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**Quantic Industries Inc.
Slapper Detonator Performance**

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Livermore
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Introduction:

Under the Lawrence Livermore National Laboratories (LLNL) Small Business Technology Transfer Program, assistance was given to Quantic Industries Inc. to use our High Explosive Applications Facility (HEAF), its apparatus, and LLNL expertise to characterize the performance of Quantic's micro-clad copper/kapton slapper detonator assemblies and establish their threshold to detonate HNS-IV. This task was assigned LLNL case number 93026. Ronald S. Lee is responsible for the effort, Ralph L. Hodgins performed the experiments, and Jack L. Cutting analyzed the data and authored this report.

The project involved measuring the performance of these slapper detonators, otherwise known as Exploding Foil Initiators (EFI's), manufactured by Quantic Industries Inc. Slapper performance was measured by using a laser velocimeter, which is an expensive and specialized facility which Quantic does not own. We measured slapper velocity vs. time as a function of charging voltage. Quantic supplied slappers which were coated with ~100 nm of Al to provide a reflective surface for the laser velocimeter measurements. LLNL provided a capacitor discharge unit (CDU) to fire the slappers and matched the Quantic CDU waveforms as close as possible.

Although the original proposal was submitted in November of 1993 the actual work did not start until February 1994. The level of effort did not exceed \$5k and this was estimated to be approximately one weeks worth of experimental time in the HEAF "C" tank firing facility. There was initial difficulty with the Al coated slappers as the coating covered the flyer area. Alignment holes were provided by Quantic but the holes were not aligned properly and thus we could not tell if the laser was focused directly on top of the flyer. We obtained a second batch of uncoated slappers, and we found that if the laser power was adjusted to full output and the streaking camera micro-channel plate was set at maximum gain we could obtain data without the Al coating.

Experimental Design:

The object of this task was to determine the design margin of the Quantic slappers for detonation of HNS-IV. We had some difficulty matching Quantic's fireset requirements as they used an explosively driven tack switch to discharge the fireset and we were using a Reynolds IVARC. The result was that the Quantic EFI burst slightly after peak current but still in the range of 80 ns with burst current in excess of 3.2 kA at 3.0 kV with our 0.12 μ fd capacitor fireset. The fireset parameters were calculated with the FIRESET code and matched the measured waveshape (figure 1). Burst current waveshapes were calculated for 12 mils square and 15 mils square 175 μ inch thick EFI's with 0.106, 0.12, and 0.16 μ fd capacitors which were all charged to 3.0 kV (figure 2). Figure 3 is the measured current and voltage at 3.0 kV charge voltage with our fireset.

The Quantic Inc. slappers that were supplied to us were known ahead of time to be rejects from production runs and we observed that there were sometimes large scale defects in the kapton flyer material directly over the exploding foil. Fifty percent of the slappers supplied were not of high enough quality to attempt Fabry-Perot experiments (figure 4), however, the cross sectional area of the exploding foil was 12 mils square and 175 micro inches thick and it was held to good tolerance. This was verified both optically and with resistance measurements.

The material specification for HNS-IV as indicated by Naval Sea Systems Command document WS32972, dated 17 November 1989, specifies in paragraph 3.2 that 1.57 ± 0.006 gm/cc HNS-IV shall detonate with flyer velocities less than 3.00 mm/ μ s and greater than 2.70 mm/ μ s with a 175 μ inch thick by 15 mils square copper EFI and a .001 inch thick flyer.

Results and Discussion:

Velocity measurements were made at 1.8, 2.0, 2.5, 2.75, 3.0, 3.25, and 3.5 kV and those data points were plotted in figure 5. Figure 5 also plots the burst current and peak current at the same charge voltages noting that the burst occurs after peak current. Figure 6 plots the velocity versus charge voltage at 0.1 and 0.2 mm. Peak velocities range from 2.41 k/sec at 1.8 kV to 4.69 k/sec at 3.5 kV. These peak velocities may be at distances greater than 0.2 mm as they were determined automatically by the computer program. The ratio of flyer kinetic energy ($1/2 MV^2$) at threshold to flyer kinetic energy at the operating voltage gives an estimate of the design margin for that voltage. We take the threshold velocity to be 3 km/s (a conservative estimate) so the kinetic energy ratio is given by $V_F^2/9$ where V_F is the flyer velocity in km/s. Figure 7 indicates curves for 0.1 mm and 0.2 mm barrel lengths and peak measured velocity.

Conclusion:

The design threshold for the Quantic Inc. fireset/slapper detonator system has not been disclosed to us. It appears that the threshold is less than 2.0 kV with this circuit. Our conclusion is that at a charge voltage of 2.0 kV the 0.2 mm flyer distance just barely exceeds the required 2.7 mm/ μ s for HNS-IV, and at 0.1 mm distance the 2.58 mm/ μ s measured velocity is below the threshold for HNS-IV detonation.

We do not know the operating voltage selected by Quantic, but at 3 kV and barrel lengths >0.2 mm, the velocity vs voltage curve is rather flat. This is a desirable situation from the standpoint of design margin because if the charging voltage varies, there is not much change in flyer velocity. It is not our place to suggest what should be an adequate design margin, but the data we have provided should enable Quantic, Inc. to make an informed decision.

FIGURE 1: The fireset code calculates the circuit waveform from the Quantic fireset component values and then we compare that to the measured waveform.

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QUANTIC FIRESET

48.3 nH
.106 µfd
3 kV
83.3 mΩ

Recalculate or File Data? (R/F):

FIGURE 2: Calculated burst current waveshapes for 12 and 15 mil² bridges with three values of fireset capacitance each charged to 3 kV.

FIGURE 3: The measured current and voltage of our fireset with a Quantic 12 mil² slapper.

QUANTIC

#4M1

FIGURE 4A: Shows a 12 mil² area superimposed over a relatively good slapper.

QWANTIC # 614

FIGURE 4B: Indicates a scratch in the center of the slapper.

QUAN.CVR

SHOT #	CHARGE V	I-PEAK	I-BURST	L	PK VELOCITY k/sec
QUAN 12	1800	2180	1260	38.019	2.41
QUAN 11	2000	2860	1860	38.019	2.92
QUAN 10	2500	3340	2900	38.019	3.8
QUAN 15	2500	3220	2780	20.009	3.75
QUAN 16	2750	3820	3220	20.009	4.19
QUAN 18	3000	3780	3380	20.009	4.2
QUAN 17	3250	4020	3780	20.009	4.58
QUAN 13	3500	4100	3900	20.009	4.69

FIGURE 5: This figure plots burst current and velocity vs charge voltage.

QUANCOMP.XLD

	Voltage	VELOCITY AT .1mm	VELOCITY AT .2mm
	1800	2.02877	2.24567
	2000	2.58415	2.78658
	2500	2.90577	3.35478
QUAN15A	2500	2.9802	3.46901
QUAN16A	2750	3.21624	3.74517
QUAN18A	3000	3.2746	3.74051
QUAN17A	3250	3.51617	4.01011
	3500	3.51883	4.17181

QUANTIC .12SQ. BRIDGE VELOCITY COMPARISON

FIGURE 6: This figure plots velocity vs charge voltage at 0.1 and 0.2 mm.

FIGURE 7: This set of curves indicate design margins for the detonation of HNS-IV with the Quantic slapper/fireset.

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