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LIGHT GAS GUN CALIBRATION REPORT

MASTER

AUGUST 1, 1968

PROJECT 507-1

BY: S.H. CARPENTER
L.J. THOMPSON

**@ TECHNICAL
report**

from the Texas A&M
RESEARCH FOUNDATION

College Station, Texas

EARTH PENETRATION AND DYNAMIC SOIL MECHANICS

This Work Performed For
Sandia Corporation
Albuquerque, New Mexico
Sandia Corporation Purchase Contract No. 48-5932
Buyer M. S. Cotter 4314
Requestor J. L. Colp 9327

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I. PURPOSE OF REPORT

The final design of the velocity generating system calls for the use of a compressed air gas gun to propel the projectiles¹. The theoretical equation used to design the gas gun has never been experimentally verified. The ability of a compressed air gas gun to deliver a given projectile at the same velocity for a series of shots, given constant gun parameters (i.e., chamber pressure, chamber volume, barrel length), is not known.

The purpose of this report is twofold. The small compressed nitrogen gas gun presently installed in the Terramechanics Lab at Texas A&M University is to be used in this study. The small gas gun will be used to verify the accuracy of the theoretical study from which the design of the large gas gun was taken. Secondly, the small gas gun will be used to predict the accuracy with which a gas gun will be able to reproduce a given velocity under stated conditions.

¹ Final Report, dated August 1, 1968

II. DESCRIPTION OF TESTS & EQUIPMENT

A series of firings was conducted at the Terramechanics Lab at the request of Sandia Corporation. A complete series, ten shots, was run at 100 psi chamber pressure. Nine shots were run at 200 psi, and three shots at 300 psi chamber pressure. In every test but two the same projectile was used. In the two exceptions, the geometry of the instrument casing was changed to note any effect on the velocity.

To assure repeatability a firing sequence was established prior to testing. It was felt by the personnel conducting the tests that this would lessen any possible differences between tests. Referring to Figure 1, the schematic of the gas gun, the firing procedure is as follows:

1. Open valve B to pressure gage.
2. Open valve A, and fill set air line to 150 psi.
3. Open valve C to optional bleedoff.
4. Allow pressure to bleed off to a valve of 20 psi.
5. Close valve C; close valve A.
6. Open valve C to chamber airline, and fill chamber to desired pressure.
7. Close valve C.
8. Fill trigger airline to 300 psi, and close valve B.
9. Activate high pressure solenoid valve D which allows pressure into trigger assembly, thus raising the free piston firing the projectile.
10. Open valve C to optional bleedoff.
11. Deactivate high pressure solenoid valve D.
12. Open valve A & B to drain off pressure.
13. Close all valves..

FIGURE 1. SCHEMATIC OF GAS GUN AND MANIFOLD

One projectile was used for every test represented in this report.

The physical properties of this projectile are:

Nose shape	-	blunt
Total length	-	14 1/2 inches
Total weight	-	7.29 pounds
Material	-	spent uranium in steel casing
Diameter	-	1.257 inches

The gas gun itself is the main piece of equipment. The net chamber volume, i.e., total volume less volume occupied by the trigger assembly, is 0.58 cubic feet. The barrel length is 4 feet (with a diameter of 1.258 inches), but due to the necessary mounting technique the total barrel length is not used. A 1/16-inch deep groove machined around the tail portion of the projectile 1 inch from the end is matched to a 1/16 inch hole drilled in the barrel. The projectile is supported by a fine wire run through the hole into the groove. This hole was drilled 7 inches from the top of the barrel to accommodate the antenna. As the antenna was not used during these shots, the effective barrel length was only 3.5 ft. Blast deflectors threaded onto the barrel serve two purposes. They guide the projectile after it leaves the barrel, and they deflect the air blast away from the surface of the target. In this way, the only deformation of the surface will be that caused by the projectile.

The repeatability is dependent on the accuracy of the pressure gage and velocity measuring device used, and also upon the correct functions of the trigger. The pressure gage used was a bourdon type with a 4-inch diameter face, registering 0-300 psi. This gage had never been calibrated and came from a dual motor Worthington compressor. For these reasons the gage is considered accurate to only ± 3 percent, but

this is just a guess to supply a figure. The accuracy and operation of the chronograph is less than $1/2$ of 1% and was described in the Fourth Quarterly Report dated March 15, 1968.

The operation of the trigger assembly has a direct influence on the repeatability of this gas gun. For true repeatability this influence must be a constant. When set air is applied, (see Fig. I.), the double piston is seated on the bottom. When the solenoid valve is opened trigger air enters the top section, lifting the piston. This allows chamber air to escape around the bottom of the piston down the barrel. The quicker the piston raises, i.e., the higher the trigger pressure, the more efficient the firing. That is, the chamber air is applied to the projectile all at once when the trigger is raised very rapidly. If the trigger is raised slowly the chamber air leaks slowly into the barrel giving a poor firing. For these reasons the pressure used was a constant.

III. TEST DATA

The data collected during these tests are presented in three tables. Each table represents a series of constant chamber pressure tests. The average velocity and the standard deviation from the mean are given to indicate the repeatability.

TABLE I

TEST No.	MEASURED VELOCITY (fps.)	DEPTH OF PENETRATION TO NOSE (inches)
1	63.480	37.50
2	57.537*	38.50
3	63.797	34.75
4	63.351	34.50
5	62.399	34.00
6	61.132	31.50
7	62.395	31.00
8	62.921	29.75
9	61.512	29.50
10	63.347	27.75

AVERAGE VELOCITY 62.704 fps.

STANDARD DEVIATION ± 0.867 fps .

DATA COLLECTED FOR 100 psi. CHAMBER PRESSURE SERIES.

*Correct firing procedure not followed on these tests,
results not valid.

TABLE II

TEST No.	MEASURED VELOCITY (fps.)	DEPTH OF PENETRATION TO NOSE (inches)
1	86.289	31.50
2	86.813	36.25
3	85.536	36.75
4	87.078	37.50
5	82.994 [*]	40.25
6	86.133 [†]	39.50
7	85.244	39.00
8	86.170	39.00
9	86.319	38.50 [‡]

AVERAGE VELOCITY 86.198 fps.

STANDARD DEVIATION ± 0.561 fps.

DATA COLLECTED FOR 200 psi. CHAMBER SERIES.

*Correct firing procedure not followed on these tests,
results not valid

†Weight of projectile changed by adding plug weighing
40 grams.

‡These shots were made into 40 - 50 mesh silica sand
compacted by vibration, but no control was exercised,
all other shots made into commercial grade concrete
sand with no compaction or control.

TABLE III

TEST No.	MEASURED VELOCITY (fps)	DEPTH OF PENETRATION TO NOSE (inches)
1	104.710	39.50 ^ψ
2	105.430	41.50 ^ψ
3	105.496	42.50 ^ψ

AVERAGE VELOCITY 105.212 fps.

STANDARD DEVIATION ± 0.256 fps .

DATA COLLECTED FOR 300 psi CHAMBER PRESSURE SERIES.

^ψ These shots made into 40 -50 mesh silica sand, compacted by vibration, with no control.

IV. CONCLUSIONS

The necessity of a constant firing sequence is evident in that the shots which were thrown out were ones in which the correct firing sequence was not followed due to delays or mistakes.

All of the shots but two were conducted firing with a hollow instrument cavity. For two shots the cavity was plugged to see if this would have any effect on the velocity. There was no noticeable difference.

The theoretical velocities as calculated from the formula which is shown in the Final Report dated August 1, 1968 are:

100 psi → 60.67 ft/sec

200 psi → 85.80 ft/sec

300 psi → 105.08 ft/sec

The formula is:

$$V_f = \frac{2(g)}{W_p} P_o \times V_o \left[\ln \left(1 + \frac{A_p L}{V_o} \right) \right]$$

V_f = final velocity (ft/sec)

g = acceleration due to gravity (ft/sec²)

W_p = weight of projectile (lbs)

V_o = chamber volume (ft³)

P_o = chamber pressure (pcf)

A_p = cross-sectional area of projectile (ft²)

L = barrel length (ft)

These values agree very favorably with the average velocities for each test. The tendency to be higher at lower pressures may relate to the inaccuracy of pressure gages at lower pressures. The close agreement indicates the assumptions made in order to derive the gas

gun formula are correct.

The repeatability of the gas gun system is very good. With the present gages and manifold system the repeatability is very nearly ± 2 percent. With a better manifold system and pressure gage and a method to calibrate the gages a repeatability of ± 1 percent could be expected.

The repeatability and theoretical velocity are compared in Figure 2 . The spread of velocity for a given pressure is shown by the dark band. The theoretical velocity is given by the solid line.

Figure 2.