INVESTIGATION OF DIAMAGNETIC DIAGNOSTICS FOR THE ELECTRON RINGS

by

Kenneth H. Carpenter

Department of Electrical Engineering
University of Missouri - Rolla
Rolla, Missouri 65401

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# RESEARCH SUPPORT FOR PLASMA DIAGNOSTICS ON ELMO BUMPY TORUS - INVESTIGATION OF DIAMAGNETIC DIAGNOSTICS FOR THE ELECTRON RINGS

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University of Missouri - Rolla
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## ABSTRACT

Diamagnetic diagnostics for the EBT electron rings are fundamental to the experiment. The diamagnetic flux pickup loops on each cavity output signals proportional to ring perpendicular energy. A data analysis technique is described, which in its simplest form is subtracting 1/4 the signal from each neighboring cavity pickup loop from the central one's, which provides a signal proportional to the energy in a single ring. The calibration factor relating absolute perpendicular energy to diamagnetic signal depends weakly on the geometrical model for the ring. Calculations with a bumpy cylinder MHD equilibrium code give calibration factors in reasonable agreement (20%) to the values obtained using a simple, concentric cylindrical current sheet model. The cylindrical current sheet model is used to show that diamagnetic field components measured external to the plasma require high precision or correlation with other diagnostics in order to fix model parameters. A computer simulation shows an assumption of constant ring thickness and energy density with increasing length (and energy) is compatible to diamagnetic field observations on NBT.

# FORWARD

This report covers the work performed during the period May 15, 1980, to January 31, 1981, under Basic Agreement No. 7676, Project Authorization No. X01, a subcontract from Union Carbide Corporation to the University of Missouri. This is the final report for this Project Authorization. The work was performed by the Principal Investigator, Dr. Kenneth H. Carpenter, with assistance from Mr. Frank Zykan during Summer 1980. Dr. Carpenter is Associate Professor in the Department of Electrical Engineering of the University of Missouri - Rolla, and Mr. Zykan was a Graduate Research Assistant in that department.

ACKNOWLEDGEMENTS

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Research Support for Plasma Diagnostics on Elmo Bumpy Torus - Investigation of diamagnetic diagnostics for the electron rings

## I. INTRODUCTION

Determination of the parameters of the hot electron rings in EBT is one of the basic goals of the experiment[1], having a significant roll to play in plasma power balance[2] and stability[3] considerations. Diamagnetic flux pickup loops have been used since the beginning of the experiment as a diagnostic for the ring stored energy[4]. A single attempt was made to obtain data needed to establish ring geometry by measurement of the diamagnetic field axial components near the outside of the plasma[5], but this measurement was not sufficiently useful to be made a part of the standard diagnostics. In a similar way, diamagnetic measurements have been made on the NBT experiment[6] and the STM experiment.[7] The fundamental importance of these diamagnetic measurements prompted studies into the calibration of existing diagnostics and feasibility of additional diamagnetic diagnostics. In this report the results of studies into three aspects of diamagnetic diagnostics will be presented -- elimination of intercavity cross talk effects in perpendicular energy signals via data analysis, assessment of possible observation of ring geometry using diamagnetic measurements, and calibration of perpendicular energy diagnostics using current sheet and MHD equilibrium models.

The use of diamagnetic flux pickup loops encircling each EBT cavity to indicate electron ring perpendicular energy ($W_\perp$) in the corresponding cavity is complicated by the fact that each $W_\perp$ signal contains varying contributions due to energy in neighboring cavities. To facilitate use of these $W_\perp$ signals in determining ring power distribution among the cavities a method was developed to resolve individual cavity $W_\perp$ values from the array of 24 cross coupled $W_\perp$ signals. For a wide range of ring geometries the cross coupling can be compensated to about 3% by the simple method of subtracting 1/4 of the raw $W_\perp$ signal from the two adjacent cavities from the raw $W_\perp$

signal of a given cavity and then multiplying the result by 8/7. A more accurate compensation algorithm has been incorporated in the computer code used to analyze data from plasma turn-downs. This is described in section II of this report.

Although ring perpendicular energy is an important plasma parameter, the confinement properties of that ring -- expressed by ring geometry and "beta" -- are equally important. Satisfactory diagnostics for ring geometry have not yet been achieved on EBT by means of diamagnetic measurements. Early attempts using small relay coils for diamagnetic field measurement lacked sufficient sensitivity to ring geometry to fix model parameters and simulation studies made then were not encouraging.[5,8] Use of a Hall probe array on the STM experiment for this purpose[7] prompted a fresh look at this possibility for EBT. Also a reported relationship between diamagnetic signals and (presumed) ring axial length for NBT[9] prompted further comparisons of model rings and external diamagnetic field components. These studies are described in section III of this report.

Calibration of $W_\perp$ signals from the diamagnetic flux pickup loops is somewhat model dependent and of such importance as to merit study by more than one approach. In section IV we present results from preliminary calculations using a bumpy cylinder MHD equilibrium code for calibration of the $W_\perp$ signals.

Following the concluding comments and recommendations in section V, we present in the appendix the FORTRAN listings and sample inputs and outputs for the computer programs written for use in this work.

## II. CORRECTION OF PERPENDICULAR ENERGY DIAMAGNETIC SIGNALS FOR CROSS TALK BETWEEN SECTORS

The $W_\perp$ signals used routinely as an indication of ring plasma energy in each EBT sector are subject to significant cross talk from adjacent sectors. A method to unfold the twenty-four $W_\perp$ signals to give twenty-four signals, each proportional to the perpendicular energy in a single electron ring, was developed and subsequently included in the data analysis program. A derivation of the algorithm and its implementation as a universal correction method is given in what follows.

### Derivation of voltage-energy calibration in the presence of cross talk

Let the signal output by the integrator connected to the pickup loops on the i'th sector be $v_i$, and let $F_i$ be the diamagnetic flux linking one turn of the pickup loop. Then $v_i = F_i N/t$ where N is the number of turns and t is the integrator time constant (assumed the same for all i). Let the electron ring in each EBT sector be modeled by two current sheets. Let the inner current sheet have total current magnitude $I_{i1}$ and the outer current sheet have total current magnitude $I_{i2}$. Let the mutual inductance coupling current sheet $I_{i1}$ and pickup loop j be $M_{ji1}$, and let that linking $I_{i2}$ and pickup loop j be $M_{ji2}$. The total flux linking one turn of pickup loop i is thus

$$F_i = \sum_{j=1}^{24} (M_{ij1} I_{j1} - M_{ij2} I_{j2}) + F_c \qquad (1)$$

where the minus sign is used so that all M and I values can be positive with the outer and inner current sheets oppositely directed. $F_c$ is the diamagnetic flux due to plasma not represented by the current sheets, i.e., the toroidal core plasma.

Given a specific geometry for a current sheet model, $M_{ij1}$ and $M_{ij2}$ can be calculated. We choose to use the concentric cylindrical current sheet model described in another report[10]

Based on it, a FORTRAN function DM has been written to calculate the M's. (A listing of the FORTRAN is given in the appendix.)

Lacking any knowledge to the contrary, we make the following key assumption: The geometry of all 24 electron rings is the same; that is, the $M_{ij}$ values depend only on the difference between i and j (modulo 24) not on i and j separately. While this is not exactly true, computer studies show that the $M_{ij}$ are only weakly geometry dependent[10] so that the assumption does not introduce serious error.

The perpendicular energy in the model is given by

$$W_{\perp i} = 2\pi r(\Delta r)\, B_{avg}\, \frac{1}{2}(I_{i1} + I_{i2}) \tag{2}$$

where $B_{avg}$ is a suitable average value for magnitude of total magnetic field (vacuum plus diamagnetic) over the region occupied by the ring. In (v-1) we have a set of 24 equations in 49 unknowns, the $I_{i1}$'s, $I_{i2}$'s, and $F_c$. To reduce the unknowns to 24 to allow for solution for the $W_\perp$'s via Eq.(2) we do the following. First $F_c << F_i$ is assumed and $F_c$ is set to zero. Second the theoretical formula for drift current[10] is used to fix the difference of $I_{i1}$ and $I_{i2}$:

$$I_{i2} - I_{i1} = \frac{\Delta B}{2B}(I_{i2} + I_{i1}) \tag{3}$$

where $\Delta B$ is the difference between the magnetic field at the inner current sheet and that at the outer, and B is the mean value. This provides the additional 24 relations needed to solve eq(V-1) for the $I_{j1}$ and $I_{j2}$ values. (The term DF = $(1 + \Delta B/2B)$ is used in the computer codes to represent this "drift factor".) If we let $I_i = (I_{i1} + I_{i2})$ then $I_{i1} = I_i(1 - \Delta B/2B)$ and $I_{i2} = I_i(1 + \Delta B/2B)$ so that Eq.(1) becomes

$$F_i = \sum_{j=1}^{24} [M_{ij1}(1 - \Delta B/2B) - M_{ij2}(1 + \Delta B/2B)]\, I_j \tag{4}$$

$$= \sum_{j=1}^{24} C_{ij} I_j$$

Now from the assumed identity of the geometrical factors for all sectors one has the property that $C_{ij}$ is a symmetric circulant matrix:

$$C_{ij} = C_{ji}$$
$$C_{i+n,\, j+n} = C_{ij}\ , \text{ addition mod 24.} \tag{5}$$

Thus there are only 13 independent matrix elements for $C_{ij}$. Such a matrix can be inverted by Fourier techniques to give an inverse matrix $D_{ij}$ having the same properties. Thus we have

$$I_i = \sum_j D_{ij} F_j \tag{6}$$

and through Eq.(2) the separated ring perpendicular energies.

FORTRAN subroutines have been written to evaluate the $C_{ij}$ and $D_{ij}$ and to calculate (normalized) $I_i$'s given a set of $F_j$'s. These are listed in the appendix.

Correction matrix for diamagnetic flux signals

This same technique can be used to correct the $v_i$ values to those that would be obtained if only flux from the i'th ring contributed. Let such corrected values be labeled $w_i$. Then

$$w_i = C_{ii} I_i N/t = C_{ii} \sum_j D_{ij} v_j \tag{7}$$
$$= (d^{-1})_{11} \sum_{j=1}^{24} d_{ij} v_j$$

where $d_{ii} = 1$. There are only 12 independent elements to the correction matrix $C_{ij}$ which can be represented in terms of the normalized matrix $d_{ij}$ having ones for all diagonal elements. The normalizing factor is the diagonal element of the inverse of the $d_{ij}$ matrix. Let the twelve independent elements of $d_{ij}$ be labeled as $f_i = d_{1,\, i+1}$ , $i = 1,2...12$ and let $f_0 = (d^{-1})_{11}$. Then the correction algorithm to yield the signals due to the rings in a single sector only is

$$w_i = f_0(v_i + (v_{i+1} + v_{i-1})f_2 + (v_{i+2} + v_{i-2})f_3 \quad (8)$$

$$+ \ldots + (v_{i+11} + v_{i-11})f_{12} + (v_{i+12})f_{13})$$

where addition of indices is modulo 24.

Results of a few representative runs are given in Table 1. One sees that for the model parameters tested one can use a universal "average" set $f_i$ to correct for cross talk between sectors and still achieve an accuracy of at least 2% of the largest of the uncorrected readings. Since the precision of the $v_i$ values is not better than 2%, this fixed, average $f_i$ set was programmed into the EBTOFF data reduction routine used on the PDP-10. Thus EBTOFF now provides a cross talk correction option for analysis of plasma turn down data. A listing of the FORTRAN for this revised EBTOFF is given in the appendix.

Hand calculation algorithm

Note that nearly all the correction for cross talk comes from the two adjacent sectors. In fact, since the next nearest pair of sectors has the opposite sign ($f_3 > 0$; $f_i < 0$, $i > 3$) from the remaining ones, only about another 1% of error will be introduced if only the nearest neighbor sector corrections are made. For hand calculations to 3% accuracy, simply subtract one-fourth of each neighboring sector $W_\perp$ voltage signal from the one whose corrected value is desired; then multiply this result by 1.15 to obtain the value that would have resulted if only that sector's ring had produced flux to link the pickup loop.

| | | | | | mean values | maximum deviations |
|---|---|---|---|---|---|---|
| ring thickness | 2.0 | 2.0 | 4.0 | 2.0 | | |
| ring mean radius | 13.32 | 13.32 | 13.32 | 12.22 | | |
| drift factor | 1.065 | 1.065 | 1.129 | 1.058 | | |
| ring length | 5.0 | 10.0 | 10.0 | 10.0 | | |
| $f_0$ | 1.1424 | 1.1461 | 1.1448 | 1.1538 | 1.1468 | 0.007 |
| $f_2$ | -0.2475 | -0.2505 | -0.2494 | -0.2565 | -0.2510 | 0.0055 |
| $f_3$ | 0.0176 | 0.0188 | 0.0184 | 0.0213 | 0.0190 | 0.0023 |
| $f_4$ | -0.0066 | -0.0068 | -0.0067 | -0.0071 | -0.0068 | 0.0003 |
| $f_5$ | -0.0013 | -0.0012 | -0.0012 | -0.0011 | -0.0012 | 0.0001 |
| $f_6$ | -0.0010 | -0.0010 | -0.0010 | -0.0010 | -0.0010 | 0 |
| $f_7$ | -0.0006 | -0.0006 | -0.0006 | -0.0006 | -0.0006 | 0 |
| $f_8$ | -0.0004 | -0.0004 | -0.0004 | -0.0004 | -0.0004 | 0 |
| $f_9$ | -0.0003 | -0.0003 | -0.0003 | -0.0003 | -0.0003 | 0 |
| $f_{10}$ | -0.0002 | -0.0002 | -0.0002 | -0.0002 | -0.0002 | 0 |
| $f_{11}$ | -0.0001 | -0.0001 | -0.0001 | -0.0001 | -0.0001 | 0 |
| $f_{12}$ | -0.0005 | -0.0005 | -0.0005 | -0.0005 | -0.0005 | 0 |
| $f_{13}$ | -0.0006 | -0.0006 | -0.0006 | -0.0006 | -0.0006 | 0 |

Table 1. Data from typical model ring calculations for perpendicular energy signal correction coefficients.

## III. EXAMINATION OF RELATIONSHIP OF EBT ELECTRON RING GEOMETRY TO DIAMAGNETIC FIELD COMPONENTS WHICH CAN BE OBSERVED FROM OUTSIDE THE PLASMA

The fact that diamagnetic flux loop signals, which are used as a ring energy diagnostic, are insensitive to geometry is an indication that determination of ring geometry from diamagnetic field measurements will be difficult. A single attempt was made during the EBT-I period to obtain data to establish ring geometry by measurement of the diamagnetic field axial component at several points near the outside of the plasma[5]. This measurement was not sufficiently useful to be made part of the standard diagnostics.

Diamagnetic measurements have also been made recently on the NBT experiment[6] and the STM experiment[7]. In order to understand the NBT results for the radial component of the magnetic field near the midplane versus ring energy[9] and to assess the possibility of successfully applying the techniques used on STM to EBT, a re-examination of the relationship of parameters for a current sheet model of the rings to the diamagnetic field components was carried out. The details follow.

### Previous ring field simulations and revised simulation code

In late 1976 a set of measurements of diamagnetic field axial components near the outside of the plasma was made using small relay coils as pickups. The resulting data was noisy and not able to give a definitive fit to the ring model parameters. This prompted a simulation study of the fields due to model rings to search for possible locations where field component measurements could discriminate between different ring geometries. (This study has been reported elsewhere[5,8].) The computer program used for this study output "arrow plots" which showed diamagnetic field versus position for given values of ring model parameters. The results were pessimistic for determination of ring model parameters by field component measurement at accessible locations. The lack of sensitivity of field components to model parameters is due to the fact

that field values a distance R from the center of a cylindrical current sheet having length L and radius A varies with A and L as $(A/R)^2 + (L/R)^2$ compared to one. Thus the requirement that measurements of field components be made outside the region containing the plasma (in order to prevent the probes' modifying the ring geometry itself) was responsible for the lack of success of the observations using the relay coils.

Reported use of Hall probes to obtain high precision magnetic field readings on the STM and NBT experiments prompted a restudy of feasibility of use of an array of diamagnetic field component measurements to determine ring geometry on EBT. The original "arrow plot" computer code was employed again, but this time including the theoretical $\Delta B/B$ drift current effect[10] to reduce the number of free model parameters. A revised field simulation code (FLDEQ) was written to output the field components at fixed positions as functions of ring model parameters. (This code is listed in the appendix.) FLDEQ was used to simulate the NBT experimental data as well as to look again at the possibility of ring geometry determination for EBT using high precision field measurements.

Simulation of NBT radial diamagnetic field measurements

The NBT experiment used a Hall effect device, rather than a relay coil, to measure the plasma diamagnetic field. The Hall probe was oriented to give no output due to the vacuum field, hence its signal was the diamagnetic component normal to the vacuum field. This arrangement was simulated using the FLDEQ code by looking at the radial component of the magnetic field due to a concentric cylindrical current sheet model when the field point was 1 cm from the midplane and 5 cm from the outer current sheet.

The simulated signal for the magnetic field reproduces qualitatively the variation of the signals reported for NBT from a Hall effect detector as the ring energy is increased[9]. The qualitative result is compatible with an increase in ring axial extent (length) with increase in energy while maintaining a constant energy density. The simulated $B_r$ signal is plotted versus axial extent assumed for the ring, in NBT geometry, in Fig. 1. The location of maximum $B_r$ at

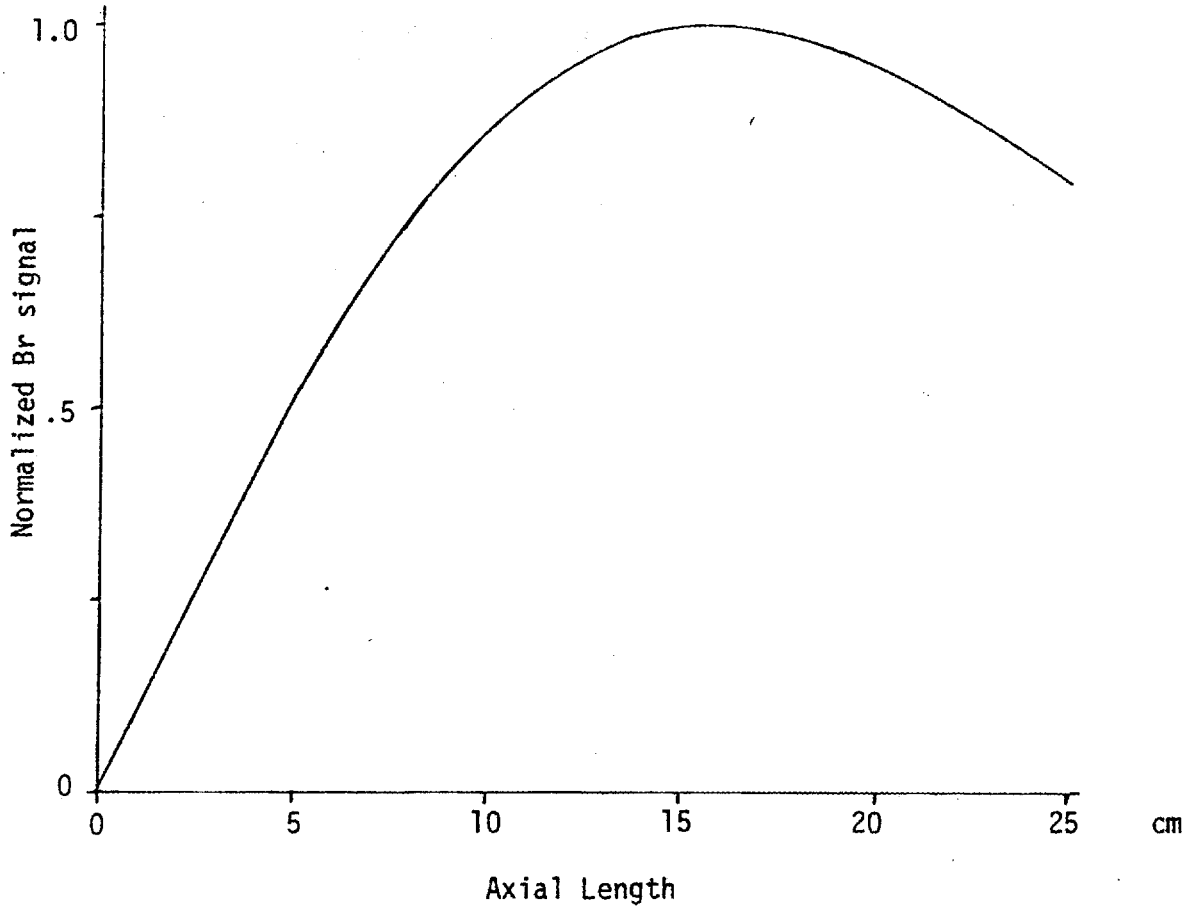


Fig. 1. Simulated radial diamagnetic field component versus length of model ring for a detector 1 cm away from midplane and 5 cm away from edge of ring. (NBT conditions) (Adjacent cavity effects included)

about 16cm for total length does not vary significantly with changes in assumed values for drift current effects and ring thickness.

Next the possibility of a similar variation of radial field with ring energy was explored for EBT conditions. Plots for $B_r$ versus ring axial extent are given in Fig. 2 for EBT-I geometry for several possible detector locations at the outside of the EBT cavity. The maximum in signal occurs for larger ring lengths than in the NBT case primarily because the detector locations are farther from the model rings. Although it would be interesting to look for this fall off of field with increasing energy for EBT, it is not likely to be observed unless the rings are longer and nearer the outside of the machine than anticipated.

Finally we note that this result of decrease in magnetic field with increase in current sheet length is exactly what one would anticipate on a purely intuitive basis. For a constant energy density in the ring one has current sheets in the model with constant surface current densities. Zero length for the current sheet gives zero field. As the energy and length increase, the field at a fixed outside location increases at first, but as the length increases sufficiently the "ends" of the ideal solenoid become more distant, ultimately leading to continuously decreasing fields.

EBT ring geometry from external field measurements

The previous studies using "arrow plots" gave little hope for determination of ring parameters by external field measurements. In order to see what one might be able to do with more precise values for field components using Hall probes a study was carried out, using the FLDEQ simulation program. This study attempted to find how parameters of the current sheet model for EBT rings could be related by measuring diamagnetic field components at the outside edge of the cavity. If one assumes only relative calibration between detectors is available and not absolute field values then one can determine if the data is compatible with the model but cannot fix the model parameters. The ratios between detector signals are predicted to be nearly constant for a wide variation of choices for ring length and thickness, provided the radial location of the ring is set near the heating resonance and the drift current effect is near

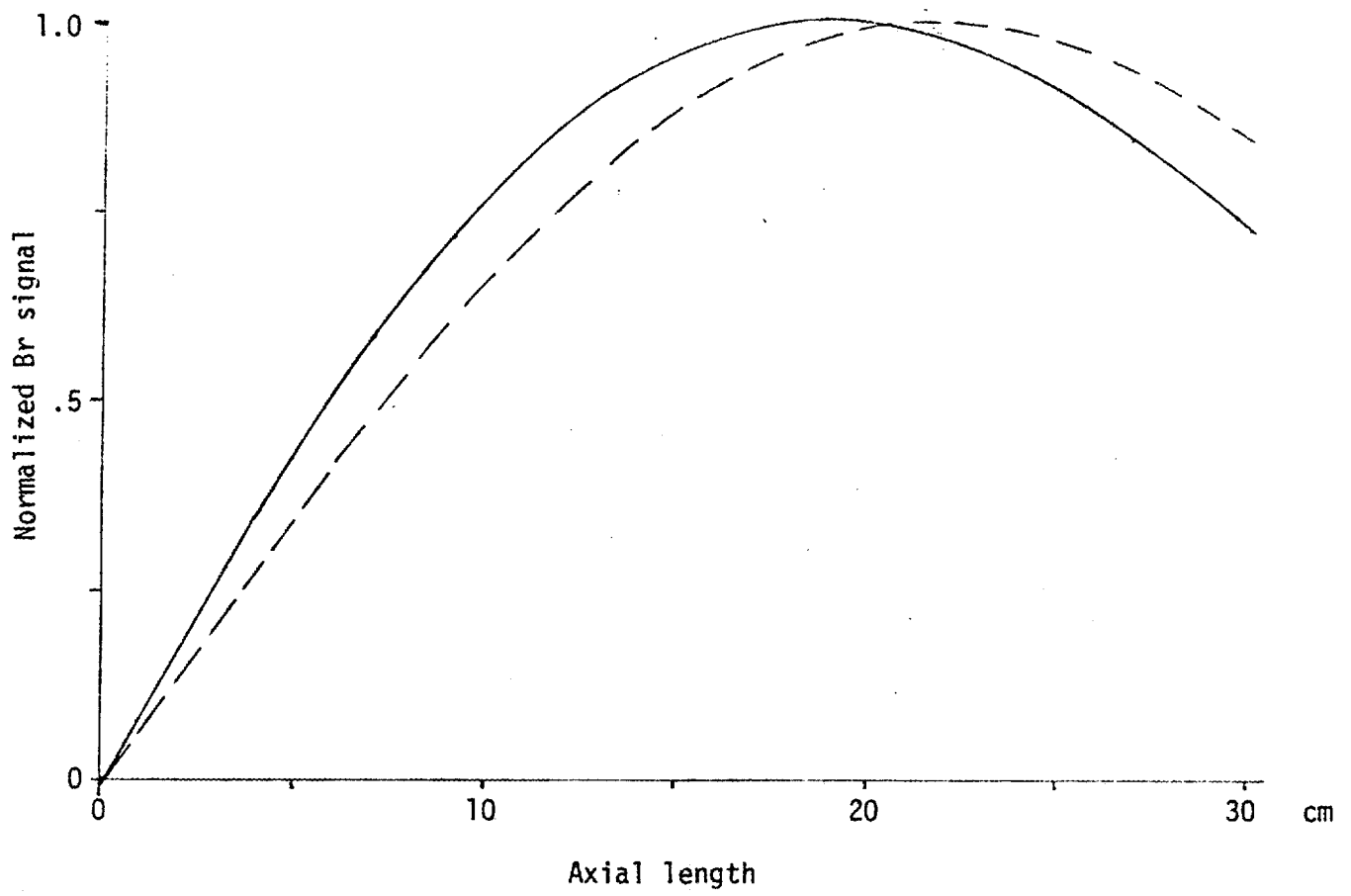


Fig. 2. Simulated radial diamagnetic field versus length of model ring. Solid line for detector at coordinates (1,30), dashed line for detector at coordinates (10,30) with respect to cavity center. (Ring model thickness 2 cm assumed)(EBT-I geometry--adjacent cavity effects included)

the theoretical value. If an absolute calibration could be obtained for field component measurements as well as for the flux loop signals used to measure perpendicular energy then a determination of length, given thickness, could perhaps be made since the perpendicular energy measurement is less sensitive to length and thickness of the ring than some field component measurements. An attempt was made to make this connection between field and flux signals with the data taken in 1976, but some discrepancy was present in the relative calibration which prevented reaching any conclusions.

Simulated data was obtained for field components at several detector locations versus model ring length with other model parameters fixed. The field values were ratioed to the values obtained at the location nearest the midplane in order to eliminate an assumption of absolute calibration for experimental data. The resulting curves are plotted for one choice of ring thickness and radius in Fig. 3. Note that the slopes of the curves are small. Thus in the presence of experimental uncertainty accurate determination of length is difficult even with the model parameters of thickness, radius, and drift current effect known.

Since the other model parameters are not known a priori one can consider cases with both length and thickness unknown. Then for each field component a curve of length versus thickness can be made. An example is given in Fig. 4 using simulated $B_r$ readings for a particular length and thickness. In this case the curves are nearly parallel so that the point of common intersection could not be found accurately in the presence of experimental uncertainties, although model length could be determined more accurately than thickness.

There is a need for field measurements at a combination of precision, absolute calibration and locations that would fix the parameters of the ring model -- not only tc evaluate these parameters but also to determine the validity and usefulness of the model in further plasma calculations (from the goodness of the fit of the model to the data). The STM results indicate a more complicated ring model will be needed for good fits [7]. A possible approach is to use a MHD equilibrium model such as is described in the next section of this report.

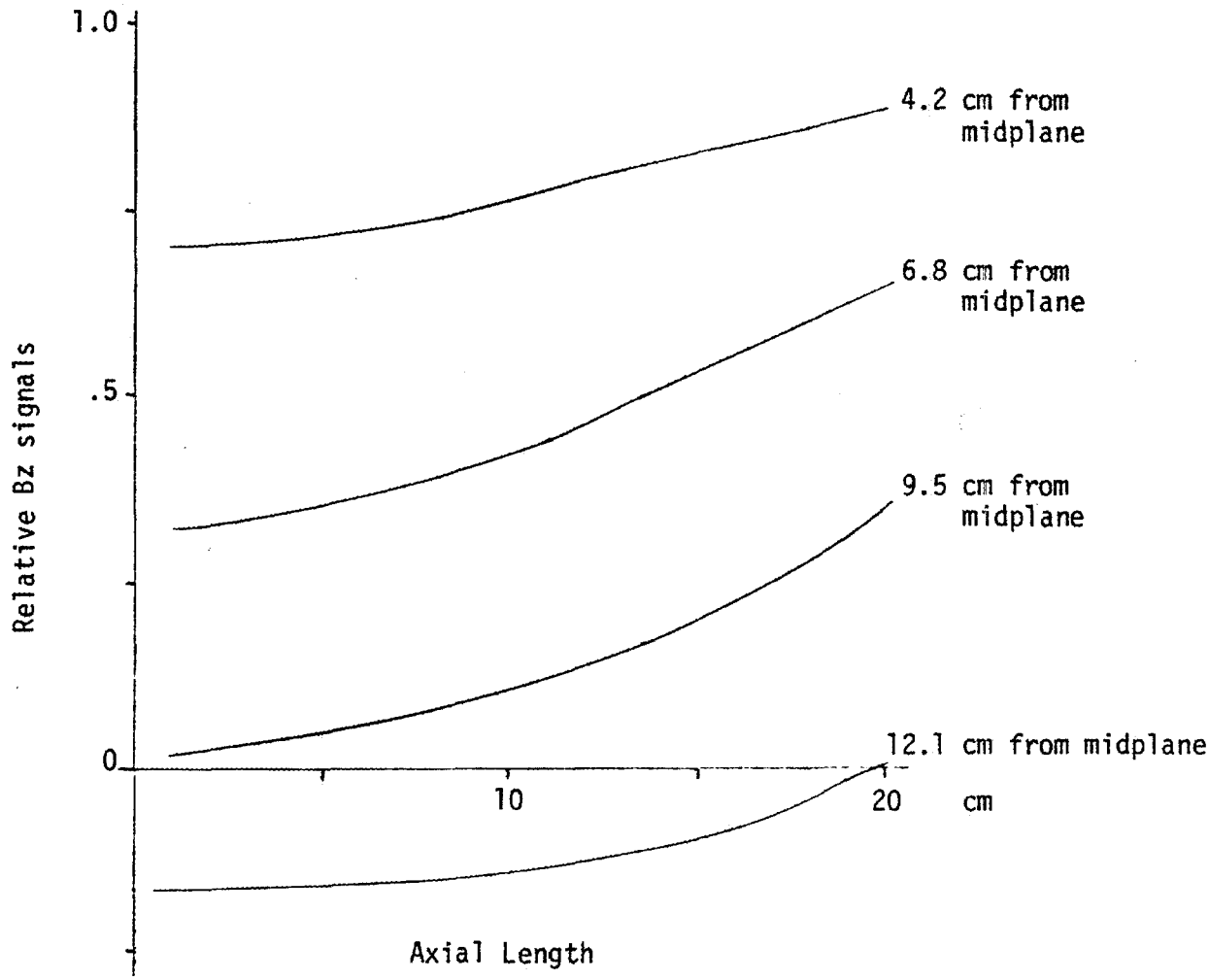


Fig. 3. Simulated axial diamagnetic field components at outside of plasma (23.5cm from cavity center) relative to component at coordinates (1.6,23.5) near the midplane, versus length of model ring. (Ring thickness 2cm, mean radius 13.3cm assumed--EBT-I geometry, adjacent cavity effects included)

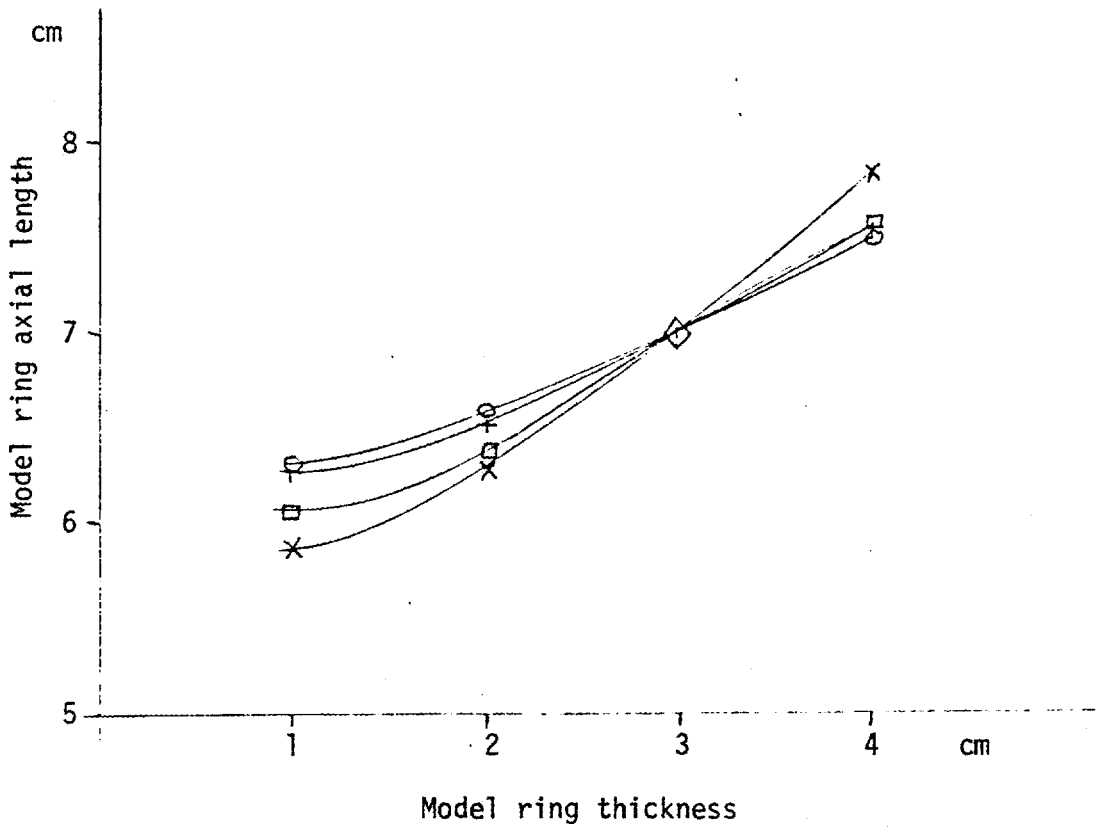


Fig. 4. Length - thickness curves for simulated experimental Bz data for detectors at:
(4.2,23.5) - o
(6.8,23.5) - +
(9.5,23.5) - □
(12.1,23.5) - ×
Values ratioed to signal from detector at (1.6,23.5)

## IV. "BUMPY CYLINDER" MHD EQUILIBRIUM CODE MODEL FOR CALIBRATION OF ELECTRON RING ENERGY DIAGNOSTIC - COMPARISON TO CURRENT SHEET MODEL

The concentric cylindrical current sheet model that has been used to provide a calibration for the diamagnetic flux loops' perpendicular energy signal has been studied extensively.[10] Although the calibration results obtained are quite insensitive to the model parameters (a fact attributed in part to the near Helmholtz coil arrangement of the pickup loops), which should imply similar calibration results would be obtained with other models, two questions still remain as to the validity of the result. The first question is on the adequacy of the handling of the drift current effect for the current sheets. The second is what is the proper choice of average magnetic flux density to use to multiply total magnetic moment to obtain perpendicular energy. Both of these questions are answered automatically if a MHD equilibrium model is used in place of current sheets.* In this section we will describe the modifications made to an existing MHD code, the normalization factors associated with the code output, and the problems and limitations of the code. The results of the MHD equilibrium code being applied to typical ring situations will be discussed and compared to the analogous current sheet results.

### The bumpy cylinder MHD equilibrium code

We were provided a copy of the FORTRAN of the bumpy cylinder MHD code written by Hedrick[11] to serve as the basis for this work. The code uses a model of pressure as a separable function of flux, $\psi$, and field magnitude B with

---

*Remaining questions as to valid range of model parameters must be answered through the use of other diagnostic methods. Testing of these models has been done by assuming reasonable dimensions for electron rings centered near the rings' heating resonance.

$$g(\psi) = \begin{cases} (\psi - \psi_1)^2(\psi + \psi_1 - 2\psi_2)^2/(\psi_2 - \psi_1)^4, & \psi_1 \le \psi \le \psi_2 \\ 1\ , & \psi_2 \le \psi \le \psi_3 \\ (\psi - \psi_4)^2(\psi + \psi_4 - 2\psi_3)^2/(\psi_3 - \psi_4)^4, & \psi_3 \le \psi \le \psi_4 \\ 0, \text{ otherwise} & \end{cases} \tag{9}$$

as the flux function and

$$\begin{aligned} P_\perp &= \tfrac{1}{2}S(B_c{}^2 - B^2)g(\psi) \\ P_{11} &= \tfrac{1}{2}S(B_c - B)^2 g(\psi) \end{aligned} \tag{10}$$

as the pressure functions. S is a positive constant less than one and $B_c$ is a cutoff field value - pressure is zero for $B > B_c$. The code chooses the $\psi_1$, $\psi_2$, $\psi_3$, $\psi_4$, values at proper flux coordinates to give fixed (input) values for the radial position of the pressure profile in the midplane. The resultant equilibrium ring is thus a function of six input parameters to the code: four radial values $r_i$ corresponding to the flux values $\psi_i$; the cutoff field $B_c$; and the constant S. The code calculates the equilibrium by iteration on the nonlinear MHD equation

$$\Delta^*\psi_p + \nabla(\ln\sigma) \cdot \nabla\psi_p = \frac{r^2}{\sigma}\ \frac{\partial p_\Pi}{\partial\psi} - \nabla(\ln\sigma) \cdot \nabla\psi_c \tag{11}$$

where $\sigma = 1 + (p_\perp - p_\Pi)/B^2$ and $\psi = \psi_p + \psi_c$ with $\psi_c$ the vacuum flux. The right hand side and $\nabla(\ln\sigma)$ values are calculated using previous solutions for $\psi$, then Eq. (11) is solved by an S.O.R. finite difference algorithm and the process repeated. The code fixes the boundary conditions for Eq.(11) by using a multipole expansion of the field due to the plasma.[11]

There are several auxilary input parameters required by the code: number of sectors to represent an infinite bumpy cylinder, number of terms in multipole expansion, S.O.R. acceleration parameter, and outer loop solution mixing parameter. In addition the number of iterations to be performed on both inner and outer loops must be specified. Only a few of the many possible combinations of these

auxilary parameters have been used, the choices being guided by trial runs and the experience of other users of the code.[12]

Several modifications were required to the FORTRAN of the MHD equilibrium code (titled EQUIL) in order to obtain the necessary output for calibration of the perpendicular energy diamagnetic signals. Most of the added code was placed in subroutine BATS to provide, on the final iteration, a numerical integration of pressure over space to give energy, and to provide an output of perpendicular pressure versus position in a format which gives a pressure map on the line printer. An output of total flux linking a specified circle of constant radial coordinate was also included. A number of smaller changes were made to input/output to make the code compatible with the UM computer network FORTRAN system. Certain sections of the code whose results were not needed for the present purpose were bypassed to reduce time required for execution, and some changes were made in the control of the iterations and the extent of the output. Since the code is over 2000 lines long a complete listing is not included with this report, but listings of the main program, which describes the modifications in comments, and of subroutine BATS, which contains the major additions, are given in the appendix.

Normalization of variables in EQUIL code - specification of input values - interpretation of output values

All length variables in EQUIL are assumed to be in centimeters. All plasma variables are normalized to the magnitude of magnetic flux density at the center of the midplane, $B_0$. Further, factors of $\mu_0$ that would be required for SI units are omitted. The FORMAT statements in the code specify how the input variables must be entered, but the input variables and their interpretations are repeated in the output. Since the interpretation of variables given in the computer output is not always clear, and since an understanding of these is necessary for use of the code and interpretation of the results, the input parameters and output values are briefly described in the appendix where a sample output is given.

The normalization of the output values produced by EQUIL was carefully traced through the FORTRAN listing to be sure all the numerical constants were taken into account. Since the code only treats one-half a mirror section due to symmetry the total ring energy is a factor of two times the value obtained by numerical integration in the code. As a result the values given in Table 2 were obtained. In particular we note that the ring "beta" relative to the field at the center of the midplane, $\beta_\perp = 2p_\perp\mu_0/B_0^2$, is just twice the computed value of PERP; the perpendicular energy of the ring in Joules is ten times the computed value WPER multiplied by $B_0^2$ in $(\text{Tesla})^2$; the flux linking a circle of radius corresponding to the index L in SI(L) in Webers equals the SI(L) value times $6.28 \times 10^{-4}$ times $B_0$ in Tesla. Note that local ring beta is typically a factor of 2 ½ times greater than $B_\perp$ defined with respect to $B_0$.

General observations on EQUIL output

Sample output from representative runs of the MHD equilbrium program EQUIL are given in the appendix. Some general comments on qualitative results and limitations on their reliability will be presented here. First we note that the pressure model built into the code implies that, for a fixed radial profile for the ring, the higher the beta the longer the ring in the toroidal direction. Whether or not this implication of the model is also true for the actual ring is significant for ring diagnostics, since a ring long enough to be "high" beta is too long to be adequately represented by a circular cylinder model. In EQUIL runs we have made to date we have achieved less than 20% beta for rings when the length was forced to be about 10 cm.

We note that for the runs of EQUIL made to date that had beta values high enough to achieve a local minimum in B versus r, the $W_\perp$ values that resulted should produce diamagnetic flux signal voltages (>500 mV) that are greater than those observed for EBT-I turn-downs (<300 mV). However, no systematic study has been made on this topic.

There remain matters of numerical precision to be resolved with the EQUIL code itself. The code is written in single precision

| beta % | 2 | 8 | 18 | 23 |
|---|---|---|---|---|
| radial shape | triangle | trapezoid | triangle | trapezoid |
| $r_1$ | 11 | 11 | 11 | 11 |
| $r_2$ | 13 | 12 | 13 | 12 |
| $r_3$ | 13 | 14 | 13 | 14 |
| $r_4$ | 15 | 15 | 15 | 15 |
| $\left(\frac{W_\perp}{Volt}\right)$ | 32 | 32 | 30 | 28 |

Table 2. Diamagnetic flux pickup loop calibration factors from MHD equilibrium model. ($B_o$ = 5000(G)).

FORTRAN and executed on a 32 bit word computer. Since the solution is done by iteration, roundoff errors are less of a problem, but a test case should be run in double precision. The size of the finite difference mesh was checked at two values, and though the results changed, the finer mesh moved the calibration factor for the diamagnetic flux signal toward a smaller energy per volt. The number of iterations on a given run was increased successively until only small changes in results occurred for additional iterations in both outer and inner loops. We note that increasing the number of iterations also reduces the energy per volt factor. We also observe that the values for pressure converged much more rapidly than the values for diamagnetic flux. This is due to pressure being determined by the total flux on which the diamagnetic value is only a perturbation. The number of multipole terms in the boundary condition expansion was fixed at 10 and the number of sectors to approximate an infinite bumpy cylinder was fixed at 7. Obviously a great deal more effort could be spent assessing the effects of these numerical matters, but the qualitative conclusions are not expected to change.

Current sheet model for bumpy cylinder

In order to make a direct comparison of diamagnetic flux signal calibration in a MHD and a current sheet model, a program was written, similar to the one used to calculate the mutual inductances for the bumpy torus, to provide the calibration factor for a bumpy cylinder with an arbitrary number of sectors. This code (BUMCAL) is listed in the appendix. The code outputs normalized flux linkage for single current sheets. The drift factor effect for the concentric current sheet model is then calculated by hand. The input values given to the program are the number of sectors, the current sheet radius, the current sheet width, and the separation between adjacent sectors (all in centimeters). The output is a value APT which is the normalized flux linkage for a pickup loop in a position similar to the diamagnetic flux loops on EBT (radius 28cm, location 9.5cm from midplane). The normalization in the code is such that to obtain the dimensional flux linking one turn of the pickup loop one must multiply the value of APT by $\mu_0 RI/2$ where R is pickup coil radius and I is total current

for the sheet. Thus the formula to obtain the flux pickup loop calibration factor is

$$\frac{W_\perp}{\text{Volts}} = \frac{B_{avg}}{(\mu_o/4\pi)} \frac{r(\Delta r)t}{RN} \frac{1}{[(1 + (\Delta B/2B))AP_{out} - (1 - (\Delta B/2B))AP_{in}]} \quad (12)$$

where $B_{avg}$ is the proper "average" value of total magnetic flux density over the model ring to convert dipole moment to energy. $\Delta r$ is ring thickness, $r$ is ring mean radius, N is number of turns on the pickup coil, t is integrator time constant , $\Delta B$ is change in magnetic field across the ring thickness and B the mean value.

One case was run for comparison to the MHD values. For it R = 28 cm, r = 13 cm, $\Delta r$ = 2 cm, L = 10 cm and BUMCAL gave $AP_{out}$ = 1.0076 and $AP_{in}$ = 0.7394. The values assumed for $\Delta B/B$ and $B_{avg}$ have a significant bearing on the result. To agree with the procedure used for the EBT current sheet model the value taken for $\Delta B/B$ corresponded to the vacuum field in the midplane (as read from the output for a low beta case from EQUIL). If $B_{avg}$ is taken as the value near the center of a corresponding low beta run of EQUIL then $B_{avg}$ = 0.255 (T) for a field of 5000 Gauss at the center of the midplane. Substituting these values in Eq. ( 12 ) gives a numerical value for the calibration factor of 26 (Joule/volt). Obviously there is room for considerable uncertainty in the $B_{avg}$ value used as well as in $\Delta B/B$. No other cases have been checked, but experience with the bumpy torus current sheet model shows that little change is to be expected for different thickness $\Delta r$ or length L as long as the other values remain the same.

Comparison of MHD equilibrium model and current sheet model flux loop energy calibration factors

Four cases have been run with EQUIL using input values that yield rings that can reasonable be compared with the cylindrical current sheet model. Each had a length of about 10cm and was approximately cylindrical in geometry (as can be seen in the EQUIL sample output in the appendix). The radial cross section, beta

values, and flux loop calibration factors are summarized in Table 3. We note that pickup loop calibration factors exceeded the current sheet model value of 26 (Joule/volt) by a range of 10 to 20%.

A 20% agreement between as crude a model as cylindrical current sheets compared to a MHD equilibrium is encouraging. The difference is no doubt due in part to the choice of $B_{avg}$ and $\Delta B/B$ for the current sheet model. A concern for the accuracy of the MHD model results needs to be mentioned however. In each case listed in Table 3 the radial increment for the finite differences was 0.25cm. This put only 16 points across the ring. The case of 2% beta and triangular radial profile was also run with a 0.5cm radial increment. A result of 39 (Joule/volt) was obtained, which is 20% higher than the result for 0.25cm increments. A further reduction in increment size could reduce the calibration factor to a value more nearly in agreement with the current sheet model. Time did not allow such runs of EQUIL to be made during the period of this subcontract.

A word of caution must be given about using these bumpy cylinder flux pickup loop calibrations for the $W_\perp$ signals on EBT. First, although the loop placement was chosen to be as near to the EBT value as possible, there is still a difference between the toroidal and cylindrical geometries. Second, the EQUIL code runs and BUMCAL runs were made using a separation between adjacent mirror coils of 44.5 cm. The separation at $15^o$ for a 150 cm major radius torus would be 39cm. The proper equivalent separation for a bumpy cylinder for comparison of calibration factors is not clear, but it is clear that adjacent sector cross talk is a bigger factor for the bumpy cylinder, all other effects being equal. However, the current sheet model for EBT gives values for $W_\perp$ signal calibration not far different from those found for the bumpy cylinder.[10]

| Computer Output Numbers → | multiply by → | dimensional quality when $B_0$ = 5000 (Gauss) → | multiply by | for dimensional quantity for any $B_0$ |
|---|---|---|---|---|
| P-PERP | $1.989 \times 10^5$ (Nt-m$^{-2}$) | perpendicular pressure | $(B_0/5000\ (\text{Gauss}))^2$ |
| P-PERP | 2 | ring beta | 1 |
| SI(L) | $6.283 \times 10^{-4}$ (Weber) | magnetic flux linkage | $B_0/5000$ (Gauss) |
| MODB | 5000 (Gauss) | magnetic flux density | $B_0/5000$ (Gauss) |
| WPER | 2.50 (Joules) | ring perpendicular energy | $(B_0/5000\ (\text{Gauss}))^2$ |
| WPAR | 1.25 (Joules) | ring parallel energy | $(B_0/5000\ (\text{Gauss}))^2$ |
| (WPER/SI(L)) | 3.79 $(\frac{\text{Joule}}{\text{Volt}})$ | flux pickup loop calibration factor | $B_0/5000$ (Gauss) |

Table 3. Numerical factors to convert output from EQUIL computer code to dimensional quantities.

## V. CONCLUDING COMMENTS AND RECOMMENDATIONS

The work discussed above is by no means the last word on diamagnetic diagnostics for EBT electron rings. However, important advances have been made in understanding these diagnostics, which we will point out again along with giving our recommendations for additional work in these areas.

The cavity cross talk compensation algorithm for the perpendicular energy signals described in section II is simple and has proven successful in use. The implementation in the EBTOFF code is applicable to EBT-I/S only, however a similar program could easily be written for other machines. One must caution users that the "universal" set of correction numbers written into EBTOFF works best for rings with mean radii near 13cm. Accuracy will be reduced if the machine is run in a mode that would produce rings significantly larger or smaller. In any event, the test of accuracy is the corrected signal output for a cavity with zero input power (which should be near zero).

The examination given to the possibility of obtaining ring geometrical data from diamagnetic field component measurements leaves the projected outcome of such an experiment with a great deal of uncertainty. It is the feeling of the author that the best possible set of diamagnetic data should be obtained. If this is not definitive in itself, it can be correlated to non-diamagnetic diagnostics as they become available. Further work is needed on the use of alternate models for ring geometry, including parameterizations of 3-D MHD equilibria.

The 2-D bumpy cylinder MHD equilibrium calculations have confirmed the basic validity of the use of a current sheet model for calibration of the diamagnetic perpendicular energy diagnostic. There still remain a sizeable number of calculations and code modifications to be done to finally establish the best values and check out possible numerical problems in the code. As 3-D MHD equilibria are generated for geometrical modeling they can also be used to check the $W_\perp$ calibration. As yet optimization has not been attempted on the pickup coil sizes, locations and orientations.

While not a major task, this needs to be considered, especially for application on any new or modified plasma experiment, such as EBT-P.

## VI. REFERENCES


1. N. A. Uckan, ed., Proceedings of the Workshop on EBT Ring Physics: Dec. 3-5, 1979: Oak Ridge, Tenn., Oak Ridge National Laboratory, CONF-791228, April 1980.
2. N. A. Uckan, Op. cit., section 6, pp. 317-380.
3. N. A. Uckan, Op. cit., section 7, pp. 381-490.
4. R. A. Dandl, et. al., Summary of EBT-I Experimental Results, ORNL/TM-6457, Oak Ridge National Laboratory, October 1978, pp. 9-12.
5. K. H. Carpenter, "Diamagnetic Measurements for Experimental Determination of EBT Ring Paramters", in N. A. Uckan, op. cit., p. 147.
6. M. Fujiwara, et. al., "The Ring Formation in Nagoya Bumpy Torus", in N. A. Uckan, op. cit., pp. 123-141.
7. B. H. Quon, et. al., "Spatially Resolved Measurements of the Diamagnetic Field," Bulletin of the APS, Vol. 25 (October 1980), p. 994.
8. K. H. Carpenter, "Modeling the Electron Annulus in EBT from Diamagnetic Field and Flux Measurements," in Fusion Energy Division, Annual Progress Report For Period Ending December 31, 1976, ORNL-5275, Oak Ridge National Laboratory, June 1977, pp. 14-16.
9. G. R. Haste and C. L. Hedrick, ORNL Foreign Trip Report, ORNL/FTR-767 Oct. 8, 1979.
10. K. H. Carpenter, R. A. Dandl, M. W. McGuffin, Calibration of a Diamagnetic Diagnostic for Stored Energy of High Temperature Electron Annuli in Elmo Bumpy Torus (EBT), ORNL/TM-7076, to be issued.
11. D. B. Nelson, C. L. Hedrick, "Macroscopic Stability and Beta Limit in the Elmo Bumpy Torus," Nuclear Fusion, Vol. 19 (1979), p. 283.
12. R. C. Goldfinger, private communication.

## APPENDIX - FORTRAN Listings and Inputs and Outputs

### Cross talk compensation programs

The routines written to achieve the unfolding of intercavity cross talk between $W_{\perp}$ signals have their FORTRAN listings given on the following pages. These listings are in the form of a compressed format file used with the UM computer network IBM-CMS software. Subroutines called, but not in the listing, were used in prior work at ORNL and are available on the FED PDP-10 computer.

All the main programs listed prompt for input interactively or else read as input a file produced by one of the other main programs. All output is via the NAMELIST method for easy data identification. Outputs used in determining the universal correction values programmed in EBTOFF are given in the pages following the FORTRAN listings.

```
FILE: AIMI      CPR       A   UNIVERSITY OF MISSOURI COMPUTER NETWORK


:READ  AIMI      EXEC      A1 TEMP   07/21/80 09:55:02
 &1 &2 LTAIMI    EXEC      A1
 &1 &2 CAIMI     EXEC      A1
 &1 &2 AIOC      FORTRAN   A1
 &1 &2 BMNORM    FORTRAN   A1
 &1 &2 DM        FORTRAN   A1
 &1 &2 EBTOFT    FORTRAN   A1
 &1 &2 MIJE1     FORTRAN   A1
 &1 &2 SYMCIR    FORTRAN   A1
 &1 &2 TAIMI     FORTRAN   A1
 &1 &2 TDM       FORTRAN   A1
 &1 &2 TSTSYM    FORTRAN   A1
 &1 &2 ZEROIN    FORTRAN   A1
:READ  LTAIMI    EXEC      A1 TEMP   07/21/80 09:40:43
LOAD TAIMI MIJE1 AIOC SYMCIR DM ZEROIN SLFL AS1 SASIMP SGAUS8 (NOMAP
GENMOD TAI
:READ  CAIMI     EXEC      A1 TEMP   07/21/80 09:40:43
FORTGI TAIMI    (NOPRINT NOTERM
FORTGI MIJE1    (NOPRINT NOTERM
FORTGI AIOC     (NOPRINT NOTERM
FORTGI DM       (NOPRINT NOTERM
FORTGI SYMCIR   (NOPRINT NOTERM
FORTGI ZEROIN   (NOPRINT NOTERM
:READ  AIOC      FORTRAN   A1 TEMP   07/21/80 09:40:43
      SUBROUTINE AIOC(AIO,EF)
C     K.H.CARPENTER 11JUL80.
C     APPLIES INVERSE MUTUAL INDUCTANCE MATRIX BM TO INPUT WPER SIGNAL
C     VALUES EF TO GIVE UNFOLDED WPER VALUES AIO (NORMALIZED).
C     NORMALIZATION OF WPER FOR I'TH CAVITY IS:
C        WP(I) = (AIO(I) - AIO(K))*BV(I)/CPHI/NTURN/(MUO/TWOPI)
C     WHERE BV(I) IS "AVERAGE" MAGNETIC FLUX DENSITY OVER ANNULUS,
C     CPHI IS VALUE FLUX LINKING PICKUP COIL IS MULTIPLIED BY TO
C     OBTAIN EF(I), AND NTURN IS TOTAL NO. OF TURNS IN SERIES
C     IN PICKUP COILS ON CAVITY I.  AIO(K) IS RESIDUAL VALUE FOR
C     CAVITY WITH NO ANNULUS.
C     FOR DETAILS SEE KHC 9JUL80.
C
      COMMON/CMIJE1/BM(13),AM(13),V1
      DIMENSION AIO(24),EF(24)
C     MULTIPLIES INPUT VECTOR EF BY MATRIX BM TO OBTAIN OUTPUT
C     VECTOR AIO.
C     BM IS A SYMMETRIC, CIRCULANT MATRIX OF DIMENSION 24.
      DO 100 I=1,24
      N=MOD(I+12,24)
      IF(N.EQ.0)N=24
      AIO(I)=BM(1)*EF(I)+BM(13)*EF(N)
      DO 50 J=2,12
         N1=MOD(I+J-1,24)
         IF(N1.EQ.0)N1=24
         N2=MOD(25+I-J,24)
         IF(N2.EQ.0)N2=24
         AIO(I)=AIO(I)+BM(J)*(EF(N1)+EF(N2))
 50   CONTINUE
 100  CONTINUE
      RETURN
```

```
      END
:READ  BMNORM   FORTRAN  A1 TEMP   07/21/80 09:40:43
C     BMNORM    K.H.CARPENTER  16JUL80
C     PROGRAM TO OUTPUT NORMALIZED ARRAY OF BM WITH BM(1)=1
C     AND AN ARRAY NORMALIZED BY MULTIPLYING BY AM(1).
      DIMENSION AI0(24),EF(24),BM(13),AM(13),BN(13),BMN(13)
      NAMELIST/NORM/BN,BMN,AL,RT,DF,B0,GHZ,RR,XR,BZ
      NAMELIST/TAIOUT/AL,RT,DF,B0,GHZ,EF,AI0,BM,AM,V1,RR,XR,BZ,IERR
  5   READ(3,TAIOUT,END=100)
      DO 10 K=1,13
      BN(K)=BM(K)/BM(1)
      BMN(K)=BM(K)*AM(1)
 10   CONTINUE
      WRITE (7,NORM)
      GO TO 5
100   STOP
      END
:READ  DM       FORTRAN  A1 TEMP   07/21/80 09:40:44
      FUNCTION DM(DEG,RI,RO,CO,AL,DF,RB.Z0,AMR,IERR)
C     K.H.CARPENTER 8JUL80
C     RETURNS NORMALIZED MUTUAL INDUCTANCE VALUE BETWEEN
C     DIAMAGNETIC PICKUP LOOPS AND EBT ANNULUS IN CURRENT
C     SHEET MODEL.  ARGUMENTS ARE:
C        DEG = ANGLE IN DEGREES BETWEEN CAVITY WITH ANNULUS
C              AND CAVITY WITH PICKUP LOOPS
C        RI  = RADIUS OF INNER CURRENT SHEET
C        RO  = RADIUS OF OUTER CURRENT SHEET
C        CO  = OUTWARD DISTANCE FROM CENTER OF CURRENT SHEET
C              TO CENTER OF PICKUP LOOP
C        AL  = LENGTH OF CURRENT SHEETS
C        DF  = DRIFT FACTOR (1 + DB/B/2)
C        RB  = RADIUS OF PICKUP LOOPS
C        Z0  = HALF OF DISTANCE BETWEEN PICKUP LOOPS
C        AMR = DISTANCE FROM CENTER OF MACHINE TO CENTER
C              OF PICKUP LOOPS
C     RESULT IS INDEPENDENT OF UNITS USED FOR DISTANCE,BUT
C     UNITS MUST BE THE SAME FOR ALL ARGUMENTS.
C     THE ARGUMENTS ABOVE ARE UNCHANGED ON RETURN.
C        IERR= ERROR INDICATOR. IF IERR=0, NO ERROR.
C     ON RETURN DM CONTAINS THE VALUE OF THE NORMALIZED
C     MUTUAL INDUCTANCE BETWEEN THE PICKUP LOOPS AND THE CURRENT
C     SHEETS. THE NORMALIZATION IS:
C        M  =  DM*N*T*MU0/(2*PI)  WHERE
C              N = TOTAL TURNS IN PICKUP LOOPS
C              T = RO-RI
C     VOLTAGE SIGNAL FROM PICKUP LOOPS (2 IN SERIES WITH TOTAL
C     TURNS N) DUE TO THIS ANNULUS IS EQUAL TO M*TC*JM*AL WHERE
C        TC IS INTEGRATOR TIME CONSTANT AND
C        JM IS MAGNETIC DIPOLE MOMENT PER UNIT VOLUME
C        FOR ANNULUS ELECTRONS (MEAN SURFACE CURRENT).
C
      DOUBLE PRECISION DPI
        COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ
        COMMON/CSLFL/FL,B,XB,ZB,ADEG,CX,SX,XBR,BSX,BCX
        DATA DPI/3.141592653589793D0/
```

```
      DATA NG/4/,NS/8/
      IERR = 0
      NG1=NG
C     PICK UP ARGUMENTS AND PUT IN COMMONS:
      ADEG = DEG
      AL2 = AL/2.0
      B = RB
C     SET FOR OUTER CURRENT SHEET
      R1=RO
C     CALCULATE VALUES FOR ROTATIONAL TRANSFORM
      ARAD=DEG*DPI/180.D0
      CA=COS(ARAD)
      SA=SIN(ARAD)
      ZC=Z0*CA
      TZC=2.*ZC
      ZS=Z0*SA
      TZS=2.*ZS
C     SET XB,ZB FOR 1ST COIL
      ZB=ZC+AMR*SA
      XB=-ZS+AMR*CA-AMR+CO
C     NO INTEGRATION REQUIRED IN SLFL FOR SYMMETRIC CASE
      IF((ADEG.EQ.0.OR.ADEG.EQ.180.).AND.CO.EQ.0.)NG1=0
      CALL SLFL(NG1,NS)
      AM1=FL
C     SET XB,ZB FOR 2ND COIL
      ZB=ZB-TZC
      XB=XB+TZS
      CALL SLFL(NG1,NS)
      AM1=AM1+FL
C     SET FOR INNER CURRENT SHEET
      R1=RI
      CALL SLFL(NG1,NS)
      AM2=FL
C     SET FOR 1ST COIL AGAIN
      ZB=ZB+TZC
      XB=XB-TZS
      CALL SLFL(NG1,NS)
      AM2=AM2+FL
      DM=(DF*AM1+(DF-2.)*AM2)*RB*RB/AL2/(RO-RI)
      RETURN
      END
:READ  EBTOFT   FORTRAN  A1 TEMP   07/21/80 09:48:14
C     EBTOFT    K.H.CARPENTER  21JUL80
C     PROGRAM TO OUTPUT NORMALIZED ARRAY OF AIO WITH
C     WITH AION(K)=AIO(K)*AM(1).
      DIMENSION AION(24),AIO(24),EF(24),BM(13),AM(13),BN(13),BMN(13)
      NAMELIST/NORM/AION,AIO,AL,RT,DF,BO,GHZ,RR,XR,BZ
      NAMELIST/TAIOUT/AL,RT,DF,BO,GHZ,EF,AIO,BM,AM,V1,RR,XR,BZ,IERR
    5 READ(3,TAIOUT,END=100)
      DO 10 K=1,24
      AION(K)=AM(1)*AIO(K)
   10 CONTINUE
      WRITE (7,NORM)
      GO TO 5
  100 STOP
```

```
      END
:READ  MIJE1    FORTRAN  A1 TEMP   07/21/80 09:40:44
      SUBROUTINE MIJE1(AL,RT,DF,B0,GHZ,IERR)
C     K.H.CARPENTER 14JUL80
      DOUBLE PRECISION A(13),B(13),V(13),W(5),DET
      COMMON/CMIJE1/BM(13),AM(13),V1
      COMMON/CWPER/RR,XR,BZ
      DATA Z0/9.5/, AMR/150./, RB/30.0/
      EXTERNAL ZERFUN
C**************
C     This routine accepts annululs parameters and calculates
C     normalized mutual inductance matrix AM and its inverse BM
C     as per KHC 9JUL80.  Annulus offset from cavity center
C     and mean radius calculated from Colestock midplane field
C     model as in WPER1 code.
C     This subroutine written for EBT-I/S - could be
C     modified for EBT-P, etc., by change of major radius AMR,
C     pickup coil separation 2.*Z0, and midplane field model.
C
C     INPUT ARGUMENTS:
C
C               AL      =       total length of assumed annulus in
C                               toroidal direction (in cm)
C
C               RT      =       radial thickness assumed for annulus
C                               (in cm)
C
C               DF      =       drift current factor (=1 for none,
C                               >1 for aiding annulus flux, <1 for
C                               opposing annulus; =0 for routine to
C                               calculate value)
C
C               B0      =       midplane central vacuum field (in Gauss)
C
C               GHZ     =       res. freq. of annulus electrons(in GHz)
C
C       :ON OUTPUT:
C
C               IERR    =       0, if no error
C                               -1, if argument in error on call.
C                               >0, if error detected in num. method.
C
C               DF      =       unchanged if >0 on call; set to
C                               calculated value if =0 on call
C
C               AM      =       normalized mutual inductance matrix
C                               values - normalization is:
C                                  M = AM*NTURN*RT*MU0/TWOPI
C
C               BM      =       inverse matrix to AM
C
C                 Element I of AM(I) or BM(I) corresponds to M(1,I)
C                  of symmetric, circulant matrix M of mutual ind.
C
C               V1      =       1st eigenvalue of AM.
```

```
C
C*****************
C
C       TEST INPUT ARGUMENTS FOR RANGE:
        IF(GHZ.LE.0..OR.B0.LE.0..OR.AL.LE.0..OR.RT.LE.0.)GO TO 100
C
C       FIND RING MEAN RADIUS AND CENTER FROM RESONANCE AT
C       GHZ AND COLESTOCK FIELD MODEL
C
        BZ=357.3*GHZ/B0
        XOUT=ZEROIN(-2.,30.,ZERFUN,0.1)
        XIN =ZEROIN(-30.,-2.,ZERFUN,0.1)
        XR=0.5*(XOUT+XIN)
        RR=0.5*(XOUT-XIN)
C
C       IF DF<0, CALCULATE DF FROM COLESTOCK FIELD MODEL AND FORMULA
C               DF=1.+0.5*DELB/B
C
        IF(DF.LE.0)DF=1.+0.5*(PAT(XOUT-0.5*RT)-PAT(XOUT+0.5*RT))/BZ
C
C     SET FIXED PARAMETERS FOR CALL TO DM
      RI=RR-0.5*RT
      RO=RI+RT
      CO=-XR
C     INITIALIZE LOOP
      IERR=0
      DEG=-15.0
C     CALCULATE AM MATRIX ELEMENTS
      DO 50 I=1,13
         DEG=DEG+15.0
         A(I)=DM(DEG,RI,RO,CO,AL,DF,RB,Z0,AMR,IER)
         AM(I)=A(I)
         IERR=IERR+IER
 50   CONTINUE
C     INVERT AM TO GET BM
      IFLG=1
      CALL SYMCIR(A,V,B,W,DET,24,IFLG)
      IF(IFLG.NE.3)IERR=IERR+200
      V1=V(1)
      DO 60 I=1,13
 60   BM(I)=B(I)
      RETURN
100   IERR=-1
      RETURN
      END
        FUNCTION ZERFUN(X)
        COMMON/CWPER/RR,XR,BZ
        ZERFUN=BZ-PAT(X)
        RETURN
        END
        FUNCTION PAT(X)
C       Colestock fit to midplane field  restricted to zero angle.
C       (Agrees with measured values.  For agreement with calculated
C       values, multiply values by 1.0176.)
        T2=0.
```

```
      R=X
      IF(X.GE.0.)GO TO 10
      T2=3.14159**2
      R=-X
 10   PT=T2*(1.-3.724E-2*T2)
      C1=(PT+20.81)*1.046E-4
      C2=C1-2.04158E-3
      C3=(PT+12.43)*.5966
      AL=C1+C2*SIN((R-13.8)/C3)
      PAT=EXP(-AL*((X+2.90281)**2))
      RETURN
      END
:READ  SYMCIR   FORTRAN  A1 TEMP   07/21/80 09:40:46
C     SUBROUTINE SYMCIR(U,V,B,W,D,N,I)
C         FINDS EIGENVALUES, DETERMINANT, AND INVERSE FOR A REAL,
C         SYMMETRIC, CIRCULANT, N X N MATRIX A(I,J) HAVING
C         A(I,J)=A(J,I) AND A(I,J)=A(I+L,J+L), (SUBSCRIPTS ADDED MOD N).
C
C     AUTHOR:  KENNETH H. CARPENTER
C              DEPARTMENT OF ELECTRICAL ENGINEERING
C              UNIVERSITY OF MISSOURI - ROLLA
C     DATE:    17APRIL1980
C
C    U,V,B DIMENSIONS ARE:     M = N/2 + 1, N EVEN; OR
C                              M = (N+1)/2, N ODD.
C    W DIMENSION IS:   M - 1, N ODD; N/4 - 1, N EVEN.
C
C    ARGUMENTS:  ON INPUT -
C    U IS A ONE DIMENSIONAL ARRAY CONTAINING THE INDEPENDENT ELEMENTS
C         OF A(I,J):  U(J) = A(1,J), J = 1,2,. . .M
C    N IS THE DIMENSION OF A(I,J)
C    I IS A STATUS FLAG (= 0 OR 1 IF THIS IS THE FIRST CALL FOR THE
C         CURRENT VALUE OF N AND 2 OR 3 FOR SUBSEQUENT CALLS FOR THE
C         SAME N WITH THE CONTENTS OF W UNCHANGED SINCE THE PREVIOUS
C         CALL);
C         FOR I=0 OR 2, B IS NOT CALCULATED AND U IS UNCHANGED, WHILE
C         FOR I=1 OR 3, B IS CALCULATED AND U IS OVERWRITTEN.
C
C         ON OUTPUT -
C    V IS A ONE DIMENSIONAL ARRAY CONTAINING THE M INDEPENDENT
C         EIGENVALUES OF A(I,J). (ALL EXCEPT V(1) (AND, FOR EVEN N,
C         VM(M)) ARE DOUBLY DEGENERATE.)
C    D HAS THE VALUE OF THE DETERMINANT OF A(I,J) ON RETURN.
C
C    IF I=1 OR 3, THEN THE V(I) VALUES ARE TESTED, AND IF THE SMALLEST
C         ABS(V(I)) IS GREATER THAN N/AMMAX, WHERE AMMAX IS THE LARGEST
C         FLOATING POINT NUMBER REPRESENTABLE WITHOUT OVERFLOW,
C         THEN B IS RETURNED AS A ONE DIMENSIONAL ARRAY CONTAINING
C         THE INDEPENDENT ELEMENTS OF THE INVERSE OF A.
C
C    ON RETURN THE VALUES OF I HAVE THE FOLLOWING INTERPRETATIONS:
C         = -2 IF I = 2 OR 3 ON CALL AND ROUTINE DETECTS CHANGE IN N
C         = -1 IF N < 1 ON CALL
C         =  2 IF B NOT CALCULATED AND U UNCHANGED FROM CALL
C         =  3 IF B CALCULATED AND U OVERWRITTEN.
```

```
C
C     W IS A ONE DIMENSIONAL WORK ARRAY USED BY THE ROUTINE TO STORE
C          COSINE VALUES; W SHOULD NOT BE CHANGED BETWEEN CALLS.
C
C      ENTRY POINTS DEFINED IN THIS ROUTINE: SYMCIR, CCCOS, CCCCOS
C
C     THE FOLLOWING IS A DOUBLE PRECISION VERSION. TO CONVERT TO
C          SINGLE PRECISION, REMOVE THE "CS" CHARACTERS FROM THE
C          LINES BEGINNING WITH "CS", AND ADD "CD" CHARACTERS
C          TO THE FIRST OF THE FOLLOWING LINES.
C
C     THIS VERSION USES THE SYMMETRY OF THE MATRIX TO REDUCE THE AMOUNT
C       OF COMPUTATION, BUT DOES NOT USE AN FFT APPROACH.  THIS VERSION
C       WILL BE THE MOST EFFICIENT IF N IS PRIME OR CONTAINS A LARGE
C       PRIME FACTOR.  IF N IS A PRODUCT OF SMALL PRIMES IT WILL BE MORE
C       EFFICIENT TO IGNORE THE SYMMETRIC NATURE OF THE MATRIX AND USE
C       THE FFT METHOD TO INVERT THE GENERAL CIRCULANT MATRIX.
C
      SUBROUTINE SYMCIR(U,V,B,W,D,N,I)
CS    REAL U(1),V(1),B(1),W(1),D
      DOUBLE PRECISION U(1),V(1),B(1),W(1),D
CS    REAL
      DOUBLE PRECISION CCCOS,AN,A,T,PN,AMMAX,ONE,VM,VM2,SINT,SIN1
      COMMON/CCCCOS/NO,NO2,NO4,IFOUR,IODD,IUP,IUPP
C     THE FOLLOWING VALUES MUST BE SET TO THE LARGEST ALLOWABLE FLOATING
C       POINT VALUE FOR THE COMPUTER BEING USED:
CS    DATA AMMAX/1.E37/
      DATA AMMAX/1.D37/
CS    DATA T/2.0/,ONE/1.0/
      DATA T/2.0D0/,ONE/1.0D0/
C     TEST N AND I AND BRANCH:
      IF(N.GE.1)GO TO 10
      I=-1
      RETURN
 10   IF(N-2)300,400,20
 20   IF(I.GT.1)GO TO 100
C     INITIALIZE COSINE ARRAY FOR THIS N:
      NO=N
      NO2=N/2
      NO4=N/4
      IFOUR=MOD(N,4)
      IODD=MOD(N,2)
CS    PN=T*T*T*ATAN(1.0)/FLOAT(N)
      PN=T*T*T*DATAN(1.0D0)/DBLE(FLOAT(N))
      L=N/4 - 1 + IFOUR/2
      IF(IODD.EQ.1)L=(N-1)/2
      IF(L.LT.1)GO TO 50
CS    W(1)=COS(PN)
      W(1)=DCOS(PN)
      IF(L.LT.2)GO TO 50
CS    SIN1=SIN(PN)
      SIN1=DSIN(PN)
      IF(L.EQ.2)GO TO 40
      SINT=SIN1
      DO 30 K=2,L
```

```
      W(K)=W(K-1)*W(1)-SINT*SIN1
      SINT=SINT*W(1)+SIN1*W(K-1)
 30   CONTINUE
      GO TO 50
 40   W(2)=W(1)*W(1)-SIN1*SIN1
 50   IUP=N/2 + IODD
      IUPP=IUP + 1 - IODD
C     CHECK STORED N:
 100  IF(N.NE.NO)GO TO 500
C    CALCULATE EIGENVALUES:
      ISIGI=1
      DO 150 L=1,IUPP
CS    V(L)=U(1)+U(IUPP)*FLOAT(ISIGI*(1-IODD))
      V(L)=U(1)+U(IUPP)*DBLE(FLOAT(ISIGI*(1-IODD)))
          DO 130 K=2,IUP
          V(L)=V(L)+T*U(K)*CCCOS((L-1)*(K-1),W)
 130      CONTINUE
 150  CONTINUE
C    CALCULATE DETERMINANT:
      D=V(1)
      IF(IODD.EQ.0)D=D*V(IUPP)
      DO 160 K=2,IUP
 160  D=D*V(K)*V(K)
C    CHECK IF INVERSE TO BE ATTEMPTED:
      IF((I.EQ.0).OR.(I.EQ.2))GO TO 180
C    DETERMINE IF INVERSE CAN BE CALCULATED:
CS    VM=ABS(V(1))
      VM=DABS(V(1))
      DO 170 K=2,IUPP
CS    VM2=ABS(V(K))
      VM2=DABS(V(K))
 170  IF(VM2.LT.VM)VM=VM2
CS    IF(VM.GT.(FLOAT(N)/AMMAX))GO TO 200
      IF(VM.GT.(DBLE(FLOAT(N))/AMMAX))GO TO 200
 180  I=2
      RETURN
C    CALCULATE INVERSE:
 200  I=3
C      IN THIS VERSION WE OVERWRITE U WITH THE RECIPROCALS OF V VALUES
      DO 210 K=1,IUPP
CS    U(K)=1.0/V(K)/FLOAT(N)
      U(K)=1.0D0/V(K)/DBLE(FLOAT(N))
 210  CONTINUE
      ISIGI=1
      DO 250 L=1,IUPP
CS    B(L)=U(1)+U(IUPP)*FLOAT((1-IODD)*ISIGI)
      B(L)=U(1)+U(IUPP)*DBLE(FLOAT((1-IODD)*ISIGI))
      ISIGI=-ISIGI
          DO 230 K=2,IUP
          B(L)=B(L)+T*U(K)*CCCOS((K-1)*(L-1),W)
 230      CONTINUE
 250  CONTINUE
      RETURN
C    SPECIAL CASE N=1:
 300  D=U(1)
```

```
      V(1)=U(1)
      IF((I.EQ.0).OR.(I.EQ.2).OR.(D.LT.(ONE/AMMAX)))GO TO 310
      I=3
      B(1)=ONE/D
      RETURN
 310  I=2
      RETURN
C    SPECIAL CASE N=2:
 400  V(1)=U(1)+U(2)
      V(2)=U(1)-U(2)
      D=V(1)*V(2)
CS    VM=ABS(V(1))
      VM=DABS(V(1))
CS    VM2=ABS(V(2))
      VM2=DABS(V(2))
      IF(VM.GT.VM2)VM=VM2
      IF((I.EQ.0).OR.(I.EQ.2).OR.(VM.LT.(T/AMMAX)))GO TO 310
      I=3
      U(1)=T/V(2)
      U(2)=T/V(2)
      B(1)=U(1)+U(2)
      B(2)=U(1)-U(2)
      RETURN
 500  I=-2
      RETURN
      END
C
C    FUNCTION CCCOS(M,W) RETURNS COS(2*PI*M/N) USING THE
C         VALUES PASSED IN W.
CS    FUNCTION CCCOS(M,W)
      DOUBLE PRECISION FUNCTION CCCOS(M,W)
CS    REAL W(1)
      DOUBLE PRECISION W(1),ONE,SI,ZERO
      COMMON/CCCCOS/N,NO2,NO4,IFOUR,IODD,IUP,IUPP
CS    DATA ONE/1.0/,ZERO/0.0/
      DATA ONE/1.0D0/,ZERO/0.0D0/
      IP=MOD(M,N)
      IF(IP.EQ.0)GO TO 200
      SI=ONE
      IF(IP.GT.NO2)IP=N-IP
      IF((IODD.EQ.1).OR.(IP.LE.NO4))GO TO 100
      IF(IP.EQ.NO2)GO TO 400
      SI=-ONE
      IP=NO2-IP
 100  IF((IP.EQ.NO4).AND.(IFOUR.EQ.0))GO TO 300
      CCCOS=W(IP)*SI
      RETURN
 200  CCCOS=ONE
      RETURN
 300  CCCOS=ZERO
      RETURN
 400  CCCOS=-ONE
      RETURN
      END
:READ  TAIMI    FORTRAN  A1 TEMP   07/21/80 09:40:46
```

```
C       PROGRAM TAIMI  K.H.CARPENTER 14JUL80
C       PROVIDES A TEST DRIVER FOR ROUTINES MIJE1 AND AIOC.
        DOUBLE PRECISION A(13),B(13),V(13),W(5),DET
        COMMON/CMIJE1/BM(13),AM(13),V1
        COMMON/CWPER/RR,XR,BZ
        DIMENSION AIO(24),EF(24)
        NAMELIST/TAIOUT/AL,RT,DF,BO,GHZ,EF,AIO,BM,AM,V1,RR,XR,BZ,IERR
 10     WRITE(5,20)
 20     FORMAT(' TAIMI: ENTER AL,RT,DF,BO,GHZ,IOUT: (-1/ TO STOP)')
        READ(5,*)AL,RT,DF,BO,GHZ,IOUT
        IF(AL.LT.0.)STOP
        WRITE(5,30)
 30     FORMAT(' ENTER EF ARRAY')
        READ(5,*)EF
        CALL MIJE1(AL,RT,DF,BO,GHZ,IERR)
        IF(IERR.NE.0)GO TO 40
        CALL AIOC(AIO,EF)
 40     WRITE(IOUT,TAIOUT)
        GO TO 10
        END
:READ  TDM       FORTRAN  A1 TEMP   07/21/80 09:40:46
C       PROGRAM TDM  TESTS FUNCTION DM
C       TO USE: INPUT DATA TO PROMPT, ENTER -1/ TO STOP.
        NAMELIST/TDMOUT/DMO,IERR,DEG,RI,RO,CO,AL,DF,RB,ZO,AMR
 10     WRITE(5,20)
 20     FORMAT(/' ENTER DEG,AL,DF,RI,RO,RB,ZO,AMR,IOUT: (-1/ TO STOP)')
        READ(5,*)DEG,AL,DF,RI,RO,RB,ZO,AMR
        IF(DEG.EQ.-1.0)STOP
        DMO=DM(DEG,RI,RO,CO,AL,DF,RB,ZO,AMR,IERR)
        WRITE(IOUT,TDMOUT)
        GO TO 10
        END
:READ  TSTSYM   FORTRAN  A1 TEMP   07/21/80 09:40:47
C       PROGRAM TSTSYM
C       THIS IS A TEST MAIN PROGRAM TO CALL SYMCIR
C       DOUBLE PRECISION VERSION ONLY GIVEN HERE.
        DOUBLE PRECISION U(10),V(10),B(10),W(10),D,CCCOS
 10     WRITE(6,20)
 20     FORMAT(' ENTER N,I,U(K),K=1,M - I2,G10.5')
        READ(5,30)N,I
 30     FORMAT(I2)
        J=N/2+1
        READ(5,35)(U(K),K=1,J)
 35     FORMAT(G10.5)
        CALL SYMCIR(U,V,B,W,D,N,I)
        WRITE(6,40)U,V,B,W,D,N,I
 40     FORMAT(8(5D13.5/),D13.5,I5,I5)
        DO 60 K=1,N
        D=CCCOS(K,W)
        WRITE(6,50)D
 50     FORMAT(D15.5)
 60     CONTINUE
        IF(I.GT.0)GO TO 10
        STOP
        END
```

```
&TAIOUT
AL=  10.0000000    ,RT=  3.00000000    ,DF=  1.09708023    ,B0=
  5000.00000    ,GHZ=  9.00000000    ,EF=  114.600006    ,  92.0000000    ,
  48.0000000    ,  104.000000    ,  113.600006    ,  116.199997    ,
  87.3999939    ,  40.8000031    ,  82.8000031    ,  99.6000061    ,
  81.6000061    ,  93.6000061    ,  108.000000    ,  110.000000    ,
  103.199997    ,  62.8000031    ,  40.8000031    ,  93.3999939    ,
  115.199997    ,  33.6000061    ,  63.6000061    ,  122.000000    ,
  126.399994    ,  111.600006    ,AI0=  6.43681145    ,  5.27251625    ,
  .997003913E-01,  6.50013256    ,  5.90026093    ,  6.65853691    ,
  4.94625378    ,  .164234638E-01,  4.83514404    ,  5.85643291    ,
  3.49065208    ,  4.79494190    ,  5.84751987    ,  5.82244015    ,
  6.04162216    ,  2.82667542    ,  .404716969    ,  5.39013100    ,
  8.28197670    , -.896388590    ,  2.69840908    ,  7.45606613    ,
  6.93386841    ,  5.35542011    ,BM=  .994147062E-01, -.248593614E-01,
  .135210351E-02, -.670516165E-03, -.121717356E-03, -.975675357E-04,
 -.570394041E-04, -.391296198E-04, -.281329267E-04, -.232965103E-04,
 -.115305647E-04, -.488360820E-04,  .565953669E-04,AM=  11.5228319    ,
  2.97878742    ,  .599358559    ,  .197660506    ,  .869194269E-01,
  .456470028E-01,  .270777345E-01,  .176216699E-01,  .124043711E-01,
  .939476490E-02,  .766484067E-02,  .676430762E-02,  .647735596E-02,V1=
  19.5079041    ,RR=  13.3253174    ,XR= -1.85566235    ,BZ=  .643140078
IERR=          0
&END
&TAIOUT
AL=  5.00000000    ,RT=  2.00000000    ,DF=  1.06949806    ,B0=
  5000.00000    ,GHZ=  8.50000000    ,EF=  114.600006    ,  92.0000000    ,
  48.0000000    ,  104.000000    ,  113.600006    ,  116.199997    ,
  87.3999939    ,  40.8000031    ,  82.8000031    ,  99.6000061    ,
  81.6000061    ,  93.6000061    ,  108.000000    ,  110.000000    ,
  103.199997    ,  62.8000031    ,  40.8000031    ,  93.3999939    ,
  115.199997    ,  33.6000061    ,  63.6000061    ,  122.000000    ,
  126.399994    ,  111.600006    ,AI0=  5.86416721    ,  4.78445053    ,
  .155811429    ,  5.88731003    ,  5.39787102    ,  6.06513882    ,
  4.49230576    ,  .676904917E-01,  4.38873482    ,  5.32783508    ,
  3.20556450    ,  4.37227058    ,  5.33065796    ,  5.31733894    ,
  5.49566936    ,  2.58036804    ,  .405781746    ,  4.91212559    ,
  7.49050140    , -.747633278    ,  2.46193790    ,  6.77848625    ,
  6.32378101    ,  4.90179729    ,BM=  .892719626E-01, -.217317082E-01,
  .142146717E-02, -.565325841E-03, -.119711083E-03, -.881914893E-04,
 -.524385105E-04, -.357543904E-04, -.258233194E-04, -.211221777E-04,
 -.112800544E-04, -.428857893E-04,  .492925756E-04,AM=  12.7411957    ,
  3.21279240    ,  .652116299    ,  .216091335    ,  .952306390E-01,
  .500676930E-01,  .297175273E-01,  .193418711E-01,  .136220455E-01,
  .103174075E-01,  .842146948E-02,  .743104517E-02,  .712260231E-02,V1=
  21.3786163    ,RR=  14.0956726    ,XR= -1.77191162    ,BZ=  .607410014
IERR=          0
&END
```

Output from runs of TAIMI as main program, using actual $W_{\perp}$ data for input as "EP".

```
&NORM
AION=  74.1702881     ,  60.7543182     ,  1.14883041     ,  74.8999329     ,
  67.9877014     ,  76.7251892     ,  56.9948425     ,  .189244807     ,
  55.7145386     ,  67.4826813     ,  40.2221832     ,  55.2512970     ,
  67.3799744     ,  67.0909882     ,  69.6165924     ,  32.5713043     ,
  4.66348553     ,  62.1095734     ,  95.4318237     , -10.3289347     ,
  31.0933075     ,  85.9149933     ,  79.8977966     ,  61.7095947     ,AIO=
  6.43681145     ,  5.27251625     ,  .997003913E-01,  6.50013256     ,
  5.90026093     ,  6.65853691     ,  4.94625378     ,  .164234638E-01,
  4.83514404     ,  5.85643291     ,  3.49065208     ,  4.79494190     ,
  5.84751987     ,  5.82244015     ,  6.04162216     ,  2.82667542     ,
  .404716969     ,  5.39013100     ,  8.28197670     , -.896388590     ,
  2.69840908     ,  7.45606613     ,  6.93386841     ,  5.35542011     ,AL=
  10.0000000     ,RT=  3.00000000     ,DF=  1.09708023     ,BO=  5000.00000
GHZ=  9.00000000     ,RR=  13.3253174     ,XR= -1.85566235     ,BZ=
  .643140078
&END
&NORM
AION=  74.7164917     ,  60.9596100     ,  1.98522377     ,  75.0113678     ,
  68.7753296     ,  77.2771149     ,  57.2373352     ,  .862457752     ,
  55.9177246     ,  67.8829803     ,  40.8427124     ,  55.7079468     ,
  67.9189453     ,  67.7492523     ,  70.0213928     ,  32.8769684     ,
  5.17014408     ,  62.5863495     ,  95.4379425     , -9.52574158     ,
  31.3680267     ,  86.3660126     ,  80.5725250     ,  62.4547577     ,AIO=
  5.86416721     ,  4.78445053     ,  .155811429     ,  5.88731003     ,
  5.39787102     ,  6.06513882     ,  4.49230576     ,  .676904917E-01,
  4.38873482     ,  5.32783508     ,  3.20556450     ,  4.37227058     ,
  5.33065796     ,  5.31733894     ,  5.49566936     ,  2.58036804     ,
  .405781746     ,  4.91212559     ,  7.49050140     , -.747633278     ,
  2.46193790     ,  6.77848625     ,  6.32378101     ,  4.90179729     ,AL=
  5.00000000     ,RT=  2.00000000     ,DF=  1.06949806     ,BO=  5000.00000
GHZ=  8.50000000     ,RR=  14.0956726     ,XR= -1.77191162     ,BZ=
  .607410014
&END
```

Output from run of EBTOFT using output from TAIMI on previous page as input.

The following four pages list outputs from a run of TAIMI as the main program made to test effect of different ring parameters on compensation for cross talk.

```
&TAIOUT
AL=  5.00000000    ,RT=  2.00000000    ,DF=  1.06486034    ,B0=
  5000.00000    ,GHZ=  9.00000000    ,EF=  1.00000000    ,  1.10000038    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  .899999976    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,AI0=  .489672050E-01,  .613326654E-01,
  .490226261E-01,  .514102019E-01,  .537977777E-01,  .414877385E-01,
  .538532026E-01,  .512305349E-01,  .514714420E-01,  .514199734E-01,
  .514176227E-01,  .514147505E-01,  .514093116E-01,  .514186285E-01,
  .514077134E-01,  .514102019E-01,  .514126904E-01,  .514017753E-01,
  .514110886E-01,  .514056571E-01,  .514027812E-01,  .514004305E-01,
  .513489544E-01,  .515898652E-01,BM=  .990983248E-01, -.245274417E-01,
  .173927657E-02, -.651784008E-03, -.125958351E-03, -.975625735E-04,
 -.573625875E-04, -.393594819E-04, -.282255060E-04, -.233532046E-04,
 -.119005717E-04, -.482466567E-04,  .557601597E-04,AM=  11.5278931    ,
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  .455598831E-01,  .270307399E-01,  .175967328E-01,  .123821869E-01,
  .938211381E-02,  .765378401E-02,  .675084069E-02,  .646394119E-02,V1=
  19.4513702    ,RR=  13.3253174    ,XR= -1.85566235    ,BZ=  .643140078
IERR=          0
&END
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  .489381552E-01,  .513734594E-01,  .538087636E-01,  .413803384E-01,
  .538667664E-01,  .511788167E-01,  .514373221E-01,  .513827354E-01,
  .513809100E-01,  .513780303E-01,  .513724610E-01,  .513819903E-01,
  .513708778E-01,  .513734594E-01,  .513760410E-01,  .513649844E-01,
  .513744541E-01,  .513688885E-01,  .513660125E-01,  .513641834E-01,
  .513095930E-01,  .515681058E-01,BM=  .998100638E-01, -.250309035E-01,
  .188937155E-02, -.677948818E-03, -.120861834E-03, -.979338074E-04,
 -.570778648E-04, -.392881921E-04, -.280924869E-04, -.234509789E-04,
 -.113690639E-04, -.492614199E-04,  .570950069E-04,AM=  11.4863062    ,
  2.97735882    ,  .598560870    ,  .197297215    ,  .867392421E-01,
  .455484614E-01,  .270160288E-01,  .175858475E-01,  .123718567E-01,
  .937622041E-02,  .764355063E-02,  .675517693E-02,  .646110252E-02,V1=
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IERR=          0
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  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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  .487596467E-01,  .511643924E-01,  .535691455E-01,  .412446633E-01,
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  .511717983E-01,  .511689298E-01,  .511634424E-01,  .511728004E-01,
  .511618592E-01,  .511643924E-01,  .511669219E-01,  .511559807E-01,
  .511653386E-01,  .511598550E-01,  .511569902E-01,  .511549525E-01,
  .511018895E-01,  .513520725E-01,BM=  .990743041E-01, -.247115232E-01,
  .181984040E-02, -.664131949E-03, -.122437021E-03, -.972918497E-04,
 -.569572730E-04, -.390834466E-04, -.280735549E-04, -.232446619E-04,
 -.115874645E-04, -.485625496E-04,  .562350033E-04,AM=  11.5544739    ,
  2.97996807    ,  .600070715    ,  .197984815    ,  .870789886E-01,
  .457363129E-01,  .271314979E-01,  .176585019E-01,  .124286041E-01,
  .941408798E-02,  .768080354E-02,  .677836314E-02,  .649178773E-02,V1=
  19.5448151    ,RR=  13.3253174    ,XR= -1.85566235    ,BZ=  .643140078
 IERR=          0
 &END
:READ  TAI      DATAO    A1 EBT1   07/16/80 12:15:41
 &TAIOUT
 AL=  10.0000000    ,RT=  2.00000000    ,DF=  1.06486034    ,B0=
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   1.00000000    ,  1.00000000    ,  1.00000000    ,  .899999976    ,
   1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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   1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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   .513388328E-01,  .513359345E-01,  .513304099E-01,  .513398610E-01,
   .513288192E-01,  .513313822E-01,  .513339490E-01,  .513228439E-01,
   .513323620E-01,  .513268262E-01,  .513239279E-01,  .513220802E-01,
   .512678027E-01,  .515246019E-01,BM=  .996612906E-01, -.249662362E-01,
   .187515398E-02, -.675019575E-03, -.121180856E-03, -.978387106E-04,
  -.570504781E-04, -.392017682E-04, -.281514222E-04, -.233308092E-04,
  -.115145758E-04, -.489770027E-04,  .568088872E-04,AM=  11.5000076    ,
   2.97789383    ,  .598870754    ,  .197425544    ,  .868030787E-01,
   .455883741E-01,  .270383172E-01,  .175970830E-01,  .123852938E-01,
   .937997550E-02,  .765311718E-02,  .674944371E-02,  .647038594E-02,V1=
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 IERR=          0
 &END
 &TAIOUT
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   5000.00000    ,GHZ=  9.00000000    ,EF=  1.00000000    ,  1.10000038    ,
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   .703197718E-01,  .736503601E-01,  .769810081E-01,  .595809072E-01,
   .770562887E-01,  .734175444E-01,  .737339258E-01,  .736650825E-01,
   .736609101E-01,  .736568570E-01,  .736492276E-01,  .736621022E-01,
   .736469030E-01,  .736503601E-01,  .736537576E-01,  .736385584E-01,
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  .736514330E-01,  .736439228E-01,  .736397505E-01,  .736356378E-01,
  .735667944E-01,  .738831162E-01,BM=  .140509367    , -.341980867E-01,
  .224578637E-02, -.891749049E-03, -.187678510E-03, -.138853327E-03,
 -.823327573E-04, -.563217618E-04, -.405385508E-04, -.332245399E-04,
 -.177399925E-04, -.672791502E-04,  .773137726E-04,AM=  8.09443665    ,
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  .317491293E-01,  .188409388E-01,  .122670084E-01,  .863580406E-02,
  .654101744E-02,  .533758849E-02,  .470673293E-02,  .451265648E-02,V1=
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 IERR=          0
 &END
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  .445367955E-01,  .466873683E-01,  .488379486E-01,  .377056561E-01,
  .488874838E-01,  .465287566E-01,  .467421748E-01,  .466963686E-01,
  .466940776E-01,  .466914922E-01,  .466865823E-01,  .466949418E-01,
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  .466881506E-01,  .466832407E-01,  .466806516E-01,  .466783643E-01,
  .466325618E-01,  .468459725E-01,BM=  .897013545E-01, -.220893584E-01,
  .153389643E-02, -.583656831E-03, -.115707313E-03, -.882687164E-04,
 -.521559996E-04, -.355875382E-04, -.256969215E-04, -.211314182E-04,
 -.109161447E-04, -.434395333E-04,  .500975148E-04,AM=  12.7181473    ,
  3.24121857    ,  .654892445    ,  .216522872    ,  .953212380E-01,
  .500889122E-01,  .297242701E-01,  .193403512E-01,  .136210918E-01,
  .103177540E-01,  .841687620E-02,  .742683187E-02,  .712139904E-02,V1=
  21.4190369    ,RR=  14.0956726    ,XR= -1.77191162    ,BZ=  .607410014
 IERR=          0
 &END
 &TAIOUT
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   1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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  .678210258E-01,  .715072751E-01,  .751935244E-01,  .571264774E-01,
  .752912760E-01,  .711454153E-01,  .716135502E-01,  .715169907E-01,
  .715180635E-01,  .715137720E-01,  .715051889E-01,  .715199709E-01,
  .715030432E-01,  .715072751E-01,  .715113878E-01,  .714945793E-01,
  .715092421E-01,  .715007782E-01,  .714964867E-01,  .714976788E-01,
  .714008808E-01,  .718691945E-01,BM=  .143674135    , -.379802398E-01,
  .354029634E-02, -.111770467E-02, -.135483919E-03, -.140913879E-03,
 -.784238655E-04, -.545675284E-04, -.389870111E-04, -.331950869E-04,
 -.134392558E-04, -.745957805E-04,  .878777209E-04,AM=  8.10222626    ,
  2.20501041    ,  .437428951    ,  .142914355    ,  .625991821E-01,
  .328071117E-01,  .194396973E-01,  .126425028E-01,  .889838114E-02,
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  .674027205E-02,  .549839810E-02,  .485224649E-02,  .464780256E-02,V1=
  13.9845362    ,RR=  10.7714005    ,XR= -2.14836407    ,BZ=  .757476091
IERR=          0
&END
&TAIOUT
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  7200.00000    ,GHZ=  14.0000000    ,EF=  1.00000000    ,  1.10000038    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  .899999976    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,AI0=  .560667850E-01,  .706872940E-01,
  .561389849E-01,  .590401143E-01,  .619411692E-01,  .473926254E-01,
  .620134026E-01,  .587856770E-01,  .591192096E-01,  .590497255E-01,
  .590488054E-01,  .590454116E-01,  .590387583E-01,  .590501390E-01,
  .590369627E-01,  .590401143E-01,  .590432622E-01,  .590300262E-01,
  .590414666E-01,  .590348169E-01,  .590314232E-01,  .590305030E-01,
  .589610152E-01,  .592945553E-01,BM=  .116346359    , -.298474319E-01,
  .247903890E-02, -.835952815E-03, -.128437387E-03, -.113927192E-03,
 -.653440657E-04, -.449940708E-04, -.323111162E-04, -.270379387E-04,
 -.123822056E-04, -.585173548E-04,  .683706021E-04,AM=  9.91672516    ,
  2.62516117    ,  .524640083    ,  .172266483    ,  .756148696E-01,
  .396756232E-01,  .235246234E-01,  .152997077E-01,  .107689612E-01,
  .815641880E-02,  .665655732E-02,  .587049127E-02,  .563263893E-02,V1=
  16.9376221    ,RR=  12.2245407    ,XR= -1.97731590    ,BZ=  .694749832
IERR=          0
&END
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The following two pages list the output from program BMNORM when the output from TAIMI on the preceding four pages is the input.

```
&NORM
BN=  1.00000000    , -.247506082    ,  .175510161E-01, -.657714158E-02,
 -.127104414E-02, -.984502723E-03, -.578845153E-03, -.397176016E-03,
 -.284823123E-03, -.235656902E-03, -.120088516E-03, -.486856326E-03,
  .562675064E-03,BMN=  1.14239407    , -.282749712    ,  .200501941E-01,
 -.751369447E-02, -.145203434E-02, -.112469075E-02, -.661269762E-03,
 -.453731744E-03, -.325380592E-03, -.269213226E-03, -.137188516E-03,
 -.556182116E-03,  .642796978E-03,AL=  5.00000000    ,RT=  2.00000000    ,DF
  1.06486034    ,B0=  5000.00000    ,GHZ=  9.00000000    ,RR=  13.3253174
XR= -1.85566235    ,BZ=  .643140078
&END
&NORM
BN=  1.00000000    , -.250785351    ,  .189296678E-01, -.679238886E-02,
 -.121091818E-02, -.981201651E-03, -.571864657E-03, -.393629540E-03,
 -.281459419E-03, -.234956053E-03, -.113906979E-03, -.493551604E-03,
  .572036486E-03,BMN=  1.14644814    , -.287512600    ,  .217018984E-01,
 -.778712705E-02, -.138825597E-02, -.112489751E-02, -.655613607E-03,
 -.451276079E-03, -.322678825E-03, -.269365031E-03, -.130588538E-03,
 -.565831549E-03,  .655810582E-03,AL=  10.0000000    ,RT=  1.00000000    ,DF
  1.03247261    ,B0=  5000.00000    ,GHZ=  9.00000000    ,RR=  13.3253174
XR= -1.85566235    ,BZ=  .643140078
&END
&NORM
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 -.123580988E-02, -.982008874E-03, -.574894482E-03, -.394486124E-03,
 -.283358386E-03, -.234618463E-03, -.116957308E-03, -.490162754E-03,
  .567604322E-03,BMN=  1.14475060    , -.285528600    ,  .210272968E-01,
 -.767369196E-02, -.141469529E-02, -.112415594E-02, -.658111181E-03,
 -.451588538E-03, -.324374996E-03, -.268579694E-03, -.133887050E-03,
 -.561114633E-03,  .649765832E-03,AL=  10.0000000    ,RT=  4.00000000    ,DF
  1.12904644    ,B0=  5000.00000    ,GHZ=  9.00000000    ,RR=  13.3253174
XR= -1.85566235    ,BZ=  .643140078
&END
&NORM
BN=  1.00000000    , -.250510812    ,  .188152678E-01, -.677313656E-02,
 -.121592684E-02, -.981712248E-03, -.572443474E-03, -.393349910E-03,
 -.282470835E-03, -.234101011E-03, -.115537085E-03, -.491434475E-03,
  .570019474E-03,BMN=  1.14610481    , -.287111878    ,  .215642825E-01,
 -.776273012E-02, -.139358058E-02, -.112514570E-02, -.656080898E-03,
 -.450820429E-03, -.323741464E-03, -.268304255E-03, -.132417699E-03,
 -.563235721E-03,  .653302530E-03,AL=  10.0000000    ,RT=  2.00000000    ,DF
  1.06486034    ,B0=  5000.00000    ,GHZ=  9.00000000    ,RR=  13.3253174
XR= -1.85566235    ,BZ=  .643140078
&END
&NORM
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 -.133570097E-02, -.988213811E-03, -.585959060E-03, -.400839839E-03,
 -.288511161E-03, -.236457825E-03, -.126254861E-03, -.478823204E-03,
  .550239114E-03,BMN=  1.13734341    , -.276814222    ,  .181783736E-01,
 -.721820444E-02, -.151915173E-02, -.112393941E-02, -.666437205E-03,
 -.455892878E-03, -.328136608E-03, -.268933829E-03, -.143595244E-03,
 -.544586685E-03,  .625811284E-03,AL=  10.0000000    ,RT=  2.00000000    ,DF
  1.00000000    ,B0=  5000.00000    ,GHZ=  9.00000000    ,RR=  13.3253174
XR= -1.85566235    ,BZ=  .643140078
&END
```

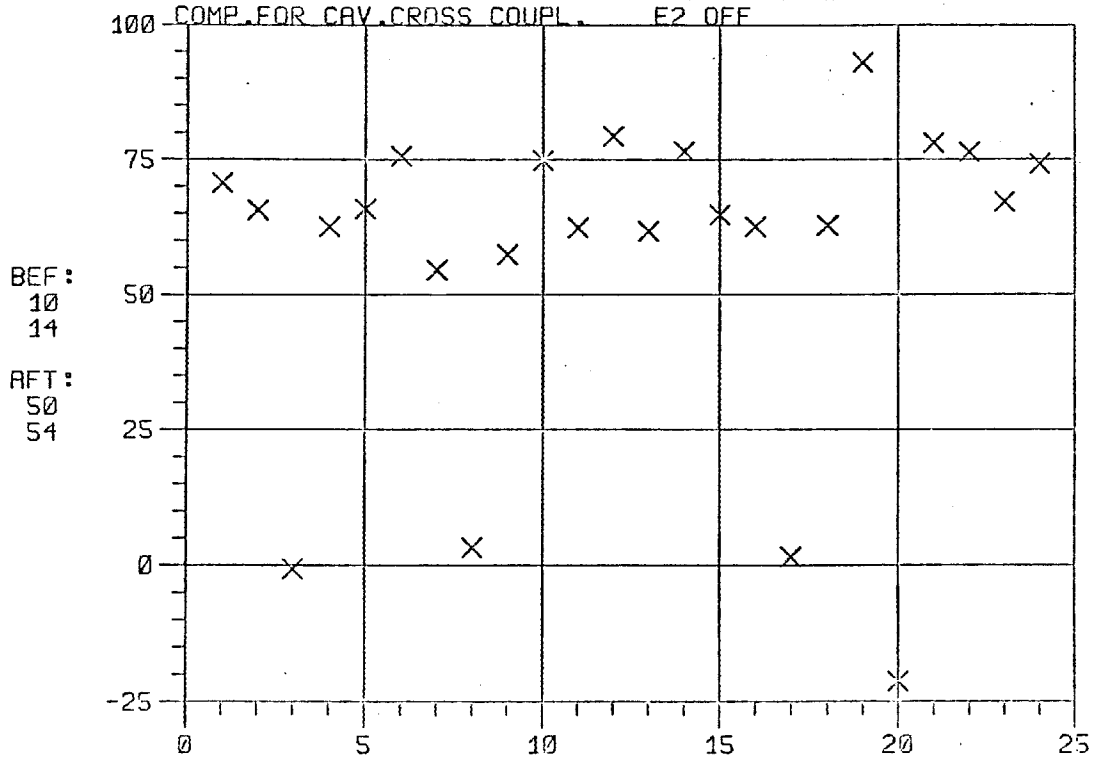
FILE: BMNORM  TESTDATA B  UNIVERSITY OF MISSOURI COMPUTER NETWORK

```
&NORM
BN=  1.00000000    , -.246254444    ,  .171000361E-01, -.650666654E-02,
 -.128991692E-02, -.984028680E-03, -.581440283E-03, -.396733405E-03,
 -.286471797E-03, -.235575237E-03, -.121694306E-03, -.484268414E-03,
  .558492262E-03,BMN=  1.14083481    , -.280935705    ,  .195083171E-01,
 -.742303208E-02, -.147158257E-02, -.112261437E-02, -.663327519E-03,
 -.452607404E-03, -.326817157E-03, -.268752454E-03, -.138833129E-03,
 -.552470330E-03,  .637147343E-03,AL=  10.0000000    ,RT=  2.00000000    ,DF
  1.06949806    ,B0=  5000.00000    ,GHZ=  8.50000000    ,RR=  14.0956726
XR= -1.77191162    ,BZ=  .607410014
&END
&NORM
BN=  1.00000000    , -.264349818    ,  .246411525E-01, -.777944177E-02,
 -.942994375E-03, -.980787911E-03, -.545845367E-03, -.379800564E-03,
 -.271357130E-03, -.231044265E-03, -.935398275E-04, -.519201159E-03,
  .611645868E-03,BMN=  1.16407967    , -.307724476    ,  .286842803E-01,
 -.905589387E-02, -.109772128E-02, -.114171603E-02, -.635407865E-03,
 -.442118384E-03, -.315881567E-03, -.268954085E-03, -.108887878E-03,
 -.604391797E-03,  .712004956E-03,AL=  10.0000000    ,RT=  2.00000000    ,DF
  1.04995728    ,B0=  5000.00000    ,GHZ=  10.6000004    ,RR=  10.7714005
XR= -2.14836407    ,BZ=  .757476091
&END
&NORM
BN=  1.00000000    , -.256539404    ,  .213074014E-01, -.718503445E-02,
 -.110392249E-02, -.979206990E-03, -.561633846E-03, -.386725180E-03,
 -.277714804E-03, -.232391787E-03, -.106425374E-03, -.502957962E-03,
  .587647082E-03,BMN=  1.15377426    , -.295983739    ,  .245839469E-01,
 -.828991085E-02, -.127367815E-02, -.112978462E-02, -.647999113E-03,
 -.446193619E-03, -.320420368E-03, -.268127769E-03, -.122790923E-03,
 -.580300344E-03,  .678012380E-03,AL=  10.0000000    ,RT=  2.00000000    ,DF
  1.05822468    ,B0=  7200.00000    ,GHZ=  14.0000000    ,RR=  12.2245407
XR= -1.97731590    ,BZ=  .694749832
&END
```

EBTOFF program

The EBTOFF program runs on the Fusion Energy Division PDP-10 computer at Oak Ridge National Laboratory. It is an interactive program which needs to be run from a graphics terminal. The program prompts for input. The modification made during the work described in this report was to include correction for intercavity cross talk on $W_\perp$ signals as an option. A sample output plot for $W_\perp$ with this option in effect is given on the next page. On the following pages the FORTRAN listing of EBTOFF, as modified, is given.

W PER (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W6)
(EBTOFF VS ) WTS FROM A36AG6.WTS TURN DOWN, EBT I, 50/0, N3, SS, AND
COMP.FOR CAV.CROSS COUPL. E2 OFF




A3BEAF.EBB EBTDAT VSI 3/11/80-14:27:56
SLOPRD= 1 FASPRD= 1

```
      PROGRAM EBTOFF   !K.H.CARPENTER 15SEP79
C     28JUL80:KHC: VERSION 5 : Added compensation for cavity cross
C                              coupling for WPER
C     10APR80:KHC:             Write of WPER to EBTOFF.DAT
C                              added.
C     10MAR80:KHC: VERSION 4 : Added weights to W-Per curve,
C                              for correction of unequal gains.
C     11APR79:KHC: VERSION 3 : Added BEF & AFT values to plot, and
C                              added looping on curve choice, and
C                              corrected DO limits on BEF & AFT loops.
C     13FEB79:KHC: VERSION 2 : Added choice of curves 1,2,3 and
C                              plot at BEF time only if greater than AFT
C     Outputs plot or print of W-Per. in ADC units
C     as determined from diamagnetic loops on turn-down
C     of microwave power.
C     Subroutines called are in EBD10B or TEK AG2
C     LOAD with EBD10B.REL and ADETEK.REL
C
      PARAMETER MAX=256,NID=24,MAXP=257
      LOGICAL LDIFF
      DOUBLE PRECISION DWT
      COMMON/CEBB10/IN,FILNA(2),DATIM(4),VERSNO,ISLOPR,IFASPR,IVRD,
     1 IFAD,IFPR,ISAMPF,IDPPS,NOWDC,IBUF(342)
      COMMON/CADEOU/IPLTU      !FOR PLOT UNIT NO. USING TEKADE
      DIMENSION IDAR(NID),IFADAT(MAX,NID),PLOTNO(MAXP),XAX(4)
      DIMENSION WTS(24),ITIW(4)
      DATA WTS/24*1.0/,IWT/0/
      DATA IUNIT/50/,XAX/-1.,24.,0.,1./
      DATA IVERS/' V5 )'/
C     OPEN UNIT 17 FOR ASCII OUTPUT OF RESULTS:
      OPEN(UNIT=17,DEVICE='DSK',FILE='EBTOFF.DAT',ACCESS='APPEND')
C     INITIALIZE FOR PLOTS AND TYPE HEADER OUT
 1    IOLDCR=0
      IPLTU=-1
      CALL IHITT(1)
      CALL SETBUF(1)
      CALL ANMODE
      CALL SLP(1)
 5    TYPE 10
 10   FORMAT(' EBTOFF V5 - WANT TO ENTER FILE SPEC. OR TIME?:'$)
      ACCEPT 20,MODEIN
 20   FORMAT(A1)
      IF(MODEIN.EQ.'T')GO TO 50
      TYPE 30
 30   FORMAT(' EBB FORMAT FILE SPEC.:'$)
      ACCEPT 40,IDAR
 40   FORMAT(24A5)
      OPEN(UNIT=IUNIT,DIALOG=IDAR,ACCESS='SEQIN',MODE='IMAGE')
      CALL UNIT(IUNIT)
      GO TO 80
 50   TYPE 60
 60   FORMAT(' ENTER MO-DA-YR HR:MI:SE (6G):'$)
      ACCEPT 70,MONTH,IDAY,IYEAR,IHR,IMIN,ISEC
 70   FORMAT(6G)
      CALL RECHD(IUNIT,MONTH,IDAY,IYEAR,IHR,IMIN,ISEC)
C     INPUT FILE NOW OPENED - TYPE COMMENTS
 80   CALL TYCOM
 82   TYPE 85
```

```
 85     FORMAT(' PLOT CURVE # 1,2,or 3? (0 TO EXIT; -1 FOR NEW FILE):'$)
        ACCEPT 86,ICURVE
 86     FORMAT(G)
        IF(ICURVE.EQ.0.OR.ICURVE.GT.3)STOP' '
        IF(ICURVE.LT.0)GO TO 1
C       SET UP TO READ IN DATA
        IF(ICURVE.EQ.IOLDCR)GO TO 100
        IDAR(1)=ICURVE-1
        DO 90 K=2,NID
 90     IDAR(K)=IDAR(K-1)+3
C       GO READ IT
        CALL FRMARY(IDAR,NID,N,MAX,IFADAT)
        IOLDCR=ICURVE
 100    TYPE 110
 110    FORMAT(' PLOT DATA FOR SECTOR # (0 TO STOP):'$)
        ACCEPT 70,ISECT
        IF(ISECT.LE.0)GO TO 150 !OUT OF PLOT LOOP
        XAX(2)=N
        XAX(3)=0.
        PLOTNO(1)=N
        DO 120 K=2,N+1
 120    PLOTNO(K)=IFADAT(K-1,ISECT)
        CALL NEWPAG
        CALL ANMODE
        CALL SLP(1)
        CALL BINITT
        CALL CHECK(XAX,PLOTNO)
        CALL DSPLAY(XAX,PLOTNO)
        CALL MOVABS(0,30)
        CALL ANMODE
        WRITE(IPLTU,130)ISECT
 130    FORMAT(' SECT.=',I3)
        GO TO 100
 150    CALL HOME
        CALL ANMODE      !TO DUMP PLOT BUFFER
        TYPE 160
 160    FORMAT(' Enter limits of "before" then "after" intervals',
     1  ' on time axis - 4G'/' (-1 to skip):'$)
        ACCEPT 70,IT1,IT2,IT3,IT4
        IF(IT1.LT.0)GO TO 260
        LDIFF=IT1+IT2.GE.IT3+IT4
        XAX(2)=NID
        XAX(3)=1.
        DO 200 I=1,NID
        BEF=0.
        AFT=0.
        DO 180 J=IT1+1,IT2+1
 180    BEF=BEF+IFADAT(J,I)
        DO 190 J=IT3+1,IT4+1
 190    AFT=AFT+IFADAT(J,I)
        IF(IT2.GT.IT1)BEF=BEF/(IT2-IT1+1)
        IF(IT4.GT.IT3)AFT=AFT/(IT4-IT3+1)
        PLOTNO(I+1)=BEF-AFT
 200    IF(LDIFF)PLOTNO(I+1)=BEF
        PLOTNO(1)=NID
        IF(ICURVE.NE.2)GO TO 202
        IF(IWT.NE.0)GO TO 2050
        TYPE 2010
```

```
 2010   FORMAT(' UNWEIGHTED: USE,GET,OR MAKE?:'$)
        ACCEPT 20,IWW
        IF(IWW.EQ.'U'.OR.IWW.EQ.'u')GO TO 202
        IF(IWW.EQ.'M'.OR.IWW.EQ.'m')GO TO 2100
 2015   TYPE 2020
 2020   FORMAT( ' WEIGHT FILE SPEC:'$)
        ACCEPT 40,IDAR
        OPEN(UNIT=30,DIALOG=IDAR,ACCESS='SEQIN')
        READ(30,2030)WTS
 2030   FORMAT(6G)
        READ(30,2040)DWT,ITIW
 2040   FORMAT(1X,A10,7X,2I5,7X,2I5)
        IWT=-1
 2500   DO 2510 K=1,24
 2510   PLOTNO(K+1)=PLOTNO(K+1)*WTS(K)
        GO TO 202
 2050   CALL NEWPAG
        CALL ANMODE
        CALL SLP(1)
        TYPE 2060,DWT,WTS
 2060   FORMAT(' WEIGHTS FROM ',A10,' ARE:'/4(6F12.4/)/
     1  ' USE,GET,MAKE,or RESET?:'$)
        ACCEPT 20,IWW
        IF(IWW.EQ.'U'.OR.IWW.EQ.'u')GO TO 2500
        IF(IWW.EQ.'M'.OR.IWW.EQ.'m')GO TO 2100
        IF(IWW.EQ.'G'.OR.IWW.EQ.'g')GO TO 2015
C       RESET WEIGHTS TO UNWEIGHTED
        DO 2070 K=1,24
 2070   WTS(K)=1.0
        IWT=0
        GO TO 202
C       MAKE WEIGHTS:
 2100   IWT=-1
        ENCODE(10,2110,DWT)FILNA
 2110   FORMAT(A5,A1,'.WTS')
        OPEN(UNIT=25,FILE=DWT,DEVICE='DSK',ACCESS='SEQOUT')
        DO 2120 K=1,24
        IF(PLOTNO(K+1).LT.10.)WTS(K)=0.
        IF(PLOTNO(K+1).GE.10.)WTS(K)=PLOTNO(2)/PLOTNO(K+1)
 2120   CONTINUE
        WRITE(25,2130)WTS,DWT,IT1,IT2,IT3,IT4
 2130   FORMAT(4(6F12.4/),1X,A10,'   BEF:',2I5,'   AFT:',2I5)
        ITIW(1)=IT1
        ITIW(2)=IT2
        ITIW(3)=IT3
        ITIW(4)=IT4
        CALL NEWPAG
        CALL ANMODE
        CALL SLP(1)
        TYPE 2140,DWT
 2140   FORMAT(' Weights for W-PER written to DSK:',A10/)
        IOLDCR=0
        GO TO 5
 202    IF(ICURVE.NE.2)GO TO 2022
        TYPE  310
 310    FORMAT(' COMPENSATE FOR CAVITY CROSS COUPLING?(Y OR N):'$)
        ACCEPT 20,ICOMP
        IF(ICOMP.NE.'Y'.AND.ICOMP.NE.'y')GO TO 2022
```

```
230     FORMAT($' PRESSURE (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=WS)'
      1 /' (EBTOFF',A5)
        IPLTU=-1
        CALL NEWPAG
        CALL ANMODE
        CALL SLP(1)
        TYPE 235
235     FORMAT(' PRESSURE VS CAVITY OUTPUT TO LPT')
        GO TO 82
240     WRITE(IPLTU,250)IVERS
250     FORMAT($' POWER (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=WS)'
      1 /' (EBTOFF',A5)
        IPLTU=-1
        CALL NEWPAG
        CALL ANMODE
        CALL SLP(1)
        TYPE 255
255     FORMAT(' POWER VS CAVITY OUTPUT TO LPT')
        GO TO 82
260     IPLTU=-1
        CALL NEWPAG
        CALL ANMODE
        CALL SLP(1)
        GO TO 82
        END

        SUBROUTINE AI0CP(AI0,EF)
C       K.H.CARPENTER 28JUL80
C       Same code as AI0  except that COMMON/CMIJE1/ removed
C       and BM(13) added to "DIMENSION" statement, and values
C       placed in "DATA" statement for universal normalized correction.
        DIMENSION AI0(1),EF(1),BM(13)
        DATA BM/1.145,-0.2863,0.0229,
      1 -0.0080,-0.0011,-0.0011,-0.0007,-0.0005,
      2 -0.0003,-0.0002,-0.0001,-0.0006,-0.0007/
C       Data values chosen to correct to approximately 5%
C       accuracy PLOTNO output values to those that would be
C       obtained if only flux from each cavity's own annulus
C       linked it.
C       Values are valid to 5% for all reasonable EBT-I/S annuli.
C     SUBROUTINE AI0C(AI0,EF)
C     K.H.CARPENTER 11JUL80.
C     APPLIES INVERSE MUTUAL INDUCTANCE MATRIX BM TO INPUT WPER SIGNAL
C     VALUES EF TO GIVE UNFOLDED WPER VALUES AI0 (NORMALIZED).
C     NORMALIZATION OF WPER FOR I'TH CAVITY IS:
C        WP(I) = (AI0(I) - AI0(K))*BV(I)/CPHI/NTURN/MU0/TWOPI
C     WHERE BV(I) IS "AVERAGE" MAGNETIC FLUX DENSITY OVER ANNULUS,
C     CPHI IS VALUE FLUX LINKING PICKUP COIL IS MULTIPLIED BY TO
C     OBTAIN EF(I), AND NTURN IS TOTAL NO. OF TURNS IN SERIES
C     IN PICKUP COILS ON CAVITY I.  AI0(K) IS RESIDUAL VALUE FOR
C     CAVITY WITH NO ANNULUS.
C     FOR DETAILS SEE KHC 9JUL80.
C
C      COMMON/CMIJE1/BM(13),AM(13),V1
C     DIMENSION AI0(24),EF(24)
C     MULTIPLIES INPUT VECTOR EF BY MATRIX BM TO OBTAIN OUTPUT
C     VECTOR AI0.
C     BM IS A SYMMETRIC, CIRCULANT MATRIX OF DIMENSION 24.
```

```
      DO 320 K=2,25
320   PLOTNO(K+25)=PLOTNO(K)
      CALL A10CP(PLOTNO(2),PLOTNO(27))
2022  IPLTU=-3
      CALL BINITT
      CALL NEWPAG
C  INSERT HERE MODIFICATIONS TO CHANGE SCALE OF PLOT,ETC
      SAVE1=PLOTNO(2)
      SAVE2=PLOTNO(3)
      PLOTNO(2)=0.
      PLOTNO(3)=100.
      CALL CHECK(XAX,PLOTNO)
      PLOTNO(2)=SAVE1
      PLOTNO(3)=SAVE2
      CALL LINE(-1)
      CALL SYMBL(2)
      CALL DSPLAY(XAX,PLOTNO)
      CALL MOVABS(0,500)
      CALL ANMODE
      WRITE(IPLTU,205)IT1,IT2,IT3,IT4
205   FORMAT(' BEF:'/1X,I3/1X,I3//' AFT:'/1X,I3/1X,I3)
      CALL MOVABS(0,50)
      CALL ANMODE
      CALL WRCOM(IPLTU)
      CALL HOME
      CALL ANMODE
      IF(ICURVE.NE.2)GO TO 220
      IF(IWT.NE.0)WRITE(IPLTU,208)IVERS,DWT
208   FORMAT(' W PER. (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W6)'
    1 /' (EBTOFF',A5,' WTS FROM ',A10)
      IF(IWT.EQ.0)WRITE(IPLTU,210)IVERS
210   FORMAT(' W PER. (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W6)'
    1 /' (EBTOFF',A5)
      IF(ICOMP.EQ.'Y'.OR.ICOMP.EQ.'y')WRITE(IPLTU,330)
330   FORMAT(10X,' COMP.FOR CAV.CROSS COUPL.')
      IPLTU=-1
      CALL NEWPAG
      CALL ANMODE
      CALL SLP(1)
      TYPE 215
215   FORMAT(' W PER VS CAVITY OUTPUT TO LPT')
      WRITE(17,3010)(PLOTNO(K),K=2,25)
3010  FORMAT(/1H1,' EBTOFF-V4   W PER (in ADC counts) N1-N6,'
    1 ,' E1-E6, S1-S6, W1-W6'//4(6F12.4/))
      IF(ICOMP.EQ.'Y'.OR.ICOMP.EQ.'y')WRITE(17,340)
340   FORMAT(' COMPENSATED FOR CAVITY CROSS COUPLING')
      WRITE(17,3015)IT1,IT2,IT3,IT4
3015  FORMAT('  Samples averaged -      BEF:',2I5,'  AFT:',2I5/)
      IF(IWT.NE.0)WRITE(17,3020)DWT,ITIW
3020  FORMAT('  Weighted by ',A10,'  BEF:',2I5,'  AFT:',2I5/)
      WRITE(17,3025)
3025  FORMAT('  Data file I.D. and comments:')
      CALL WRCOM(17)
      TYPE 3030
3030  FORMAT(' W PER WRITTEN TO EBTOFF.DAT')
      GO TO 82
220   IF(ICURVE.NE.1)GO TO 240
      WRITE(IPLTU,230)IVERS
```

```
      DO 100 I=1,24
      N=MOD(I+12,24)
      IF(N.EQ.0)N=24
      AIO(I)=BM(1)*EF(I)+BM(13)*EF(N)
      DO 50 J=2,12
         N1=MOD(I+J-1,24)
         IF(N1.EQ.0)N1=24
         N2=MOD(25+I-J,24)
         IF(N2.EQ.0)N2=24
         AIO(I)=AIO(I)+BM(J)*(EF(N1)+EF(N2))
50    CONTINUE
100   CONTINUE
      RETURN
      END
```

FLDEQ program

The FLDEQ program was used to provide the simulation of the NBT Hall probe versus perpendicular energy data as well as to provide the simulated data for EBT diamagnetic field components as functions of ring parameters. The main program and all subroutines are contained in a single FORTRAN file. FLDEQ is documented with comment lines in the listing. The program prompts for input. A sample terminal session showing the input dialog and the resultant output produced is given on the next page. The program listing then follows.

```
R;

.LOAD FLDEQ(NOMAP START
EXECUTION BEGINS...
WHICH PARAMETER DO YOU WISH TO VARY ?: L=LENGTH, R=MEAN RADIUS, T=THICKNESS :
.L
ENTER INITIAL VALUES OF THE PARAMETERS : TOTAL LENGTH, MEAN RADIUS, THICKNESS,    AND CURRE
?
.1 13.33 1 .937
ENTER THE UPPER LIMIT OF THE PARAMETER BEING VARIED:
?
.20
HOW MANY VALUES DO YOU WANT CALCULATED (UP TO 100) ?
?
.20
ENTER FIELD POINT COORDINATES X,R (IN CENTIMETERS)
?
.1.5 25.
ENTER ANNULUS OFFSET VALUE :
?
.-1.856
INCLUDE ADJACENT CAVITY EFFECTS ? (Y OR N):
.Y
DO YOU WANT ANOTHER CASE ? (Y OR N):
.N
R;

.
```

```
TY FILE FT08F001

(X,R)=(   1.50,  25.00)   OFFSET= -1.856    ADJACENT INCLUDED ? : Y

    BZMAX=  0.047467    BRMAX= -0.010009    APMAX= -2.074389
```

| LENGTH | RADIUS | THICKNESS | CR | BZ | BR | AP |
|---|---|---|---|---|---|---|
| 1.000 | 13.330 | 1.000 | 0.937 | 0.083843 | 0.110523 | 0.054503 |
| 2.000 | 13.330 | 1.000 | 0.937 | 0.166958 | 0.219387 | 0.108919 |
| 3.000 | 13.330 | 1.000 | 0.937 | 0.248625 | 0.324994 | 0.163166 |
| 4.000 | 13.330 | 1.000 | 0.937 | 0.328171 | 0.425862 | 0.217159 |
| 5.000 | 13.330 | 1.000 | 0.937 | 0.404952 | 0.520668 | 0.270816 |
| 6.000 | 13.330 | 1.000 | 0.937 | 0.478383 | 0.608288 | 0.324075 |
| 7.000 | 13.330 | 1.000 | 0.937 | 0.547952 | 0.687811 | 0.376853 |
| 8.000 | 13.330 | 1.000 | 0.937 | 0.613222 | 0.758586 | 0.429089 |
| 9.000 | 13.330 | 1.000 | 0.937 | 0.673811 | 0.820196 | 0.480735 |
| 10.000 | 13.330 | 1.000 | 0.937 | 0.729453 | 0.872421 | 0.531734 |
| 11.000 | 13.330 | 1.000 | 0.937 | 0.779936 | 0.915253 | 0.582039 |
| 12.000 | 13.330 | 1.000 | 0.937 | 0.825133 | 0.948927 | 0.631607 |
| 13.000 | 13.330 | 1.000 | 0.937 | 0.864963 | 0.973691 | 0.680430 |
| 14.000 | 13.330 | 1.000 | 0.937 | 0.899425 | 0.990067 | 0.728498 |
| 15.000 | 13.330 | 1.000 | 0.937 | 0.928611 | 0.998665 | 0.775741 |
| 16.000 | 13.330 | 1.000 | 0.937 | 0.952603 | 1.000000 | 0.822190 |
| 17.000 | 13.330 | 1.000 | 0.937 | 0.971540 | 0.994709 | 0.867831 |
| 18.000 | 13.330 | 1.000 | 0.937 | 0.985615 | 0.983473 | 0.912676 |
| 19.000 | 13.330 | 1.000 | 0.937 | 0.995027 | 0.966922 | 0.956724 |
| 20.000 | 13.330 | 1.000 | 0.937 | 1.000000 | 0.945676 | 1.000000 |

```
R;

.
```

```
C     PROGRAM FLDE2:     F.ZYKAN  24JUL80                                FLD00
CZ    F.W.ZYKAN     28AUG80 : OUTPUT NORMALIZED ; MAXIMUM FIELD         FLD00
CZ       VALUES LISTED .                                                FLD00
CK    K.H.CARPENTER 08AUG80 : R1S INSERTED IN COMMON/CFB/ IN MAIN PROG. FLD00
CK       OUTPUT CHANGED TO UNIT 8; ALTERNATE OUTPUT LOOP INSERTED AS    FLD00
CK       COMMENTS BEGINNING CK                                          FLD00
C                                                                       FLD00
C          THIS PROGRAM WILL CALCULATE THE RADIAL AND AXIAL B-FIELDS    FLD00
C      DUE TO TWO COAXIAL CURRENT CYLINDERS WHOSE CENTERS ARE AT THE    FLD00
C      REFERENCE, OR PRIMARY ORIGIN. THE PROGRAM IS USER-INTERACTIVE,   FLD00
C      AND IS DESIGNED FOR USE ON THE IBM VIRTUAL MACHINE/CMS TERMI-    FLD00
C      NALS.                                                            FLD00
C          THE PROGRAM PROMPTS THE USER FOR THE INPUT DATA, WHICH       FLD00
C      CONSISTS OF THE CYLINDER (OR ANNULUS) LENGTH, RADIUS, THICKNESS, FLD00
C      CURRENT RATIO, AND OFFSET. THESE TERMS REPRESENT THE FOLLOWING : FLD00
C          LENGTH---THE TOTAL LENGTH OF THE CYLINDERS IN CM.            FLD00
C          RADIUS---THE ARITHMETIC MEAN OF THE RADII OF THE TWO         FLD00
C                   CYLINDERS IN CM.                                    FLD00
C          THICKNESS---THE DIFFERENCE BETWEEN THE RADII OF THE TWO      FLD00
C                      CYLINDERS IN CM.                                 FLD00
C          CURRENT RATIO---THIS IS THE RATIO OF THE INNER CYLINDER      FLD00
C                          CURRENT DENSITY TO THE OUTER CYLINDER        FLD00
C                          CURRENT DENSITY.                             FLD00
C          OFFSET---THE DISTANCE THAT THE ANNULUS IS DISPLACED FROM     FLD00
C                   THE CENTER OF THE EBT CAVITY, DUE TO THE NON-       FLD00
C                   UNIFORMITY OF THE MAGNETIC FIELD WHICH THE ELECTRONSFLD00
C                   MOVE THROUGH, IN CM.                                FLD00
C          THE USER MUST ALSO CHOOSE WHICH PARAMETER IS TO BE VARIED,   FLD00
C      WHETHER IT IS LENGTH, MEAN RADIUS, OR THICKNESS, AND ALSO HOW    FLD00
C      MANY VALUES ARE TO BE CALCULATED, ALONG WITH THE UPPER LIMIT     FLD00
C      OF THE PARAMETER BEING VARIED. THE PROGRAM WILL PROMPT FOR EACH. FLD00
C      THE USER MUST ALSO DECIDE WHETHER OR NOT TO INCLUDE THE EFFECTS  FLD00
C      OF TWO SIMILAR ANNULI WHICH ARE ON EITHER SIDE OF THE 'CENTER'   FLD00
C      ANNULUS, AND IN A CONFIGURATION LIKE THE CAVITIES IN 'EBT'(15-   FLD00
C      DEGREES OFF OF A LINE FROM THE CENTER OF 'EBT' TO THE CENTER     FLD00
C      OF THE FIRST ANNULUS, AND EACH 150 CM. AWAY FROM THE CENTER OF   FLD00
C      THE 'EBT' MACHINE).                                              FLD00
C          THE FINAL PIECE OF INFORMATION NECESSARY FOR THE CALCULATIONS FLD00
C      IS THE POINT AT WHICH THE USER WANTS THE FIELDS CALCULATED.      FLD00
C          THE OUTPUT IS DISPLAYED ON THE CRT TERMINAL, AND MUST EITHER FLD00
C      BE COPIED OR PRINTED FOR A HARD COPY LISTING OF THE DATA OUTPUT. FLD00
C                                                                       FLD00
C          THE PROGRAM USES A SINGLE-PRECISION ADAPTIVE SIMPSON'S RULE  FLD00
C      FOR INTEGRATION, AND ALL ELLIPTIC INTEGRALS ARE DONE IN-LINE.    FLD00
C                                                                       FLD00
C                                                                       FLD00
      COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPRS2,RMR1S2                 FLD00
      DIMENSION BZZ(100),BRR(100),AL(100),ANMR(100),APP(100)            FLD00
     1,ATHK(100)                                                        FLD00
C         INITIALIZATION.                                               FLD00
      DATA IL,IR,IT,IY/'L','R','T','Y'/                                 FLD00
      C15=COS(.26179938)                                                FLD00
      S15=SIN(.26179938)                                                FLD00
C         AMR IS THE DISTANCE FROM THE PHYSICAL CENTER OF THE ANNULI    FLD00
C         TO THE CENTER OF 'EBT'.                                       FLD00
```

```
      AMR=150                                                           FLD00
10    IVL=0                                                             FLD00
      IVR=0                                                             FLD00
      IVT=0                                                             FLD00
C         INPUT OF PARAMETERS.                                          FLD00
15    WRITE(6,20)                                                       FLD00
20    FORMAT(' WHICH PARAMETER DO YOU WISH TO VARY ?: L=LENGTH, R=MEAN RFLD00
     1ADIUS, T=THICKNESS :')                                            FLD00
      READ(5,30)IVAR                                                    FLD00
30    FORMAT(A1)                                                        FLD00
C         SETTING UP INCREMENTING 'FLAG' SO THAT PROPER PARAMETER       FLD00
C         IS INCREMENTED.                                               FLD00
      IF(IVAR.NE.IL.AND.IVAR.NE.IR.AND.IVAR.NE.IT)GOTO15                FLD00
      IF(IVAR.EQ.IL)IVL=1                                               FLD00
      IF(IVAR.EQ.IR)IVR=1                                               FLD00
      IF(IVAR.EQ.IT)IVT=1                                               FLD00
      WRITE(6,40)                                                       FLD00
40    FORMAT(' ENTER INITIAL VALUES OF THE PARAMETERS : TOTAL LENGTH, MEFLD00
     1AN RADIUS, THICKNESS,    AND CURRENT RATIO :')                    FLD00
      READ(5,*)AL(1),ANMR(1),ATHK(1),CR                                 FLD00
      WRITE(6,60)                                                       FLD00
60    FORMAT(' ENTER THE UPPER LIMIT OF THE PARAMETER BEING VARIED:')   FLD00
      READ(5,*)FINISH                                                   FLD00
      WRITE(6,80)                                                       FLD00
80    FORMAT(' HOW MANY VALUES DO YOU WANT CALCULATED (UP TO 100) ?')   FLD00
      READ(5,*)NMPT                                                     FLD00
      WRITE(6,100)                                                      FLD00
100   FORMAT(' ENTER FIELD POINT COORDINATES X,R (IN CENTIMETERS)')     FLD00
      READ(5,*)XL,RLL                                                   FLD00
      WRITE(6,110)                                                      FLD00
110   FORMAT(' ENTER ANNULUS OFFSET VALUE :')                           FLD00
      READ(5,*)OFF                                                      FLD00
      WRITE(6,120)                                                      FLD00
120   FORMAT(' INCLUDE ADJACENT CAVITY EFFECTS ? (Y OR N):')            FLD00
      READ(5,130)NEI                                                    FLD00
130   FORMAT(A1)                                                        FLD00
      IF(NMPT.LE.1)GOTO135                                              FLD00
C         CALCULATING INCREMENTAL VALUE FOR APPROPRIATE PARAMETER.      FLD00
      IF(IVAR.EQ.IL)DEL=(FINISH-AL(1))/(NMPT-1)                         FLD00
      IF(IVAR.EQ.IR)DEL=(FINISH-ANMR(1))/(NMPT-1)                       FLD00
      IF(IVAR.EQ.IT)DEL=(FINISH-ATHK(1))/(NMPT-1)                       FLD00
C         ALL FIELD OUTPUT DATA IS STORED IN ARRAYS.                    FLD00
C         THIS PORTION SETS UP FIRST VALUES TO BE CALCULATED.           FLD00
C                                                                       FLD00
C      INITIALIZE 'MAXIMUM' REGISTERS.                                  FLD01
      BZMAX=0.                                                          FLD01
      BRMAX=0.                                                          FLD01
      APMAX=0.                                                          FLD01
135   N=1                                                               FLD01
140   AL2=AL(N)/2.                                                      FLD01
      AR1=ANMR(N)-ATHK(N)/2.                                            FLD01
      AR2=ANMR(N)+ATHK(N)/2.                                            FLD01
CC                                                                      FLD01
CC       CALCULATE FIELD DUE TO CENTER ANNULUS                          FLD01
CC                                                                      FLD01
```

```
C          'RL' IS THE RADIAL DISTANCE OF THE POINT TO THE ANNULUS CENTERFLD01
C          ADJUSTED FOR THE 'OFFSET' VALUE.                              FLD01
      RL=RLL-OFF                                                        FLD01
C          'SXC' IS USED TO OBTAIN THE CORRECT SIGN FOR THE COMPONENTS   FLD01
C          REGARDLESS OF POINT'S LOCATION IN 'QUADRANT' ABOUT THE ANNULUSFLD01
      SXC=SIGN(1.,XL)*SIGN(1.,RL)                                       FLD01
C          THE POINT, (X,R), AND RADIUS, R1, ARE SET UP FOR CALCULATION  FLD01
      X=XL                                                              FLD01
      R=ABS(RL)                                                         FLD01
C          INNER CURRENT-SHEET RADIUS (AR1).                             FLD01
      R1=AR1                                                            FLD01
C          FBI CALCULATES THE AXIAL B-FIELD COMPONENT                    FLD01
      CALL FBI                                                          FLD01
      BZ=CR*FB                                                          FLD01
C          FBR CALCULATES THE RADIAL B-FIELD COMPONENT                   FLD01
      CALL FBR                                                          FLD01
      BR=FB*CR                                                          FLD01
C          AS1 CALCULATES THE MAGNETIC VECTOR POTENTIAL COMPONENT        FLD01
      CALL AS1                                                          FLD01
      AP=FB*CR*R*2.                                                     FLD01
C                                                                       FLD01
C          SIMILARLY, THE OUTER SHEET VALUES (BZ,BR,&AP) ARE CALCULATED. FLD01
C                                                                       FLD01
C          OUTER CURRENT-SHEET RADIUS (AR2).                             FLD01
      R1=AR2                                                            FLD01
      CALL FBI                                                          FLD01
      BZ=BZ-FB                                                          FLD01
      CALL FBR                                                          FLD01
      BR=BR-FB                                                          FLD01
      CALL AS1                                                          FLD01
      AP=AP-FB*2.*R                                                     FLD01
      BR=BR*SXC                                                         FLD01
C      ADJ. VALUES ARE NOW SET TO ZERO(IN CASE ADJACENT NOT CONSIDERED).FLD01
      BNR=0.                                                            FLD01
      BNZ=0.                                                            FLD01
      ANP=0.                                                            FLD01
C          CHECK TO SEE IF ADJACENT ANNULI ARE TO BE CONSIDERED.         FLD01
      IF(NEI.NE.IY)GOTO150                                              FLD01
CC                                                                      FLD01
CC         CALCULATE ADJACENT ANNULUS EFFECTS                           FLD01
CC                                                                      FLD01
CC        FIRST ADJACENT ANNULUS :                                      FLD01
C                                                                       FLD01
C          OFFSET EFFECT IS NOW INCLUDED.                                FLD01
      RMA=AMR+OFF                                                       FLD01
C          A COORDINATE-TRANSFORMATION IS PERFORMED TO CORRECTLY         FLD01
C          INCLUDE THE EFFECTS OF THE ADJACENT ANNULI:                   FLD01
      RP=RL+RMA                                                         FLD01
      R1=AR1                                                            FLD01
      R=RP*C15+XL*S15-RMA                                               FLD01
      X=XL*C15-RP*S15                                                   FLD01
      SX=SIGN(1.,X)*SIGN(1.,R)                                          FLD01
      SA=SIGN(1.,R)                                                     FLD01
      R=ABS(R)                                                          FLD01
C          AS BEFORE, THE FIELDS ARE CALCULATED WITH THE PROPER VALUES   FLD01
```

```
C          FOR THE INNER AND OUTER CURRENT SHEETS OF ONE ADJACENT ANNULUSFLD01
      CALL FBI                                                          FLD01
      BNZ=FB*CR                                                         FLD01
      CALL FBR                                                          FLD01
      BNR=FB*CR*SX                                                      FLD01
      CALL AS1                                                          FLD01
      ANP=FB*CR*R*2.*SA                                                 FLD01
      R1=AR2                                                            FLD01
      CALL FBI                                                          FLD01
      BNZ=BNZ-FB                                                        FLD01
      CALL FBR                                                          FLD01
      BNR=BNR-FB*SX                                                     FLD01
      CALL AS1                                                          FLD01
      ANP=ANP-FB*2.*R*SA                                                FLD01
C          TRANFORMED COMPONENT VALUES ADDED TO THE CENTER-ANNULUS FIELD FLD01
      BZ=BZ+BNZ*C15+BNR*S15                                             FLD01
      BR=BR+BNR*C15-BNZ*S15                                             FLD01
      AP=AP+ANP                                                         FLD01
CC                                                                      FLD01
CC       SECOND ADJACENT ANNULUS :                                      FLD01
CC                                                                      FLD01
C          AS FOR THE FIRST ADJACENT ANNULUS, THE TRANSFORMED FIELD     FLD01
C          COMPONENTS FROM THE SECOND ADJACENT ANNULUS ARE ADDED TO     FLD01
C          THE FIELD TOTALS:                                            FLD01
      R=R-XL*S15*2.                                                     FLD01
      X=RP*S15+XL*C15                                                   FLD01
      R1=AR1                                                            FLD01
      SA=SIGN(1.,R)                                                     FLD01
      SX=SIGN(1.,X)*SIGN(1.,R)                                          FLD01
      R=ABS(R)                                                          FLD01
      CALL FBI                                                          FLD01
      BNZ=FB*CR                                                         FLD01
      CALL FBR                                                          FLD01
      BNR=FB*CR*SX                                                      FLD01
      CALL AS1                                                          FLD02
      ANP=FB*CR*R*2.*SA                                                 FLD02
      R1=AR2                                                            FLD02
      CALL FBI                                                          FLD02
      BNZ=BNZ-FB                                                        FLD02
      CALL FBR                                                          FLD02
      BNR=BNR-FB*SX                                                     FLD02
      CALL AS1                                                          FLD02
      ANP=ANP-FB*2.*R*SA                                                FLD02
CC                                                                      FLD02
CC       FINAL SUM OF FIELDS                                            FLD02
CC                                                                      FLD02
C        ARRAY STORAGE OF SUMS:                                         FLD02
150   BZZ(N)=BZ+BNZ*C15-BNR*S15                                         FLD02
      BRR(N)=(BR+BNR*C15+BNZ*S15)*SXC                                   FLD02
      APP(N)=AP+ANP                                                     FLD02
C        COMPARE TO PREVIOUS MAX.                                       FLD02
      IF(ABS(BZMAX).LT.ABS(BZZ(N)))BZMAX=BZZ(N)                         FLD02
      IF(ABS(BRMAX).LT.ABS(BRR(N)))BRMAX=BRR(N)                         FLD02
      IF(ABS(APMAX).LT.ABS(APP(N)))APMAX=APP(N)                         FLD02
C          LAST SET TO CALCULATE ?                                      FLD02
```

```
      IF(N.GE.NMPT)GOTO160                                              FLD02
C         IF NOT, INCREMENT APPROPRIATE VALUES AND CALCULATE NEW        FLD02
C         FIELD COMPONENTS:                                             FLD02
      N=N+1                                                             FLD02
      AL(N)=AL(N-1)+IVL*DEL                                             FLD02
      ANMR(N)=ANMR(N-1)+IVR*DEL                                         FLD02
      ATHK(N)=ATHK(N-1)+IVT*DEL                                         FLD02
      GOTO140                                                           FLD02
C       NORMALIZING SCHEME.                                             FLD02
160   DO 161 I=1,NMPT                                                   FLD02
      BZZ(I)=BZZ(I)/BZMAX                                               FLD02
      BRR(I)=BRR(I)/BRMAX                                               FLD02
161   APP(I)=APP(I)/APMAX                                               FLD02
CC                                                                      FLD02
CC       OUTPUT LOOP                                                    FLD02
CC          SETS UP A TABLE OF OUTPUT FOR ALL INPUT AND OUTPUT VALUES.  FLD02
CK                                                                      FLD02
      WRITE(8,162)XL,RLL,OFF,NEI                                        FLD02
162   FORMAT(/' (X,R)=(',F7.2,',',F7.2,')',3X,'OFFSET=',F7.3,           FLD02
     1'    ADJACENT INCLUDED ? : ',A1)                                  FLD02
      WRITE(8,165)BZMAX,BRMAX,APMAX                                     FLD02
165   FORMAT(/5X,'BZMAX=',F10.6,4X,'BRMAX=',F10.6,4X,'APMAX=',F10.6)    FLD02
      WRITE(8,170)                                                      FLD02
170   FORMAT(/'  LENGTH   RADIUS  THICKNESS   CR        BZ         BR   FLD02
     1    AP')                                                          FLD02
      DO 190 N=1,NMPT                                                   FLD02
      WRITE(8,185)AL(N),ANMR(N),ATHK(N),CR,BZZ(N),BRR(N),APP(N)         FLD02
185   FORMAT(4(F8.3,1X),3(F10.6,1X))                                    FLD02
190   CONTINUE                                                          FLD02
CK                                                                      FLD02
CK160   WRITE(8,162)XL,RLL,OFF,NEI                                      FLD02
CK162   FORMAT(/' (X,R)=(',F7.2,',',F7.2,')',3X,'OFFSET=',F7.3,         FLD02
CK    1'    ADJACENT INCLUDED ? : ',A1)                                 FLD02
CK    WRITE(8,170)                                                      FLD02
CK170 FORMAT(/'  LENGTH   RADIUS  THICKNESS   CR        BZ          BR  FLD02
CK    1        - APHI')                                                 FLD02
CK    WRITE(8,185)(AL(N),ANMR(N),ATHK(N),CR,BZZ(N),BRR(N),APP(N),       FLD02
CK    1 N=1,NMPT)                                                       FLD02
CK185   FORMAT(0PF8.3,3F9.3,1P3E13.3)                                   FLD02
C         ASKS IF USER WANTS ANOTHER CASE:                              FLD02
      WRITE(6,200)                                                      FLD02
200   FORMAT(' DO YOU WANT ANOTHER CASE ? (Y OR N):')                   FLD02
      READ(5,130)ID                                                     FLD02
      IF(ID.EQ.IY)GOTO10                                                FLD02
      END                                                               FLD02
C                                                                       FLD02
C                                                                       FLD02
        SUBROUTINE FBI                                                  FLD02
C       CALCULATES INTEGRAL FB OF KHC 20OCT76 USING SASIMP              FLD02
        EXTERNAL FBFUN                                                  FLD02
        COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ              FLD02
        X=ABS(X)                                                        FLD02
        ET=1.E-4                                                        FLD02
        N=1                                                             FLD02
        RS=R*R                                                          FLD02
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```
      R1S=R1*R1                                                         FLD02
      R1R4=4.*R*R1                                                      FLD02
      RPR1SQ=(R+R1)**2                                                  FLD02
      RMR1SQ=(R-R1)**2                                                  FLD02
      IF(X.LT.AL2)GO TO 10                                              FLD02
      FB=SASIMP(-AL2,AL2,ET,M,N,FBFUN)                                  FLD02
      RETURN                                                            FLD02
 10   FB=SASIMP(-AL2,X,ET,M,N,FBFUN)+SASIMP(X,AL2,ET,M,N,FBFUN)         FLD02
      RETURN                                                            FLD02
      END                                                               FLD02
                                                                        FLD02
      FUNCTION FBFUN(Z)                                                 FLD02
C     MODIFIED 30MAY77 TO CALCULATE K & E IN-LINE. IN-LINE CODE         FLD02
C     FROM ROUTINE CEIB. (REPLACES CALLS TO CEL2)                       FLD02
      COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ                FLD02
      DATA P/1.E-5/,PI2/1.570796326794897/                              FLD02
      XZS=(X-Z)**2                                                      FLD02
      DENM=RPR1SQ+XZS                                                   FLD02
      AK2=R1R4/DENM                                                     FLD02
C     CALCULATE RK=K(AK2) AND RE=E(AK2)                                 FLD02
      IF((AK2.LT.0.).OR.(AK2.GT..9999999))GOTO55                        FLD02
      A=1.                                                              FLD02
      B=SQRT(1.-AK2)                                                    FLD02
      C=.5*AK2                                                          FLD02
      CM=.25                                                            FLD03
 10   T=A-B                                                             FLD03
      IF(T.LE.P)GO TO 20                                                FLD03
      A1=A                                                              FLD03
      A=.5*(A+B)                                                        FLD03
      B=SQRT(A1*B)                                                      FLD03
      C=C+CM*T*T                                                        FLD03
      CM=CM*2.                                                          FLD03
      GO TO 10                                                          FLD03
 20   RK=PI2/A                                                          FLD03
      RE=RK-RK*C                                                        FLD03
      FBFUN=(RK+RE*(R1S-RS-XZS)/(RMR1SQ+XZS))/SQRT(DENM)                FLD03
      RETURN                                                            FLD03
 55   WRITE(6,60)                                                       FLD03
 60   FORMAT(' *** BAD ARGUMENT TO K IN FBI ***')                       FLD03
      STOP                                                              FLD03
      END                                                               FLD03
C                                                                       FLD03
C                                                                       FLD03
      SUBROUTINE FBR                                                    FLD03
C     MODIFICATION OF FBI TO CALCULATED RADIAL FIELD COMPONENT.         FLD03
C     CALCULATES INTEGRAL FB OF KHC 20OCT76 USING SASIMP                FLD03
      EXTERNAL FRFUN                                                    FLD03
      COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ                FLD03
      X=ABS(X)                                                          FLD03
      ET=1.E-4                                                          FLD03
      N=1                                                               FLD03
      RS=R*R                                                            FLD03
      R1S=R1*R1                                                         FLD03
      R1R4=4.*R*R1                                                      FLD03
      RPR1SQ=(R+R1)**2                                                  FLD03
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      RMR1SQ=(R-R1)**2                                                  FLD03
      IF(X.LT.AL2)GO TO 10                                              FLD03
      AX=.0-AL2                                                         FLD03
      FB=SASIMP(AX,AL2,ET,M,N,FRFUN)                                    FLD03
      RETURN                                                            FLD03
10    AX=.0-AL2                                                         FLD03
      FB=SASIMP(AX,X,ET,M,N,FRFUN)+SASIMP(X,AL2,ET,M,N,FRFUN)           FLD03
      RETURN                                                            FLD03
      END                                                               FLD03
CC                                                                      FLD03
      FUNCTION FRFUN(Z)                                                 FLD03
C     MODIFIED 30MAY77 TO CALCULATE K & E IN-LINE. IN-LINE CODE         FLD03
C     FROM ROUTINE CEIB. (REPLACES CALLS TO CEL2)                       FLD03
      COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ                FLD03
      DATA P/1.E-5/,PI2/1.570796326794897/                              FLD03
      XZ=X-Z                                                            FLD03
      XZS=XZ*XZ                                                         FLD03
      DENM=RPR1SQ+XZS                                                   FLD03
      AK2=R1R4/DENM                                                     FLD03
C     CALCULATE RK=K(AK2) AND RE=E(AK2)                                 FLD03
      IF((AK2.LT.0.).OR.(AK2.GT..9999999))GOTO55                        FLD03
      A=1.                                                              FLD03
      B=SQRT(1.-AK2)                                                    FLD03
      C=.5*AK2                                                          FLD03
      CM=.25                                                            FLD03
 10   T=A-B                                                             FLD03
      IF(T.LE.P)GO TO 20                                                FLD03
      A1=A                                                              FLD03
      A=.5*(A+B)                                                        FLD03
      B=SQRT(A1*B)                                                      FLD03
      C=C+CM*T*T                                                        FLD03
      CM=CM*2.                                                          FLD03
      GO TO 10                                                          FLD03
 20   RK=PI2/A                                                          FLD03
      RE=RK-RK*C                                                        FLD03
      FRFUN=XZ*((.0-RK)+RE*(R1S+RS+XZS)/(RMR1SQ+XZS))/(R*SQRT(DENM))    FLD03
      RETURN                                                            FLD03
 55   WRITE(6,60)                                                       FLD03
 60   FORMAT(' *** BAD ARGUMENT TO K IN FBR ***')                       FLD03
      STOP                                                              FLD03
      END                                                               FLD03
C                                                                       FLD03
C                                                                       FLD03
      FUNCTION SASIMP(A1,B,EE,M,N,FUN)                                  FLD03
C       This is a SINGLE PRECISION version of ASIMP.                    FLD03
C PROGRAM AUTHOR K. HILLSTROM                                           FLD03
C  ARGONNE NATIONAL LABORATORY                                          FLD03
C  CHICAGO,ILL.                                                         FLD03
C                                                                       FLD03
C       THIS VERSION HAS BEEN MODIFIED TO ELIMINATE ASIMP'S CHANGING    FLD03
C       OF ANY OF ITS ARGUMENTS EXCEPT M. IF A1=B ON CALL, THEN         FLD03
C       A VALUE OF ZERO IS RETURNED IMMEDIATELY, AND M = 0.             FLD03
C                                                                       FLD03
      REAL                                                              FLD03
     &                SASIMP,A1,B,EP,FUN,A,EPS,ABSAR,EST,FA,FM,FB,DX,SX,FLD03
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     >  F1,F2,FBP,EST2,NRTR,EST1,SUM,DAFT,ESUM,TSUM,DA,DIFF                FLD03
      REAL AEST2,FTST,FMAX,AF1,AF2,AEST1,DELTA,AEST                        FLD03
      DIMENSION F2(30) ,FBP(30),EST2(30),NRTR(30)                          FLD03
      DIMENSION AEST2(30),FTST(3)                                          FLD03
C     THE PARAMETER SETUP FOR THE INITIAL CALL                             FLD03
        IF((B-A1).EQ.0.E0)GO TO 200                                        FLD03
        EP=EE                                                              FLD03
      IF (N.LE.0) GO TO 40                                                 FLD03
      IF (N.GT.3) GO TO 50                                                 FLD03
      A=A1                                                                 FLD03
      EPS=EP*15.0E0                                                        FLD03
      ESUM=0.0E0                                                           FLD03
      TSUM=0.0E0                                                           FLD03
      LVL=1                                                                FLD03
      DA=B-A                                                               FLD04
      FA=FUN(A)                                                            FLD04
      FM=FUN((A+B)*0.5E0)                                                  FLD04
      FB=FUN(B)                                                            FLD04
      M=3                                                                  FLD04
      FMAX=ABS(FA)                                                         FLD04
      FTST(1)=FMAX                                                         FLD04
      FTST(2)=ABS(FM)                                                      FLD04
      FTST(3)=ABS(FB)                                                      FLD04
      DO 10 I=2,3                                                          FLD04
         IF (FMAX.GE.FTST(I)) GO TO 10                                     FLD04
         FMAX=FTST(I)                                                      FLD04
   10    CONTINUE                                                          FLD04
      EST=(FA+4.0E0*FM+FB)*DA/6.0E0                                        FLD04
      ABSAR=(FTST(1)+4.0E0*FTST(2)+FTST(3))*DA/6.0E0                       FLD04
      AEST=ABSAR                                                           FLD04
C     1=RECUR                                                              FLD04
   20 DX=DA/(2.0E0**LVL)                                                   FLD04
      SX=DX/6.0E0                                                          FLD04
      F1=FUN(A+0.5E0*DX)                                                   FLD04
      F2(LVL)=FUN(A+1.5E0*DX)                                              FLD04
      EST1=SX*(FA+4.0E0*F1+FM)                                             FLD04
      FBP(LVL)=FB                                                          FLD04
      EST2(LVL)=SX*(FM+4.0E0*F2(LVL)+FB)                                   FLD04
      SUM=EST1+EST2(LVL)                                                   FLD04
      FTST(1)=ABS(F1)                                                      FLD04
      FTST(2)=ABS(F2(LVL))                                                 FLD04
      FTST(3)=ABS(FM)                                                      FLD04
      AEST1=SX*(ABS(FA)+4.0E0*FTST(1)+FTST(3))                             FLD04
      AEST2(LVL)=SX*(FTST(3) +4.0E0*FTST(2)+ABS(FB))                       FLD04
      ABSAR=ABSAR-AEST+AEST1+AEST2(LVL)                                    FLD04
      M=M+2                                                                FLD04
      GO TO (60,30,70),N                                                   FLD04
   30 DELTA=ABSAR                                                          FLD04
      GO TO 90                                                             FLD04
   40 PRINT 10000                                                          FLD04
      RETURN                                                               FLD04
   50 PRINT 10100                                                          FLD04
      RETURN                                                               FLD04
   60 DELTA=1.0E0                                                          FLD04
      GO TO 90                                                             FLD04
```

```
   70 DO 80 I=1,2                                                       FLD04
         IF (FMAX.GE.FTST(I)) GO TO 80                                  FLD04
         FMAX=FTST(I)                                                   FLD04
   80    CONTINUE                                                       FLD04
      DELTA=FMAX                                                        FLD04
   90 DIFF=ABS(EST-SUM)                                                 FLD04
      DAFT= (EST-SUM)/15.0E0                                            FLD04
      IF (DIFF-EPS*DELTA) 110,110,100                                   FLD04
  100 IF (LVL-30) 140,120,120                                           FLD04
  110 IF (LVL-1) 120,140,120                                            FLD04
C     2=UP                                                              FLD04
  120 A=A+2.0E0*DX                                                      FLD04
  130 LVL=LVL-1                                                         FLD04
      ESUM=ESUM+DAFT                                                    FLD04
      L=NRTR(LVL)                                                       FLD04
      TSUM=TSUM+SUM                                                     FLD04
      GO TO (160,170),L                                                 FLD04
C     11=R1,12=R2                                                       FLD04
  140 NRTR(LVL)=1                                                       FLD04
      EST=EST1                                                          FLD04
      AEST=AEST1                                                        FLD04
      FB=FM                                                             FLD04
      FM=F1                                                             FLD04
      EPS=EPS/2.0E0                                                     FLD04
  150 LVL=LVL+1                                                         FLD04
      GO TO 20                                                          FLD04
  160 NRTR(LVL)=2                                                       FLD04
      FA=FB                                                             FLD04
      FM=F2(LVL)                                                        FLD04
      FB=FBP(LVL)                                                       FLD04
      EST=EST2(LVL)                                                     FLD04
      AEST=AEST2(LVL)                                                   FLD04
      GO TO 150                                                         FLD04
  170 EPS=2.0E0*EPS                                                     FLD04
      SUM=0.0E0                                                         FLD04
      IF (LVL-1) 180,180,130                                            FLD04
  180 SASIMP=TSUM                                                       FLD04
      A=ABS(ESUM)                                                       FLD04
      EP=DIFF/DELTA                                                     FLD04
      IF (A.GE.EP) GO TO 190                                            FLD04
      SASIMP=SASIMP-ESUM                                                FLD04
  190 RETURN                                                            FLD04
 200    SASIMP = 0.E0                                                   FLD04
        M = 0                                                           FLD04
        RETURN                                                          FLD04
10000 FORMAT(' ERROR RETURN-N.LE.0')                                    FLD04
10100 FORMAT(' ERROR RETURN-N.GT.3')                                    FLD04
      END                                                               FLD04
C                                                                       FLD04
C                                                                       FLD04
        SUBROUTINE  AS1                                                 FLD04
C       THIS SUBROUTINE CALCULATES INTEGRAL AS1 OF KHC 14DEC76.         FLD04
C       ARGUMENTS ARE IN COMMON/CFB/; RETURNED VALUE IS IN FB.          FLD04
        EXTERNAL ASFUN                                                  FLD04
        COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1S2,RMR1S2              FLD04
```

```
      ET=1.E-4                                                          FLD04
      N=1                                                               FLD04
      XU=X+AL2                                                          FLD04
      XL=X-AL2                                                          FLD04
      RR=R/R1                                                           FLD05
      IF(RR.LT.1.E-3)GOTO40                                             FLD05
      COEF=SQRT(R1/R)/R                                                 FLD05
      R1R4=4.*R*R1                                                      FLD05
      RPR1SQ=(R+R1)**2                                                  FLD05
      IF(XL.LT.0.)  TO 10                                               FLD05
      FB=SASIMP(XL,XU,ET,NFUNCT,N,ASFUN)*COEF                           FLD05
C10   FB=(SASIMP(XL,0.,ET,M,N,ASFUN)+SASIMP(0.,XU,ET,M,N,ASFUN))*COEF FLD05
      RETURN                                                            FLD05
 10   IF(ABS(1.-RR).LT.1.E-3)GOTO30                                     FLD05
      FB=2.*COEF*SASIMP(XL,0.,ET,NFUNCT,N,ASFUN)                        FLD05
 20   FB=FB+COEF*SASIMP(-XL,XU,ET,NFUNCT,N,ASFUN)                       FLD05
      RETURN                                                            FLD05
 30   R1R4=R1*R1*1.001*4.                                               FLD05
      RPR1SQ=(R1*(2.001))**2                                            FLD05
      FB=COEF*SASIMP(XL,0.,ET,NFUNCT,N,ASFUN)                           FLD05
      R1R4=R1*R1*0.999*4.                                               FLD05
      RPR1SQ=(R1*(1.999))**2                                            FLD05
      FB=FB+COEF*SASIMP(XL,0.,ET,NFUNCT,N,ASFUN)                        FLD05
      GOTO20                                                            FLD05
 40   R1S=R1*R1                                                         FLD05
      FB=(3.141592653589793D0/4.)*(XU/SQRT(R1S+XU*XU)                   FLD05
     1 -XL/SQRT(R1S+XL*XL))                                             FLD05
      END                                                               FLD05
                                                                        FLD05
      FUNCTION ASFUN(Z)                                                 FLD05
C     MODIFIED 30MAY77 TO CALC. K & E IN-LINE.IN-LINE CODE              FLD05
C     FROM ROUTINE CEIB. (REPLACES CALLS TO CEL2)                       FLD05
      COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ                FLD05
      DATA P/1.E-5/,PI2/1.570796326794897/                              FLD05
      AK2=R1R4/(RPR1SQ+Z*Z)                                             FLD05
      AK=SQRT(AK2)                                                      FLD05
C     CALCULATE RK=K(AK2) AND RE=E(AK2)                                 FLD05
      IF((AK2.LT.0.).OR.(AK2.GT..9999999))GOTO55                        FLD05
      A=1.                                                              FLD05
      B=SQRT(1.-AK2)                                                    FLD05
      C=.5*AK2                                                          FLD05
      CM=.25                                                            FLD05
 10   T=A-B                                                             FLD05
      IF(T.LE.P)GOTO20                                                  FLD05
      A1=A                                                              FLD05
      A=.5*(A+B)                                                        FLD05
      B=SQRT(A1*B)                                                      FLD05
      C=C+CM*T*T                                                        FLD05
      CM=CM*2                                                           FLD05
      GOTO10                                                            FLD05
 20   RK=PI2/A                                                          FLD05
      RE=RK-RK*C                                                        FLD05
C     USE RK & RE TO GET ASFUN:                                         FLD05
      ASFUN=((1-AK2/2.)*RK-RE)/AK                                       FLD05
      RETURN                                                            FLD05
```

```
 55     WRITE(6,60)                                                    FLD05
 60     FORMAT(' BAD ARG. TO K IN AS1')                                FLD05
        STOP                                                           FLD05
        END                                                            FLD05
```

EQUIL program

The EQUIL FORTRAN code produces the MHD equilibrium for a two-dimensional bumpy cylinder. The code of Hedrick[11] has been modified. The majority of changes are in the main program and subroutine BATS, hence only these are listed here. Following this listing we have included the outputs from the code for the four cases summarized above in Table 2.

The meaning of output values (which include echoing of input) are not always clear, so a description of them is tabulated here. Table 4 has the input variables while Table 5 has the output variables. The listings of sample output (following the tables) may be consulted for more details.

| VARIABLE | SAMPLE VALUE | MEANING |
|---|---|---|
| ALFNU1,2 | EBTI KT8 | identification label |
| IMX | 181 | no. of increments in r |
| XMAX | 45.0 | distance from center of cavity to radial boundary in cm |
| KMXM1 | 41 | no. of increments in z |
| YMAX | 22.225006 | Separation of coil plane and midplane in cm |
| IBUG | 0 | code for extra debugging output |
| KMX | 42 | KMXM1 + 1 |
| LMX | 7602 | IMX*KMX |
| SEP | 44.5 | separation between coils in cm |
| RADIUS ... | 9.525 | radius of mirror coil (average) cm (single loop approximation used) |
| NP | 4 | no. pairs of mirror coils used to approximate infinite set |
| NOM | 5 | no. pairs of rings used to calculate boundary values |
| ITERMX | 20 | no. of iterations over outer loop. |
| INMX | 25 | initial no. of iterations for inner loop |
| IDOUB | 5 | double INMX when ITER a multiple of IDOUB |
| KCUT | 38 | don't calculate vacuum field when this close to coil (K < KCUT or I < ICUT required) |
| ICUT | 36 | don't calculate vac.field when this close to coil |
| ORC | 1.9 | acceleration parameter for SOR |

Table 4. Explanation of values that must be input to EQUIL code.

| VARIABLE | SAMPLE VALUE | MEANING |
|---|---|---|
| ITNSC | 0 | zero for tensor pressure only |
| SLOP | 1. | mixing parameter for outer loop |
| INPUT | 1 | one for pressure model chosen |
| RSI1,2,3,4 | 11,13,13,15 | radial limits in midplane for pressure function |
| BC | 0.60 | normalized cutoff field for pres. mode |
| S | 0.20 | coef. in pressure model |
| IMNDL | 20 | begin output for this I |
| IMXDL | 80 | end output for this I |
| IMDEL | 2 | increment for I on output |
| IBC | 1 | one for regular boundary cond. |
| RMSC | 8.0 | value used by multipole expansion |
| JCUT | 10 | no. terms in multipole expansion used to set boundary cond. |

Table 4. (continued)

| VARIABLE | SAMPLE VALUE | MEANING |
|---|---|---|
| ITER | 10 | outer loop iteration no. |
| N | 25 | inner loop iteration no. |
| RES | 0.17E-2 | residual for SOR at ITER, N |
| RMID | 0.475E+01 | radius in midplane in cm |
| CURD | -0.599E-04 | current density at RMID |
| MODB | 0.916E+00 | normalized B field at RMID |
| P-PERP | 0.0 | perpendicular pressure (normalized) |
| P-PARA | 0.0 | parallel pressure (normalized) |
| DLOB | 0.0 | not calculated by this version |
| SI | -0.142E-02 | diamagnetic flux value (normalized) |
| SIV | 0.108E+02 | vacuum flux coordinate |
| WPER | 0.80354E+00 | perpendicular energy (normalized) |
| WPAR | 0.48644E-01 | parallel energy (normalized) |
| RAD | 4.75 | radius for pressure map (cm) |
| Z | .56 | axial coord. for pres. map (cm) |
| pressure map follows | | |
| RS | 2.8000E+01 | pickup coil radius (cm) |
| ZS | 9.5 | pickup coil axial position (cm from midplane) |
| SI | -9.5891E+02 | diamagnetic flux linked by pickup coil (normalized) |
| SIV | 1.4291E+02 | vacuum flux linked |
| STP | 1.4282E+02 | SI + SIV |

Table 5. Explanation of calculated values output by EQUIL code.

```
CKHC      VERSION WITH MAXIMUM ARRAY DIMENSIONS. REQUIRES 1M TO LOAD.     EQU00
CKHC   VERSION WITHOUT PHI,PHIR,VR,VZ,RMID USE; HENCE NO DLOB CALC.       EQU00
CKHC   20JAN81 CORRECT INCORRECT OUTPUT OF SOME ZEROS IN P MAP.           EQU00
CKHC   13JAN81 ADD DOUBLING OF ITERATIONS OF DESI AT ITER = MULTIPLES     EQU00
CKHC      OF IDOUB. ADD STOP IN DESI WHEN RES.GT.100 AND IBUG=0.          EQU00
CKHC   10JAN81 ADD INPUT OF IMDEL; CHANGE OUTPUT OF WPER MAP.             EQU00
CKHC   05JAN81 CORRECT PLACEMENT OF LL & II INSIDE LOOP IN CALB.          EQU00
CKHC   03JAN81 INSERT SECTION IN BATS TO CALCULATE WPER, OUTPUT P MAP     EQU00
CKHC      AND PSI VALUES; OTHER CHANGES AT CK COMMENT LINES.              EQU00
CKHC   22DEC80 CHANGE READS TO 5 WRITES TO 6 TO ALLOW OVER 80 CHAR LINES EQU00
CKHC   18DEC80 THIS VERSION RESTORES LINES KRIS HAD COMMENTED OUT         EQU00
CKHC   18DEC80 CHANGE READ UNIT FROM 50 TO 7, WRITE UNIT FROM 51 TO 8.    EQU00
C       PROGRAM EQUIL(DATA,TAPE50=DATA,OUTPUT,TAPE51=OUTPUT,              EQU00
C      *                EULER,TAPE52=EULER)                               EQU00
C                                                                         EQU00
C      MAIN PROG AXIALLY SYMMETRIC EQUILIBRIA                             EQU00
C                                                                         EQU00
       COMMON/DEX/ IMX,KMX,IMXM1,KMXM1,LMX,KFLG,KCUT,ICUT,ITERMX,INMX     EQU00
       COMMON/GEO/ XMAX,XMIN,DELX,YMAX,YMIN,DELY,SEP,RADL                 EQU00
       COMMON/SCALE/ SC1(250),SC2,SC3,SC4,SC5,SC6(250),SC7,SC8,SC9(250),  EQU00
      * SC10(250),SC12(250),SC13                                          EQU00
       COMMON/BCAL/ IMIN1(250),IMAX1(250)                                 EQU00
       COMMON/PCAL/ SI0,BA,BA2,BC,SIMN,SIMX,BETA                          EQU00
       COMMON/NPCA/ ICALP,ISICR                                           EQU00
       COMMON/ADE/ ORC                                                    EQU00
       COMMON/MODGR/ KMXGR,IMNGR,IMXGR                                    EQU00
       COMMON/BCDEX/ IBC,JCUT                                             EQU00
       COMMON/RETI/ ITER                                                  EQU00
       COMMON/NUALF/ ALFNU1,ALFNU2                                        EQU00
       COMMON/PRSTP/ ITNSC                                                EQU00
       COMMON/PAIRS/ NP,NPM                                               EQU00
       COMMON/ADAUX/ IMXTP,IMNTP,IMDEL                                    EQU00
       COMMON/BUG/ IBUG                                                   EQU00
       DIMENSION SI(12000),SIV(12000),STP(12000),SIGMA(12000),CO1(12000),EQU00
      * CO2(12000),DTRM(12000),CTRM(12000),B(12000),                      EQU00
      *                PHI(1),PHIR(1)                                     EQU00
       DIMENSION VR(1),VZ(1),                                             EQU00
      * RMID(1)                                                           EQU00
 1000  FORMAT(1H ,2(I4,2X,F14.6,2X),I4)                                   EQU00
 1001  FORMAT(1H ,6HIMX = ,I4,2X,7HXMAX = ,F14.6/                         EQU00
      * 1H ,8HKMXM1 = ,I4,2X,7HYMAX = ,F14.6/                             EQU00
      * 1H ,7HIBUG = ,I4,5X,33HIBUG OF ZERO GIVES MIN DIAG PRINT)         EQU00
 1002  FORMAT(1H ,4(F14.6,2X))                                            EQU00
 1003  FORMAT(1H ,13HINPUT BETA = ,F14.6,2X,11HCUTOFF B = ,F14.6/         EQU00
      * 1H ,9HMIN SI = ,F14.6,2X,9HMAX SI = ,F14.6)                       EQU00
 1004  FORMAT(1H ,2(F14.6,2X),2(I4,2X))                                   EQU00
 1005  FORMAT(1H ,6HSEP = ,F14.6,2X,17HRADIUS OF LOOP = ,F14.6/           EQU00
      * 1H ,20HNO COIL PAIRS  NP = ,I4/                                   EQU00
      * 1H ,37HNO PLASMA PAIRS FOR MULTIPOLE  NPM = ,I4)                  EQU00
 1006  FORMAT(1H ,5(I4,2X),F14.6)                                         EQU00
 1007  FORMAT(1H ,39HMAX NO OF OVERALL ITERATIONS  ITERMX = ,I4/          EQU00
      * 1H ,37HMAX NO OF ITERATIONS FOR DE   INMX = ,I4/                  EQU00
      * 1H ,40HDOUBLE INMX WHEN ITER A MULT. OF IDOUB= ,I4/               EQU00
      * 1H ,50HTO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION/        EQU00
      * 1H ,45HIT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT/             EQU00
```

```
     * 1H ,7HKCUT = ,I4,5X,7HICUT = ,I4/1H ,6HORC = ,F14.6//)          EQU00
 1008 FORMAT(1H ,7HSIMN = ,E14.6,5X,7HSIMX = ,E14.6,5X,7HKFLG = ,I6)   EQU00
 1009 FORMAT(1H ,4HK = ,I4,1X,8HIMIN1 = ,I6,1X,8HIMAX1 = ,I6)          EQU00
 1010 FORMAT(1H ,7HITER = ,I4,5X,14HB AT ORIGIN = ,E14.6)              EQU00
 1100 FORMAT(2A4)                                                      EQU00
 1101 FORMAT(1H1/1H ,2A4)                                              EQU00
 1200 FORMAT(1H ,17HNOTE THAT  KMX = ,I5,5X,6HLMX = ,I5)               EQU00
C                                                                      EQU00
C  INPUT:                                                              EQU00
C                                                                      EQU00
C  ALPNU1,ALFNU2 - ALPHA-NUMERIC LABEL (TOTAL OF 8 CHARACTERS)         EQU00
C  IMX           - NUMBER OF GRID POINTS FROM THE AXIS TO XMAX         EQU00
C  XMAX          - GRID DISTANCE RADIALLY OUT FROM THE AXIS            EQU00
C  KMXM1         - NUMBER OF GRID POINTS MINUS 1 ALONG THE AXIS        EQU00
C                  (Z DIRECTION, FROM MID-PLANE TO COIL PLANE)         EQU00
C  YMAX          - GRID DISTANCE FROM THE MID-PLANE TOWARD THE COIL PLANEQU00
C  IBUG          - CAUSES DEBUGGING OUTPUT IN MAIN AND SUBROUTINE DESI EQU00
C                  WHEN NON-ZERO                                       EQU00
C  SEP           - DISTANCE BETWEEN LOOPS                              EQU00
C  RADL          - RADIUS OF LOOP                                      EQU00
C  NP            - NUMBER PAIRS USED TO CALCULATE PSI(VACCUMM)         EQU00
C                  IN SUBROUTINE VACSI                                 EQU00
C  NPM           - NUMBER OF PAIRS USED TO CALCULATE GR IN             EQU00
C                  SUBROUTINE FCMULT                                   EQU00
C  ITERMX        - TOTAL NUMBER OF OVER ALL CODE ITERATIONS            EQU00
C  INMX          - NUMBER OF SUCCESSIVE OVER-RELAXATION ITERATIONS IN  EQU00
C                  SUBROUTINE DESI                                     EQU00
C  KCUT          - LIMIT IN Z DIRECTION TO AVOID CALCULATION OVER      EQU00
C                  SINGULARITY, IN SUBROUTINES JDISP AND VACSI         EQU00
C  ICUT          - LIMIT IN RADIAL DIRECTION TO AVOID CALCULATION OVER EQU00
C                  SINGULARITY, IN SUBROUTINES JDISP AND VACSI         EQU00
C  ORC           - SCALES RESULT OF SOR IN SUBROUTINE DESI             EQU00
C                                                                      EQU00
C  SEE SUBROUTINES CALP, FCMULT, AND JDISP FOR OTHER INPUT INFORMATION. EQU00
C                                                                      EQU00
C      CALL CHANGE(8H+EQUILGO)                                         EQU00
   50 ISTART=0                                                         EQU00
  100 READ(5,1100,END=102)  ALFNU1,ALFNU2                              EQU00
C      IF (EOF,50) 102,104                                             EQU00
        GO TO 104                                                      EQU00
  102 CALL EXIT                                                        EQU00
  104 WRITE(6,1101) ALFNU1,ALFNU2                                      EQU00
      READ(5,1000)  IMX,XMAX,KMXM1,YMAX,IBUG                           EQU00
      WRITE(6,1001) IMX,XMAX,KMXM1,YMAX,IBUG                           EQU00
      IMXM1=IMX-1                                                      EQU01
      DELX=XMAX/FLOAT(IMXM1)                                           EQU01
      XMIN=0.                                                          EQU01
      KMX=KMXM1+1                                                      EQU01
      LMX=IMX*KMX                                                      EQU01
      DELY=YMAX/FLOAT(KMXM1-1)                                         EQU01
      WRITE(6,1200) KMX,LMX                                            EQU01
      YMIN=0.                                                          EQU01
      KMXGR=KMXM1                                                      EQU01
      IMXGR=IMXM1                                                      EQU01
      IMNGR=1                                                          EQU01
```

```
      READ(5,1004)  SEP,RADL,MP,NPM                                     EQU01
      WRITE(6,1005) SEP,RADL,MP,NPM                                     EQU01
      READ(5,1006)  ITERMX,INMX,IDOUB,KCUT,ICUT,ORC                     EQU01
      WRITE(6,1007) ITERMX,INMX,IDOUB,KCUT,ICUT,ORC                     EQU01
      ITER=0                                                            EQU01
      IF(ISTART .NE. 0) GO TO 120                                       EQU01
      DO 115 L=1,LMX                                                    EQU01
      DTRM(L)=0.                                                        EQU01
      CTRM(L)=0.                                                        EQU01
      SIGMA(L)=1.                                                       EQU01
  115 SI(L)=0.                                                          EQU01
C                                                                       EQU01
C  CALCULATE SCALE FACTORS USED IN ???                                  EQU01
C                                                                       EQU01
      CALL SCFAC                                                        EQU01
C                                                                       EQU01
C  CALCULATE VACUUM PSI PRODUCED BY COILS                               EQU01
C                                                                       EQU01
      CALL VACSI (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)                 EQU01
      ISTART=1                                                          EQU01
  120 ICALP=0                                                           EQU01
      ISICR=0                                                           EQU01
C                                                                       EQU01
C  READ PRESSURE DATA                                                   EQU01
C                                                                       EQU01
      CALL CALP(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,    EQU01
     * RMID)                                                            EQU01
      IJDSP=0                                                           EQU01
C                                                                       EQU01
C  READ FIELD INTEGRAL STUFF, SET WEIGHTS                               EQU01
C                                                                       EQU01
      CALL JDISP(SI,SIV,STP,CO1,CO2,B,PHI,PHIR,VR,VZ,RMID,IJDSP,        EQU01
     * IJDSP1)                                                          EQU01
C                                                                       EQU01
C  CALCULATE MULTIPOLE EXPANSION                                        EQU01
C                                                                       EQU01
      CALL FCMULT                                                       EQU01
C                                                                       EQU01
C  CALCULATE B, CALLS CALP TO CALCULATE PRESSURE                        EQU01
C                                                                       EQU01
  200 CALL CALB(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,    EQU01
     * RMID)                                                            EQU01
CK                                                                      EQU01
CK    WRITE(6,7007)(CTRM(L),L=IMNTP,IMXTP)                              EQU01
 7007 FORMAT(250(1X,1P10E12.3))                                         EQU01
      IJDSP=1                                                           EQU01
      IJDSP1=0                                                          EQU01
C                                                                       EQU01
C  PREPARE FOR FIELD LINE INTEGRALS (PSI=CONSTANT ON FIELD LINE)        EQU01
C                                                                       EQU01
      CALL JDISP(SI,SIV,STP,CO1,CO2,B,PHI,PHIR,VR,VZ,RMID,IJDSP,IJDSP1) EQU01
C                                                                       EQU01
C  COMPUTE INTEGRAL DL OVER B FOR STABILITY CRITERION                   EQU01
C                                                                       EQU01
      CALL BATS(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,    EQU01
```

```
     * RMID)                                                          EQU01
C                                                                     EQU01
C  DAVE NELSON'S PERSONAL STUFF, DONE ON FINAL ITERATION              EQU01
C                                                                     EQU01
CK    CALL DAVE(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,  EQU01
CK   * RMID)                                                          EQU01
C                                                                     EQU01
C  DETERMINE DRIVING TERMS AND COEFFECIENTS FOR DEL*PSI, MULTIPOLE MOMENEQU01
C                                                                     EQU01
      CALL DTCOF (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)               EQU01
      IF(IBC .EQ. 0) GO TO 201                                        EQU01
C                                                                     EQU01
C  SET UP LATERAL BOUNDARY CONDITIONS BASED ON MULTIPOLE MOMENTS      EQU01
C                                                                     EQU01
      CALL SETBC (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)               EQU01
  201 WRITE(6,1010) ITER,B(1)                                         EQU01
CK                                                                    EQU01
CK    WRITE(6,7007)(DTRM(L),L=IMNTP,IMXTP)                            EQU01
C 201 CONTINUE                                                        EQU01
      IF(IBUG .EQ. 0) GO TO 211                                       EQU01
      WRITE(6,1008) SIMN,SIMX,KFLG                                    EQU01
      DO 210 K=1,KMXM1                                                EQU01
      WRITE(6,1009) K,IMIN1(K),IMAX1(K)                               EQU01
  210 CONTINUE                                                        EQU01
  211 IF(ITER .GE. ITERMX) GO TO 500                                  EQU01
      ITER =ITER+1                                                    EQU01
CK                                                                    EQU01
      IF(MOD(ITER,IDOUB).EQ.0)INMX=INMX*2                             EQU01
C                                                                     EQU01
C  SOLVE DEL*PSI+GRAD(SIGMA)/SIGMA.GRAD(PSI(P))=-(R**2/SIGMA)...      EQU01
C    FOR FIXED SIGMA AND P-PARALLEL                                   EQU01
C                                                                     EQU01
  215 CALL DESI  (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)               EQU01
      GO TO 200                                                       EQU01
  500 CONTINUE                                                        EQU02
      IJDSP=1                                                         EQU02
      IJDSP1=1                                                        EQU02
C                                                                     EQU02
C  PREPARE FOR FINAL FIELD LINE INTEGRALS                             EQU02
C                                                                     EQU02
      CALL JDISP(SI,SIV,STP,CO1,CO2,B,PHI,PHIR,VR,VZ,RMID,IJDSP,      EQU02
     * IJDSP1)                                                        EQU02
      GO TO 100                                                       EQU02
      END                                                             EQU02
C                                                                     EQU02
C***-------------------------------------------------------------------EQU02
```

```
      SUBROUTINE BATS(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,
     * VR,VZ,RMID)
C
C        COMPUTES DL OVER B AND ITS PSI DERIVATIVE AND INTEGRAL
C        B DL AND INTEGRAL DL OVER B-CUBED
C        ALSO FORMS STABILITY CRITERIA BASED ON FIELD LINE INTEGRALS
C
      COMMON/DEX/ IMX,KMX,IMXM1,KMXM1,LMX,KFLG,KCUT,ICUT,ITERMX,INMX
      COMMON/SCALE/ SC1(250),SC2,SC3,SC4,SC5,SC6(250),SC7,SC8,SC9(250),
     * SC10(250),SC12(250),SC13
      COMMON/GEO/ XMAX,XMIN,DELX,YMAX,YMIN,DELY,SEP,RADL
      COMMON/PCAL/ SI0,BA,BA2,BC,SIMN,SIMX,BETA
      COMMON/PAVE/ AVEP,PSCL,PSCLP,PERP,PERPP,PARA,PARAP,CHAT,G0,GP0,
     * IOUT
      COMMON/STAB/ DLOB(250),BDL(250),DLOB3(250),DLOBP(250),PSAVE(250),
     * PPSAVE(250)
      COMMON/ADAUX/ IMXTP,IMNTP,IMDEL
      COMMON/RETI/ITER
      DIMENSION SI(1),SIV(1),STP(1),SIGMA(1),CO1(1),CO2(1),DTRM(1),
     * CTRM(1),B(1),PHI(1),PHIR(1),VR(1),VZ(1),RMID(1)
      DIMENSION WTS(7)
      DATA WTS(1)/.3042245/,WTS(2)/1.460384/,WTS(3)/.45344640/
      DATA WTS(4)/1.471429/,WTS(5)/.7393932/,WTS(6)/1.082474/
      DATA WTS(7)/.9886326/
C
 1002 FORMAT(1H ,7(E10.3,1X))
 1022 FORMAT(1H ,8(E10.3,1X))
 1003 FORMAT(1H ,2(5X,E14.6))
 1006 FORMAT(1H ,6(E14.6,1X))
 1000 FORMAT(/7X,4HRMID,7X,4HPSCL,6X,5HPSCLP,5X,6HP-PERP,5X,
     *       6HP-PARA,7X,4HDLOB)
 1020 FORMAT(/7X,4HRMID,7X,4HCURD,6X,5HMODB ,5X,6HP-PERP,5X,
     *       6HP-PARA,7X,4HDLOB,7X,4HSI  ,7X,4HSIV  )
 1004 FORMAT(1H1/1H ,4X,6HRADIUS,5X,14HPPRIME+GAMMA*P,2X,
     * 13HUPRIME-PPRIME
     * ,1X,14HUPRIME-PPRIME*,4X,11HGENERALIZED,3X,10HBALLOONING/
     * 1H ,15X,9H*UPRIME/U,8X,6HU**2/I,7X,15HDL OVER B-CUBED,4X,
     * 11HINTERCHANGE/)
C
CK    SKIP DLOB CAL TO ELIMINATE USE OF PHI,PHIR,VR,VZ,RMID
      GO TO 150
C        CALC DLOB BDL DLOB3
C
CK
 10   IF(ITER.LT.ITERMX)RETURN
CK
CK100DO 110 I=1,IMXTP
      DO 110 I=IMNTP,IMXTP
      DLOB(I)=0.
      BDL(I)=0.
      DLOB3(I)=0.
      L=I-IMX
      DO 110 K=1,KMXM1
      L=L+IMX
      DUM=CO2(L)
```

```
      IF(K .LE. 7) DUM=DUM*WTS(K)                                       BAT00
        KTMP=KMX-K                                                      BAT00
      IF(K .GE. KMXM1-6) DUM=DUM*WTS(KTMP)                              BAT00
      DLOB(I)=DLOB(I)+DUM/CO1(L)                                        BAT00
      BDL(I)=BDL(I)+CO1(L)*DUM                                          BAT00
      DLOB3(I)=DLOB3(I)+DUM/(CO1(L)**3)                                 BAT00
  110 CONTINUE                                                          BAT00
C                                                                       BAT00
C        CALC DLOBP OR U PRIME                                          BAT00
C                                                                       BAT00
  120 DLOBP(1)=(16.*DLOB(2)-DLOB(3)-15.*DLOB(1))/6.                     BAT00
      DLOBP(2)=(DLOBP(1)+(DLOB(3)-4.*DLOB(2)+3.*DLOB(1))/3.)/CO1(2)     BAT00
      DLOBP(1)=DLOBP(1)/CO1(1)                                          BAT00
      IDUM=IMXTP-1                                                      BAT00
CK                                                                      BAT00
      ID2=IMNTP+2                                                       BAT00
CK    DO 122 I=3,IDUM                                                   BAT00
      DO 122 I=ID2,IDUM                                                 BAT00
  122 DLOBP(I)=(DLOB(I+1)-DLOB(I-1))/(2.*CO1(I)*FLOAT(I-1))             BAT00
      DLOBP(IMXTP)=(DLOB(IMXTP)-DLOB(IMXTP-1))/(CO1(IMXTP)*FLOAT(IDUM)) BAT00
      DUM=1./(DELX**2)                                                  BAT00
      DO 125 I=1,IMXTP                                                  BAT00
  125 DLOBP(I)=DUM*DLOBP(I)                                             BAT00
C                                                                       BAT00
C        CALC P AND P-PRIME AND MAKE FIRST TABLE                        BAT00
C                                                                       BAT00
 150  IF (ITER .LT. ITERMX) RETURN                                      BAT00
  200 IHOLD=IOUT                                                        BAT00
        IOUT=0                                                          BAT00
      IOUT=2                                                            BAT00
      WRITE(6,1020)                                                     BAT00
CK    WRITE(6,1000)                                                     BAT00
CK    DO 210 I=1,IMXTP                                                  BAT00
      DO 210 I=IMNTP,IMXTP                                              BAT00
      SI0=STP(I)                                                        BAT00
CK    BA=CO1(I)                                                         BAT00
      BA=B(I)                                                           BAT00
      CALL CALP(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,    BAT00
     * RMID)                                                            BAT00
      PSAVE(I)=PSCL                                                     BAT00
      PPSAVE(I)=PSCLP                                                   BAT00
      PER=PERP-PSCL                                                     BAT00
      PAR=PARA-PSCL                                                     BAT00
      CJT=-0.5*SC13*SC12(I)*(SI(I+1)+SI(I-1)-2.*SI(I))+                 BAT00
     1  SC9(I)*SC12(I)*(SI(I+1)-SI(I-1))                                BAT01
CK    WRITE(6,1002) SC6(I),PSAVE(I),PPSAVE(I),PER,PAR,DLOB(I)           BAT01
      WRITE(6,1022) SC6(I),CJT,BA,PER,PAR,DLOB(I),SI(I),SIV(I)          BAT01
  210 CONTINUE                                                          BAT01
CK    SKIP SECOND TABLE                                                 BAT01
      GO TO 220                                                         BAT01
C                                                                       BAT01
C        MAKE SECOND TABLE                                              BAT01
C                                                                       BAT01
C     WRITE(6,1004)                                                     BAT01
CK    DO 220 I=1,IMXTP                                                  BAT01
```

```
CK      DUM1=PPSAVE(I)+1.6666667*PSAVE(I)*DLOBP(I)/DLOB(I)                BAT01
CK      DUM2=DLOBP(I)-PPSAVE(I)*(DLOB(I)**2)/BDL(I)                       BAT01
CK      DUM3=DLOBP(I)-PPSAVE(I)*DLOB3(I)                                  BAT01
CK      DUM4=DUM1*DUM2                                                    BAT01
CK      DUM5=DUM1*DUM3                                                    BAT01
C       WRITE(6,1006) SC6(I),DUM1,DUM2,DUM3,DUM4,DUM5                     BAT01
  220   CONTINUE                                                          BAT01
CKHC                                                                      BAT01
CK      CALCULATE WPER, WPAR AND OUTPUT PLASMA PER P MAP:                 BAT01
        WPER=0.                                                           BAT01
        WPAR=0.                                                           BAT01
        DVOL1=0.25/SC5                                                    BAT01
        L1C=-IMX                                                          BAT01
        DO 360 K=1,KMX                                                    BAT01
        L1C=L1C+IMX                                                       BAT01
        DO 350 I=1,IMX                                                    BAT01
        IF((K.GE.KCUT).AND.(I.GE.ICUT))GO TO 350                          BAT01
        L=L1C+I                                                           BAT01
        BA=B(L)                                                           BAT01
CK      IF(BA.GE.BC)GO TO 350                                             BAT01
        IF(BA.LT.BC)GO TO 340                                             BAT01
        DTRM(L)=0.                                                        BAT01
        GO TO 350                                                         BAT01
 340    SI0=STP(L)                                                        BAT01
        CALL CALP(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,    BAT01
      * RMID)                                                             BAT01
CK      NOTE USE OF PSAVE AND DTRM - NO LONGER AVAILABLE FOR DAVE.        BAT01
        DTRM(L)=PERP                                                      BAT01
        IF((PERP.EQ.0.).AND.(PARA.EQ.0.))GO TO 350                        BAT01
        DVOL=DVOL1/SC9(I)                                                 BAT01
        WPER=WPER+DVOL*PERP                                               BAT01
        WPAR=WPAR+DVOL*PARA                                               BAT01
 350    CONTINUE                                                          BAT01
 360    CONTINUE                                                          BAT01
        WPAR=0.5*WPAR                                                     BAT01
        WRITE(6,3001)WPER,WPAR                                            BAT01
 3001   FORMAT(/6H WPER= ,E14.5,8H   WPAR= ,E14.5/)                       BAT01
CK      OUTPUT MAP OF WPER                                                BAT01
        WRITE(6,3002)                                                     BAT01
 3002   FORMAT(1H1/27H RAD    P-PER: MID TO COIL    )                    BAT01
        MSTEP=KMXM1/21                                                    BAT01
        IF(MSTEP.LT.1)MSTEP=1                                             BAT01
        MAXST=21*MSTEP                                                    BAT01
        IF(KMXM1.LT.21)MAXST=KMXM1                                        BAT01
        WRITE(6,3102)(SC1(K),K=1,MAXST,MSTEP)                             BAT01
 3102   FORMAT(/6H  Z = ,21F6.2/)                                         BAT01
        DO 370 I = IMNTP,IMXTP,IMDEL                                      BAT01
        DO 365 K=1,MAXST,MSTEP                                            BAT01
 365    PSAVE(K)=DTRM((K-1)*IMX+I)                                        BAT01
        WRITE(6,3003)SC6(I),(PSAVE(K),K=1,MAXST,MSTEP)                    BAT01
 3003   FORMAT(1X,F5.2,21F6.3)                                            BAT01
 370    CONTINUE                                                          BAT01
CK      OUTPUT SI AT SPECIFIED LOCATIONS                                  BAT01
        WRITE(6,3004)                                                     BAT01
 3004   FORMAT(8X,2HRS,14X,2HZS,14X,2HSI,14X,3HSIV,13X,3HSTP )            BAT01
```

```
 380  READ(5,3005,END=500)RS,ZS                                    BAT01
 3005 FORMAT(2G8.4)                                                BAT01
      I=1+RS/DELX                                                  BAT01
      K=1+ZS/DELY                                                  BAT01
      L=I+(K-1)*IMX                                                BAT01
      WRITE(6,3006)RS,ZS,SI(L),SIV(L),STP(L)                       BAT01
 3006 FORMAT(1P5E16.4)                                             BAT01
      GO TO 380                                                    BAT01
 500  STOP                                                         BAT01
CKHC                                                               BAT01
CK    IOUT=IHOLD                                                   BAT01
CK    RETURN                                                       BAT01
      END                                                          BAT01
C                                                                  BAT01
```

```
1
EBTI KT8
IMX =  181  XMAX =       45.000000
KMXM1 =   41  YMAX =       22.225006
IBUG =    0     IBUG OF ZERO GIVES MIN DIAG PRINT
NOTE THAT  KMX =    42     LMX =  7602
SEP =      44.449997  RADIUS OF LOOP =       9.525000
NO COIL PAIRS  NP =    4
NO PLASMA PAIRS FOR MULTIPOLE  NPM =    5
MAX NO OF OVERALL ITERATIONS  ITERMX =   20
MAX NO OF ITERATIONS FOR DE   INMX =   25
DOUBLE INMX WHEN ITER A MULT. OF IDOUB=    5
TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
KCUT =   38     ICUT =   36
ORC =       1.900000


DATA FOR CALP
ITNSC =    0     SLOP =   1.000000
INPUT =    1
RADII FOR SI DEP OF TENSOR PART
RSI1 =  11.00     RSI2 =  13.00     RSI3 =  13.00     RSI4 =  15.00
BC =   0.60
SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
S =   0.200000
CONSTANTS FOR JDISP
IMNDL =   20     IMXDL =   80     IMDEL =    2
IBC =    1
RMSC =       8.000000
JCUT =   10
IF IBC IS ZERO FLUX CONSERVING BC ARE USED
RMSC IS USED FOR THE MULTIPOLE EXPANSION
JCUT IS THE NUMBER OF TERMS IN THE MULTIPOLE EXPANSION
```

(Output from EQUIL for 2% "beta" case)
(on this and next 3 pages)

```
ITER =    0     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.167818E-01
N =   25  RES =   0.512126E-02
ITER =    1     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.948173E-02
N =   25  RES =   0.321801E-02
ITER =    2     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.631712E-02
N =   25  RES =   0.241754E-02
ITER =    3     B AT ORIGIN =   0.100009E+01
N =    1  RES =   0.360836E-02
N =   25  RES =   0.178328E-02
ITER =    4     B AT ORIGIN =   0.100008E+01
N =    1  RES =   0.212197E-02
N =   50  RES =   0.638005E-03
ITER =    5     B AT ORIGIN =   0.100006E+01
N =    1  RES =   0.110653E-02
N =   50  RES =   0.428791E-03
ITER =    6     B AT ORIGIN =   0.100008E+01
N =    1  RES =   0.656961E-03
N =   50  RES =   0.317713E-03
ITER =    7     B AT ORIGIN =   0.100009E+01
N =    1  RES =   0.395834E-03
N =   50  RES =   0.242864E-03
ITER =    8     B AT ORIGIN =   0.100010E+01
N =    1  RES =   0.243099E-03
N =   50  RES =   0.190866E-03
ITER =    9     B AT ORIGIN =   0.100011E+01
N =    1  RES =   0.189859E-03
N =  100  RES =   0.122536E-03
ITER =   10     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.122095E-03
N =  100  RES =   0.840853E-04
ITER =   11     B AT ORIGIN =   0.100013E+01
N =    1  RES =   0.837450E-04
N =  100  RES =   0.582655E-04
ITER =   12     B AT ORIGIN =   0.100014E+01
N =    1  RES =   0.580286E-04
N =  100  RES =   0.405851E-04
ITER =   13     B AT ORIGIN =   0.100014E+01
N =    1  RES =   0.404433E-04
N =  100  RES =   0.282933E-04
ITER =   14     B AT ORIGIN =   0.100014E+01
N =    1  RES =   0.281512E-04
N =  200  RES =   0.135819E-04
ITER =   15     B AT ORIGIN =   0.100015E+01
N =    1  RES =   0.181005E-04
N =  200  RES =   0.661921E-05
ITER =   16     B AT ORIGIN =   0.100015E+01
N =    1  RES =   0.129368E-04
N =  200  RES =   0.327134E-05
ITER =   17     B AT ORIGIN =   0.100015E+01
N =    1  RES =   0.841391E-05
N =  200  RES =   0.172169E-05
ITER =   18     B AT ORIGIN =   0.100015E+01
N =    1  RES =   0.547791E-05
N =  200  RES =   0.899626E-06
ITER =   19     B AT ORIGIN =   0.100015E+01
N =    1  RES =   0.341564E-05
N =  400  RES =   0.317566E-06
```

| RMID | CURD | MODB | P-PERP | P-PARA | DLOB | SI | SIV |
|---|---|---|---|---|---|---|---|
| 0.475E+01 | -0.599E-04 | 0.916E+00 | 0.0 | 0.0 | 0.0 | -0.142E-02 | 0.108E+02 |
| 0.500E+01 | -0.660E-04 | 0.907E+00 | 0.0 | 0.0 | 0.0 | -0.149E-02 | 0.119E+02 |
| 0.525E+01 | -0.730E-04 | 0.898E+00 | 0.0 | 0.0 | 0.0 | -0.154E-02 | 0.131E+02 |
| 0.550E+01 | -0.804E-04 | 0.888E+00 | 0.0 | 0.0 | 0.0 | -0.157E-02 | 0.143E+02 |
| 0.575E+01 | -0.890E-04 | 0.878E+00 | 0.0 | 0.0 | 0.0 | -0.158E-02 | 0.155E+02 |
| 0.600E+01 | -0.983E-04 | 0.869E+00 | 0.0 | 0.0 | 0.0 | -0.155E-02 | 0.168E+02 |
| 0.625E+01 | -0.109E-03 | 0.858E+00 | 0.0 | 0.0 | 0.0 | -0.148E-02 | 0.181E+02 |
| 0.650E+01 | -0.121E-03 | 0.848E+00 | 0.0 | 0.0 | 0.0 | -0.137E-02 | 0.195E+02 |
| 0.675E+01 | -0.134E-03 | 0.837E+00 | 0.0 | 0.0 | 0.0 | -0.120E-02 | 0.209E+02 |
| 0.700E+01 | -0.149E-03 | 0.826E+00 | 0.0 | 0.0 | 0.0 | -0.963E-03 | 0.223E+02 |
| 0.725E+01 | -0.166E-03 | 0.815E+00 | 0.0 | 0.0 | 0.0 | -0.655E-03 | 0.238E+02 |
| 0.750E+01 | -0.185E-03 | 0.803E+00 | 0.0 | 0.0 | 0.0 | -0.260E-03 | 0.252E+02 |
| 0.775E+01 | -0.207E-03 | 0.791E+00 | 0.0 | 0.0 | 0.0 | 0.237E-03 | 0.268E+02 |
| 0.800E+01 | -0.231E-03 | 0.779E+00 | 0.0 | 0.0 | 0.0 | 0.852E-03 | 0.283E+02 |
| 0.825E+01 | -0.260E-03 | 0.767E+00 | 0.0 | 0.0 | 0.0 | 0.160E-02 | 0.299E+02 |
| 0.850E+01 | -0.292E-03 | 0.755E+00 | 0.0 | 0.0 | 0.0 | 0.251E-02 | 0.315E+02 |
| 0.875E+01 | -0.329E-03 | 0.742E+00 | 0.0 | 0.0 | 0.0 | 0.361E-02 | 0.331E+02 |
| 0.900E+01 | -0.371E-03 | 0.730E+00 | 0.0 | 0.0 | 0.0 | 0.492E-02 | 0.347E+02 |
| 0.925E+01 | -0.420E-03 | 0.718E+00 | 0.0 | 0.0 | 0.0 | 0.648E-02 | 0.364E+02 |
| 0.950E+01 | -0.476E-03 | 0.705E+00 | 0.0 | 0.0 | 0.0 | 0.832E-02 | 0.380E+02 |
| 0.975E+01 | -0.540E-03 | 0.692E+00 | 0.0 | 0.0 | 0.0 | 0.105E-01 | 0.397E+02 |
| 0.100E+02 | -0.614E-03 | 0.679E+00 | 0.0 | 0.0 | 0.0 | 0.131E-01 | 0.414E+02 |
| 0.103E+02 | -0.700E-03 | 0.667E+00 | 0.0 | 0.0 | 0.0 | 0.161E-01 | 0.431E+02 |
| 0.105E+02 | -0.798E-03 | 0.654E+00 | 0.0 | 0.0 | 0.0 | 0.197E-01 | 0.448E+02 |
| 0.108E+02 | -0.910E-03 | 0.641E+00 | 0.0 | 0.0 | 0.0 | 0.238E-01 | 0.465E+02 |
| 0.110E+02 | -0.104E-02 | 0.629E+00 | 0.0 | 0.0 | 0.0 | 0.287E-01 | 0.483E+02 |
| 0.113E+02 | -0.118E-02 | 0.616E+00 | 0.0 | 0.0 | 0.0 | 0.344E-01 | 0.500E+02 |
| 0.115E+02 | 0.335E-03 | 0.603E+00 | 0.0 | 0.0 | 0.0 | 0.411E-01 | 0.517E+02 |
| 0.118E+02 | 0.453E-02 | 0.589E+00 | 0.487E-03 | 0.443E-05 | 0.0 | 0.477E-01 | 0.534E+02 |
| 0.120E+02 | 0.951E-02 | 0.574E+00 | 0.171E-02 | 0.371E-04 | 0.0 | 0.511E-01 | 0.552E+02 |
| 0.123E+02 | 0.137E-01 | 0.559E+00 | 0.354E-02 | 0.125E-03 | 0.0 | 0.473E-01 | 0.569E+02 |
| 0.125E+02 | 0.169E-01 | 0.543E+00 | 0.579E-02 | 0.291E-03 | 0.0 | 0.328E-01 | 0.586E+02 |
| 0.128E+02 | 0.163E-01 | 0.524E+00 | 0.825E-02 | 0.555E-03 | 0.0 | 0.478E-02 | 0.603E+02 |
| 0.130E+02 | 0.115E-01 | 0.509E+00 | 0.101E-01 | 0.832E-03 | 0.0 | -0.370E-01 | 0.620E+02 |
| 0.133E+02 | 0.520E-02 | 0.495E+00 | 0.111E-01 | 0.106E-02 | 0.0 | -0.890E-01 | 0.637E+02 |
| 0.135E+02 | -0.228E-02 | 0.482E+00 | 0.112E-01 | 0.122E-02 | 0.0 | -0.146E+00 | 0.654E+02 |
| 0.138E+02 | -0.108E-01 | 0.471E+00 | 0.102E-01 | 0.123E-02 | 0.0 | -0.203E+00 | 0.671E+02 |
| 0.140E+02 | -0.175E-01 | 0.462E+00 | 0.821E-02 | 0.106E-02 | 0.0 | -0.251E+00 | 0.687E+02 |
| 0.143E+02 | -0.205E-01 | 0.455E+00 | 0.566E-02 | 0.775E-03 | 0.0 | -0.284E+00 | 0.704E+02 |
| 0.145E+02 | -0.189E-01 | 0.449E+00 | 0.303E-02 | 0.435E-03 | 0.0 | -0.300E+00 | 0.720E+02 |
| 0.148E+02 | -0.115E-01 | 0.441E+00 | 0.901E-03 | 0.137E-03 | 0.0 | -0.299E+00 | 0.737E+02 |
| 0.150E+02 | -0.100E-02 | 0.430E+00 | 0.0 | 0.0 | 0.0 | -0.287E+00 | 0.753E+02 |
| 0.153E+02 | 0.177E-02 | 0.419E+00 | 0.0 | 0.0 | 0.0 | -0.274E+00 | 0.769E+02 |
| 0.155E+02 | 0.140E-02 | 0.407E+00 | 0.0 | 0.0 | 0.0 | -0.262E+00 | 0.785E+02 |
| 0.158E+02 | 0.116E-02 | 0.396E+00 | 0.0 | 0.0 | 0.0 | -0.251E+00 | 0.800E+02 |
| 0.160E+02 | 0.987E-03 | 0.385E+00 | 0.0 | 0.0 | 0.0 | -0.242E+00 | 0.816E+02 |
| 0.163E+02 | 0.851E-03 | 0.374E+00 | 0.0 | 0.0 | 0.0 | -0.233E+00 | 0.831E+02 |
| 0.165E+02 | 0.742E-03 | 0.364E+00 | 0.0 | 0.0 | 0.0 | -0.225E+00 | 0.846E+02 |
| 0.168E+02 | 0.650E-03 | 0.353E+00 | 0.0 | 0.0 | 0.0 | -0.218E+00 | 0.861E+02 |
| 0.170E+02 | 0.573E-03 | 0.343E+00 | 0.0 | 0.0 | 0.0 | -0.211E+00 | 0.875E+02 |
| 0.173E+02 | 0.507E-03 | 0.332E+00 | 0.0 | 0.0 | 0.0 | -0.205E+00 | 0.890E+02 |
| 0.175E+02 | 0.451E-03 | 0.322E+00 | 0.0 | 0.0 | 0.0 | -0.199E+00 | 0.904E+02 |
| 0.178E+02 | 0.402E-03 | 0.313E+00 | 0.0 | 0.0 | 0.0 | -0.194E+00 | 0.918E+02 |
| 0.180E+02 | 0.360E-03 | 0.303E+00 | 0.0 | 0.0 | 0.0 | -0.189E+00 | 0.931E+02 |
| 0.183E+02 | 0.322E-03 | 0.294E+00 | 0.0 | 0.0 | 0.0 | -0.184E+00 | 0.945E+02 |
| 0.185E+02 | 0.290E-03 | 0.285E+00 | 0.0 | 0.0 | 0.0 | -0.180E+00 | 0.958E+02 |
| 0.188E+02 | 0.261E-03 | 0.277E+00 | 0.0 | 0.0 | 0.0 | -0.176E+00 | 0.971E+02 |
| 0.190E+02 | 0.236E-03 | 0.268E+00 | 0.0 | 0.0 | 0.0 | -0.172E+00 | 0.984E+02 |
| 0.193E+02 | 0.214E-03 | 0.259E+00 | 0.0 | 0.0 | 0.0 | -0.169E+00 | 0.997E+02 |
| 0.195E+02 | 0.195E-03 | 0.251E+00 | 0.0 | 0.0 | 0.0 | -0.165E+00 | 0.101E+03 |
| 0.198E+02 | 0.177E-03 | 0.243E+00 | 0.0 | 0.0 | 0.0 | -0.162E+00 | 0.102E+03 |

WPER= 0.80354E+00 WPAR= 0.48644E-01

1

(Pressure Map)

RAD P-PER: MID TO COIL

| Z = | 0.0 | 0.56 | 1.11 | 1.67 | 2.22 | 2.78 | 3.33 | 3.89 | 4.45 | 5.00 | 5.56 | 6.11 | 6.67 | 7.22 | 7.78 | 8.33 | 8.89 | 9.45 | 10.00 | 10.56 | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.75 | 0.000 | 0.000 | 0.000 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.25 | 0.004 | 0.004 | 0.003 | 0.003 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.75 | 0.008 | 0.008 | 0.008 | 0.007 | 0.006 | 0.005 | 0.003 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.25 | 0.011 | 0.011 | 0.010 | 0.010 | 0.008 | 0.007 | 0.005 | 0.003 | 0.001 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.75 | 0.010 | 0.010 | 0.009 | 0.008 | 0.006 | 0.005 | 0.003 | 0.001 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.25 | 0.006 | 0.005 | 0.005 | 0.004 | 0.002 | 0.001 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.75 | 0.001 | 0.001 | 0.000 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| RS | ZS | SI | SIV | STP |
|---|---|---|---|---|
| 2.8000E+01 | 9.5000E+00 | -9.5891E-02 | 1.4291E+02 | 1.4282E+02 |

R; T=802.58/812.35 11:50:37

```
1
 EBTI KT8
 IMX =  181  XMAX =      45.000000
 KMXM1 =   41  YMAX =      22.225006
 IBUG =    0     IBUG OF ZERO GIVES MIN DIAG PRINT
 NOTE THAT  KMX =    42     LMX =  7602
 SEP =      44.449997  RADIUS OF LOOP =       9.525000
 NO COIL PAIRS  NP =    4
 NO PLASMA PAIRS FOR MULTIPOLE  NPM =    5
 MAX NO OF OVERALL ITERATIONS  ITERMX =   20
 MAX NO OF ITERATIONS FOR DE   INMX =   25
 DOUBLE INMX WHEN ITER A MULT. OF IDOUB=    5
 TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
 IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
 KCUT =   38     ICUT =   36
 ORC =       1.900000


 DATA FOR CALP
 ITNSC =    0     SLOP =   1.000000
 INPUT =    1
 RADII FOR SI DEP OF TENSOR PART
 RSI1 =  11.00     RSI2 =  12.00     RSI3 =  14.00     RSI4 =  15.00
 BC =   0.75
 SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
 S =   0.200000
 CONSTANTS FOR JDISP
 IMNDL =   20     IMXDL =   80     IMDEL =    2
 IBC =    1
 RMSC =       8.000000
 JCUT =   10
 IF IBC IS ZERO FLUX CONSERVING BC ARE USED
 RMSC IS USED FOR THE MULTIPOLE EXPANSION
 JCUT IS THE NUMBER OF TERMS IN THE MULTIPOLE EXPANSION
```

(Output from EQUIL for 8% "beta" case)

```
ITER =    0     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.110719E+00
N =   25  RES =   0.337880E-01
ITER =    1     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.646567E-01
N =   25  RES =   0.218734E-01
ITER =    2     B AT ORIGIN =   0.999994E+00
N =    1  RES =   0.454155E-01
N =   25  RES =   0.169182E-01
ITER =    3     B AT ORIGIN =   0.999836E+00
N =    1  RES =   0.274437E-01
N =   25  RES =   0.115533E-01
ITER =    4     B AT ORIGIN =   0.999739E+00
N =    1  RES =   0.171078E-01
N =   50  RES =   0.422405E-02
ITER =    5     B AT ORIGIN =   0.999573E+00
N =    1  RES =   0.102930E-01
N =   50  RES =   0.283454E-02
ITER =    6     B AT ORIGIN =   0.999766E+00
N =    1  RES =   0.676787E-02
N =   50  RES =   0.219039E-02
ITER =    7     B AT ORIGIN =   0.999884E+00
N =    1  RES =   0.217318E-02
N =   50  RES =   0.173019E-02
ITER =    8     B AT ORIGIN =   0.999966E+00
N =    1  RES =   0.311370E-02
N =   50  RES =   0.135644E-02
ITER =    9     B AT ORIGIN =   0.100002E+01
N =    1  RES =   0.212428E-02
N =  100  RES =   0.893424E-03
ITER =   10     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.167390E-02
N =  100  RES =   0.621322E-03
ITER =   11     B AT ORIGIN =   0.100018E+01
N =    1  RES =   0.129173E-02
N =  100  RES =   0.438386E-03
ITER =   12     B AT ORIGIN =   0.100022E+01
N =    1  RES =   0.973638E-03
N =  100  RES =   0.311862E-03
ITER =   13     B AT ORIGIN =   0.100025E+01
N =    1  RES =   0.722693E-03
N =  100  RES =   0.220827E-03
ITER =   14     B AT ORIGIN =   0.100027E+01
N =    1  RES =   0.530768E-03
N =  200  RES =   0.107683E-03
ITER =   15     B AT ORIGIN =   0.100030E+01
N =    1  RES =   0.430695E-03
N =  200  RES =   0.550411E-04
ITER =   16     B AT ORIGIN =   0.100031E+01
N =    1  RES =   0.321586E-03
N =  200  RES =   0.293434E-04
ITER =   17     B AT ORIGIN =   0.100032E+01
N =    1  RES =   0.221352E-03
N =  200  RES =   0.162069E-04
ITER =   18     B AT ORIGIN =   0.100032E+01
N =    1  RES =   0.147608E-03
N =  200  RES =   0.967245E-05
ITER =   19     B AT ORIGIN =   0.100032E+01
N =    1  RES =   0.959320E-04
N =  400  RES =   0.440669E-05
```

| RMID | CURD | MODB | P-PERP | P-PARA | DLOB | SI | SIV |
|---|---|---|---|---|---|---|---|
| 0.475E+01 | -0.387E-03 | 0.915E+00 | 0.0 | 0.0 | 0.0 | -0.106E-01 | 0.108E+02 |
| 0.500E+01 | -0.421E-03 | 0.906E+00 | 0.0 | 0.0 | 0.0 | -0.112E-01 | 0.119E+02 |
| 0.525E+01 | -0.459E-03 | 0.897E+00 | 0.0 | 0.0 | 0.0 | -0.117E-01 | 0.131E+02 |
| 0.550E+01 | -0.499E-03 | 0.887E+00 | 0.0 | 0.0 | 0.0 | -0.121E-01 | 0.143E+02 |
| 0.575E+01 | -0.544E-03 | 0.878E+00 | 0.0 | 0.0 | 0.0 | -0.123E-01 | 0.155E+02 |
| 0.600E+01 | -0.590E-03 | 0.869E+00 | 0.0 | 0.0 | 0.0 | -0.123E-01 | 0.168E+02 |
| 0.625E+01 | -0.644E-03 | 0.858E+00 | 0.0 | 0.0 | 0.0 | -0.121E-01 | 0.181E+02 |
| 0.650E+01 | -0.696E-03 | 0.848E+00 | 0.0 | 0.0 | 0.0 | -0.116E-01 | 0.195E+02 |
| 0.675E+01 | -0.759E-03 | 0.837E+00 | 0.0 | 0.0 | 0.0 | -0.108E-01 | 0.209E+02 |
| 0.700E+01 | -0.822E-03 | 0.826E+00 | 0.0 | 0.0 | 0.0 | -0.964E-02 | 0.223E+02 |
| 0.725E+01 | -0.893E-03 | 0.815E+00 | 0.0 | 0.0 | 0.0 | -0.808E-02 | 0.238E+02 |
| 0.750E+01 | -0.966E-03 | 0.804E+00 | 0.0 | 0.0 | 0.0 | -0.606E-02 | 0.252E+02 |
| 0.775E+01 | -0.105E-02 | 0.792E+00 | 0.0 | 0.0 | 0.0 | -0.351E-02 | 0.268E+02 |
| 0.800E+01 | -0.114E-02 | 0.781E+00 | 0.0 | 0.0 | 0.0 | -0.356E-03 | 0.283E+02 |
| 0.825E+01 | -0.123E-02 | 0.769E+00 | 0.0 | 0.0 | 0.0 | 0.347E-02 | 0.299E+02 |
| 0.850E+01 | -0.133E-02 | 0.757E+00 | 0.0 | 0.0 | 0.0 | 0.807E-02 | 0.315E+02 |
| 0.875E+01 | -0.144E-02 | 0.745E+00 | 0.0 | 0.0 | 0.0 | 0.135E-01 | 0.331E+02 |
| 0.900E+01 | -0.155E-02 | 0.733E+00 | 0.0 | 0.0 | 0.0 | 0.199E-01 | 0.347E+02 |
| 0.925E+01 | -0.168E-02 | 0.721E+00 | 0.0 | 0.0 | 0.0 | 0.274E-01 | 0.364E+02 |
| 0.950E+01 | -0.181E-02 | 0.708E+00 | 0.0 | 0.0 | 0.0 | 0.361E-01 | 0.380E+02 |
| 0.975E+01 | -0.195E-02 | 0.696E+00 | 0.0 | 0.0 | 0.0 | 0.460E-01 | 0.397E+02 |
| 0.100E+02 | -0.209E-02 | 0.683E+00 | 0.0 | 0.0 | 0.0 | 0.575E-01 | 0.414E+02 |
| 0.103E+02 | -0.225E-02 | 0.671E+00 | 0.0 | 0.0 | 0.0 | 0.706E-01 | 0.431E+02 |
| 0.105E+02 | -0.239E-02 | 0.659E+00 | 0.0 | 0.0 | 0.0 | 0.854E-01 | 0.448E+02 |
| 0.108E+02 | -0.255E-02 | 0.646E+00 | 0.0 | 0.0 | 0.0 | 0.102E+00 | 0.465E+02 |
| 0.110E+02 | 0.867E-02 | 0.632E+00 | 0.0 | 0.0 | 0.0 | 0.121E+00 | 0.483E+02 |
| 0.113E+02 | 0.398E-01 | 0.613E+00 | 0.375E-02 | 0.376E-03 | 0.0 | 0.134E+00 | 0.500E+02 |
| 0.115E+02 | 0.600E-01 | 0.588E+00 | 0.126E-01 | 0.153E-02 | 0.0 | 0.120E+00 | 0.517E+02 |
| 0.118E+02 | 0.493E-01 | 0.561E+00 | 0.220E-01 | 0.316E-02 | 0.0 | 0.611E-01 | 0.534E+02 |
| 0.120E+02 | 0.226E-01 | 0.539E+00 | 0.272E-01 | 0.444E-02 | 0.0 | -0.354E-01 | 0.552E+02 |
| 0.123E+02 | 0.128E-01 | 0.522E+00 | 0.290E-01 | 0.518E-02 | 0.0 | -0.151E+00 | 0.569E+02 |
| 0.125E+02 | 0.139E-01 | 0.506E+00 | 0.306E-01 | 0.594E-02 | 0.0 | -0.279E+00 | 0.586E+02 |
| 0.128E+02 | 0.145E-01 | 0.489E+00 | 0.324E-01 | 0.683E-02 | 0.0 | -0.421E+00 | 0.603E+02 |
| 0.130E+02 | 0.138E-01 | 0.473E+00 | 0.339E-01 | 0.767E-02 | 0.0 | -0.577E+00 | 0.620E+02 |
| 0.133E+02 | 0.151E-01 | 0.458E+00 | 0.353E-01 | 0.852E-02 | 0.0 | -0.747E+00 | 0.637E+02 |
| 0.135E+02 | 0.169E-01 | 0.441E+00 | 0.368E-01 | 0.954E-02 | 0.0 | -0.933E+00 | 0.654E+02 |
| 0.138E+02 | 0.150E-01 | 0.424E+00 | 0.383E-01 | 0.106E-01 | 0.0 | -0.114E+01 | 0.671E+02 |
| 0.140E+02 | -0.640E-02 | 0.411E+00 | 0.394E-01 | 0.115E-01 | 0.0 | -0.136E+01 | 0.687E+02 |
| 0.143E+02 | -0.726E-01 | 0.409E+00 | 0.353E-01 | 0.104E-01 | 0.0 | -0.158E+01 | 0.704E+02 |
| 0.145E+02 | -0.122E+00 | 0.423E+00 | 0.231E-01 | 0.644E-02 | 0.0 | -0.174E+01 | 0.720E+02 |
| 0.148E+02 | -0.102E+00 | 0.439E+00 | 0.801E-02 | 0.209E-02 | 0.0 | -0.178E+01 | 0.737E+02 |
| 0.150E+02 | -0.158E-01 | 0.441E+00 | 0.0 | 0.0 | 0.0 | -0.174E+01 | 0.753E+02 |
| 0.153E+02 | 0.769E-02 | 0.431E+00 | 0.0 | 0.0 | 0.0 | -0.168E+01 | 0.769E+02 |
| 0.155E+02 | 0.582E-02 | 0.418E+00 | 0.0 | 0.0 | 0.0 | -0.162E+01 | 0.785E+02 |
| 0.158E+02 | 0.474E-02 | 0.406E+00 | 0.0 | 0.0 | 0.0 | -0.157E+01 | 0.800E+02 |
| 0.160E+02 | 0.404E-02 | 0.394E+00 | 0.0 | 0.0 | 0.0 | -0.153E+01 | 0.816E+02 |
| 0.163E+02 | 0.352E-02 | 0.382E+00 | 0.0 | 0.0 | 0.0 | -0.148E+01 | 0.831E+02 |
| 0.165E+02 | 0.313E-02 | 0.371E+00 | 0.0 | 0.0 | 0.0 | -0.144E+01 | 0.846E+02 |
| 0.168E+02 | 0.280E-02 | 0.359E+00 | 0.0 | 0.0 | 0.0 | -0.141E+01 | 0.861E+02 |
| 0.170E+02 | 0.252E-02 | 0.349E+00 | 0.0 | 0.0 | 0.0 | -0.137E+01 | 0.875E+02 |
| 0.173E+02 | 0.227E-02 | 0.338E+00 | 0.0 | 0.0 | 0.0 | -0.134E+01 | 0.890E+02 |
| 0.175E+02 | 0.206E-02 | 0.328E+00 | 0.0 | 0.0 | 0.0 | -0.131E+01 | 0.904E+02 |
| 0.178E+02 | 0.187E-02 | 0.318E+00 | 0.0 | 0.0 | 0.0 | -0.128E+01 | 0.918E+02 |
| 0.180E+02 | 0.171E-02 | 0.308E+00 | 0.0 | 0.0 | 0.0 | -0.125E+01 | 0.931E+02 |
| 0.183E+02 | 0.155E-02 | 0.298E+00 | 0.0 | 0.0 | 0.0 | -0.123E+01 | 0.945E+02 |
| 0.185E+02 | 0.142E-02 | 0.289E+00 | 0.0 | 0.0 | 0.0 | -0.120E+01 | 0.958E+02 |
| 0.188E+02 | 0.130E-02 | 0.281E+00 | 0.0 | 0.0 | 0.0 | -0.118E+01 | 0.971E+02 |
| 0.190E+02 | 0.119E-02 | 0.272E+00 | 0.0 | 0.0 | 0.0 | -0.116E+01 | 0.984E+02 |
| 0.193E+02 | 0.109E-02 | 0.263E+00 | 0.0 | 0.0 | 0.0 | -0.114E+01 | 0.997E+02 |
| 0.195E+02 | 0.101E-02 | 0.254E+00 | 0.0 | 0.0 | 0.0 | -0.112E+01 | 0.101E+03 |
| 0.198E+02 | 0.925E-03 | 0.246E+00 | 0.0 | 0.0 | 0.0 | -0.110E+01 | 0.102E+03 |

WPER= 0.57328E+01 WPAR= 0.57892E+00

1

RAD P-PER: MID TO COIL

| Z = | 0.0 | 0.56 | 1.11 | 1.67 | 2.22 | 2.78 | 3.33 | 3.89 | 4.45 | 5.00 | 5.56 | 6.11 | 6.67 | 7.22 | 7.78 | 8.33 | 8.89 | 9.45 | 10.00 | 10.56 | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.007 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.001 | 0.002 | 0.002 | 0.000 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.25 | 0.004 | 0.004 | 0.005 | 0.006 | 0.009 | 0.011 | 0.012 | 0.012 | 0.009 | 0.006 | 0.001 | 0.009 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.75 | 0.022 | 0.022 | 0.023 | 0.023 | 0.023 | 0.021 | 0.020 | 0.017 | 0.014 | 0.011 | 0.007 | 0.002 | 0.016 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.25 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.025 | 0.024 | 0.022 | 0.019 | 0.016 | 0.012 | 0.006 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.75 | 0.032 | 0.032 | 0.032 | 0.031 | 0.030 | 0.029 | 0.028 | 0.026 | 0.023 | 0.020 | 0.010 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.25 | 0.035 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.031 | 0.029 | 0.020 | 0.007 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.75 | 0.038 | 0.038 | 0.038 | 0.037 | 0.036 | 0.033 | 0.024 | 0.012 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.25 | 0.035 | 0.034 | 0.032 | 0.027 | 0.019 | 0.010 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.75 | 0.008 | 0.007 | 0.004 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| RS | ZS | SI | SIV | STP |
|---|---|---|---|---|
| 2.8000E+01 | 9.5000E+00 | -6.8994E-01 | 1.4291E+02 | 1.4222E+02 |

R; T=800.82/807.96 17:47:55

```
1
 EBTI KT8
 IMX =  181  XMAX =      45.000000
 KMXM1 =   41  YMAX =      22.225006
 IBUG =    0     IBUG OF ZERO GIVES MIN DIAG PRINT
 NOTE THAT  KMX =    42     LMX =  7602
 SEP =      44.449997  RADIUS OF LOOP =       9.525000
 NO COIL PAIRS  NP =    4
 NO PLASMA PAIRS FOR MULTIPOLE  NPM =    5
 MAX NO OF OVERALL ITERATIONS  ITERMX =   20
 MAX NO OF ITERATIONS FOR DE   INMX =   25
 DOUBLE INMX WHEN ITER A MULT. OF IDOUB=    5
 TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
 IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
 KCUT =   38     ICUT =   36
 ORC =       1.900000


 DATA FOR CALP
 ITNSC =    0     SLOP =   1.000000
 INPUT =    1
 RADII FOR SI DEP OF TENSOR PART
 RSI1 =  11.00     RSI2 =  13.00     RSI3 =  13.00     RSI4 =  15.00
 BC =   0.60
 SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
 S =   0.800000
 CONSTANTS FOR JDISP
 IMNDL =   20     IMXDL =   80     IMDEL =    2
 IBC =    1
 RMSC =       8.000000
 JCUT =   10
 IF IBC IS ZERO FLUX CONSERVING BC ARE USED
 RMSC IS USED FOR THE MULTIPOLE EXPANSION
 JCUT IS THE NUMBER OF TERMS IN THE MULTIPOLE EXPANSION
```

(Output from EQUIL for 18% "beta" case)

```
ITER =    0     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.657514E-01
N =   25  RES =   0.200650E-01
ITER =    1     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.493689E-01
N =   25  RES =   0.163373E-01
ITER =    2     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.403318E-01
N =   25  RES =   0.143359E-01
ITER =    3     B AT ORIGIN =   0.100000E+01
N =    1  RES =   0.312744E-01
N =   25  RES =   0.125747E-01
ITER =    4     B AT ORIGIN =   0.999930E+00
N =    1  RES =   0.248373E-01
N =   50  RES =   0.430526E-02
ITER =    5     B AT ORIGIN =   0.999789E+00
N =    1  RES =   0.199719E-01
N =   50  RES =   0.347072E-02
ITER =    6     B AT ORIGIN =   0.999903E+00
N =    1  RES =   0.165749E-01
N =   50  RES =   0.294961E-02
ITER =    7     B AT ORIGIN =   0.999982E+00
N =    1  RES =   0.137704E-01
N =   50  RES =   0.253894E-02
ITER =    8     B AT ORIGIN =   0.100004E+01
N =    1  RES =   0.115135E-01
N =   50  RES =   0.220934E-02
ITER =    9     B AT ORIGIN =   0.100008E+01
N =    1  RES =   0.970452E-02
N =  100  RES =   0.107873E-02
ITER =   10     B AT ORIGIN =   0.100016E+01
N =    1  RES =   0.794937E-02
N =  100  RES =   0.798922E-03
ITER =   11     B AT ORIGIN =   0.100022E+01
N =    1  RES =   0.745048E-02
N =  100  RES =   0.615208E-03
ITER =   12     B AT ORIGIN =   0.100027E+01
N =    1  RES =   0.645208E-02
N =  100  RES =   0.482136E-03
ITER =   13     B AT ORIGIN =   0.100030E+01
N =    1  RES =   0.557166E-02
N =  100  RES =   0.382962E-03
ITER =   14     B AT ORIGIN =   0.100033E+01
N =    1  RES =   0.481144E-02
N =  200  RES =   0.202673E-03
ITER =   15     B AT ORIGIN =   0.100037E+01
N =    1  RES =   0.426033E-02
N =  200  RES =   0.121323E-03
ITER =   16     B AT ORIGIN =   0.100039E+01
N =    1  RES =   0.371663E-02
N =  200  RES =   0.803160E-04
ITER =   17     B AT ORIGIN =   0.100040E+01
N =    1  RES =   0.319615E-02
N =  200  RES =   0.583668E-04
ITER =   18     B AT ORIGIN =   0.100041E+01
N =    1  RES =   0.273660E-02
N =  200  RES =   0.443551E-04
ITER =   19     B AT ORIGIN =   0.100041E+01
N =    1  RES =   0.234167E-02
N =  400  RES =   0.175014E-04
```

| RMID | CURD | MODB | P-PERP | P-PARA | DLOB | SI | SIV |
|---|---|---|---|---|---|---|---|
| 0.475E+01 | -0.471E-03 | 0.915E+00 | 0.0 | 0.0 | 0.0 | -0.167E-01 | 0.108E+02 |
| 0.500E+01 | -0.507E-03 | 0.906E+00 | 0.0 | 0.0 | 0.0 | -0.179E-01 | 0.119E+02 |
| 0.525E+01 | -0.573E-03 | 0.897E+00 | 0.0 | 0.0 | 0.0 | -0.190E-01 | 0.131E+02 |
| 0.550E+01 | -0.617E-03 | 0.887E+00 | 0.0 | 0.0 | 0.0 | -0.199E-01 | 0.143E+02 |
| 0.575E+01 | -0.697E-03 | 0.878E+00 | 0.0 | 0.0 | 0.0 | -0.206E-01 | 0.155E+02 |
| 0.600E+01 | -0.754E-03 | 0.869E+00 | 0.0 | 0.0 | 0.0 | -0.211E-01 | 0.168E+02 |
| 0.625E+01 | -0.850E-03 | 0.858E+00 | 0.0 | 0.0 | 0.0 | -0.214E-01 | 0.181E+02 |
| 0.650E+01 | -0.922E-03 | 0.848E+00 | 0.0 | 0.0 | 0.0 | -0.213E-01 | 0.195E+02 |
| 0.675E+01 | -0.104E-02 | 0.837E+00 | 0.0 | 0.0 | 0.0 | -0.208E-01 | 0.209E+02 |
| 0.700E+01 | -0.113E-02 | 0.826E+00 | 0.0 | 0.0 | 0.0 | -0.199E-01 | 0.223E+02 |
| 0.725E+01 | -0.128E-02 | 0.815E+00 | 0.0 | 0.0 | 0.0 | -0.184E-01 | 0.238E+02 |
| 0.750E+01 | -0.140E-02 | 0.804E+00 | 0.0 | 0.0 | 0.0 | -0.163E-01 | 0.252E+02 |
| 0.775E+01 | -0.158E-02 | 0.793E+00 | 0.0 | 0.0 | 0.0 | -0.134E-01 | 0.268E+02 |
| 0.800E+01 | -0.174E-02 | 0.781E+00 | 0.0 | 0.0 | 0.0 | -0.972E-02 | 0.283E+02 |
| 0.825E+01 | -0.196E-02 | 0.769E+00 | 0.0 | 0.0 | 0.0 | -0.500E-02 | 0.299E+02 |
| 0.850E+01 | -0.216E-02 | 0.758E+00 | 0.0 | 0.0 | 0.0 | 0.896E-03 | 0.315E+02 |
| 0.875E+01 | -0.244E-02 | 0.746E+00 | 0.0 | 0.0 | 0.0 | 0.813E-02 | 0.331E+02 |
| 0.900E+01 | -0.271E-02 | 0.734E+00 | 0.0 | 0.0 | 0.0 | 0.169E-01 | 0.347E+02 |
| 0.925E+01 | -0.306E-02 | 0.722E+00 | 0.0 | 0.0 | 0.0 | 0.275E-01 | 0.364E+02 |
| 0.950E+01 | -0.340E-02 | 0.710E+00 | 0.0 | 0.0 | 0.0 | 0.402E-01 | 0.380E+02 |
| 0.975E+01 | -0.384E-02 | 0.698E+00 | 0.0 | 0.0 | 0.0 | 0.553E-01 | 0.397E+02 |
| 0.100E+02 | -0.428E-02 | 0.686E+00 | 0.0 | 0.0 | 0.0 | 0.731E-01 | 0.414E+02 |
| 0.103E+02 | -0.482E-02 | 0.675E+00 | 0.0 | 0.0 | 0.0 | 0.941E-01 | 0.431E+02 |
| 0.105E+02 | -0.537E-02 | 0.663E+00 | 0.0 | 0.0 | 0.0 | 0.119E+00 | 0.448E+02 |
| 0.108E+02 | -0.603E-02 | 0.651E+00 | 0.0 | 0.0 | 0.0 | 0.147E+00 | 0.465E+02 |
| 0.110E+02 | -0.670E-02 | 0.640E+00 | 0.0 | 0.0 | 0.0 | 0.181E+00 | 0.483E+02 |
| 0.113E+02 | -0.749E-02 | 0.629E+00 | 0.0 | 0.0 | 0.0 | 0.220E+00 | 0.500E+02 |
| 0.115E+02 | -0.828E-02 | 0.617E+00 | 0.0 | 0.0 | 0.0 | 0.265E+00 | 0.517E+02 |
| 0.118E+02 | 0.950E-02 | 0.604E+00 | 0.0 | 0.0 | 0.0 | 0.317E+00 | 0.534E+02 |
| 0.120E+02 | 0.642E-01 | 0.582E+00 | 0.525E-02 | 0.797E-04 | 0.0 | 0.364E+00 | 0.552E+02 |
| 0.123E+02 | 0.138E+00 | 0.544E+00 | 0.202E-01 | 0.986E-03 | 0.0 | 0.362E+00 | 0.569E+02 |
| 0.125E+02 | 0.188E+00 | 0.491E+00 | 0.436E-01 | 0.436E-02 | 0.0 | 0.254E+00 | 0.586E+02 |
| 0.128E+02 | 0.170E+00 | 0.432E+00 | 0.680E-01 | 0.111E-01 | 0.0 | -0.402E-02 | 0.603E+02 |
| 0.130E+02 | 0.961E-01 | 0.387E+00 | 0.842E-01 | 0.182E-01 | 0.0 | -0.404E+00 | 0.620E+02 |
| 0.133E+02 | 0.662E-02 | 0.363E+00 | 0.893E-01 | 0.220E-01 | 0.0 | -0.891E+00 | 0.637E+02 |
| 0.135E+02 | -0.761E-01 | 0.359E+00 | 0.845E-01 | 0.213E-01 | 0.0 | -0.139E+01 | 0.654E+02 |
| 0.138E+02 | -0.140E+00 | 0.373E+00 | 0.714E-01 | 0.167E-01 | 0.0 | -0.184E+01 | 0.671E+02 |
| 0.140E+02 | -0.169E+00 | 0.399E+00 | 0.526E-01 | 0.106E-01 | 0.0 | -0.217E+01 | 0.687E+02 |
| 0.143E+02 | -0.153E+00 | 0.428E+00 | 0.329E-01 | 0.550E-02 | 0.0 | -0.236E+01 | 0.704E+02 |
| 0.145E+02 | -0.110E+00 | 0.450E+00 | 0.161E-01 | 0.230E-02 | 0.0 | -0.242E+01 | 0.720E+02 |
| 0.148E+02 | -0.552E-01 | 0.459E+00 | 0.459E-02 | 0.613E-03 | 0.0 | -0.237E+01 | 0.737E+02 |
| 0.150E+02 | -0.827E-03 | 0.453E+00 | 0.0 | 0.0 | 0.0 | -0.227E+01 | 0.753E+02 |
| 0.153E+02 | 0.126E-01 | 0.441E+00 | 0.0 | 0.0 | 0.0 | -0.218E+01 | 0.769E+02 |
| 0.155E+02 | 0.103E-01 | 0.426E+00 | 0.0 | 0.0 | 0.0 | -0.209E+01 | 0.785E+02 |
| 0.158E+02 | 0.858E-02 | 0.413E+00 | 0.0 | 0.0 | 0.0 | -0.201E+01 | 0.800E+02 |
| 0.160E+02 | 0.738E-02 | 0.400E+00 | 0.0 | 0.0 | 0.0 | -0.193E+01 | 0.816E+02 |
| 0.163E+02 | 0.637E-02 | 0.388E+00 | 0.0 | 0.0 | 0.0 | -0.187E+01 | 0.831E+02 |
| 0.165E+02 | 0.560E-02 | 0.376E+00 | 0.0 | 0.0 | 0.0 | -0.181E+01 | 0.846E+02 |
| 0.168E+02 | 0.489E-02 | 0.364E+00 | 0.0 | 0.0 | 0.0 | -0.175E+01 | 0.861E+02 |
| 0.170E+02 | 0.436E-02 | 0.353E+00 | 0.0 | 0.0 | 0.0 | -0.170E+01 | 0.875E+02 |
| 0.173E+02 | 0.383E-02 | 0.342E+00 | 0.0 | 0.0 | 0.0 | -0.165E+01 | 0.890E+02 |
| 0.175E+02 | 0.344E-02 | 0.331E+00 | 0.0 | 0.0 | 0.0 | -0.160E+01 | 0.904E+02 |
| 0.178E+02 | 0.304E-02 | 0.321E+00 | 0.0 | 0.0 | 0.0 | -0.156E+01 | 0.918E+02 |
| 0.180E+02 | 0.276E-02 | 0.310E+00 | 0.0 | 0.0 | 0.0 | -0.152E+01 | 0.931E+02 |
| 0.183E+02 | 0.244E-02 | 0.301E+00 | 0.0 | 0.0 | 0.0 | -0.149E+01 | 0.945E+02 |
| 0.185E+02 | 0.224E-02 | 0.291E+00 | 0.0 | 0.0 | 0.0 | -0.145E+01 | 0.958E+02 |
| 0.188E+02 | 0.199E-02 | 0.283E+00 | 0.0 | 0.0 | 0.0 | -0.142E+01 | 0.971E+02 |
| 0.190E+02 | 0.183E-02 | 0.273E+00 | 0.0 | 0.0 | 0.0 | -0.139E+01 | 0.984E+02 |
| 0.193E+02 | 0.163E-02 | 0.264E+00 | 0.0 | 0.0 | 0.0 | -0.137E+01 | 0.997E+02 |
| 0.195E+02 | 0.152E-02 | 0.256E+00 | 0.0 | 0.0 | 0.0 | -0.134E+01 | 0.101E+03 |
| 0.198E+02 | 0.135E-02 | 0.247E+00 | 0.0 | 0.0 | 0.0 | -0.131E+01 | 0.102E+03 |

WPER= 0.59176E+01 WPAR= 0.53484E+00

RAD P-PER: MID TO COIL

| Z = | 0.0 | 0.56 | 1.11 | 1.67 | 2.22 | 2.78 | 3.33 | 3.89 | 4.45 | 5.00 | 5.56 | 6.11 | 6.67 | 7.22 | 7.78 | 8.33 | 8.89 | 9.45 | 10.00 | 10.56 | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.25 | 0.020 | 0.021 | 0.021 | 0.022 | 0.022 | 0.020 | 0.016 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.75 | 0.068 | 0.067 | 0.067 | 0.066 | 0.062 | 0.055 | 0.041 | 0.024 | 0.007 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.25 | 0.089 | 0.089 | 0.085 | 0.078 | 0.067 | 0.051 | 0.032 | 0.015 | 0.005 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.75 | 0.071 | 0.069 | 0.063 | 0.053 | 0.039 | 0.024 | 0.011 | 0.003 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.25 | 0.033 | 0.031 | 0.026 | 0.018 | 0.010 | 0.004 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.75 | 0.005 | 0.004 | 0.002 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| RS | ZS | SI | SIV | STP |
|---|---|---|---|---|
| 2.8000E+01 | 9.5000E+00 | -7.8596E-01 | 1.4291E+02 | 1.4213E+02 |

R; T=798.82/811.35 17:40:40

```
1
EBTI KT8
IMX =  181  XMAX =      45.000000
KMXM1 =   41  YMAX =      22.225006
IBUG =    0     IBUG OF ZERO GIVES MIN DIAG PRINT
NOTE THAT  KMX =    42     LMX =  7602
SEP =      44.449997  RADIUS OF LOOP =       9.525000
NO COIL PAIRS  NP =    4
NO PLASMA PAIRS FOR MULTIPOLE  NPM =    5
MAX NO OF OVERALL ITERATIONS  ITERMX =   20
MAX NO OF ITERATIONS FOR DE   INMX =   25
DOUBLE INMX WHEN ITER A MULT. OF IDOUB=    5
TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
KCUT =   38     ICUT =   36
ORC =       1.900000


DATA FOR CALP
ITNSC =    0     SLOP =   1.000000
INPUT =    1
RADII FOR SI DEP OF TENSOR PART
RSI1 =  11.00     RSI2 =  12.00     RSI3 =  14.00     RSI4 =  15.00
BC =   0.60
SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
S =   0.800000
CONSTANTS FOR JDISP
IMNDL =   20     IMXDL =   80     IMDEL =    2
IBC =    1
RMSC =       8.000000
JCUT =   10
IF IBC IS ZERO FLUX CONSERVING BC ARE USED
RMSC IS USED FOR THE MULTIPOLE EXPANSION
JCUT IS THE NUMBER OF TERMS IN THE MULTIPOLE EXPANSION
```

(Output from EQUIL for 23% "beta" case)

```
ITER =    0     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.874668E-01
N =   25  RES =   0.266914E-01
ITER =    1     B AT ORIGIN =   0.100012E+01
N =    1  RES =   0.734369E-01
N =   25  RES =   0.241016E-01
ITER =    2     B AT ORIGIN =   0.100011E+01
N =    1  RES =   0.636881E-01
N =   25  RES =   0.222830E-01
ITER =    3     B AT ORIGIN =   0.999948E+00
N =    1  RES =   0.527849E-01
N =   25  RES =   0.195203E-01
ITER =    4     B AT ORIGIN =   0.999831E+00
N =    1  RES =   0.440358E-01
N =   50  RES =   0.643954E-02
ITER =    5     B AT ORIGIN =   0.999589E+00
N =    1  RES =   0.351536E-01
N =   50  RES =   0.546023E-02
ITER =    6     B AT ORIGIN =   0.999746E+00
N =    1  RES =   0.171483E-01
N =   50  RES =   0.450835E-02
ITER =    7     B AT ORIGIN =   0.999857E+00
N =    1  RES =   0.210369E-01
N =   50  RES =   0.394541E-02
ITER =    8     B AT ORIGIN =   0.999908E+00
N =    1  RES =   0.243801E-01
N =   50  RES =   0.352267E-02
ITER =    9     B AT ORIGIN =   0.999948E+00
N =    1  RES =   0.104967E-01
N =  100  RES =   0.163332E-02
ITER =   10     B AT ORIGIN =   0.100004E+01
N =    1  RES =   0.666540E-02
N =  100  RES =   0.115009E-02
ITER =   11     B AT ORIGIN =   0.100011E+01
N =    1  RES =   0.182192E-01
N =  100  RES =   0.966513E-03
ITER =   12     B AT ORIGIN =   0.100018E+01
N =    1  RES =   0.159997E-01
N =  100  RES =   0.815854E-03
ITER =   13     B AT ORIGIN =   0.100025E+01
N =    1  RES =   0.141629E-01
N =  100  RES =   0.691086E-03
ITER =   14     B AT ORIGIN =   0.100030E+01
N =    1  RES =   0.126106E-01
N =  200  RES =   0.382972E-03
ITER =   15     B AT ORIGIN =   0.100039E+01
N =    1  RES =   0.115560E-01
N =  200  RES =   0.251327E-03
ITER =   16     B AT ORIGIN =   0.100044E+01
N =    1  RES =   0.105046E-01
N =  200  RES =   0.182810E-03
ITER =   17     B AT ORIGIN =   0.100047E+01
N =    1  RES =   0.944036E-02
N =  200  RES =   0.143187E-03
ITER =   18     B AT ORIGIN =   0.100049E+01
N =    1  RES =   0.843725E-02
N =  200  RES =   0.118888E-03
ITER =   19     B AT ORIGIN =   0.100051E+01
N =    1  RES =   0.756030E-02
N =  400  RES =   0.467685E-04
```

| RMID | CURD | MODB | P-PERP | P-PARA | DLOB | SI | SIV |
|---|---|---|---|---|---|---|---|
| 0.475E+01 | -0.717E-03 | 0.914E+00 | 0.0 | 0.0 | 0.0 | -0.232E-01 | 0.108E+02 |
| 0.500E+01 | -0.747E-03 | 0.906E+00 | 0.0 | 0.0 | 0.0 | -0.247E-01 | 0.119E+02 |
| 0.525E+01 | -0.864E-03 | 0.897E+00 | 0.0 | 0.0 | 0.0 | -0.260E-01 | 0.131E+02 |
| 0.550E+01 | -0.904E-03 | 0.887E+00 | 0.0 | 0.0 | 0.0 | -0.272E-01 | 0.143E+02 |
| 0.575E+01 | -0.104E-02 | 0.878E+00 | 0.0 | 0.0 | 0.0 | -0.280E-01 | 0.155E+02 |
| 0.600E+01 | -0.110E-02 | 0.869E+00 | 0.0 | 0.0 | 0.0 | -0.285E-01 | 0.168E+02 |
| 0.625E+01 | -0.126E-02 | 0.858E+00 | 0.0 | 0.0 | 0.0 | -0.287E-01 | 0.181E+02 |
| 0.650E+01 | -0.133E-02 | 0.848E+00 | 0.0 | 0.0 | 0.0 | -0.283E-01 | 0.195E+02 |
| 0.675E+01 | -0.152E-02 | 0.837E+00 | 0.0 | 0.0 | 0.0 | -0.273E-01 | 0.209E+02 |
| 0.700E+01 | -0.162E-02 | 0.827E+00 | 0.0 | 0.0 | 0.0 | -0.257E-01 | 0.223E+02 |
| 0.725E+01 | -0.184E-02 | 0.816E+00 | 0.0 | 0.0 | 0.0 | -0.233E-01 | 0.238E+02 |
| 0.750E+01 | -0.198E-02 | 0.805E+00 | 0.0 | 0.0 | 0.0 | -0.200E-01 | 0.252E+02 |
| 0.775E+01 | -0.225E-02 | 0.793E+00 | 0.0 | 0.0 | 0.0 | -0.156E-01 | 0.268E+02 |
| 0.800E+01 | -0.242E-02 | 0.782E+00 | 0.0 | 0.0 | 0.0 | -0.990E-02 | 0.283E+02 |
| 0.825E+01 | -0.275E-02 | 0.771E+00 | 0.0 | 0.0 | 0.0 | -0.284E-02 | 0.299E+02 |
| 0.850E+01 | -0.297E-02 | 0.759E+00 | 0.0 | 0.0 | 0.0 | 0.587E-02 | 0.315E+02 |
| 0.875E+01 | -0.337E-02 | 0.747E+00 | 0.0 | 0.0 | 0.0 | 0.165E-01 | 0.331E+02 |
| 0.900E+01 | -0.367E-02 | 0.736E+00 | 0.0 | 0.0 | 0.0 | 0.292E-01 | 0.347E+02 |
| 0.925E+01 | -0.415E-02 | 0.724E+00 | 0.0 | 0.0 | 0.0 | 0.444E-01 | 0.364E+02 |
| 0.950E+01 | -0.453E-02 | 0.713E+00 | 0.0 | 0.0 | 0.0 | 0.625E-01 | 0.380E+02 |
| 0.975E+01 | -0.511E-02 | 0.701E+00 | 0.0 | 0.0 | 0.0 | 0.837E-01 | 0.397E+02 |
| 0.100E+02 | -0.560E-02 | 0.689E+00 | 0.0 | 0.0 | 0.0 | 0.109E+00 | 0.414E+02 |
| 0.103E+02 | -0.631E-02 | 0.678E+00 | 0.0 | 0.0 | 0.0 | 0.138E+00 | 0.431E+02 |
| 0.105E+02 | -0.692E-02 | 0.667E+00 | 0.0 | 0.0 | 0.0 | 0.172E+00 | 0.448E+02 |
| 0.108E+02 | -0.775E-02 | 0.655E+00 | 0.0 | 0.0 | 0.0 | 0.211E+00 | 0.465E+02 |
| 0.110E+02 | -0.850E-02 | 0.644E+00 | 0.0 | 0.0 | 0.0 | 0.257E+00 | 0.483E+02 |
| 0.113E+02 | -0.948E-02 | 0.634E+00 | 0.0 | 0.0 | 0.0 | 0.309E+00 | 0.500E+02 |
| 0.115E+02 | -0.104E-01 | 0.623E+00 | 0.0 | 0.0 | 0.0 | 0.370E+00 | 0.517E+02 |
| 0.118E+02 | 0.117E-01 | 0.610E+00 | 0.0 | 0.0 | 0.0 | 0.439E+00 | 0.534E+02 |
| 0.120E+02 | 0.724E-01 | 0.586E+00 | 0.648E-02 | 0.747E-04 | 0.0 | 0.501E+00 | 0.552E+02 |
| 0.123E+02 | 0.122E+00 | 0.549E+00 | 0.233E-01 | 0.102E-02 | 0.0 | 0.510E+00 | 0.569E+02 |
| 0.125E+02 | 0.144E+00 | 0.503E+00 | 0.426E-01 | 0.373E-02 | 0.0 | 0.424E+00 | 0.586E+02 |
| 0.128E+02 | 0.148E+00 | 0.453E+00 | 0.620E-01 | 0.867E-02 | 0.0 | 0.222E+00 | 0.603E+02 |
| 0.130E+02 | 0.144E+00 | 0.404E+00 | 0.787E-01 | 0.153E-01 | 0.0 | -0.103E+00 | 0.620E+02 |
| 0.133E+02 | 0.141E+00 | 0.357E+00 | 0.929E-01 | 0.235E-01 | 0.0 | -0.552E+00 | 0.637E+02 |
| 0.135E+02 | 0.123E+00 | 0.311E+00 | 0.105E+00 | 0.333E-01 | 0.0 | -0.113E+01 | 0.654E+02 |
| 0.138E+02 | 0.691E-01 | 0.274E+00 | 0.114E+00 | 0.424E-01 | 0.0 | -0.182E+01 | 0.671E+02 |
| 0.140E+02 | -0.389E-01 | 0.259E+00 | 0.117E+00 | 0.466E-01 | 0.0 | -0.258E+01 | 0.687E+02 |
| 0.143E+02 | -0.240E+00 | 0.282E+00 | 0.105E+00 | 0.379E-01 | 0.0 | -0.332E+01 | 0.704E+02 |
| 0.145E+02 | -0.422E+00 | 0.354E+00 | 0.681E-01 | 0.175E-01 | 0.0 | -0.386E+01 | 0.720E+02 |
| 0.148E+02 | -0.327E+00 | 0.436E+00 | 0.211E-01 | 0.333E-02 | 0.0 | -0.403E+01 | 0.737E+02 |
| 0.150E+02 | -0.468E-01 | 0.469E+00 | 0.0 | 0.0 | 0.0 | -0.389E+01 | 0.753E+02 |
| 0.153E+02 | 0.272E-01 | 0.461E+00 | 0.0 | 0.0 | 0.0 | -0.371E+01 | 0.769E+02 |
| 0.155E+02 | 0.206E-01 | 0.444E+00 | 0.0 | 0.0 | 0.0 | -0.354E+01 | 0.785E+02 |
| 0.158E+02 | 0.164E-01 | 0.428E+00 | 0.0 | 0.0 | 0.0 | -0.340E+01 | 0.800E+02 |
| 0.160E+02 | 0.137E-01 | 0.414E+00 | 0.0 | 0.0 | 0.0 | -0.327E+01 | 0.816E+02 |
| 0.163E+02 | 0.116E-01 | 0.400E+00 | 0.0 | 0.0 | 0.0 | -0.315E+01 | 0.831E+02 |
| 0.165E+02 | 0.101E-01 | 0.387E+00 | 0.0 | 0.0 | 0.0 | -0.305E+01 | 0.846E+02 |
| 0.168E+02 | 0.878E-02 | 0.374E+00 | 0.0 | 0.0 | 0.0 | -0.295E+01 | 0.861E+02 |
| 0.170E+02 | 0.781E-02 | 0.362E+00 | 0.0 | 0.0 | 0.0 | -0.286E+01 | 0.875E+02 |
| 0.173E+02 | 0.681E-02 | 0.350E+00 | 0.0 | 0.0 | 0.0 | -0.277E+01 | 0.890E+02 |
| 0.175E+02 | 0.615E-02 | 0.338E+00 | 0.0 | 0.0 | 0.0 | -0.269E+01 | 0.904E+02 |
| 0.178E+02 | 0.537E-02 | 0.328E+00 | 0.0 | 0.0 | 0.0 | -0.262E+01 | 0.918E+02 |
| 0.180E+02 | 0.490E-02 | 0.317E+00 | 0.0 | 0.0 | 0.0 | -0.255E+01 | 0.931E+02 |
| 0.183E+02 | 0.429E-02 | 0.306E+00 | 0.0 | 0.0 | 0.0 | -0.249E+01 | 0.945E+02 |
| 0.185E+02 | 0.396E-02 | 0.297E+00 | 0.0 | 0.0 | 0.0 | -0.243E+01 | 0.958E+02 |
| 0.188E+02 | 0.347E-02 | 0.288E+00 | 0.0 | 0.0 | 0.0 | -0.238E+01 | 0.971E+02 |
| 0.190E+02 | 0.324E-02 | 0.278E+00 | 0.0 | 0.0 | 0.0 | -0.233E+01 | 0.984E+02 |
| 0.193E+02 | 0.283E-02 | 0.268E+00 | 0.0 | 0.0 | 0.0 | -0.228E+01 | 0.997E+02 |
| 0.195E+02 | 0.268E-02 | 0.260E+00 | 0.0 | 0.0 | 0.0 | -0.223E+01 | 0.101E+03 |
| 0.198E+02 | 0.233E-02 | 0.251E+00 | 0.0 | 0.0 | 0.0 | -0.219E+01 | 0.102E+03 |

WPER= 0.93756E+01 WPAR= 0.11633E+01

RAD P-PER: MID TO COIL

| Z = | 0.0 | 0.56 | 1.11 | 1.67 | 2.22 | 2.78 | 3.33 | 3.89 | 4.45 | 5.00 | 5.56 | 6.11 | 6.67 | 7.22 | 7.78 | 8.33 | 8.89 | 9.45 | 10.00 | 10.56 | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.25 | 0.023 | 0.023 | 0.023 | 0.023 | 0.021 | 0.019 | 0.016 | 0.010 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.75 | 0.062 | 0.061 | 0.061 | 0.061 | 0.060 | 0.058 | 0.053 | 0.044 | 0.027 | 0.003 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.25 | 0.093 | 0.093 | 0.093 | 0.092 | 0.091 | 0.086 | 0.076 | 0.050 | 0.014 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.75 | 0.114 | 0.113 | 0.112 | 0.109 | 0.101 | 0.078 | 0.037 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.25 | 0.105 | 0.102 | 0.092 | 0.071 | 0.038 | 0.009 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.75 | 0.021 | 0.017 | 0.009 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| RS | ZS | SI | SIV | STP |
|---|---|---|---|---|
| 2.8000E+01 | 9.5000E+00 | -1.2915E+00 | 1.4291E+02 | 1.4162E+02 |

R; T=799.16/812.61 12:43:51

BUMCAL program

The BUMCAL program calculates the flux linkage for the diamagnetic pickup loop for a bumpy cylinder current sheet model. The next page gives a sample interactive terminal session using BUMCAL. The following pages provide a FORTRAN listing for BUMCAL and the ideal solenoid code, SOLBA, called by it.

```
 LOAD BUMCAL (NOMAP START
EXECUTION BEGINS...
 ENTER NOC,RS,SL,SEP,:
?
.5 11 10 44.45
$BUMCAL
RF=  28.0000000000000000    ,ZF1=  9.50000000000000000    ,RS=  11.0000000000000000    ,SL=  10.0000000000000000    ,
NOC=          5,SEP=  44.4499999999999993    ,APT=  .619572240251832690
$END
   .619572240251832690
 ENTER NOC,RS,SL,SEP,:
?
.-1/
R;

.
```

FILE: BUMCAL FORTRAN B UNIVERSITY OF MISSOURI COMPUTER NETWORK

```
C     PROGRAM BUMCAL    K.H.CARPENTER   22JAN81                          BUM00
C     KHC 06FEB81  CORRECT LOOP ON NOC TO START AT 1.                    BUM00
C        OUTPUTS DATA NEEDED TO CALIBRATE A BUMPY CYLINDER DIAMAGNETIC   BUM00
C        DIAGNOSTIC USING A CURRENT SHEET MODEL.                         BUM00
      IMPLICIT REAL*8 (A-H,O-Z)                                          BUM00
      COMMON/CISOL/RS,SL,RF,ZF,BR,BZ,AP                                  BUM00
      NAMELIST/BUMCAL/RF,ZF1,RS,SL,NOC,SEP,APT                           BUM00
C     SEP=44.45D0                                                        BUM00
      RF=28.D0                                                           BUM00
      ZF1=9.5D0                                                          BUM00
 10   WRITE(5,20)                                                        BUM00
 20   FORMAT(' ENTER NOC,RS,SL,SEP,:')                                   BUM00
      READ(5,*)NOC,RS,SL,SEP                                             BUM00
      IF(NOC.LT.0)STOP                                                   BUM00
      ZF=ZF1                                                             BUM00
      CALL SOLBA                                                         BUM00
      APT=AP                                                             BUM00
      IF(NOC.LE.1)GO TO 40                                               BUM00
      NOC1=NOC-1                                                         BUM00
      DO 30 K=1,NOC1                                                     BUM00
      ZF=ZF1+K*SEP                                                       BUM00
      CALL SOLBA                                                         BUM00
      APT=APT+AP                                                         BUM00
      ZF=ZF1-K*SEP                                                       BUM00
      CALL SOLBA                                                         BUM00
 30   APT=APT+AP                                                         BUM00
 40   WRITE(6,BUMCAL)                                                    BUM00
      WRITE(5,*)APT                                                      BUM00
      GO TO 10                                                           BUM00
      END                                                                BUM00
```

```
      SUBROUTINE SOLBA                                                  SOL00
      IMPLICIT REAL*8 (A-H,O-Z)                                         SOL00
      COMMON/CISOL/RS,SL,RF,ZF,BR,BZ,AP                                 SOL00
C     K.H.CARPENTER 29SEP80  UMR DEPT. OF EE.                           SOL00
C****                                                                   SOL00
C     Calculates the B-field and A-field components for an ideal        SOL00
C     solenoid using the method of M.W.Garrett, JAP Vol.34 p2567 (1963).SOL00
C     This version is an adaption of the BIDSOL subroutine written by   SOL00
C     Tommy Tucker of Oak Ridge Nat. Lab., Computer Sciences Div.       SOL00
C     (BIDSOL converted to double precision, normalization changed, and SOL00
C      calculation of vector potential added.)                          SOL00
C****                                                                   SOL00
C     Input values:                                                     SOL00
C        RS - RADIUS OF SOLENOID CURRENT SHEET                          SOL00
C        SL - LENGTH OF SOLENOID CURRENT SHEET                          SOL00
C        RF - FIELD POINT RADIAL DISTANCE FROM SOLENOID AXIS            SOL00
C        ZF - FIELD POINT AXIAL DISTANCE FROM CENTER OF SOLENOID        SOL00
C     (Input values can be in any unit of length, but all four must     SOL00
C        be in the same units.)                                         SOL00
C     Output values:                                                    SOL00
C        BR - NORMALIZED RADIAL FIELD COMPONENT                         SOL00
C        BZ - NORMALIZED AXIAL FIELD COMPONENT                          SOL00
C        AP - NORMALIZED ANGULAR VECTOR POTENTIAL COMPONENT             SOL00
C     To obtain dimensional values for components:                      SOL00
C        Multiply all components by surface current density and         SOL00
C        multiply all components by permeability divided by 4 times pi. SOL00
C        In addition, multiply AP by the dimensional length of the      SOL00
C        solenoid current sheet.                                        SOL00
C****                                                                   SOL00
      DATA PI/3.14159 265389 793238 D0/                                 SOL00
      DATA TOL/1.D-12/, CUT/5.D-4/, CUTSQ/25.D-8/                       SOL00
      RSMRF=RS-RF                                                       SOL00
      RSPRF=RF+RS                                                       SOL00
      RSPFSQ=RSPRF**2                                                   SOL00
      DZ1=ZF-0.5D0*SL                                                   SOL00
      DZ2=DZ1+SL                                                        SOL00
      DZ1SQ=DZ1*DZ1                                                     SOL00
      R1SQ=RSPFSQ+DZ1SQ                                                 SOL00
      R1=DSQRT(R1SQ)                                                    SOL00
      DZ2SQ=DZ2*DZ2                                                     SOL00
      R2SQ=RSPFSQ+DZ2SQ                                                 SOL00
      R2=DSQRT(R2SQ)                                                    SOL00
      IF(RF.GT.1.0D-6)GO TO 20                                          SOL00
C  ON AXIS THE CALCULATION SIMPLIFIES TO                                SOL00
      BZ=2.D0*PI*(DZ2/R2-DZ1/R1)                                        SOL00
      BR=0.D0                                                           SOL00
      AP=0.D0                                                           SOL00
      RETURN                                                            SOL00
 20   CONTINUE                                                          SOL00
      RSRFT4=RS*RF*4.D0                                                 SOL00
      PAR1=RSRFT4/R1SQ                                                  SOL00
      CMOD1=DSQRT(1.D0-PAR1)                                            SOL00
      A1=1.D0                                                           SOL00
      B1=CMOD1                                                          SOL00
      CPRIME=RSMRF/RSPRF                                                SOL00
```

```
      CCHAR=CPRIME**2                                                   SOL00
      IF(CCHAR.GE.CUTSQ)GO TO 30                                        SOL00
C  TO CALCULATE BZ AT OR NEAR THE RADIUS OF THE CURRENT SHEET,          SOL00
C    MODIFY CCHAR TO ALLOW THE ITERATION TO PROCEED WITHOUT             SOL00
C    ZERO DIVIDED OR OVERFLOW.  THE BZ CALCULATION IS CORRECTED         SOL00
C    FOR THE SMALL ERROR INTRODUCED AT THE END OF THE ROUTINE.          SOL00
      CPRIMA=CUT                                                        SOL00
      IF(RSMRF.LT.0.D0)CPRIMA=-CPRIMA                                   SOL00
      CCHAR=CUTSQ                                                       SOL00
 30   CONTINUE                                                          SOL00
      D1=CCHAR/CMOD1                                                    SOL00
      CHAR=1.D0-CCHAR                                                   SOL00
      E1=CHAR/CCHAR                                                     SOL00
      F1=0.D0                                                           SOL00
      S1=0.D0                                                           SOL00
      PAR2=RSRFT4/R2SQ                                                  SOL00
      CMOD2=DSQRT(1.D0-PAR2)                                            SOL00
      A2=1.D0                                                           SOL00
      B2=CMOD2                                                          SOL00
      D2=CCHAR/CMOD2                                                    SOL00
      E2=E1                                                             SOL00
      F2=0.D0                                                           SOL00
      S2=0.D0                                                           SOL00
      TWOP=1.D0                                                         SOL00
 100  CONTINUE                                                          SOL00
      TWOP=TWOP*2.D0                                                    SOL00
      C=A1                                                              SOL00
      A1=(A1+B1)*0.5D0                                                  SOL00
      B1=DSQRT(C*B1)                                                    SOL00
      CSQ1=(C-A1)**2                                                    SOL00
      S1=S1+CSQ1*TWOP                                                   SOL00
      C=A2                                                              SOL00
      A2=(A2+B2)*0.5D0                                                  SOL00
      B2=DSQRT(C*B2)                                                    SOL00
      CSQ2=(C-A2)**2                                                    SOL00
      S2=S2+CSQ2*TWOP                                                   SOL00
      C=F1                                                              SOL00
      F1=(E1+F1)*0.5D0                                                  SOL00
      DPONE=D1+1.D0                                                     SOL00
      E1=(D1*E1+C)/DPONE                                                SOL00
      D1=B1*0.25D0*DPONE*DPONE/(A1*D1)                                  SOL00
      C=F2                                                              SOL00
      F2=(E2+F2)*0.5D0                                                  SOL00
      DPONE=D2+1.D0                                                     SOL00
      E2=(D2*E2+C)/DPONE                                                SOL01
      D2=B2*0.25D0*DPONE*DPONE/(A2*D2)                                  SOL01
      IF((CSQ1.GT.TOL).OR.(CSQ2.GT.TOL))GO TO 100                       SOL01
C  ONE ADDITIONAL 'A' STEP WILL HALVE THE ERROR                         SOL01
      A1=(A1+B1)*0.5D0                                                  SOL01
      A2=(A2+B2)*0.5D0                                                  SOL01
C  BR CAN NOW BE CALCULATED FROM ELLIPTIC INTEGRAL VALUES               SOL01
      BR=0.5D0*PI*(R2*S2/A2-R1*S1/A1)/RF                                SOL01
C  CONTINUE ITERATIONS TO IMPROVE ACCURACY OF 3RD COMPLETE ELL. INTEGRALSOL01
 200  CONTINUE                                                          SOL01
      C=F1                                                              SOL01
```

```
      F1=(E1+F1)*0.5D0                                                  SOL01
      DPONE=D1+1.D0                                                     SOL01
      E1=(D1*E1+C)/DPONE                                                SOL01
      D1=0.25D0*DPONE*DPONE/D1                                          SOL01
      C=F2                                                              SOL01
      F2=(E2+F2)*0.5D0                                                  SOL01
      DPONE=D2+1.D0                                                     SOL01
      E2=(D2*E2+C)/DPONE                                                SOL01
      D2=0.25D0*DPONE*DPONE/D2                                          SOL01
      IF((D1*D2-1.D0).GT.TOL)GO TO 200                                  SOL01
      F1=(E1+F1)*0.5D0                                                  SOL01
      F2=(E2+F2)*0.5D0                                                  SOL01
C  BZ AND AP CAN NOW BE CALCULATED                                      SOL01
      BZ=PI*(DZ2*(RS+RS+RSMRF*F2)/(RSPRF*R2*A2)-                        SOL01
     >       DZ1*(RS+RS+RSMRF*F1)/(RSPRF*R1*A1))                        SOL01
      IF((CCHAR.EQ.CUTSQ).AND.(CPRIME.NE.0.D0))BZ=BZ+PI*                SOL01
     >  DABS(CPRIMA-CPRIME)/CPRIMA*(DZ2/(R2*CMOD2)-DZ1/(R1*CMOD1))     SOL01
      RSMRFS=RSMRF**2                                                   SOL01
      AP=(DZ2*(R2*0.5D0*(PAR2+S2)-RSMRFS*F2/R2)/A2 -                    SOL01
     >    DZ1*(R1*0.5D0*(PAR1+S1)-RSMRFS*F1/R1)/A1)*0.5D0*PI/(RF*SL)    SOL01
      RETURN                                                            SOL01
      END                                                               SOL01
```