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TITLE THE HIGH DENSITY Z-PINCH II EXPERIMENT

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The High Density Z-Pinch II Experiment

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The HDZP II is an experiment with the objective of taking a z-pinch plasma, created from a small diameter solid deuterium fiber, up to the Pease-Braginskii current limit while maintaining Bennett equilibrium (constant radius) throughout the current pulse. This type of operation is very different from the classical implosion pinch that is characterized by a thin sheath boundary between the plasma and the surrounding B-field. The implosion pinch configuration is highly unstable to the MHD m=0 mode and breaks up when the implosion approaches the axis. The usual attempt at the control of the m=0 is through an imposed B_z field that, however, introduces severe complications and density limitations.

The approach taken for the HDZP is to form the plasma column at the highest possible density and maintain pressure equilibrium (constant radius pinch) with a large dI/dt. This allows the current to diffuse into the plasma column. Certain regions of diffuse profiles are stable to the m=0 mode with the limit of the stable region being the Kadomtsev profile. With the objective of having a deuterium plasma at the highest density while avoiding implosion dynamics, the concept of using frozen deuterium fibers to create a solid density diffuse-current pinch that is ohmically heated at nearly constant radius was developed and experimentally achieved at Los Alamos.[1]

The HDZP II device that has been constructed and is now in the test stage will drive a current with sufficient dI/dt to maintain equilibrium up to, ultimately, the Pease-Braginskii current of 1.4 MA where steady state equilibrium is reached. This current is driven by a 200-kJ, 3.2-MV Marx charged water transmission line and rises in 100 ns. With a 40-μm-diameter fiber, a Bennett temperature of 10 keV is reached at 1.4 MA. Solid deuterium fiber

[1]Scudder, D.W., "Experiments on High-Density Z Pinches from Solid Deuterium Fibers," *Bull. Am. Phys. Soc.* **309** (1985) 1408.

experiments will begin with the HDZP II in the summer 1989. An isometric view of the device is shown in Fig. 1.

The initial diagnostics for the experiment will be:

1. Schlieren and shadowgraph photography using a mode locked, Q-switched, and frequency doubled YAG laser with 100-ps pulse width.

2. X-ray diode detectors with attenuation filters for electron temperature measurements.

3. Multiple-pinhole x-ray streak photographs giving a time-resolved view of the x-ray emission.[2]

4. Interferometric density measurements of the corona surrounding the pinch column.

5. Neutron activation measurements for total yield.

6. Time-resolved neutron measurements for detailed neutron source analysis.

At a later date, experiments will be started to obtain a preconditioned (preionized) corona. This will be important in controlling the break-down and the initial conditions for the current distribution.

The HDZP II experiment is based on the results from HDZP I. The solid deuterium fiber maker designed by Ed Grilly was developed on this experiment and is capable of producing fibers as small as 20 μm diameter and more than 25 cm long.[3] The current available was 200 kA rising in 125 ns. With this device the dI/dt was not large enough to satisfy the required equilibrium current curve, and the column was observed to expand at a rate of about 4×10^6 cm/s. A schlieren photograph of the column at about 50 ns is shown in Fig.

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[2]Choi, Peter, private communication.

[3]Grilly, E.R., Hammel, J.E., Rodriguez, D.J., Scudder, D.W., and Shlachter, J.S., "Production of Solid D_2 Threads for Dense Z-pinch Plasmas," *Rev. Sci. Instrum.* **56** (10), October 1985.

2. The column was usually well behaved up to about the peak of the current while frequent shots showed $m=0$ at earlier times. $m=1$ was never observed. The density and temperature as determined by schlieren photographs and x-ray measurements was 2×10^{21} cm^{-3} and 400 eV. The neutron yield was as high as 5×10^7 per shot. The number of Alfven times during the instability free period was usually greater than 100.

Important theoretical progress has been made in Los Alamos on the solid density Z pinch. Two codes use the Braginskii fluid equations for a magnetized plasma. Another code in 1-d and 2-d versions treats the problem of transforming a solid deuterium cold fiber to a plasma and taking this plasma to kilovolt temperatures. This computation of a cold start uses the Los Alamos SESAME equation of state data to determine resistivity, pressure, and internal energy. The detailed results from the Los Alamos theoretical work on the solid fiber Z pinch are covered in papers in this session by Alan Glasser and Irv Lindemuth.

Theory indicates there are several phases in the development of the pinch during the rise to 1.4 MA. These different phases are predicted to have quite different characteristics with respect to the stability of the plasma column. First, current starts in a very low density corona around the dense fiber and this hot coronal region causes the surface of the fiber to abliate until the fiber is completely ionized in 10 to 20 ns. This ablation process as seen in the cold start simulation is consistent with the results of HDZP I. The second region of interest is up to the point where the Lundquist number is about 100. The HDZP I experiment did not reach a current giving a Lunquist number greater than about 150. Thus resistive effects were dominant in that experiment. The next region is at a large Lunquist number, but not a collision free plasma. The final stage is a collision free plasma reached in the HDZP II experiment at about 600 kA. Conclusions from the theoretical calculations are not able to give a solid answer for the stability of the pinch, but speculation using the theory results as a guide is that a $m=0$ instability starting at the boundary of the pinch will drive the plasma pressure distribution toward the stable Kadomtsev profile and might give stability to the bulk of the plasma column.

The experiment will be closely coupled with the theoretical work. Because of the small dimensions and high density of the plasma column it will be essential to draw conclusions about the pinch from external measurements in conjunction with theoretical models of current, temperature, and density profiles.

David Scudder and Jack Shlachter are the principal contributors to the experimental work covered in this paper. Diagnostic development contributions were made by Peter Forman of Los Alamos and Ralph Lovberg of the University of California at San Diego.

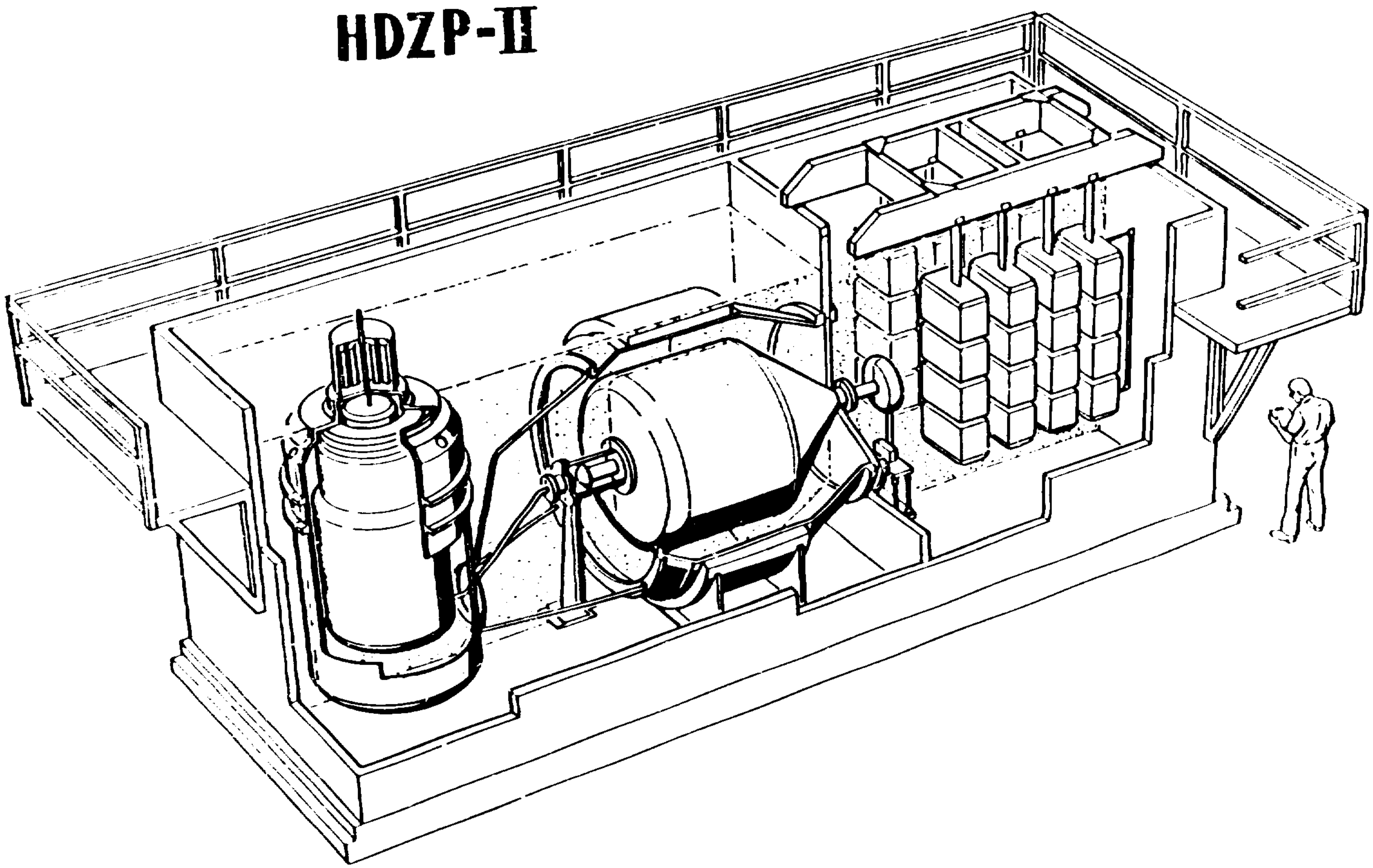

Fig. 1. HDZP II showing Marx, Intermediate Energy Store, Vertical Transmission Line, and Fiber Maker on the Load Chamber.