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Abstract

We are pursuing designs for high explosive pulsed power (HEPP) systems to power isentropic compression experiments (ICE) at pressures of 20 Mbar or beyond. To date, we have based design studies on components with which we have relevant experience. We have developed a simultaneously initiated coaxial magnetic flux compression generator that has been previously referred to as the Ranchero generator. These generators have been tested at 50 MA, and should operate at currents approaching 100 MA. Ranchero experiments to date have been limited to 50 MA by our firing point capacitor bank that will deliver only 3.3 MA initial (seed) current to a full size Ranchero device. To achieve higher total currents, we will employ a booster generator to provide larger seed currents. We have examined cases with up to 12 MA seed current in system design studies. For pulse conditioning, we have experience with explosively formed fuse (EFF) opening switches at currents up to 25 MA and voltages up to 500 KV. We have also used a plasma compression switch (PCS) in systems that would produce 1-2 Mbar pressure profiles in ICE loads, and we describe projections based on scaling those results to much higher currents. In this paper, we explore systems that will produce waveforms for 1.6, 3.4, 12, and 17 Mbar ICE research. In another paper in this conference, we describe a system we are using for our entry into ICE work.

Equally as important as HEPP system design for these applications is the dynamic performance of the load. Low inductance loads with good current distribution can be designed, but at such pressures, the dynamic properties of the load can overwhelm other parameters on time scales of interest, as will be seen. As a result, each ICE system must carefully integrate pulsed power design with load design. In the following, we present the techniques we are using for evaluation, and the resulting system concepts that could provide both intermediate level pressures, and pulses that would provide 20 Mbar isentropic profiles.

Introduction

For most of the history of high-pressure research, equation of state (EOS) data for materials isentropically compressed to multi-megabar pressures has been unavailable. Recently, Asay and others [1] have demonstrated that pulsed power techniques can be used to gather isentropic pressure curves at the 1 MB level, and have achieved magnetic loading at 4 Mbar. We have begun experiments using existing HEPP techniques that can deliver isentropic pressures up to ~2 Mb [2], with samples 1-2 cm wide and up to 2 mm thick. Looking into the future, data at pressures of 20 Mbar would be valuable, and we are considering system design options that can produce shockless pressure profiles up to those levels. For our projections, we are examining ICE load dynamics assuming performance parameters from HEPP hardware with which we have direct experience. Our high current flux compression generator (FCG) for these purposes is the Ranchero simultaneously initiated coaxial generator [3] that has been tested up to 50 MA, and should scale to well over 80 MA without substantial redesign [4]. For our highest current experiments, we would use a booster generator that would deliver up to12 MA to the Ranchero generator. Initial estimates suppose the use of our MK-IX generator [5] as a booster in this application, although this is far from an optimum use for that high current generator. Pulse forming is an extremely important part or our ICE HEPP designs, since the Ranchero generator will not produce the necessary sub-microsecond current risetime, and tailoring of the leading edge of the load pulse is further necessary for some materials. We have experience with EFF opening switches at currents up to 25 MA [6] and voltages up to 500 kV [7]. To operate at substantially larger currents, we will investigate operating EFF's at higher current density, but using parallel switches that operate in the range of our experience is also possible. There appear to be advantages to using opening switches in parallel anyway. Available detonation systems will allow opening switch voltages as high as 1.4 MV to be developed. At such voltages, transmission line issues are surely the largest single problem. We also have limited experience with plasma compression opening switches [8], and are aware that other researchers [9] have pushed the performance of these devices into regimes of interest to ICE designs. As a result, we are also considering the advantages of using PCS's.

Circuit Design

A typical circuit for use in ICE experiments is shown in fig. 1. This shows an initial energy source (C), a booster generator (FCG1), a high current generator (FCG2), a storage inductor (Ls), an opening switch (Rsw) (with inductance Lsw

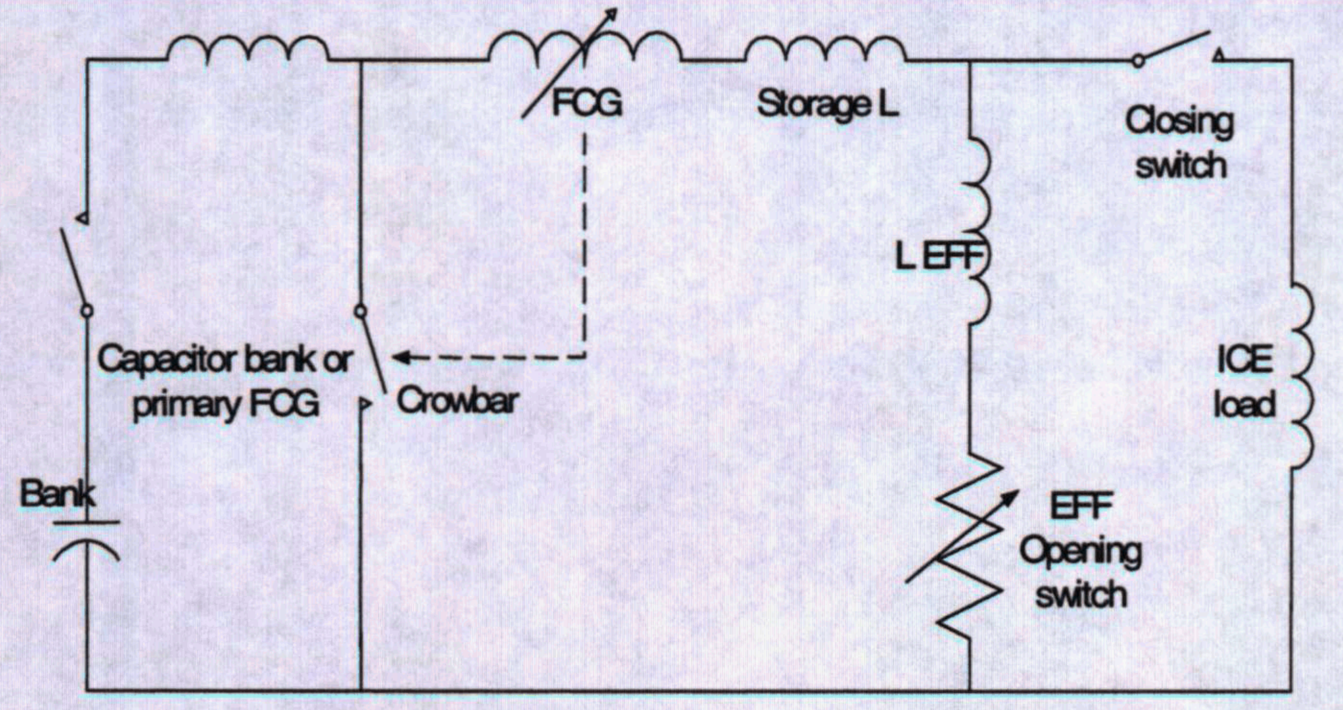

Figure 1. Circuit representing components in a general HEPP ICE circuit.

included in the switch leg of the circuit, although this is not necessary [10]), a closing switch (S1), and a load (L and dL/dt). An optimized design for this circuit would have components designed specifically for the system at hand, and this would be our ultimate goal. However, we have approached the system design from the perspective of establishing feasibility, and we will describe a system based initially on components with which we have experience. In this vein, the capacitor bank is an existing 12 mF, 20 kV bank and FCG1 is our MK-IX generator. FCG2 is a Ranchero simultaneously initiated coaxial generator. For the opening switch, we will discuss the relative merits of two candidates, and we will describe the load in great detail in a later section.

Ranchero

The Ranchero generator system was originally designed to support our heavy liner implosion program [11], and may be nearly optimum for ICE needs. In early development phases, we experimented with a few design options, especially for attaching transmission lines to the basic module. Some of these options were previously published [4], and pave the way for some of the ICE system considerations we present here. The mainstream effort for Ranchero, however, was to support the Atlas imploding heavy liner program, and the hardware shown in fig. 2 was chosen to simulate Atlas waveforms. This configuration connected well to a passive fuse opening switch, for pulse conditioning, and further to the coaxial imploding load designed to emulate an original Atlas design. Atlas experiments were planned in the 20-30 MA range, and the Ranchero/fuse system was capable of operating in that range without a booster generator. Using our end output Ranchero design, and with no optimization of the fuse-opening switch [12], we achieved the results shown in fig. 3. Minor improvements would have allowed us to operate easily in the 20-30 MA load current range. We can also consider the projected performance of that system using a booster generator to supply the seed flux to Ranchero. On the experiment shown, with only 3.3 MA seed current, the generator developed 26 MA in the fuse circuit, and eighteen MA were delivered to the load. Simple scaling suggests that using a booster generator to put 6 MA initial current into the Ranchero generator, and re-sizing the fuse for greater current, we would generate generator currents up to 47 MA, and load currents approaching 33 MA. A direct scaling of earlier results [13] provides that our MK-IX would deliver 8.4 MA to Ranchero. With no further losses due to changes in the

Figure 2A. Full-scale Ranchero imploding liner experiment. Generator is 1.4 m in length, fuse is __m long.

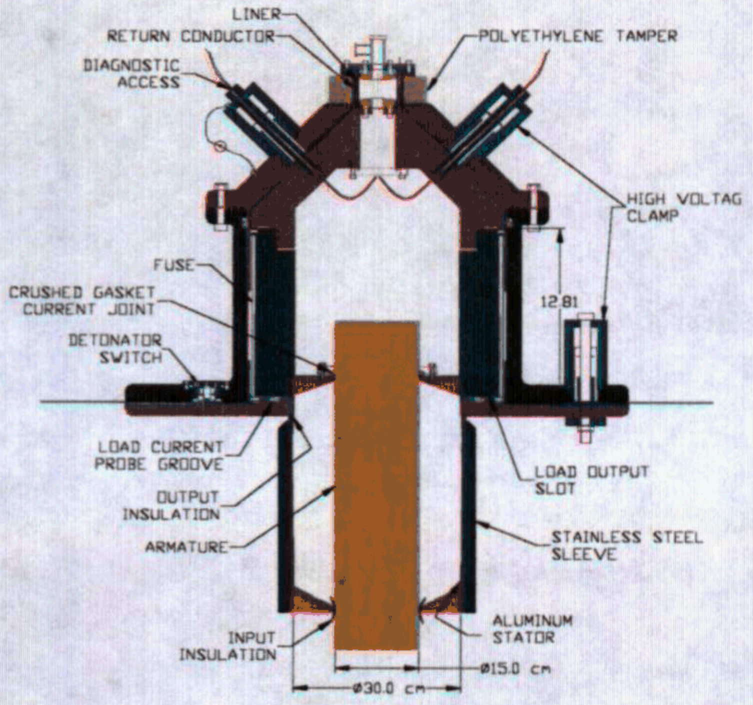

Figure 2B. Cross-section of a Ranchero imploding liner experiment. Generator shown is 43 cm long, rather than the 1.4-m generator pictured in 2A.

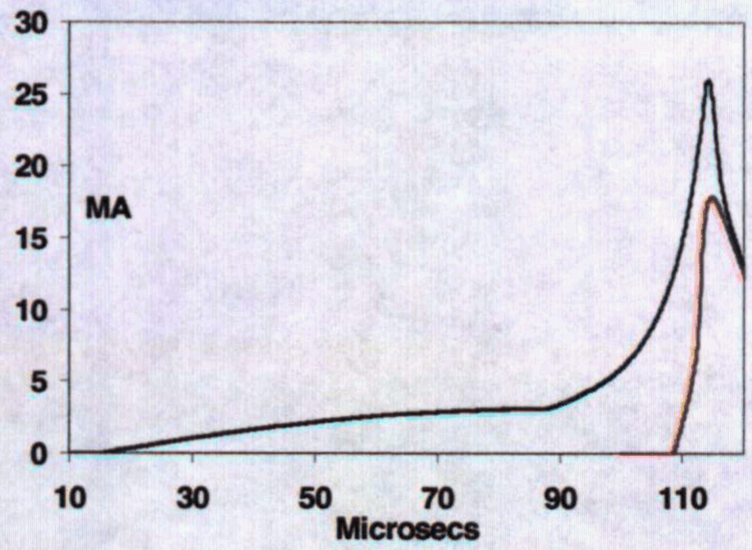

Figure 3. Generator current (long pulse) and load current (short pulse) for a full-scale Ranchero liner experiment.

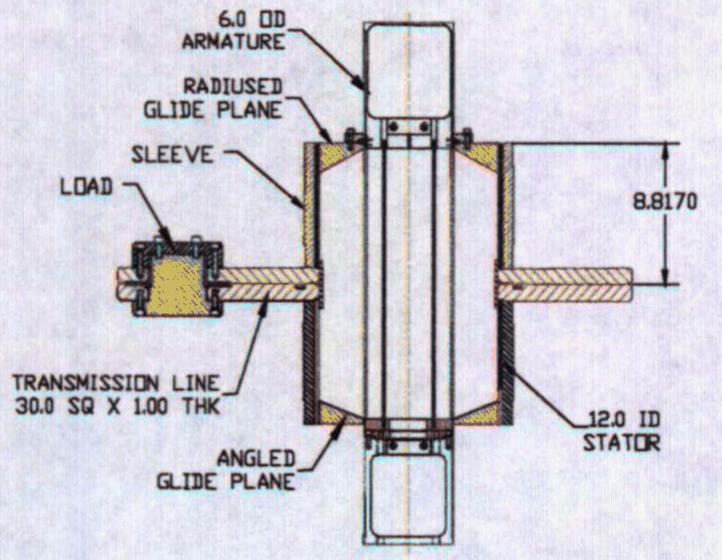

Figure 4A. Cross-section of a Ranchero experiment with load attached to the midplane of the generator.

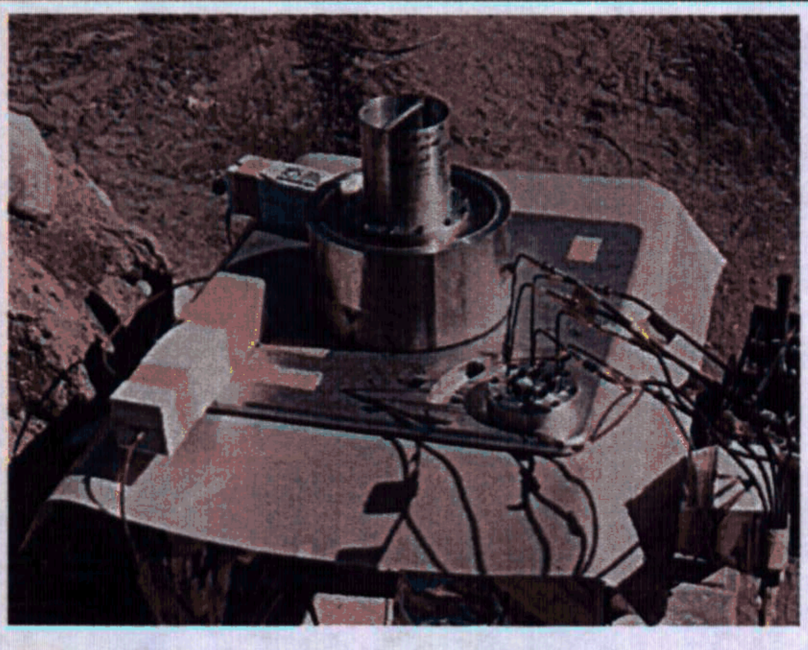

Figure 4B. Hardware for experiment conducted with mid-plane load connection.

fuse design, such an experiment would generate 66 MA, and deliver 46 MA to the load. MHD calculations indicate that we should not see substantial losses in a Ranchero system until currents approaching 100 MA are reached, so boosting the Ranchero system at this level, or well beyond, is possible.

Because ICE data is best gathered in planar geometry, the coaxial connection made to the Atlas simulation experiment is not the best way to connect to an ICE load. We believe that taking the output current from the middle of the generator, as shown in fig. 4 provides the best way. As shown in the figure, loads have been attached to planar transmission plates at the mid-plane of the Ranchero modules. The load shown was a massive cylinder, and although we never powered cylindrical implosions this way, such a configuration is well suited to ICE loads. With symmetric current distribution emanating from the Ranchero module along the mid-plane, we have achieved the highest degree of flux conservation that we have ever measured in an FCG. When current flows preferentially in one direction out of the center-connected transmission plates (as in figure 4), there are noticeable effects. We have made 3-D field calculations that show the degree of current bunching toward the output side, and these do not show it to be an extreme effect. Further, experiments performed in this configuration indicate that we add ~ 2 nH to the load inductance above the inductance of a perfect radial flow out of the generator. Since any coaxial-to-flat plate coupler will have inductance, and since we do not expect to push the current to the limits of a Ranchero module's capability, we believe this is the best approach to attaching the desirable flat plate loads.

MK-IX generator

The MK-IX generator is not optimized for this application, which is to deliver 12 MA to a 190 nH load. It is better suited to the role of the primary system power supply in systems such as Procyon that need 20 to 30 MA storage inductor current. However, 12 MA is easily generated by a MK-IX, and should require only ~650 KA initial current to develop that level into a Ranchero module. A series parallel configuration of our capacitor bank, which operates it at 3 mF and 39 kV, should supply the necessary current without over stressing the MK-IX windings [14]. Ultimately, an FCG with a current capacity of only ~12 MA, and with much more gain and less explosive mass should be easy to design and preferable to the MK-IX.

EFF switch

We have used EFF's in many applications, and have published a wide variety of the results. There are some points worth making about our switches in the context of this paper, however. In an earlier paragraph, we noted that the inductance in an opening switch may, or may not be included in the vertical leg of the circuit corresponding to the opening switch. The difference is in topology, as noted earlier [10]. In general, the switches we dubbed "flux conserving" in our earlier publication are more efficient switches. This is because all the magnetic flux that is allowed to diffuse through the opening switch resistance in these designs is trapped in the load circuit, and contributes to load current. On the other hand, there is inherent inductance associated with the load-output transmission lines in these designs, and this inductance adds to the total load inductance. For EFF devices in the conserving topology, this inherent inductance is on the order of our desired load inductance, and as a result, the EFF voltage (V_{EFF}) necessary for a prescribed dI/dt in the load essentially doubles. With the non-conserving topology, more voltage also has to be generated than is applied to the load, but load transmission lines need not be insulated for the total voltage. In considering ICE designs to date, it is best to operate the switch in the less efficient mode, and maintain the flat-plate transmission lines needed for ICE research. Each application deserves careful scrutiny on this point, however, and improved designs may change the desired topology.

We have limited experience with wide ranges of linear current density in our EFF designs. Unpublished small scale experiments show that the switches work very well at much smaller current densities than that at which we have typically used them, and that seems to contradict conclusions we reached about the switching mechanism in our 1989 publications [15]. More research is needed on that point. However, lower current density applications are usually not the direction of our research, and we typically are contemplating the need for higher current density levels. A great deal of our experience is in the current density range around 0.1 MA/cm, and our well publicized Procyon work was conducted at ~0.2 MA/cm. We have never successfully tested small-scale switches at levels much in excess of that. One possible reason is the magnetic pressure applied to the thin EFF conductor is transferred directly to the explosive. This pressure may compress the HE to a density at which it will not detonate, and hence lead to failure. We have a solution to this problem, in principle, but it is somewhat speculative, and we are reluctant to extrapolate designs in that way without further work. As a result, in our EFF designs we have worked with ICE systems that remain at the 0.2 MA/cm level or below. For large currents, this either requires a large-diameter switch, or multiple parallel switches at smaller diameters. In initial analysis, it appears that there are advantages to using parallel switches at smaller diameter. Among these is reducing the total explosive weight, and the ability to further form the resistance profile by staggering the actuation time of parallel devices.

Coupling Ranchero, Opening Switch, and ICE Load

Figure 5 shows a configuration that tightly couples a Ranchero generator and two parallel EFF switches. The generator shown is 1.4 m long, and the two switches are 50 cm long. EFF switches have been successfully operated at ~10 KV/cm of length, so that those shown should develop at least 500 KV. In this arrangement, we have preserved the resistance profile, given in figure 6, of our initial experiments [2], and the diameter of each switch is 23.5 cm. We can, as needed, adjust R(t) for the switches by changing the switch alloy or the length to diameter ratio. At 0.2 MA/cm linear current density, the two switches would have a capacity for 29.5 MA. PCS switches differ in detail from the EFF designs shown, but would resemble the switches in the figure in gross dimensions. In the following predictions for load performance, we discuss experiments using just the capacitor bank for initial current, a 1.4 m Ranchero generator, and both EFF and PCS switches. The projections are repeated with a booster generator to provide 12 MA seed current. As will be seen, the configuration shown in the figure is adequate for cases where the bank only is used for seed current. Fully boosted systems (12 MA seed current), will require expansion of the EFFs or development allowing them to be operated at higher current density. Among the projections is a case in which the peak generator current reaches 88 MA, the driving voltage is 830 KV, and a 17 Mb isentropic profile is produced. The EFF in this calculation develops 1.3 MV and would require our longest detonator system. PCS devices have been reported to develop voltages of 100 KV/cm [9], and could considerably reduce the length required to do this job. With no achievement in higher current density, the most practical arrangement would be four parallel switches, to

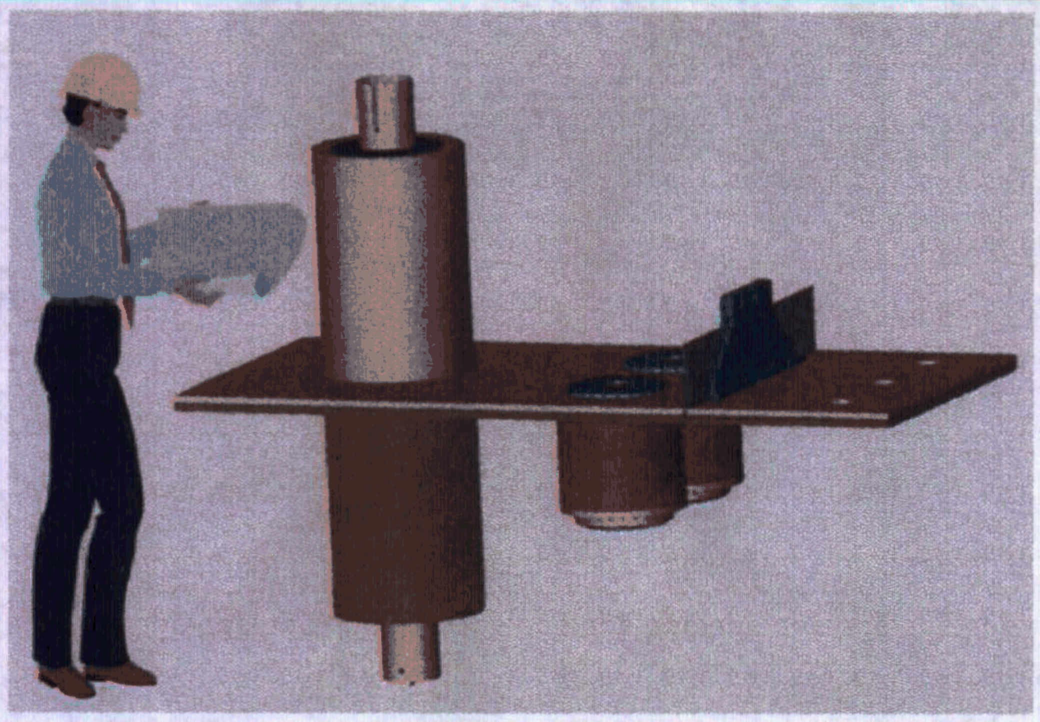

Figure 5. Artists concept of a Ranchero-powered ICE experiment. The generator is 1.4 m long, and the two switches are 50 cm long. The switches pictured are EFF switches, but could represent PCS switches as well. EFF switches will sustain a voltage (V_{EFF}) of 10 KV/cm, so could generate 500 KV, as drawn. PCS devices may allow higher voltage per unit length.

minimize the total HE required. With either adequate EFF performance at higher

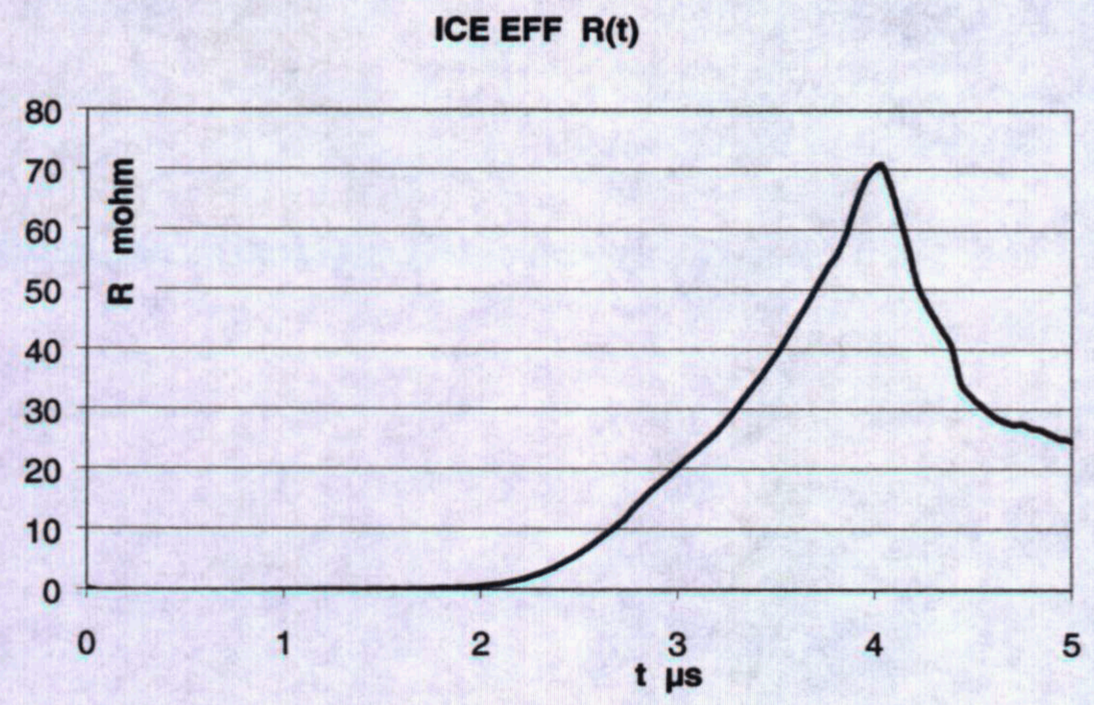

Figure 6. EFF resistance curve currently in use on ICE experiments. The switches in figure 5 would follow this curve, but the ratio of length to circumference can be changed, or alloy in the switch can be changed, to allow different profiles.

current density, or a scaled up PCS operating at higher I/w, then fewer, or smaller units are required.

Load Design and Predictions

Designs are created using the Los Alamos Scat 95 circuit code in combination with the Lawrence Livermore National Laboratory Trac-II magnetohydrodynamic (MHD) code. Scat 95 solves the circuit equations, which consist of dynamic inductance and resistance of all elements including load, EFF, and FCG. The MHD code is used to determine the dynamic inductance of the load in an iterative process. First, the voltage waveform is computed with Scat 95. Second, the voltage is applied to a simulation of the load in Trac-II. Third, the dynamic load inductance is determined from L(t) in the MHD, which specifically provides electrode separation and resistive effects. Fourth, the new load inductance is input into Scat 95. This process is repeated until convergence is obtained (as measured by the current waveform) between Scat 95 and Trac-II. In the end we obtain a load current and pressure loading profile.

Our first designs using this method were performed on the plate FCG design discussed elsewhere in this conference. This employed an EFF opening switch and large (26 nH) storage inductor. We obtain are a peak current of 7.4 MA to the load which consists of 1.2 x 2.6 cm parallel plate of Tungsten (Design 1, table 1 and 2).

In our first attempt to scale up, we replaced the plate FCG with a Ranchero 190 nH 1.4 m coaxial FCG and performed the same calculations. The load was taken to be 1.5 x 1.5 mm parallel plate of tungsten and the storage inductor was 20 nH. Switching time to the load was taken to be late in the FCG run where final inductance is a minimum (7 nH). The FCG inductance waveform, as well as the EFF resistance/inductance waveform, was taken from experimental data. The EFF circuit parameters were also scaled to maintain an acceptable current density (0.15 MA/cm). Initial FCG current was taken to be 12 MA. We found that this gave us approximately 33 MA to the load with a peak pressure of 12 Mbar (Design 2, table 1 and 2).

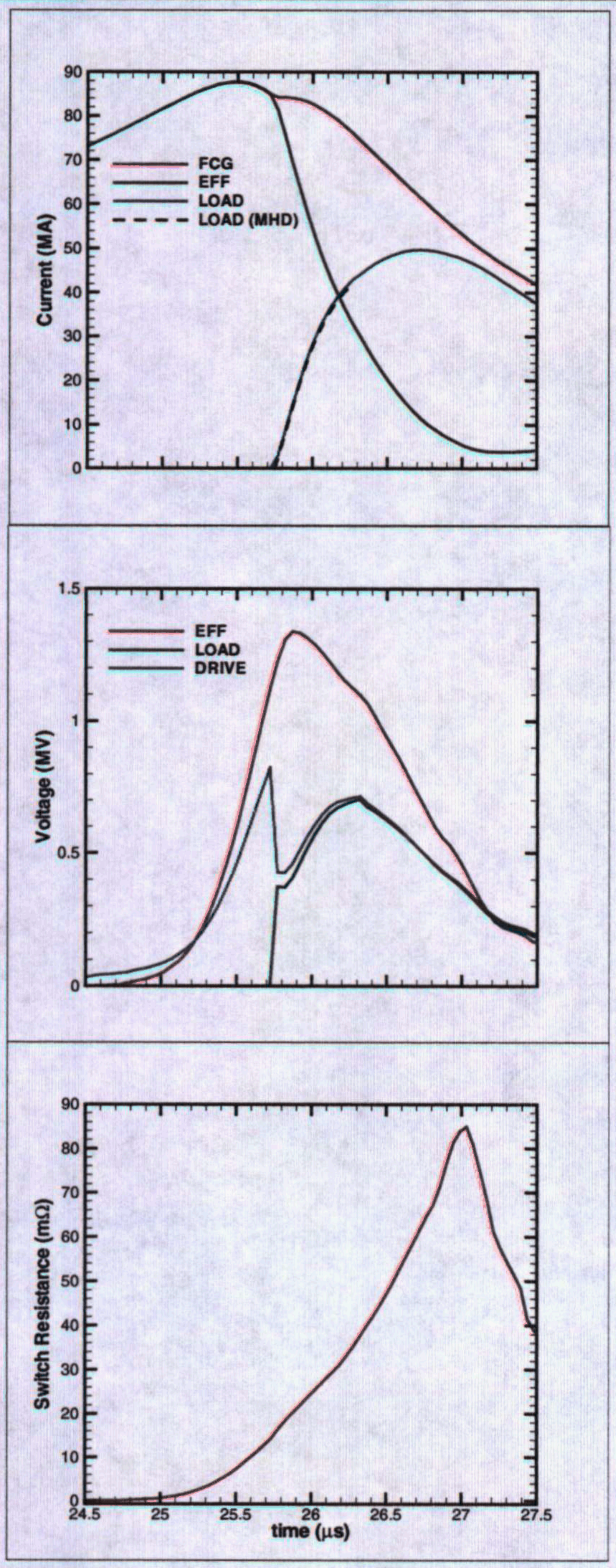

Figure 7. Circuit performance for 17 Mbar ICE design.

Further calculations were performed with a somewhat different approach. The EFF and closing switches were triggered earlier in the FCG run and storage inductor reduced to 3 nH. Essentially, this design replaces the storage inductor with the residual inductance (18 nH) of the FCG. We found that this gave us our best results owing to the fact that current levels have not yet started to decrease at switching time as in the previous calculation. We transferred 50 MA into a 2x2 cm tungsten load, giving a peak pressure of 17 Mbar (Design 3, Table 1 and 2). The results are shown in figures 7-9. We note that although the final plate separation is large (~5 mm), planarity of the pressure drive remains good – over 1 cm (figure 8).

Several issues should be noted about the previous calculations. First, in all the ranchero/EFF designs we assumed an insulating package at the load of 1 mm. Assuming this to be layered Kapton which can reasonably hold off 7 kV/mil, we can sustain a maximum of 280 kV. The peak voltage at the load reached in these designs are 420 and 700 kV, clearly exceeding this maximum. We would have to increase the insulation in these designs to 2-4 mm unless magnetic insulation can be invoked in such a configuration. For increased insulation thickness, transmission plates can be made wider to recoup some of the inductance increase, except in the load region where we must converge to create a large current density and magnetic pressure. We are examining the value of magnetic insulation in this apparatus. Second, we note that tungsten, chosen for its high conductivity and

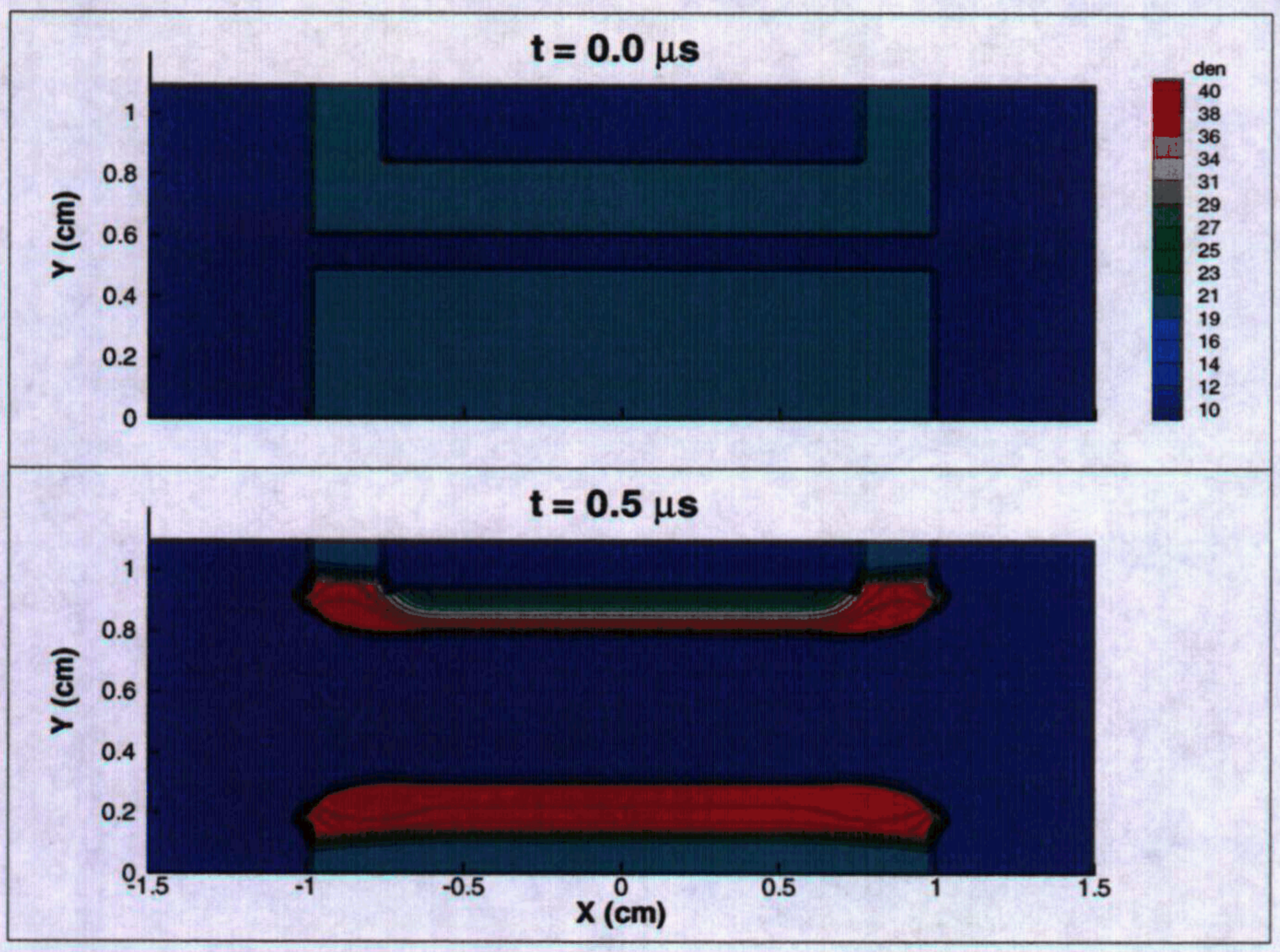

Figure 8. 2D MHD calculation showing density contours initially and late into calculation. Note that the AK gap has incrased from 1mm to 5 mm at the time of peak compression

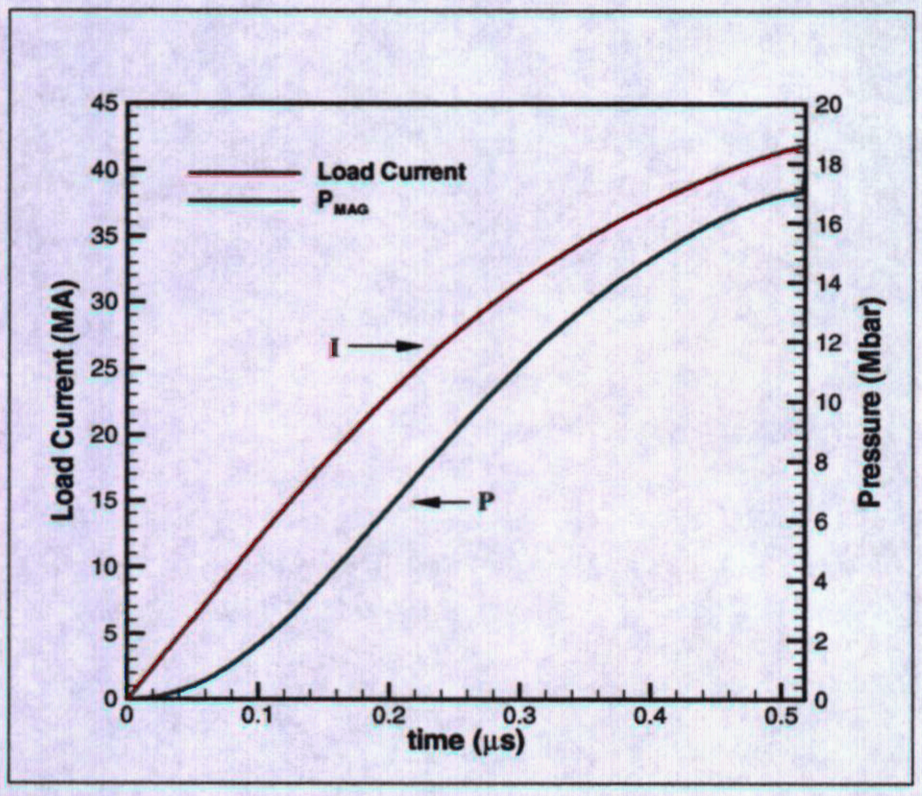

Figure 9 Current and magnetic pressure histories for 17 Mbar ICE design

high density, has not been validated at the current density levels of our calculations. We have isentropically loaded tungsten to 300 kbar with no unusual effects but higher levels are unknown. Sensitivity studies with Trac-II on the 18

MA design indicate that a 50% increase in resistivity can decrease the peak pressure by 1 Mbar. The alternative to Tungsten – copper electrodes – would greatly increase our dynamic load inductance and degrade the peak pressure as well as reduce the planarity of the magnetic pressure drive.

Alternative circuit – Pavlovskii switch

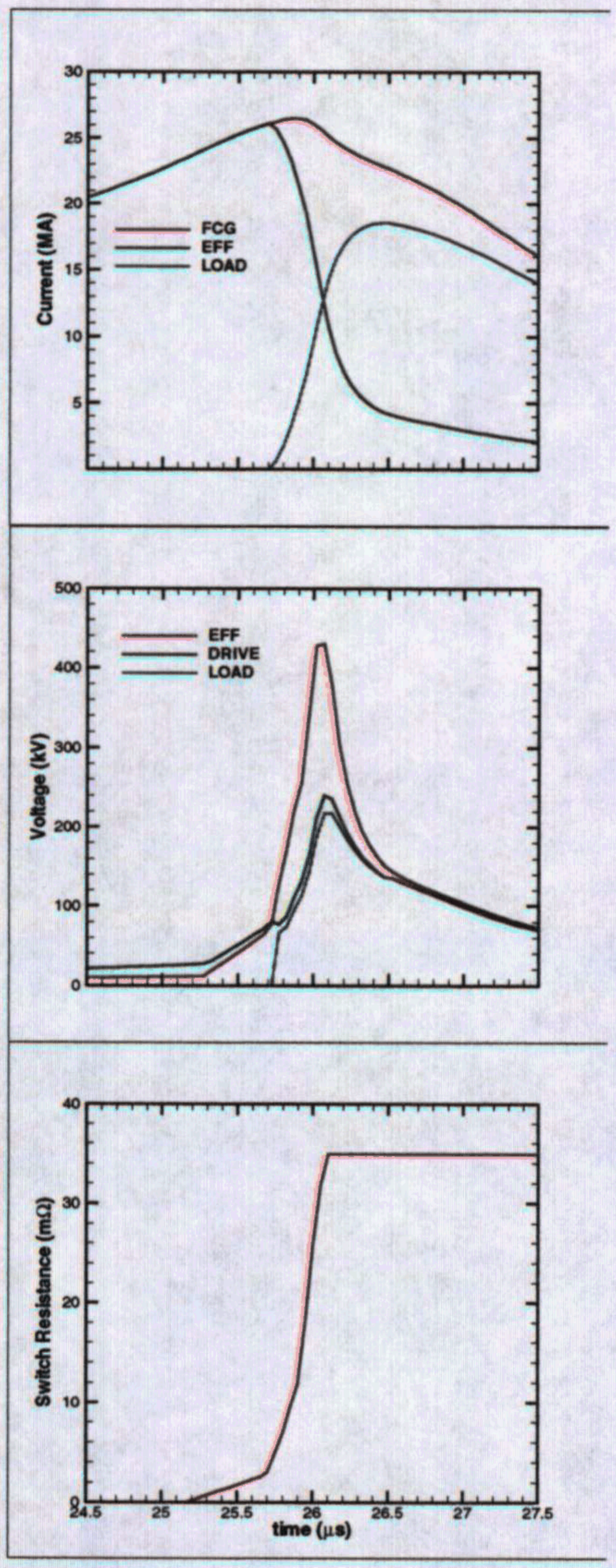

Figure 10 Circuit performanch for Ranchero/Pavlovskii design

Almost two decades ago experiments were performed at Los Alamos which, similar to ICE shots being pursued today, employed a plate generator an and low inductance (6.5-15 nH) load in planar geometry[16]. The only difference was the method of current diversion, which was a plasma compression switch of the type first developed by Pavlovskii. We shall refer to this as the Pavlovskii switch even though in the Russian literature in is referred to as the explosive plasma switch (EPS).

We have performed one ICE calculation using a Pavlovskii switch, with results shown in figures 10 and 11. As in the previous scaled-up calculations, we employed the Ranchero FCG. The plasma switch was taken from a design successfully fired at LANL. Although two types were tested – a planar and a cylindrical version – we chose the cylindrical since it offered the greatest overlap with Russian efforts and better scaling possibilities to high currents. It consisted of a 12.7 cm diameter, 12.7 length design with a 5000 vapor deposited aluminum layer to initiate the plasma. The results of that experiment included a 35 mOhm peak resistance and a 4 MA load current, with a 10-90% risetime of 300 ns. An external breakdown limited peak resistance in the test, and we have scaled R(t) from the data, flattening it at the experimentally achieved peak. This should be a conservative approach to using these data. We employed the resistance waveform thus obtained (shown in figure 10) scaling dimensions appropriately. We neglected opening switch dynamic voltage and inductance, although both effects would improve peak FCG currents, and used the static value of 2.7 nH.

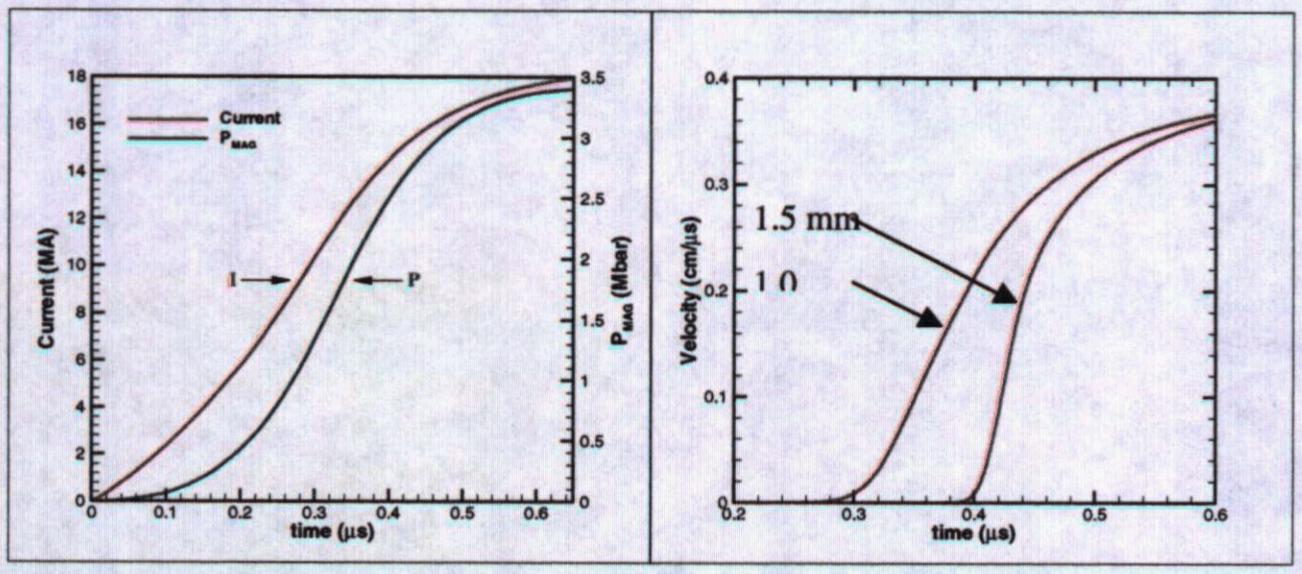

Figure 11 A) Current and Pressure profiles for Ranchero/Pavlovskii design. B) Corresponding in situ copper velocity wave profiles at 1.0 and 1.5 mm of sample thicknessness.

This first Ranchero/Pavlovskii design calculation was an entry-level system without a booster. The Ancho Canyon capacitor bank can deliver an initial current of 3.3 MA into a 1.4 Ranchero FCG, and we took this to be our initial current. As in design 3, we used a 3 nH storage inductor and fired the EFF/closing switches earlier in the FCG run to capture some residual inductance. The load was also chosen to be a conservative 2x2 mm parallel plate copper design. The insulation package was taken to be 1 mm along the load, adequate to hold off the peak voltage of 230 kV.

From this design we obtain a peak load current of 18 MA, as shown in fig. 10, which gives approximately 3.4 Mbar of magnetic pressure to the load (figure 11). Voltages across the EFF and FCG, 200 and 140 kV, are reasonable. We conclude that this system could be easily fired using the almost identical arrangement being pursued now at Ancho Canyon. It would provide an excellent test bed for studying such coaxial FCG/Pavlovskii switch system with the goal of ultimately scaling it to much higher currents and pressures.

Shown in figure 11B are the in situ velocity profiles at two Lagrangian distances for a sample in this configuration. We conclude that this design is capable of isentropically loading copper up to a peak pressure of 3 Mbar in samples up to 1.5 mm thick.

These results are encouraging, and from a Los Alamos viewpoint, based only on our previous experience, the major questions about Pavlovskii switch performance relate to energy dissipation during current amplification and the power that such a switch can dissipate and still maintain its resistance profile. We are well aware that other researchers have pushed the performance far beyond what we have achieved [9], and we will review the literature accordingly.

Conclusions

We have investigated our ability to perform ICE research at very high pressure levels. Using HEPP techniques available to us, we can produce pressure profiles of 17 Mbar, and with additional adjustments of parameters, can reach 20Mbar. The single largest risk apparent from the calculations is the very high voltages needed to drive ICE loads. These voltages are, in part, due to the dynamics of the ICE loads. Further research on power flow is needed to say with certainty that such voltages can be managed. One solution is operating the system in vacuum where magnetic insulation can be applied. In the interim, there are stages of development that can produce interesting results without solving the highest voltage problems, and we have designed a system that can do this job without extending technology beyond what has already been done. We will examine the use of Pavlovskii switches to shorten the opening switch in our high voltage systems.

Design	FCG/Opening Switch	I_0	I_{FCG}	V_{EFF}	V_{DRIVE}	L_{store} (ext.)
1	Plate/EFF	2	12	180	110	26
2	Ranchero/EFF	12	55	800	500	30
3	Ranchero/EFF	12	88	1300	830	3
4	Ranchero /Pavlovskii	3.3	26	430	240	3

Table 1 General Circuit Parameters

Design	Load Type	I_{load}	V_{load}	Risetime 10-90%/e-fold	Pressure
1	1.2x2.6 Cu	7.4 MA	48 kV	610/340 ns	1.6 Mbar
2	1.5x1.5 W	33	420	620/360	12
3	2x2 W	50	700	550/320	17
4	2x2 Cu	11	230	390/340	3.4

Table 2 Specific load parameters

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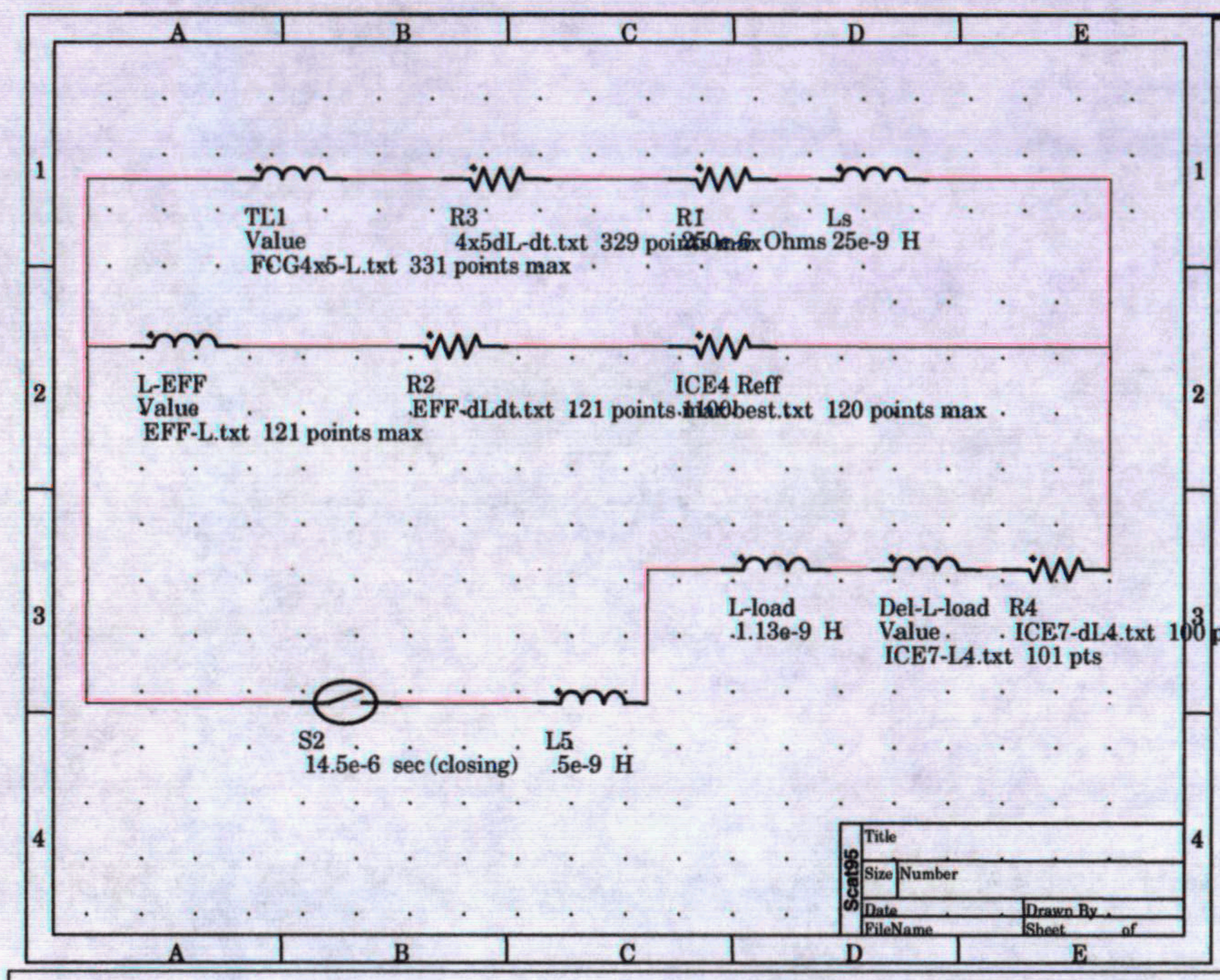
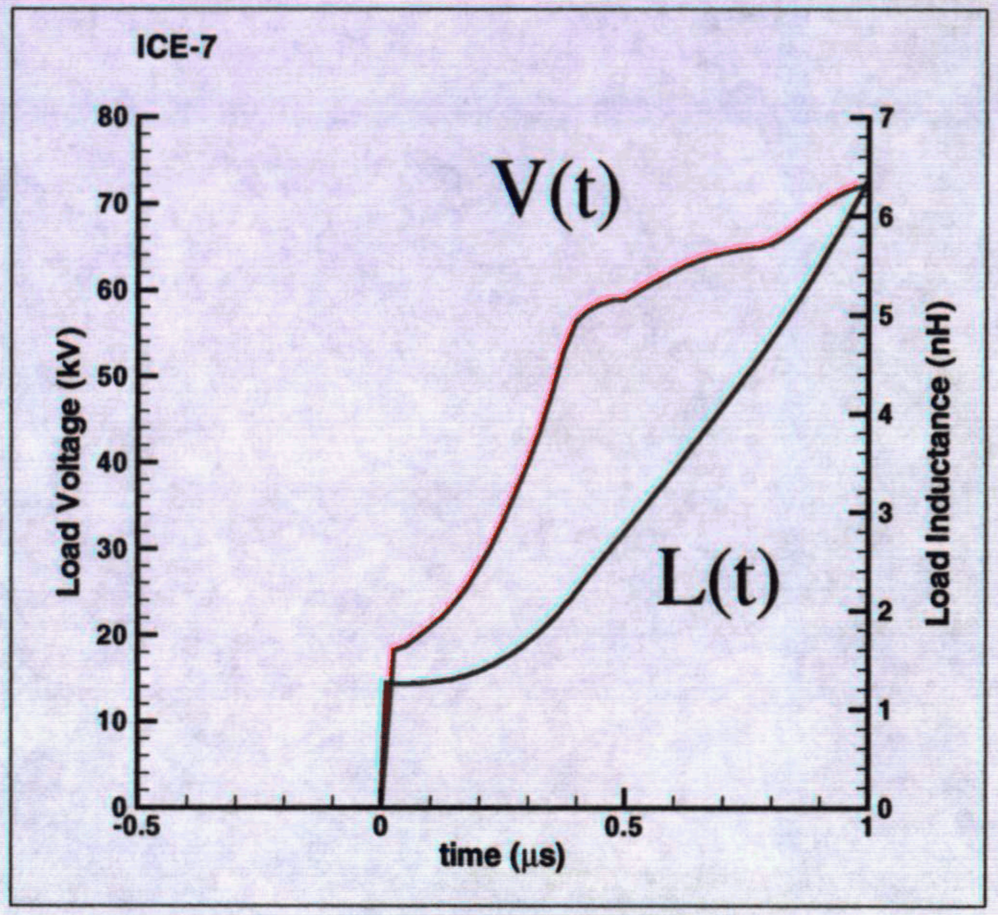
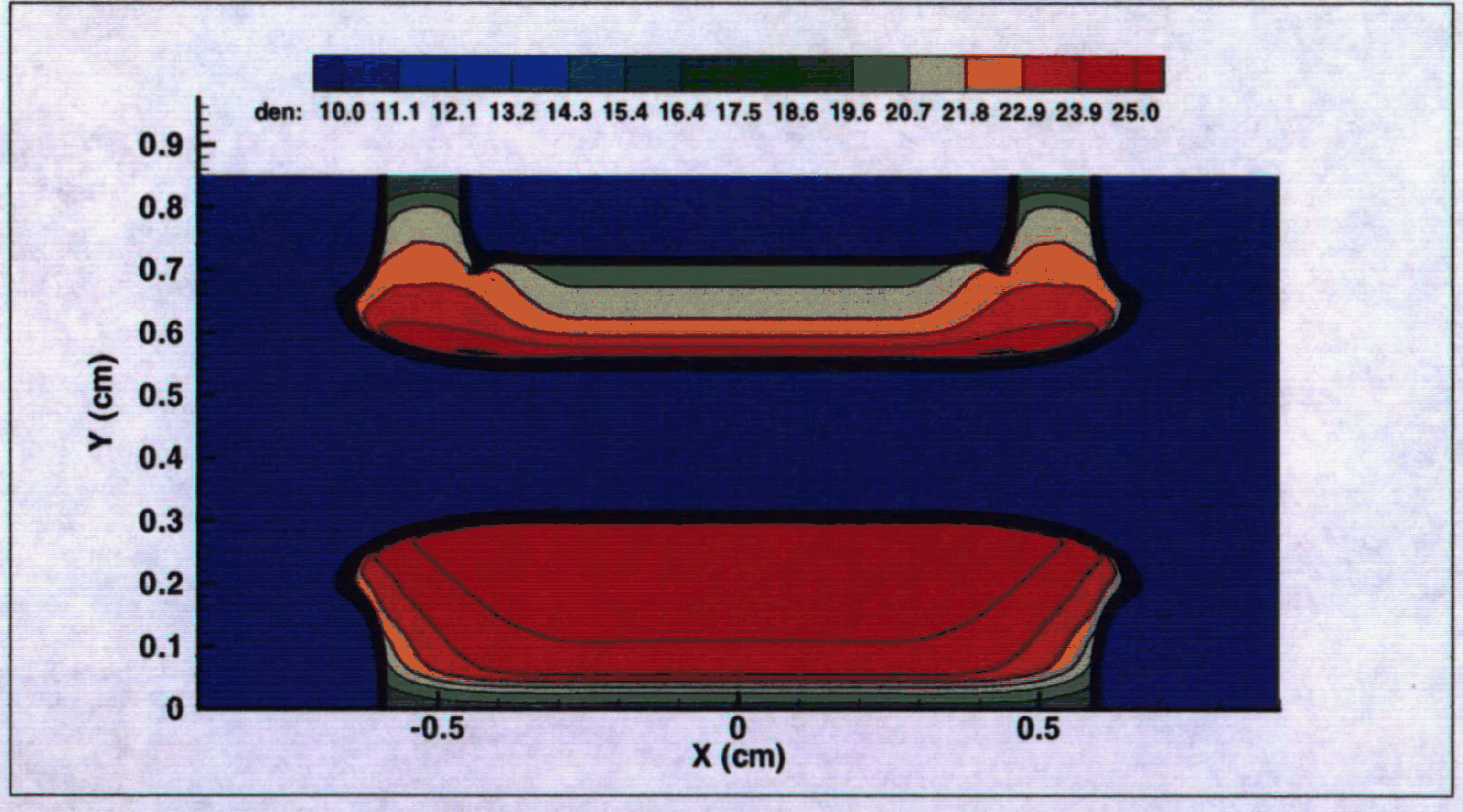
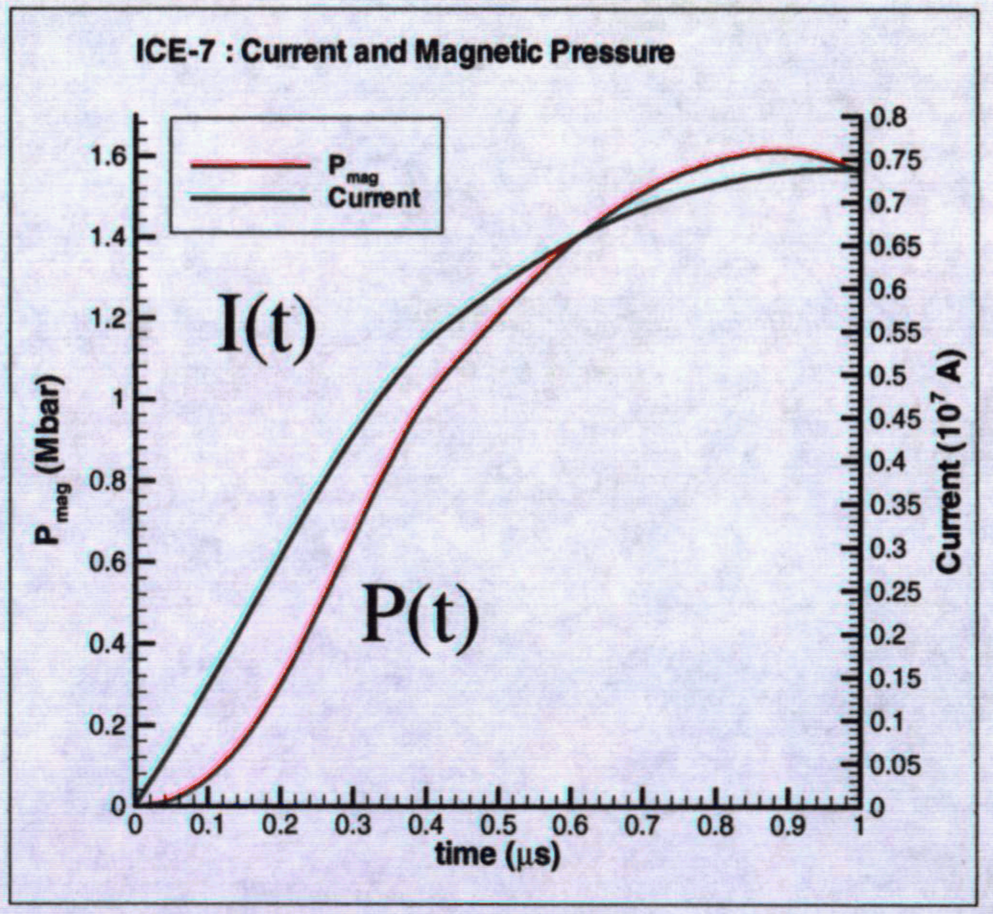
16. J.H. Goforth, et al, Explosiveily Formed Fuse Opening Switches for Use in Flux-Compression Generator Circuits, Fifth International Conference on Megagauss Magnetic Field Generation and Related Topics, 1989, Novosibirsk, RUSSIA, pp.515. Titov and Shvetsov eds
17. J.H.Goforth, et al, Multimegampere Operation of Plasma Compression Opening Switches in Planar Geometry, (Proceedings of the Fifth IEEE International Pulsed Power Conference), Arlington, VA, 1985, p. 212

MHD simulations, coupled with circuit calculations, predict load voltage, current, pressure drive, and planarity

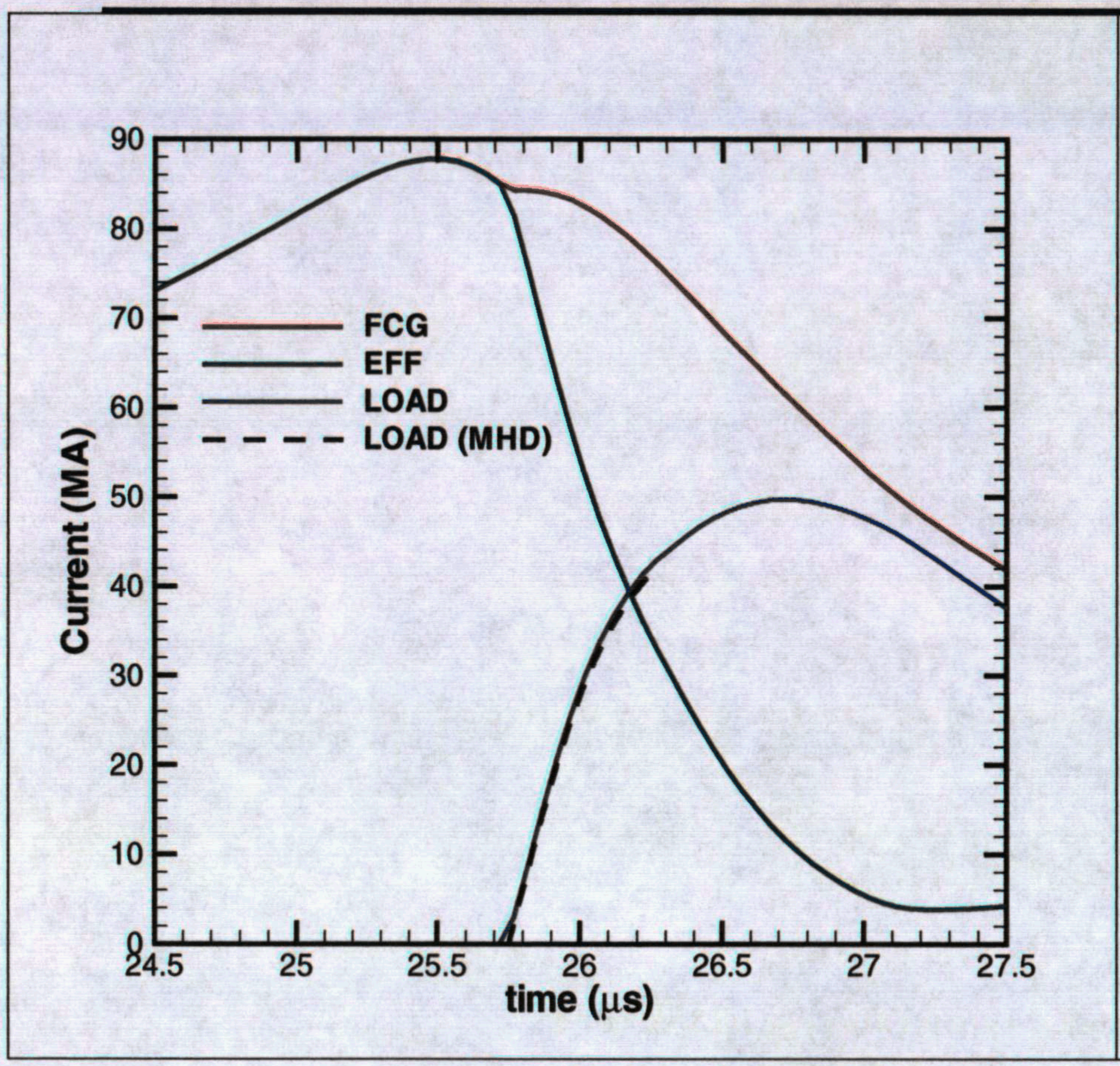


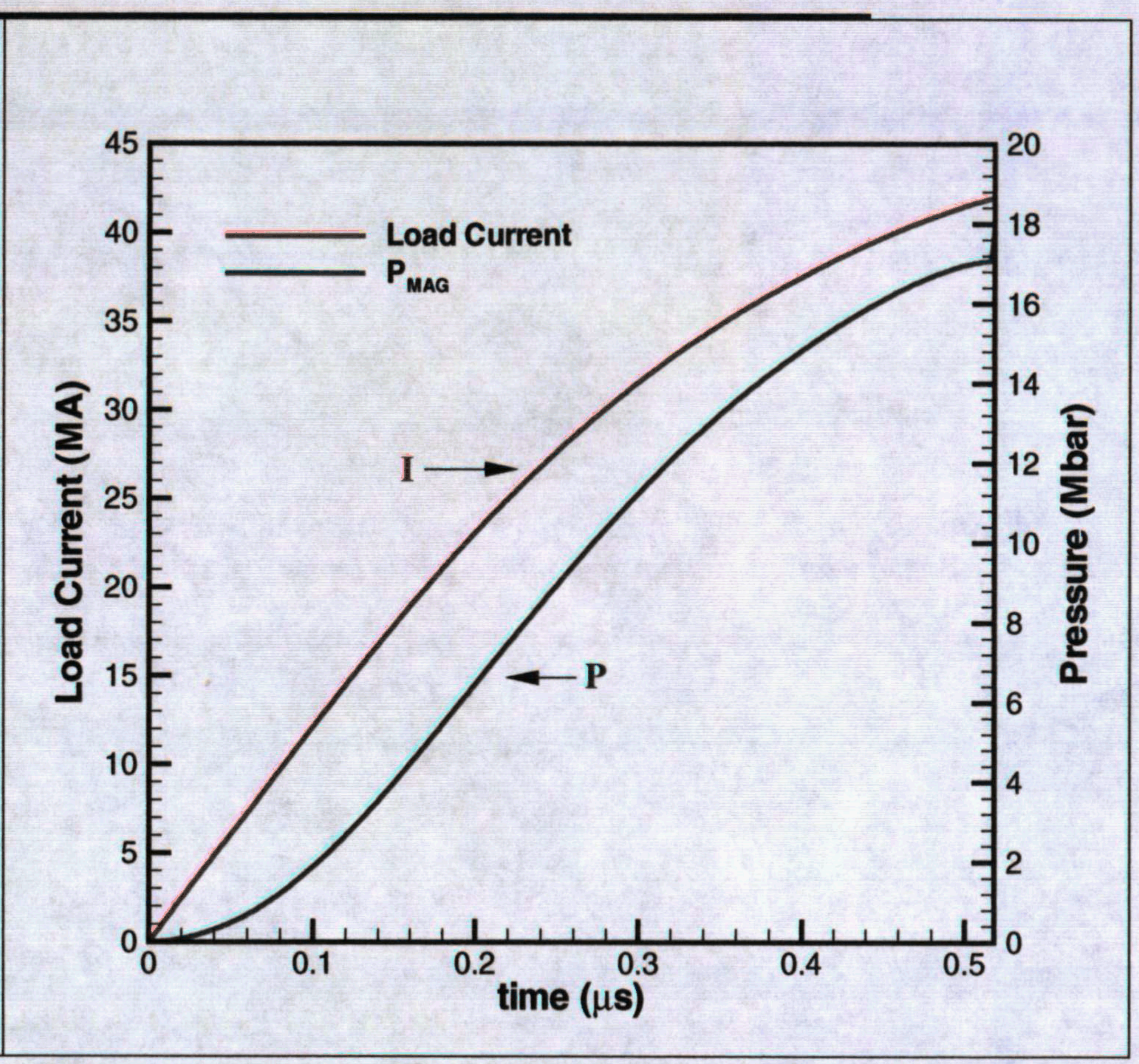






EFF/Ranchero design can reach pressures of 17 Mbar





- Boosted (I_0 = 12 MA) Ranchero FCG reaches 88 MA
- 50 MA is diverted to the load
- MHD calculation run for 500 ns

- Load current risetime (10-90%) is 550 ns
- 17 Mbars of magnetic pressure at 500 ns

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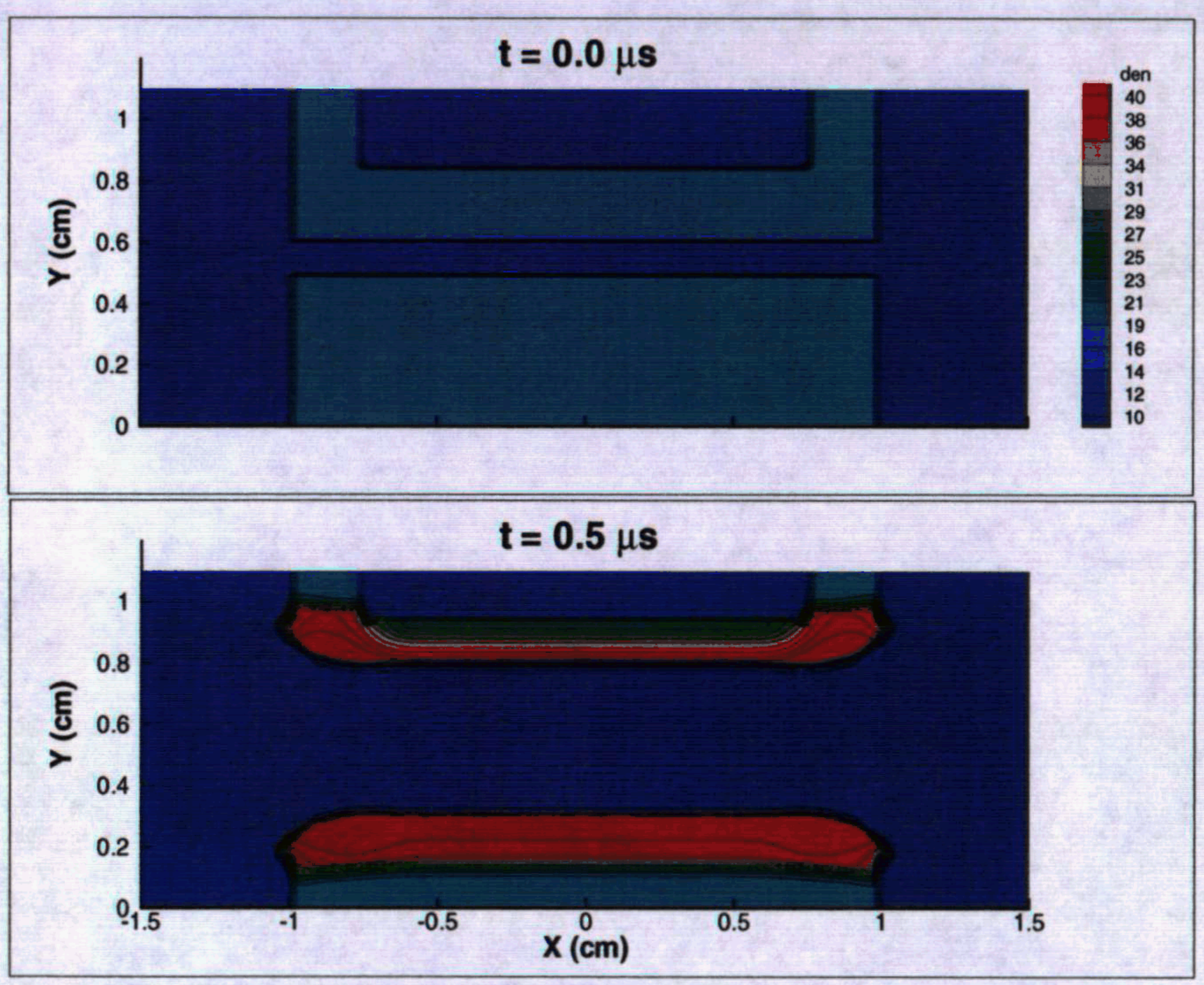
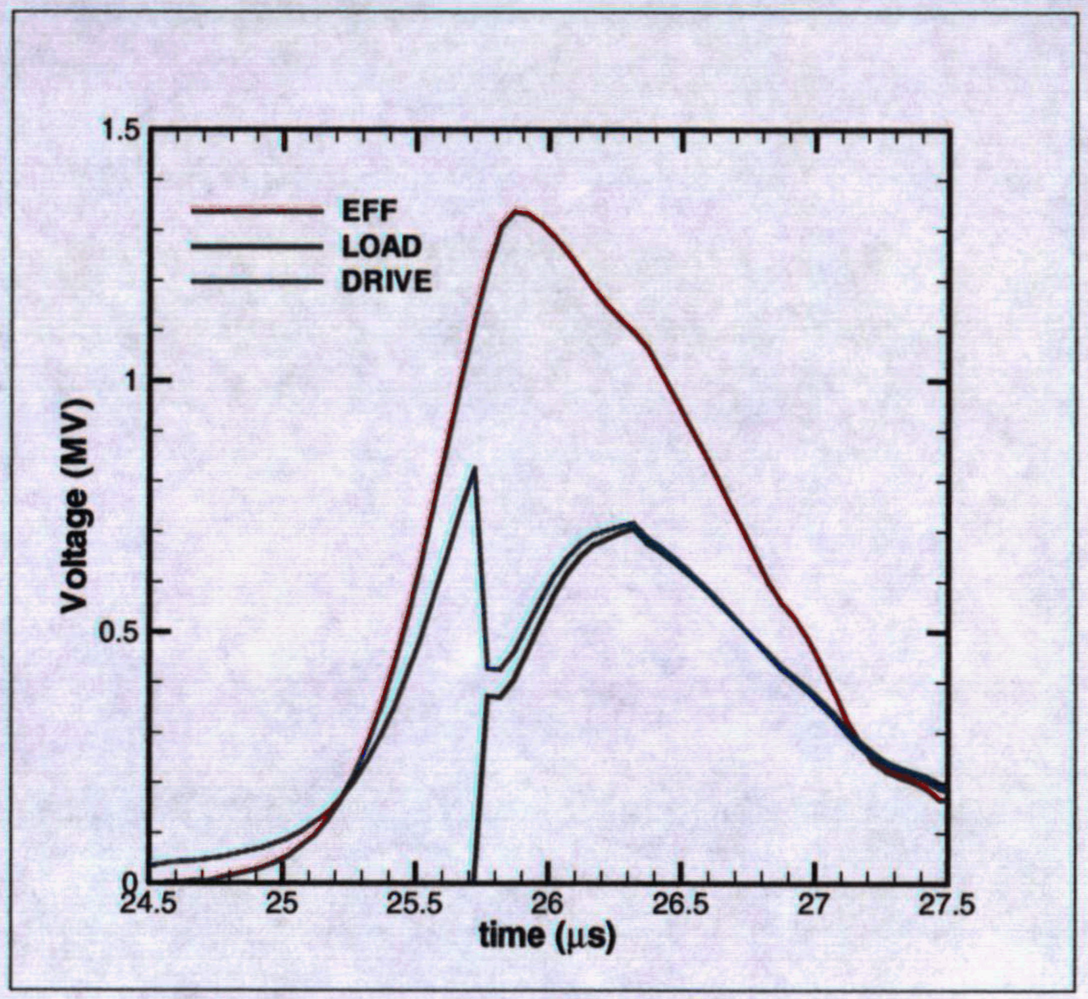
MHD simulations show good planarity of pressure drive and very high voltages in load region





- Load is 2x2 cm tungsten, 1 mm gap
- Anode-cathode separate by over 5 mm during pressure drive
- Load voltage dominated by IdL/dt

- Load voltage reaches 700 kV
- Magnetic insulation must be explored

LANL (circa 1984) demonstrated a HEPP circuit capability similar to that being pursued now

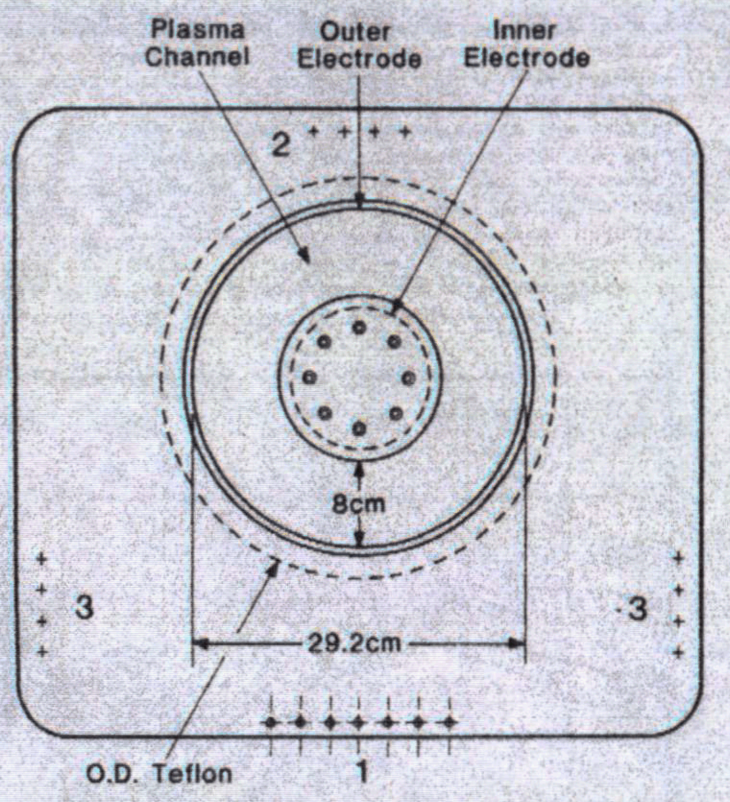
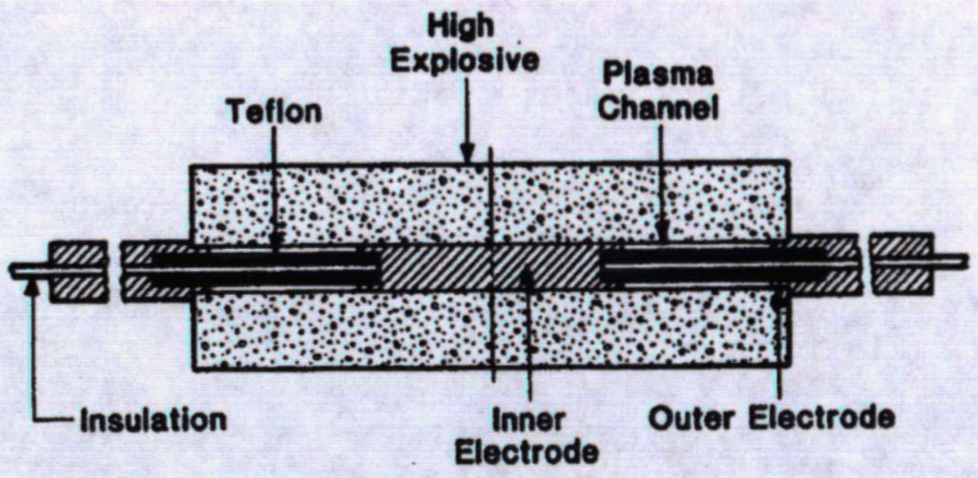


Fig. 2. Top view of planar plasma compression switch. Current flows radially between inner and outer electrodes. Generator attaches at 1 and loads at either 2 or 3.



- "Pavlovskii experiments" used a plate FCG with a planar EPS
- All experiments successful
- 4-7 MA transferred to load with ~300 ns risetimes – ideal for ICE

Fig. 5. Final few microseconds of generator current pulse for four experiments. Generator flux compression begins at zero on this time scale.

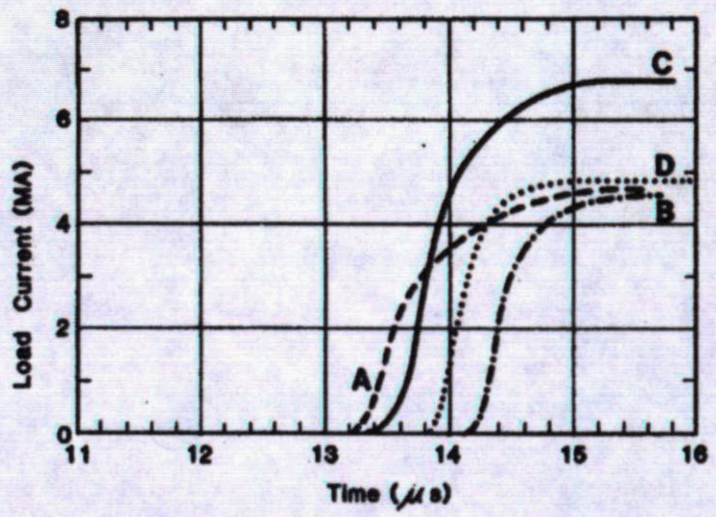


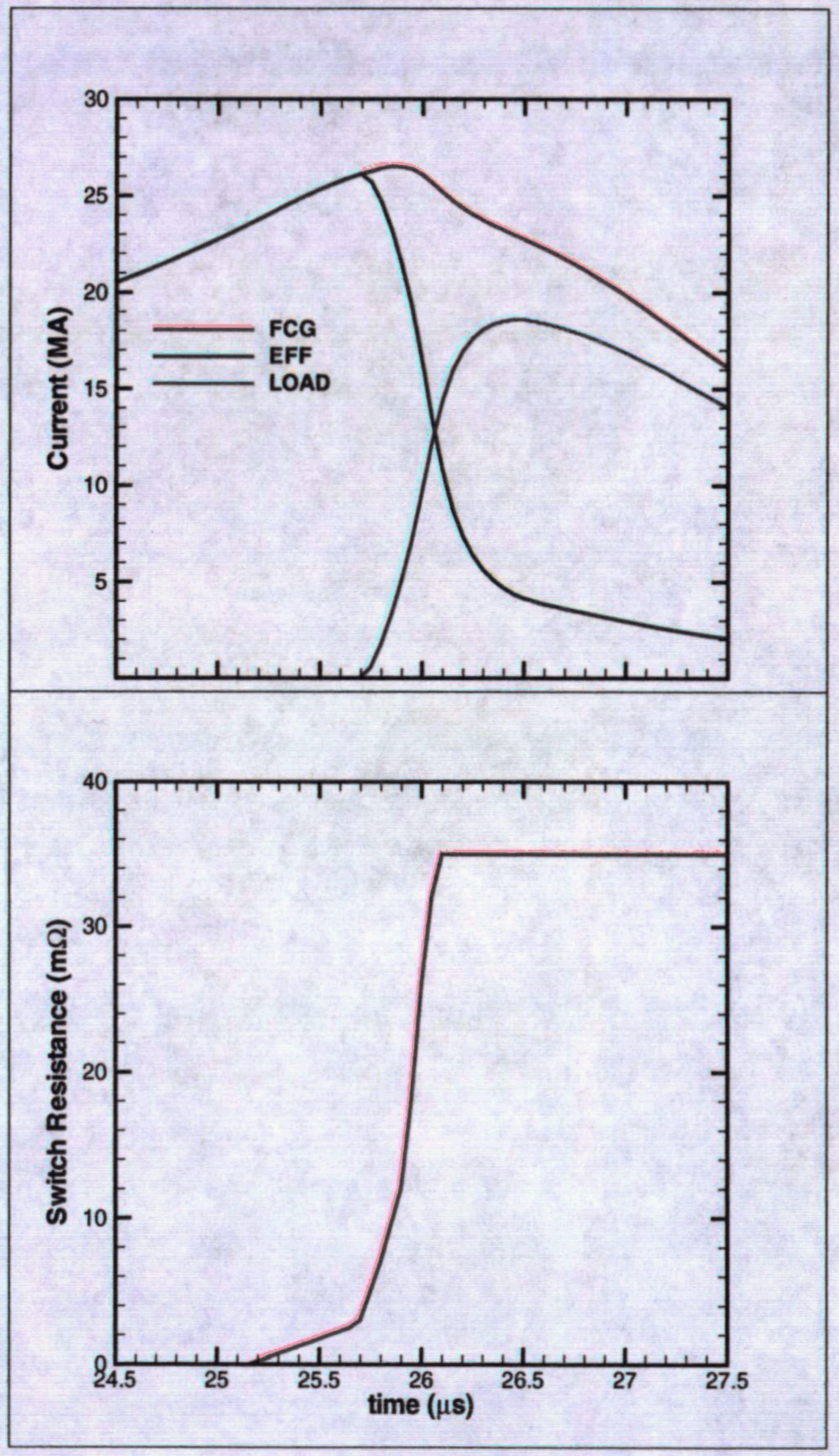
Fig. 6. Load pulses for tests shown in Fig. 5.

Table I. Load Pulse Parameters

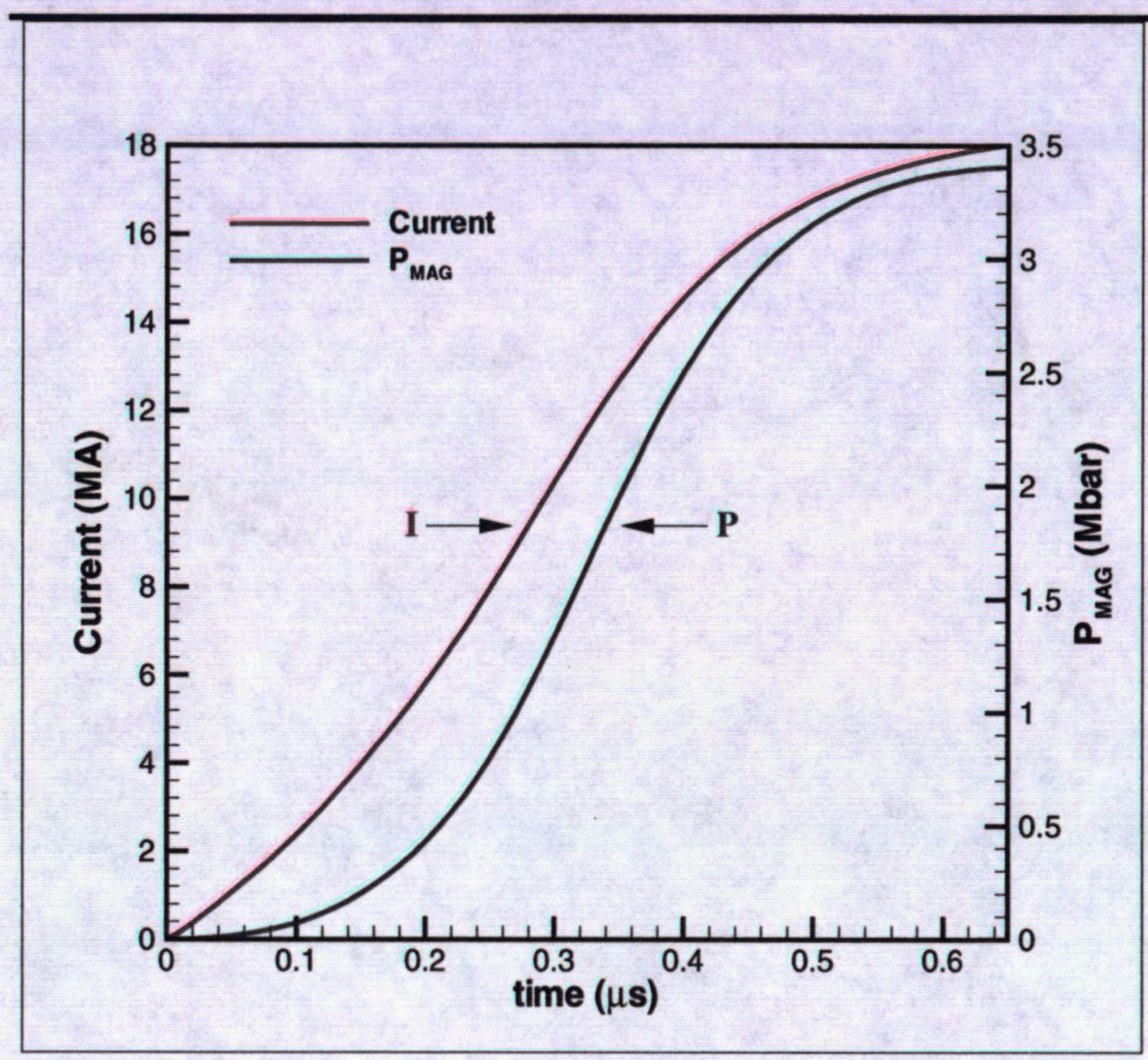
Experiment	I_3(max)	Risetime (e-fold)	Risetime (10-90%)	L_3
A	4.7 MA	0.45 μs	1.10 μs	15.0 nH
B	4.6	0.35	0.54	15.0
C	6.7	0.45	0.90	6.5
D	4.8	0.30	0.45	8.0

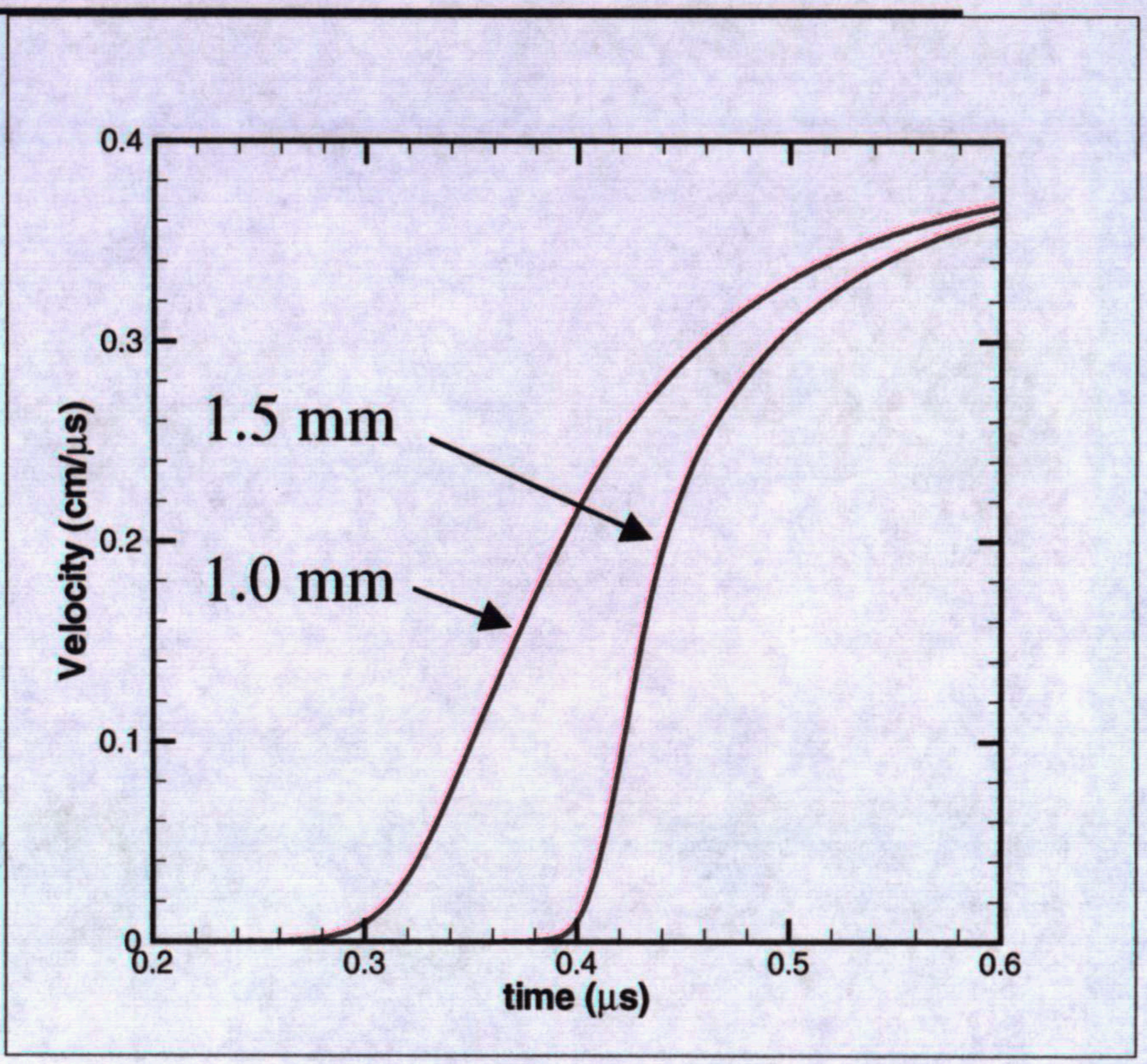
We have designed an ICE experiment using the Pavlovskii switch in combination with the Ranchero FCG

- Experimental resistance waveform from a cylindrical LANL EPS
- 1.4 Ranchero with I_0=3.3 MA (no booster generator)
- Load: 2x2 cm Copper, 1 mm solid insulated AK gap
- Peak FCG current of 26 MA
- Peak load current of 18 MA with 390 ns risetime (10-90%)



Ranchero/Pavlovskii design can isentropically load copper up to 3 Mbar





- Current reaches 18 MA with a maximum magnetic pressure of 3.4 Mbar
- Pressure profile is automatically "tailored"
- In Situ Velocity profiles for copper samples
- Isentropic loading up to 1.5 mm sample thickness

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Conclusions

- We have designed a HEPP isentropic compression experiment capable of delivering magnetic pressures of 17 Mbar.
- The design was based on the Ranchero 1.4 m coaxial FCG and EFF.
- Several issues must be addressed for such high-voltage HEPP designs such as magnetic insulation and power flow.
- Pavlovskii switch experiments performed at LANL in the early 80's delivered current profiles ideal for ICE
- A design based on the coaxial Ranchero FCG and Pavlovskii (EPS) switch can deliver isentropic loading in copper up to 3 Mbar
- We believe that with an appropriate EPS this can be extended to much higher pressures