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ADB279163
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NATIONAL DEFENSE RESEARCH COMMITTEE

ARMOR AND ORDNANCE REPORT NO. A-302 (OSRD NO. 4389)

DIVISION 2

PROGRESS REPORT ON THE STUDY OF

THE EFFECT OF MUZZLE BRAKE DESIGN ON THE RECOIL OF GUNS, I

by

Frank R. Simpson and Nicol H. Smith

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Frank R. Simpson and Nicol H. Smith

Approved on NOV 14 1944
for submission to the Division Chief

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Approved on NOV 14 1944
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E. B. Wilson, Jr., Chief
Division 2
Effects of Impact and Explosion

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Preface

The work described in this report is pertinent to the project designated by the War Department Liaison Officer as OD-160.

The report for the period ending October 31, 1944 is submitted by The Franklin Institute in partial fulfillment of Contract OEMsr-1398. Because the investigation is still in progress it is understood that the conclusions expressed in it are tentative and subject to modification in the light of later evidence.

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this report and prepared it for duplication.

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PROGRESS REPORT ON THE STUDY OF THE EFFECT OF MUZZLE-BRAKE DESIGN ON THE RECOIL OF GUNS, I

Abstract

A caliber .50 ballistic pendulum for measuring the efficiency of various muzzle-brake designs is described.

The effect of (i) baffle spacing, (ii) nozzle angle, (iii) diffuser-cone angle and (iv) outlet (reversal) angle has been determined. The results show that

(i) There is not much gain in efficiency when the baffle spacing exceeds a 1-in. opening (2 calibers).

(ii) A nozzle angle of 30° with a baffle spacing of $1\frac{1}{4}$ in. is the most efficient.

(iii) A diffuser cone is not necessary to obtain greater efficiency in brake action.

(iv) A flat baffle is more efficient than a baffle having any degree of reversal angle up to 60°.

1. Object

The object of this program is twofold — (i) to arrive at an explanation of all of the factors influencing brake design and efficiency, and (ii) to establish three standardized design types giving three ranges of efficiency, so that for any given weapon any one of these design types might be applied depending upon the amount of "back blast" considered tolerable for that particular weapon.

The present report describes the results of initial experiments to determine the efficiency of several muzzle-brake designs. The investigation is still in progress and the conclusions are subject to modification in the light of later evidence.

2. Description of equipment

A ballistic pendulum that uses the caliber .50 erosion-testing gun developed for erosion-testing work being done at The Franklin Institute was constructed for the present experiments. The pendulum assembly, which is

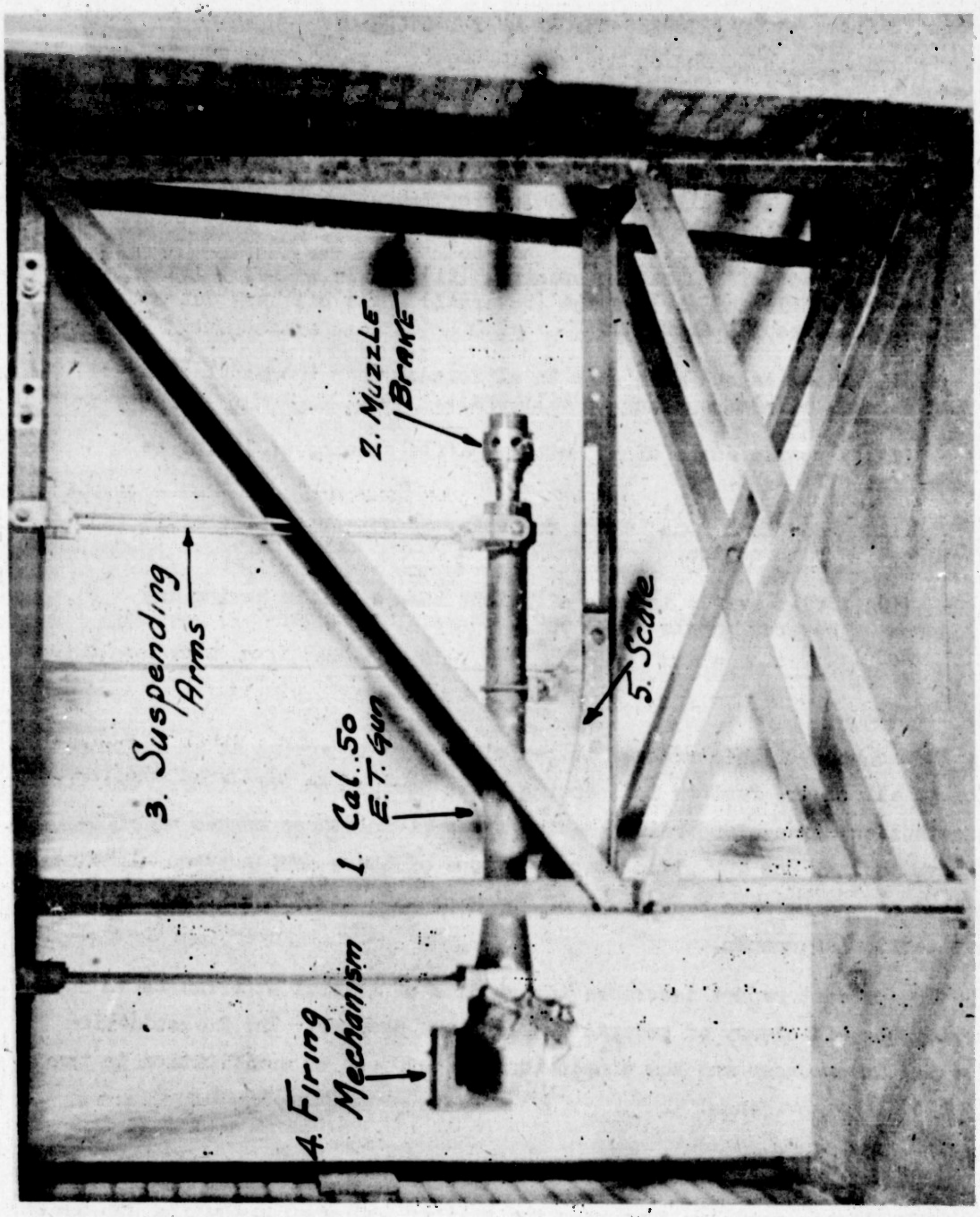


Fig. 1. Photograph showing assembly of the ballistic pendulum.

supported from a rugged "A" frame, is shown in Fig. 1. In order to obtain the minimum frictional resistance within the test mount, the gun is suspended by four pendulum arms from hardened knife-edges and seats carried on rigid trunnion arms. The total weight of the pendulum is 216.4 lb, of which 208.0 lb is the weight of gun, receiver and firing mechanism, and 8.4 lb is the weight of the muzzle brake.

(a) Gun. — This consists of a caliber .50 erosion-testing barrel mounted in its receiver. The muzzle of this barrel, which protrudes from the receiver, has been threaded to receive the muzzle-brake attachment. The gun, constants are: volume of powder chamber, 1.945 in^3; travel of projectile, 40.8 in.; land diameter, 0.490 in.; groove diameter, 0.510 in.; groove depth, 0.010 in.

(b) Muzzle-brake attachment. — The brake consists of a nozzle screwed into a holder carrying a baffle whose relationship to the nozzle can be varied by screwing it into or out of the holder.

(c) Suspending arms. — The pendulum arms were made of rigid steel rods, as light in weight as possible, and are suspended from hardened knife-edges. The length of the arms between knife-edges is 3.25 ft.

(d) The firing mechanism. — To eliminate any effect caused by the pull of the lanyard, a solenoid was mounted on the breech mechanism of the receiver and all firings were done electrically.

(e) Scale to measure angle through which pendulum is rotated. — The recoil of the gun was measured by means of a circular rack carried on the lower part of the frame. The rack is divided into equally spaced notches each of which was found to be 0.319°.

A floating pawl, attached to the gun, holds the gun at the maximum position of recoil. The difference between the position of the pawl before and after firing multiplied by 0.319° gives the angle through which the pendulum is rotated.

3. Load used in firings

(a) Composition of the powder. — FNH, M1 (85-10-5) powder was used throughout the test. This type of powder was chosen since it was found to

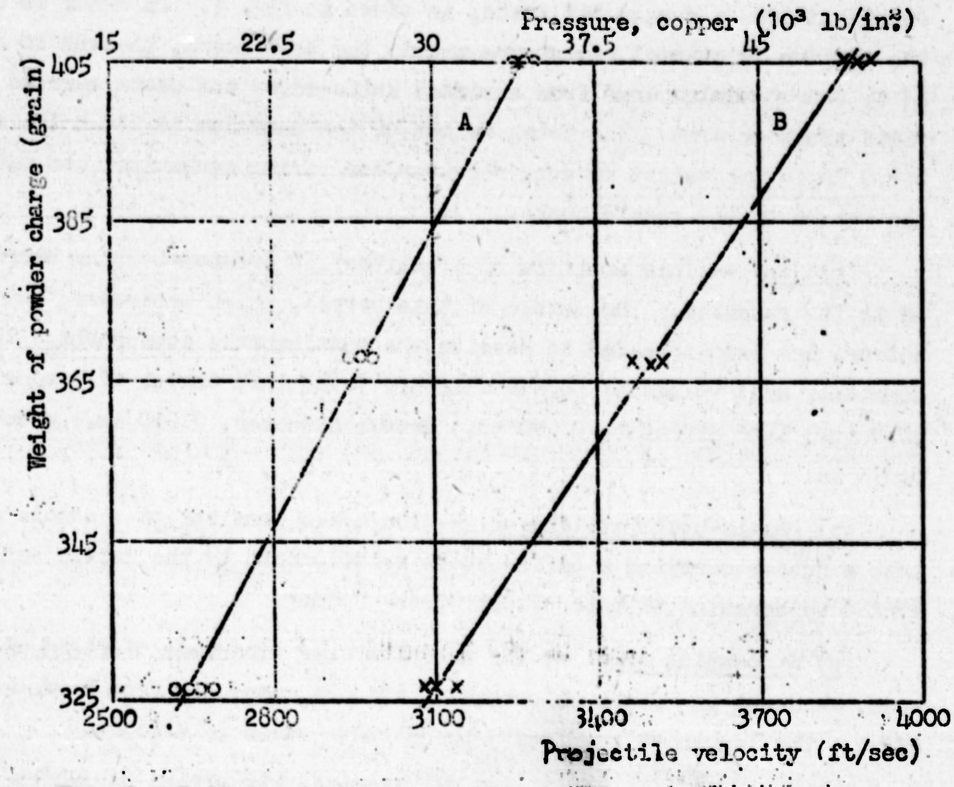


Fig. 2. Relationship among pressure, velocity, and powder charge for Ex. No. 4964 powder in caliber .50 erosion-testing gun. Curve A is for velocity versus charge, curve B is for pressure versus charge.

be only slightly erosive in the caliber .50 erosion-testing gun. Therefore, the ballistics of the gun would remain fairly uniform over a great number of firings.

The composition of FNH, M1 (85-10-5) powder Ex. No. 4964 is given in the adjacent tabulation.

Constituent	Percentage
Nitrocellulose (13.15% N)	82.62
Dinitrotoluene and dibutylphthalate	14.66
Diphenylamine	1.00
Total volatiles	0.86
Moisture	.60
Residual solvent	.26

(b) Size of charge. — The powder charges used in all the experiments with the corresponding pressures (copper) and projectile velocities are given in the adjacent tabulation.

Weight of Charge (grain)	Weight of Charge (lb)	Copper Pressure (lb/in.²)	Projectile Velocity (ft/sec)
327	0.047	30000	2640
368	.053	40000	2965
405	.058	50000	3270

The relationships among pressure, velocity, and powder charge for Ex. No. 4964 powder in the caliber .50 erosion-testing gun are plotted in Fig. 2.

(c) Grain dimensions. — The dimensions of the grains used were: length, 0.0892 in.; diameter 0.0620 in.; diameter of perforation, 0.0137 in.; mean web, 0.0241 in.

4. Variables of experiment

In this work a muzzle brake was considered to consist essentially of a nozzle, an expansion chamber, and a baffle. The expansion chamber is the space between the nozzle and the baffle. The nozzle may be straight or expanding in any degree forward. The baffle may be of such type as to take straight impact of the gases (such as a flat baffle) or it may incorporate a conical nose (diffuser cone) that tends to scoop and deflect the gases outward radially. At the same time the outer part of the baffle may be shaped to form a cylindrical reaction blade to further increase the efficiency of the brake.

Initial tests in the ballistic pendulum were conducted with a simple flat baffle suspended in changeable relation to the gun. Later tests were performed to determine the effect of

(i) Baffle spacing, that is, distance between nozzle and flat plate baffle.

(ii) Varying the nozzle angle — from 0° to 60°.

(iii) Varying the diffuser-cone angle — from 5° to 15°.

(iv) Varying the outlet (reversal) plate angle — from 60° to 0° (flat plate).

It was originally planned to measure the recoil of the muzzle brake alone, but this was found to be so great that about 40 lb additional weight on the muzzle brake was required to hold it within the range of the scale. It was therefore decided to fire the gun with the muzzle brake firmly attached at all times. In doing this the front pendulum arms were disconnected and the front pawl removed from the front scale.

In all the tests performed the recoiling parts weighed 216.4 lb and the projectile weighed 0.101 lb (710 grains). The powder charge and pressures are those given in Sec. 3(b).

5. Quantities measured or calculated

The following quantities were determined in the tests:

Symbol	Unit	Definition
A	deg	Angle through which the pendulum is rotated.
L	ft	Length of pendulum.
M	lb	Weight of projectile.
v	ft/sec	Velocity of projectile.
P	lb/in.^{2}	Powder pressure (copper).
W	lb	Weight of recoiling parts.
H	ft	Height to which the center of gravity of the pendulum swings. This is calculated from the measured value of A from the formula $H = L(1 - \cos A)$.
V	ft/sec	Velocity of free recoil. This is calculated from the value of H by the formula $V = \sqrt{2gH}$.
E	ft lb	Kinetic energy of recoil; $E = \frac{1}{2}MV^2$. This is equal to the potential energy MgH. $MgH = MgL(1 - \cos A) = WL(1 - \cos A) = WH$.
E_1	ft lb	Kinetic energy of recoil without brake.
E_2	ft lb	Kinetic energy of recoil with brake.
R	percent	Percentage reduction in kinetic energy of recoil, or efficiency of the brake. This is calculated from the equation $R = \frac{E_1 - E_2}{E_1} \times 100$.

As a basis for comparison with tests in which the brake components were varied, recoil without the brake was determined. The gun was fired with the brake removed from the muzzle, but strapped to the gun so that the weight of the recoiling parts (with and without the brake acting) remained constant throughout the tests. The observed angles of swing A and the calculated values of H, V, and E_1 are given in Table I. The values are the same for all the designs tested. The values given here for E_1 are those used later in the calculation of efficiencies.

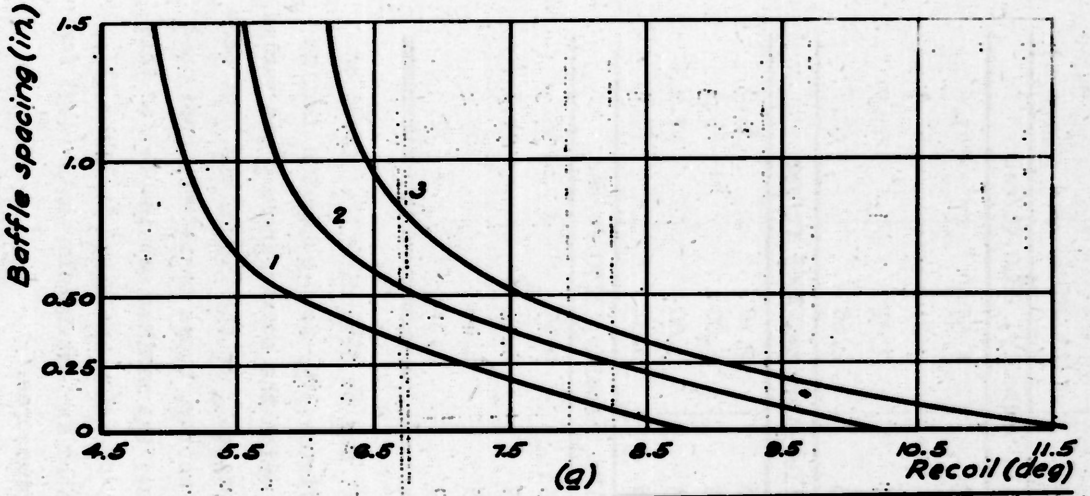
Table I. Recoil without muzzle brake acting.

Pressure, Copper (lb/in.²)	Projectile Velocity (ft/sec)	A (deg)	H (ft)	V (ft/sec)	E_1 (ft lb)
30000	2640	8.78	0.0381	1.57	8.26
40000	2965	10.23	.0517	1.82	11.20
50000	3270	11.58	.0661	2.06	14.31

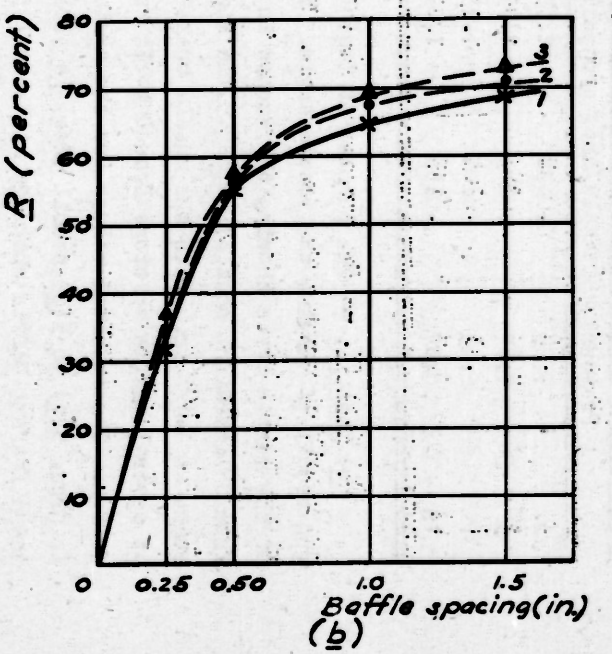
6. Results

(a) Test I. — The purpose of Test I was to determine the effect of baffle spacing on gun recoil. The baffle spacing A [Fig. 3(a)] was varied from $\frac{1}{4}$ to $1\frac{1}{2}$ in., the maximum obtainable. The schematic diagram [Fig. 3(a)] shows the effect of this variation on the expansion chamber.

The values of angle of swing A were observed at pressures of 30000, 40000, and 50000 lb/in.² and the kinetic energy of recoil and the efficiency were calculated. [In the calculation of the latter, values of E_1 given in Table I were used.] The results of these observations and calculations are recorded in Table II and Figs. 4(a) and 4(b). The curves of Fig. 4(a) show the relationship between baffle spacing and gun recoil in degrees, while the curves of Fig. 4(b) show the relationship between the reduction in kinetic energy of recoil and baffle spacing. A comparison of these figures shows that there is not much gain in efficiency when the baffle spacing exceeds a 1-in. (2-caliber) opening.



(a)



(b)

Curve No.	Pressure (lb/in.²)	Projectile velocity (ft/sec)
1	30,000	2640
2	40,000	2965
3	50,000	3270

(a) Baffle spacing versus recoil in degrees

(b) Baffle spacing versus percentage reduction in kinetic energy of recoil

Fig. 4. Test I. Effect of baffle spacing on recoil.

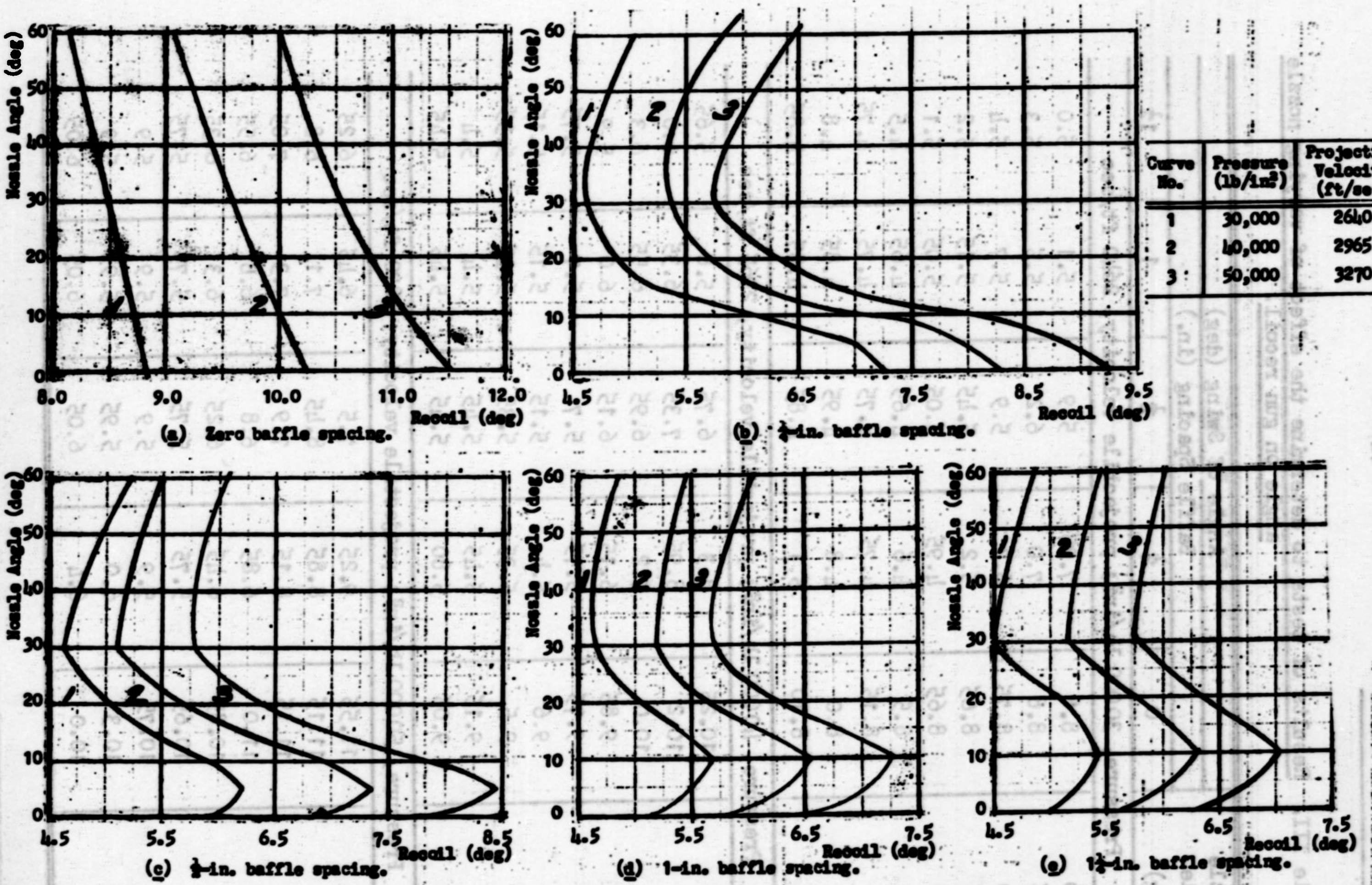
Table II. Results of varying baffle spacing from ¼ to 1½ in.

Baffle Spacing (in.)	A (deg)	H (ft)	V (ft/sec)	E_2 (ft lb)	$R = \frac{E_1 - E_2}{E_1}$ (percent)
Pressure, 30000 lb/in.²; projectile velocity, 2640 ft/sec					
¼	7.27	0.0261	1.30	5.65	31.6
½	5.88	.0171	1.05	3.71	55.1
1	5.12	.0130	0.92	2.82	64.9
1½	4.90	.0119	0.88	2.60	68.5
Pressure, 40000 lb/in.²; projectile velocity, 2965 ft/sec					
¼	8.30	0.0341	1.48	7.39	34.0
½	6.77	.0231	1.22	5.00	55.3
1	5.80	.0166	1.03	3.60	67.9
1½	5.55	.0153	0.99	3.32	70.4
Pressure, 50000 lb/in.²; projectile velocity, 3270 ft/sec					
¼	9.25	0.0422	1.65	9.15	36.0
½	7.57	.0283	1.35	6.12	57.2
1	6.43	.0205	1.15	4.44	69.0
1½	6.07	.0185	1.09	4.01	72.0

(b) Test II. -- The purpose of Test II was to determine the effect on gun recoil of varying the nozzle angle. Figure 3(b) is a schematic diagram of the muzzle brake showing the manner in which the nozzle angle C was varied from 0° (straight nozzle) to 60°. The distance B on the figure was kept constant at 1-1/8 in. With the muzzle brake acting, these tests were conducted at several baffle spacings from 0 to 1¼ in., the maximum obtainable for this design. The observed values for the angle of swing are given in Table III. In Figs. 5(a) to 5(e) recoil (deg) is plotted against nozzle angle (deg) for the different baffle spacings at several pressures.

The results show that the least recoil is obtained with a 30° nozzle angle and a baffle spacing of 1¼ in.

The efficiency, or percentage reduction in the kinetic energy of recoil, for the best baffle spacing of 1¼ in. is tabulated in Table IV for varying nozzle angles at several pressures. Plots of these values are given in Fig. 6. The data show that a nozzle angle of 30° is the most efficient.



Curve No.	Pressure (lb/in^2)	Projectile Velocity (ft/sec)
1	30,000	2640
2	40,000	2965
3	50,000	3270

(a) Zero baffle spacing.
(b) $\frac{1}{4}$-in. baffle spacing.
(c) $\frac{1}{2}$-in. baffle spacing.
(d) 1-in. baffle spacing.
(e) $1\frac{1}{2}$-in. baffle spacing.

Fig. 5. Test II. Effect of nozzle angle on recoil. See Fig. 3(b) for details of muzzle brake.

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Table III. Results of tests to determine the effect of varying nozzle angle on gun recoil.

Nozzle Angle (deg)	Angle of Swing (deg)				
	Baffle Spacing (in.)				
	0	¼	½	1	1¼
Pressure, 30000 lb/in²; projectile velocity, 2640 ft/sec					
0	8.8	7.25	5.9	5.1	5.0
5	8.8	7.0	6.2	5.5	5.3
10	8.75	6.2	5.9	5.7	5.4
15	8.65	5.2	5.45	5.15	5.2
20	8.65	4.95	5.05	5.05	5.1
30	8.5	4.6	4.65	4.65	4.5
40	8.15	4.75	4.75	4.75	4.75
50	8.0	4.8	4.95	4.85	4.8
60	8.10	5.1	4.85	4.85	4.85
Pressure, 40000 lb/in²; projectile velocity, 2965 ft/sec					
0	10.25	8.3	6.75	5.8	5.65
5	10.2	8.95	7.35	6.35	6.0
10	10.0	7.2	6.95	6.55	6.3
15	9.85	6.15	6.15	6.0	5.9
20	9.75	5.75	5.7	5.7	5.75
30	9.6	5.4	5.15	5.15	5.15
40	9.5	5.35	5.35	5.35	5.35
50	9.15	5.45	5.45	5.4	5.4
60	9.05	5.80	5.45	5.45	5.45
Pressure, 50000 lb/in²; projectile velocity, 3270 ft/sec					
0	11.55	9.25	7.5	6.45	6.25
5	11.15	8.85	8.45	7.1	6.8
10	11.15	8.15	7.9	7.3	7.05
15	11.0	6.85	6.8	6.8	6.55
20	10.85	6.45	6.25	6.3	6.35
30	10.65	5.75	5.75	5.75	5.75
40	10.75	5.9	5.9	5.9	5.9
50	10.3	6.0	5.95	5.95	5.9
60	10.0	6.4	6.05	6.05	6.05

Table IV. Reduction in kinetic energy of recoil, baffle spacing $1\frac{1}{4}$ in.

Nozzle Angle (deg)	A (deg)	H (ft)	V (ft/sec)	E_2 (ft lb)	$R = \frac{E_1 - E_2}{E_1}$ (percent)
Pressure, 30000 lb/in²; projectile velocity, 2640 ft/sec; E_1, 8.26 ft lb, no brake action					
0	5.0	0.0124	0.89	2.68	67.5
5	5.3	.0139	.95	3.02	63.5
10	5.4	.0144	.96	3.12	62.2
15	5.2	.0134	.93	2.90	64.9
20	5.1	.0129	.91	2.80	66.1
30	4.5	.0100	.80	2.16	73.8
40	4.75	.0112	.85	2.43	70.6
50	4.8	.0114	.86	2.47	70.0
60	4.85	.0116	.86	2.51	69.6
Pressure, 40000 lb/in²; projectile velocity, 2965 ft/sec; E_1, 11.20 ft lb, no brake action					
0	5.65	0.0169	1.04	3.66	67.3
5	6.0	.0173	1.05	3.75	66.5
10	6.3	.0196	1.12	4.25	62.0
15	5.9	.0172	1.05	3.72	66.9
20	5.75	.0163	1.02	3.54	68.4
30	5.15	.0131	0.92	2.84	74.7
40	5.35	.0142	.96	3.08	72.5
50	5.4	.0144	.96	3.12	72.1
60	5.45	.0147	.97	3.18	71.6
Pressure, 50000 lb/in²; projectile velocity, 3270 ft/sec; E_1, 14.31 ft lb, no brake action					
0	6.25	0.0193	1.11	4.08	71.5
5	6.8	.0228	1.21	4.94	65.4
10	7.05	.0246	1.26	5.32	62.8
15	6.55	.0212	1.17	4.59	67.9
20	6.35	.0200	1.13	4.33	69.8
30	5.75	.0164	1.03	3.55	75.2
40	5.9	.0172	1.05	3.72	73.9
50	5.9	.0172	1.05	3.72	73.9
60	6.05	.0181	1.08	3.92	72.6

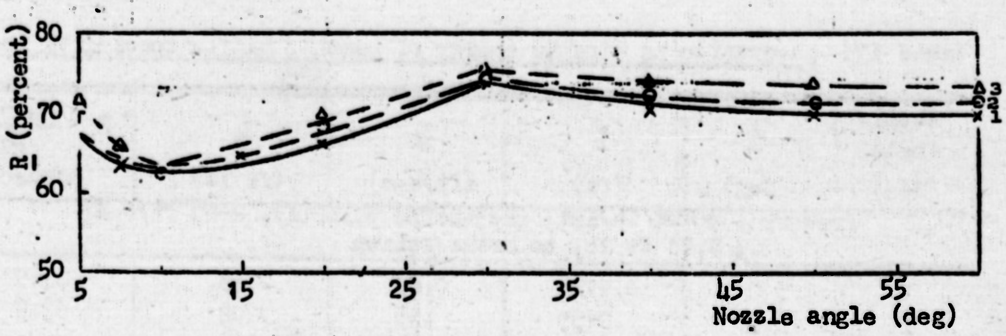


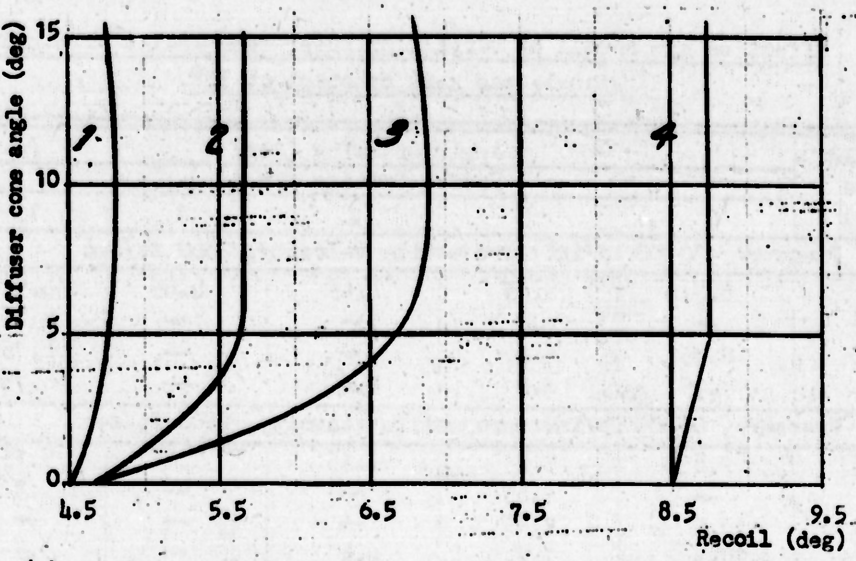
Fig. 6. Test II. Nozzle angle versus percentage reduction in kinetic energy of recoil with $1\frac{1}{4}$-in. flat baffle spacing. Curve 1 for 30000 lb/in² pressure, 2640 ft/sec projectile velocity; curve 2 for 40000 lb/in² and 2965 ft/sec; curve 3 for 50000 lb/in² and 3270 ft/sec.

(c) Test III. — The purpose of Test III was to determine the effect on gun recoil of varying the diffuser-cone angle with nozzle angle of 30°. The drawing of Fig. 3(c) shows the manner in which this angle D was varied from 0° (flat plate) to 15°. The observed angle of swing is given in Table V for several baffle spacings from 0 to $1\frac{1}{4}$ in., the maximum obtainable, and for pressures of 30000, 40000, and 50000 lb/in² The results show that the least recoil is obtained with a baffle spacing of $1\frac{1}{4}$ in. and no diffuser cone.

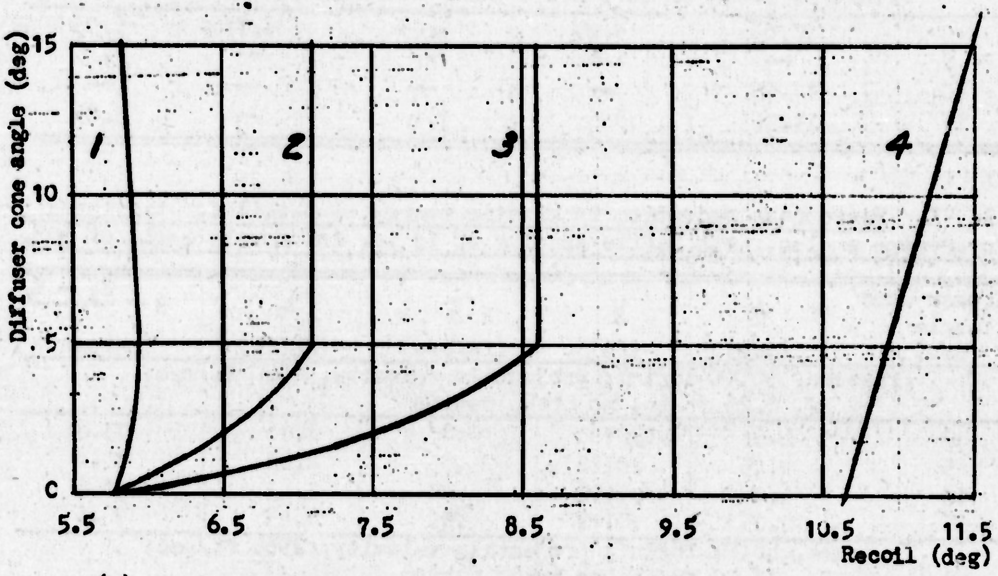
These data are plotted in Figs. 7(a) and 7(b) in which angle of recoil (deg) versus diffuser-cone angle (deg) is given for pressures of 30000 and 50000 lb/in² and various baffle spacings.

The efficiency, or percentage reduction in kinetic energy of recoil, was calculated for the best baffle spacing of $1\frac{1}{4}$ in. for several diffuser-cone angles. These values are tabulated in Table VI, and plotted in Fig. 8. The results indicate that a diffuser cone is not necessary to obtain the greatest efficiency in brake action.

(d) Test IV. — The purpose of Test IV was to determine the effect on gun recoil of varying the reflecting-plate (baffle) angle. Figure 3(d) is a schematic diagram of the manner in which the reflecting-plate angle E was varied from 60° to 0° (flat baffle).



(a) Diffuser cone angle versus r·coil at pressure of 30,000 lb/in.^{2}



(b) Diffuser cone angle versus recoil at pressure of 50,000 lb/in.^{2}

Curve No.	1	2	3	4
Baffle spacing (in.)	1¼	½	¼	0

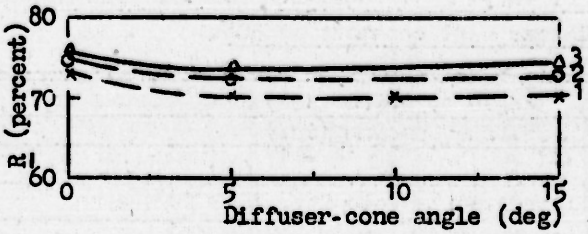
Fig. 7. Test III. Effect of diffuser cone angle on recoil at several baffle spacings. See Fig. 3(c) for details of muzzle brake.

Table V. Effect on gun recoil of varying diffuser-cone angle. The nozzle angle was kept constant at 30°.

Nozzle Angle (deg)	Angle of Swing (deg)				
	Baffle Spacing (in.)				
	0	1/4	1/2	1	1 1/4
Pressure, 30000 lb/in²; projectile velocity, 2640 ft/sec					
0	8.5	4.65	4.65	4.65	4.5
5	—	6.7	—	—	4.75
10	8.75	6.9	—	—	4.75
15	8.75	6.8	5.65	—	4.75
Pressure, 40000 lb/in²; projectile velocity, 2965 ft/sec					
0	9.6	5.4	5.15	5.15	5.15
5	—	7.65	—	—	5.3
10	10.0	7.55	—	—	—
15	10.3	7.7	6.4	—	5.3
Pressure, 50000 lb/in²; projectile velocity, 3270 ft/sec					
0	10.65	5.75	5.75	5.75	5.75
5	—	8.6	—	—	5.95
10	11.05	—	—	—	—
15	11.55	8.6	7.1	—	5.85

Table VI. Percentage reduction in kinetic energy of recoil for varying diffuser-cone angles, with baffle spacing of 1 1/4 in. and nozzle angle of 30°.

Diffuser-Cone Angle (deg)	A (deg)	H (ft)	V (ft/sec)	E_2 (ft lb)	$R = \frac{E_1 - E_2}{E_1}$ (percent)
Pressure, 30000 lb/in²; projectile velocity, 2640 ft/sec; E_1, 8.26 ft lb, no brake action					
0	4.5	0.0100	0.80	2.16	73.8
5	4.75	.0112	.85	2.43	70.6
10	4.75	.0112	.85	2.43	70.6
15	4.75	.0112	.85	2.43	70.6
Pressure, 40000 lb/in²; projectile velocity, 2965 ft/sec; E_1, 11.20 ft lb, no brake action					
0	5.15	0.0131	0.92	2.84	74.6
5	5.3	.0139	.95	3.02	73.0
10	—	—	—	—	—
15	5.3	.0139	.95	3.02	73.0
Pressure, 50000 lb/in²; projectile velocity, 3270 ft/sec; E_1, 14.31 ft lb, no brake action					
0	5.75	0.0163	1.02	3.54	75.3
5	5.95	.0175	1.06	3.79	73.5
10	—	—	—	—	—
15	5.85	.0169	1.04	3.66	74.4



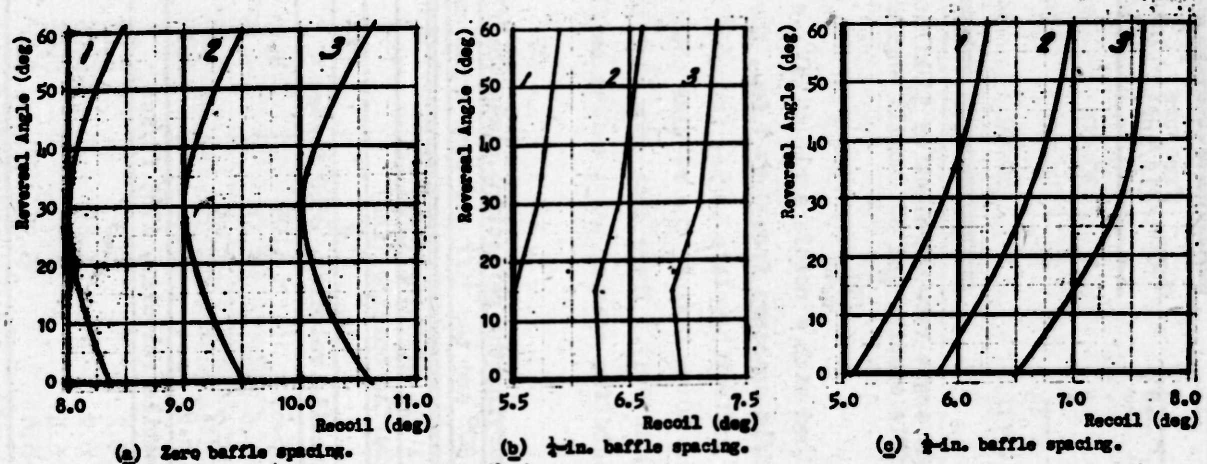
Curve	Pressure (lb/in^2)	Projectile Velocity (ft/sec)
1	30000	2640
2	40000	2965
3	50000	3270

Fig. 8. Test III. Diffuser-cone angle versus reduction in kinetic energy of recoil with 1¼-in. flat baffle spacing and 30° nozzle angle.

The angle of swing A was determined with a nozzle angle of 30°, a diffuser-cone angle of 15°, and with baffle spacings from 0 to 1 in., the maximum obtainable with this design, for reflecting-plate angles from 60° to 0° and for pressures of 30000, 40000, and 50000 lb/in^2 The results obtained are given in Table VII and Figs. 9(a) to 9(d). These data show that the least recoil is obtained with a 1-in. baffle spacing using a flat baffle, that is, zero reflecting angle.

Table VII. Effect on gun recoil of varying the reflecting-plate (baffle) angle. The nozzle angle was 30° and the diffuser-cone angle was 15°.

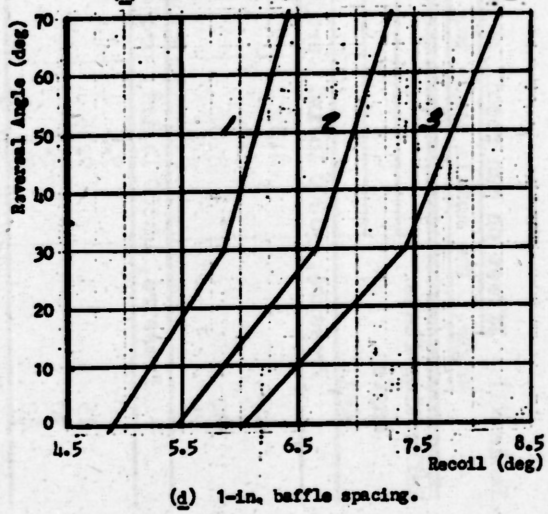
Reflecting-Plate Angle (deg)	Angle of Swing (deg) Baffle Spacing (in.)			
	0	¼	½	1
Pressure, 30000 lb/in^2; projectile velocity, 2640 ft/sec				
0	8.35	5.5	5.05	4.9
15	8.5	5.5	5.45	5.35
30	8.0	5.7	5.95	5.85
60	8.45	5.9	6.25	6.25
Pressure, 40000 lb/in^2; projectile velocity, 2965 ft/sec				
0	9.5	6.2	5.8	5.45
15	9.35	6.2	6.25	6.05
30	9.0	6.4	6.7	6.65
60	9.5	6.6	6.95	7.1
Pressure, 50000 lb/in^2; projectile velocity, 3270 ft/sec				
0	10.6	6.95	6.5	6.0
15	10.2	6.85	7.05	6.75
30	10.0	7.1	7.4	7.4
60	10.6	7.25	7.6	8.0



(a) Zero baffle spacing.

(b) ¼-in. baffle spacing.

(c) ½-in. baffle spacing.



(d) 1-in. baffle spacing.

Curve No.	Pressure (lb/in²)	Projectile Velocity (ft/sec)
1	30,000	2640
2	40,000	2965
3	50,000	3270

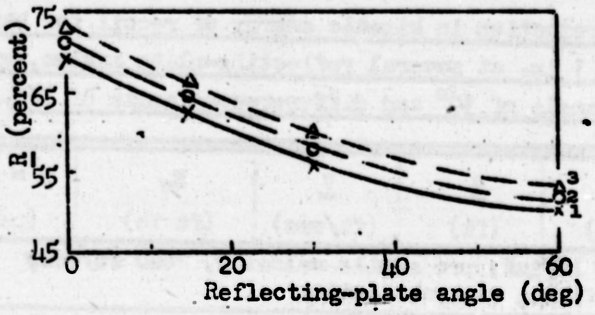
Fig. 9. Test IV. Effect of reversal angle on recoil. See Fig. 3(d) for details of muzzle brake.

The calculated values for the percentage reduction in the kinetic energy of recoil for a baffle spacing of 1 in. with varying reflecting-plate angles are given in Table VIII. The results indicate that the reflecting-plate angle used in this design decreased the efficiency of the muzzle brake; that a flat baffle is more efficient.

Table VIII. Percentage reduction in kinetic energy of recoil for baffle spacing of 1 in. at several reflecting-plate angles, with nozzle angle of 30° and diffuser-cone angle of 15°.

Reflecting-Plate Angle (deg)	A (deg)	H (ft)	V (ft/sec)	E_2 (ft lb)	$R = \frac{E_1 - E_2}{E_1}$ (percent)
Pressure, 30 000 lb/in²; projectile velocity, 2640 ft/sec; E_1, 8.26 ft lb, no brake action					
0	4.9	0.0119	0.88	2.60	69.5
15	5.35	.0142	0.96	3.08	62.7
30	5.85	.0169	1.04	3.66	55.6
60	6.25	.0193	1.11	4.08	50.7
Pressure, 40 000 lb/in²; projectile velocity, 2965 ft/sec E_1, 11.20 ft lb, no brake action					
0	5.45	0.0147	0.97	3.18	71.6
15	6.05	.0181	1.08	3.92	65.0
30	6.65	.0218	1.19	4.73	57.8
60	7.1	.0249	1.27	5.40	51.8
Pressure, 50 000 lb/in²; projectile velocity, 3270 ft/sec E_1, 14.31 ft lb, no brake action					
0	6.0	0.0178	1.10	3.86	73.0
15	6.75	.0225	1.20	4.87	65.9
30	7.4	.0270	1.32	5.85	59.0
60	8.0	.0316	1.42	6.85	52.1

In Fig. 10 the reflecting-plate angle versus reduction in kinetic energy of recoil is plotted for 1-in. baffle spacing, 30° nozzle angle and 15° diffuser-cone angle.



Curve	Pressure (lb/in^2)	Projectile Velocity (ft/sec)
1	30000	2640
2	40000	2965
3	50000	3270

Fig. 10. Test IV. Reflecting-plate angle (reversal angle) versus reduction in kinetic energy of recoil with 1-in. baffle spacing, 30° nozzle angle, and 15° diffuser-cone angle.

7. Conclusion

These preliminary muzzle-brake design tests in the caliber .50 ballistic pendulum show

(a) There is not much gain in efficiency when the baffle spacing exceeds a 1-in. opening (2 calibers).

(b) A nozzle angle of 30° with a baffle spacing of $1\frac{1}{4}$ in. is the most efficient.

(c) A diffuser cone is not necessary to obtain greater efficiency in brake action.

(d) A flat baffle is more efficient than a baffle having any value of reversal angle up to 60°.

Further tests now in progress will determine the effect of the following design variables on the efficiency of the brake;

(i) Outlet diameter of the muzzle-brake baffle,

(ii) Nozzle length,

(iii) Multiple flat baffles,

(iv) Jet reaction, using baffles of reaction blade design.

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TITLE: Progress Report on the Study of the Effect of Muzzle Brake Design on the Recoil of Guns, I

AUTHOR(S): Simpson, Frank R.; Smith, Nicol H.

ORIGINATING AGENCY: Franklin Institute, Philadelphia, Pa.

PUBLISHED BY: Office of Scientific Research and Development, NDRC, Div 2

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ATI- 24910

REVISION (None)

ORIG. AGENCY NO. (None)

PUBLISHING AGENCY NO. [redacted]-4389

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
Nov '44	[redacted]	U.S.	Eng.	24	photo, tables, diagrs, graphs

ABSTRACT:

Tests were conducted to determine the effect of baffle spacing of muzzle brakes on gun recoil, the effect on gun recoil of varying the nozzle angle, the diffuser-cone angle with nozzle angle of 30°, and the reflecting plate angle. A ballistic pendulum that uses the caliber .50 erosion-testing gun was used for the testing, with FNH, M1 (85-10-5) powder being used throughout the test. It was found that there is not much gain in efficiency when the baffle spacing exceeds a 1-in. opening (2 calibers), a nozzle angle of 30° with a baffle spacing of 1-1/4 in. is the most efficient, a diffuser cone is not necessary to obtain greater efficiency in brake action, and a flat baffle is more efficient than a baffle having any degree of reversal angle up to 60°.

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ATI SHEET NO.: R-22-2-7

SUBJECT HEADINGS: Guns - Muzzle brakes - Design (47457.5)

Air Documents Division, Intelligence Department
Air Materiel Command

AIR TECHNICAL INDEX

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Reclassified per Auth OSRD List # 33
dtd. Sept 9-27, 1946 by [illegible]
on 8 Aug 49