OBSERVATION OF NEUTRON AND X-RAY SAWTEETH IN ALCATOR

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ABSTRACT

Sawtooth oscillations in the thermonuclear neutron production rate have been observed in Alcator. They are correlated with oscillations in soft x-ray emission from the plasma and indicate large (>15%) oscillations of central ion temperature.

Soft x-ray emission from the Alcator plasma has been observed using a multi-diode imaging apparatus built by Petrasco et al [1]. The x-ray flux exhibits the characteristic sawtooth behavior first noted by Von Goeler [2]. In addition, similar fluctuations have now been seen in the emission of D-D fusion neutrons (Figure 1). The strong temporal correlation between these two diagnostic signals indicates that similar processes affect both the electron and ion temperatures during the internal disruption. This would follow if present theories of the disruption process are correct [3, 4].

The rapid growth of magnetic islands from the q=1 surface and reconnection of magnetic field lines is a process which should affect both the electron and ion radial temperature profiles. We have developed a quantitative picture by fitting temperature profiles to the experimental data and studying the effects of the disruptions on the calculated x-ray and neutron emission.

Prior to the internal disruption, the temperature profiles are approximated by Gaussian functions [5]. The peak electron temperature is determined by matching the measured x-ray flux with that calculated using a computer code developed here [6]. The code takes into account the specialized geometry of the detectors and aperture, the transmission effects
of various x-ray filters, and the assumed density, temperature, and impurity-profiles. The electron temperature calculated by this method is in excellent agreement with temperatures determined by Thompson scattering [7].

Immediately after the disruption, it is assumed that the temperature profile becomes flattened in the central section of the plasma while remaining constant elsewhere (Figure 2). By requiring conservation of total energy (both kinetic and magnetic) during the internal disruption, we can relate the radius of flattening to the temperature of the flattened region, thus leaving only one independent parameter to vary. This parameter was determined by again matching the measured x-ray signal with the computer model.

In a disruption, we theorize that the ion temperature profile is perturbed in essentially the same manner as the electron temperature profile. Previous experimental measurements [8] indicate that the ion temperature in Alcator is lower than the electron temperature by an amount which is related to the ion-electron thermal equilibration time. Therefore, prior to the disruption, the ion profile is assumed to be Gaussian but with a peak temperature 70 eV below the electron central temperature. During the disruption it is postulated that the ion profile flattens out to the same radius as the electron profile. Since the time scale for this process is so short (<20 usec), the electron-ion energy transfer can be neglected; therefore, energy conservation requires that the ion temperature drop be about the same as the electron drop, or approximately 130 eV for the discharge in Figure 1. Given these temperature profiles, the change in the neutron production rate was calculated and was found to agree with that which is observed.

Additionally, the fitted electron temperature profiles were used to calculate the current density immediately before and after the internal

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1The neutron signal is averaged with a time constant of 0.5 msec, resulting in the apparent difference in the shape of the neutron and x-ray sawteeth.
disruption. The resulting current density profiles (which are quite flat in the central region due to inductive effects) were then used to determine safety factor profiles, \( q(r) \) (Figure 3). The results are in good agreement with theory.

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REFERENCES


FIGURE 1

SHOT 21 3/9/78
N₀ = 7 X 10¹⁴ / CM³
I₀ = 155 KA
B = 60 KG

X-RAYS  NEUTRONS

0 25 50 75 100 125 150 175 200  MSECF

X-RAYS  NEUTRONS

105 110 115 120 125 130  MSECF
FIGURE 2

PROFILES FITTED TO SAWTOOTH DISRUPTION AT 115 MSEC

PRIOR TO DISRUPTION

AFTER DISRUPTION

EXPERIMENT

CALCULATED

CHANGE IN X-RAY SIGNAL

DETECTOR CHORD INTERCEPT (CM)