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A computer program for evaluating the main
physical and technological parameters
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Summary

SYSTEMS is a program system for evaluating the main physical and technological parameters of fusion reactors. The current version should be regarded as a preliminary one. Further refinements and extensions will be provided in the future.

The first part of this report describes the calculation procedure and lists all formulas used. The second part is devoted to explaining the program structure and includes a series of remarks on the input and output operations.

A reference list of all output quantities as well as an input and an output sample are presented in the Appendix.

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1. Introduction

Evaluation of the main physical and technological parameters of a fusion reactor is not very complicated if based on rather simple relationships. From the technological point of view, such equations are in first approximation appropriate for obtaining the most interesting parameters with a sufficient degree of accuracy.

It depends on the amount of information desired whether such calculations are very time-consuming or not when performed by hand. In general, however, not only is a single set of parameters required, it is also necessary to investigate the dependence of a rather large series of quantities on special variations in the assumptions. In such cases the time required becomes rather long and as a consequence the calculations are very susceptible to errors. This is usually aggravated by the frequent need to convert the units of single variables.

To overcome these difficulties, a computer program affording a certain convenience in performing such calculations was developed. SYSTEMS is mainly a collection of formulas yielding the results in the most convenient units. The calculation procedure is straightforward without any iteration loops. Therefore, the computing time is very short. For this reason it was not found worthwhile to separate the program entries dependent on the variables to be changed; any change in any quantity causes the program to start at the very beginning and to run through the entire calculation part. Special output routines, however, permit the user to suppress unnecessary information.

2. Input requests

In writing a computer program for this purpose, it first has to be decided which quantities to start with. This decision depends mainly on the problems entailed. Because the objectives involved are, in general, not always the same,

the input parameter list of SYSTEMS cannot be optimum for all cases studied. A long period of experience with this program showed the following input list proved to be the most suitable:

nominal thermal power	P_N	[W]
total wall loading	P_W	[W/cm ²]
plasma aspect ratio	A_p	[-]
ratio of plasma and wall radius	y	[-]
ion temperature	T_i	[keV]
deviation from critical beta	f_β	[-]
coolant temperature rise	Δt_c	[C]
thickness of shield	s_S	[cm]
current density in super-		
conducting magnets	j	[A/cm ²]
number of single coils	n_C	[-]
specific costs of super-		
conducting material	c'	[DM/A kg cm]
safety margin (distance from		
Kruskal-limit)	q	[-]
deviation from theoretical		
plasma conductivity (see	f_λ	[-]
chapter 3.8)		

This set of parameters together with a more detailed description of the blanket and shield regions specified below enables the user to calculate a large set of further quantities of interest for both stellarator and tokamak-type reactors.

The choice of the nominal thermal power P_N and the total wall loading P_W as input quantities is a proper one from the reactor engineer's point of view. The safety margin q and the deviation from the theoretical plasma conductivity f_λ , which are actually only needed for tokamak reactor calculations, are like the aspect ratio A_p and the deviation from critical beta f_β , parameters which can be conceived as typical of a certain confinement scheme. The ion temperature T_i was chosen

as the only independent plasma parameter directly describing the reaction conditions. The specification of the coolant temperature rise Δt_c is not of too great importance and is restricted in the current version to the case of direct cooling by liquid lithium. The current density j in the magnet and the specific costs C' of the superconducting material are the only input parameters needed for calculating the magnets. The number of single coils n_C is needed for the decision on the topological feasibility.

This set of input parameters is completed by a more detailed description of the blanket and shield regions which is essentially intended to allow the program to produce some figures on the involved material inventories as well as some estimates of the power multiplication and neutron flux characteristics. The following quantities are needed to describe the blanket:

${}^6\text{Li}$ - breeding gain	T_6	[-]
${}^7\text{Li}$ - breeding gain	T_7	[-]
ratio of the total and primary		
14 MeV neutron flux	f_ϕ	[-]
ratio of 1st wall power density		
and total neutron flux	f_p	[J/cm]
mean blanket temperature	t_B	[C]
number of radial blanket regions	n_B	[-]

for each region:

absolute radial extent	s_n	[cm]
number of materials included	m_n	[-]

for each material:

material number code	$k_{n,m}$	[-]
material volume fraction	$\epsilon_{n,m}$	[-]

As opposed to the blanket region, in the current version of the program the shield region is described by geometrical and materials quantities alone:

number of radial shield regions n_S [-]

for each region:

relative radial extent s_n [-]

number of materials included m_n [-]

for each material:

material number code $k_{n,m}$ [-]

material volume fraction $\epsilon_{n,m}$ [-]

3. Calculation procedure and formulas used

In spite of the straightforward calculation procedure the entire program is subdivided into a number of subroutines in order to obtain a clear and understandable program structure.

3.1 The subroutine MAKEUP

This subroutine is for evaluating some fundamental quantities which can be directly derived from the input parameters and will be needed in almost all of the subsequent routines.

Depending on the reactor type to be considered, first the critical beta is evaluated. For the stellarator the equation given by GIBSON [1] is used:

$$\beta_{\text{crit}} = 0.015 A_p [-] \quad (1)$$

for tokamak-type reactors this value is defined according to SHAFRANOV [2] by

$$\beta_{\text{crit}} = \frac{1}{A_p^{3/2} \cdot q^2} [-] \quad (2)$$

The actual beta can then be obtained by

$$\beta = f_\beta \cdot \beta_{\text{crit}} \quad [-] \quad (3)$$

The total tritium breeding ratio

$$T = T_6 + T_7 \quad [-] \quad (4)$$

is defined for almost each blanket concept. This is not true, however, of the energy multiplication factor. Therefore, in first approximation the blanket energy gain is calculated with the following equation:

$$E_B = E_{\text{Fu}} + T_6 \cdot E_6 + T_7 \cdot E_7 \quad [\text{J}] \quad (5)$$

using the characteristic reaction energies of

$$E_{\text{Fu}} = 2.8 \cdot 10^{-12} \text{ J} \cong 17.6 \text{ MeV}$$

$$E_6 = 7.7 \cdot 10^{-13} \text{ J} \cong 4.8 \text{ MeV}$$

$$E_7 = -3.95 \cdot 10^{-13} \text{ J} \cong -2.5 \text{ MeV}$$

If the tritium breeding ratio is not defined, i.e. $T = 0$, then the well-known assumption long in use is introduced:

$$E_B = E_{\text{Fu}} + E_6 = 3.6 \cdot 10^{-12} \text{ J} \cong 22.4 \text{ MeV}$$

The energy multiplication factor E_B/E_{Fu} is then used to calculate the thermonuclear power produced in the plasma:

$$P_{\text{Fu}} = P_N \cdot \frac{E_{\text{Fu}}}{E_B} \quad [\text{W}] \quad (6)$$

With the nominal thermal power P_N and the total wall loading P_W the surface area of the first wall is calculated:

$$F_W = \frac{P_N}{P_W} \quad [\text{cm}^2] \quad (7)$$

This value, the aspect ratio, and the ratio of plasma and wall radius determine the geometrical parameters of the plasma:

plasma radius:

$$r_p = \sqrt{\frac{1}{4\pi^2} \cdot y \cdot F_w / A_p} \quad [\text{cm}] \quad (8)$$

torus radius:

$$R = A_p \cdot r_p \quad [\text{cm}] \quad (9)$$

plasma volume:

$$V_p = 19.74 \cdot A_p \cdot r_p^3 \quad [\text{cm}^3] \quad (10)$$

3.2 The subroutine PLASMA

In the subroutine PLASMA the most interesting plasma parameters are evaluated. In the current version of the program rectangular profiles for both the ion temperature and density are assumed. Furthermore, no difference between the ion and electron temperatures is made. These are, indeed, significant simplifications which will be eliminated in the next step of program refinement.

First the thermonuclear power density in the plasma is calculated from the total thermonuclear power and the plasma volume:

$$q_p = \frac{P_{Fu}}{V_p} \quad [\text{W/cm}^3] \quad (11)$$

With the fusion reaction energy gain the reaction rate, which is required to yield the indicated power density, is evaluated:

$$R_R = \frac{q_p}{E_{Fu}} \quad [\text{cm}^{-3} \text{ s}^{-1}] \quad (12)$$

This value yields the required ion density:

$$n_i = 2 \cdot \sqrt{\frac{R}{\zeta_{SV}}} \quad [\text{cm}^{-3}] \quad (13)$$

The value of the plasma reactivity ζ_{SV} is supplied by a function subprogram depending on the ion temperature. This subprogram, called SV, evaluates the ζ_{SV} values by interpolation within a table presented by MILLS [3].

From the ion density and temperature it is possible to calculate the bremsstrahlung power density of the plasma using the formula given by, for instance, CARRUTHERS et al [4]:

$$q_{br} = 5.35 \cdot 10^{-31} \cdot n_i^2 \cdot \sqrt{T_i} \quad [\text{W/cm}^3] \quad (14)$$

This value is used to determine both the total bremsstrahlung power

$$P_{br} = q_{br} \cdot V_p \quad [\text{W}] \quad (15)$$

and the contribution of the bremsstrahlung power to the wall loading

$$P_{Wbr} = P_{br} / F_w \quad [\text{W/cm}^2] \quad (16)$$

The plasma power balance, which was likewise stated by CARRUTHERS et al.[4], yields the product of the ion density and confinement time:

$$n_i \tau = \frac{3 n_i^2 \cdot T_i \cdot E'_p}{q_p \cdot E_{Fu}} - q_{br} \quad [\text{s/cm}^3] \quad (17)$$

In this equation E'_p is a conversion factor

$$E'_p = 1.602 \cdot 10^{-16} \quad \text{J/keV}$$

E_α is the energy of the α -particles produced in the fusion reactions:

$$E_\alpha = 5.64 \cdot 10^{-13} \text{ J} \cong 3.52 \text{ MeV}$$

Equation (17) therefore describes the plasma energy balance in the steady state if the plasma heating is only accomplished by internal energy exchange.

The required confinement time can be evaluated using eq. (17) and the ion density defined by eq. (13):

$$\tau = \frac{n_i \tau}{n_i} \quad [\text{s}] \quad (18)$$

The fuel burn-up is calculated by a formula also given by CARRUTHERS et al.[4]:

$$f_b = \frac{1}{2} n_i \tau \cdot \langle \sigma v \rangle \quad [-] \quad (19)$$

One of the most important quantities evaluated by this routine is the magnetic field strength on the torus axis.

From the definition of β ,

$$\beta = \frac{2 n_i k T}{B_0^2 / 2 \mu_0}$$

an equation was derived yielding B_0 directly in units of kilogauss:

$$B_0 = 2.84 \cdot 10^{-7} \sqrt{\frac{n_i T_i}{\beta}} \quad [\text{kG}] \quad (20)$$

From the plasma parameters evaluated up to now some further interesting figures can be calculated.

The total number of ions present in the plasma:

$$Z_i = n_i \cdot V_p \quad [-] \quad (21)$$

The average burnup rate:

$$z_b = f_b \cdot z_i / \tau \quad [s^{-1}] \quad (22)$$

The ion injection rate in the case of steady-state operation:

$$z_{in} = z_i / \tau \quad [s^{-1}] \quad (23)$$

The ion extraction rate in the case of steady-state operation:

$$z_{ex} = (1 - f_b) \cdot z_{in} + \frac{1}{2} z_b \quad [s^{-1}] \quad (24)$$

With regard to energy balance considerations it is important to know the total plasma energy:

$$E_p = 3 \cdot E_p^! \cdot T_i \cdot n_i \cdot V_p \quad [J] \quad (25)$$

From the engineering point of view the power carried by the ions to the divertor device is of interest:

$$P_{Div} = z_{ex} \cdot E_p / z_i \quad [W] \quad (26)$$

This formula, however, is only valid on the assumption that no energy is transported to the wall.

To complete the set of plasma parameters, finally, some diffusion parameters are evaluated by this subroutine. The classical diffusion time is determined by the equation

$$\tau_{c1} = 1.42857 \cdot 10^{10} \cdot B_o^2 \cdot r_p^2 \cdot \sqrt{T_i / n_i} \quad [s] \quad (27)$$

which was derived from an expression given by ARZIMOWITSCH [5].

Additionally the Bohm diffusion time is calculated:

$$\tau_{Bo} = 2.766 \cdot 10^{-8} \cdot r_p^2 \cdot B_o / (y^2 \cdot T_i) \quad [s] \quad (28)$$

This equation results from the expression given by ROSE [6] using

$$\tau_{Bo} = \frac{16 \cdot \lambda^2 \cdot e \cdot B_0}{kT}$$

given by ROSE [6] using

$$\lambda = r_W/2.405$$

for determining the mean free path of the ions. Both the classical and the Bohm diffusion time are subsequently related to the confinement time to yield

$$\alpha_{cl} = \tau/\tau_{cl} \quad (29)$$

$$\alpha_{Bo} = \tau/\tau_{Bo} \quad (30)$$

3.3 The subroutine WALL

The third subroutine in the calculation part of the program system performs the evaluation of a series of parameters either depending on or important for the first wall.

After the inner wall radius

$$r_W = r_p/y \quad [\text{cm}] \quad (31)$$

is fixed, first the 14 MeV neutron current impinging on the first wall is calculated from the reaction rate, the plasma volume, and the first wall surface area:

$$\phi_{14} = R_R \cdot V_p / F_W \quad [\text{cm}^{-2} \text{ s}^{-1}] \quad (32)$$

From this figure the total neutron flux at the first wall

$$\phi_{tot} = f_\phi \cdot \phi_{14} \quad [\text{cm}^{-2} \text{ s}^{-1}] \quad (33)$$

is evaluated using the factor f_ϕ specified in the blanket input list; subsequently, the 1-year neutron dose:

$$D_{1a} = 3.1536 \cdot 10^7 \cdot \phi_{tot} \quad [\text{cm}^{-2}] \quad (34)$$

and the neutron wall loading

$$P_{W\phi} = \phi_{14} \cdot E_n \quad [\text{w/cm}^2] \quad (35)$$

are calculated, where E_n is the primary neutron energy:

$$E_n = 2.2524 \cdot 10^{-12} \text{ J} \cong 14.08 \text{ MeV.}$$

From the thickness of the first blanket zone the outer wall radius

$$r_{W2} = r_W + s_1 \quad [\text{cm}] \quad (36)$$

and the total wall volume

$$V_W = 19.739 \cdot R \cdot (r_{W2}^2 - r_W^2) \quad [\text{cm}^3] \quad (37)$$

are specified and then the weight of the total first wall is calculated

$$W_W = V_W \cdot \rho_W \quad [\text{g}] \quad (38)$$

The density ρ_W of the wall material is thereby supplied by a subprogram named PROP which contains all material properties needed in the whole program system.

The remaining calculations of the subroutine WALL are concerned with certain safety considerations. In the event of a malfunctioning of the divertor device the entire plasma energy could be dissipated on the first wall. The wall would then be exposed to an adiabatic temperature rise which is determined by its heat capacity:

$$\Delta t_W = E_p / (W_W \cdot c_W) \quad [\text{C}] \quad (39)$$

The same event could, if it happens within a very short time, lead to the vaporization of a certain amount of wall material. The amount of vaporized material can be determined in first approximation by

$$\Delta W_V = \frac{E_P}{c_W(t_V - t_B) + \Delta i_s + \Delta i_v} \quad [9] \quad (40)$$

In this equation t_V , Δi_v , and Δi_s denote the temperature and the heat of vaporization and the heat of fusion. All these specific material properties are supplied by the subprogram PROP, as is the specific heat c_W .

From the amount of material evaporated it is possible to calculate the material volume evaporated

$$\Delta V_V = \Delta W_V / \rho_W \quad [\text{cm}^3] \quad (41)$$

and hence the loss of wall thickness

$$\Delta s_W = \Delta V_V / F_W \quad [\text{cm}] \quad (42)$$

Actually, these final results are only first-order estimations, because it is assumed 1) that the specific heat of the wall material is the same in the solid and the liquid state, and 2) that the energy deposition is uniform on the entire wall.

3.4 The subroutine BLANK

As the next step, the subroutine BLANK calculates the materials inventories and some power parameters of the blanket. In the current version this subroutine is, however, restricted to a rather narrow field of blanket concepts.

From the specifications of the thickness and the material compositions of the single blanket regions first the total blanket volume

$$V_B = 19.739 \cdot R \sum_{n=1}^{n_B} (r_{n+1}^2 - r_n^2) \quad [\text{cm}^3] \quad (43)$$

is evaluated with

$$r_{n+1} = r_n + s_n$$

followed by a similar calculation of the total blanket weight

$$W_B = 19.739 \cdot R \cdot \sum_{n=1}^{n_B} (r_{n+1}^2 - r_n^2) \cdot \rho_n \quad [g] \quad (44)$$

using a mean region density ρ_n resulting from the material composition

$$\rho_n = \sum_{m=1}^{m_n} \epsilon_{n,m} \cdot \rho_{n,m}$$

In the current version the program can handle up to 10 different regions with up to 5 different materials in each of them.

To complete the set of bulk blanket parameters, the total blanket thickness

$$s_B = r_W + \sum_{n=1}^{n_B} s_n \quad [cm] \quad (45)$$

and the outer blanket radius, which equals the inner shielding radius, are evaluated:

$$r_S = r_W + s_B \quad [cm] \quad (46)$$

During the evaluation of the total volume and weight of the blanket the single contributions of each material and region are stored. Therefore, the program is able to scan all these figures once more to extract the specific contributions of distinct materials. This scanning is performed in the current version, however, only for the coolant and the reflector material to yield the

$$\text{coolant volume} \quad V_c \quad [\text{g}] \quad (47)$$

$$\text{coolant weight} \quad W_c \quad [\text{g}] \quad (48)$$

$$\text{reflector weight} \quad W_r \quad [\text{g}] \quad (49)$$

Subsequently, all weights which are neither coolant nor reflector are said to be

$$\text{structure weight} \quad W_s \quad [\text{g}] \quad (50)$$

The calculation of power and cooling parameters starts with the total blanket power:

$$P_B = P_{br} + P_N \frac{E_n + T_6 \cdot E_6 + T_7 \cdot E_7}{E_B} [W] \quad (51)$$

According to this equation the blanket power is the sum of the bremsstrahlung power and that contribution of the nominal thermal power which goes with the neutrons. From this total power the mean blanket power density

$$q_B = P_B / V_B \quad [\text{W/cm}^3] \quad (52)$$

and the mean power density in the coolant as a more or less fictitious quantity

$$q_c = (P_B - P_{br}) / V_c \quad [\text{W/cm}^3] \quad (53)$$

are evaluated. The total blanket power must be removed by a coolant mass flow rate given by

$$\dot{m}_c = P_B / (c_c \cdot \Delta t_c) \quad [\text{g/s}] \quad (54)$$

which corresponds to a coolant volume flow rate of

$$\dot{V}_c = \dot{m}_c / \beta_c \quad [\text{cm}^3/\text{s}] \quad (55)$$

These calculations are at present restricted to lithium cooling systems, the specific heat and the density of the coolant again being taken from the subprogram PROP.

The blanket calculations are finished with the determination of the real nuclear wall loading

$$P_{Wnu} = f_p \cdot \emptyset_{tot} \cdot s_W \quad [W/cm^2] \quad (56)$$

and the real wall loading

$$P_{Wth} = P_{Wnu} + P_{Wbr} \quad [W/cm^2] \quad (57)$$

being the sum of the nuclear and the bremsstahlung wall loading.

3.5 The subroutine MAGNET

One of the most significant parts of the program system is the subroutine MAGNET, because it yields a series of parameters for the coil layout and for restrictions concerning the topological feasibility of the reactor.

With the shield thickness and the inner shield radius first the inner coil radius

$$r_{Ci} = r_S + s_S \quad [cm] \quad (58)$$

and the coil aspect ratio

$$A_C = R/r_{Ci} \quad [-] \quad (59)$$

are evaluated. This aspect ratio and the field strength on the axis determine the maximum field strength at the coil

surface as one of the most important technological parameters:

$$B_{\max} = B_0 \cdot A_C / (A_C - 1) \quad [\text{kG}] \quad (60)$$

With the overall coil current density specified by the input list the total coil cross-section and, according to the number of coils indicated, that of a single coil are calculated:

$$\begin{aligned} F_{C\text{tot}} &= 2\pi R \cdot B_0 / j \cdot \mu_0 \quad [\text{cm}^2] \\ &= 5000 R \cdot B_0 / j \end{aligned} \quad (61)$$

$$F_C = F_{C\text{tot}} / n_C \quad [\text{cm}^2] \quad (62)$$

Assuming a square cross-section of the coil as a compromise between manufacturing and cooling requirements the edge length is given by

$$b_C = \sqrt{F_C} \quad [\text{cm}] \quad (63)$$

and therefore the outer coil radius by

$$r_{Ca} = r_{Ci} + b_C \quad [\text{cm}] \quad (64)$$

To get a feeling for the material inventory involved and for the problem of heat influx from the environment to the superconducting coil the volumes and surface areas of both a single coil and all coils together are of interest:

$$V_C = \pi \cdot b_C (r_{Ca}^2 - r_{Ci}^2) \quad [\text{cm}^3] \quad (65)$$

$$V_{C\text{tot}} = n_C \cdot V_C \quad [\text{cm}^3] \quad (66)$$

$$O_C = 2 V_C / b_C + 2\pi (r_{Ci} + r_{Ca}) \cdot b_C \quad [\text{cm}^2] \quad (67)$$

$$O_{C\text{tot}} = n_C \cdot O_C \quad [\text{cm}^2] \quad (68)$$

The total field volume

$$V_F = 19.739 \cdot R \cdot r_{Ci}^2 \quad [\text{cm}^3] \quad (69)$$

the total field energy

$$E_F = 3.98 \cdot 10^{-2} \cdot B_o^2 \cdot V_F \quad [J] \quad (70)$$

and the field energy density

$$e_F = E_F / V_F \quad [J/cm^3] \quad (71)$$

are, furthermore, significant quantities for comparing different systems.

With the mean coil radius

$$r_{Cm} = r_{Ci} + 0.5 \cdot b_C \quad [cm] \quad (72)$$

it is possible to evaluate a quantity which, according to SCHMITTER [7], is a measure of the superconducting material inventory.

$$M_s = 15.7 \cdot 10^3 \cdot R \cdot r_{Cm} \cdot B_o^2 \left(1 + \frac{A_C}{A_C - 1}\right) \quad [A \cdot kG \cdot cm] \quad (73)$$

The specific costs of superconductors as specified in the input list enables the program to calculate the magnet's contribution to the installation costs:

$$C_{spec} = C' \cdot M_s / P_N \quad [DM/W] \quad (74)$$

In order to determine the topological feasibility of the reactor evaluated by this program, the innermost circumference of the torus

$$u_{Ca} = 2\pi (R - r_{Ca}) \quad [cm] \quad (75)$$

is compared with the total axial extension of the coil

$$b_{Ctot} = n_C \cdot b_C \quad [cm] \quad (76)$$

The ratio of these two quantities

$$\varphi = b_{C\text{tot}} / u_{Ca} \quad [-] \quad (77)$$

is called the "cover factor". Topological feasibility is assured if this factor is

$$\varphi \leq 1$$

A further geometrical restriction at least for Tokamak reactors using an iron core is determined by the free space available around the major torus axis. From the inner torus radius

$$R_i = R - r_{Ca} \quad [\text{cm}] \quad (78)$$

this free space is calculated:

$$A_i = \pi R_i^2 \quad [\text{cm}^2] \quad (79)$$

Also the outer torus radius

$$R_a = R + r_{Ca} \quad [\text{cm}] \quad (80)$$

is evaluated to get information about the absolute size of the reactor.

After calculation of the reactor's overall power density

$$q_{\text{tot}} = P_N / (V_F + V_{C\text{tot}}) \quad [\text{W/cm}^3] \quad (81)$$

as the last parameter of the magnet the average mechanical stress in the toroidal magnet coils is determined according to KNOBLOCH [8]:

$$\sigma_C = 0.398 \cdot B_o^2 \cdot r_{Ci} / b_C \quad [\text{N/cm}^2] \quad (82)$$

3.6 The subroutine SHIELD

In a similar way to BLANK the subroutine SHIELD calculates the

$$\text{total volume } V_S \quad [\text{cm}^3] \quad (83)$$

$$\text{total weight } W_S \quad [\text{g}] \quad (84)$$

of the magnet shield. In the current version of the program this subroutine is restricted to a narrow range of variations in the material composition. In the course of the calculation distinct figures for the

$$\text{weight of lead } W_{\text{pb}} \quad [\text{g}] \quad (85)$$

$$\text{weight of water } W_{\text{H}_2\text{O}} \quad [\text{g}] \quad (86)$$

$$\text{weight of graphite } W_{\text{Gra}} \quad [\text{g}] \quad (87)$$

$$\text{weight of structure } W_{\text{str}} \quad [\text{g}] \quad (88)$$

are extracted. The total shield weight is finally added to the total blanket weight to obtain approximately the whole reactor weight except that of the magnet coils.

$$W_{\text{tot}} = W_B + W_S \quad [\text{g}] \quad (89)$$

3.7 The subroutine TOKAM

A special subroutine has been added to the program system for evaluating some characteristic quantities of Tokamak fusion reactors. For investigating reactors of the Stellarator type this subroutine is skipped. Most of the following quantities are evaluated using equations formulated by KNOBLOCH [8].

The plasma current

$$I_P = 5000 \cdot \frac{B_0 \cdot r_P}{q \cdot A_P} \quad [\text{A}] \quad (90)$$

and the plasma inductance

$$L_P = 1.257 \cdot 10^{-8} \cdot R (0.25 + \log A_P) [\Omega s] \quad (91)$$

are needed to determine the magnetic energy of the poloidal field:

$$E_{pol} = 0.5 \cdot L_P \cdot I_P^2 [J] \quad (92)$$

The poloidal field strength

$$B_{pol} = B_0 / q \cdot A_P [kG] \quad (93)$$

is used to calculate the poloidal β :

$$\beta_{pol} = 8.05 \cdot 10^{-14} \cdot n_i \cdot T_i / B_{pol}^2 [-] \quad (94)$$

and the ratio of the poloidal and axial β :

$$\beta_{pol}/\beta_{ax} = \beta_{pol}/\beta [-] \quad (95)$$

The value of β_{pol} gained by this formula is consistent with the assumption

$$\beta_{pol} = \sqrt{A_P}$$

which is implicitly used in eq. (2).

The plasma conductivity

$$\lambda_P = f_\lambda \cdot \lambda_{Spitzer} (T_i, n_i) [\Omega^{-1} cm^{-1}] \quad (96)$$

is calculated from the theoretical conductivity defined by SPITZER [9] and a factor f_λ permitting the investigation of deviations from ideal plasma behaviour. The theoretical conductivity is supplied by the subprogram SPITZ.

With the plasma conductivity it is possible to calculate the plasma resistance

$$R_P = 2 \cdot A_P / (r_P \cdot \lambda_P) \quad [\Omega] \quad (97)$$

and together with the inductance the electromagnetic time constant

$$\tau_e = L_P / R_P \quad [s] \quad (98)$$

This quantity, in turn, permits the evaluation of the flat-top energy

$$E_{FT} = \tau_e \cdot I_P^2 \cdot R_P \quad [J] \quad (99)$$

a quantity most valuable for overall energetic considerations. This formula results from economical considerations [8].

Finally, the necessary iron core cross-section and radius are determined by making use of the assumption that the flux swing in the core can be made $\Delta B = 50$ kG. With this value the cross-section and the radius can be calculated by using the equations

$$A_{core} = 2000 \cdot L_P \cdot I_P \quad [\text{cm}^2] \quad (100)$$

$$r_{core} = 0.654 \sqrt{A_{core}} \quad [\text{cm}] \quad (101)$$

The comparison of these values with those of A_i in eq. (79) and R_i in eq. (78) respectively again determines the geometrical feasibility in the case of Tokamak reactors.

3.8 Further subroutines

As indicated in the preceding sections the program system makes use of three further subprograms within its calculation part.

The first one is the function subprogram SV, which calculates the reactivity of a D-T plasma $\langle \sigma v \rangle$ as a function of the ion temperature.

The second subprogram is the subroutine PROP. Depending on the material number code and the operation temperature, it supplies the density, the specific heat, the thermal conductivity, the heat of fusion and evaporation, the melting point and the vaporization temperature. In the current version this subroutine is not very accurate because for most of the materials a temperature dependence has not been introduced. For the present purpose of this program system, however, such a refinement is not necessary. At present time data are available for the following materials: vanadium, niobium, molybdenum, lithium, graphite, lead, water, and iron. A refinement of this data library and an extension to other materials is suggested, however, with regard to a number of other applications of this program.

The third subprogram used in the calculation part is the function program SPITZ, which calculates the ideal plasma conductivity as a function of the ion temperature and density according to the equation presented by SPITZER [9] for the specific resistivity

$$\gamma_p = 6.53 \cdot 10^3 \cdot \frac{\ln \Lambda}{T^{3/2}} \quad [\Omega \text{cm}]$$

with

$$\Lambda = \frac{3}{2} \cdot \frac{1}{Z \cdot Z_1 \cdot e^3} \left(\frac{(kT)^3}{\pi n_e} \right)^{1/2} \cdot \left(\frac{4.2 \cdot 10^5}{T} \right)^{1/2}$$

When applied to the problem of a D-T plasma, these formulae result in the expression

$$\lambda_p = \frac{T_i^{1.5}}{6.53 \cdot 10^3 \ln (6.2 \cdot 10^{13} \cdot T_i / \sqrt{n_i})} \quad (102)$$

4. Program structure and organization

4.1 Program structure requirements

Whereas the preceding section was devoted to explaining the calculation part of the program system, this section deals with the program structure and the organization of the input and output operations.

Since the number of input quantities is relatively large and it is desired to vary all of them arbitrarily, a special program structure was applied. This structure should meet the following requirements:

- 1) It should allow simple input in general and simple variation of special input parameters.
- 2) It should permit the possibility of either obtaining comprehensive output of all quantities evaluated or selecting special quantities for output.
- 3) It should allow ready graphical display of selected output quantities.
- 4) It should avoid large storage requirements for both input parameters and calculated quantities.
- 5) It should afford maximum clearness in the formulation of statements, thus preserving the possibility of easily extending the calculation part whenever necessary.
- 6) It should permit easy and reliable handling of the entire program system.

4.2 Input and output routines

To meet these requirements a strict separation between the calculation part and the control part was introduced. As in the case of the calculation part, the control part of the program is also subdivided into a number of subroutines:

INPUT accomplishes the input operations for all quantities needed for both the calculation and control operations. It is only used, however, at the start of the program and therefore the quantities specified here are only related to the initial reactor model to be evaluated.

CHANGE, in contrast, is used to change any of the input parameters for a subsequent run. If there are no more requests for subsequent alterations or if the total output storage is filled up the program control is switched to the subroutine OUTPUT.

OUTPUT performs the output operations specified by the initial input. There is the possibility of choosing between getting the entire information (in the current version a total of 120 different quantities) or only a selected part of it. If there is a request for graphical display, this routine keeps all information in a special array until, at the end of the program run, it is required by the subroutine GRAPH.

GRAPH accomplishes the graphical display. The program is able to provide up to 10 diagrams, each showing the dependence of one single output quantity on the same input parameter. If a graphical display is wanted by the user, some special input restrictions have, however, to be observed:

- 1) There is allowance for changing only one of the input quantities up to a total of 10 times.
- 2) It is permissible to change afterwards a second input quantity. This must be followed by a variation of the first input quantity according to the first remark.

- 3) This procedure may be performed up to 10 times.
Before changing the second input quantity,
however, an empty input has to be provided.

This procedure results in the graphical display showing the dependence of the desired output quantity on the first varying input quantity with the second varying input quantity as a parameter. The input restrictions specified above are not valid if no graphical display is requested.

4.3 Special routines for graphical display

Since the output quantities to be shown in the form of diagrams, in general, vary widely in their orders of magnitude, special means had to be provided for convenient performance of the plot output. Therefore, for this purpose a plot subroutine developed by the author just for this kind of application is used.

UNIPLT is a universal plot program performing an optimum plot output with a minimum of programming effort. It is adapted to the special features of the IBM 360/91 operating system and the facilities available at the computer of IPP. It makes use of the basic plotting routines implemented in this machine, but offers at the same time a great deal of comfort to the user. The most remarkable features of this subroutine are:

- 1) It is possible to show up to 10 curves on a single sheet.
- 2) The program automatically chooses an optimum scale on both abscissa and ordinate.
- 3) Both axes are provided with a scale subdivision which can be optionally extended to an entire grid.

- 4) The scale marks of both axes are labeled with the actual figures of the data plotted on each sheet.
- 5) To distinguish the single lines of one sheet, they are automatically marked by figures.
- 6) Provision is made for an additional text at the bottom of each sheet which can be specified by the user.
- 7) An option is introduced for the choice of the order of interpolation. Automatic interpolation is performed if there are only few data available.

This plot routine, which has been tested in a number of other applications, needs three further subroutines named CHARAC, SORT, and INPOL. A detailed description of all of these four subroutines is, however, beyond the scope of this report.

4.4 Program connections

Figure 1 presents a simple flow diagram of the program system showing once more the connections between the single subroutines. All these subprograms are incorporated in a short main program.

The program starts by reading the input information by means of the subroutine INPUT. Then the calculation part is entered using successively the routines MAKEUP, PLASMA, WALL, BLANK, MAGNET, and SHIELD and the routines SV and PROP called by them. If Tokamak type reactors are to be handled, the calculation part is extended to the subroutine TOKAM, otherwise it is skipped. Now control is transferred to the subroutine CHANGE, which at first saves all data evaluated before requesting an alteration. If a change in any one of the input parameters is wanted, it reads the new figure from the input unit and replaces the old by the new information. Program control is then trans-

ferred back to the beginning of the calculation part. If there are no more requests or if the output storage is filled up, control is transferred to the subroutine OUTPUT, which prints all information required. If there are more outstanding requests, control is again transferred to the beginning of the calculation part, changing that information meanwhile kept by CHANGE. If all calculations have been done and graphical display was requested, control is finally transferred to the subroutine GRAPH.

To perform this operating sequence in an easy way without losing clarity in the statement formulation, two special methods of FORTRAN programming have been applied.

All constants and variables involved in the calculation procedure are transferred from one subprogram to another by use of COMMON statements. All variables needed for control operations, however, are transferred by argument lists. In this way a clear separation of calculation and control can be guaranteed.

The initial input routine and all calculation routines call all variables involved in the calculation procedure by name. This ensures clear formulation of the arithmetic statements not being subjected to a great amount of errors. The entire field of variables is referred to by the subroutine CHANGE by means of a one-dimensional array, thus permitting a direct change of an input parameter without calling it by name. The same sequence within the array is provided for the three-dimensional output array, which is also transferred by a COMMON statement between the routines CHANGE, OUTPUT, and GRAPH. To have the names of the variables available in the output routine, too, they are stored in the equivalent order in a DATA statement.

Up to now experience with this program system has shown that this kind of structure is suitable for the purpose of introducing changes and extensions without too much programming effort.

5. Final remarks and conclusions

The program system SYSTEMS described in this report is a first step in the direction of developing a computer program for fusion reactor system studies. In its current version it has already proved its usefulness on the one hand and its easy practicability on the other hand. The structure chosen for this program seems to meet the requirements very well. It is suitable for introducing program changes and extensions in a rather easy way.

Changes and extensions both for refinement and for the purpose of getting more information are still necessary and are to be made in the near future. It is hoped by the author that the work already done might be a good starting point for more detailed fusion reactor systems analyses.

6. Acknowledgements

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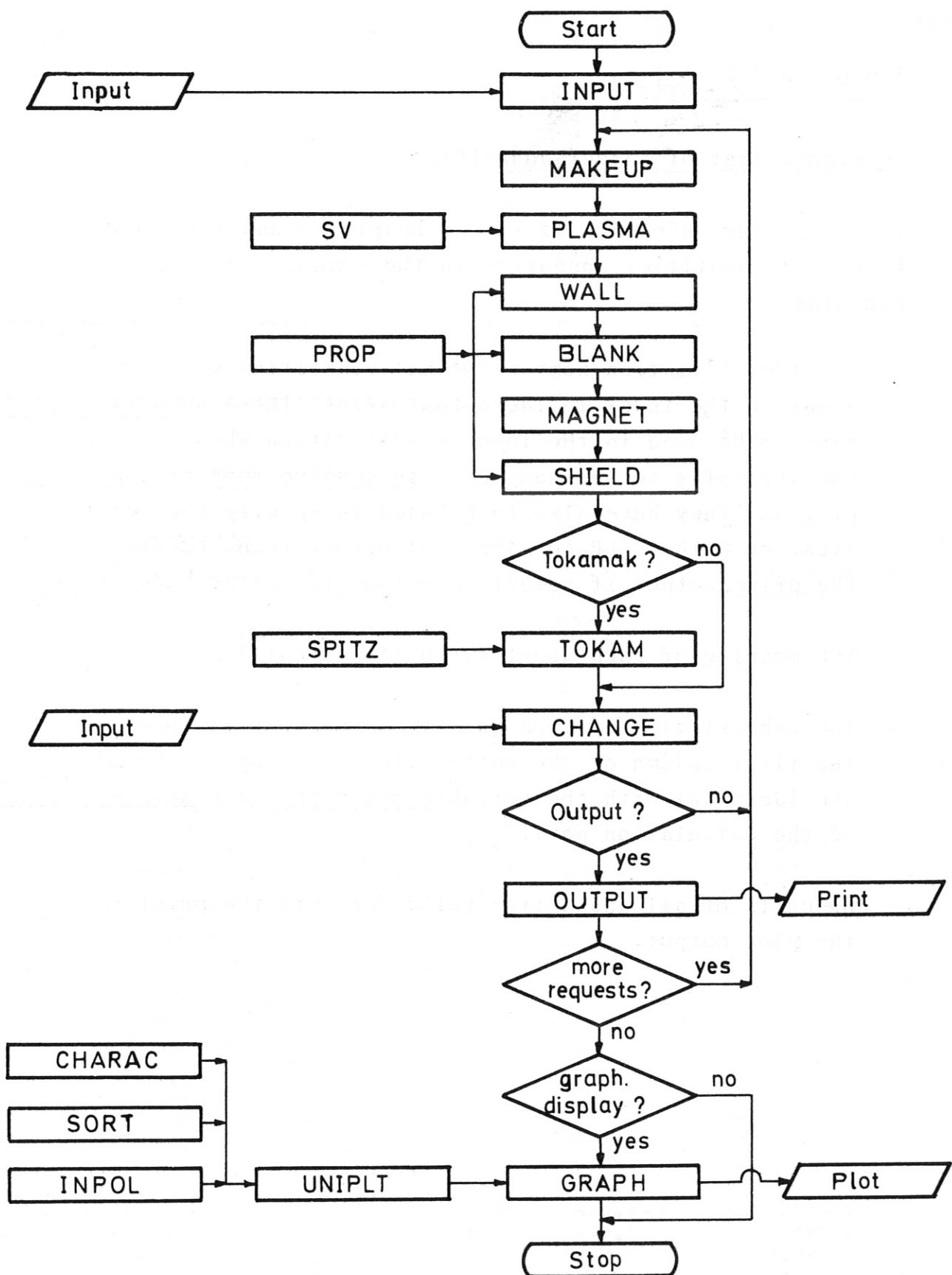


Fig. 1: Flow Diagram of "SYSTEMS"

Appendix I

Reference list of output quantities

The following reference list is a helpful means for identifying all quantities appearing in the output list. The list contains:

- the identification numbers of all quantities which are equal to the index in the output array. These numbers have to be used in the input specification when defining the variables to be changed in successive runs of the program. They have also to be used to specify the identification numbers LP for the plot output resp. LR for the print output if selective output is wanted ($LPRT \neq 0$).
- the meaning of each quantity in the output list.
- the abbreviation of each quantity. These names appear in the first column of the output list (see app. III) and are identical with the variable names in the routines of the calculation part.
- the units of all quantities valid for both the print and the plot output.

NR. QUANTITY	ABBR.	DIMENSION	IN OUTPUT	10
		PRINT	PLOT	20
1. NOMINAL THERMAL POWER	PNOM	W	MW	30
2. FICTIONAL WALL LOADING.....	PWF	W/CM2	W/CM2	40
3. PLASMA ASPECT RATIO.....	ASPP	-	-	50
4. PLASMA/WALL RADIUS.....	YPW	-	-	60
5. ION TEMPERATURE.....	TI	KEV	KEV	70
6. PLASMA/MAGNETIC FIELD PRESSURE..	BETA	-	-	80
7. DEVIATION FROM CRITICAL BETA....	DBCR	-	-	90
8. LITHIUM-6 BREEDING GAIN.....	BT6	-	-	100
9. LITHIUM-7 BREEDING GAIN.....	BT7	-	-	110
10. TOTAL BREEDING GAIN.....	BT	-	-	120
11. SAFETY MARGIN.....	Q	-	-	130
12. CRITICAL BETA.....	BECR	-	-	140
13. TOTAL FUSION POWER.....	PFU	W	MW	150
14. FIRST WALL SURFACE AREA.....	FW	CM2	M2	160
15. PLASMA RADIUS.....	RP	CM	CM	170
16. MAIN TORUS RADIUS.....	R	CM	CM	180
17. PLASMA VOLUME.....	VP	CM3	M3	190
18. PLASMA POWER DENSITY.....	QP	W/CM3	W/CM3	200
19. FUSION REACTION RATE.....	RR	CM-3*S-1	E 12*CM-3*S-1	210
20. FUSION REACTION CROSS SECTION...	SIGV	CM3/S	E-16*CM3/S	220
21. ION DENSITY.....	XNI	CM-3	E 14*CM-3	230
22. BREMSSTRAHLUNG POWER DENSITY....	QB	W/CM3	W/CM3	240
23. TOTAL BREMSSTRAHLUNG POWER.....	PBR	W	MW	250
24. BREMSSTRAHLUNG WALL LOADING.....	PWBR	W/CM2	W/CM2	260
25. CONFINEMENT PARAMETER N*TAU.....	XNT	S/CM3	E 14*S/CM3	270
26. CONFINEMENT TIME.....	TAU	S	S	280
27. FUEL BURNUP.....	FB	-	-	290
28. MAGNETIC FIELD STRENGTH.....	BO	KGAUSS	KGAUSS	300
29. TOTAL NUMBER OF IONS.....	ZION	-	E 22*-	310
30. BURNUP RATE.....	ZARB	S-1	E 22*S-1	320
31. ION INJECTION RATE.....	ZIN	S-1	E 22*S-1	330
32. ION EXTRACTION RATE.....	ZEX	S-1	F 22*S-1	340
33. PLASMA ENERGY.....	ENPL	J	MJ	350
34. DIVERTOR POWER.....	PDIV	W	MW	360
35. CLASSICAL DIFFUSION TIME.....	TCL	S	S	370
36. BOHM DIFFUSION TIME.....	TBO	S	S	380
37. CONFINEMENT/CLASSICAL DIFF.TIME.	ALCL	-	-	390
38. CONFINEMENT/BOHM DIFF.TIME.....	ALBO	-	-	400
39. TOTAL/PRIMARY NEUTRON FLUX.....	FXM	-	-	410
40. FIRST WALL THICKNESS.....	SW	CM	CM	420
41. FIRST WALL MATERIAL NUMBER.....	XMAT	-	-	430
42. FIRST WALL TEMPERATURE.....	TMW	C	C	440
43. FIRST WALL INNER RADIUS.....	RW1	CM	CM	450
44. FIRST WALL OUTER RADTUS.....	RW2	CM	CM	460
45. FIRST WALL VOLUME.....	VW	CM3	M3	470
46. FIRST WALL WEIGHT.....	WW	G	T	480
47. PRIMARY NEUTRON FLUX.....	FX14	CM-2*S-1	E 14*CM-2*S-1	490
48. TOTAL WALL NEUTRON FLUX.....	FXTO	CM-2*S-1	E 14*CM-2*S-1	500
49. ONE YEAR WALL NEUTRON DOSE.....	DOSE	CM-2	E 22*CM-2	510
50. NEUTRON ENERGY WALL LOADING....	PWNE	W/CM2	W/CM2	520
51. FIRST WALL PLASMA ENERGY LOAD...	EWPL	J/CM2	J/CM2	530
52. ADIABATIC WALL TEMPERATURE RISE.	DTAD	C	C	540
53. WALL WEIGHT LOSS BY EVAPORATION.	WEVA	G	KG	550
54. WALL VOLUME LOSS BY EVAPCRATION.	VEVA	CM3	M3	560

NR. QUANTITY	ABBR.	DIMENSION	IN OUTPUT	
		PRINT	PLOT	
55. LOSS IN WALL THICKNESS.....	DSW	CM	CM	580
56. COOLANT TEMPERATURE RISE.....	DTCO	C	C	590
57. THERM. WALL LOADING/NEUTRON FLUX.	QWM	J/CM	E-14*J/CM	600
58. SHIELDING RADIUS.....	RSH	CM	CM	610
59. TOTAL BLANKET VOLUME.....	VB	CM3	M3	620
60. TOTAL BLANKET WEIGHT.....	WB	G	T	630
61. COOLANT VOLUME.....	VCOO	CM3	M3	640
62. COOLANT WEIGHT.....	WC00	G	T	650
63. REFLECTOR WEIGHT.....	WREF	G	T	660
64. BLANKET STRUCTURE WEIGHT.....	WSTR	G	T	670
65. TOTAL BLANKET POWER.....	PBL	W	MW	680
66. BLANKET POWER DENSITY.....	QBL	W/CM3	W/CM3	690
67. COOLANT POWER DENSITY.....	QC00	W/CM3	W/CM3	700
68. COOLANT MASS FLOW RATE.....	FLOW	G/S	T/S	710
69. COOLANT VOLUME FLOW RATE.....	VOLF	CM3/S	M3/S	720
70. NUCLEAR THERMAL WALL LOADING....	PNUU	W/CM2	W/CM2	730
71. REAL THERMAL WALL LOADING.....	PWTH	W/CM2	W/CM2	740
72. TOTAL BLANKET THICKNESS.....	SB	CM	CM	750
73. TOTAL SHIELDING THICKNESS.....	SSH	CM	CM	760
74. COIL CURRENT DENSITY.....	CURR	A/CM2	A/CM2	770
75. NUMBER OF COILS.....	YNC	-	-	780
76. SUPERCONDUCTOR SPECIFIC COSTS...	COST	DM/A*KG*CM	MDM/A*KG*CM	790
77. INNER COIL RADIUS.....	RCI	CM	CM	800
78. COIL ASPECT RATIO.....	ASPC	-	-	810
79. MAXIMUM FIELD STRENGTH.....	BMAX	KGAUSS	KGAUSS	820
80. TOTAL COIL CROSS SECTION.....	ACTO	CM2	M2	830
81. SINGLE COIL CROSS SECTION.....	AC	CM2	M2	840
82. COIL EDGE LENGTH.....	BC	CM	CM	850
83. OUTER COIL RADIUS.....	RCA	CM	CM	860
84. SINGLE COIL VOLUME.....	VC	CM3	M3	870
85. TOTAL COIL VOLUME.....	VCTO	CM3	M3	880
86. SINGLE COIL SURFACE AREA.....	FC	CM2	M2	890
87. TOTAL COIL SURFACE AREA.....	FCTO	CM2	M2	900
88. MAGNETIC FIELD VOLUME.....	VF	CM3	M3	910
89. MAGNETIC FIELD ENERGY.....	EF	J	GJ	920
90. FIELD ENERGY DENSITY.....	ENF	J/CM3	J/CM3	930
91. SUPERCONDUCT. MATERIAL INVENTORY	XMS	A*KGAUSS*CM	E 12*A*KG*CM	940
92. SPECIFIC SUPERCONDUCTOR COSTS...	COSP	DM/W	DM/W	950
93. INNER TORUS CIRCUMFERENCE.....	UCT	CM	CM	960
94. COIL CIRCUMF. REQUIREMENTS.....	BCTO	CM	CM	970
95. COIL COVER FACTOR.....	COV	-	-	980
96. INNER TORUS RADIUS.....	RT	CM	CM	990
97. OUTER TORUS RADIUS.....	RO	CM	CM	1000
98. TORUS FREE SPACE AREA.....	AI	CM2	M2	1010
99. OVERALL POWER DENSITY.....	OTO	W/CM3	W/CM3	1020
100. MECHANICAL COIL STRESS.....	STRS	N/CM2	N/CM2	1030
101. SHIELDING VOLUME.....	VSH	CM3	M3	1040
102. SHIELDING WEIGHT.....	WSH	G	T	1050
103. LEAD WEIGHT IN SHIELD.....	WPB	G	T	1060
104. WATER WEIGHT IN SHIELD.....	WH20	G	T	1070
105. SHIELD STRUCTURE WEIGHT.....	WSSH	G	T	1080
106. GRAPHITE WEIGHT IN SHIELD.....	WGRS	G	T	1090
107. TOTAL BLANKET+SHIELD WEIGHT....	WTOT	G	T	1100
108. DEVIATION FROM SPITZER CONDUCT..	DSPI	-	-	1110

NR. QUANTITY	ARBF.	DIMENSION IN	OUTPUT	
	PRTNT	PLOT		
109. PLASMA CURRENT.....	PLCU	A	MA	1150
110. PLASMA INDUCTANCE.....	PLIN	OHM*S	E-6*OHM*S	1160
111. POLOIDAL FIELD ENERGY.....	ENFP	J	MJ	1170
112. POLOIDAL FIELD STRENGTH.....	BPOL	KGAUSS	KGAUSS	1180
113. POLOIDAL BETA.....	BEPO	-	-	1190
114. POLOIDAL/AXIAL BETA RATIO.....	POTO	-	-	1200
115. PLASMA CONDUCTIVITY.....	PLCO	1/OHM*CM	E 6*1/OHM*CM	1210
116. PLASMA RESISTANCE.....	PLRE	OHM	E-9*OHM	1220
117. ELECTROMAGNETIC TIME CONSTANT...	TICO	S	E 3*S	1230
118. POLOIDAL FIELD FLAT TOP ENERGY..	ENFT	J	MJ	1240
119. IRON CORE CROSS SECTION.....	ACOR	CM2	M2	1250
120. IRON CORE RADIUS.....	RCOR	CM	CM	1260

A p p e n d i x I I

Sample input

The following list presents an example of the input specification. It can be divided into five parts:

- | | |
|-------------------------|--|
| I) lines 50 to 150: | Control part |
| line 50: | total output requested |
| 60: | 7 plots requested |
| 70: | options for plot routine |
| 80: | specification of quantities to be plotted |
| 90 -150: | text specifications for the 7 plot output sheets |
| II) lines 160 to 290: | Specification of the initial reactor model |
| III) lines 300 to 500: | Specification of the blanket region |
| IV) lines 510 to 580: | Specification of the shield region |
| V) lines 590 to 780: | Specification of variables to be changed in successive runs
Note: line 680 represents the "empty input" (see section 4.2) |

The contents of the first 12 positions in each input card is optional and may even be filled up with blanks. It is ignored by the program. The reason for this arrangement of the input data has only to be seen in the special features of the AMOS-system implemented in the IBM 360/90 computer of the IPP. If these positions are used for defining the name of the quantity as is the case in the sample input, modifications of the input list can be done in an easy way.

```

/*CCNTROL STEP=1, REST=Y          100
// EXEC FUG,LIB=WOD,NAME=SYSTEMS 200
//G.PLOT P DD DUMMY             300
//G.SYSIN DD *                  400
LPRT.....= 0                   500
LPLT.....= 7                   600
NETZ,INTER= 0      4           700
LP.....= 28   79   15   16   17   60   92           800
NTEXT(1)..=B0 VS. PWF FOR ASPP=3.0 AND 3.5       (TOK 5000)  900
NTEXT(2)..=BMAX VS. PWF FOR ASPP=3.0 AND 3.5     (TOK 5000) 1000
NTEXT(3)..=RP VS. PWF FOR ASPP=3.0 AND 3.5       (TOK 5000) 1100
NTEXT(4)..=R VS. PWF FOR ASPP=3.0 AND 3.5        (TOK 5000) 1200
NTEXT(5)..=VP VS. PWF FOR ASPP=3.0 AND 3.5       (TOK 5000) 1300
NTEXT(6)..=AB VS. PWF FOR ASPP=3.0 AND 3.5       (TOK 5000) 1400
NTEXT(7)..=COSP VS. PWF FOR ASPP=3.0 AND 3.5     (TOK 5000) 1500
MTYPE.....= 2                   1600
PNCM.....= 5.0000E 09            1700
PWF.....= 1.0000E 02            1800
ASPP.....= 3.0000E 00            1900
YPW.....= 0.9000E 00            2000
TI.....= 1.5000E 01              2100
DBCR.....= 1.0000E 00            2200
DTCO.....= 1.6900E 02            2300
SSH.....= 5.0000E 01              2400
CURR.....= 2.0000E 03            2500
XNC.....= 3.0000E 01              2600
COST.....= 2.5000E-06             2700
Q.....= 2.0000E 00              2800
DSPI.....= 1.0000E 00             2900
BT6.....= 0.9000E 00              3000
BT7.....= 0.4300E 00              3100
FXM.....= 8.3333E 00              3200
QWM.....= 3.2432E-14             3300
TMW.....= 6.0000E 02              3400
XZBL.....= 6.0000E 00              3500
SBL,XM(1)..= 0.5000E 00          1.0000E 00           3600
XMT,CNT..= 4.1000E 03          1.0000E 00           3700
SBL,XM(2)..= 3.0000E 00          2.0000E 00           3800
XMT,CONT..= 3.0000E 02          0.9400E 00           3900
.....= 4.1000E 03          0.0600E 00           4000
SBL,XM(3)..= 0.5000E 00          1.0000E 00           4100
XMT,CNT..= 4.1000E 03          1.0000E 00           4200
SBL,XM(4)..= 6.0000E 01          2.0000E 00           4300
XMT,CONT..= 3.0000E 02          0.9400E 00           4400
.....= 4.1000E 03          0.0600E 00           4500
SBL,XM(5)..= 3.0000E 01          1.0000E 00           4600
XMT,CONT..= 6.0000E 02          1.0000E 00           4700
SBL,XM(6)..= 6.0000E 00          2.0000E 00           4800
XMT,CNT..= 3.0000E 02          0.9400E 00           4900
.....= 4.1000E 03          0.0600E 00           5000
XZSH.....= 3.0000E 00            5100
ZSH,XS(1)..= 0.5500E 00          2.0000E 00           5200
XMSH,CONS.= 2.6000E 03          0.8000E 00           5300
.....= 1.1000E 02          0.2000E 00           5400
ZSH,XS(2)..= 0.3500E 00          1.0000E 00           5500
XMSH,CONS.= 1.1000E 02          1.0000E 00           5600
ZSH,XS(3)..= 0.1000E 00          1.0000E 00           5700

```

XMSH,CONS.=	8.2000E 03	1.0000E 00	5800
PWF.....=	2	1.2500E 02	5900
PWF.....=	2	1.5000E 02	6000
PWF.....=	2	1.7500E 02	6100
PWF.....=	2	2.0000E 02	6200
PWF.....=	2	2.2500E 02	6300
PWF.....=	2	2.5000E 02	6400
PWF.....=	2	2.7500E 02	6500
PWF.....=	2	3.0000E 02	6600
PWF.....=	2	3.2500E 02	6700
NEW LINE...=	0	0.0000E 00	6800
ASPP.....=	3	3.5000E 00	6900
PWF.....=	2	3.0000E 02	7000
PWF.....=	2	2.7500E 02	7100
PWF.....=	2	2.5000E 02	7200
PWF.....=	2	2.2500E 02	7300
PWF.....=	2	2.0000E 02	7400
PWF.....=	2	1.7500E 02	7500
PWF.....=	2	1.5000E 02	7600
PWF.....=	2	1.2500E 02	7700
PWF.....=	2	1.0000E 02	7800

A p p e n d i x III

Sample output

The following pages contain an output example produced by the sample input specified in appendix II. Both the print and the plot output are, in connection with the reference list (see appendix I), self-explaining.

MAIN SYSTEM PARAMETERS FOR TOKAMAK REACTOR

1. PHOM=	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09
2. PWF =	1.0000E 02	1.2500E 02	1.5000E 02	1.7500E 02	2.0000E 02	2.2500E 02	2.5000E 02	2.7500E 02	3.0000E 02	3.2500E 02	3.5000E 02	3.7500E 02	4.0000E 02
3. ASPP=	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00	3.0000E 00
4. YPW =	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01
5. TI =	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01
6. BETAF=	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02
7. DBCR=	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00
8. BT6 =	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01
9. BT7 =	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01
10. BT =	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00
11. Q =	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00
12. BECR=	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02	4.8113E-02
13. PFU =	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09
14. FW =	5.0000E 07	4.0000E 07	3.3333E 07	2.8571E 07	2.5023E 11	3.6481E 11	4.2727E 11	1.8182E 07	1.6666E 07	1.5385E 07	1.5385E 07	1.5385E 07	1.5385E 07
15. RP =	6.1640E 02	5.5133E 02	5.0329E 02	4.6596E 02	4.3586E 02	4.1093E 02	3.8985E 02	3.7170E 02	3.5588E 02	3.4192E 02	3.4192E 02	3.4192E 02	3.4192E 02
16. R =	1.8492E 03	1.6540E 03	1.5099E 03	1.3979E 03	1.3076E 03	1.2328E 03	1.1695E 03	1.1151E 03	1.0676E 03	1.0258E 03	1.0258E 03	1.0258E 03	1.0258E 03
17. VP =	1.3869E 10	9.9237E 09	7.5492E 09	5.9908E 09	4.9034E 09	4.1093E 09	3.5086E 09	3.0412E 09	2.6691E 09	2.3671E 09	2.3671E 09	2.3671E 09	2.3671E 09
18. QP =	3.0442E-01	4.2544E-01	5.5925E-01	7.0474E-01	8.6103E-01	1.0274E 00	1.2033E 00	1.3883E 00	1.5818E 00	1.7836E 00	1.7836E 00	1.7836E 00	1.7836E 00
19. RR =	1.08C9E 11	1.5106E 11	1.9858E 11	2.5023E 11	3.0573E 11	3.6481E 11	4.2727E 11	4.9293E 11	5.6166E 11	6.3331E 11	6.3331E 11	6.3331E 11	6.3331E 11
20. SIGV=	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16
21. XNI =	4.0017E 13	4.7307E 13	5.4239E 13	6.0887E 13	6.7300E 13	7.3516E 13	7.9561E 13	8.5456E 13	9.1219E 13	9.6863E 13	9.6863E 13	9.6863E 13	9.6863E 13
22. QB =	3.3181E-03	4.6371E-03	6.0957E-03	7.6814E-03	9.3849E-03	1.1198E-02	1.3116E-02	1.5132E-02	1.7241E-02	1.9441E-02	2.1741E-02	2.4041E-02	2.7040E-02
23. PBR =	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07
24. PWBR=	9.2035E-01	1.1504E 00	1.3805E 00	1.6106E 00	1.8407E 00	2.0708E 00	2.3009E 00	2.5310E 00	2.7611E 00	2.9911E 00	2.9911E 00	2.9911E 00	2.9911E 00
25. XNT =	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14
26. TAU =	5.0053E 00	4.2340E 00	3.6929E 00	3.2897E 00	2.9762E 00	2.72446E 00	2.5175E 00	2.3439E 00	2.1958E 00	2.0679E 00	2.0679E 00	2.0679E 00	2.0679E 00
27. FB =	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02
28. BO =	3.1722E 01	3.4490E 01	3.6931E 01	3.9129E 01	4.1138E 01	4.2996E 01	4.4728E 01	4.6356E 01	4.7893E 01	4.9353E 01	4.9353E 01	4.9353E 01	4.9353E 01
29. ZION=	5.5499E 23	4.6946E 23	4.0944E 23	3.6476E 23	3.3000E 23	3.0210E 23	2.7914E 23	2.5989E 23	2.4347E 23	2.2928E 23	2.2928E 23	2.2928E 23	2.2928E 23
30. ZABB=	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21
31. ZIN =	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23
32. ZFX =	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23
33. ENPL=	4.0019E 09	3.3843E 09	2.9513E 09	2.6295E 09	2.3789E 09	2.0778E 09	1.80213E 09	1.6123E 09	1.4873E 09	1.3525E 09	1.26529E 09	1.16529E 09	1.06529E 09
34. PDIV=	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08
35. TCL =	5.2862E 05	4.2289E 05	3.52241E 05	3.0207E 05	2.6431E 05	2.3494E 05	2.1145E 05	1.9222E 05	1.7621E 05	1.6265E 05	1.5225E 05	1.4225E 05	1.3215E 05
36. TBO =	2.7438E-02	2.3887E-02	2.1296E-02	1.9340E-02	1.7792E-02	1.6529E-02	1.5476E-02	1.4581E-02	1.3809E-02	1.3135E-02	1.2462E-02	1.2135E-02	1.2135E-02
37. ALCL=	9.4687F-06	1.0012F-05	1.0479F-05	1.0810E-05	1.1260E-05	1.1597E-05	1.1906E-05	1.2193E-05	1.2494E-05	1.2713E-05	1.3013E-05	1.3313E-05	1.3613E-05
38. RW1=	1.8242E 02	1.7744E 02	1.7341E 02	1.7010E 02	1.6728E 02	1.6484E 02	1.6268E 02	1.6075E 02	1.5901E 02	1.5733E 02	1.5573E 02	1.5403E 02	1.5243E 02
39. FXM =	8.3333F 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00
40. SW =	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01
41. XMAT=	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03
42. TMW =	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02
43. RW2 =	6.8439E 02	6.1258E 02	5.5921E 02	5.1773E 02	4.8429E 02	4.5659E 02	4.3316E 02	4.1300E 02	3.9542E 02	3.7991E 02	3.6542E 02	3.5133E 02	3.4133E 02
44. FW1 =	6.8539E 02	6.1308E 02	5.5971E 02	5.1823E 02	4.8479E 02	4.55709E 02	4.3366F 02	4.1350E 02	3.9592E 02	3.8041E 02	3.6642E 02	3.5243E 02	3.4243E 02
45. VWH =	2.5011E 07	2.0007E 07	1.6673E 07	1.4293E 07	1.2507E 07	1.1116E 07	1.0006E 07	9.0961E 06	8.3374E 06	7.6978E 06	7.0978E 06	6.5816E 06	6.0000E 06
46. WH =	2.1384E 08	1.7106E 08	1.4255E 08	1.2220E 08	1.0693E 08	9.5043E 08	8.5552E 08	7.7772E 07	7.1285E 07	6.5816E 07	6.0000E 07	5.5000E 07	5.0000E 07
47. FX14=	2.9982E 13	3.7477E 13	4.4973E 13	5.2468E 13	5.9964E 13	6.7459E 13	7.4955E 13	8.2450E 13	8.9496E 13	9.7441E 13	10.4411E 13	11.1411E 13	11.8411E 13
48. FX10=	2.4985E 14	3.1231E 14	3.7477E 14	4.3723E 14	4.970E 14	5.6216E 14	6.2462E 14	6.8708E 14	7.4954E 14	8.1201E 14	8.7441E 14	9.3441E 14	9.9441E 14
49. DSSE=	7.8779E 21	9.8490E 21	1.1319E 22	1.3789E 22	1.5758E 22	1.7728E 22	1.9698E 22	2.1669E 22	2.3638E 22	2.5607E 22	2.7607E 22	2.9607E 22	3.1607E 22
50. PWHE=	6.7531E 01	8.4414E 01	1.0130E 02	1.1818E 02	1.3506E 02	1.5195E 02	1.6883E 02	1.8571E 02	2.0259E 02	2.1948E 02	2.3948E 02	2.5948E 02	2.7948E 02

MAIN SYSTEM PARAMETERS FOR TOKAMAK REACTOR

51. EWP1 = 8.0018E 01 8.4609E 01 8.8554E 01 9.2034E 01 9.5158E 01 9.8001E 01 1.0062E 02 1.0304E 02 1.0531E 02 1.0744E 02
 52. DTAD= 7.0075E 01 7.4100E 01 7.7553E 01 8.0590E 01 8.3323E 01 8.5820E 01 8.8097E 01 9.0225E 01 9.2216E 01 9.4059E 01
 53. WEVA= 4.4815E 05 3.7909E 05 3.3064E 05 2.9454E 05 2.6647E 05 2.4394E 05 2.2541E 05 2.0986E 05 1.9660E 05 1.8514E 05
 54. VEV= 5.2415E 04 4.4338E 04 3.8671E 04 3.4449E 04 3.1166E 04 2.8531E 04 2.6364E 04 2.4545E 04 2.2994E 04 2.1654E 04
 55. DSW = 1.0433E-03 1.1084E-03 1.1601E-03 1.2057E-03 1.2467E-03 1.2839E-03 1.3182E-03 1.3500E-03 1.3796E-03 1.4075E-03
 56. DTC0= 1.6900E 02
 57. QWM = 3.2432E-14
 58. RSH = 7.8489E 02 7.1258E 02 6.5921E 02 6.1773E 02 5.8429E 02 5.5659E 02 5.3316E 02 5.1308E 02 4.9542E 02 4.7991E 02
 59. VB = 5.3649E 09 4.3264E 09 3.6313E 09 3.1330E 09 2.7580E 09 2.4655E 09 2.2308E 09 2.0383E 09 1.8774E 09 1.7409E 09
 60. WB = 7.6030E 09 6.1334E 09 5.1514E 09 4.4473E 09 3.9172E 09 3.5035E 09 3.1715E 09 2.8991E 09 2.66714E 09 2.4782E 09
 61. VC00= 3.4233E 09 2.7556E 09 2.3092E 09 1.9894E 09 1.7490E 09 1.5615E 09 1.4112E 09 1.2880E 09 1.1851E 09 1.0979E 09
 62. WCUU= 1.6225E 09 1.2061E 09 1.0945E 09 9.4291E 08 8.2395E 08 7.4010E 08 6.6886E 08 6.1046E 08 5.6169E 08 5.2034E 08
 63. WLEF= 3.6806E 09 2.9804E 09 2.5107E 09 2.1734E 09 1.9191E 09 1.7204E 09 1.5607E 09 1.4295E 09 1.3197E 09 1.2265E 09
 64. WSTR= 2.2970E 09 1.9470E 09 1.5462E 09 1.3310E 09 1.1691E 09 1.0430E 09 9.4196E 08 8.5912E 08 7.8996E 08 7.3139E 08
 65. PBL = 4.2007E 09
 66. QBL = 7.8299E-01 9.7094E-01 1.1568E 00 1.3408E 00 1.5231E 00 1.7038E 00 1.8830E 00 2.0609E 00 2.2375E 00 2.4129E 00
 67. QC00= 1.2137E 00 1.5077E 00 1.7992E 00 2.0884E 00 2.3755E 00 2.6606E 00 2.9440E 00 3.2257E 00 3.5058E 00 3.7843E 00
 68. FLOW= 5.9102E 06
 69. VJLF= 1.2470E 07
 70. PWNU= 4.0515E 00 5.0644E CC 6.0773E 00 8.1031E 00 9.1159E 00 1.0129E 01 1.1142E 01 1.2155E 01 1.3167E 01 1.4159E 01
 71. PWTI= 4.9719E 00 6.2149E 00 7.4578E 00 8.7008E 00 9.9438E 00 1.1187E 01 1.2430E 01 1.3673E 01 1.4916E 01 1.6159E 01
 72. Sb = 1.0000E 02
 73. SSH = 5.0000E 01
 74. CURR= 2.0000E 03
 75. XNC = 3.0000E 01
 76. COST= 2.5000E-06
 77. RCI = 8.3489E 02 7.6258E 02 7.0921E 02 6.6773E 02 6.3422E 02 6.0659E 02 5.8316E 02 5.6304E 02 5.4542E 02 5.2991E 02
 78. ASPC= 2.2149E 00 2.1289E 00 2.0935E 00 2.0615E 00 2.0323E 00 2.0055E 00 1.9806E 00 1.9575E 00 1.9357E 00 1.9070E 00
 79. BMAX= 5.7832E 01 6.3997E 01 6.9644E 01 7.4913E 01 7.9393E 01 8.4645E 01 8.9212E 01 9.3627E 01 9.7915E 01 1.0210E 02
 80. ACT0= 1.4665E 05 1.4262E 05 1.3940E 05 1.3674E 05 1.3448E 05 1.3251E 05 1.3078E 05 1.2923E 05 1.2783E 05 1.2656E 05
 81. AC = 4.8883E 03 4.77538E 03 4.6467E 03 4.5580E 03 4.4832E 03 4.4171E 03 4.3593E 03 4.3077E 03 4.2611E 03 4.2186E 03
 82. BC = 6.9916E 01 6.8948E 01 6.8167E 01 6.7513E 01 6.6952E 01 6.6461E 01 6.6025E 01 6.5633E 01 6.5277E 01 6.4951E 01
 83. RCA = 9.0481E 02 8.3153E 02 7.7738E 02 7.3524E 02 7.0124E 02 6.7305E 02 6.4919E 02 6.2884E 02 6.1070E 02 5.9486E 02
 84. VC = 2.6717E 07 2.3807E 07 2.1701E 07 2.0090E 07 1.8808E 07 1.7757E 07 1.6877E 07 1.6126E 07 1.5476E 07 1.4907E 07
 85. VCT0= 8.0150E 08 7.1422E 08 6.5104E 08 6.0269E 08 5.6423E 08 5.3272E 08 5.0631E 08 4.8379E 08 4.6429E 08 4.4720E 08
 86. FC = 1.5285E 06 1.3812E 06 1.2734E 06 1.1903E 06 1.1236E 06 1.0687E 06 1.0225E 06 9.8282E 05 9.4833E 05 9.1803E 05
 87. FCT0= 4.5855E 07 4.1435E 07 3.8203E 07 3.5708E 07 3.3709E 07 3.2062E 07 3.0574E 07 2.9485E 07 2.8451E 07 2.7541E 07
 88. VF = 2.5443E 10 1.8986E 10 1.4990E 10 1.2302E 10 1.0394E 10 8.9539E 09 7.8509E 09 6.9770E 09 6.2692E 09 5.6855E 09
 89. EF = 1.0190E 11 8.9889E 10 8.1372E 10 7.4966E 10 6.9942E 10 6.5879E 10 6.2513E 10 5.9671E 10 5.7233E 10 5.5116E 10
 90. ENF = 4.0049E 00 4.7345E 00 5.4283E 00 6.0936E 00 6.7355E 00 7.3575E 00 7.9625E 00 8.5525E 00 9.1293E 00 9.6941E 00
 91. XMS = 7.1777E 13 7.0342E 13 6.9385E 13 6.8733E 13 6.8289E 13 6.7996E 13 6.7816E 13 6.7723E 13 6.7698E 13 6.7729E 13
 92. CJSR= 3.5839E-02 3.5171E-02 3.4692E-02 3.4366E-02 3.4145E-02 3.3998E-02 3.3908E-02 3.3861E-02 3.3849E-02 3.3865E-02
 93. UCI = 6.3731E 03 5.6008E 03 5.0397E 03 4.5876E 03 4.2304E 03 3.9446E 03 3.6843E 03 3.4690E 03 3.2812E 03 3.1155E 03
 94. BCT0= 2.0975E 03 2.0684E 03 2.0450E 03 2.0254E 03 2.0086E 03 1.9938E 03 1.9807E 03 1.9690E 03 1.9583E 03 1.9485E 03
 95. CDV = 3.2912E-01 3.69331E-01 4.0651E-01 4.415CE-01 4.7479E-01 5.0675E-01 5.3762E-01 5.6760E-C1 5.9683E-01 6.2544E-01
 96. RI = 9.4440E 02 8.2244E 02 7.3249E 02 6.6262E 02 6.0334E 02 5.5975E 02 5.2035E 02 4.8647E 02 4.5694E 02 4.3089E 02
 97. RD = 2.7540E 03 2.4855E 03 2.2872E 03 2.0897E 03 1.8098E 03 1.9059E 03 1.8187E 03 1.7437E 03 1.6206E 03
 98. AI = 2.8019E 06 2.1250E 06 1.3794E 06 1.0550E 06 8.8431E 06 9.5063E 06 9.8330E 06 7.4348E 06 5.8330E 06
 99. QTO = 1.9052E-01 2.5381E-01 3.1966E-01 4.5669E-01 5.9820E-01 6.2706E-01 6.7017E-01 7.4256E-01 8.1530E-01
 100. STRS= 4.781CE 03 5.2350E 03 6.0250E 03 6.6460E C3 6.3792E 03 6.7133E 03 7.0308E 03 7.6258E 03 7.9068E 03

MAIN SYSTEM PARAMETERS FOR TOKAMAK REACTOR

101. VSH =	2.9562E 09	2.4081E 09	2.0392E 09	1.7734E 09	1.5726E 09	1.4153E 09	1.2885E 09	1.1842E 09	1.0967E 09	1.0223E 09
102. WSH =	1.4909E 10	1.2141E 10	1.0279E 10	8.9376E 09	7.9239E 09	7.1300E 09	6.4906E 09	5.9642E 09	5.5229E 09	5.1474E 09
103. WPB =	3.4444E 09	2.8131E 09	2.3877E 09	2.0808E 09	1.8486E 09	1.6665E 09	1.5196E 09	1.3986E 09	1.2971E 09	1.2106E 09
104. WH2D=	1.3697E 09	1.1651E 09	9.4605E 08	8.2322E 08	7.3035E 08	6.5758E 08	5.9896E 08	5.5067E 08	5.1018E 08	4.7572E 08
105. WSSH=	1.0094E 10	8.2113E 09	6.9451E 09	6.0335E 09	5.3450E 09	4.8059E 09	4.3720E 09	4.0149E 09	3.7157E 09	3.4611E 09
106. WGRS=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
107. WTOT=	2.2509E 10	1.8274E 10	1.5430E 10	1.3385E 10	1.1841E 10	1.0633E 10	9.6621E 09	8.8633E 09	8.1943E 09	7.6256E 09
108. DSP1=	1.0000E 00									
109. PLCU=	1.6294E 07	1.5846E 07	1.5489E 07	1.5194E 07	1.4942E 07	1.4724E 07	1.4531E 07	1.4359E 07	1.4204E 07	1.4062E 07
110. PLIN=	3.1339E-05	2.8030E-05	2.5588E-05	2.3690E-05	2.2160E-05	2.0892E-05	1.9820E-05	1.8898E-05	1.8093E-05	1.7384E-05
111. EJFP=	4.1603E 09	3.5192E 09	3.0694E 09	2.7343E 09	2.4737E 09	2.2646E 09	2.0925E 09	1.9482E 09	1.8251E 09	1.7188E 09
112. BPOL=	5.2869E 00	6.1552E 00	6.5214E 00	6.8563E 00	7.1659E 00	7.4547E 00	7.7260E 00	7.9822E 00	8.2255E 00	8.4792E 00
113. BEPO=	1.7292E 00									
114. POTU=	3.5942E 01									
115. PLCU=	1.0185E 07	1.0231E 07	1.0268E 07	1.0300E 07	1.0328E 07	1.0353E 07	1.0375E 07	1.0395E 07	1.0413E 07	1.0430E 07
116. PLRE=	9.5569E-10	1.0637E-09	1.1610E-09	1.2502E-09	1.3329E-09	1.4104E-09	1.4835E-09	1.5529E-09	1.6190E-09	1.6824E-09
117. TICO=	3.2792E 04	2.6351E 04	2.2039E 04	1.8950E 04	1.6626E 04	1.4814E 04	1.3361E 04	1.2170E 04	1.1175E 04	1.0333E 04
118. ENFT=	8.3206E 09	7.0384E 09	6.1389E 09	5.4686E 09	4.9475E 09	4.5292E 09	4.1850E 09	3.8963E 09	3.6502E 09	3.4375E 09
119. ACOR=	1.702CE 06	1.4804E 06	1.3210E 06	1.1997E 06	1.1036E 06	1.0253E 06	9.5993E 05	9.0442E 05	8.5655E 05	8.1475E 05
120. RCDR=	7.3604E 02	6.8646E 02	6.4844E 02	6.1795E 02	5.9269E 02	5.7127E 02	5.5277E 02	5.3655E 02	5.2216E 02	5.0926E 02

MAIN SYSTEM PARAMETERS FOR TOKAMAK REACTOR

1.	PNOM =	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09	5.0000E 09					
2.	PWF =	3.2500E 32	3.0000E 02	2.7500E 02	2.5000E 02	2.2500E 02	2.0000E 02	1.7500E 02	1.5000E 02	1.2500E 02	1.0000E 02	1.2500E 02	1.0000E 02	1.2500E 02	1.0000E 02
3.	ASPP =	3.5000E 00	3.5000E 00	3.5000E 00	3.5000E 00	3.5000E 00	3.5000E 00	3.5000E 00	3.5000E 00	3.5000E 00					
4.	YPW =	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01
5.	T1 =	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01	1.5000E 01					
6.	BETA=	3.8130E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02
7.	DBCR=	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00					
8.	BT6 =	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01	9.0000E-01
9.	BT7 =	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01	4.3000E-01
10.	BT =	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00	1.3300E 00					
11.	Q =	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00	2.0000E 00					
12.	BECR=	3.8130E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02	3.8118E-02
13.	PFU =	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09	4.2219E 09					
14.	FW =	1.5385E 07	1.6667E 07	1.8182E 07	2.0000E 07	2.2222E 07	2.5000E 07	2.8571E 07	3.3333E 07	4.0000E 07					
15.	RP =	3.1655E 02	3.2948E 02	3.4413E 02	3.6093E 02	3.8045E 02	4.0353E 02	4.3139E 02	4.6596E 02	5.1043E 02	5.7068E 02				
16.	R =	1.1079E 03	1.1532E 03	1.2045E 03	1.2632E 03	1.3316E 03	1.4124E 03	1.4944E 03	1.5765E 03	1.6584E 03	1.7365E 03	1.8165E 03	1.8945E 03	1.9744E 03	1.9974E 03
17.	VP =	2.1915E 09	2.4711E 09	2.8156E 09	3.2483E 09	3.8045E 09	4.5396E 09	5.5464E 09	6.9892E 09	9.1876E 09	1.2840E 10	1.5839E 10	1.8838E 10	2.1838E 10	2.4838E 10
18.	QP =	1.9265E 00	1.7085E 00	1.4995E 00	1.2997E 00	1.1097E 00	9.3000E 00	7.6120E 00	6.0406E 00	4.5953E 00	3.2881E 01	2.1675E 01	1.6317E 01	1.1675E 01	1.1675E 01
19.	RR =	6.8405E 11	6.0666E 11	5.3243E 11	4.6150E 11	3.9404E 11	3.3022E 11	2.7028E 11	2.1449E 11	1.6317E 11	1.1675E 11				
20.	SIGV=	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16	2.7000E-16
21.	XNI =	1.0067E 14	9.4803E 13	8.8814E 13	8.2687E 13	7.6404E 13	6.9944E 13	6.3279E 13	5.6370E 13	4.9166E 13	4.1589E 13	3.4166E 13	2.7040E 13	2.0739E 13	1.4161E 14
22.	QB =	2.0998E-02	1.8623E-02	1.6344E-02	1.4167E-02	1.2096E-02	1.0137E-02	8.2969E-03	6.5841E-03	5.0087E-03	3.5839E-03	2.7040E-02	2.0739E-02	1.4161E 00	1.4161E 00
23.	PBR =	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07	4.6018E 07					
24.	PMBR=	2.9911E 00	2.7611E 00	2.5310E 00	2.3009E 00	2.0708E 00	1.8407E 00	1.6106E 00	1.3805E 00	1.1504E 00	9.2035E 01	7.8852E 01	6.5340E 01	5.3400E 01	5.3400E 01
25.	XNT =	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14	2.0030E 14					
26.	TAU =	1.9897E 00	2.1128E 00	2.2553E 00	2.4224E 00	2.6216E 00	2.8637E 00	3.1653E 00	3.5533E 00	4.0739E 00	4.8161E 00	5.5333E 00	6.2944E 00	7.0455E 00	7.8166E 00
27.	FB =	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02	2.7040E-02
28.	BO =	5.6479E 01	5.4809E 01	5.3050E 01	5.1187E 01	4.9204E 01	4.7797E 01	4.4779E 01	4.0938E 01	3.6924E 01	3.2472E 01	2.8462E 01	2.4462E 01	2.0462E 01	1.6462E 01
29.	ZION=	2.2061E 23	2.3426E 23	2.5062E 23	2.6859E 23	2.9068E 23	3.1752E 23	3.5097E 23	3.9398E 23	4.5171E 23	5.1711E 23	5.8522E 23	6.5400E 23	7.2982E 23	7.9982E 23
30.	ZABB=	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21	2.9982E 21					
31.	ZIN =	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23	1.1088E 23					
32.	ZEX =	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23	1.0938E 23					
33.	EMPL=	1.5904E 09	1.6888E 09	1.8027E 09	1.9363E 09	2.0955E 09	2.2890E 09	2.5301E 09	2.8402E 09	3.2403E 09	3.6404E 09	4.0405E 09	4.4406E 09	4.8407E 09	5.2408E 09
34.	PDIV=	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08	7.8852E 08					
35.	TCL =	1.7568E 05	1.9032E 05	2.0763E 05	2.2839E 05	2.5377E 05	2.85549E 05	3.2627F 05	3.8971E-02	4.7452E-02	5.6213E-02	6.5180E-02	7.4090E-02	8.3411E-02	9.6915E-02
36.	TBO =	1.2884E-02	1.3545E-02	1.4302E-02	1.5180E-02	1.6213E-02	1.7452E-02	1.8711E-02	1.9711E-02	2.0890E-02	2.0890E-02	2.0890E-02	2.0890E-02	2.0890E-02	2.0890E-02
37.	ALCL =	1.1325E-05	1.1101E-05	1.0862E-05	1.0606E-05	1.0331E-05	1.0031E-05	9.7015E-06	9.3348E-06	9.0348E-06	8.9188E-06	8.4349E-06	8.0439E-06	7.6439E-06	7.2439E-06
38.	ALBO=	1.5443E 02	1.5598E 02	1.5768E 02	1.5957E 02	1.6169E 02	1.6409E 02	1.6685E 02	1.6965E 02	1.7245E 02	1.7525E 02	1.7805E 02	1.8085E 02	1.8365E 02	1.8645E 02
39.	FXM =	8.3333E CC	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00	8.3333E 00				
40.	SW =	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01
41.	XMAT=	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03	4.1000E 03					
42.	TW =	6.0000E C2	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02	6.0000E 02				
43.	RW1 =	3.5173E 02	3.6609E 02	3.8233E 02	4.0103E 02	4.2272E 02	4.4837E 02	4.7932E 02	5.1773E 02	5.6714E 02	6.1714E 02	6.6714E 02	7.1714E 02	7.6714E 02	8.1714E 02
44.	KW2 =	3.5223E 02	3.6659E 02	3.8237E 02	4.0153E 02	4.2322E 02	4.4887E 02	4.7982E 02	5.1823E 02	5.6764E 02	6.1764E 02	6.6764E 02	7.1764E 02	7.6764E 02	8.1764E 02
45.	VW =	7.6931E 06	8.3339E 06	9.0968E 06	1.0005E 07	1.1116E 07	1.2505E 07	1.4294E 07	1.6675E 07	1.9010E 07	2.0400E 07	2.1800E 07	2.3199E 07	2.4598E 07	2.5997E 07
46.	WW =	6.5819E 07	7.1304E 07	7.7778E 07	8.5545E 07	9.5545E 07	1.0546E 07	1.1692E 07	1.2222E 08	1.4257E 08	1.7108E 08	2.1384E 08	2.5198E 08	2.9982E 08	3.4777E 08
47.	FX14=	9.7441E 13	8.9946E 13	8.2450E 13	7.4955E 13	6.7459E 13	5.9964E 13	5.2468E 13	4.4973E 13	3.7477E 13	3.0477E 13	2.3477E 13	1.6477E 13	1.0477E 13	5.0477E 13
48.	FXTD=	8.1201E 14	7.4954E 14	6											

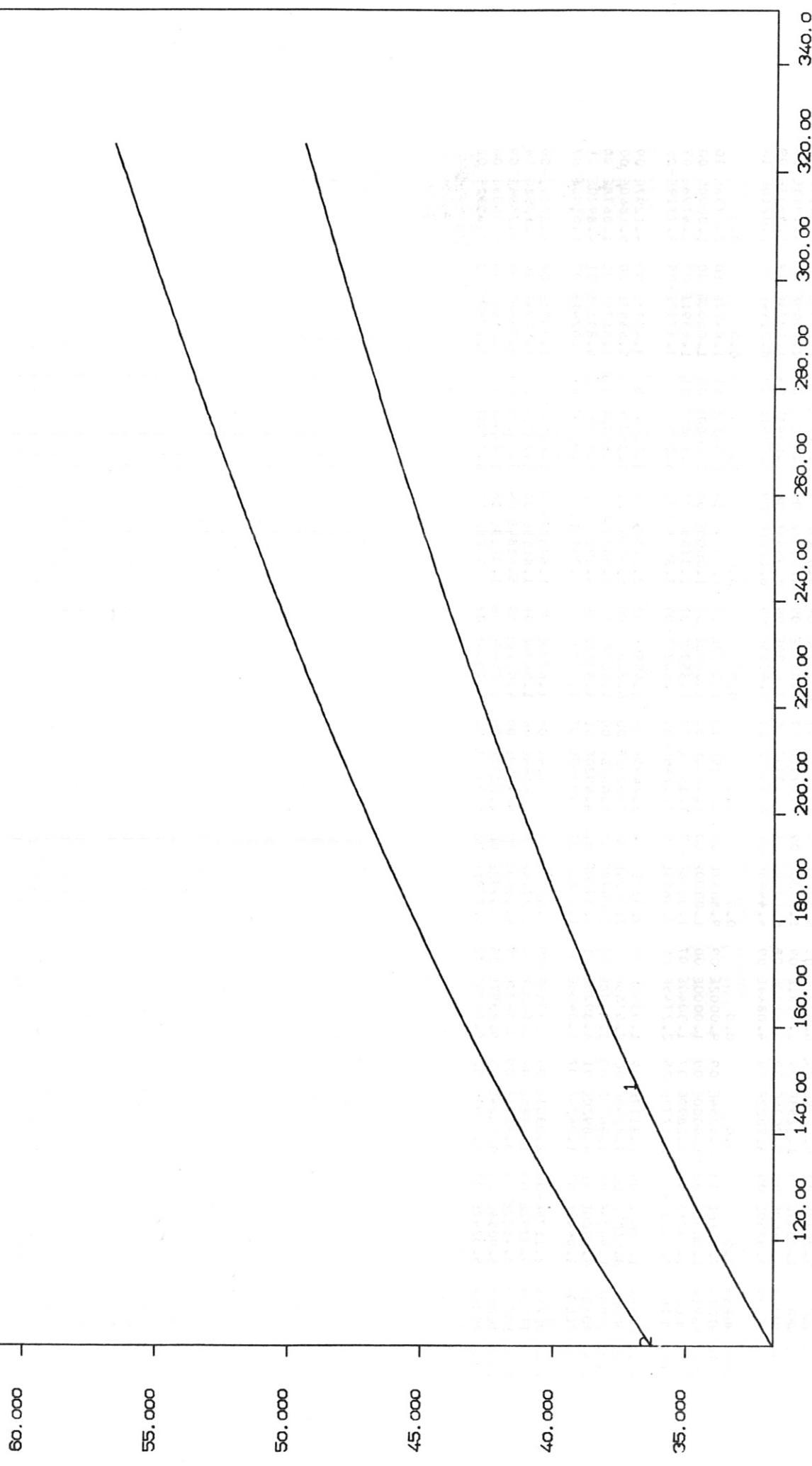
MAIN SYSTEM PARAMETERS FOR TOKAMAK REACTOR

51. EWPL=	1.0338E 02	1.0133E 02	9.9148E 01	9.6813E 01	9.4297E 01	9.1560E 01	8.8554E 01	8.5207E 01	8.1410E 01	7.6993E 01
52. DTAD=	9.0500E 01	8.8706E 01	8.6807E 01	8.4774E 01	8.2573E 01	8.0183E 01	7.7535E 01	7.4612E 01	7.1288E 01	6.7424E 01
53. WFVA=	1.7815E 05	1.8917E 05	2.0192E 05	2.1689E 05	2.3472E 05	2.5640E 05	2.8341E 05	3.1814E 05	3.6476E 05	4.3121E 05
54. VFVA=	2.0836E 04	2.2125E 04	2.3617E 04	2.5367E 04	2.7453E 04	2.9988E 04	3.3147E 04	3.7209E 04	4.2666E 04	5.0434E 04
55. DSW =	1.3543E-03	1.3275E-03	1.2989E-03	1.2683E-03	1.2354E-03	1.1995E-03	1.1601E-03	1.1163E-03	1.06665E-03	1.0087E-03
56. DTC0=	1.6900E 02	1.6900E 02								
57. QWM =	3.2432E-14	3.2432E-14								
58. RSH =	4.5173E 02	4.6609E 02	4.8237E 02	5.0103E 02	5.2272E 02	5.4837E 02	5.7932E 02	6.1773E 02	6.6714E 02	7.3408E 02
59. VB =	1.7571E 09	1.8943E 09	2.0559E 09	2.2493E 09	2.4850E 09	2.7787E 09	3.1551E 09	3.6352E 09	4.3525E 09	5.3941E 09
60. WB =	2.5034E 09	2.6976E 09	2.9264E 09	3.2002E 09	3.5337E 09	3.9492E 09	4.4815E 09	5.1885E 09	6.1740E 09	7.6453E 09
61. VCOU=	1.1059E 09	1.1934E 09	1.2967E 09	1.4204E 09	1.5712E 09	1.7592E 09	2.0003E 09	2.3210E 09	2.7686E 09	3.4377E 09
62. WC00=	5.2414E 08	5.6564E 08	6.1459E 08	6.7319E 08	7.4676E 08	8.3379E 08	9.4808E 08	1.1201E 09	1.2122E 09	1.6293E 09
63. WREF=	1.2434E 09	1.4473E 09	1.6479E 09	1.8580E 09	2.0740E 09	2.3196E 09	2.5535E 09	3.0077E 09	3.7111E 09	4.5111E 09
64. WSTR=	7.3580E 08	7.9460E 08	8.6394E 08	9.4700E 08	1.0483E 09	1.1747E 09	1.3370E 09	1.5528E 09	1.8542E 09	2.3050E 09
65. PBL =	4.2007E 09	4.2007E 09								
66. QBL =	2.3907E 00	2.2176E 00	2.0432E 00	1.8675E 00	1.6904E 00	1.5117E 00	1.3314E 00	1.1492E 00	9.6511E-01	7.7875E-01
67. QC00=	3.7569E CC	3.4813E 00	3.2040E 00	2.9251E 00	2.6443E 00	2.3617E 00	2.0770E 00	1.7900E 00	1.5007E 00	1.2086E 00
68. FLOW=	5.9122E 06	5.9102E 06	5.9102E 06							
69. VOLF=	1.2470E 07	1.2470E 07								
70. PWNU=	1.3167E 01	1.2155E 01	1.1142E 01	1.0129E 01	9.1159E 00	8.1031E 00	7.0902E 00	6.0773E 00	5.0644E 00	4.0515E 00
71. PWTI=	1.6159E 01	1.4916E 01	1.3673E 01	1.2430E 01	1.1187E 01	9.9438E 00	8.7008E 00	7.4578E 00	6.2149E 00	4.9719E 00
72. SB =	1.0000E 02	1.0000E 02								
73. SSH =	5.0000E 01	5.0000E 01								
74. CURR=	2.0000E 03	2.0000E 03								
75. XNC =	3.0000E 01	3.0000E 01								
76. COST=	2.5000E-06	2.5000E-06								
77. FCI =	5.0173E 02	5.1609E 02	5.3237E 02	5.5103E 02	5.7272E 02	5.9837E 02	6.2932E 02	6.6773E 02	7.1714E 02	7.8408E 02
78. ASPC=	2.2033E 00	2.2345E 00	2.2625E 00	2.2925E 00	2.3250E 00	2.3603E 00	2.3922E 00	2.4424E 00	2.4911E 00	2.5474E 00
79. BMAX=	1.0322E 02	9.9209E 01	9.5071E 01	9.0790E 01	8.6340E 01	8.1686E 01	7.6782E 01	7.1656E 01	6.5941E 01	5.9763E 01
80. ACTD=	1.5644E 05	1.5810E 05	1.5974E 05	1.6166E 05	1.6380E 05	1.6623E 05	1.6933E 05	1.7231E 05	1.7622E 05	1.8127E 05
81. AC =	5.2146E 03	5.2671E 03	5.3247E 03	5.3885E 03	5.4599E 03	5.5409E 03	5.6342E 03	5.7438E 03	5.8762E 03	6.0424E 03
82. BC =	7.2213E 01	7.2575E 01	7.2970E 01	7.3406E 01	7.3891E 01	7.4437E 01	7.5061E 01	7.5788E 01	7.6656E 01	7.7733E 01
83. RCA =	5.7394E 02	5.8866E 02	6.0534E 02	6.2444E 02	6.4661E 02	6.7280E 02	7.0438E 02	7.4352E 02	7.9380E 02	8.6182E 02
84. VC =	1.7622E 07	1.8280E 07	1.9031E 07	1.9899E 07	2.0915E 07	2.2128E 07	2.3607E 07	2.5465E 07	2.7893E 07	3.1244E 07
85. VCTU=	5.2865F 08	5.4841E 08	5.7094E 08	5.9696E 08	6.2745E 08	6.6338E 08	7.0821E 08	7.6396E 08	8.36779E 08	9.3731E 08
86. FC =	9.7611E 05	1.0075E 06	1.0432E 06	1.0843E 06	1.1322E 06	1.1891E 06	1.2580E 06	1.3440E 06	1.4555E 06	1.6077E 06
87. FC TU=	2.9283E 07	3.0226E 07	3.1297E 07	3.2529E 07	3.3966E 07	3.5672E 07	3.7740E 07	4.0321E 07	4.3664E 07	4.8232E 07
88. VF =	5.5052E 09	6.0628E 09	6.7381E 09	7.5712E 09	8.6215E 09	9.9816E 09	1.1803E 10	1.4353E 10	1.8136E 10	2.4239E 10
89. EF =	6.9834E 10	7.2488E 10	7.5473E 10	7.8953E 10	8.3075E 10	8.8049E 10	9.4198E 10	1.0204E 11	1.2454E 11	1.2713E 11
90. ENF =	1.2676E 01	1.1956E 01	1.1201E 01	1.0428E 01	9.6358E 00	8.8211E 00	7.9805E 00	7.1092E 00	6.2006E 00	5.2451E 00
91. XMS =	8.4422E 13	3.4465E 13	8.4569E 13	8.4756E 13	8.5048E 13	8.5477E 13	8.6091E 13	8.6961E 13	8.8208E 13	9.0043E 13
92. CDSF=	4.2214E-02	4.2233E-02	4.2285E-02	4.2378E-02	4.2524E-02	4.2739E-02	4.3046E-02	4.3481E-02	4.4104E-02	4.5022E-02
93. JCI =	3.8089E 03	4.0030E 03	4.2229E 03	4.4750E 03	4.7680E 03	5.1144E 03	5.5326E 03	6.0514E 03	6.7190E 03	7.6233E 03
94. BCTU=	2.1664E 03	2.1772E 03	2.1891E 03	2.2022E 03	2.2167E 03	2.2331E 03	2.2518E 03	2.2736E 03	2.2997E 03	2.3320E 03
95. CJV =	5.6876E-01	5.4391E-01	5.1840E-01	4.9211E-01	4.6492E-01	4.3663E-01	4.0701E-01	3.7572E-01	3.4227E-01	3.0590E-01
96. RI =	5.3400E 02	5.6452E 02	5.9912E 02	6.3881E 02	6.8496E 02	7.3955E 02	8.0548E 02	8.8733E 02	9.9270E 02	1.1355E 03
97. RU =	1.6819E 03	1.8098E 03	1.8877E 03	1.9782E 03	2.0522E 03	2.1243E 03	2.2143E 03	2.3744E 03	2.5803E 03	2.8592E 03
98. A1 =	8.9584E 05	1.0012E 06	1.1277E 06	1.4740E 06	1.7182E 06	2.0383E 06	2.4051E 06	3.0150E 06	3.9860E 06	4.0510E 06
99. QTU =	8.2865F-01	7.5633E-01	6.8408E-01	6.1214E-01	5.4060E-01	4.6969E-01	3.9963E-01	3.3076E-01	2.6354E-01	1.9860E-01
100. STRS=	8.8185E 03	8.4998E 03	8.1694E 03	7.8257E 03	7.4665E 03	7.0389E 03	6.6891E 03	6.2618E 03	5.7992E 03	5.2891E 03

MAIN SYSTEM PARAMETERS FOR TOKAMAK REACTOR

101.	VSH =	1.0426E 09	1.1178E 09	1.2063E 09	1.3117E 09	1.4396E 09	1.5985E 09	1.8011E 09	2.0690E 09	2.4408E 09	2.9928E 09
102.	WSH =	5.2482E 09	5.6278E 09	6.0737E 09	6.6055E 09	7.2511E 09	8.0524E 09	9.0749E 09	1.0427E 10	1.2303E 10	1.5090E 10
103.	WPB =	1.2377E 09	1.3253E 09	1.4281E 09	1.5506E 09	1.6991E 09	1.8832E 09	2.1178E 09	2.4276E 09	2.8569E 09	3.4933E 09
104.	WH2D=	4.8549E 08	5.2035E 08	5.6129E 08	6.1009E 08	6.6932E 08	7.4280E 08	8.3653E 08	9.6043E 08	1.1323E 09	1.3873E 09
105.	WSSH=	3.5250E 09	3.7822E 09	4.0844E 09	4.44448E 09	4.8827E 09	5.4265E 09	6.1206E 09	7.0391E 09	8.3144E 09	1.0210E 10
106.	WGRS=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
107.	WTOT=	7.7516E 09	8.3254E 09	9.0002E 09	9.8057E 09	1.0785E 10	1.2002E 10	1.3556E 10	1.5616E 10	1.8477E 10	2.2736E 10
108.	DSP1=	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00
109.	PLCU=	1.2771E 07	1.2899E 07	1.3040E 07	1.3196E 07	1.3371E 07	1.3570E 07	1.3798E 07	1.4066E 07	1.4391E 07	1.4798E 07
110.	PLIN=	2.0923E-05	2.11777E-05	2.2745E-05	2.3855E-05	2.5146E-05	2.6671E-05	2.8513E-05	3.0797E-05	3.3737E-05	3.7719E-05
111.	ENFP=	1.7061E 09	1.8117E 09	1.9338E 09	2.0771E 09	2.2479E 09	2.4555E 09	2.7142E 09	3.0468E 09	3.4933E 09	4.1297E 09
112.	BPOL=	8.0685E 00	7.8299E 00	7.5786E 00	7.3125E 00	7.0292E 00	6.7255E 00	6.3970E 00	6.0377E 00	5.6387E 00	5.1860E 00
113.	BEPO=	1.8678E 00	1.8678E 00	1.8678E 00	1.8678E 00	1.8678E 00	1.8678E 00	1.8678E 00	1.8678E 00	1.8678E 00	1.8678E 00
114.	PNT0=	4.8920E 01	4.8920E 01	4.8920E 01	4.8920E 01	4.8920E 01	4.8920E 01	4.8920E 01	4.8920E 01	4.8920E 01	4.8920E 01
115.	PLC0=	1.0441E 07	1.0424E 07	1.0406E 07	1.0386E 07	1.0363E 07	1.0339E 07	1.0311E 07	1.0279E 07	1.0241E 07	1.0196E 07
116.	PLRE=	2.1178E-09	2.0381E-09	1.9548E-09	1.8674E-09	1.7754E-09	1.6779E-09	1.5737E-09	1.4615E-09	1.3391E-09	1.2031E-09
117.	TICD=	9.8792E 03	1.0685E 04	1.1636E 04	1.2774E 04	1.4164E 04	1.5896E 04	1.8118E 04	2.1072E 04	2.5194E 04	3.1352E 04
118.	ENFT=	3.4122E 09	3.6223E 09	3.8677E 09	4.1543E 09	4.4959E 09	4.9111E 09	5.4284E 09	6.0937E 09	6.9866E 09	8.2594E 09
119.	ACDR=	8.9056E 05	9.3624E 05	9.8857E 05	1.0492E 05	1.1207E 06	1.2063E 06	1.3113E 06	1.4439E 06	1.6182E 06	1.8603E 06
120.	RCDR=	5.3242E 02	5.4591E 02	5.6095E 02	5.7791E 02	5.9726E 02	6.1965E 02	6.4605E 02	6.7794E 02	7.1769E 02	7.6952E 02

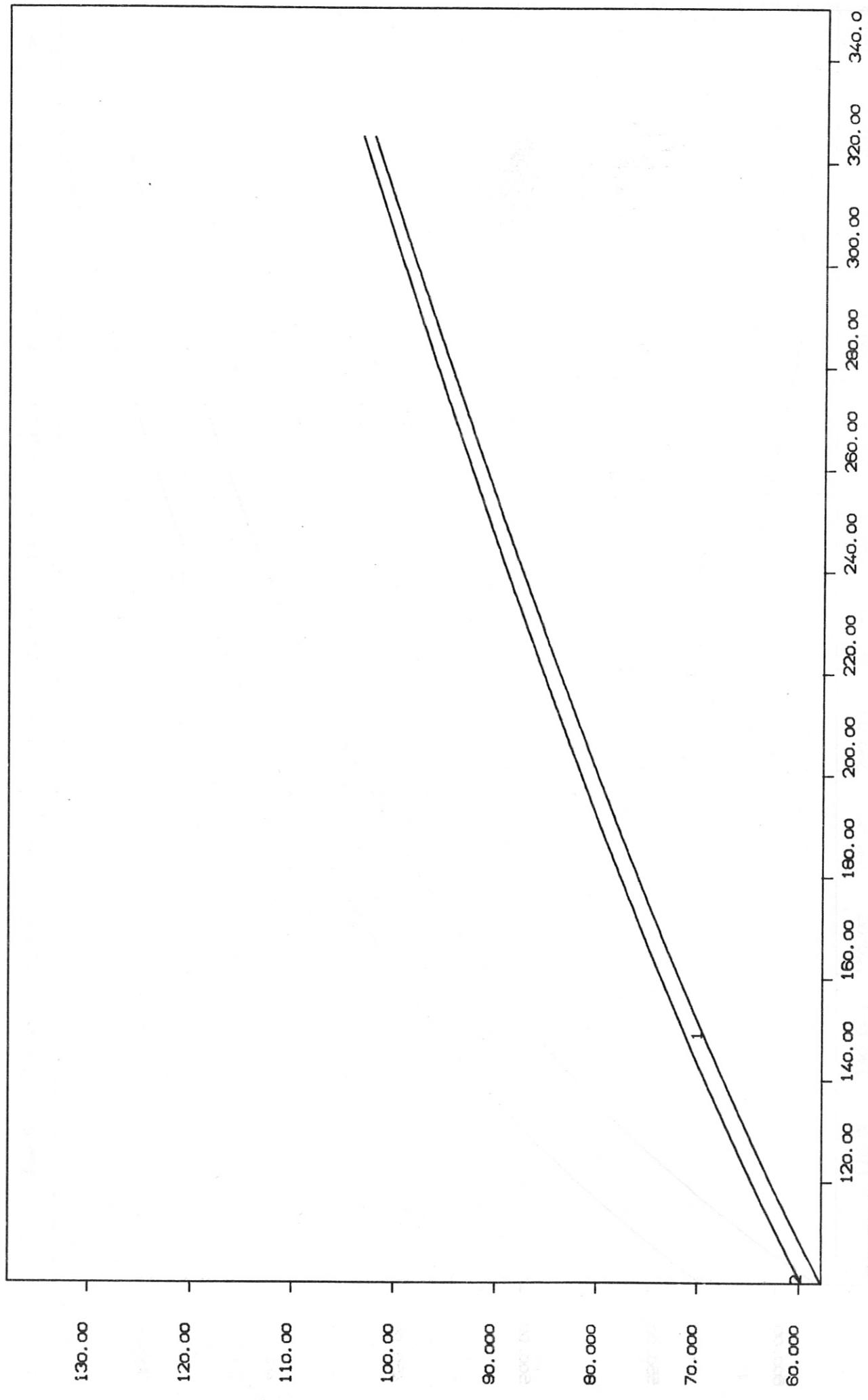
J2-11 WOD031 13. NOV. 74 O1 +



Bo VS. PUF FOR ASPP=3.0 AND 3.5

(TOK 5000)

J2-11 WODO31 13. NOV. 74 02 +

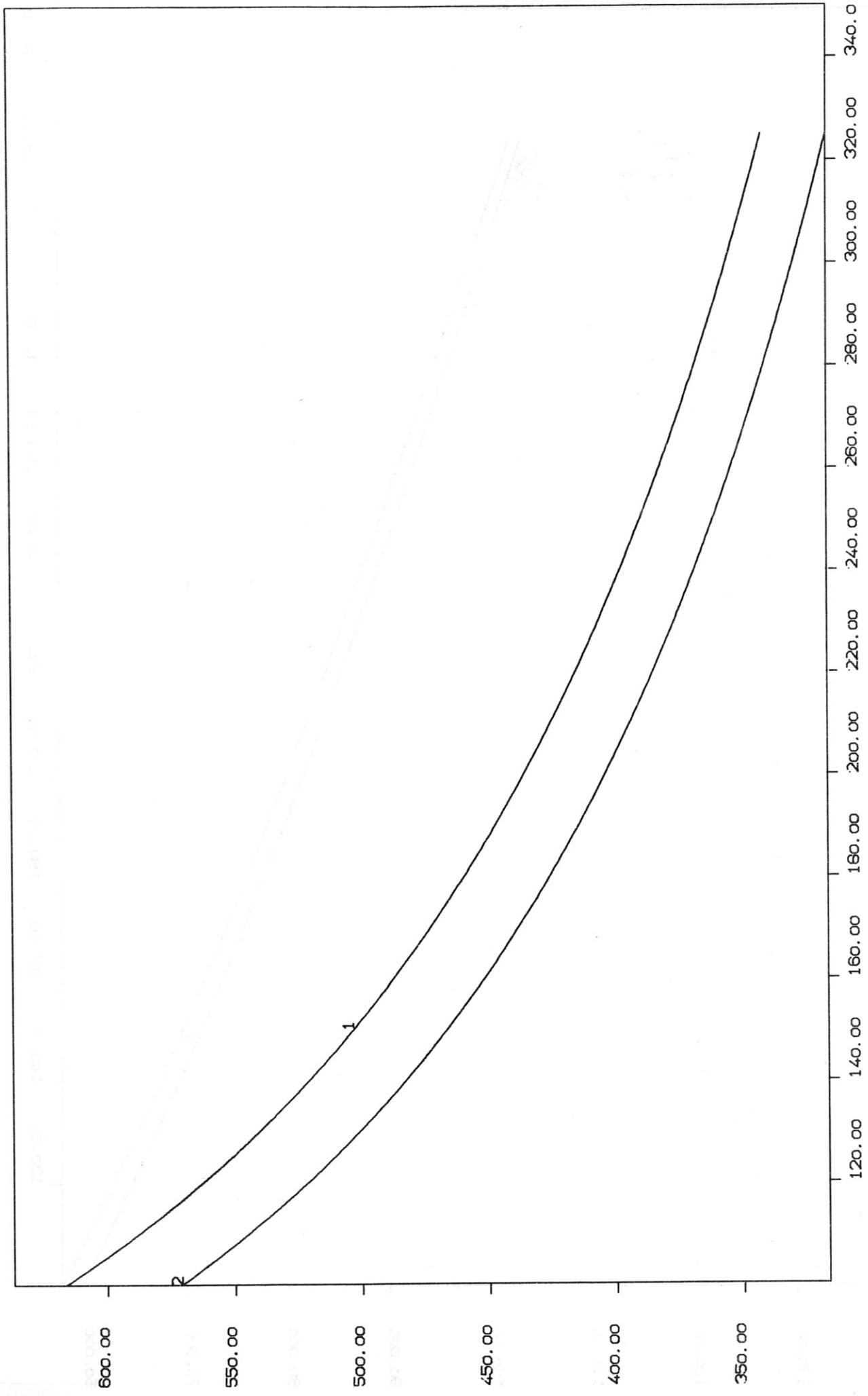


B_{MAX} VS. PUF FOR ASPP=3.0 AND 3.5

(TOK 5000)

BLWV 800 1000 1200 1400 1600 1800

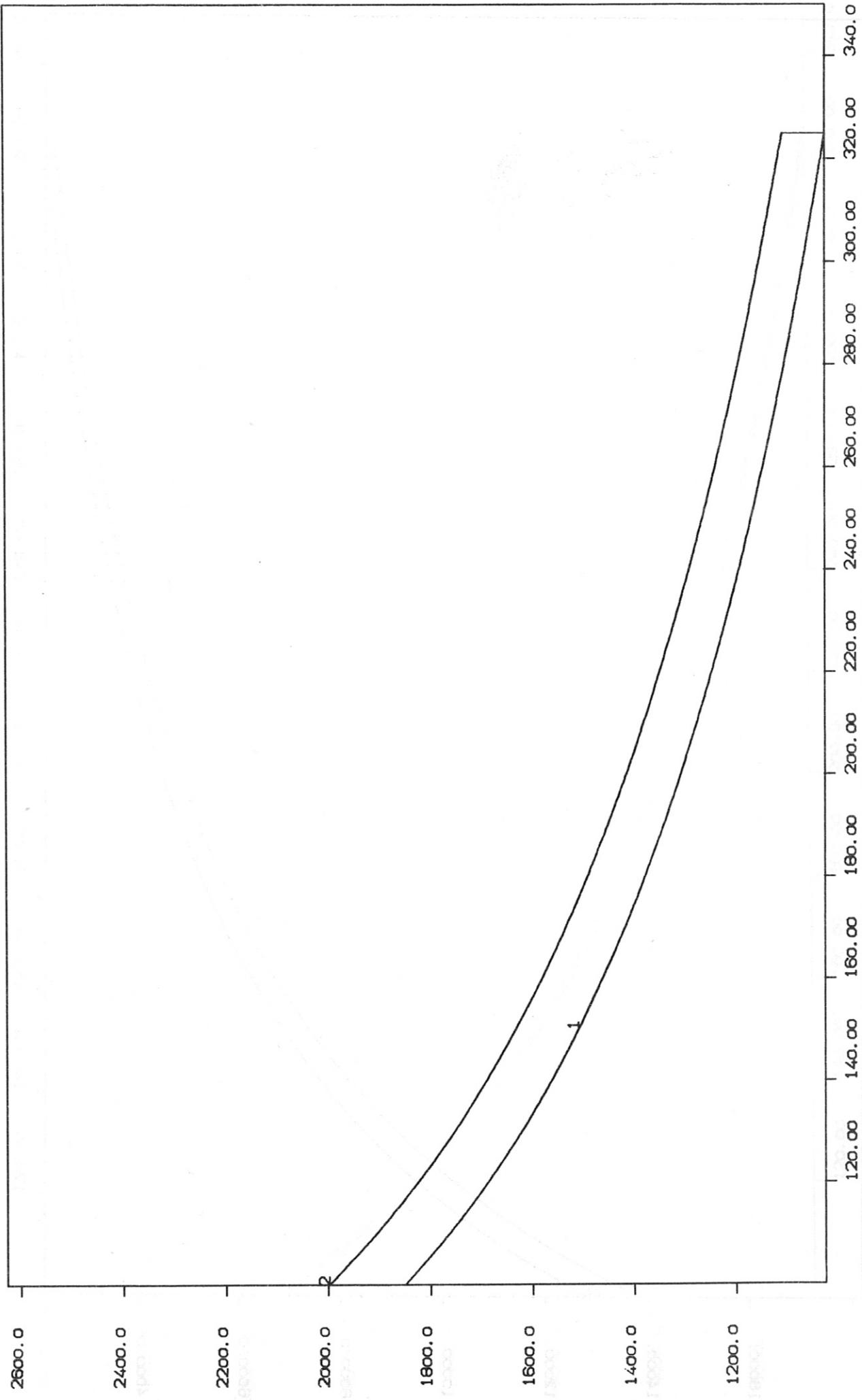
J2-11 WDDO31 13. NOV. 74 03 +



RP VS. PUF FOR ASPP=3.0 AND 3.5

(TOK 5000)

J2-11 WDDO31 13. NOV. 74 O4 +

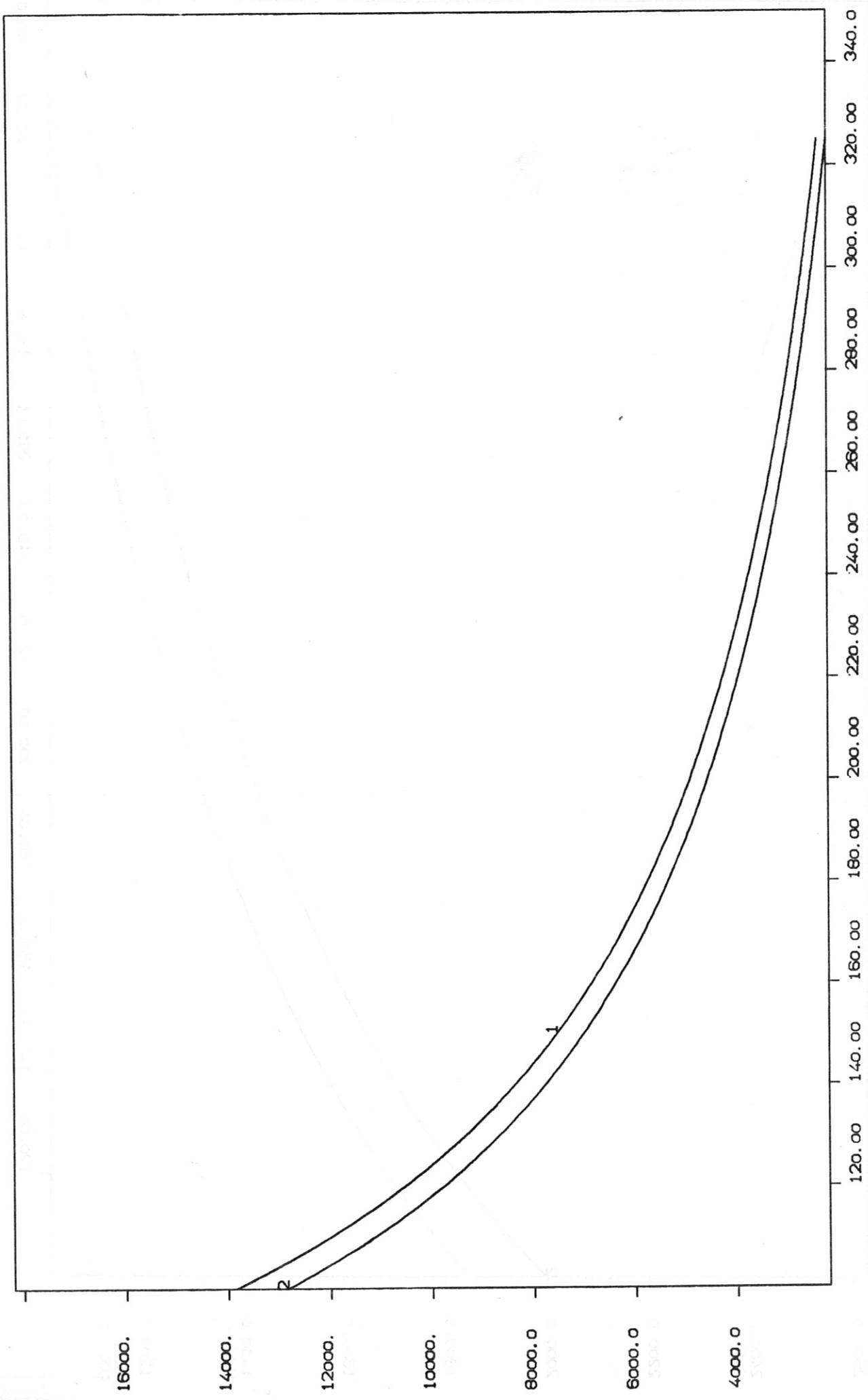


R VS. PUJ FOR ASPP=3.0 AND 3.5

(TOK 5000)

11. Ac⁺ 1000 V_{ASPP} = 3.0 V_D = 3.0

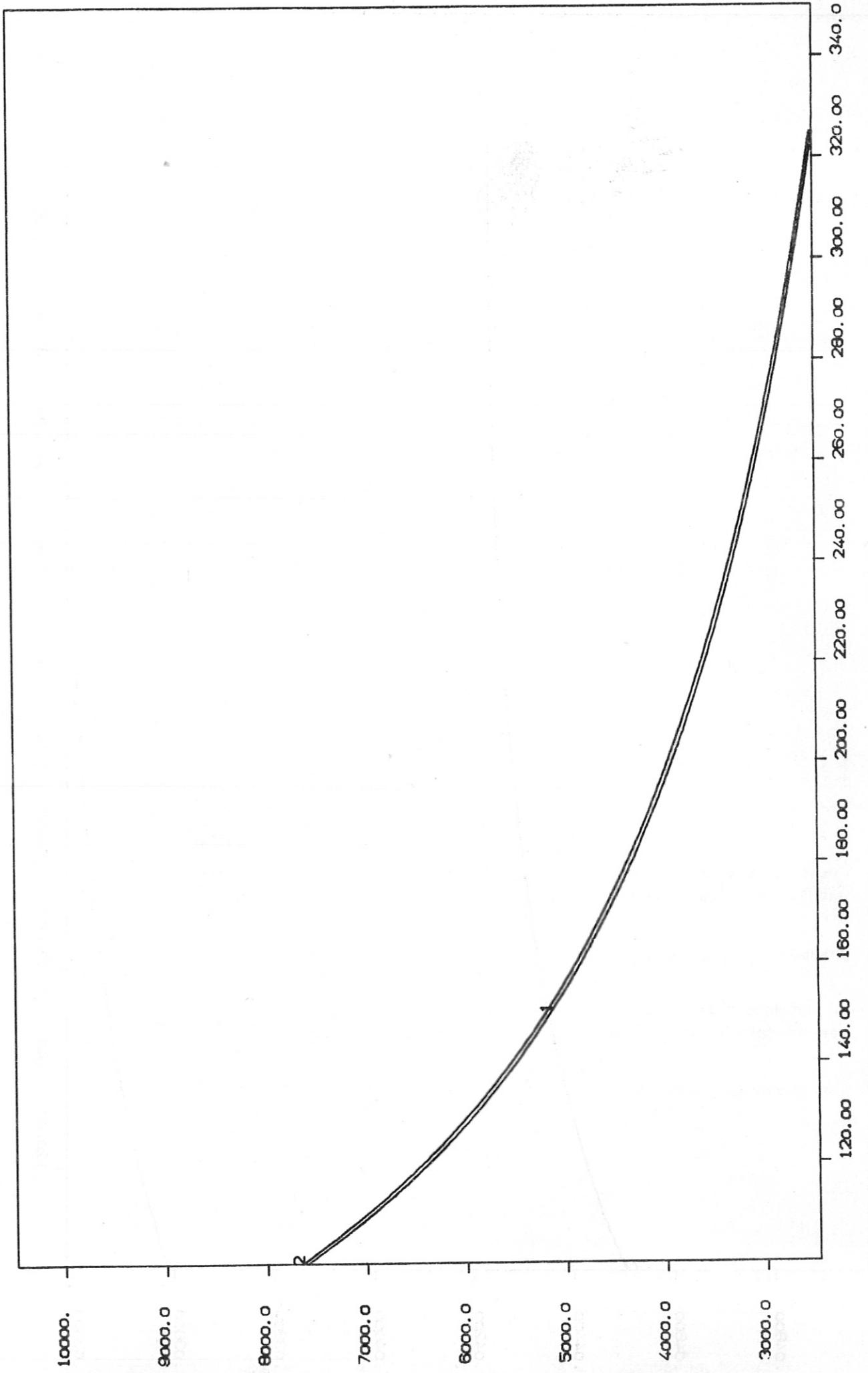
J2-11 W00031 13. NOV. 74 05 +



VP VS. PUF FOR ASPP=3.0 AND 3.5

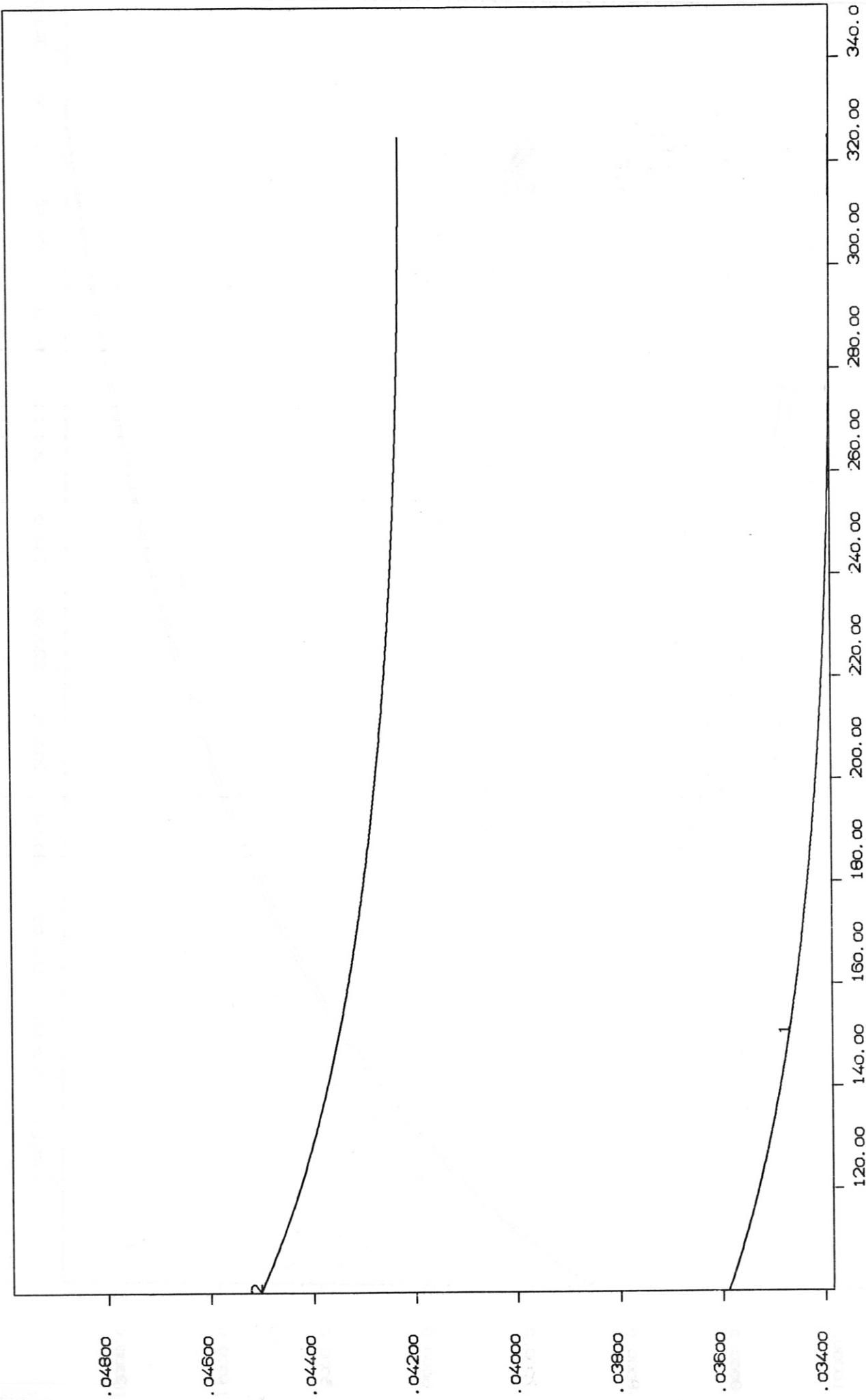
(TO_K 5000)

J2-11 WOD031 13. NOV. 74 06 +



re A₀ = 0.03 vs T₀

J2-11 WODo31 13. NOV. 74 07 +



COSP VS. PUJF FOR ASPP=3.0 AND 3.5

(TOK 5000)