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RELIABILITY ASSESSMENT OF A 1 MV LTD

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Abstract

A 1 MV linear transformer driver (LTD) is being tested with a large area e-beam diode load at Sandia National Laboratories (SNL). The experiments will be utilized to determine the repeatability of the output pulse and the reliability of the components. The 1 MV accelerator is being used to determine the feasibility of designing a 6 MV LTD for radiography experiments. The peak voltage, risetime, and pulse width as well as the cavity timing jitter are analyzed to determine the repeatability of the output pulse.

I. INTRODUCTION

The LTD consists of seven cavities, or modules, with 10 bricks each [1] [2]. Each brick is composed of a switch and two 20 nF capacitors charged to $\pm$ 100 kV. There are also five peaking capacitors connected in parallel across the output of the cavity. The seven cavity circuit produces a output voltage of 1 MV into a matched large area diode load.

The seven cavity LTD circuit was constructed and tested at the High Current Electronics Institute. It was then shipped to SNL where it has been reassembled. Initial tests of the seven cavity LTD at SNL resulted in the failure of several peaking capacitors and damage to two of the vacuum insulators. Testing resumed utilizing six of the seven cavities while a replacement insulator was machined. The peaking capacitors were removed from all of the cavities and one of the damaged capacitors was disassembled and inspected. A new peaking capacitor has been designed and is being manufactured.

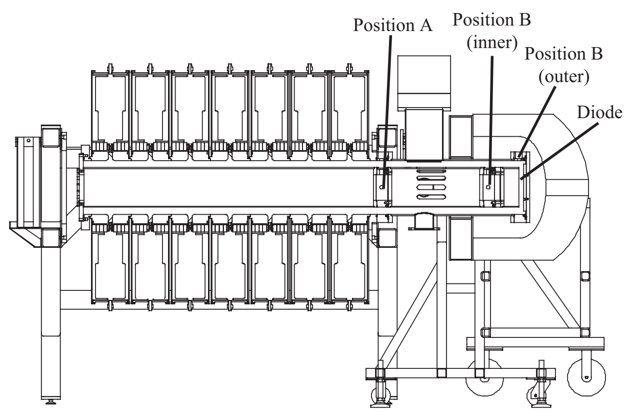

Figure 1. Cutaway drawing of the LTD system including support structure and lead shielding.

II. EXPERIMENTAL SETUP

The experiments reported below represent testing of six series LTD cavities at SNL without peaking capacitors. A long aluminum stalk, 21.5 cm diameter, extends through the center bore of the six cavities forming a coaxial vacuum transmission line with a 29 cm outer diameter, Figure 1. A large area e-beam diode load with adjustable AK gap spacing is attached to the end of the center stalk, spacers behind the carbon anode adjust the gap length. A large lead enclosure around the diode region of the LTD provides x-ray shielding.

The positive and negative output terminals of each of the six cavities are connected to resistive voltage dividers through high voltage coaxial cables. The sum of the resistive voltage divider measurements is used to determine the approximate load voltage. Rogowski, B-dot, and V-dot probes are mounted in two locations between the last LTD

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Table 1. LTD Shot Description

Shot Number	Number of Cavities	Charge Voltage	AK gap
103-114	6	$\pm$ 95 kV	3 cm
115-126	6	$\pm$ 95 kV	2.5 cm

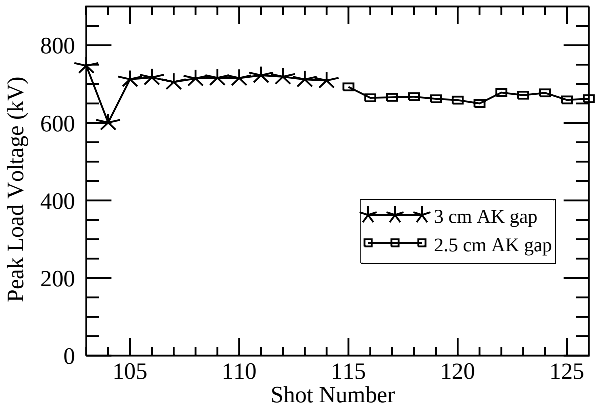

Figure 2. This plot shows the peak load voltage for 24 consecutive shots with two different AK gaps.

cavity and the diode on the inner stalk and the outer spool, as shown in Figure 1. Probes are placed on the inner and outer conductors at position A, located 73.5 cm from the load, on the inner stalk at position B, located 16.3 cm from the load, and on the outer conductor at position B, located at the cathode tip. A pin diode is placed in front of the diode to measure the x-ray dose as a function of time.

III. OUTPUT PULSE REPEATABILITY

Sets of 12 consecutive shots were fired at diode AK gaps of 3 cm and 2.5 cm with all other parameters remaining constant, see Table 1. The load voltage and load current measurements were used to assess the repeatability of the LTD output pulse. For each pulse the peak load voltage, peak load current, pulsewidth, risetime, and cavity timing spread were measured.

The peak load voltage and peak load current, shown in Figures 2 and 3, remained very constant over the 24 shot series. The shorter AK gap for shots 115 - 126 results in a lower load impedance and accounts for the decreased voltage and increased current compared to the first set of shots. The standard deviation of the peak voltage and current is less than 5% of the average value for both sets of data, Table 2.

The load current pulse width is measured as the full width at 80% of the peak value, which is approximately equal to the full width half maximum radiation pulse width. As shown in Figure 4, the pulsewidth is not significantly effected by the small change in AK gap spacing

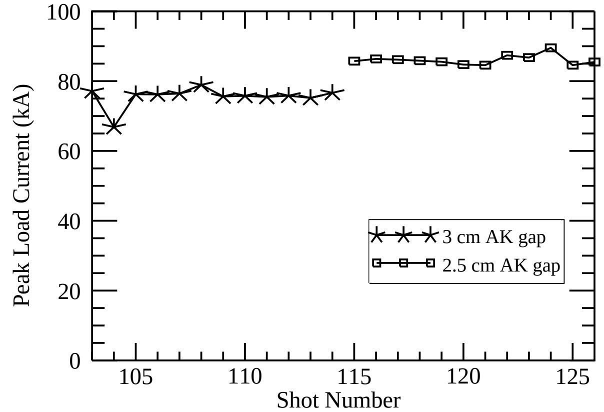

Figure 3. This plot shows the peak load current for 24 consecutive shots with two different AK gaps.

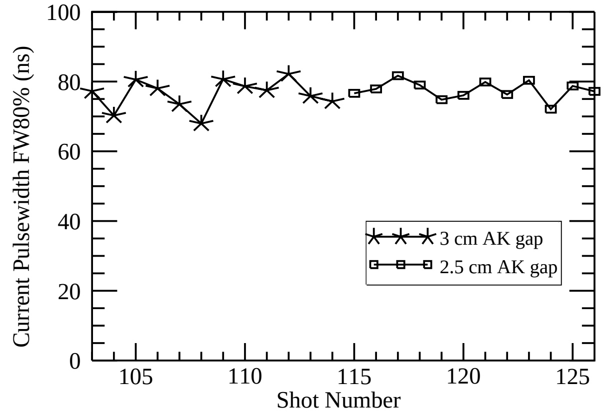

Figure 4. Plot of the pulsewidth, measured at 80% of the peak current.

and remains constant from shot to shot. The variation in pulsewidth for the experiments with a 2.5 cm AK gap was somewhat less than for the 3 cm AK gap shots. The standard deviation of the pulsewidth was less than 6% of the average value for both sets of data.

The current risetime is measured as the time from 10% to 90% of the peak load current. Figure 5 shows that the risetime remained constant for both AK gap spacings. The standard deviation of the current risetime was less than 6% of the average risetime for both AK gaps.

The timing of the individual cavities is important to maintaining the desired output pulse shape. The total one way transit time along the coaxial vacuum transmission line from the first to the last cavity is about 5 ns. Due to this short propagation time, the cavities can all be triggered simultaneously, from the same source. A single cable connects the trigger generator to each cavity and triggers all ten switches within the cavity. Switch jitter leads to a variation in cavity timing, which is measured as the total time delay from the earliest to latest cavity to fire,

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Table 2. LTD Output Statistics

	Shots 103 - 114		Shots 115 - 126	
	Average	Standard Deviation	Average	Standard Deviation
Peak Load Voltage	708 kV	35 kV	667 kV	11 kV
Peak Load Current	75 kA	2.9 kA	86 kA	1.4 kA
Load Current Pulsewidth at 80%	76 ns	4.3 ns	77 ns	2.6 ns
Load Current Risetime (10-90%)	56 ns	3.1 ns	54 ns	2.3 ns
Cavity Timing Spread (excluding shot 104)	6.8 ns	1.3 ns	4.9 ns	0.9 ns

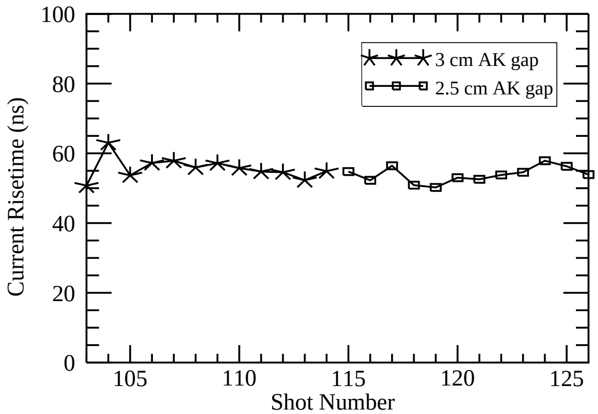

Figure 5. Plot of the 10-90% risetime of the load current as measured with the outer Rogowski coil at position A, 73.5 cm from the cathode.

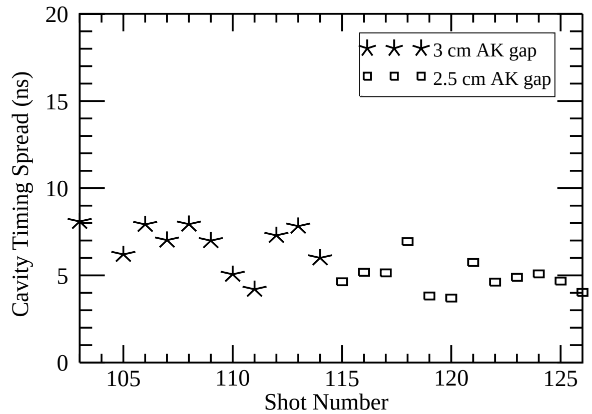

Figure 6. Plot of the cavity timing spread, which is defined as the delay from the first to last cavity to fire for a given shot. Shot 104 is omitted due to unknown timing of prefire.

Figure 6. The small variation in cavity timing, reported in Table 2 and Figure 6, is comparable to the propagation time delay along the coaxial vacuum transmission line. This small variation in cavity timing contributes to the high repeatability of the output pulse, Table 2.

The second shot of the 24 shot series, shot 104, resulted in a single cavity prefire, where the remaining cavities were triggered after an unknown delay. The resulting peak load voltage, shown in Figure 2, was about 15% below the average for the other 11 shots with a 3 cm AK gap. The peak current was also about 15% lower than the average value, Figure 3. All oscilloscopes are triggered from an external source and consequently none is configured to capture a prefire event. Since the timing of the prefire is unknown, the cavity timing spread could not be determined for shot 104, and this data point is omitted from Figure 6. The cavity timing is the only parameter that could not be measured for shot 104, this shot is therefore included in all other measurements in this report.

IV. SUMMARY

Results are reported from a series of 24 consecutive shots with a six cavity LTD tested with a e-beam diode load. Additional series LTD cavities would decrease the percentage of load energy contributed by each cavity, therefore, decreasing the effect of a single fault on the load pulse. The tests also show that the output pulse is highly repeatable when there are no system faults. One of the 24 shots resulted in the prefire of a single cavity, reducing the peak output voltage and current. Future tests will be used to assess the reliability of the system and individual components.

V. REFERENCES

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