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Threshold Studies on TNT, Composition B, and C-4 Explosives Using the Steven Impact Test

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THRESHOLD STUDIES ON TNT, COMPOSITION B, AND C-4 EXPLOSIVES USING THE STEVEN IMPACT TEST

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Abstract. Steven Impact Tests were performed at low velocity on the explosives TNT, Comp B, and C-4 in attempts to obtain a threshold for reaction. A 76 mm helium driven gas gun was used to accelerate the Steven Test projectiles up to approximately 200 m/s in attempts to react (ignite) the explosive samples. Blast overpressure gauges, acoustic microphones, standard video and high-speed photography were used to characterize the level of any high explosive reaction violence. No bulk reactions were observed in the TNT, Composition B, or C-4 explosive samples impacted up to velocities in the range of 190-200 m/s. This work will outline the experimental details and discuss the lack of reaction when compared to the reaction thresholds of other common explosives.

INTRODUCTION

In basic terms, the Steven Impact Test involves a target with High Explosives (HE) that you impact at increasingly higher velocities with projectiles until you get a "GO" (reaction). These reactions involve a burning or deflagration process in lieu of a full-scale detonation. Naturally, the lowest velocity where you get a "GO" is the "reaction threshold" and typically involves several experiments to determine. Both the "reaction threshold" and violence level data can be utilized in various hydrodynamic reactive low models for safety predictions that may not be directly tested.

Research on the Steven Test has been performed at Lawrence Livermore National Laboratory [1-7] as well as a modified version of this test at Los Alamos National Laboratory [8-10]. The use of overpressure gauges dates back to the Susan Test [11] and the overpressure transit data is used to calculate an equivalent point source energy [12].

The Steven Impact Test results to date have increased the fundamental knowledge and practical predictions of impact safety hazards for confined and unconfined explosive charges. As discussed in the prior publications [1-10], friction, shear, and strain are the main contributing mechanisms to reaction although continuing research is still investigating these individual areas and combinations of mechanisms.

EXPERIMENTAL PROCEDURE

The experimental geometry of the Steven Impact Test target and details of the projectile used are shown in Fig. 1. The projectile head consists of a steel cylinder with a 30.05 mm radius hemispherical impact surface and mass of 1.2 kg. A gas gun accelerates the steel projectile head attached to an aluminum sabot into a 110 mm diameter by 12.85 mm thick explosive charge confined by a 3.18 mm thick steel plate on the impact face, a 19.05 mm thick steel plate on the rear surface, and 26.7 mm thick steel side confinement. A Teflon ring around the explosive provides radial confinement.

For these experiments, a 76 mm diameter smooth bore gas gun located at LLNL Site 300, bunker 850 was utilized and fires onto an outdoor firing table. The steel projectile head (see Fig. 1) is attached to an aluminum sabot body that is accelerated via compressed helium gas into the target. External blast overpressure gauges were placed around the target at a 3.05 m standoff for direct comparison to the Susan test data [11]. Acoustic microphones, standard video, and high speed digital photography were also used to characterize the event.

Test target pucks were cast from TNT (trinitrotolulene) and Composition B (63% RDX, 36% TNT, and 1% wax by weight) to be assembled into the target fixture. In the case of the putty like explosive C-4 (91% RDX, 5.3% Di (2-ethylhexyl) sebacate, 2.1% Polyisobutylene, and 1.6% motor oil by weight), the material was hand packed into the test target cavity. Figure 2 displays photographs of a typical Steven Test target before and after loading of the explosive sample.

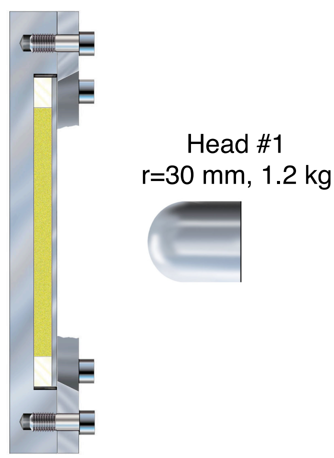

FIGURE 1. Schematic diagram of the Steven Impact Test arrangement with the projectile head used in this work.

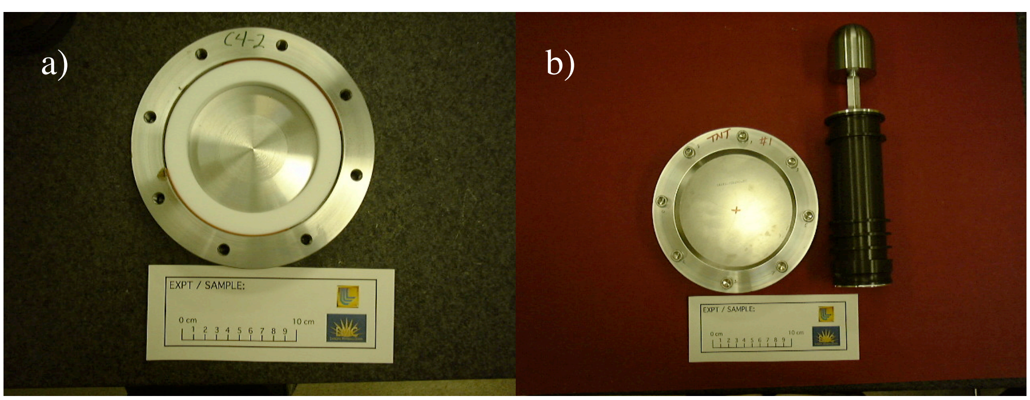

FIGURE 2. Photographs showing (a) the Steven Test target before loading and (b) after assembly with a projectile assembly.

RESULTS/DISCUSSION

The tabulated results for this work are included in Table I. The description includes the shot number, material, velocity of impact, whether the test was a "GO" or a "NOGO," and any notes that might be relevant to the particular test. Note that some of the targets were hit more than once as indicates in the last two digits of the shot number (.01 is first hit, .02 is second hit, and so on) as well as in the notes column of whether the target was in tact and able to be hit again.

As seen in Table I, all of the experiments were "NOGO's" indicating no bulk reactions in the materials up to the range of 190-200 m/s. Because friction and shear are known mechanisms for reaction in the Steven Test, these results suggest that the friction is somehow minimized in the impact event. In the case of C-4, it is a putty like explosive that contains a small amount of motor oil so it is not hard to believe that the material is allowed to flow rather easily upon impact. A small fireball was seen in the highest velocity experiment (195 m/s), but this appears to just be a very small amount of material becoming pinched between the deformed cover and the back of the target.

For the TNT and composition B materials that are solid in nature, the flow of material does not appear to be the obvious case. However, TNT has a relatively low melting point of 80°C, which might be melting under the friction of impact and allowing the material to flow. This would explain the result for both TNT and Composition B (containing 36% TNT), but without any further investigation this is just a simple guess. The relatively large crystal size of the TNT and Composition B material may also be a contributing factor to the high threshold, even if melting of the TNT is not a dominating factor.

TABLE I. Test results for Steven Test experiments.

Shot #	Material	Velocity (m/s)	GO / NOGO?	Notes:
HESST001.01	TNT	75 m/s	NOGO	Okay to hit again
HESST001.02	TNT	87 m/s	NOGO	Tear in front cover
HESST002.01	TNT	98 m/s	NOGO	Okay to hit again
HESST002.02	TNT	108 m/s	NOGO	Possible slight GO, tear in cover
HESST003.01	TNT	108 m/s	NOGO	Okay to hit again
HESST003.02	TNT	116 m/s	NOGO	Tear in front cover
HESST004.01	TNT	155 m/s	NOGO	Okay to hit again
HESST004.02	TNT	182 m/s	NOGO	Tear in front cover
HESST005.01	TNT	189 m/s	NOGO	Tear in front cover
HESST006.01	Comp B	66 m/s	NOGO	Okay to hit again
HESST006.02	Comp B	87 m/s	NOGO	Okay to hit again
HESST006.03	Comp B	116 m/s	NOGO	Target broke apart
HESST007.01	Comp B	153 m/s	NOGO	Target broke apart
HESST008.01	Comp B	198 m/s	NOGO	Target broke apart
HESST011.01	C-4	157 m/s	NOGO	Okay to hit again
HESST011.02	C-4	183 m/s	NOGO	Broke cover plate
HESST012.01	C-4	190 m/s	NOGO	Okay to hit again
HESST012.02	C-4	195 m/s	NOGO	Broke cover plate, small fireball from high speed camera

For comparison purposes, threshold values for several HMX based explosives are included in Table II. It can be seen that for these materials, commonly called plastic bonded explosive (or PBX) formulations, have a relatively low threshold of approximately 35-45 m/s. It is not expected that any melting of the HMX material would be observed in this material under impact.

Table II. Steven Impact Test thresholds for common "pristine" (i.e. not aged) HMX based explosives [3].

Explosive	Composition (weight %)	Density (g/cc)	Threshold Velocity (m/s)
PBX9404	94% HMX, 3% nitrocellulose, 3% CEF	1.835	34.0 (+0, -3.0)
LX-10	94.5% HMX, 5.5% Viton	1.865	41.5 (+0, -6.5)
LX-14	95.5% HMX, 4.5% Estane	1.822	41.2 (+0, -1.9)
LX-04	85% HMX, 15% Viton A	1.870	45.0 (+0, -5.0)
PBX9501	94.9% HMX, 2.5% BDNPA-F, 2.5% Estane, 0.1% DPA or Irganox	1.843	43.0 (+0, -4.0)

SUMMARY AND FUTURE WORK

Steven Impact Tests were performed at low velocity using a 76 mm helium driven gas gun on the explosive samples TNT, Comp B, and C-4 to obtain a threshold for reaction. No bulk reactions were observed in the TNT, Composition B, or C-4 explosive samples impacted up to velocities in the range of 190-200 m/s. These results display that these materials are relatively safe in impact type scenarios.

Future work is planned to test additional materials of interest to answer questions about the relative safety in impact scenarios.

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