No. K-26/67

Technical Memorandum

NAVAL GUNFIRE DISPERSION

M. A. THOMAS
T. E. GOSWICK

COMPUTATION AND ANALYSIS LABORATORY

U. S. Naval Weapons Laboratory
Dahlgren, Virginia

U. S. NAVAL WEAPONS LABORATORY

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M. A. Thomas
T. E. Goswick

Computation and Analysis Laboratory

Approved by:

Ralph A Niemann

RALPH A. NIEMANN
Director, Computation and
Analysis Laboratory

While the contents of this memorandum are considered to be correct, they are subject to modification upon further study.

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ABSTRACT

The memorandum provides estimates of naval gunfire dispersions for the most common projectiles. The source of all data used to compute these estimates as well as the methodology involved is discussed in detail.

FOREWORD

The U. S. Naval Weapons Laboratory, Dahlgren, Virginia, is responsible for the development and application of computer models in the field of amphibious warfare. This work is supported by the Office of Chief of Naval Operations (Op-06C), and is currently being conducted under Task Assignment AIR50300/291-1/F0180501.

INTRODUCTION

Since 1959, the U. S. Naval Weapons Laboratory has been formulating digital simulation models in the area of amphibious warfare. Among those which are now complete are the Supporting Arms (SA) and Firing Assessment (FA) Models (see [23] and [24] for model descriptions). The SA Model is a detailed simulation of the supporting arms phase of an amphibious operation and the FA Model, smaller in scope, is a detailed simulation of a surface-to-surface firing or an air-to-surface strike. Both models require, as basic input, the characteristics of all weapons systems being examined, and the characteristics of prime importance are terminal weapons effects and delivery accuracies. With respect to naval gunfire, much emphasis has been placed on the former. However, delivery accuracy of naval gunfire has received little attention. Reference [26] lists a table of adjusted true mean dispersions as a function of range which are to be used for all naval projectiles. Reference [25] lists average dispersions in mils standard deviation for the 3"/50, 5"/38, 5"/54, 6"/47, and 8"/55 guns without regard to projectile type. Data in both of these references appear to be extremely gross and inadequate for the comparison of weapons systems.

Since early 1966, the laboratory has utilized the SA and FA Models in various studies concerning weapons systems effectiveness. These studies required a closer examination of naval gunfire dispersions which were to be used as input in the aforementioned models. It was for this reason that a set of working papers depicting range dispersions of the 5"/38, 5"/54, 6"/47, 8"/55, and 16"/50 naval guns (see [27]) was assembled.

Copies of these working papers were, upon request, sent to various organizations for whom studies were being conducted. Since that time, the laboratory has received many requests for these papers, for even in the rough form of working papers, they appeared to be more complete with respect to naval gunfire range dispersion than any document in existence. These requests stimulated the publication of this report which is a slight modification and extension of reference [27].

DATA SOURCE

Since the early part of the century, the U. S. Naval Weapons Laboratory (previous to 1959, U. S. Naval Proving Ground), Dahlgren, Virginia, has conducted a large number of test firings of naval guns. Most of the firings were conducted for the purposes of acceptance tests of projectiles, charge determinations, experimental tests of power, erosion checks, calibration of mechanical time fuses, etc. However, some firings were conducted for the sole purpose of determining range table data and, hence, were conducted using "acceptable" tubes and "acceptable" projectiles. It is felt by these authors that one must turn to these data, i.e., ranging data, to obtain reliable estimates of dispersion.

The first source of ranging data is the corresponding range tables, published as Ordnance Pamphlets (OP's), which were based on these firings. While none of the OP's list the actual fall of shot of individual rounds, the older OP's (say, prior to 1950) do list the number of rounds in each group of shots fired under nearly identical conditions, the angle of elevation of the gun, the average range of each group of shots, and the

mean error, D, of each group of shots where

$$D = \frac{\Sigma \left| x_i - \bar{x} \right|}{n} \tag{1}$$

and where x_i is the distance of the actual fall of shot, $\bar{x}$ is the average distance, and n is the number of shots in the group. While the mean error was a standard measure of dispersion when the older OP's were written, a more precise and useful measure of dispersion is given by the sample standard deviation, s, where

$$s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1} \tag{2}$$

While it is impossible to determine s from the mean error, an unbiased estimate of σ, the true or population standard deviation, can be obtained from the mean error. (This will be discussed in the next section.) Hence, the old OP's can be used to estimate σ as a function of range, and they were used as the basis for most of the dispersion data in this report.

A second data source is the actual ranging sheets which list the fall of shot of individual rounds. Many of these sheets have been destroyed over the years. However, a search through the Federal Records Center, Alexandria, Virginia, revealed a considerable amount of raw data still in existence. Analyses of these data are extremely time consuming, for one must first search through the ranging sheets to find rounds that were fired for ranging purposes and not for experimental and/or

acceptance purposes. This was done for only the 16"/45 and 16"/50 naval guns. A search through ranging sheets dated 3 June 1935 to 14 May 1945, detected 196 rounds of 16"/45 and 16"/50 ammunition that were fired for ranging purposes. The merit in using the ranging sheets which list individual fall of shot versus using the OP's which list mean errors for groups of rounds is as follows: (1) The estimate of σ does not have to be based on the mean error; the more precise estimate, s, can be computed from the data. (2) More data are contained in the ranging sheets than in the OP's. (3) An estimate of drift or deflection dispersion can be computed from the individual fall of shot. A measure of deflection dispersion is not contained in the older OP's.

A third data source is the newer OP's (say, post 1949). These publications do not list any data on actual fall of shot. They do list estimates of σ in 1,000 yard increments based on <u>corrected</u> fall of shot. That is, each round was corrected for initial velocity, weight of the projectile, atmospheric conditions, etc., before the standard deviations were computed. The corresponding estimates of σ represent dispersion in gun jump and ballistic coefficient only and do <u>not</u> reflect dispersion that would exist in an actual firing. These data, by themselves, should not be used as estimates of σ; they can, however, be used as lower bounds for σ. To avoid the time involved in searching the ranging sheets for actual fall of shot, these corrected dispersions are listed for the 5"/38 (full charge), 5"/54 (full and reduced charges), 3"/50, and 3"/70 projectiles.

A fourth data source is the OP's which display data in neither of the above two forms. Here, mean errors, range, and pattern size are given for groups of rounds, but angle of elevation is not. There are no indications of whether the mean errors are based on actual fall of shot or corrected fall of shot (see [12] and [13]). Because of the lack of other readily available data, these data were used to estimate dispersion of projectiles fired from the 6"/47 Duel Purpose Gun.

METHODS OF ANALYSES

The method of analysis used for any particular set of data was dependent upon the source of the data. Since various data sources were used, so, too, were various methods of analyses. These methods will be listed as Method 1, Method 2, etc., with the understanding that a method may be no more than a listing of data and not an analysis per se.

Method 1: This method was used to analyze data which were taken from the older Ordnance Pamphlets. As aforementioned, the older range tables (published as OP's) contain range dispersion data on range firings conducted for the preparation of the tables. These data are: the number of rounds in each group which was fired from the same gun at the same angle of elevation during a short interval of time, the angle of elevation of the gun for each group, the average range and mean error of each group of rounds, the pattern of each group of rounds, and the average initial velocity and mean error in initial velocity for each group of rounds. Of these items, the ones used in this method of analysis were angel of elevation of each group, number of rounds in each group, and mean error

of each group. It should be noted that the gun mounts were fixed so that the dispersions, measured in mean errors, do not take fire control systems errors into account. Also, these dispersions do not take into account group to group (between group) variations. The mean errors are measures of dispersions within groups only, all rounds in each group being fired from the same fixed mount during a short interval of time at the same angle of elevation.

Assuming that the fall of shot of individual rounds with respect to range is distributed normally with mean μ and variance $\sigma,^2$ the expected value of the mean error D is $\sqrt{\left(\frac{n-1}{n}\right)\left(\frac{2}{\pi}\right)}\,\sigma$. Hence, a mean error can be converted to an unbiased estimate of σ by multiplication of the factor $\sqrt{\left(\frac{n}{n-1}\right)\left(\frac{\pi}{2}\right)}$ where n is the number of rounds in the group. This procedure was used to convert the mean error of each group to an unbiased estimate of σ, the round to round standard deviation within the group. These estimates of standard deviations could then be plotted against either average range or against angle of elevation. The latter abscissa was felt to provide a more meaningful plot, the rationale being that each group of rounds was fired on a different occasion and, hence, under different meteorological conditions and/or from different tubes. These conditions varied widely and, thus, produced biases in average range from group to group for a given angle of elevation. The varied conditions between groups also caused differences in dispersion, but, it was felt that this dispersion between groups due to these conditions was small in comparison with the dispersion between groups due to

random fluctuations.

The goal in the analysis was to fit a second degree least squares curve to the data. Points on the fitted curve would then provide us with unbiased estimates of range σ for any given angle of elevation within range of the data (provided, of course, that the relationship between angle of elevation and dispersion is quadratic). This would mean that to find an estimate of σ for a given projectile at 10,000 yards range, say, we would have to determine, from range tables, the angle of elevation to obtain 10,000 yards range for this projectile. The dispersion curve would then be evaluated at that angle to obtain an estimate of σ at 10,000 yards range. To avoid this difficulty, all angles of elevation were converted to range in yards under standard conditions and the estimates of σ were plotted against this corrected or theoretical range. A second degree least squares curve was then fit to these data points. See, for example, pages 26, 27, and 28 in the appendix. These pages pertain to the 5"/38 A. A. Common projectile with a reduced charge. Page 26 lists the pertinent data from OP 1285, the corrected or theoretical range for each group and the estimate of σ for each group. Page 27 evaluates the resulting dispersion curve in 1,000 yard increments from the minimum through the maximum ranges for these data. These are unbiased estimates of range σ at each of the given ranges. Page 28 shows a plot of the data (indicated by the circles) and the resulting least squares fit. The results for all projectiles analyzed by this method are displayed in the same fashion.

Method 2: This method of analysis was used when the data source was the actual ranging sheets which list the fall of shot of individual rounds. It was used only for the 16"/45 and 16"/50 projectiles. As aforementioned, a search through ranging sheets dated 3 June 1935 to 14 May 1945, detected 196 rounds of 16"/45 and 16"/50 ammunition that was fired for ranging purposes (see [22]). The rounds were fired from fixed mounts in groups of size 2, 3, 4, and 5. Rounds within each group were fired from the same gun at the same angle of elevation during a short interval of time so that, as before, for all practical purposes, conditions could be considered identical within each group. The analysis then followed the same lines as Method 1 with the following exceptions: (1) The actual fall of shot of individual rounds was used to compute s, the sample standard deviation for each group. While s is a slightly biased estimate of σ, it is more precise, i.e., has a smaller variance than the estimate based on the mean error and for this reason is a better estimate. (2) The actual fall of shot provided means of estimating the drift or deflection dispersions. This was not possible when using data from the OP's. The sample standard deviations were then plotted against the corrected or theoretical range as before except that here we have plots for both range and deflection dispersion. Second degree least square fits were made to the data and the results displayed identical to the results under Method 1 except that estimates of deflection σ are also included.

It will be noted that for the 16"/45 and 16"/50 projectiles using reduced charge, the results are listed for 16"/45-50 projectiles. This is because there were insufficient data for either the 16"/45 or 16"/50 reduced charge

projectiles and the data were pooled.

Method 3: This method was no more than a listing of estimates of dispersion taken from the newer OP's based on corrected fall of shot, i.e., each round was corrected to standard conditions before estimates of σ were computed. A plot of the estimates versus range was also constructed. It was used for the 3"/50, 3"/70, 5"/38 full charge, and 5"/54 full and reduced charge projectiles. See, for example, pages 21 and 22. Page 21 lists the estimates taken from OP 551 (see [3]) and page 22 is a plot of the data. As mentioned earlier, these estimates can be used for lower bounds on σ but should not be used alone as an estimate of dispersion within groups. These data are inconsistent with the other dispersion data in this publication, but the only alternatives were to omit them or search through the actual ranging sheets for ranging data which could be used to compute estimates of σ based on actual fall of shot. Time involved for the latter alternative was prohibitive and rather than omit data on these weapons, the corrected dispersions were included.

Method 4: This method was used to analyze data taken from references [12] and [13] for the 6"/47 Duel Purpose Gun. The method is identical to Method 1 except the angle of fall is not given and, hence, the estimates of σ, based on the listed mean errors, were plotted against the ranges given. These data are not well defined and interpretation of the resulting estimates is impossible.

USE OF DISPERSION DATA

Results of proving ground data of the kind displayed in this report can be used to estimate the single shot hit probability (SSHP) of a naval ordnance firing at a target of area A at any given range. It is first necessary to combine the estimated dispersion given here (round to round dispersion from a fixed mount) with the dispersion due to the fire control system on the ship. This latter dispersion is due to the inability of the fire control system to maintain a constant mean point of impact (MPI) of the fall of shot. Assuming these errors to be independent, they can be combined by forming

$$\sigma_R = \sqrt{\sigma_{SR}^2 + \sigma_{BR}^2}$$

where σ_R = total range dispersion

σ_{SR} = fire control systems range dispersion

σ_{BR} = proving ground round to round range dispersion

Similarly, a total deflection dispersion can be combined by forming

$$\sigma_D = \sqrt{\sigma_{SD}^2 + \sigma_{BD}^2}$$

where σ_D = total deflection dispersion

σ_{SD} = fire control systems deflection dispersion

σ_{BD} = proving ground round to round deflection dispersion

Accurate values of σ_{SR} and σ_{SD} are unknown, but estimates of these values based on professional judgment are given in reference [25]. Estimates of σ_{BD} for some projectiles are given in this report. For those projectiles not given, one can use the mil errors listed in reference [25]. Values

for σ_{BR} and σ_{BD} given in this report for the 3"/50, 3"/70, 5"/38 full charge, and 5"/54 full and reduced charge projectiles should not be used alone for they represent only lower bounds for these values.

Once these estimates of σ_R and σ_D are obtained, it is customary to assume that the fall of shot is distributed according to an uncorrelated bivariate normal distribution so that an estimate of the SSHP can be obtained by evaluating

$$\widehat{SSHP} = \iint_A \frac{1}{2\pi\,\sigma_R\sigma_D}\, e^{-\frac{1}{2}\left[\left(\frac{x}{\sigma_R}\right)^2 + \left(\frac{y}{\sigma_D}\right)^2\right]}\, dx\, dy$$

where x is taken parallel with the gun target line and y is taken perpendicular.

CONCLUSIONS

This report is not a sophisticated treatise on naval gunfire dispersion nor was it intended to be. It was intended to provide naval gunfire analysts with a document containing estimates of naval gunfire dispersion for the most common projectiles. The goodness of these estimates, in many cases, is open to argument. These authors cannot support the data used; we have only analyzed them and presented the results as we have found them.

The first page in the appendix, page 15, lists the 21 projectiles for which estimates of dispersion are given in this report. These are numbered (1) through (21). For each projectile, the first page lists the original data used (this page is omitted where Method 3 was used),

the second page lists the resulting estimates of dispersion and the third page shows a plot of the original data and the least squares fit from which the estimates were taken. The following table lists each method of analysis and data source and the projectiles which pertain to each via the numbering on the first page in the appendix.

1st Data Source Method 1	2nd Data Source Method 2	3rd Data Source Method 3	4th Data Source Method 4
(4)	(18)	(1)	(12)
(5)	(19)	(2)	(13)
(8)	(20)	(3)	-
(9)	(21)	(6)	-
(10)	-	(7)	-
(11)	-	-	-
(14)	-	-	-
(15)	-	-	-
(16)	-	-	-
(17)	-	-	-

REFERENCES

[1] NAVORD OP 1795 (second revision), Range Table for 3-Inch 50-Caliber Gun Firing Projectile Mark 33 Mod 0 (Surface Targets), 15 September 1966.

[2] OP 1872, Range Table for 3-Inch 70-Caliber Gun Firing HE-VT Projectile Mark 34 Mods 1, 2, and 3 (Surface Targets), 7 October 1959.

[3] OP 551 (third revision), Range Table for 5-Inch 38-Caliber Gun Mark 12 Firing FCL(VT) Projectile Mark 49 and Mods (Surface Targets), 10 May 1958.

[4] OP 1285 (first revision), Range Table for 5-Inch 38-Caliber Gun, 1200 F. S. Initial Velocity, A. A. Common Projectile Mark 35, 26 September 1945.

[5] Ordnance Pamphlet 1487, Range Table for 5-Inch 38-Caliber Gun, 2600 F. S. Initial Velocity, 53-lb. W. P. Smoke Projectile, 17 April 1945.

[6] OP 1182 (first revision), Range Table for 5-Inch 54-Caliber Guns, Mark 16 and Mark 18, Firing FCL(VT) Projectile Mark 41 and Mods (Surface Targets), 24 March 1958.

[7] NAVORD OP 3495, Range Table for 5-Inch 54-Caliber Guns Firing Projectile Mark 41 and Mods with Reduced Charges (Surface Targets), 15 January 1967.

[8] Ordnance Pamphlet No. 830 (first revision), Range Table for 6-Inch 47-Caliber Gun, 2500 F. S. Initial Velocity, 130-Pound Armor-Piercing Projectile, 6 January 1944.

[9] OP 1008 (first revision), Range Table for 6-Inch 47-Caliber Gun, 2665 F. S. Initial Velocity 105-lb. High Capacity Projectile, 28 September 1945.

[10] Ordnance Pamphlet No. 832 (first revision), Range Table for 6-Inch 47-Caliber Gun, 2050 F. S. Initial Velocity, 130-Pound Projectiles, 7 March 1944.

[11] Ordnance Pamphlet 1366, Range Table for 6-Inch 47-Caliber Gun, 2225 F. S. Initial Velocity, 105-lb. H. C. Projectile, 28 July 1945.

[12] OP 1612, Range Table (Surface Targets) for 6-Inch 47-Caliber DP Gun, 2565 F. S. Initial Velocity, 105-lb. High Capacity Projectile Mark 39, 28 April 1947.

[13] OP 1614, Range Table (Surface Targets) for 6-Inch 47-Caliber DP Gun, 2125 F. S. Initial Velocity, 105-lb. High Capacity Mark 39, 28 April 1947.

[14] Ordnance Pamphlet No. 807, 8-Inch Range Table, 2500 F. S. Initial Velocity, to 30,500 Yards, January 1942.

[15] Ordnance Pamphlet No. 1041 (first revision), Range Table for 8-Inch 55-Caliber Gun, 260-Pound High-Capacity Projectile, I. V. 2700 and 2800 F. S., 1 March 1944.

[16] Ordnance Pamphlet No. 858, 8-Inch Range Table, 2000 F. S. Initial Velocity, May 1942.

[17] Ordnance Pamphlet 1333, Range Table for 8-Inch 55-Caliber Gun, 2200 F. S. Initial Velocity, 260-Pound H. C. Projectile, 27 November 1944.

[18] Ordnance Pamphlet No. 770, 16-Inch Range Table, 2500 F. S. Initial Velocity, to 42,345 Yards, October 1941.

[19] Ordnance Pamphlet No. 1100, Range Table for 16-Inch 50-Caliber Gun, 2690 F. S. Initial Velocity, 1900-Pound High-Capacity Projectile, 8 December 1943.

[20] Ordnance Pamphlet No. 758, 16-Inch Range Table, 1800 F. S. Initial Velocity, to 23,930 Yards, October 1940.

[21] Ordnance Pamphlet 1543, Range Table for 16-Inch 45- and 50-Caliber Guns, 2075 F. S. Initial Velocity, 1900-lb. H. C. Projectile, 21 June 1945.

[22] Container No. 5, National Archives and Records Service, 16"/45 and 16"/50 Range Sheets #143-577, 3 June 1935 - 14 May 1945.

[23] Thomas, M. A., and Hornbaker, G. E., The Supporting Arms Model, NWL Unclassified Technical Memorandum No. K-28/64, June 1964.

[24] Hornbaker, G. E., and Goswick, T. E., The Firing Assessment Model, Description and User's Guide, NWL Unclassified Technical Memorandum No. K-29/65, February 1965.

[25] Department of the Navy, Office of the Chief of Naval Operations, U. S. Navy (Including Marine Air) Combat Consumable Requirements (Non-Nuclear Ordnance Study (U), Second Edition, Volume 5, Secret.

[26] . . ., NWIP 22-2(A), Supporting Arms in Amphibious Operations (U), Supplement, Confidential.

[27] Thomas, M. A., and Goswick, T. E., Naval Gunfire Dispersion, NWL Working Papers, February 1966.

APPENDIX

The following is a list of the dispersion data contained in this appendix:

(1) 3"/50, A. A. Projectile, Range and Deflection Dispersion.

(2) 3"/70, HE-VT Projectile, Range Dispersion.

(3) 5"/38, FCL(VT) Projectile, Full Charge, Range Dispersion.

(4) 5"/38, W. P. Smoke Projectile, Full Charge, Range Dispersion.

(5) 5"/38, A. A. Common Projectile, Reduced Charge, Range Dispersion.

(6) 5"/54, FCL(VT) Projectile, Full Charge, Range Dispersion.

(7) 5"/54, FCL(VT) Projectile, Reduced Charge, Range and Deflection Dispersion.

(8) 6"/47, AP Projectile, Full Charge, Range Dispersion.

(9) 6"/47, HC Projectile, Full Charge, Range Dispersion.

(10) 6"/47, AP Projectile, Reduced Charge, Range Dispersion.

(11) 6"/47, HC Projectile, Reduced Charge, Range Dispersion.

(12) 6"/47 DP, HC Projectile, Full Charge, Range Dispersion.

(13) 6"/47 DP, HC Projectile, Reduced Charge, Range Dispersion.

(14) 8"/55, AP Projectile, Full Charge, Range Dispersion.

(15) 8"/55, HC Projectile, Full Charge, Range Dispersion.

(16) 8"/55, AP Projectile, Reduced Charge, Range Dispersion.

(17) 8"/55, HC Projectile, Reduced Charge, Range Dispersion.

(18) 16"/50, AP Projectile, Full Charge, Range and Deflection Dispersion.

(19) 16"/50, HC Projectile, Full Charge, Range and Deflection Dispersion.

(20) 16"/45-50, AP Projectile, Reduced Charge, Range and Deflection Dispersion.

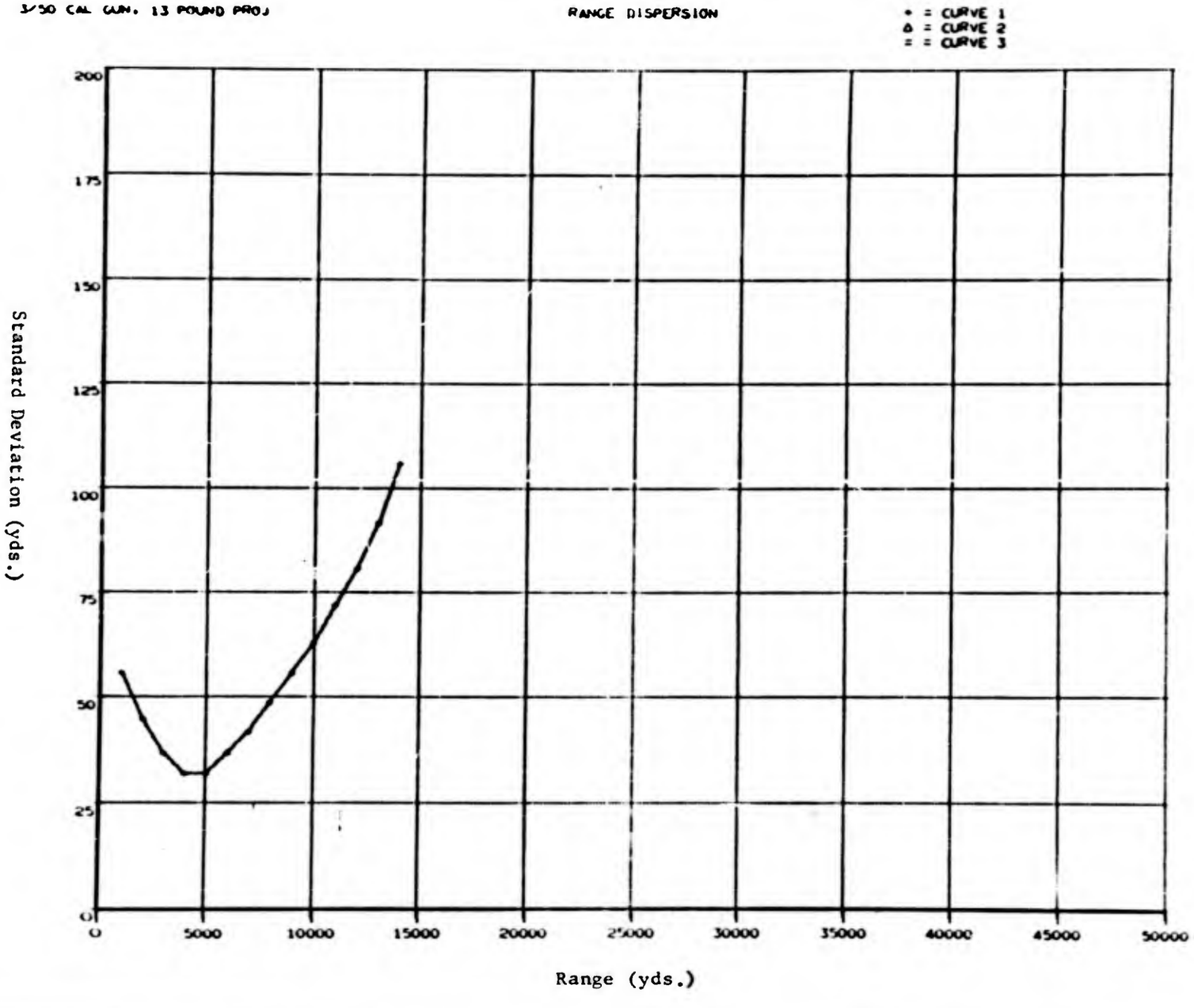
(21) 16"/45-50, HC Projectile, Reduced Charge, Range and Deflection Dispersion.

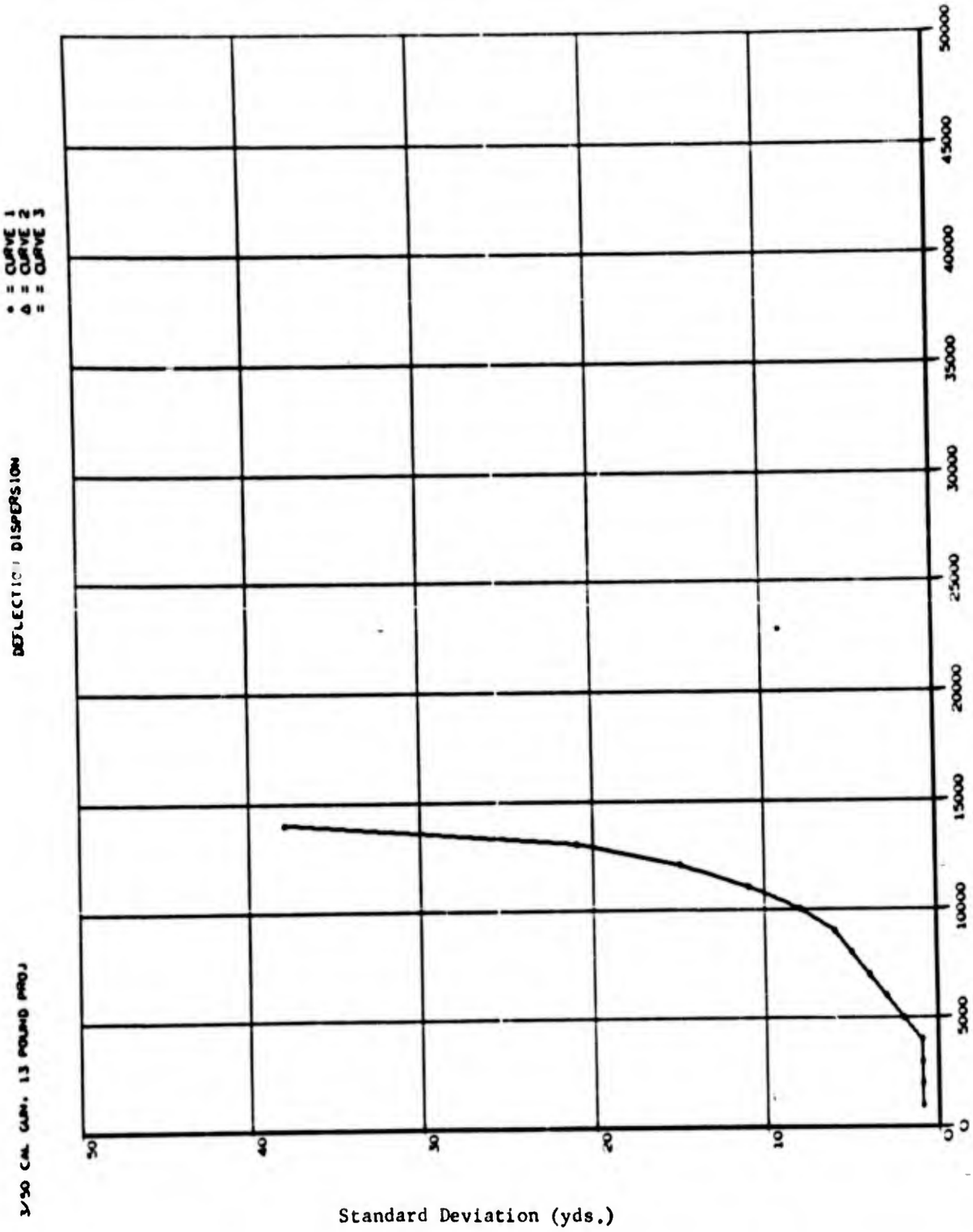
3"/50 Caliber Gun
Type Projectile: Mark 33 (A.A. Projectile - 13 lbs.)
Initial Velocity: 2650 ft/sec

Estimated Dispersion

Range (yds.)	Standard Deviation (yds.) Range	Deflection
1,000	56	1
2,000	45	1
3,000	37	1
4,000	32	1
5,000	32	2
6,000	37	3
7,000	42	4
8,000	49	5
9,000	56	6
10,000	63	8
11,000	72	11
12,000	81	15
13,000	92	21
14,000	106	38

See [1]


3/50 CAL GUN. 13 POUND PROJ
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Standard Deviation (yds.)
Range (yds.)

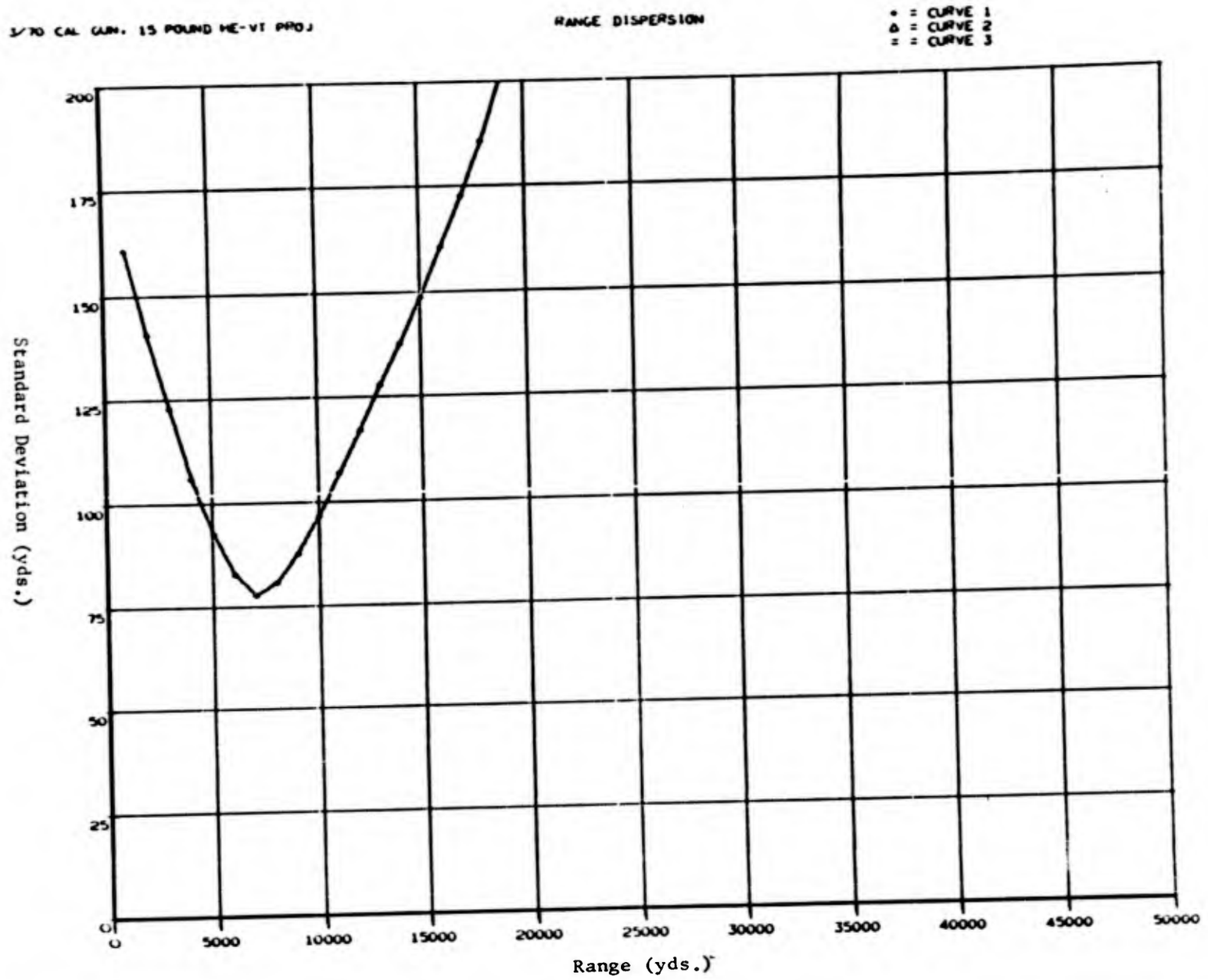

50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
50
40
30
20
10
0
Range (yds.)
Standard Deviation (yds.)
DEFLECTION DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
.50 CAL. GUN, 13 POUND PROJ

3"/70 Caliber Gun
Type Projectile: Mark 34 (HE-VT - 15 lbs.)
Initial Velocity: 3400 ft/sec

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
1,000	161
2,000	141
3,000	123
4,000	106
5,000	93
6,000	83
7,000	78
8,000	81
9,000	88
10,000	97
11,000	107
12,000	117
13,000	128
14,000	138
15,000	149
16,000	161
17,000	173
18,000	186
19,000	202
20,000	222

See [2]

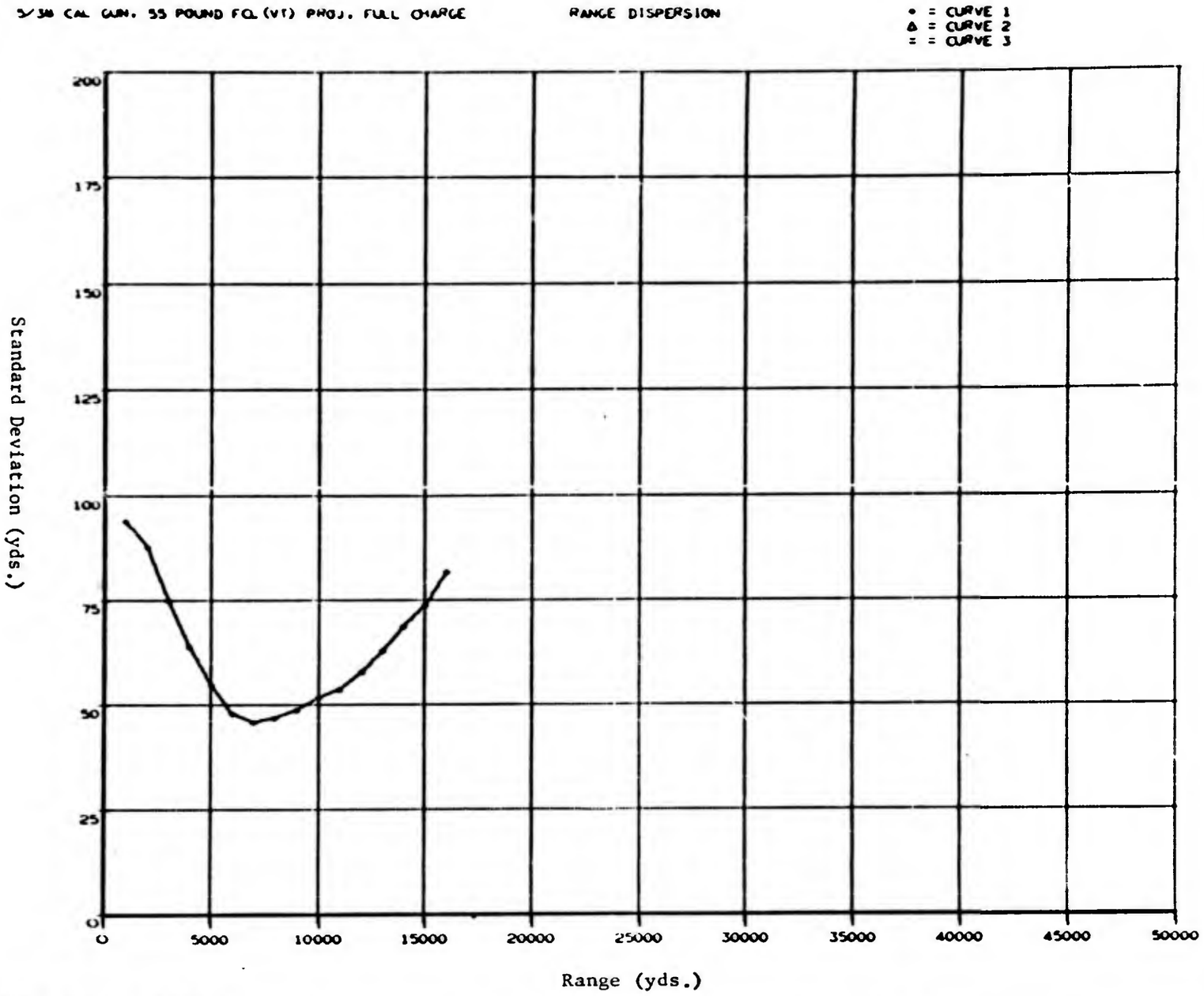

1/70 CAL GUN. 15 POUND HE-VT PROJ
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

5"/38 Caliber Gun, Mark 12
Type Projectile: Mark 49 [FCL(VT)-55 lbs.]
Full Charge (Initial Velocity: 2500 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
1,000	94
2,000	88
3,000	75
4,000	64
5,000	55
6,000	48
7,000	46
8,000	47
9,000	49
10,000	52
11,000	54
12,000	58
13,000	63
14,000	69
15,000	74
16,000	82

See [3]


3/38 CAL GUN. 55 POUND FOL (VT) PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Standard Deviation (yds.)
Range (yds.)

5"/38 Caliber Gun
Type Projectile Fired: Mark 30 (W.P. Smoke Projectile - 53 lbs.)
Full Charge (Initial Velocity: 2600 ft/sec)

Original Data

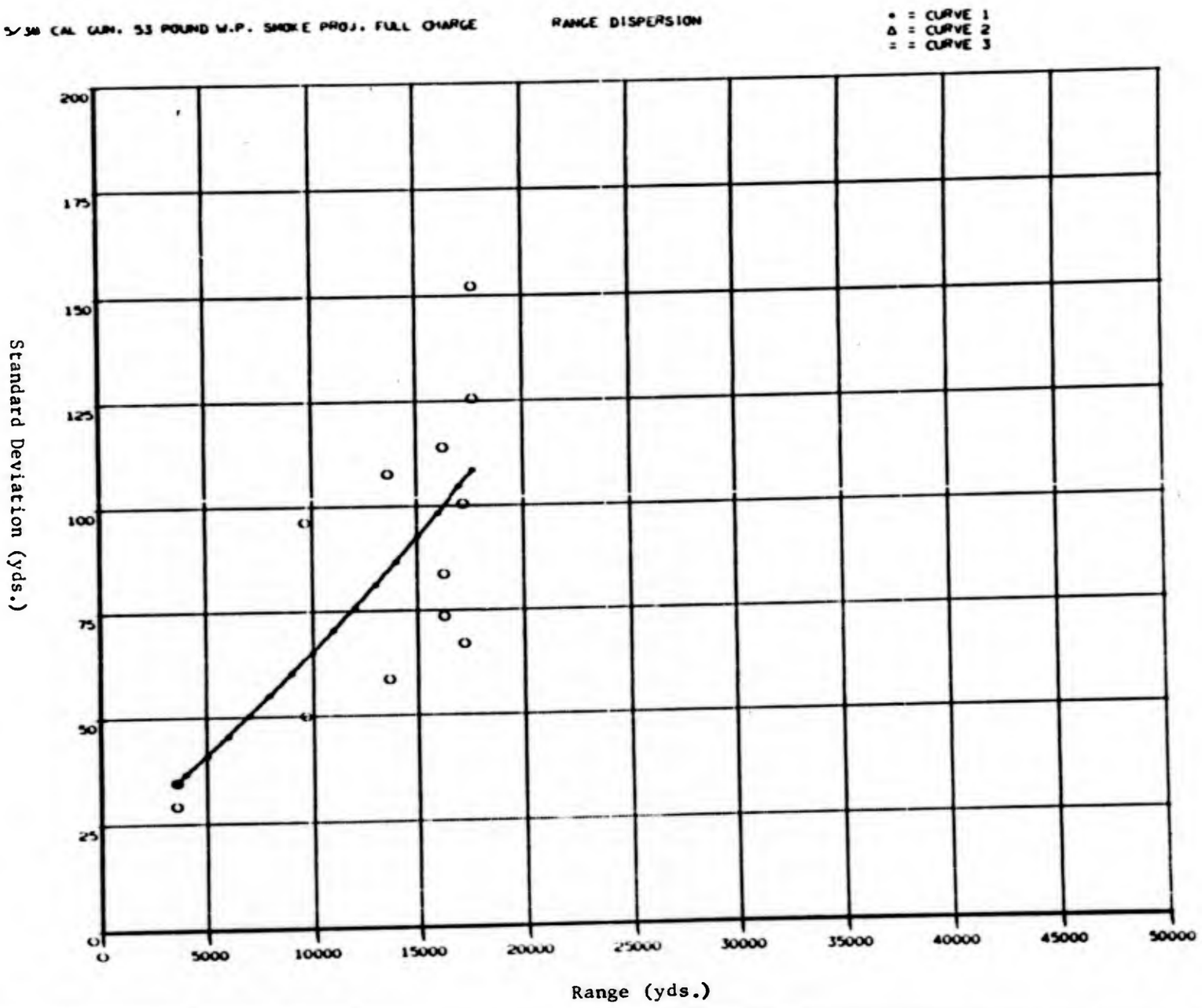
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
3716	5	2°	3,553	29.4
3770	5	2° 01′	3,577	35.0
3716	5	10°	9,683	96.7
3770	5	10° 01′	9,692	50.4
3731	5	20°	13,632	107.9
3770	5	20° 01′	13,637	58.9
3731	4	30°	16,210	114.3
3716	3	30°	16,210	73.7
3770	5	30° 01′	16,213	84.1
3731	5	36°	17,159	100.9
3770	5	36° 01′	17,161	67.3
3731	6	50°	17,648	152.4
3770	2	50° 01′	17,648	125.8

See [5] and extractions from NWL ranging sheets listed above.

5"/38 Caliber Gun
Type Projectile Fired: Mark 30 (W.P. Smoke Projectile - 53 lbs.)
Full Charge (Initial Velocity: 2600 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
3,553	35
4,000	37
5,000	41
6,000	46
7,000	51
8,000	56
9,000	60
10,000	66
11,000	71
12,000	76
13,000	82
14,000	87
15,000	93
16,000	99
17,000	105
17,648	109


.30 CAL GUN. 53 POUND W.P. SMOKE PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
25
50
75
100
125
150
175
200
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

5"/38 Caliber Gun
Type Projectile Fired: Mark 35 (A. A. Common Projectile - 54 lbs.)
Reduced Charge (Initial Velocity: 1200 ft/sec)

Original Data

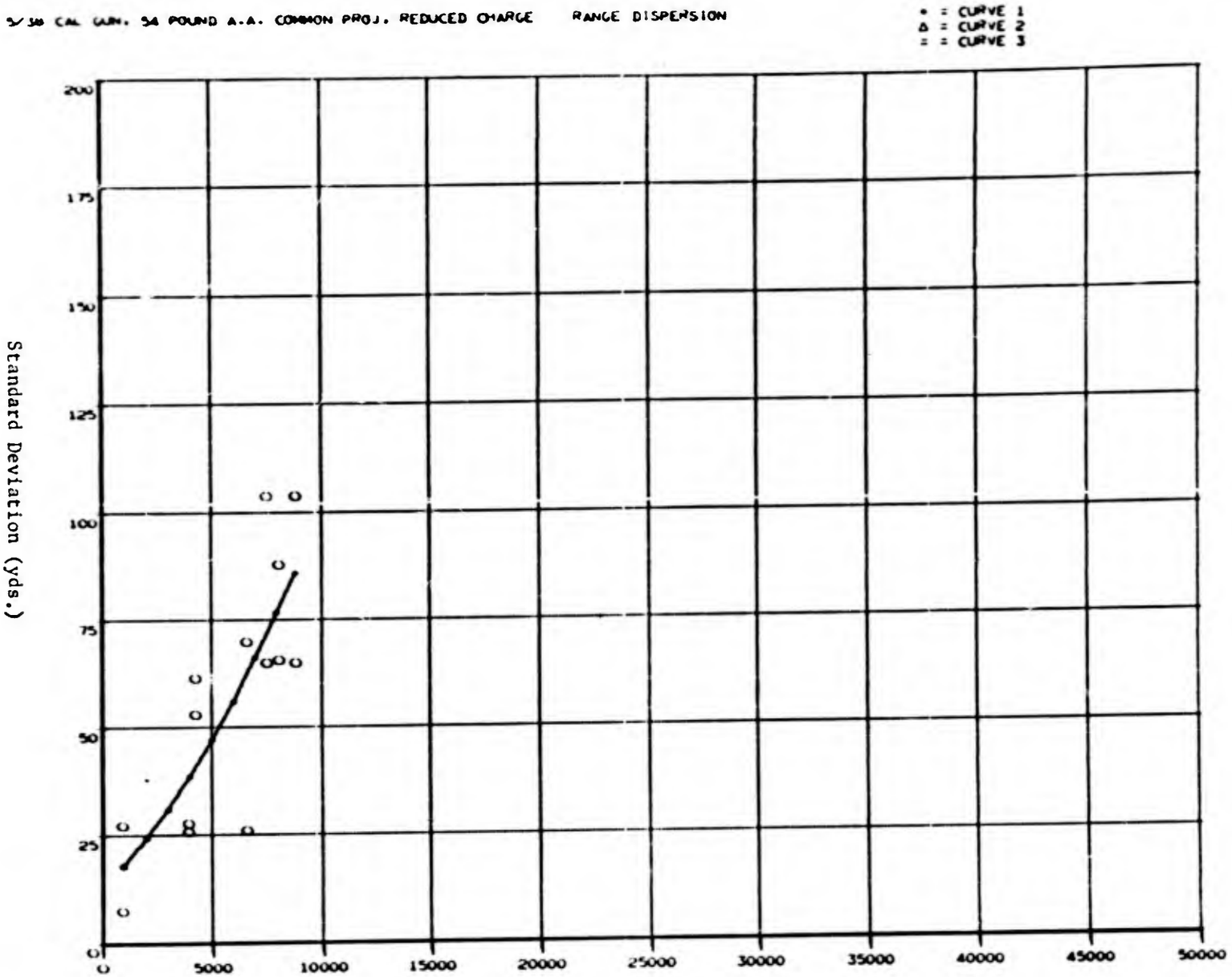
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
3,565	4	2°	939	27.5
3,572	3	2°	939	7.7
3,565	5	10°	3929	28.0
3,572	4	10°	3929	26.0
3,565	3	20° 30′	6600	26.1
3,572	5	20° 30′	6600	70.0
3,565	4	30°	8104	88.3
3,572	5	30°	8104	65.8
3,565	5	45°	8830	103.7
3,572	4	45°	8830	65.1
3,565	5	60°	7557	103.7
3,572	4	60°	7557	65.1
3,565	5	75°	4268	53.2
3,572	5	75°	4268	61.6

See [4] and extractions from NWL ranging sheets listed above.

5"/38 Caliber Gun
Type Projectile Fired: Mark 35 (A. A. Common Projectile - 54 lbs.)
Reduced Charge (Initial Velocity: 1200 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
939	18
1,000	18
2,000	24
3,000	31
4,000	39
5,000	47
6,000	56
7,000	66
8,000	77
8,830	86

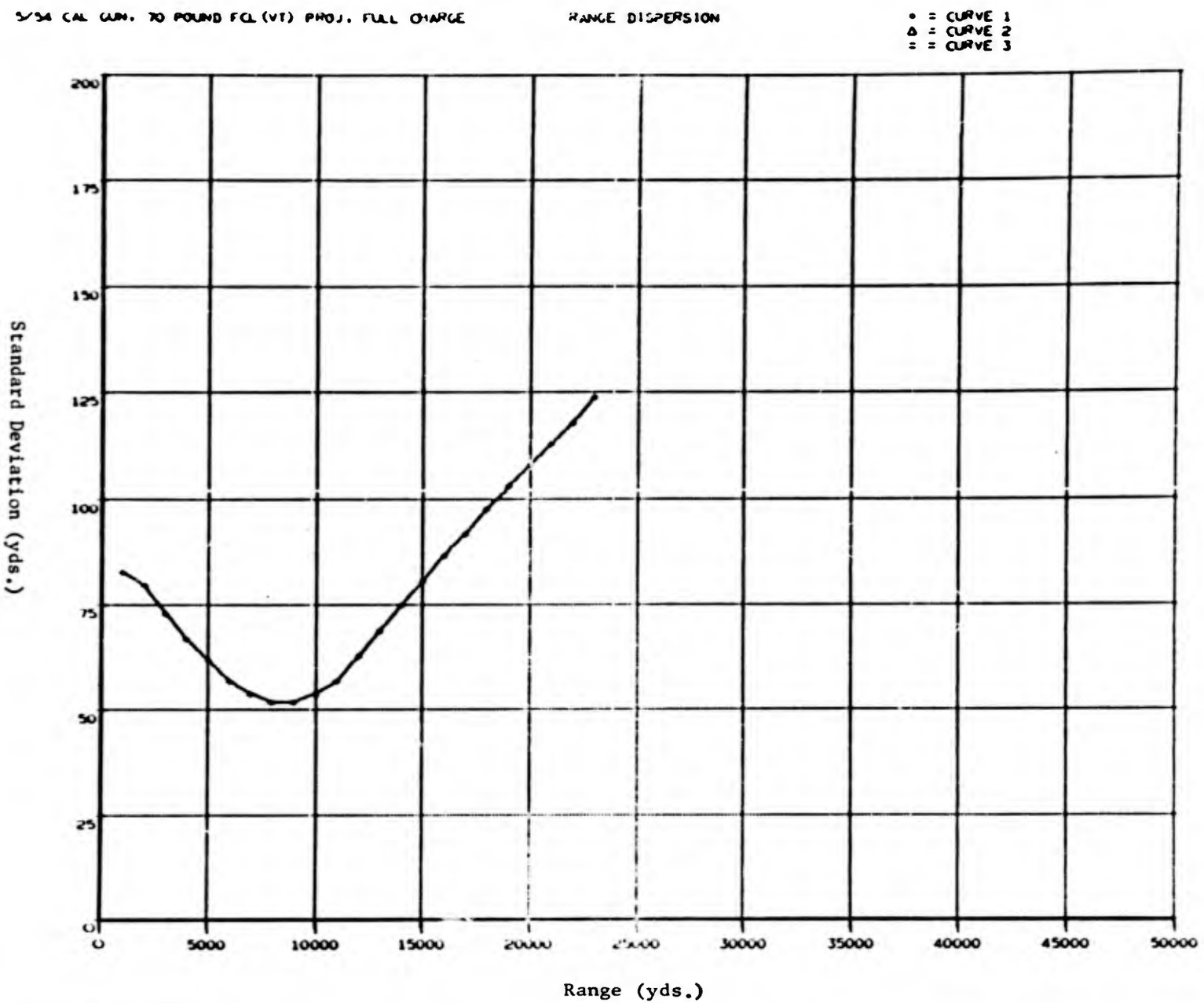

90 CAL GUN. 54 POUND A.A. COMMON PROJ. REDUCED CHARGE RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= CURVE 3
Standard Deviation (yds.)
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

5"/54 Caliber Gun, Mark 16, 18
Type Projectile: Mark 41 [FCL(VT)-70 lbs.]
Full Charge (Initial Velocity: 2500 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
1,000	83
2,000	80
3,000	73
4,000	67
5,000	62
6,000	57
7,000	54
8,000	52
9,000	52
10,000	54
11,000	57
12,000	63
13,000	69
14,000	75
15,000	81
16,000	87
17,000	92
18,000	98
19,000	103
20,000	108
21,000	113
22,000	118
23,000	124

See [6]

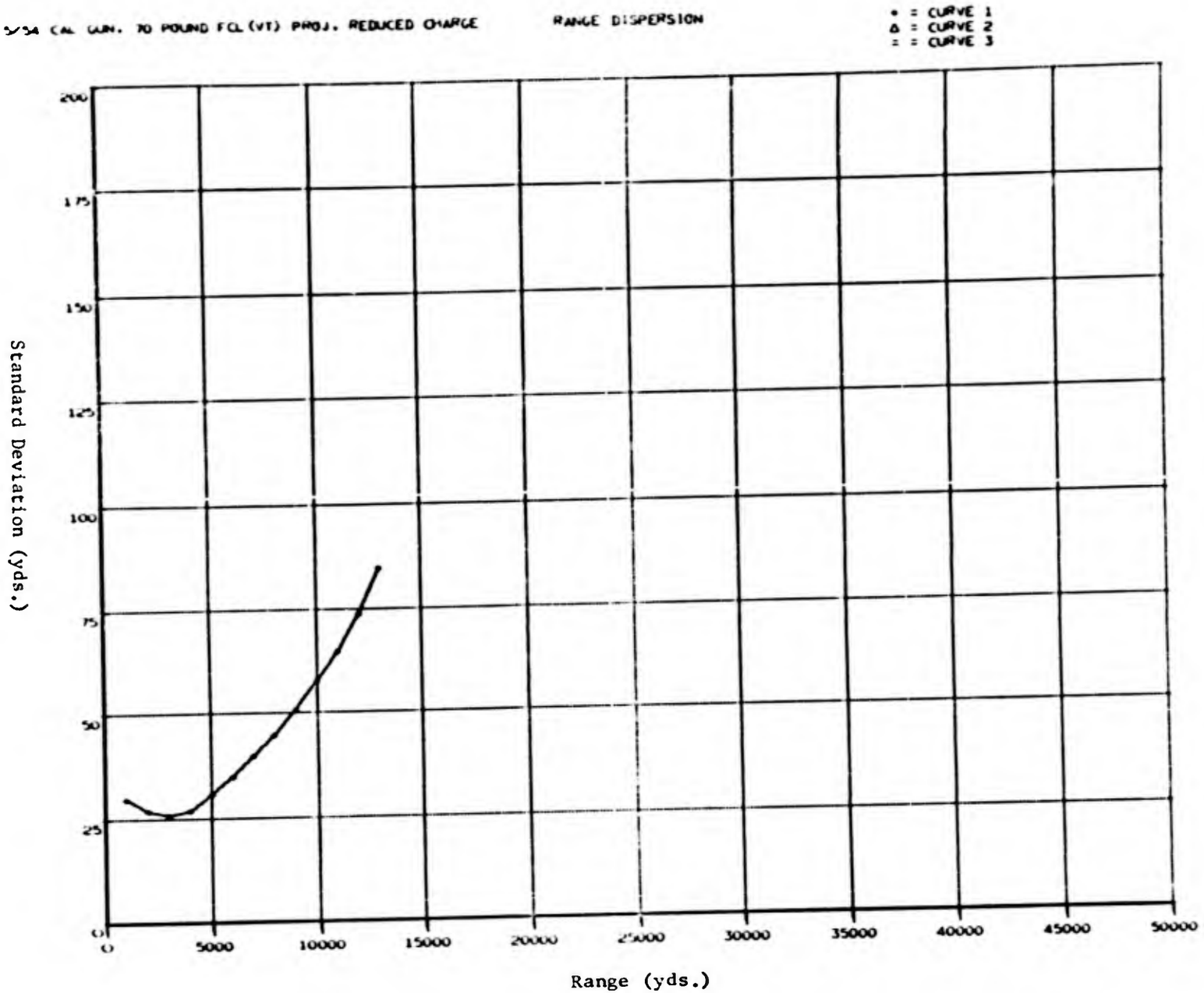

5/54 CAL GUN. 70 POUND FCL (VT) PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

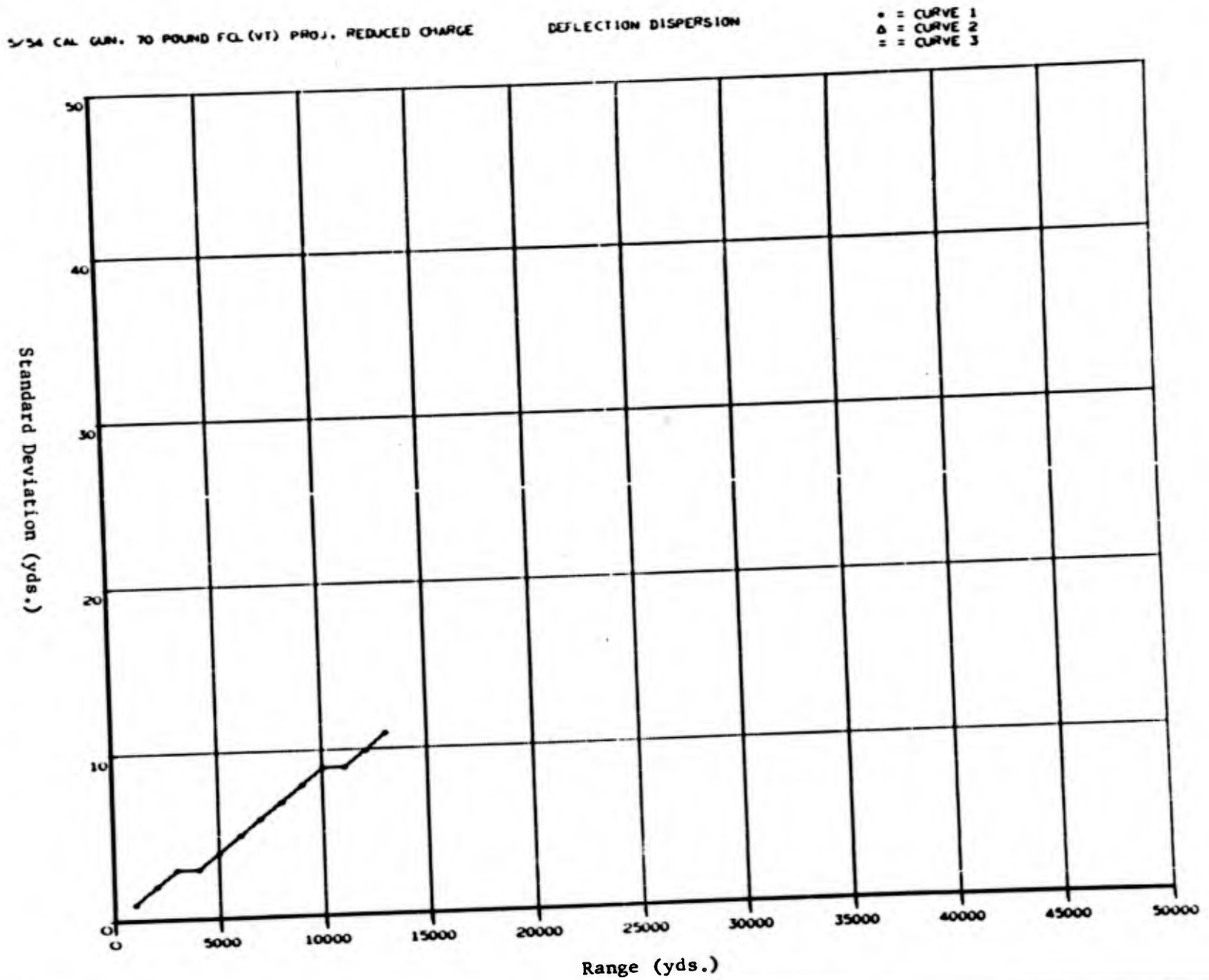
5"/54 Caliber Gun
Type Projectile: Mark 41 [FCL(VT)-70 lbs.]
Reduced Charge (Initial Velocity: 1500 ft/sec)

Estimated Dispersion

Range (yds.)	Standard Deviation (yds.)	
	Range	Deflection
1,000	30	1
2,000	27	2
3,000	26	3
4,000	27	3
5,000	31	4
6,000	35	5
7,000	40	6
8,000	45	7
9,000	51	8
10,000	58	9
11,000	65	9
12,000	74	10
13,000	85	11

See [7]


CAL GUN. 70 POUND FCL (VT) PROJ. REDUCED CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= CURVE 3
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Standard Deviation (yds.)
Range (yds.)


5/54 CAL GUN. 70 POUND FCL (VT) PROJ. REDUCED CHARGE
DEFLECTION DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
50
40
30
20
10
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

6"/47 Caliber Gun, Mark 16
Type Projectile Fired: Mark 36 (AP Projectile - 130 lbs.)
Full Charge (Initial Velocity: 2500 ft/sec)

Original Data

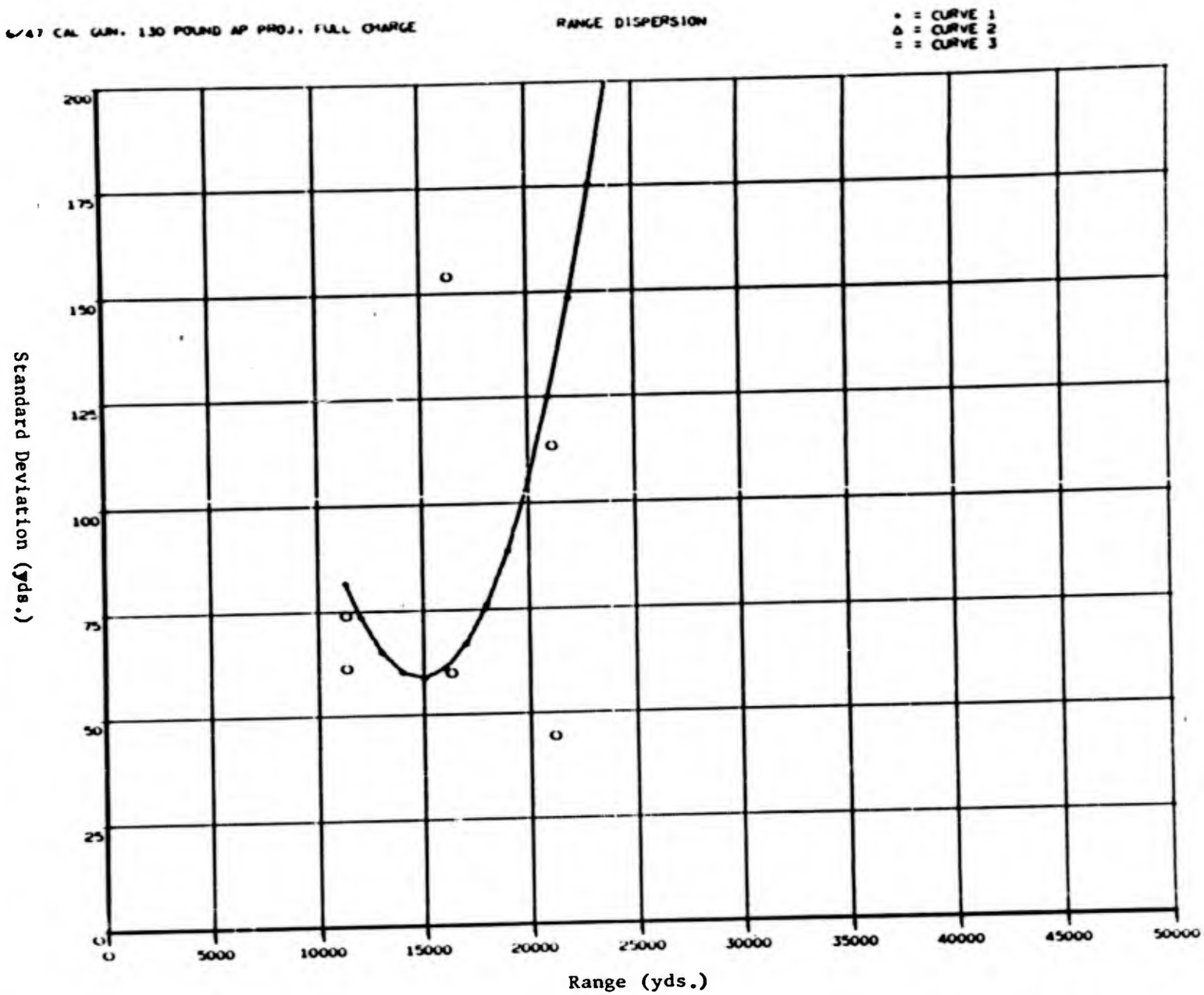
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
474	5	8	11,285	74.2
480	5	8	11,285	61.6
474	5	15	16,307	60.2
480	5	15	16,307	154.1
476	5	25	21,127	44.8
481	5	25	21,127	113.5
481	5	39	25,275	285.8
476	5	40	25,485	259.2

See [8] and extractions from NWL ranging sheets listed above.

6"/47 Caliber Gun, Mark 16
Type Projectile Fired: Mark 36 (AP Projectile - 130 lbs.)
Full Charge (Initial Velocity: 2500 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
11,285	82
12,000	74
13,000	65
14,000	60
15,000	59
16,000	61
17,000	67
18,000	76
19,000	89
20,000	105
21,000	125
22,000	149
23,000	176
24,000	206
25,000	240
25,485	258


CAL GUN. 130 POUND AP PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
25
50
75
100
125
150
175
200
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

6"/47 Caliber Gun, Mark 16
Type Projectile Fired: Mark 34 (HC Projectile - 105 lbs.)
Full Charge (Initial Velocity: 2665 ft/sec)

Original Data

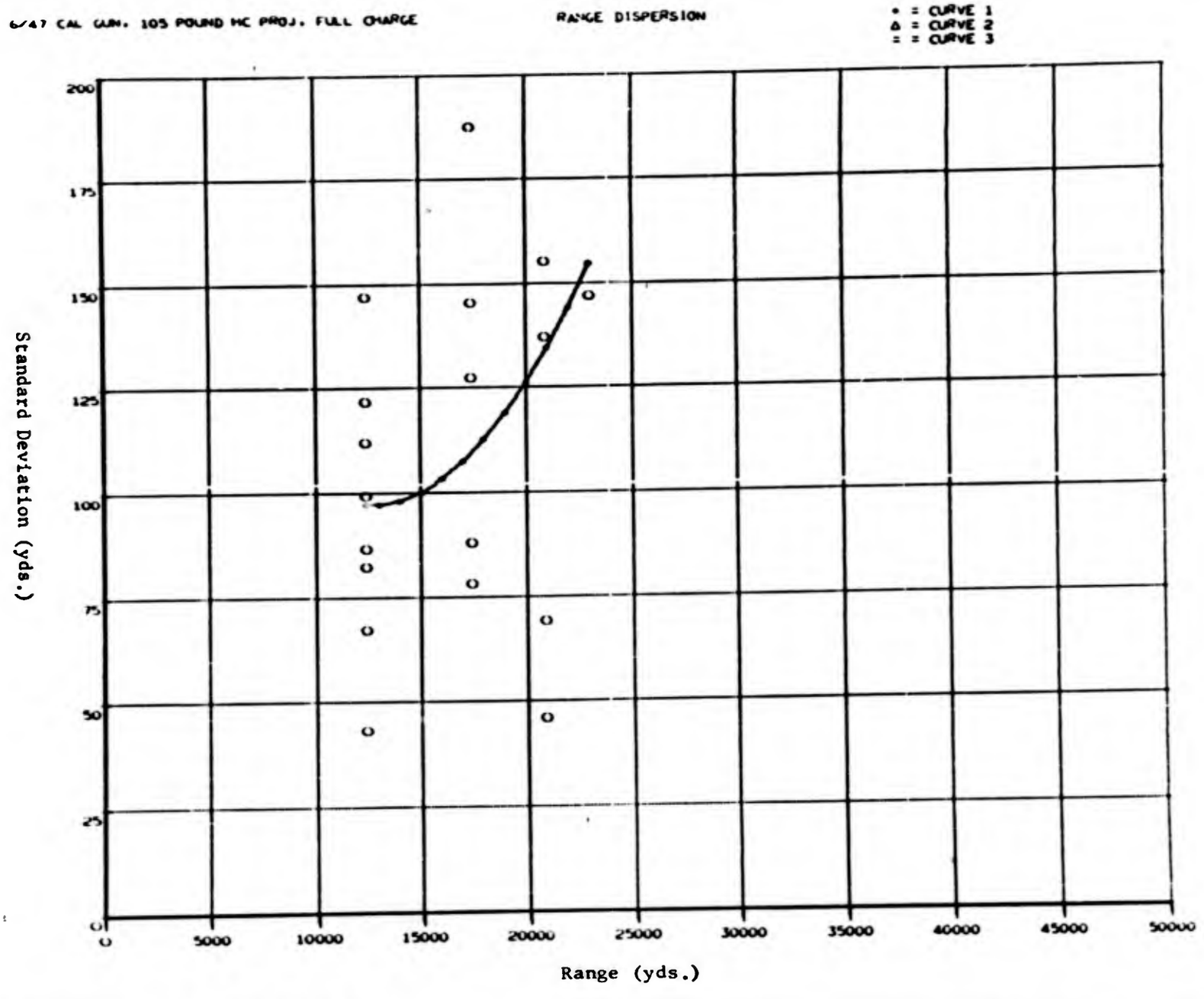
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
551	5	10°	12,336	112.1
551	5	10°	12,336	121.9
552	5	10°	12,336	147.1
553	5	10°	12,336	82.6
553	5	10°	12,336	43.4
559	5	10°	12,336	99.5
572	5	10°	12,336	67.5
572	5	10°	12,336	86.9
568	5	20°	17,393	78.4
568	5	20°	17,393	145.7
568	5	20°	17,393	127.5
572	5	20°	17,393	187.7
572	5	20°	17,393	88.3
570	4	30°	20,886	46.3
570	5	30°	20,886	137.3
572	5	30°	20,886	155.4
572	4	30°	20,886	69.4
568	5	40°	23,025	147.1
572	4	40°	23,025	225.1

See [9] and extractions from NWL ranging sheets listed above.

6"/47 Caliber Gun, Mark 16
Type Projectile Fired: Mark 34 (HC Projectile - 105 lbs.)
Full Charge (Initial Velocity: 2665 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
12,336	97
13,000	97
14,000	98
15,000	100
16,000	103
17,000	107
18,000	113
19,000	119
20,000	126
21,000	135
22,000	144
23,000	155
23,025	155


6/47 CAL GUN. 105 POUND HC PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

6"/47 Caliber Gun
Type Projectile Fired: Mark 36 (AP Projectile - 130 lbs.)
Reduced Charge (Initial Velocity: 2050 ft/sec)

Original Data

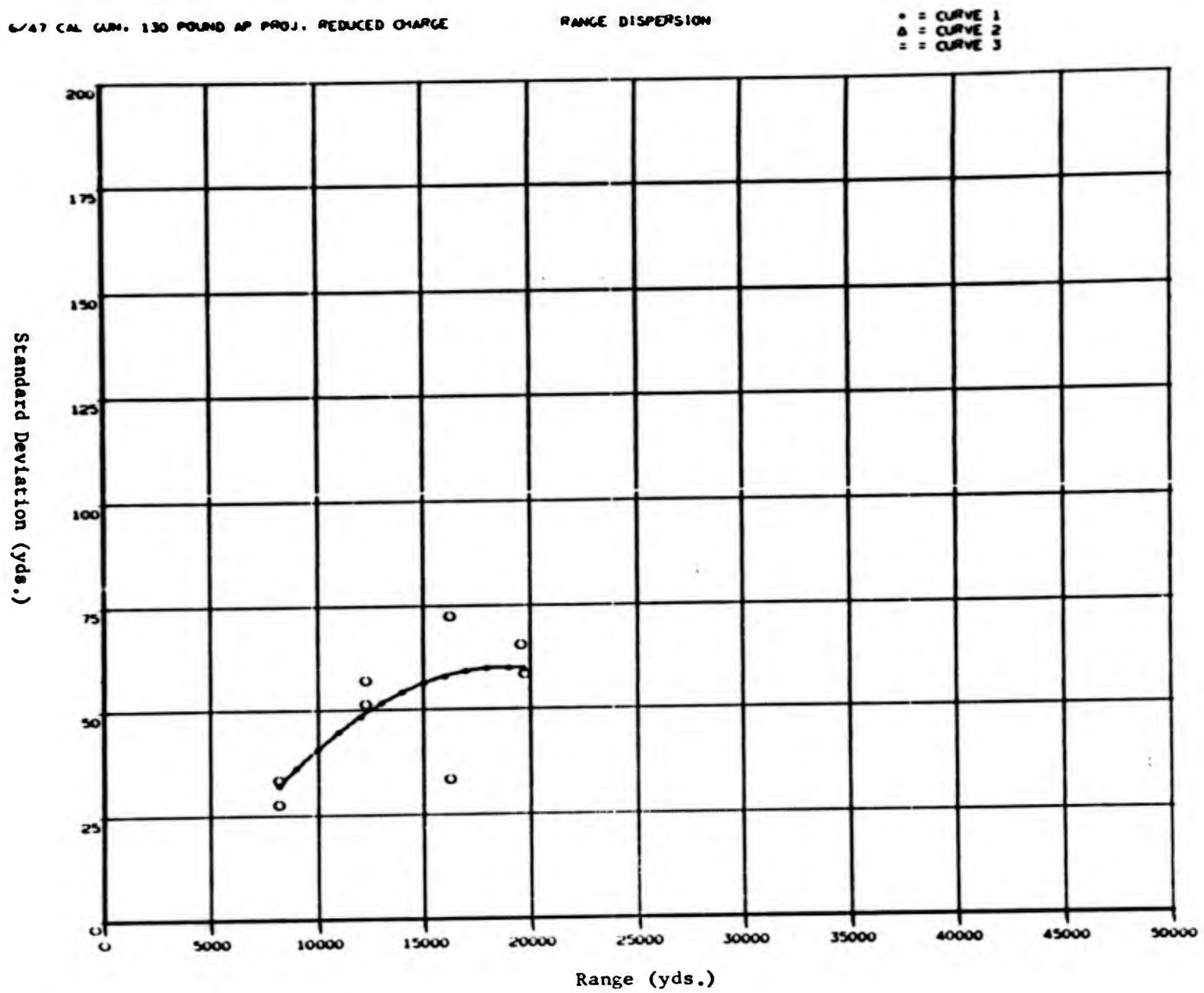
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
476	5	8°	8,218	28.0
478	5	8°	8,218	33.6
474	5	15°	12,258	51.8
478	5	15°	12,258	57.4
476	5	25°	16,233	33.6
478	5	25°	16,233	72.8
478	5	39°	19,586	65.8
476	5	40°	19,714	58.8

See [10] and extractions from NWL ranging sheets listed above.

6"/47 Caliber Gun
Type Projectile Fired: Mark 36 (AP Projectile - 130 lbs.)
Reduced Charge (Initial Velocity: 2050 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
8,218	32
9,000	36
10,000	41
11,000	45
12,000	49
13,000	52
14,000	55
15,000	57
16,000	58
17,000	60
18,000	60
19,000	60
19,714	60


6/47 CAL GUN. 130 POUND AP PROJ. REDUCED CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
25
50
75
100
125
150
175
200
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

6"/47 Caliber Gun
Type Projectile Fired: Mark 34 (HC Projectile - 105 lbs.)
Reduced Charge (Initial Velocity: 2225 ft/sec)

Original Data

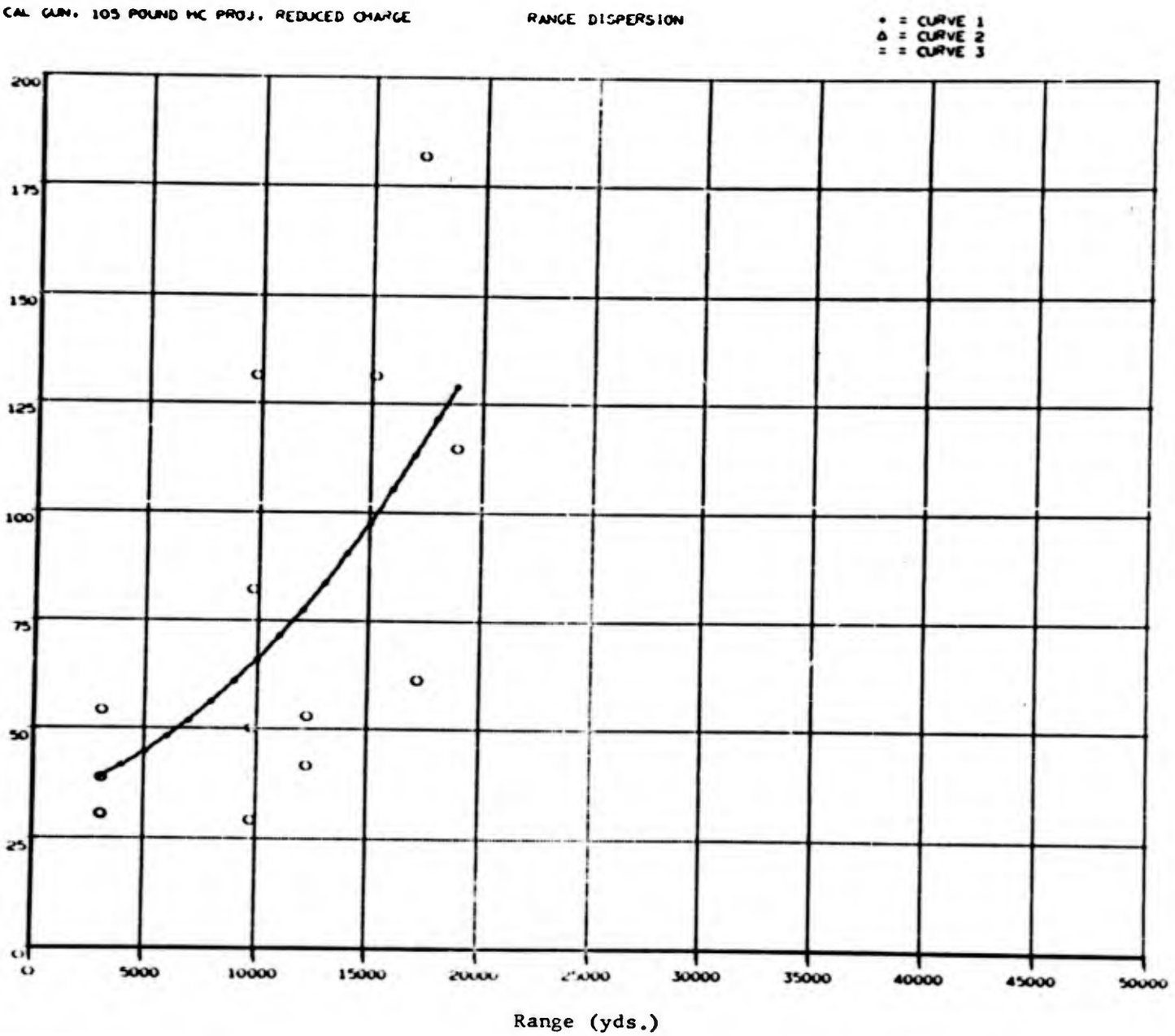
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
621	5	2°	3,054	54.6
623	4	2°	3,054	39.1
928	5	2°	3,054	30.8
929	5	2°	3,054	30.8
621	5	10°	9,770	82.6
623	5	10°	9,770	29.4
928	5	10°	9,770	131.7
929	5	10°	9,770	50.4
621	5	15°	12,257	53.2
623	5	15°	12,257	42.0
623	5	22°30′	15,111	131.7
621	5	30°	17,219	182.1
623	5	30°	17,219	61.6
621	5	40°	18,870	114.9

See [11] and extractions from NWL ranging sheets listed above.

6"/47 Caliber Gun
Type Projectile Fired: Mark 34 (HC Projectile - 105 lbs.)
Reduced Charge (Initial Velocity: 2225 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
3,054	39
4,000	42
5,000	45
6,000	48
7,000	52
8,000	57
9,000	61
10,000	66
11,000	72
12,000	78
13,000	84
14,000	91
15,000	98
16,000	105
17,000	113
18,000	122
18,870	129


6/47 CAL GUN. 105 POUND HC PROJ. REDUCED CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

6"/47 Caliber DP Gun
Type Projectile: Mark 39 (HC Projectile - 105 lbs.)
Full Charge (Initial Velocity: 2565 ft/sec)

Original Data

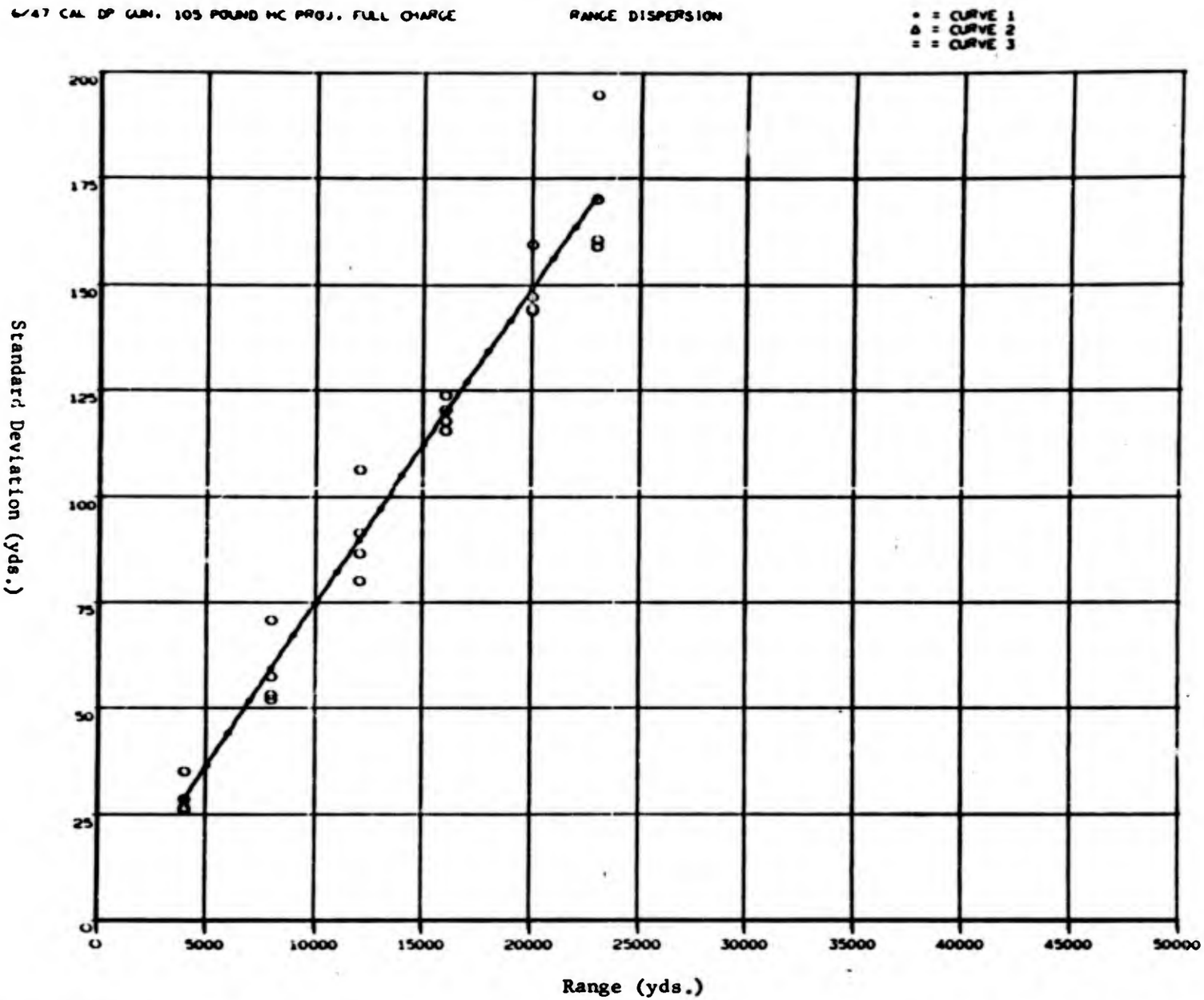
No. of Rounds	Range (yds.)	Standard Deviation (yds.)
2	4,000	35.4
4	4,000	28.9
8	4,000	26.8
12	4,000	26.2
2	8,000	70.9
4	8,000	57.9
8	8,000	53.6
12	8,000	52.4
2	12,000	106.3
4	12,000	86.8
8	12,000	80.4
12	12,000	91.6
2	16,000	124.1
4	16,000	115.8
8	16,000	120.6
12	16,000	117.8
2	20,000	159.5
4	20,000	144.7
8	20,000	147.4
12	20,000	144.0
2	23,000	195.0
4	23,000	159.2
8	23,000	160.8
12	23,000	170.2

See [12]

6"/47 Caliber DP Gun
Type Projectile: Mark 39 (HC Projectile - 105 lbs.)
Full Charge (Initial Velocity: 2565 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
4,000	29
5,000	37
6,000	44
7,000	52
8,000	60
9,000	67
10,000	75
11,000	82
12,000	90
13,000	98
14,000	105
15,000	112
16,000	120
17,000	127
18,000	135
19,000	142
20,000	149
21,000	156
22,000	164
23,000	171


6/47 CAL DP GUN. 105 POUND HC PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
25
50
75
100
125
150
175
200
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

6"/47 Caliber DP Gun
Type Projectile: Mark 39 (HC Projectile - 105 lbs.)
Reduced Charge (Initial Velocity: 2125 ft/sec)

Original Data

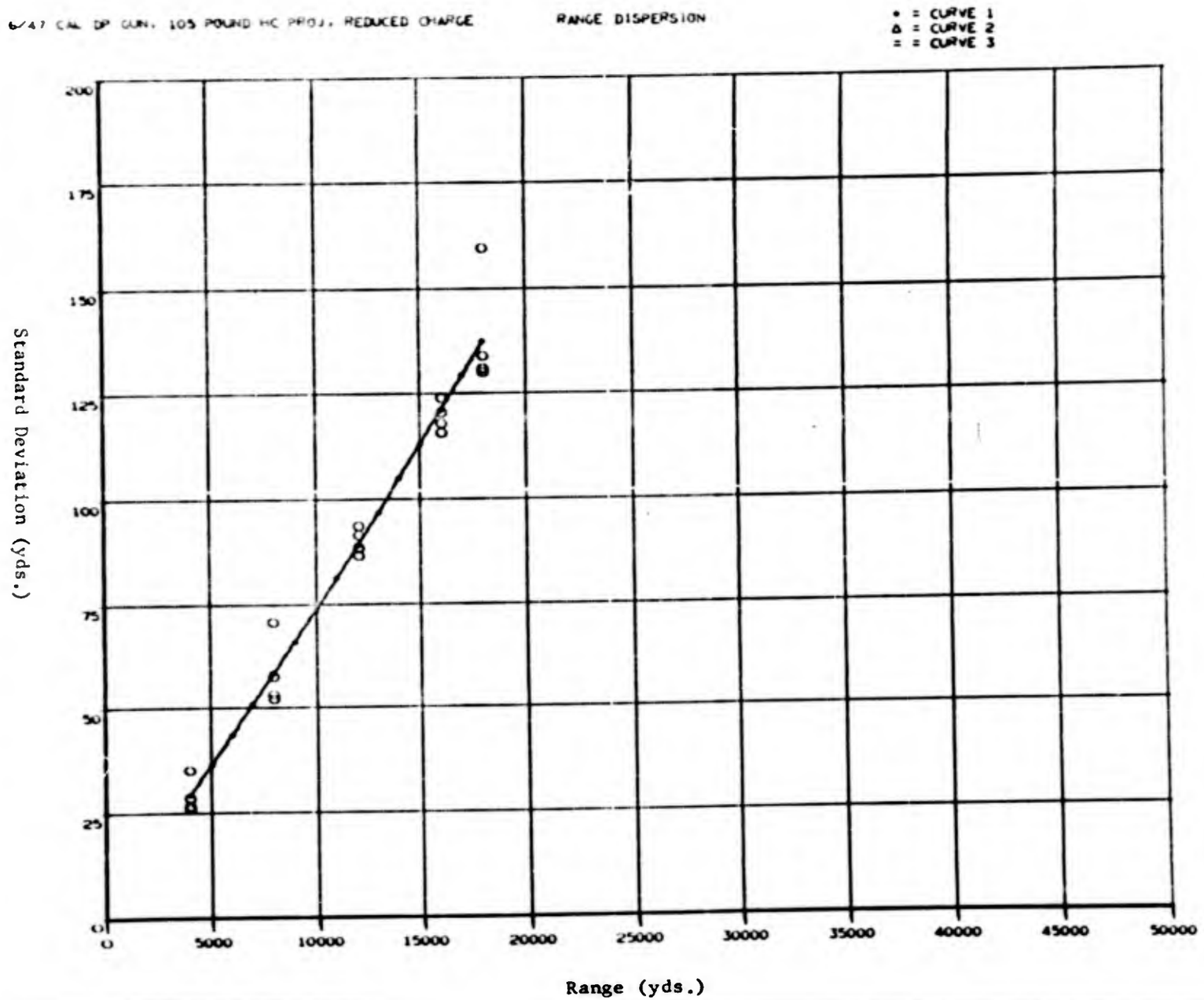
No. of Rounds	Range (yds.)	Standard Deviation (yds.)
2	4,000	35.4
4	4,000	28.9
8	4,000	26.8
12	4,000	26.2
2	8,000	70.9
4	8,000	57.9
8	8,000	53.6
12	8,000	52.4
2	12,000	88.6
4	12,000	86.8
8	12,000	93.8
12	12,000	91.6
2	16,000	124.1
4	16,000	115.8
8	16,000	120.6
12	16,000	117.8
2	18,000	159.5
4	18,000	130.2
8	18,000	134.0
12	18,000	130.9

See [13]

6"/47 Caliber DP Gun
Type Projectile: Mark 39 (HC Projectile - 105 lbs.)
Reduced Charge (Initial Velocity: 2125 ft/sec)

Estimated Range Dispersions

Range (yds.)	Standard Deviation (yds.)
4,000	29
5,000	37
6,000	44
7,000	51
8,000	59
9,000	66
10,000	74
11,000	82
12,000	89
13,000	97
14,000	105
15,000	113
16,000	121
17,000	129
18,000	138


6/47 CAL DP GUN, 105 POUND HC PROJ., REDUCED CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

8"/55 Caliber Gun, Mark 12
Type Projectile Fired: Mark 23 (AP Projectile - 335 lbs.)
Full Charge (Initial Velocity: 2500 ft/sec)

Original Data

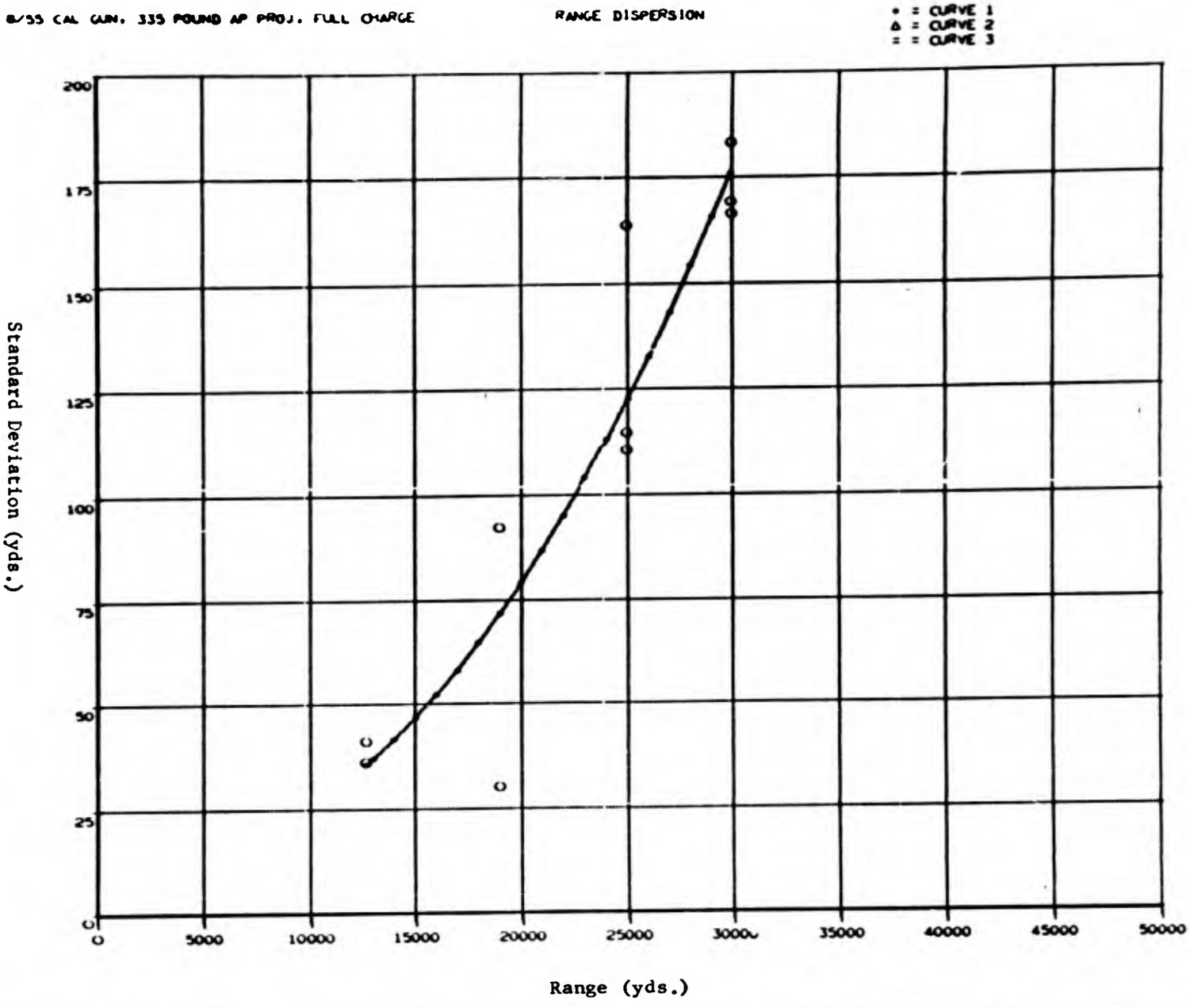
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
369	5	15°	18,969	92.5
369	5	25°	24,908	163.9
369	5	40°	29,875	169.5
370	5	8°	12,650	36.4
370	5	25°	24,908	110.7
370	5	40°	29,875	183.5
372	3	8°	12,650	41.4
372	4	15°	18,969	30.4
372	5	25°	24,908	114.9
372	5	40°	29,875	166.7

See [14] and extractions from NWL ranging sheets listed above.

8"/55 Caliber Gun, Mark 12
Type Projectile Fired: Mark 23 (AP Projectile - 335 lbs.)
Full Charge (Initial Velocity: 2500 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
12,650	36
13,000	37
14,000	42
15,000	47
16,000	53
17,000	59
18,000	65
19,000	72
20,000	79
21,000	87
22,000	95
23,000	104
24,000	113
25,000	123
26,000	133
27,000	144
28,000	154
29,000	166
29,875	176


8/55 CAL GUN, 335 POUND AP PROJ, FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
25
50
75
100
125
150
175
200
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

8"/55 Caliber Gun, Mark 12, 14
Type Projectile Fired: Mark 24 (HC Projectile - 260 lbs.)
Full Charge (Initial Velocity: 2700 ft/sec)

Original Data

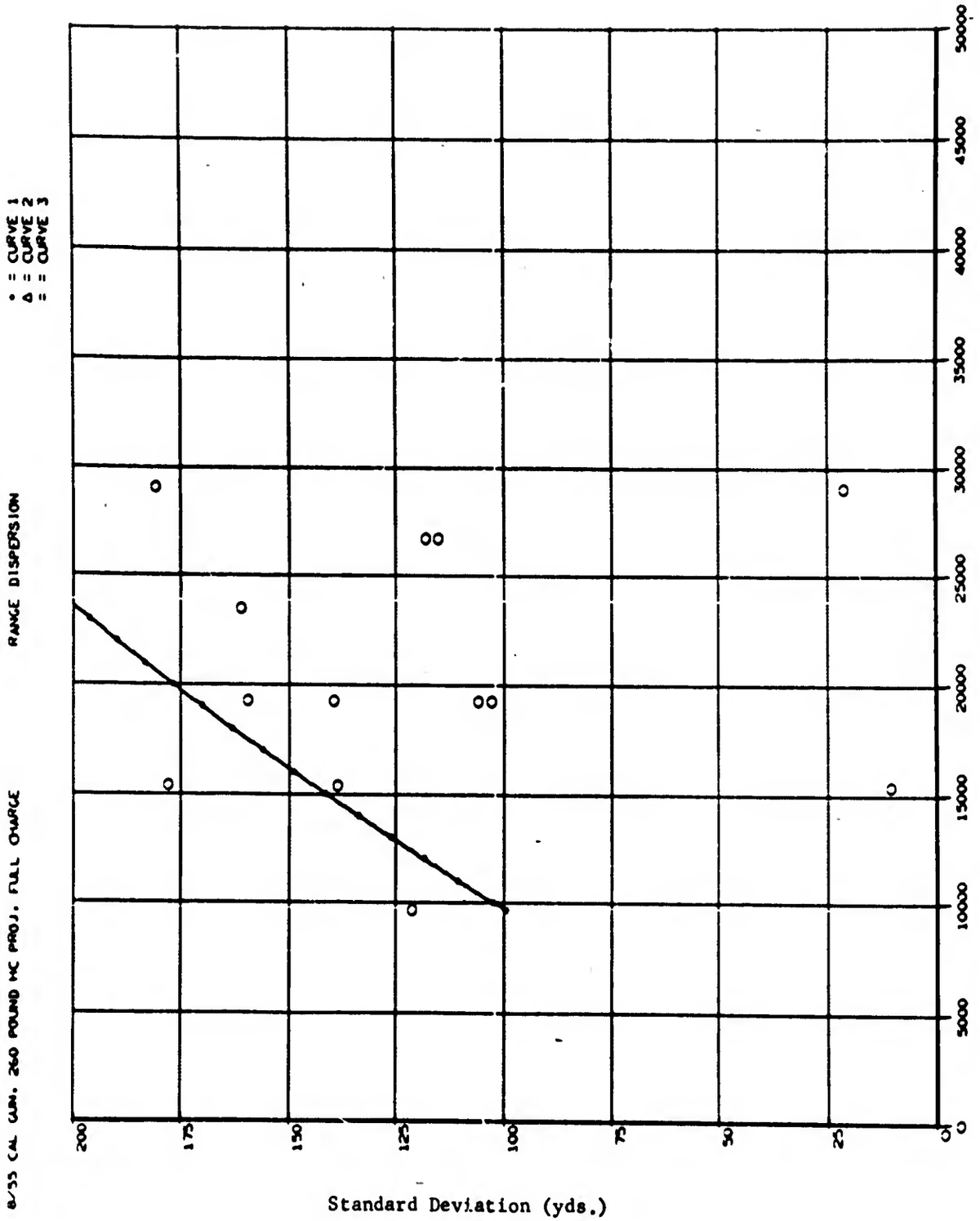
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
446	4	5°	9,681	121.5
456	4	10°	15,336	138.9
493	3	10°	15,336	178.1
495	3	10°	15,336	10.7
503	3	10°	15,336	205.7
473	3	15°	19,222	105.9
474	3	15°	19,222	102.8
493	3	15°	19,222	139.7
495	3	15°	19,222	288,6
503	3	15°	19,222	159.6
495	3	22°30′	23,492	161.2
503	3	22°30′	23,492	474.3
433	5	30°	26,676	201.7
493	3	30°	26,676	118.2
495	2	30°	26,676	115.2
493	3	37°30′	29,029	21.5
503	2	37°30′	29,029	549.3
503	3	37°30′	29,029	181.1
447	4	40°	29,610	243.1

See [15] and extractions from NWL ranging sheets listed above.

8"/55 Caliber Gun, Mark 12, 14
Type Projectile Fired: Mark 24 (HC Projectile - 260 lbs.)
Full Charge (Initial Velocity: 2700 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
9,681	100
10,000	102
11,000	111
12,000	119
13,000	126
14,000	134
15,000	142
16,000	149
17,000	156
18,000	163
19,000	170
20,000	177
21,000	184
22,000	190
23,000	196
24,000	203
25,000	209
26,000	214
27,000	220
28,000	226
29,000	231
29,610	234


8/55 CAL GUN. 260 POUND HC PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
200
175
150
125
100
75
50
25
0
Standard Deviation (yds.)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Range (yds.)

8"/55 Caliber Gun, Mark 12
Type Projectile Fired: Mark 23 (AP Projectile - 335 lbs.)
Reduced Charge (Initial Velocity: 2000 ft/sec)

Original Data

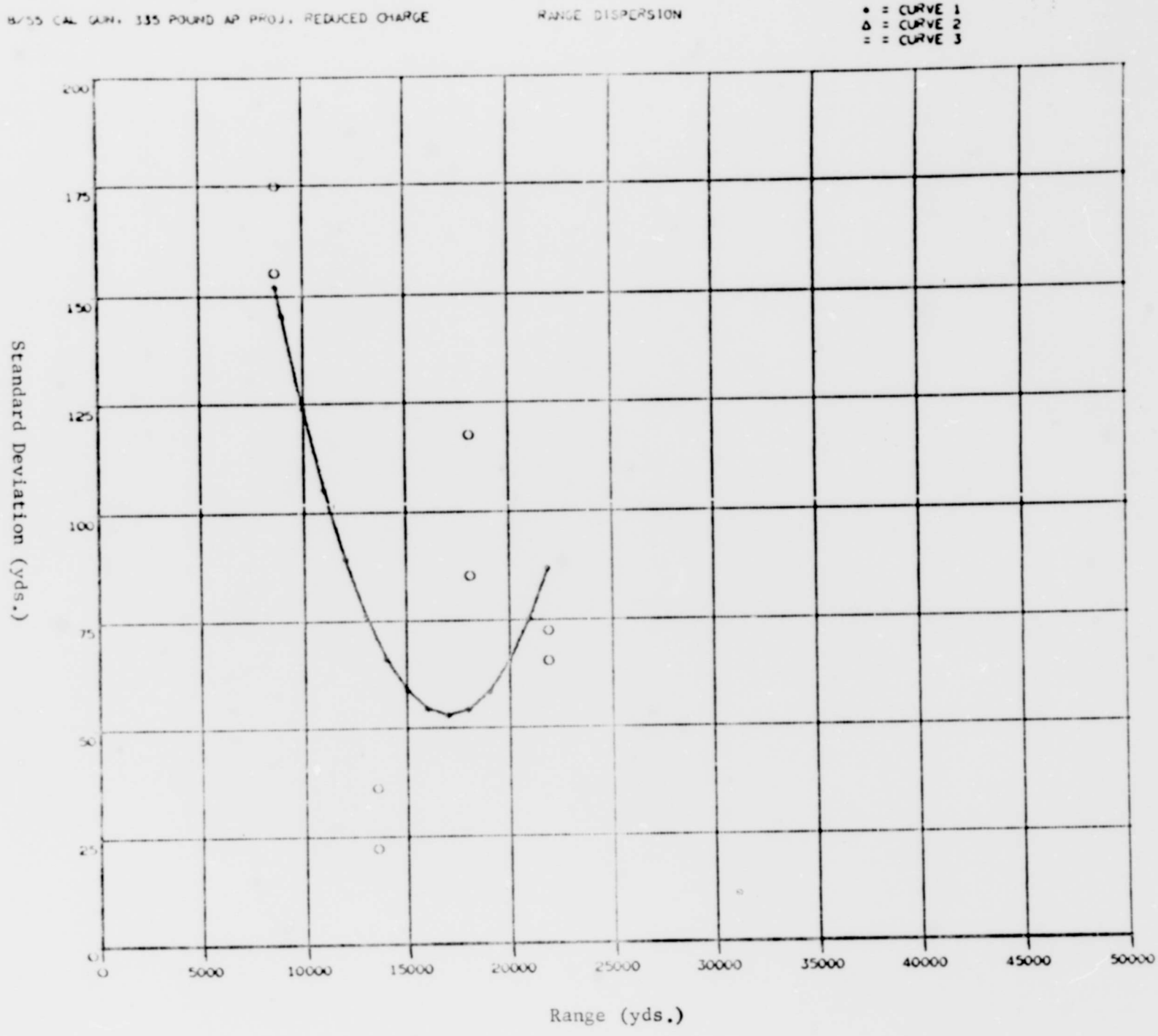
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
390	5	8°	8,711	155.5
390	5	15°	13,482	36.4
390	5	25°	18,081	117.7
390	5	40°	21,930	72.8
392	5	8°	8,711	175.1
392	5	15°	13,482	22.4
392	5	25°	18,081	85.5
392	5	40°	21,930	65.8

See [16] and extractions from NWL ranging sheets listed above.

8"/55 Caliber Gun, Mark 12
Type Projectile Fired: Mark 23 (AP Projectile - 335 lbs.)
Reduced Charge (Initial Velocity: 2000 ft/sec)

Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
8,711	152
9,000	145
10,000	124
11,000	105
12,000	89
13,000	77
14,000	66
15,000	59
16,000	55
17,000	53
18,000	55
19,000	59
20,000	66
21,000	76
21,930	87


8/55 CAL GUN. 335 POUND AP PROJ. REDUCED CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

8"/55 Caliber Gun
Type Projectile Fired: Mark 24 (HC Projectile - 260 lbs.)
Reduced Charge (Initial Velocity: 2220 ft/sec)

Original Data

Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)
468	4	5°	6,943	24.6
462	5	10°	11,391	49.0
465	5	10°	11,391	77.0
496	3	10°	11,391	76.8
498	3	10°	11,391	52.2
496	3	15°	14,545	84.4
498	3	15°	14,545	89.0
498	2	22°30′	18,071	58.5
496	3	27°30′	19,993	109.0
465	5	30°	20,740	222.8
498	3	30°	20,740	96.7
496	3	32°30′	21,464	105.9
465	5	40°	23,014	263.4
470	4	40°	23,014	89.7

See [17] and extractions from NWL ranging sheets listed above.

8"/55 Caliber Gun
Type Projectile Fired: Mark 24 (HC Projectile - 260 lbs.)
Reduced Charge (Initial Velocity: 2220 ft/sec)

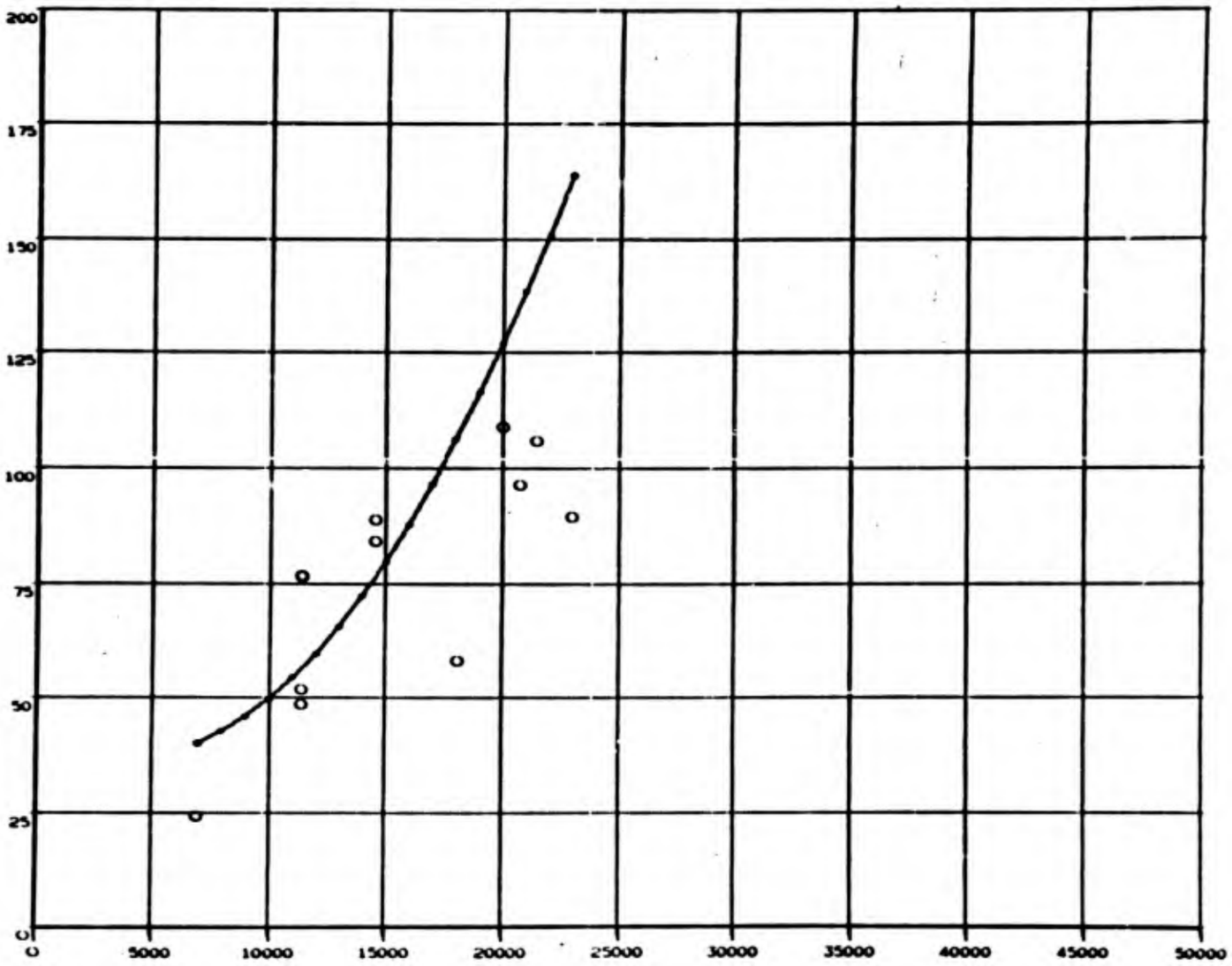
Estimated Range Dispersion

Range (yds.)	Standard Deviation (yds.)
6,943	40
7,000	40
8,000	43
9,000	46
10,000	50
11,000	55
12,000	60
13,000	66
14,000	73
15,000	80
16,000	88
17,000	97
18,000	106
19,000	116
20,000	127
21,000	139
22,000	151
23,000	164
23,014	164

8/55 CAL GUN. 260 POUND HC PROJ. REDUCED CHARGE

RANGE DISPERSION

• = CURVE 1
▲ = CURVE 2
= = CURVE 3



16"/50 Caliber Gun, Mark D, 7
Type Projectile Fired: Mark 9-1, 8-2 (AP Projectile - 2700 lbs.)
Full Charge (Initial Velocity: 2500 ft/sec)

Original Data

Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)	
				Range	Deflection
549	3	2°30′	4,306	20.78	0.58
549	3	5°30′	9,931	39.88	3.46
549	3	15°30′	23,877	58.51	7.81
445	4	2°	4,290	46.75	2.45
224	5	15°	23,868	118.92	28.50
443	5	2°	4,290	16.18	0.00
224	5	45°	42,345	71.17	36.15
224	4	30°	36,728	152.73	26.76
224	5	25°	33,249	126.61	7.70
222	5	10°	17,645	39.91	12.12
222	5	15°	23,868	48.21	2.39
222	5	25°	33,249	101.96	10.50
222	5	45°	42,345	65.12	23.78
224	5	20°	28,983	89.27	19.02
541	2	15°	23,868	94.75	14.85
541	2	15°	23,868	89.10	4.24
226	3	15°	23,868	97.99	12.74

See [18] and extractions from NWL ranging sheets listed above.

16"/50 Caliber Gun, Mark D, 7
Type Projectile Fired: Mark 9-1, 8-2 (AP Projectile - 2700 lbs.)
Full Charge (Initial Velocity: 2500 ft/sec)

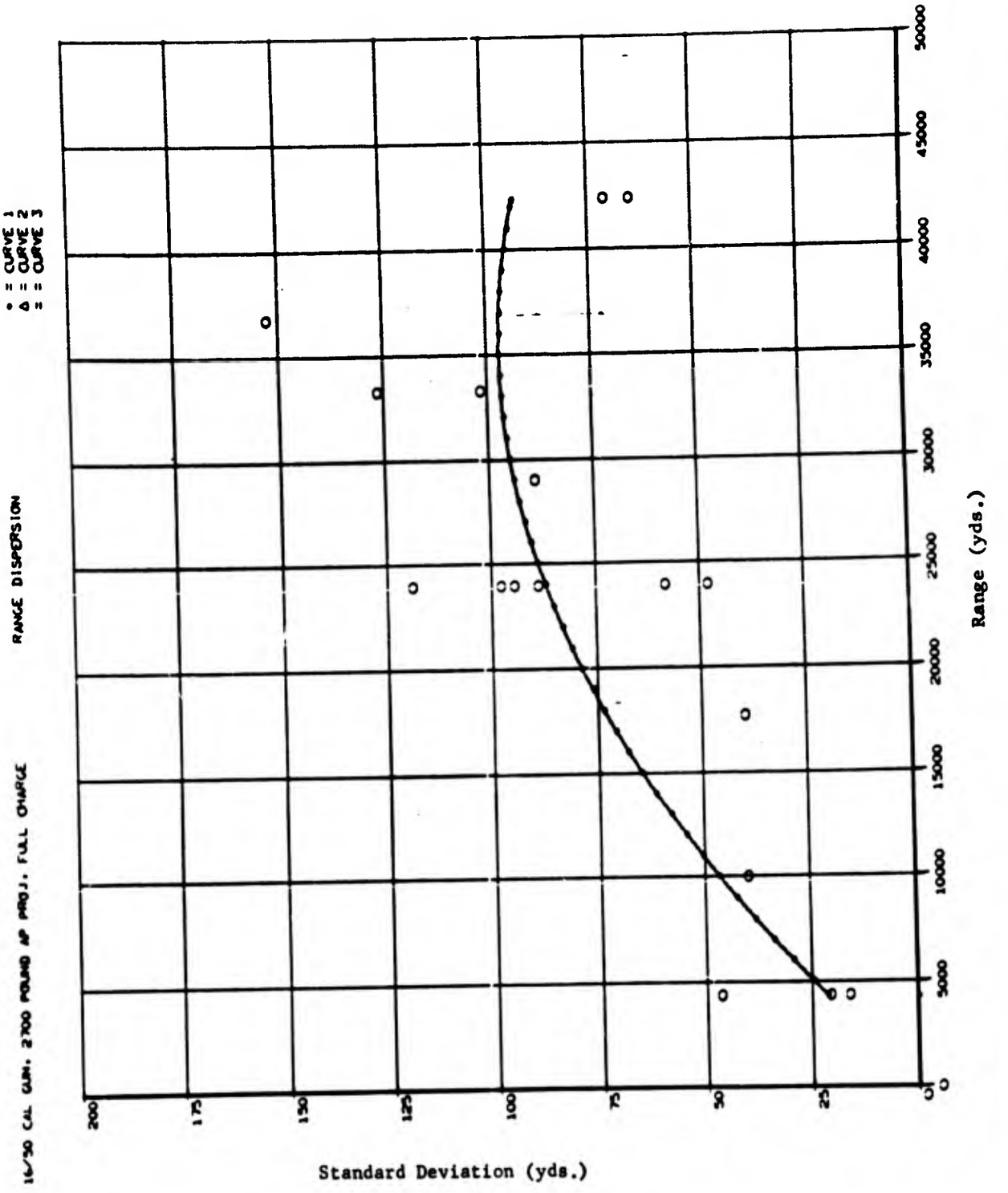
Estimated Dispersion

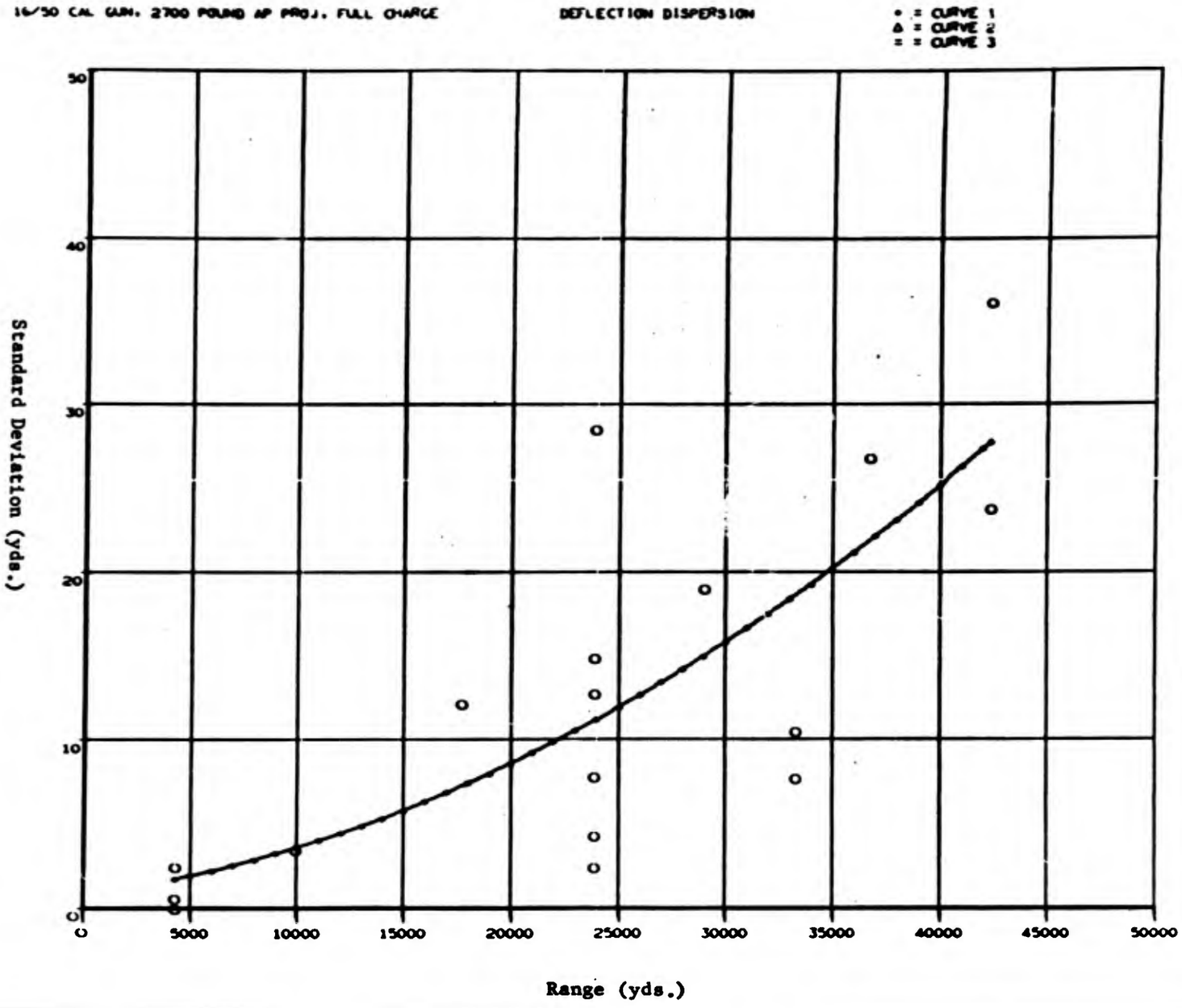
	Standard Deviation (yds.)	
Range (yds.)	Range	Deflection
4,290	21	2
5,000	25	2
6,000	29	2
7,000	34	3
8,000	38	3
9,000	43	3
10,000	47	4
11,000	51	4
12,000	54	4
13,000	58	5
14,000	62	5
15,000	65	6
16,000	68	6
17,000	71	7
18,000	74	7
19,000	76	8
20,000	79	9
21,000	81	9
22,000	83	10
23,000	85	11
24,000	87	11
25,000	89	12
26,000	91	13
27,000	92	13
28,000	93	14
29,000	94	15
30,000	95	16
31,000	96	17
32,000	96	18
33,000	97	18

16"/50 Caliber Gun, Mark D, 7
Type Projectile Fired: Mark 9-1, 8-2 (AP Projectile - 2700 lbs.)
Full Charge (Initial Velocity: 2500 ft/sec)

Estimated Dispersion

Range (yds.)	Standard Deviation (yds.)	
	Range	Deflection
34,000	97	19
35,000	97	20
36,000	97	21
37,000	97	22
38,000	97	23
39,000	96	24
40,000	95	25
41,000	95	26
42,000	94	27
42,345	93	28


16/50 CAL GUN. 2700 POUND AP PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
200
175
150
125
100
75
50
25
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000


16/50 CAL GUN. 2700 POUND AP PROJ. FULL CHARGE
DEFLECTION DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
0
10
20
30
40
50
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

16"/50 Caliber Gun, Mark 7
Type Projectile Fired: EX1-1 (HC Projectile - 1900 lbs.)
Full Charge (Initial Velocity: 2690 ft/sec)

Original Data

Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.)	
				Range	Deflection
361	3	2°	4,470	19.42	2.08
361	3	15°	24,062	23.03	6.08
361	3	15°	24,062	61.76	11.02
361	3	30°	35,988	93.06	26.06
361	3	10°	18,228	8.33	8.62
364	3	2°	4,470	43.98	2.31
364	3	15°	24,062	12.53	5.51
364	3	22°30′	30,819	123.39	2.08
361	3	40°	40,560	175.50	6.00
364	3	30°	35,988	113.65	6.11
364	3	10°	18,228	65.59	19.97

See [19] and extractions from NWL ranging sheets listed above.

16"/50 Caliber Gun, Mark 7
Type Projectile Fired: EX1-1 (HC Projectile - 1900 lbs.)
Full Charge (Initial Velocity: 2690 ft/sec)

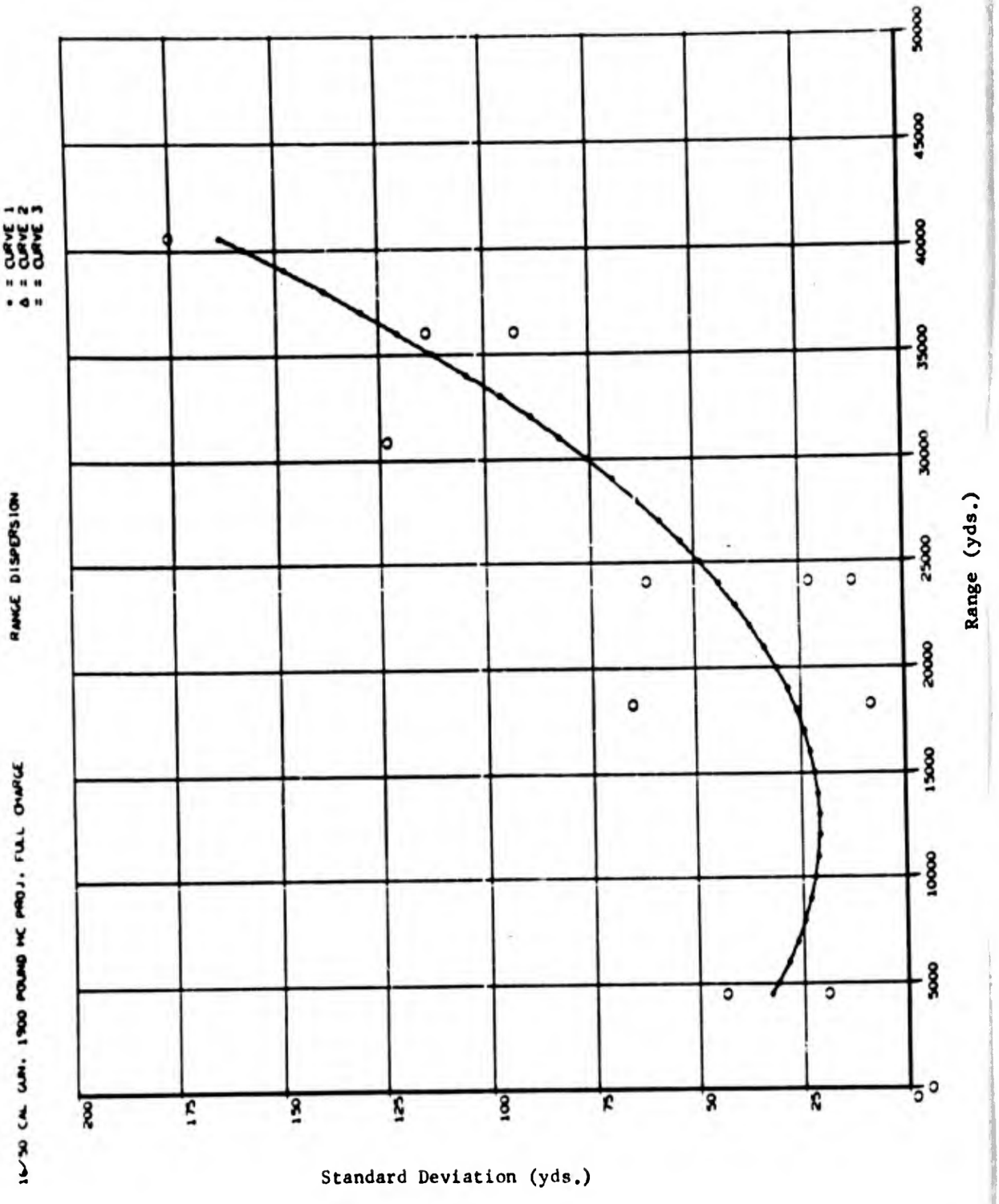
Estimated Dispersion

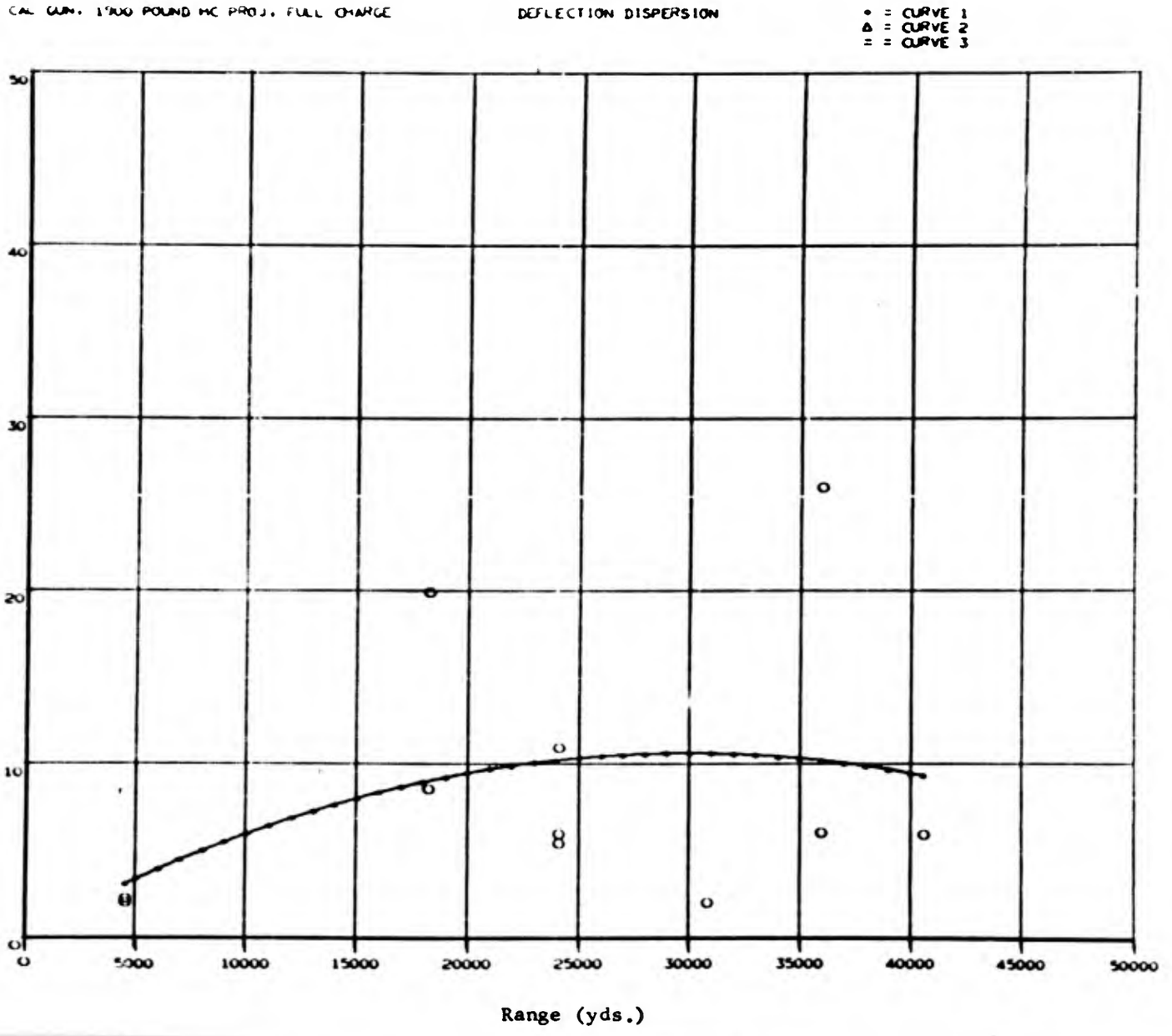
Range (yds.)	Standard Deviation (yds.)	
	Range	Deflection
4,470	33	3
5,000	31	3
6,000	29	4
7,000	27	5
8,000	25	5
9,000	23	6
10,000	22	6
11,000	21	6
12,000	21	7
13,000	21	7
14,000	21	8
15,000	22	8
16,000	23	8
17,000	24	9
18,000	26	9
19,000	28	9
20,000	31	10
21,000	34	10
22,000	37	10
23,000	41	10
24,000	45	10
25,000	49	10
26,000	54	11
27,000	59	11
28,000	64	11
29,000	70	11
30,000	76	11
31,000	83	11
32,000	90	11
33,000	97	11

16"/50 Caliber Gun, Mark 7
Type Projectile Fired: EX1-1 (HC Projectile - 1900 lbs.)
Full Charge (Initial Velocity: 2690 ft/sec)

Estimated Dispersion

Range (yds.)	Standard Deviation (yds.)	
	Range	Deflection
34,000	104	10
35,000	112	10
36,000	121	10
37,000	129	10
38,000	139	10
39,000	148	10
40,000	158	10
40,560	163	9


16/50 CAL GUN. 1900 POUND HC PROJ. FULL CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= CURVE 3
200
175
150
125
100
75
50
25
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Standard Deviation (yds.)
Range (yds.)


16/50 CAL GUN. 1900 POUND HC PROJ. FULL CHARGE
DEFLECTION DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
10
20
30
40
50
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

16"/45-50 Caliber Gun, Mark D, 6-1, 6-V, 7, 8
Type Projectile Fired: Mark 9-1, C (AP Projectile - 2700 lbs)
Reduced Charge (Initial Velocity: 1800 ft/sec)

Original Data

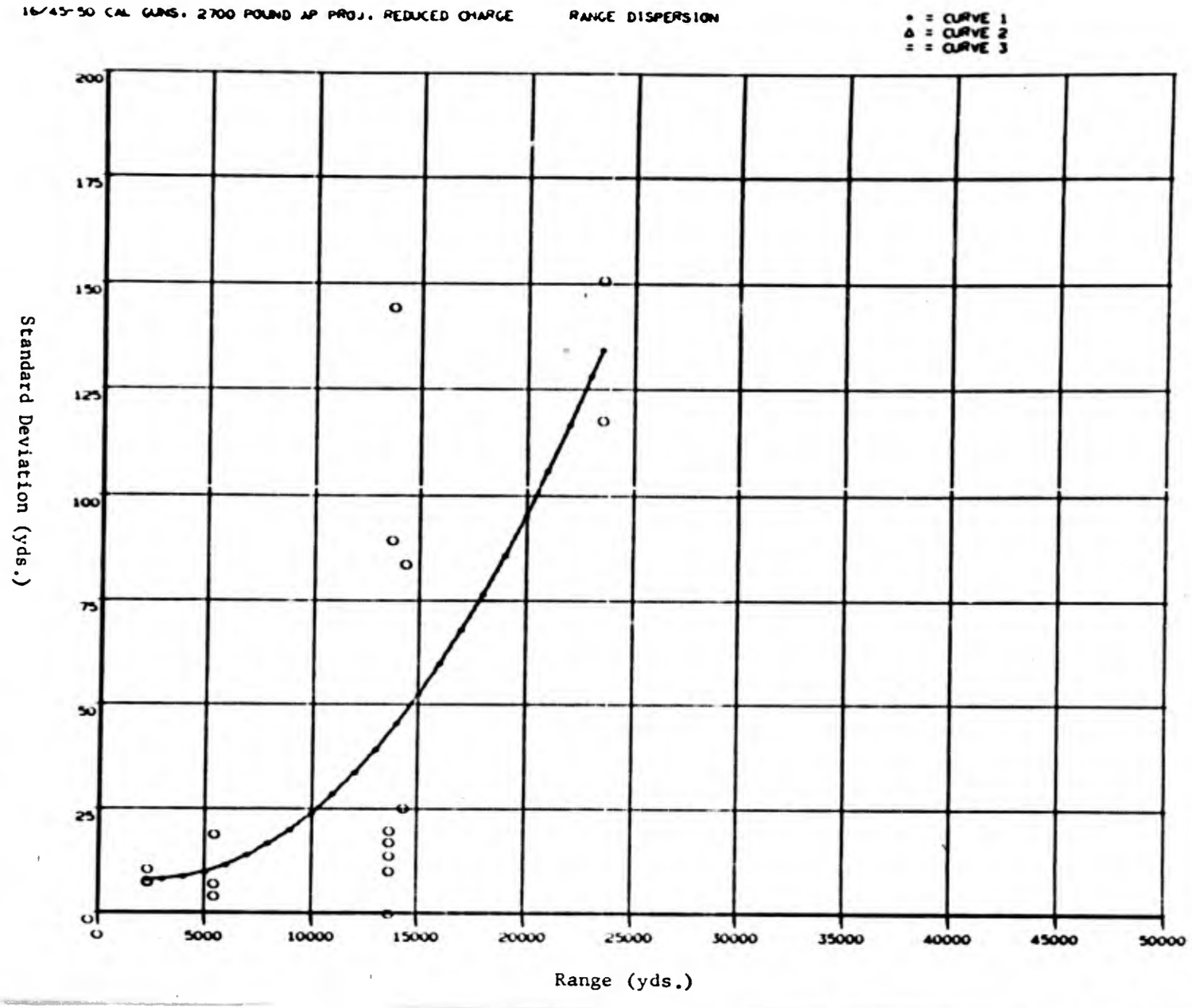
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.) Range	Deflection
226	3	15°	13,672	144.34	5.20
448	3	15°	13,672	17.06	5.51
549	3	5°30′	5,408	19.05	0.58
549	3	15°30′	13,672	10.02	3.21
549	3	2°30′	2,282	7.51	0.58
448	2	15°	13,672	19.80	2.83
456	3	2°	2,273	10.54	0.58
456	3	5°	5,400	4.04	1.15
456	3	15°	13,672	13.86	1.73
173	4	16°	14,340	83.83	2.65
185	5	40°	23,536	117.78	3.94
185	4	16°	14,340	25.29	6.60
173	5	40°	23,536	150.95	6.12
457	3	5°	5,400	6.93	1.73
457	3	15°	13,672	0.00	0.00
457	3	2°	2,273	7.51	0.00
538	3	15°	13,672	89.44	9.61

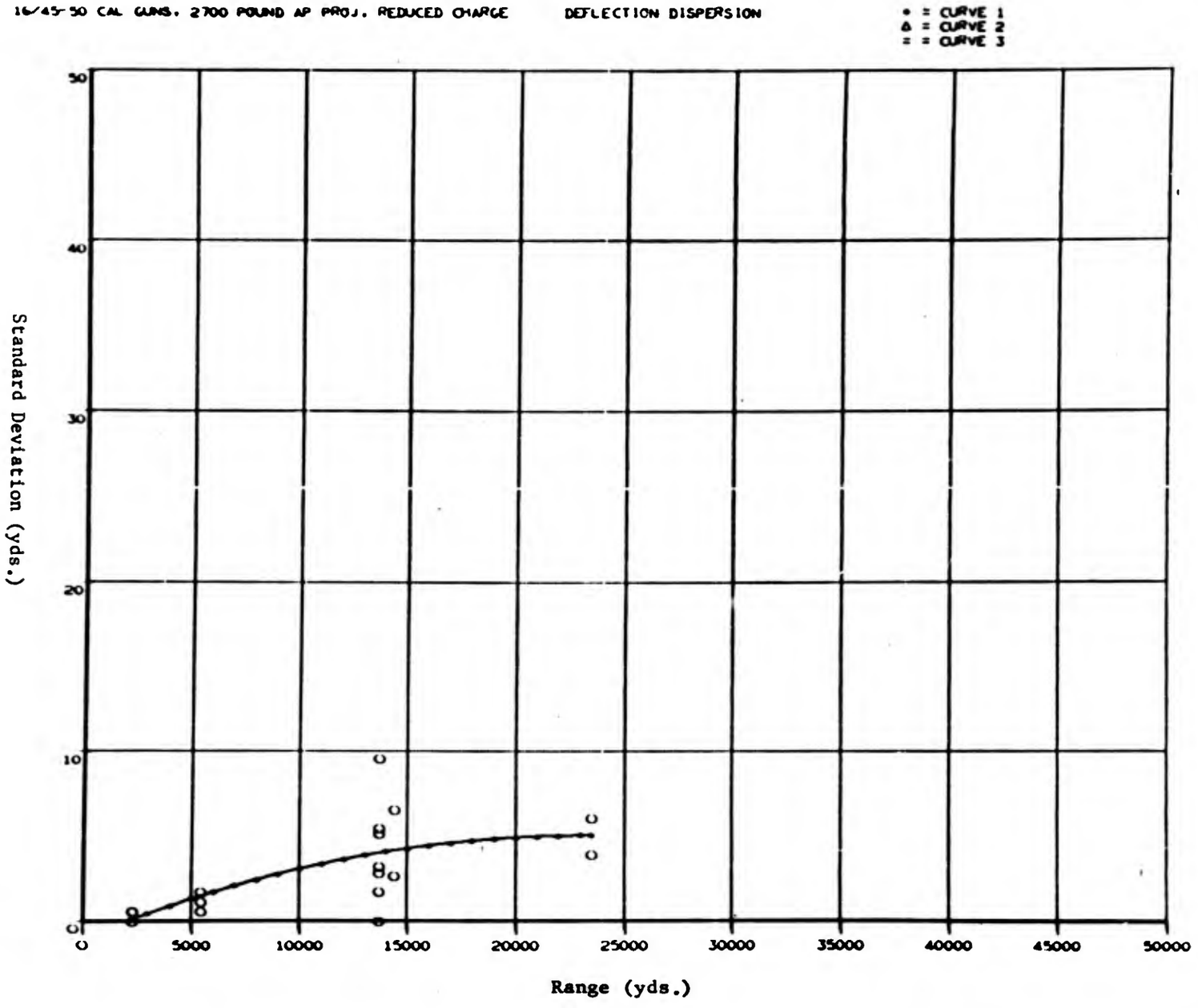
See [20] and extractions from NWL ranging sheets listed above.

16"/45-50 Caliber Gun, Mark D, 6-1, 6-V, 7, 8
Type Projectile Fired: Mark 9-1, C (AP Projectile - 2700 lbs.)
Reduced Charge (Initial Velocity: 1800 ft/sec)

Estimated Dispersion

	Standard Deviation (yds.)	
Range (yds.)	Range	Deflection
2,273	8	0
3,000	8	0
4,000	9	1
5,000	10	1
6,000	12	2
7,000	14	2
8,000	17	2
9,000	20	3
10,000	24	3
11,000	29	3
12,000	34	4
13,000	40	4
14,000	46	4
15,000	53	4
16,000	60	4
17,000	68	5
18,000	77	5
19,000	86	5
20,000	96	5
21,000	106	5
22,000	117	5
23,000	128	5
23,536	135	5


16/45-50 CAL GUNS. 2700 POUND AP PROJ. REDUCED CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
25
50
75
100
125
150
175
200
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000


16/45-50 CAL GUNS. 2700 POUND AP PROJ. REDUCED CHARGE
DEFLECTION DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
50
40
30
20
10
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

16"/45-50 Caliber Gun, Mark 6, 7, 8
Type Projectile Fired: Mark 13-2 (HC Projectile - 1900 lbs.)
Reduced Charge (Initial Velocity: 2075 ft/sec)

Original Data

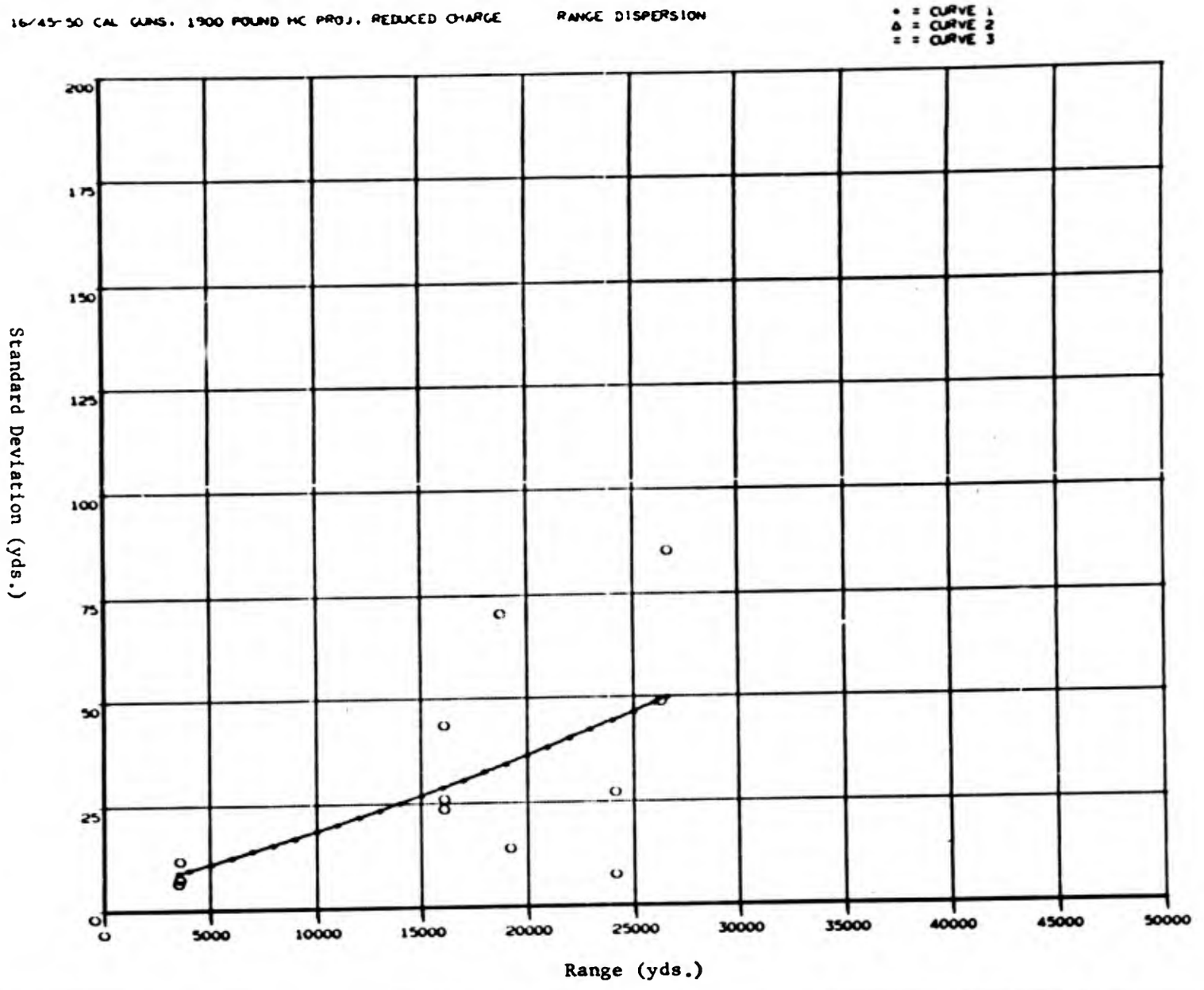
Ranging Sheet	No. of Rounds	Angle of Elevation	Theoretical Range (yds.)	Standard Deviation (yds.) Range	Deflection
541	3	2°30′	3,511	6.51	0.58
541	3	15°	16,062	23.69	5.86
541	2	19°	18,760	70.71	3.54
541	3	30°	24,082	7.55	18.33
541	3	40°	26,585	85.62	23.07
537	3	2°31½′	3,545	7.70	-
537	3	15°01½′	16,080	26.10	-
537	3	19°39½′	19,165	14.20	-
537	3	30°01½′	24,091	27.60	-
537	3	38°01½′	26,258	49.10	-
538	3	2°31′	3,534	7.55	3.46
536	3	15°01′	16,074	43.84	5.69
536	3	2°31′	3,534	12.06	3.46

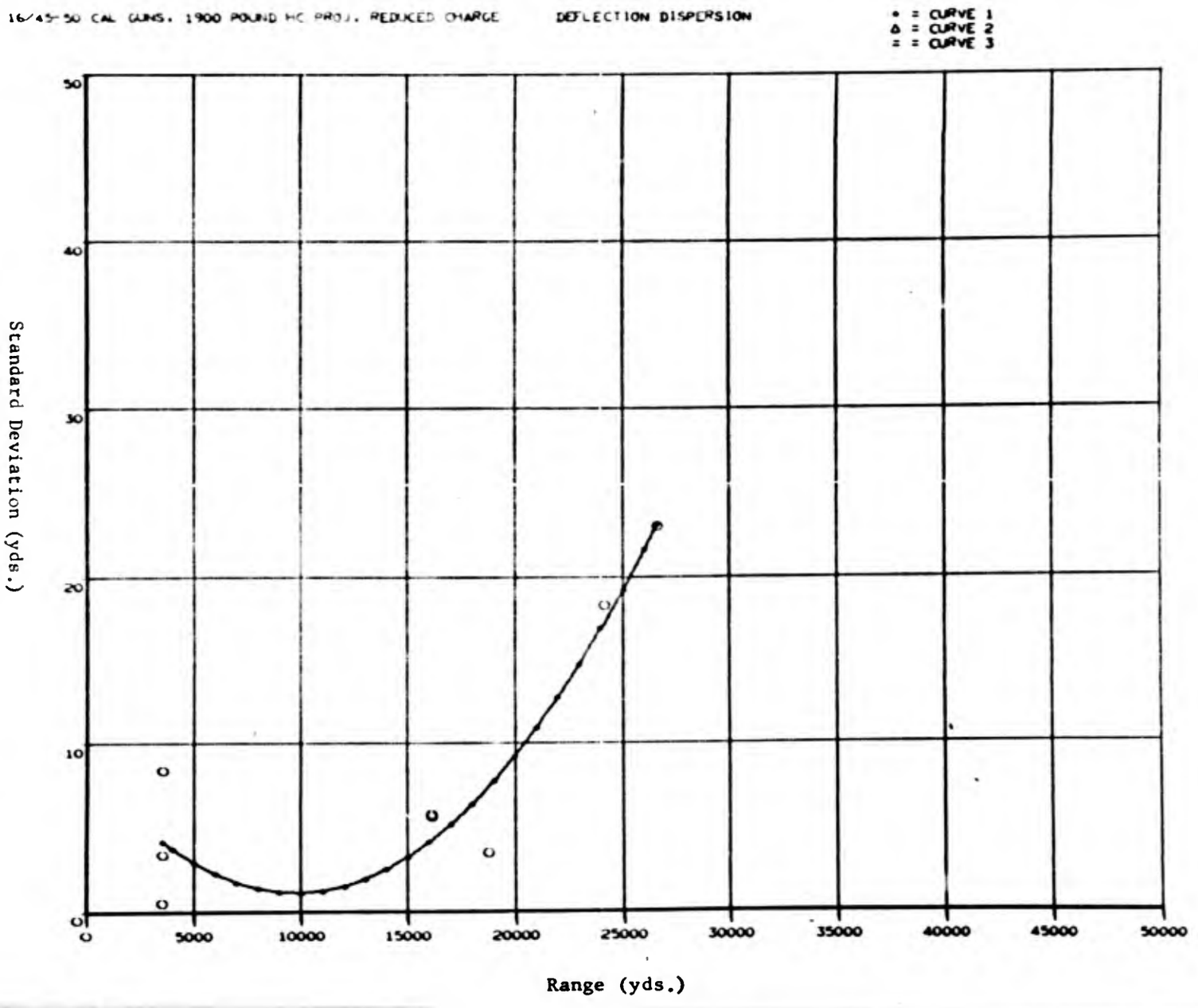
See [21] and extractions from NWL ranging sheets listed above.

16"/45-50 Caliber Gun, Mark 6, 7, 8
Type Projectile Fired: Mark 13-2 (HC Projectile - 1900 lbs.)
Reduced Charge (Initial Velocity: 2075 ft/sec)

Estimated Dispersion

	Standard Deviation (yds.)	
Range (yds.)	Range	Deflection
3,511	9	4
4,000	10	4
5,000	11	3
6,000	13	2
7,000	14	2
8,000	16	1
9,000	17	1
10,000	19	1
11,000	20	1
12,000	22	2
13,000	24	2
14,000	25	3
15,000	27	3
16,000	29	4
17,000	31	5
18,000	33	6
19,000	35	8
20,000	37	9
21,000	38	11
22,000	41	13
23,000	43	15
24,000	45	17
25,000	47	19
26,000	49	22
26,585	50	23


16/45-50 CAL GUNS. 1900 POUND HC PROJ. REDUCED CHARGE
RANGE DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
Range (yds.)
0
25
50
75
100
125
150
175
200
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000


16/45-50 CAL GUNS. 1900 POUND HC PROJ. REDUCED CHARGE
DEFLECTION DISPERSION
• = CURVE 1
Δ = CURVE 2
= = CURVE 3
Standard Deviation (yds.)
0
10
20
30
40
50
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Range (yds.)

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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10. DISTRIBUTION STATEMENT

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

The memorandum provides estimates of naval gunfire dispersions for the most common projectiles. The source of all data used to compute these estimates as well as the methodology involved is discussed in detail.