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Scaling the plasma focus for fusion energy considerations

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SUMMARY

Using the Lee model code for dense plasma focus, series of numerical experiments were systematically carried out to determine the scaling of bank energies with total current and focus pinch current and the scaling of neutron yields with energies and currents. The numerical experiments were carried out over a range of bank energies from 8 kJ extending up to 24 MJ on the PF1000 and a proposed less damped modern bank. It also includes a study on the effects of increasing bank energies by increasing bank charging voltage and capacitance of the bank for a practical optimum plasma focus machine. The results provide convincing data to show that it is possible to scale up the plasma focus machine at just 3 MJ for D-D neutron yield of 10^{13} per shot and 10^{15} neutrons per shot when it is converted to operate in D-T. Copyright © 2010 John Wiley & Sons, Ltd.

KEY WORDS

dense plasma focus; neutrons source; focus pinch current; fusion energy; neutron scaling law

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1. INTRODUCTION

Plasma focus machines consistently produce considerable amounts of neutrons. The scalability of the device to fusion reactor conditions remains an area of research [1]. Even a simple machine such as the UNU ICTP PFF 3 kJ machine consistently produces 10^8 neutrons when operated in deuterium [2]. A big machine such as the PF1000 typically produces 10^{11} neutrons per shot [3]. Gribkov *et al.* [4] had pointed out that $Y_n = 10^{13}$ in Deuterium is a desired landmark to achieve in a plasma focus device; from the point of view of possible exploitation as a powerful source of fusion neutrons for testing of prospective materials for the first wall components and construction elements in magnetic confinement fusion and also in inertial confinement fusion reactors. Converting such a plasma focus yield to operation in D-T, with $Y_n = 10^{15}$ could produce, during a 1-year run, an overall fluence-affecting materials to the order of 0.1–1.0 displacements per atom (DPA) (1 DPA is equal to a mean neutron flux of 4.5×10^{16} neutrons $m^{-2}\,s^{-1}$ for 1 year) for such testing purposes, at a very low cost relative to other methods currently being considered. We now examine the requirements to reach this landmark.

This paper presents the results from a series of numerical experiments systematically carried out using the Lee model code [5] to investigate the scalability of the plasma focus to achieve $Y_n = 10^{13}$ D-D yield. In relation to this, it was necessary to determine the scaling laws between bank energies and peak total current and peak pinch current; and between Y_n and peak total current and peak pinch current [6–9].

2. THE LEE MODEL CODE

2.1. Description of the model

The Lee model code couples the electrical circuit with plasma focus dynamics, thermodynamics and radiation, enabling realistic simulation of all gross focus properties. The basic model, described in 1984 [10] was successfully used to assist several projects [11–13]. Radiation-coupled dynamics was included in the five-phase code leading to numerical experiments on