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FIRST RESULTS ON PETULA TOKAMAK

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ABSTRACT : Tokamak discharges of 40 to 65 kA have been achieved in the PETULA installation using a metallic liner. Measurements of $T_e(r,t)$, $n_e(r,t)$.. at 50 kA and 16 KGauss are reported.

INTRODUCTION. PETULA is a moderate size Tokamak designed for R.F. heating, especially T.T.M.P. heating. In order to get the penetration of the high frequency electromagnetic field inside the plasma, the vacuum vessel will be made of six identical alumina sectors, each of 30° arc length, connected to six observation and pumping ports by stainless steel belows. Six coils located between the copper shell and the alumina sectors will produce a 3% modulation of the toroïdal magnetic field. During the construction phase we decided to use the anticipated interval between the completion of the toroïdal field system and the alumina vacuum vessel to carry out some experiments with the usual metallic liner. Apart from the obvious aim of testing PETULA and its diagnostics these experiments allow us a reference for direct comparison with the existing Tokamak discharges and that which we will have with the alumina liner.

APPARATUS. Main dimensions of the torus are : Large radius 72 cm, maximum limiter radius 15 cm. Toroïdal magnetic field is produced by means of 24 bitter coils : its maximum value with existing rectifier is 16 KGauss which will be increased to 25 KGauss next year for the second phase of the experiment. Current is induced by discharging a capacitor bank into different sets of coils which are coupled to the plasma through a 0,5 Wb central transformer core with six return limbs. Coil configuration can be changed in order to vary vertical field. A 2 cm thick copper shell with about 50ms e-folding time is used to stabilize the plasma discharge. Its 23 cm radius was a compromise between desirable stabilizing effect and dissipation produced by the R.F. coils to be located inside. The whole machine is divided into six identical parts. Each part has a large horizontal port ($15 \times 45\ cm^2$) for diagnostics and pumping as well as smaller vertical ones, adjacent to a 0.5 mm thick stainless steel bellows.

EXPERIMENTAL RESULTS. As a standard Tokamak, PETULA has been in operation since February. After a few weeks it was found that the maximum current in stable regime was 65 kA, with a density of 3 $10^{13} cm^{-3}$ and 580 eV electron temperature. However most results were obtained at 50 kA with B_ϕ = 16 KGauss. Typical results are presented in Fig. 1 as a function of time. Radial profiles of n_e and T_e along a vertical line are given in fig. 2. Base pressure is in the range 1-5 10^{-8}Torr and hydrogen filling pressure is 8 10^{-4}Torr. Measurements of electron temperature, T_e, by Thomson scattering show that it increases to a maximum of 410 eV pretty well following the evolution of discharge current which reaches its peak of 50 kA at 30 msec whereas the density, n_e, peaks at 4.2 $10^{13} cm^{-3}$ at 40 msec. The radial profile for t > 10 msec shows neither skin effect nor pronounced peaking since at r = 12 cm, T_e > 100 eV. Magnetic probes and radial profiles measurements show a downward displacement due to toroïdal field errors which has now been corrected by a steady state radial field. Average density obtained by scattering is in good agreement with interferometric results at 2 mm. T_i by line broadening measurements of O_{VII} 1638 Å, N_V 1238.8 and C_{IV} 1548, show maxima of 180, 100 and 50 eV respectively. Radial profiles which will be so obtained are to be compared to T_i measured by charge exchange. Calculations based upon our measurements at maximum current show that $\bar{Z}_{eff}$ lies between 3.8 and 4.8 for arc voltages between 4 and 5 volts, β poloïdal is 0.4, and the energy confinement time is 1.6 msec.

NUMERICAL SIMULATION. Using the numerical code developped at Fontenay-aux-Roses by Mercier, Soubbarameyer and Boujot, a first attempt has given a correct simulation of the time evolution of the mean electron density and T_e, T_i on the axis (fig. 1). The energy confinement time is then about 1 ms and β poloïdal between 0.25 and 0.30. These results have been obtained assuming ions in the plateau regime and setting the electron thermal conductivity in the Pfirsch-Schlüter one but increased by a factor 2000. This factor was moreover enhanced in the central part of the plasma to take into account induced turbulence when q is less than unity.

This work will be completed in order to get a better simulation of the T_e radial profile which is presently more peaked than the experimental one thus explaining the low computed value of β poloïdal.

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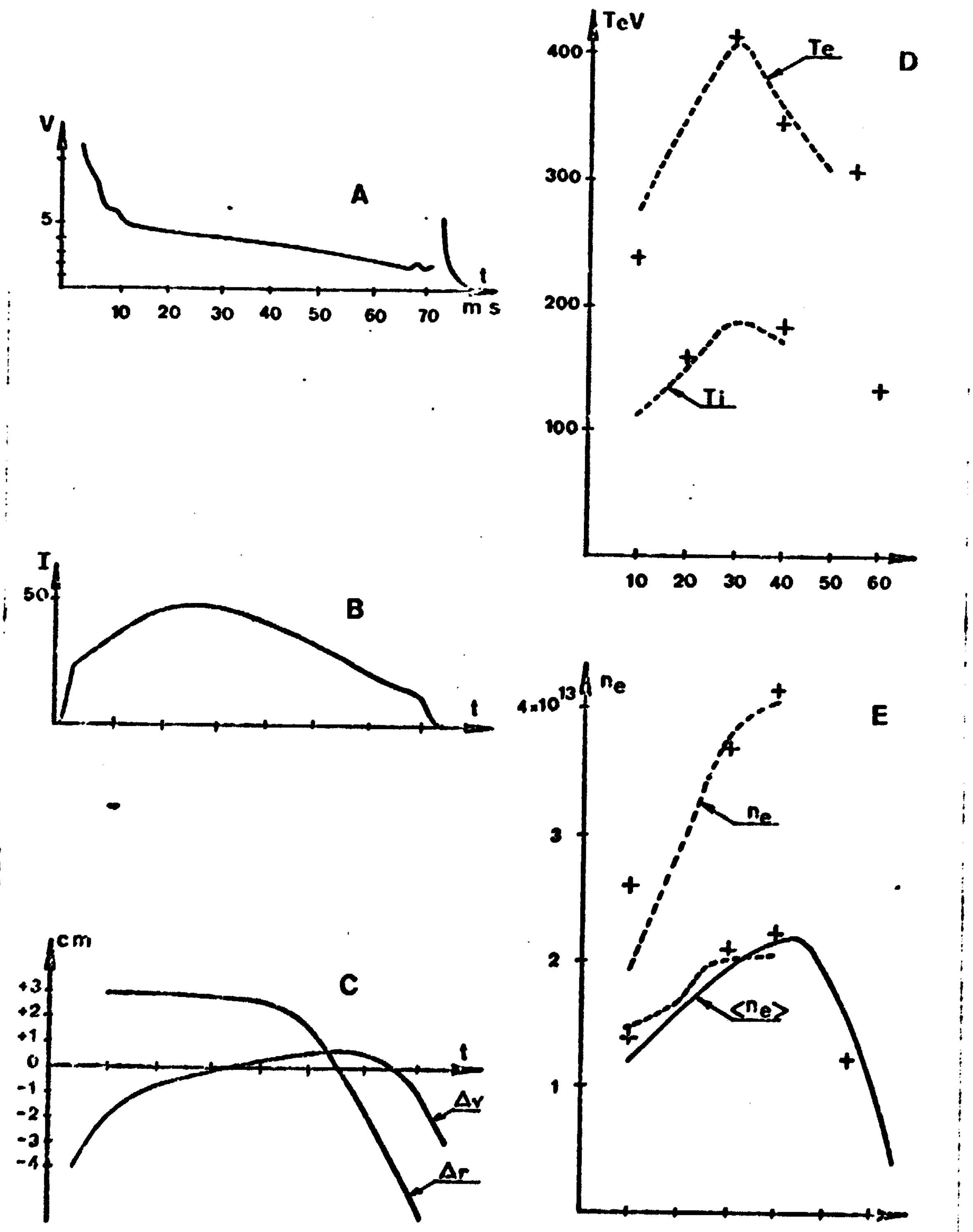

Fig. 1 - A typical 50 kA discharge ; A) loop voltage, B) plasma current, C) radial and vertical displacement, D) electron and ion temperature : + experimental results (Thomson scattering and Doppler broadening of O_{VII} line), E) peak and average electron densities + Thomson scattering results ; solid line : 2 mm interferometry.

On d and e, dashed line are discharge simulation results.

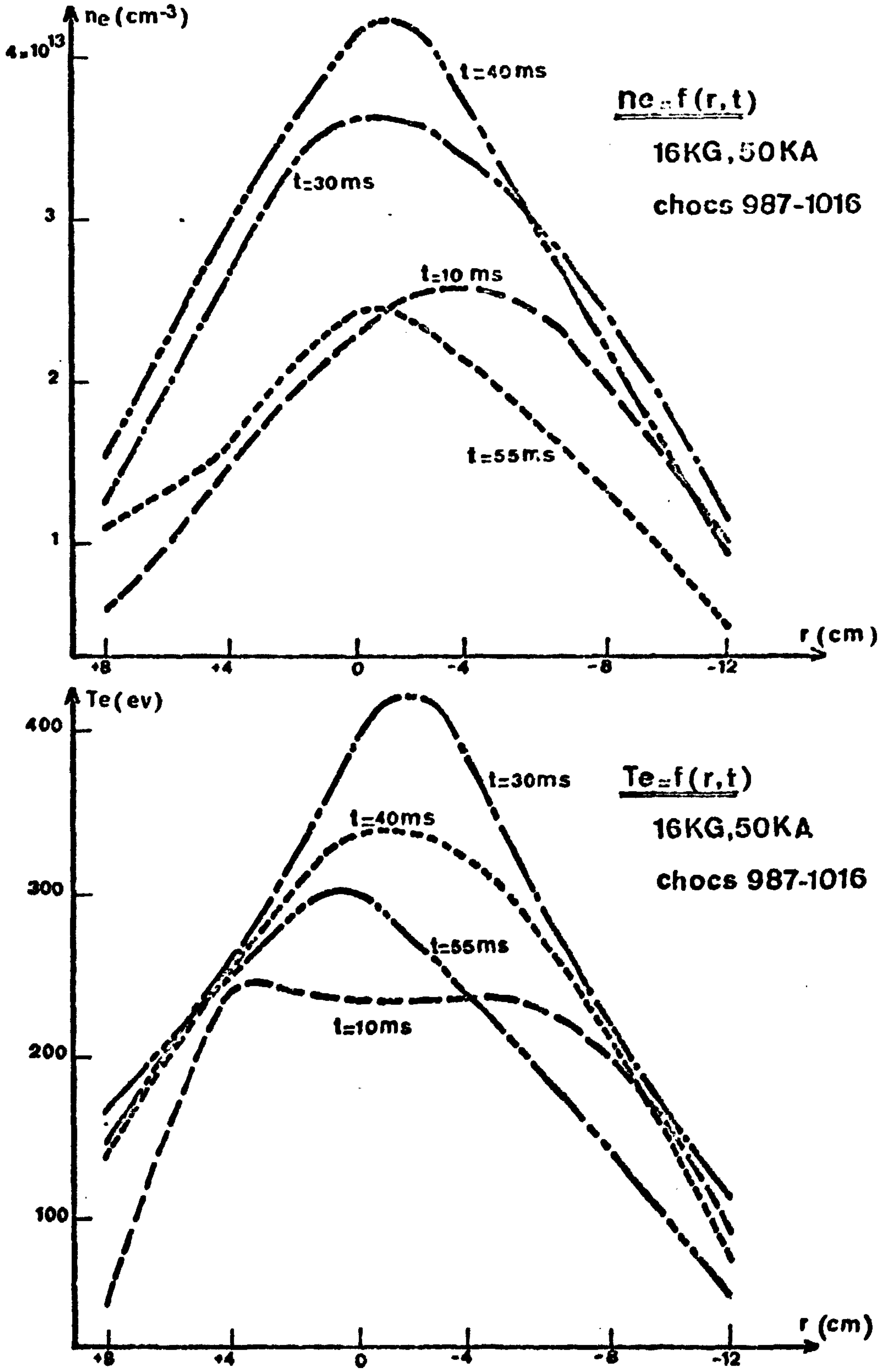

Fig. 2 - Radial profiles of electron temperature and density along a vertical chord at R = 72 cm.

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The plasma current in PETULA has been increased to 80 kAmps. ($q_{limiter}$ = 3.1) with the plasma centered by vertical and radial DC magnetic fields. Fig. 1 to 3 show typical results for 73 kAmps. discharges, as well as a numerical simulation of the discharge using the Mercier Soubbarameyer code. The best fit is obtained when neglecting charge exchange (radial density profils has of course to be entered into the data) and when increasing electron losses on axis as soon as q = 1 at 20 ms. The largest discrepancy is on loop voltage which is found experimentally to vary from 3 to 5 volts as the time of maximum current depending on wall conditions. Plasma resistivity tends to increase with shot number. Energy confinent time is in the range 1.4 to 2.ms and poloïdal β is.25 while the ratio of plasma resistivity to Spitzer's formula is 4.5.

Ion temperature on axis (Fig. 4) as measured by neutral charge exchange (solid line) or by Doppler broadening of O^{VII} line (broken line) are in good agreement with Artsimovitch law (points).

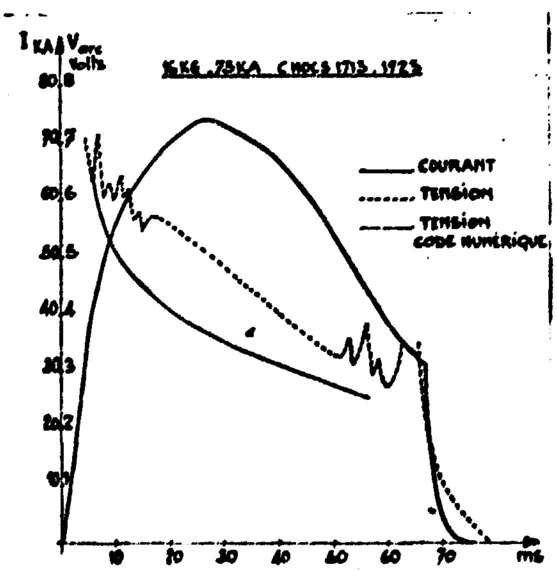

Fig. 1

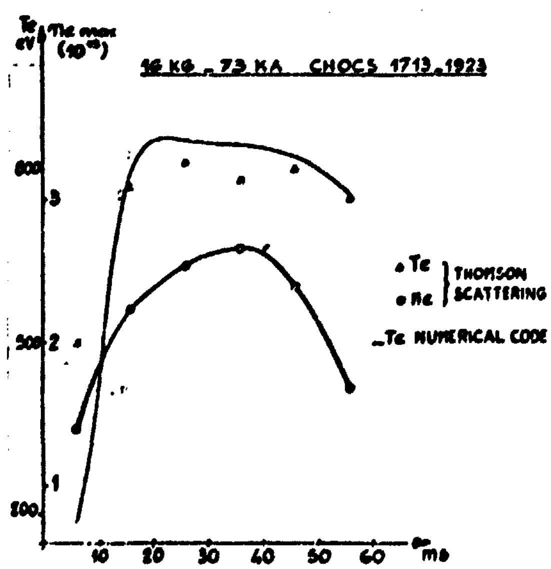

Fig. 2

Fig. 5 shows intensity of 1623 Å O^{VII} line in arbitrary units as a function of time for three plasma currents. Due to the faster increase in electron temperature, the line appears sooner the higher the plasma current. The maximum intensity remains constant which indicates a constant amount of oxygen impurity.

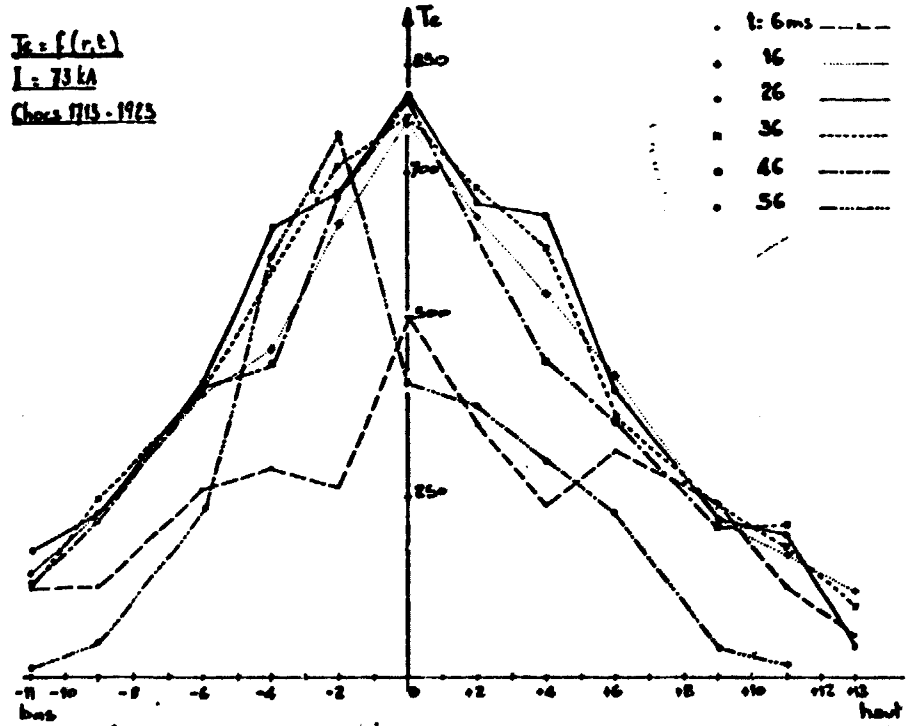

Fig. 3

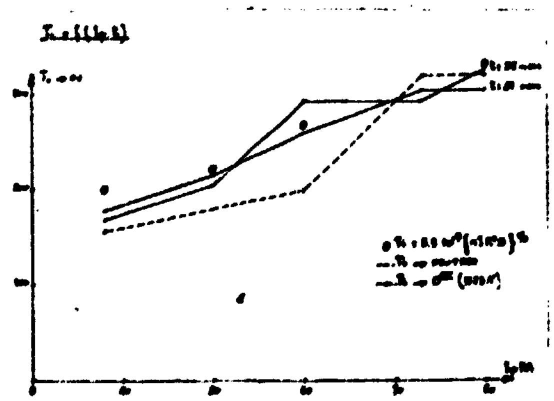

Fig. 4

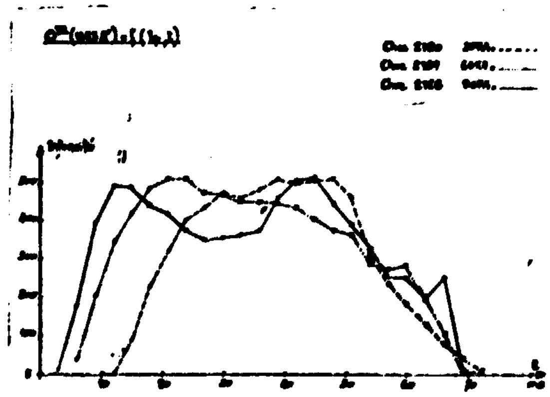

Fig. 5

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