RECEIVED BY TIC JUN 13 1972

MASTER

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

UCRL - 73932
PREPRINT

Conf-720804--1

LAWRENCE LIVERMORE LABORATORY
University of California/Livermore, California

PLASMA FOCUS - SOLID TARGET INTERACTIONS

Bruce Freeman
John Luce
Harry Sahlin

May 17, 1972

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This paper was prepared for publication in the proceedings of the Fifth European Conference on Controlled Fusion and Plasma Physics, Grenoble, France, Aug. 21-25, 1972.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Fig

PLASMA FOCUS - SOLID TARGET INTERACTIONS*

Bruce Freeman, John Luce, and Harry Sahlin

Lawrence Livermore Laboratory, University of California
Livermore, California 94550, U.S.A.

Abstract: In an attempt to get a zero-order approximation of the behavior of matter in a plasma focus, a one-dimensional computer calculation has been performed.

We have recently begun work on the development of a plasma-focus "coaxial gun" driven by a 1-MJ capacitor bank. This gun will have a fixed center electrode with a removable center target rod that may be changed through a vacuum lock. This feature will allow a wide variety of experiments to be done in fairly short periods of time after a single initial bakeout phase. Experiments that may be of particular interest involve an extruded target filament that will be subjected to pinching by an energetic electron burst produced by a plasma focus operated at low pressure (Fig. 1). To explore the consequences of subjecting the filament to these conditions, we have performed a number of calculations using a hydrodynamic code containing a thermonuclear burn calculation. The effect of the magnetic field at pinch time was simulated by applying a pressure profile on the outer zone of a Lagrangian mesh proportional to r^{-2} and equal to $I^2/200\pi$ at a radius of 1 cm, where I is the current in amperes and the pressure is in units of ergs/cm^3 (the effects of both resistive heating and cyclotron radiation cooling were neglected in the initial calculation). All particles are retained within the pinch, while all radiation is permitted to escape. This paper gives the results for two of these calculations.

Fig. 1. Extrusion target.

Each problem was set up as follows. The current of the pinch was assumed to be constant during the period of interest (2×10^{-9} sec after the collapse of the target is initiated): 5×10^6 A. It is assumed by the nature of the calculation that there is no magnetic field inside the region of interest, since the field diffusion time is greater than times of interest. An initial momentum was placed on the outer three problem zones by placing on the inner zone an initial velocity profile that decreases linearly to zero from -5×10^7 cm/sec at the outer radius; this

simulates the momentum transferred due to the collision of the snowplowed plasma with the target. For example, this momentum would be equal to 1.6×10^3 g-cm/sec per centimeter length of the target for an initial radius of 1×10^{-2} cm. In all cases, a solid-density target of a 50% mixture of deuterium and tritium was used. For the results presented here, the initial kinetic temperature was taken to be 10 eV. Differences in this parameter did not seem to significantly affect the results between 1 and 100 eV. Thus, the only variable involved in the calculations to be changed from run to run was the initial target radius (for a target length of 1.0×10^{-2} cm). Results of the computations for initial radii of 1.0×10^{-2} and 2.5×10^{-3} cm are presented.

The calculations suggest that we should look for at least three effects in experimental work. First, from Fig. 2 we see that, as the initial target radius decreases, the energy produced due to thermonuclear reactions increases markedly, probably up to some optimal radius. At 5 nsec into the problem, the energy yields were 1.95×10^3 and 5.35×10^2 J for the 2.5×10^{-3} and 1.0×10^{-2} cm initial radii, respectively. Another phenomenon, which is indicated by Fig. 3, is the possible oscillatory behavior that may be exhibited by the pinched plasma in the focus. This oscillation could provide another possible explanation for the anomalous stability of the focus itself. One possible method of detecting these oscillations would be to monitor the microwave radiation that could be produced by these oscillations. Finally, in Fig. 4 the computation for a

Fig. 2. Energy-time curves for various initial radii.

target of 1.0×10^{-2} cm initial radius indicates that rather extreme compressions may be possible at relatively low temperatures compared with the usual shock compression techniques. This effect occurs because the initial temperature is too low to produce significant energy release by fusion, and in addition the bremsstrahlung cooling rate, which is proportional to $n\sqrt{T}$, becomes sufficiently rapid to cool the plasma faster than it is heated by adiabatic compressions, which results in a miniature cylindrical "white dwarf." In this run, the density had risen to about 3.0×10^3 g/cm³ within 2 nsec of the onset of compression, but with a kinetic temperature of only 814 eV.

In conclusion, we have provided a rough simulation of the violent pinch driven by an electron burst produced by a 1 MJ plasma focus. While granting the shortcomings of

Fig. 3. Outer radius and ion temperature as a function of time.

a one-dimensional, straight hydrodynamic calculation relative to a three-dimensional, magneto-hydrodynamic one, we note that the relative timing of various processes are reasonably realistic and the radial oscillations might have a bearing on such problems as the anomalous stability of the focus. Thus, while we do not pretend that these results accurately simulate all aspects of physical reality, we do suggest that they may act as pointers toward physical effects that might be seen experimentally. Also, these calculations indicate that our experimental conditions could promote stellar-like collapse of the target. Experiments, as well as more complete MHD calculations, will be conducted during the next year.

Acknowledgment. We would like to thank George Zimmerman for the use of his code, which with minor modifications was employed in these calculations.

*This work was performed under the auspices of the U.S. Atomic Energy Commission.

Fig. 4. Outer radius as a function of time for a 1×10^{-2} cm inner radius and a 10 eV ion temperature. The final density is 2.99×10^3 g/cc and the final temperature is 0.814 keV.