Statistical Distribution of High Density Discharges in the Pulsator Tokamak[+]

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Abstract

The experimental data reported indicate that even the small variations, from shot to shot, of the gas influx due to wall recycling lead to a deviation from the programmed discharge conditions and hence to disruption.

High density discharges of long duration are obtained in Pulsator by tentatively programming the compensating vertical magnetic field for a given set of discharge parameters, e.g. $B\varphi = 27$ kG; $q(a_L) = 3.5$; $I = 65$ kA; $\Delta \bar{N}e_{max} > 10^{14}cm^{-3}$.

In Fig.1a) a statistical display of about one thousand shots shows that the bulk of the discharges is focused to density increments $\Delta\bar{N}e$ of over $10^{14}cm^{-3}$ for discharge durations $t = 40$ ms + Δt. In Fig.1 Δt represents the time interval between the start of the pulsed gas and the current disruption. The curves labeled Δt were deduced experimentally. The density measurements were made by means of a 7-channel $\lambda = 2$ mm interferometer. The wave beams irradiate the plasma vertically and are symmetrically displaced to the centre of the discharge tube.

The following limitations of the discharges are apparent in Fig.1. There is a maximum value of the density increase $\Delta\bar{N}e_{max} \approx 1.2 - 1.3 \times 10^{14}cm^{-3}$ which cannot be exceeded either by increasing or by decreasing the gas flow rate to about the optimum values corresponding in Fig.1 to $2 < \Delta\bar{N}e/\Delta t < 3.5 \times 10^{12}cm^{-3}ms^{-1}$, where $\Delta\bar{N}e/\Delta t$ gives the mean value of the rate of density increase measured during the first 20 ms after the additional gas inflow.

For a given $\Delta\bar{N}e/\Delta t$ the maximum discharge duration is obtained by programming the stabilizing field, but a few per cent variation of $\Delta\bar{N}e/\Delta t$, shortly after the additional pulsed gas, is enough the destroy the discharge at shorter times than the optimum duration. A series of pulse cleaning resets the optimum discharge conditions as, for example, for shot 10598, whose density distribution is shown in Fig.1b) up to $\Delta t = 50$ ms. The onset of the disruption for this shot is at $\Delta t > 60$ ms, for a total discharge duration of $t > 120$ ms. In Fig.2, shot 10596 shows that a reduction of a few per cent from the programmed optimum value of the density increase, which may be due to a reduction of the gas recycling from the walls, leads to disruption at $\Delta t = 20$ ms. Conversely, an <u>increment</u> of about the previous amount of the programmed density increase can be supported for a larger duration than in the former case, as shown in Fig.2 by shot 10597, $\Delta t = 40$ ms, the density profile of which, not Abel-inverted, shows a growing off-centering tendency. In the latter case of the $\Delta \bar{N}e/\Delta t$ increment, the increasing energy associated with the slightly off-centering growth of the density may cause a strong interaction with the outer limiter wall at high values of $\Delta \bar{N}e$, thus leading to the observed disruption. The density increases with a sawtooth-like relaxation, as shown in Fig.3 for shots 10597 and 10598. The sawtooth period increases from 2 to 4 ms, and its amplitude reaches a value of about 3 to 5 per cent of the total density upon the onset of disruption. The above observations may suggest that the sawtooth density relaxation, which is associated with the observed $m = 0$, $n = 0$ mode-like behavior of the current distribution, /1//2/, may be excited by a periodic scraping of the off-centered discharge against the limiter. This may also explain the strong increase of the amplitude of the sawtooth oscillations with $\bar{N}e$ /2/, instead of being stabilized by both the flattening of the Te profile and the increasing density.

This "excitation" mechanism is also supported by the density distribution of the optimum discharge 10598, Fig.1b and Fig.3, which is also slightly off-centered and exhibits the same sawtooth density relaxation as shot 10597. In the first case of <u>reduction</u> of $\Delta \bar{N}e/\Delta t$ from the programmed value, as seen for shot 10596 in Fig.2, the sawtooth relaxation cannot reach a detectable amplitude owing to the early disruption, which presumably occurs owing to the slightly higher value of the preset compensating magnetic field, which pushes the plasma toward the inside wall of the limiter.

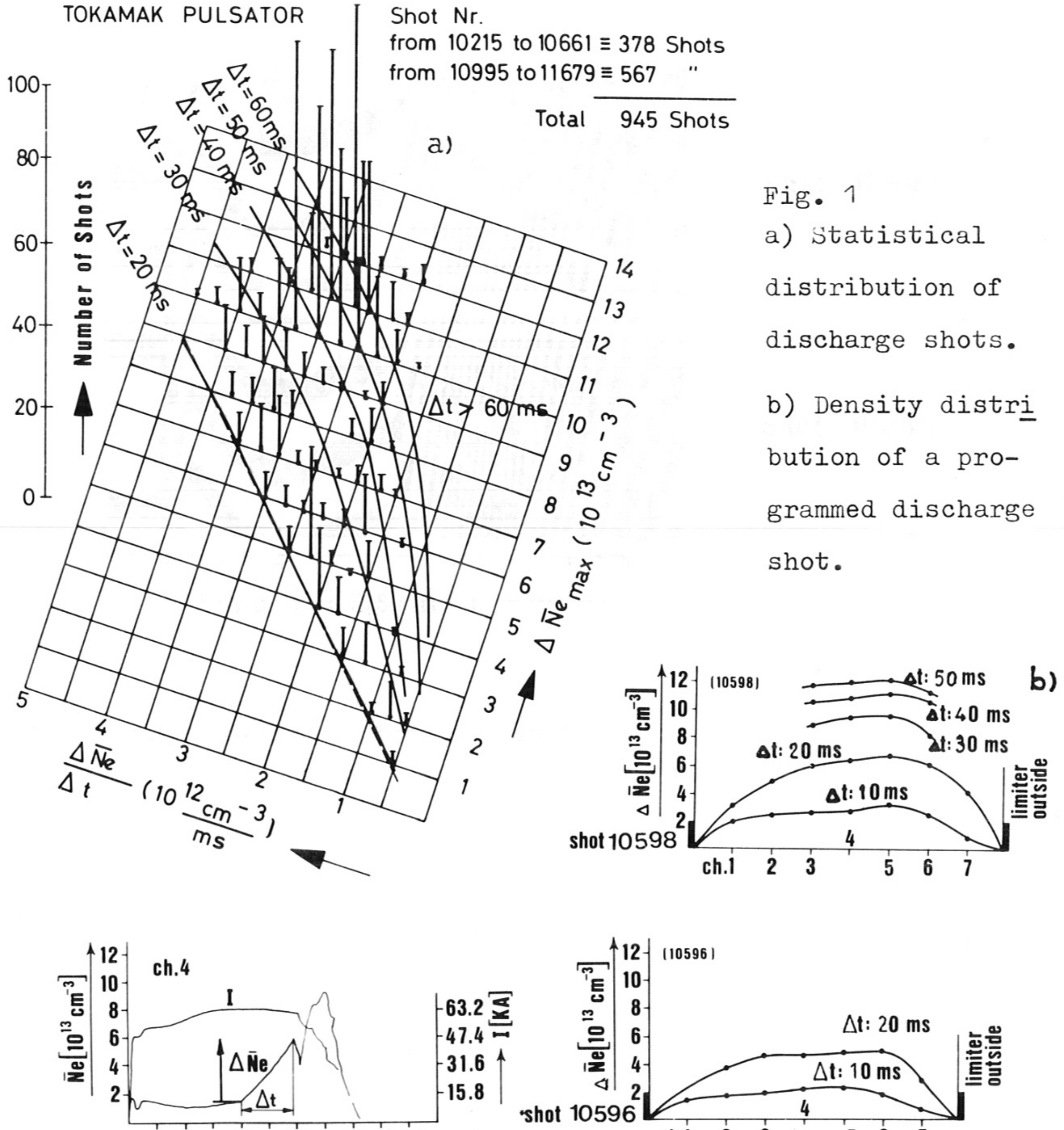

Fig. 1

a) Statistical distribution of discharge shots.

b) Density distribution of a programmed discharge shot.

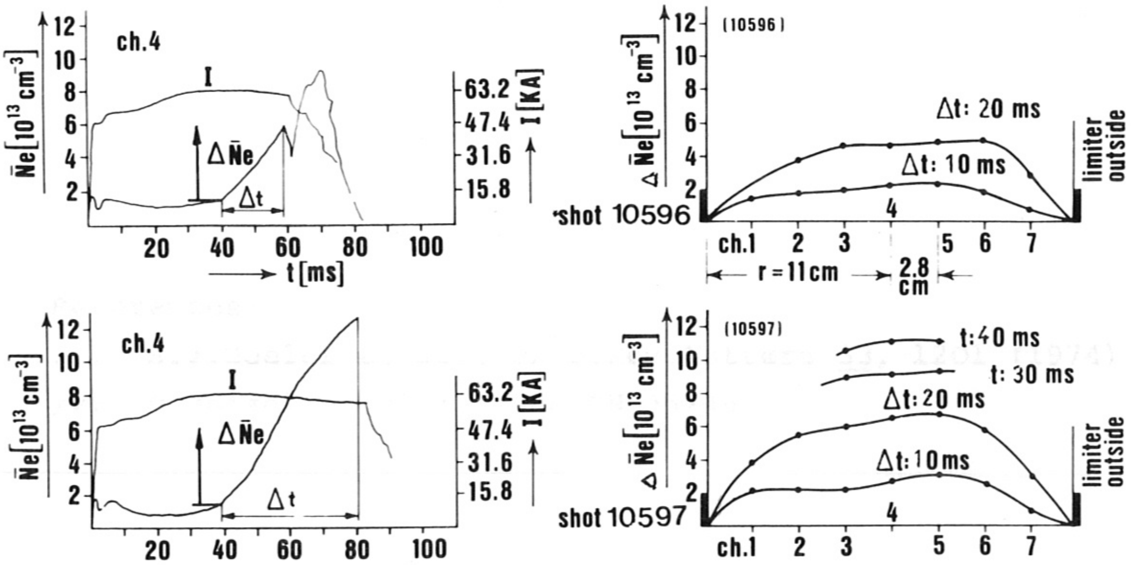

Fig. 2: Current disruption and density distribution

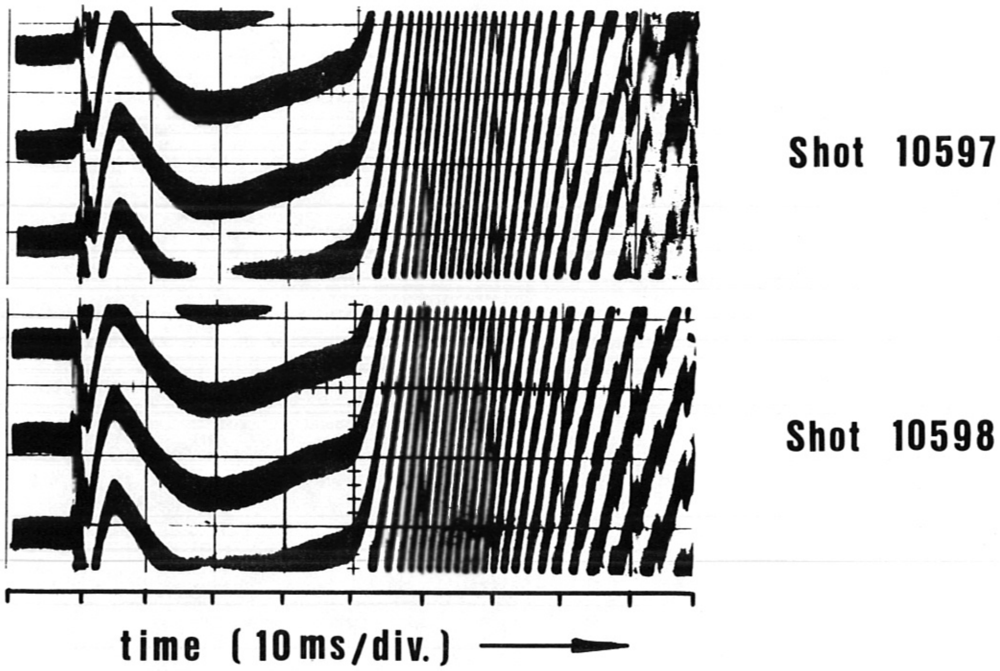

Fig.3: Sawtooth density fluctuations

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