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Technical Memorandum 4-60

AN EVALUATION OF OBSERVER ERRORS IN SPOTTING ROUND FIRE CONTROL

OCO, Nuclear Special Components Branch Project No. TN2-8051

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AN EVALUATION OF OBSERVER ERRORS IN SPOTTING ROUND FIRE CONTROL

By

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MARCH 1960

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ABSTRACT

A field investigation was conducted at Aberdeen Proving Ground, Maryland to measure human errors associated with spotting round fire control.

Ten mortar observers from Ft. George G. Meade were used to direct fire of a 60mm mortar at each of five 8' x 8' vertical targets randomly positioned within the range of the weapon. They were allowed 5 rounds to adjust fire and were instructed to call on target when they thought a round fell within 25 yds. of the target.

Nearly all the subjects thought they had determined the range after 5 rounds, however the distribution of range error when calling on target had an average deviation from the target of 7% of the range of the target.

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AN EVALUATION OF OBSERVER ERRORS IN SPOTTING ROUND FIRE CONTROL

INTRODUCTION

Military operations are highly dependent upon the accurate delivery of firepower.. In the absence of precise range finding devices one of the most difficult tasks confronting an operator in direct fire control operations is that of determining the range from weapon to target. The generally accepted inaccuracy associated with unaided visual range estimation is approximately 25 percent of the range. In order to assist the operator in range determination various techniques have been developed. One of these techniques utilizes sub-caliber matched trajectory spotting rounds. With such a system, the operator fires spotting rounds until he observes a hit on the target or is within certain error limits around the target.

One of the difficulties in using spotting rounds comes about in judging the magnitude of the spotting round miss distance. This judgment is one of the important parameters in the preliminary analysis and evaluation of a weapon system using spotting rounds for fire control. It is this error in judgment which can determine the number of spotting rounds used and time to get on target for firing the major caliber weapon.

Because of the absence of reliable information relating to the accuracy of sensing spotting round miss distance, a field study was conducted to obtain the necessary information.

This study was designed to investigate the accuracy of experienced mortar observers, located near the weapon, to direct high angle spotting rounds to targets of unknown range.

METHODS

The subjects (Ss) used for this study were 10 mortar observers obtained from Ft. George G. Meade, Maryland. Mortar observers were selected because their training and experience most closely satisfied the requirements of the spotting round technique to be used viz, high angle fire.

The spotting rounds used were 60mm mortar training rounds which when detonated provided a black powder burst approximately 6 feet in diameter. These rounds were selected as the best available vehicle which could provide an adequate display and for which a delivery system was available.

All testing was conducted at the Trench Warfare Range, Aberdeen Proving Ground, during October 1959. This range was selected because it afforded a relatively flat terrain for a distance of approximately 2000 yards. The vegetation consisted of dun colored grass approximately 2 feet in height.

The targets were 8' x 8' vertical sheets of plywood painted black for better visibility. The targets were located at distances of 690, 873, 1225, 1581 and 1680 yards from the gun positions. The location of targets with respect to gun positions is shown in Figure 1. The terrain between gun positions A and C and the targets was practically level, except for a slight depression extending from immediately behind target No. 2 to immediately in front of target Nos. 3, 4 and 5. The terrain between gun position B and the

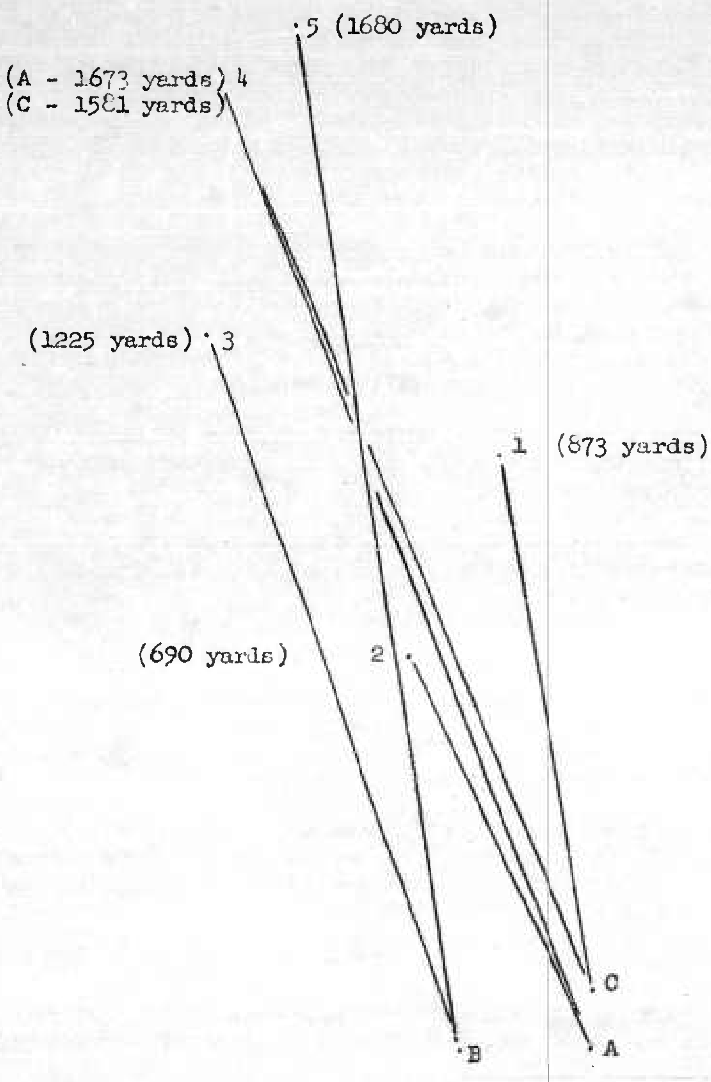


Fig. 1. Sketch of Relative Target and Gun Positions (Approx.) A, B and C Denote Gun Positions

the targets was practically level, but contained some small bushes between the gun and targets. While these small bushes did not obscure the targets they did increase somewhat the difficulty of observation. No other trees or landmarks were located within the target area.

PROCEDURE

The Ss individually directed fire of up to 5 rounds at each of the targets. The targets were randomly presented at the different ranges and the 3 different firing positions were used in order to avoid any positive transfer effects of range information. The typical procedure for any one S was as follows: The S located near the weapon viewed the target and called out an estimated range. One round was delivered at this range. After observing the round burst in relation to the target, the observer called for a correction in range. This procedure was continued until the observer reported that the last burst was within 25 yards of the target or that his correction would put the next round within 25 yards of the target.

The data were recorded in the following manner: The location of each target, firing position, and spotting burst was obtained by survey from 3 range towers. Each S's initial range estimation, and subsequent corrections, and the round he called on target were recorded at the firing site. In addition, meteorological data were recorded hourly during the study.

RESULTS

While this study was designed to use experienced mortar observers, all of the Ss obtained did not meet the original requirements as set forth. Three of the 10 Ss did not have experience as an observer and one of the three, only had vision in one eye. It should be pointed out, however, that they all had experience in Korea and were assigned to an active artillery company. In addition, their commanding officer gave them all a refresher course in directing fire one day before the study began.

The considered opinion of an experienced artillery officer was that, the Ss used would be better qualified as a group than 10 observers picked at random from a combat situation. Furthermore, the best performance was turned in by the inexperienced S with one eye (See Appendix A), and the worst performance by far, was by a S with 9 years of experience in all phases of artillery. (His errors were excluded in the overall results.)

It must be pointed out that the 60mm mortar round does not have the accuracy that would be expected from a well designed spotting round. This situation was somewhat aggravated by 10 to 20 mph winds during the course of the study. Careful attention was given to this aspect during data analysis. A model of performance as a function of miss distance was used to analyze performance as a function of spot deflection from target. There was found to be a slight degradation of performance out to 25 mils over which performance dropped rapidly. For this reason, all data on rounds exceeding 25 mils deflection error were excluded, this being a reasonable maximum spread for an accurate round.

Because the normality of the distribution could not be established, three measures of dispersion were calculated viz, probable error (PE), average deviation (AD), and standard deviation (SD). These measures were calculated assuming the target position as the mean. Actually the group means were close enough to the target to give essentially the same results.

All data were grouped together by expressing errors as a percentage of range to the target. The assumption that observer performance would then be independent of target range is borne out by the results (see Table I).

As is shown in Table I, the error of on target calls was of considerable magnitude. This error was larger than anticipated.

The number of spotting rounds necessary to get on target is also of interest. Table II presents the best estimate of target location with each round and the percentage of calls on target for each round. (It should be mentioned that the accuracy of the calls was independent of the number of rounds used.) For these results a 25 mil deflection limit was used in order to have more complete trials as only 9 trials remained within the 15 mil limit.

In order to predict performance for observer correction error as a function of miss distance, a mathematical model was developed. This model was based on data from other studies of sensing error and compared to the results of this study. This comparison is shown in Figure 2. The significance of this figure is that knowing the average deviation of a previous round, the predicted average deviation of the next round can be read from the ordinate of the graph.

A graphic presentation of range error as a function of spotting round number is shown in Figure 3. This figure shows the expected correction error from a sequence of spotting rounds.

An important finding in this investigation was the fact that the observers would quite often make an error in sensing the direction of the spot from the target. When this happened it would usually destroy the pattern of their technique and result in a large error when they called on target. Of the 118 rounds that landed within 15 mils of the target, the following performance was recorded:

54% - improved their estimates

26% - called for no change (generally calling on target)

10% - overcorrected

10% - corrected in the wrong direction

DISCUSSION

Within the context of this study it is apparent that the errors associated with the use of high angle spotting rounds are quite large. Of course, no particular technique was enforced in this study as the intent was to evaluate the performance of experienced personnel. It can be stated that the best performance was obtained by those Ss who consistently used good artillery techniques such as making gross initial corrections or bracketing the target.

TABLE 1

MISS DISTANCE FOR CALLS ON TARGET EXPRESSED AS A PERCENTAGE OF RANGE TO TARGET ONLY FOR ROUNDS WITHIN 15 MILS DEFLECTION OF TARGET

PERFORMANCE BY SUBJECT

Subject No.	1	2	3	4	5	6	7	8	9*	10
Number of Calls	4	4	4	4	4	5	3	3	5	4
A. D. (%)	10	2.8	4.4	3.6	7.3	5.5	10	7.9	34	12

* Subject #9 was excluded from all other results

PERFORMANCE BY TARGET

Target Range (Yd.)	690	873	1225	1581	1673	1680
Number of Calls	7	5	6	5	1	6
A. D. (%)	7.1	6.1	12.6	6.7	4.7	6.2

PERFORMANCE BY ROUND

Number of Rounds	1	2	3	4	5
Percent of Calls	0	11	22	67	100
A. D. of Calls (%)	-	11	6.0	6.8	7.1

TOTAL PERFORMANCE

Standard Deviation (S.D.)	9.8
Average Deviation (A.D.)	6.9
Probable Error (P.E.)	4.5

TABLE II

RANGE ERROR (%) AS A FUNCTION OF SPOTTING ROUND NUMBER
(For all trials within 25 mils deflection)

Spotter Number	Original Estimate 0	1	2	3	4	5
Standard Deviation (S.D.)	45	25	20	15	11.0	10.8
Average Deviation (A.D.)	29	20	15	11	7.7	7.3
Probable Error (P.E.)	28	15	11	7.0	4.5	3.7
Number of Trials*	43	39	35	32	25	23
Percent Calls on Target	0	2.5	11	19	60	92
A.D. of Calls on Target**	-	34.2	14.8	10.1	6.7	7.7

* The number of trials decreases because they were discontinued if a round exceeded 25 mils.

** One bad call on the first round is responsible for the apparently decreasing error with more rounds, otherwise accuracy of calls would be independent of the number of rounds used.

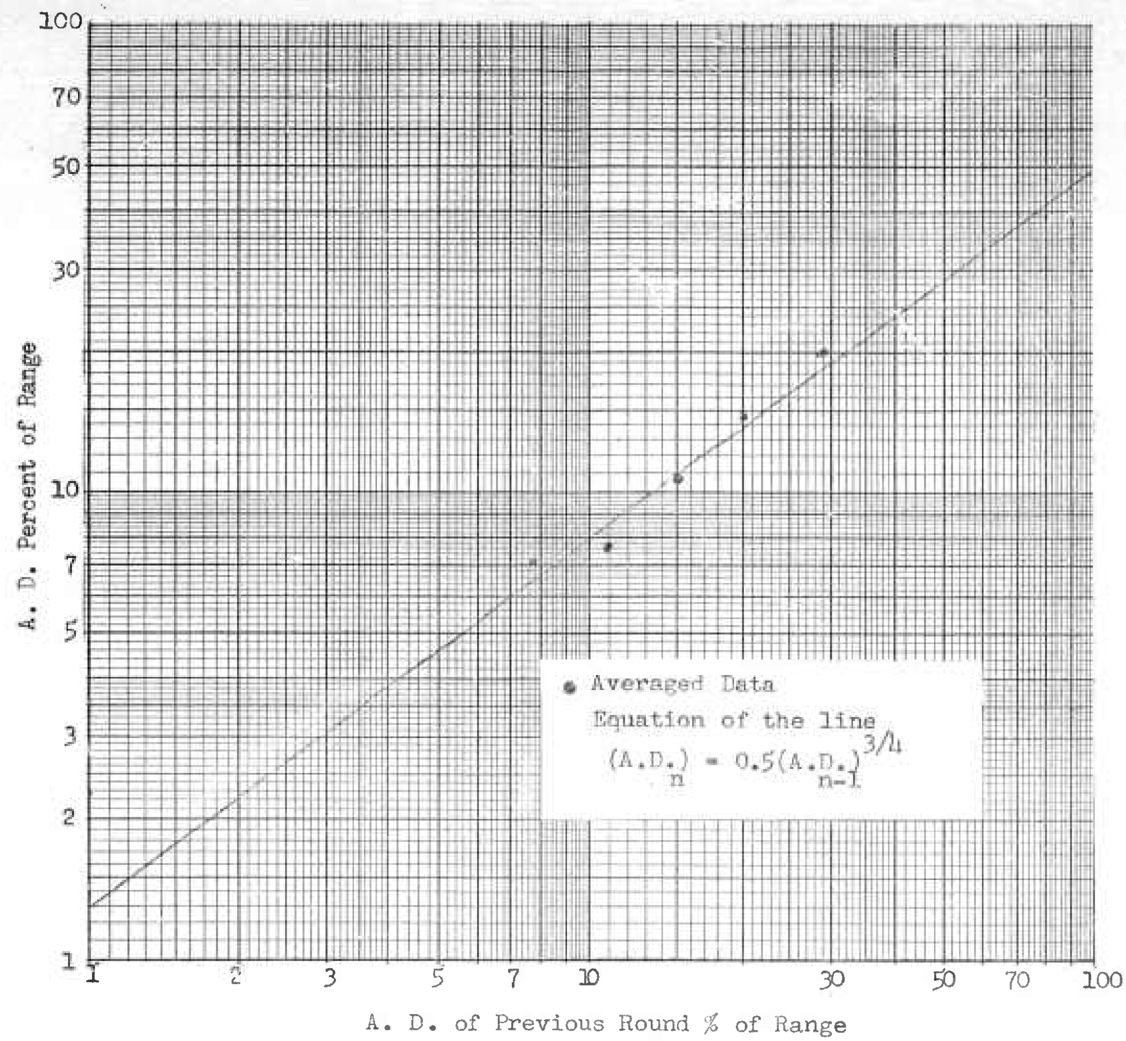


Fig. 2. Range Error as a Function of Previous Round Range Error

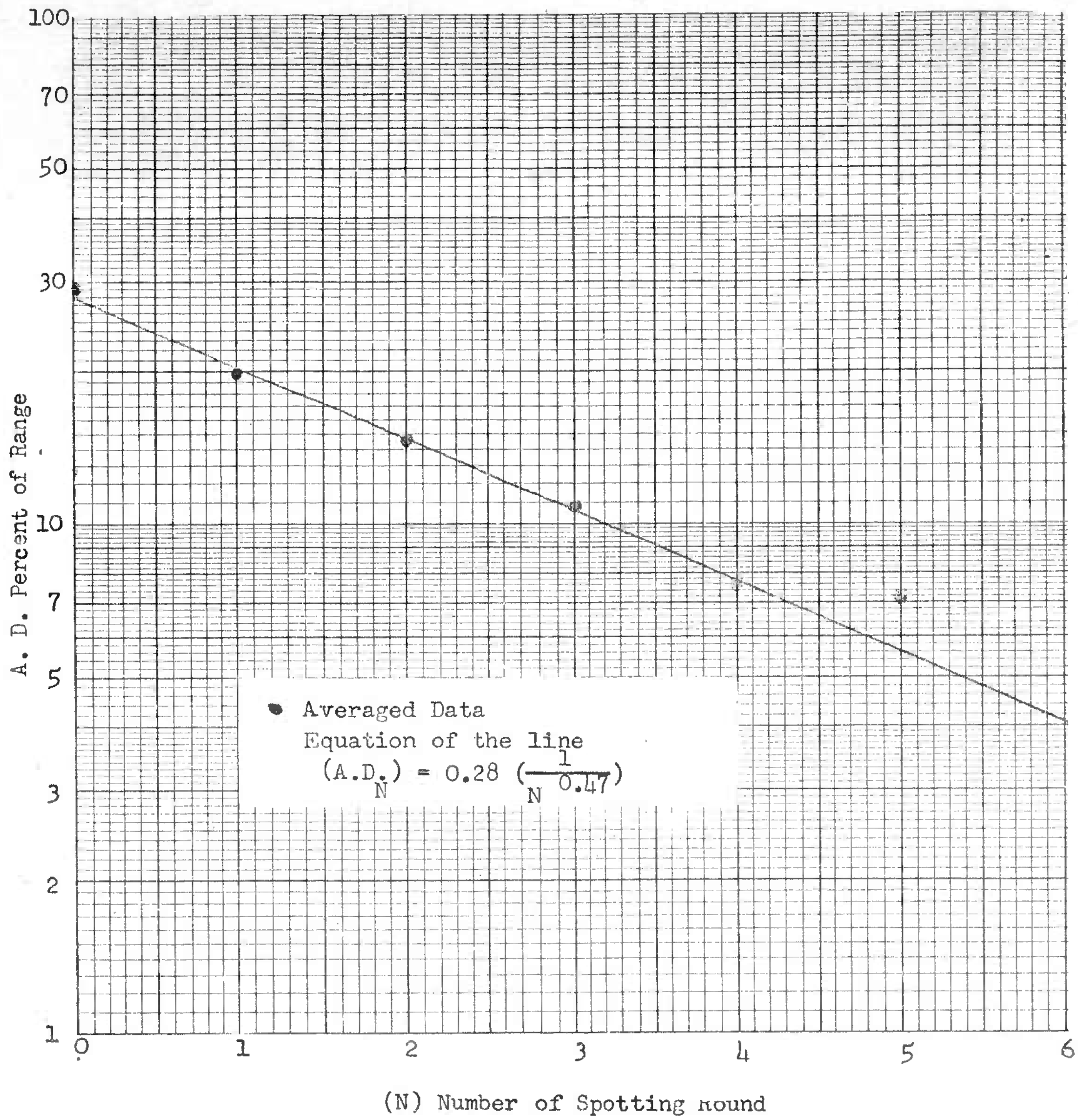


Fig. 3. Range Error as a Function of Spotting Round Number

The effective utilization of spotting rounds can seriously be hampered by large deflection errors. With large deflection errors the observer has difficulty in locating the spot in relation to the target in the range dimension.

One finding which is difficult to interpret is the performance of the one-eyed S. This would seem to question the effectiveness of depth perception in the use of spotting rounds. It was expected that this S would have the poorest performance of the group. One possible interpretation is that this S consistently used good artillery technique in his direction of fire. This in turn may indicate that good technique is more important than good depth perception.

It must also be remembered that this study was conducted under a single terrain condition. It would be impossible to predict the effects of using spotting rounds under more severe conditions like rolling terrain with dense vegetation which may partially obscure the target and/or visibility of the spotter. However, the accuracy of spotting round observation would be increased when viewing from an elevated position, thus making spot sensing easier.

RECOMMENDATIONS

There are several possibilities that could be investigated in an effort to improve fire direction utilizing the spotting round technique. It is recommended that the following be investigated for purposes of increasing the accuracy of and/or decreasing the number of spotting rounds required to get on target.

1. An observer positioned some distance to the side of the weapon should be better able to sense large range errors than an observer close to the weapon, assuming there is little deflection error.

2. A simple range finder (such as a one meter base, coincidence type) should reduce the number of spotting rounds used, by reducing the original range estimation error.

3. A procedure by which several spotting rounds are fired originally should reduce the overall time of acquisition. Each round would be fired to different predetermined points. Some of the advantages of multiple firings of this type would be:

a. a mapping of the terrain in range

b. bracketing of the target

c. indications of whether the target was within range of the weapon

d. disclosure of hidden terrain features

APPENDICES

A. Observer Error When Calling on Target.

   1. The Average Deviation for Calls on Target is Presented in Chronological Order for the Various Targets.

   2. The Subjects are Rated According to their Performance When Calling on Target.

B. A Method of Normalizing the Distribution of Error.

C. Raw Data

APPENDIX A

OBSERVER ERROR WHEN CALLING ON TARGET

THE AVERAGE DEVIATION FOR CALLS ON TARGET IS PRESENTED IN CHRONOLOGICAL ORDER FOR THE VARIOUS TARGETS

DATE (Oct '59)	RANGE (Yd)	A.D. (%)
13	1673	4.7
19	690	7.1
19	1680	6.2
20	1225	12.6
20	1581	6.7
23	873	6.1

THE SUBJECTS ARE RATED ACCORDING TO THEIR PERFORMANCE WHEN CALLING ON TARGET

SUBJECT NO.	A.D. (%)	REMARKS
2	2.8	No experience No vision in one eye
4	3.6	Experienced
3	4.4	No experience No measurable depth perception
6	5.5	Experienced
5	7.3	Experienced
8	7.9	Experienced
1	10	No experience
7	10	Experienced
10	12	Experienced
9	34	Experienced

APPENDIX B

A METHOD OF NORMALIZING THE DISTRIBUTION OF ERROR

An interesting method of analyzing human errors is to classify them in two separate groups. One group includes mistakes, the other group is the limiting accuracy of humans when there are no mistakes (referred to as the homogeneous portion).

For the purpose of this study, mistakes are defined as trials when the observer did not bracket the target and/or he made an error in sensing the direction of the spot from the target. The data for errors when calling on target (38 trials) were separated according to this criteria and are tabulated below:

Homogeneous Portion

45% of trials

S. D. 3.1% of range (normally distributed)

Mistakes

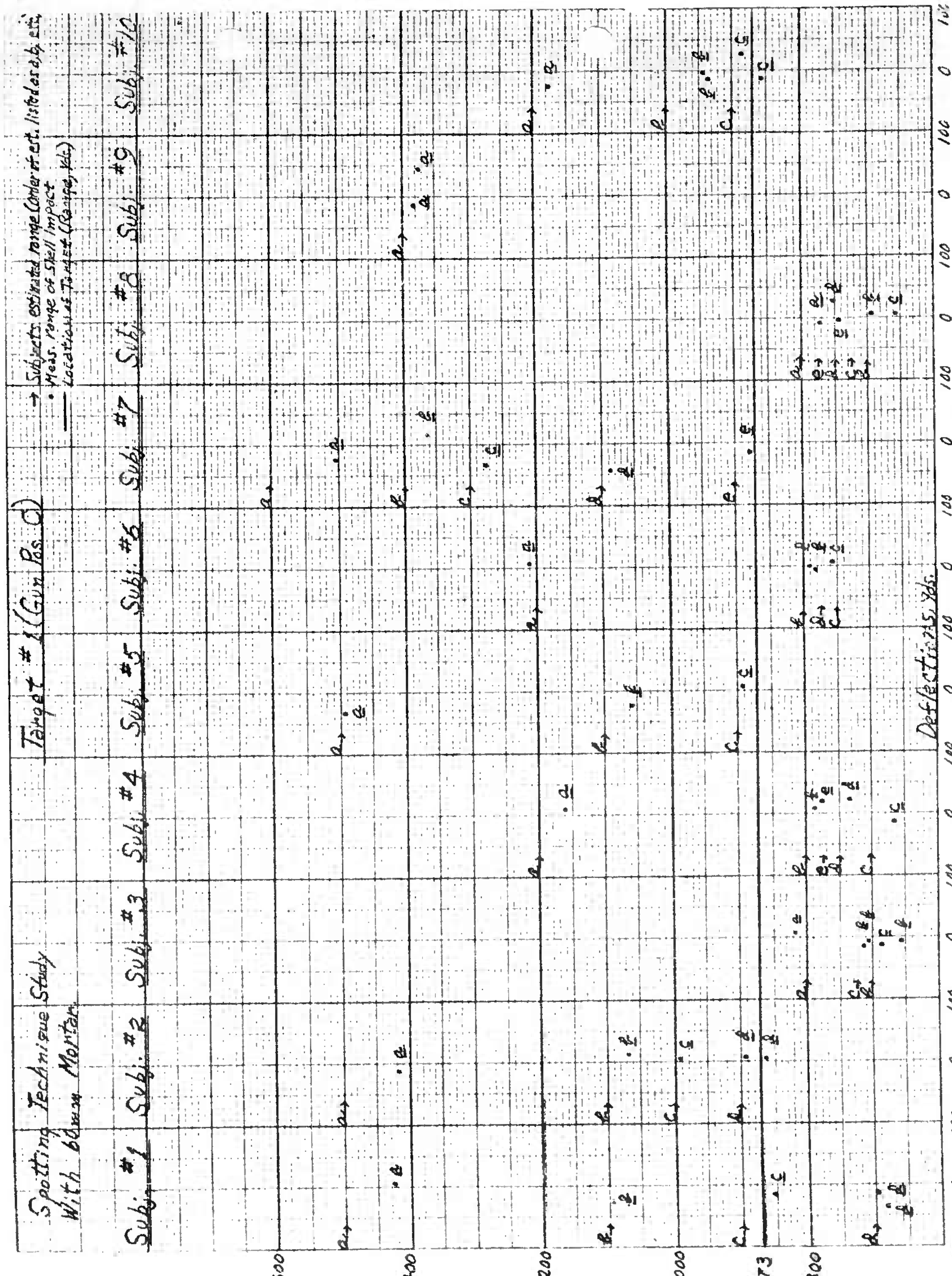
55% of trials

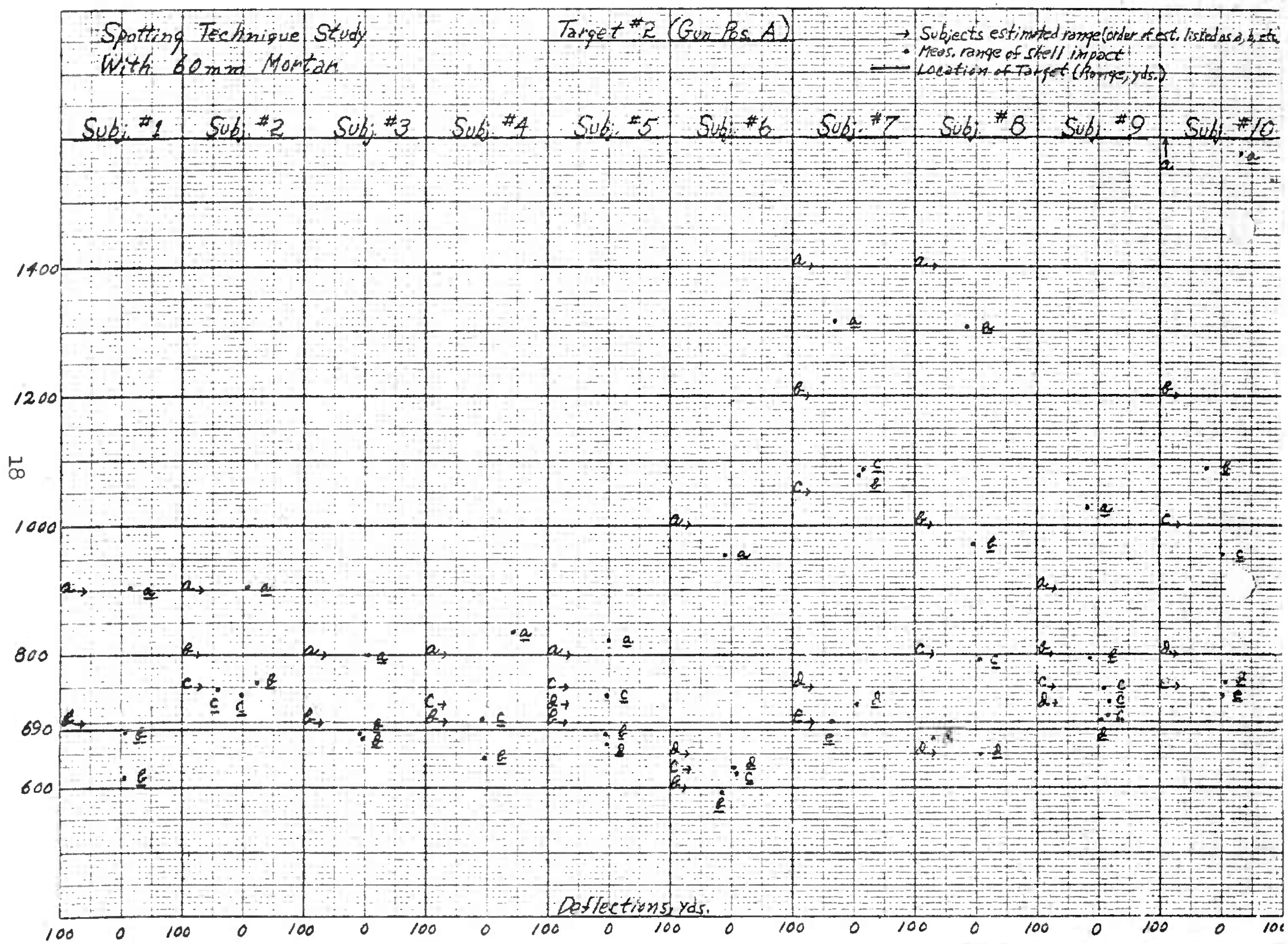
A. D. 15.4% of range (not normally distributed)

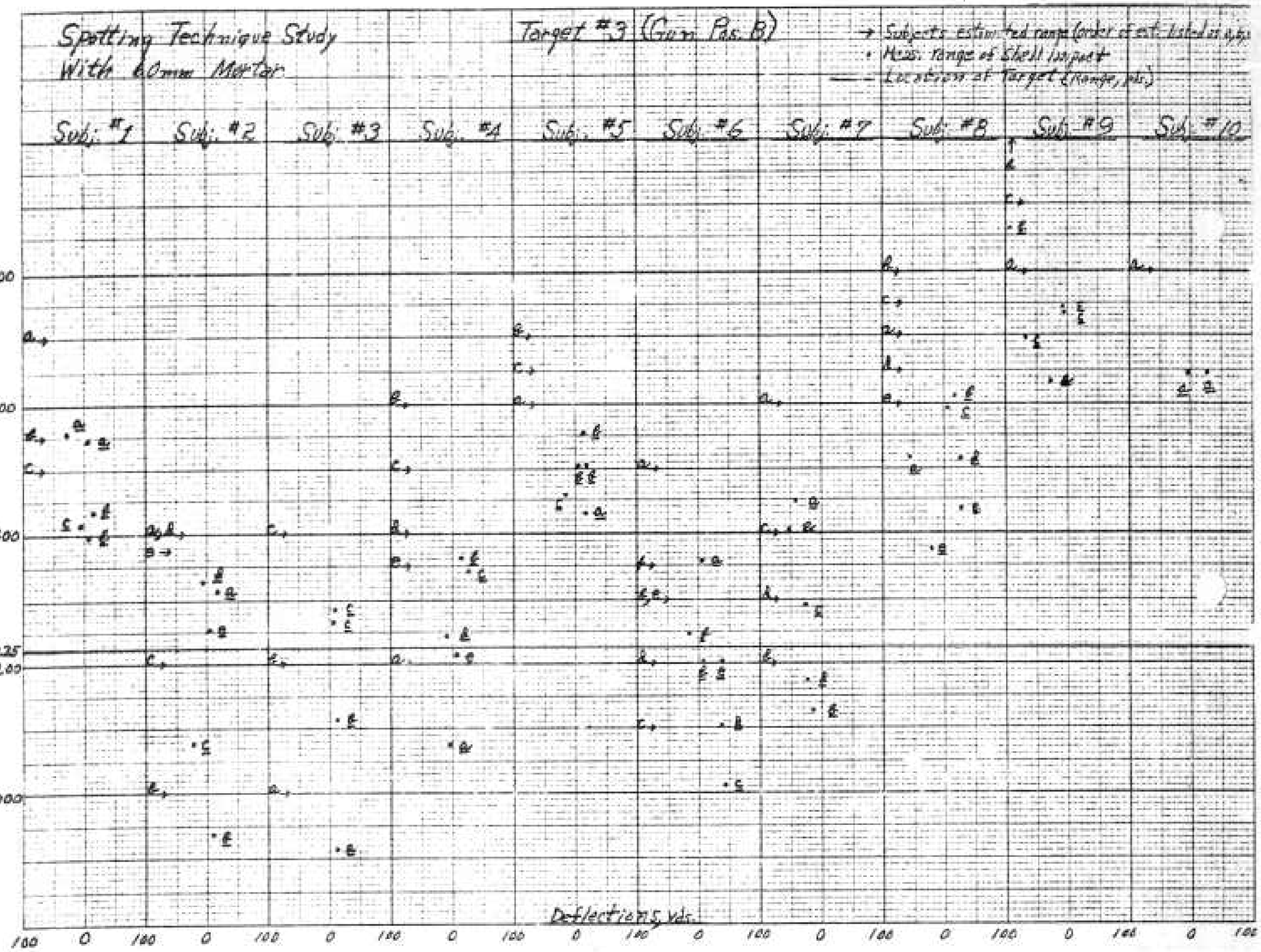
APPENDIX C

RAW DATA

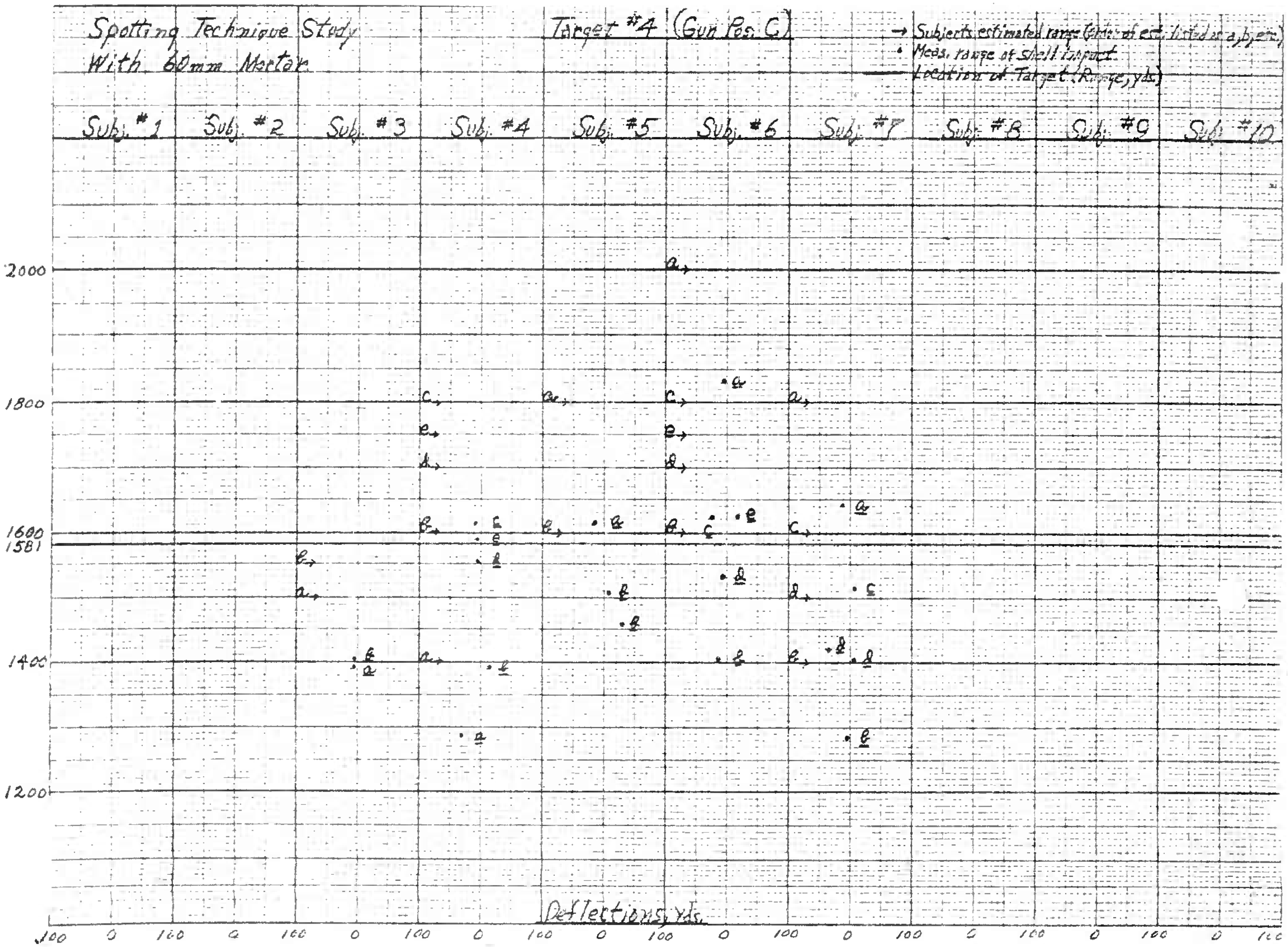
(Pages 17 through 22)

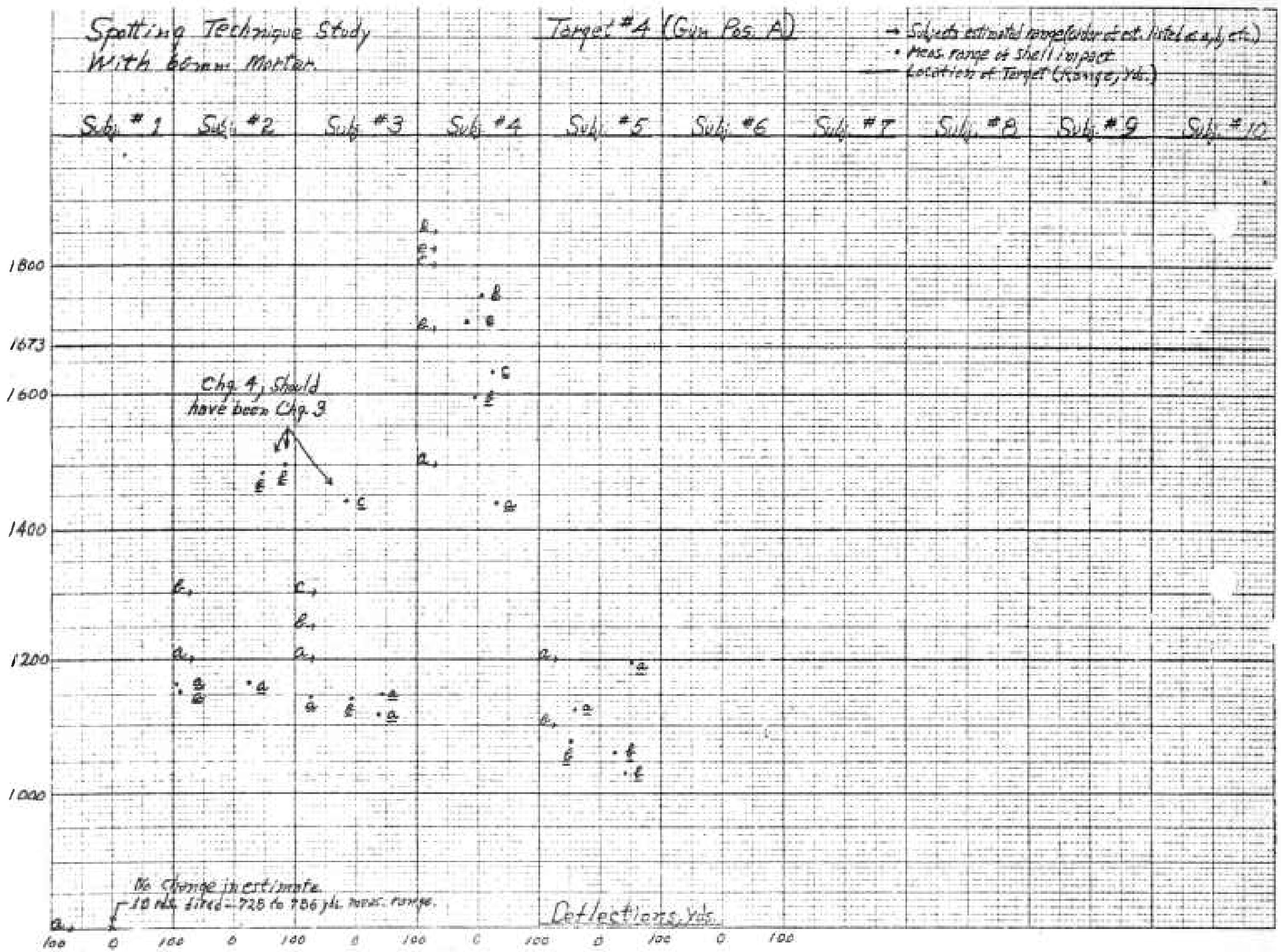

Spotting Technique Study
With 60mm Mortar
Target #1 (Gun Pos. C)
→ Subjects estimated range Center of est. listed as a, b, etc.
• Meas. Range of Shell Impact
— Locations of Target (Range, Yds.)
Subj. #1
Subj. #2
Subj. #3
Subj. #4
Subj. #5
Subj. #6
Subj. #7
Subj. #8
Subj. #9
Subj. #10
Deflections, Yds.
1600
1400
1200
1000
873
800

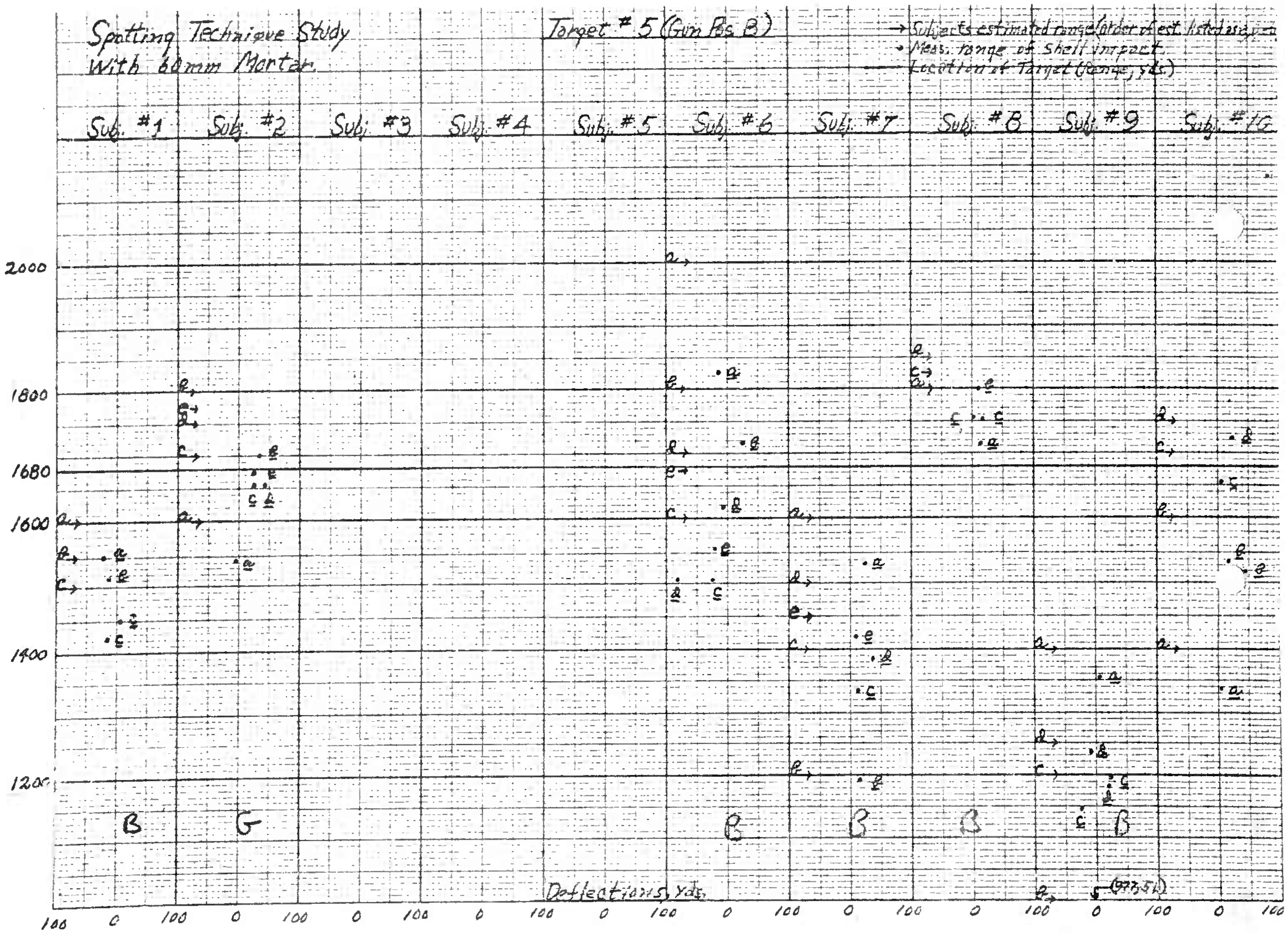

Spotting Technique Study
With 60mm Mortar
Target #2 (Gun Pos. A)
→ Subjects estimated range (order of est. listed as a, b, etc.)
• Meas. range of shell impact
Location of Target (Range, yds.)
Sub. #1
Sub. #2
Sub. #3
Sub. #4
Sub. #5
Sub. #6
Sub. #7
Sub. #8
Sub. #9
Sub. #10
1400
1200
1000
800
690
600
Deflections, Yds.
100 0 100 0 100 0 100 0 100 0 100 0 100 0 100 0 100 0 100 0 100



Spotting Technique Study
With 60mm Mortar
Target #3 (Gun Pos. B)
→ Subjects estimated range
• Meas. range of Shell impact
— Location of Target (Range, yds.)
Sub. #1
Sub. #2
Sub. #3
Sub. #4
Sub. #5
Sub. #6
Sub. #7
Sub. #8
Sub. #9
Sub. #10
1800
1600
1400
1225
1200
1000
Deflections, yds.


Spotting Technique Study
With 60mm Mortar
Target #4 (Gun Pos. C)
→ Subjects estimated range (order of est. listed as a, b, etc.)
• Meas. range of shell impact
— Location of Target (Range, yds.)
Subj. #1
Subj. #2
Subj. #3
Subj. #4
Subj. #5
Subj. #6
Subj. #7
Subj. #8
Subj. #9
Subj. #10
2000
1800
1600
1581
1400
1200
Deflections, Yds.
100
0


Spotting Technique Study
Target #4 (Gun Pos. A)
→ Subjects estimated range (under est. listed a, b, c, etc.)
• Meas. range of shell impact
— Location of Target (Range, Yds.)
Subj. #1
Subj. #2
Subj. #3
Subj. #4
Subj. #5
Subj. #6
Subj. #7
Subj. #8
Subj. #9
Subj. #10
1800
1673
1600
1400
1200
1000
Chg. 4, Should have been Chg. 3
No change in estimate.
10 rds. fired – 725 to 786 yds. meas. range.
Deflections, Yds.


Spotting Technique Study
With 60mm Mortar
Target # 5 (Gun Pos B)
→ Subjects estimated range (order of est. listed a, b, c)
• Meas. range of shell impact
— Location of Target (range, yds)
Subj. #1
Subj. #2
Subj. #3
Subj. #4
Subj. #5
Subj. #6
Subj. #7
Subj. #8
Subj. #9
Subj. #10
2000
1800
1680
1600
1400
1200
Deflections, yds.