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MODAL ANALYSIS OF EDDY CURRENT IN JT-60 MULTI-TORUS SYSTEM

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Modal Analysis of Eddy Current in JT-60 Multi-torus System

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For the purpose of plasma control analysis including an eddy current effect, numerical computations of eddy current in JT-60 tokamak were carried out using the computer program EDDYMULT. Our numerical model of JT-60 tokamak includes most of main components such as a vacuum vessel, toroidal field coils, a central column and support plates, each of which have the complicated geometrical and electrical characteristics. 464 eigen modes of eddy current in this JT-60 multi-torus system were numerically obtained by the modal expansion technique. Typical contour maps of the obtained eddy current eigen functions were graphically illustrated. Linear parameters of the state-space model were numerically evaluated to perform the control analysis of JT-60 plasma current and position including an eddy current effect. The complicated magnetic structures produced by the corresponding eddy current mode were graphically illustrated.

Keywords ; Eddy Current, Eigen Mode, Multi-torus, JT-60 Tokamak, Finite Element Circuit Method, Plasma Control

JT－60多連続導体トーラス系における渦電流モーダル解析

日本原子力研究所東海研究所大型トカマク開発部
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（1983年9月9日受理）

動的な渦電流効果を含むプラズマ制御解析に用いるため，原研で開発された渦電流計算コードEDDYMULTを用い，JT－60トカマクにおける渦電流のモーダル解析を行った。JT－60トカマクの計算モデルでは，それぞれが複雑な幾何学的，電気的な特性を有する真空容器，トロイダルコイル，中心支柱，支持架台等ほとんど全ての主要構造物が含まれている。これらの体系において，モーダル解析を基調とする数値計算により464ケの渦電流固有モードを得たが，特徴的な固有関数を図形的に例示した。渦電流効果を含むJT－60プラズマの電流・位置制御問題を考える上で，必要となる状態空間モデルの線形システムパラメータを定量的に評価した。又，各渦電流固有モードが造る複雑な磁場構造を，図形表示を用い例示した。

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1. Introduction

As is well recognized in tokamak CTR research & development, the eddy current study is one of the most important works from the standpoint of a mechanical design and a control analysis of plasma position, current and its cross-sectional shape. In spite of these important requirements, the rational evaluations of eddy current and its resultant magnetic field are quite difficult because of the complexity of machine geometry and/or its electrical property[1,2]. In the earlier phase of JT-60 design studies, the eddy current problem had been solved using a primitive model for the considered torus, and then, the torus conductor was assumed to be consisted of the assembly of axisymmetric loop coils, neglecting the distribution of the actual torus resistivity due to the bellows section or the electrical insulation. The advanced approach based on the finite element circuit method was investigated in order to solve the general eddy current problem in an arbitrarily shaped and resistive torus[3]. In order to apply this method to the design studies of tokamak device, computer program EDDYTORUS neglecting the mutual coupling between conductors was developed in JAERI to solve an eddy current problem in a single torus system. However, the self-consistent evaluation of eddy current in the actual tokamak system must be carried out including most of the main structural components such as a vacuum vessel, toroidal field coils and various kinds of support structures. Particularly, the eddy current analysis for plasma control study must be carried out in this composite torus system.

A state-space approach to the analysis and its synthesis of plasma control system including eddy current effect will be a promising way, where the lumped parameter sub-system of eddy current must be described as a part of the state-space model. For this reason, the modal expansion technique of eddy current is considered to be decidedly superior to the other approach, such as FEM. Computer program EDDYMULT solving the eddy current problem in a multi-torus system was newly developed in JAERI[4,5], and using this code numerical computations of eddy current in JT-60 tokamak were carried out to obtain the state-space model describing eddy current effect. As was mentioned above, the numerical model of JT-60 multi-torus system includes most of the main torus components such as a vacuum vessel, toroidal field coils, a central column and two sets of support plates. This report shows the numerical results of eddy current analysis in JT-60 multi-torus system using EDDYMULT as one of the indispensable basic data of the plasma control analysis.

In the following chapter, outline of numerical procedure of computer program EDDYMULT is roughly described, therefore, one interested in the detailed procedure should refer to the paper by Nakamura and Ozeki (1981)[4]. In Chap. 3, the machine structure of JT-60 tokamak is briefly represented and the numerical model of JT-60 multi-torus system is discussed assuming a symmetry with respect to an equatorial plane and periodicities along a toroidal direction. In Sec. 3.3, the plasma model is shortly represented to obtain the linear parameters of magnetic interactions between a torus plasma and the individual eddy current modes. In Sec. 4.1, the results of eigen value analysis of eddy current in JT-60 tokamak are summarized in the numerical tables of eigen values and the schematic illustrations of eigen functions. Because the plasma control analysis of radial expansive mode is one of the most important and essential problem in tokamak fusion research, the relating linear system parameters of a state-space model are evaluated to be listed as the numerical tables in Sec. 4.2. The other parameters of mutual coupling between the individual eddy current modes and each set of poloidal field coil systems such as an ohmic heating coil, a vertical field coil, a quadrupole field coil and a magnetic limiter coil are also numerically shown. In Sec. 4.3, the complicated magnetic structures corresponding to the each eddy current eigen mode are graphically shown. In Chap. 5, the model order reduction of a linear state-equation including an eddy current effect is pointed out to be essential to perform the control analysis and synthesis of plasma control system successfully.

2. Computer program EDDYMULT

To perform the eddy current analysis in a multi-torus system, numerical code EDDYMULT based on the finite element circuit method was developed in JAERI[4]. In our computer program, each sub-torus was assumed to be infinitely thin and symmetrically assembled with respect to an equatorial plane of the considered system. Each sub-torus is also considered to be electrically disconnected with the others. However, our numerical code gives no restrictions for the shape of a torus cross-section, the aspect ratio and the distribution of torus electrical resistivity. Any kinds of electrical cut corresponding to an electrical insulation and the port holes of individual sub-torus can be considered. In this chaper, we will outline the numerical procedure of EDDYMULT.

As is discussed in the papers by Kameari et. al. (1977)[3] and Nakamura et. al. (1981)[4], one can largely reduce a system order of the considered finite element circuits using a symmetry of torus geometry with respect to an equatorial plane and a periodicity along a toroidal direction. Let us consider a cylindrical coordinate system (R, ϕ, Z), where $Z = 0$ means an equatorial plane of torus system. Generally speaking, current potential $V(z)$ on the considered sub-torus can be decomposed into its odd parity part V_z^- and even parity part V_z^+ with respect to this equatorial plane;

$$V_z^+ = \frac{1}{2} (V(z^+) + V(z^-)) \quad , \tag{1}$$

$$V_z^- = \frac{1}{2} (V(z^+) - V(z^-)) \quad , \tag{2}$$

where, $z^+ \geq 0$ and $z^- < 0$. Because of a symmetry of torus geometry with respect to an equatorial plane, the odd and even parity parts of current potential magnetically and resistively decouple with each other, so that, one can discuss separately the usual eddy current problem with every parity part of current potential. Furthermore, the actual torus geometry have often a some kind of periodicity along a toroidal direction. Using this periodicity, the individual parity part with respect to an equatorial plane V_z^{ε} (ε = +, -) can be rewritten by

$$V_{z,\phi}^{\varepsilon,+} = \frac{1}{2}\,(V_z^{\varepsilon}(\phi^+) + V_z^{\varepsilon}(\phi^-)) \quad ,$$
$$V_{z,\phi}^{\varepsilon,-} = \frac{1}{2}\,(V_z^{\varepsilon}(\phi^+) - V_z^{\varepsilon}(\phi^-)) \quad . \qquad (3)$$

ϕ means a toroidal angle measured from the origin of periodicity. From these discussions, the usual current potentical V can be represented as follows;

$$V = \sum_{\varepsilon}^{+,-} \sum_{\eta}^{+,-} V_{z,\phi}^{\varepsilon,\eta} \quad , \qquad (4)$$

where, η (= +,-) is a parity of toroidal periodicity. In the case of ideally arranged torus system, the individual parity parts of current potential are magnetically decoupled with each other, so that, one can largely reduce a system order of circuit equation. The magnetic structures due to the individual parity parts are illustrated in Fig. 1. In this report, we show the numerical results of eddy current only for the odd parity part with respect to an equatorial plane and the even parity part with respect to a periodicity along a toroidal direction which couples only with the even parity part of externally applied magnetic vector potential of axisymmetric current.

Dividing the i-th sub-torus into the finite elements as shown in Fig. 2, a set of circuit equations can be defined, such that

$$M_i \dot{X} + R_i X = E_i \qquad (5)$$

here, $M_i \in R^{n_i \times n_i}$ and $R_i \in R^{n_i \times n_i}$ denote an inductance and a electrical resistance matrix which is obtainable by means of energy integration, respectively[3,4] $E_i \in R^{n_i}$ means the externally applied electromotive force vector. $X \in R^{n_i}$ means a current vector defined on the nodal points of these finite element circuits.

Figure 3 roughly shows the main procedure of EDDYMULT based on the method of eigen value analysis. For the eddy current problem in a multi-torus system consisted of I sub-torus components, we can also represent the similar circuit equation to Eq. (5). For the convenience of a practical computation in a multi-torus system, however, we take two steps of consideration to avoid the restrictions of computer storage and computing time.

At first, neglecting the magnetic coupling between sub-tori we solve the following eigen value problem for the i-th sub-torus;

$$M_i X = D_i(\lambda) R_i X \tag{6}$$

where, $D_i(\lambda)$ denotes the diagonal matrix with its eigen value λ in the diagonal element. The k-th element $x_k(\phi, \ell)$ of eigen vector X denotes the current potential of the k-th finite element circuit as follows;

$$J_k = \nabla \times x_k \quad , \tag{7}$$

where J_k is a current density vector lying on the considered sub-torus. Generally speaking, the magnetic coupling of higher modes to any eigen modes on the other sub-torus are negligible becase of its physical nature and these higher modes does not essentially play an important role in the eddy current system. So that, we can eliminate a part of higher modes on the individual sub-torus from the full set of original eigen modes in a multi-torus system and can avoid the limitation of computer storage and computing time which should be inevitable in the eddy current analysis of the orginal complete system.

Secondly, we solve the following reduced eigen value equation for the multi-torus system after evaluating the mutual inductance between the individual sub-torus;

$$M' X = D(\tau) X \quad , \tag{8}$$

where, τ is eigen value for multi-torus system and

$$M' = \begin{bmatrix} D_1(\lambda) & M_{12} \cdots & M_{1I} \\ & D_2(\lambda) & \vdots \\ \text{Sym.} & \ddots & M_{I-1I} \\ & & D_I(\lambda) \end{bmatrix} \tag{9}$$

$M_{ij} \in R^{n_i \times n_j}$ (i, j = 1,...I) denotes a sub-matrix corresponding to the magnetic coupling between the i-th and j-th sub-tori. After solving the eigen value problem given by Eq. (8), we can finally obtain the eigen modes of eddy current in the considered multi-torus system. For the obtained eigen mode ℓ, a circuit equation is represented by

$$\tau_\ell \dot{\xi}_\ell + \xi_\ell = \varepsilon_\ell \quad , \tag{10}$$

where, ξ_ℓ means a corrent of the eigen mode ℓ and ε_ℓ denotes the externally applied electromotive force. The solution of this equation can be easilly obtained such that

$$\xi_\ell(t) = \xi_\ell(0) \exp(-\frac{t}{\tau_\ell}) + \frac{1}{\tau_\ell} \int_0^t \varepsilon_\ell \exp(\frac{t'-t}{\tau_\ell}) dt' \tag{11}$$

where, $\xi_\ell(0)$ means an initial current of the eigen mode ℓ at t = 0.

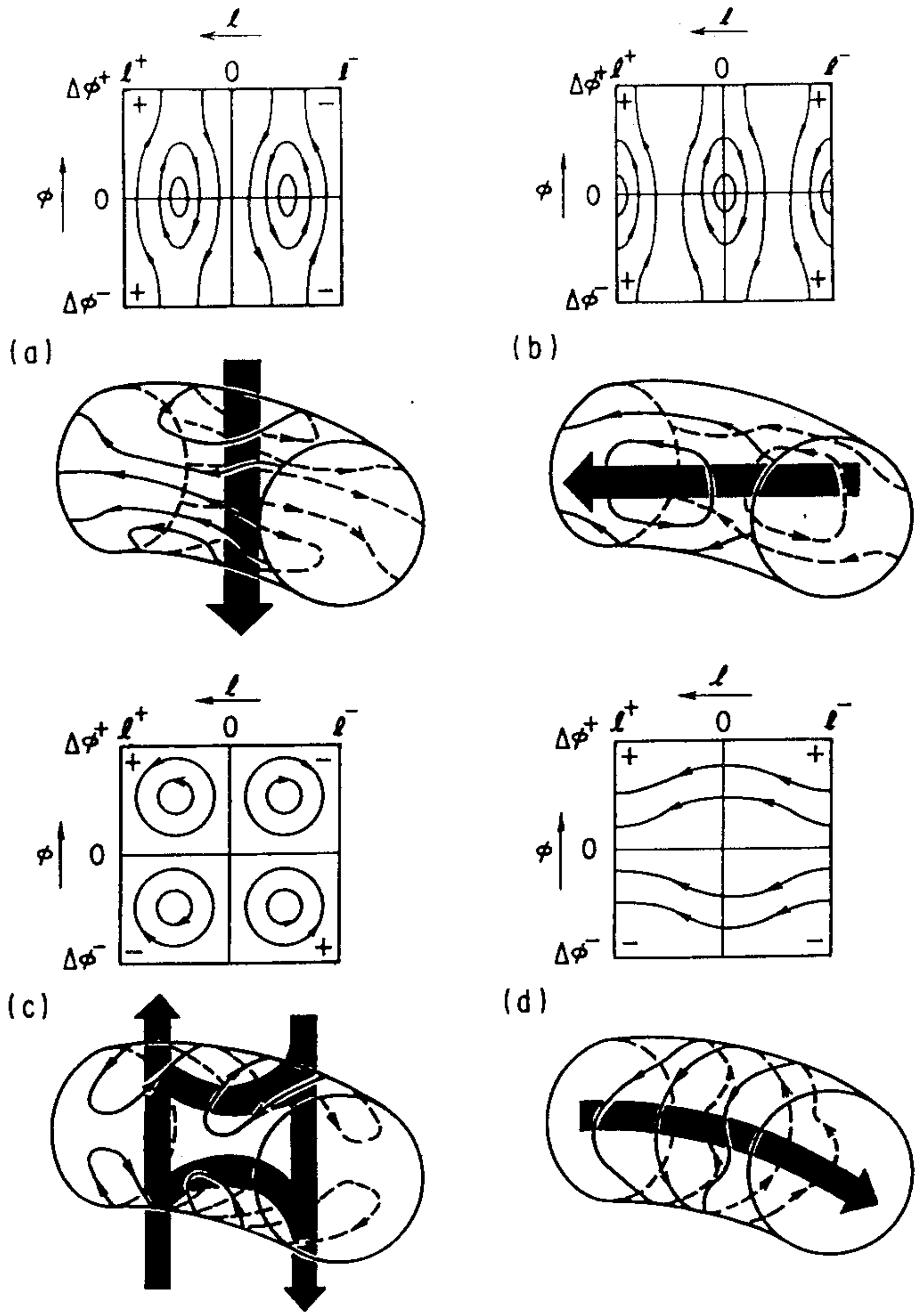

Fig.1 Parity of eddy current potential (shown by a thin arrow) and its corresponding magnetic structure (shown by a thick arrow). $2\Delta\phi$ is the toroidal angle of minimum periodicity and $|\ell^+|$ $(=|\ell^-|)$ is the circumferential length along a torus cross-section from the outer most radial point of the torus. In the case of $\Delta\phi = \pi$ there are only these four cases, but in the case of $n\Delta\phi = \pi (n=2,3,...)$ there are many parities like figure (c).

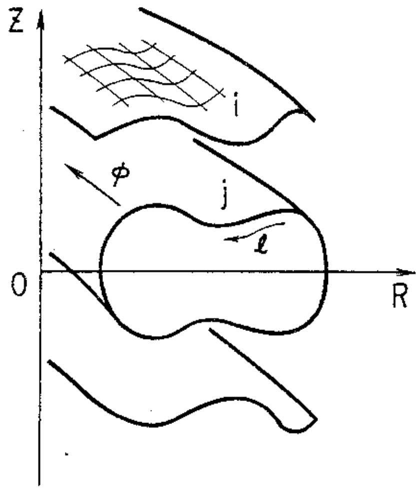

Fig.2 Multi-torus system and division of the i-th sub-torus into finite elements

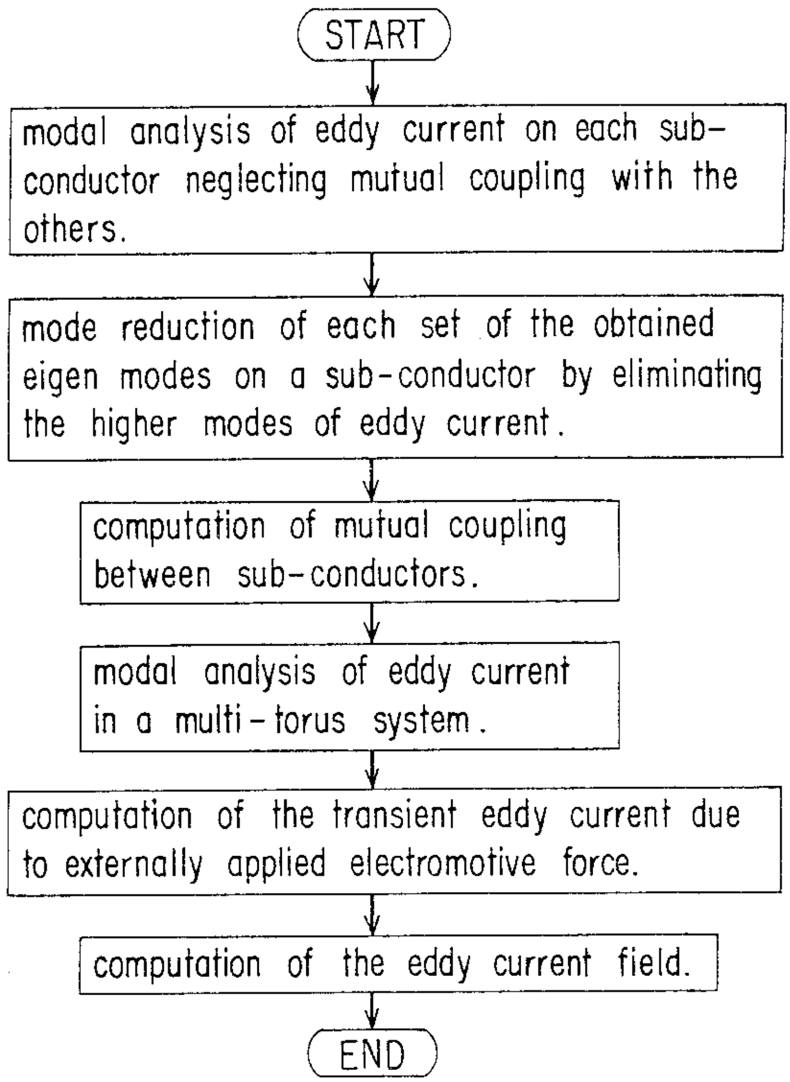

Fig. 3 Outline of EDDYMULT flow diagram

3. Outline of JT-60 tokamak and numerical model

JT-60 is a large tokamak aiming at the fusion reactor like plasma condition with a major radius 3.03 m and a minor radius 0.95 m. The maximum strength of a toroidal magnetic field is 4.5 Wb/m^2 and the maximum plasma current of 2.7 MA is obtainable. Because that the eddy current behaviour in the actual torus system largely depends on the structural geometry and the electrical characteristics of the considered device, one must take sufficient care not to overlook those remarkable features. This chapter is mainly spent for the brief representation of JT-60 machine structure to obtain a valid tokamak model in the numerical calculation and for the description of axisymmetric plasma model neglecting a deformation of plasma shape.

3.1 Outline of JT-60 tokamak

Bird's-eye view of JT-60 tokamak is shown in Fig. 4 and the main device specifications are listed in Table 1. The following structural components of JT-60 tokamak are interesting from the standpoint of plasma control analysis, i.e., a vacuum vessel, toroidal field coils, a central column, two sets of support structures and poloidal field coil systems. The other main facilities such as neutral beam injectors, a radio frequency heating system, a vacuum pumping system and a support column of a vacuum vessel can be probably ignored since they are assembled keeping away from the main components of JT-60 tokamak.

Figure 5 shows JT-60 vacuum vessel composed of Inconel 625 eight rigid and bellows sectors with the shape of non-circular cross-section. The necessary one-turn resistivity of a vacuum vessel is designed to obtain 1.3 m Ω mainly by the bellows sectors. Two sectors and the other six ones extend for 60° and 40° along a toroidal direction, respectively.

Figure 6 shows a coil unit of the toroidal field coil system, which generates the maximum toroidal field 4.5 Wb/m^2 at the major radius position 3.03 m. Eighteen toroidal field coils are assembled axisymmetrically around the torus axis. One coil are consisted of two wedge-shaped pancakes, each of which is composed of 36-turned copper conductors.

Figure 7 shows a pair of high manganese steel support plates holding the toroidal field coil system against its twisting moment due to $J \times B$ electromagnetic force caused by a poloidal magnetic field. Each pair of support plates is composed of upper and lower one, respectively. Although the thickness of upper and lower ones is slightly different with each other, as will be mentioned in the later section, we assume that they are same in the numerical model. In order to reduce the eddy current field, a support plate is designed to be electrically insulated along a toroidal direction. Eight poloidal insulations are formed at the same toroidal positions as those of bellows sections of a vacuum vessel.

The central column is located near by a torus axis in order to hold firmly the toroidal field coils against the centripetal electro-magnetic force as shown in Fig. 7. This column is a pile set of eleven high mangenese steel cylindrical blocks without an electrical insulation and is electrically connected in a toroidal direction. The concentrated part of magnetic flux of the ohmic heating coil is surrounded by this central column.

Poloidal field coils are axisymmetrically arranged inside the toroidal field coil bore and outside a vacuum vessel. Poloidal coil system is consisted of an ohmic heating coil, a vertical field coil, a horizontal field coil, a quadrupole field coil and a magnetic limiter coil. These have individual electric power sources. Location and dimension of poloidal field coils are shown in Fig. 8.

3.2 Numerical model of JT-60

In this section, we carry out the discussion to obtain a numerical model of JT-60 tokamak by simplifing the actual system outlined in the last section. The device components in a numerical model are considered to be a vacuum vessel, toroidal field coils, a central column and two sets of support plates. As was mentioned in Chap. 2, we take into account only an odd parity part of current potential with respect to an equatorial plane and an even parity par with respect to the periodicities along a toroidal direction, because that the radial expansive mode of torus plasma is a key problem in a plasma control analysis. In the case of the control analysis of a vertical plasma displacement, an even parity part of current potential with respect to an equatorial plane must be considered. When the multi-torus system is arranged asymmetrically with respect to an equatorial plane, one must treat simultaneously an even and odd parity part of current potential with respect to an equatorial plane since the mutual coupling between these individual parity parts. We assume that JT-60 tokamak is symmetric with respect to an equatorial plane. The schematic drawing of JT-60 tokamak model is shown in Fig. 9.

For the convenience of practical computations, the periodicity of JT-60 multi-torus system along a toroidal direction is assumed to be 40°, although that of JT-60 actual system is 180° since the combination of 40° and 60° sectors of a vacuum vessel and support plates.

To avoid the restrictions of computer storage and computing time, which become a serious problem in the practical computations, each pancake of toroidal field coils was assumed to be composed of 4 equivalent resistive sub-tori instead of the actual 36-turned copper conductors. This assumption is considered to be reasonable because that the actual conductors are wound closely with each other.

From the discussion above, we can finally obtain the following numerical model of JT-60 multi-torus system; The considered JT-60 multi-torus system is ideally arranged to be geometrically symmetry with respect to an equatorial plane and to be periodic along a toroidal direction with the minimum periodicity of 40°. The torus components are a vacuum vessel consisted of 9 rigid and bellows sectors, a toroidal field coil system assembled by 18 coil units consisted of 4-turned sub-tori, a cylindrical central column and two sets of 9 upper and lower support plates. The individual mesh charts given by deviding these sub-tori into finite elements are shown in Fig. 10.

Since we consider only an odd parity part of current potential with respect to an equatorial plane, which decouples with the even parity part of externally applied magnetic vector potential, the horizontal field coil system can be excluded from our model, so that, the poloidal field coil system was assumed to be composed of an ohmic heating coil, a vertical field coil, a quadrupole field coil and a magnetic limiter coil.

3.3 Plasma model

Supposing that

1) Plasma cross-sectional shape is circular,
2) Plasma pressure is enough low comparing with a magnetic pressure ($\beta_p = 0$) ,
3) Plasma current distribution is parabolic ($\ell_i = 1.0$),

the vector potential $A_\phi(R,Z)$ of axisymmetric plasma can be described by

$$A_{\phi}(R,Z) = \frac{\mu_0 I_p}{2\pi k} \sqrt{\frac{R_p}{R}} \{ (2 - k^2) K(k) - 2E(k) \} \quad . \qquad (12)$$

Here, I_p and R_p denotes plasma current and the equivalent major radius of axisymmetric plasma, respectively. K and E are the respective complete elliptic integrals of modulus k

$$k = \sqrt{\frac{4R R_p}{(R+R_p)^2 + Z^2}} \quad . \qquad (13)$$

R_p can be represented using the effective radial shift δ as follows;

$$R_p = R_{p0} + \delta \quad , \qquad (14)$$

where, R_{p0} denotes the major radius of the outer most magnetic surface of equilibrium plasma. From the discussion of usual plasma equilibrium, δ can be easily written by

$$\delta = \frac{a^2}{2R_{p0}} (\Lambda + \frac{1}{2}) \quad . \qquad (15)$$

Here, $\Lambda = \beta_p + \frac{\ell_i}{2} - 1$ and a is a plasma minor radius. In our investigation, R_p (= R_{p0}) is taken to be 3.03 m since the assumptions mentioned above.

In our investigations, the coupling between an eddy current eigen mode and the deformations of plasma cross-section is neglected. For the control analysis including the effect of plasma deformation and the dynamics of plasma current distribution, the numerical calculation of plasma equilibrium must be carried out to obtain numerically the linear system parameters of system matrix describing a state-space model including these state variables.

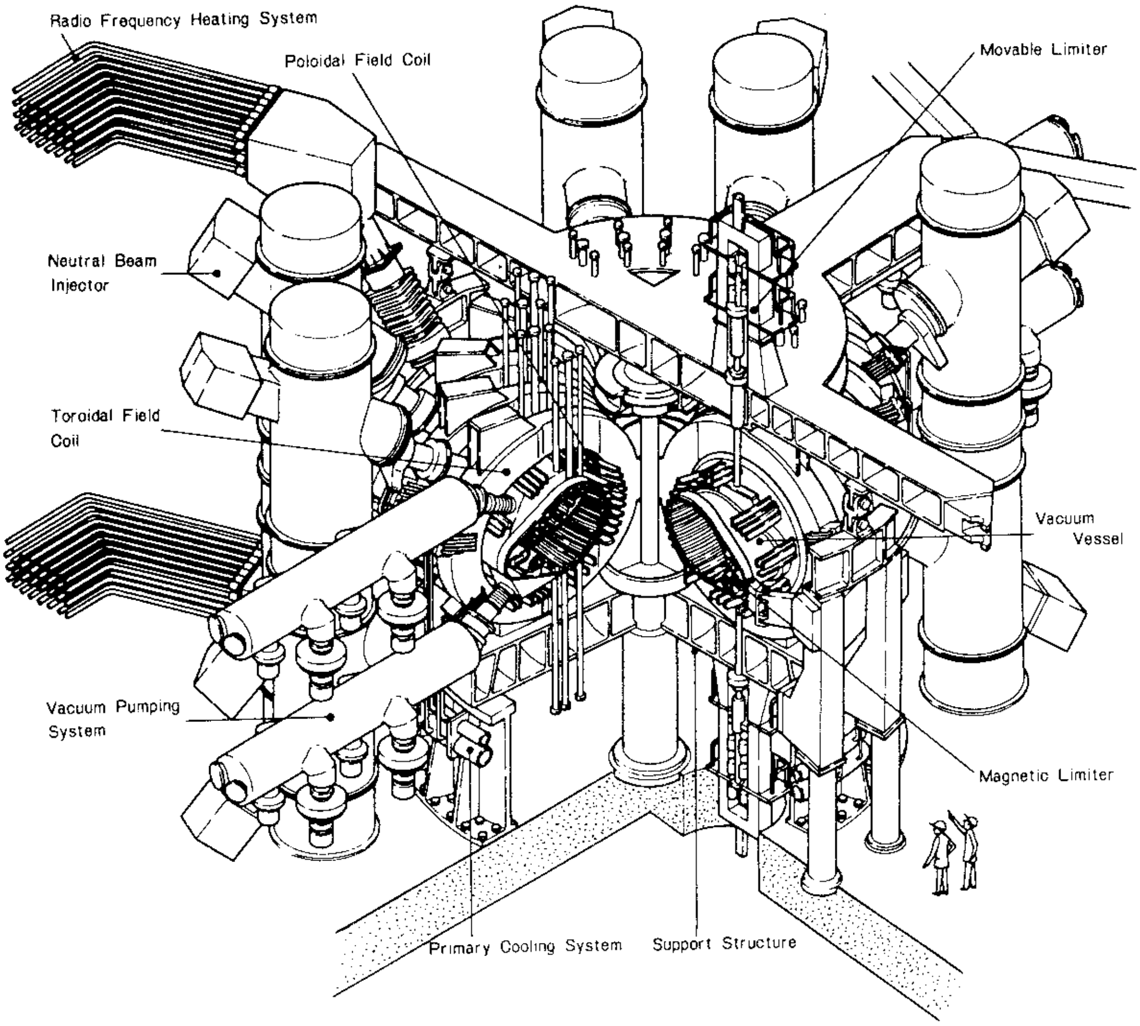

Fig.4 Bird's-eye view of JT-60 tokamak machine

Table 1 Main device specification of JT-60 tokamak

Vacuum vessel	Material	Inconel 625 (129 μΩ·cm)
	Structure	assembly of U-shaped bellows and rigid ring
	Cross-sectional shape	non-circular
	Bellows section · height	67.5 mm
	pitch	20.0 mm
	thickness	2.5 mm
	Rigid section thickness	65.0 mm
Toroidal field coil	Material	oxygen free copper (1.72 μΩ·cm)
	Number of coils	18
	(one coil is composed of two pancakes)	
	Number of turn	36 per pancake
	Coil major radius	3.32 m
	Mean thickness of conductor	21.0 mm
	Maximum width of conductor	270 mm
Upper and lower support structure	Material	high manganese steel (71 μΩ·cm)
	Structure	assembly of 8 sectors ellectrically insulated with each other
	Mean thickness	85 mm
	General inside radius	2.0 m
	General outside radius	5.5 m
Central column	Material	high manganese steel (71 μΩ·cm)
	Structure	a pile set of eleven cylindrical blocks
	Total height	5.6 m
	Mean thickness	200 mm
	Mean radius of cylinder	226 mm

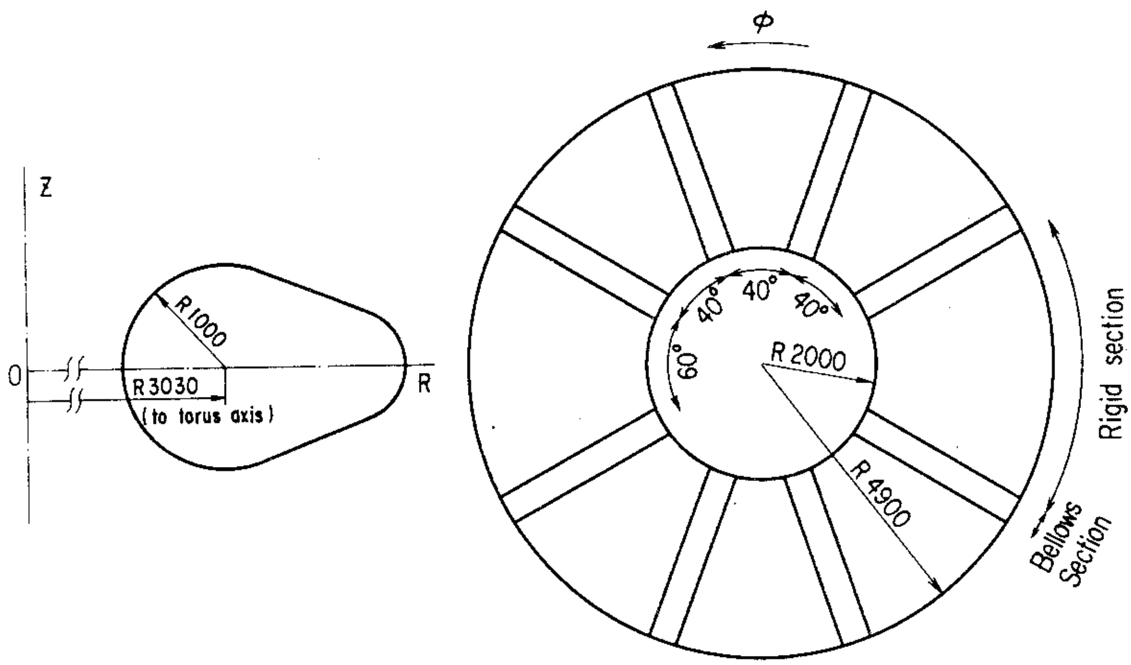

Fig.5 JT-60 vacuum vessel

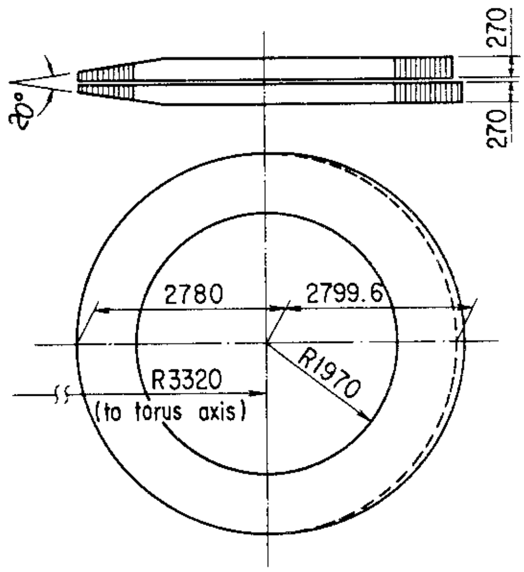

Fig.6 Toroidal field coil

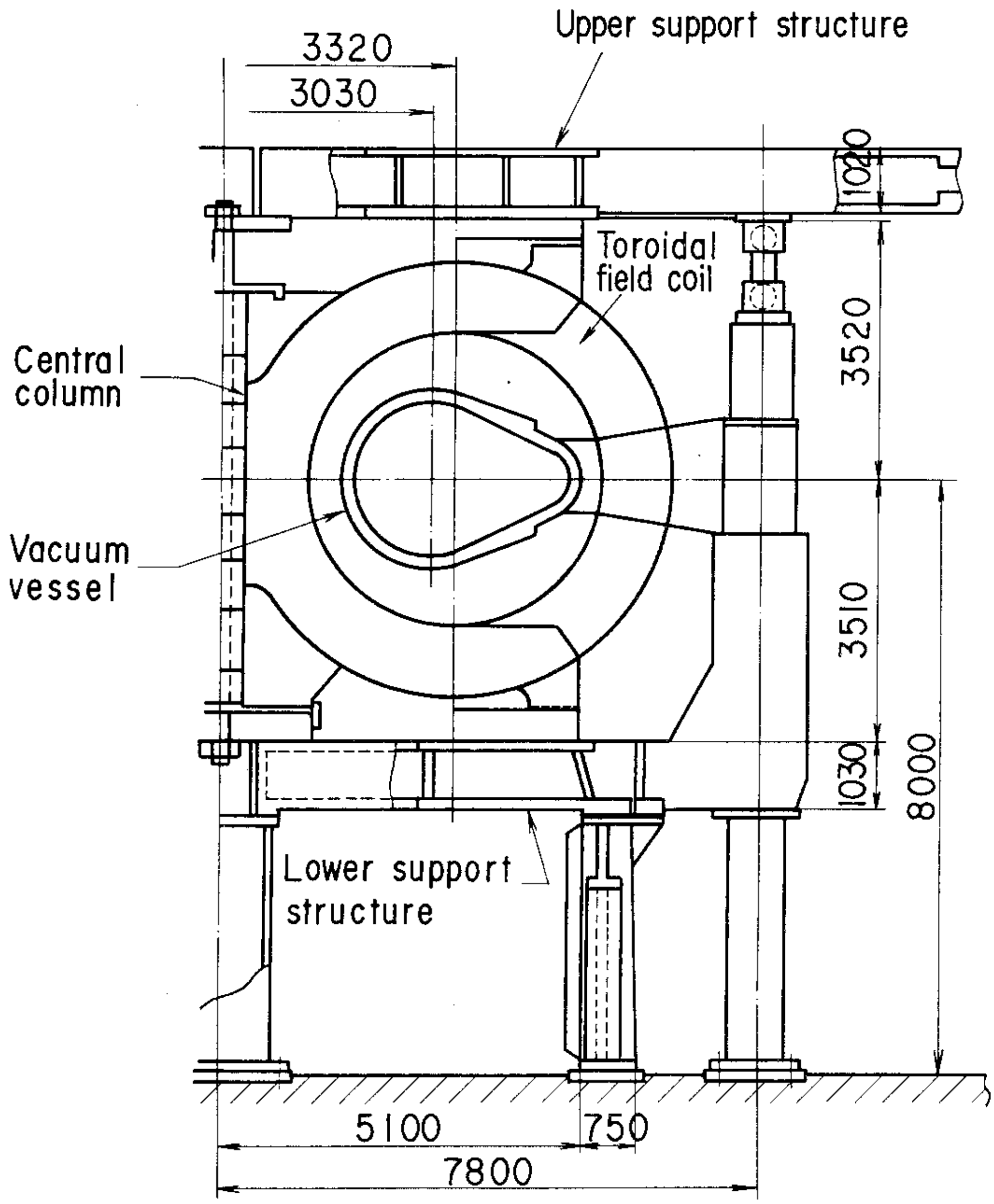

Fig. 7 Cross sectional view of JT-60 tokamak

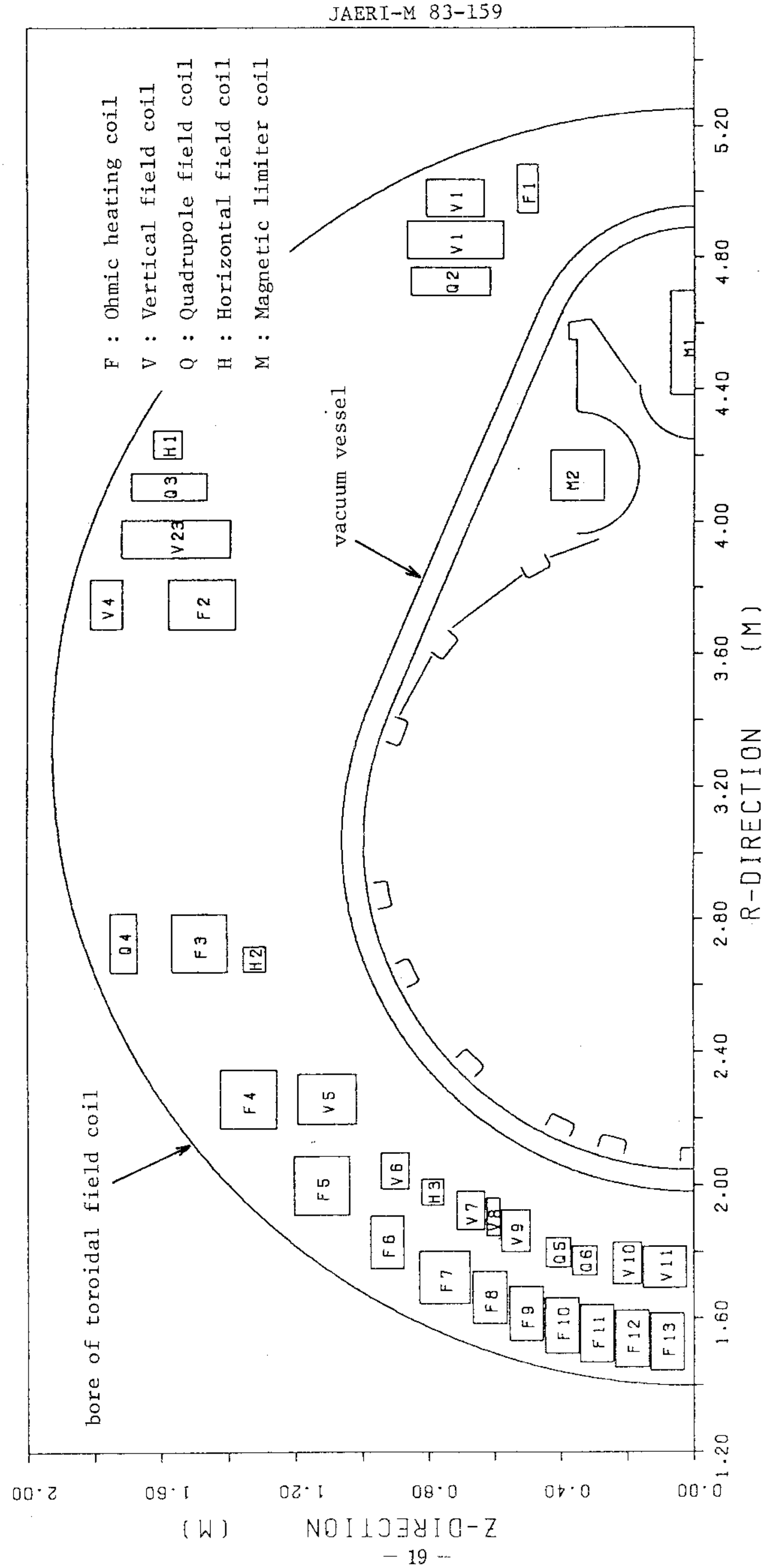

Fig.8 Cross sectional view of poloidal field coils

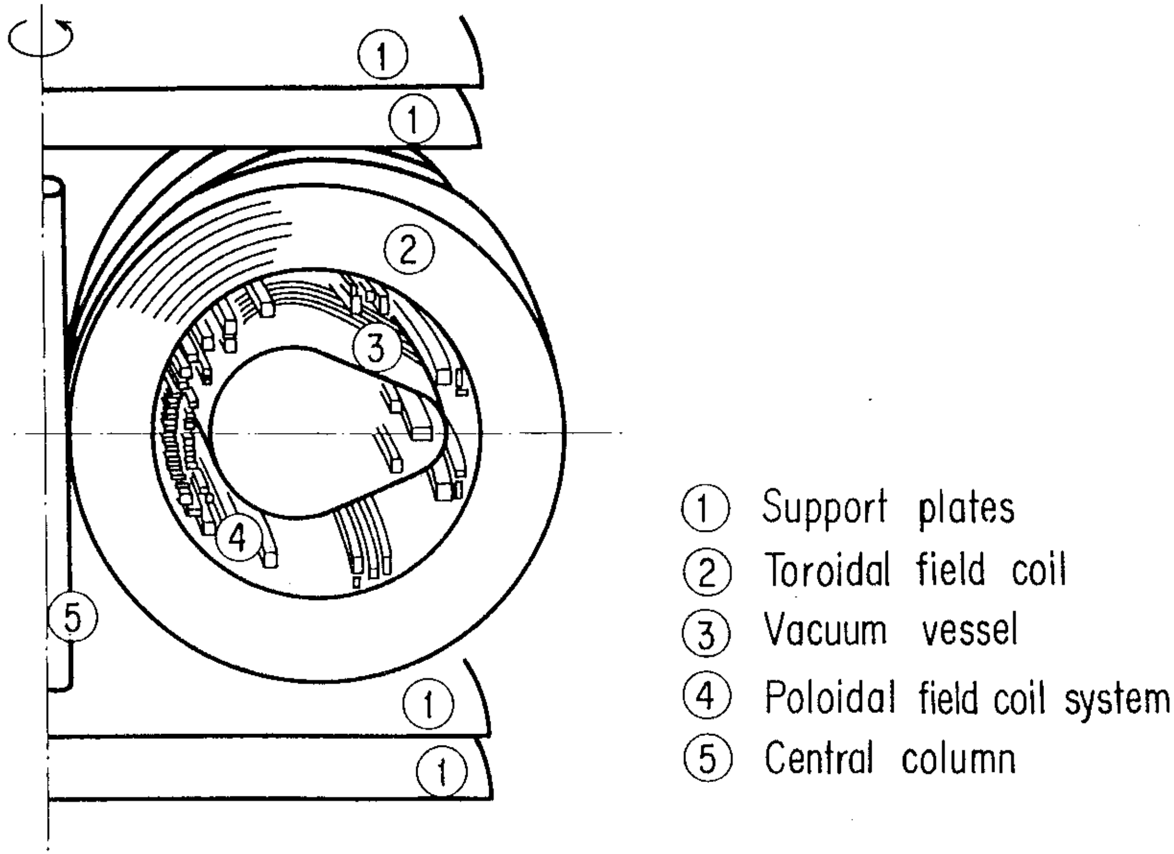

Fig.9 Scematic drawing of JT-60 tokamak model

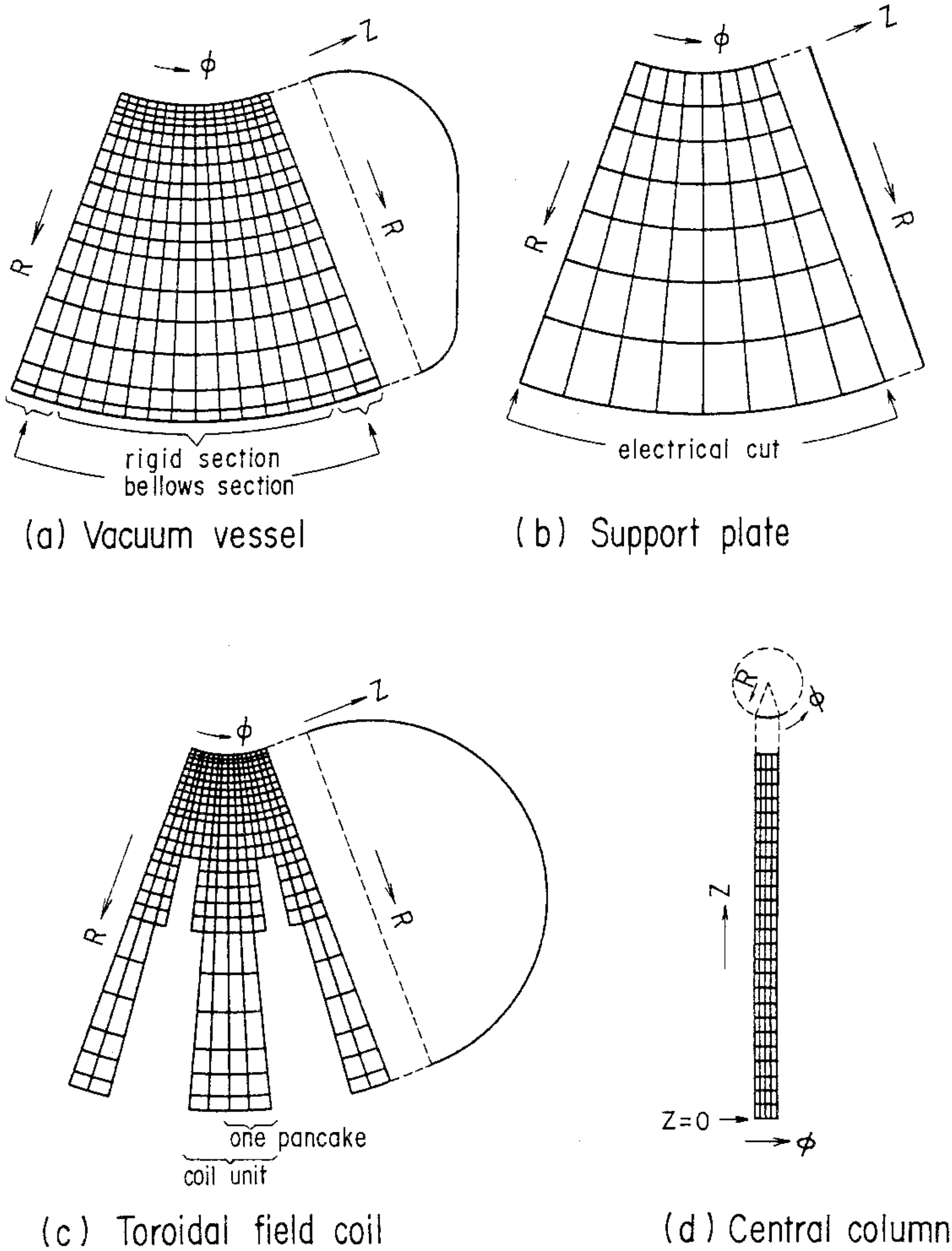

Fig.10 40° toroidal cut of mesh chart of JT-60 multi-torus components

4. Numerical results

Supposing the symmetrical arrangement of individual torus components with respect to an equatorial plane and 40° periodicity along a toroidal direction, the parity of eddy current potential is assumed odd with respect to an equatorial plane and even with respect to the poloidal plane of toroidal periodicities. 464 eigen modes of this parity part of eddy current in JT-60 multi-torus system were numerically obtained by the computer program EDDYMULT using FACOM M-200 computer. The numerical error due to eigen value analysis can be estimated according to the following principles which are well known in linear algebra;

1) $\mathrm{trace}\ (M') = \sum_{\ell} \tau_{\ell}$ (16)

   here, M' and τ_{ℓ} means a system matrix and an eigen value of ℓ-th eigen mode given by Eq. (8), respectively.

2) $(\chi_{\ell} , \chi_m) = \delta_{\ell,m}$ (17)

   Obtained eigen function must be orthonormal in principle. Here, $\delta_{\ell,m}$ is Kronecker's simbol.

The similarity of matrix linear transformation 1) was checked to be approved within the error of 0.01% in JT-60 calculation. The orthonormality of numerically obtained eigen functions 2) was also confirmed to hold within the error of 9%.

In Sec. 4.1, all of the obtained eigen values and the typical eigen functions are summerized. In Sec. 4.2, the mutual inductances between the eddy current mode and individual poloidal field coil system, such as an ohmic heating coil, a vertical field coil, a quadrupole field coil and a magnetic limiter coil, are listed in the numerical tables. For the control analysis of radial plasma expansive mode, the linear parameters in a state-space model are also numerically evaluated by Taylor expanding around the equilibrium state.

In Sec. 4.3, the magnetic structures of each eddy current modes were illustrated, so that, one can roughly discuss the effect of eddy current on the plasma shape control.

4.1 Eigen value analysis of JT-60 eddy current

To obtain the eddy current eigen mode in JT-60 multi-torus system, firstly, the usual eigen value analysis for individual torus components neglecting a mutual coupling with the others is carried out according to the numerical procedure adopted in EDDYMULT. The obtained 154 eigen values for a vacuum vessel eigen modes are listed in Table 2. The numerical model of toroidal field coils is simplified to 4 turns, therefore, 4 sets of 110 eigen values for individual conductors are listed in Table 3, 4, 5, 6, respectively. Here, No. 1 and No. 4 toroidal field coils means the inner most conductor and the outer most one, respectively. 2 sets of 24 eigen values for support plates are listed in Table 7 and 8, respectively. Here, No. 1 support plate means the inner one of two sets of support plates. 73 eigen values for a central column are listed in Table 9.

Using the eddy current eigen modes individually obtained by the eddy current analysis of each sub-torus, we can describe a set of circuit equation in the multi-torus system. However, as was discussed in Chap. 2 this direct approach is not practical in the continuing analysis since the computer restrictions. To avoid these restrictions of computer storage and computing time in practical computations, those obtained eigen modes are reduced by eliminating the higher modes of individual torus component as shown in Table 10.

Secondly, according to the numerical procedure of computer program EDDYMULT outlined in Fig. 3, the eigen value problem in those multi-torus system is solved after the evaluation of mutual coupling between each torus component by means of energy integration. 464 eigen values of system eigen modes for JT-60 multi-torus are summerized in Table 11. As will be schematically shown, eigen modes numbered from 1 to 200 are mainly distributed on the conductors of JT-60 toroidal field coils. The higher modes than the mode No. 216 (τ = 17.0 msec) are mainly distributed on a vacuum vessel. Mode number 201 (τ = 45.5 msec), 205 (τ = 31.6 msec) and 211 (τ = 21.9 msec) mainly lie on the outer and inner support plates. Mode No. 202 (τ = 40.7 msec) is mainly distributed on a central column. Those contour maps of system eigen functions are illustrated in Figs. 11-21.

Roughly speaking, a toroidal field coil system weakly couples with the other torus-conductors in JT-60 multi-torus system. On the contrary, the torus conductors except for a toroidal fiedl coil system, such as a vacuum vessel, a central column and support plates, strongly couple with each other through the magnetic interaction.

4.2 Numerical tables for a state-space model

Considering the eddy current eigen modes obtained in the last section to be the sub-system of a linear state-space model, we can represent JT-60 plasma position and current control model neglecting the deformation of plasma shape and the dynamic behavior of plasma current distribution. Letting v_p be a plasma radial velocity, the equation of plasma motion can be expressed as follows;

$$m_p \dot{v}_p = \frac{\mu_0 I_p^{\ 2}}{2} \left(\ell n \frac{8R_p}{a} + \Lambda - \frac{1}{2}\right) - 2\pi R_p I_p B_z \quad , \qquad (18)$$

where, m_p is a plasma mass and B_z is a vertical field for plasma equilibrium. Linearizing Eq. (18) by expanding around the equilibrium state and combining this with the circuit equation of eddy current, a linear state equation can be represented by

$$\dot{X} = A X + B U , \tag{19}$$

where, $X \in R^n$ and $U \in R^n$ are a state variable and a control input. respectively.

The coupling term between state variables in the system matrix $A \in R^{n\times n}$ is obtainable by use of the numerically obtained eigen functions of eddy current. Namely, the mutual inductance M_{kj} between the externally applied axisymmetric vector potential $A_\phi(k)$ of the k-th coil system and the j-th eddy current mode and a linear parameter $\partial M_p/\partial R$ due to a plasma radial motion can be numerically evaluated. Since the eigen function of each eddy current mode was normalized so that its joule loss is 1 watt, the physical unit of all of the mutual inductances M_{kj} is $H/\sqrt{\Omega}$. Using the definition of mutual inductance;

$$M_{kj} = \mu_0 \iint A_\phi(k) \frac{\partial V_j}{\partial \ell} R \, d\phi \, d\ell , \tag{20}$$

the numerical values of M_{kj} are summerized in Table 12 and those are also graphically shown in Figs. 22-26. The parameter $\partial M_p/\partial R$ is numerically listed in Table 13 and graphically shown in Fig. 27.

Each eddy current mode x_j produces a vertical field δB_{zj} on a equilibrium position;

$$\delta B_{zj} = \nu_j x_j , \tag{21}$$

where, ν_j (Wb/m²Amp.$\sqrt{\Omega}$) means a vertical field due to eddy current of its joule loss of 1 joule/sec. Although ν_j is distributed along a toroidal direction because of the toroidal distribution of resistivity of considered multi-torus system, the averaged value $\bar{\nu}_j$ over a toroidal periodicity is interesting from a standpoint of radial plasma position and current control analysis. $\bar{\nu}_j$ relates with a parameter $\partial M_p/\partial R$

summarized in Table 13 by the relation[6];

$$\bar{\nu}_j = \frac{1}{2\pi R_p} \cdot \frac{\partial M_p}{\partial R} \qquad (22)$$

Those are summerized in Table 14.

In the case of control study of a plasma deformation and a plasma current distribution, one must carry out the numerical calculation to obtain the linear parameters corresponding to these state variables using the numerically obtained plasma equilibrium function $A_\phi(R,Z)$ instead of that given by Eq. (12).

4.3 Flux map of magnetic force line due to eigen mode

The complicated flux maps of magnetic force lines averaged over the toroidal periodicity are graphically shown in Fig. 28. The numerical value along a force line means the magnetic flux function due to eddy current of individual eigen mode, here its physical unit is Wb/Amp. $\sqrt{\Omega}$. From these figures graphically shown, it appears that the magnetic structures corresponding to the eigen modes numbered from 1 to 200 except the mode No. 5 are mainly determined by the distributed eddy current on the toroidal field coils. The magnetic structures corresponding to the higher modes than the mode No. 216 (τ = 17.0 msec) are mainly produced by the current on a vacuum vessel. The magnetic structures corresponding to the mode No. 201 (τ = 45.5 msec), 205 (τ = 31.6 msec) and 211 (τ = 21.9 msec) are mainly determined by the eddy current on the outer and inner support plates. The eddy current mainly distributed on a central column produces the magnetic fields shaped like that of the mode No. 202.

Table 2 Eigen value of vacuum vessel eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.1620038E-01	2	0.1163685E-01	3	0.9219471E-02	4	0.7756624E-02	5	0.6689657E-02
6	0.6526783E-02	7	0.5693860E-02	8	0.5500339E-02	9	0.5056392E-02	10	0.4750654E-02
11	0.4646558E-02	12	0.4231796E-02	13	0.4062824E-02	14	0.3989942E-02	15	0.3856435E-02
16	0.3593571E-02	17	0.3536707E-02	18	0.3511932E-02	19	0.3291531E-02	20	0.3179757E-02
21	0.3175369E-02	22	0.3096374E-02	23	0.2935637E-02	24	0.2894830E-02	25	0.2872365E-02
26	0.2746746E-02	27	0.2741305E-02	28	0.2672920E-02	29	0.2667628E-02	30	0.2546862E-02
31	0.2492994E-02	32	0.2474891E-02	33	0.2381230E-02	34	0.2280604E-02	35	0.2273511E-02
36	0.2270119E-02	37	0.2229488E-02	38	0.2116801E-02	39	0.2075700E-02	40	0.2061365E-02
41	0.2017722E-02	42	0.2002630E-02	43	0.1992833E-02	44	0.1928800E-02	45	0.1895034E-02
46	0.1879385E-02	47	0.1826191E-02	48	0.1815569E-02	49	0.1769197E-02	50	0.1754504E-02
51	0.1752051E-02	52	0.1747011E-02	53	0.1726376E-02	54	0.1649978E-02	55	0.1643386E-02
56	0.1631414E-02	57	0.1623164E-02	58	0.1607392E-02	59	0.1601500E-02	60	0.1541374E-02
61	0.1515872E-02	62	0.1510856E-02	63	0.1501945E-02	64	0.1492786E-02	65	0.1447640E-02
66	0.1426100E-02	67	0.1425303E-02	68	0.1404194E-02	69	0.1401222E-02	70	0.1337189E-02
71	0.1336977E-02	72	0.1329847E-02	73	0.1299371E-02	74	0.1297605E-02	75	0.1269989E-02
76	0.1242425E-02	77	0.1224868E-02	78	0.1223516E-02	79	0.1179266E-02	80	0.1177669E-02
81	0.1170188E-02	82	0.1158133E-02	83	0.1139780E-02	84	0.1120023E-02	85	0.1094045E-02
86	0.1064897E-02	87	0.1043828E-02	88	0.1037304E-02	89	0.9997443E-03	90	0.9881102E-03
91	0.9659589E-03	92	0.9414323E-03	93	0.9398069E-03	94	0.9003810E-03	95	0.8872901E-03
96	0.8690238E-03	97	0.8428614E-03	98	0.8326352E-03	99	0.7992249E-03	100	0.7854651E-03
101	0.7646515E-03	102	0.7391542E-03	103	0.7156462E-03	104	0.6977229E-03	105	0.6831293E-03
106	0.6818906E-03	107	0.5379869E-03	108	0.4460711E-03	109	0.4258309E-03	110	0.3420187E-03
111	0.3370801E-03	112	0.3153591E-03	113	0.2910146E-03	114	0.2789861E-03	115	0.2648407E-03
116	0.2478214E-03	117	0.2324093E-03	118	0.2086166E-03	119	0.1933946E-03	120	0.1821961E-03
121	0.1711888E-03	122	0.1666497E-03	123	0.1441129E-03	124	0.1414161E-03	125	0.1335404E-03
126	0.1301247E-03	127	0.1147228E-03	128	0.1052308E-03	129	0.1039936E-03	130	0.9693766E-04
131	0.8379566E-04	132	0.8275799E-04	133	0.8122451E-04	134	0.7392085E-04	135	0.6991318E-04
136	0.6906156E-04	137	0.6028128E-04	138	0.5915228E-04	139	0.5827719E-04	140	0.5371679E-04
141	0.4874587E-04	142	0.4621928E-04	143	0.4288170E-04	144	0.3854616E-04	145	0.3759311E-04
146	0.3459162E-04	147	0.3137620E-04	148	0.2856430E-04	149	0.2618546E-04	150	0.2421047E-04
151	0.2111570E-04	152	0.2054663E-04	153	0.1711688E-04	154	0.1403230E-04		

Table 3 Eigen value of No.1 toroidal field coil eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.4030529E+00	2	0.4012490E+00	3	0.3788359E+00	4	0.3757759E+00	5	0.3662777E+00
6	0.3452641E+00	7	0.3412729E+00	8	0.3309736E+00	9	0.3201681E+00	10	0.3194863E+00
11	0.3039268E+00	12	0.3013440E+00	13	0.2998601E+00	14	0.2991401E+00	15	0.2848772E+00
16	0.2809718E+00	17	0.2736230E+00	18	0.2653146E+00	19	0.2562444E+00	20	0.2550226E+00
21	0.2496068E+00	22	0.2449569E+00	23	0.2352337E+00	24	0.2345856E+00	25	0.2219750E+00
26	0.2194402E+00	27	0.2157926E+00	28	0.2132408E+00	29	0.2063758E+00	30	0.2037143E+00
31	0.2027751E+00	32	0.1994481E+00	33	0.1910691E+00	34	0.1886556E+00	35	0.1869806E+00
36	0.1843413E+00	37	0.1833445E+00	38	0.1818364E+00	39	0.1816415E+00	40	0.1775702E+00
41	0.1742147E+00	42	0.1682003E+00	43	0.1671519E+00	44	0.1666837E+00	45	0.1664713E+00
46	0.1643744E+00	47	0.1583709E+00	48	0.1548927E+00	49	0.1547702E+00	50	0.1530151E+00
51	0.1521891E+00	52	0.1518863E+00	53	0.1451096E+00	54	0.1445589E+00	55	0.1440012E+00
56	0.1416109E+00	57	0.1401987E+00	58	0.1362071E+00	59	0.1338611E+00	60	0.1335946E+00
61	0.1326377E+00	62	0.1319069E+00	63	0.1276748E+00	64	0.1217724E+00	65	0.1193641E+00
66	0.1180934E+00	67	0.1153571E+00	68	0.1135217E+00	69	0.1088423E+00	70	0.1072819E+00
71	0.1070307E+00	72	0.1034473E+00	73	0.1032406E+00	74	0.9703696E-01	75	0.9611696E-01
76	0.9516579E-01	77	0.9281164E-01	78	0.9214824E-01	79	0.8693135E-01	80	0.8391327E-01
81	0.8264613E-01	82	0.8166420E-01	83	0.7954055E-01	84	0.7701147E-01	85	0.7350004E-01
86	0.7263315E-01	87	0.7208949E-01	88	0.6732154E-01	89	0.6398517E-01	90	0.6361133E-01
91	0.6287694E-01	92	0.5804049E-01	93	0.5636013E-01	94	0.5555620E-01	95	0.5350906E-01
96	0.4996543E-01	97	0.4915673E-01	98	0.4827945E-01	99	0.4455896E-01	100	0.4170379E-01
101	0.4089482E-01	102	0.3618634E-01	103	0.3323276E-01	104	0.2843567E-01	105	0.2633695E-01
106	0.2139571E-01	107	0.2016239E-01	108	0.1487928E-01	109	0.1413167E-01	110	0.7688470E-02

Table 4 Eigen value of No.2 toroidal field coil eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.4298686E+00	2	0.4279579E+00	3	0.4055572E+00	4	0.4025546E+00	5	0.4011651E+00
6	0.3715118E+00	7	0.3675488E+00	8	0.3622206E+00	9	0.3511137E+00	10	0.3505235E+00
11	0.3301418E+00	12	0.3299957E+00	13	0.3281326E+00	14	0.3251861E+00	15	0.3140827E+00
16	0.3083580E+00	17	0.3009348E+00	18	0.2920989E+00	19	0.2821101E+00	20	0.2803441E+00
21	0.2745889E+00	22	0.2686998E+00	23	0.2597163E+00	24	0.2594471E+00	25	0.2457467E+00
26	0.2420197E+00	27	0.2377595E+00	28	0.2342221E+00	29	0.2289186E+00	30	0.2240540E+00
31	0.2234123E+00	32	0.2191200E+00	33	0.2147676E+00	34	0.2075168E+00	35	0.2065819E+00
36	0.2047012E+00	37	0.2032334E+00	38	0.2001461E+00	39	0.1989014E+00	40	0.1987069E+00
41	0.1946633E+00	42	0.1945527E+00	43	0.1913921E+00	44	0.1846768E+00	45	0.1840754E+00
46	0.1823426E+00	47	0.1821604E+00	48	0.1813681E+00	49	0.1755397E+00	50	0.1749050E+00
51	0.1697911E+00	52	0.1693717E+00	53	0.1692790E+00	54	0.1680606E+00	55	0.1646285E+00
56	0.1613601E+00	57	0.1583807E+00	58	0.1577848E+00	59	0.1570216E+00	60	0.1554064E+00
61	0.1491214E+00	62	0.1462979E+00	63	0.1457413E+00	64	0.1456110E+00	65	0.1440380E+00
66	0.1374387E+00	67	0.1343548E+00	68	0.1317459E+00	69	0.1306919E+00	70	0.1260204E+00
71	0.1258587E+00	72	0.1233382E+00	73	0.1199322E+00	74	0.1159461E+00	75	0.1149777E+00
76	0.1128393E+00	77	0.1108967E+00	78	0.1101315E+00	79	0.1059593E+00	80	0.1044793E+00
81	0.1030498E+00	82	0.1005945E+00	83	0.9637177E-01	84	0.9472835E-01	85	0.9412634E-01
86	0.9124207E-01	87	0.8694077E-01	88	0.8625275E-01	89	0.8586013E-01	90	0.8217627E-01
91	0.7951355E-01	92	0.7803237E-01	93	0.7782555E-01	94	0.7377774E-01	95	0.7349855E-01
96	0.7130533E-01	97	0.6908870E-01	98	0.6537402E-01	99	0.6525540E-01	100	0.6079746E-01
101	0.5761214E-01	102	0.5309550E-01	103	0.5064829E-01	104	0.4610877E-01	105	0.4444220E-01
106	0.3983041E-01	107	0.3902765E-01	108	0.3420120E-01	109	0.3395762E-01	110	0.2791010E-01

Table 5 Eigen value of No.3 toroidal field coil eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.4848941E+00	2	0.4827505E+00	3	0.4667021E+00	4	0.4591691E+00	5	0.4561104E+00
6	0.4231443E+00	7	0.4207591E+00	8	0.4190134E+00	9	0.4101368E+00	10	0.4072739E+00
11	0.3839859E+00	12	0.3825109E+00	13	0.3786961E+00	14	0.3743922E+00	15	0.3684307E+00
16	0.3595502E+00	17	0.3516425E+00	18	0.3424598E+00	19	0.3299038E+00	20	0.3270009E+00
21	0.3213466E+00	22	0.3131766E+00	23	0.3068632E+00	24	0.3046001E+00	25	0.2909258E+00
26	0.2845052E+00	27	0.2806830E+00	28	0.2752305E+00	29	0.2715676E+00	30	0.2636948E+00
31	0.2629738E+00	32	0.2555931E+00	33	0.2544993E+00	34	0.2456215E+00	35	0.2441107E+00
36	0.2402755E+00	37	0.2362192E+00	38	0.2352661E+00	39	0.2309456E+00	40	0.2306095E+00
41	0.2300848E+00	42	0.2296228E+00	43	0.2253011E+00	44	0.2229840E+00	45	0.2207752E+00
46	0.2151166E+00	47	0.2148138E+00	48	0.2116646E+00	49	0.2115395E+00	50	0.2112806E+00
51	0.2048740E+00	52	0.2014866E+00	53	0.2008882E+00	54	0.1991200E+00	55	0.1967658E+00
56	0.1967071E+00	57	0.1913583E+00	58	0.1900197E+00	59	0.1863549E+00	60	0.1832920E+00
61	0.1832069E+00	62	0.1830691E+00	63	0.1773492E+00	64	0.1747556E+00	65	0.1693278E+00
66	0.1687003E+00	67	0.1662083E+00	68	0.1641956E+00	69	0.1590244E+00	70	0.1556964E+00
71	0.1540425E+00	72	0.1533288E+00	73	0.1478707E+00	74	0.1453884E+00	75	0.1442432E+00
76	0.1418304E+00	77	0.1376501E+00	78	0.1354992E+00	79	0.1350538E+00	80	0.1319877E+00
81	0.1276964E+00	82	0.1266295E+00	83	0.1262820E+00	84	0.1227496E+00	85	0.1191869E+00
86	0.1184506E+00	87	0.1178496E+00	88	0.1137388E+00	89	0.1127366E+00	90	0.1104208E+00
91	0.1093484E+00	92	0.1075823E+00	93	0.1050055E+00	94	0.1040083E+00	95	0.1005699E+00
96	0.9858787E-01	97	0.9669268E-01	98	0.9219599E-01	99	0.8882499E-01	100	0.8430338E-01
101	0.8158278E-01	102	0.7704055E-01	103	0.7495594E-01	104	0.7042009E-01	105	0.6915390E-01
106	0.6457335E-01	107	0.6409442E-01	108	0.5960406E-01	109	0.5945477E-01	110	0.5363462E-01

Table 6 Eigen value of No.4 toroidal field coil eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.6235723E+00	2	0.6212872E+00	3	0.6184757E+00	4	0.5904674E+00	5	0.5870488E+00
6	0.5610180E+00	7	0.5510113E+00	8	0.5479555E+00	9	0.5435656E+00	10	0.5426143E+00
11	0.5131191E+00	12	0.5105448E+00	13	0.4984877E+00	14	0.4969728E+00	15	0.4920912E+00
16	0.4818540E+00	17	0.4723251E+00	18	0.4644351E+00	19	0.4444413E+00	20	0.4376522E+00
21	0.4331298E+00	22	0.4202519E+00	23	0.4197904E+00	24	0.4123731E+00	25	0.4020990E+00
26	0.3866383E+00	27	0.3861157E+00	28	0.3740173E+00	29	0.3736816E+00	30	0.3600992E+00
31	0.3591540E+00	32	0.3474521E+00	33	0.3444330E+00	34	0.3333912E+00	35	0.3275927E+00
36	0.3216297E+00	37	0.3206463E+00	38	0.3115789E+00	39	0.3105819E+00	40	0.3072349E+00
41	0.3069378E+00	42	0.3031343E+00	43	0.2974362E+00	44	0.2973909E+00	45	0.2888656E+00
46	0.2869453E+00	47	0.2817389E+00	48	0.2814523E+00	49	0.2800181E+00	50	0.2766023E+00
51	0.2732611E+00	52	0.2690223E+00	53	0.2669603E+00	54	0.2650463E+00	55	0.2621151E+00
56	0.2620049E+00	57	0.2594904E+00	58	0.2567990E+00	59	0.2553231E+00	60	0.2525156E+00
61	0.2482331E+00	62	0.2449372E+00	63	0.2443722E+00	64	0.2402139E+00	65	0.2381561E+00
66	0.2289630E+00	67	0.2277722E+00	68	0.2236364E+00	69	0.2224532E+00	70	0.2170224E+00
71	0.2170169E+00	72	0.2082629E+00	73	0.2077696E+00	74	0.2062534E+00	75	0.1998763E+00
76	0.1992607E+00	77	0.1986603E+00	78	0.1921172E+00	79	0.1920781E+00	80	0.1900450E+00
81	0.1869634E+00	82	0.1851674E+00	83	0.1820599E+00	84	0.1805746E+00	85	0.1790165E+00
86	0.1755096E+00	87	0.1749366E+00	88	0.1707745E+00	89	0.1705176E+00	90	0.1688040E+00
91	0.1660454E+00	92	0.1622947E+00	93	0.1616953E+00	94	0.1568674E+00	95	0.1530028E+00
96	0.1480924E+00	97	0.1446982E+00	98	0.1397326E+00	99	0.1368318E+00	100	0.1318305E+00
101	0.1296114E+00	102	0.1245613E+00	103	0.1230065E+00	104	0.1179688E+00	105	0.1172011E+00
106	0.1122390E+00	107	0.1121500E+00	108	0.1083016E+00	109	0.1072520E+00	110	0.1024043E+00

Table 7 Eigen value of No.1 support plate eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.3725410E-01	2	0.2816160E-01	3	0.2067525E-01	4	0.1806082E-01	5	0.1576611E-01
6	0.1493693E-01	7	0.1265218E-01	8	0.1216327E-01	9	0.1109814E-01	10	0.1087809E-01
11	0.9446949E-02	12	0.9326980E-02	13	0.9018134E-02	14	0.8248564E-02	15	0.8134022E-02
16	0.7450730E-02	17	0.7066950E-02	18	0.7032663E-02	19	0.6115563E-02	20	0.6087150E-02
21	0.5278695E-02	22	0.5233895E-02	23	0.4563164E-02	24	0.3935389E-02		

Table 8 Eigen value of No.2 support plate eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.3741643E-01	2	0.2818026E-01	3	0.2068438E-01	4	0.1807439E-01	5	0.1576694E-01
6	0.1494141E-01	7	0.1265479E-01	8	0.1216478E-01	9	0.1109967E-01	10	0.1088065E-01
11	0.9447876E-02	12	0.9327572E-02	13	0.9019122E-02	14	0.8248623E-02	15	0.8135363E-02
16	0.7450879E-02	17	0.7067043E-02	18	0.7033605E-02	19	0.6115671E-02	20	0.6087705E-02
21	0.5278766E-02	22	0.5234085E-02	23	0.4563224E-02	24	0.3935423E-02		

Table 9 Eigen value of central column eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.4077637E-01	2	0.3717226E-01	3	0.3226753E-01	4	0.2949240E-01	5	0.2607149E-01
6	0.2306800E-01	7	0.2046800E-01	8	0.1623105E-01	9	0.1631029E-01	10	0.1465883E-01
11	0.1323605E-01	12	0.1200718E-01	13	0.1094320E-01	14	0.1002055E-01	15	0.9219900E-02
16	0.8525893E-02	17	0.7925853E-02	18	0.7409811E-02	19	0.6969765E-02	20	0.6599233E-02
21	0.6293286E-02	22	0.6047748E-02	23	0.5859729E-02	24	0.5726993E-02	25	0.5647838E-02
26	0.3817304E-02	27	0.3814653E-02	28	0.3809405E-02	29	0.3801895E-02	30	0.3792033E-02
31	0.3779652E-02	32	0.3764600E-02	33	0.3746670E-02	34	0.3725674E-02	35	0.3701445E-02
36	0.3673827E-02	37	0.3642727E-02	38	0.3608162E-02	39	0.3570253E-02	40	0.3529279E-02
41	0.3465767E-02	42	0.3440507E-02	43	0.3394533E-02	44	0.3349233E-02	45	0.3306231E-02
46	0.3267361E-02	47	0.3234548E-02	48	0.3209572E-02	49	0.3193928E-02	50	0.1647270E-02
51	0.1647145E-02	52	0.1646932E-02	53	0.1646673E-02	54	0.1646318E-02	55	0.1645863E-02
56	0.1645341E-02	57	0.1644737E-02	58	0.1644041E-02	59	0.1643261E-02	60	0.1642388E-02
61	0.1641417E-02	62	0.1640347E-02	63	0.1639153E-02	64	0.1637930E-02	65	0.1636607E-02
66	0.1635210E-02	67	0.1633756E-02	68	0.1632211E-02	69	0.1630915E-02	70	0.1629617E-02
71	0.1628489E-02	72	0.1627633E-02	73	0.1627086E-02				

Table 10 Mode reduction of eigen modes

	Obtained eigen mode No.	Reduced eigen mode No.
Vacuum vessel	154	154
No.1 toroidal field coil	110	50
No.2 toroidal field coil	110	50
No.3 toroidal field coil	110	50
No.4 toroidal field coil	110	50
No.1 support plate	24	20
No.2 support plate	24	20
Central column	73	70

Table 11 Eigen value of JT-60 multi-torus system eigen mode

Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
1	0.7559462E+00	2	0.7423792E+00	3	0.6948228E+00
4	0.6839647E+00	5	0.6784201E+00	6	0.6328883E+00
7	0.6275573E+00	8	0.6160707E+00	9	0.6010122E+00
10	0.5875053E+00	11	0.5562863E+00	12	0.5504298E+00
13	0.5475945E+00	14	0.5437455E+00	15	0.5375657E+00
16	0.5355268E+00	17	0.5245137E+00	18	0.5168314E+00
19	0.5059233E+00	20	0.5034504E+00	21	0.4994289E+00
22	0.4955867E+00	23	0.4782710E+00	24	0.4724334E+00
25	0.4671729E+00	26	0.4641352E+00	27	0.4616958E+00
28	0.4606892E+00	29	0.4516160E+00	30	0.4465113E+00
31	0.4391256E+00	32	0.4366246E+00	33	0.4273859E+00
34	0.4258018E+00	35	0.4195291E+00	36	0.4175762E+00
37	0.4143232E+00	38	0.4101570E+00	39	0.4078256E+00
40	0.3969592E+00	41	0.3968344E+00	42	0.3924602E+00
43	0.3888193E+00	44	0.3875460E+00	45	0.3863769E+00

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Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
46	0.3853353E+00	47	0.3798131E+00	48	0.3762876E+00	49	0.3746380E+00	50	0.3653561E+00
51	0.3648232E+00	52	0.3643268E+00	53	0.3629155E+00	54	0.3625174E+00	55	0.3534054E+00
56	0.3517215E+00	57	0.3510495E+00	58	0.3458872E+00	59	0.3438680E+00	60	0.3383495E+00
61	0.3375365E+00	62	0.3368171E+00	63	0.3355858E+00	64	0.3351247E+00	65	0.3338482E+00
66	0.3311743E+00	67	0.3281379E+00	68	0.3225843E+00	69	0.3209656E+00	70	0.3207102E+00
71	0.3186669E+00	72	0.3183237E+00	73	0.3160681E+00	74	0.3121642E+00	75	0.3119367E+00
76	0.3106785E+00	77	0.3080030E+00	78	0.3077919E+00	79	0.3051716E+00	80	0.3044543E+00
81	0.3041533E+00	82	0.3018140E+00	83	0.2994893E+00	84	0.2979044E+00	85	0.2975414E+00
86	0.2973558E+00	87	0.2935668E+00	88	0.2916228E+00	89	0.2913809E+00	90	0.2883515E+00
91	0.2882423E+00	92	0.2870036E+00	93	0.2864668E+00	94	0.2854640E+00	95	0.2819080E+00
96	0.2815643E+00	97	0.2802297E+00	98	0.2799592E+00	99	0.2791622E+00	100	0.2775151E+00
101	0.2766914E+00	102	0.2735201E+00	103	0.2711518E+00	104	0.2683794E+00	105	0.2674559E+00
106	0.2673404E+00	107	0.2661551E+00	108	0.2645571E+00	109	0.2639767E+00	110	0.2608265E+00
111	0.2604769E+00	112	0.2574990E+00	113	0.2572657E+00	114	0.2570431E+00	115	0.2548048E+00
116	0.2501002E+00	117	0.2491818E+00	118	0.2479875E+00	119	0.2477004E+00	120	0.2475507E+00
121	0.2470551E+00	122	0.2465516E+00	123	0.2430975E+00	124	0.2429422E+00	125	0.2422256E+00
126	0.2382262E+00	127	0.2374205E+00	128	0.2365257E+00	129	0.2355421E+00	130	0.2343693E+00
131	0.2342855E+00	132	0.2331999E+00	133	0.2331327E+00	134	0.2312728E+00	135	0.2311766E+00
136	0.2303488E+00	137	0.2288325E+00	138	0.2284339E+00	139	0.2273734E+00	140	0.2263959E+00
141	0.2263266E+00	142	0.2259505E+00	143	0.2236373E+00	144	0.2233309E+00	145	0.2209609E+00
146	0.2200374E+00	147	0.2188582E+00	148	0.2187570E+00	149	0.2166713E+00	150	0.2152789E+00
151	0.2150730E+00	152	0.2130806E+00	153	0.2129792E+00	154	0.2108269E+00	155	0.2096849E+00
156	0.2093886E+00	157	0.2079235E+00	158	0.2076247E+00	159	0.2059262E+00	160	0.2056006E+00
161	0.2049096E+00	162	0.2043380E+00	163	0.2018970E+00	164	0.2012128E+00	165	0.2011139E+00
166	0.2008969E+00	167	0.2003653E+00	168	0.1971952E+00	169	0.1965590E+00	170	0.1944020E+00
171	0.1941213E+00	172	0.1935395E+00	173	0.1857519E+00	174	0.1855878E+00	175	0.1851915E+00
176	0.1849225E+00	177	0.1846075E+00	178	0.1839215E+00	179	0.1838399E+00	180	0.1831831E+00
181	0.1781504E+00	182	0.1756153E+00	183	0.1750669E+00	184	0.1744215E+00	185	0.1743303E+00
186	0.1740736E+00	187	0.1736799E+00	188	0.1736295E+00	189	0.1733084E+00	190	0.1721489E+00
191	0.1656626E+00	192	0.1624411E+00	193	0.1617377E+00	194	0.1617185E+00	195	0.1616066E+00
196	0.1579311E+00	197	0.1544115E+00	198	0.1543850E+00	199	0.1530852E+00	200	0.1515230E+00
201	0.4550281E-01	202	0.4072154E-01	203	0.3716004E-01	204	0.3326356E-01	205	0.3164372E-01
206	0.2949119E-01	207	0.2925469E-01	208	0.2607067E-01	209	0.2454525E-01	210	0.2306723E-01
211	0.2187661E-01	212	0.2046720E-01	213	0.1941533E-01	214	0.1906312E-01	215	0.1823026E-01
216	0.1701286E-01	217	0.1630942E-01	218	0.1616120E-01	219	0.1595129E-01	220	0.1539079E-01
221	0.1534404E-01	222	0.1465791E-01	223	0.1441872E-01	224	0.1323514E-01	225	0.1286506E-01
226	0.1240264E-01	227	0.1228081E-01	228	0.1202793E-01	229	0.1200610E-01	230	0.1155455E-01
231	0.1124042E-01	232	0.1099673E-01	233	0.1094214E-01	234	0.1088548E-01	235	0.1070039E-01
236	0.1001960E-01	237	0.9521972E-02	238	0.9363223E-02	239	0.9344514E-02	240	0.9265024E-02
241	0.9218968E-02	242	0.9179495E-02	243	0.9060238E-02	244	0.8958161E-02	245	0.8525081E-02
246	0.8228995E-02	247	0.8195218E-02	248	0.8043550E-02	249	0.7924918E-02	250	0.7749401E-02
251	0.7697783E-02	252	0.7459436E-02	253	0.7438358E-02	254	0.7408857E-02	255	0.7081628E-02

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Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)	Mode No.	Eigen value (sec)
256	0.7050760E-02	257	0.6974790E-02	258	0.6968789E-02	259	0.6688211E-02	260	0.6598290E-02
261	0.6582271E-02	262	0.6523486E-02	263	0.6292604E-02	264	0.6124571E-02	265	0.6104033E-02
266	0.6053787E-02	267	0.6046679E-02	268	0.5858786E-02	269	0.5726162E-02	270	0.5683318E-02
271	0.5647197E-02	272	0.5498972E-02	273	0.5047955E-02	274	0.4751168E-02	275	0.4666682E-02
276	0.4333664E-02	277	0.4199542E-02	278	0.4062355E-02	279	0.3988627E-02	280	0.3854332E-02
281	0.3817711E-02	282	0.3814546E-02	283	0.3809324E-02	284	0.3801815E-02	285	0.3791982E-02
286	0.3779629E-02	287	0.3764590E-02	288	0.3746601E-02	289	0.3725598E-02	290	0.3701400E-02
291	0.3673803E-02	292	0.3642671E-02	293	0.3608139E-02	294	0.3593123E-02	295	0.3570188E-02
296	0.3536010E-02	297	0.3529226E-02	298	0.3511630E-02	299	0.3485734E-02	300	0.3440496E-02
301	0.3394490E-02	302	0.3349217E-02	303	0.3306182E-02	304	0.3291262E-02	305	0.3267338E-02
306	0.3234526E-02	307	0.3209574E-02	308	0.3193861E-02	309	0.3179045E-02	310	0.3174247E-02
311	0.3095435E-02	312	0.2935719E-02	313	0.2894247E-02	314	0.2871141E-02	315	0.2746632E-02
316	0.2740789E-02	317	0.2672499E-02	318	0.2666440E-02	319	0.2546489E-02	320	0.2492942E-02
321	0.2474502E-02	322	0.2381004E-02	323	0.2279902E-02	324	0.2273193E-02	325	0.2268916E-02
326	0.2229014E-02	327	0.2115838E-02	328	0.2074908E-02	329	0.2060644E-02	330	0.2016928E-02
331	0.2001779E-02	332	0.1992354E-02	333	0.1928026E-02	334	0.1894285E-02	335	0.1878537E-02
336	0.1825870E-02	337	0.1814923E-02	338	0.1768534E-02	339	0.1754050E-02	340	0.1751712E-02
341	0.1746318E-02	342	0.1725289E-02	343	0.1649102E-02	344	0.1646962E-02	345	0.1646827E-02
346	0.1646555E-02	347	0.1646213E-02	348	0.1645752E-02	349	0.1645242E-02	350	0.1644894E-02
351	0.1644578E-02	352	0.1643905E-02	353	0.1643178E-02	354	0.1642599E-02	355	0.1642286E-02
356	0.1641321E-02	357	0.1640255E-02	358	0.1639103E-02	359	0.1637806E-02	360	0.1636519E-02
361	0.1635081E-02	362	0.1633632E-02	363	0.1632207E-02	364	0.1630797E-02	365	0.1630540E-02
366	0.1629517E-02	367	0.1622784E-02	368	0.1606408E-02	369	0.1600924E-02	370	0.1540430E-02
371	0.1515043E-02	372	0.1509654E-02	373	0.1501328E-02	374	0.1492268E-02	375	0.1446410E-02
376	0.1425448E-02	377	0.1424526E-02	378	0.1403536E-02	379	0.1400333E-02	380	0.1336711E-02
381	0.1336050E-02	382	0.1329162E-02	383	0.1299183E-02	384	0.1297148E-02	385	0.1270039E-02
386	0.1241510E-02	387	0.1224419E-02	388	0.1222961E-02	389	0.1178894E-02	390	0.1169521E-02
391	0.1169475E-02	392	0.1155352E-02	393	0.1139152E-02	394	0.1119565E-02	395	0.1093145E-02
396	0.1064660E-02	397	0.1043403E-02	398	0.1036611E-02	399	0.9990365E-03	400	0.9879537E-03
401	0.9654243E-03	402	0.9405499E-03	403	0.9392018E-03	404	0.8999151E-03	405	0.8866931E-03
406	0.8680508E-03	407	0.8427051E-03	408	0.8324618E-03	409	0.7984187E-03	410	0.7852924E-03
411	0.7642538E-03	412	0.7387383E-03	413	0.7150823E-03	414	0.6968889E-03	415	0.6818997E-03
416	0.6811603E-03	417	0.5371235E-03	418	0.4438951E-03	419	0.4252458E-03	420	0.3410990E-03
421	0.3365823E-03	422	0.3150357E-03	423	0.2903051E-03	424	0.2789558E-03	425	0.2640514E-03
426	0.2478464E-03	427	0.2320155E-03	428	0.2079440E-03	429	0.1929599E-03	430	0.1817751E-03
431	0.1706653E-03	432	0.1664273E-03	433	0.1438216E-03	434	0.1408847E-03	435	0.1334299E-03
436	0.1298774E-03	437	0.1146557E-03	438	0.1053528E-03	439	0.1036521E-03	440	0.9691122E-04
441	0.8379552E-04	442	0.8254674E-04	443	0.8117974E-04	444	0.7387377E-04	445	0.6953548E-04
446	0.6859702E-04	447	0.6002042E-04	448	0.5847884E-04	449	0.5767506E-04	450	0.5344338E-04
451	0.4819360E-04	452	0.4562087E-04	453	0.4262089E-04	454	0.3812199E-04	455	0.3680980E-04
456	0.3392334E-04	457	0.3081835E-04	458	0.2800470E-04	459	0.2581473E-04	460	0.2367589E-04
461	0.2121265E-04	462	0.1980398E-04	463	0.1668945E-04	464	0.1398611E-04		

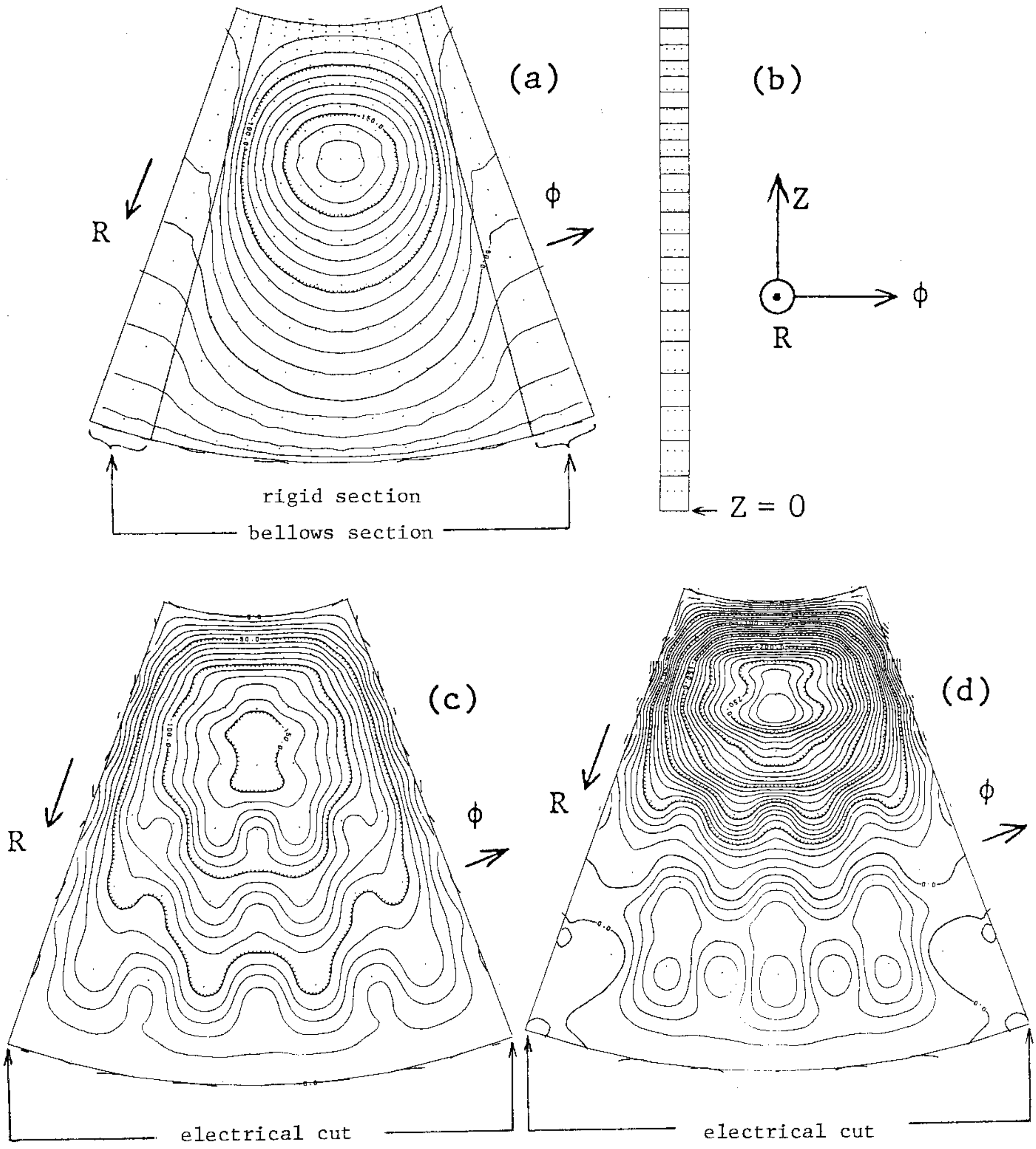
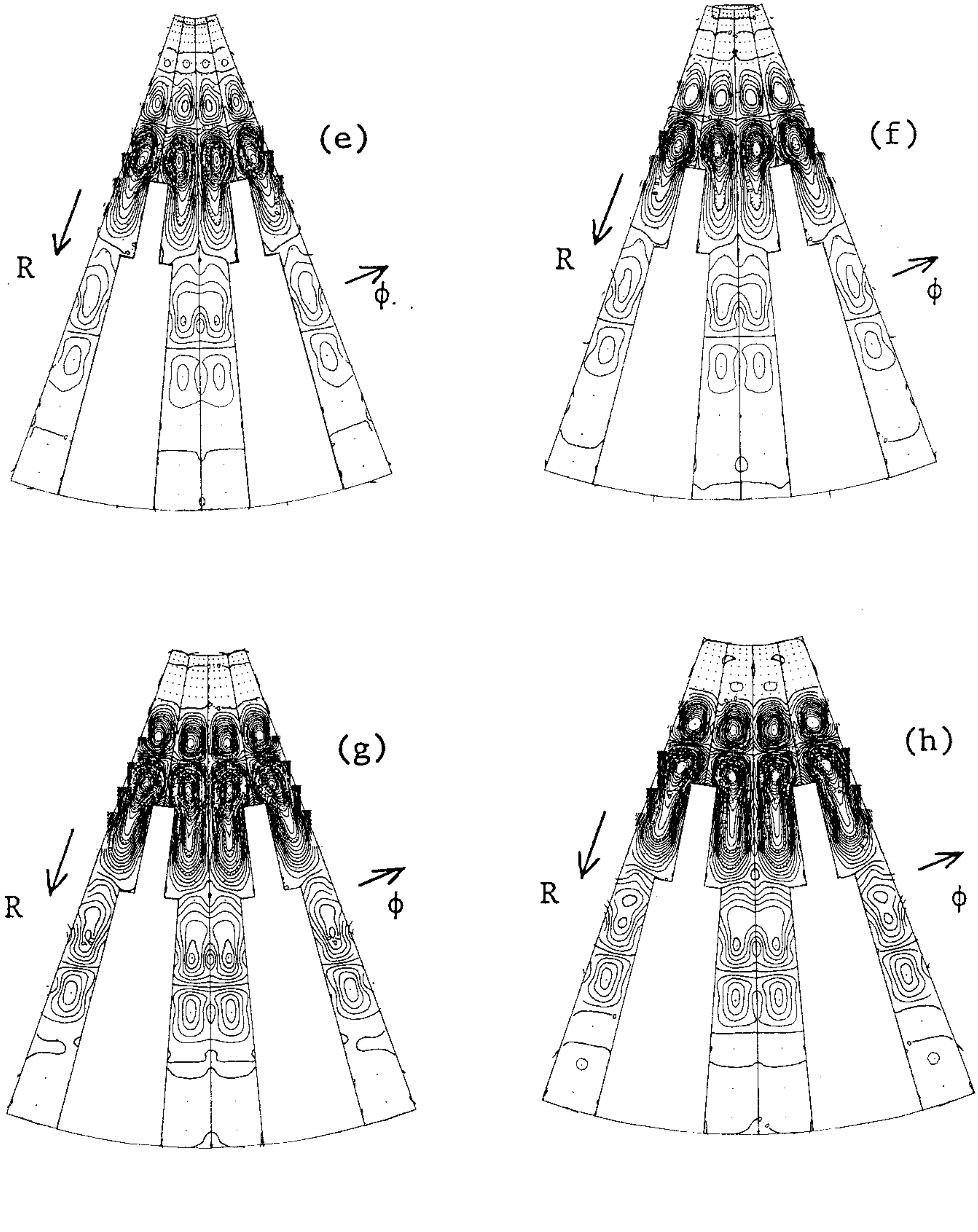


Fig. 11 40° cuts of the 17-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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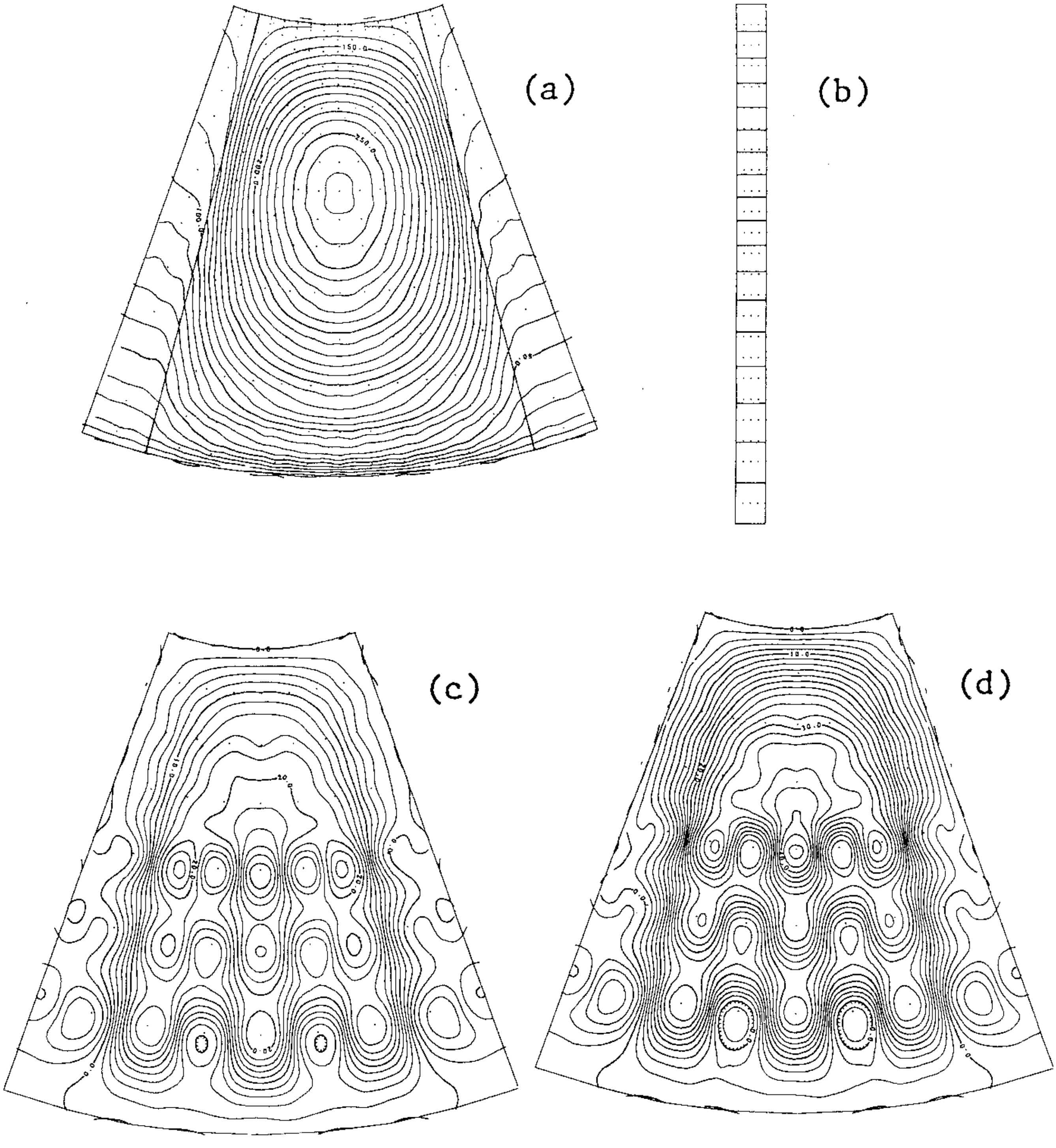
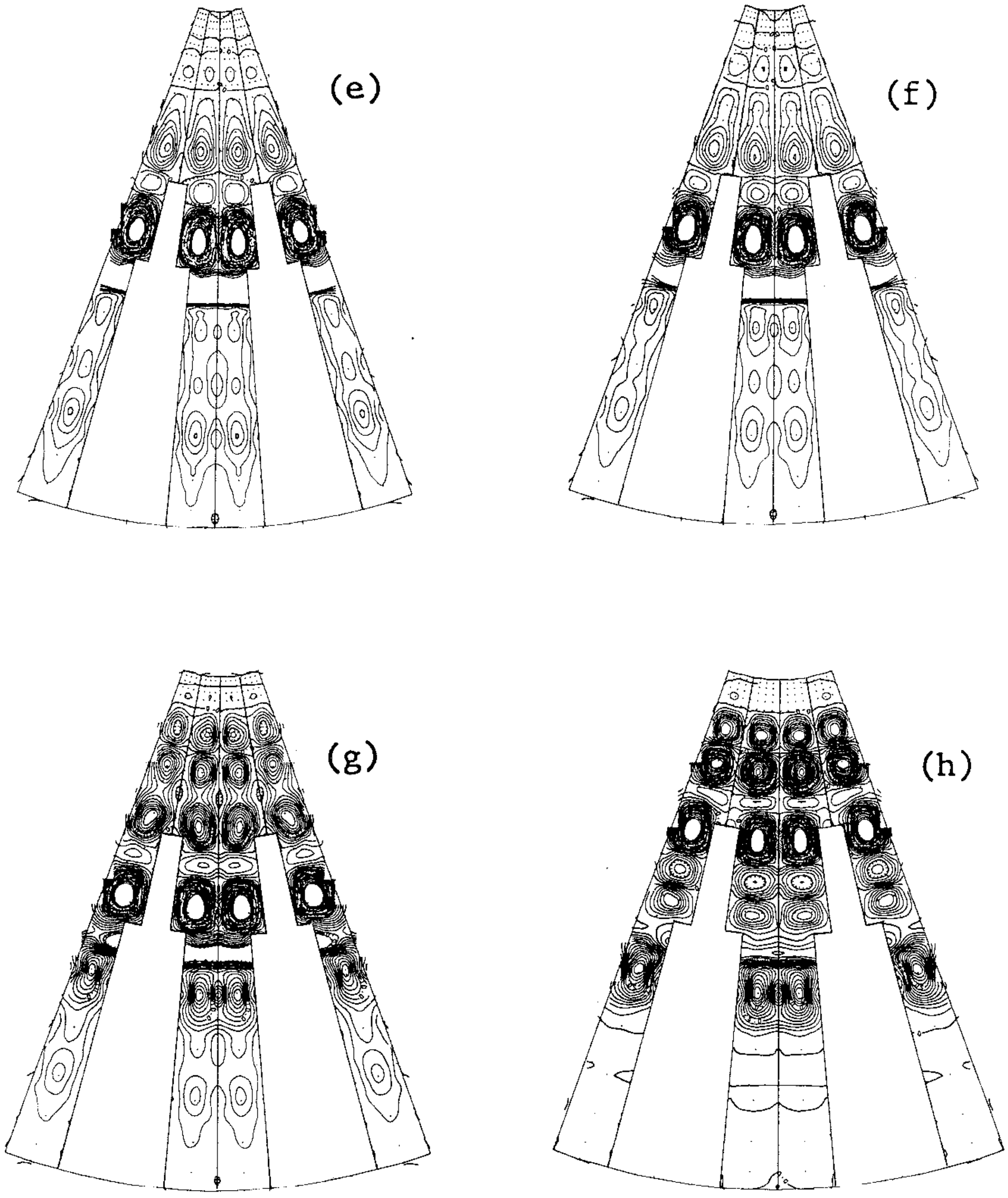


Fig. 12 40° cuts of the 32-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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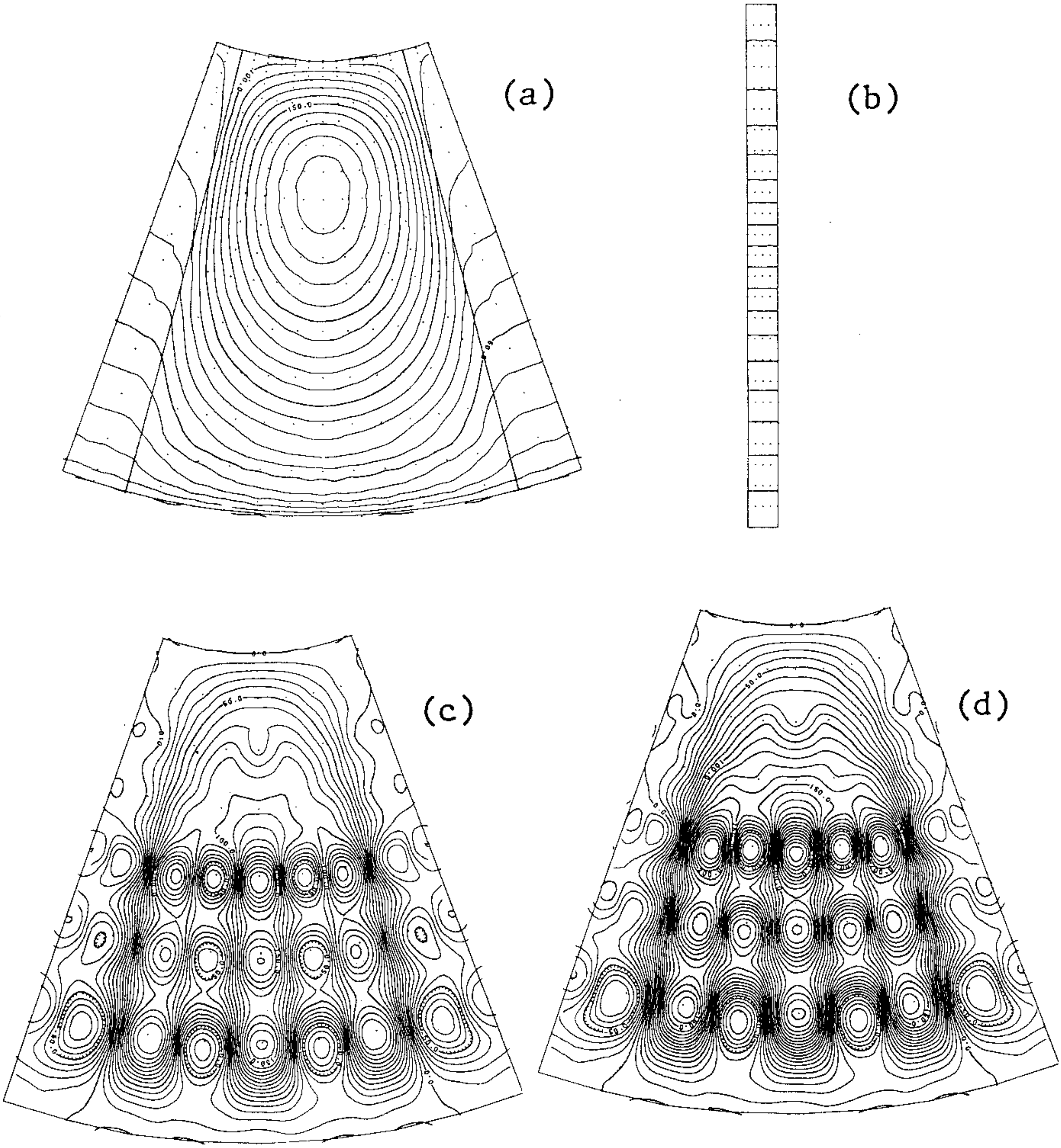
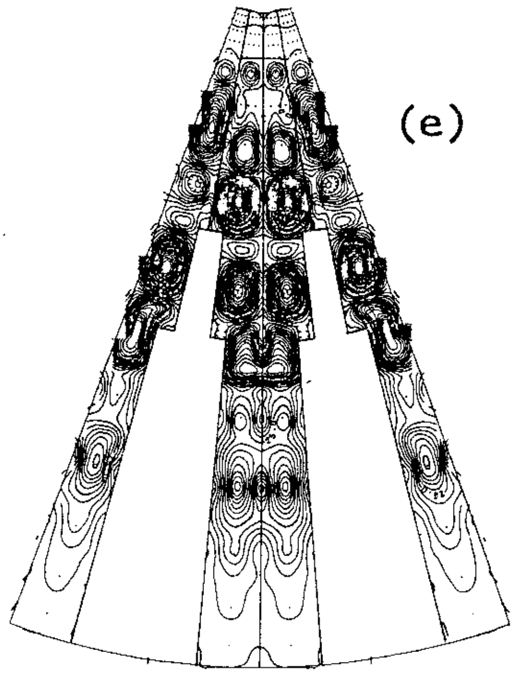
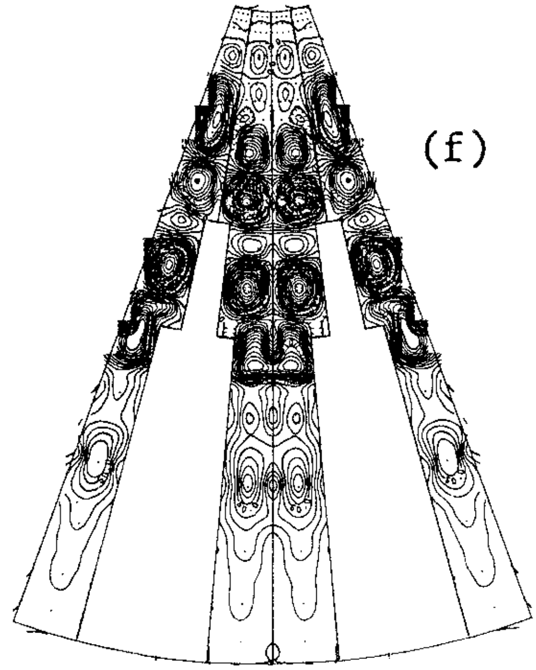
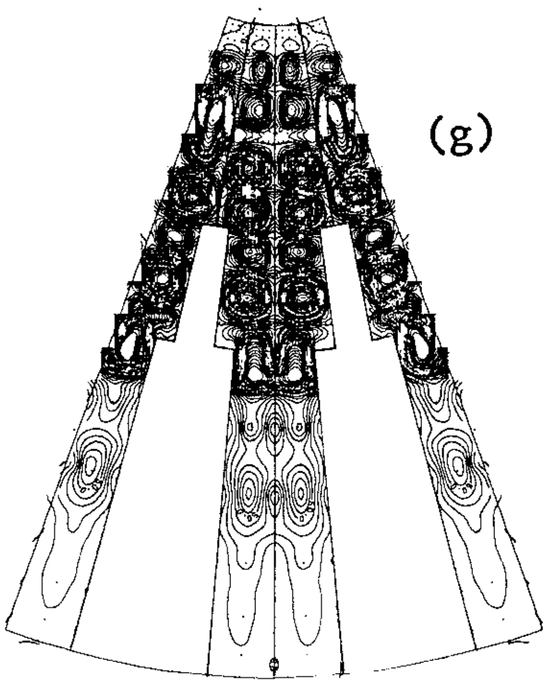
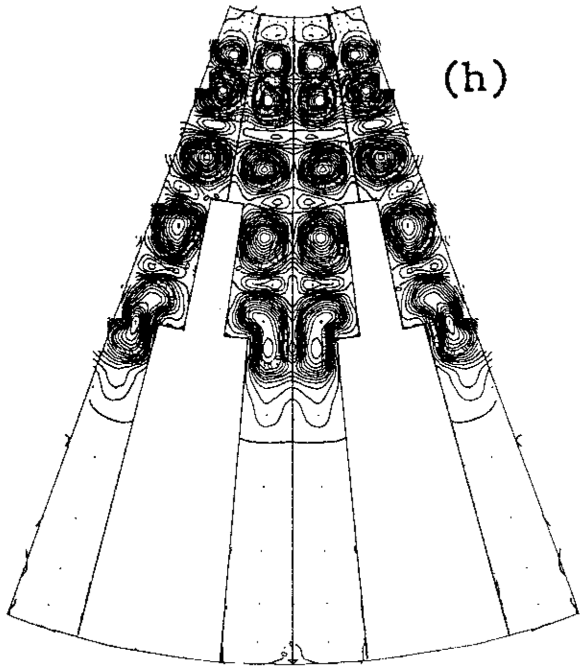


Fig. 13 40° cuts of the 41-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.









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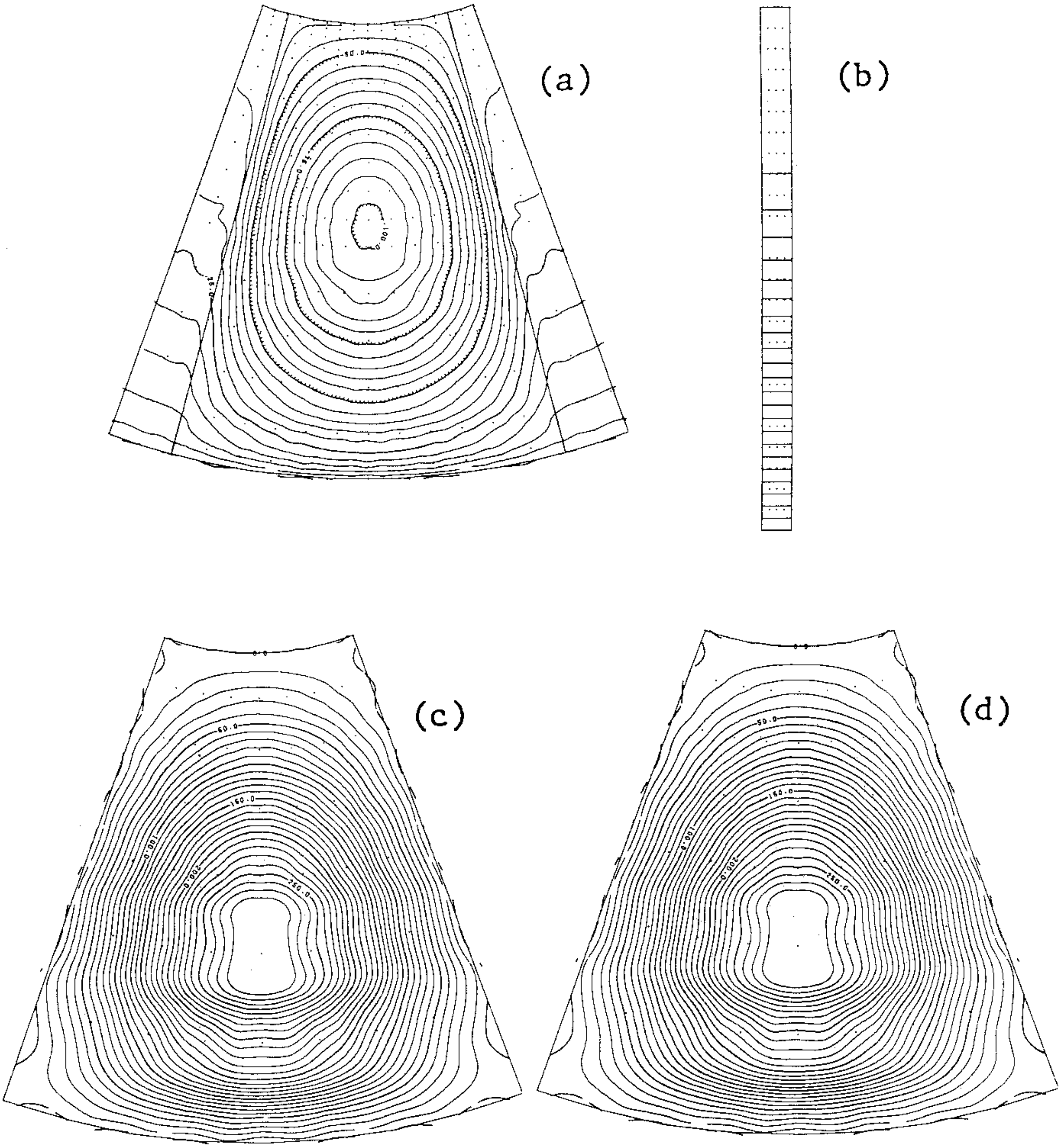
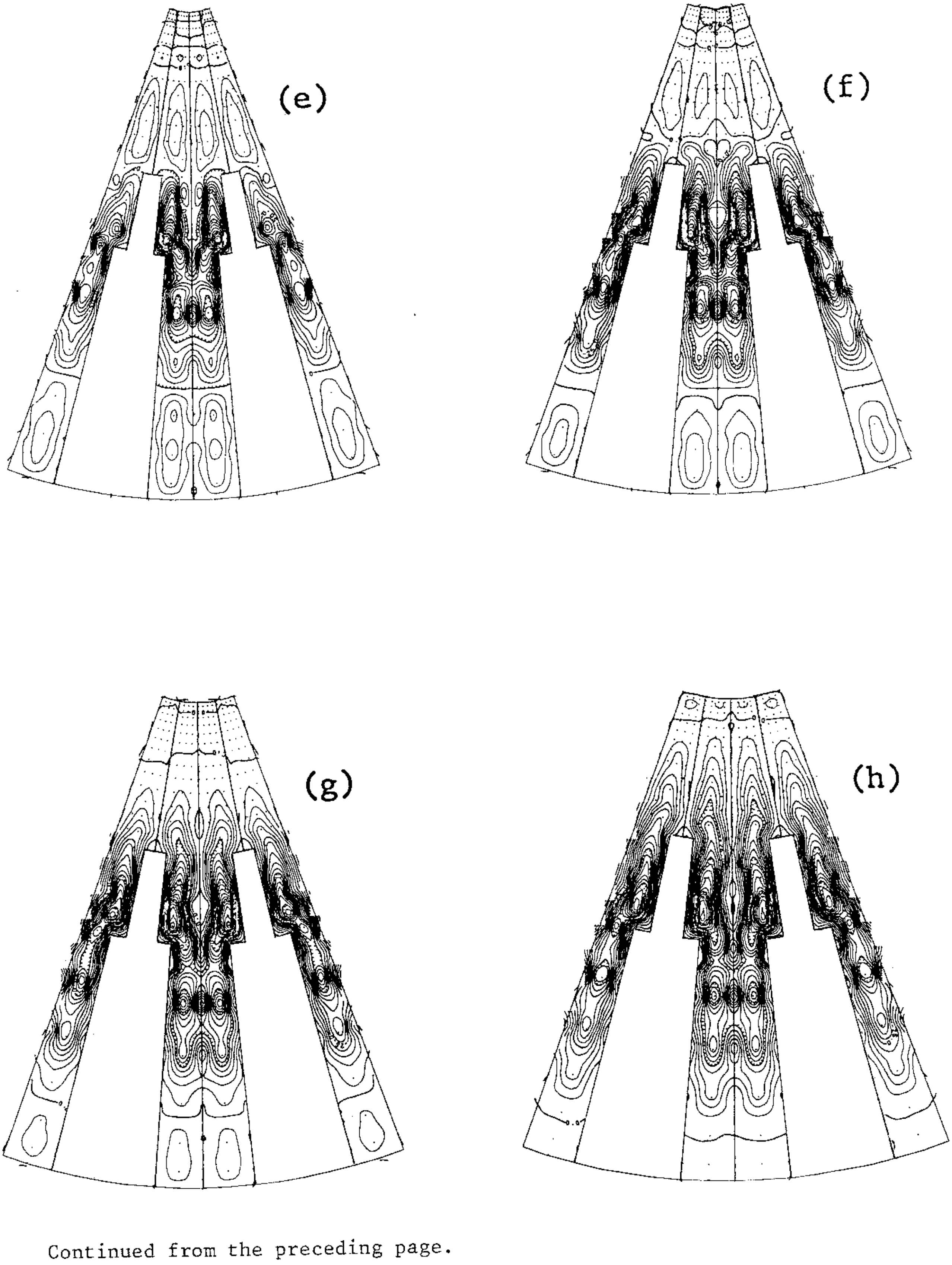


Fig. 14 40° cuts of the 201-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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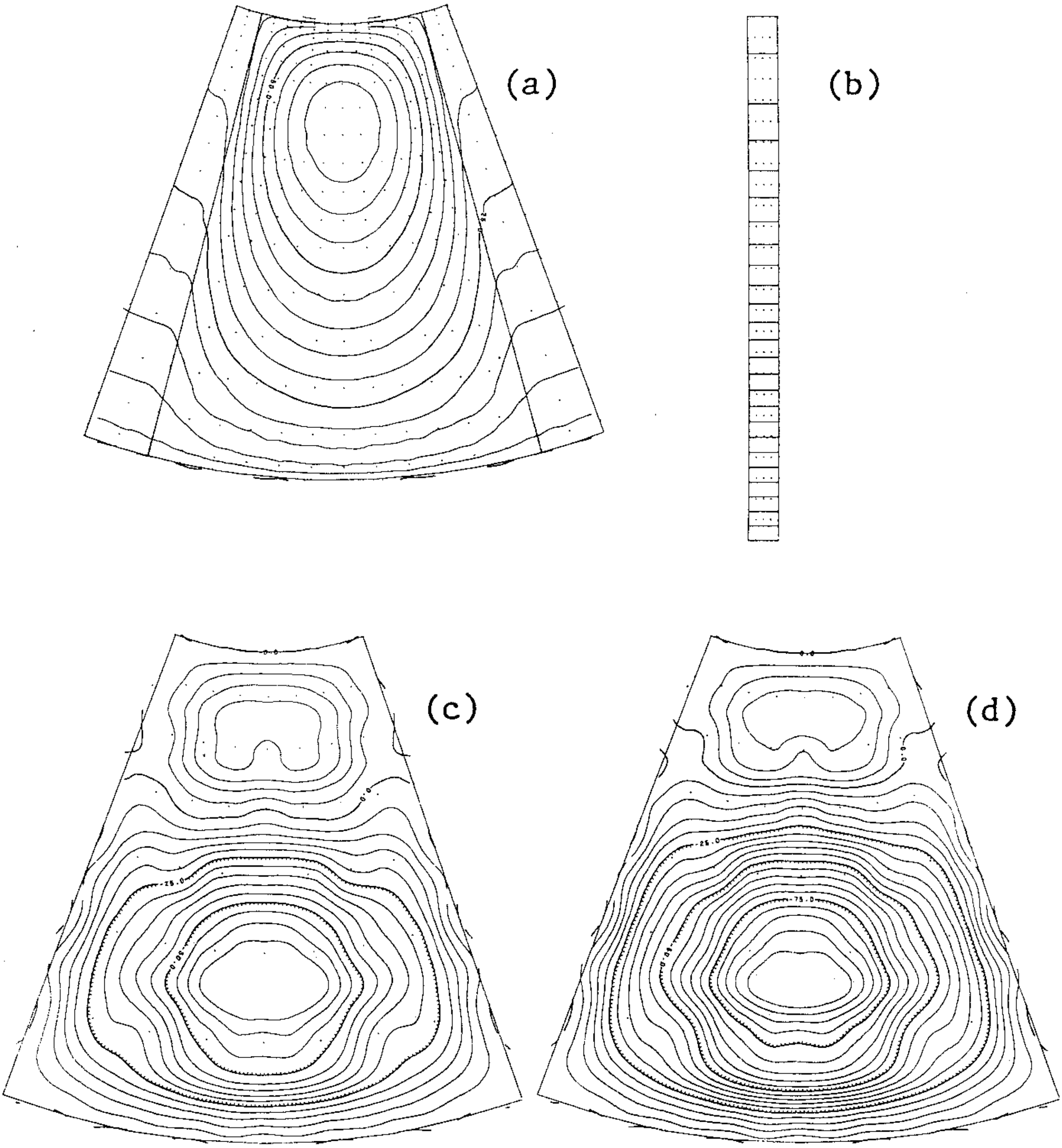
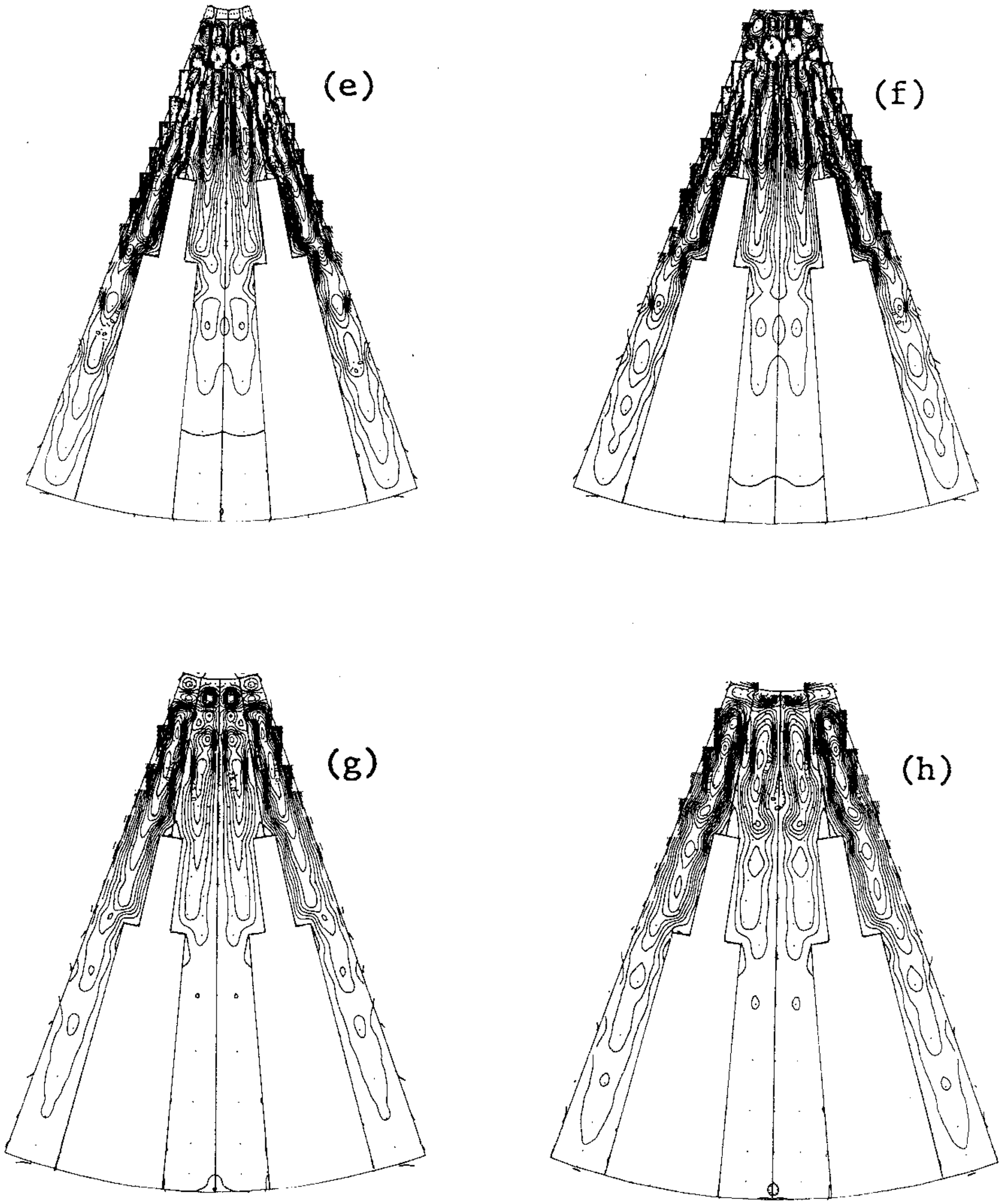


Fig. 15 40° cuts of the 202-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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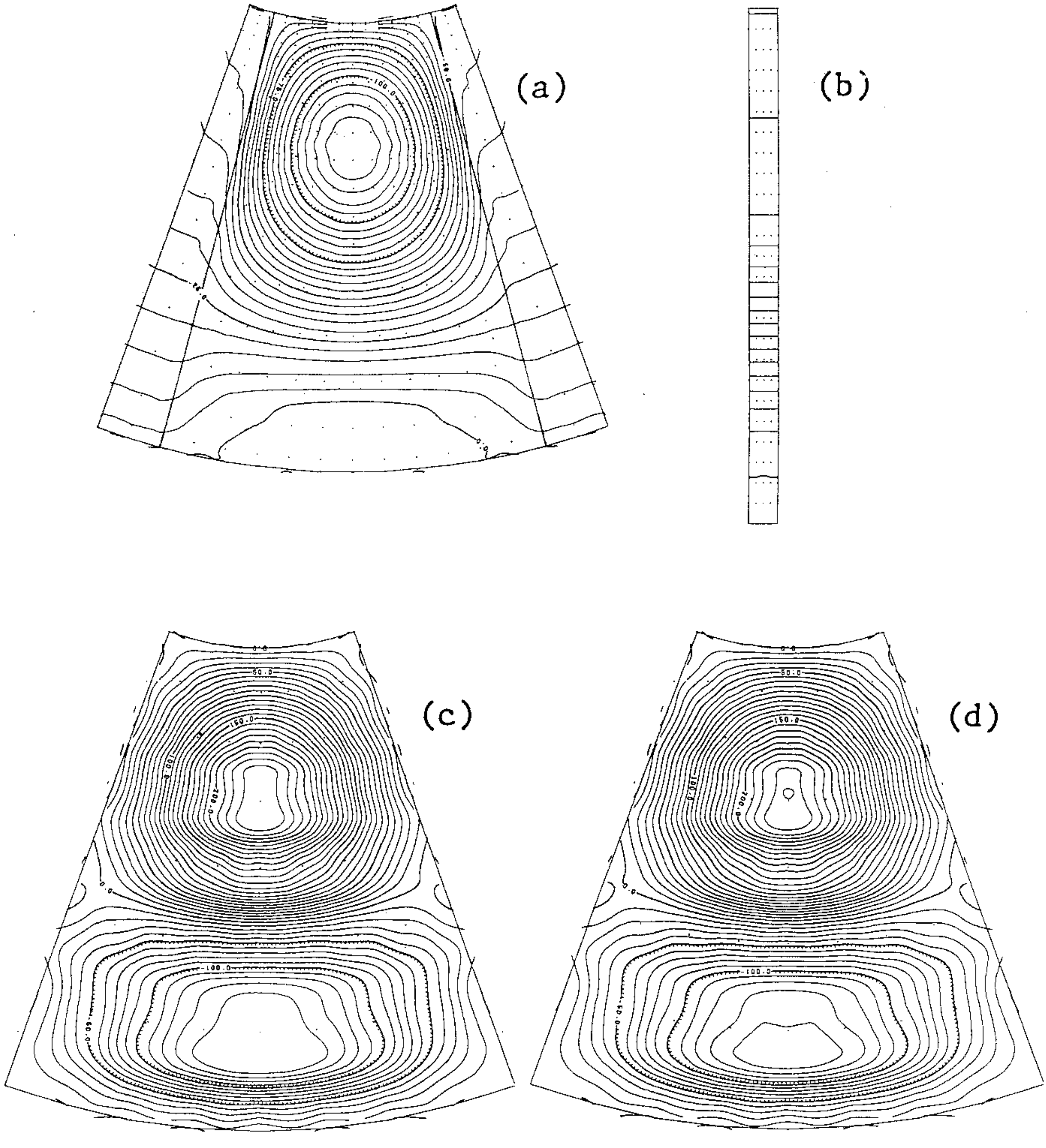
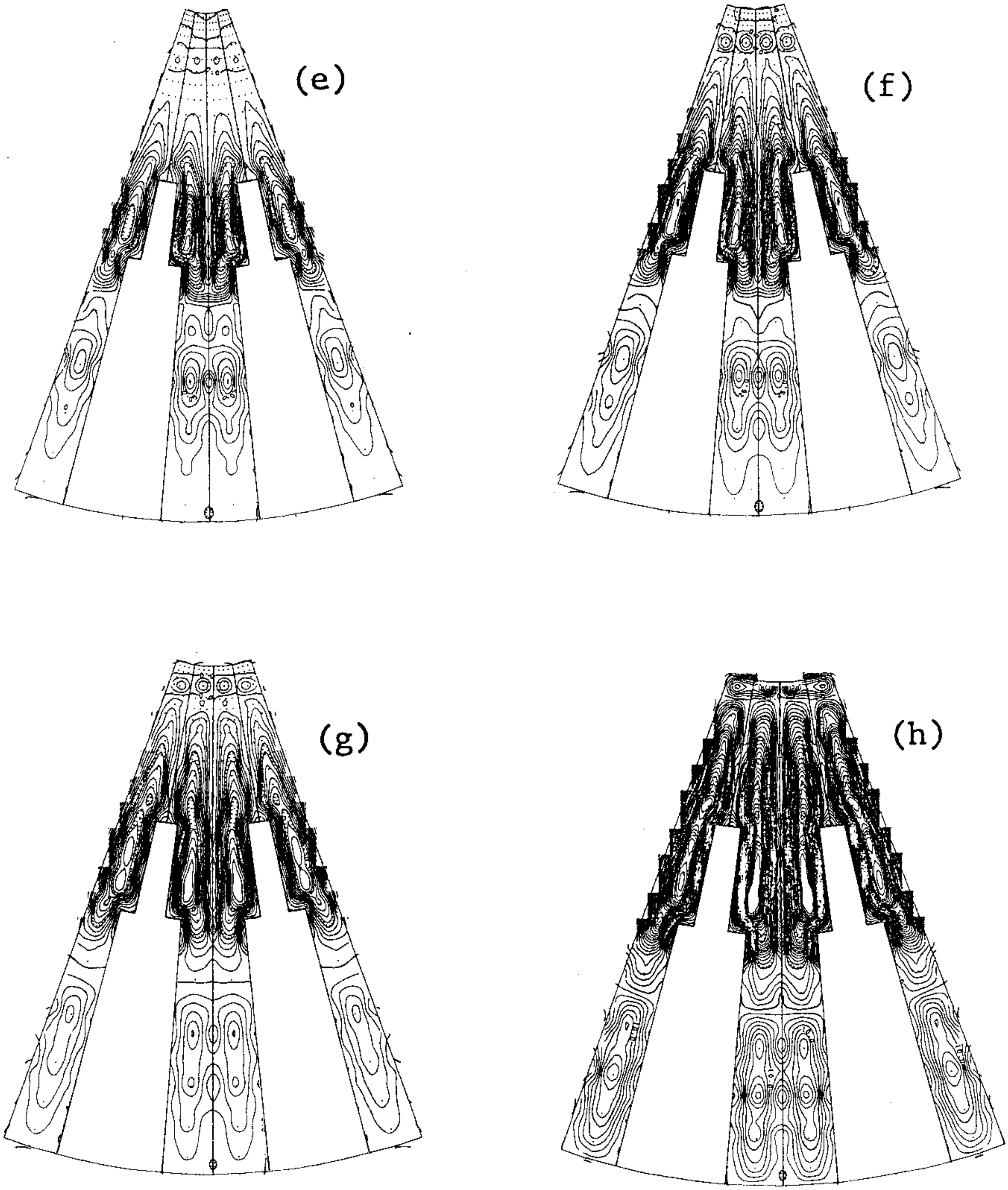


Fig. 16 40° cuts of the 205-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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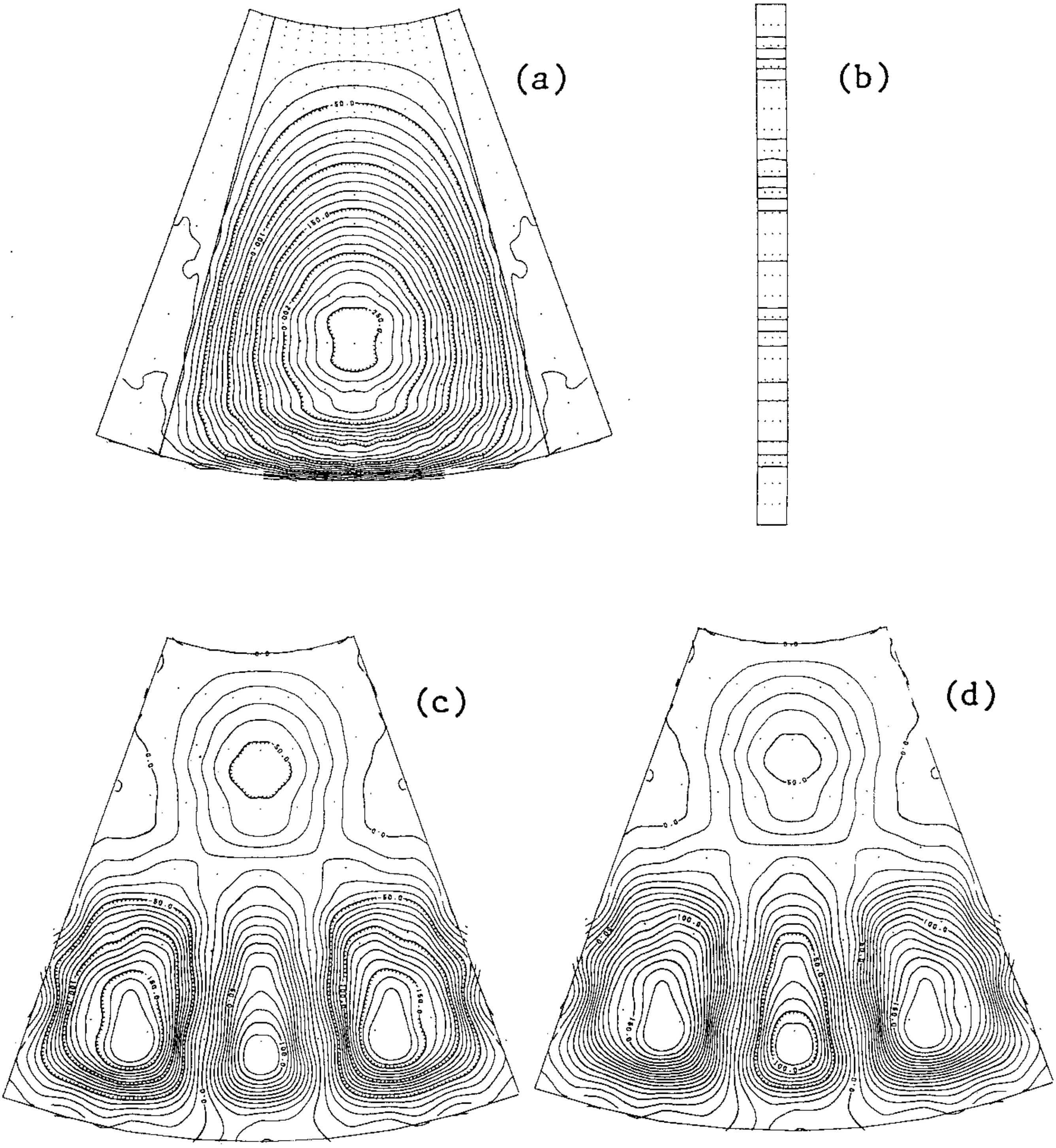
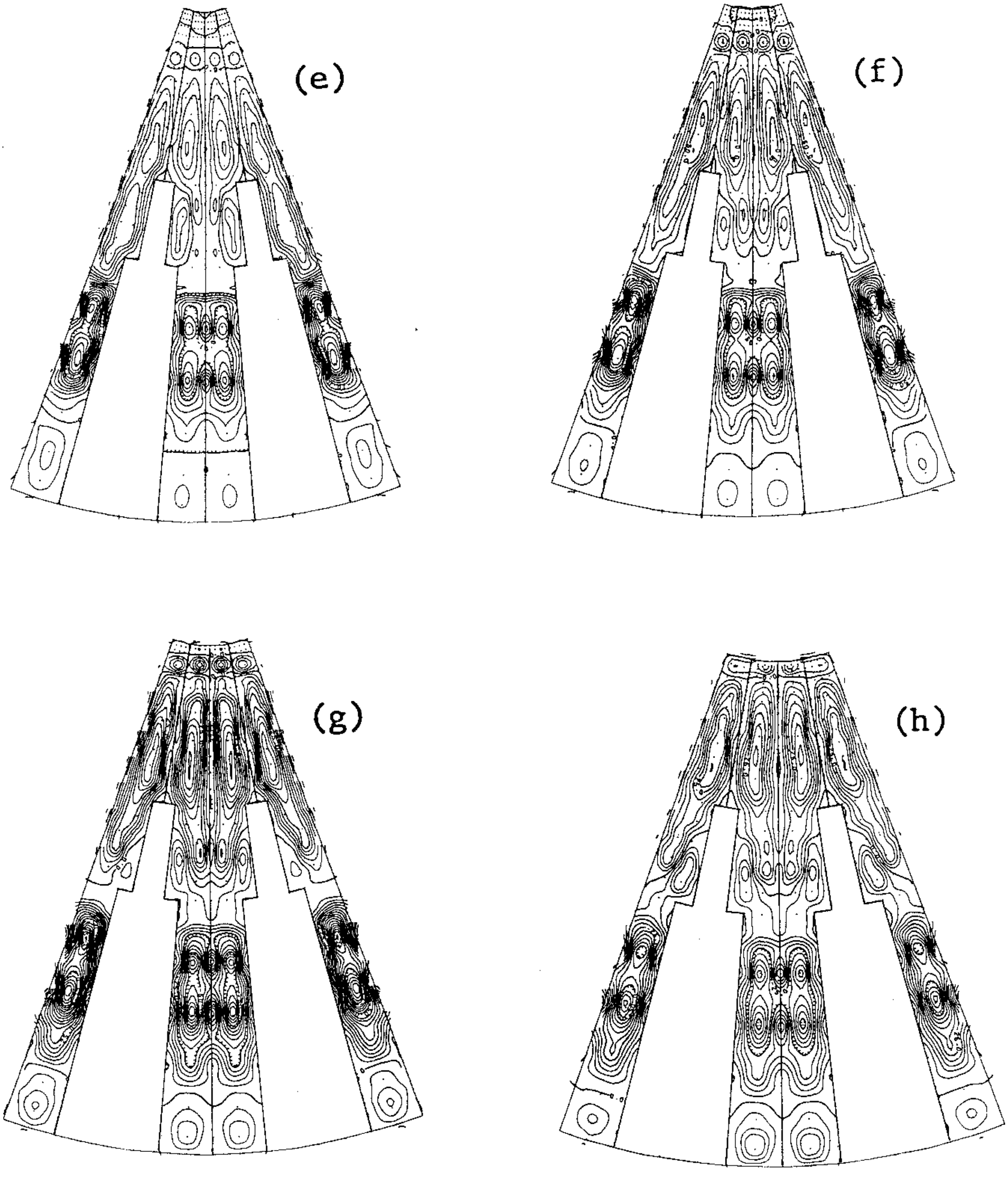


Fig. 17 40° cuts of the 216-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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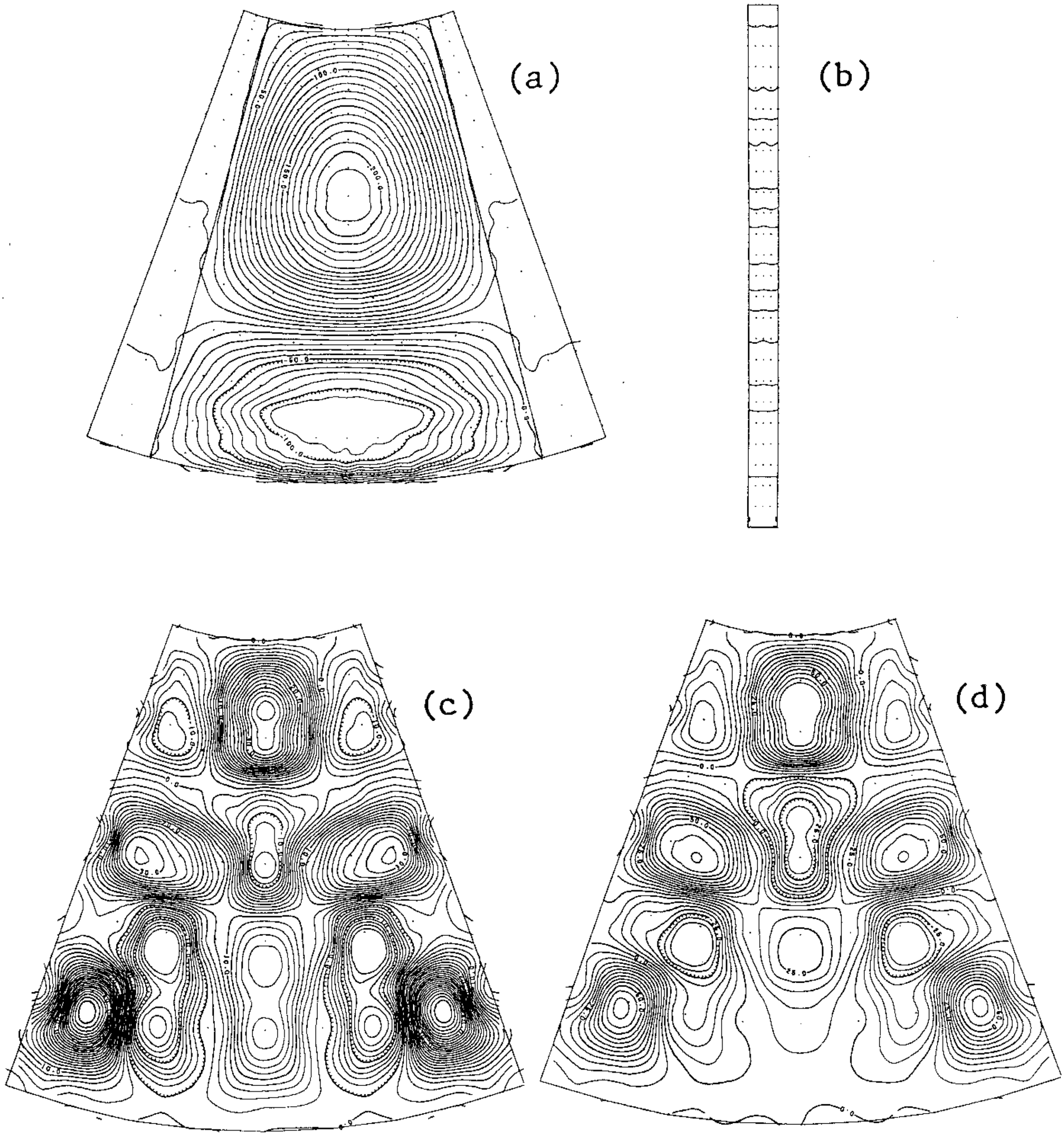
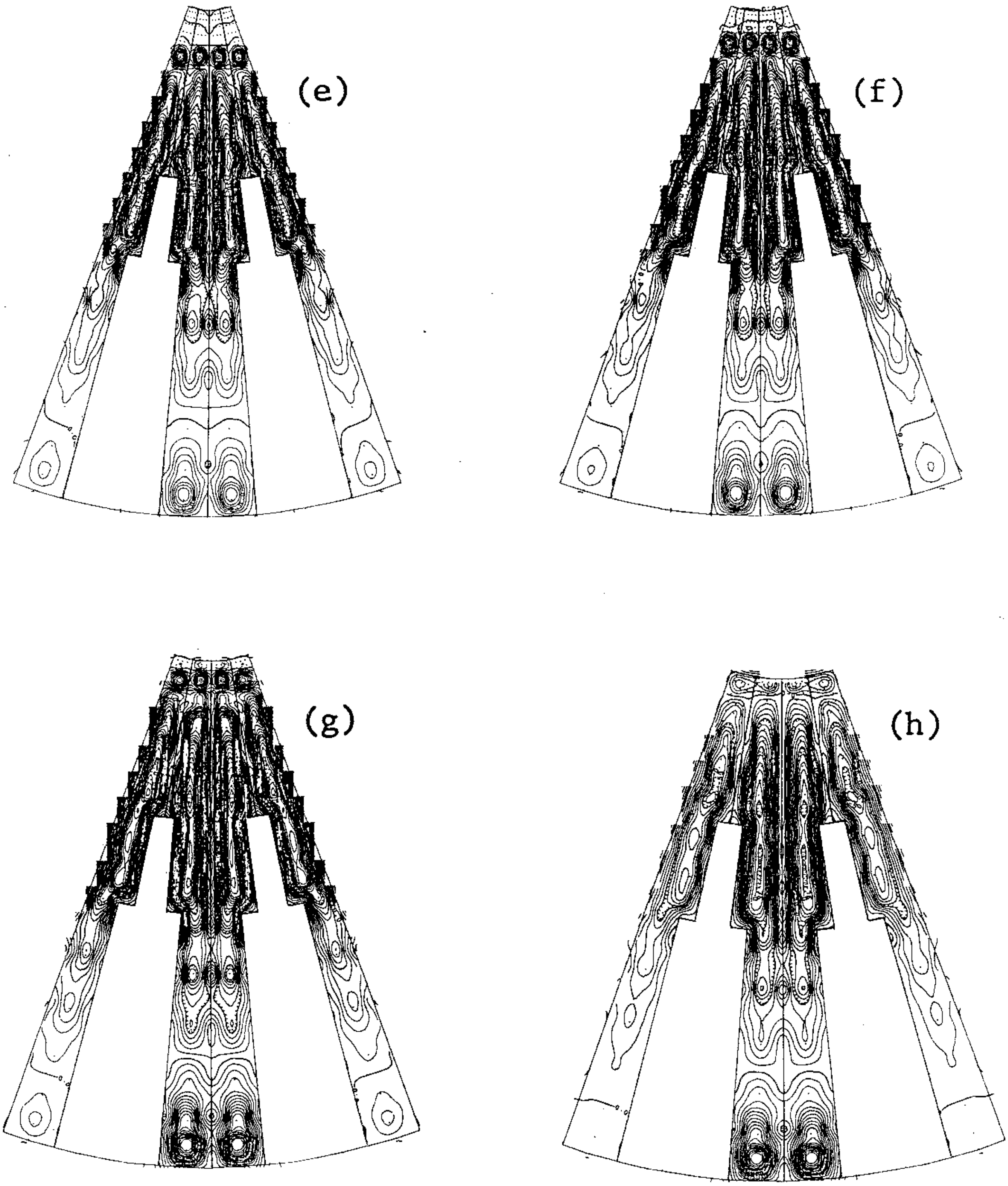


Fig. 18 40° cuts of the 230-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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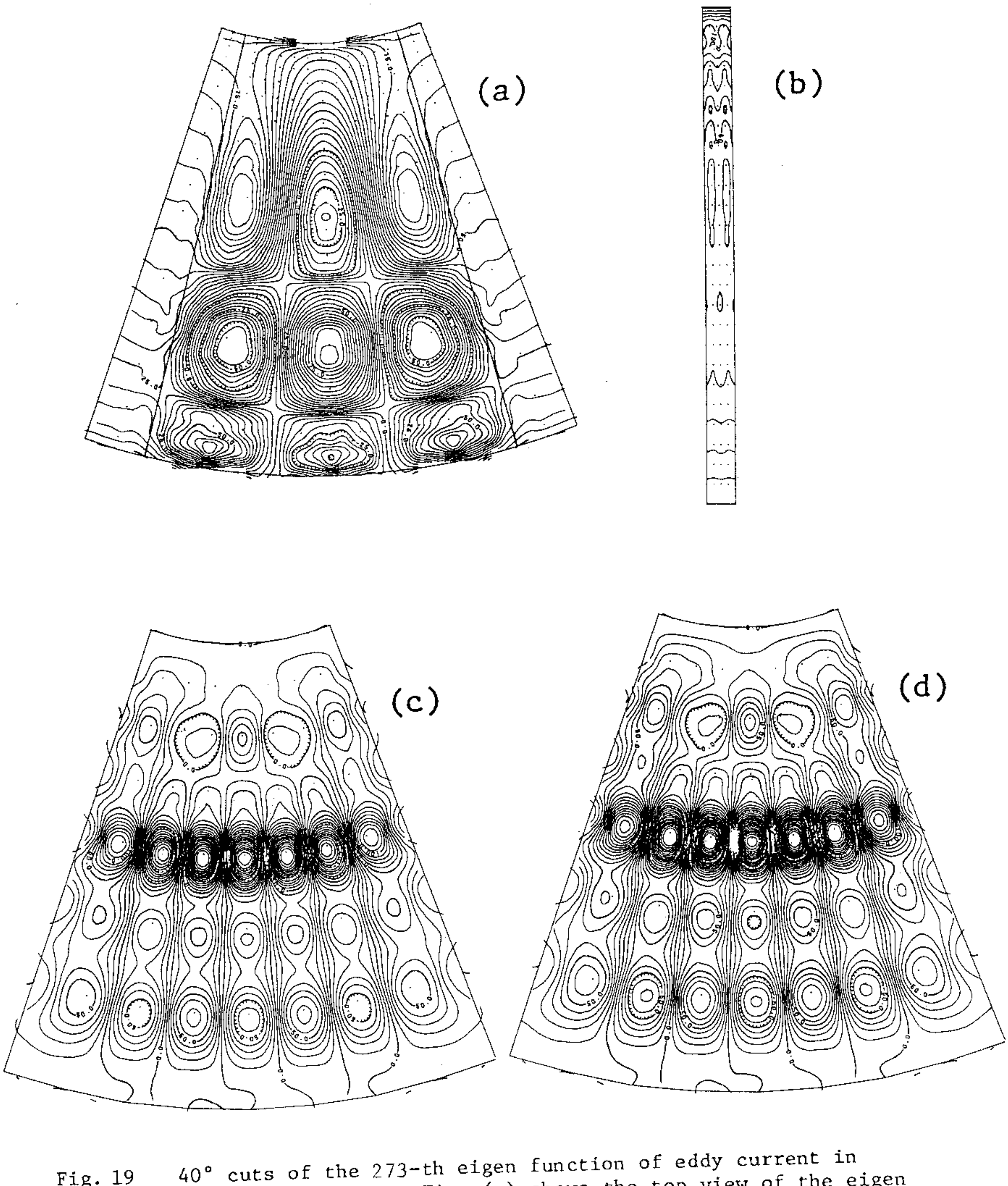
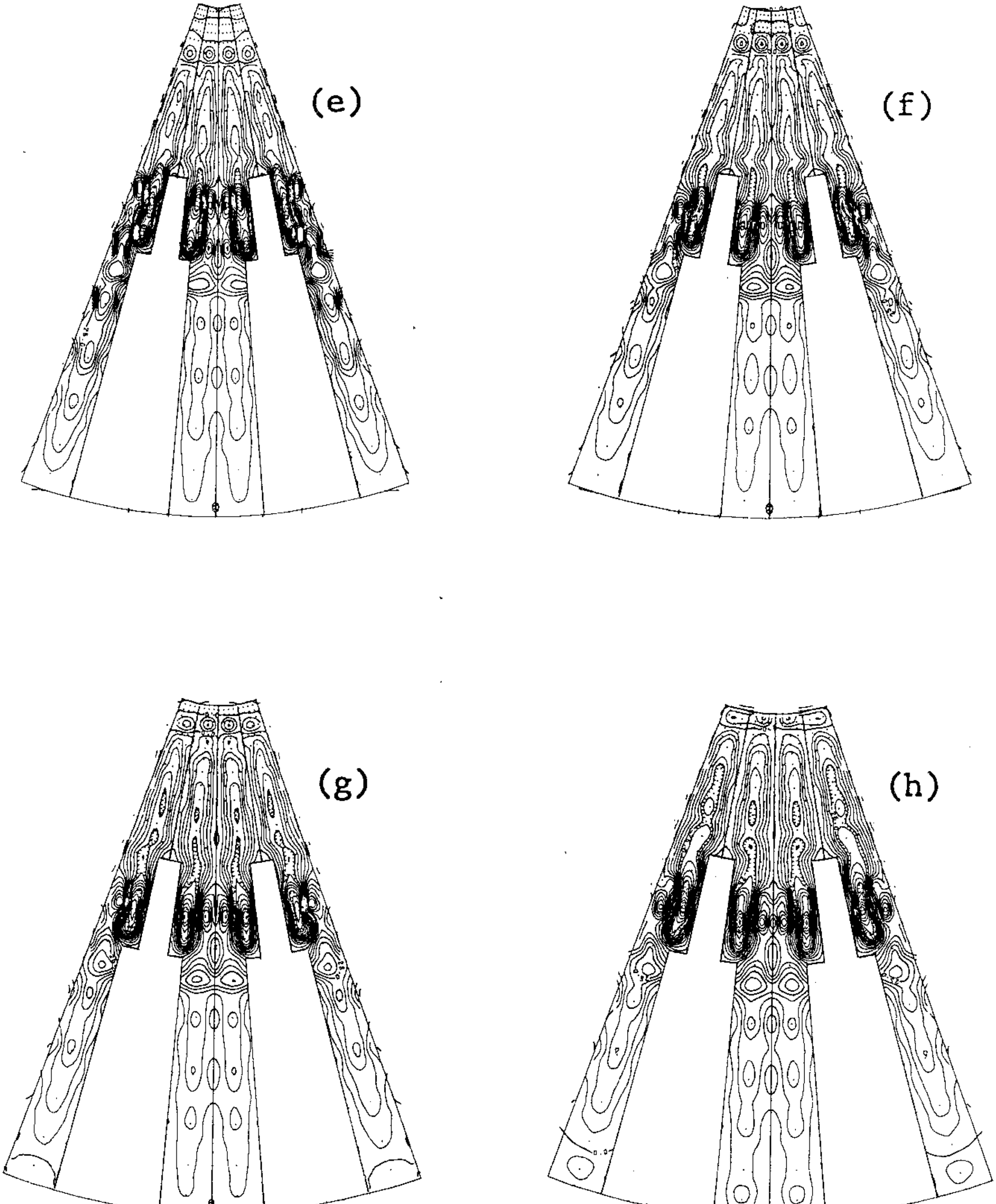


Fig. 19   40° cuts of the 273-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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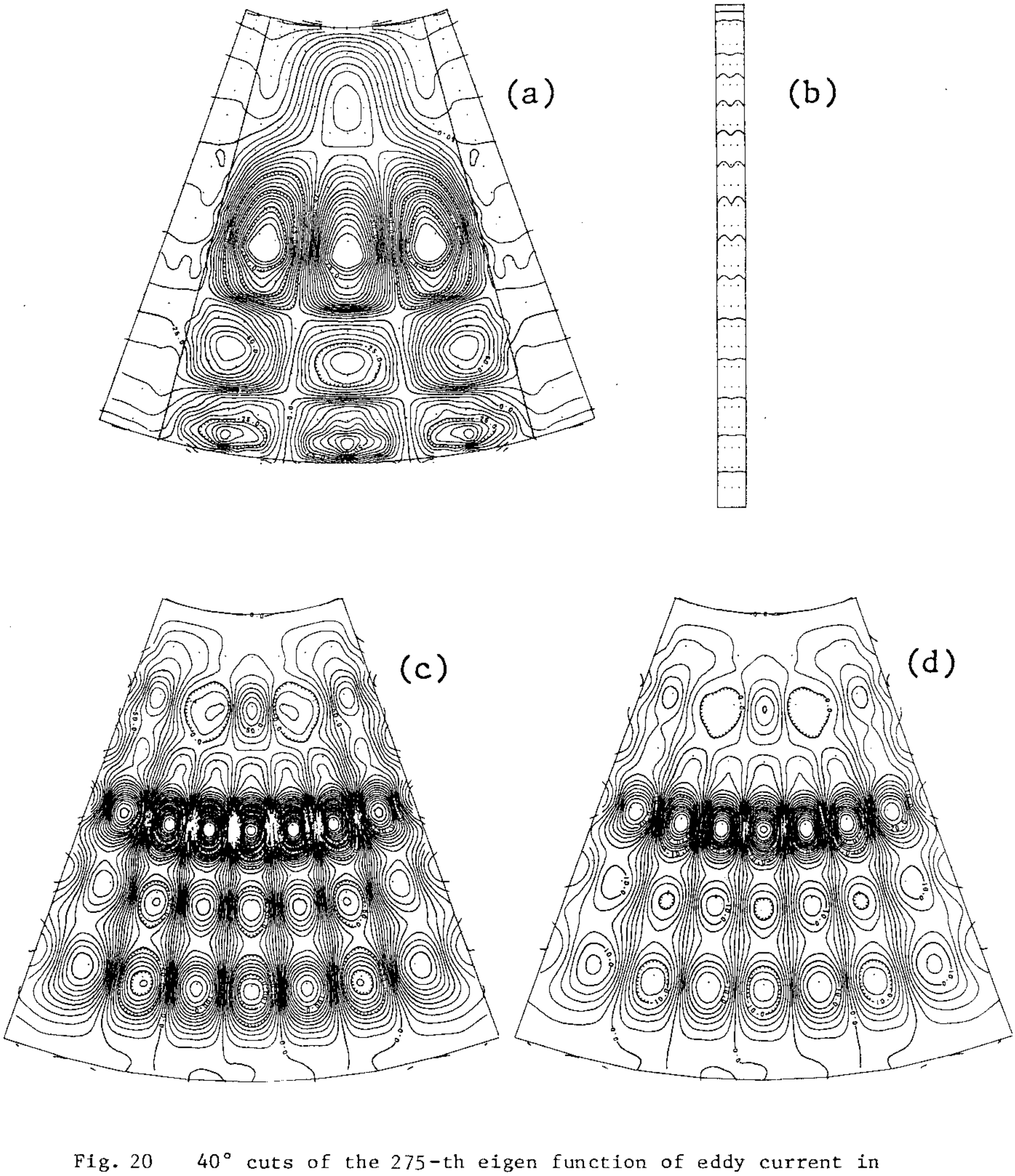
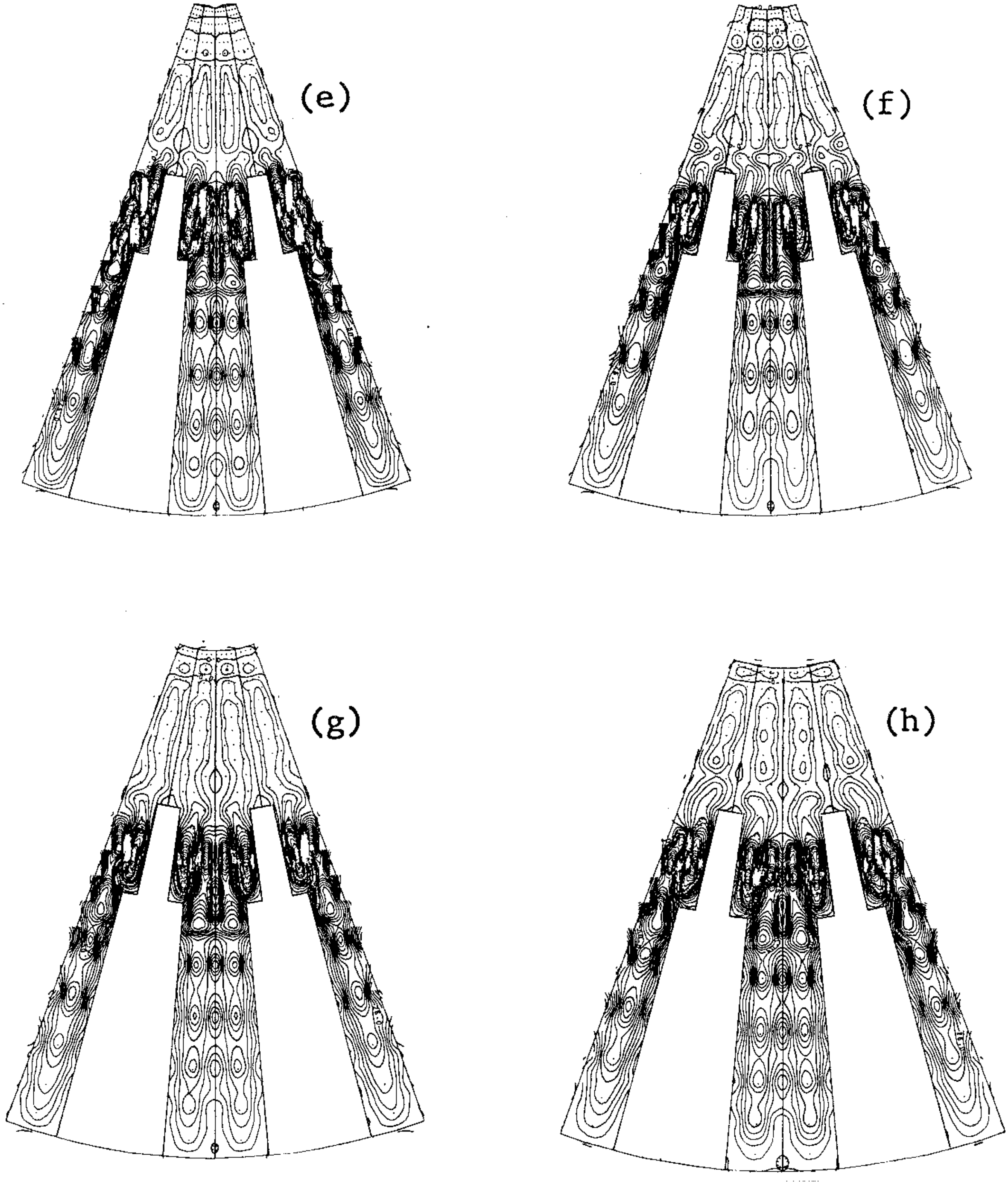


Fig. 20 40° cuts of the 275-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.



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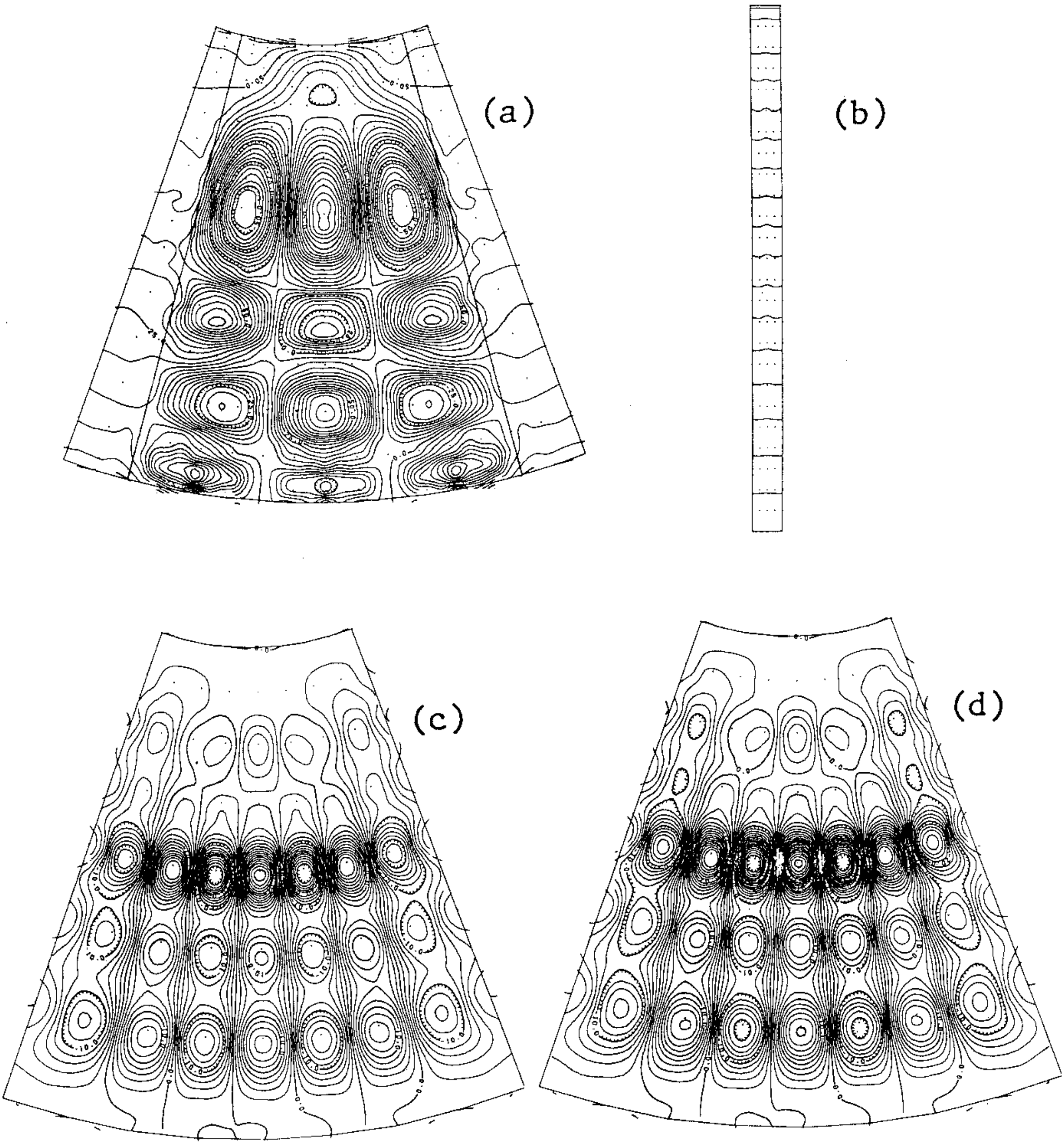

Fig. 21 40° cuts of the 277-th eigen function of eddy current in JT-60 multi-torus system. Fig. (a) shows the top view of the eigen function on a vacuum vessel. Fig. (b) shows the side view of that on a central column. Figs (c) and (d) show the top views of those on the outer and the inner support plates, respectively. Figs (e)-(h) show the top views of those on each conductor of the toroidal coil in the order from the out side.

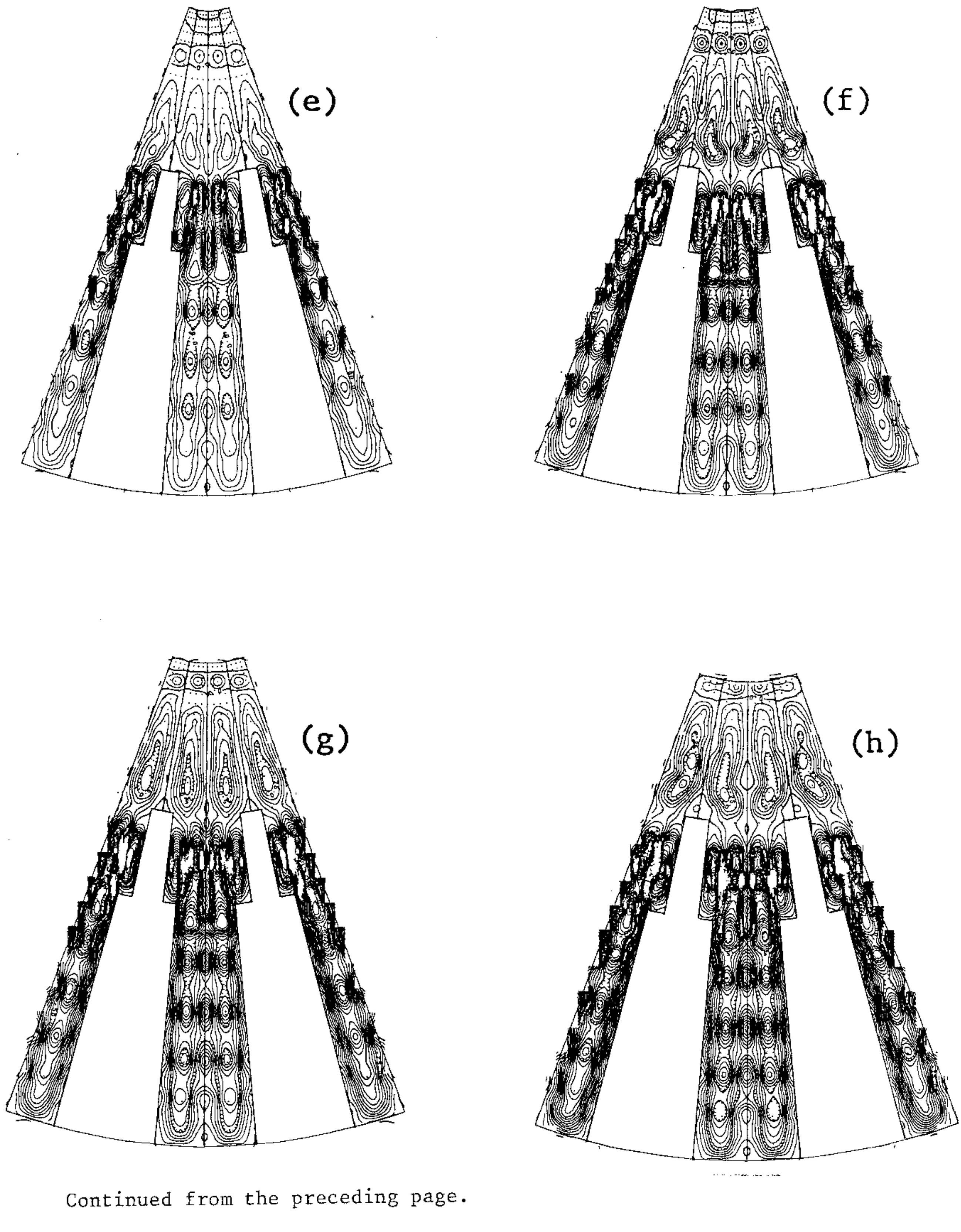

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Table 12 The mutual inductance of each eddy current eigen mode with individual poloidal field coils and a torus plasma (Rp=3.03m)

Mode No.	Plasma (H/√Ω)	F-coil (H/√Ω)	V-coil (H/√Ω)	Q-coil (H/√Ω)	M-coil (H/√Ω)
1	0.169254E-05	0.703719E-04	-0.211817E-03	0.160447E-03	0.117308E-03
2	0.141317E-04	0.542984E-03	-0.167672E-02	0.133143E-02	0.858309E-03
3	0.383994E-05	0.985099E-04	-0.720139E-03	0.580353E-03	0.131130E-03
4	-0.187566E-04	-0.437691E-03	0.348298E-02	-0.287486E-02	-0.559828E-03
5	-0.954058E-07	-0.400085E-05	-0.137657E-05	0.608815E-05	0.294906E-06
6	0.545769E-06	0.128718E-04	-0.605791E-04	0.151137E-04	0.121114E-05
7	-0.369621E-05	-0.535742E-04	0.435489E-03	-0.495631E-03	-0.898656E-04
8	-0.229596E-04	-0.292668E-03	0.236689E-02	-0.299861E-02	-0.534636E-03
9	0.220165E-04	0.426559E-03	-0.322183E-02	0.129305E-02	0.681201E-04
10	-0.441726E-06	-0.805300E-05	0.648590E-04	-0.223573E-04	-0.920603E-06
11	-0.202133E-05	-0.208342E-04	0.233214E-03	-0.219393E-03	-0.381023E-04
12	-0.164912E-05	-0.334547E-04	0.135065E-03	0.430575E-04	-0.330980E-05
13	0.305041E-05	0.227818E-03	0.280425E-03	-0.201763E-02	-0.245398E-03
14	0.329304E-04	0.540128E-03	-0.318726E-02	0.913620E-03	0.269214E-03
15	-0.512726E-06	0.619110E-05	0.176214E-03	-0.127405E-03	0.353136E-04
16	-0.669642E-06	0.127193E-04	0.257522E-03	-0.196927E-03	0.579933E-04
17	-0.586253E-04	-0.993116E-03	0.499315E-02	0.797723E-03	-0.792812E-04
18	-0.167544E-05	-0.266661E-04	0.136282E-03	0.326672E-04	-0.240079E-05
19	-0.109466E-05	-0.434811E-05	-0.371018E-04	-0.121612E-04	0.150473E-04
20	0.408362E-05	0.278121E-04	0.467875E-04	0.245767E-04	-0.386082E-04
21	0.968930E-06	0.157189E-04	-0.645236E-04	-0.282209E-04	0.558986E-06
22	0.394072E-04	0.620822E-03	-0.258937E-02	-0.100381E-02	0.240132E-04
23	0.299439E-08	0.196036E-06	-0.555139E-04	0.466886E-04	0.706053E-05
24	-0.575325E-06	-0.991197E-05	0.746053E-04	-0.155970E-04	-0.530310E-05
25	0.885518E-05	0.116303E-03	-0.242394E-02	0.986340E-03	0.186747E-03
26	0.102421E-05	0.232224E-04	-0.172409E-03	0.267173E-04	0.133988E-04
27	-0.333842E-06	-0.454845E-05	0.330969E-04	0.121673E-04	-0.821738E-06
28	-0.334073E-05	-0.102064E-03	0.611964E-03	-0.501319E-04	-0.586222E-04
29	0.105227E-05	0.174662E-04	-0.894934E-04	-0.115292E-04	0.180288E-05
30	-0.119627E-04	-0.159537E-03	0.731681E-03	0.288986E-03	0.125756E-04
31	-0.117025E-06	-0.366486E-05	-0.159833E-04	0.144055E-04	0.128382E-05
32	0.778471E-04	0.156261E-02	-0.735450E-02	-0.901247E-03	0.196201E-03
33	0.207499E-05	0.456276E-04	-0.218648E-04	-0.110266E-03	-0.513959E-05
34	0.241544E-04	0.516347E-03	-0.498474E-03	-0.115116E-02	-0.422555E-04
35	-0.446240E-06	0.888386E-05	0.824000E-04	0.372650E-04	0.925256E-07
36	0.301588E-06	-0.116999E-03	-0.282668E-03	-0.213382E-03	-0.510306E-05
37	0.194864E-07	0.623497E-05	-0.227295E-04	0.530255E-05	0.442928E-05
38	-0.178312E-05	0.479518E-04	0.124918E-03	0.134632E-03	0.409254E-04
39	0.946744E-06	0.165124E-04	-0.855892E-04	-0.171677E-04	0.676727E-06
40	0.908801E-05	0.169905E-03	-0.840745E-03	-0.139979E-03	0.167895E-04
41	0.542195E-04	0.101670E-02	-0.499386E-02	-0.824874E-03	0.991510E-04
42	-0.149925E-05	-0.313783E-04	0.108922E-03	0.315055E-04	-0.139704E-05
43	-0.234008E-06	-0.720721E-05	-0.401953E-05	-0.338855E-05	-0.969535E-05
44	-0.249045E-04	-0.621323E-03	0.224763E-02	0.214595E-03	-0.529812E-04
45	-0.566347E-06	-0.160545E-04	0.123173E-04	0.313727E-05	-0.117665E-04
46	-0.139626E-04	-0.375615E-03	-0.494189E-03	0.736276E-03	0.517003E-04
47	-0.352010E-06	-0.823958E-05	0.582663E-05	0.135738E-04	0.491484E-06
48	0.177679E-04	0.612110E-03	-0.154871E-02	0.183486E-03	0.562364E-04
49	0.138985E-05	0.486452E-04	-0.114386E-03	0.159477E-04	0.425205E-05
50	0.489286E-04	0.104167E-02	-0.385745E-02	-0.843622E-03	0.673480E-04
51	-0.244394E-05	-0.592235E-04	0.185453E-03	0.337813E-04	-0.461793E-05
52	-0.842868E-06	-0.255385E-04	0.104871E-03	-0.402688E-04	-0.181581E-04
53	-0.136197E-05	-0.403153E-04	0.157866E-03	-0.440073E-04	-0.237878E-04
54	0.632030E-06	0.160573E-04	-0.472887E-04	-0.628636E-05	0.194900E-05
55	0.371722E-06	0.227342E-04	-0.878758E-05	-0.595339E-04	-0.831507E-05
56	-0.275647E-05	-0.146713E-03	0.148634E-03	0.288439E-03	0.385828E-04
57	0.193981E-04	0.369610E-03	-0.745282E-03	-0.657618E-03	-0.177570E-04
58	0.709650E-07	0.185683E-05	-0.272760E-05	-0.341897E-06	0.172002E-06
59	0.329008E-06	0.128800E-04	-0.151992E-04	-0.177244E-05	0.212753E-06
60	0.644554E-07	0.191997E-05	-0.197037E-04	0.266620E-04	0.534662E-05

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Mode No.	Plasma (H/√Ω)	F-coil (H/√Ω)	V-coil (H/√Ω)	Q-coil (H/√Ω)	M-coil (H/√Ω)
61	-0.473301E-06	-0.232529E-04	-0.288510E-04	0.793453E-04	0.153240E-04
62	-0.549161E-06	-0.236209E-04	-0.483598E-04	0.123962E-03	0.229906E-04
63	0.201189E-04	0.329464E-03	-0.128045E-02	-0.569959E-03	0.590170E-05
64	0.554294E-05	0.132320E-03	-0.352298E-03	-0.823285E-04	0.713963E-05
65	-0.194751E-04	-0.538514E-03	0.116271E-02	0.259477E-03	-0.191497E-04
66	-0.327061E-04	-0.959978E-03	0.210014E-02	0.120769E-03	-0.699123E-04
67	0.367179E-06	0.118272E-04	-0.241719E-04	0.158720E-06	0.887983E-06
68	0.219495E-04	0.425762E-03	-0.105976E-02	-0.566822E-03	0.182131E-05
69	0.633169E-06	-0.101475E-03	-0.288856E-03	0.612582E-04	0.199346E-04
70	-0.870649E-07	0.309655E-04	0.783433E-04	-0.204277E-04	-0.575275E-05
71	-0.287428E-05	-0.107052E-03	0.113858E-03	0.470444E-04	0.203880E-05
72	-0.101019E-04	-0.404079E-03	0.344933E-03	0.180011E-03	0.105605E-04
73	0.619456E-06	0.267203E-04	-0.157337E-04	-0.106614E-04	-0.823315E-06
74	-0.119151E-05	-0.214503E-04	0.622788E-04	0.331414E-04	-0.441730E-07
75	-0.223074E-04	-0.414768E-03	0.114824E-02	0.579786E-03	-0.408963E-05
76	0.272137E-06	0.654896E-05	-0.135108E-04	-0.579596E-05	0.723351E-07
77	-0.121537E-05	-0.294742E-04	0.915502E-04	-0.316323E-04	-0.947806E-06
78	0.504072E-06	0.119157E-04	-0.372598E-04	0.123219E-04	0.743886E-06
79	0.792152E-06	0.235141E-04	-0.807902E-04	0.407806E-04	0.958420E-05
80	-0.849981E-07	0.288425E-04	-0.136974E-03	0.176727E-03	0.257177E-04
81	-0.721450E-05	-0.811072E-04	0.211586E-03	0.237096E-03	0.146668E-05
82	-0.257262E-05	-0.701209E-04	0.157427E-03	0.238281E-04	-0.420525E-05
83	-0.275488E-04	-0.769975E-03	0.175699E-02	0.263299E-03	-0.416901E-04
84	0.176605E-04	0.327883E-03	-0.960024E-03	-0.410647E-03	0.937110E-05
85	-0.284501E-05	-0.660925E-04	0.441192E-04	0.958622E-04	0.279992E-05
86	0.835384E-06	0.206409E-04	-0.577154E-04	-0.854047E-05	0.138436E-05
87	0.263892E-06	0.492494E-05	-0.263620E-04	0.565648E-07	0.952382E-06
88	0.295708E-04	0.858319E-03	-0.191245E-02	-0.172721E-03	0.584508E-04
89	-0.382085E-05	-0.119596E-03	0.209688E-03	0.352488E-04	-0.493933E-05
90	0.563545E-07	0.151640E-03	0.576388E-03	-0.166986E-03	-0.367148E-04
91	0.136711E-06	0.199008E-04	0.507553E-04	-0.174822E-04	-0.345911E-05
92	0.134797E-04	0.269481E-03	-0.501976E-03	-0.376148E-03	-0.353010E-05
93	-0.166046E-06	-0.495346E-05	0.127446E-04	-0.840787E-05	-0.487458E-05
94	-0.201366E-07	0.397774E-06	0.187894E-05	0.104426E-05	0.127345E-07
95	0.243577E-06	0.940183E-05	-0.630877E-05	-0.551244E-07	0.712465E-06
96	-0.180545E-05	-0.167923E-04	0.225002E-03	0.537548E-04	0.367364E-05
97	-0.226836E-06	-0.621327E-05	0.185493E-04	-0.985422E-05	-0.569097E-05
98	-0.415231E-07	-0.134475E-05	0.157567E-05	0.785506E-06	0.454551E-07
99	0.471096E-06	0.147104E-04	-0.208098E-04	-0.748723E-05	0.242989E-06
100	0.579048E-06	0.197538E-04	-0.330316E-04	-0.360932E-05	0.996224E-06
101	-0.781331E-05	-0.139071E-03	0.289815E-03	0.205252E-03	0.922363E-06
102	-0.171876E-04	-0.476678E-03	0.100758E-02	0.204371E-03	-0.248940E-04
103	-0.257951E-04	-0.813149E-03	0.138504E-02	0.293764E-03	-0.243704E-04
104	-0.571684E-06	-0.196283E-04	0.272505E-04	0.442708E-05	-0.885461E-06
105	-0.979953E-06	-0.278304E-04	0.808311E-04	-0.304176E-04	-0.129004E-04
106	0.834522E-06	0.255096E-04	-0.464650E-04	-0.520879E-05	0.230448E-05
107	0.429219E-07	0.211229E-05	-0.218678E-05	-0.175349E-07	-0.417462E-06
108	0.904807E-05	0.299854E-03	-0.569732E-03	0.269223E-04	0.281732E-04
109	-0.844739E-07	0.267725E-05	0.274706E-04	-0.315763E-04	-0.112727E-04
110	0.187044E-05	0.629674E-04	-0.686194E-04	-0.314125E-04	0.861888E-07
111	-0.180732E-04	-0.592297E-03	0.730517E-03	0.288699E-03	-0.490515E-05
112	-0.345604E-05	-0.157609E-03	0.911006E-04	0.379708E-04	0.293336E-05
113	0.378728E-05	0.149466E-03	-0.158002E-03	-0.311142E-04	0.129892E-05
114	0.364122E-06	0.119646E-04	-0.141868E-04	-0.580550E-05	0.140740E-06
115	0.407185E-05	0.135981E-03	-0.236963E-03	-0.203012E-04	0.636124E-05
116	0.141364E-05	0.357677E-04	-0.132792E-03	0.562361E-04	0.176519E-04
117	0.472323E-06	0.123143E-04	-0.309964E-04	0.494853E-05	0.328462E-05
118	0.399968E-06	0.213220E-05	-0.939321E-04	0.765969E-04	0.180523E-04
119	-0.157862E-05	-0.508836E-04	0.749555E-04	0.200074E-04	-0.145748E-05
120	-0.118004E-04	-0.377251E-03	0.526508E-03	0.171008E-03	-0.852305E-05
121	0.956433E-05	0.310641E-03	-0.429742E-03	-0.138650E-03	0.547353E-05
122	-0.108205E-04	-0.355383E-03	0.479409E-03	0.170298E-03	-0.237131E-05
123	0.727436E-05	0.265162E-03	-0.341058E-03	-0.409994E-04	0.949113E-05
124	-0.855477E-05	-0.311133E-03	0.409326E-03	0.433381E-04	-0.119236E-04
125	0.396242E-07	0.126074E-06	-0.509076E-05	0.103347E-06	0.285307E-06
126	-0.606042E-06	-0.196120E-04	0.236941E-04	0.102465E-04	-0.125518E-06
127	-0.106585E-04	-0.358217E-03	0.413007E-03	0.161881E-03	-0.321840E-05
128	0.243633E-06	0.881234E-05	-0.816861E-05	-0.357761E-05	-0.987770E-09
129	-0.910686E-06	-0.616249E-04	-0.152224E-04	0.667182E-05	0.274689E-05
130	-0.900395E-06	-0.369444E-04	-0.296432E-04	0.369100E-04	0.321072E-05

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Mode No.	Plasma (H/$\sqrt{\Omega}$)	F-coil (H/$\sqrt{\Omega}$)	V-coil (H/$\sqrt{\Omega}$)	Q-coil (H/$\sqrt{\Omega}$)	M-coil (H/$\sqrt{\Omega}$)
131	0.100345E-05	0.369254E-04	0.190953E-04	-0.383179E-04	-0.278973E-05
132	0.520051E-05	0.125128E-03	-0.349759E-03	-0.637998E-04	0.883838E-05
133	0.384202E-05	0.878592E-04	-0.262303E-03	-0.504827E-04	0.668184E-05
134	0.807185E-05	0.264992E-03	-0.301610E-03	-0.150656E-03	-0.401311E-06
135	0.483142E-05	0.160199E-03	-0.184807E-03	-0.858910E-04	0.762594E-07
136	-0.895631E-05	-0.314021E-03	0.359990E-03	0.130265E-03	-0.128319E-05
137	0.145257E-05	0.352823E-04	-0.130305E-03	0.405120E-04	0.124158E-04
138	-0.282511E-06	-0.825265E-05	0.147256E-04	0.422285E-05	-0.170210E-06
139	0.150393E-05	0.326002E-04	-0.147945E-03	0.559295E-04	0.157249E-04
140	0.118570E-06	0.101028E-04	0.214100E-04	-0.218625E-04	-0.397007E-05
141	0.521285E-05	0.182140E-03	-0.200112E-03	-0.629347E-04	0.383104E-05
142	0.193218E-06	0.621371E-05	-0.102332E-04	-0.181089E-07	0.582496E-06
143	0.466773E-06	0.165651E-04	-0.272323E-04	-0.708809E-06	0.861974E-06
144	0.107639E-04	0.356803E-03	-0.697325E-03	0.120268E-04	0.279939E-04
145	0.107348E-04	0.302063E-03	-0.656093E-03	-0.102332E-03	0.180811E-04
146	-0.607377E-05	-0.201249E-03	0.194521E-03	0.114733E-03	0.102819E-06
147	0.113187E-04	0.411050E-03	-0.434210E-03	-0.142070E-03	0.376539E-05
148	-0.788293E-05	-0.285181E-03	0.314216E-03	0.943186E-04	-0.329316E-05
149	0.230284E-07	-0.637049E-06	-0.328948E-05	-0.106463E-05	0.450573E-07
150	0.348749E-07	0.783137E-06	-0.303077E-05	-0.222221E-06	0.841534E-07
151	-0.251378E-06	-0.824703E-05	0.129177E-04	0.256110E-05	-0.257527E-06
152	-0.161825E-06	-0.217943E-05	0.217048E-04	0.629967E-05	0.198703E-06
153	0.599200E-06	0.681285E-05	-0.839763E-04	-0.219971E-04	-0.625119E-06
154	-0.529272E-05	-0.147626E-03	0.264209E-03	0.802195E-04	-0.485137E-05
155	-0.163684E-05	-0.472317E-04	0.582540E-04	0.385397E-04	0.569468E-06
156	0.793676E-05	0.234532E-03	-0.258776E-03	-0.191126E-03	-0.370879E-05
157	0.432222E-05	0.147572E-03	-0.172486E-03	-0.561494E-04	0.248171E-05
158	0.174849E-04	0.607615E-03	-0.701600E-03	-0.214251E-03	0.105209E-04
159	0.272562E-05	0.102514E-03	-0.936943E-04	-0.373822E-04	0.409220E-07
160	-0.992928E-05	-0.377145E-03	0.338388E-03	0.124227E-03	-0.172351E-05
161	0.868197E-06	0.287093E-04	-0.424959E-04	-0.948942E-06	0.225526E-05
162	-0.103766E-05	-0.295684E-04	0.670641E-04	-0.126068E-04	-0.552765E-05
163	0.589055E-06	0.165899E-04	-0.471653E-04	0.683807E-05	0.286211E-05
164	0.378832E-06	0.107901E-04	-0.297607E-04	0.309917E-05	0.160769E-05
165	-0.140847E-06	0.724990E-05	0.565149E-04	-0.210371E-05	-0.170569E-05
166	-0.217037E-05	-0.573132E-04	0.184067E-03	-0.240828E-04	-0.107574E-04
167	0.171633E-05	0.466263E-04	-0.140874E-03	0.183773E-04	0.829826E-05
168	-0.117502E-05	-0.371386E-04	0.492239E-04	0.136880E-04	-0.147686E-05
169	0.692955E-07	0.231768E-05	-0.313242E-05	-0.418088E-06	0.134182E-06
170	0.226215E-05	0.674449E-04	-0.127516E-03	-0.296496E-04	0.159715E-05
171	-0.275758E-06	-0.104347E-04	0.106132E-04	0.284392E-05	-0.133080E-06
172	0.111308E-04	0.435878E-03	-0.382472E-03	-0.114738E-03	0.448251E-05
173	-0.323481E-05	-0.127695E-03	0.131399E-03	0.197788E-04	-0.288117E-05
174	0.321575E-06	0.125679E-04	-0.129461E-04	-0.226622E-05	0.252621E-06
175	-0.164428E-06	-0.374460E-05	0.145419E-04	-0.708479E-07	-0.574368E-06
176	0.723228E-07	0.174564E-05	-0.660843E-05	0.346806E-06	0.300970E-06
177	-0.212869E-05	-0.612169E-04	0.152504E-03	0.579362E-05	-0.525913E-05
178	-0.161914E-06	-0.503722E-05	0.103829E-04	0.116379E-05	-0.242510E-06
179	0.203952E-05	0.619657E-04	-0.134645E-03	-0.160547E-04	0.307728E-05
180	-0.449957E-08	0.629526E-06	0.138165E-05	0.488038E-06	-0.130788E-07
181	-0.804940E-06	-0.176302E-04	0.631449E-04	0.927875E-05	-0.139855E-05
182	0.809924E-08	0.881236E-06	0.216770E-05	-0.881638E-06	-0.160019E-06
183	0.101342E-04	0.385412E-03	-0.318528E-03	-0.132669E-03	0.163792E-05
184	-0.177823E-07	-0.220125E-06	0.132440E-05	0.401826E-06	-0.221939E-07
185	-0.132307E-05	-0.381883E-04	0.952392E-04	0.613902E-06	-0.386403E-05
186	0.650213E-06	0.158487E-04	-0.606221E-04	0.448753E-05	0.298548E-05
187	0.265275E-05	0.784610E-04	-0.185985E-03	-0.258674E-05	0.710499E-05
188	0.145310E-06	0.602410E-05	-0.497363E-05	-0.908538E-06	0.118065E-06
189	0.433306E-05	0.123139E-03	-0.322905E-03	0.256082E-06	0.128420E-04
190	0.101802E-04	0.394505E-03	-0.358523E-03	-0.100772E-03	0.519269E-05
191	-0.100691E-05	-0.321758E-04	0.553980E-04	0.971089E-05	-0.108311E-05
192	-0.384008E-07	-0.133971E-05	0.157681E-05	0.498734E-06	-0.167436E-07
193	-0.705936E-06	-0.221657E-04	0.450240E-04	0.315830E-05	-0.132314E-05
194	0.389426E-07	0.230969E-05	-0.161071E-06	0.285263E-07	0.471186E-08
195	-0.223657E-05	-0.693337E-04	0.145480E-03	0.971349E-05	-0.442441E-05
196	0.700646E-05	0.293806E-03	-0.195359E-03	-0.655432E-04	0.190695E-05
197	0.228283E-07	0.442430E-05	0.175594E-04	-0.758879E-05	-0.158599E-05
198	0.164471E-07	-0.400343E-05	-0.259461E-04	0.102836E-04	0.220724E-05
199	0.247666E-06	0.829328E-05	-0.109830E-04	-0.346444E-05	0.908834E-08
200	-0.219657E-07	-0.805590E-06	0.841547E-06	0.241043E-06	-0.153586E-07

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Mode No.	Plasma (H/√Ω)	F-coil (H/√Ω)	V-coil (H/√Ω)	Q-coil (H/√Ω)	M-coil (H/√Ω)
201	0.376042E-04	0.123838E-02	-0.240690E-02	0.116420E-03	0.120366E-03
202	0.288864E-04	0.194813E-02	0.382961E-03	0.709402E-04	-0.114468E-04
203	0.301068E-05	-0.926408E-05	-0.247526E-03	-0.103893E-03	0.283820E-05
204	0.159869E-05	0.942756E-04	-0.152959E-04	0.544550E-06	0.528724E-06
205	0.185453E-04	0.723613E-03	-0.808811E-03	-0.167220E-03	0.116970E-04
206	0.120234E-05	0.606652E-04	-0.104615E-04	-0.115887E-04	-0.590861E-06
207	-0.270088E-05	-0.156079E-04	0.396991E-03	-0.618917E-04	-0.231074E-04
208	0.939533E-06	0.451167E-04	-0.167243E-04	-0.573402E-05	0.245667E-06
209	0.422774E-05	0.146321E-03	-0.241454E-03	-0.564728E-04	0.140559E-05
210	0.715600E-06	0.346872E-04	-0.124100E-04	-0.464176E-05	0.134552E-06
211	0.102595E-04	0.402788E-03	-0.445152E-03	-0.387211E-04	0.155049E-04
212	-0.575355E-06	-0.280410E-04	0.934869E-05	0.375338E-05	-0.970823E-07
213	0.184590E-05	0.690881E-04	-0.860248E-04	-0.132672E-04	0.209178E-05
214	-0.905574E-05	-0.288460E-03	0.609241E-03	-0.461368E-04	-0.338730E-04
215	0.530394E-06	0.247354E-04	-0.123366E-04	-0.250556E-05	0.413463E-06
216	0.411999E-06	-0.737215E-05	-0.618098E-04	0.105057E-04	0.241784E-07
217	0.405742E-06	0.189977E-04	-0.129452E-04	-0.256123E-06	0.116818E-05
218	0.322832E-05	0.156363E-03	-0.572304E-06	-0.694343E-04	-0.161465E-04
219	0.188219E-04	0.521922E-03	-0.440516E-02	0.121902E-02	0.731554E-03
220	0.650815E-05	0.231406E-03	-0.398138E-03	-0.336238E-05	0.207609E-04
221	0.125017E-05	0.581705E-04	-0.351924E-04	-0.183686E-04	0.114310E-06
222	-0.342582E-06	-0.165329E-04	0.443844E-05	0.260761E-05	0.253039E-06
223	0.116692E-05	0.273141E-04	-0.123793E-03	0.473227E-05	0.727022E-05
224	-0.271923E-06	-0.131271E-04	0.331679E-05	0.199219E-05	0.208857E-06
225	0.465408E-05	0.180894E-03	-0.269223E-03	-0.704427E-05	0.168105E-04
226	0.654120E-06	0.218733E-04	-0.712467E-04	-0.111729E-05	0.601656E-05
227	0.309634E-05	0.148726E-03	-0.154379E-03	-0.776570E-05	0.162616E-04
228	0.468898E-06	0.279352E-04	-0.352392E-04	-0.330685E-05	0.577157E-05
229	-0.285312E-06	-0.132285E-04	0.585345E-05	0.196417E-05	0.475914E-07
230	0.598226E-04	0.762727E-03	-0.243254E-02	-0.301377E-03	-0.511321E-03
231	0.112592E-05	0.588089E-04	-0.112742E-03	0.335027E-04	0.248204E-04
232	0.620182E-05	0.201611E-03	-0.299221E-03	-0.200429E-04	-0.269130E-05
233	0.322642E-06	0.144129E-04	-0.914481E-05	-0.146016E-05	0.295859E-06
234	0.601267E-06	0.266010E-04	0.613598E-05	-0.178041E-04	-0.608118E-05
235	0.147048E-05	0.373120E-04	-0.101427E-03	-0.297160E-05	0.531724E-06
236	-0.175703E-06	-0.876169E-05	0.246108E-05	0.115725E-05	-0.840820E-07
237	0.268909E-05	0.836152E-04	-0.168698E-03	0.639591E-05	0.865102E-05
238	0.194669E-05	0.785272E-04	-0.991921E-04	-0.202543E-07	-0.151058E-05
239	0.359206E-06	-0.194328E-05	-0.450284E-04	0.214314E-05	0.535646E-05
240	-0.752765E-06	-0.160402E-04	0.628010E-04	0.490802E-06	-0.317982E-05
241	-0.214664E-06	-0.880001E-05	0.551815E-05	0.168815E-05	-0.583163E-06
242	0.297133E-04	0.501661E-03	-0.141780E-02	-0.471926E-03	0.295093E-03
243	-0.520185E-05	-0.163287E-03	0.236441E-03	0.457128E-04	-0.192422E-04
244	-0.125369E-05	-0.383940E-04	0.639453E-04	0.122943E-04	-0.319905E-05
245	0.127861E-06	0.644065E-05	-0.168498E-05	-0.839262E-06	0.123200E-07
246	0.199848E-07	-0.115655E-05	-0.931555E-05	0.418819E-05	0.129623E-05
247	-0.262161E-05	-0.898519E-04	0.156529E-03	0.905785E-05	-0.572840E-05
248	0.730158E-06	0.161708E-04	-0.686376E-04	0.616220E-06	0.205686E-05
249	0.114753E-06	0.573123E-05	-0.189637E-05	-0.828932E-06	0.345125E-07
250	-0.116218E-04	-0.256872E-03	0.412436E-03	0.625820E-04	0.155344E-03
251	-0.386360E-05	-0.127109E-03	0.156964E-03	-0.504195E-04	-0.166289E-04
252	-0.138039E-05	-0.526620E-04	0.615601E-04	0.754676E-05	-0.159254E-05
253	-0.312818E-06	-0.113722E-04	0.153751E-04	0.321316E-05	-0.188213E-06
254	0.106855E-06	0.516033E-05	-0.178724E-05	-0.589426E-06	0.224141E-07
255	0.216385E-05	0.796309E-04	-0.121765E-03	-0.123653E-04	0.318995E-05
256	-0.410884E-06	-0.153492E-04	0.170842E-04	0.358507E-05	0.396765E-08
257	-0.438561E-06	-0.974362E-05	0.482757E-04	0.445928E-05	-0.904554E-06
258	0.102118E-06	0.466861E-05	-0.295854E-05	-0.763225E-06	0.241628E-07
259	-0.162152E-04	-0.606019E-03	0.949141E-03	-0.299150E-03	-0.222312E-03
260	0.443264E-07	0.336009E-05	-0.284461E-05	0.749688E-06	0.114714E-05
261	0.243232E-05	0.439118E-04	0.417087E-04	-0.496955E-04	-0.491765E-04
262	0.505158E-05	0.983440E-04	0.541122E-04	-0.186980E-03	0.504021E-04
263	-0.590943E-07	-0.285270E-05	0.802259E-06	0.340629E-06	0.341873E-08
264	-0.145455E-05	-0.600867E-04	0.889933E-04	0.117146E-04	-0.347846E-05
265	0.410155E-06	0.158875E-04	-0.170672E-04	-0.235302E-05	0.100494E-06
266	0.168224E-08	-0.108485E-05	-0.283903E-04	-0.604259E-05	0.122954E-05
267	-0.505434E-07	-0.243505E-05	0.130813E-05	0.409840E-06	-0.328193E-07
268	-0.307577E-07	-0.158378E-05	0.469157E-06	0.252674E-06	-0.756874E-08
269	0.103253E-07	0.743540E-06	-0.439200E-07	-0.214202E-06	0.767695E-08
270	-0.453148E-04	-0.137548E-02	0.115677E-02	-0.253543E-03	0.255719E-04

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Mode No.	Plasma (H/√Ω)	F-coil (H/√Ω)	V-coil (H/√Ω)	Q-coil (H/√Ω)	M-coil (H/√Ω)
271	-0.168428E-07	-0.700812E-06	0.341716E-06	0.390758E-07	0.430071E-08
272	0.190824E-06	0.107581E-04	-0.879071E-04	0.891637E-04	0.301001E-04
273	0.756988E-04	0.238432E-02	-0.129840E-02	0.156092E-03	0.621987E-04
274	-0.159119E-05	-0.604842E-04	0.822615E-04	-0.741125E-04	-0.497763E-04
275	0.601070E-04	0.204662E-02	-0.837084E-03	0.207198E-03	0.604874E-04
276	-0.213906E-04	-0.661271E-03	0.120117E-03	0.151082E-05	-0.252691E-05
277	0.449278E-04	0.159871E-02	-0.224176E-03	0.125526E-03	0.225795E-04
278	-0.367171E-06	-0.179096E-05	-0.805381E-04	0.473937E-04	0.382618E-04
279	0.151455E-04	0.456861E-03	0.300495E-04	-0.473911E-04	-0.932035E-04
280	0.206192E-04	0.797660E-03	-0.149402E-04	0.137124E-03	0.188036E-04
281	-0.321027E-07	-0.112668E-05	0.329274E-07	-0.229948E-06	-0.135018E-07
282	0.209147E-08	0.790262E-07	-0.341136E-07	0.140847E-07	0.184566E-08
283	-0.286413E-08	-0.982935E-07	0.269964E-07	-0.160353E-07	-0.205148E-08
284	-0.113276E-08	-0.427776E-07	0.122429E-07	-0.262695E-08	-0.954198E-09
285	-0.560545E-09	-0.197039E-07	0.976226E-08	-0.245268E-10	-0.594449E-09
286	0.450025E-09	0.174777E-07	-0.697891E-08	-0.978585E-10	0.426477E-09
287	0.364346E-09	0.142173E-07	-0.583746E-08	-0.234562E-09	0.347659E-09
288	-0.276056E-09	-0.857309E-08	0.607180E-08	0.396744E-09	-0.325750E-09
289	-0.271419E-09	-0.115575E-07	0.384054E-08	0.184157E-09	-0.223135E-09
290	-0.189478E-09	-0.657296E-08	0.443858E-08	0.450349E-09	-0.180394E-09
291	0.160941E-09	0.582206E-08	-0.372702E-08	-0.356145E-09	0.177328E-09
292	0.175557E-09	0.744674E-08	-0.277236E-08	-0.413920E-09	0.160953E-09
293	-0.165205E-09	-0.714714E-08	0.222692E-08	0.197086E-09	-0.266633E-09
294	-0.734319E-06	-0.292394E-04	0.367755E-04	-0.688589E-05	-0.256100E-04
295	-0.427887E-10	0.479113E-09	0.373142E-08	0.697083E-09	0.395825E-10
296	-0.310165E-05	-0.468775E-04	-0.279661E-04	0.110122E-03	0.747192E-05
297	0.916816E-10	0.566729E-08	-0.224607E-08	0.258265E-08	0.256476E-09
298	0.163867E-04	0.613219E-03	0.112719E-03	0.262063E-04	-0.113918E-04
299	-0.120125E-09	-0.549139E-08	0.135249E-08	-0.417509E-10	-0.615288E-10
300	-0.602159E-10	-0.126392E-08	0.219335E-08	0.311691E-09	-0.823879E-10
301	0.118318E-09	0.652545E-08	-0.214248E-09	0.116379E-09	0.535689E-10
302	-0.378342E-10	0.178510E-09	0.209695E-08	0.550089E-09	-0.827316E-10
303	0.713058E-10	0.444423E-08	-0.274047E-10	-0.121959E-09	-0.232214E-11
304	0.453542E-05	0.208358E-03	0.163827E-04	0.727604E-04	0.976285E-05
305	0.631057E-12	0.163275E-08	0.157853E-08	0.114745E-09	-0.421572E-10
306	0.220285E-10	0.253123E-08	0.162476E-08	0.291258E-09	-0.383105E-10
307	0.169900E-09	0.119744E-07	0.264897E-08	0.608762E-09	-0.230072E-11
308	-0.188926E-09	-0.123113E-07	-0.328452E-08	-0.686836E-09	-0.768882E-10
309	-0.207748E-05	-0.762992E-04	-0.554653E-04	0.214063E-04	0.251748E-05
310	0.940236E-05	0.366947E-03	0.694192E-04	0.136539E-04	0.177377E-04
311	-0.196723E-05	-0.928004E-04	-0.254077E-04	-0.340152E-04	0.676256E-06
312	0.377415E-06	0.211911E-04	-0.211914E-04	-0.159876E-05	0.212701E-05
313	0.649255E-05	0.281805E-03	0.119679E-03	0.914873E-05	-0.356610E-05
314	-0.511545E-06	-0.250307E-04	-0.314585E-05	-0.905008E-05	-0.117629E-05
315	0.390413E-05	0.113929E-03	0.796129E-04	-0.249812E-04	-0.516397E-04
316	0.339718E-06	0.749444E-05	0.170341E-04	-0.338367E-05	-0.545954E-05
317	0.423311E-05	0.200776E-03	0.947302E-04	0.192616E-04	0.400785E-05
318	0.609332E-06	0.318539E-04	0.125333E-04	0.168348E-04	0.577949E-06
319	0.687230E-07	0.274231E-05	-0.342991E-05	0.407923E-05	-0.154074E-06
320	0.296464E-05	0.154715E-03	0.953468E-04	0.301215E-04	0.348668E-05
321	-0.497143E-05	-0.166072E-03	-0.130289E-03	0.488111E-04	0.302356E-04
322	0.216648E-05	0.114782E-03	0.718334E-04	0.240524E-04	0.730698E-06
323	-0.340766E-06	-0.124770E-04	-0.832292E-05	-0.143450E-05	0.100461E-06
324	-0.117561E-06	-0.482549E-05	-0.169211E-04	0.726896E-05	-0.226604E-07
325	-0.411901E-05	-0.155473E-03	-0.100206E-03	0.247468E-04	0.147513E-05
326	0.248038E-05	0.138142E-03	0.960257E-04	0.374879E-04	0.191259E-05
327	-0.312854E-05	-0.131325E-03	-0.984067E-04	0.126799E-04	0.239435E-05
328	0.166956E-05	0.498893E-04	0.495026E-04	-0.116160E-04	-0.262800E-04
329	-0.169869E-05	-0.103506E-03	-0.726427E-04	-0.383660E-04	-0.125688E-05
330	0.141281E-06	0.627523E-05	0.787000E-06	0.300849E-05	-0.407965E-06
331	0.279660E-05	0.129913E-03	0.995668E-04	-0.487340E-05	-0.315021E-05
332	0.225429E-06	0.847229E-05	0.986147E-05	-0.397641E-05	-0.293024E-06
333	-0.105128E-05	-0.692788E-04	-0.451034E-04	-0.321953E-04	-0.138929E-05
334	0.239926E-05	0.120178E-03	0.100086E-03	0.163137E-05	-0.188271E-05
335	0.241548E-05	0.800424E-04	0.876966E-04	-0.282039E-04	-0.242298E-04
336	0.405817E-06	0.296315E-04	0.222112E-04	0.171249E-04	0.717485E-06
337	-0.593308E-07	-0.203256E-05	-0.415808E-05	0.176409E-05	0.370040E-06
338	-0.724673E-06	-0.239423E-04	-0.252844E-04	0.554090E-05	0.907244E-05
339	0.182646E-06	0.287228E-05	0.201983E-06	-0.334825E-05	-0.930082E-06
340	0.251824E-05	0.976862E-04	0.929831E-04	-0.203651E-04	-0.998375E-05

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Mode No.	Plasma (H/√Ω)	F-coil (H/√Ω)	V-coil (H/√Ω)	Q-coil (H/√Ω)	M-coil (H/√Ω)
341	-0.191329E-05	-0.107586E-03	-0.975954E-04	-0.121989E-04	0.683113E-06
342	0.984267E-07	0.684644E-05	0.679409E-05	0.194180E-05	0.164110E-06
343	0.245535E-05	0.988811E-04	0.953570E-04	-0.177012E-04	-0.641813E-05
344	-0.188069E-07	-0.896149E-06	-0.566703E-06	0.385325E-06	0.697833E-07
345	-0.230498E-08	-0.210067E-06	-0.432451E-07	0.143913E-06	0.208506E-07
346	-0.153487E-07	-0.654353E-06	-0.561663E-06	0.510334E-07	0.381723E-07
347	-0.138906E-07	-0.583549E-06	-0.520104E-06	-0.196943E-06	0.151248E-07
348	-0.182943E-07	-0.752148E-06	-0.702144E-06	-0.593574E-06	-0.716701E-08
349	-0.585275E-07	-0.235715E-05	-0.229515E-05	-0.199320E-05	-0.325267E-07
350	0.158888E-06	0.635200E-05	0.630168E-05	0.556538E-05	0.100499E-06
351	0.617757E-07	0.245470E-05	0.246621E-05	0.232242E-05	0.516520E-07
352	0.241846E-07	0.959355E-06	0.986053E-06	0.979716E-06	0.264011E-07
353	0.145625E-07	0.564385E-06	0.579852E-06	0.633494E-06	0.186987E-07
354	-0.396568E-07	-0.257720E-05	-0.358430E-05	0.197574E-06	0.264364E-07
355	-0.101393E-07	-0.393385E-06	-0.412164E-06	-0.469318E-06	-0.155940E-07
356	0.763468E-08	0.296588E-06	0.316366E-06	0.376198E-06	0.138617E-07
357	0.618877E-08	0.239456E-06	0.257006E-06	0.313078E-06	0.119301E-07
358	0.511579E-08	0.197455E-06	0.214768E-06	0.269394E-06	0.107581E-07
359	0.441159E-08	0.169135E-06	0.186572E-06	0.236656E-06	0.961346E-08
360	0.369583E-08	0.142446E-06	0.156106E-06	0.204549E-06	0.856697E-08
361	-0.309497E-08	-0.118650E-06	-0.131631E-06	-0.179428E-06	-0.781142E-08
362	0.266501E-08	0.101994E-06	0.113967E-06	0.153838E-06	0.666797E-08
363	-0.227938E-08	-0.875187E-07	-0.965224E-07	-0.132812E-06	-0.587142E-08
364	0.204066E-08	0.691720E-07	0.845715E-07	0.996678E-07	0.407972E-08
365	0.253190E-07	0.321958E-07	0.820094E-06	-0.108595E-05	-0.959859E-07
366	0.144944E-08	0.545035E-07	0.627725E-07	0.885834E-07	0.398889E-08
367	0.886595E-07	0.550862E-05	0.713230E-05	-0.104754E-05	0.823337E-07
368	-0.192106E-05	-0.108456E-03	-0.105792E-03	-0.146342E-04	0.217027E-05
369	-0.808383E-06	-0.270259E-04	-0.329502E-04	0.101070E-04	0.915085E-05
370	0.275299E-05	0.121600E-03	0.120624E-03	-0.147548E-04	-0.783049E-05
371	-0.285330E-07	-0.103963E-05	-0.155862E-05	0.419794E-06	0.135530E-06
372	0.184735E-07	0.822762E-06	0.216329E-05	-0.114815E-05	0.539747E-08
373	0.106157E-05	0.416823E-04	0.455855E-04	-0.893555E-05	-0.666478E-05
374	-0.133655E-05	-0.825714E-04	-0.840796E-04	-0.184743E-04	0.109687E-05
375	-0.265601E-05	-0.128123E-03	-0.132803E-03	0.855944E-05	0.784996E-05
376	-0.119435E-06	-0.538610E-05	-0.450145E-05	0.319864E-06	0.398655E-06
377	0.290978E-07	0.110109E-05	0.259168E-05	-0.150159E-05	-0.146604E-06
378	-0.118500E-05	-0.465673E-04	-0.513605E-04	0.109754E-04	0.554411E-05
379	-0.129405E-05	-0.785260E-04	-0.795560E-04	-0.173814E-04	0.197502E-05
380	0.144971E-05	0.741552E-04	0.807638E-04	-0.456414E-06	-0.481355E-05
381	0.173111E-05	0.880520E-04	0.968910E-04	-0.148613E-05	-0.587684E-05
382	-0.607548E-06	-0.430774E-04	-0.410917E-04	-0.171998E-04	0.355470E-06
383	-0.193352E-05	-0.854117E-04	-0.964326E-04	0.115354E-04	0.886805E-05
384	0.651525E-06	0.285751E-04	0.315257E-04	-0.382367E-05	-0.297066E-05
385	-0.803591E-06	-0.495136E-04	-0.510642E-04	-0.132045E-04	0.190053E-05
386	0.403689E-05	0.194423E-03	0.223445E-03	-0.119414E-04	-0.181249E-04
387	-0.295210E-05	-0.138071E-03	-0.158992E-03	0.107889E-04	0.144615E-04
388	0.139892E-05	0.568539E-04	0.688573E-04	-0.167507E-04	-0.816374E-05
389	0.700705E-06	0.345248E-04	0.409590E-04	-0.108563E-05	-0.345747E-05
390	-0.102182E-04	-0.460346E-03	-0.551039E-03	0.572779E-04	0.582895E-04
391	0.150778E-04	0.679409E-03	0.812726E-03	-0.841978E-04	-0.859591E-04
392	-0.126634E-04	-0.553475E-03	-0.667648E-03	0.864936E-04	0.769219E-04
393	0.320941E-05	0.138584E-03	0.168841E-03	-0.226654E-04	-0.203595E-04
394	-0.472540E-07	-0.198210E-05	-0.345810E-05	0.140334E-05	0.293263E-06
395	-0.163549E-05	-0.582107E-04	-0.743538E-04	0.240808E-04	0.133738E-04
396	0.880648E-06	0.334886E-04	0.430120E-04	-0.987920E-05	-0.720418E-05
397	0.440034E-07	0.105486E-05	0.896988E-06	-0.776417E-06	-0.453019E-06
398	-0.558448E-06	-0.934554E-05	-0.158504E-04	0.188917E-04	0.676410E-05
399	0.297319E-06	0.731355E-05	0.103758E-04	-0.678378E-05	-0.342766E-05
400	-0.217915E-06	0.414317E-05	0.522584E-06	0.157606E-04	0.421873E-05
401	0.312400E-08	-0.504134E-07	-0.357750E-06	-0.827595E-07	-0.160776E-07
402	0.199156E-06	-0.794496E-06	0.142843E-05	-0.104192E-04	-0.354828E-05
403	-0.334793E-07	0.851593E-05	0.690840E-05	0.115737E-04	0.210127E-05
404	-0.355530E-07	0.738623E-05	0.666078E-05	0.959243E-05	0.208100E-05
405	0.106614E-06	-0.229452E-05	-0.157630E-05	-0.670202E-05	-0.239992E-05
406	0.239692E-08	-0.262687E-05	-0.315773E-05	-0.225753E-05	-0.588879E-06
407	0.632985E-07	-0.517022E-05	-0.450286E-05	-0.745683E-05	-0.240519E-05
408	0.265643E-08	-0.147210E-06	-0.747372E-06	0.154260E-06	-0.536180E-07
409	0.420110E-07	-0.568912E-05	-0.507890E-05	-0.717522E-05	-0.217053E-05
410	-0.357622E-08	-0.981660E-06	-0.893726E-06	-0.657848E-06	-0.275910E-06

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Mode No.	Plasma (H/√Ω)	F-coil (H/√Ω)	V-coil (H/√Ω)	Q-coil (H/√Ω)	M-coil (H/√Ω)
411	0.421055E-07	-0.626625E-05	-0.572707E-05	-0.735192E-05	-0.253719E-05
412	0.410540E-07	-0.358083E-05	-0.323300E-05	-0.468443E-05	-0.181690E-05
413	-0.243844E-07	-0.302912E-06	-0.629745E-06	0.769870E-06	0.406319E-06
414	0.338351E-05	0.138564E-03	0.199084E-03	-0.360920E-04	-0.312586E-04
415	0.135853E-05	0.269210E-03	0.312185E-03	0.123399E-03	0.645606E-04
416	-0.774161E-07	-0.126367E-04	-0.148944E-04	-0.535516E-05	-0.261764E-05
417	-0.554528E-06	0.768736E-05	-0.185240E-04	-0.106741E-04	0.524123E-04
418	0.656757E-06	-0.200384E-03	-0.238241E-03	-0.163450E-03	-0.677222E-04
419	0.168275E-06	0.145399E-04	0.384728E-05	-0.762582E-06	0.251828E-04
420	-0.139549E-06	0.164190E-05	-0.107845E-04	0.150763E-04	-0.210653E-05
421	0.180772E-06	0.136311E-04	0.202749E-04	0.151059E-05	-0.220749E-06
422	-0.167252E-06	0.146770E-04	0.150895E-04	0.131091E-04	0.109096E-04
423	-0.166088E-06	-0.208722E-04	-0.387290E-04	-0.315896E-04	0.190547E-04
424	0.246256E-07	0.266223E-05	0.143876E-04	-0.388508E-05	-0.633027E-05
425	-0.347075E-06	-0.359961E-04	-0.761464E-04	-0.585051E-04	0.456220E-04
426	0.390238E-07	0.372162E-05	0.680872E-05	0.559390E-05	-0.326886E-05
427	0.187543E-07	0.920420E-06	-0.513716E-05	0.429073E-05	0.386770E-05
428	0.167689E-07	0.189283E-06	0.875434E-06	-0.896482E-06	0.477293E-06
429	-0.492179E-09	-0.806095E-06	0.564306E-05	-0.234723E-05	-0.273011E-05
430	0.354432E-06	0.163210E-04	0.128627E-04	0.384983E-05	0.172776E-04
431	0.118180E-08	-0.209124E-06	0.173407E-05	-0.166803E-05	-0.725536E-06
432	0.441046E-08	0.663201E-06	-0.122742E-05	0.265055E-06	0.101831E-05
433	0.561933E-08	0.677222E-06	-0.184563E-05	0.500661E-06	-0.711160E-07
434	-0.300773E-08	-0.459878E-06	0.184600E-05	-0.207679E-05	-0.119650E-05
435	-0.716785E-07	0.427219E-05	-0.164098E-04	0.219523E-04	0.212048E-05
436	-0.128504E-08	0.845393E-07	-0.101020E-05	0.166108E-05	0.148393E-06
437	-0.180837E-08	-0.336584E-06	0.180911E-05	-0.101294E-05	-0.837306E-06
438	0.196122E-09	-0.176586E-06	-0.109663E-05	0.127269E-05	0.833342E-06
439	-0.375357E-07	0.285171E-06	0.789490E-05	-0.453997E-05	-0.651312E-05
440	0.337889E-08	0.778816E-08	0.334469E-06	0.179720E-06	-0.284516E-06
441	-0.581745E-08	-0.836083E-07	0.341829E-06	-0.148010E-06	0.115506E-06
442	0.127830E-07	0.169960E-05	-0.572582E-05	0.355468E-05	0.377904E-05
443	-0.108282E-09	-0.516217E-07	0.330411E-06	0.150237E-07	0.311353E-06
444	-0.800539E-09	-0.779068E-07	0.930791E-08	0.311392E-06	0.369541E-07
445	0.506765E-08	-0.680756E-06	0.395582E-05	-0.574019E-06	-0.113266E-05
446	0.347908E-08	0.405957E-07	0.834671E-06	-0.189599E-06	-0.104311E-06
447	0.487992E-08	0.481144E-06	0.134574E-06	-0.433384E-06	-0.375619E-06
448	0.263687E-08	0.594236E-07	0.118418E-06	-0.306080E-06	-0.371758E-07
449	-0.210416E-08	-0.371710E-07	0.233704E-06	-0.929079E-07	0.501111E-07
450	-0.156351E-08	0.357080E-06	-0.179583E-05	0.704060E-06	-0.181097E-06
451	-0.291686E-09	-0.119502E-07	0.359328E-07	-0.273151E-07	-0.147733E-07
452	0.272620E-08	0.117709E-06	-0.248787E-06	0.207622E-06	-0.268497E-07
453	0.763631E-08	0.387798E-06	-0.161400E-05	0.113353E-05	-0.681270E-07
454	-0.157848E-08	-0.439846E-07	0.163850E-07	0.111164E-06	-0.771148E-08
455	0.183136E-08	0.102296E-06	0.217781E-06	-0.823291E-07	-0.253869E-07
456	-0.714753E-08	-0.141178E-06	-0.417701E-06	0.133696E-05	-0.563480E-08
457	-0.185428E-08	0.126388E-07	0.613079E-07	0.242742E-06	0.182119E-07
458	0.694206E-08	0.250315E-06	-0.542081E-06	0.843998E-06	-0.324872E-07
459	0.451922E-09	-0.226724E-07	-0.413476E-07	0.162201E-07	-0.468738E-08
460	-0.262654E-08	0.363677E-07	-0.401979E-06	0.394007E-06	0.304541E-07
461	-0.726026E-09	-0.591086E-09	0.524515E-06	-0.290736E-06	0.120877E-07
462	-0.109413E-09	-0.164096E-07	-0.150241E-06	-0.235331E-08	0.227956E-07
463	0.271647E-10	-0.971599E-08	0.189063E-06	-0.116869E-06	-0.193398E-08
464	-0.614484E-09	-0.702335E-08	-0.222732E-07	0.303929E-07	0.176854E-08

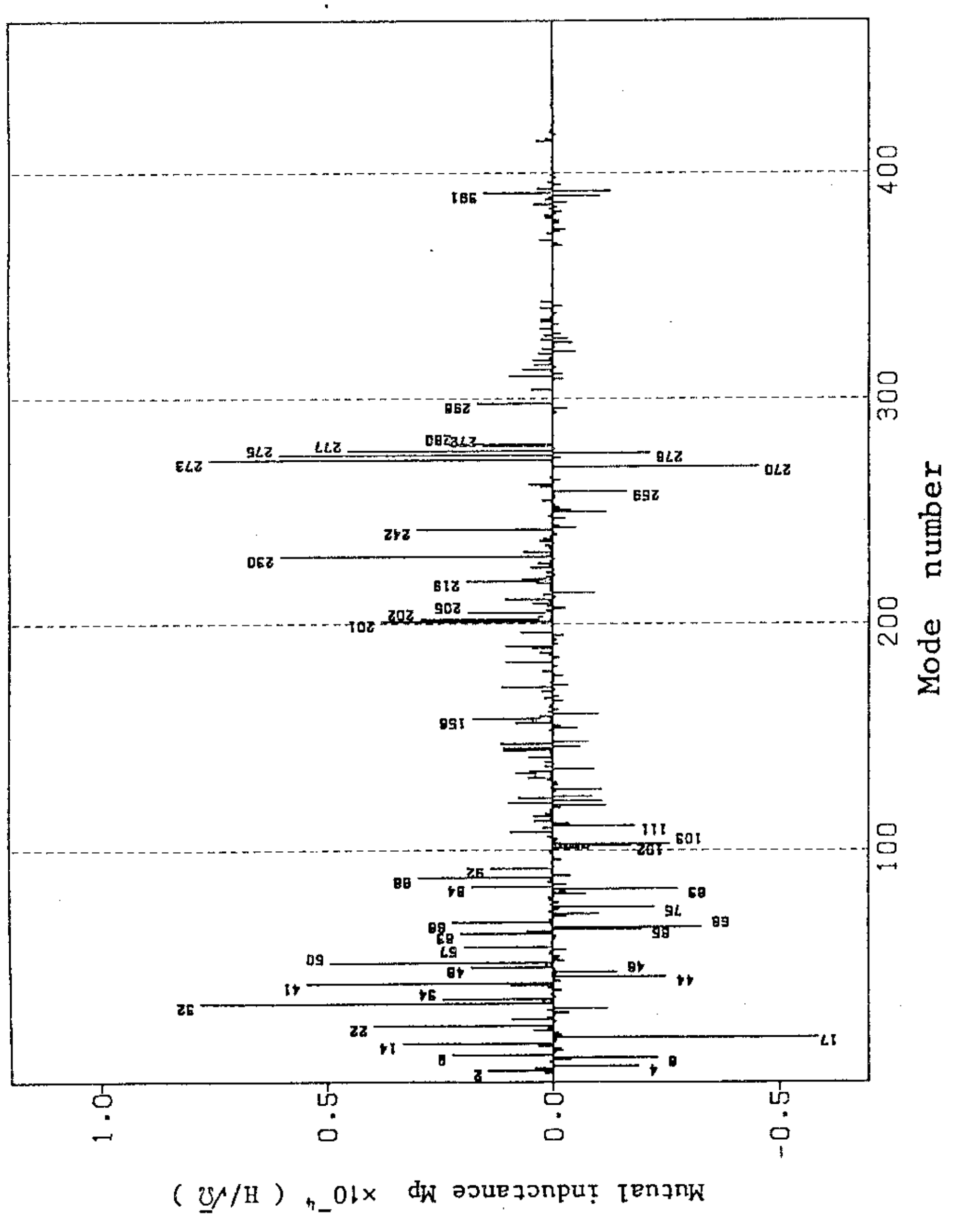

Fig.22 Mutual inductance between eddy current eigen mode and plasma.

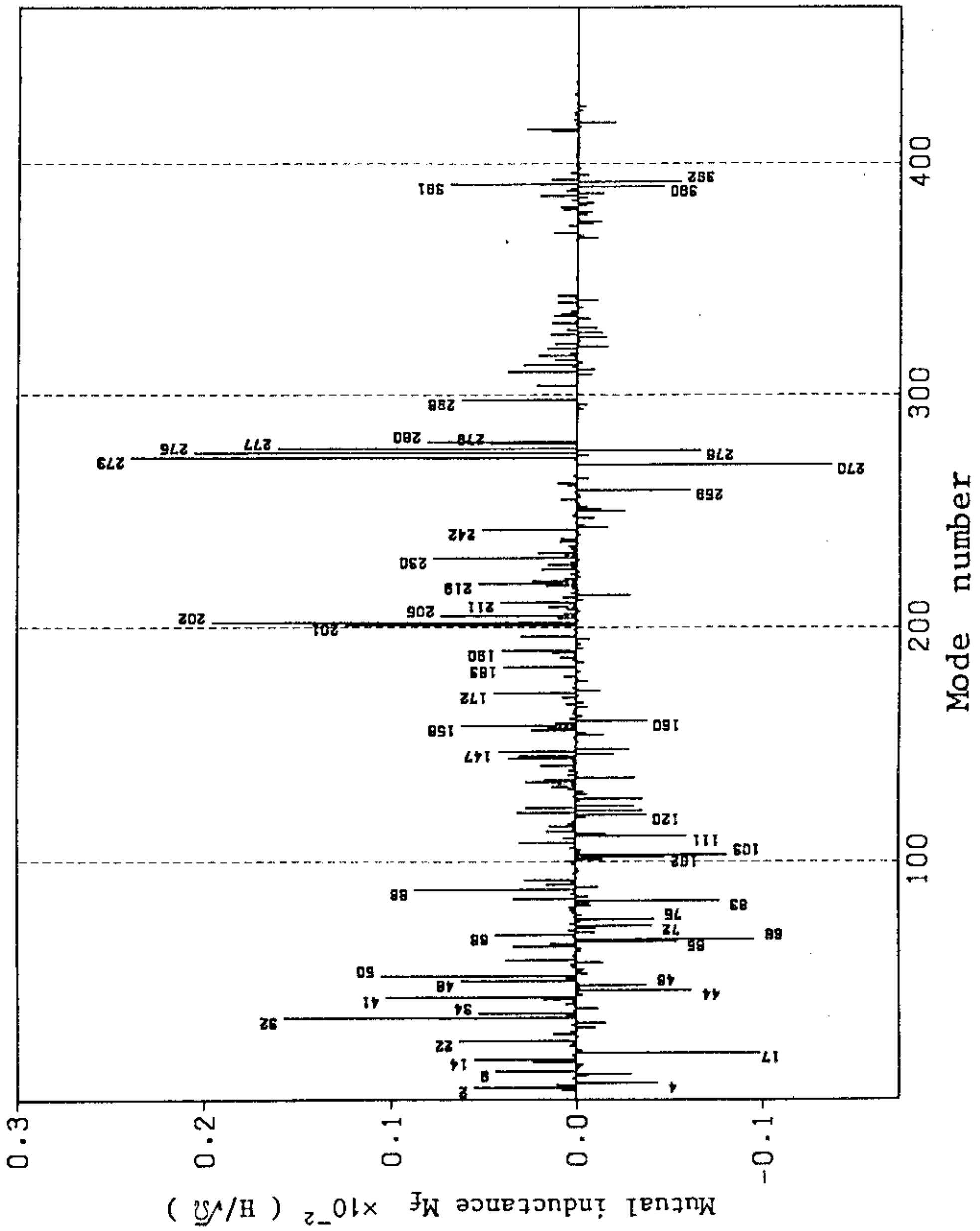

Fig.23 Mutual inductance between eddy current eigen mode and an ohmic heating coil.

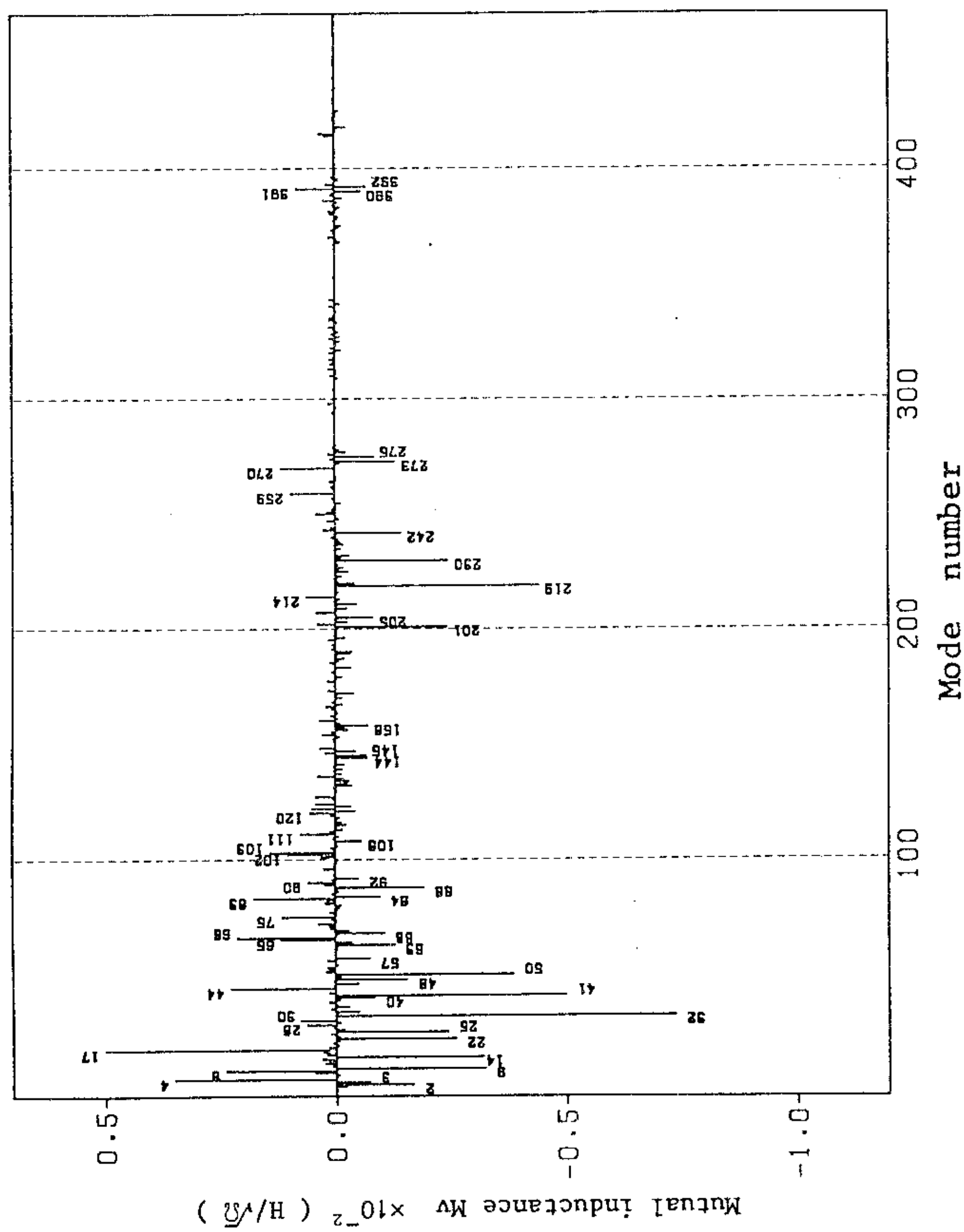

Fig.24 Mutual inductance between eddy current eigen mode and a vertical field coil.

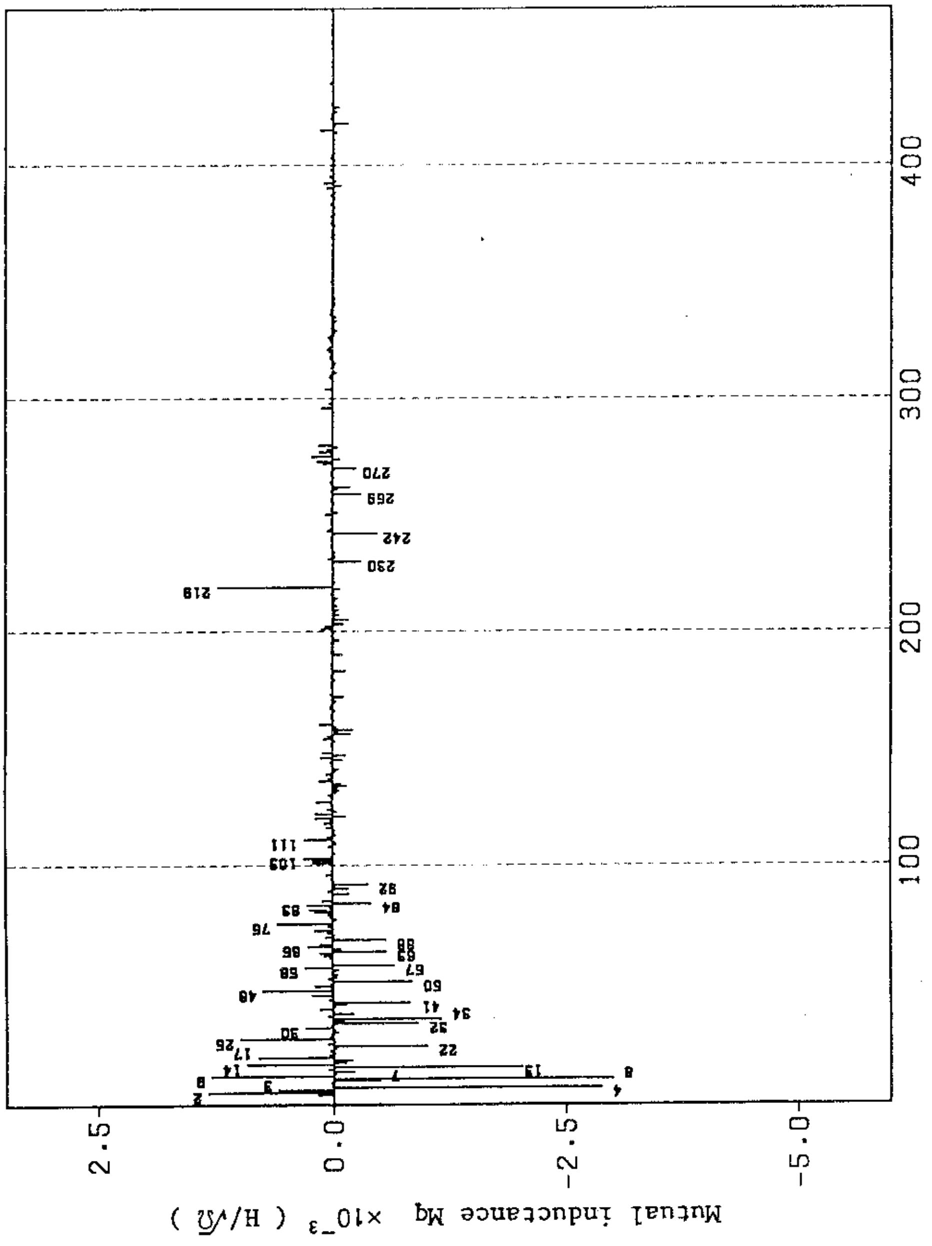

Fig.25 Mutual inductance between eddy current eigen mode and a quadrupole field coil.

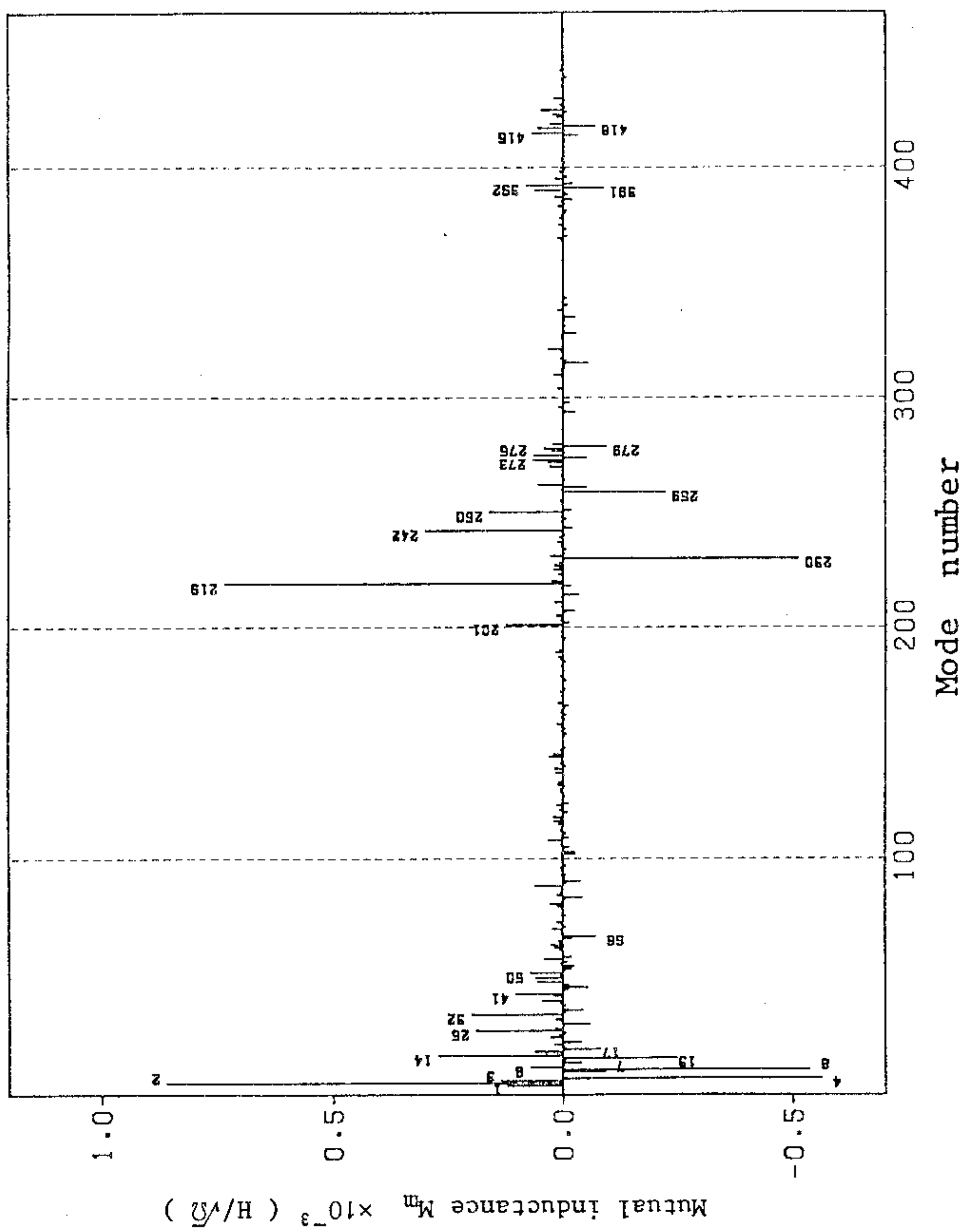

Fig.26 Mutual inductance between eddy current eigen mode and a magnetic limiter coil.

Table 13 Radial derivative of mutual inductance ∂Mp/∂R

Mode No.	$\frac{\partial Mp}{\partial R}$ (H/√Ωm)	Mode No.	$\frac{\partial Mp}{\partial R}$ (H/√Ωm)	Mode No.	$\frac{\partial Mp}{\partial R}$ (H/√Ωm)	Mode No.	$\frac{\partial Mp}{\partial R}$ (H/√Ωm)	Mode No.	$\frac{\partial Mp}{\partial R}$ (H/√Ωm)
1	0.2792902E-05	2	0.2194109E-04	3	0.5971109E-05	4	-0.2856302E-04	5	-0.4852404E-07
6	0.6871933E-06	7	-0.5698414E-05	8	-0.3481399E-04	9	0.3133563E-04	10	-0.6288856E-06
11	-0.3444853E-05	12	-0.1601048E-05	13	-0.8098084E-05	14	0.4168997E-04	15	-0.4616563E-06
16	-0.4977184E-06	17	-0.6217262E-04	18	-0.1738820E-05	19	-0.1055021E-05	20	0.4181827E-05
21	0.9186164E-06	22	0.3639310E-04	23	0.5296153E-06	24	-0.8879192E-06	25	0.2316415E-04
26	0.1933436E-05	27	-0.4408072E-06	28	-0.6696426E-05	29	0.1148168E-05	30	-0.1101901E-04
31	0.1186105E-06	32	0.8501338E-04	33	0.9783062E-06	34	0.1363384E-04	35	-0.9668101E-06
36	0.3501043E-05	37	0.3615127E-07	38	-0.2893385E-05	39	0.1063310E-05	40	0.9854366E-05
41	0.5856644E-04	42	-0.1359685E-05	43	-0.2907046E-06	44	-0.2466774E-04	45	-0.5759240E-06
46	-0.2053821E-05	47	-0.2088526E-06	48	0.1542662E-04	49	0.1151549E-05	50	0.4696063E-04
51	-0.2226003E-05	52	-0.1028170E-05	53	-0.1566002E-05	54	0.5506686E-06	55	-0.4101603E-07
56	-0.6352776E-06	57	0.1371993E-04	58	0.5232589E-07	59	0.1619903E-06	60	0.1862294E-06
61	0.2255237E-06	62	0.3463455E-06	63	0.1788151E-04	64	0.4573998E-05	65	-0.1484333E-04
66	-0.2578896E-04	67	0.2862415E-06	68	0.1659610E-04	69	0.3784028E-05	70	-0.9983714E-06
71	-0.1449618E-05	72	-0.4324980E-05	73	0.2069768E-06	74	-0.9394257E-06	75	-0.1737315E-04
76	0.1822718E-06	77	-0.1260126E-05	78	0.5293089E-06	79	0.9245707E-06	80	0.9718069E-06
81	-0.4948920E-05	82	-0.2008074E-05	83	-0.2179522E-04	84	0.1421130E-04	85	-0.1293034E-05
86	0.7278483E-06	87	0.3075169E-06	88	0.2340367E-04	89	-0.2640441E-05	90	-0.5941129E-05
91	-0.5219260E-06	92	0.8783702E-05	93	-0.2024208E-06	94	-0.2766319E-07	95	0.1267893E-06
96	-0.2377963E-05	97	-0.2720222E-06	98	-0.2625212E-07	99	0.2826377E-06	100	0.3982223E-06
101	-0.5207290E-05	102	-0.1300035E-04	103	-0.1743040E-04	104	-0.3488607E-06	105	-0.1007791E-05
106	0.5985570E-06	107	0.1643041E-07	108	0.6773202E-05	109	-0.3755429E-06	110	0.9847181E-06
111	-0.1018627E-04	112	-0.1108287E-05	113	0.1917322E-05	114	0.2022238E-06	115	0.2844591E-05
116	0.1590831E-05	117	0.4135917E-06	118	0.1042109E-05	119	-0.9837931E-06	120	-0.7153352E-05
121	0.5741312E-05	122	-0.6356838E-05	123	0.4230318E-05	124	-0.5048479E-05	125	0.6368111E-07
126	-0.3359849E-06	127	-0.5785603E-05	128	0.1177436E-06	129	0.2132267E-06	130	0.3928989E-07
131	0.1066072E-06	132	0.4456871E-05	133	0.3370942E-05	134	0.4356388E-05	135	0.2621312E-05
136	-0.4789184E-05	137	0.1571913E-05	138	-0.1944770E-06	139	0.1792116E-05	140	-0.2250974E-06
141	0.2764738E-05	142	0.1324186E-06	143	0.3190115E-06	144	0.8147560E-05	145	0.8285257E-05
146	-0.3025125E-05	147	0.5828319E-05	148	-0.4160787E-05	149	0.4433507E-07	150	0.3557586E-07
151	-0.1631120E-06	152	-0.2161730E-06	153	0.8530224E-06	154	-0.3658902E-05	155	-0.9231761E-06
156	0.4234411E-05	157	0.2374552E-05	158	0.9530710E-05	159	0.1277149E-05	160	-0.4610635E-05
161	0.5616213E-06	162	-0.8681824E-06	163	0.5544496E-06	164	0.3477031E-06	165	-0.5604902E-06
166	-0.2158170E-05	167	0.1659846E-05	168	-0.7028071E-06	169	0.4246553E-07	170	0.1611249E-05
171	-0.1377591E-06	172	0.5086162E-05	173	-0.1605216E-05	174	0.1592751E-06	175	-0.1716337E-06
176	0.7645480E-07	177	-0.1808638E-05	178	-0.1224436E-06	179	0.1592499E-05	180	-0.1891446E-07
181	-0.7743033E-06	182	-0.2135432E-07	183	0.4532601E-05	184	-0.1818740E-07	185	-0.1134496E-05
186	0.6925536E-06	187	0.2214982E-05	188	0.6395408E-07	189	0.3816410E-05	190	0.4795580E-05
191	-0.6910444E-06	192	-0.2136048E-07	193	-0.5370320E-06	194	0.1549209E-08	195	-0.1733682E-05

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Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$
196	0.2700967E-05	197	-0.1688683E-06	198	0.2520060E-06	199	0.1455267E-06	200	-0.1162351E-07
201	0.2814054E-04	202	-0.4822470E-05	203	0.3696069E-05	204	0.1419711E-06	205	0.9434911E-05
206	0.1815641E-06	207	-0.4517140E-05	208	0.2510604E-06	209	0.2669045E-05	210	0.1963083E-06
211	0.5142717E-05	212	-0.1385491E-06	213	0.9355755E-06	214	-0.7069907E-05	215	0.1526538E-06
216	0.5870207E-06	217	0.2077338E-06	218	-0.3471213E-06	219	0.6121317E-04	220	0.4442911E-05
221	0.3300988E-06	222	-0.7132093E-07	223	0.1330111E-05	224	-0.4820098E-07	225	0.2483009E-05
226	0.4404728E-06	227	0.7532230E-06	228	-0.1350448E-06	229	-0.8341993E-07	230	0.9384731E-04
231	-0.5178929E-06	232	0.4904582E-05	233	0.1143359E-06	234	0.2373698E-06	235	0.1534852E-05
236	-0.1625616E-07	237	0.2076544E-05	238	0.1126280E-05	239	0.6623557E-06	240	-0.8433979E-06
241	-0.9806462E-07	242	0.3091169E-04	243	-0.3897385E-05	244	-0.9949044E-06	245	0.2837698E-07
246	0.1090485E-06	247	-0.2059430E-05	248	0.8423463E-06	249	0.3280979E-07	250	-0.5909188E-05
251	-0.1424380E-05	252	-0.8098084E-06	253	-0.2083221E-06	254	0.2431839E-07	255	0.1559287E-05
256	-0.2286264E-06	257	-0.5969806E-06	258	0.3259284E-07	259	-0.9161094E-05	260	0.1333963E-07
261	0.6577268E-06	262	0.5015964E-05	263	-0.1011936E-07	264	-0.1031374E-05	265	0.2152730E-06
266	0.2789826E-06	267	-0.2082787E-07	268	-0.7931199E-08	269	-0.5252649E-09	270	-0.2474559E-04
271	-0.6458134E-08	272	-0.1453857E-05	273	0.2804497E-04	274	-0.1731817E-06	275	0.1025466E-04
276	-0.7725557E-05	277	0.3713865E-05	278	0.2709053E-06	279	0.3069023E-05	280	-0.1798118E-05
281	-0.3104754E-08	282	0.5729635E-09	283	-0.5943537E-09	284	-0.2287709E-09	285	-0.1621432E-09
286	0.1150368E-09	287	0.9812082E-10	288	-0.1017956E-09	289	-0.6666102E-10	290	-0.8214551E-10
291	0.6835317E-10	292	0.4779753E-10	293	-0.3558563E-10	294	-0.1648864E-06	295	-0.7225603E-10
296	-0.1563895E-05	297	-0.1378494E-10	298	-0.2044044E-05	299	-0.2074090E-10	300	-0.3293522E-10
301	0.4021986E-11	302	-0.3066507E-10	303	0.4868525E-11	304	-0.1454923E-05	305	-0.2629119E-10
306	-0.2608289E-10	307	-0.4676758E-10	308	0.6917704E-10	309	0.8853717E-06	310	-0.3304504E-05
311	0.8428834E-06	312	-0.6357510E-07	313	-0.4299423E-05	314	0.2300152E-06	315	0.1695437E-06
316	0.3229536E-07	317	-0.3491995E-05	318	-0.5962946E-06	319	-0.1709933E-07	320	-0.3171067E-05
321	0.9711512E-06	322	-0.2315330E-05	323	0.1531578E-06	324	0.1300738E-06	325	0.1949928E-05
326	-0.2966842E-05	327	0.2518418E-05	328	-0.1956915E-06	329	0.2297352E-05	330	-0.9406568E-07
331	-0.2919654E-05	332	-0.1044746E-06	333	0.1557604E-05	334	-0.2981621E-05	335	-0.7147062E-06
336	-0.6985287E-06	337	0.2262163E-07	338	0.2317101E-06	339	0.9935781E-07	340	-0.1522240E-05
341	0.2928022E-05	342	-0.1688806E-06	343	-0.1853249E-05	344	0.1946329E-07	345	0.5274142E-08
346	0.1217708E-07	347	0.8439411E-08	348	0.7696485E-08	349	0.2265852E-07	350	-0.5929201E-07
351	-0.2134171E-07	352	-0.7894783E-08	353	-0.3818723E-08	354	0.7661521E-07	355	0.2497422E-08
356	-0.1787535E-08	357	-0.1332081E-08	358	-0.1029806E-08	359	-0.8573822E-09	360	-0.6503491E-09
361	0.4593330E-09	362	-0.4140916E-09	363	0.3290972E-09	364	-0.4763563E-10	365	0.1976290E-07
366	-0.1946873E-09	367	-0.1681634E-06	368	0.2935737E-05	369	0.3040561E-06	370	-0.2797677E-05
371	0.1860904E-07	372	-0.1541902E-07	373	-0.7177227E-06	374	0.2348116E-05	375	0.3344157E-05
376	0.1268120E-06	377	-0.3046721E-07	378	0.8830374E-06	379	0.2165112E-05	380	-0.2006588E-05
381	-0.2382631E-05	382	0.1207951E-05	383	0.2011242E-05	384	-0.6672679E-06	385	0.1356400E-05
386	-0.5039353E-05	387	0.3453448E-05	388	-0.1346345E-05	389	-0.8807702E-06	390	0.1124493E-04
391	-0.1659192E-04	392	0.1312229E-04	393	-0.3226819E-05	394	0.4243764E-07	395	0.1082806E-05
396	-0.6566307E-06	397	-0.6199794E-08	398	-0.9665871E-07	399	-0.2293521E-07	400	-0.3721285E-06

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Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$	Mode No.	$\frac{\partial Mp}{\partial R}(H/\sqrt{\Omega}m)$
401	0.1066656E-07	402	0.2428789E-06	403	-0.3827003E-06	404	-0.3577725E-06	405	0.2348214E-06
406	0.1189480E-06	407	0.3218813E-06	408	0.9972329E-08	409	0.3194913E-06	410	0.4741763E-07
411	0.3592494E-06	412	0.2278070E-06	413	-0.8187701E-08	414	-0.3304473E-05	415	-0.1339649E-04
416	0.6073777E-06	417	-0.2063886E-05	418	0.1205243E-04	419	-0.2610809E-06	420	-0.4612820E-06
421	-0.5591051E-06	422	-0.1118886E-05	423	0.3909284E-06	424	0.4790206E-08	425	0.4150971E-06
426	-0.2491714E-07	427	0.3561636E-07	428	0.3489492E-07	429	-0.2648570E-07	430	0.3567866E-06
431	0.2057541E-07	432	-0.8481035E-08	433	0.7110112E-09	434	0.1080755E-07	435	-0.3409833E-06
436	-0.1034601E-07	437	-0.9541747E-08	438	0.1088524E-07	439	-0.5689459E-07	440	-0.2078249E-09
441	-0.1956703E-08	442	0.5066655E-07	443	0.3709091E-08	444	-0.1306320E-08	445	0.9459448E-08
446	-0.1965277E-08	447	-0.1064054E-07	448	0.6793184E-09	449	-0.1844060E-08	450	0.7199986E-08
451	-0.2387332E-10	452	-0.9619201E-09	453	0.4393964E-08	454	-0.5867782E-09	455	-0.3189719E-08
456	0.1472708E-08	457	-0.1926005E-08	458	0.1068530E-08	459	0.2290448E-08	460	-0.3485598E-08
461	-0.1101996E-08	462	0.9686458E-09	463	0.4444418E-09	464	-0.8356442E-09		

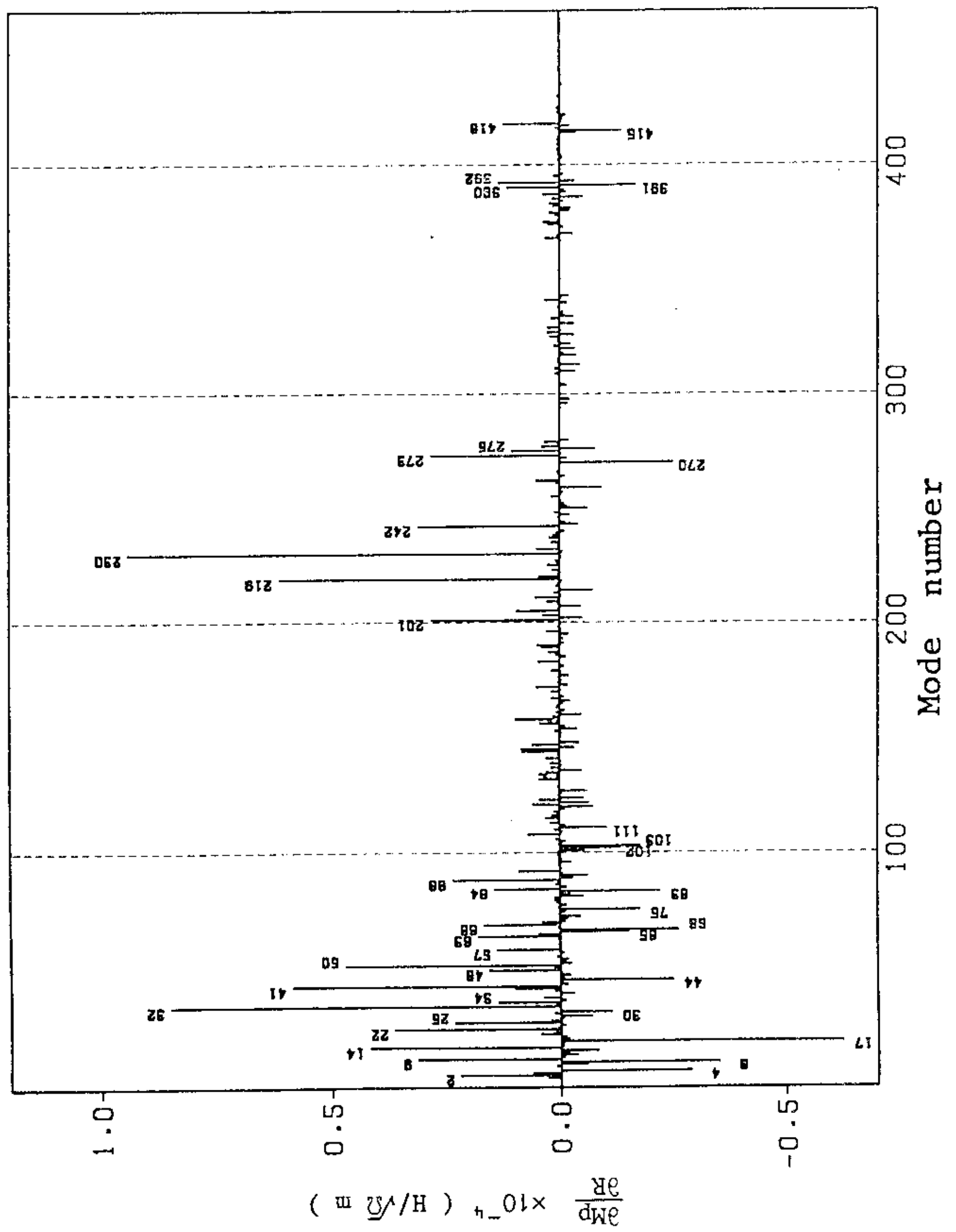

Fig.27 Radial derivative of mutual inductance $\partial M_p/\partial R$

Table 14 Vertical field of eigen mode on a plasma equilibrium position

Mode No.	$\bar{\nu}_j$ (Wb/m^{2}A$\sqrt{\Omega}$)	Mode No.	$\bar{\nu}_j$ (Wb/m^{2}A$\sqrt{\Omega}$)	Mode No.	$\bar{\nu}_j$ (Wb/m^{2}A$\sqrt{\Omega}$)	Mode No.	$\bar{\nu}_j$ (Wb/m^{2}A$\sqrt{\Omega}$)	Mode No.	$\bar{\nu}_j$ (Wb/m^{2}A$\sqrt{\Omega}$)
1	0.1465858E-06	2	0.1153820E-05	3	0.3140634E-06	4	-0.1503498E-05	5	-0.2583426E-08
6	0.3619189E-07	7	-0.3002456E-06	8	-0.1835976E-05	9	0.1646792E-05	10	-0.3305430E-07
11	-0.1819761E-06	12	-0.8411337E-07	13	-0.4335490E-06	14	0.2198125E-05	15	-0.2487543E-07
16	-0.2699327E-07	17	-0.3271496E-05	18	-0.9157623E-07	19	-0.5598422E-07	20	0.2211250E-06
21	0.4837190E-07	22	0.1918474E-05	23	0.2816708E-07	24	-0.4699607E-07	25	0.1230024E-05
26	0.1029626E-06	27	-0.2333694E-07	28	-0.3580232E-06	29	0.6060748E-07	30	-0.5810869E-06
31	0.6312430E-08	32	0.4480766E-05	33	0.5087030E-07	34	0.7109381E-06	35	-0.5095415E-07
36	0.1848417E-06	37	0.2134729E-08	38	-0.1505462E-06	39	0.5588554E-07	40	0.5185235E-06
41	0.3081400E-05	42	-0.7151505E-07	43	-0.1556916E-07	44	-0.1298667E-05	45	-0.3053010E-07
46	-0.1060613E-06	47	-0.1095309E-07	48	0.8154096E-06	49	0.6091886E-07	50	0.2470169E-05
51	-0.1170265E-06	52	-0.5353186E-07	53	-0.8173754E-07	54	0.2894638E-07	55	-0.3360084E-08
56	-0.2709050E-07	57	0.7199138E-06	58	0.2826678E-08	59	0.8515229E-08	60	0.1006538E-07
61	0.1246560E-07	62	0.1917115E-07	63	0.9380169E-06	64	0.2406595E-06	65	-0.7822953E-06
66	-0.1359976E-05	67	0.1512093E-07	68	0.8721400E-06	69	0.1987944E-06	70	-0.5241280E-07
71	-0.7626448E-07	72	-0.2276349E-06	73	0.1089060E-07	74	-0.4933942E-07	75	-0.9134112E-06
76	0.9570307E-08	77	-0.6614101E-07	78	0.2779124E-07	79	0.4880214E-07	80	0.5182471E-07
81	-0.2590422E-06	82	-0.1055574E-06	83	-0.1145236E-05	84	0.7446327E-06	85	-0.6790293E-07
86	0.3827280E-07	87	0.1612672E-07	88	0.1231352E-05	89	-0.1390305E-06	90	-0.3102457E-06
91	-0.2718255E-07	92	0.4606583E-06	93	-0.1053593E-07	94	-0.1441432E-08	95	0.6647912E-08
96	-0.1253471E-06	97	-0.1413410E-07	98	-0.1388777E-08	99	0.1484033E-07	100	0.2090593E-07
101	-0.2723655E-06	102	-0.6820529E-06	103	-0.9142740E-06	104	-0.1839093E-07	105	-0.5320254E-07
106	0.3145176E-07	107	0.9971795E-09	108	0.3592519E-06	109	-0.1955074E-07	110	0.5185581E-07
111	-0.5363416E-06	112	-0.5702713E-07	113	0.9977128E-07	114	0.1066561E-07	115	0.1486997E-06
116	0.8384956E-07	117	0.2160851E-07	118	0.5519309E-07	119	-0.5176295E-07	120	-0.3745609E-06
121	0.3014792E-06	122	-0.3348068E-06	123	0.2226915E-06	124	-0.2656502E-06	125	0.3279228E-08
126	-0.1767248E-07	127	-0.3042821E-06	128	0.6134961E-08	129	0.1118912E-07	130	0.2037578E-08
131	0.5591467E-08	132	0.2342999E-06	133	0.1770536E-06	134	0.2280098E-06	135	0.1374156E-06
136	-0.2530582E-06	137	0.8300975E-07	138	-0.1022756E-07	139	0.9471870E-07	140	-0.1194952E-07
141	0.1451612E-06	142	0.7005696E-08	143	0.1667044E-07	144	0.4271928E-06	145	0.4350252E-06
146	-0.1593296E-06	147	0.3057362E-06	148	-0.2182595E-06	149	0.2334498E-08	150	0.1929823E-08
151	-0.8522804E-08	152	-0.1131015E-07	153	0.4484439E-07	154	-0.1918601E-06	155	-0.4836042E-07
156	0.2221558E-06	157	0.1248057E-06	158	0.5009720E-06	159	0.6689226E-07	160	-0.2423636E-06
161	0.3031504E-07	162	-0.4767460E-07	163	0.2942597E-07	164	0.1849931E-07	165	-0.2877054E-07
166	-0.1146164E-06	167	0.8830449E-07	168	-0.3711723E-07	169	0.2273923E-08	170	0.8508471E-07
171	-0.7240327E-08	172	0.2677305E-06	173	-0.8588859E-07	174	0.8536915E-08	175	-0.9071140E-08
176	0.4033847E-08	177	-0.9550627E-07	178	-0.6466770E-08	179	0.8303357E-07	180	-0.1001262E-08
181	-0.4081146E-07	182	-0.1106804E-08	183	0.2375646E-06	184	-0.9536134E-09	185	-0.5938087E-07
186	0.3625041E-07	187	0.1160270E-06	188	0.3372904E-08	189	0.2000265E-06	190	0.2512274E-06
191	-0.3635867E-07	192	-0.1136129E-08	193	-0.2814948E-07	194	0.7351475E-10	195	-0.9083425E-07

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Mode No.	$\bar{\nu}_j(Wb/m^2A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j(Wb/m^2A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j(Wb/m^2A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j(Wb/m^2A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j(Wb/m^2A\sqrt{\Omega})$
196	0.1408520E-06	197	-0.8781200E-08	198	0.1311639E-07	199	0.7709641E-08	200	-0.6235368E-09
201	0.1493107E-05	202	-0.2540856E-06	203	0.1940408E-06	204	0.7474579E-08	205	0.4970175E-06
206	0.9420013E-08	207	-0.2415786E-06	208	0.1259510E-07	209	0.1421623E-06	210	0.9405209E-08
211	0.2697867E-06	212	-0.7314224E-08	213	0.4956441E-07	214	-0.3747526E-06	215	0.8993680E-08
216	0.3217709E-07	217	0.9956452E-08	218	-0.1858252E-07	219	0.3197688E-05	220	0.2350242E-06
221	0.1721635E-07	222	-0.3683523E-08	223	0.7088755E-07	224	-0.3325755E-08	225	0.1306948E-06
226	0.2350641E-07	227	0.3826965E-07	228	-0.7606861E-08	229	-0.4591666E-08	230	0.5010277E-05
231	-0.2829597E-07	232	0.2600612E-06	233	0.5810143E-08	234	0.1262245E-07	235	0.8182400E-07
236	-0.1482286E-08	237	0.1101222E-06	238	0.5997367E-07	239	0.3494222E-07	240	-0.4482908E-07
241	-0.4702827E-08	242	0.1600595E-05	243	-0.2039015E-06	244	-0.5228663E-07	245	0.1134538E-08
246	0.5733607E-08	247	-0.1089917E-06	248	0.4488975E-07	249	0.1381279E-08	250	-0.2806817E-06
251	-0.7631405E-07	252	-0.4258250E-07	253	-0.1095788E-07	254	0.1231252E-08	255	0.8242313E-07
256	-0.1211622E-07	257	-0.3190410E-07	258	0.2044743E-08	259	-0.4720777E-06	260	0.5775851E-09
261	0.3999255E-07	262	0.2887435E-06	263	-0.6239476E-09	264	-0.5423911E-07	265	0.1134249E-07
266	0.1490145E-07	267	-0.8534786E-09	268	-0.3125198E-09	269	-0.7105486E-10	270	-0.1309284E-05
271	-0.3264264E-09	272	-0.9087711E-07	273	0.1487788E-05	274	-0.1610817E-07	275	0.5298268E-06
276	-0.4052798E-06	277	0.1927581E-06	278	0.2748499E-07	279	0.1658720E-06	280	-0.8990980E-07
281	-0.1663062E-09	282	0.3039713E-10	283	-0.3169985E-10	284	-0.1218849E-10	285	-0.8544838E-11
286	0.6478943E-11	287	0.5527745E-11	288	-0.5357457E-11	289	-0.3683098E-11	290	-0.3992876E-11
291	0.3652277E-11	292	0.2415191E-11	293	-0.2522045E-11	294	-0.6847742E-08	295	-0.3584123E-11
296	-0.8561864E-07	297	0.5859500E-13	298	-0.1055478E-06	299	-0.5118760E-12	300	-0.2577974E-11
301	0.1795798E-12	302	-0.1814224E-11	303	-0.9105488E-13	304	-0.7379259E-07	305	-0.1380640E-11
306	-0.2233682E-11	307	-0.2792683E-11	308	0.3542567E-11	309	0.3379063E-07	310	-0.1812479E-06
311	0.4054638E-07	312	-0.1116786E-07	313	-0.2317940E-06	314	0.1617731E-07	315	0.1089374E-07
316	0.3929578E-08	317	-0.1870908E-06	318	-0.2374331E-07	319	-0.3317465E-08	320	-0.1648875E-06
321	0.4797890E-07	322	-0.1228549E-06	323	0.5437659E-08	324	0.4457850E-09	325	0.1030048E-06
326	-0.1571836E-06	327	0.1339008E-06	328	-0.9420582E-08	329	0.1186249E-06	330	-0.6936247E-08
331	-0.1570529E-06	332	-0.1141302E-07	333	0.8226903E-07	334	-0.1586581E-06	335	-0.3587952E-07
336	-0.3550991E-07	337	0.2822890E-08	338	0.1203285E-07	339	0.1405351E-08	340	-0.7883483E-07
341	0.1540955E-06	342	-0.9514590E-08	343	-0.9701381E-07	344	0.1018291E-08	345	0.2769078E-09
346	0.6368133E-09	347	0.4403271E-09	348	0.4007248E-09	349	0.1180507E-08	350	-0.3085876E-08
351	-0.1111790E-08	352	-0.4064666E-09	353	-0.2049749E-09	354	0.2973884E-08	355	0.1312851E-09
356	-0.9350332E-10	357	-0.6909487E-10	358	-0.5289738E-10	359	-0.4391422E-10	360	-0.3342140E-10
361	0.2381337E-10	362	-0.2085723E-10	363	0.1740390E-10	364	-0.8496192E-11	365	0.3663732E-09
366	-0.1005783E-10	367	-0.8155443E-08	368	0.1559315E-06	369	0.1544288E-07	370	-0.1486800E-06
371	0.9869454E-09	372	-0.1357189E-08	373	-0.3746344E-07	374	0.1229319E-06	375	0.1778401E-06
376	0.7064472E-08	377	-0.1432355E-08	378	0.4609476E-07	379	0.1140248E-06	380	-0.1055324E-06
381	-0.1251726E-06	382	0.6288587E-07	383	0.1061494E-06	384	-0.3528901E-07	385	0.7129154E-07
386	-0.2661424E-06	387	0.1820507E-06	388	-0.7147355E-07	389	-0.4623928E-07	390	0.5917283E-06
391	-0.8731873E-06	392	0.6905869E-06	393	-0.1698741E-06	394	0.2254971E-08	395	0.5677740E-07
396	-0.3423623E-07	397	-0.3747318E-09	398	-0.4973085E-08	399	-0.1143447E-08	400	-0.1947792E-07

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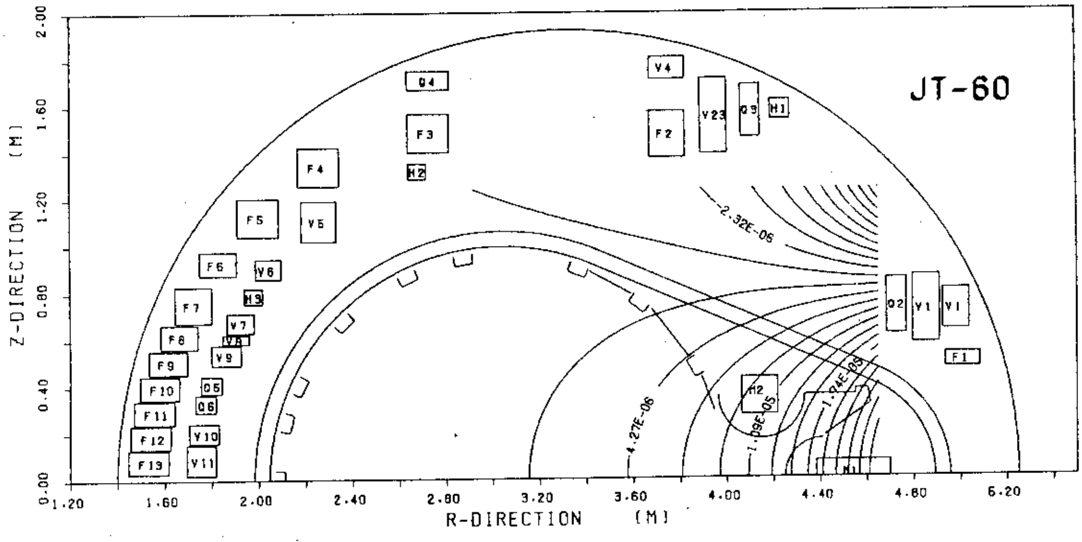
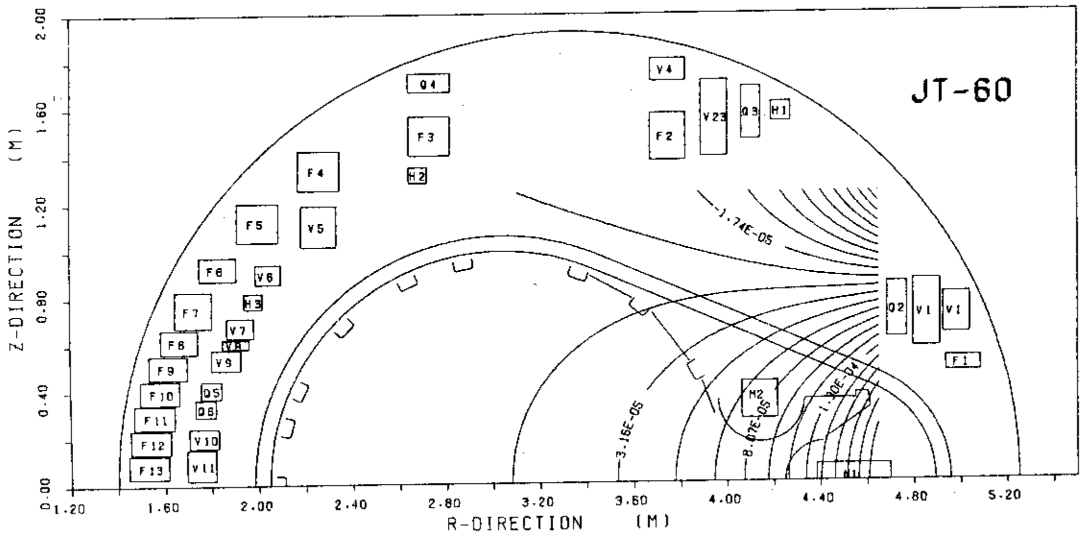
Mode No.	$\bar{\nu}_j (Wb/m^2 A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j (Wb/m^2 A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j (Wb/m^2 A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j (Wb/m^2 A\sqrt{\Omega})$	Mode No.	$\bar{\nu}_j (Wb/m^2 A\sqrt{\Omega})$
401	0.5438821E-09	402	0.1287462E-07	403	-0.2000992E-07	404	-0.1872824E-07	405	0.1242355E-07
406	0.6241958E-08	407	0.1700294E-07	408	0.5016494E-09	409	0.1688315E-07	410	0.2512577E-08
411	0.1901161E-07	412	0.1208421E-07	413	-0.4359964E-09	414	-0.1729927E-06	415	-0.7126678E-06
416	0.3228458E-07	417	-0.1148918E-06	418	0.6405735E-06	419	-0.1263104E-07	420	-0.2692136E-07
421	-0.2959678E-07	422	-0.5988113E-07	423	0.1772747E-07	424	0.1399623E-08	425	0.1562131E-07
426	-0.6806113E-09	427	0.2739721E-08	428	0.2090411E-08	429	-0.1995614E-08	430	0.2286673E-07
431	0.1277616E-08	432	-0.1227838E-08	433	-0.8572303E-09	434	0.5189984E-09	435	-0.2024992E-07
436	-0.1024681E-08	437	-0.7736451E-09	438	0.1186665E-08	439	-0.3267276E-08	440	0.1351035E-09
441	0.3242029E-09	442	0.3890104E-08	443	0.6934580E-09	444	-0.1477744E-09	445	0.1296804E-08
446	-0.2851970E-09	447	-0.1875095E-08	448	-0.1555641E-09	449	0.2029298E-10	450	0.9688430E-09
451	0.9384414E-11	452	-0.2093706E-09	453	-0.6189169E-09	454	0.1292881E-10	455	-0.3510381E-09
456	0.6037020E-09	457	0.3480655E-10	458	-0.2920058E-09	459	0.1119836E-09	460	0.5886103E-10
461	-0.6151239E-10	462	0.7759007E-10	463	0.5839829E-10	464	-0.6353285E-10		



EDDY CURRENT FLUX DATA (MODE DATA NO. 1)



EDDY CURRENT FLUX DATA (MODE DATA NO. 2)

Fig.28 Magnetic structure of eddy current eigen mode in JT-60 multi-torus system

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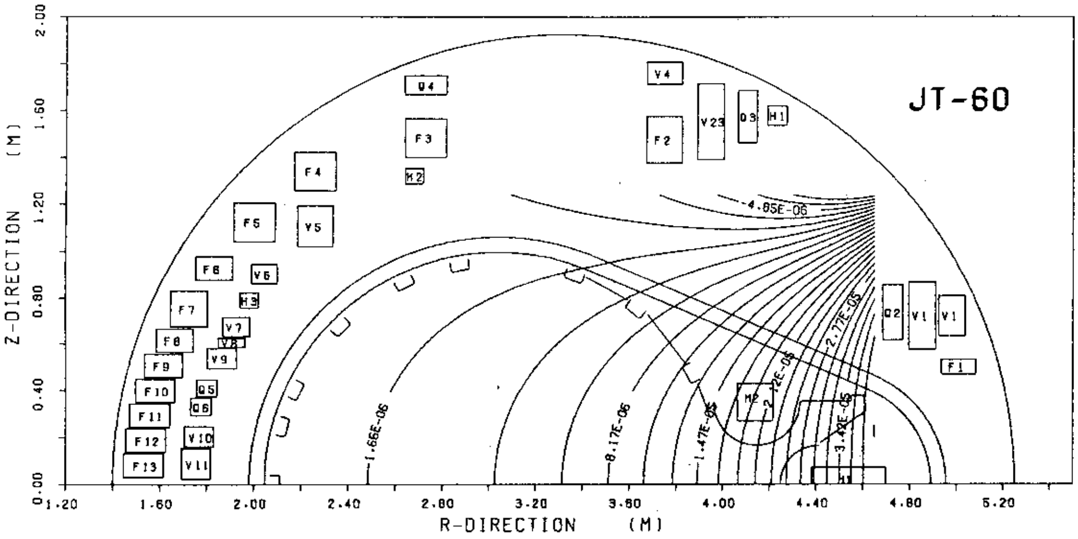
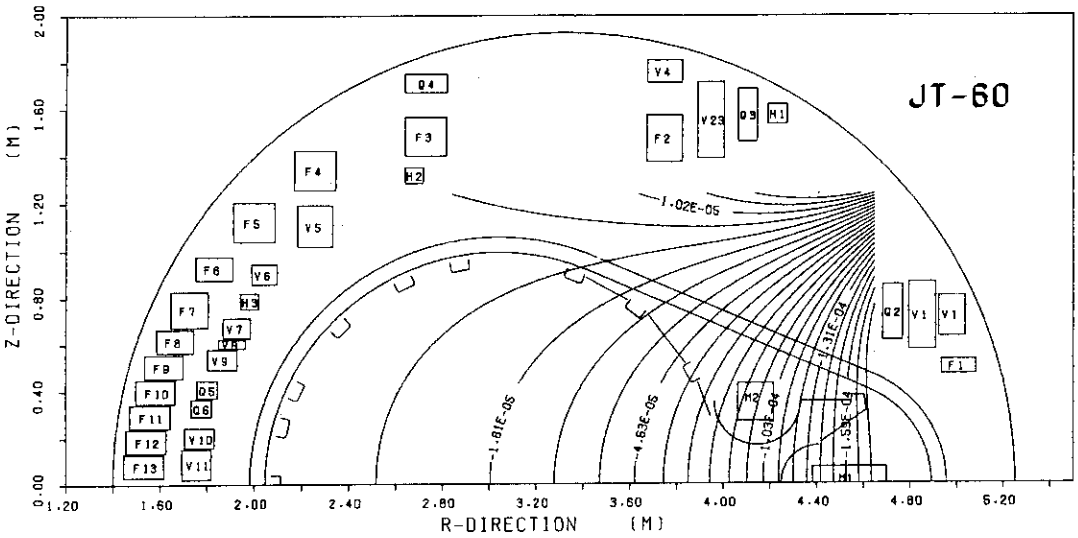
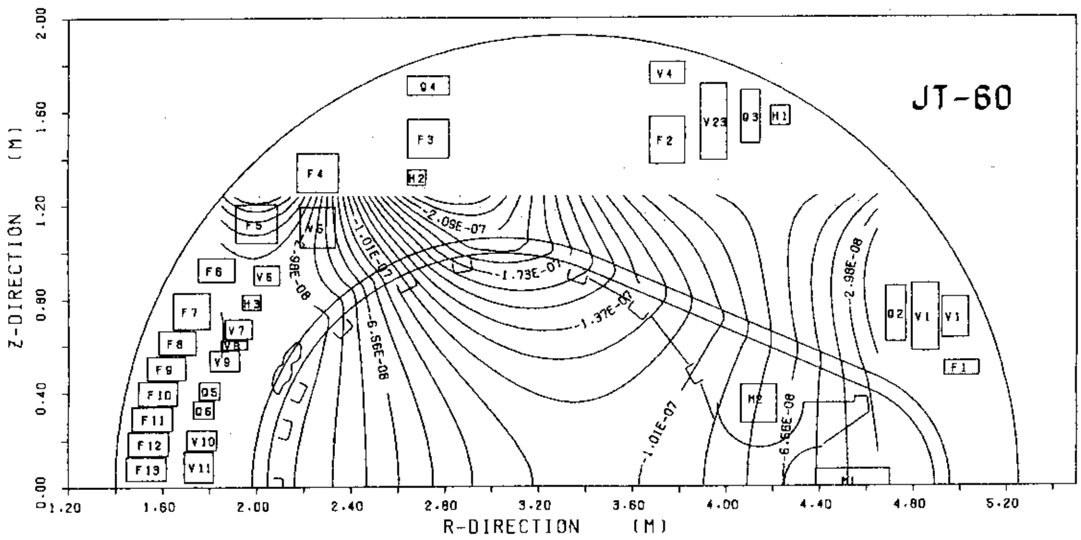


EDDY CURRENT FLUX DATA (MODE DATA NO. 3)



EDDY CURRENT FLUX DATA (MODE DATA NO. 4)



EDDY CURRENT FLUX DATA (MODE DATA NO. 5)

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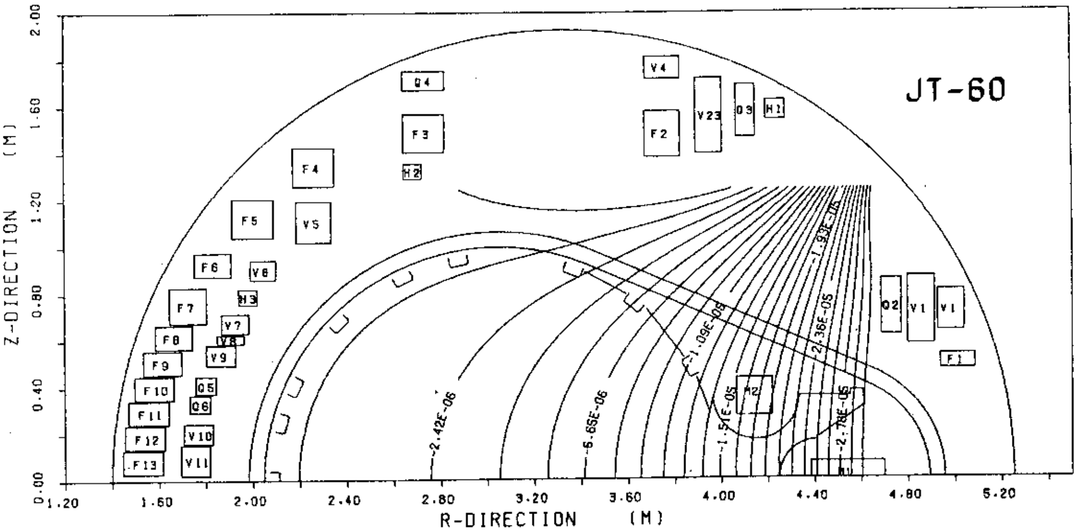
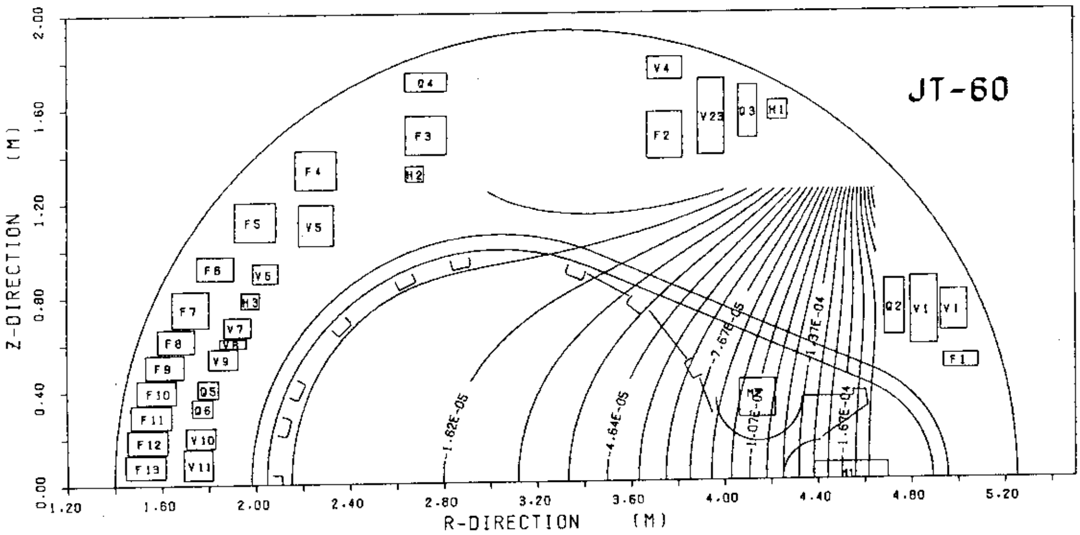
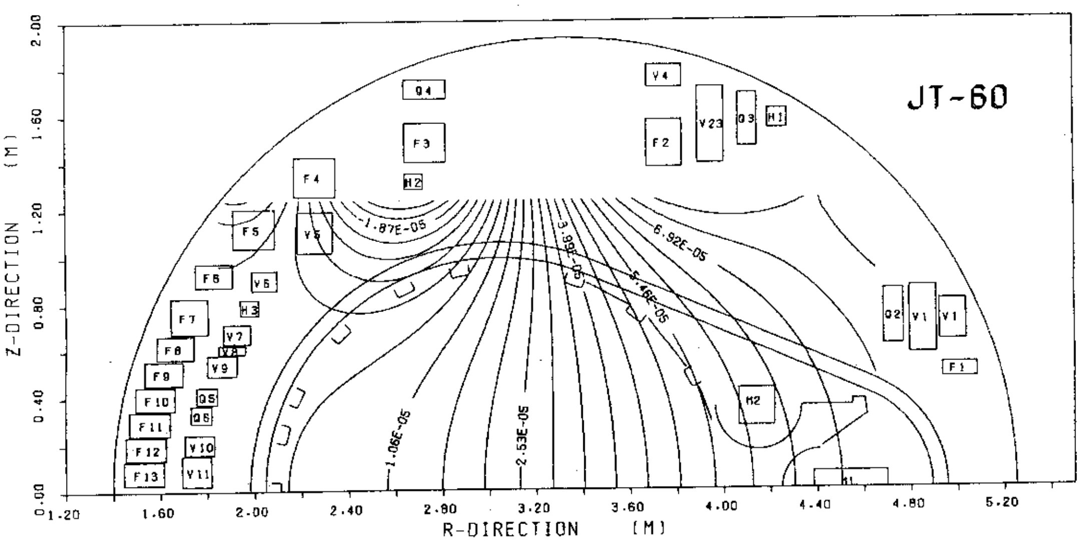


EDDY CURRENT FLUX DATA (MODE DATA NO. 7)



EDDY CURRENT FLUX DATA (MODE DATA NO. 8)



EDDY CURRENT FLUX DATA (MODE DATA NO. 9)

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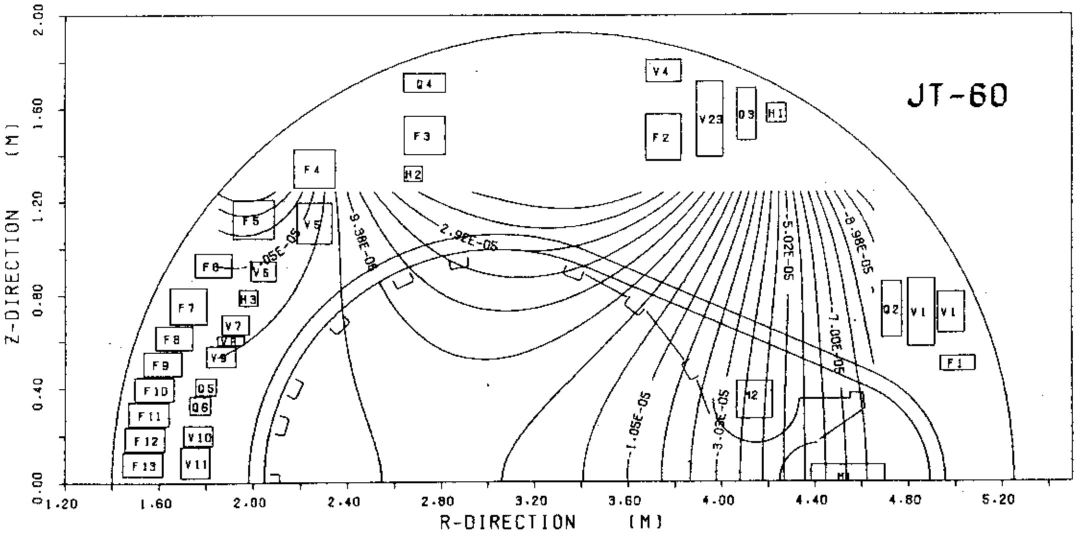
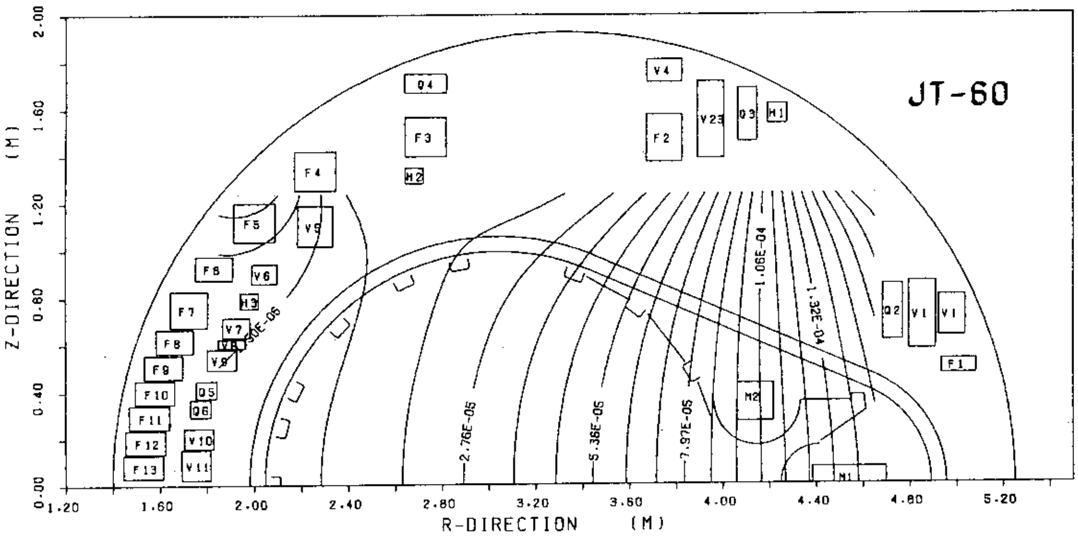


EDDY CURRENT FLUX DATA (MODE DATA NO. 13)



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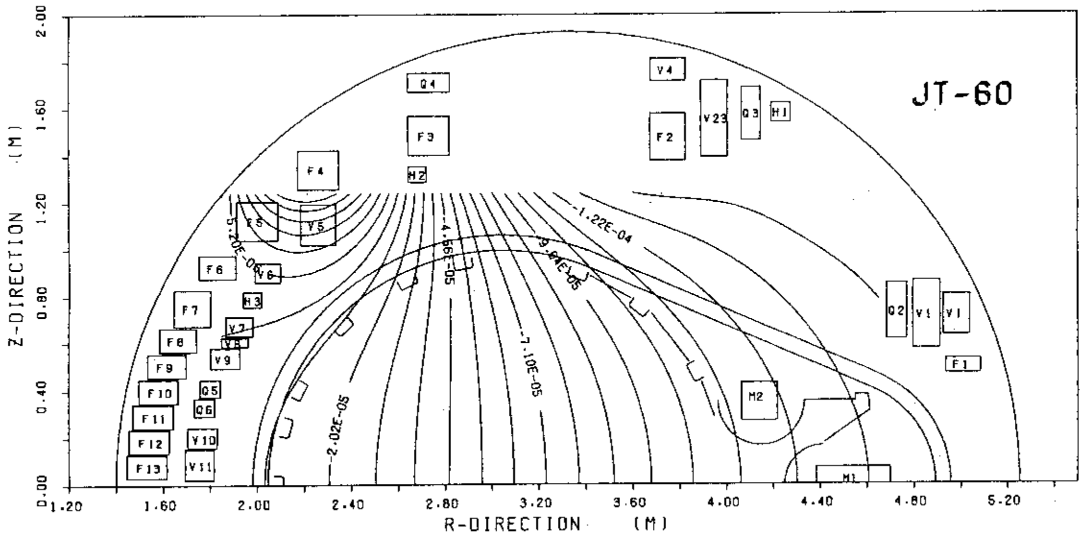

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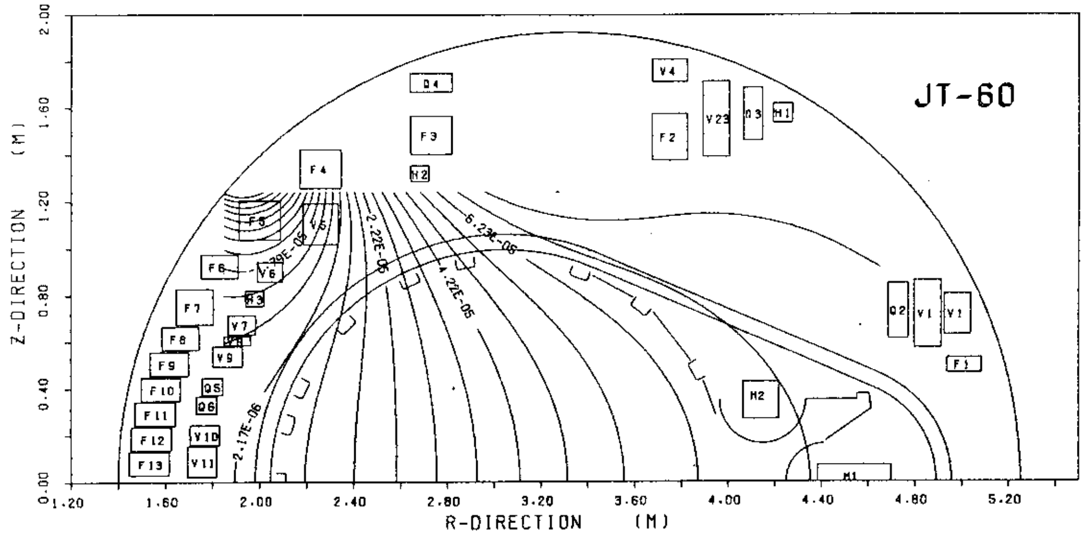

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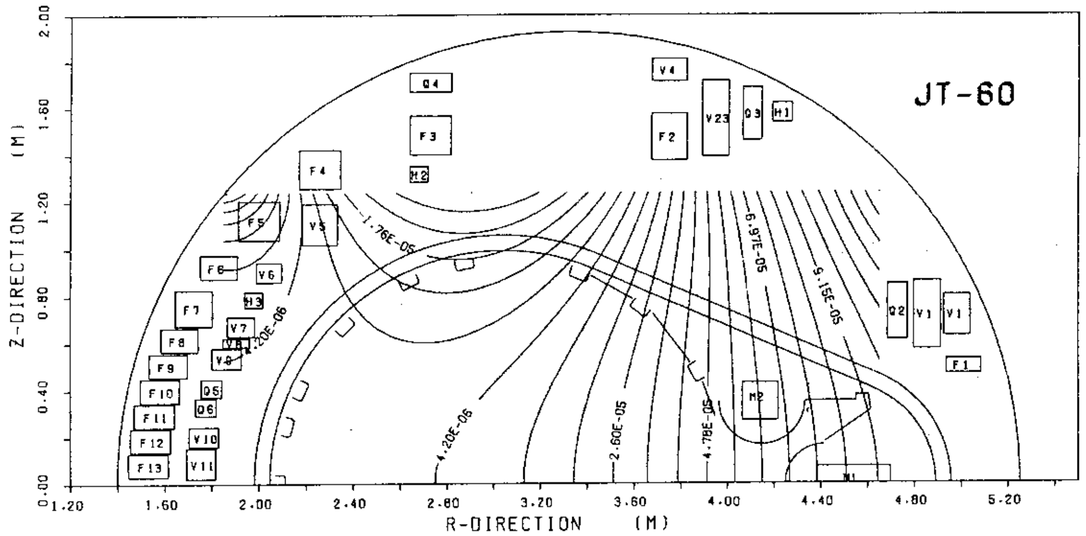

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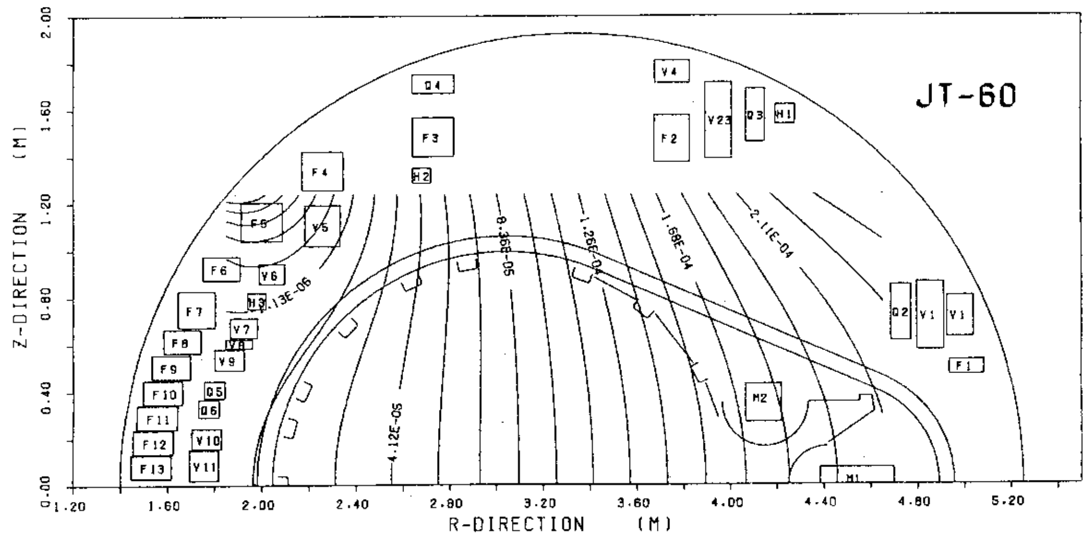

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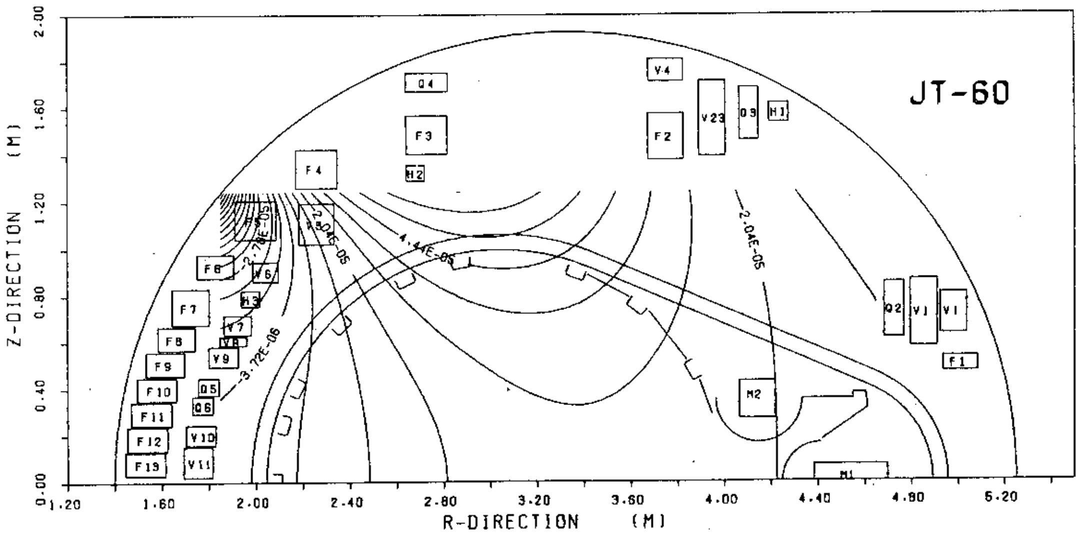

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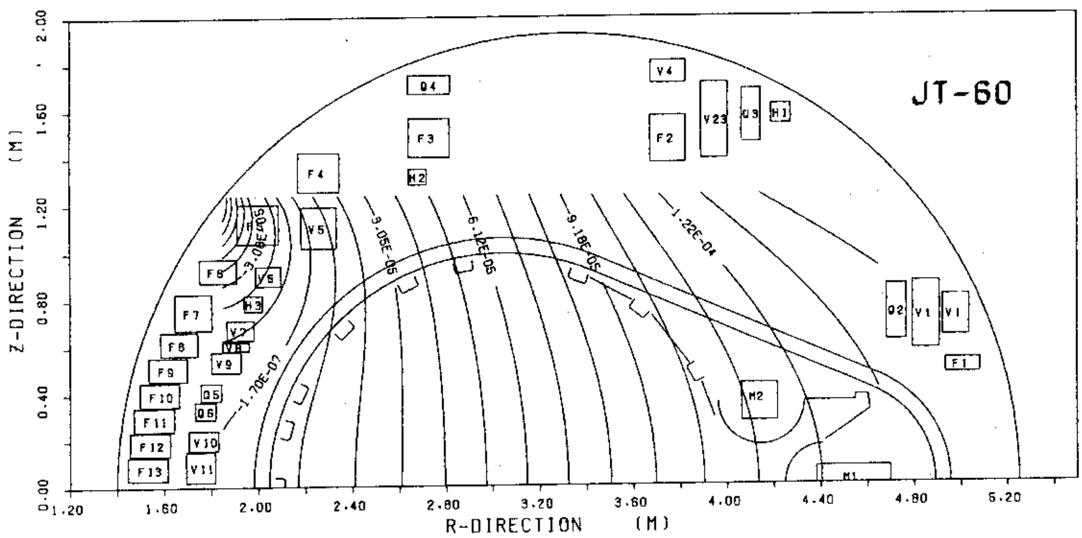

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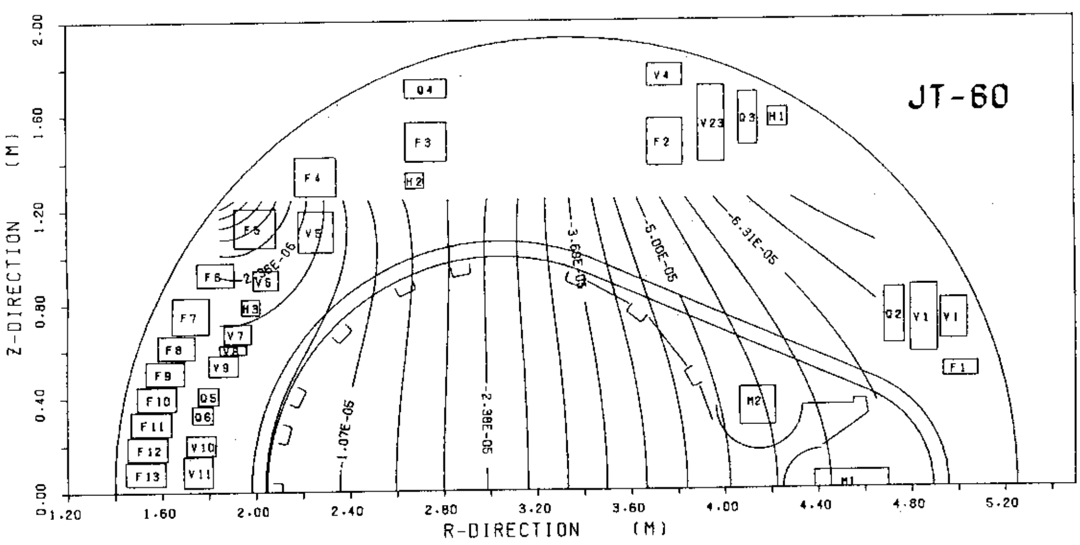

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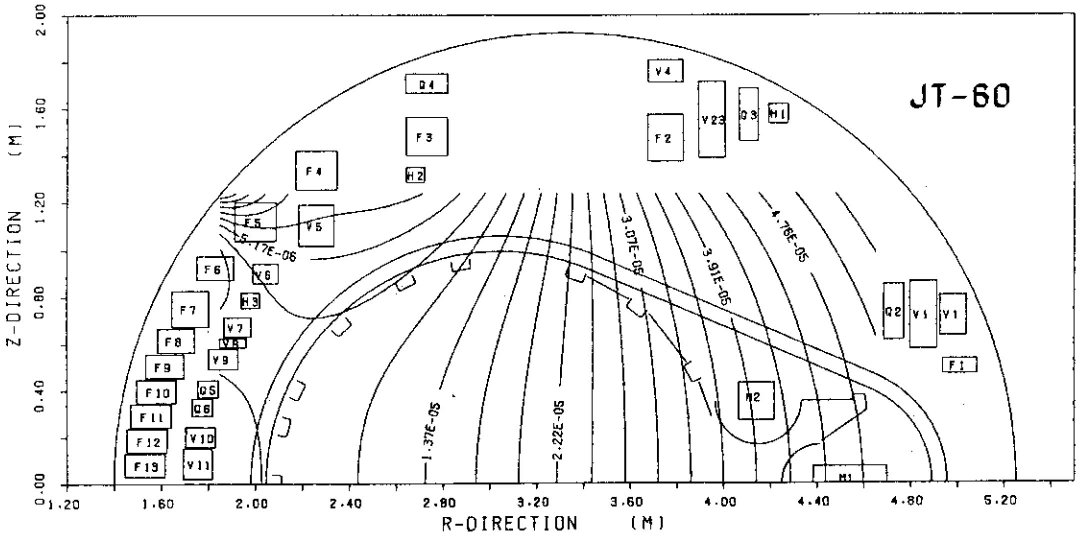

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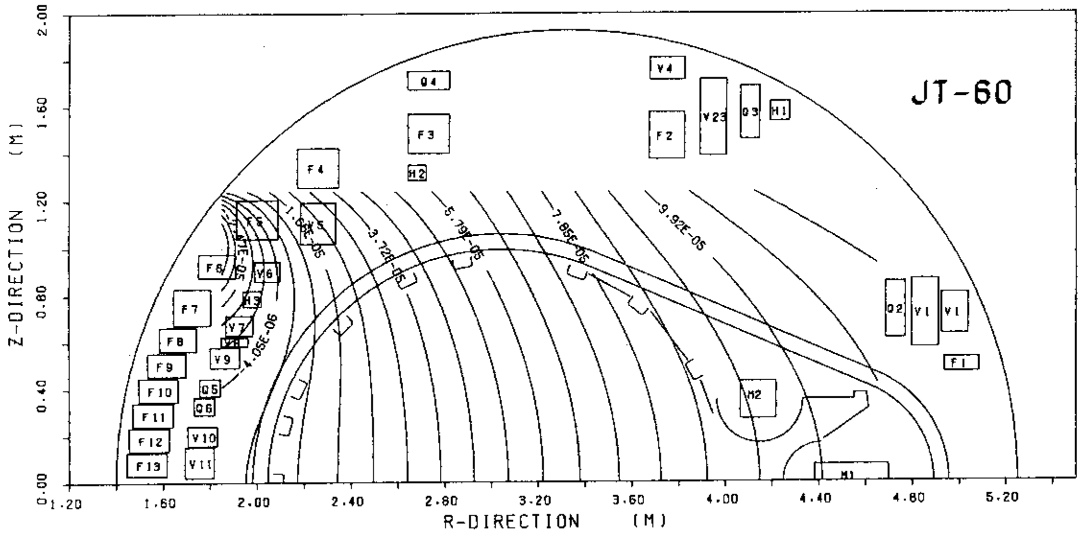

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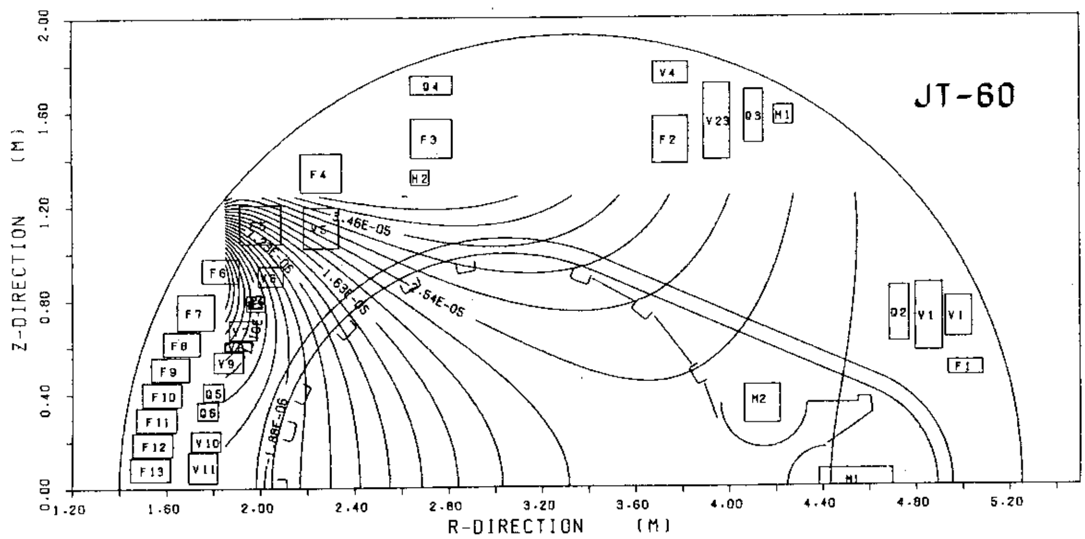

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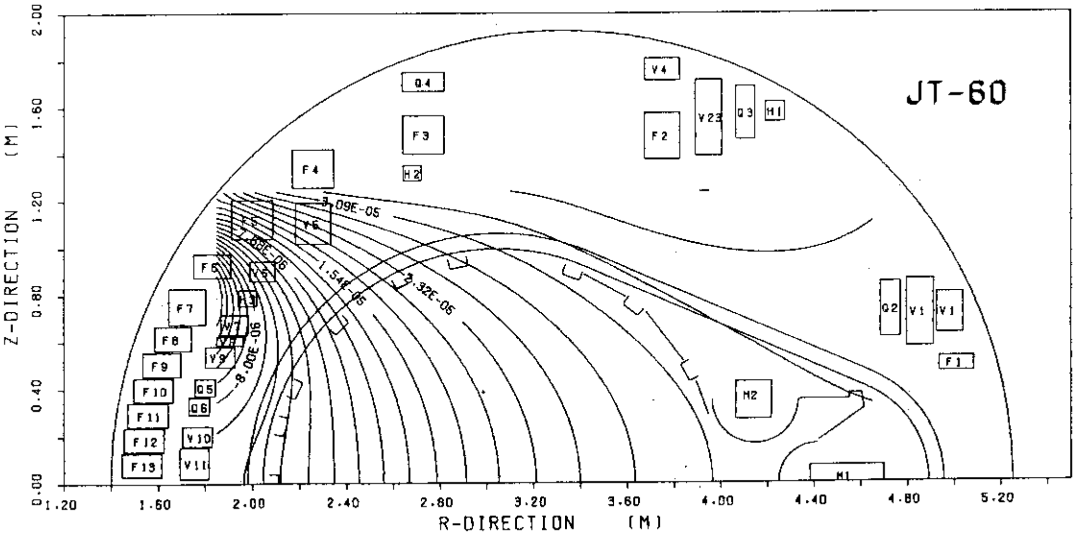

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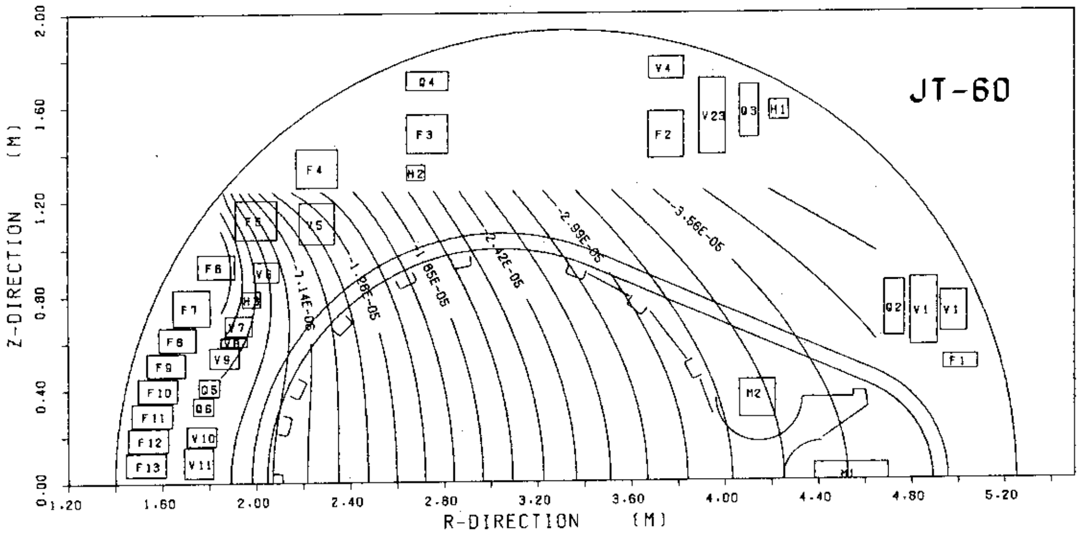

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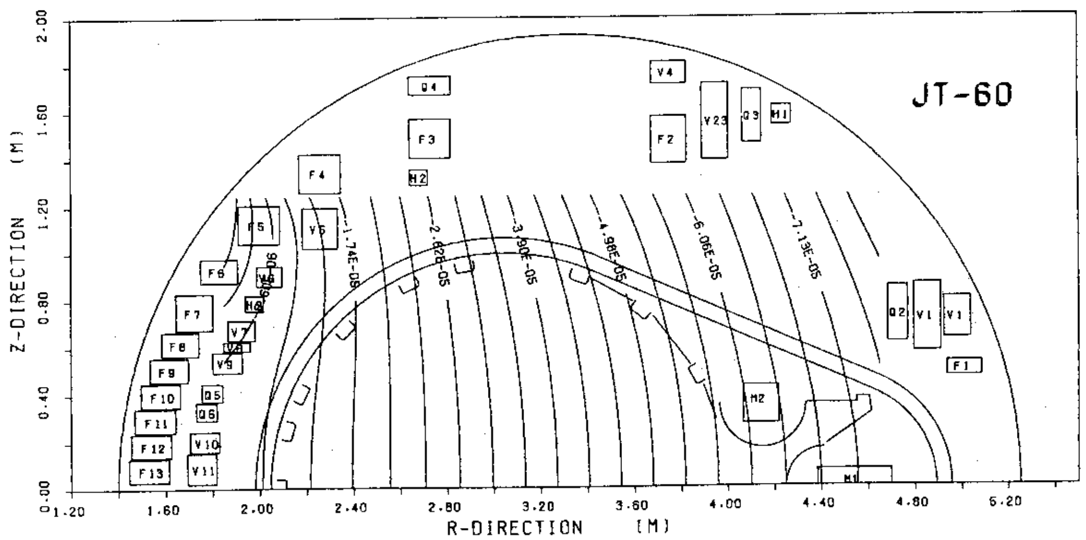

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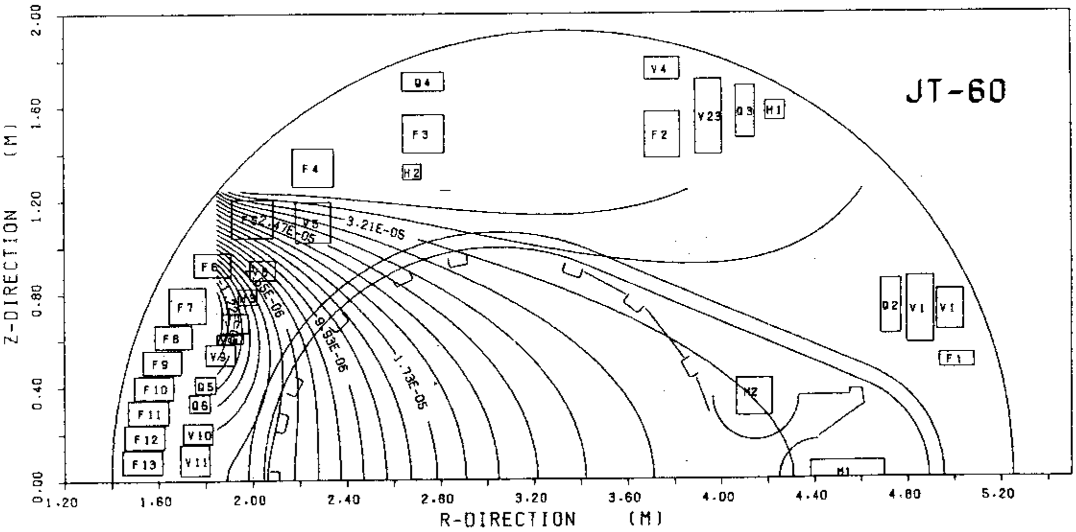

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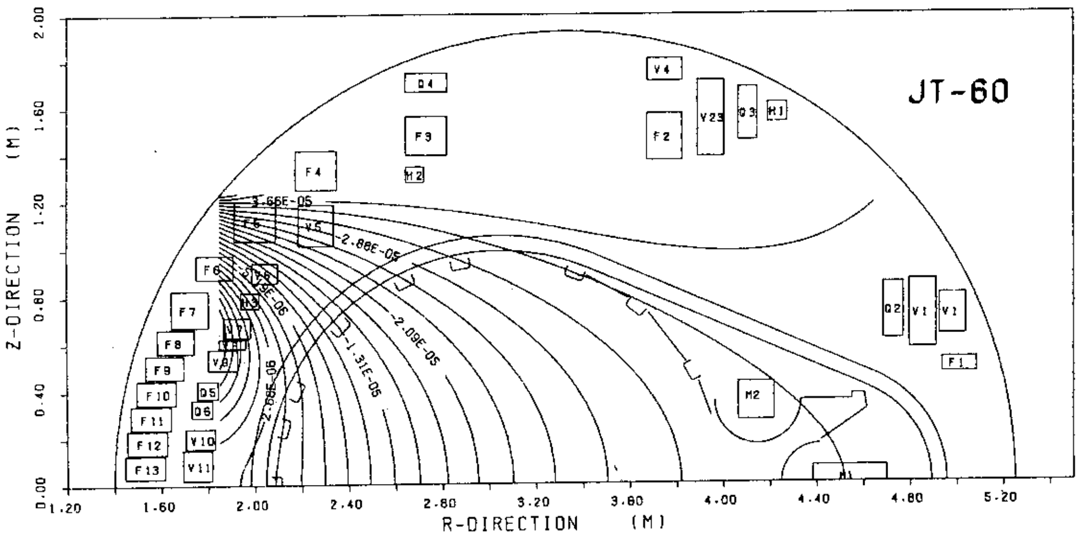

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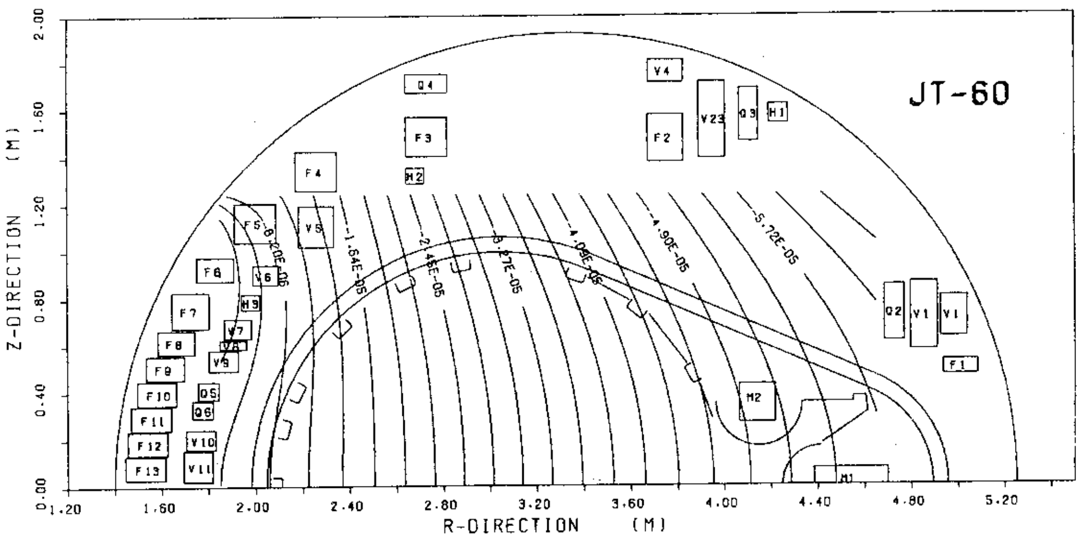

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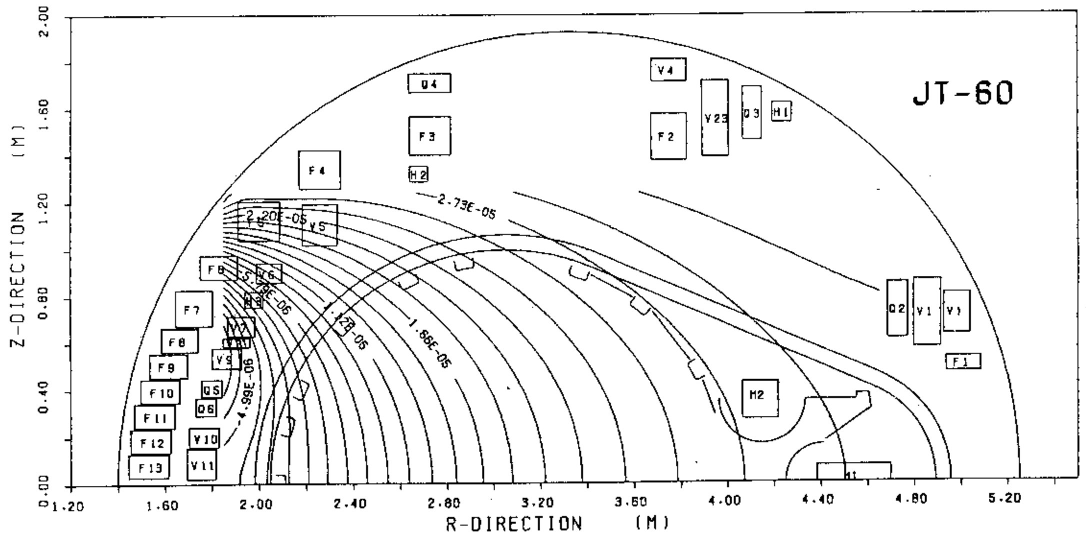

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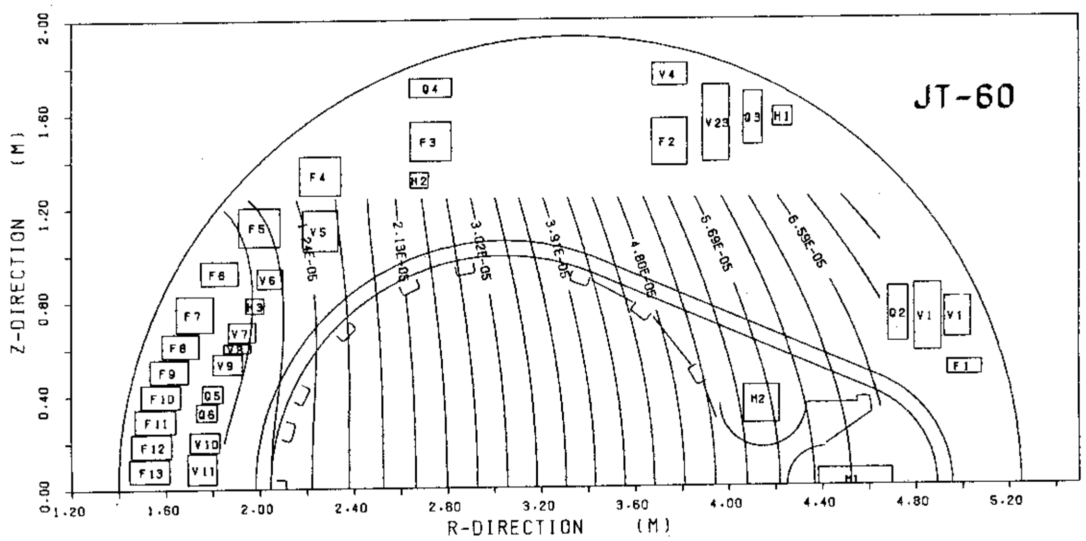

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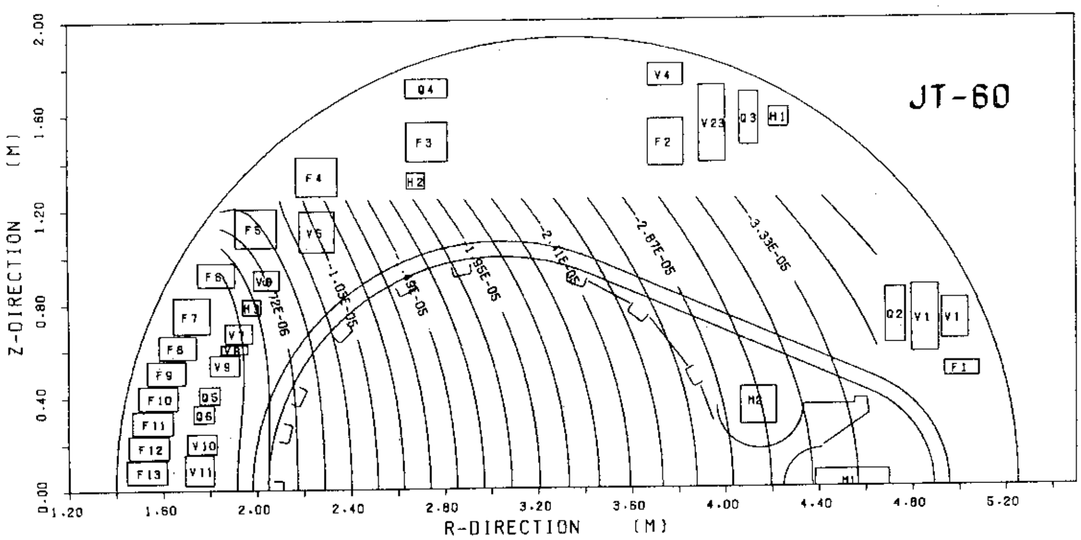

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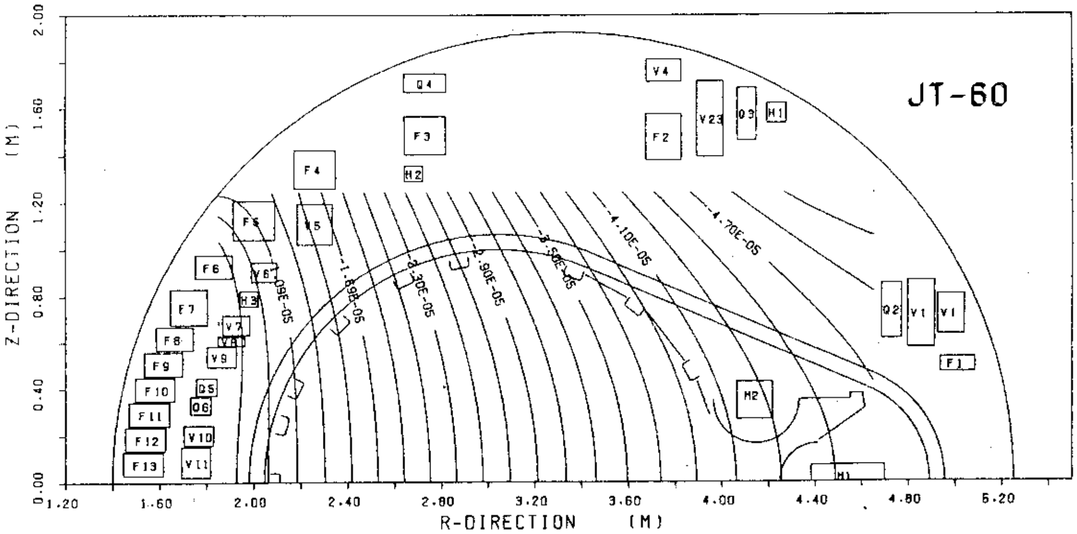

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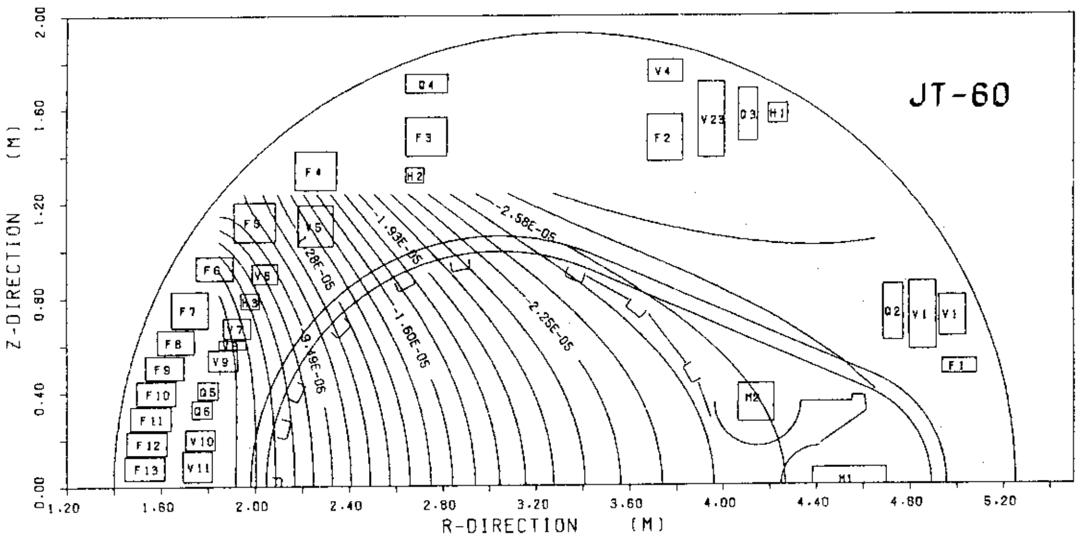

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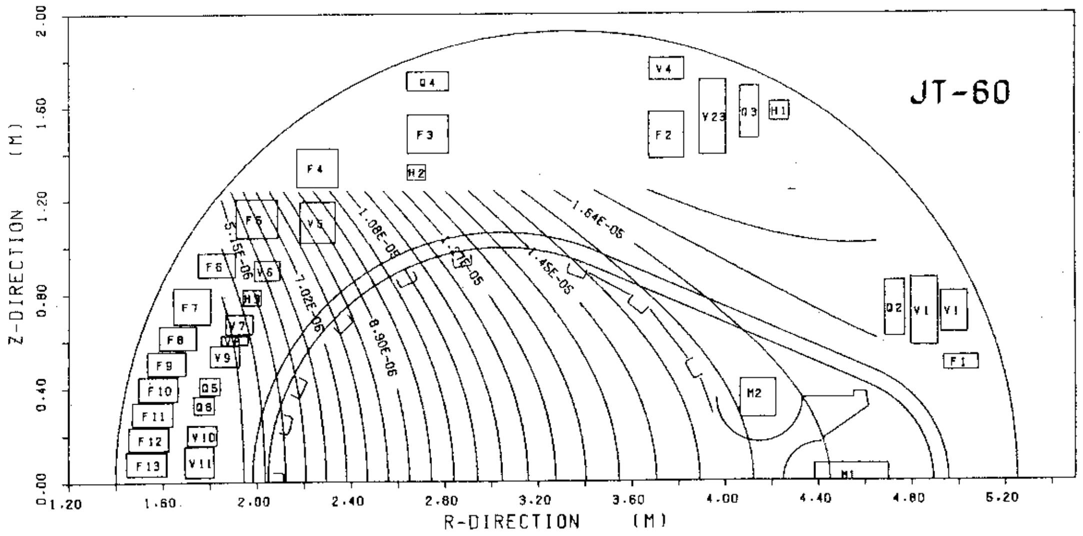

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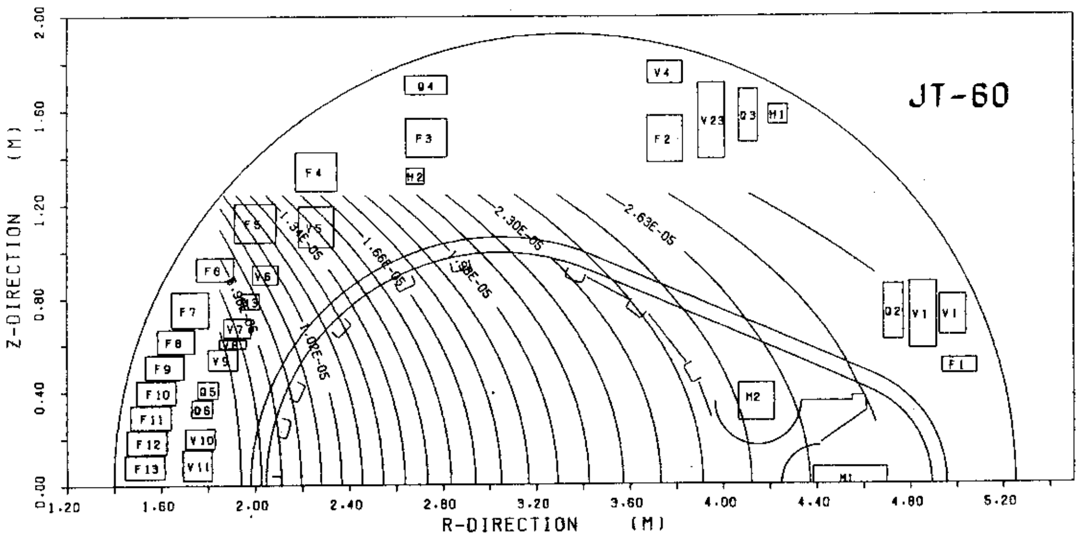

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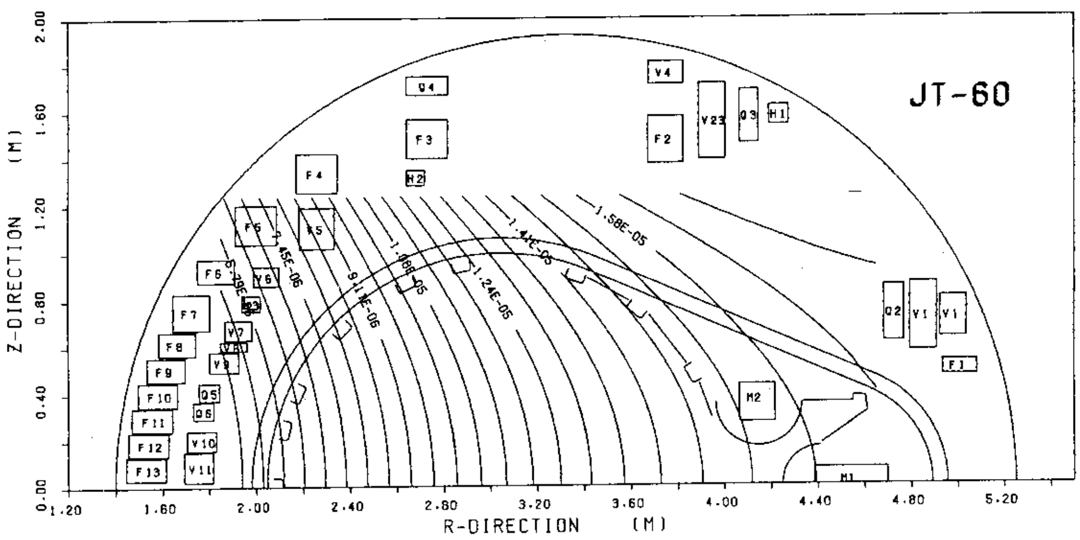

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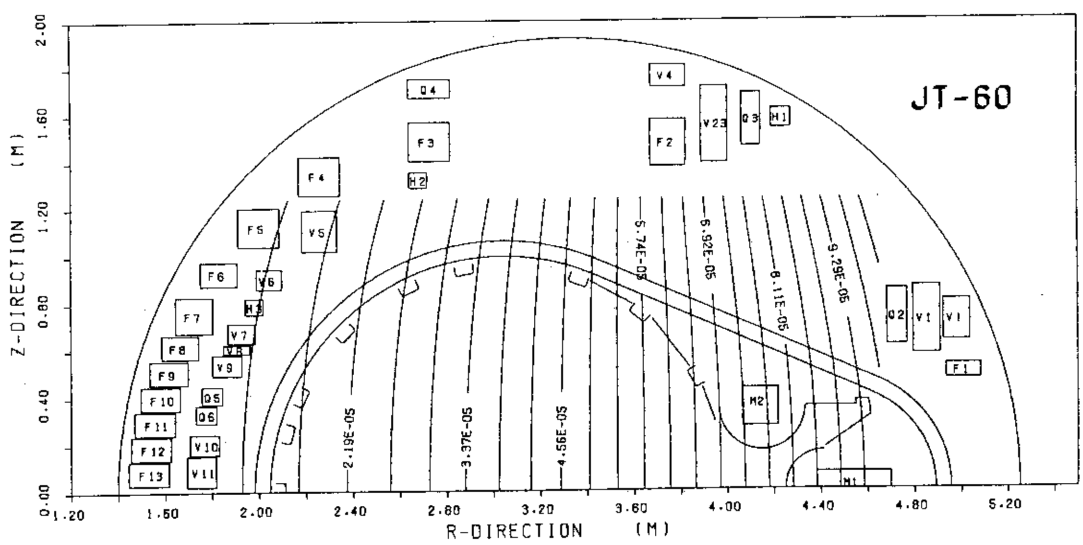

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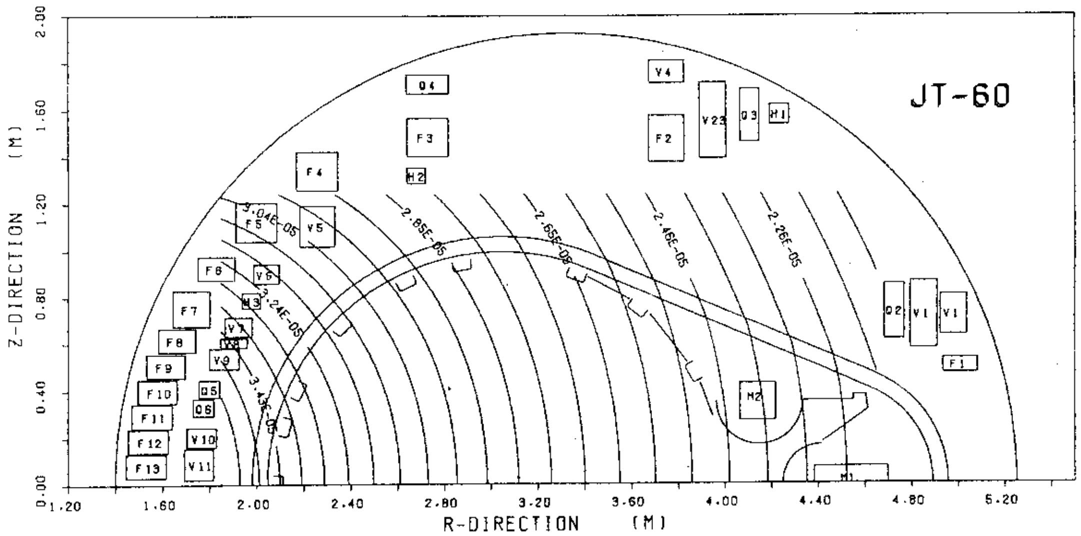

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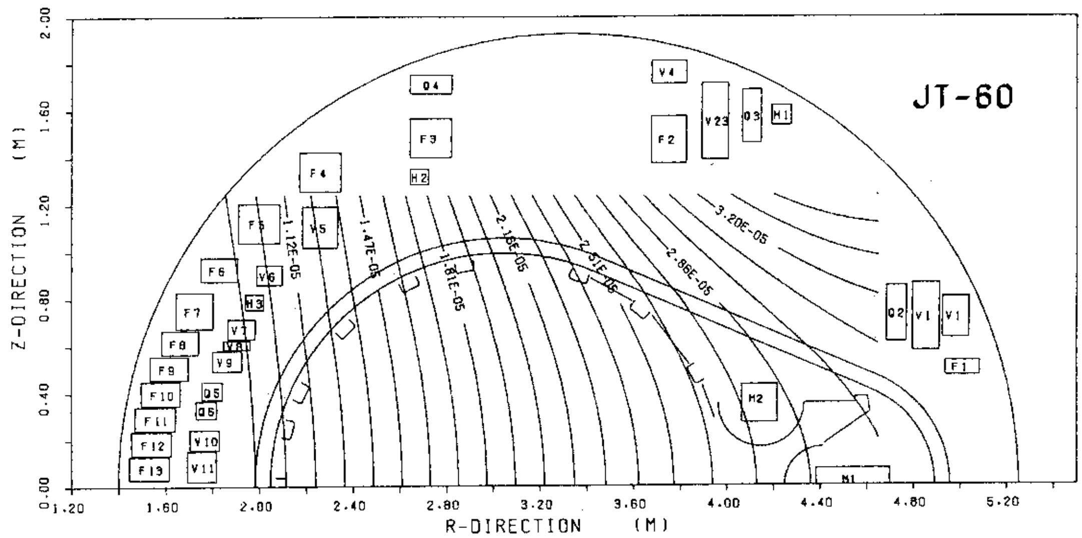

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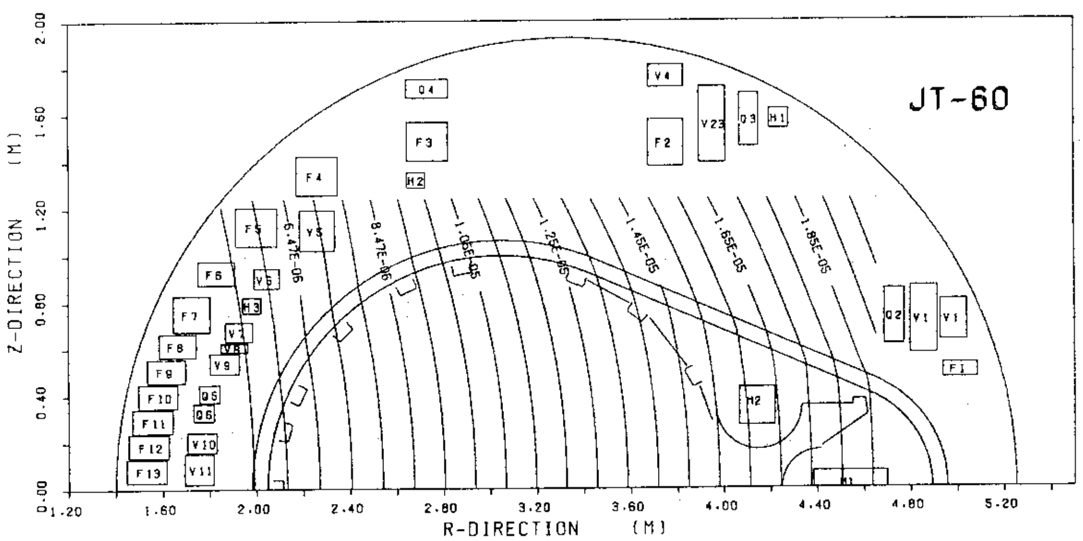

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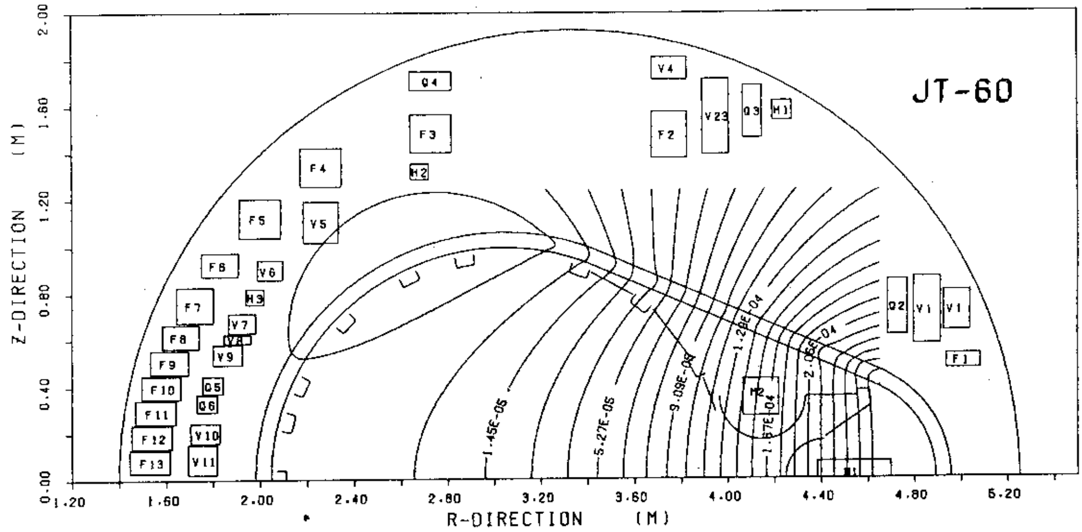

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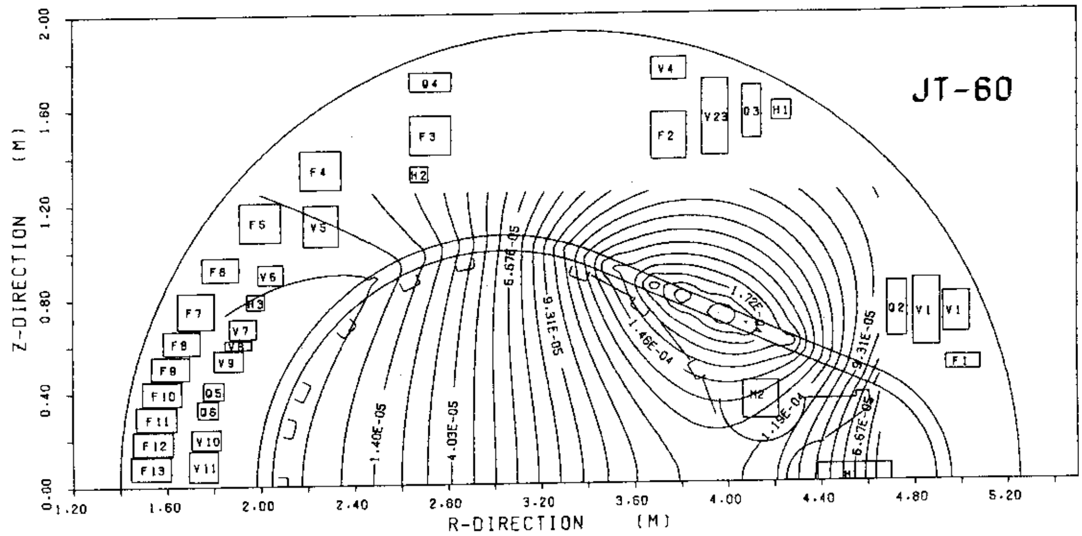

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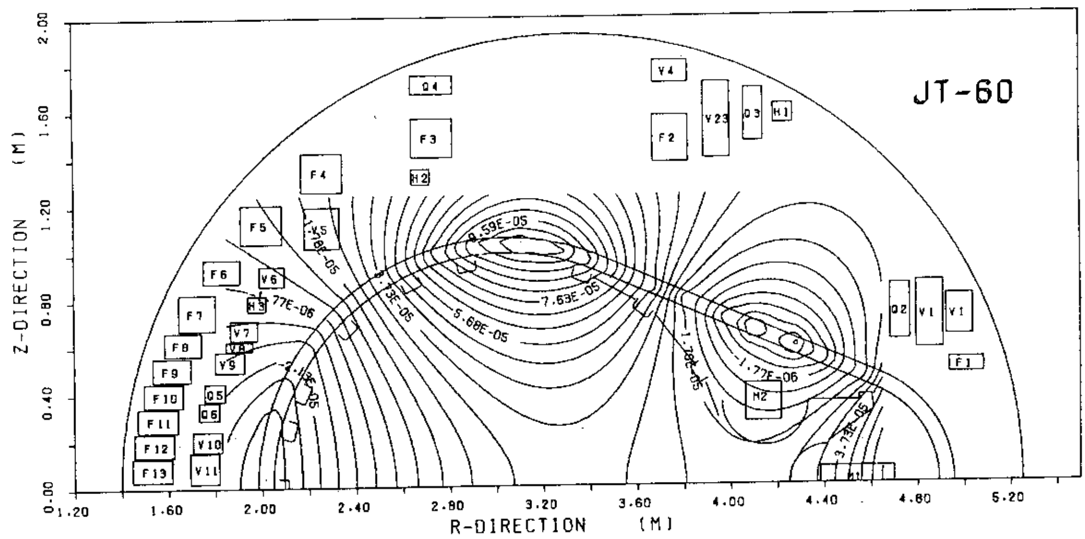

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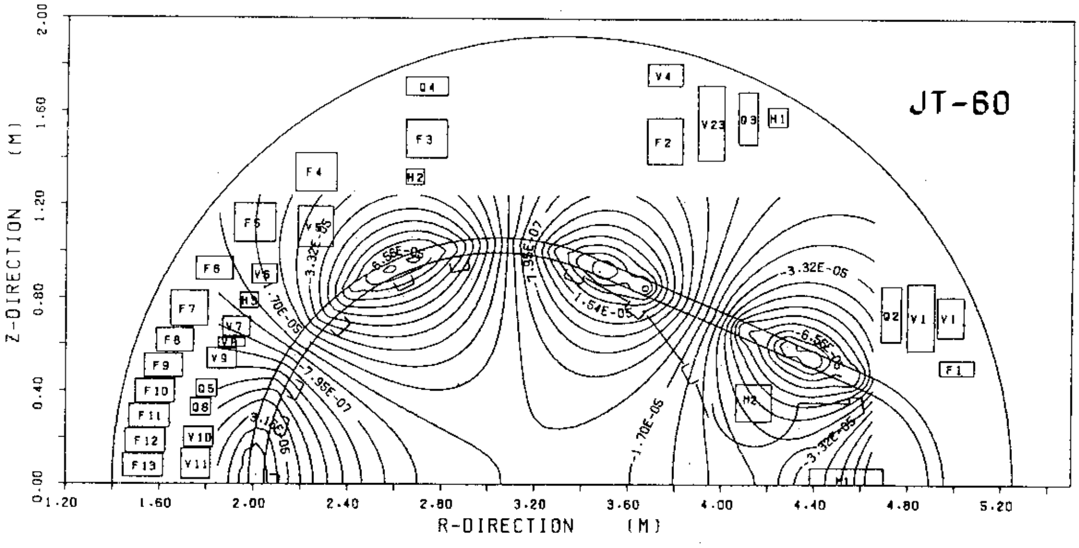

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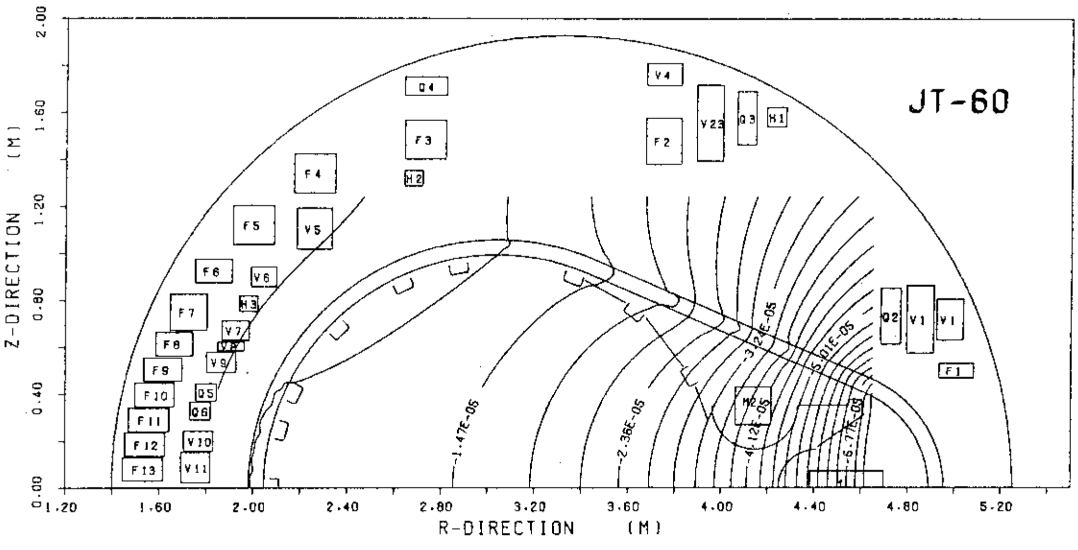

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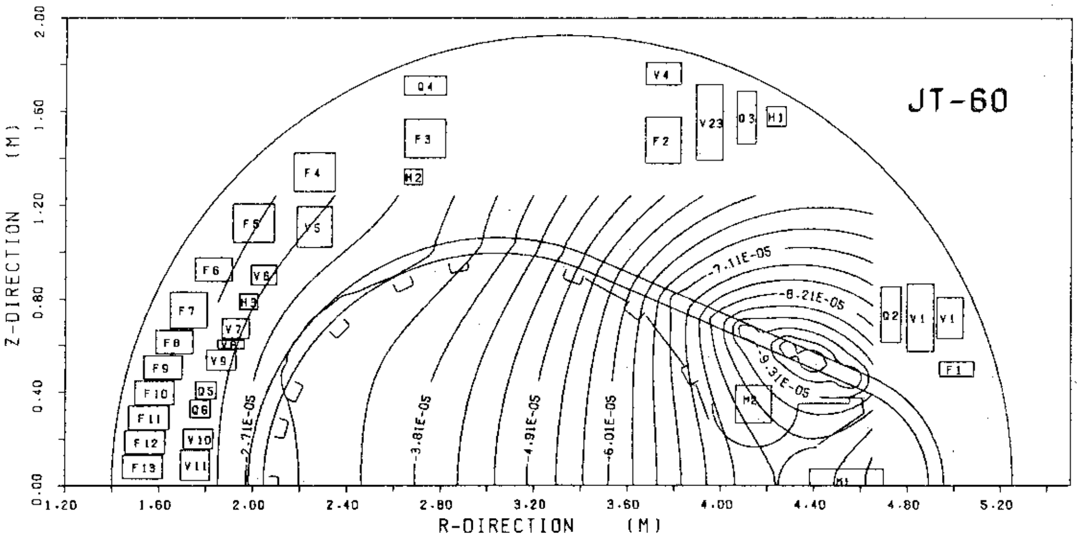

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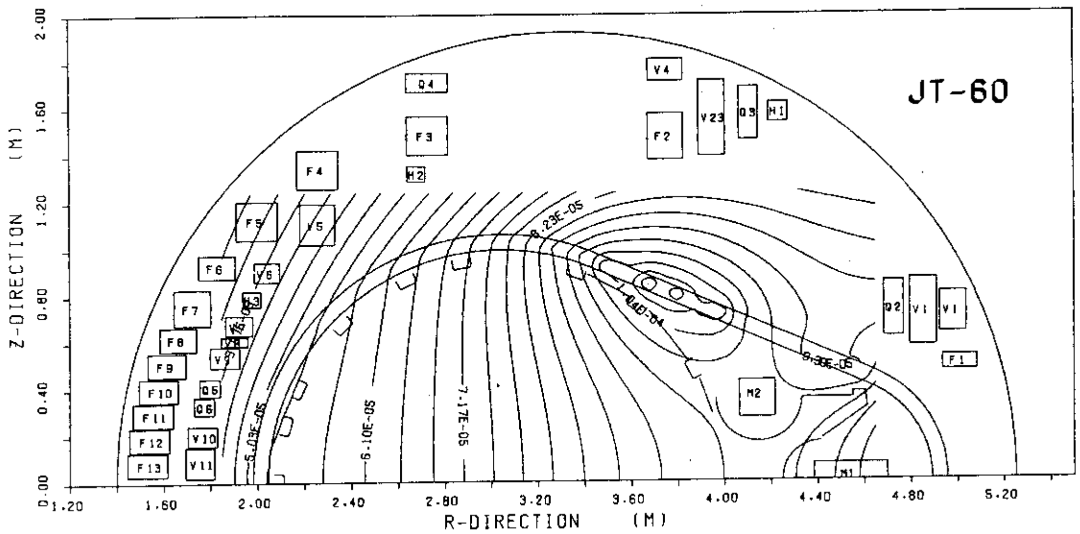

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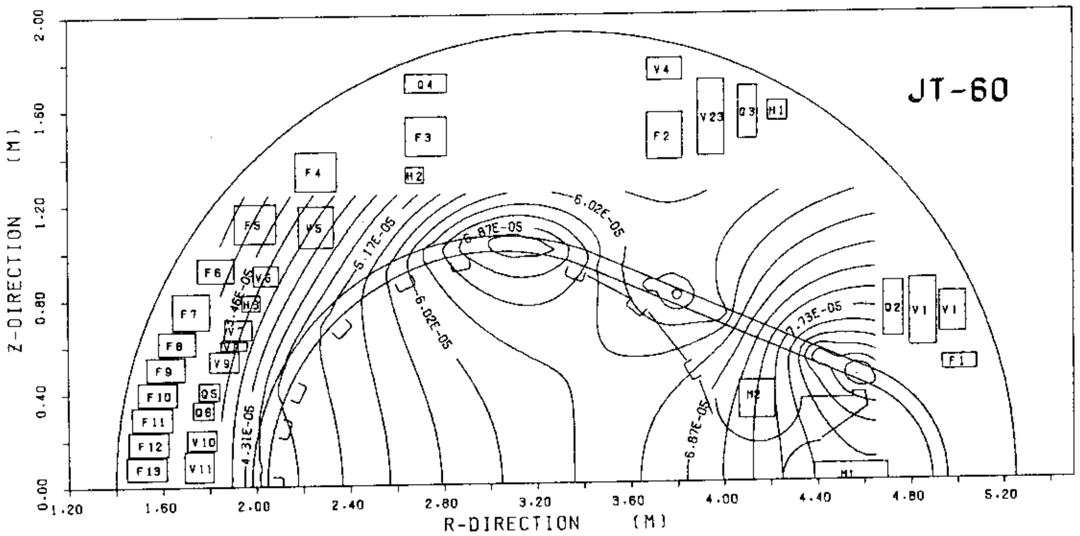

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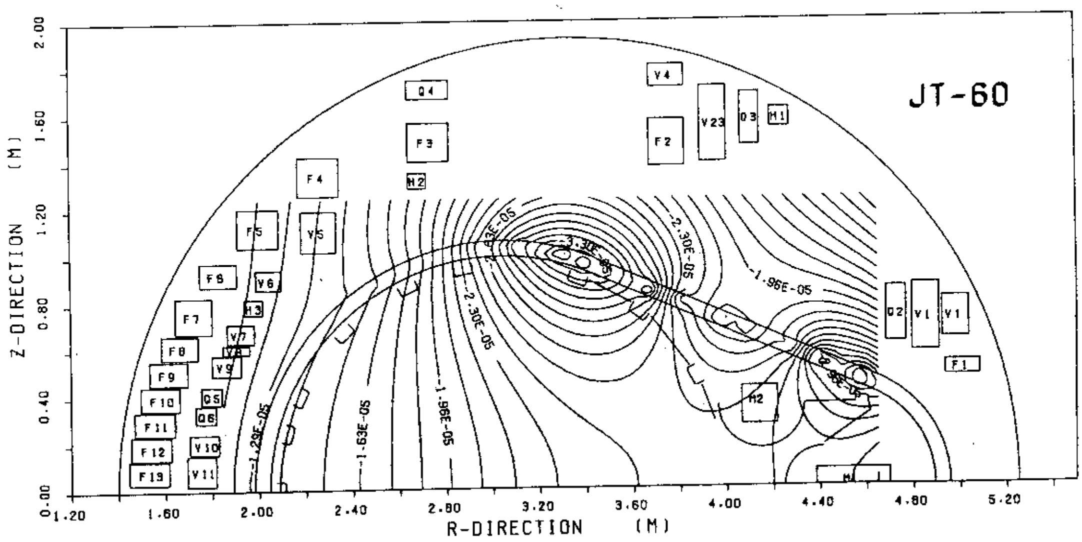

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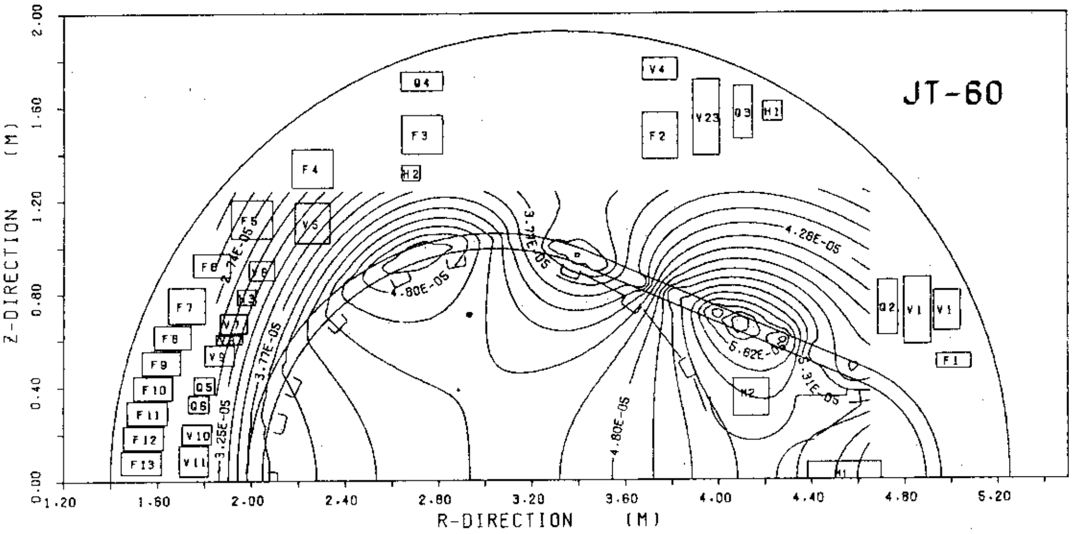

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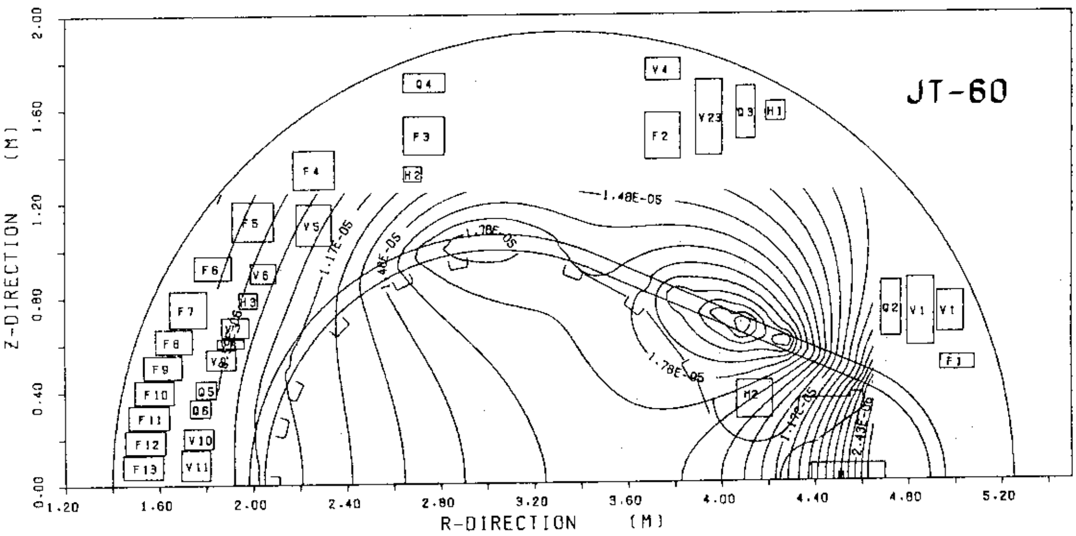

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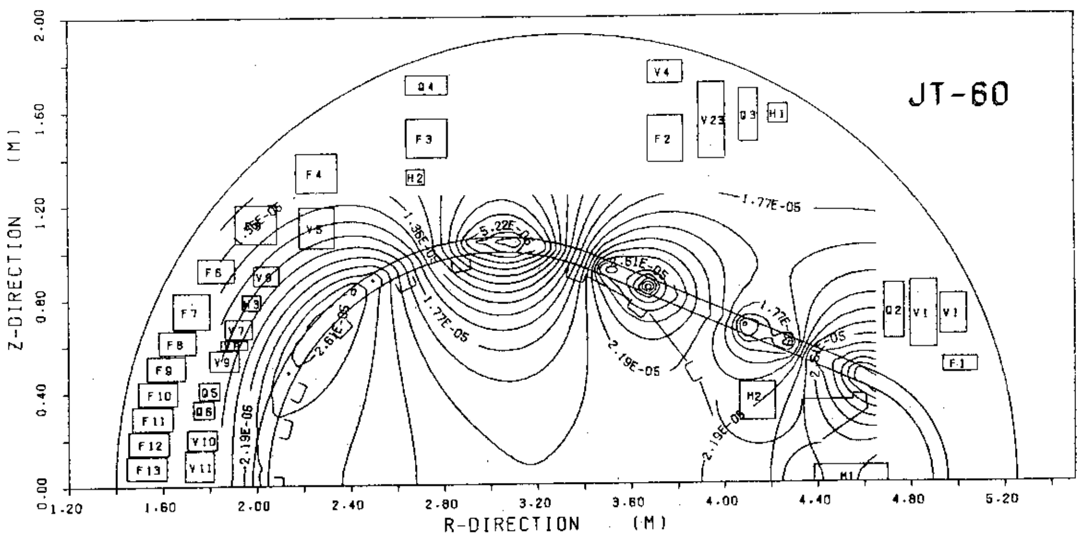

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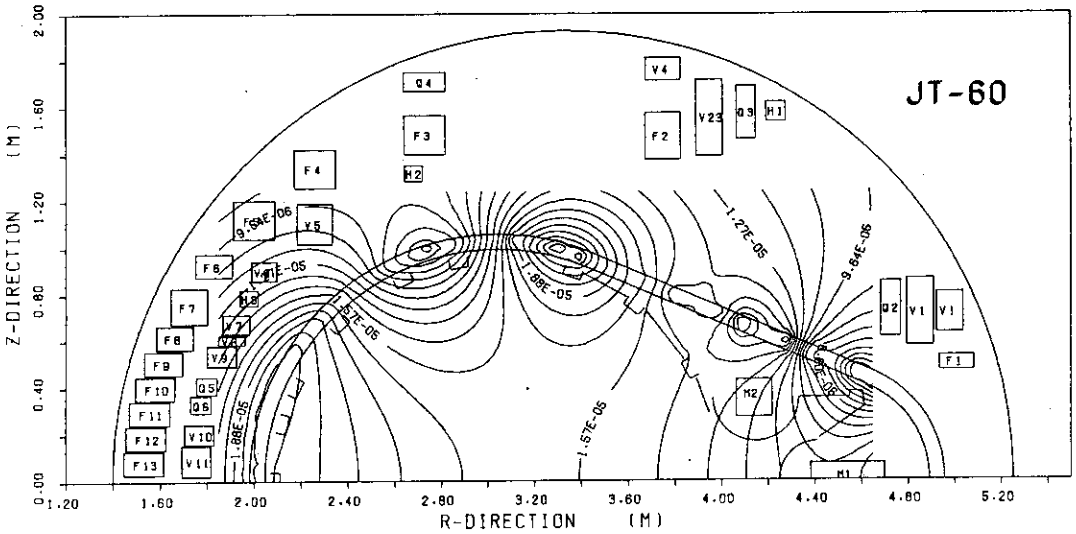

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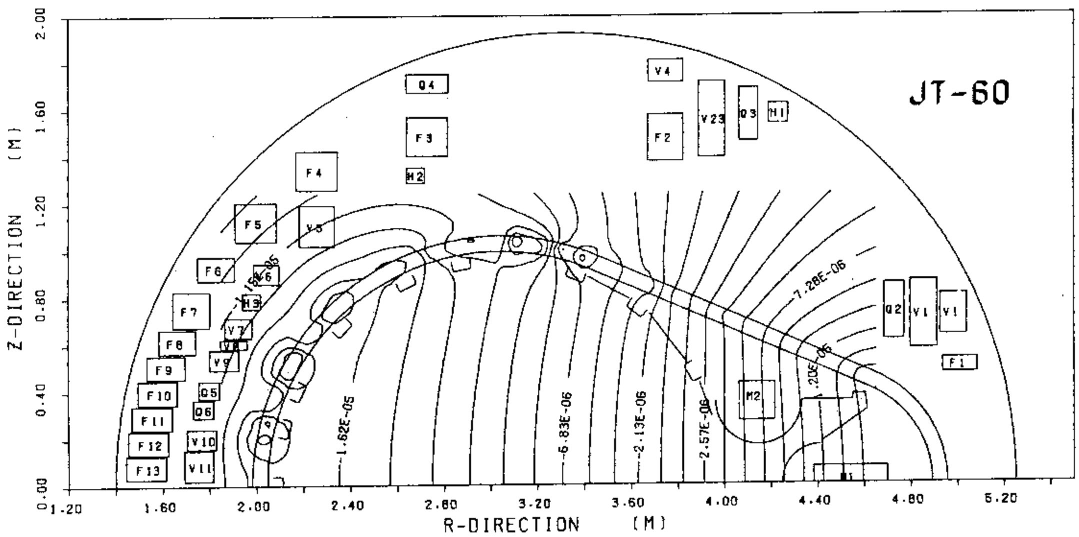

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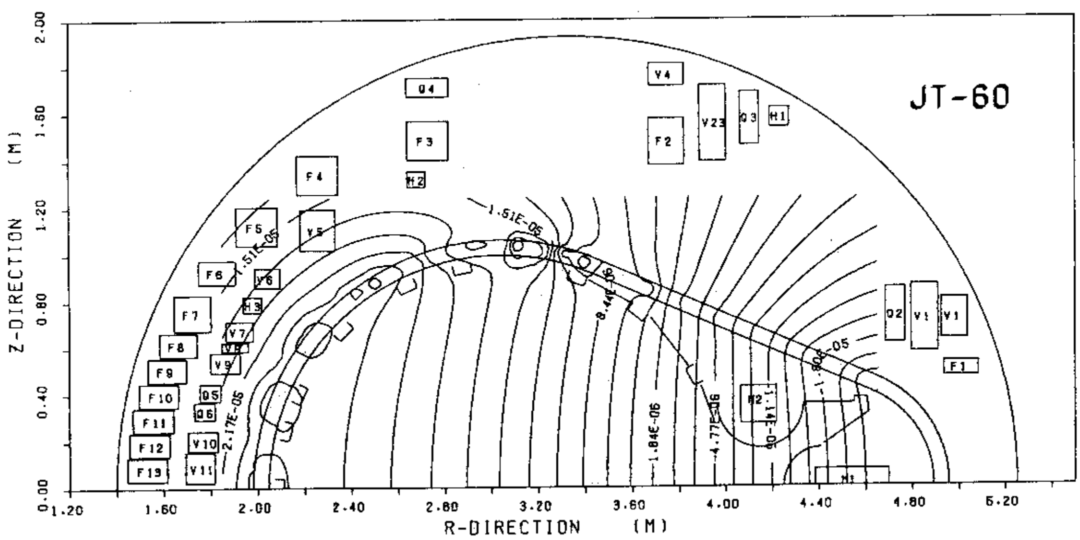

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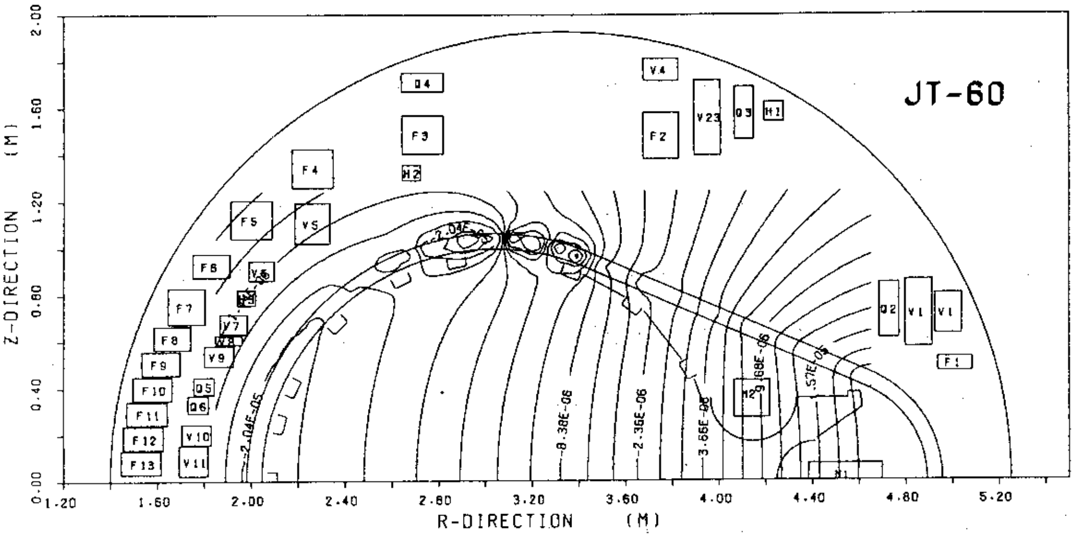

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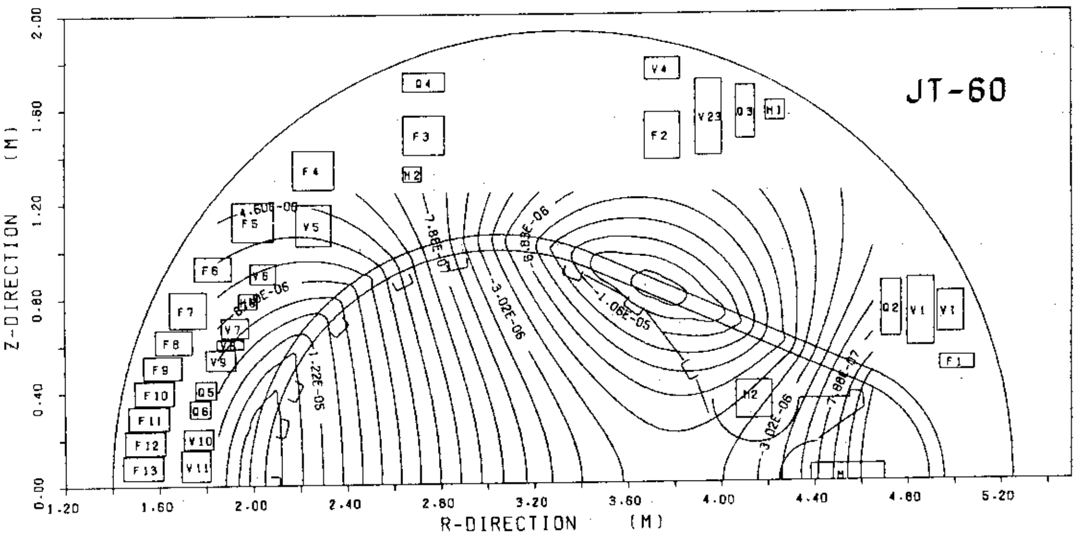

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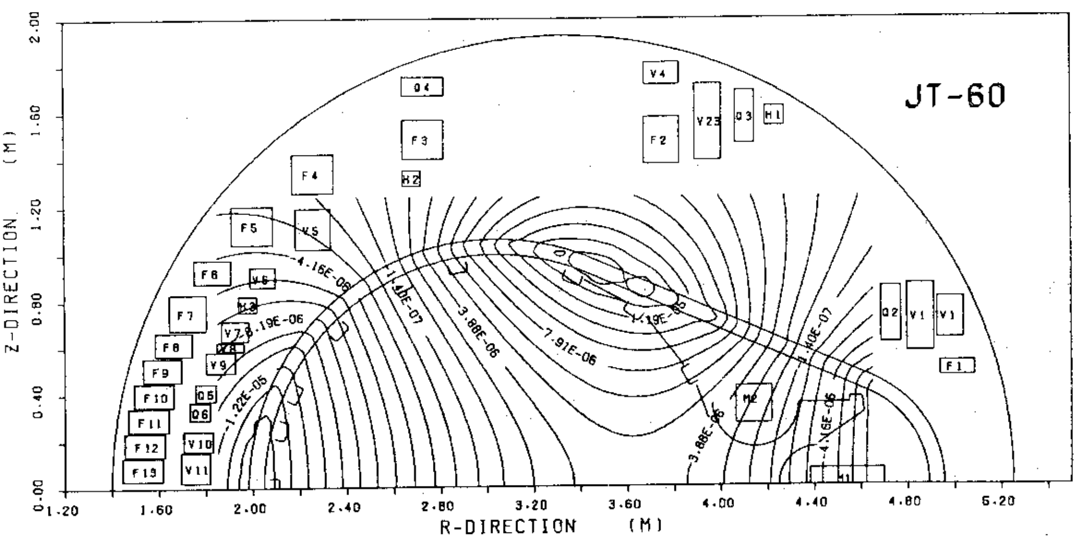

EDDY CURRENT FLUX DATA (MODE DATA NO.418)

5. Discussions

For the purpose of control analysis of plasma position and current including eddy current effect, the eddy current problem in JT-60 multi-torus system was solved by the modal expansion technique using the computer program EDDYMULT. The numerical parameters to represent a linear state-space model were compiled as one of indispensable basic data which will be used for the plasma control analysis and controller design including an eddy current effect.

These numerical computations of eddy current in JT-60 multi-torus system, which includes most of the main structural components of JT-60 tokamak, were performed with a high accuracy. In this report, the only oddy parity part of current potential with respect to an equatorial plane of torus geometry was considered and the radial expansive mode of plasma was discussed to represent a linear state-space model of tokamak control problem assuming an ideally symmetric arrangement of JT-60 device structure with respect to an equatorial plane. In this case of symmetric arrangement of tokamak device, one can discuss separately the control problems of radial expansive mode and vertical displacement mode since the both are ideally decoupled with each other. On the contrary, when the tokamak device is assembled asymmetrically with respect to an equatorial plane, the plasma radial expansive mode couples with the vertical displacement mode through eddy current effects and vice versa. The even parity part of current potential, which couples the plasma vertical displacement mode, is planned to be shown in the future report. Particularly, the control analysis of vertical displacement mode is important rather than that of radial expansive mode, as is well known in the usual control study of high-β_p plasma position.

We assumed that plasma current distribution is time-invariant and neglected the deformation of plasma cross-sectional shape, however, which are both essential in the practical control study in tokamak experiments. To introduce these dynamic behaviour into plasma control analysis, the additional linear parameters must be evaluated using a plasma equilibrium function instead of plasma function given by Eq. (12) in this report.

Our final purpose is to solve a plasma control problem including eddy current effects in tokamaks by means of a state-space approach. We will have to determine the feedback gain matrix using the optimal control theory or the pole-asignment technique and design the optimal state observer for the unmeasurable state variables. The optimal preprogram functions of input variables are also necessary in tokamak experiments. However, the linear control model given by Eq. (19) includes a great number of eddy current mode, therefore, the order reduction of a linear state equation including the eddy current effect is a key problem to carry out these control study successfully. To solve this problem, two methods of model order reduction using a singular value decomposition and a singular perturbation technique will be useful and the intensive investigation is now under way.[7]

Acknowledgment

The authors are grateful to Drs. H. Yoshida, S. Seki and H. Ninomiya for their useful advice and fruitful discussion. It is a pleasure to thank Dr. T. Takeda for his permission to use the graphic routine ARGUS for the purpose of illustration of magnetic structures. They also wish to thank Drs. T. Iijima and M. Ohta for the continuous encouragement.

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[1] Kameari, A., Aikawa, H., Ninomiya H. and Suzuki, Y.; JAERI-M 6468 (1976).

[2] Suzuki, Y., Ninomiya, H., Ogata, A., Kameari, A. and Aikawa, H.; J.J.A.P., Vol. 16, No. 12 (1977) pp. 2237/2244.

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[6] Seki, S., Momota, H. and Itatani, R.; J.J.A.P., Vol. 36, No. 6 (1974) pp. 1667/1673.

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Acknowledgment

The authors are grateful to Drs. H. Yoshida, S. Seki and H. Ninomiya for their useful advice and fruitful discussion. It is a pleasure to thank Dr. T. Takeda for his permission to use the graphic routine ARGUS for the purpose of illustration of magnetic structures. They also wish to thank Drs. T. Iijima and M. Ohta for the continuous encouragement.

References

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[7] Nakamura, Y., Kurihara, K. and Yokomizo, H.; private communications.