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A GLOVEBOX-CONTAINED FORTY-MILLIMETER GUN SYSTEM FOR THE STUDY OF ONE-DIMENSIONAL SHOCK WAVES IN TOXIC MATERIALS*

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ABSTRACT

A new gun system is being constructed at the Lawrence Livermore Laboratory for studies of the behavior of toxic materials under shock-loaded conditions. Due to the extreme toxicity of some materials, such as plutonium, the entire gun system must be enclosed in gloveboxes. This report describes a) some of the experimental requirements that affected the design of the system, b) various diagnostic techniques that will be employed with the system, and c) some details of the final design that is presently under assembly.

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INTRODUCTION

The prime sources of high pressure equation-of-state (EOS) data are derived from the observation of transient shock waves, their interactions and measured velocities which can be generated in a sample material.

An excellent source of reproducible one-dimensional shock waves is the high velocity impact produced by gunpowder or compressed light gas gun systems. To carry out the study of the shock wave phenomena in highly toxic materials such as plutonium with its attendant operational safety procedures, it was decided that a new compressed gas- and gunpowder-driven gun system including the experimental tanks, catch tanks and connecting rails,would be installed inside a huge glovebox (Figure 1).

EXPERIMENTAL REQUIREMENTS

The peak stress level induced in the targets of steel or tungsten is to range upwards from 30 GPa (300 kb) to 70 GPa (700 kb) when the impact is arranged symmetrically; that is, impactor and target made from identical materials. This level can be achieved with an impactor velocity near 1.4 mm/μs (4600'/sec). This velocity was chosen as our design maximum.

For optical considerations, the target must remain stationary before projectile impact. This requires that the barrel recoil freely, and the target must mount rigidly to the base. The required impacted diameter was calculated to be near 40 mm , which allows observation of one-dimensional shock-accelerated target surfaces for a few μs before two-dimensional edge effects perturb the analyzed area.

INSTRUMENTATION

The instruments we will use for the observation of transient shock waves in materials are designed to measure velocities via the shock arrival times at selected interfaces, the stress time history at these interfaces, and the free surface velocities on the rear of the target sample.

The primary diagnostic techniques which are planned for use on this gun system follow:

1. Barrel strain gauge and wire contact pins for projectile velocity determination.
2. Self-shorting and crystal pins for high stress level transit time determinations and impact planarity.
3. Parallel plate capacitor velocity transducer for free surface velocity measurements for metallic targets.
4. Manganin pressure gauges for stress/time histories of internal target interfaces.
5. Ultra-high-speed streaking and framing cameras for observing surface effects and three-dimensional perturbations after target surface jump-off.
6. 180 kV and 600 kV pulsed flash-xray exposures revealing gross particle dispersion or internal material integrity.
7. Laser-driven diffuse velocity interferometry (DVI) for free surface velocity determination on non-metallic or small, spot-sized targets.

40 mm DESIGN

Using ballistic equations generated by Taylor and Yagi,[1] R. Strittmater,[2] S. Kravitz[3] and H. Hitchcock,[4] it was concluded that the 40 mm M-25 cartridge case, primed with the MK-22 primer and burning M-1 powder, could be safely adapted to a smoothbore 40 mm x 90 calibre barrel to produce the desired 1.4 mm/μs sabot velocity. Aluminum sabots and their impactors, together weighing near one pound, have been designed and are ready for testing in the near future. The rear of the sabot is flared, which provides a vacuum seal and allows a slightly higher starting pressure. Using the Hitchcock tables[4] a pressure/time curve based on these parameters reveals a P_{max} near 36 kpsi, which is safely within the design pressure limits of the gun system. Additionally, the breech and receiver sections will be hydrostatically tested to a pressure of 60 kpsi before ballistic firing begins.

The gun barrel mounting system depicted in Figure 1 is roller-bearing supported and allows for a free recoil of the 2300-lb barrel and bulkheads of approximately 3 mm, after which the adjustable shock absorbers begin to couple the recoil impulse into the four tension tubes. At nearly the same time, the opposing impulse, created by the impact of the target and projectile debris upon the catch tank, will be coupled into the tension tubes via the rear shock absorber. This 3"-stroked adjustable shock absorber can be programmed to partially offset the barrel recoil force and minimize the resultant displacement within the glovebox. Any theoretical motion analysis of the system is complicated by the non-specific dispersion of the projectile and target shrapnel, and the composition and energy absorption characteristics of the catchtank stuffing materials. An arduous schedule of non-toxic test shots is planned in order to evaluate the effects of various parameters on the recoil characteristics of the gun.

In order for the target to remain stationary before impact, it will be necessary to isolate the target from the barrel, both physically and aerodynamically. Shock-isolated, remotely operated gimbals will be used in the target mounting; and the chamber, catch tanks and the barrel will be evacuated for firing and let up to atmospheric pressure with N_2 or CO_2 (Fig. 2).

Experience with two earlier gun systems has affected the design of this 40 mm system. A simpler 20 mm system, where the target is effectively coupled directly to the muzzle, has been fired (approximately 150 times) in a glovebox facility. Another smaller bore 19 mm gun system utilizing a freely recoiling barrel has been successfully demonstrated for use with the laser diffuse velocity interferometer.

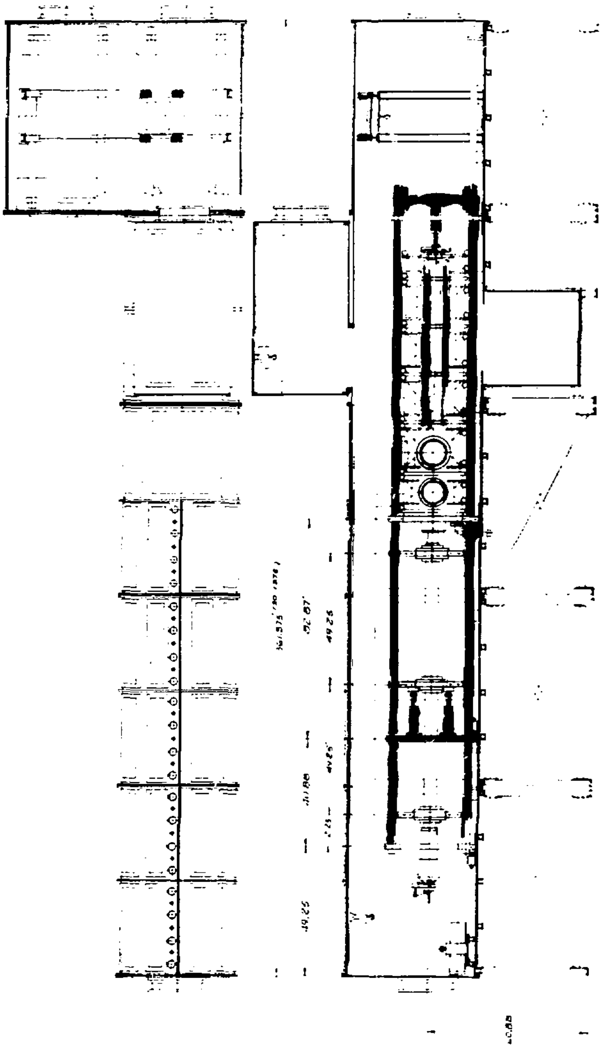

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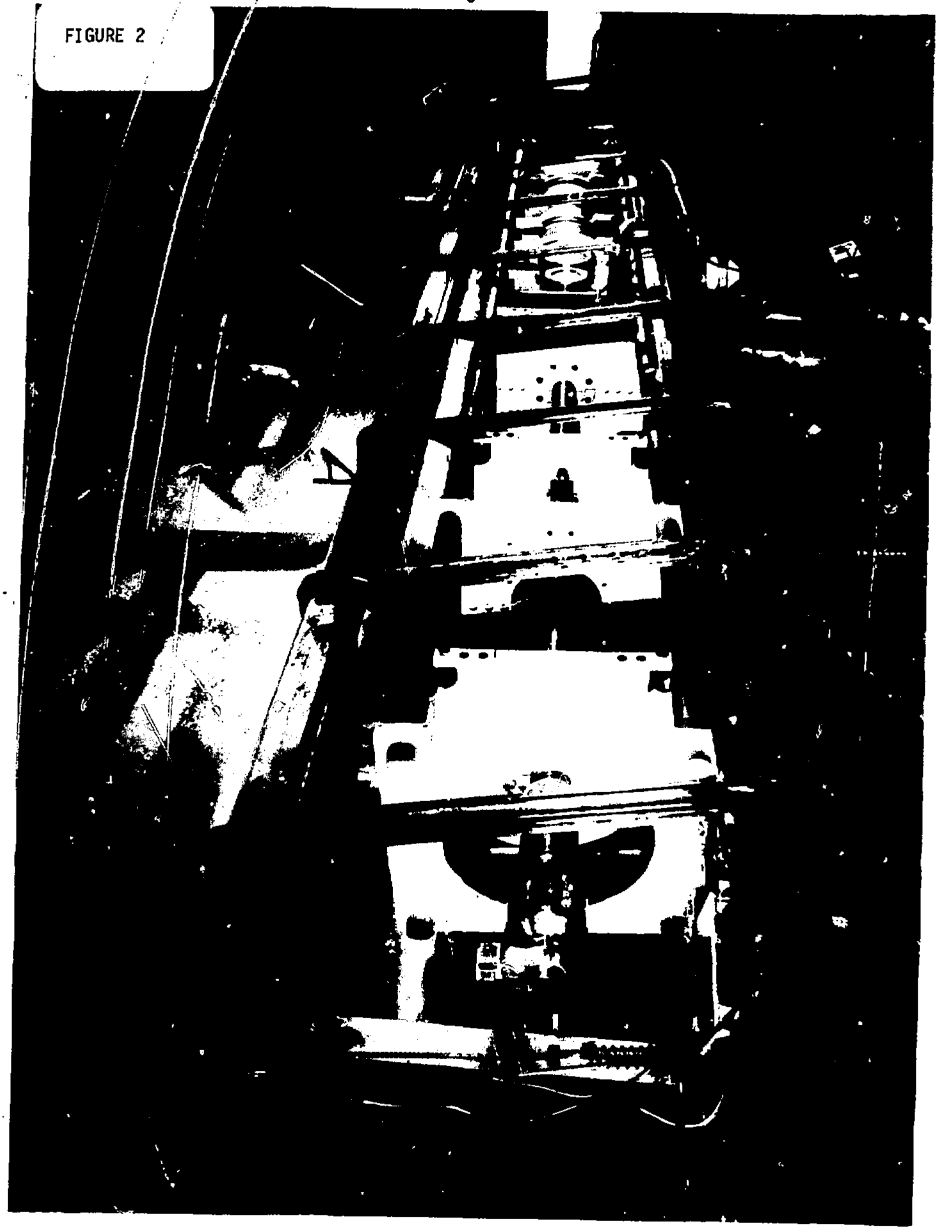
FIGURE 1

FIGURE 2



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This 40 mm gun system just now taking shape represents many hundreds of man hours of calculation, design, fabrication and assembly. To date, the Mechanical Engineering Group headed by Dewey Ravenscroft and Adrian Van Dyk has provided the bulk of effort. Elmer Ries supervised the design, and Don Starcher has coordinated the fabrication and assembly efforts which are ably being carried out by Doug Bakker, Ivan Miller, Gary Devine, and a talented technician group.

The Electronics effort will be directed by Roger Brier, and the technician staff, including Ken Pimentel, Butch Moyle and Wally West, are preparing for an exciting test program.