GA–A26037

ALTERNATE CONCEPTS FOR GENERATING HIGH SPEED DT PELLETS FOR FUELING ITER

by
R.W. CALLIS, L.R. BAYLOR, P.B. PARKS, N.B. ALEXANDER, and C.P. MOELLER

MAY 2008

GENERAL ATOMICS

DISCLAIMER

GA–A26037

ALTERNATE CONCEPTS FOR GENERATING HIGH SPEED DT PELLETS FOR FUELING ITER

by
R.W. CALLIS, L.R. BAYLOR,* P.B. PARKS, N.B. ALEXANDER, and C.P. MOELLER

This is a preprint of a synopsis of a paper to be presented at the 22nd IAEA Fusion Energy Conference, October 13-18, 2008, in Geneva, Switzerland, and to be published in the *Proceedings.*

*Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Work supported in part by
the U.S. Department of Energy
under DE-AC05-00OR22725

GENERAL ATOMICS PROJECT 49008
MAY 2008

GENERAL ATOMICS

Alternate Concepts for Generating High Speed DT Pellets for Fueling ITER FT

R.W. Callis[1], L.R. Baylor[2], P.B. Parks[1], N.B. Alexander[1], and C.P. Moeller[1]
e-mail: callis@fusion.gat.com

[1]General Atomics, P O Box 85608, San Diego, California 92138-9784, USA
[2]Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

There is a growing concern that the velocity of the DT-ice pellets being proposed to fuel ITER will not have the velocity to effectively penetrate through the pedestal of the plasma edge [1,2], because even with velocities as high as 500 m/s, high field side launched pellets will only penetrate to r/a = 0.65. For ITER, the present pellet fueling concept has DT-ice pellets traversing through a guide tube to reach the high field side (HFS) launch location. The forces on the ice pellet as it goes around bends causes the pellets to disintegrate at velocities above 300 m/s [3]. Thus, in order to achieve deeper penetration the pellet velocity has to be increased.

To achieve this, either the pellet needs to have its velocity increased after the pellet has passed the last bend, or the pellet has to be made stronger to survive the increased forces higher velocities create. Previously Parks and Perkins [4-6] have proposed a novel concept to accelerate DT-ice pellets using microwave power from MW gyrotrons to develop high-pressure gas, by absorbing the microwave in a composite "pusher" medium attached to the backside of the pellet. This gas boost is created in the last meter of the guide tube after the last bend. Methods have also been evaluated to increase the strength of the ice pellets using the technologies developed in the production of the fuel pellets used in Inertial Confinement Fusion. That is to either encapsulate the pellet inside a solid shell of either metal or plastic. Or to stiffen the ice by integrating it into a plastic foam sphere, where the foam acts like the strands of fiberglass used to strengthen resin based composites. Surprisingly the foam or shell only needs to be 2% of the volume of the original pellet in order to gain an order of magnitude increase in strength.

Validation of Microwave Absorption. The basic concept behind the Gyrotron Pellet Accelerator (GPA) is that the microwaves launched by the gyrotron are absorbed in the "pusher medium", which is a composite of D_2 ice slug seeded with micron size lossy particles. The heated particles transfer their absorbed energy to the D_2 vaporizing the ice and creating a high-pressure gas cloud. Since the seed particles do not evaporate they continue to absorb microwave energy even as the D_2 gas cloud is expanding, thus continuing to heat the gas to ever higher pressures. The theory predicts [7] that the damping distance elongates exactly in proportion to the length of the expanding pusher gas, such that the wave absorption remains constant in time (self-matched heating). Thus, as long as the microwave power is being applied the pressure in the pusher gas will increase (disregarding any blow-by gas leakage or other loss mechanisms). This basic concept was validated in the lab by measuring the losses in a section of fundamental waveguide with circular TE_{01} mode fields loaded with paraffin and various mixtures of 1-2 micron zinc powder. The length of the paraffin in the waveguide was adjusted to have all samples contain the same total amount of Zn powder. Figure 1 shows that for constant number of particles in the waveguide the absorption is found to be constant. The next test is to actually heat a sample of naphthalene seeded with 1-2 micron Zn powder. For this test a 500 kW pulse from a 110 GHz gyrotron will be pulsed into a naphthalene slug 4 mm diameter, 25 mm long for 1–2 ms. The pressure and temperature of the generated gas will be measured and compared to theory.

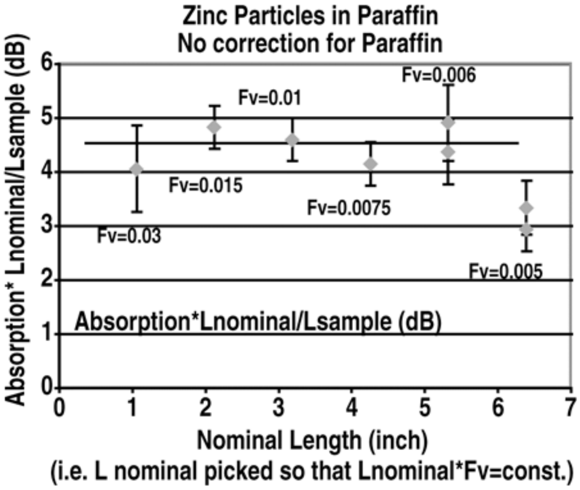

Fig. 1. Microwave losses for different volume loading fractions and lengths of paraffin samples.

Reinforced DT-ice Pellets. The ICF community has developed several configurations for containing DT-ice prior to compression and heating by lasers or indirect drive [8]. These and similar configurations, but fully filled with DT, can be applied to the fuel pellets anticipated for ITER. Pellet configurations evaluated have been plastic shells, beryllium shells, foam pellets and foam shells. For the plastic shells and foam they consist of only C and D atoms, no other atomic impurities. For all configurations the maximum allowable non-hydrogenic content was 5%. The increase in strength for the cases mentioned above was calculated to be 110, 50, 30, and 95. Foam shells have been provide to Oak Ridge National Laboratory for testing in the ITER pellet launcher mockup.

[1] A. Loarte, *et al.*, Nucl. Fusion **47** (2007) S203-S263.
[2] A.R. Polevoi and M. Shimada, Plasma Phys. Control. Fusion **43** (2001) 1525.
[3] S.K. Combs, *et al.,* Proc. of 17th IEEE Symposium on Fusion Engineering, Vol. 2, 1102 (1997).
[4] P.B. Parks and F.W. Perkins, Nucl. Fusion **46** (2006) 770.
[5] P.B. Parks and F.W. Perkins, US patent application No. 11/256.663 “Microwave-Powered Pellet Accelerator,” filed on October 21, 2005.
[6] F.W. Perkins and P.B. Parks, “A Gyrotron Powered Pellet Accelerator for ITER,” Proc. of 21st IAEA Fusion Energy Conference, Chengdu, China, 2006.
[7] P.B. Parks and F.W. Perkins, “A High-Velocity Microwave-Powered Pellet Launcher for ITER,” Proc. of 33rd EPS Conference on Controlled Fusion and Plasma Physics, Rome, Italy, 2006.
[8] D.T. Goodin, *et al.,* Phys. Plasmas **13** (2006) 056305.