13. DISPERSION DEVELOPMENT PROGRAM

By

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SUMMARY

The requirement for the predictable dispersion of small munitions over large areas from ground support missile systems has resulted in the development of a fin stabilized submissile and "sling" ejection system for the Little John warhead. The progressive development of this system is traced including a comparison of simulator, sled test, and flight test results. The results indicate that it is not only necessary but also possible to eject long slender bodies, from a missile warhead at Mach 1, in a stable, uniform and predictable manner.

INTRODUCTION

The Little John warhead was selected as a test bed for this development because of its availability and scaling factor relationship between submissile, munition, and missile when compared to larger missile systems (such as Lance). To maintain development cost at a minimum, the aft section only of the warhead was selected for packaging of the submissiles. By modifying the aft bulkhead it was possible to have a cylindrical cargo bay 76.2 cm long by 30.48 cm in diameter. Packaging of two sizes of subassemblies carrying munitions with a 3.96 cm diameter was desirable. Therefore, submissiles containing four (4) munitions and one (1) munition in cross section were selected for development. This resulted in submissiles with equivalent length to diameter (L/D) ratios of 8 and 16 respectively. Figure 1 illustrates the Little John warhead with the submissiles in the aft cargo bay.

The cargo is ejected from the warhead at event by the "sling" action generated when the two skin panels separate pulling the "sling" taut. Figure 2 illustrates this technique.

Once the preliminary submissile packaging envelope was defined, the design of the submissile was undertaken based upon design criteri: generated from prior development programs involving other missile and aircraft dispenser systems. The development process included an aerodynamic analysis to define the ballistic characteristics of the two submissiles to obtain uniform ballistic characteristics and to define the fin size to provide a stable body over the flight environment design criteria specified. In addition to the aerodynamics of the submissile after it was in the air stream, it was necessary to predict its characteristics when ejected from the warhead with a sling system. Scaled simulator tests were conducted to investigate various ejection techniques prior to high speed (Mach 1) sled tests at the Naval Weapons Center (NWC). After the ejection technique and submissile dynamics were verified by sled tests, full scale flight tests were conducted at White Sands Missile Range (WSMR).

Design Criteria

Systems requirements for the design were for the submissile to survive warhead event at Mach 1.5. The submissile was to withstand the loads imposed should it see a 90° angle of attack and axial forces of 80 g's as defined by the Little John system during launch.

Submissile fin deployment was desirable in less than 40 milliseconds to prevent the submissile from tumbling through one (1) revolution prior to stable flight should it see high pitch rates at ejection. Tumbling is not conducive to repeatable characteristics over the various flight region anticipated.

Submissile Design

As mentioned earlier the submissile envelopes were defined by the missile cargo bay and the munition diameter. The use of a submissile containing four (4) munitions in cross section (quad submissile) resulted in a basic square body configuration and because of the requirement for an explosive release technique for the munitions, the single cross section submissile was also designed as a square body. The submissiles were 8.44 cm and 4.33 cm in cross section for the quad and single submissiles, respectively. The requirement for rapidly opening fins dictated more torque than available from conventional springs which could be packaged within the available space. Therefore, a high torque torsion mechanism was designed which increased the opening torque by a factor of 6 over springs.

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Sizing of the fins for the submissiles was based on the results of an aerodynamic analysis for a round body of equivalent diameter at both small and large angles of attacks. Estimates of pertinent aerodynamic parameters were made to allow computer simulations of dart flight.

Figure 3 shows the assembled submissiles and their characteristics are contained in the following table:

	Quad	Single
Length (cm)	74.0	72.4
Cross flats (cm)	8.44	4.33
Weight - grams	8285	2385
Center Gravity off base (cm)	35.7	36.9
Fin area (cm^2/fin)	69.0	47.7

Ejection System Design

As a tool to assist in the investigation of ejection characteristics, a one-half scale model ejection simulator was developed. The simulator consisted of a "bungee" cord arrangement to provide the force for exercising the sling system and a quick release system. The submissile simulators were constructed from wood with ballast added to obtain the proper weight and center of gravity. The submissile simulators did not contain fins and therefore the effect of fin torque was not included in the test program. A series of tests were conducted to determine the effects of sling length, sling shape, sling-to-warhead attachment point, sling size, ejection force, and load distribution.

Figure 4 illustrates the effect of sling shaping upon the pitch rate induced on the simulators. It varied from 2 rps nose first to 2 rps tail first. Based upon these tests, conditions which should give a near parallel ejection attitude were selected for sled tests.

The importance of the controllability of ejection conditions must not be neglected. For a vehicle constrained to pitching and heaving motion, figure 5, the linearized equations of motion may be written as

$$Z_a a + Z_q q + Z_{\dot{a}} \dot{a} = m \ddot{Z}$$

$$M_a a + M_q q + M_{\dot{a}} \dot{a} = I \ddot{\theta}$$

where

Z_i, M_i $(i = a, \dot{a}, q)$ are stability derivatives for forces and moments due to the respective aerodynamic phenomena

m is the mass of the vehicle

I is the transverse moment of inertia

This system may be solved for $\theta(t)$ and $\alpha(t)$ once the geometric constraints, figure 5, have been substituted. The oscillatory solutions obtained for θ and α may be used to determine the lateral coordinate, i.e.,

$$Z(t) = V \int (\alpha - \theta) dt$$
$$= k_1 e^{\phi_1 t} + k_2 e^{\phi_2 t} + k_4 t + k_5$$

Thus, the vehicle is moving away from its initial heading due to the time dependent k_4 term. The motion may be described as an oscillation which occurs on a time dependent trim line, figure 6.

An approximate solution for the k_4 term is given by

$$k_4 = -\theta_\circ + \alpha_\circ - \left[\frac{Z_q + Z_a}{mv}\right] \alpha_\circ - \left[\frac{IZ}{mV M_a}\right] \dot{\alpha}_\circ$$

and the angle of dispersion, called the jump angle, is given by k_4/V.

Note that the magnitude of the jump angle, and hence the dispersion, is dependent on the initial attitude and the initial angular rate. In particular, for a finned vehicle, such as a dart, the effect of the $\dot{\alpha}_\circ$ term is dominant, and large initial angular rates will cause large dispersion.

This behavior is also exemplified by the lateral ejection velocity (LEV) history as the vehicles travel down range. Figure 7 presents LEV histories showing the characteristics that the curves may have for various dart ejection attitudes. Thus it is possible that a dart may suffer LEV "speed-up" for "slow-down" as a result of initial attitude. This will greatly influence pattern characteristics.

Sled Test

The Little John warhead was attached to an expended Tiny Tim booster and accelerated down the SNORT track at NWC by five (5) Zuni rocket motors. The test was arranged so the warhead did not function until it was in free flight off the end of the rail. A pit 3.6 meters wide by 2.4 meters deep was located at track end to reduce shock wave

interference characteristics.

Two (2) tests were conducted at approximately Mach 1. On the first test the sling system tore loose of the warhead skin panel at warhead event. This was caused by the primacord which curled the skin back pulling the sling attachment loose. The submissiles did not see the proper ejection characteristics and were subjected to high initial pitch conditions since the sling caught the submissile tails. However, the submissiles were ejected and flew stable without any tumbling. The sling skin panel interface was reinforced for the second test and the sling system operated properly. Figures 8 and 9 illustrate the submissile behavior at event and over the first 100 meters of flight. It should be noted that the submissiles come out with a slight nose down attitude and tend to oscillate $\pm$ 10 degrees about the horizontal during their observed flight of 1.5 seconds or 450 meters. Also it can be noted that the submissile fins are open prior to 0.05 seconds when they become distinguishable in the photographs. Comparing the average event conditions of all submissiles for the simulator and sled tests gives a good correlation considering the limited number of test points. The average pitch rate predicted from the simulator tests was -0.01 rps and the sled test result was -0.37 rps (negative sign indicates tail first ejection). This shift was in the direction anticipated because of the fin action which was not included in simulator tests. The ejection velocities were 7.6 and 6.8 meters per second respectively for the simulator and sled tests. This comparison is also good since the sled tests results include effects of dynamic lifts which were in the negative direction as a result of the nose down ejection attitude.

Analysis of sled test data supplied sufficient data to compare the predicted submissile drag characteristics with test results. A comparison of static moment stability derivative coefficient (Cm_α) was also obtained. Test data provided a value of -10.9 radian^{-1} compared to a predicted value of approximately -11.0 radian^{-1}.

Flight Tests

Three flight tests were conducted at WSMR to demonstrate the capabilities of this system to disperse small low ballistic factor munitions over large areas. Two basic event conditions were selected for test purposes. These were missile dive angles of 57 and 17 degrees at a velocity of approximately Mach 1. These two angles were selected to illustrate the system's capabilities to provide near constant patterns independent of missile dive conditions and without need to vary the functioning time of the submissiles.

The pattern size obtained is a function of the time the submissiles fly prior to release of their cargo. For this series of tests a flight time of 1.25 seconds was used. Analysis of the limited photographic coverage obtained on these tests indicated that the 4 rps roll rate of the missile at time of event was not detrimental to overall system performance. The actual patterns obtained were slightly larger than predicted. This increase in pattern size is attributed to the increased dispersion from each submissile obtained because of the roll rate induced in the submissile by the asymmetry of the fins from assembly tolerances. This additional dispersion is a desirable condition and could be intentionally increased for future applications.

CONCLUSIONS

Slender body submissiles can be ejected from missile systems in a stable and predictable manner. They can also be used to provide dispersion of munitions over large areas with a minimum munition flight time and with the munition pattern shape relatively independent of missile event conditions.
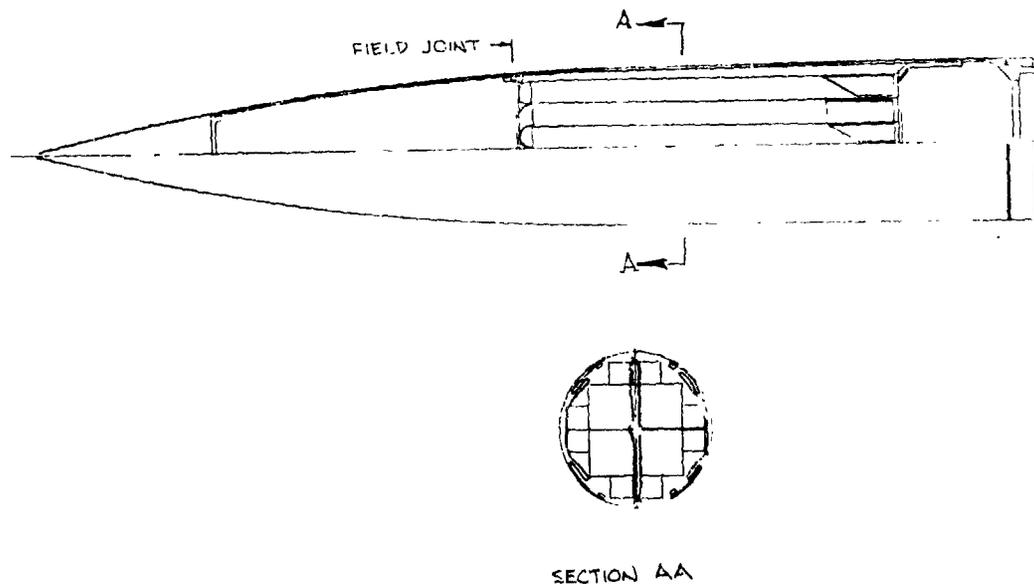
FIELD JOINT

A←

A←

SECTION AA

Figure 1   Little John Configuration

CUTTING CHARGE

SLING INITIALLY TAUT

REACTION STRUCTURE   SLING

SKIN PANEL
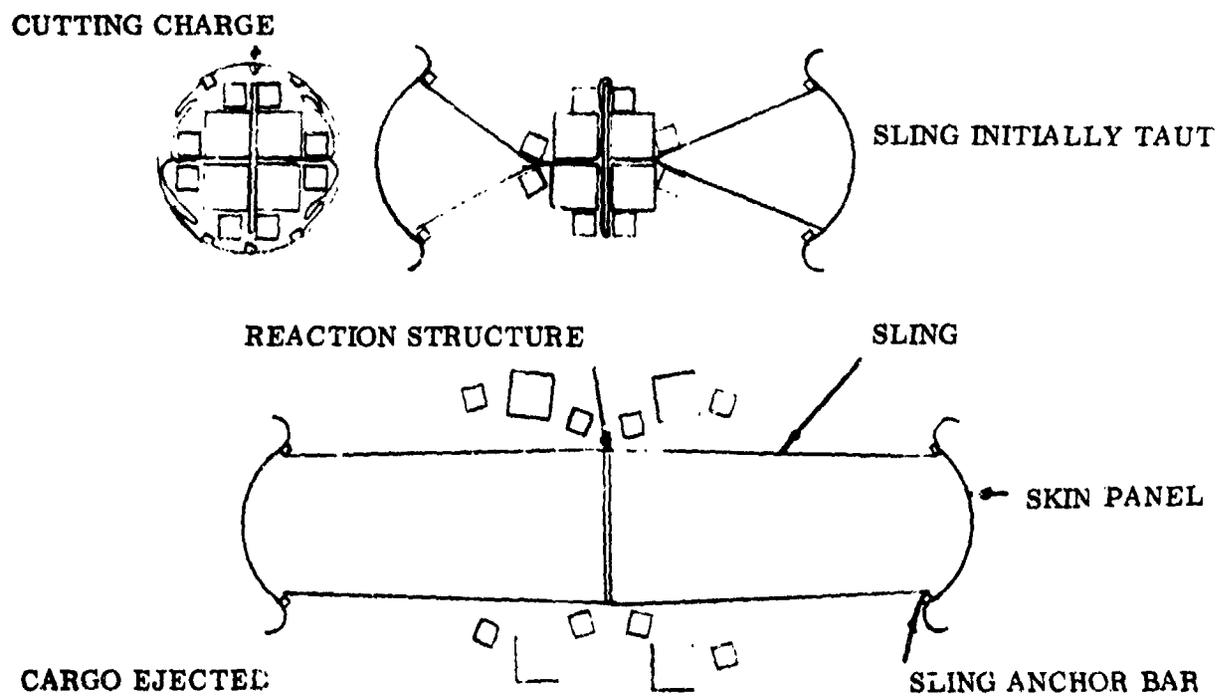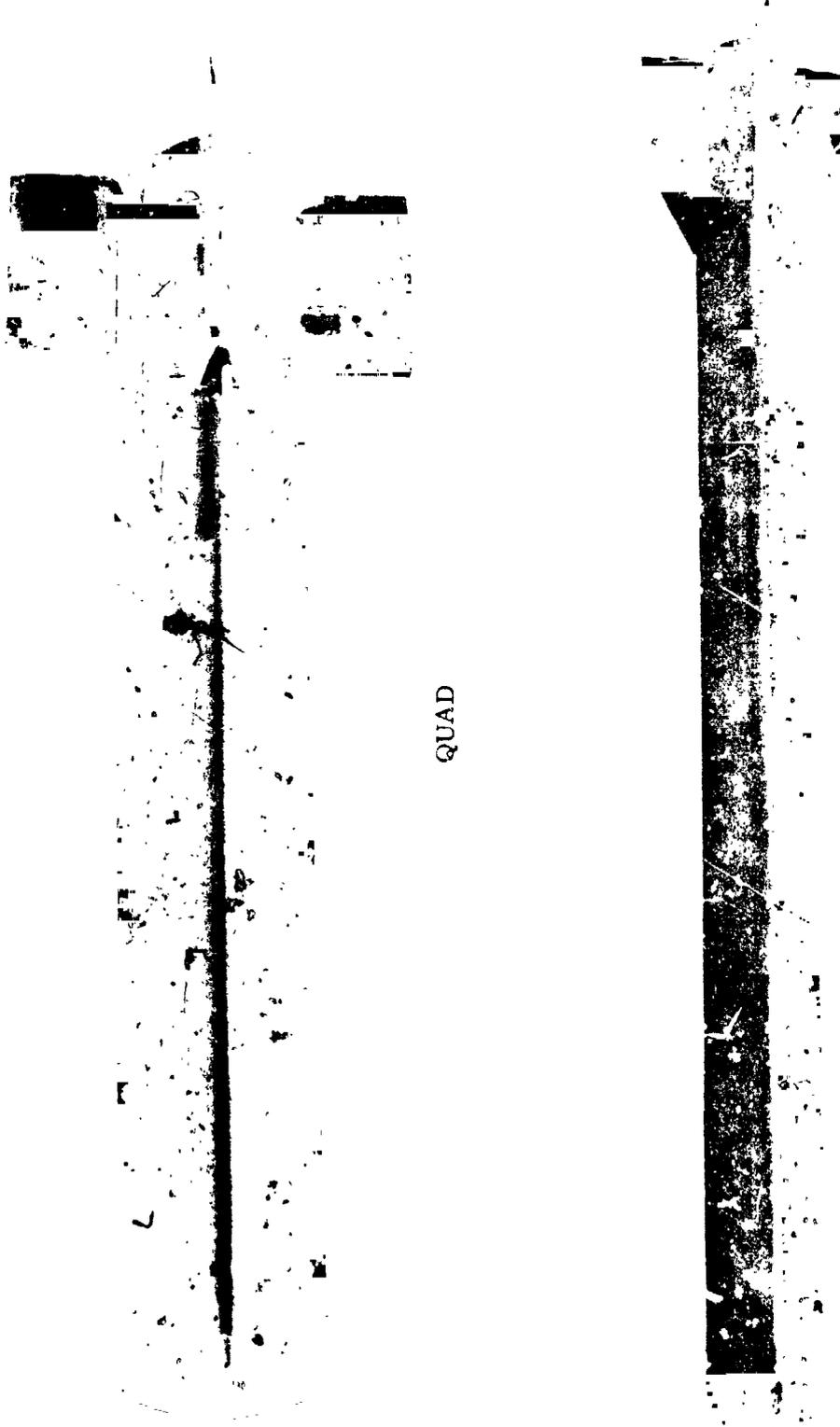
CARGO EJECTED   SLING ANCHOR BAR

Figure 2   Sling   Technique

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QUAD

ENGLE

Figure 3 Submissiles

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2 rps
NOSE FIRST

1/2 rps
NOSE FIRST

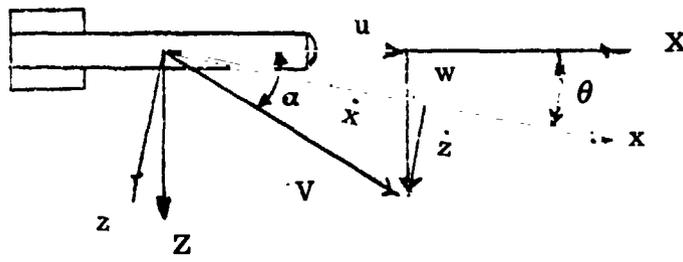2 rps
TAIL FIRST

Figure 4   Effects of Sling on Pitch Rate
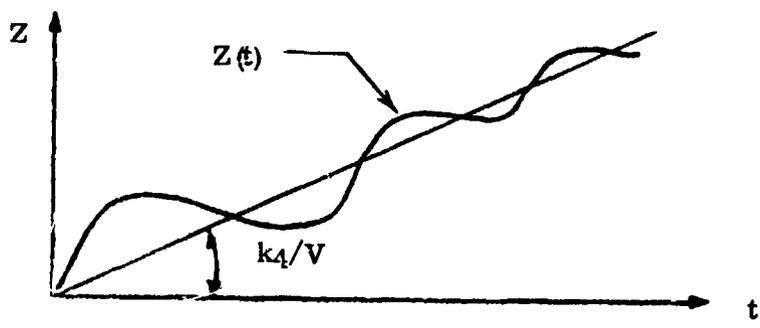
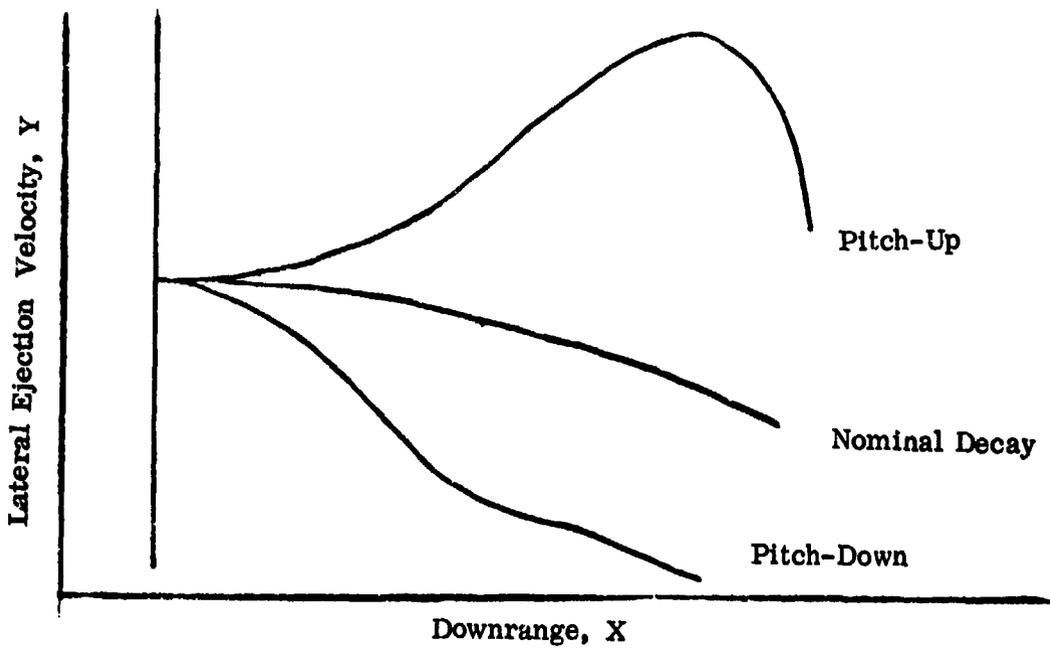Figure 5 Pitching and Heaving Vehicle

Figure 6 Jump Angle, k_4/V
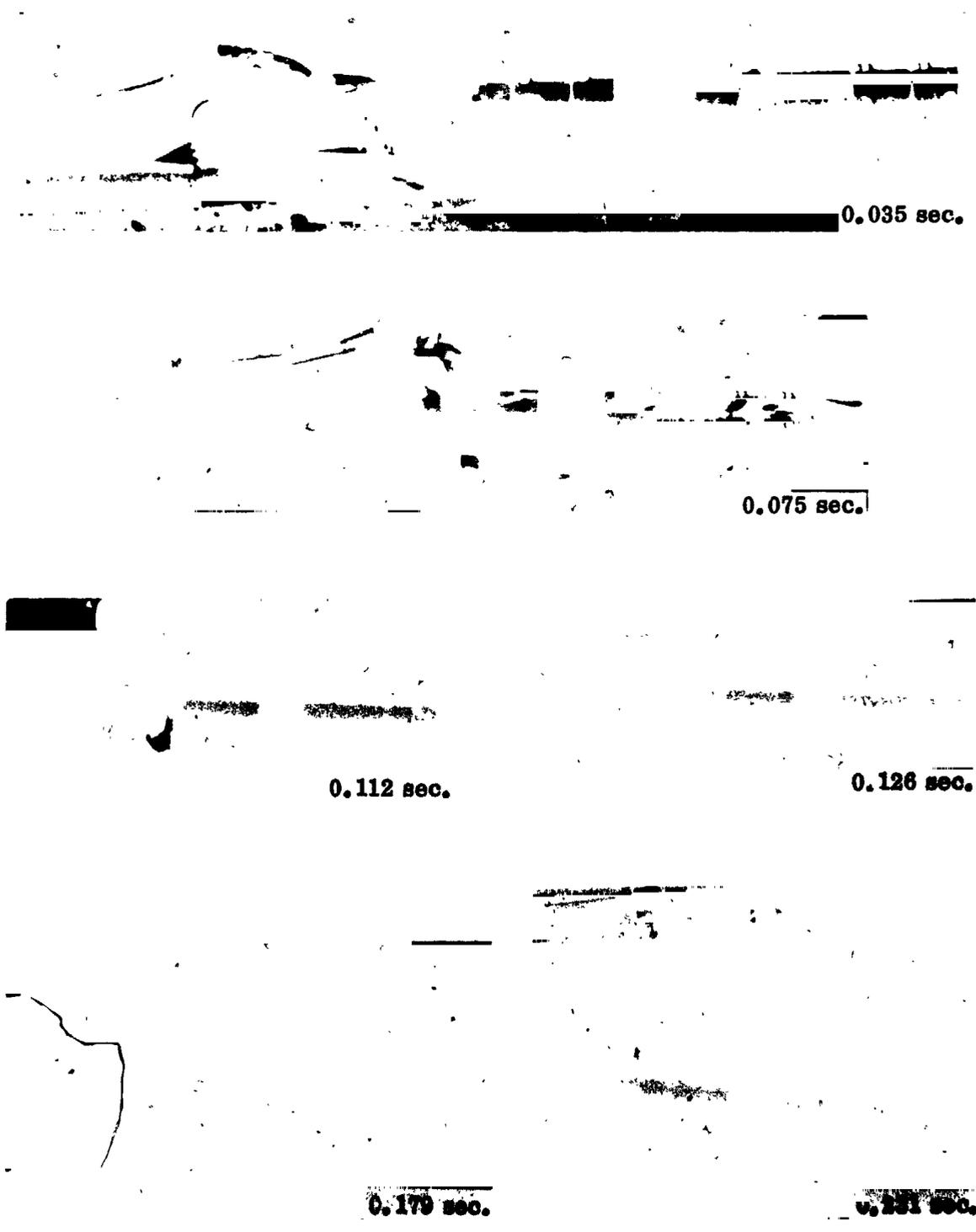

Figure 7 Lateral Ejection Velocity vs. Range

0.035 sec.

0.075 sec.

0.112 sec.

0.126 sec.

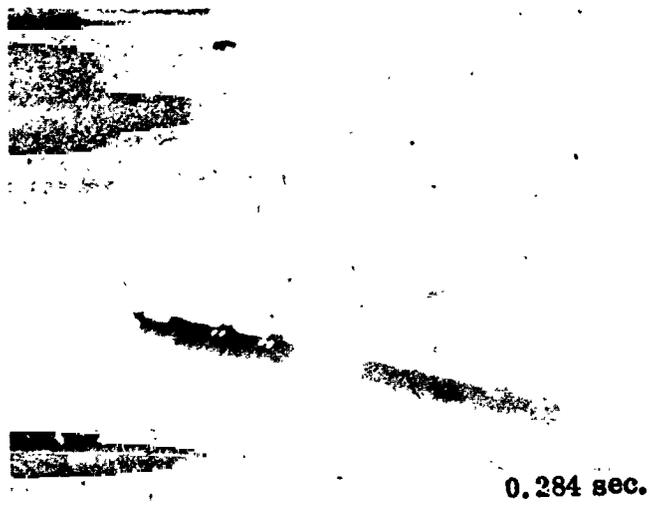0.179 sec.

0.221 sec.

Figure 8 Sled Test Results

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0.284 sec.

0.267 sec.

Figure 9 Sled Test Results Continued

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