KINETIC ENERGY WARHEADS CONSISTENT WITH A QUICK, PRECISION ATTACK SYSTEM

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Abstract

A kinetic energy projectile warhead, designed to be used against structurally-soft surface targets, has been demonstrated in a rocket sled test. Detonation of the warhead produced a high density cloud of small rod projectiles.

The rod projectiles were explosively deployed from the sled body and impacted the targets and a witness screen. Effectiveness was demonstrated against rocket motors and 0.5 inch steel plate. The uniform pattern of impacts recorded on a witness screen in front of the target area indicated that targets of representative size would be struck by at least one projectile.

Nomenclature

- C^3I Command, Control, Communication, and Intelligence
- KEP Kinetic Energy Projectile
- QPAS Quick Precision Attack System
- WMD Weapons of Mass Destruction

I. Introduction

Flight times associated with long standoff ranges can limit the ability of current weapon systems to hold targets (e.g., mobile missile launchers and other weapons of mass destruction (WMD)) at risk . The potential for collateral damage inflicted upon non-combatants in limited engagements creates added problems. A system designed for these targets would have a substantial stand-off capability, a short time of flight, and a low collateral damage kill mechanism. A quick, precision attack system (QPAS) coupled with new warhead designs has the potential to satisfy these requirements.

As defined here, a QPAS maintains high velocities (>4000 ft/sec) to the target. The kinetic energy inherent in such a hypervelocity delivery system is available for conversion into energy on the target. Unlike large unitary weapons which use a high explosive to generate over pressure and accelerate case fragments, a warhead made of small rod projectiles or larger aerodynamically stabilized projectiles could perforate the intended target by using high impact velocities. Because the lethal mechanism is kinetic, these kinetic energy projectiles (KEPs) would damage objects directly by striking targets or by creating spall or other indirect effects within the targets.

Kinetic energy penetrating weapons historically have used large mass-to-area ratios at aircraft-delivered velocities (~1000 ft/sec) to penetrate and subsequently detonate within the target. Our interest in coupling experience with hypervelocity maneuverable reentry vehicles and earth pentrating technology has led to the investigation of a variety of high velocity projectiles for use against a range of targets Several kinetic energy warhead designs, compatible with a QPAS, have been or are currently under consideration for use against targets ranging from hard, deeply-buried targets to soft surface targets. KEPs have been considered ranging from large 30 to 100 pound penetrators containing explosives to small (< 0.1 pound) rods (Figure 1).

A warhead consisting of a few 30 to 100 pound penetrators has been analyzed for use against compartmented underground bunkers. These multiple penetrators would be deployed/jettisoned from a hypersonic vehicle above the target. The penetrators have the capability of passing through more than 12 feet of concrete. Multiple explosive-filled penetrating projectiles such as these increase the probability of damaging several rooms.

Another warhead design relies on several dozen smaller penetrators to destroy the target. The 3 to 5 pound aerodynamically stabilized penetrators would be used against hardened surface and near-surface targets (e.g., bridge piers or buildings.) A test version of this warhead design is shown in Figure 2.

A third warhead design type employs smaller multiple rod KEPs. The aerodynamically unstable KEP rods are also "deployed" above the target, creating a uniform ground pattern. This warhead is effective against soft and lightly armored surface targets such as missiles, missile launchers, and C^3I vehicles.

Lethality is the key warhead design question for these types of warheads. A test series was initiated to examine this concern. In addition to powder gun testing of the larger projectiles against concrete targets, a rocket sled test of the small rod concept was peformed. The design of the test warhead and the results of the sled test are described below.

II. Design

The warhead was designed to be compatible with a potential delivery system comprised of a conical (5.25 degree half-angle) warhead section, to produce a uniform pattern of impacts, and to provide high lethality against targets of interest.

Initial small KEP studies focused on using 6-inch rods stabilized with aerodynamic fins. Static deployment tests were conducted verifying rod lateral and angular acceleration during deployment. These KEPs were placed in a cylindrical block of high density (20 pounds/ft^3) polyurethane foam. At strategic places in the foam block, line explosives were embedded to provide a lateral velocity to the rods at detonation. The line charge sizes were determined by the lateral velocity requirements, the material density of the foam block, and the number of KEPs per square inch. After initial static tests, the line explosives were changed to sheet explosives to reduce the large angular rates imparted to the rods by the line explosive (Figure 3.) Static tests using sheet explosives resulted in lower angular rates and a more uniform pattern.

This warhead evolved toward a specific design for a system level warhead test. Due to the required velocity, a test using the Sandia National Laboratory 10,000 foot sled track facility was proposed. The test incorporated the existing warhead design in a conical frustum and was accelerated down the sled track at greater than 4,000 ft/sec.

Concurrent with the sled test design, a target set was selected to evaluate warhead lethality. Soft surface targets were selected, based on concerns about mobile missile launchers and other weapons of mass destruction (WMD). Unlike hardened targets, soft surface targets don't require stabilized KEPs for lethality. The areal density and distribution of rod impacts is most important.

To increase the number of projectiles, unstabilized rods, (mechanically pre-scored to fragment upon detonation) were selected over the earlier stabilized KEP designs. The new rod maintained basic finned projectile dimensions such as length and diameter (Figure 4). The rods were made from tungsten alloy and were designed to break into four equal length segments when explosively deployed. Each segment weighed 0.071 pounds or 497 grains. A nominal warhead payload of 250 to 300 pounds could carry at least 2000 of these rods and potentially generate a pattern density which would have a high probability of striking any target of reasonable size inside of a 50 foot radius.

The sled test warhead design consisted of two half conical polyurethane foam (20/lb/ft^3) frusta holding 251 rods or 1004 rod segments. Only the upper 180 degrees of the available volume was populated with projectiles to minimize the potential for damage to the sled track (Figure 5). Both foam frusta halves were designed to fit in back-to-back bays in the sled body. The frusta core had approximately three pounds of sheet explosive wrapped around a central shaft. Additional sheet explosive (~2.5 lbs total) was sandwiched between the two annular rings to provide a KEP velocity gradient (i.e., dispersion pattern). The sled test warhead design was not optimized. However, the projectile mass, explosive mass, and average velocities expected in each annular ring are shown in Table 1. Detasheet explosive was used.

The sled design (Figure 6) included a conical forebody (57.6 inches long, 5.25 degree cone half angle) cantilevered from a cylindrical sled body that was mated to a Sprint second stage rocket motor. The two warhead sections were located in the forebody and covered with a 0.25 inch layer of cork for thermal protection. A skin cut was not attempted on this test to minimize risk. The complete sled with rocket and forebody weighed approximately 1950 lbs at ignition.

A sled test goal was demonstration of a multiple KEP warhead design in a high speed environment. A secondary goal was verification of the high speed sled concept for testing KEP warheads against a target array.

Sandia National Laboratory's 10,000 foot sled track facility at Albuquerque, NM was selected as the test site. Many different sled tests have been conducted at this facility, ranging from monorail sleds to large dual rail two stage sleds.

Velocity levels and sled weight lead to the selection of a Sprint second stage motor to accelerate the sled. This motor-body combination was estimated to provide a 4300 ft/sec terminal velocity. Before use, all extraneous hardware such as control system hardware were stripped from the Sprint motors.

Given the terminal velocity requirements and the sled acceleration capability, only the last 5,000 feet of sled track was required for the test. At the end of the track, a 120 foot long 5-foot diameter steel tube coupled with an 150 foot long 6-foot diameter concrete extension was positioned to minimize damage to the screen from sled debris.

Several cameras were placed at strategic locations along the sled track. One camera was trained on a mirror placed at the mouth of the steel tube to capture the sled reflection until the mirror was broken. Four streak photo cameras (spaced 16 feet apart) were set up perpendicular to the track starting just ahead of the detonation point. Other cameras were trained on several targets for post test evaluation.

IV. Target Description

The target set included (1) three spent rocket motors suspended from a frame at the end of the track, (2) a (45 feet high by 90 feet wide) vinyl tarpaulin witness screen 345 feet down range from the warhead detonation point, (3) a 0.5 inch steel plate 120 feet down track from the warhead detonation point and (4) a simulated submunition target 60 feet from the detonation point. To verify KEP velocities, several velocity traps were located along the flight path. The target layout is shown in Figure 7.

The spent target rocket motors included one Talos and two Honest John cases. The Talos case was filled with water; one Honest John motor was filled with dirt, and the other was empty.

The witness screen was made of 5 foot wide vinyl tarpaulin material sections and fabricated to create a 45 feet high by 90 feet wide panel to verify the KEP pattern. The screen was marked in a grid of 2.5 foot squares. Each cell was numbered to aid in post test pattern reconstruction.

The mild steel plate target (8 feet x 8 feet x 0.5 inches thick) was added to evaluate the effectiveness of the small rod projectiles against unprotected targets.

A subscale simulated ballistic missile warhead section containing submunition cannisters was also included as a target to examine the effectiveness of the multiple small rod projectiles.

Sled test objectives included KEP deployment, KEP effectiveness, sled hardware performance validation, sled debris containment tunnel feasibility, and trackside instrumentation evaluation.

The KEP event functioned as designed. The explosive event was triggered at the proper sled track position through trackside screenboxes whose electrical charge triggered onboard firesets. A streak photo sequence of the detonation/deployment event is shown in Figures 8 through 11. The first photo shows the sled immediately before warhead detonation. Photo two, shown in Figure 9, was taken about just after detonation (4 msec or 16 ft) after the first photo. The last two photos show the KEPs moving through the shock front. The terminal sled velocity, based on off-board measurements, was 4866 ft/sec.

After deployment, the KEPs struck the simulated TBM warhead target. Two velocity traps two feet behind the target indicated fragment velocities between 4657 and 4673 ft/sec. Several of the submunitions were destroyed directly or indirectly. The subscale canisters were penetrated by side-on as well as end-on KEPs.

One hundred and twenty feet after deployment, the steel plate was struck by rod segments. Approximately 127 segments perforated the steel plate. These included end-on and side-on rod orientations.

Several calculations were performed with the CTH code (Ref) on a steel plate model to determine the maximum fragment penetration depth. These calculations showed a side-on KEP could penetrate about 1.0 inch of steel at 4600 ft/sec. These results are shown in Figure 12. A similar calculation using an end-on KEP showed it could penetrate about 2.0 inches of steel at the same velocity.

After warhead detonation, the remaining KEPs continued 345 feet down the track before striking the witness screen. A uniform KEP pattern was seen on the witness screen. At the screen, any soft target larger than one square foot within a forty foot radius would have been hit. After the test, 974 of the 1004 rod-generated holes were counted in the witness screen. The impact distribution on the witness screen is shown in Figure 13. This figure has been adjusted to account for the 127 rod segments which struck the steel plate, but not adjusted to account for those which struck the cannister target. Using this information and the measured sled velocity, the maximum lateral deployment velocity was estimated to be greater than 500 ft/sec.

System effectiveness is directly related to estimates of the warhead dispersion radius, the number of KEPs within that area, and the impact velocity of the fragments. One velocity trap behind the screen measured 3356 ft/second. This results in an average drag coefficient of 4.34 using the fragment base area for a reference. The pre-test tumbling rod drag coefficient was estimated to be between 4.74 and 4.85. A comparison of impact velocity variation with deployment altitude and velocity at deployment for vertical flight path and a required 100 foot dispersion radius is shown in Figure 14 for end-on and tumbling rod drag models.

The rocket motors placed behind the witness screen experienced impacts from the small rods which would have rendered them inoperable. Rods penetrated the cases and nozzles which would have caused a mission kill and possibly a catastrophic kill from secondary explosions.

VI. Conclusions

The sled test demonstrated a KEP warhead concept for use against soft surface targets with a high velocity delivery system. Controlled deployment of a small rod warhead was demonstrated at 4866 ft/sec. In addition, it was shown that 1) a uniform pattern of small rod projectiles can be generated in a hypersonic flight environment 2) the rods are lethal against rocket motors, 3) the rods easily penetrated 0.5 inch steel plate and 4) they were more effective than expected against the cannisterized target.

The size, functionality, and lethality result in a warhead which fits within QPAS requirements and capabilities. This warhead is simple, yet a potentially lethal design, and could lead to new weapon systems that utilize the kinetic energy inherently available in hypersonic delivery systems.

References

J.M. McGlaun, S.L. Thompson, M.G. Elrick, "CTH: A Three-Dimensional Shock Wave Physics Code", Int. J. Impact Engng., Vol 10, 1990, pg 351.

Acknowledgements

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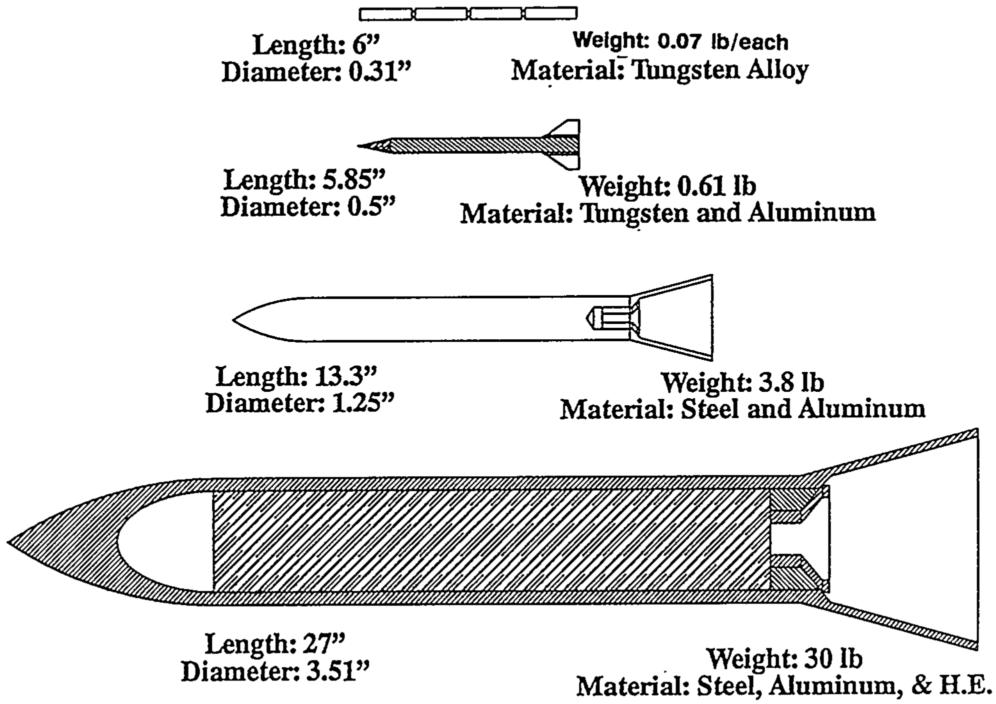


Figure 1. Kinetic Energy Projectile Comparison

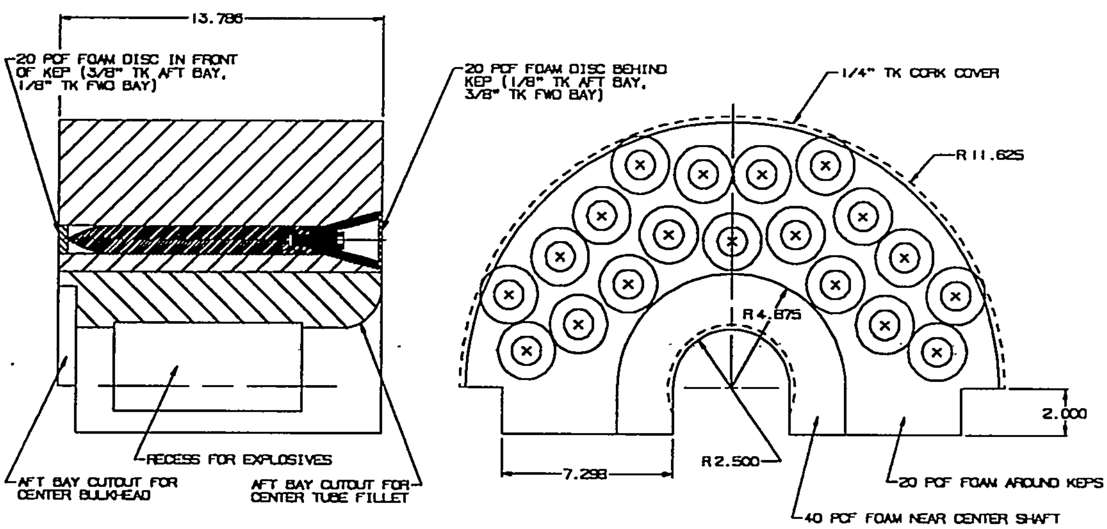


Figure 2. Warhead Design Consisting of Multiple 4 lb. Projectiles

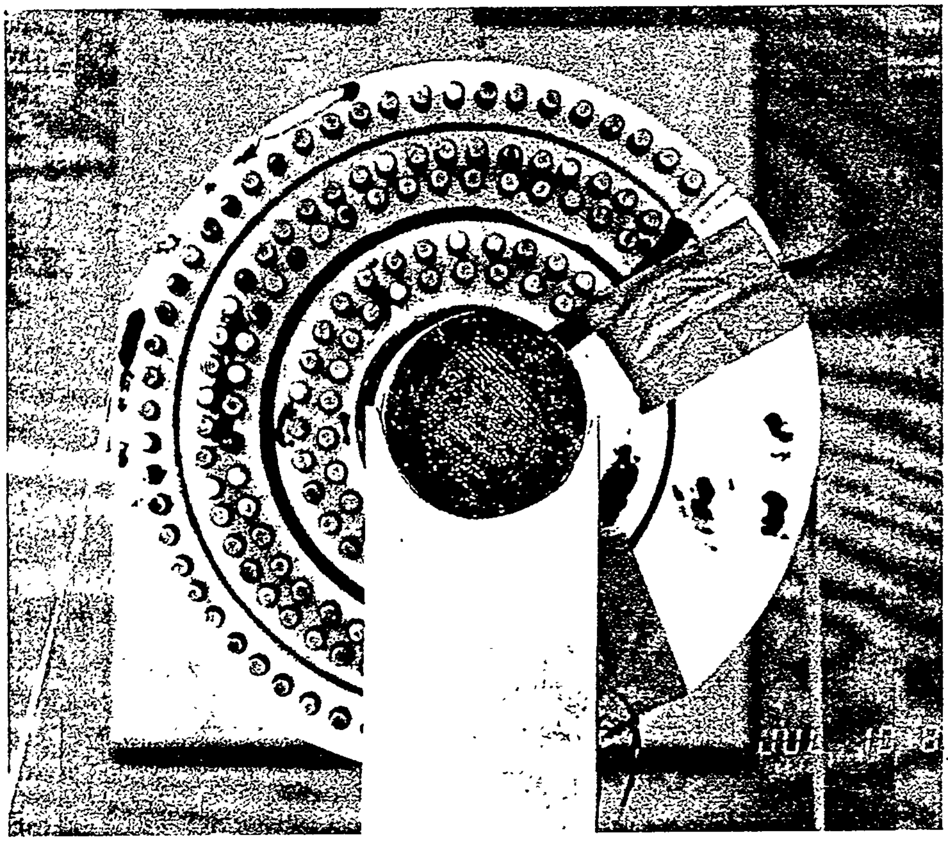


Figure 3. Static Warhead Test Hardware with Sheet Explosive

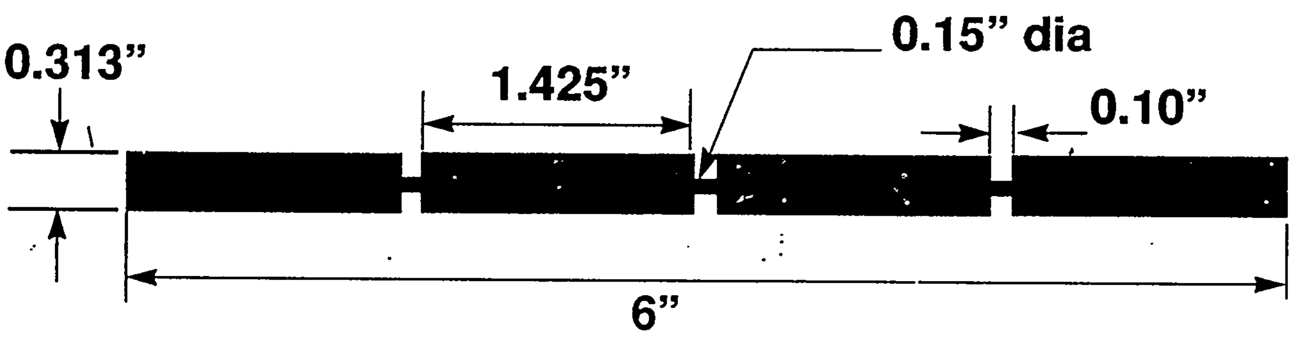


Figure 4. Segmented Rod Design

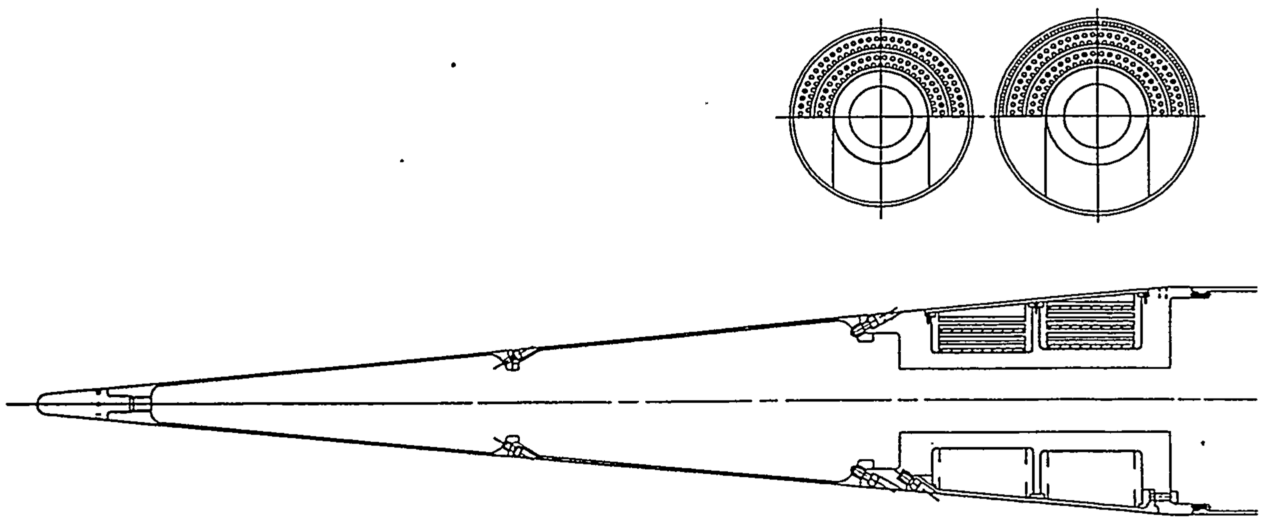


Figure 5. Sled Fore Body with Warhead Sections

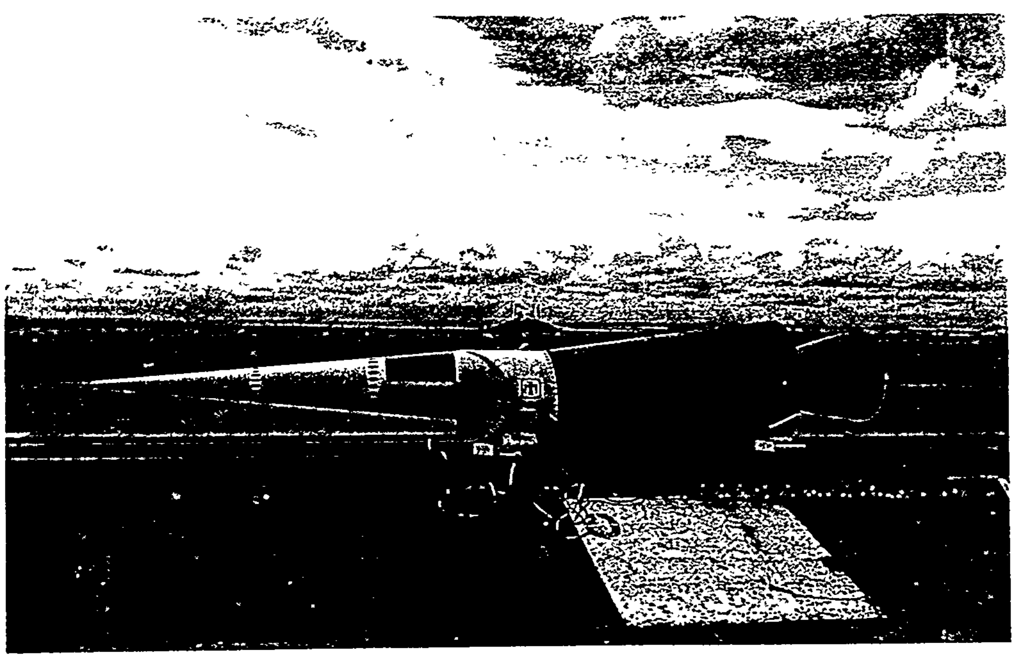


Figure 6. Sled Test Unit

Ring	Expected Average Velocity (ft/s)	Number of Fragments	Projectile Mass (lbs)	Explosive Mass (lbs)
Fwd/inner	180	188	13.3	1.33
Fwd/outer	500	252	17.8	1.33
Aft/inner	100	188	13.3	1.41
Aft/outer	350	376	26.5	1.43
Total		1004	70.9	5.50

Table 1. KEP Warhead Characteristics

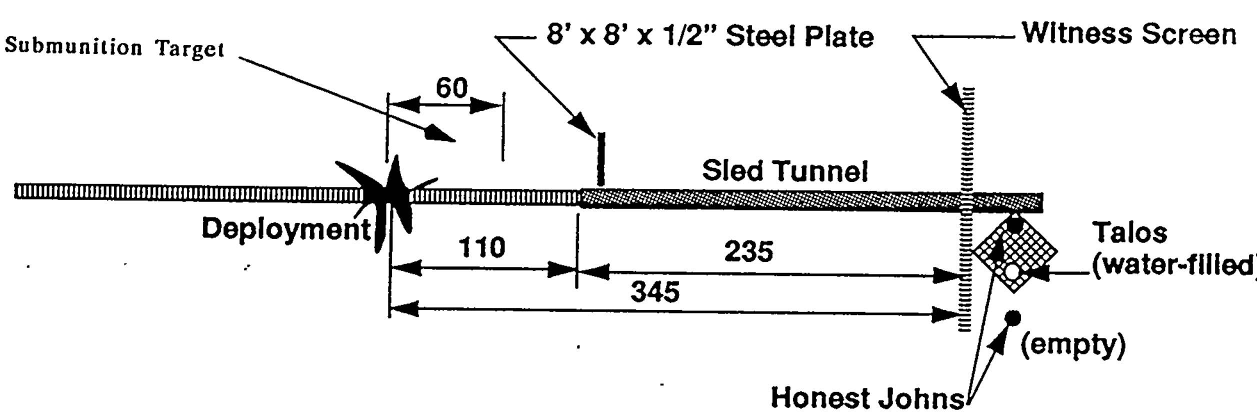


Figure 7. Target Layout

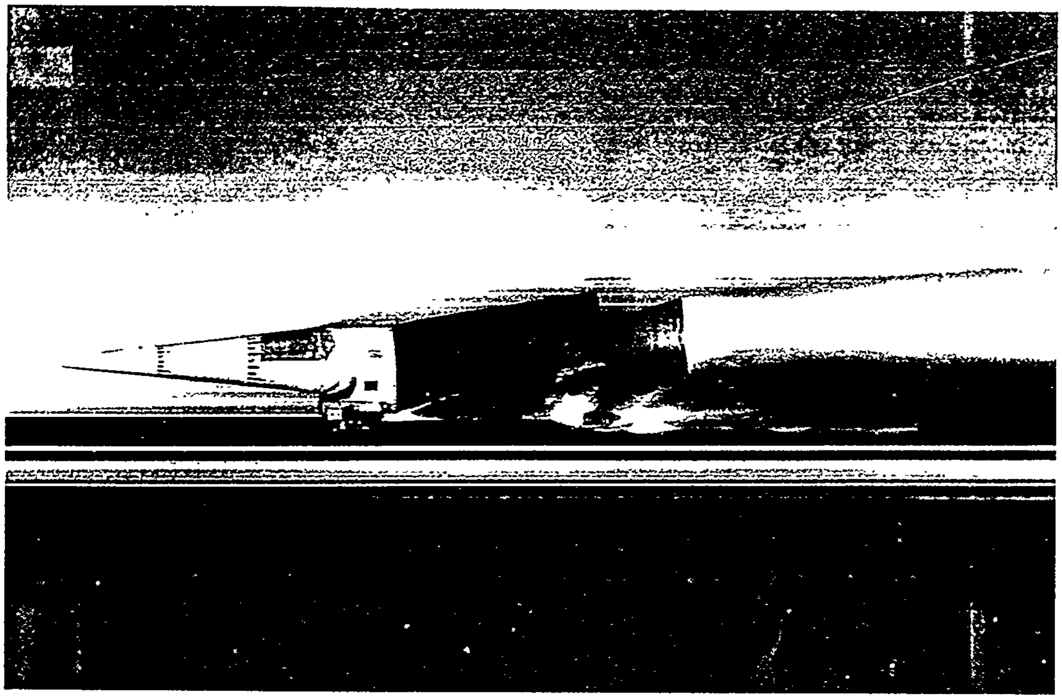


Figure 8. Streak Photo of Sled Before Warhead Detonation

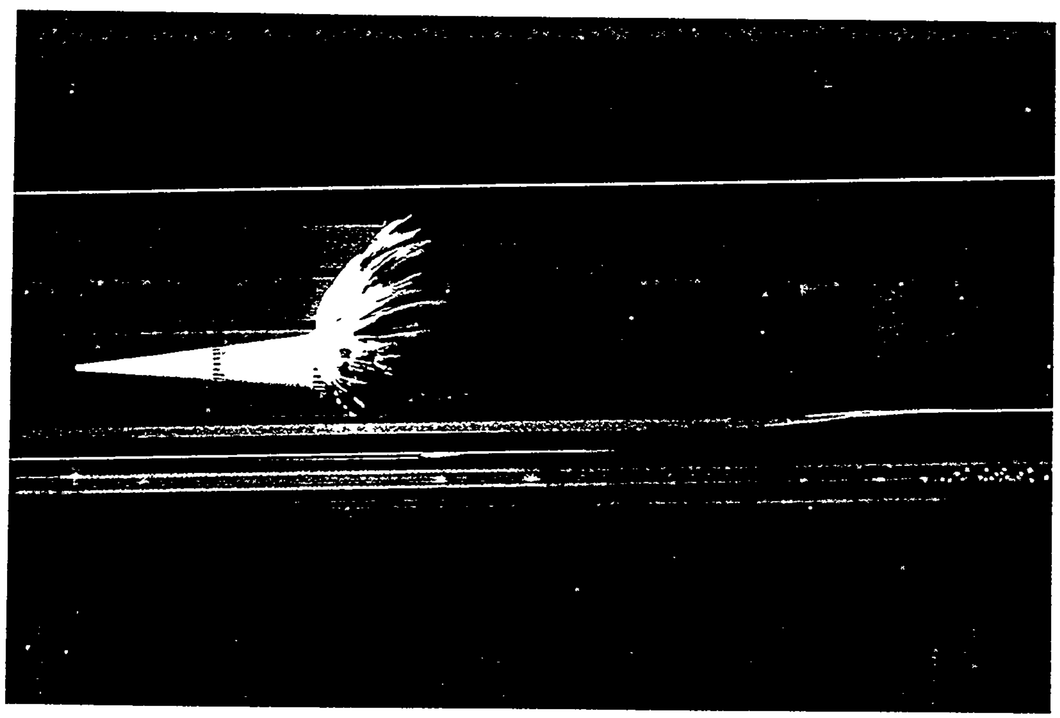


Figure 9. Streak Photo of Sled After Warhead Detonation

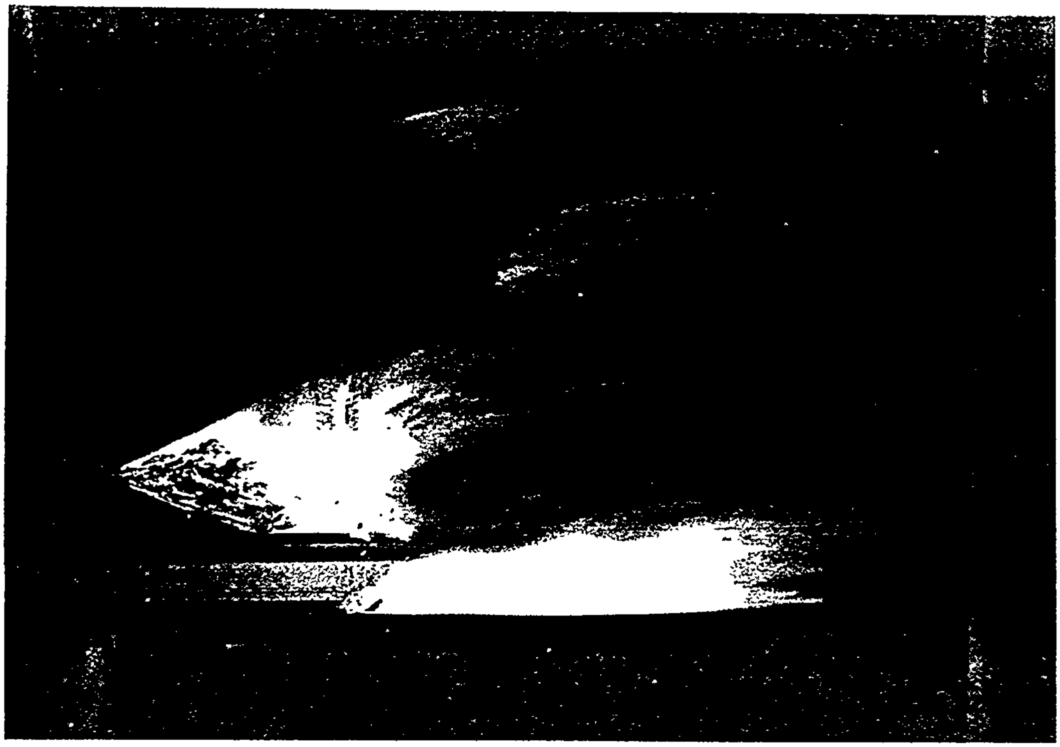


Figure 10. Streak Photo of Sled Showing Initial Warhead Deployment

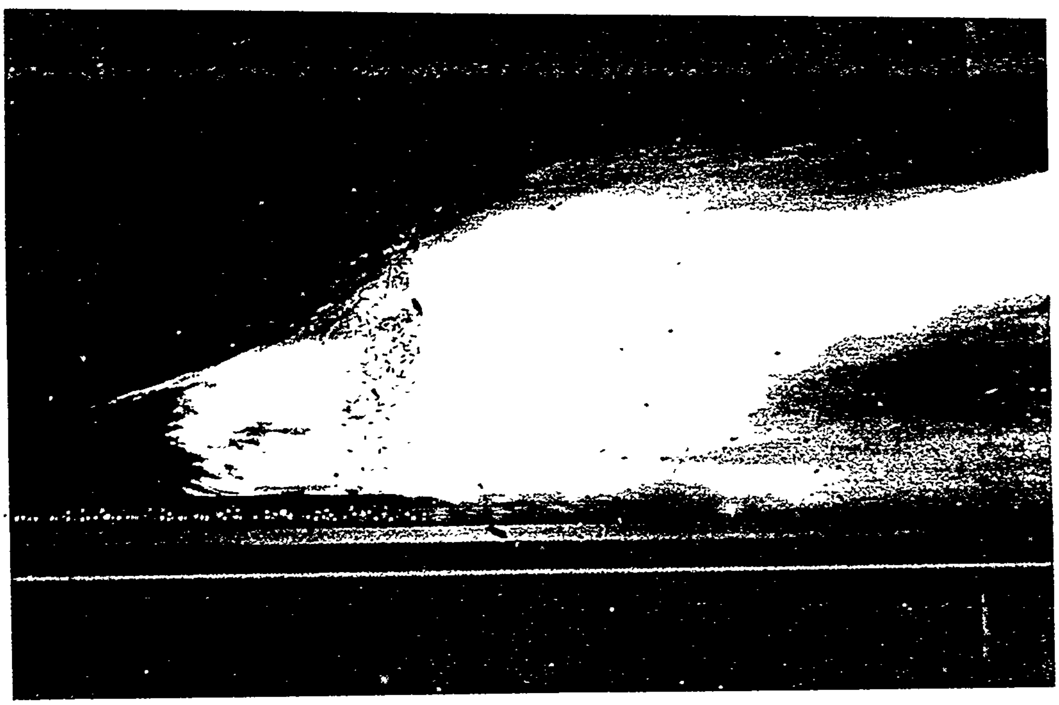
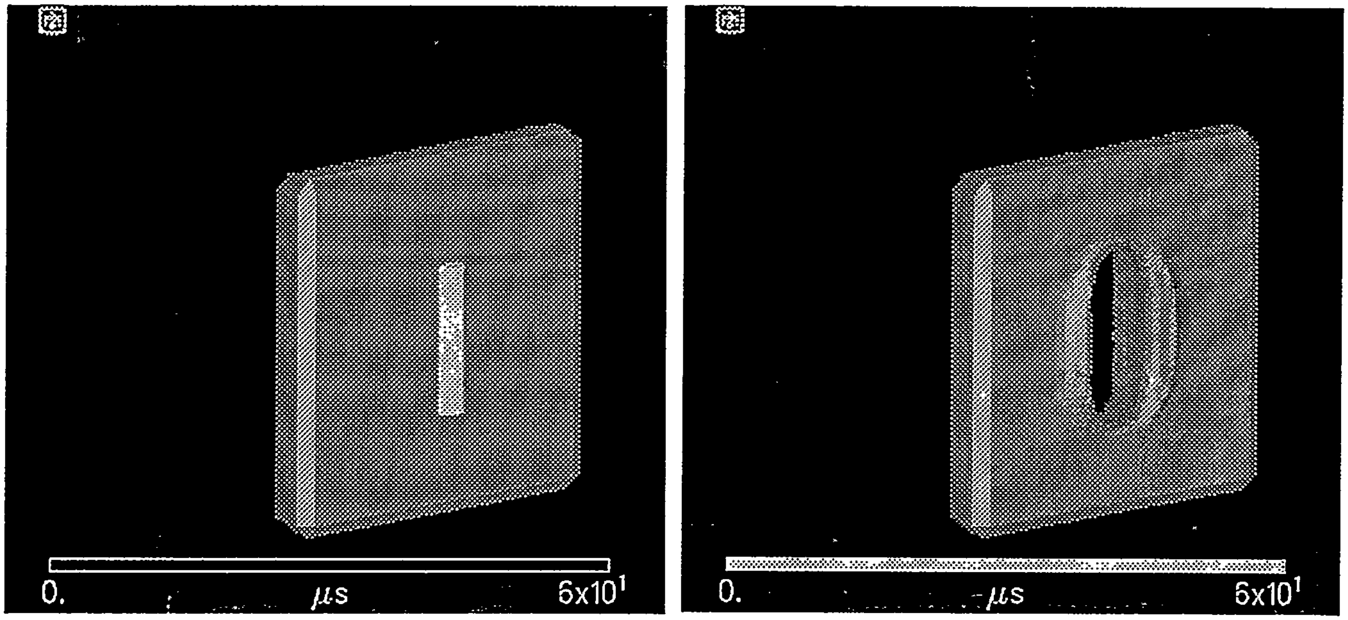


Figure 11. Streak Photo of Sled Showing Warhead Rud Segments Moving Through the Shock Front



t = 0.0 μsec   t = 60.0 μsec

Figure 12. Hydrocode Calculations

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Figure 13. KEP Deployment Pattern

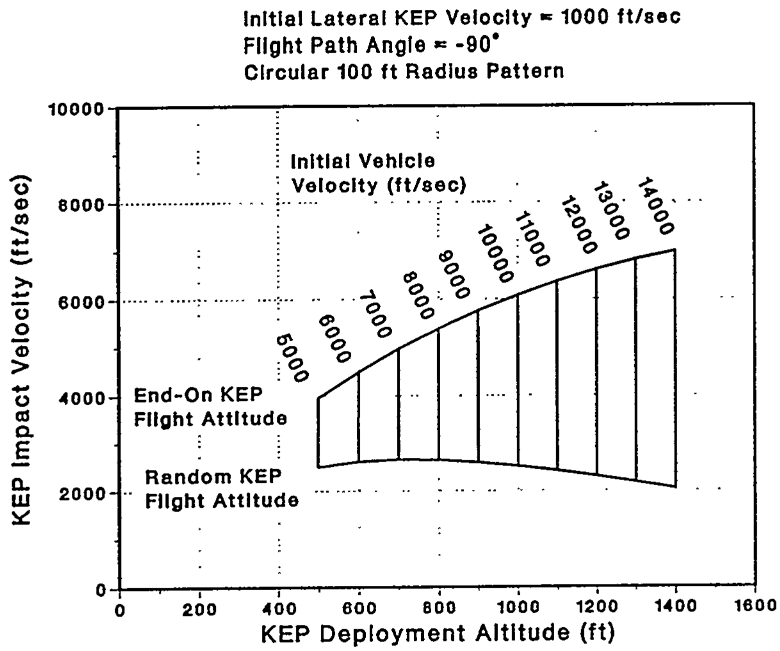

Figure 14. KEP Lateral Velocities Required for Various Initial Velocities

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