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A ZERO-DIMENSIONAL EXTRAP COMPUTER CODE

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Abstract

A zero-dimensional computer code has been designed for the EXTRAP experiment to predict the density and the temperature and their dependence upon parameters such as the plasma current and the filling pressure of neutral gas. EXTRAP is a Z-pinch immersed in a vacuum octupole field and could be either linear or toroidal. In this code the density and temperature are assumed to be constant from the axis up to a breaking point from where they decrease linearly in the radial direction out to the plasma radius. All quantities, however, are averaged over the plasma volume thus giving the zero-dimensional character of the code. The particle, momentum and energy one-fluid equations are solved including the effects of the surrounding neutral gas and oxygen impurities. The code shows that the temperature and density are very sensitive to the shape of the plasma, flatter profiles giving higher temperatures and densities. The temperature, however, is not strongly affected for oxygen concentration less than 2% and is well above the radiation barrier even for higher concentrations.

1. Introduction

The purpose of this work has been to develop a zero-dimensional computer code for the EXTRAP experiment. EXTRAP is a Z-pinch immersed in a stabilizing octupole magnetic field [1-5]. The pinch can be linear or bent into a torus. Here we only consider the toroidal case. A cross-section of EXTRAP is shown in Fig.1. The octupole vacuum field is generated by four currents, I_0, I_1, I_2 ($=I_1$) and I_3 which flow antiparallel to the plasma current, I_p, in four conductor rods situated at the distance ℓ_o from the magnetic axis. The rods are supposed to be enclosed by a vacuum vessel of radius a_o. The major radius is denoted R. The plasma is heated ohmically by the plasma current.

The present code estimates the equilibrium values of the plasma density and temperature and their dependence upon external parameters such as the filling pressure and the plasma current for the toroidal case. In order to properly account for the penetration of neutral gas, certain plasma density and temperature profiles are assumed. However, integration of all physical quantities is performed over the plasma volume, thus emphasizing the zero dimensional character of the code. At present only classical transport is taken into account, but if needed, anomalous effects can be included.
The code does not give any information of stability of the pinch, but assumes it to be stable for all combinations of the parameters that are considered here. The plasma is created from a hydrogen gas and the effect of a fraction of oxygen impurities is included.

2. The Model

In order to obtain the equilibrium values of the density and temperature, the balance equations for particles, momentum and energy have to be solved. Some of the terms in these equations will include the effect of the penetration of neutral gas. To properly account for this penetration certain profiles for the plasma density and temperature are adopted. In this chapter the aspects mentioned above will be elucidated. It should be noted that SI-units will be used in this text except for the temperature that will be given in eV ($kT = eT_{eV}$). We assume here that the equipartition time for energy exchange between ions and electrons is much shorter than the time scale of the experiment for the actual ranges of density and temperature, i.e. $T_i \approx T_e = T$.

2.1 Plasma profiles

The plasma cross section is approximated by a circular shape with the radius a and the adopted profiles are a function of r, the distance from the magnetic axis, only. The profiles are shown in Fig.2. The temperature is taken to be constant and equal to T_o from the axis of the pinch to the radial distance r_T, from where it linearly decreases to the edge temperature T_a. The plasma density equals n_o up to r_n and then linearly goes to zero at a, i.e.

$$n(r) = \begin{cases} \dfrac{n_o}{a-r_n}(a-r) & r \geq r_n \\ n_o & r < r_n \end{cases} \tag{1}$$

$$T(r) = \begin{cases} \dfrac{T_o-T_a}{a-r_T}(a-r) + T_a & r \geq r_T \\ T_o & r < r_T \end{cases} \tag{2}$$

2.2. The Balance Equations

2.2.1. The Particle Balance

The number of ions created by ionization must equal the number of ions that are lost by diffusion and recombination in each time interval.

$$\langle\dot{n}\rangle = \langle\dot{n}_{ion}\rangle - \langle\dot{n}_{rec}\rangle - \langle\dot{n}_{dif}\rangle = 0 \tag{3}$$

Here $n = n_i (\simeq n_e)$ represents the density of ions and the dot denotes the time derivative. The brackets indicate that the average of the relevant quantity is performed over the plasma volume, i.e.

$$\langle A\rangle = \frac{2}{a^2}\int_o^a rA(r)dr.$$

The rate at which hydrogen atoms become ionized by collisions with electrons can be expressed as

$$S_i\ (T) = \frac{4.83\cdot 10^{-15}}{T}\exp\left(\frac{13.59}{T}\right)10^{\left[\sum_{i=1}^{7} a_i (\ell g T)\right]}\ m^{-3}s \tag{4}$$

where the constants a_i can be found in [6]. We can now write $\dot{n}_{ion}$ as

$$\dot{n}_{ion}(r) = n(r)\ n_n(r) S_i(r) \tag{5}$$

$n_n(r)$ denotes the density of neutrals.

The rate at which ions and electrons recombine is expressed by the recombination coefficient $\alpha(n,T)$, which is taken from the tables in [7]

$$\dot{n}_{rec}(r) = n^2(r)\alpha(r) \tag{6}$$

From now on we will omit to write the dependence on r explicitly.

Classical diffusion across the magnetic field will occur at the velocity $\bar{v}_\perp = \eta_\perp \nabla p/B^2$, where $\eta_\perp$ is the transverse resistivity and according to [8] it could be written as
$\eta_\perp = 1.01\times10^{-4} \ell n\Lambda T^{-3/2}[1-(6.416x_e^2+1.837)/(x_e^4+14.79x_e^2+3.77)]$

where $x_e = \omega_{ce}\tau_e$ with ω_{ce} denoting electron cyclotron frequency, τ_e the electron-ion collision time. Finally, $p = 2neT$ is the plasma pressure and B the magnetic field strength

$$\dot{n}_{dif} = \frac{2}{a^2} \quad rnv \tag{7}$$

2.2.2. The Momentum Balance

The equation of momentum balance and Maxwell's forth equation give

$$\nabla p = \bar{j}\times(\bar{B}_v + \bar{B}_p) \tag{8}$$

$$\text{rot}\ \bar{B}_p = \mu_o \bar{j} \tag{9a}$$

$$\text{rot}\ \bar{B}_v = \bar{0} \tag{9b}$$

The magnetic field of the pinch consists of two parts; the self field, $\bar{B}_p$, originating from the plasma current and the vacuum field, $\bar{B}_v$, generated by the currents in the four rods. For the aspect ratios considered here, the vacuum magnetic field strength in the plasma region can be approximated by a similar expression as in the linear case, [9], i.e.

$$|\bar{B}_v| = 4\,\frac{\mu_o I_1}{2\pi \ell_o}\left(\frac{r}{\ell_o}\right)^3 \qquad (10)$$

Due to the cubic factor in this expression, $|\bar{B}_v|$ will be very small compared to $|\bar{B}_p|$ and we therefore neglect $|\bar{B}_v|$. From (9) we then get in cylindrical coordinates

$$\frac{dp}{dr} = jB_p \qquad (11)$$

$$\frac{1}{r}\frac{d}{dr}(rB_p) = \mu_o j \qquad (12)$$

which can be combined to get

$$B_p(r) = \left(-\frac{2\mu_o}{r^2}\int_o^r r'^2\,\frac{dp}{dr'}\,dr'\right)^{1/2} \qquad (13)$$

and

$$j(r) = \frac{1}{r}\frac{d}{dr}\left(-\frac{2}{\mu_o}\int_o^r r'^2 \frac{dp}{dr'}\, dr'\right)^{1/2} \tag{14}$$

This means that once the temperature profile (r_T, T_o and T_a) and the density profile (n_o and r_n) are chosen, eqs.(9) and (10) give the corresponding magnetic field and current density profile.

Returning to eqs. (11) and (12) together with the assumption $p(a) = 0$ we arrive at the Bennet relation

$$\int_o^a rp(r)dr = \frac{\mu_o}{16\pi^2} I_p^2 \tag{15}$$

where $I_p = \int_o^a j(r)2\pi rdr$. (When $T(r) \equiv T_o$ then one recognizes the more conventional form of the Bennet relation; $16\ eT_oN = \mu_o I^2$ where $N = \int_o^a n(r)2\pi rdr$). If $p(r)$ and I_p are given then eq. (15) determines the Bennet radius, a.

If we insert our adopted pressure profile $p(r) = 2n(r)\ eT(r)$ with $n(r)$ and $T(r)$ from (1) and (2), we arrive at

$$a^2 = \frac{3\mu_o}{8\pi^2 e}\ \alpha\ \frac{I_p^2}{n_o T_o} \tag{16}$$

where α is a factor depending on the shape of the pressure profile

$$\alpha = \frac{1-a_n}{\left[1+a_t+a_t^2-a_t^3-2a_n^3+\frac{T_a}{T_o}(1-a_t-a_t^2+a_t^3)\right]} \quad 0 \le a_n \le a_t \le 1 \tag{17}$$

with $a_n = \frac{r_n}{a}$ and $a_t = \frac{r_T}{a}$.

The separatrix of the magnetic field will have a shape very close to a square for the values of the parameters R, I_p, I_1 and ℓ_o considered here [9]. In the corners of the separatrix the magnetic field will vanish. The distance from the axis to these null points are given by

$$a_{np} = \ell_o\sqrt{2}\left(\frac{g}{4(4-g)}\right)^{1/4} \quad (18)$$

where $g = \left|\frac{I_p}{I_1}\right|$. In our zero-dimensional model the equivalent radius , i.e. the radius for which the circle has the same area as the square, becomes

$$a_{sep} = \sqrt{\frac{2}{\pi}}\ a_{np} \quad (19)$$

For reasons of stability a_{sep} must be approximately the same as a [13]. This puts a requirement on the magnitude of the vacuum current I_1.

2.2.3. The Energy Balance

The power input into the plasma by ohmic heating must balance the rate at which energy is lost from the plasma through different loss channels

$$\dot{U}=\dot{U}_{ohm}-\dot{U}_{conv}-\dot{U}_{exc}-\dot{U}_{syn}-\dot{U}_{bre}-\dot{U}_{icon}-\dot{U}_{econ}-\dot{U}_{ion}-\dot{U}_{rec}-\dot{U}_{imp} = 0 \quad (20)$$

where U is the energy density of the plasma.

In eq. (20) the ohmic heating is expressed as

$$\dot{U}_{ohm} = \langle j^2 \eta_\perp \rangle \qquad Wm^{-3} \tag{21}$$

If the diffusion velocity is much smaller than the thermal velocity, then the energy that is lost due to diffusion can be expressed as

$$\dot{U}_{conv} = \frac{5e}{2} \frac{2}{a^2} \langle rpv \rangle \tag{22}$$

The neutral hydrogen atoms will be excited by collisions with the electrons and the radiation accompanying the deexcitation is supposed to escape out of the plasma volume without being absorbed

$$\dot{U}_{exc} = \langle n n_n R_H \rangle \tag{23}$$

with $R_H = 9.2\times10^{-33} \exp(17/T)\sqrt{T}/(T+13.6)\left[T/(20T+13.6) + \ln(1.25(1+T/13.6)\right. \times$
$\times \left.(205+89.2\exp(-1.07\times10^{-3}(T-1)^2))\right] \qquad Wm^{-3}$

The synchrotron and bremstrahlung radiation are also assumed to be lost [10]

$$\dot{U}_{syn} = 6.2\times10^{-20} \langle B^2 nT \rangle \tag{24}$$

$$\dot{U}_{bre} = 1.5\times10^{-38} \langle n^2 \sqrt{T} \rangle \tag{25}$$

The heat lost through heat conduction by the electrons is

$$\dot{U}_{econ} = 2\langle r q_e \rangle / a^2 \tag{26}$$

where $q_e = \lambda_\perp^e \nabla T \ Jm^{-2}s^{-1}$. $\lambda_\perp^e$ is the electron heat conductivity perpendicular to the magnetic field [8]

$$\lambda_\perp^e = 2.8 \cdot 10^{-8} nT\tau_e \quad \frac{4.664(\omega_{ce}\tau_e)^2 + 11.92}{(\omega_{ce}\tau_e)^4 + 14.79(\omega_{ce}\tau_e)^2 + 3.77} \tag{27}$$

ω_{ce} is the gyro frequency of the electrons and τ_e the electron collision time.

Similarly, for the ion heat conduction

$$\dot{U}_{icond} = \frac{2}{a^2} \langle rq_i \rangle \tag{28}$$

where $q_i = \lambda_\perp^i \nabla T$ and

$$\lambda_\perp^i = 1.5 \cdot 10^{-11} nT\tau_i \quad \frac{2(\omega_{ci}\tau_i)^2 + 2.645}{(\omega_{ci}\tau_i)^4 + 2.7(\omega_{ci}\tau_i)^2 + 0.677} \tag{29}$$

Due to the fact that an electron looses the ionization energy each time an ionization occurs, we must also include an ionization loss term

$$\dot{U}_{ion} = \dot{n}_{ion} e\phi_{ion} \tag{30}$$

where ϕ_{ion} stands for the ionization potential in eV for hydrogen.

When an electron and an ion recombine they loose their kinetic energy provided that the emitted radiation will not be absorbed;

$$\dot{U}_{rec} = 3e \langle n^2 \alpha T \rangle \qquad (31)$$

The presence of impurities will cause radiation losses through excitation, recombination and bremsstrahlung. If one assumes that the density of the impurity ions can be expressed as $n_z(r)=f_z n(r)$, where f_z is a constant and the index z notifies the atomic number of the impurity, then the total radiation loss can be written on the form

$$\dot{U}_{imp} = \sum_z f_z \langle n^2 R_z \rangle \qquad (32)$$

Here $R_z = R_z(T)\,\mathrm{Wm}^3$ expresses the total radiation losses from the impurity ions with the atomic number z. The presence of impurities will increase the effective charge of the plasma according to

$$Z_{eff} = \frac{1+\sum_z f_z Z_z^2(T)}{1+\sum_z f_z Z_z(T)} \qquad (33)$$

where $Z_z(T)$ denotes the mean charge of the impurity ions. $R_z(T)$ and $Z_z(T)$ are taken from [11]. At present we have only taken oxygen impurities into account.

2.3. The Neutral Penetration

The relevant plasma densities in the EXTRAP experiment will be of the order 10^{21}-10^{22} and since $a \sim 10^{-2}$ our plasma will be impermeable to neutral gas. However, there will exist a partially ionized boundary layer where the penetration of neutrals is significant. To properly account for the ionization and the hydrogen line radiation we need an expression for the neutral density profile. For the case of linearly decreasing temperature and density such an expression is given by [12]

$$n_n(r) = \frac{T_a n_n(a)}{T_a + k_T x} - \frac{k_T b}{T_a + k_T x}\left(\frac{T_a x^3}{3k_T} + \frac{x^4}{2}\right) \quad r \leq a \qquad (34)$$

where $k_T = \frac{T_o - T_a}{a - r_T}$, $x = a - r$ and $b = 2m_i \xi_{in} \eta_\perp B^{-2} n_o^3 (a - r_n)^{-3}$.

Here ξ_{in} is the ion-neutral collision rate including both elastic and charge exchange impacts, and $\eta_\perp$ and B are assumed to be constant across the boundary layer. Eq. (26) is valid for $r \varepsilon [\max(r_T, r_n), a]$ only. The neutral density at the plasma edge, $n_n(a)$, is deduced from the condition that the total number of neutrals and ions should equal the number of neutral atoms that existed before ignition, i.e.

$$n_n(a) = \frac{a_o^2}{a_o^2 - a^2} n_{fill} - \langle n_n + n \rangle \frac{a^2}{a_o^2 - a^2} \qquad (35)$$

We let L_n denote the distance from the plasma edge to the point where the neutral density goes to zero.

3. The Structure of the Code

The purpose of this code is to obtain the equilibrium values of the density and temperature as a function of the plasma current, the filling pressure, the shape of the temperature and density profile and other parameter values. The three balance equations (3), (16) and (20) are at our disposal and there are three unknowns; n_o, T_o and a.

In Fig.3 the structure of the code is outlined. First the parameter values of I_p, I_1, a_o, α_n, α_T, T_a, P_{fill} (the filling pressure of neutrals) and f_{ox} are chosen. Start values of n_c and L_n are picked. Then $T_{o_{min}}$ and $T_{o_{max}}$, the temperature values between which the solution T_o is to be found, are given. The T_o for which $\dot{T}_o \cong 0$ is found by the iterative linear-shape method. Since the penetration depth L_n is dependent on $\langle B\rangle_{Ln}$, $\langle n_i\rangle_{Ln}$ and $\langle\xi_{in}\rangle_{Ln}$, where the index L_n indicate that the mean value is to be formed over $(a-L_n,a)$, an iterative procedure is needed to evaluate L_n for each T_o. Then n_o is varied until also $\dot{n}_o \cong 0$ is satisfied.

4. Results

Here we present the dependence of <n>, <T>, a and the relative contribution of the energy loss channels, upon the profiles of the temperature and the density, the plasma current, the filling pressure and the relative concentration of oxygen impurities. In the figures only <n> and <T> will be given, but their values at the axis, n_o and T_o, could easily be obtained by $n_o = 3/(1+a_n+a_n^2)\langle n\rangle$ and $T_o = 3/(1+a_t+a_t^2)\langle T\rangle - T_a(2-a_t-a_t^2)/(1+a_t+a_t^2)$.

For all the parameter values that have been tested here bremsstrahlung, synchrotron radiation and ionization all give a negligible contribution to the energy loss from the plasma and will thus be omitted from the figures.

It should be mentioned that the standard set of parameter values are: $I_p = 50$ kA, $P_{fill} = 10$ Pa (1 Pa = 7.5 mTorr), $a_n \approx a_t = 0.3$, $T_a = 2$ eV, $a_o = 0.15$ m and $\ell_o = 0.71$ m.

In Fig.4 we see how the shape parameters a_n and a_t affect <n>, <T> and a, when all other parameters are kept fixed. It is assumed that $a_n \approx a_t$. <T> increases strongly with a_t, while <n> and a decreases. That ion heat conduction is the dominant loss channel is seen in Fig.5. The flatter the profiles are, the less important is the oxygen radiation.

The effect of varying the third shape parameter T_a is displayed in Fig.6. Both temperature and density goes up when T_a increases, while the radius a decreases. The increase of heat conduction and the decrease of oxygen radiation are the major trends for the energy loss channels when T_a increases as Fig.7 shows.

That <n> and <T> go down and a goes up when the fraction of oxygen impurities is increased is shown in Fig.8. <T> stays above 40 eV even for as high concentrations of oxygen as 10%. Ion conduction decreases drastically and oxygen radiation increases with f_{ox} as is visualized in Fig.9.

Increasing I_p does not affect $\langle T \rangle$ very much, but gives an increase in both a and $\langle n \rangle$ as is shown in Fig.10. I_p does not seem to have any influence on the relative contributions of energy loss channels.

Fig.11 tells us that $\langle T \rangle$ is almost constant, while $\langle n \rangle$ increases and a decreases as P_{fill} is raised. The relative contributions of the energy loss channels are unaffected by P_{fill}.

5. Conclusions

The most important result is that the temperature, the density and the pinch radius as well as the relative contributions to the energy loss channels are very sensitive to the plasma temperature and density profile. Since these profiles are not known, nor their dependence upon I_p, P_{fill} and f_{ox}, this reveals a basic weakness of our present zero-dimensional model. It is therefore impossible to draw any conclusions about the scalings of the temperature and the density with e.g. I_p or P_{fill}. However, the code indicates some general results:

(i) The flatter the profiles are, the hotter the plasma gets.

(ii) The ion heat conduction is the dominant energy loss term for concentrations of oxygen impurities less than 2%, provided $a_n \approx a_t$.

(iii) The temperature is well above the radiation barrier for all realistic concentrations of oxygen impurities.

6. Acknowledgements

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Figure Captions

Fig.1. A cross section of the EXTRAP pinch, showing the vacuum vessel, the rods carrying the vacuum currents I_{0-3}, the plasma current I_p and magnetic field lines. The separatrix and its four null points are indicated as well as the radius of the vacuum wall, a_o, and the distance from the axis to the rods, ℓ_o. The major radius is denoted R.

Fig.2. The adopted profiles of the temperature and density.

Fig.3. Flow chart of the code.

Fig.4. <n>, <T> and a as a function of $a_t (\approx a_n)$. I_p=50 kA, P_{fill}=10 Pa, T_a=2 eV, $f_{ox}=5\times10^{-3}$, ℓ_o=0.71 m and a_o=0.15 m.

Fig.5. Relative contributions to the energy loss channels as a function of $a_t (\approx a_n)$. Same parameter values as in Fig.4.

Fig.6. <n>, <T> and a as a function of T_a. I_p =50kA, P_{fill}=10Pa, $a_n \approx a_t$=0.3, $f_{ox}=5\times10^{-3}$, ℓ_o=0.71m and a_o=0.15m.

Fig.7. Relative contributions to the energy loss channels as a function of T_a. Same parameter values as in Fig.6.

Fig.8. <n>, <T> and a as a function of f_{ox}. I_p =50kA, P_{fill}=10 Pa, $a_n \approx a_t$=0.3, T_a=2eV, ℓ_o=0.71m and a_o=0.15m.

Fig.9. Relative contributions of the energy loss channels as a function of f_{ox}. Same parameter values as in Fig.8.

Fig.10. <n>, <T> and a as a function of P_{fill}. I_p=50kA, $a_o \approx a_t$=0.3, $a_n \approx a_t$=0.3, T_a=2 eV, $f_{ox}=5\times10^{-3}$, ℓ_o=0.71m and a_o=0.15m.

Fig.11. <n>, <T> and a as a function of P_{fill}. I_p=50kA, $a_o \approx a_t$=0.3, T_a=2eV, $f_{ox}=5\times10^{-3}$, ℓ_o=0.71m and a_o=0.15m.

Fig.1

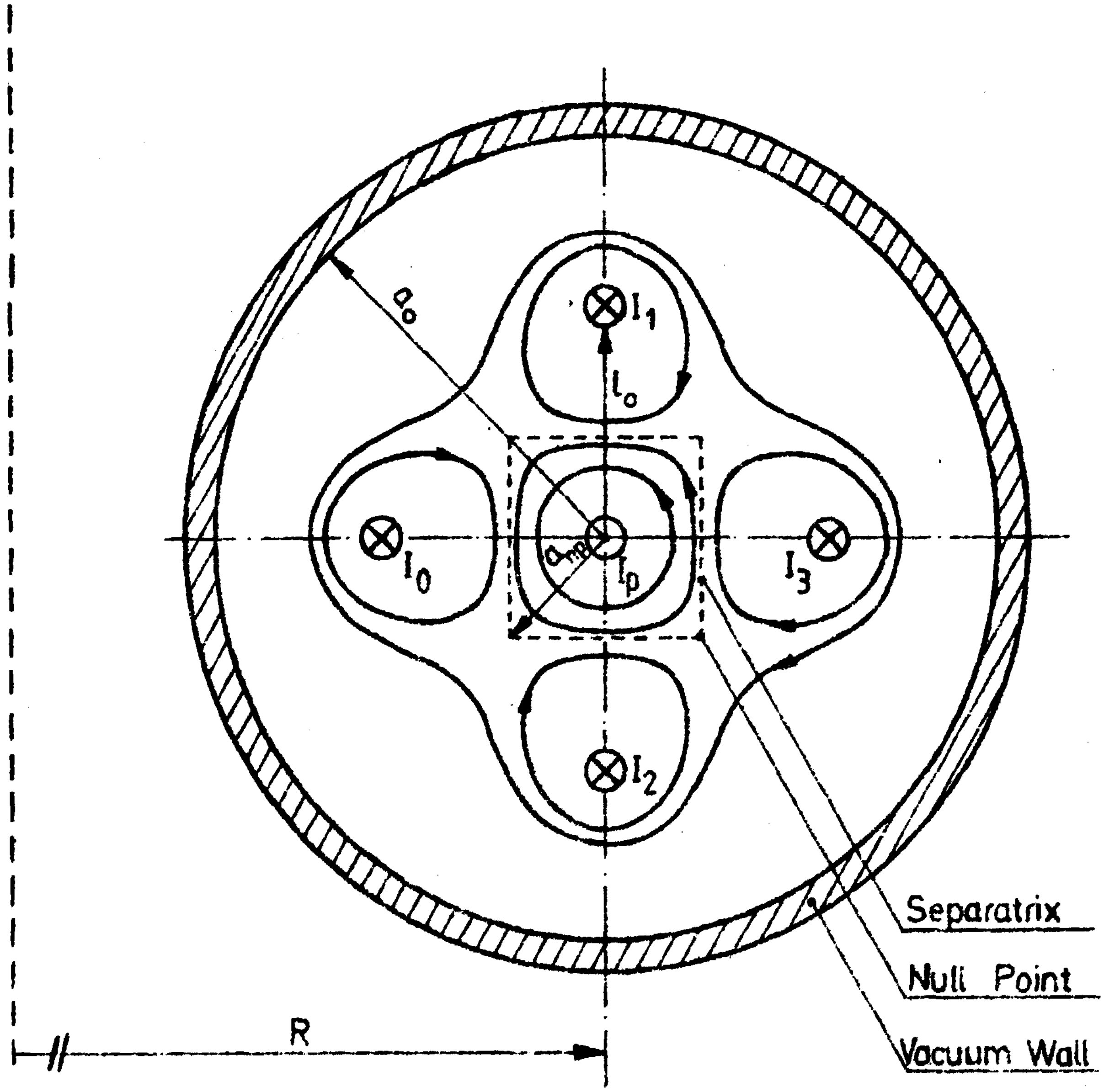


Fig. 2

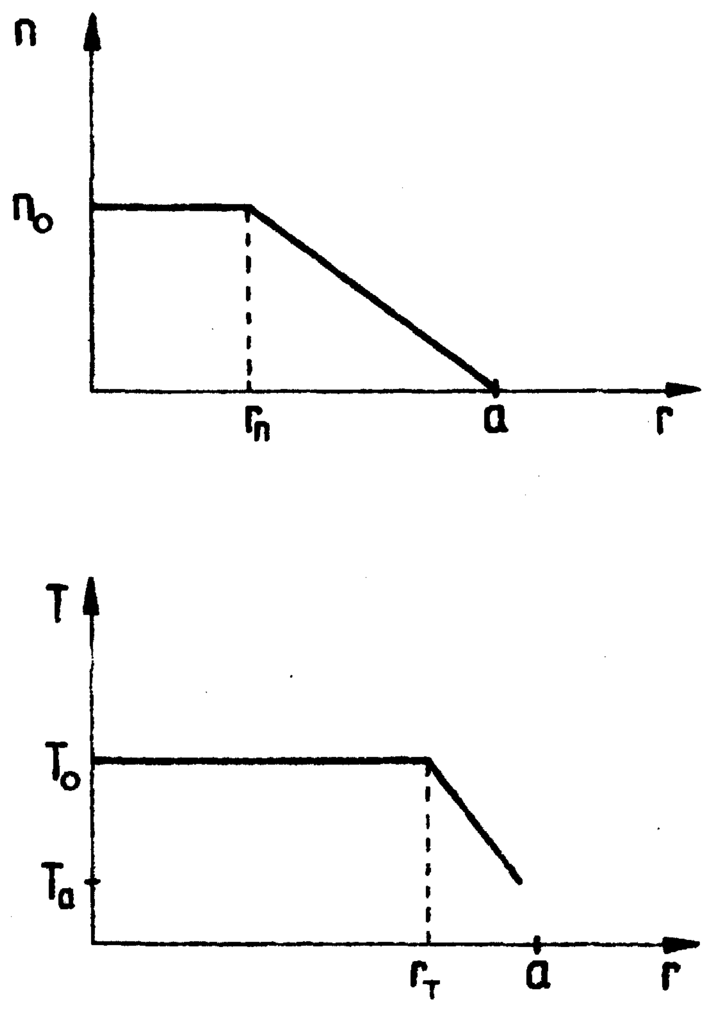


Fig. 3

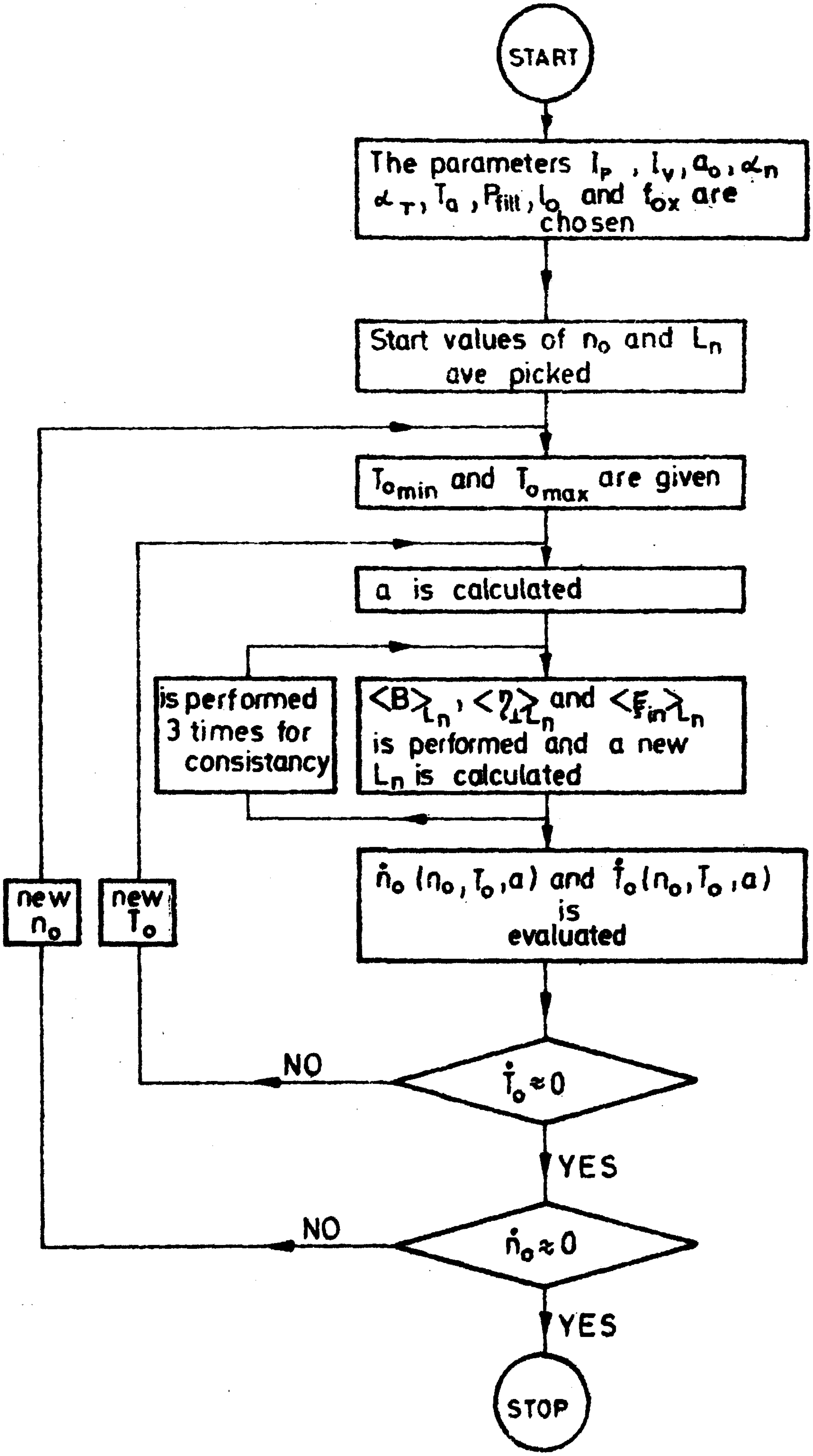
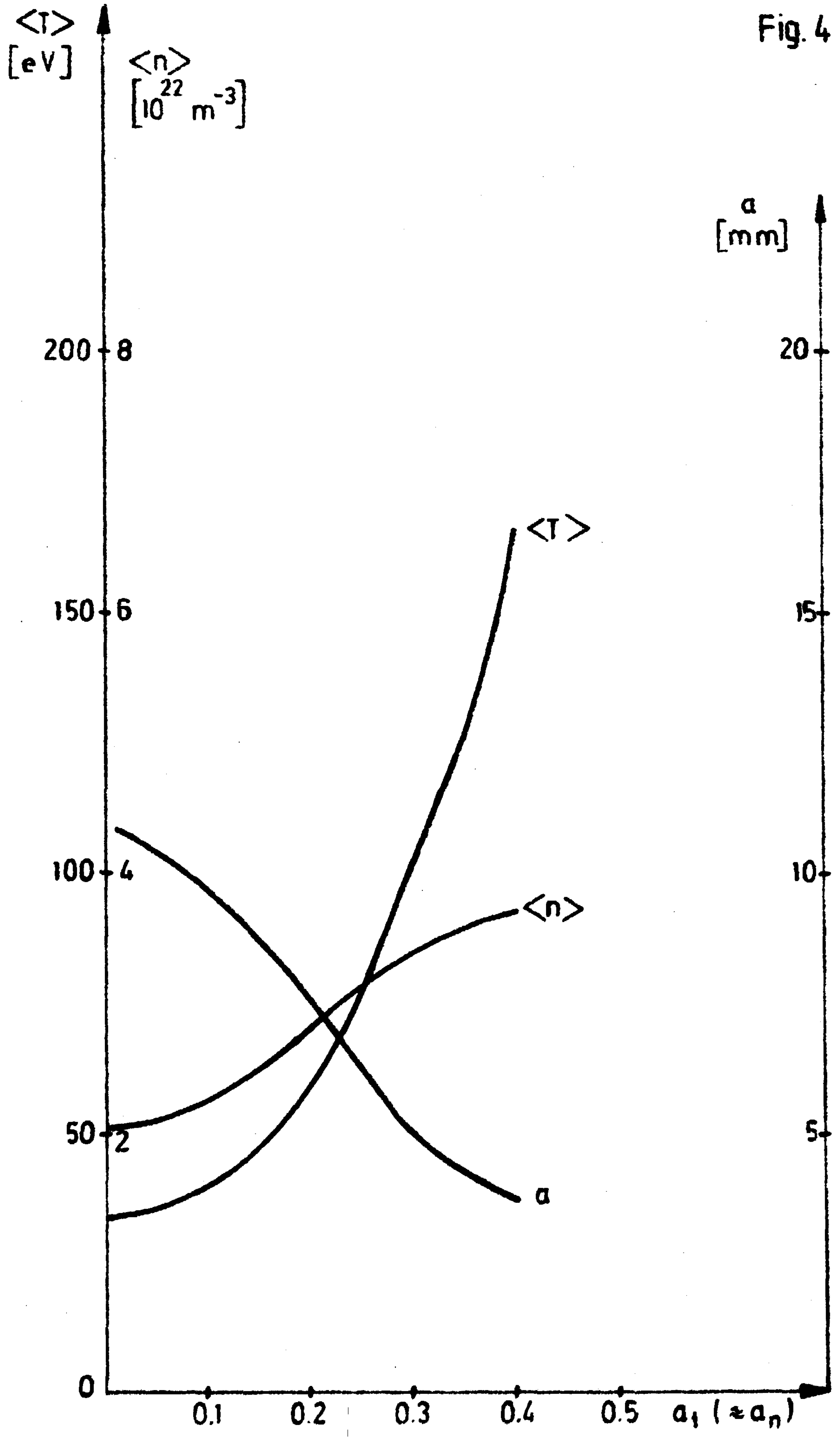
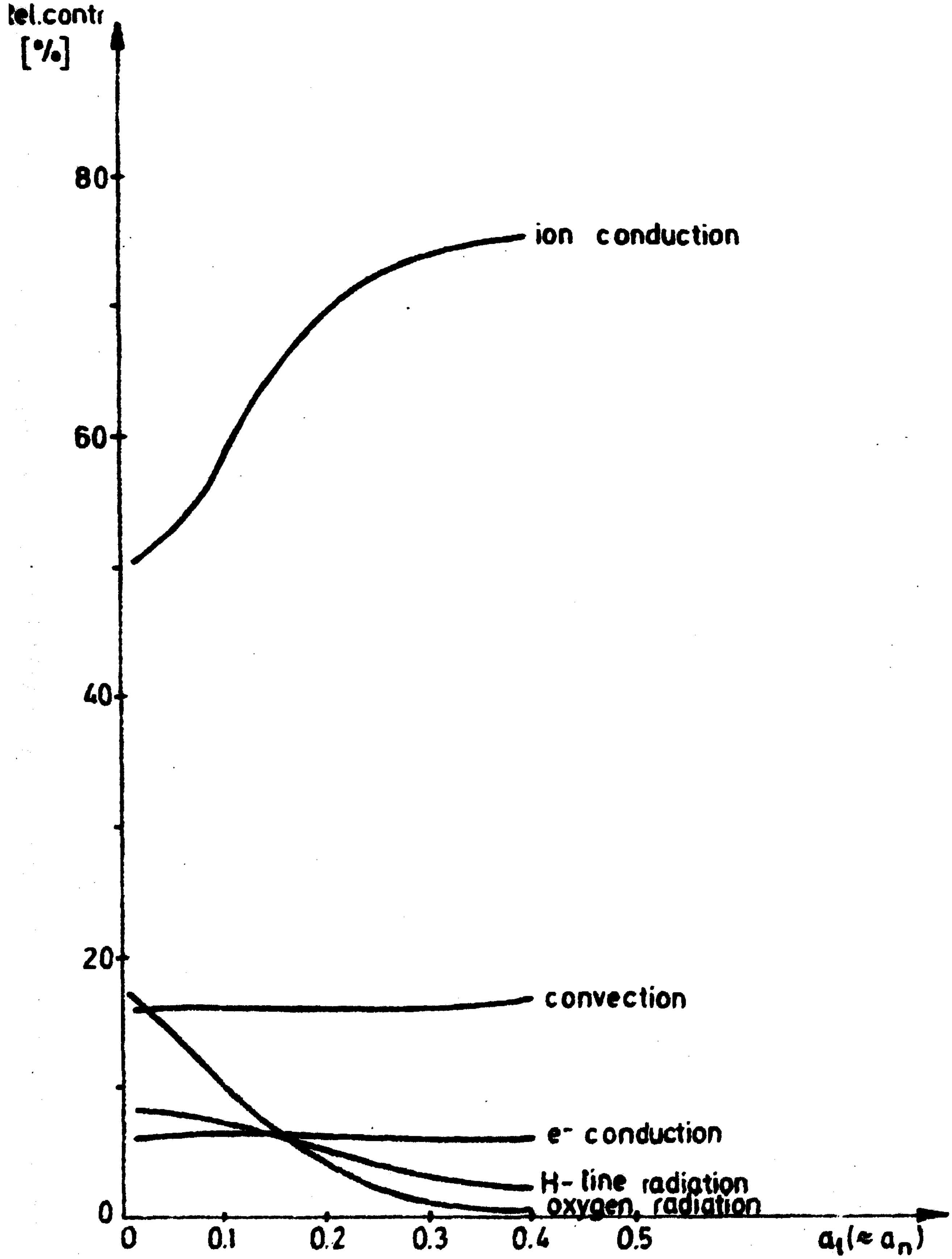

START
The parameters I_p, I_v, a_o, α_n, α_T, T_a, P_{fill}, I_o and f_{ox} are chosen
Start values of n_o and L_n ave picked
$T_{o_{min}}$ and $T_{o_{max}}$ are given
a is calculated
<B>$_{L_n}$, <$\eta_\perp$>$_{L_n}$ and <F_{in}>$_{L_n}$ is performed and a new L_n is calculated
is performed 3 times for consistancy
$\dot{n}_o(n_o, T_o, a)$ and $\dot{T}_o(n_o, T_o, a)$ is evaluated
new n_o
new T_o
$\dot{T}_o \approx 0$
NO
YES
$\dot{n}_o \approx 0$
NO
YES
STOP

Fig. 4



<T> [eV]
<n> [10^{22} m^{-3}]
a [mm]
200
150
100
50
0
8
6
4
2
20
15
10
5
<T>
<n>
a
0.1
0.2
0.3
0.4
0.5
a_t ($\approx a_n$)

Fig. 5



rel.contr
[%]
80
60
40
20
0
ion conduction
convection
e⁻ conduction
H-line radiation
oxygen radiation
0
0.1
0.2
0.3
0.4
0.5
$a_l (\approx a_n)$

Fig. 6

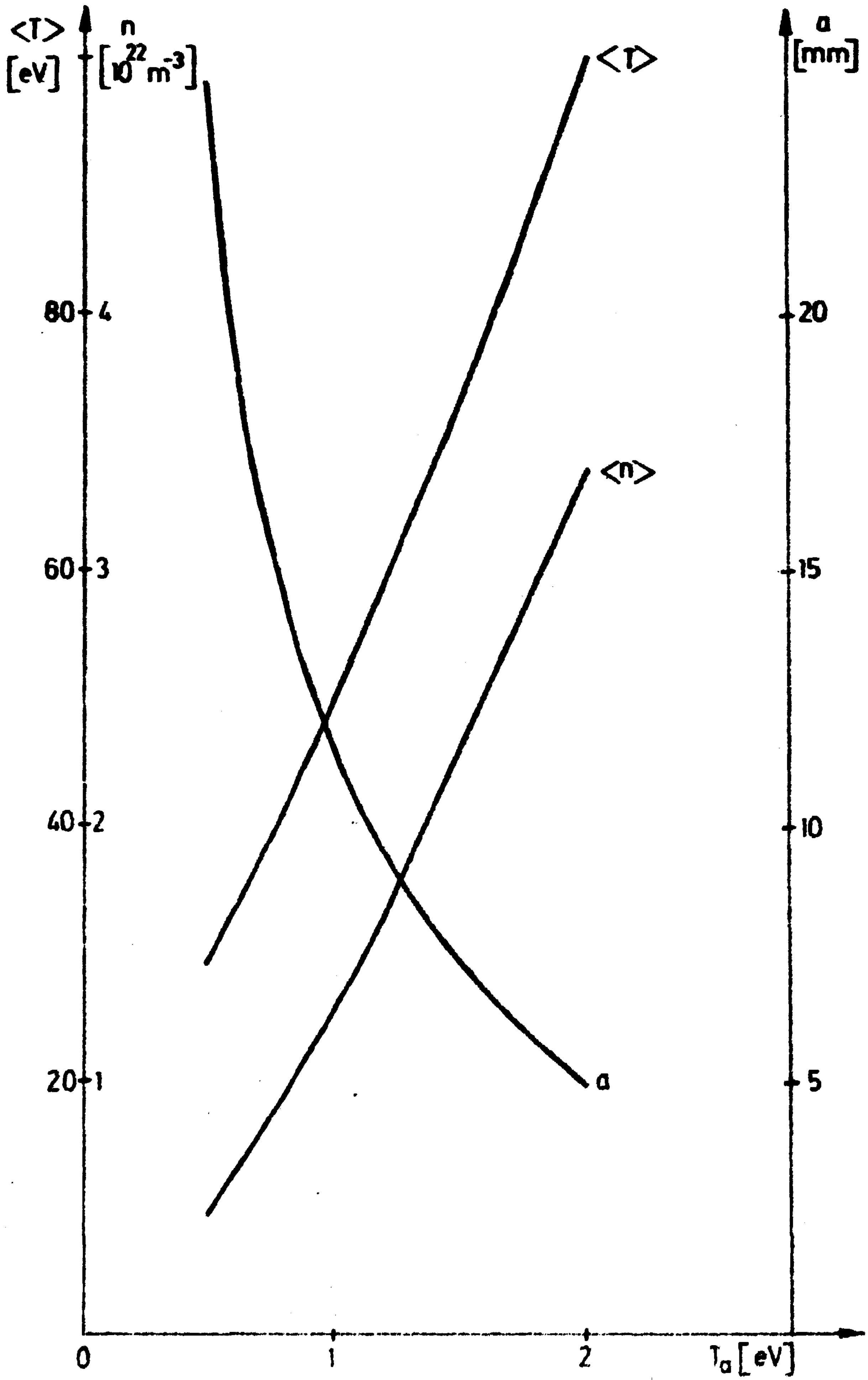
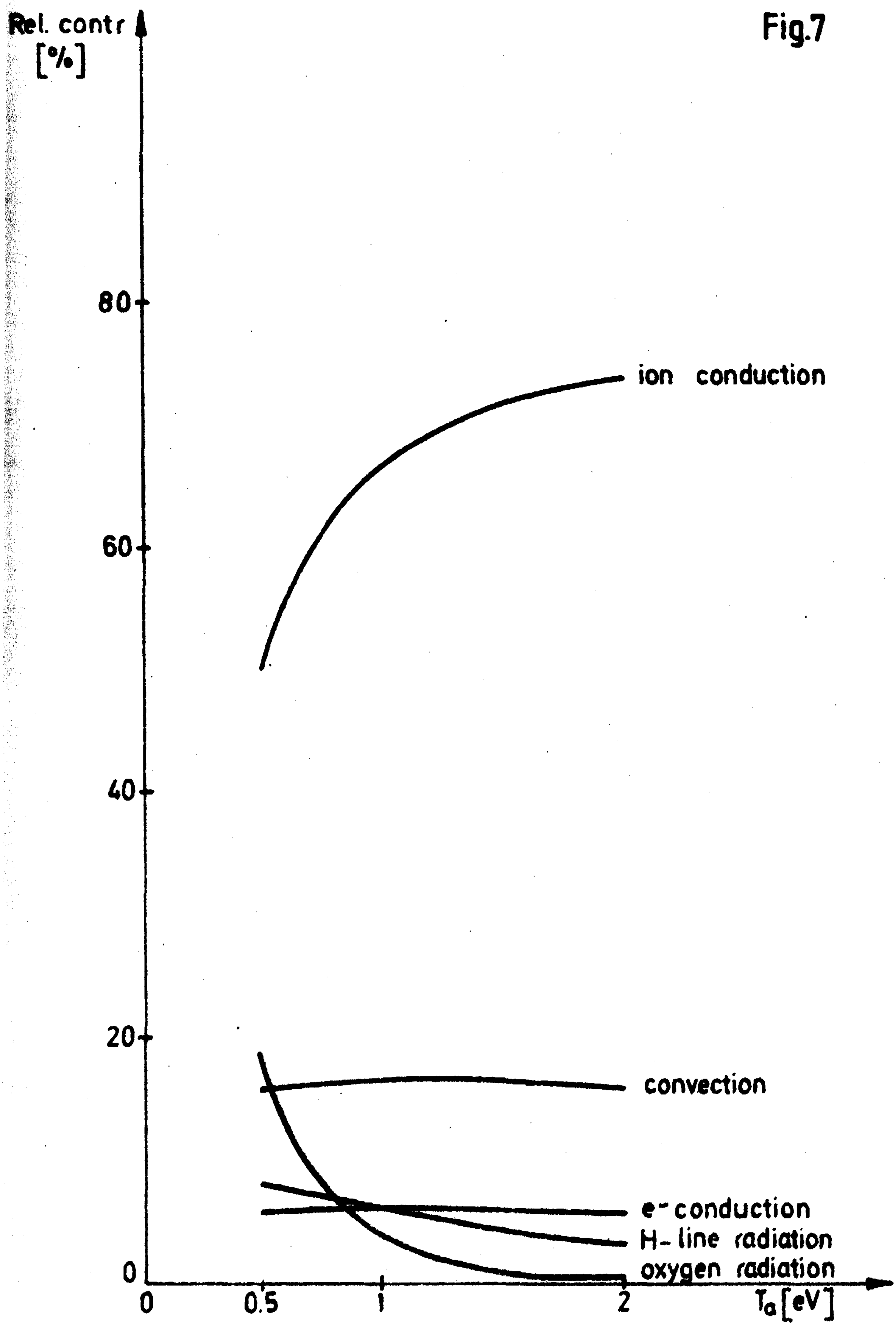


Fig.7



Rel. contr
[%]
80
60
40
20
0
0
0.5
1
2
T_a [eV]
ion conduction
convection
e⁻ conduction
H- line radiation
oxygen radiation

Fig. 8

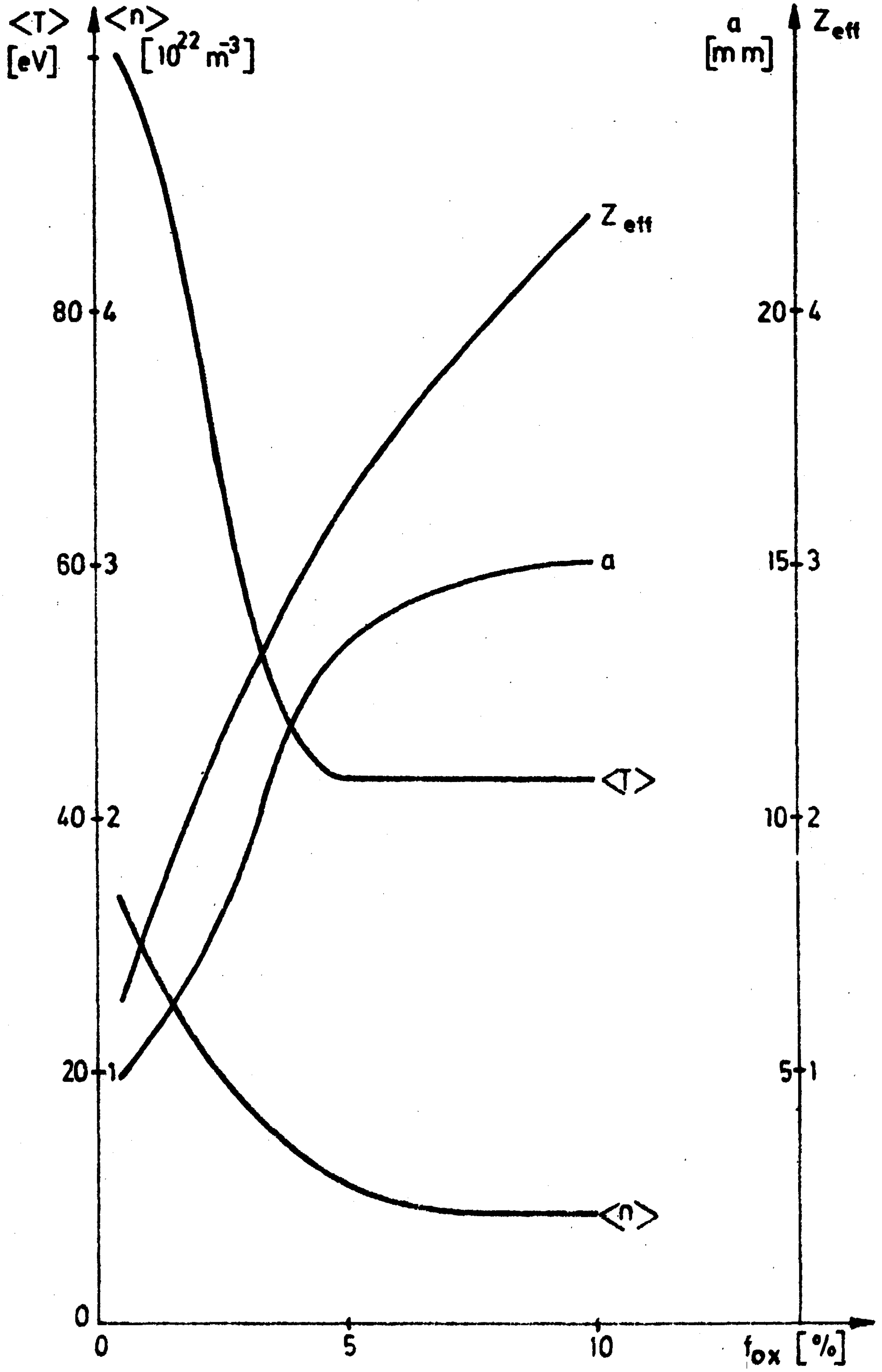

<T>
[eV]
<n>
[10^22 m^-3]
a
[mm]
Z_eff
80 4
60 3
40 2
20 1
0
20 4
15 3
10 2
5 1
Z_eff
a
<T>
<n>
0
5
10
f_ox [%]

Fig. 9

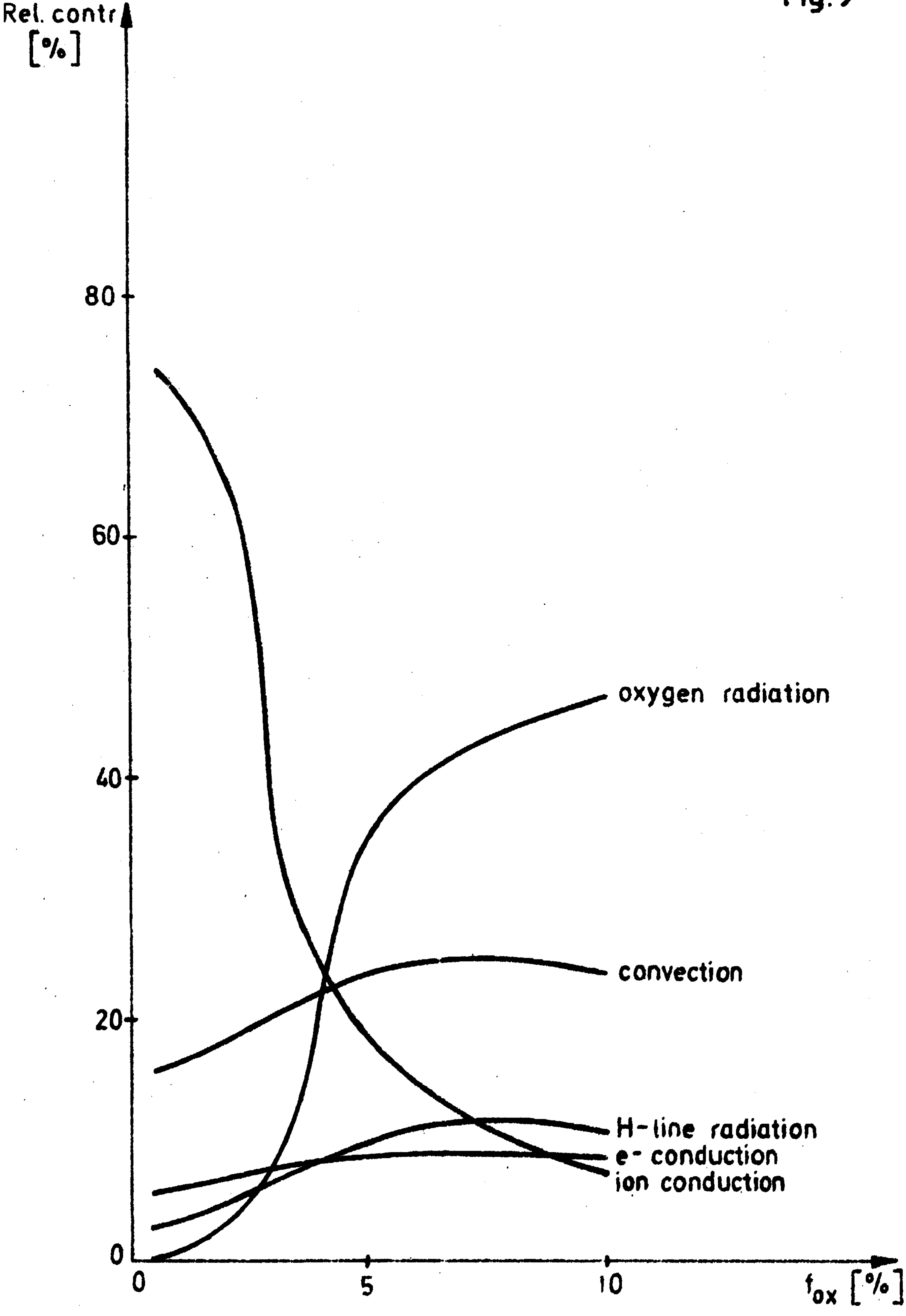
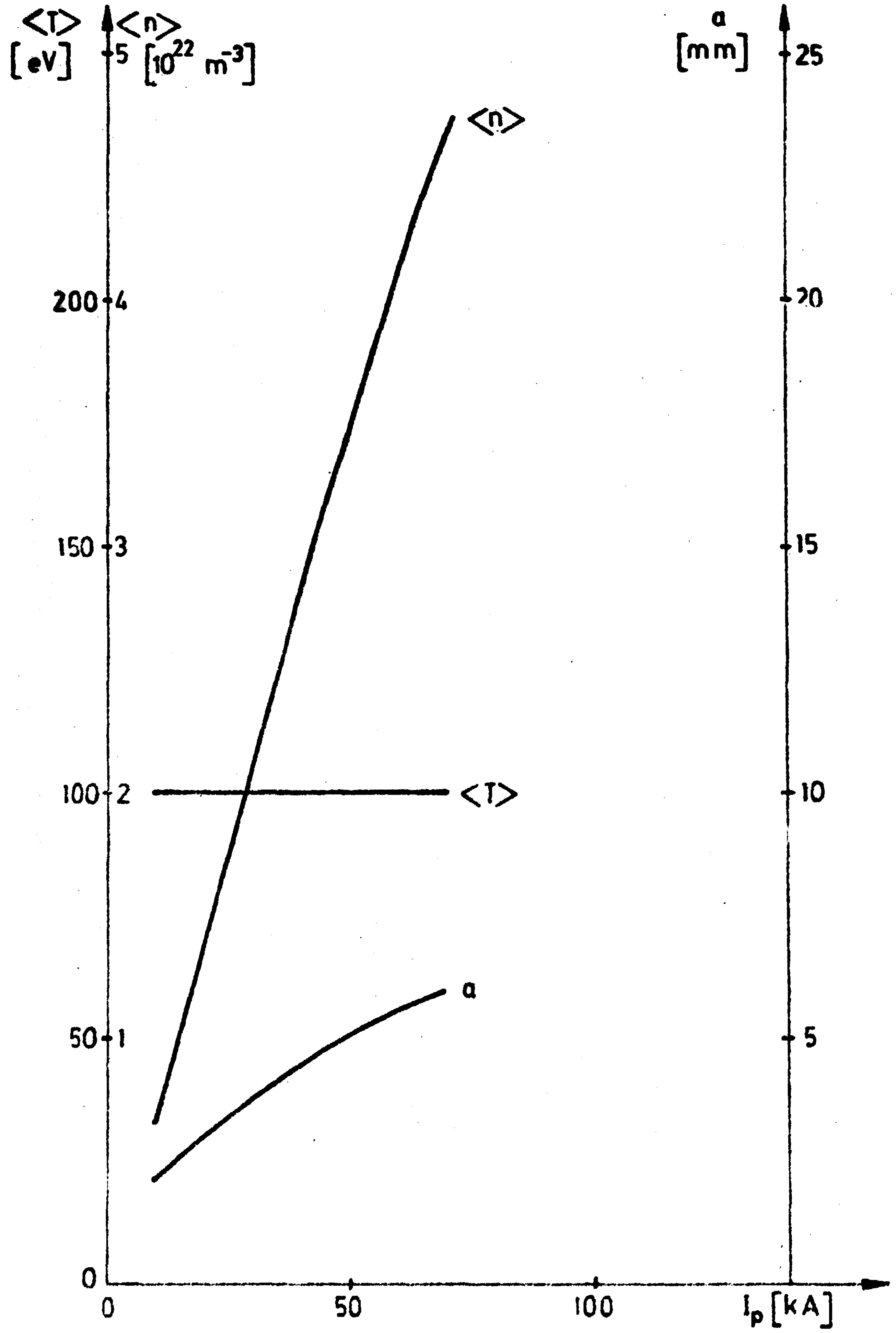
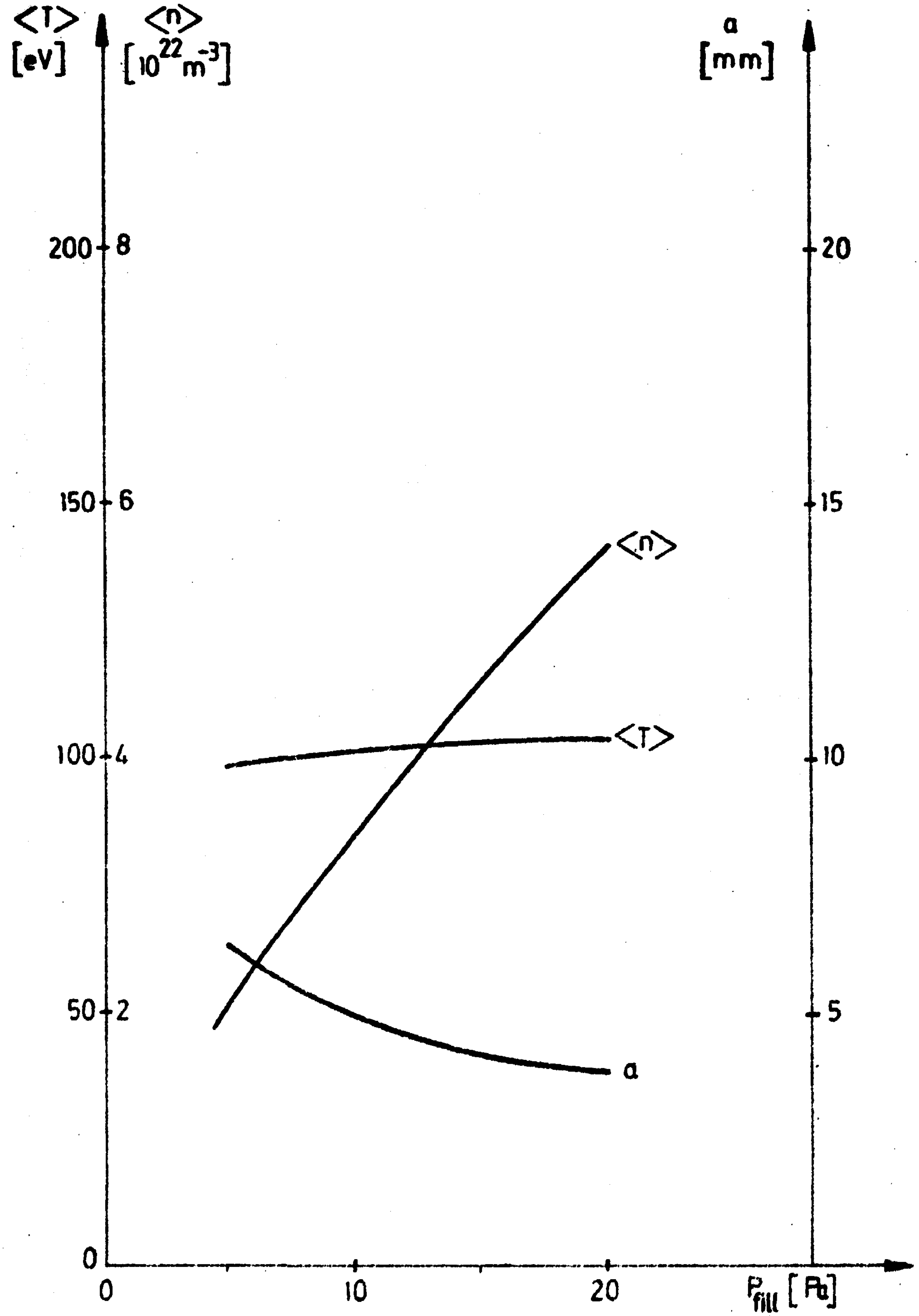

Rel. contr
[%]
80
60
40
20
0
0
5
10
f_{ox} [%]
oxygen radiation
convection
H-line radiation
e- conduction
ion conduction

Fig. 10



<T>
[eV]
<n>
[10^{22} m^{-3}]
a
[mm]
0
50
100
150
200
1
2
3
4
5
5
10
15
20
25
<n>
<T>
a
0
50
100
I_p [kA]

Fig.11



<T>
[eV]
<n>
[10^22 m^-3]
a
[mm]
200
8
20
150
6
15
100
4
10
50
2
5
0
0
10
20
<n>
<T>
a
P_fill [Pa]

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A ZERO-DIMENSIONAL EXTRAP COMPUTER CODE

P. Karlsson, October 1982, 18 p. in English

A zero-dimensional computer code has been designed for the EXTRAP experiment to predict the density and the temperature and their dependence upon parameters , such as the plasma current and the filling pressure of neutral gas. EXTRAP is a Z-pinch immersed in a vacuum octupole field and could be either linear or toroidal. In this code the density and temperature are assumed to be constant from the axis up to a breaking point from where they decrease linearly in the radial direction out to the plasma radius. All quantities, however, are averaged over the plasma volume thus giving the zero-dimensional character of the code. The particle,momentum and energy one-fluid equations are solved including the effects of the surrounding neutral gas and oxygen impurities. The code shows that the temperature and density are very sensitive to the shape of the plasma, flatter profiles giving higher temperatures and densities. The temperature, however, is not strongly affected for oxygen concentration less than 2% and is well above the radiation barrier even for higher concentrations.

Key words: Equilibrium, Z-pinch, computer code, EXTRAP configuration.