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NPG REPORT NO. 804

U. S. NAVAL PROVING GROUND  
DAHLGREN, VIRGINIA

First Partial Report  
on  
Foundational Scientific Investigations

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First Partial Report  
on  
Vibrations of Gun Barrels

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Vibrations of Gun Barrels

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PART A

SYNOPSIS

1. This is the first partial report on a study of the action of a gun barrel during the passage of the projectile through it's bore. It covers the exploratory phase of two research problems:
  - a. Vibrations of gun barrels.
  - b. Vibratory flight and engraving of projectile.
2. Firings have been conducted with a 3"/70 gun type G Mod 1 No. 24484. This gun had 969 E.S.R. at the end of the tests and the results are thus representative of a considerably worn gun.
3. The investigation to date has yielded the following information of interest.
  - a. A wave traveling between the slide adapter and the muzzle constitute the main disturbance during the passage of the projectile.
  - b. This disturbance increases in amplitude as the projectile approaches the muzzle. Axial velocities range between 3500 and 7000 ft./sec.
  - c. The entire configuration of pre-ejection vibrations is repeated in 4 milli-second intervals after ejection.

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Vibrations of Gun Barrels

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Vibrations of Gun Barrels  
-----PART BINTRODUCTION

## 1. AUTHORITY:

The research reported herein was authorized by reference (a).

## 2. REFERENCES:

a. F12a-EF:Lms L1-1(51) Serial 05436 of 20 July 1950.

b. NPG Report No. 653 of 29 September 1950.

## 3. BACKGROUND:

a. The problem of "jump" and vibratory flight has been of considerable interest in connection with the firing of Naval guns of all calibers.

b. Reference (b) reported on preliminary tests conducted with a 5"/38 gun. This work was discontinued before definite quantitative results were obtained. However, the results indicated that deviating trajectories were of composite origin. It was also apparent that a change in phase of the high frequency vibrations of the gun muzzle, if occurring at the instant of emergence of the projectile, could initiate vibratory flight and engraving of the body of the projectile.

c. Since erratic ranges and engraved projectiles are frequent occurrences with the 3"/70 caliber guns a project was undertaken to study the reactions of a 3"/70 gun to the passage of the projectile through its bore with particular interest in the action of the muzzle section at the instant of emergence of projectile.

d. The optical method previously developed and used in connection with 5"/38 tests was not entirely adequate. It was found that the highest film speed the available camera was capable of, 4000 frames per second, was not sufficiently high to arrest the violent motions of the muzzle section of this gun. Also, the gun used for this study was considerably worn, about 900 E.S.R., and added to the difficulties by the emergence of smoke preceding the projectile and obscuring the muzzle error at the most crucial time.

## Vibrations of Gun Barrels

e. To supplement the optical data, the varying strains in the gun due to the vibrations were measured. The strains were measured at isolated, one inch long sections. Two gages at each section were connected to add the effect of bending and to compensate for the strains due to the dilatations of the gun. With two sets at 90°, motions of the muzzle section, other than vertical and horizontal, may be determined.

f. The strains, although not directly convertible into angular changes corresponding to those measured optically, show excellent correlation between directional changes in angles of the respective points and supplement the optical readings where the latter are obscured.

g. The next phase, which will be conducted with a newer gun, will include a study of the effect of the 5"/38 slide adapter for the 3"/70 gun and possible remedies.

#### 4. OBJECT OF TEST:

a. The object of this investigation is the study of the nature of the actions of a gun barrel during the passage of the projectile through it's bore and their effect on the flight of the projectile and it's trajectory.

#### 5. PERIOD OF TEST:

a. The phase of the investigation reported herein was carried out during the period of December 1950 to May 1951.

Vibrations of Gun Barrels  
-----PART CDETAILS OF TEST

## 6. DESCRIPTION OF ITEM UNDER TEST:

This investigation was conducted on 3"/70 type G, Mod 1, Gun No. 24484, mounted in a 5" slide Mk 21, Mod 8, 5" mount Mk 24, Mod 9, and 5" carriage Mk 25, Mod 30. The rammer mechanism and counterweight were removed from the gun. The barrel had an E.S.R. of 969 at the end of the tests.

## 7. DESCRIPTION OF TEST EQUIPMENT AND PROCEDURE:

a. The essential elements of the optical system by which the vibrations of the barrel were amplified and recorded were mirrors affixed to the gun barrel and slide, a high speed moving picture camera, and a grid. The camera and grid were mounted on a wall approximately 100 feet directly behind the gun in such a way that the camera photographed sections of the grid by reflection from the mirrors. Any bending of the barrel or change in gun elevation produced an angular change of the mirrors in the vertical plane, resulting in different sections of the grid appearing in the mirrors and being photographed. The optical magnification of the system was such that a deflection of one inch over the grid represented a change in mirror angle of approximately 1.25 minute.

b. One mirror, about 1 by 1.5 inch, was mounted on the barrel at a distance of 8 inches from the gun muzzle and a second mirror on the slide above the trunnion. The method of mounting the mirrors will be seen in Figures 1 and 2, Appendix (A).

c. The grid consisted of a plate on which were painted horizontal lines, alternately black and white, with each line individually marked for identification in the mirror images of the grid.

d. A 35mm Fastax camera with a maximum film speed of 4000 frames per second and equipped with a 17 inch focal length lens was used. The arrangement of camera and grid for recording mirror deflections may be seen in Figure 3, Appendix (A).

e. A reference line from which to measure grid deflections was provided on each film frame by placing a white plate bearing a 0.5 inch wide black horizontal line in the camera field of view approximately 100 feet in front of the gun.

Vibrations of Gun Barrels  
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f. A calibration of the optical system is obtained from these considerations: Bending of the barrel in the vertical plane will cause a rotation of the mirrors. If a mirror is rotated through  $\theta$  radians, the beam of light from the grid reflected by the mirror to the camera is rotated  $2\theta$  radians.

g. Writing the distance from camera and grid to mirror  $r$  and the deflection of the beam over the grid  $d$ , then  $2\theta = d/r$  and  $\theta = d/2r$  radians or  $d/.00058r$  minutes. The calibrations for the mirrors as mounted on the gun were:

Mirror 8" from muzzle	1.28 min./in.
Mirror on the slide	1.50 min./in.

h. The strains developed in the barrel due to its vibrations were recorded by means of wire strain gages. The gages were installed axially in pairs  $180^\circ$  to each other on the barrel and wired into a bridge circuit in such manner that they responded to axial strains in the barrel and compensated for strains due to dilations of the tube. These gages measured axial strains in micro. inches/inch on the barrel surface at isolated one inch barrel sections. Pairs of gages were mounted at distance of 10, 22, 34, 46, and 58 inches from the gun muzzle to record vertical vibrations and at 10 inches to record horizontal vibrations.

i. Position of the projectile during its passage through the bore was determined from records of beginning of recoil and strain gages. Gages were mounted circumferentially on the barrel 1.6, 25.6, 49.6, and 91.6 inches from the muzzle to indicate passage of the rotating band of the projectile.

j. A Canadian type skyscreen, modified with respect to both the optical and electronic systems, was used to determine the time in which the projectile traveled a given distance, usually 9 feet, from the gun muzzle and the data correlated with that of projectile time-displacement in the barrel recorded by strain gages. A projectile travel curve from these sources is enclosed as Figure 15, Appendix (B).

## Vibrations of Gun Barrels

## 8. RESULTS AND DISCUSSION:

a. Curves of the vibration of the section of the barrel 8 inches from the muzzle of a 3"/70 gun during passage of the projectile through the bore with respect to time are included as Figures 5-7, Appendix (B). These curves show the angular change of this section of the barrel as measured by the optical method. Included on each plot is the curve showing the corresponding angular changes of the gun mount as measured by the mirror mounted on the slide directly over the trunnions. Dashed sections of these curves at the 8" position were drawn by comparison with corresponding records of barrel strains at 10 inches from the muzzle.

b. Curves of the vibrations of sections of the barrel as indicated by measurements of axial strains developed in the barrel are enclosed as Figures 8-11, Appendix (B). In Figure 8 the vibrations in the vertical plane at five points along the barrel are shown and in Figure 9-11 the vibrations at four points in the vertical plane and at one point in the horizontal plane.

c. A reproduction of an original oscillograph record of one round showing the strains developed in the vertical plane at four points on the barrel is enclosed as Figure 4, Appendix (A).

d. By plotting the strains developed in the vertical plane versus those in the horizontal at 10 inches from the muzzle, the curves of Figures 13-15, Appendix (B), were obtained. These curves show the gyrations of this section of the barrel. The time interval between consecutive points on the plots is .05 milliseconds and the arrow heads on the curves indicate increasing time. Dashed sections of the curves represent interpolation of the curves over the time interval during which the projectile passes the strain gages. There is evidence of interference due to strains other than bending at this point. This is assumed to be the result of unsymmetrical strain due to a tendency of the projectile to cant or the equivalent effect due to the wave propagation in the gun in relation to the projectile and/or unequal wear of band or gun.

e. A study of the progression of the wave configuration along the barrel as recorded by the strain gages was made. An examination of Figure 4, Appendix (A), a reproduction of an original record for four pairs of gages, indicates this progression from one set of gages to the next.

Vibrations of Gun Barrels  
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f. The progression of vibrations of particular interest have been plotted in Figure 16, Appendix (B). Lettered points on this figure correspond to those of Figure 4. The vibrations travel with velocities ranging from 3500 to 7000 ft./sec., the higher frequency, low amplitude vibrations, such as E, traveling at the higher velocities.

g. The upward deflection A and downward deflection B appear to be the main disturbances. Extrapolation backward shows that B originates about the time that the projectile emerges from the restraining action of the barrel adapter.

h. Also, the point of intersection of extrapolations from the main group of vibrations and those from it's first repetition are in this region. The second repetition is not sufficiently sharp to permit accurate plotting, but it occurs 4.12 milliseconds after the first repetition, which is only 0.5% less than the time interval between the initial group and the first repetition.

i. Points C are present on all rounds and appear to be associated with ejection of the rotating band.

j. The film rate of 4000 frames/second of the camera was not sufficiently high to arrest the violent motions of the muzzle section of this gun. On Round B, Figure 6, it was not possible to interpret the film record for the last millisecond preceding ejection. The amplitude of vibrations in this region will be seen to have been very large as shown by strain records for this round, Figure 9. It is also evident from an inspection of Figures 5, 6, and 7 that a higher frame rate is needed to obtain data at smaller intervals of time to adequately determine the curves.

k. A further difficulty in reading the film record was presented by the emergence of smoke and flash preceding the projectile which obscured the muzzle mirror and grid. This was no doubt a result of the worn condition of the gun.

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Vibrations of Gun Barrels

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PART D

CONCLUSIONS

9. On the basis of the results obtained with the 3"/70 gun No. 24484 it is concluded that the propagation of a wave of high velocity and increasing amplitude through the gun barrel during the travel of the projectile and the changes of phase frequently occurring as the projectile passes through the muzzle plane are contributory to vibratory flight and deviations of trajectory.

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Vibrations of Gun Barrels

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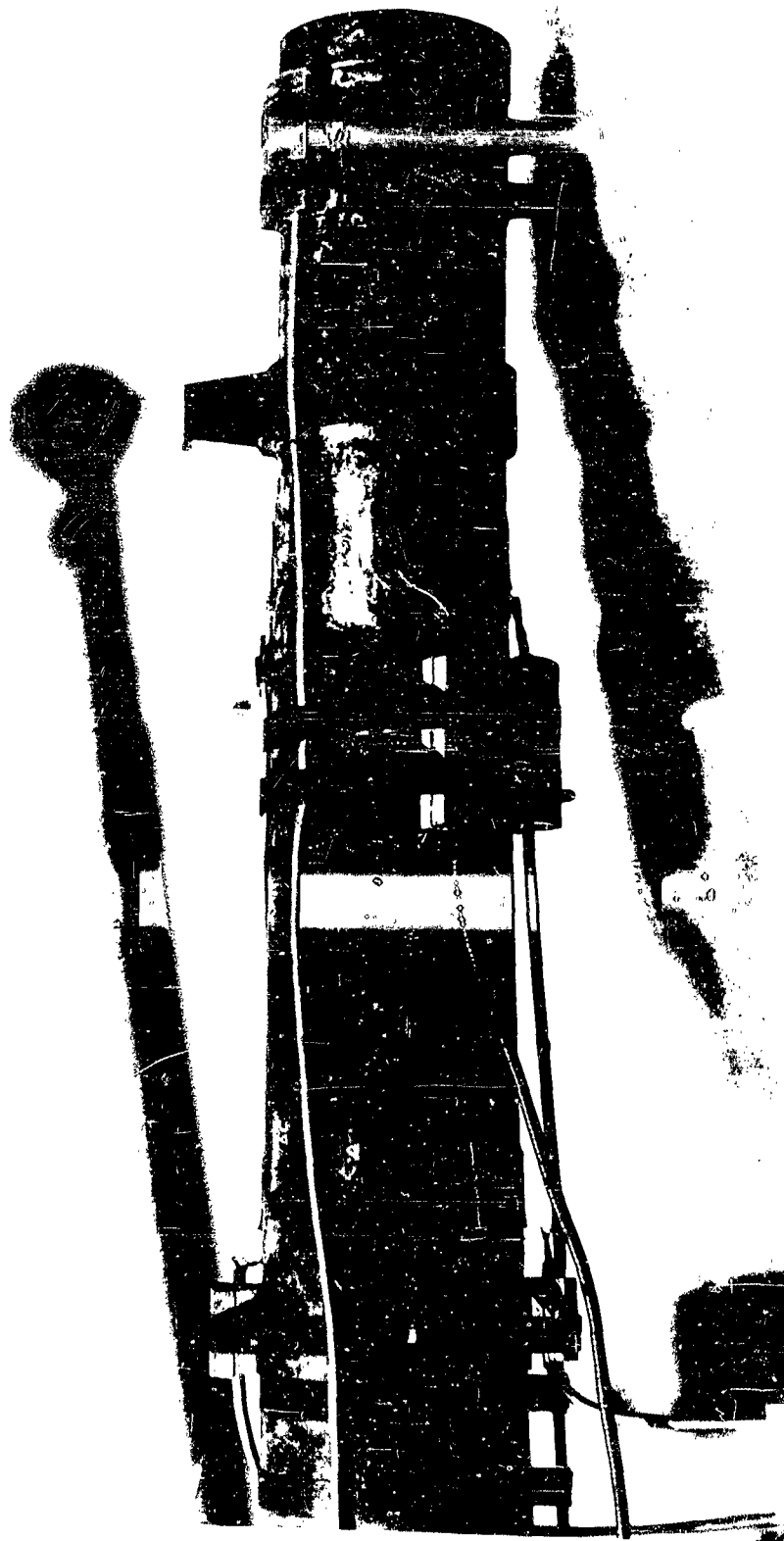
U. S. Naval Proving Ground.  
Vibrations of Gun Barrels.  
Mirror mounted on 3"/70 barrel

for optical measurement of vibrations.

APPENDIX A, Figure 1

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April 1951.



NP9-44599

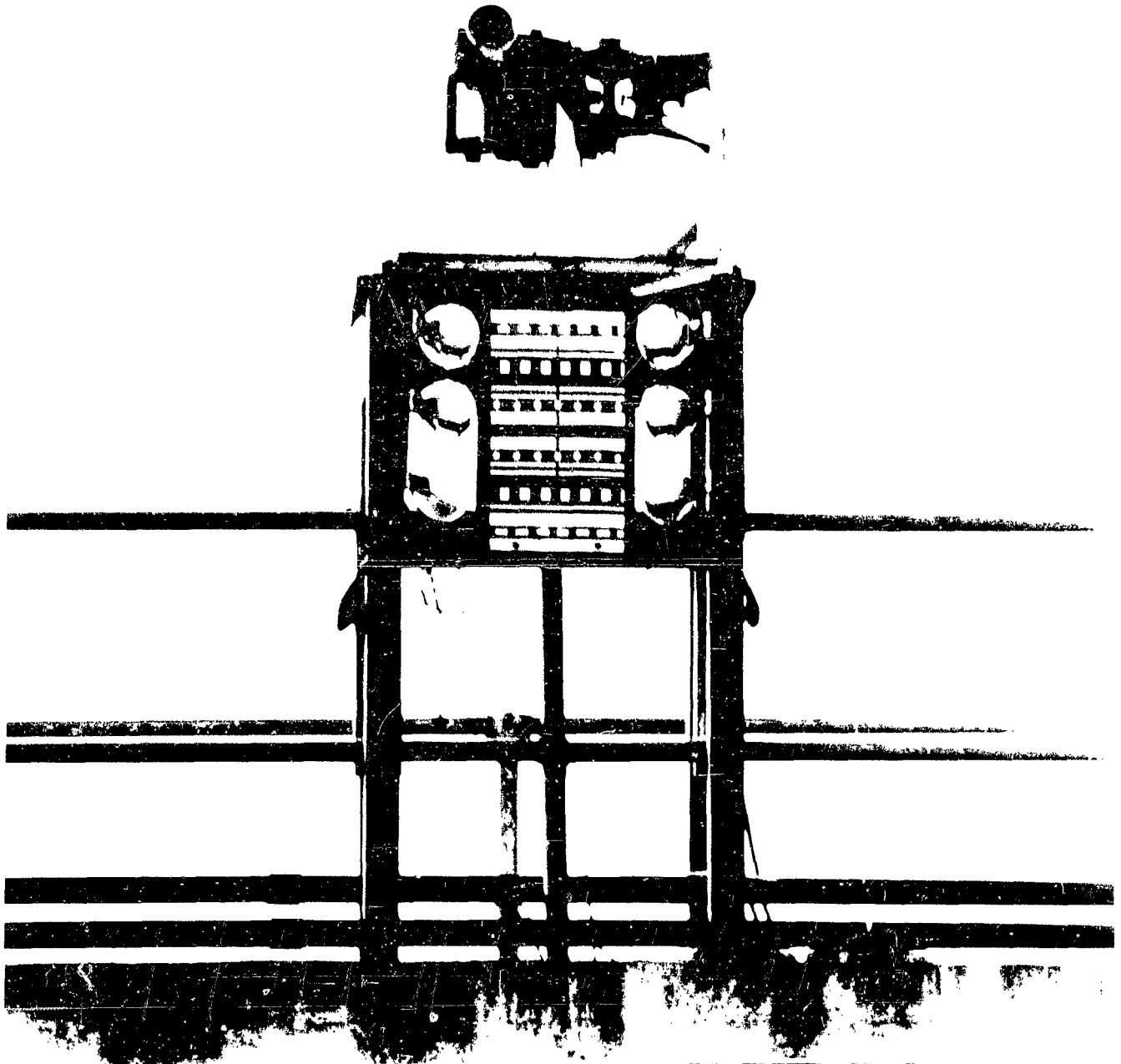
U. S. Naval Proving Ground.  
Vibrations of Gun Barrels.  
Mirror mounted on 3"/70 slide for optical measurement of vibrations.

APPENDIX A, Figure 2

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Vibrations of Gun barrels. Camera and grid as set up for optical  
measurement of vibrations. Grid shows method of identifying indi-  
vidual lines; each line is 1 inch wide.  
Figure 3

NP9-44602

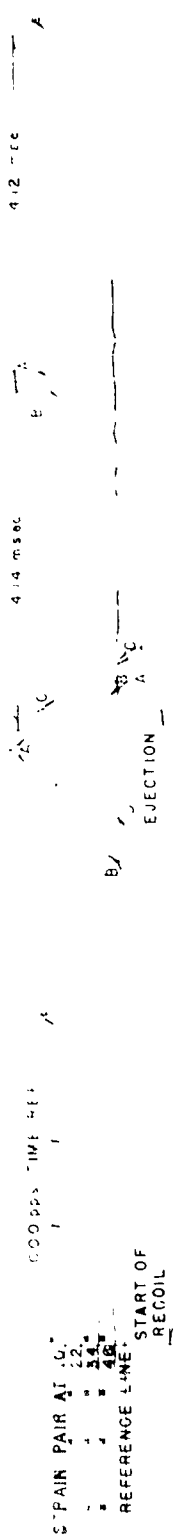
APPENDIX A, Figure 4

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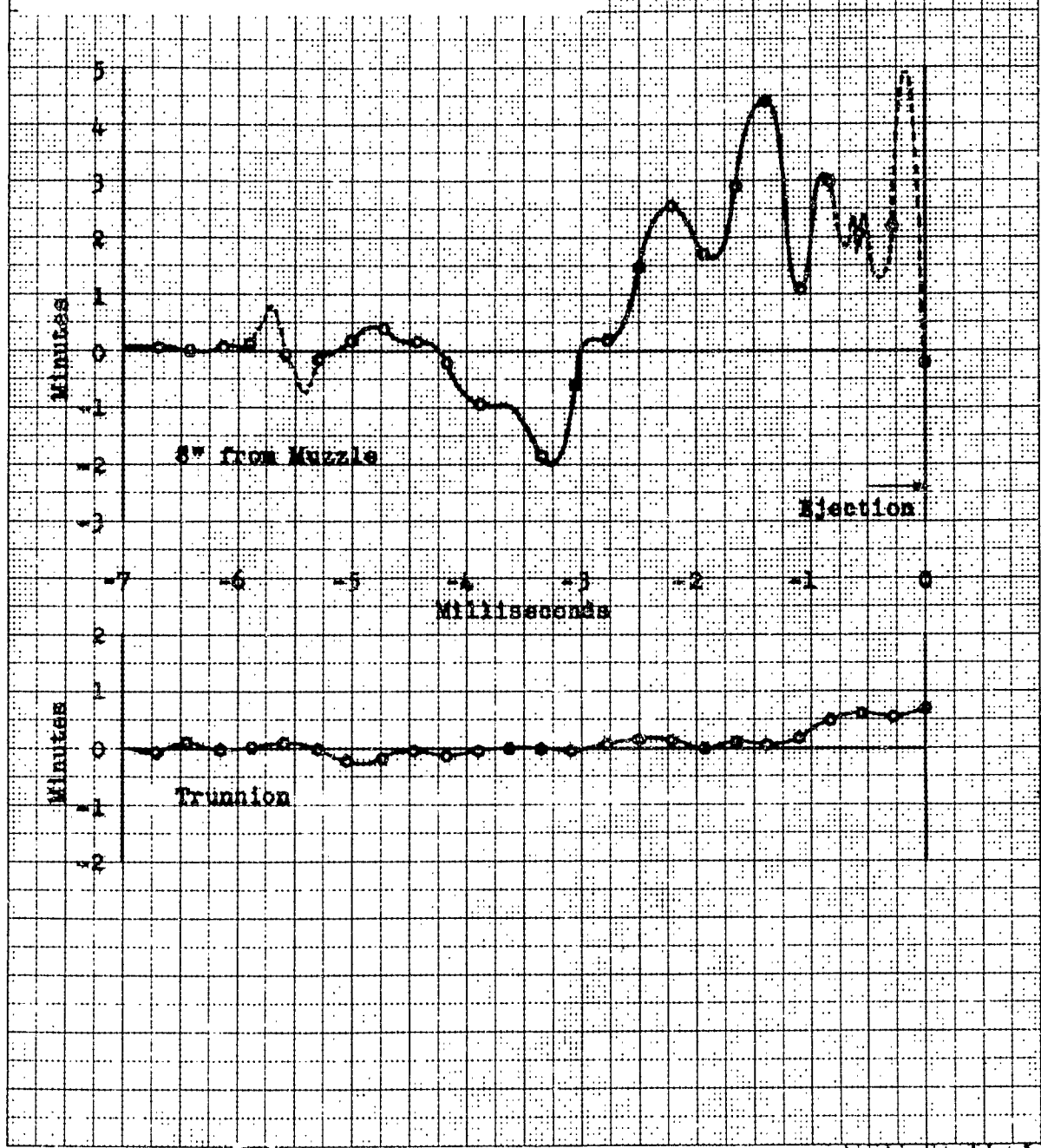
Experimental Data  
U. S. Naval Proving Ground  
April 1951

Reactions of a 3"/70 gun barrel to the passage of the projectile through its bore.  
Oscillograph record of axial strains in the vertical plane at four points on the barrel.

Round D



Experimental Data  
U. S. Naval Proving Ground  
April 1951  
Reactions of a 3"/70 gun barrel to  
the passage of the projectile through  
its bore.  
Vibrations measured by optical method.  
Round A



Appendix B Fig.

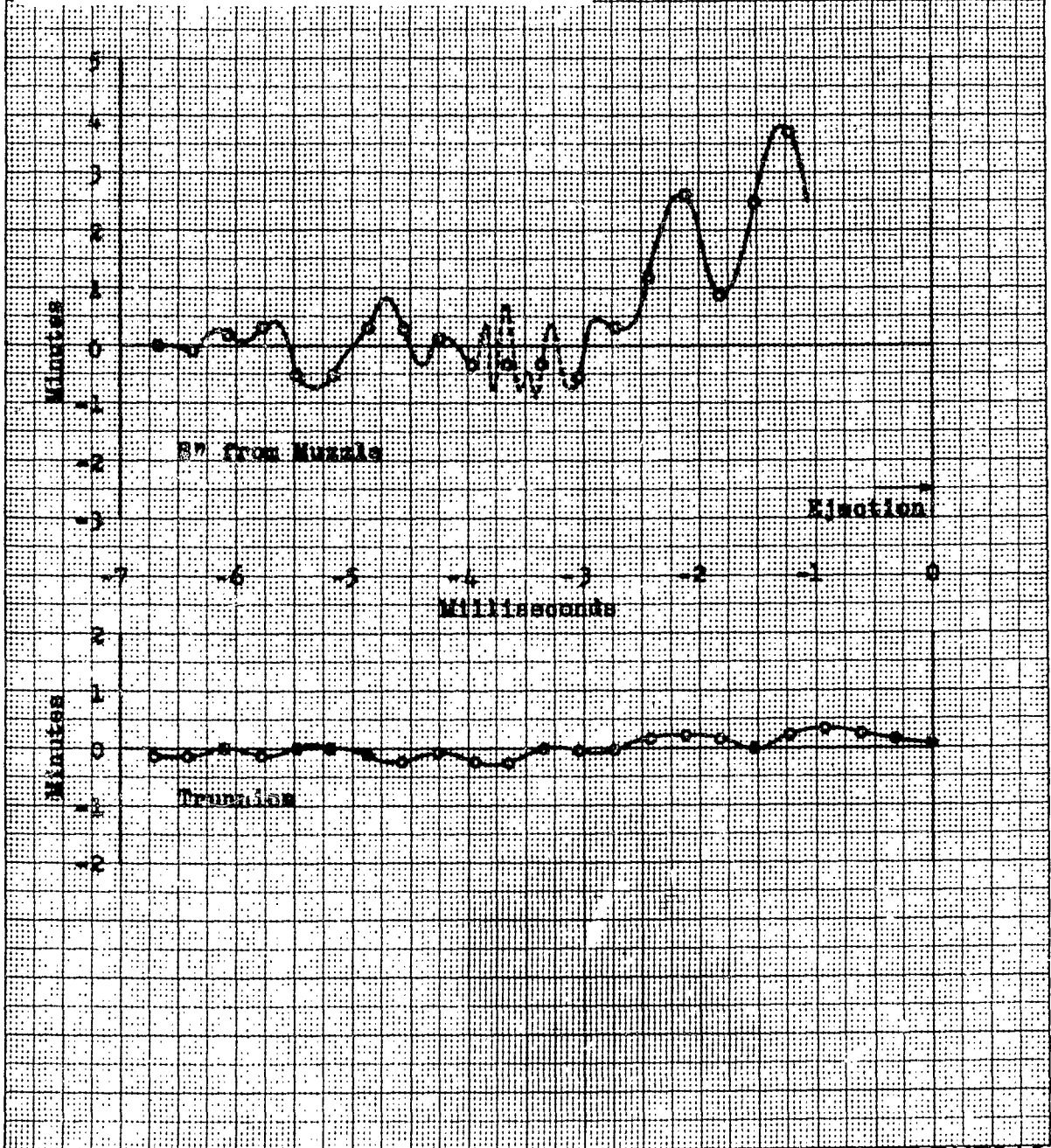
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Experimental Data  
U. S. Naval Proving Ground  
April 1951

MPG 44804

Reactions of a 3"/70 gun barrel to  
the passage of the projectile through  
its bore.  
Vibrations measured by optical method.

Round B

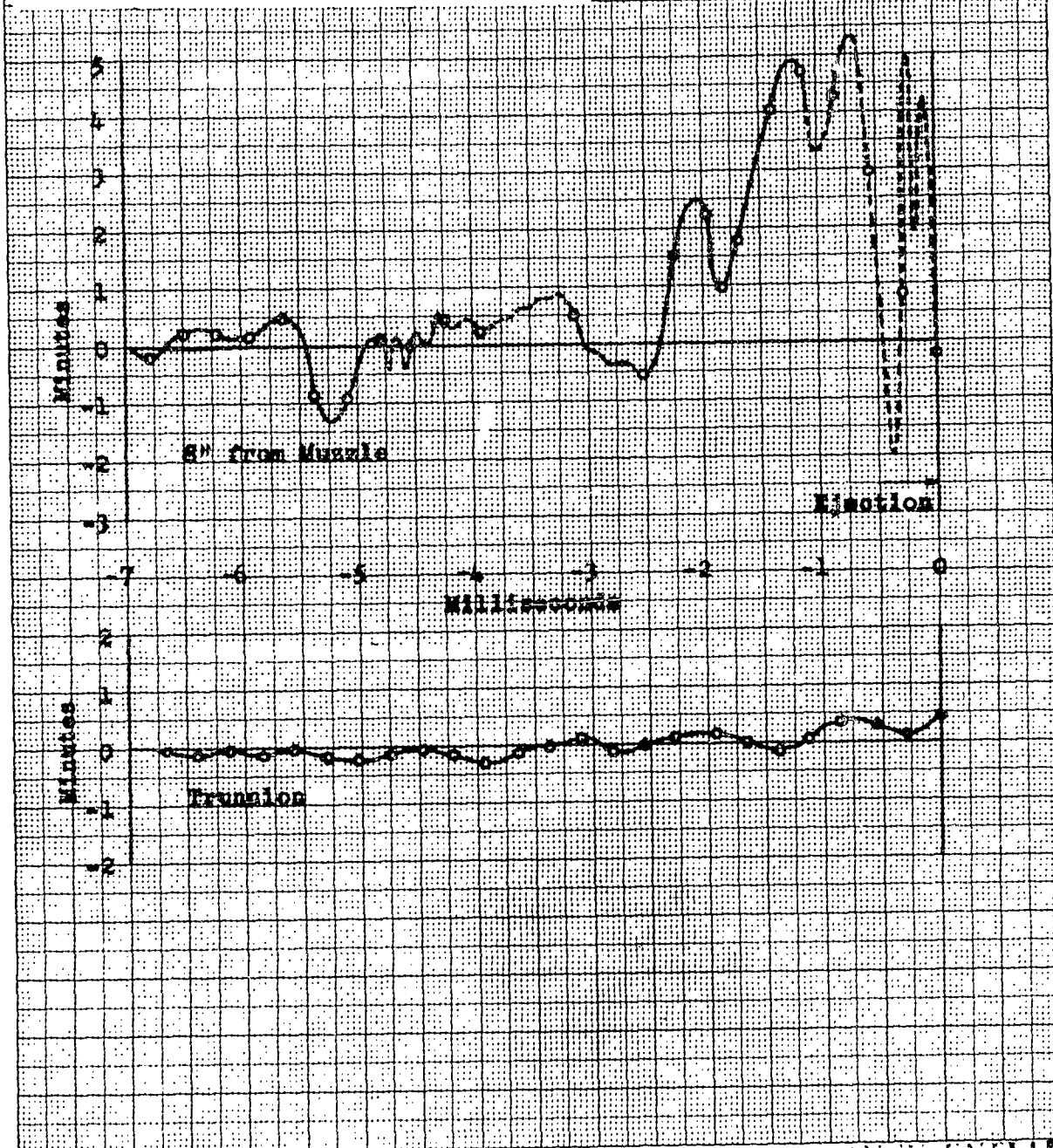


Appendix B Fig.

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Experimental Data  
U. S. ARMY Proving Ground  
April 1951  
Reactions of a 5" / 70 gun barrel to  
the passage of the projectile through  
its bore.  
Vibrations measured by optical method.

Round D



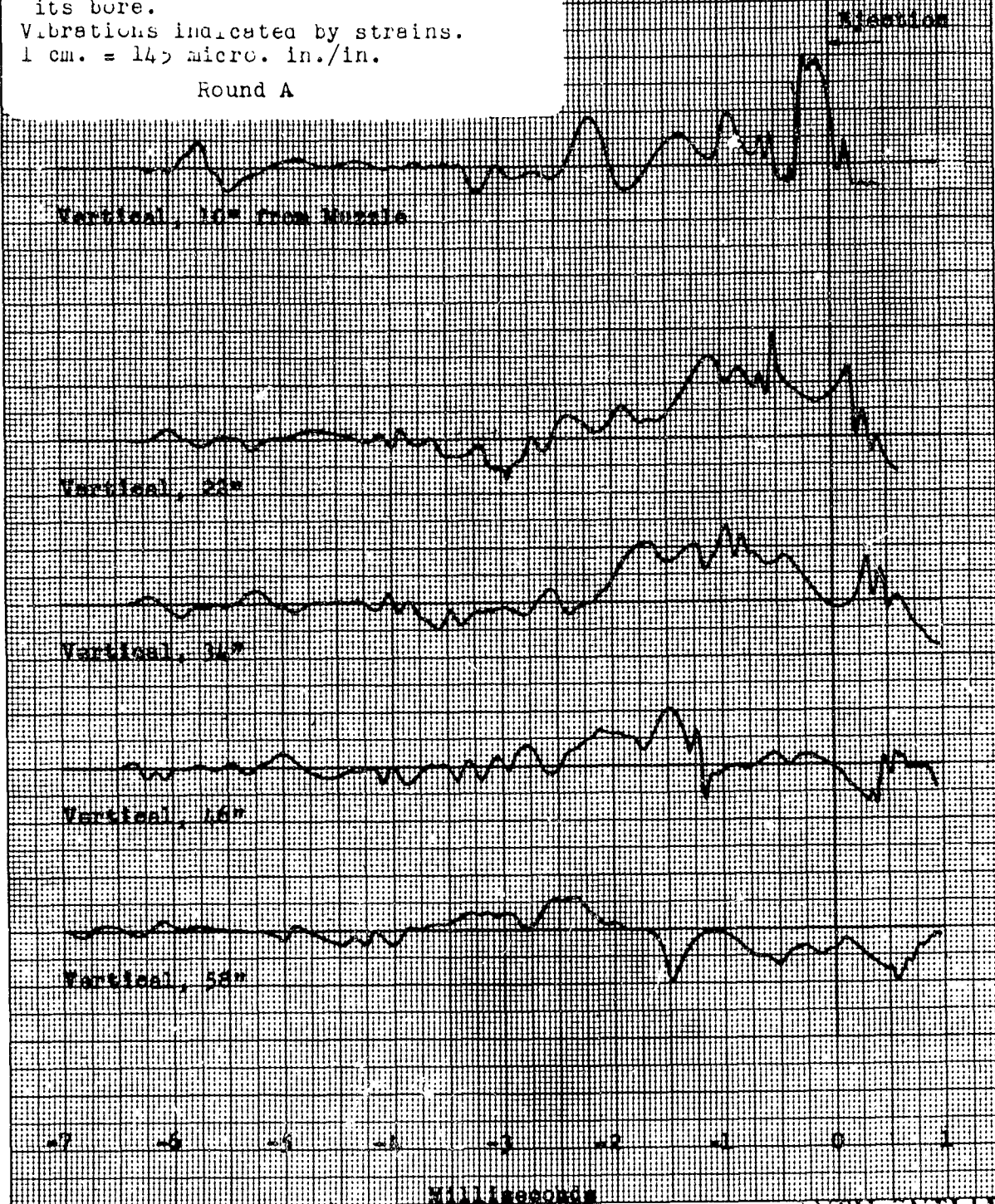
Appendix B Fig. 7

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Experimental Data  
U. S. Naval Proving Ground  
April 1951  
Reactions of a 3"/70 gun barrel to  
the passage of the projectile through  
its bore.  
Vibrations indicated by strains.  
1 cm. = 145 micro. in./in.

APR 4 1951

Round A



Appendix B Fig. 8

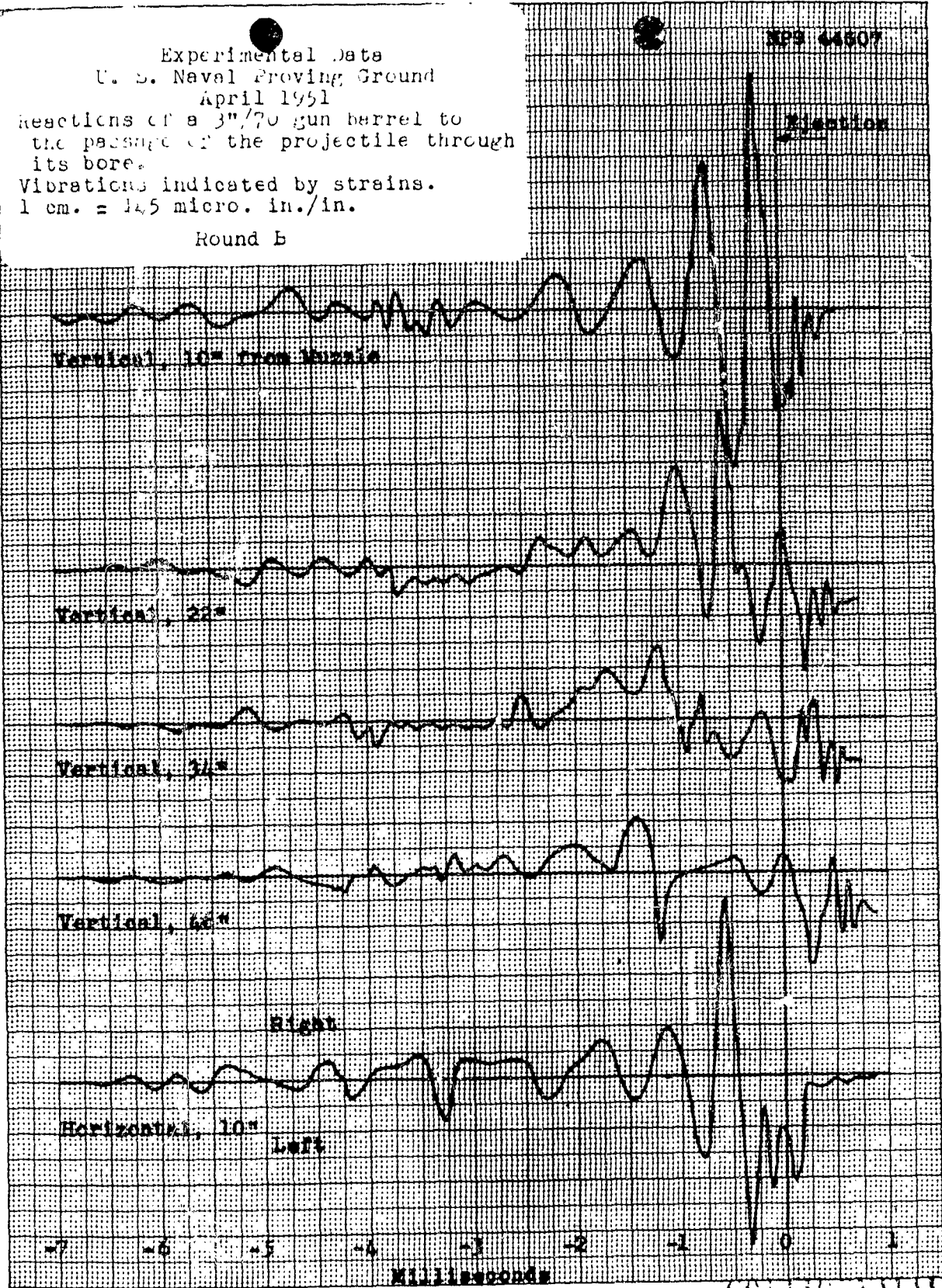
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NP9 44807

Reactions of a 3"/70 gun barrel to  
the passage of the projectile through  
its bore.  
Vibrations indicated by strains.  
1 cm. = 145 micro. in./in.

Round B



Appendix B Fig. 9

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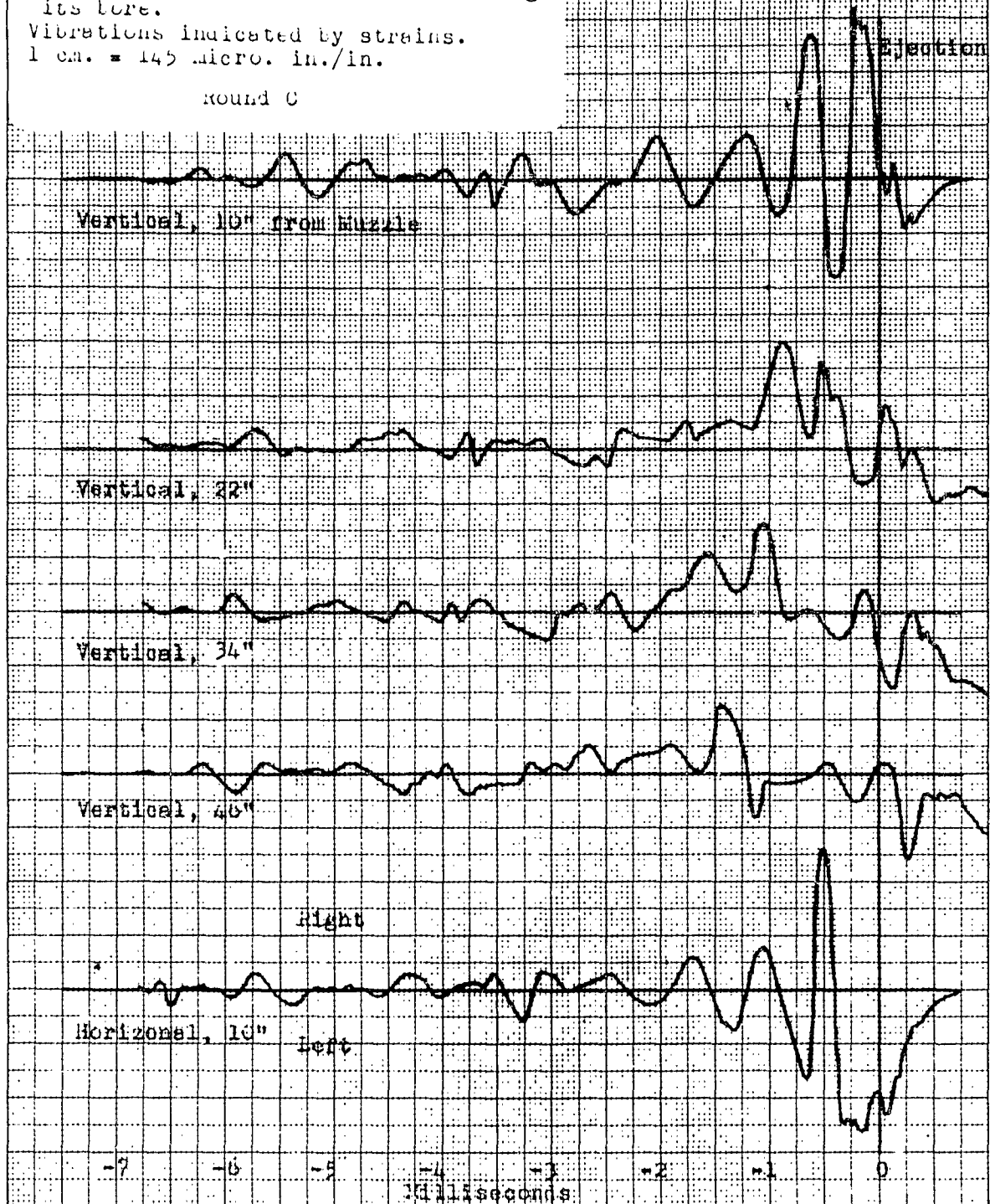
Experimental Data  
U. S. Naval Proving Ground  
April 1951

NP9 44608

Reactions of a 3"/70 gun barrel to  
the passage of the projectile through  
its bore.

Vibrations indicated by strains.  
1 cm. = 145 micro. in./in.

Round C



Appendix B Fig. 10

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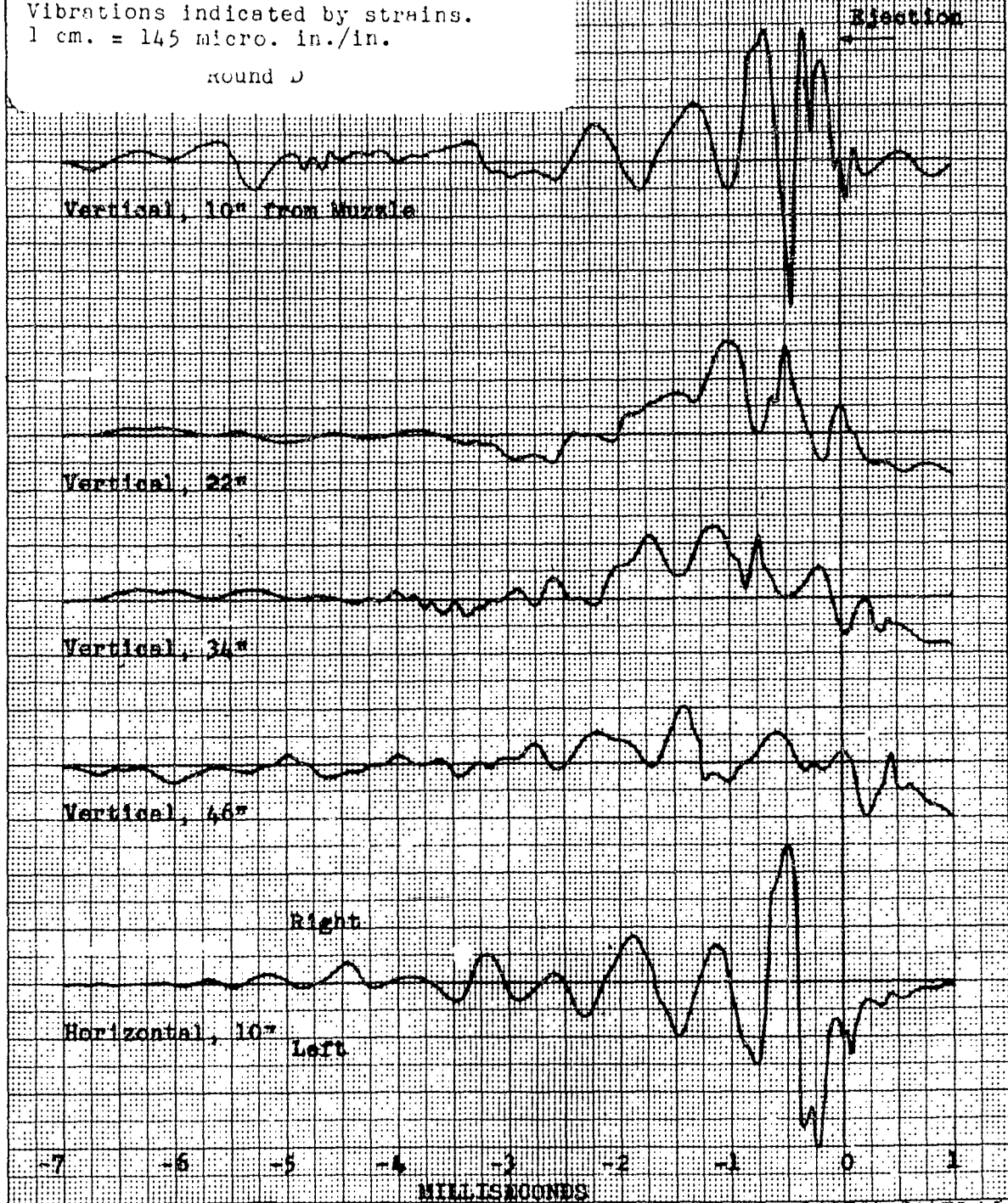
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U. S. Naval Proving Ground  
April 1951

NP9 44609

Reactions of a 3"/70 gun barrel to  
the passage of the projectile through  
its bore.

Vibrations indicated by strains.  
1 cm. = 145 micro. in./in.

round D



Appendix B Fig. 11

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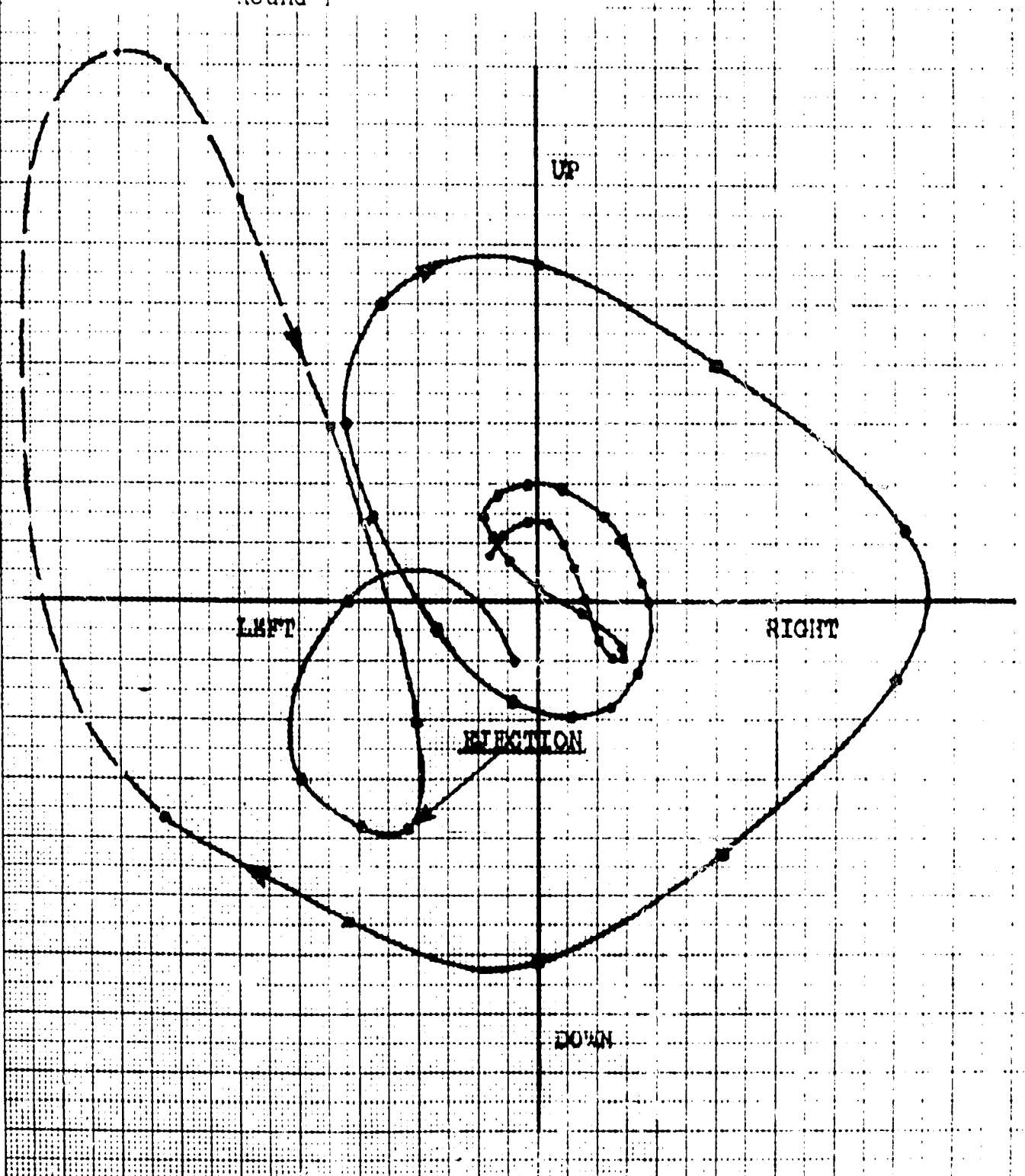
Experimental data  
U. S. Naval Proving Ground  
April 1951

Directions of a 3"/70 gun barrel to  
the passage of the projectile through  
its core.

Directions of magnetic section as measured  
12" from muzzle.

2 cm. = 145 micro. in./in.

Round 1



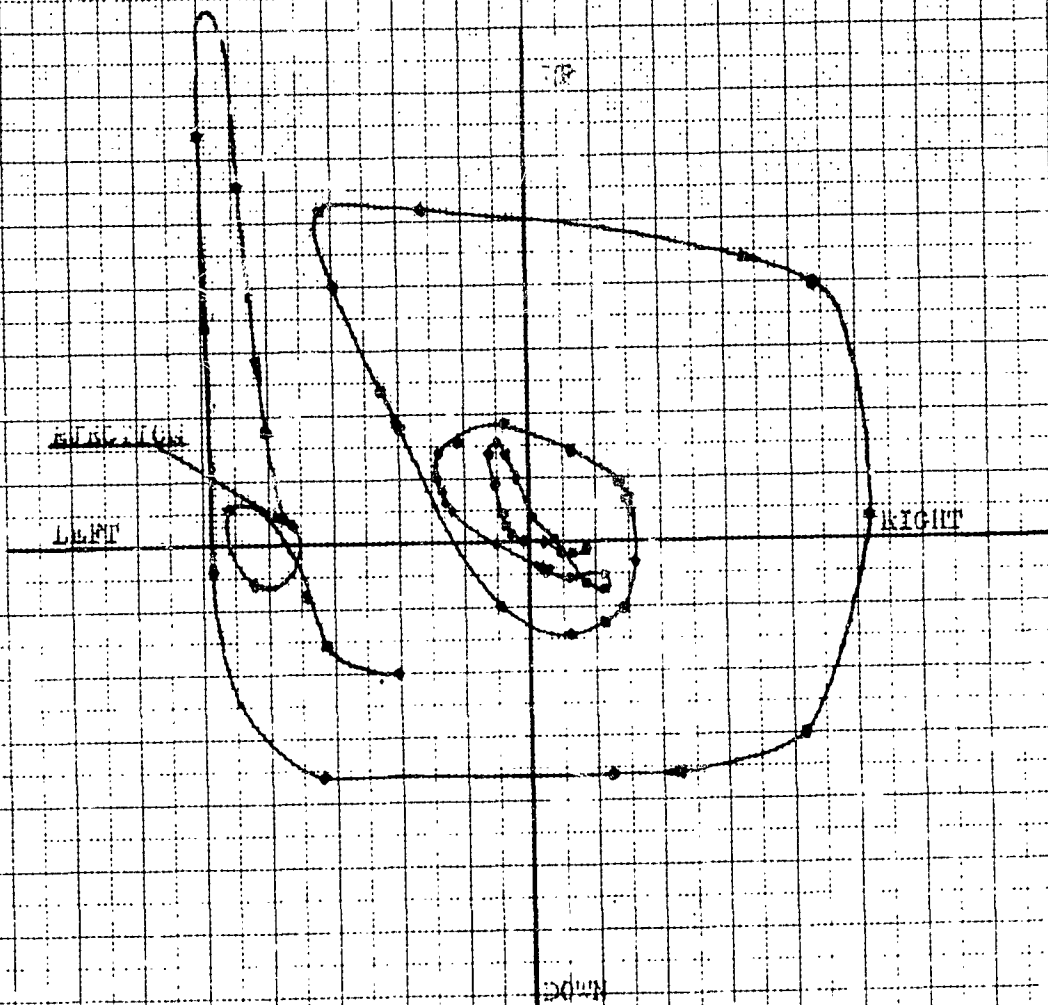
Appendix B Fig. 12

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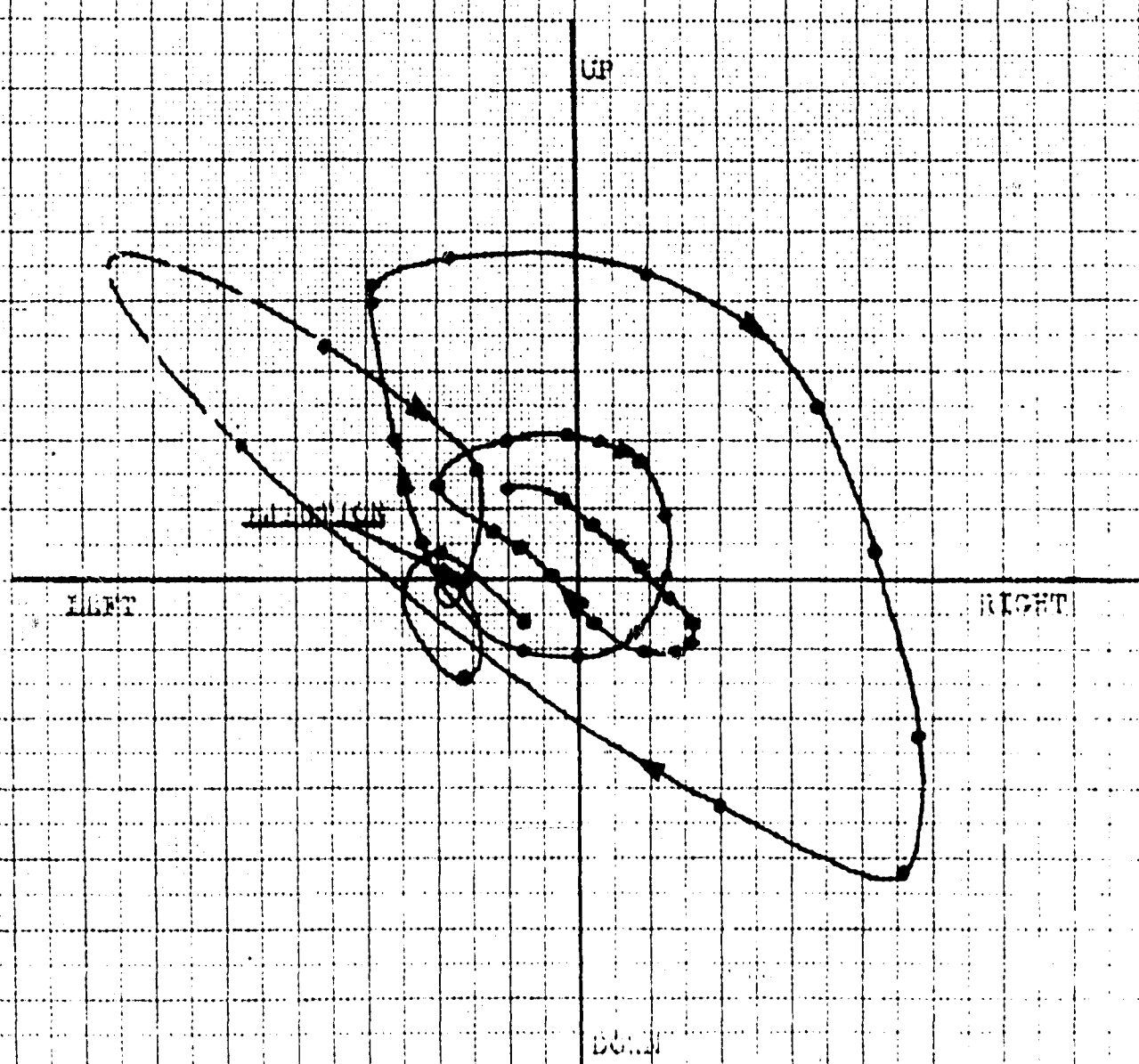
NP9 44811

EXPERIMENTAL DATA  
U. S. ARMY PROVING GROUND  
April 1951  
Reactions of a 5"/70 gun barrel to  
the passage of the projectile through  
its bore.  
Gyrations of muzzle section as measured  
10" from muzzle.  
1 cm. = 149 micro. in./in.  
Round C



Appendix B Fig. 13

... level in the ground  
 ...  
 ... barrel to  
 the center of the projectile through  
 its bore.  
 ... section as measured  
 10" from muzzle.  
 ... = 100 micro. in./in.  
 ...

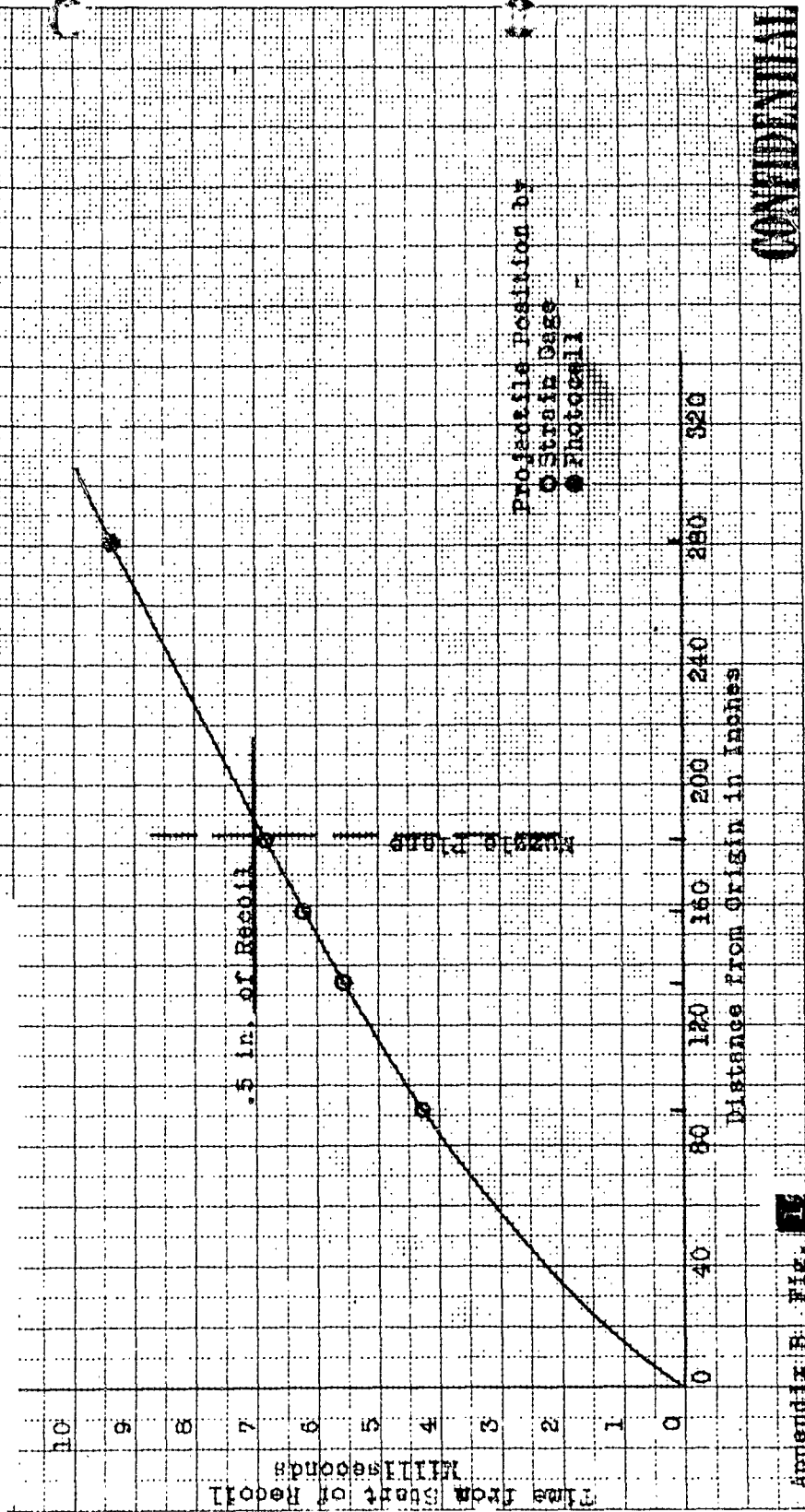


Appendix B Fig. 14

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Experimental Data  
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reactions of a 3"/70 gun barrel to  
the passage of the projectile through  
its bore.  
travel time of projectile through  
barrel.

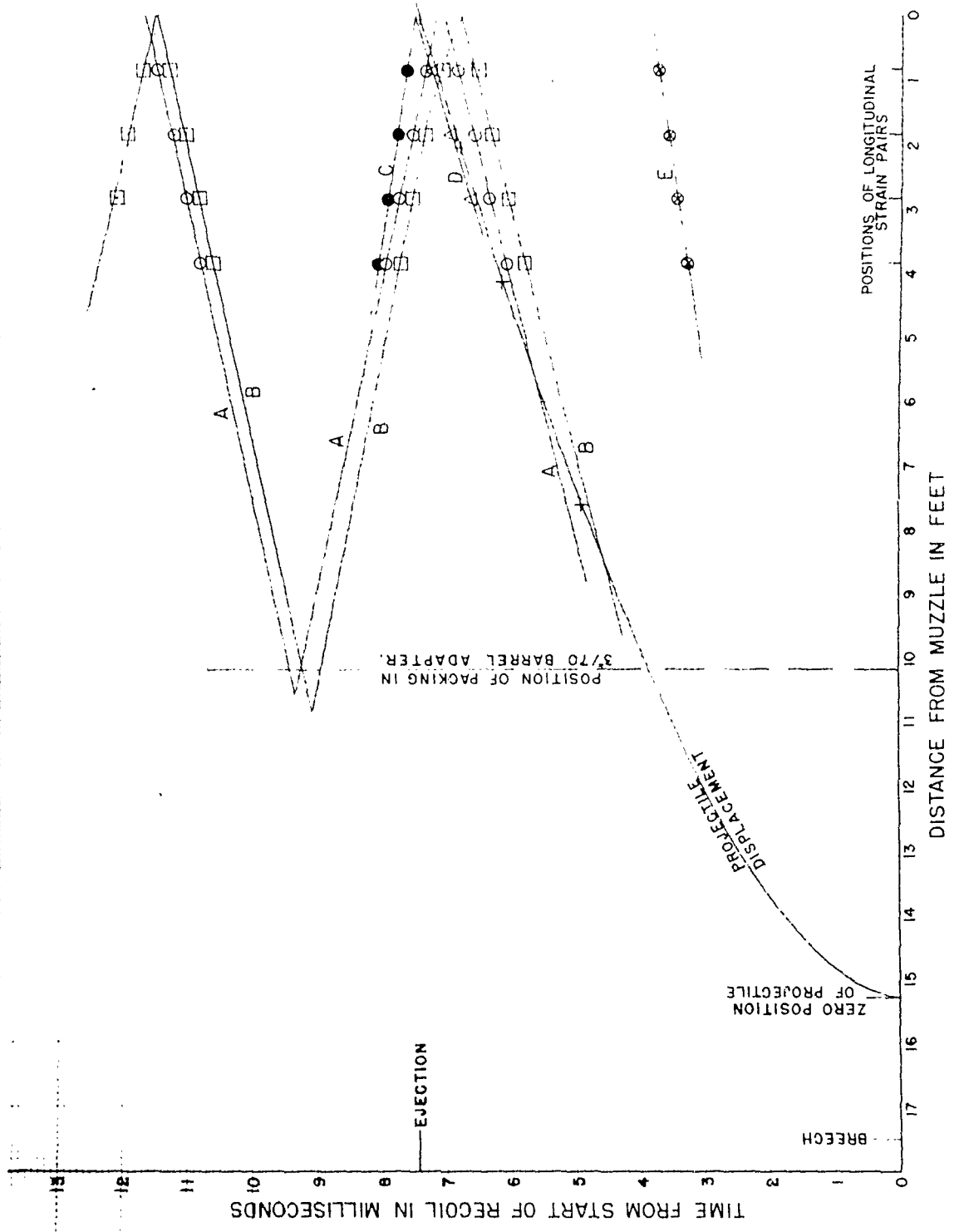
Round A



APPENDIX B FIG. 13

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... of ... and were disturbed ...  
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