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NEUTRONS FROM A θ PINCH WITHOUT REVERSED TRAPPED FIELD

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In several theta-pinch experiments[1-5] a strong correlation has been found between the neutron yield in a deuterium plasma and the presence of reversed trapped field, and it has been concluded that such trapped fields are essential to the neutron production mechanism.[2] Los Alamos[3] has reported a small yield under conditions of zero trapped B_z and 85 μ Hg initial pressure, but attributed this yield to trapped B_θ from the axial current of the preheater. The present experiments show that very large yields, up to 10^8 neutrons, can be produced at low pressures without any reversed trapped field and when B_θ is insignificant.

The apparatus[6] consists of a single-turn coil 36 cm long, 19.8 cm i.d. at the center plane, with a geometrical mirror ratio of 1.4:1, connected to a 213-μF, 60-kV capacitor bank. The peak magnetic field was 60 kG, maximum $\dot{B}$ 14 kG/μsec and half period 13.8 μsec. The discharge tube, which is made of alumina 75 cm long and 12.6 cm i.d., is terminated by metal pipes which serve as electrodes for a preheat axial discharge.

The neutrons were emitted during the first half-cycle of the main bank so there was no possibility of any reversed field being present. Axial probe measurements showed that the preheat raised the electron temperature sufficiently to prevent diffusion of parallel field when the main bank was fired; the parallel trapped field in the first 2 μsec was less than 2% of the external field (the minimum detectable). The probe showed the usual external field penetration after 2 μsec, when streak photography showed evaporation from the probe. No neutrons were observed with the probe in place.

The preheat produced a peak current of 20 kA from a 5-μF, 20-kV capacitor; this corresponded to a peak B_θ at the discharge surface of 700 gauss. However, to minimize the B_θ at the time the main bank was fired, the preheat capacitor was shorted at the end of the first current half-cycle (see Fig. 1). The main bank was then fired 30 μsec later under conditions of nearly zero axial current when the measured B_θ at the discharge surface was only 3 gauss. This is negligible compared

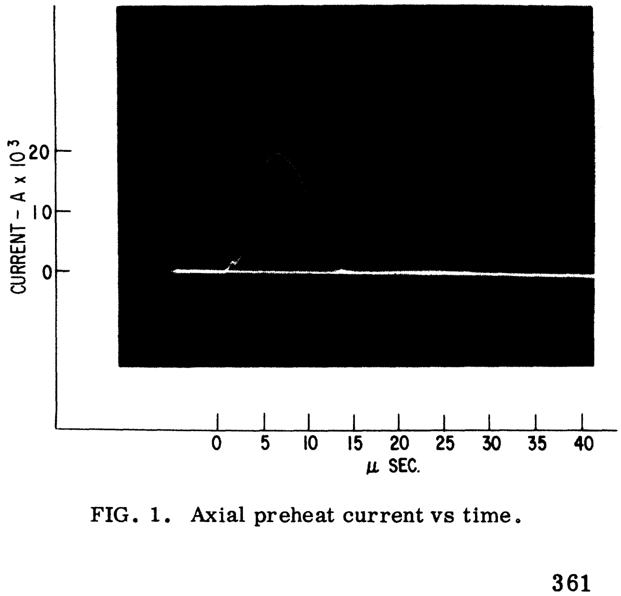

FIG. 1. Axial preheat current vs time.

to the main-bank field of 60 kG. The neutron production was insensitive within 10% to the time of firing of the main bank from 10 to 50 μsec after the preheat capacitor was shorted. If the main bank was fired during the preheat cycle the neutron yield was considerably reduced.

The neutron yield was measured by activating silver foils, and the neutron time distribution by a plastic scintillation detector. Hard x rays, above 30 keV, were not observed in hydrogen with the above preheat system in operation. In conditions where the preheat was inoperative, the counter indicated hard x rays; but then, with deuterium, no neutrons were produced on the first half-cycle.

Figure 2(a) compares the time variation of the neutron yield with that of the magnetic field. The main characteristics are a bell shaped distribution with reproducibility within 10% and a negligible yield during later half-cycles. The emission time lasts 6.5 μsec, and the peak is approximately 1 μsec before the magnetic field peak. The relative displacement of these peaks may be attributed to plasma loss. The end view streak photograph of Fig. 2(b), taken with an image converter camera with an over-all *f* number of unity, shows the plasma is grossly stable with no drift to the walls, although a definite oscillatory structure is frequently seen, which appears to start at about 3 μsec (the neutron production starts at 2 μsec). The oscillatory structure continued as long as the plasma appeared on the photograph. A decrease in the apparent diameter of the plasma in the latter part of the half-cycle indicates a loss of plasma during this time.

Figure 3(a) shows the dependence of the neutron yield on the initial pressure of D_2 from 4 μ Hg to 20 μ Hg for the case of zero bias field. An interesting feature is the rise of neutron yield as the initial density decreases in this range of pressure. When a reversed bias field of 5 kG is used the dependence of neutron yield on pressure is very dif-

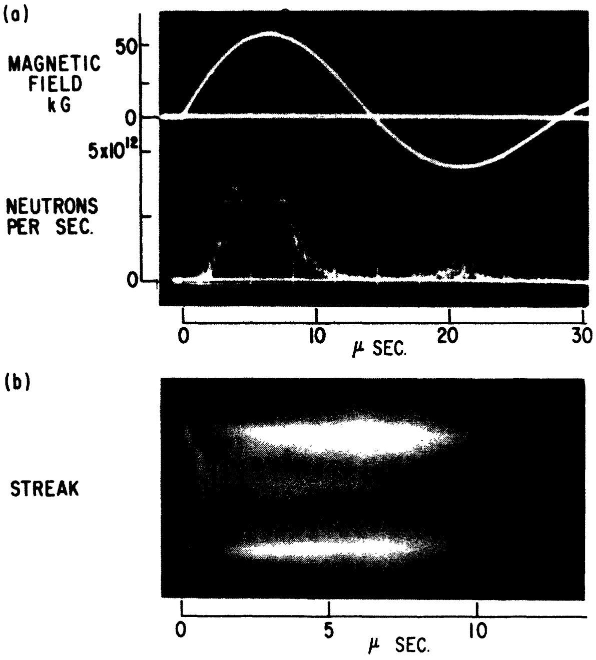

FIG. 2. (a) Field and neutron measurements with zero magnetic bias field and with 10 μ Hg pressure of D_2. (b) End-on view streak picture with similar conditions.

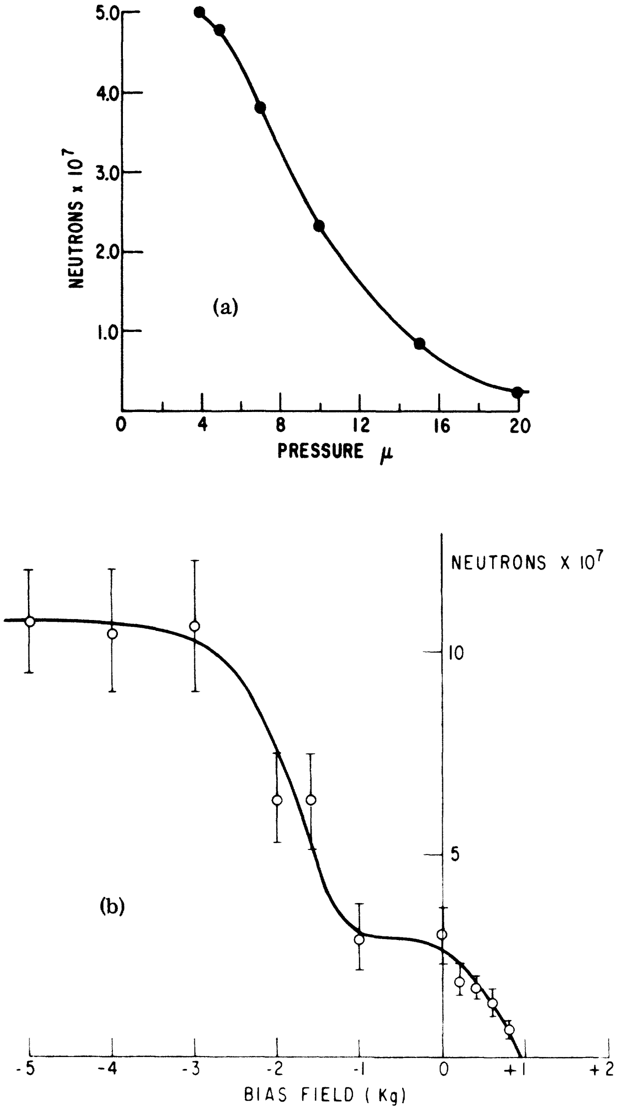

FIG. 3. (a) Neutron yield vs pressure for zero bias field. (b) First half-cycle neutron yield vs bias field at 10 μ Hg pressure of D_2.

ferent, peaking at 40 μ Hg and falling by a factor of 5 at 10 μ Hg. Similar results for reversed trapped field experiments have been reported in detail by others.[3]

The effect on neutron yield of bias field direction is shown in Fig. 3(b). It is clear that neutrons are produced not only with zero bias field, but with positive bias fields as high as 1 kG. The yield falls off smoothly as the positive bias field is increased. The conditions with negative bias field are more complicated. With negative bias above 1.5 kG, the neutron output rapidly increases with field. The increase may be related to additional plasma energy produced by axial contraction[4] or by trapped field diffusion. Streak pictures show a large increase in the plasma diameter typical of the collision of axial shocks produced by contraction. At negative bias fields larger than 3 kG the yield becomes constant and streak pictures indicate the axial contraction becoming so energetic that plasma hits the wall when the shocks collide, and the neutron production is quenched earlier in the current cycle.

For negative bias fields below 1.5 kG no evidence of axial contraction is observed and the time distribution of the neutrons for this condition is essentially the same as for the zero bias field condition.

We conclude that, at these low densities, large yields of neutrons may be produced without reversed trapped magnetic fields and under initial conditions of negligible parallel and B_θ trapped fields. It should be noted that at the low pressures and in the short time preceding the neutron production it is unlikely that the plasma is dominated by Coulomb collisions.

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ENHANCEMENT OF HYDRODYNAMIC STABILITY BY MODULATION

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We have investigated the stability of flow between rotating cylinders (Couette flow) in the case where the inner cylinder rotates and the outer cylinder is at rest. All experiments and theories to date[1] have dealt with steady rotation of the cylinders; this Letter describes the effect of modulating the rate of rotation. In many systems (e.g., classical inverted pendulum,[2] charges in an electrostatic field,[3] ferromagnetic resonance,[4,5] etc.), modulation of a suitable parameter can have marked effects on the motion and can result in increased stability of the system. The present experiments seek to explore the extent to which similar modulation techniques lead to enhancement of stability in hydrodynamics.

The technique for studying the instability is new[6] and has been developed at the University of Chicago during the past year. The apparatus shown in Fig. 1 consists of a pair of coaxial metal cylinders, electrically insulated from each other. The space between the cylinders is filled with carbon tetrachloride, the liquid under study. The current reaching the ring electrode, formed by a 0.005-in. long insulated section of the outer cyl-

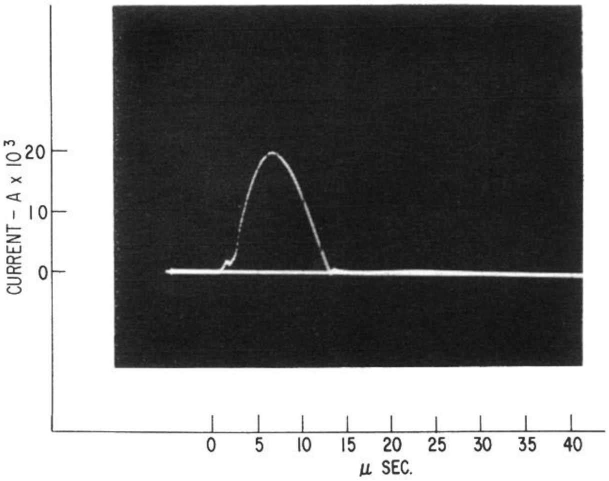

FIG. 1. Axial preheat current vs time.

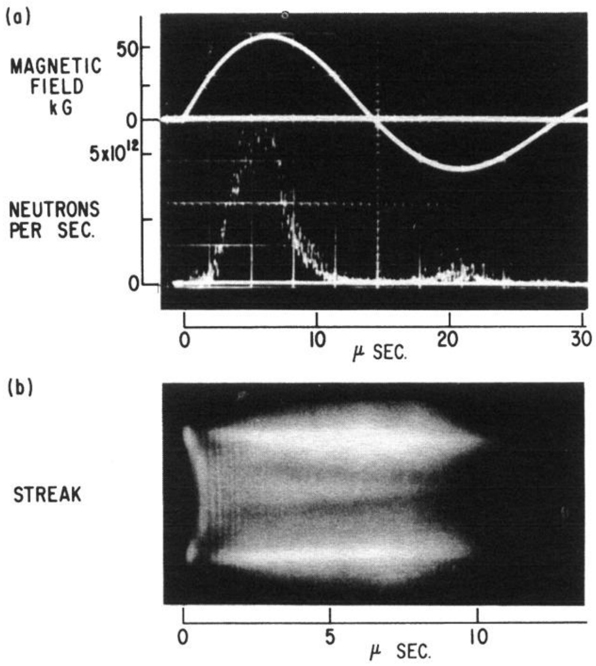

FIG. 2. (a) Field and neutron measurements with zero magnetic bias field and with 10 μ Hg pressure of D_2. (b) End-on view streak picture with similar conditions.