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Submitted to: 9th IEEE International Pulsed Power Conference, Albuquerque, New Mexico, 21-23 June 1993

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PLASMA FLOW SWITCH AND FOIL IMPLOSION EXPERIMENTS ON PEGASUS II

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Introduction

Pegasus II is the upgraded version of Pegasus, a pulsed power machine used in the Los Alamos AGH (Above Ground High) program. A goal of the program is to produce an intense (<100 TW) source of soft x-rays from the thermalization of the kinetic energy of a 1 to 10 MJ plasma implosion. The radiation pulse should have a maximum duration of several percent of nanoseconds and will be used in the study of fusion conditions and material properties. The radiating plasma source will be generated by the thermalization of the kinetic energy of an imploding cylindrical, thin metallic foil. This paper addresses experiments done on a capacitor bank to develop a switch (plasma flow switch) to switch the bank current into the load at peak current. This allows efficient coupling of bank energy into foil kinetic energy.

Figure 1 is a drawing of the Pegasus II facility. Pegasus II machine parameters include a stored energy of 4.3 MJ at 100 kV, a system inductance of 40 nH, and current capability of 18 MA. This quadruples the energy of Pegasus I at this voltage. The upgrade was accomplished by replacing the capacitors rated at 10 kJ to stored energy at 60 kV with capacitors rated at 30 kJ at 50 kV. The new capacitors have a current capability of 250 kA/capacitor and can stand up to 20 repeats at full charge for a rated lifetime of over 5000 shots. To stay within this voltage reversal specification, series fuses are employed to shut off the current after peak current. The bank itself is composed of two halves charged to opposite polarities. Each half has four modules with eighteen capacitors each. The modules are placed around a radial transmission line with the load at the center of the line. Detonator switches, which form an annular aluminum jet that penetrates the polylethylene switch material, are used to switch the bank. The facility has been used in direct drive, z-pinch implosions of thin aluminum foils, high magnetic field diffusion experiments, pulse sharpening and switching experiments, and plasma flow switch, and most recently, in other experiments, where the load is an aluminum cylinder with a 0.4 mm thick wall.

Experiment Results

The purpose of the plasma flow switch (pfs) experiments presented here is to develop a switch that demonstrates switching into a high-inductance dummy load. On previous experiments done on Pegasus I, we have observed efficient switching of all of the drive current into a static load at a radius of 5 cm (the foil radius). However, switches driven imploding loads have not been able to develop voltages necessary to drive good implosions (V > 10 kV). Speculation is that the switch cannot support a high voltage because of plasma channeled plasma flow channel or building the load slot. The experiments done on Pegasus II use a thick copper cylinder of 1 cm radius as the load. Figure 2 is a drawing of the Pegasus II power flow channel showing the location of the pfs in relation to the load slot. The pfs is made of two components: a thin aluminum "bridge" that shorts the power flow channel and a mezzanine barrier film located just downstream of the aluminum. When the bank is discharged, the aluminum becomes a plasma that conducts the current of the capacitor bank. The plasma then starts to accelerate down the power flow channel via the Joule force acting on the current carrying plasma. The barrier film inhibits the motion of the aluminum plasma until it burns away after about 200 ns (depending on film thickness). The assembled plasma then moves down the channel with a fairly well defined front. As the plasma sheath crosses the load slot, the peak bank current, the current path then includes the load. A simple model for the time to switch the current into the load slot is velocity of the pfs divided by the width of the load slot. In our experiments, this number is 200 nsec.

Figure 1 Pegasus II facility

Figure 2 Pegasus II load chamber

We are developing the plasma flow switch as opposed to the more commonly used plasma crossover switch because of the relatively
The use of an image of our current-driven plasma in the AST X program at Los Alamos with current-driven plasma formation in mind. This method of forming the plasma has been demonstrated using various devices to support the device and to control plasma formation. This method of forming the plasma has been demonstrated using various devices to support the device and to control plasma formation.

A noted initially by Linton, the plasma actually steepens the current front of the current pulse moving down the power flow system. This is shown in the figure where the current vs. time at different axial positions is shown. Note that the waveform does steepen in the plasma and that there is a "foot" on the leading portion of the current surge. This foot is greatly reduced in amplitude as observed by a shot probe placed in the load and the amplitude of this foot and its relation to plasma injection and plasma distribution is under investigation. The mass distribution of the plasma in the plasma line is also a distribution that is a change in the magnetic pressure profile. This has been done on Pegasus I by using a neutral wake and to match the magnetic pressure profile. This has been done on Pegasus II by using a neutral wake and to match the magnetic pressure profile. This has been done on Pegasus II by using a neutral wake and to match the magnetic pressure profile.

Fig. 1 shows current pulse shape as plasma moves down line.

The successful results of the "Quick Fix" series of experiments done on Shaw Star are well known. The main difference between these experiments and the ones performed on Pegasus have been current levels. Pegasus I operated at about 1 MA with a neutralized dot at switch time whereas Shaw Star operated at about 1.5 MA with plasma injection at switch time. Pegasus II is much closer to the parameters of the Shaw Star experiments with current levels approaching 2 MA at switch time and sudden while 1.5 MA is still possible.

From Fig. 1 shows current pulse shape for two plasma experiment on Pegasus II. These two experiments had plasma injection at switch time and 1 MA. The waveform occurred at lower current with the lower plasma injection of the reduced time to peak to the load dot. The second shot, the smaller plasma injection at switch time as shown in the plot in line 1 of Fig. 1, where the current switched to the initial steady state of the load at a time shown to be the correct time for the switch to occur. However, the current at the switch time is not as steep as for the higher plasma injection. The steps are associated with this initial flow in the load dot at a fast rate recede from fluid-dynamic flow. Another consequence of the higher plasma injection is that dot is more positive than with the more massive switch and switch time occurs earlier.

The use of the current pulse shape shows that the neutral plasma is sustained without a load shot by the pifs during the switching event. Note the plasma X-10 experiment of the Pegasus II experiments over the Pegasus I results. It should be noted that all of these experiments were performed with the plasma injection for all of the experiments except for the design of the load and load configuration. Calculations have shown that as current increases the effect of the trap may actually be harmful future experiments are planned to investigate this effect.

Fig. 2: Bank current and switched current for 80 usec and 100 usec pifs experiments.

Fig. 3: Switch voltage across load for Pegasus II and Pegasus I pifs experiments.

Summary

The preliminary experiment performed on Pegasus II seems to show a plasma flow switch has been made on site. We are studying the switching of the small scale in a stable, steady-state load to a switch behavior of the plasma II. The parameter of Pegasus II seem better matched to confirm the switch time performance of the pifs on Pegasus II. Pfs. To date have shown that all of the plasma current can be switched into a high impedance of the load in roughly 50 usec. Experiments are continued to optimize the switch time characteristics of the plasma flow switch.

Acknowledgments

We acknowledge the valuable and expert work of the Pegasus mechanical crew of L. Hart, R. M. Atwood, and J. B. Rodriquez.
This work is sponsored by the U. S. Department of Energy.

References:


