Bendix Aerospace Systems Division

Safe-Arm Slide Ejection Effect on Grenade Trajectory

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Prepared by: R. Lipp

P. Ireton

Approved by: D. Dewhirst

J. McDowell

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Introduction

A series of tests were run on the ASE Grenade System to obtain the relationship between the range line deployment time and the initial velocity of the individual grenades. These tests gave the necessary empirical correction to the theoretical equation so that the actual range of the grenade could be calculated. Unfortunately, when these vacuum tests were performed, the safe-arm slide was omitted from the system, and therefore, any perturbation to the trajectory due to the ejection of the safe-arm slide was not observed.

This memorandum reports the effect of the safe-arm slide ejection on the grenade range. The report also suggests a method by which the range may be computed by any interested party which includes the safe-arm slide ejection corrections.

Results

A procedure for calculating the range of the ASE Grenades was devised and is found in Appendix II. In Appendix I is found the derivation of the corrections to the range due to the ejection of the safe-arm slide. The equations of motion of the grenade after the ejection of the slide were developed from principles of conservation of energy and conservation of momentum. With the equations which were derived and the data supplied from Space Ordnance System, the range of all four grenades were computed at Launch Angles of 33°, 45° and 57°. With the data found in Table II the results of the calculations are found in Table I.

Conclusions

The safe-arm slide ejection has a negligible effect on grenade range. Worst case percentage change in range is 1.1% (-4 grenade) and the worst case absolute change in range is 10.2 feet (-1 grenade). Both worst case conditions occurred at the extremes of angle, 33°, while at 45° the change in range worst case was .07 feet.

APPENDIX 1

Development of Theory

It was assumed that the grenade launch motor burned out prior to ejection of the slide. It was also assumed that the ejector spring accelerated one third of its own weight, the weight of the slide, and the weight of the ejector. Only the slide was ejected from the grenade.

Figure 1a shows the conditions prior and after the slide ejection. Consideration of the conservation of linear and angular momentum give the following expressions:

$$(M-m)\,V' = mV_e \qquad 1.0$$

$$mV_e\,\ell = I\omega \qquad 2.0$$

where M is the mass of the grenade; m, the mass of the slide; ℓ the distance from the grenade center of mass to the ejector path; I the mass moment of inertia of the grenade; ω the angular rate of rotation of the grenade; V_e the slide velocity at ejection and V' the linear velocity of the grenade opposite to the direction of the ejector motion.

From conservation of energy, we can write:

$$1/2\,(x_2^2 - x_1^2)\,k = 1/2\,(m + m_s)V_e^2 + 1/2\,(M - m)(V')^2 + 1/2\,I\omega^2 \qquad 3.0$$

where k is the spring constant; x_2 and x_1 the springs free and compressed lengths; and m_s the combined 1/3 spring and slide weights. Note that the energy term represented by $1/2 m_s V_e^2$ will be dissipated as friction within the grenade. Substituting V' and ω from 1.0 and 2.0 into 3.0, and multiplying by 2, gives

$$k(x_2^2 - x_1^2) = 1/2\,(m + m_s)\,V_e^2 + \frac{m^2}{M - m}V_e^2 + \frac{m\ell^2}{I}V_e^2 \qquad 4.0$$

From 4.0 we can find V_e. From V_e we can in turn compute V' from equation 1.0, and a correction of the angle can be calculated from

$$(\theta - \theta') = \tan^{-1}\frac{V'}{V_o}$$

(see Figure 1b)
This equation is the final result of the Safe-Arm Ejection Theory.

In Appendix II is developed the procedure followed in the computations. The iteration criterion used was that the angle correction $(\theta - \theta')$ was less than .1% of the original angle θ. In other words, if $(\theta - \theta')$ was less than .001 of θ the iteration was suspended. In all cases only one iteration was necessary.

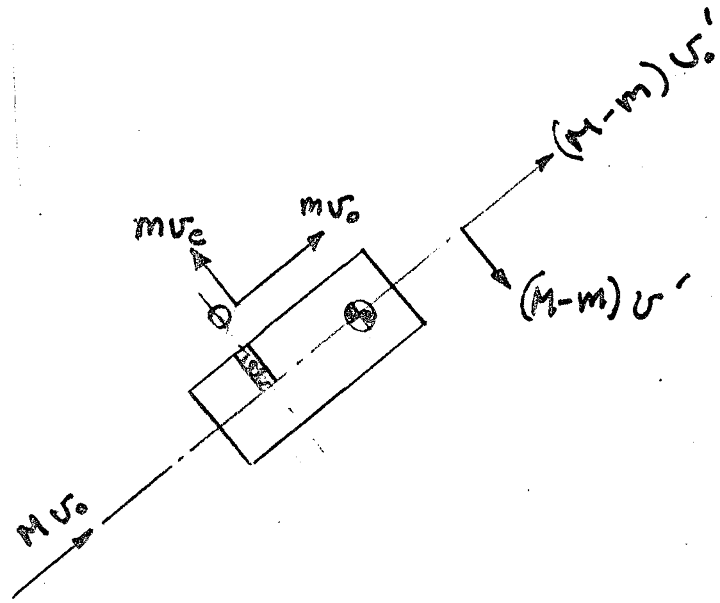

Figure 1a. Diagram showing ejection of slide and momentum before and after the event

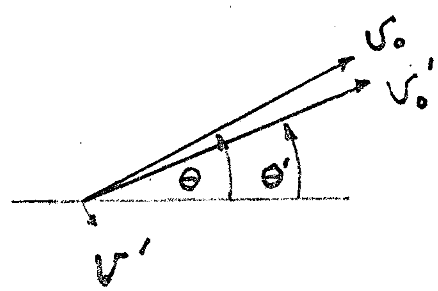

Figure 1b. Vector Diagram of velocities after the ejection of the slide

APPENDIX II
Procedure For Computing Range

(1) Obtain Telemetry Data from moon giving Launch Angle (θ) and Range Line Time (t).

(2) Convert Range Line Time to Range Line Velocity (V_{RL}).

(3) Correct V_{RL} for Range Line Spiralling and obtain a new V_{RL}.

*(4) Compute the initial velocity (Vo) from t, V_{RL} and θ by the formula

$$Vo=1/2\left(gt\sin\theta+\left[4V_{RL}^2-(gt\cos\theta)^2\right]^{1/2}\right)$$

(see reference)

(5) Using Vo calculate a new θ with the use of the formulas developed in Appendix I.

(6) Return to Step 4 and re-calculate the initial velocity Vo with the new θ. Iterate until this converges.

(7) Correct Vo for Range Line Drag U. (see table II)

(8) Compute the Range $R=\frac{Vo}{g}\sin 2\theta$.

* At Step 4, the computations were initiated which are reported in Table 1 and 2. An average corrected V_{RL} and t as obtained from the reference was used. See Table II.

TABLE 1. RESULTS OF SLIDE EJECTION ON GRENADE RANGE

Grenade No	Firing Angle (o)	V_o (equ. 7) Initial System Vel. (ft/sec)	Slide Vel. at Ejection (ft/sec)	Final Grenade Vel. (ft/sec)	Grenade Vel, Normal to Path (ft/sec)	Change in Flight Angle (o)	Range w/o Slide Ejection (ft)	Corrected Range (ft)	Range Change (%)
-1	33	170.1	13.291	170.1	.197	.0657	4969.5	4959.3	-.206
-1	45	170.2	13.291	170.2	.197	.0657	5443.4	5443.3	-.0014
-1	57	170.2	13.291	170.2	.197	.0657	4975.5	4985.6	+.203
-2	33	130.7	13.271	130.7	.243	.105	2933.3	2923.5	-.332
-2	45	130.8	13.271	130.8	.243	.105	3214.5	3214.4	-.0036
-2	57	130 [illegible]	13.271	130.8	.243	.105	2939.3	2948.8	+.325
-3	33	84.3	13.23	84.3	.321	.212	1221.4	1213.1	-.676
-3	45	84.4	13.23	84.4	.321	.212	1340.5	1340.3	-.015
-3	57	84.5	13.23	84.5	.321	.212	1227.3	1235.2	+.644
-4	33	57.73	13.207	57.73	.359	.339	572.4	576.1	-1.098
-4	45	57.89	13.207	57.89	.359	.338	630.1	629.8	-.042
-4	57	58.03	13.207	58.03	.359	.337	578.2	584.2	+1.009

TABLE II. INITIAL VALUES USED IN COMPUTATIONS

Grenade	t* (Sec)	V_{RL}* corrected (ft/sec)	M (Lbs)	I (Lbs - in^2)	l (in)	U* (Ft/Sec)
-1	.12946	171.85	2.753	11.02	.191	1.92
-2	.17077	131.55	2.241	6.631	.221	1.1
-3	.26049	86.4	1.699	3.8262	.426	2.44
-4	.37276	60.2	1.522	3.428	.518	3.0

$M = .0403$ (Lbs)

$m_s = .0077$ (Lbs)

$X_1 = .303$ in.

$X_2 = .763$ in.

$K = 6.525$ Lbs/in.

* From Reference