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DEVELOPMENT OF THE LARGE-BORE POWDER GUN FOR THE NEVADA TEST SITE

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Abstract. Plate-impact experiments on single stage guns provide very planar loading conditions suitable for studying complex phenomena such as phase transitions and material strength, and provide important data useful for constraining and validating predictive models. The objective of the current work was to develop a large-bore (3.5" or greater) powder gun capable of accelerating projectiles to moderately high velocities (greater than 2.25 km/s) for impact experiments at Nevada Test Site. This gun will span a performance gap between existing gun facilities and provide a means of examining phenomena over a wide range of stresses and time-scales. Advantages of the large-bore gun include the capability to load multiple samples simultaneously, the use of large diameter samples that significantly extend the time duration of the experiment, and minimal tilt (no bow). This new capability required the development of a disposable confinement system that used an explosively driven closure method to prevent contamination from moving up into the gun system. Experimental results for both the gun system and the explosive valve are presented.

Keywords: powder gun, large-bore, multiphase EOS, PDV velocimetry
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INTRODUCTION

There is a need for a large-bore, plate-impact facility capable of achieving velocities in the 2 km/s range for experiments to be conducted at the Nevada Test Site (NTS). Experiments are needed to obtain Hugoniot data and off-Hugoniot data with an emphasis on multiphase properties including locating phase boundaries, obtaining equation of state data for relevant pure phases, and information on transition kinetics. Many of these experiments can be achieved only through complex loading paths such as ramp-wave compression[1], shock-ramp or multistep loading[2], and cyclic shock loading[3] which may require both multiple samples and longer experimental time durations. The objective of the current work was to develop a large bore (3.5 inch or greater) powder gun capable of accelerating projectiles to moderately high velocities exceeding 2 km/s for impact experiments at the NTS U1a complex . Advantages of the large bore gun include the following: (1) the capability to load multiple samples simultaneously, (2) large-diameter samples/impactors to significantly extend the time duration of the experiment, (3) minimal tilt and bow, and (4) ability to field multiple diagnostics.

The Large-Bore Powder Gun (LBPG) system[4] is made up of three subsystems, (1) a launcher (or gun) consisting of a breech and barrel, (2) a confinement subsystem consisting of multiple components, and (3) a gas-management system. A photo of the large bore gun and a schematic of the confinement system are shown in Fig. 1. The confinement subsystem physically connects to the end of the launcher and includes a fast closure device known as an Explosively Driven Valve (EDV)[5], a target chamber, and a catch system that includes shear discs and crush foam to stop the projectile and gas flow. Experiments were conducted to: (1) to determine the system time of the EDV for various explosive loads, and (2) determine

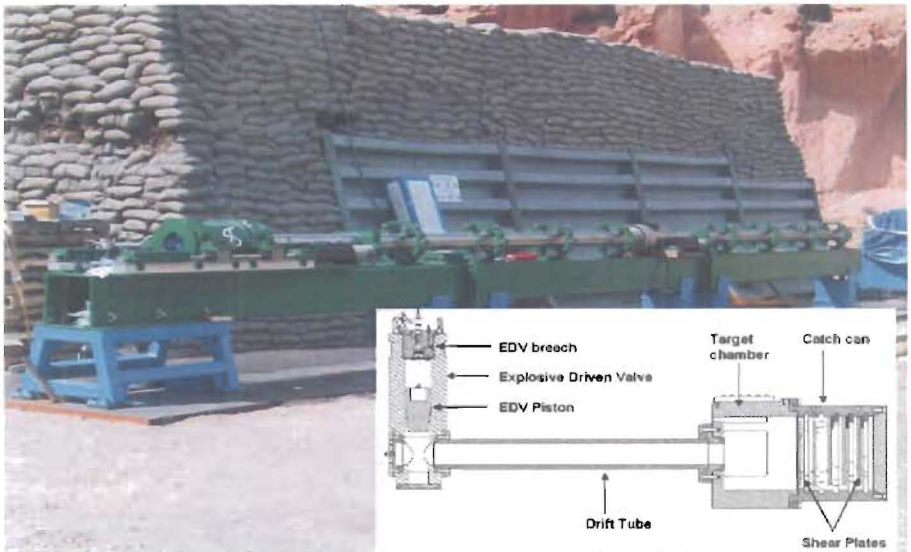

FIGURE 1. Photo of the Large-bore Powder gun located on the firing site at TA-39-06. The breech is shown to the left and the 40-foot barrel extends to the right. (Inset) Schematic of the prototype confinement system that connects to the gun barrel via a slip-tube (not shown) and uses an explosively driven valve to seal the system from the gun barrel.

the gun performance curve for powder loads up to sixteen pounds of propellant. In this paper, a brief summary of the gun and explosive valve tests required to qualify the gun for use at NTS is presented. A complete account of the LBPG gun testing and explosive valve testing is reported elsewhere[4, 5].

LAUNCHER QUALIFICATION TESTS

A total of 24 experiments were performed on the large-bore launcher to determine the gun performance curve and to verify the system's ability to remain helium leak tight before and after the experiment. A propellant charge of M14 propellant (ATK) initiated using a length of mild detonating and an SE1-PT detonator was used to launch the piston down the 40-foot barrel. The mild detonating fuse was typically coiled in a helical shape (approximate 2-inch diameter) with enough length to extend through approximately 75% of the propellant. The final projectile design consisted of a hollowed magnesium projectile body with a shear disc and tapered boot on the back of the projectile and a foam/impactor insert located in the front of the projectile. The projectile mass was nominally 1.4-1.6 kg. Projectile velocities were measured using either electrical shorting pins (impact velocity) or Photonic Doppler velocimetry (PDV) to measure the velocity history up to impact. The PDV system has been described in detail elsewhere[6] and used collimated probes (Light Path) to direct the 1550 nm laser light to and from the front of the projectile.

An example of the PDV data is shown in Fig. 3 where the projectile velocity (km/s) is plotted versus time (μs) for a test that used 15-lb of M14 propellant to launch a 1.5-kg projectile to 2.32 km/s. The data show a nearly uniform projectile velocity for approximately 150 μs up to impact. The experimental results from all experiments are summarized in Fig. 3 where the projectile velocity V_P (km/s) is plotted versus the C_M ratio (propellant charge to projectile mass). The data were fit to a polynomial curve that defined the gun performance curve given by the equation $V_p = 0.134 + 0.62C_M - 0.03C_M^2$.

An important requirement for the launcher system was the ability to maintain a helium leak tight seal

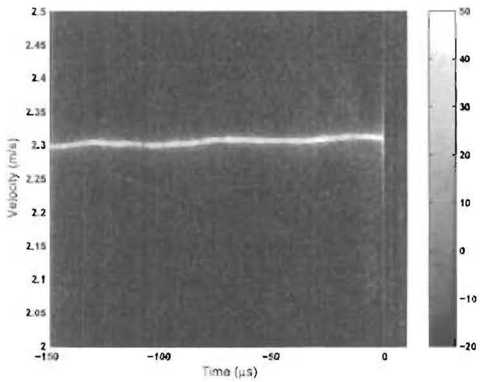

FIGURE 2. PDV data monitoring the projectile velocity as it propagates down the barrel toward the target for a 15-lb propellant load.

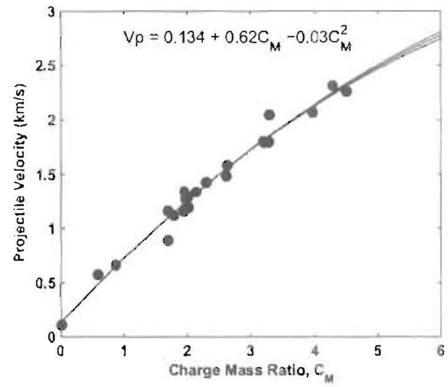

FIGURE 3. Summary of velocity data obtained from the launcher tests.

pre-shot and post-shot to prevent contamination of the gun room when hazardous materials are examined. Thus, the three final shots in the 24 shot series were performed using 7 lb (50% powder load), 11.1 lb (75% load), and 15 lb (100% load). All experiments were performed using magnesium projectiles with nominal masses of 1.5 kg and aluminum impactors backed by syntactic foam. The projectile impacted a standard velocity target with one PDV probe on center. All three experiments were successful with measured velocities of 1.336 km/s, 1.797 km/s, and 2.312 km/s, respectively. Postshot examination of the gun structure in all three experiments revealed no structural damage and the gun system had passed both the preshot and postshot leak checks, illustrating that the gun can remain helium-leak tight (1e-5 or better) throughout the normal operating range.

EXPLOSIVE VALVE TESTING

A schematic of the explosively driven valve was shown in Fig. 1 as part of the disposable confinement system. The EDV consisted of the EDV body, a breech plug, and a tapered piston (6061-T0 Al with surface finish 16 micro-inch). The piston was launched using disc(s) of PBX-9501 high explosive initiated using an SE1-PT or SE1-31 detonator. The two main requirements for the EDV system was a fast-closure time of less than 2 ms and the ability to seal the barrel volume with a leak rate of 1e-5 for helium. Three series of testing were performed on the explosively driven valve for a total of thirteen experiments to understand the valve performance, including the quantity and type of charge required for optimal operation. The first series were performed on the prototype EDV, and the second series were performed to examine various issues related to new high-voltage feedthrough and lengthened pistons. The final series used a hybrid charge (propellant + explosive) in an attempt to push the EDV piston to higher closing velocities without compromising the breech integrity.

To measure the system time of the EDV, PDV were used to monitor the piston velocity from detonator initiation to piston arrival at the bottom of the EDV body. An example of the analyzed PDV data are shown in Fig. 4 for one of the experiments. A total of 200 grams of IMR 4350 propellant (equivalent to 110 grams of PBX 9501) and 55-grams of PBX 9501 was used to launch the piston (3.8 kg) to a velocity of approximately 0.32 km/s with a estimated system of 0.8 ms. This velocity is significantly higher than the 0.15 km/s (system time 1.7 ms) observed for 55-grams of PBX 9501. The system time (ms) versus explosive charge (g) is plotted in Fig. 5 for all experiments performed in this work and show a system time less than 2 ms for 55-grams of PBX 9501 which decreases as the charge mass increases. The data were fit using a second-order polynomial to determine the EDV performance curve given by the

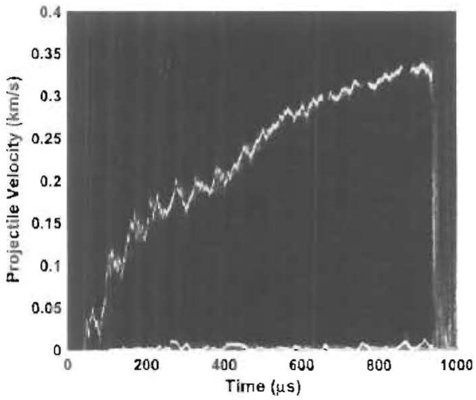

FIGURE 4. Analyzed PDV data showing the piston velocity history for an experiment using 200 gram of IMR-4350 propellant and 55 grams of PBX 9501.

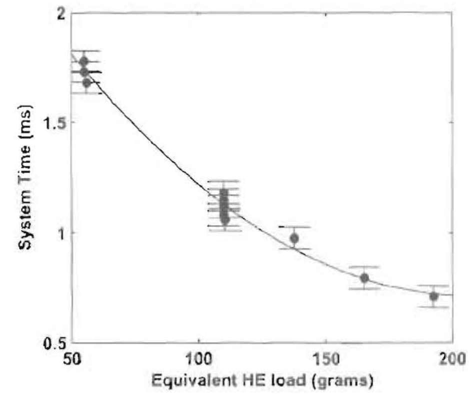

FIGURE 5. System time plotted versus equivalent HE load (PBX 9501). For hybrid propellant loads, 100 grams of IMR-4350 was assumed to be equivalent to 55-grams of PBX 9501.

equation $t = 2.63 - 0.0186m + 0.0000453m^2$ where m is the charge mass (g) and t is the system time (μs).

SUMMARY

Twenty-four experiments were conducted on the large-bore powder gun to qualify the gun for future experiments to be performed at the U1a complex of the Nevada Test Site. Experiments were performed to measure the projectile velocity, recoil distance, breech strain, and impact tilt for powder loads ranging up to 16 lb of M14 propellant. Projectile velocities were obtained up to a maximum value of 2.312 km/s exceeding our original goal of 2.25 km/s. The velocity data were used to develop the gun performance curve that relates the projectile velocity to the propellant charge mass and the projectile mass. Thirteen experiments were performed to develop an explosively driven valve capable of sealing a 3.5-inch bore gun and containment system with a system time of less than 2 milliseconds. Experimental results show that the system time for the EDV is less than 2 ms for 55-grams of PBX 9501 and that it decreases with increased charge-mass.

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