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RANCHERO EXPLOSIVE PULSED POWER EXPERIMENTS

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Introduction

We are developing the Ranchero high explosive pulsed power (HEPP) system to power cylindrically imploding solid-density liners for hydrodynamics experiments. Our near-term goal is to conduct experiments in the regime pertinent to the Atlas capacitor bank[1]. That is, we will attempt to implode liners of ~50 g mass at velocities approaching 15 km/sec. The basic building block of the HEPP system is a coaxial generator with a 304.8 mm diameter stator, and an initial armature diameter of 152 mm. The armature is expanded by a high explosive (HE) charge detonated simultaneously along its axis. We have reported a variety of experiments conducted with generator modules 43 cm long[2,3] and have presented an initial design for hydrodynamic liner experiments[4]. In this paper we give a synopsis of our first system test, and a status report on the development of a generator module that is 1.4 m long.

Implosion System Test

Our first system test had the goal of approaching 10 km/sec implosion velocity for an aluminum liner of 40g. In addition, this test demonstrated our power flow design concept, which includes some techniques planned for the Atlas capacitor bank. Figure 1 shows the apparatus in transit to the HE firing point. Mounted on a trailer for transportation are the generator, fuse opening switch (FOS), closing switch plates, conical power flow section, and the outer conductor of the implosion section. Extending outside of the picture are racks for mounting three 450 kV x-ray heads and accompanying explosive-proof film cassettes. The generator is a 43 cm long Ranchero module, and the FOS is 50μm thick copper, 30 cm long and 1.86 m wide. The closing switch plates have 12 detonator-actuated switches arranged symmetrically to puncture a 1.25 mm polyethylene sheet that can be seen protruding from the plates. The performance of these HEPP components has been previously described[4]. Fig. 2 is an illustration of the system showing the pulsed power components described above, as well as power flow and diagnostics features. Fig. 3 is a blow-up of the load region. Mounted inside the liner are optical pin and VISAR diagnostics. dB/dt probes near the liner give information about current symmetry and the voltage integrity of the insulator, which is immediately adjacent to the liner in this design. Fig. 4 shows the pulsed power results from the test. An initial current of 4 MA was delivered to Ranchero, and a

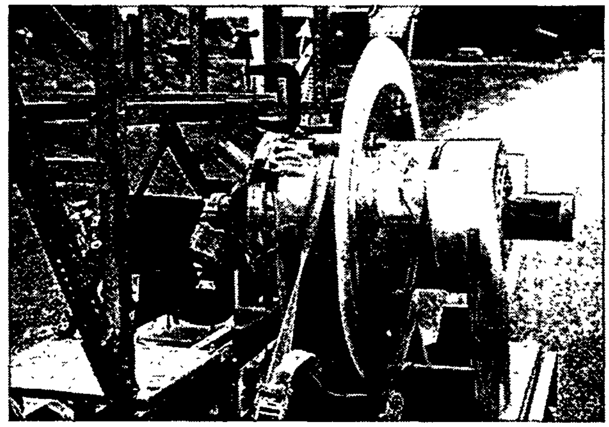
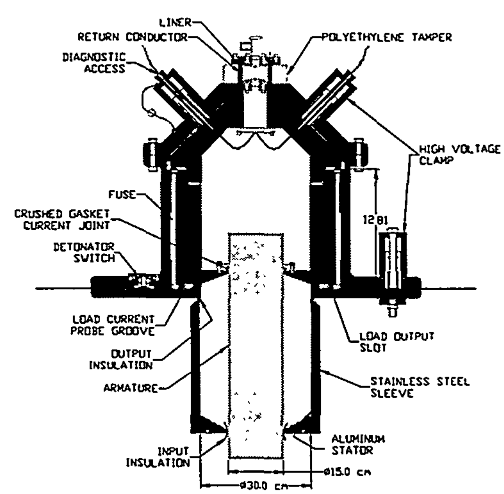


Fig. 1. Photograph of first successful Ranchero liner test. The 43 cm generator is the cylindrical component in right of picture, with its smaller diameter armature protruding furthest to the right. Polyethylene insulation protrudes from closing switch plates in the middle, and the next component to the left is the FOS section. The conical transmission line leads to the small diameter implosion section. The racks support three 450 kV x ray heads (out of the picture) and their associated HE proof film cassettes, one of which is seen below and to the left of the load section.



. Fig. 2. Cutaway drawing of system in fig. 1.

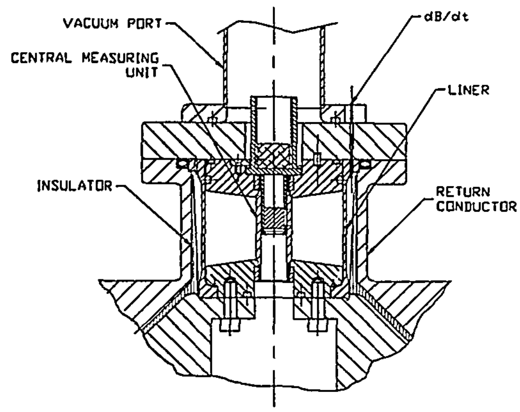


Fig. 3 Load region for Ranchero liner test. The central measuring unit houses time of arrival pins and a turning mirror for the VISAR laser.

peak current of 25.6 MA was generated. 15 MA was delivered to the load. It is possible that the generator volume shorted out with ~3 mm remaining in the armature/stator gap. This is a small amount of inductance, but represents a substantial fraction of the storage inductance on this test. We are still analyzing these data, and it is important to

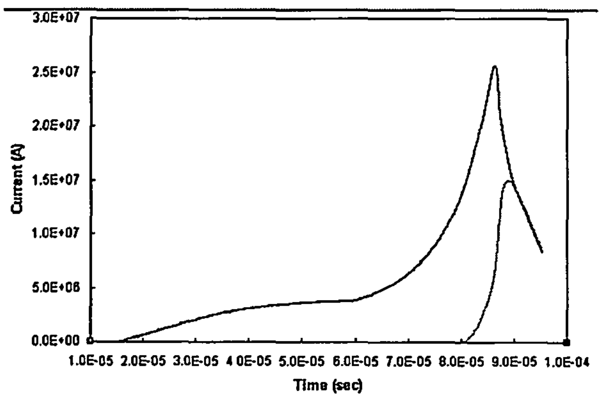


Fig. 4 Generator and load current from imploding liner test.

understand this issue for future experiments. Due to a priming circuit cable fault, the initial current was 0.5 MA less than originally planned, which resulted in delayed fuse actuation, and hence to a reduced liner current. Although we planned for 20 MA liner current, the achieved values provide us with a good first look at our system, and all diagnostics returned results. The liner reached a velocity of 6.1 km/sec, as measured by the VISAR. In addition, x-rays taken at three separate times show the liner behaving very well, and at locations consistent with computational results based on the actual waveform. Samples of these x-rays are presented in another paper in this conference[5]. The dB/dt probes indicated no restrike along the insulator surface, and good current symmetry within the errors of the measurement.

1.4 m System tests

The HE system necessary for 1.4 m Ranchero modules has required more development than we anticipated, but has recently been demonstrated to perform satisfactorily. Fig. 5 is a rotating mirror camera record showing the expansion of a 6mm-thick aluminum armature to the desired diameter. Only two-thirds of the armature is seen in the figure, as good optical resolution dictated that we cover only part of the armature with a single camera. Another camera shows equally good results from the remaining part of the system. The system is detonated at 56 discrete locations along the axis with a 112-point slapper detonator system (two points back-to-back at each site). To reduce costs, we use a room temperature castable explosive for the main charge, which is cast around the slapper/booster-pellet system. Difficulties in development included detonating the large number of points reliably, casting such large charges without disturbing the slapper system, and failure to promptly initiate the PBXN-110 cast charge with the low-density PETN detonator

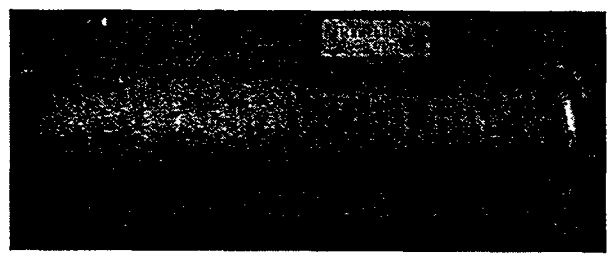


Fig. 5. Rotating mirror camera record of 1.4 m armature expanded to the approximate final diameter for use in a Ranchero generator. Only about 2/3 of the armature is shown in this frame. The remainder of the armature was seen with a second camera. The grid pattern is 25.4 mm per line.

explosive. The latter difficulty is solved by adding an intermediate booster explosive[6]. We have recently tested our first 1.4 m Ranchero module. The results are shown in fig. 6. The module had parallel stator and armature walls, and used a 4 mm-thick polyethylene insulator along the stator, in the same manner as early 43 cm Ranchero module tests[2]. In addition, as with 43 cm module tests, the generator volume is filled with atmospheric pressure SF_6. The test had a static load of 5 nH, in addition to the inductance of ~5nH left in the generator due to the thick (4mm) insulator. Pre-shot calculations based on residual inductance information previously published indicated that a peak current of 32 ±6 MA would be achieved given an initial current of 2.2 MA. Our most optimistic model predicted 38 MA. The observed current indicates that residual inductance inferred from tests

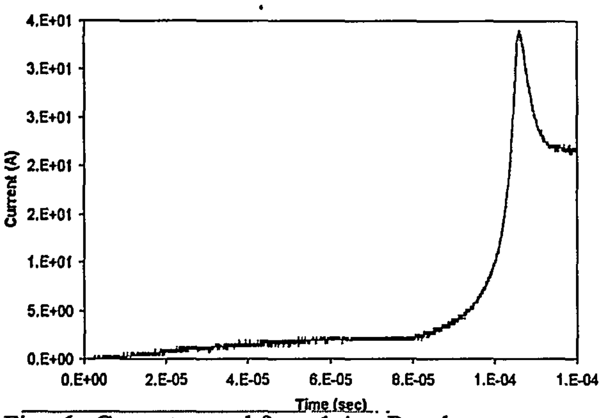


Fig. 6. Current record from 1.4 m Ranchero generator test.

with thin stator insulators represents a loss that is not completely incurred if a thick insulator is used.

Conclusions

We have demonstrated that the Ranchero system can be used to drive hydrodynamic liner experiments with an excellent compliment of diagnostics. Further experiments with 43 cm Ranchero modules could be conducted with liner drive currents of 20 MA or slightly more, but the availability of the 1.4 m module allows us to proceed to the 30 MA level, which is consistent with current programmatic goals for the Atlas capacitor bank. The 1.4 m module can be attached to the existing power flow design with no modifications, and diagnostics will not be appreciably affected by the increased HE charge. Fuse dimensions will change to reflect increased performance of the system. Early experiments will investigate the stability of liners driven with this current and time scale. Calculations show that at least part of the liner should remain solid during the implosion to maintain stability. For increased performance from the Ranchero system, we propose to first reduce the stator insulation to its minimum practical value. This reduces the residual inductance in the generator, and allows substantially higher current to be achieved. Alternatively, it allows the same current with more inductance outside the generator volume so that the generator can be crowbarred out of the circuit, if this proves to be desirable. We are exploring the potential advantages of crowbarring the generator from the circuit when flux compression is complete. Several other options remain, such as evacuating the module rather than filling it with SF_6. We will pursue these possibilities as time and programmatic needs allow.

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