July 1999 Highlights of the Pulsed Power Inertial Confinement Fusion Program

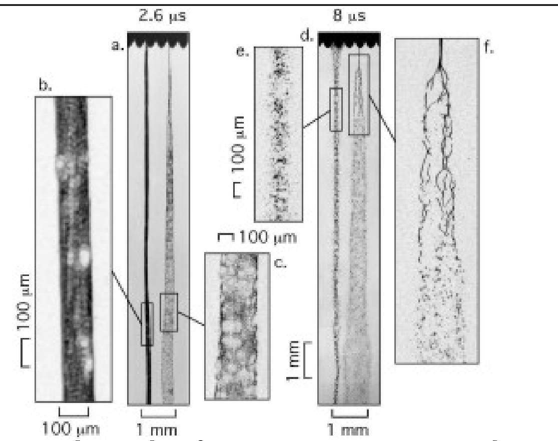

Fig. 1. Radiographs of 13-μm W wires at 2.6 μs show expanding vapor bubbles within a liquid "sponge." At 8 μs, vapor has been released, and liquid forms into thread-like structures and separate droplets in the 2D images.

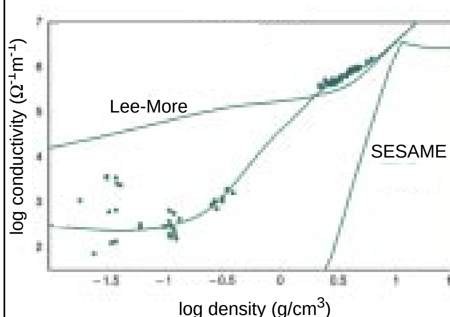

Fig. 2. Conductivity of Cu at 6000 K for new model compared to SESAME and original Lee-More models and DeSilva data.

Vacuum insulators on Z were replaced, metal rings in the stack were modified to improve the electric field grading, and new pulse-forming-line hardware for long pulses was installed during two weeks of scheduled maintenance. We had 2 power flow shots, an in-situ wire preheating shot, and 2 shots to begin assessing a two-sided pinch capability with a single-sided current feed. Radiographs of the early stage in wire explosions at Cornell show significant differences in the material state depending on the conductivity. The conductivity model in magnetohydrodynamics (MHD) codes has also been improved.

With SNL/DOE grants, Cornell is studying the expanding cores formed from exploding low and high Z wires, as well as the wispy coronal plasma structure from high Z materials with high-resolution (1-3 μm and 0.7-2 ns), direct x-ray backlighting using two Mo X pinches in parallel. In the low-current tests described here, a 1-4 kA peak current per wire, 350-ns quarter-period rise time, damped sinusoidal waveform is applied for 0.1-10 μs before the radiographs are obtained. Although the existence of dense cores within the low-density corona during the wire explosions is well established, the physical state of the expanding core, until now, had been conjecture. The time-resolved Cornell data show that, for low-conductivity metals (W, Mo, NiCr, Ti), the core has a persistent, foam-like, liquid-vapor structure (Fig. 1) and a substantial portion of the wire remains liquid. Before visible wire expansion, the applied voltage causes a breakdown in the vapor around the wire, after which time the current is carried in the vapor instead of the core. During slow cooling of the core, as the current damps out, the remaining liquid coalesces into separate droplets along the initial wire position. In contrast, for highly conductive metals with relatively low melting points (Al, Au, Cu, Ag), the expanding wire column is fully vaporized and more uniform. To model the initial stages of exploding wires during the Z prepulse in MHD codes, it is therefore essential to include specific material properties for a wide temperature and density range.

Before designing future z-pinch accelerators, we must determine if loss mechanisms exist that fundamentally limit the current density in a conductor. To pursue these studies, we have developed a new conductivity model for MHD codes. Of special interest is the regime defined by temperatures below a few eV and densities below solid. In this regime, Alan DeSilva and his U. Md. colleagues have obtained conductivity data for Cu, W, and Al wires. The discrepancy between their data and commonly used models (Lee-More and SESAME) is large below solid density (Fig. 2). We modified the Lee-More model so that it agrees with the DeSilva data, blends into the usual Lee-More model above solid density, and can be scaled to other conductors. The new algorithm also agrees with Redmer's (Universtitat Rostock) theoretical model for a partially-ionized metal plasma of arbitrary degeneracy. Compared to earlier MACH2 simulations using the SESAME tables, the new model shows much less material expansion into the anode-cathode gap.

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