ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Second Partial Report

On

PROJECT NO. 21 - DETERMINATION OF THE SOURCES, MAGNITUDE AND COSTS OF GUNNERY ERRORS

Project No. 21

INFORMATION COPY

16 June 1944

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 21
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1. PROJECT: No. 21 - Determination of the Sources, Magnitude and Costs of Gunnery Errors.

a. Authority: Letter, Office of The Surgeon General, 24 March 1944.

b. Purpose: To obtain further quantitative data to serve as a basis for critical evaluation of the capacities, limitations and expectations in firing on the move with the gyrostabilizer.

2. DISCUSSION:

a. The need for quantitative data on the effectiveness of fire with the 75 mm gun that can be maintained with present gun stabilization equipment from the moving tank was pointed out in the First Partial Report.

b. The present report deals with the effectiveness of moving fire, using the coaxial machine gun. The basic test procedures were the same as employed in the previous tests and were selected for favorable operation of the gyrostabilizer. Only the nature of targets and tank speeds were varied to approximate more nearly the combat conditions for use of the machine gun. Comparative tests were conducted with and without the gyrostabilizer, at tank speeds of 2 and 10 mph and against three types of targets: large, exposed panels; so-called area targets of considerable length and limited height; and standard silhouette of head-on prone man.

c. The test procedures and results are presented in the Appendix.

3. CONCLUSIONS:

a. The effectiveness of moving fire with the coaxial machine gun was found to be relatively low compared with stationary fire, owing to the limited stabilization provided by the present equipment.

b. The effectiveness of moving fire with the gyrostabilizer was found to decrease sharply at ranges greater than 250 yds.

c. The number of rounds required to obtain one hit on a silhouette target of a head-on, prone man, with and without the gyro-stabilizer in operation, over smooth ground at two tank speeds and at ranges up to 500 yards, were as follows:

Mean Range Yds.	With Gyro		Without Gyro	
	2 mph	10 mph	2 mph	10 mph
100	5.0	16.0	3.6	33.0
250	5.3	13.0	8.3	18.0
500	28.5	100.0	19.0	53.0

d. At a tank speed of 2 mph over smooth ground against a head-on prone man target no advantage was seen in moving fire with the gyrostabilizer over fire from the non-stabilized gun and only limited improvement was observed at 10 mph.

e. At a tank speed of 2 mph over smooth ground, against area targets, use of the stabilizer gave no improvement over the non-stabilized gun. At 10 mph, the concentration of fire from the moving tank without use of the gyrostabilizer was reduced approximately one third.

4. RECOMMENDATIONS:

a. That the data contained in this report be considered in decisions with respect to future use of the present stabilization equipment and in the development of tactical plans which involve firing on the move.

b. That in any further development of gun-stabilizing equipment for moving fire, provisions be made for horizontal as well as vertical stabilization and that the necessary degree of stabilization be determined in relation to size of targets to be engaged and maximum range of fire to be employed so that the reaction time of the gunner will have minimum influence upon the precision or frequency of fire from the moving tank.

c. That tests of any future gun-stabilizing equipment (apart from tests for determining mechanical reliability or problems of maintenance) be based upon quantitative measurements of precision of fire and rate of effective fire over the same courses against targets at various ranges out to the range of maximum employment, and that these be evaluated in relation to measurements of angular travel of the gun relative to the targets.

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2 Incls.
#1 - Appendix w/tables 1 thru 6
#2 - Figures 1 thru 17

APPENDIX

1. RELATION TO PREVIOUS REPORT:

A previous report* dealt with the capacities and limitations of the gyrostabilizer employed in moving fire with the 75 mm gun in the M4 medium tank. The present study, which is a continuation of the previous work, considers its operation with the coaxial machine gun. The objectives remain the same: to secure quantitative data on the degree of precision than can be expected in moving fire, in order to define and properly limit the conditions of use under which the gyrostabilizer can be employed with profit. Equally favorable circumstances of test were established, employing the same tanks and skilled crew, similar terrain and equivalent daily maintenance of equipment. The crew knew in advance the nature of targets, the exact ranges to be employed and the characteristics of terrain to be encountered in each test.

2. EQUIPMENT AND PROCEDURES:

a. Nature of Tests

(1) The relative effectiveness was determined for stationary fire and for moving fire with and without gyrostabilizer against the following targets:

(a) Large, 12' x 12', vertical panel
(b) Silhouette of head-on, prone man
(c) Low, area target to represent a hedge, row of bushes and the like.

(2) The ranges employed were as follows:

Stationary	Moving fire at 2 and 10 mph with and without gyrostabilizer
	Mean Range
200 yds.	100 yds.
500 "	*200 "
1000 "	250 "
	500 "

* Against large, 12' x 12', panel only

b. Firing from the stationary tank was done at the specified ranges. The moving fire tests, however, were conducted over zones centered at the specified distances, the zones being 50 yards for the 100 yard mean range, and 100 yards for the others (except in the 12' x 12' panel test at 500 yards which employed a 200 yard zone). Tank speeds of 2 and 10 mph were employed, to represent respectively, use of tanks with advancing infantry and on reconnaissance or

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* Project No. 21 - First Partial Report on Determination of the Sources, Magnitude and Costs of Gunnery Errors. Subject: Capacities and Limitations of Moving Fire with Gyrostabilizer, dated 24 May 1944.

other independent operations of movement.

(3) With only two exceptions, the unit power field of the T8 periscopic sight was employed in these tests.

b. Equipment and Test Facilities:

(1) Terrain: The tests were conducted at Rolling Fork Range, Fort Knox, Kentucky, during April and May 1944. As in the previous tests, the ground was essentially flat farm land, moderately well drained. In general, the ground was found to be more favorable than was the area used in the 75 mm gun tests and because of the later date of these tests, less trouble was experienced with mud and ruts.

(2) Targets: For the stationary fire and a limited number of moving fire tests, large vertical white panels, 12' x 12', with 3' dia. black centers were employed. In the remainder of the moving fire runs, low contrast, O. D. cloth panels 1 yard high and 6 yards long were used for both the area fire (to simulate a hedge, etc.) and fire against the silhouette of the prone man. For the last, there was placed in front of the cloth panel a standard composition board silhouette of proper dimension, as shown in the charts. Locations for the area and silhouette targets were chosen in relation to natural features of the terrain to approximate well-hidden enemy machine gun or rifle positions. Thus, the targets were placed behind tall grass, lines of small bushes, etc.

(3) Tanks: The same M4A3 tanks were employed as in the previous tests. They were maintained in excellent mechanical condition throughout the tests. The coaxial machine gun was carefully adjusted in advance for optimum operation and was so maintained during the study. Ammunition was provided with one-in-five tracer.

c. Presentation and analysis of results:

(1) The results of all tests, firing from the stationary and moving tank at the several ranges and against the various targets are shown in the form of dispersion plots in Figures 1 thru 11 and 13 to 15 inclusive. The number of rounds fired, which varied from 100 to 500, and the number of hits on the target are indicated in each case. The position of each hit is indicated in relation to horizontal and vertical coordinates.

(2) The dispersion patterns were, so far as possible, subjected to statistical analysis, as in the previous report, and expressed in terms of horizontal and vertical standard deviations. Owing to the high proportion of misses in some of the tests, however, it was necessary in the analysis to make

certain assumptions concerning the distribution of the missing rounds in relation to the target. This was done in such a way that normal probability distributions were secured. Other methods of analysis or means of presenting the results will be noted in the discussion of results.

3. RESULTS

a. Stationary fire:

The relative precision of stationary fire is demonstrated by the plots in Figs. 1, 2 and 3 and the dispersion values in Table 1. The angular dispersion was approximately equal at 200 and 500 yds. but was increased some 50% in each direction at 1000 yds. range. The observed values are in substantial agreement with firing table data for the Browning Machine Gun. The concentration of fire is great at 200 yds. and remains high at 500 yds. Against a rectangular area 26" x 19" (extreme dimensions of prone man silhouette), the probability of hits vary from practically 100% at 100 yds. range to 37% at 500 yds.

b. Moving fire, with and without gyrostabilizer, large panel target. The results of moving fire with and without the gyrostabilizer and with tank speed of 10 mph are shown for ranges of 200 and 500 yds. in Figs. 4 to 8, inclusive. Comparisons are made at 200 yds. with the periscopic sight M4 (M38 telescope) and at 500 yds. with the unit power T8 sight.

Owing to the fact that there were substantial numbers of misses, particularly at 500 yards, it was not possible to calculate MPI and σx and σy directly. They were therefore determined graphically on probability paper, the distribution of the missing rounds being assumed so as to give a normal probability curve. Thus, the following assumptions were made with respect to the misses in each test:

Range, yds.	Sight	Gyro	Assumed distribution of misses
200	M4	Yes	Equally on left and above target
200	M4	No	Equally all around target
200	T8	Yes	All on left of target
500	T8	Yes	Equally all around
500	T8	No	Equally all around

TABLE I

Dispersion of Hits in Stationary Fire
Coaxial Machine Gun - Cal. 30 Ball

Range	No. Rounds		DISPERSION					
			σ_x		σ_y		50% Area	90% Area
	Fired	On Target	Feet	mils	Feet	mils	Sq. Ft.	Sq. Ft.
200	100	100*	0.44	0.73	0.54	0.90	1.05	3.80
500	100	100	1.00	0.56	1.15	0.76	5.10	18.4
1000	200	133	4.3	1.43	4.6	1.53	87.0	317.0

* Target 6' x 6', number of hits 89. Estimated 100% hits on 12' x 12' target.

The resulting dispersion values, in terms of standard deviations and 50% and 90% areas of probability, are given in Table 2. As compared with moving fire with 75 mm gun, the dispersion of MG fire is greater, owing in part to the lower accuracy of the weapon and, in addition, to the fact that the gunner is less critical of his aim because of the more rapid action of the gun and greater quantity of ammunition which is available. Calculated probabilities of hits within a rectangular area 26" x 19" (extreme dimensions of prone man silhouette) are compared for stationary and moving fire, with and without the gyrostabilizer, in Table 3. These are for a tank speed of 10 mph and are based upon firing against the large exposed panel. The relative improvement afforded by the gyrostabilizer over moving fire without the stabilizer is evident from the data but of greater practical interest is the low probability in either case as compared with that attainable from the stationary tank.

c. Moving fire, with and without gyrostabilizer, prone man target.

In contrast to the firing tests against the large exposed panels, the target in this case was a standard silhouette of a head-on prone man. It was located in each test in a selected position which provided partial hiding by grass or small bushes and was backed up by an O.D. cloth panel one yard high and six yards long. The tests at a tank speed of 2 mph were designed to represent use of the vehicle with infantry and those at 10 mph to approximate the independent operation of tanks in movement. Results of the firing tests, with and without the gyrostabilizer, are presented in Figures 9 to 11 inclusive. The number of rounds fired and the number of hits on the target and on the panel are given with each plot.

TABLE 2

COMPARATIVE DISPERSIONS OF HITS

Moving Fire With Coaxial M.G., With and Without Gyrostabilizer

Gyro	Range	Sight	No. Rounds		MPI From Target Center, Ft.		Dispersion					
							σ_x		σ_y		50% Area $ft.^2$	90% Area $ft.^2$
			Fired	On Target	Horiz.	Vert.	ft.	mil	ft	mil		
With	200	M4	425	346	-0.8	+2.0	3.2	5.3	2.7	4.5	38.0	135.0
Without	200	M4	500	375	-0.7	+0.8	3.7	6.2	4.7	7.8	76.0	265.0
With	200	T8(1x)	500	406	-0.8	-1.0	3.5	5.8	1.3	2.2	20.0	
With	500	T8(1x)	500	226	-0.3	-0.3	5.9	3.9	5.9	3.9	158.0	
Without	500	T8(1x)	500	88	-1.5	-1.5	8.4	5.6	8.4	5.6	310.0	

TABLE 3

Probabilities of Hits on Head-On Man Target

Comparison of Moving Fire With and Without Gyrostabilizer

And Stationary Fire.

Coaxial Machine Gun

Range	Sight	Stationary Fire	Moving Fire	
			With Gyro	Without Gyro
200 yds	M4	85%	6%	3%
200 yds	T8	85+%	--	12%
500 yds	T8	37%	2%	0.9%

It will be observed that the hits on the 6 yard panel were distributed horizontally in a normal fashion with relatively high concentration in the area around the silhouette target and decreasing numbers of hits laterally. This indicates that the misses were primarily distributed above and below the panel and were so assumed in the graphical analysis of the dispersions. The results are given in Table 4. From the standard deviations thus determined, the probabilities of hits within a 26" x 19" area (which includes the silhouette target) have been calculated and are presented in the table together with the actual percentages of hits obtained on the targets in the several tests. The actual percentage hits are plotted against range for moving fire, with and without the gyrostabilizer, at 2 and 10 mph, in Figure 12. For comparison, the calculated probabilities of hitting within the same target area are also presented for stationary fire. The comparative results are striking and indicate the low order of relative precision of moving fire.

Since the machine gun is commonly fired in bursts of 5 to 8 rounds, one may, for the purpose of discussion, consider a 20% probability of hits (5 rounds per hit), as an acceptable precision of fire. Moving fire with the gyrostabilizer meets this criterion at a tank speed of 2 mph and ranges up to 250 yards. The standard is also approximately met at the same speed and ranges without the stabilizer. Beyond 250 yards range there is a rapid deterioration of precision. At 500 yards, the number of rounds per hit has increased to 20 or more and no advantage is seen in the gyrostabilizer over firing with the non-stabilized gun. The precision of fire was further reduced with a tank speed of 10 mph, requiring 7 to 10 rounds per hit with the stabilizer at ranges up to 300 yards and 50 or more rounds at 500 yards.

TABLE 4

Comparative Dispersions of Hits
Moving Fire with Coaxial M.G., with and without Gyrostabilizer
Target: Silhouette of Head-On Prone Man

Mean Range	With Gyrostabilizer						Without Gyrostabilizer					
	σ_x		σ_y		% Hits on Tgt.		σ_x		σ_y		% Hits on Tgt.	
	Ft.	mils	Ft.	mils	Obs.	Cal	Ft.	mils	Ft.	mils	Obs.	Cal.
Tank Speed: 2 MPH												
100	1.7	5.7	1.0	3.3	22.0	29.0	1.5	5.0	1.2	4.0	28.0	28.0
250	2.0	2.7	0.9	1.2	18.0	27.0	1.4	1.9	1.6	2.1	12.4	23.0
500	4.0	2.7	3.0	2.0	2.4	2.0	3.5	2.3	3.0	2.0	0.6	0.4
Tank Speed: 10 MPH												
100	3.1	10.3	1.8	6.0	9.0	10.0	2.5	8.3	1.0	3.3	6.0	21.0
250	2.9	3.9	1.3	1.7	6.8	14.0	2.8	3.7	3.3	4.4	4.8	6.4
500	7.8	5.2	4.0	2.7	1.0	1.9	7.8	5.2	4.0	2.7	1.8	1.9

It may be useful to evaluate the probabilities of hits obtained in moving fire in relation to the rates of fire that can be maintained during an advance. The number of rounds fired per 100 yards travel in the present tests averaged 88 with and 71 without the gyrostabilizer. Using these average values, the number of individual prone-man targets which could be hit during a 100 yard advance has been calculated from the data given in Table 4 and the results are tabulated for each test in Table 5.

TABLE 5

Expected Number of Prone Man Targets Hit During 100 Yard Advance
Moving Fire, Coaxial Machine Gun

Mean Range Yards	With Gyrostabilizer		Without Gyrostabilizer	
	From Obs. Data	From Cal. Prob.	From Obs. Data	From Cal. Prob.
Tank Speed: 2 mph				
100	18	25	20	20
250	17	24	9	16
500	3	2	5	0.3
Tank Speed: 10 mph				
100	5	9	2	15
250	7	12	4	5
500	1	2	1.3	1.3

d. Moving fire, with and without gyrostabilizer, area targets.

The purpose of these tests was to determine the concentration of fire that can be maintained from the moving tank against targets of some length and having no specific point of aim. Cloth panels, O. D. in color and 6 yards by 1 yard in dimension, were located at selected points of natural terrain to simulate hedges, fence lines and the like. The gunner was instructed to direct his fire over the entire length of the target. Again, tank speeds of 2 and 10 mph were employed in the tests and comparative performance with and without the stabilizer determined. The results are presented graphically in Figs. 13 to 15, inclusive. Owing to the irregularity in the horizontal distribution of hits, no statistical analysis of results is attempted. In Table 6, the actual concentrations of hits are tabulated per foot of target length (average) for the entire panel. Concentrations for the same bands, based upon the vertical dispersion obtained in the stationary fire tests, are also given for comparison. These tabulated data are plotted in Figs. 16 and 17 for the 3 feet and 1 foot bands, respectively. It will be observed that the concentrations of hits were approximately the same in stabilized fire at the two tank speeds and also at 2 mph without use of the gyrostabilizer. At a speed of 10 mph without the stabilizer there was a loss of concentration of approximately one-third.

TABLE 6 .

Concentration of Hits on Area Target 6 Yds.Long
Coaxial Machine Gun
Number of Hits per Foot Length Per 100 Rds.Fired
For Bands 1, 2 and 3 feet in Height

Height of Band	TYPE OF FIRE				
	Stationary (calculated)	With Gyrostabilizer Tank Speed		Without Gyrostabilizer Tank Speed	
		2 mph	10 mph	2 mph	10 mph
	RANGE: 100 yds.				
1 foot	4.7	1.82	2.10	2.90	1.31
2 feet	5.5	3.23	4.00	4.44	2.39
3 feet	5.55	4.27	4.32	4.95	3.05
	RANGE: 250 yds.				
1 foot	3.10	1.82	1.64	1.60	1.02
2 feet	4.95	3.17	2.68	2.87	1.71
3 feet	5.45	3.93	3.67	3.58	2.07
	RANGE: 500 yds.				
1 foot	1.67	1.05	0.96	0.82	0.57
2 feet	3.10	1.84	1.82	1.44	1.07
3 feet	4.28	2.17	2.38	1.90	1.46

4. DISCUSSION:

It is recognized that the results obtained in this study do not represent a complete evaluation of the capacities and limitations of machine gun fire from the moving tank. Compared with the wide variety of targets which may be encountered in combat, those employed in these tests are of limited significance. It is probable, however, that sufficient data are presented to show the order of magnitude of precision of fire which may be expected under favorable operating conditions, regardless of the exact nature of the target.

In many of the tests, especially at 2 mph, the gyrostabilizer failed to show any advantage over the non-stabilized gun. Undoubtedly this resulted from operation on superior terrain and is not to be expected when moving over rough ground. It must be pointed out, however, that the improvement in comparative performance in the latter case would be accompanied by an absolute reduction in precision of fire with the gyrostabilizer as well as without. The results presented here suggest that no such reduction could be accepted.

FIG. 1

OBSERVED DISPERSION – STATIONARY FIRE
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., M 4 SIGHT
RANGE – 200 YARDS
ROUNDS FIRED – 100

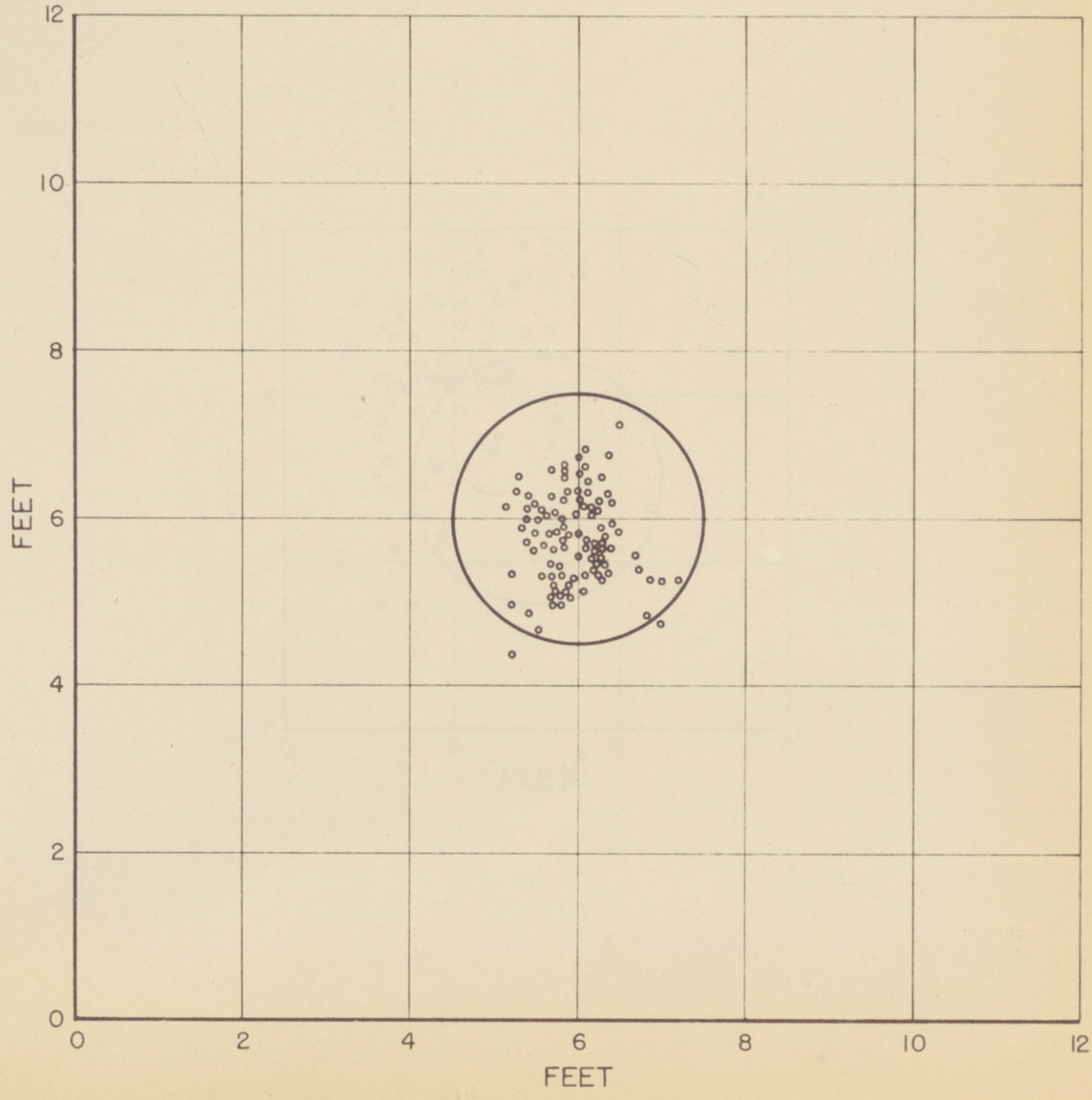


FIG. 1

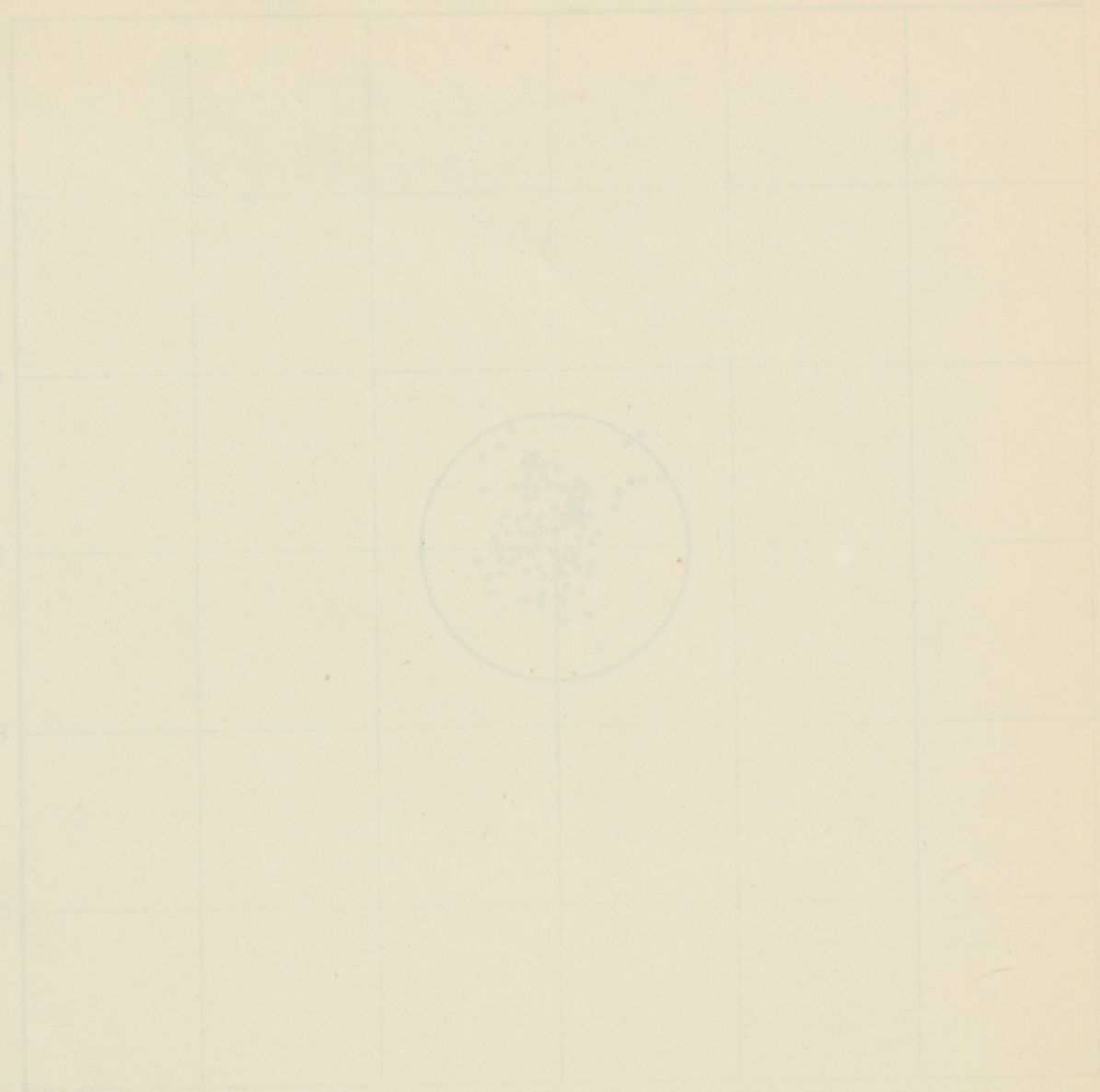


FIG. 2

OBSERVED DISPERSION - STATIONARY FIRE
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., M 4 SIGHT
RANGE - 500 YARDS
ROUNDS FIRED - 100

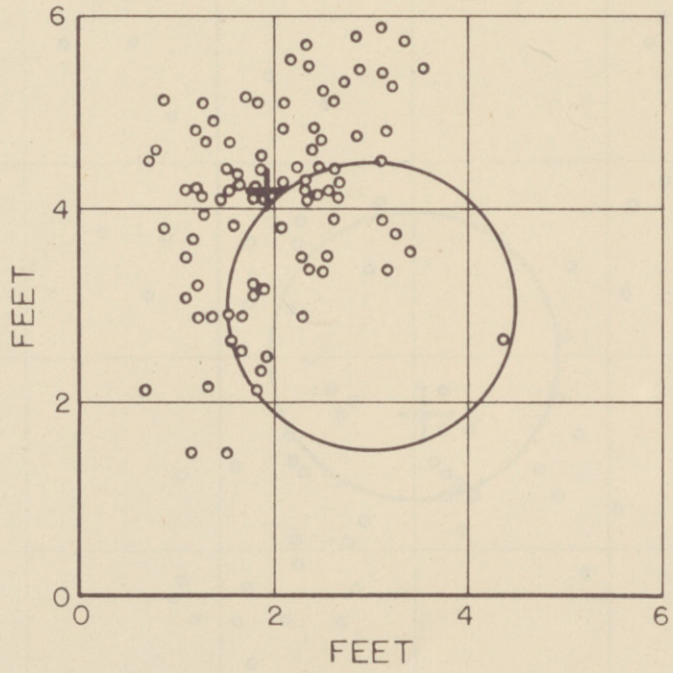


FIG. 2

FIG. 3

OBSERVED DISPERSION – STATIONARY FIRE
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., M 4 SIGHT
RANGE – 1000 YARDS
ROUNDS FIRED – 200

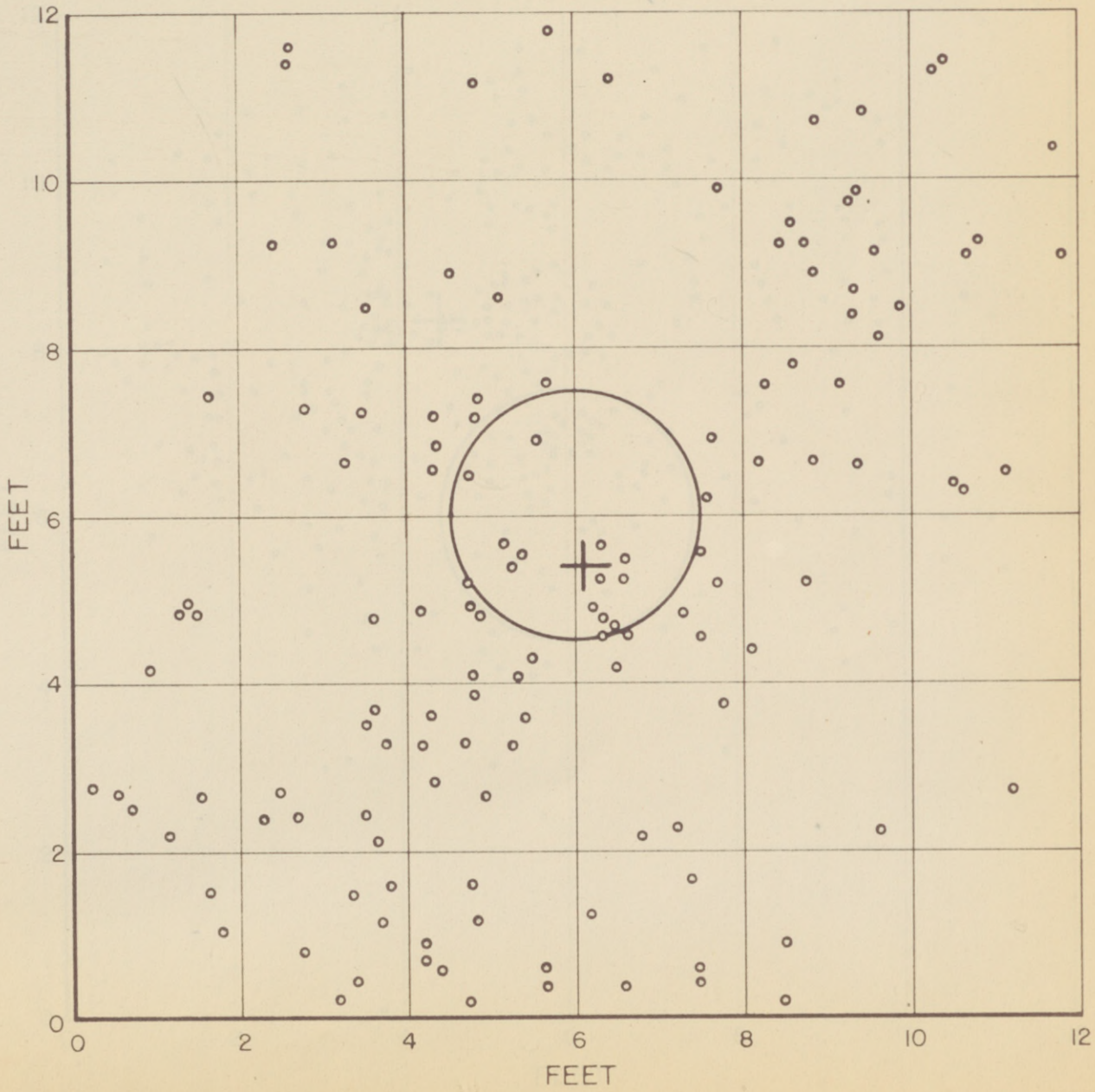


FIG. 3

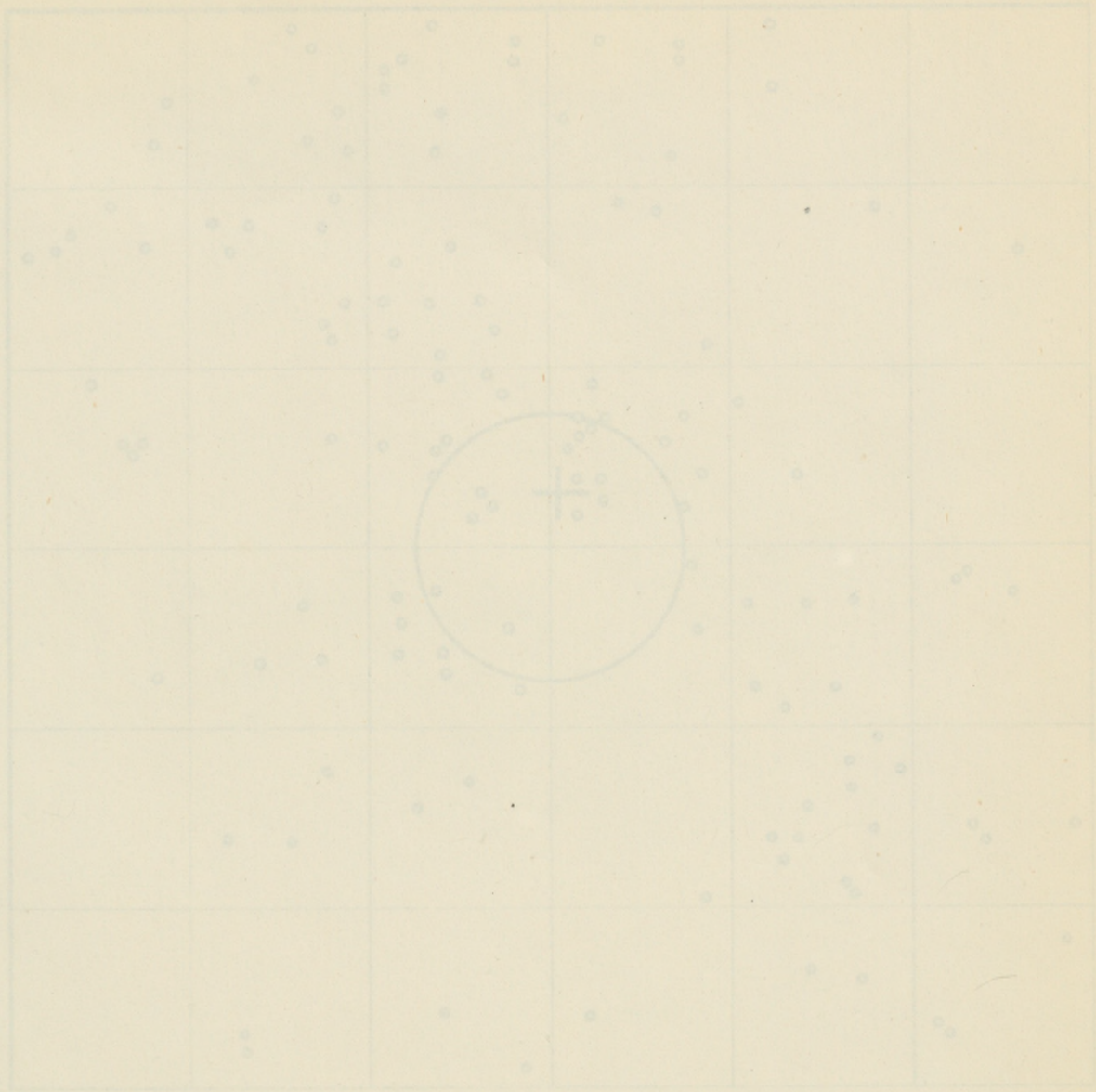


FIG. 4

OBSERVED DISPERSION
MOVING FIRE WITH GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., M 4 SIGHT

RANGE - 200 YARDS

ROUNDS FIRED - 425
ON TARGET - 346

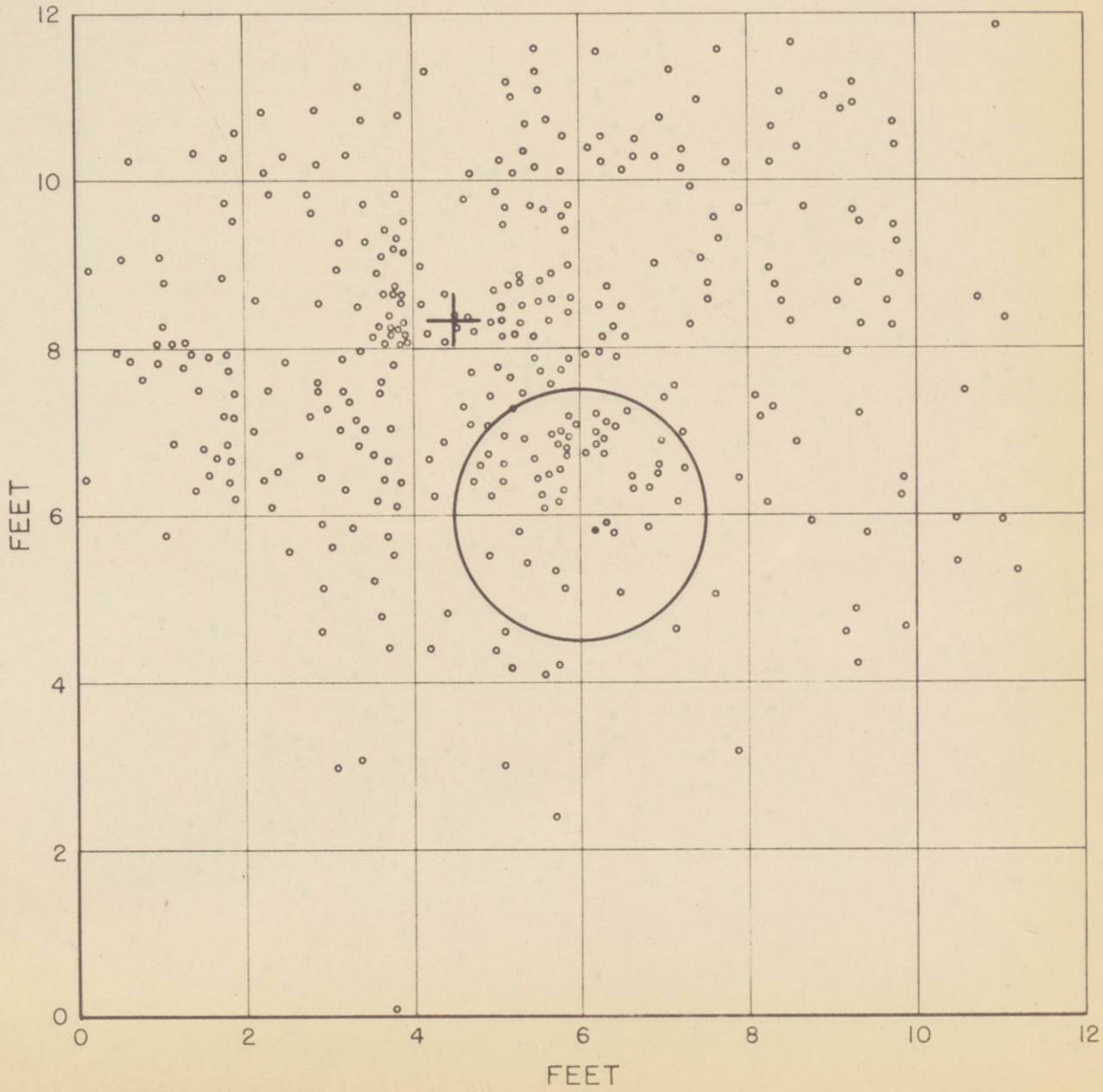


FIG. 4

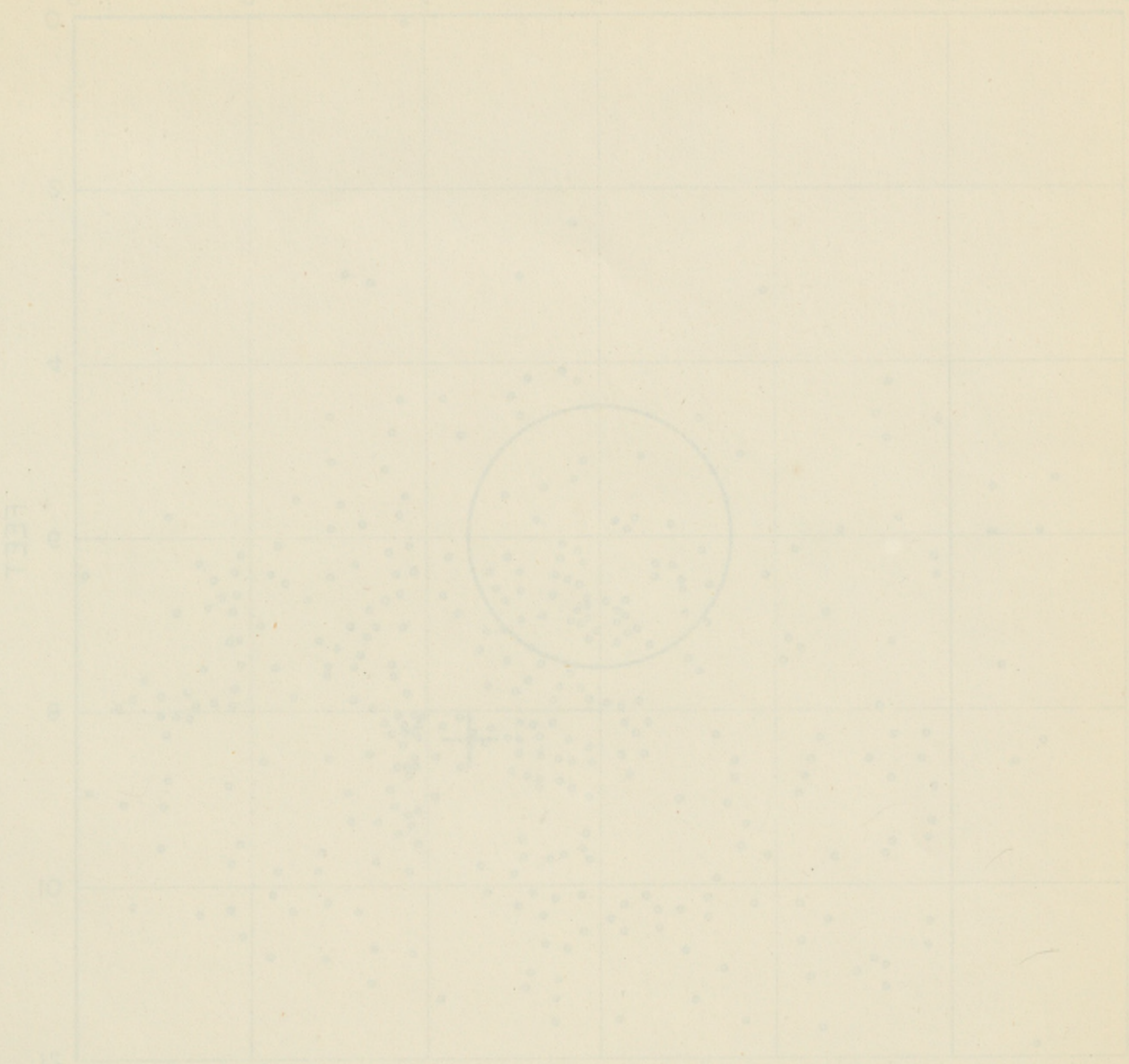


FIG. 5

OBSERVED DISPERSION
MOVING FIRE WITHOUT GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., M 4 SIGHT
RANGE - 200 YARDS

ROUNDS FIRED - 500
ON TARGET - 375

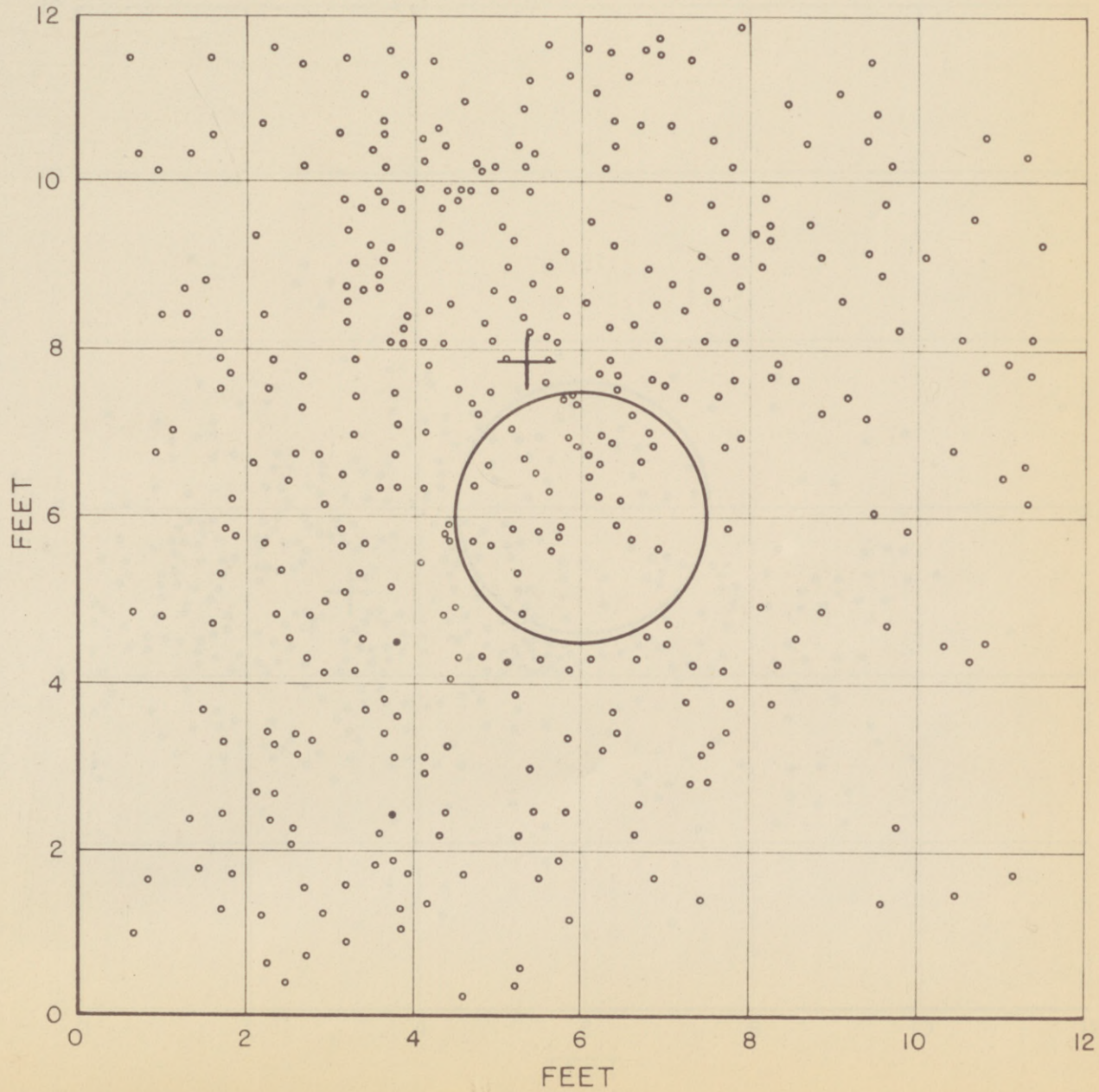


FIG. 5

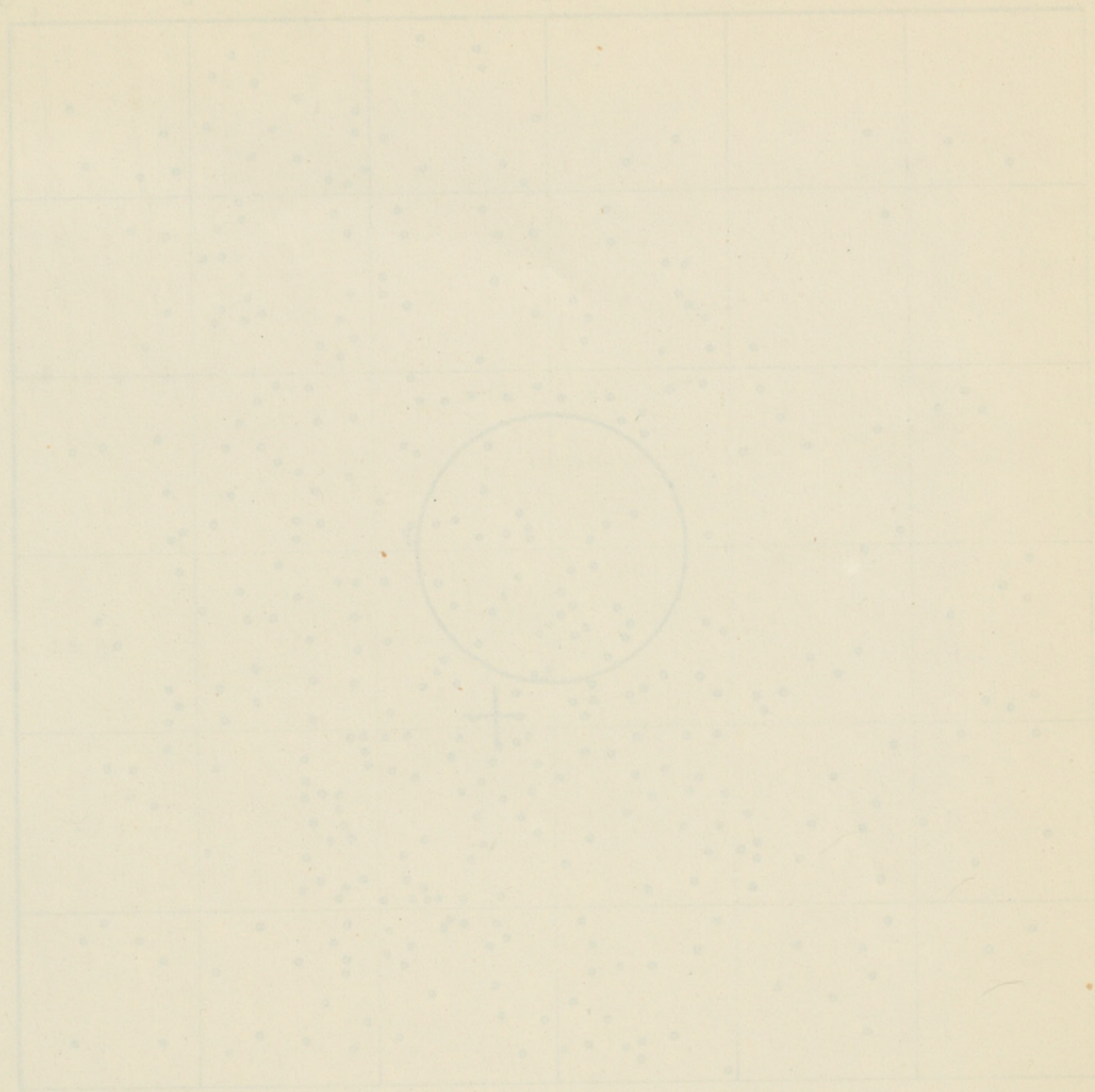


FIG. 6

OBSERVED DISPERSION
MOVING FIRE WITH GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., T8(IX) SIGHT

RANGE - 200 YARDS

ROUNDS FIRED - 500
ON TARGET - 406

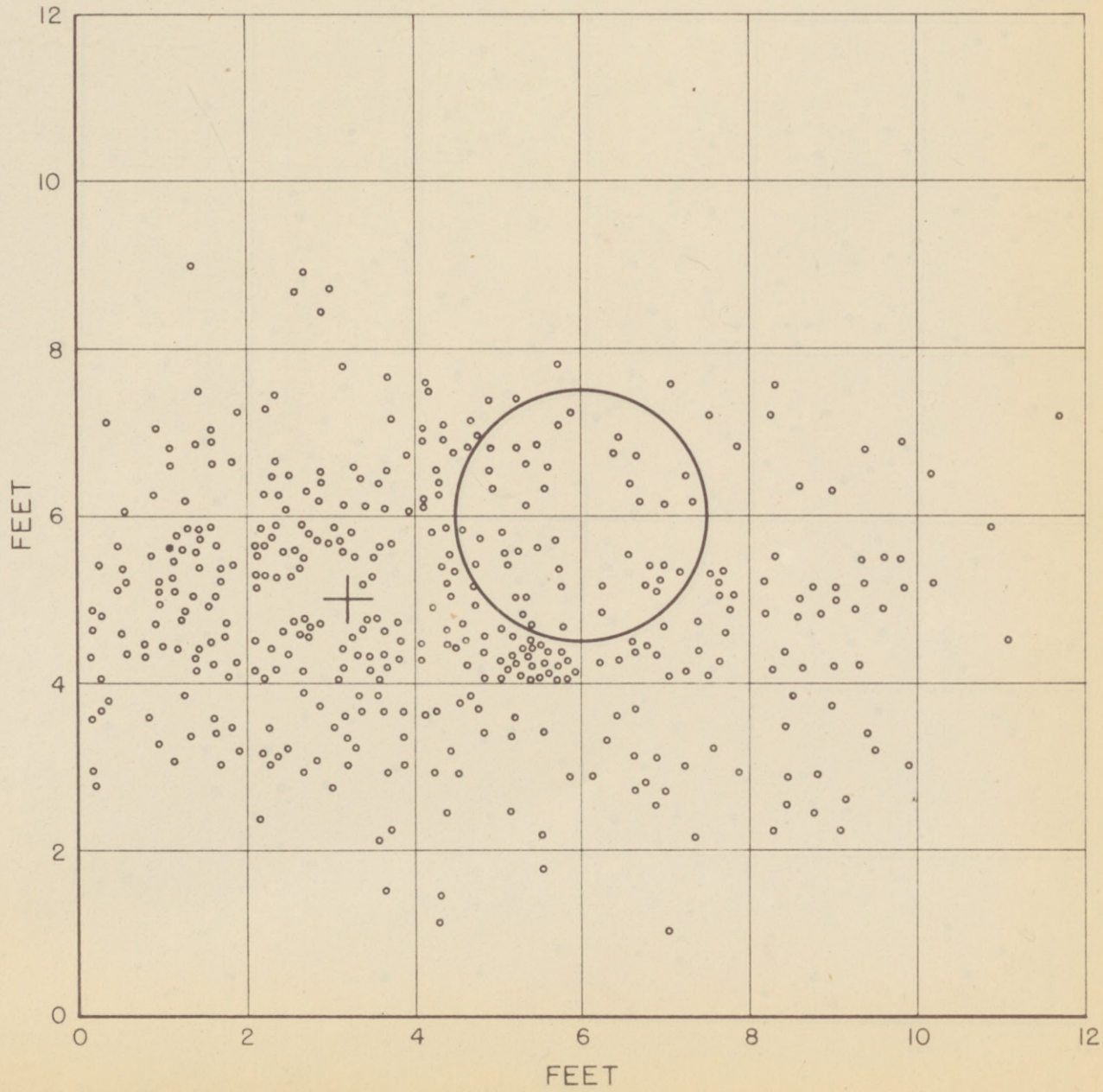


FIG. 6

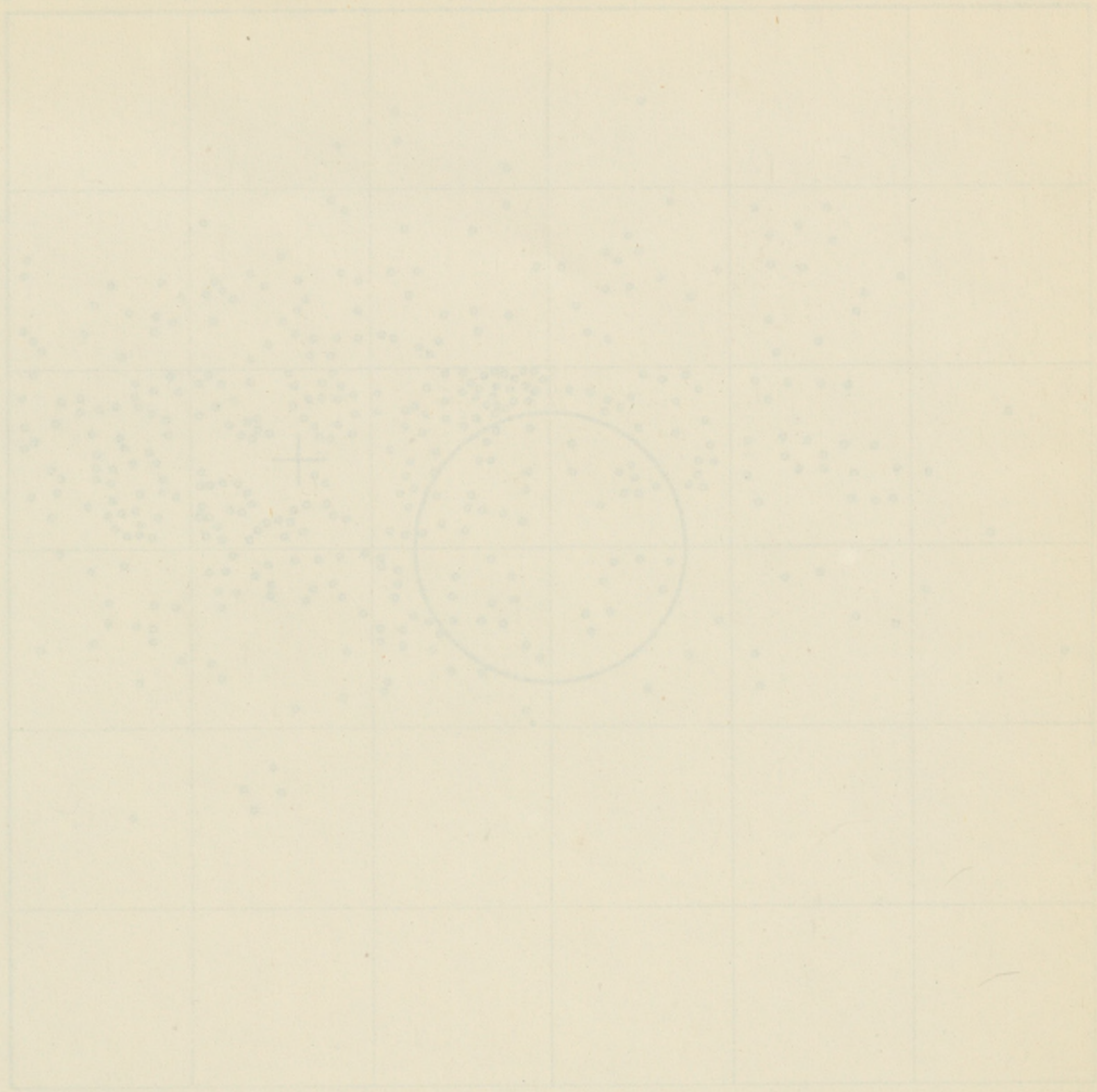


FIG. 7

OBSERVED DISPERSION
MOVING FIRE WITH GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., T8(IX) SIGHT

RANGE - 500 YARDS

ROUNDS FIRED - 500
ON TARGET - 226

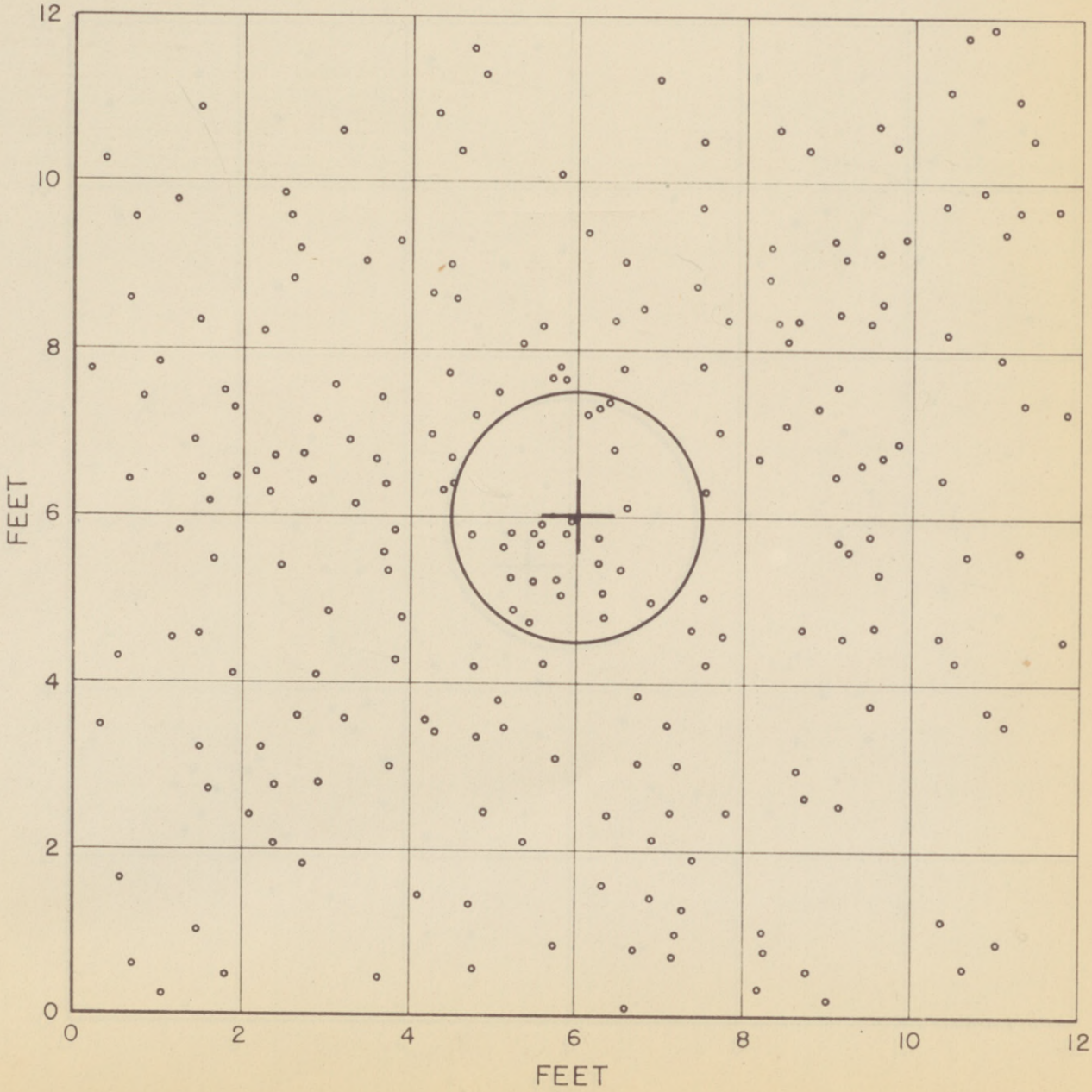


FIG. 7

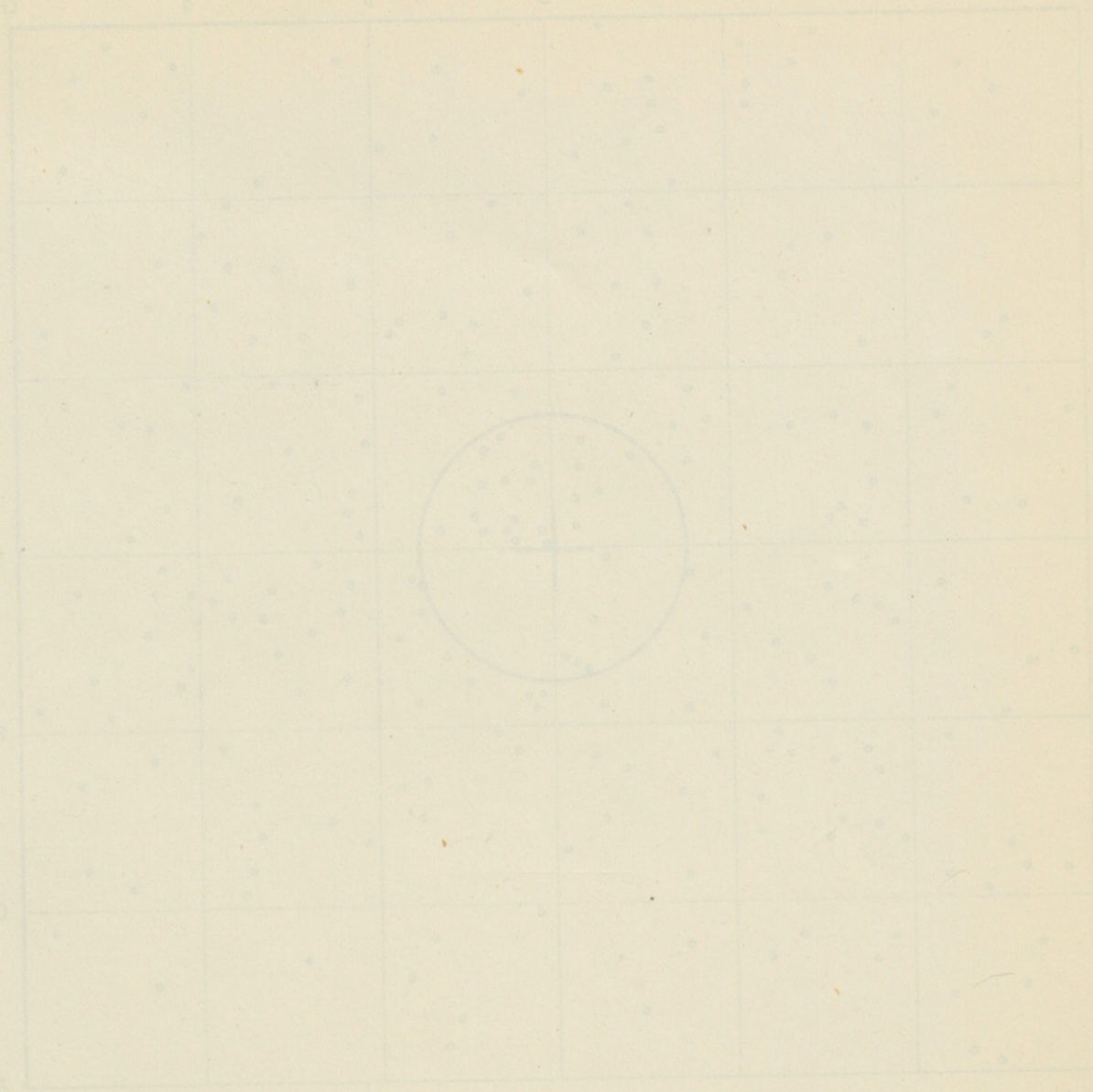


FIG. 8

OBSERVED DISPERSION
MOVING FIRE WITHOUT GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G., T8(IX) SIGHT

RANGE – 500 YARDS

ROUNDS FIRED – 500
ON TARGET – 88

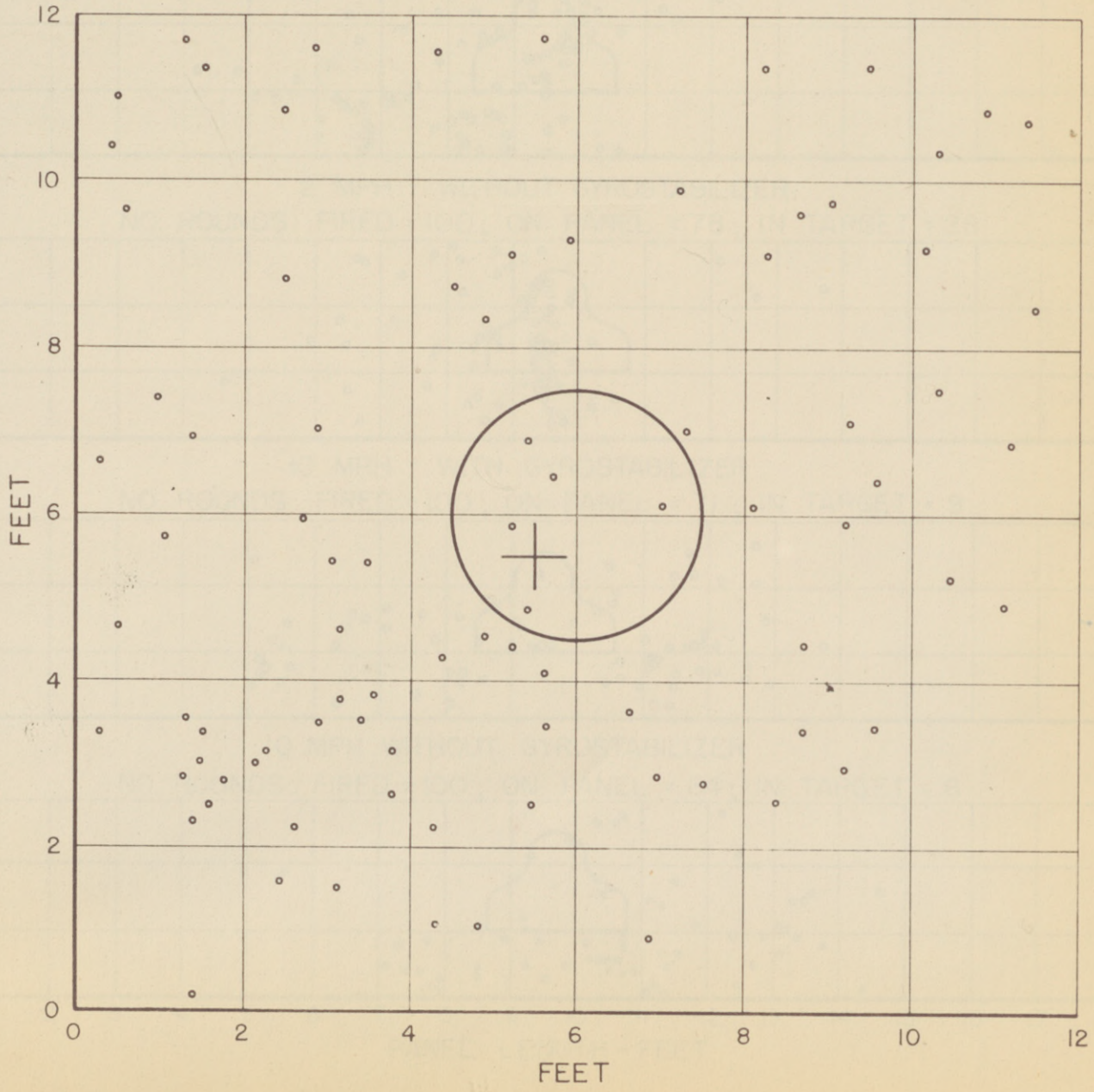


FIG. 8

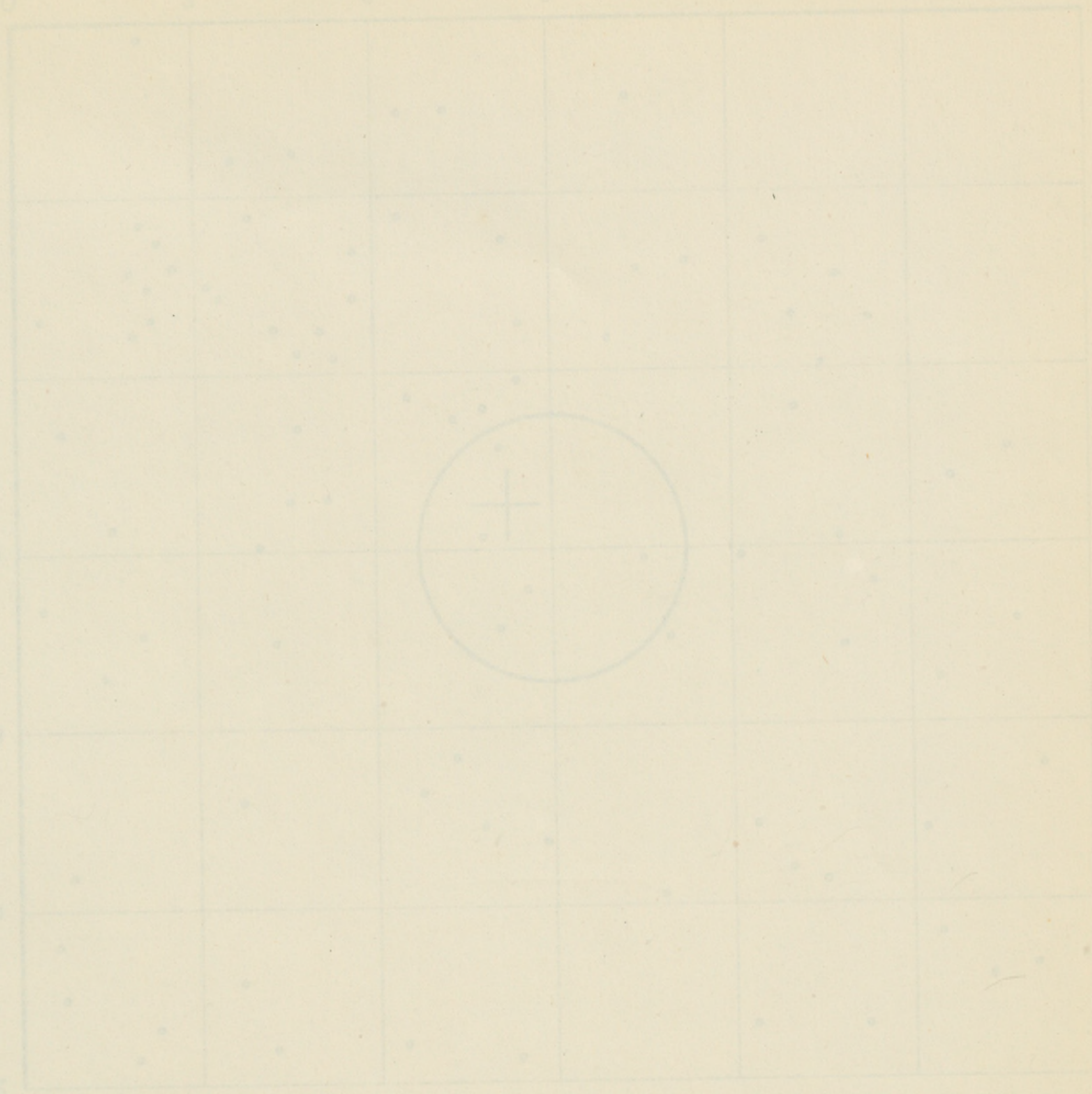


FIG. 9

OBSERVED DISPERSIONS - MOVING FIRE WITH AND WITHOUT GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G.

RANGE — 100 YARDS

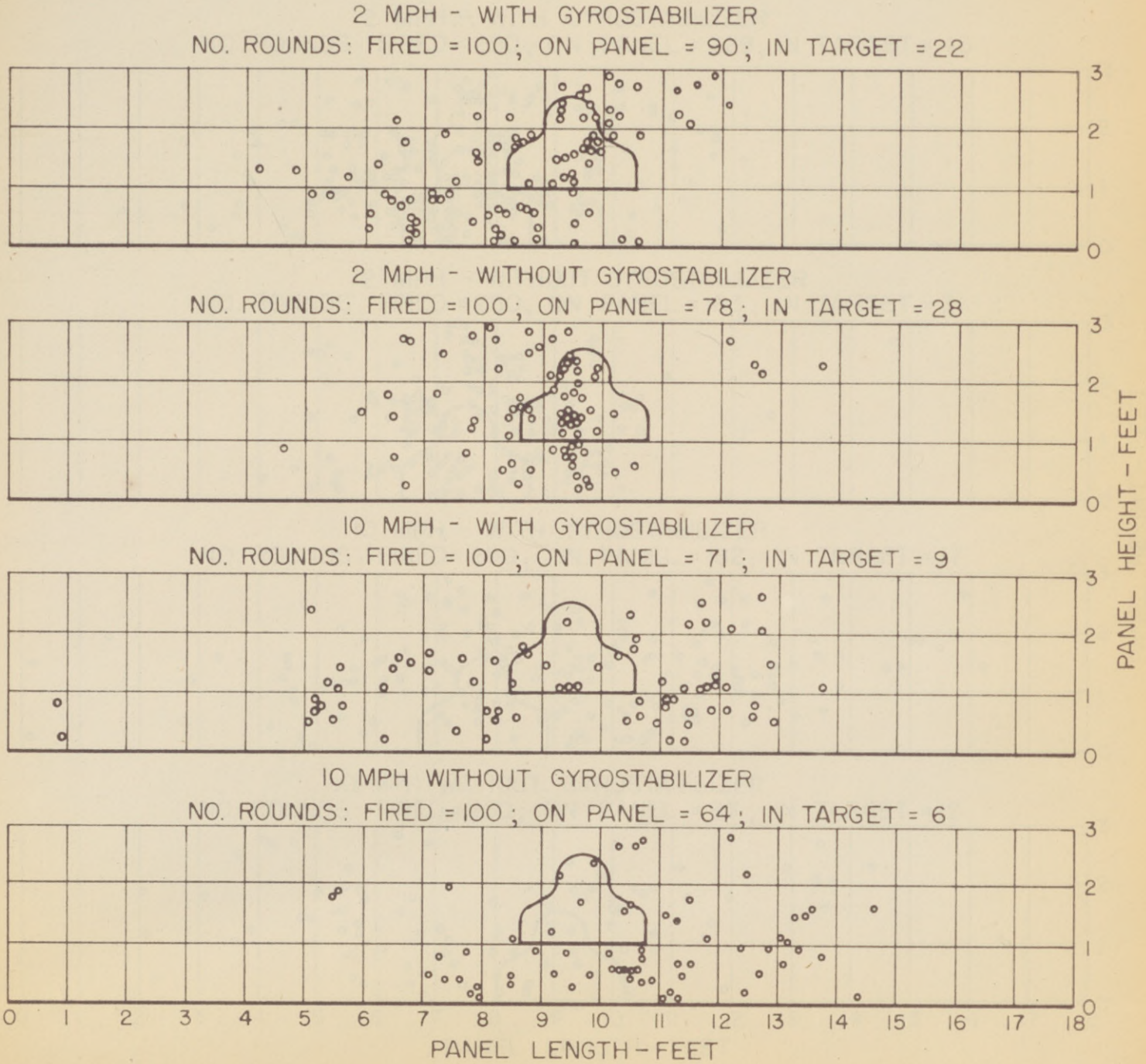
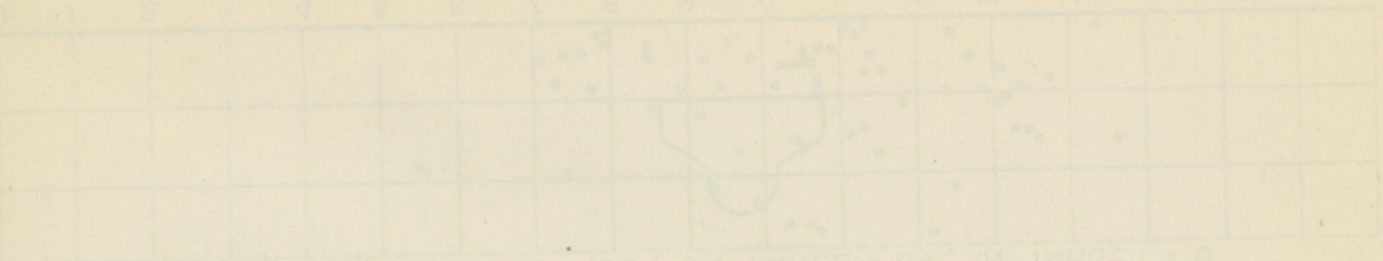
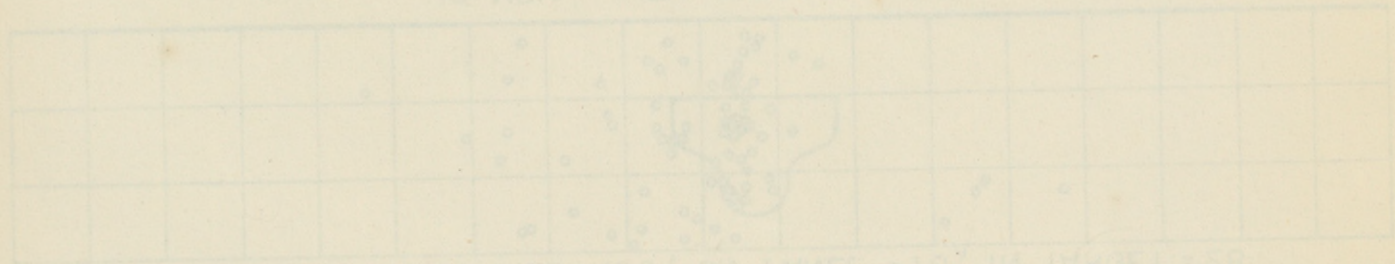


FIG. 9





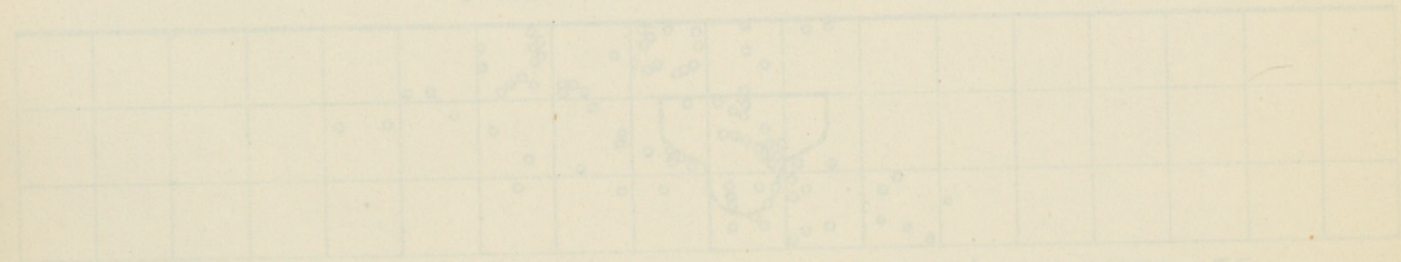


FIG. 10

OBSERVED DISPERSIONS - MOVING FIRE WITH AND WITHOUT GYROSTABILIZER

M4A3 MED. TANK, CAL. 30 COAXIAL M.G.

RANGE - 250 YARDS

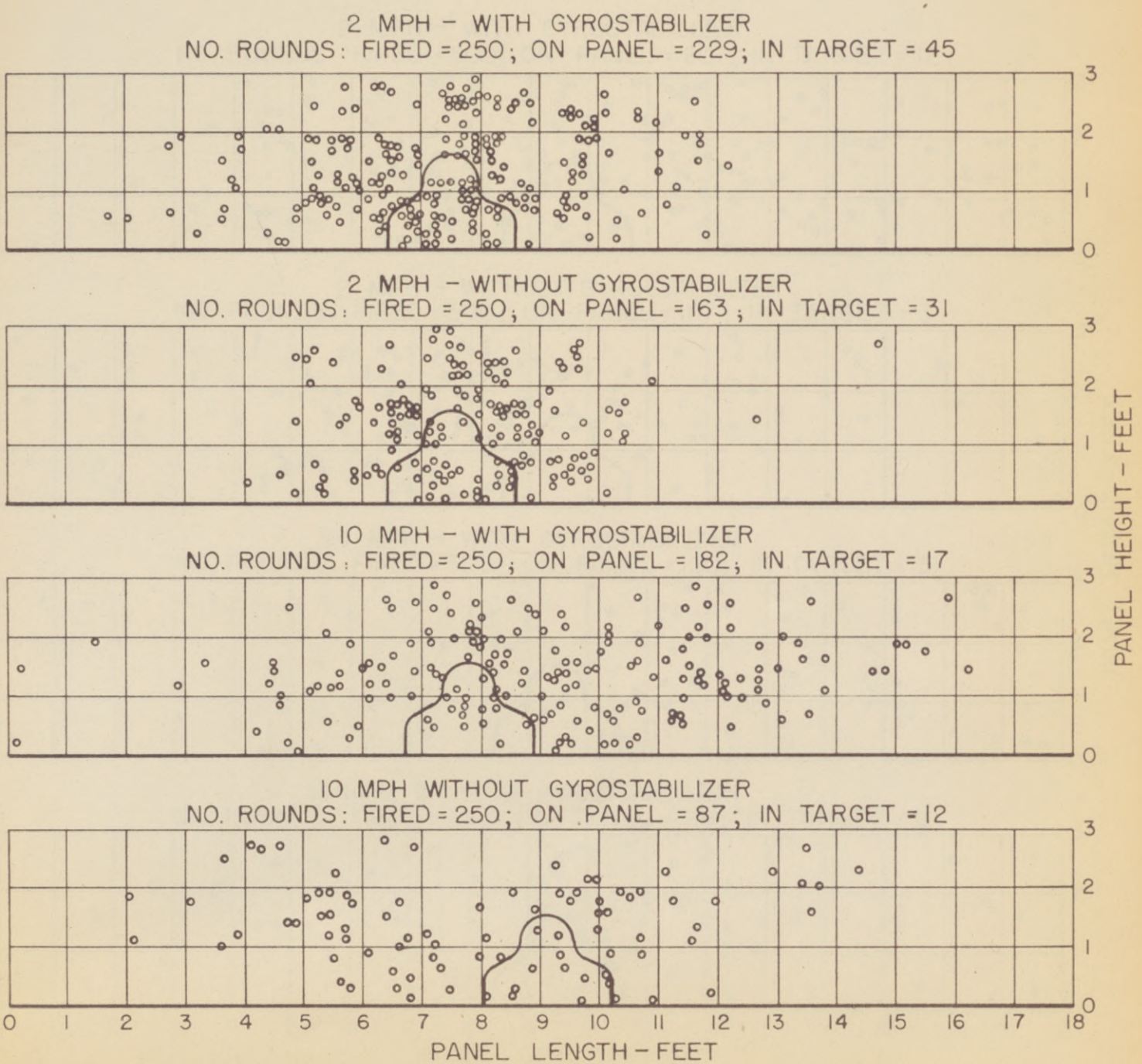
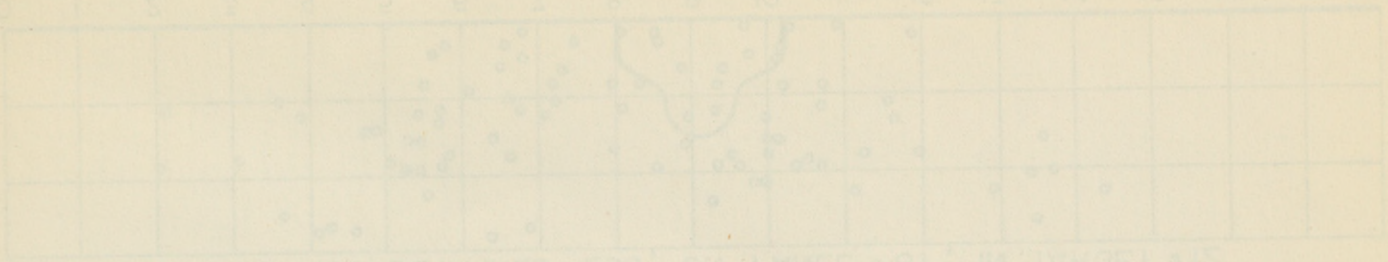
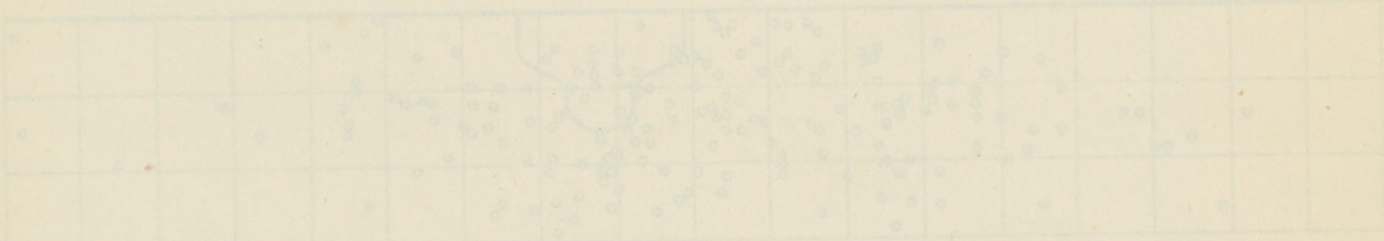


FIG. 10





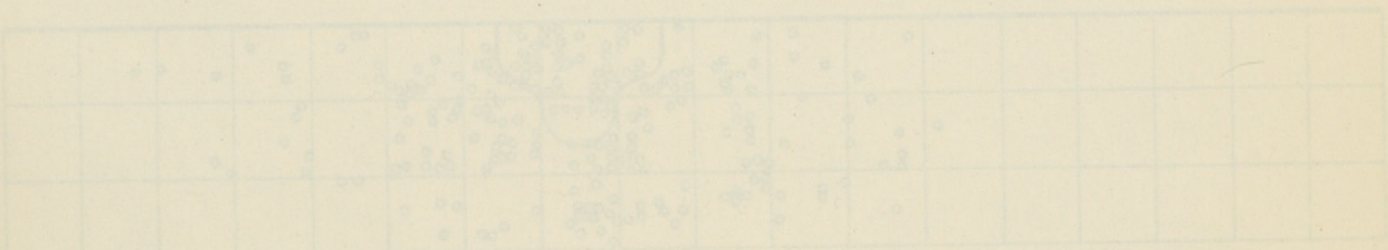


FIG. 11

OBSERVED DISPERSIONS - MOVING FIRE WITH AND WITHOUT GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G.

RANGE - 500 YARDS

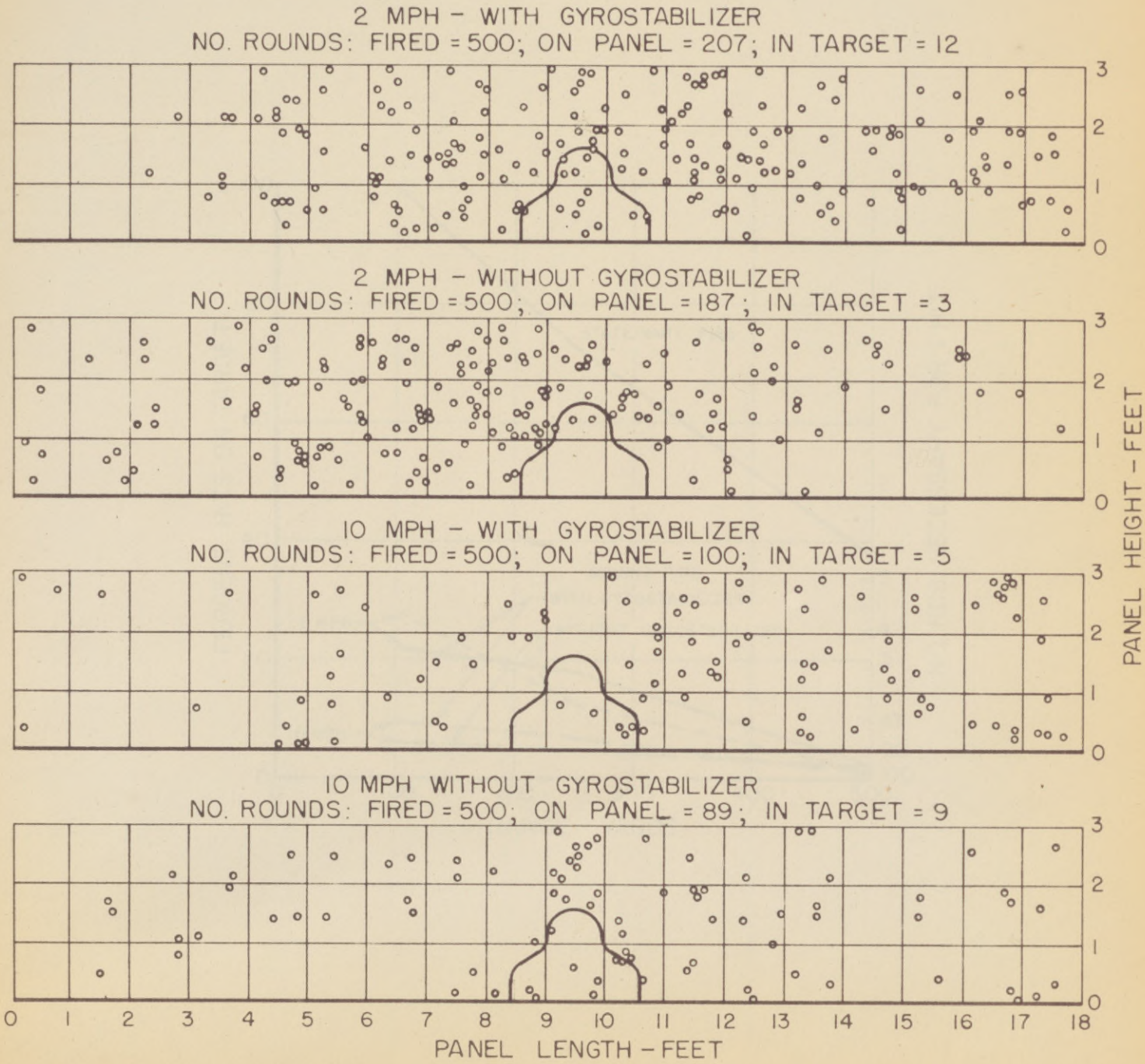


FIG. 11

FIG. 12

OBSERVED PERCENTAGE HITS ON HEAD-ON PRONE MAN TARGET
MOVING FIRE IN RELATION TO RANGE WITH AND WITHOUT GYROSTABILIZER

M4A3 MED. TANK, CAL. 30 COAXIAL M.G.

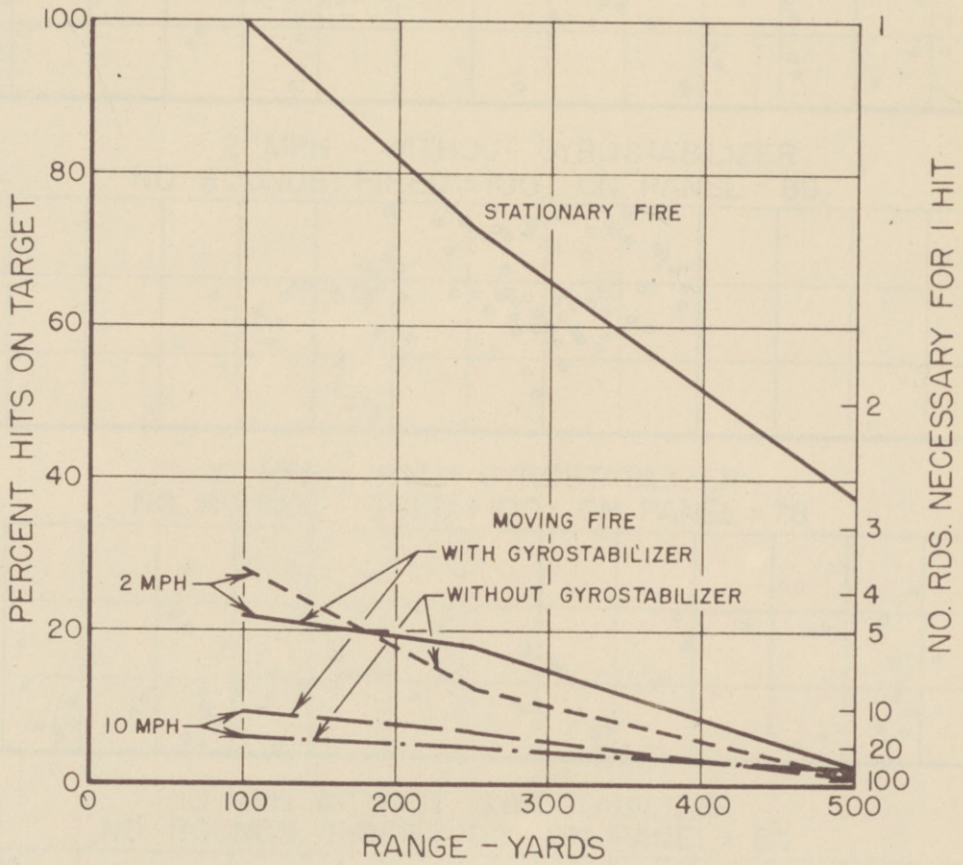


FIG. 12

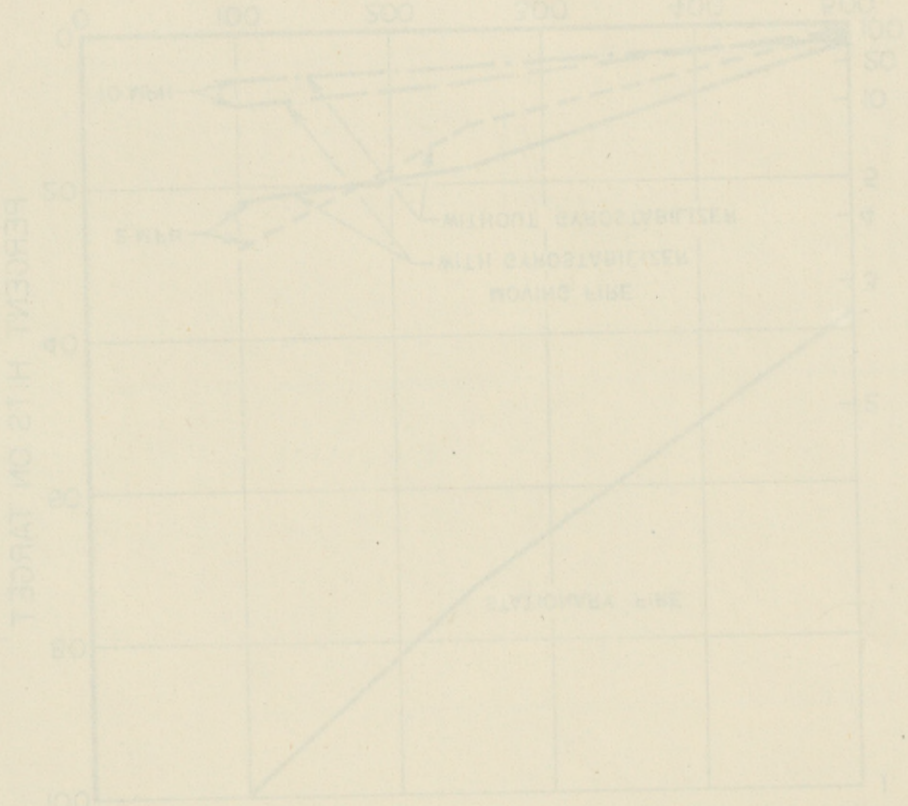


FIG. 13

OBSERVED DISPERSIONS MOVING FIRE WITH AND WITHOUT GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G.

RANGE - 100 YARDS

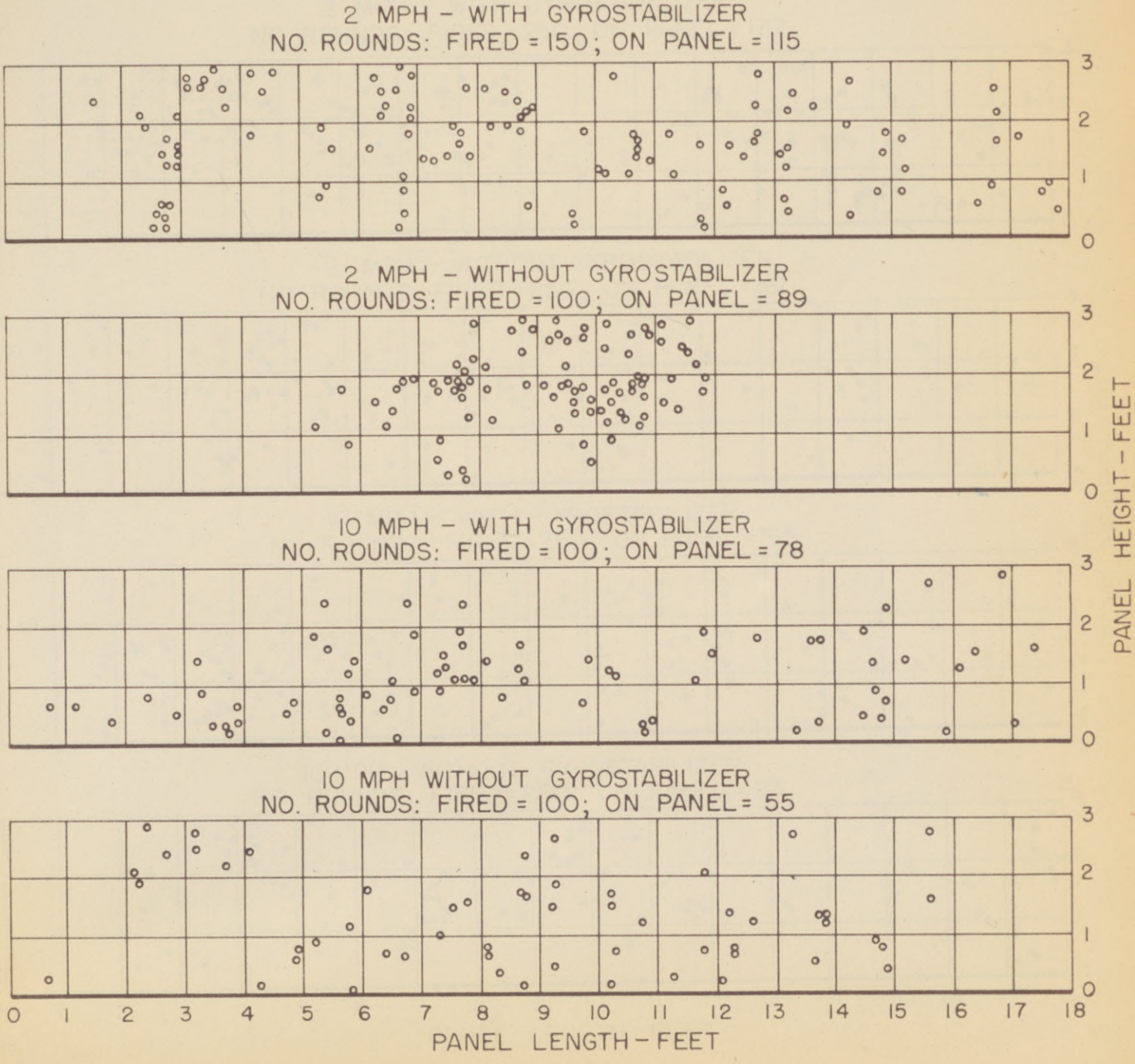
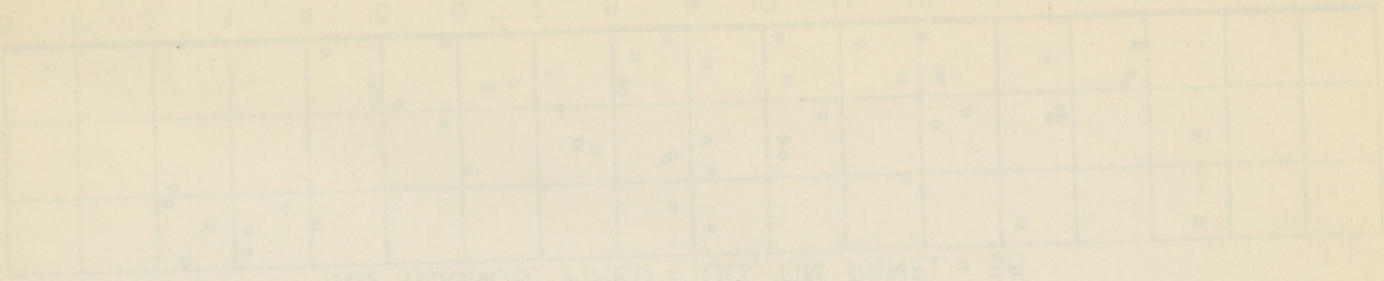


FIG. 13



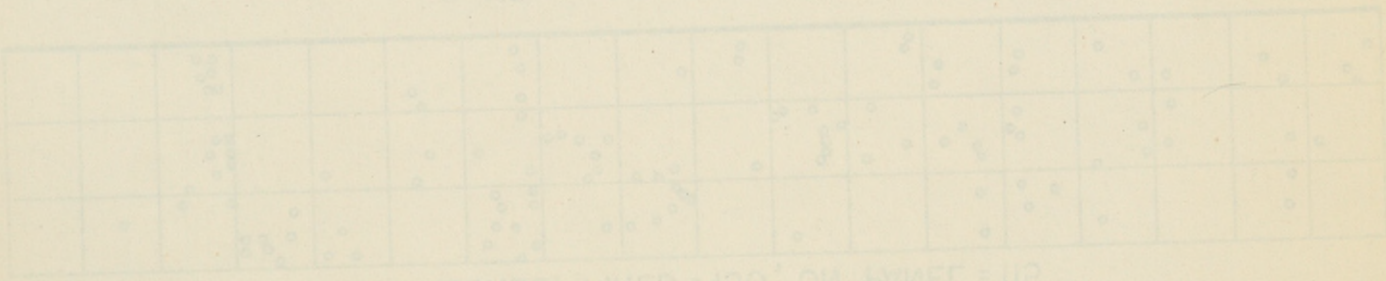


FIG. 14

OBSERVED DISPERSIONS MOVING FIRE WITH AND WITHOUT GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL. M.G.

RANGE - 250 YARDS

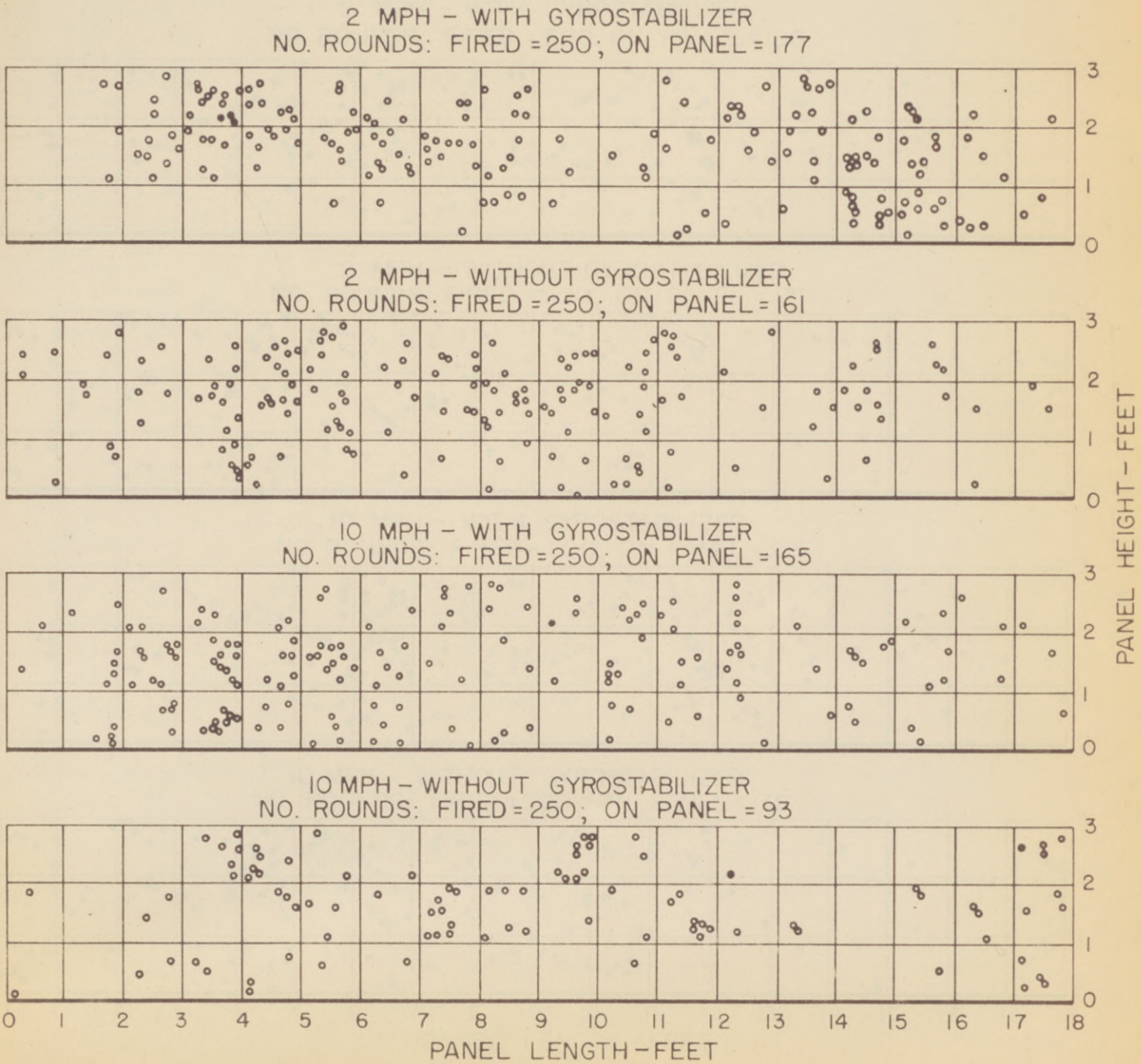
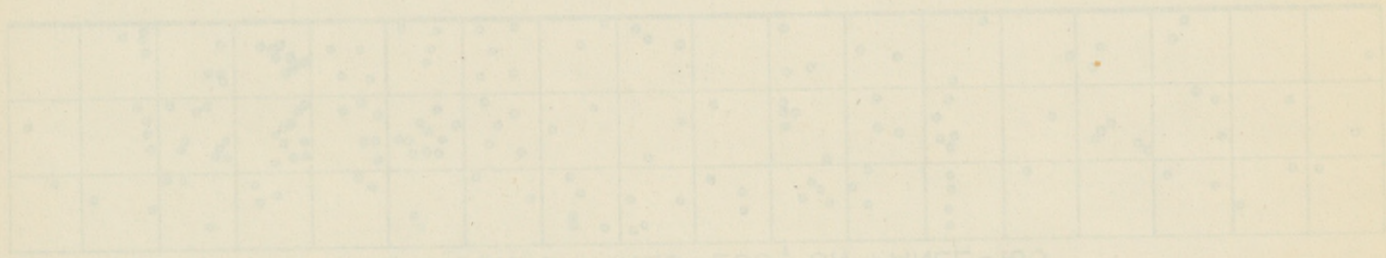


FIG. 14



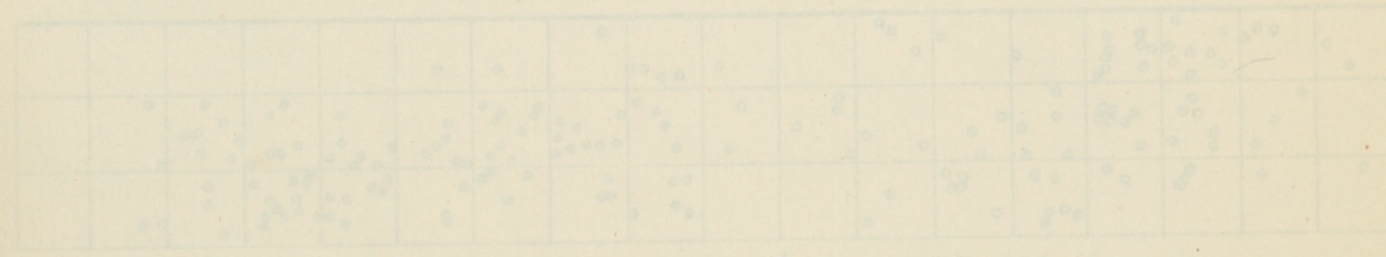


FIG. 15

OBSERVED DISPERSIONS MOVING FIRE WITH AND WITHOUT GYROSTABILIZER
M4A3 MED. TANK, CAL. 30 COAXIAL M.G.

RANGE – 500 YARDS

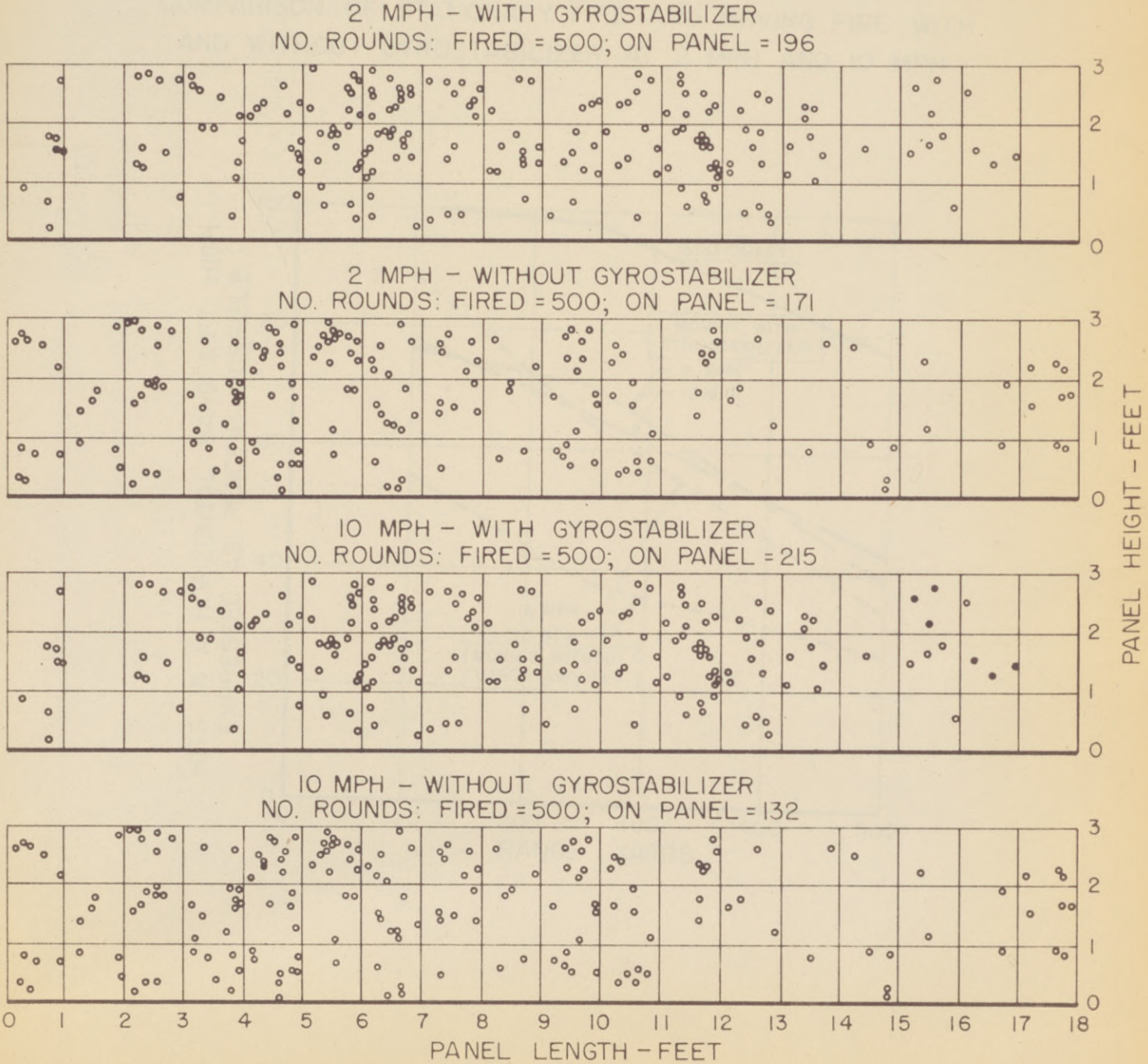


FIG. 15

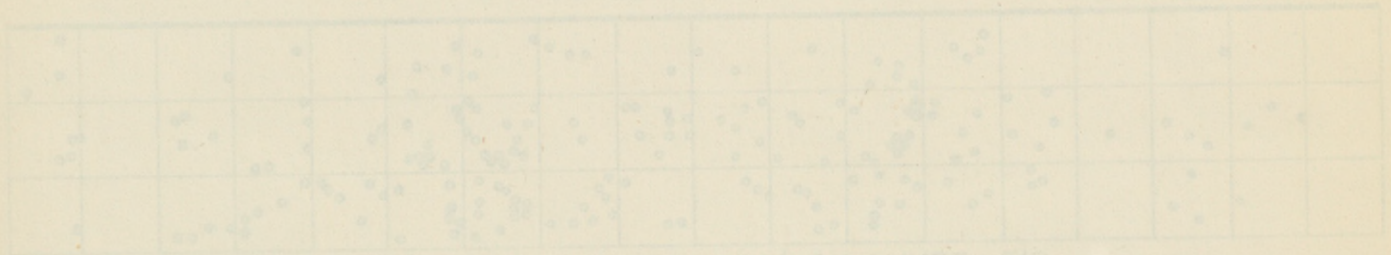


FIG. 16

CONCENTRATION OF HITS ON AREA TARGET 6 YARDS LONG IN RELATION TO RANGE

COMPARISON OF STATIONARY FIRE AND MOVING FIRE WITH AND WITHOUT GYROSTABILIZER AT 2 MPH AND 10 MPH

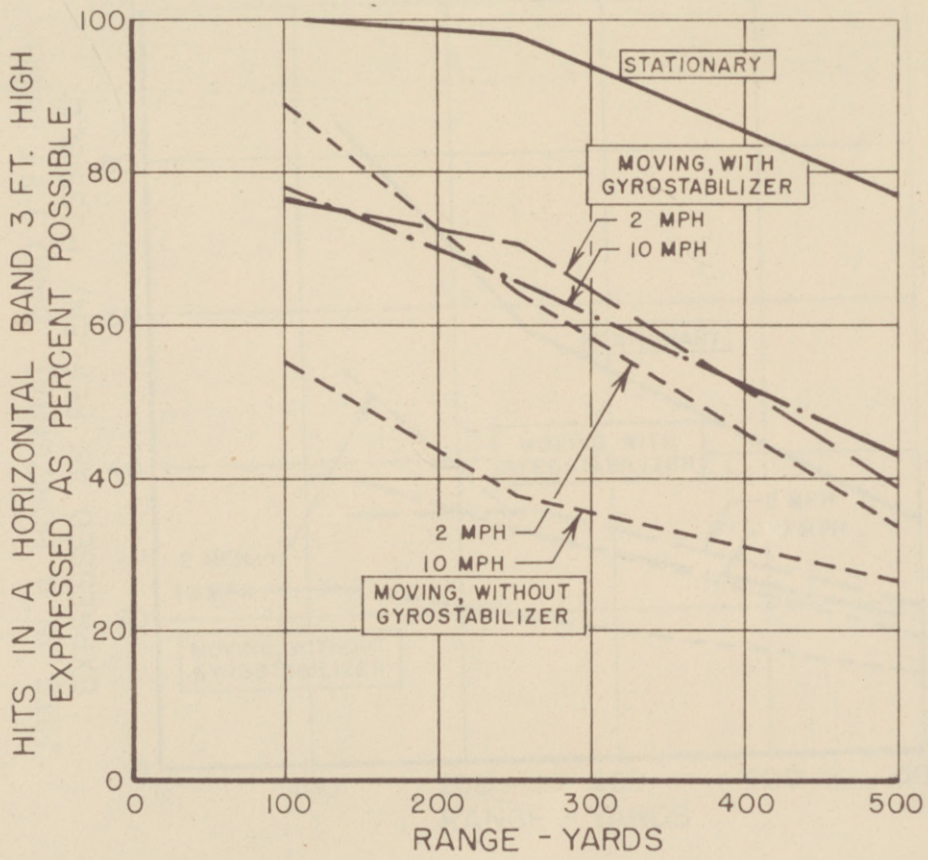


FIG. 16

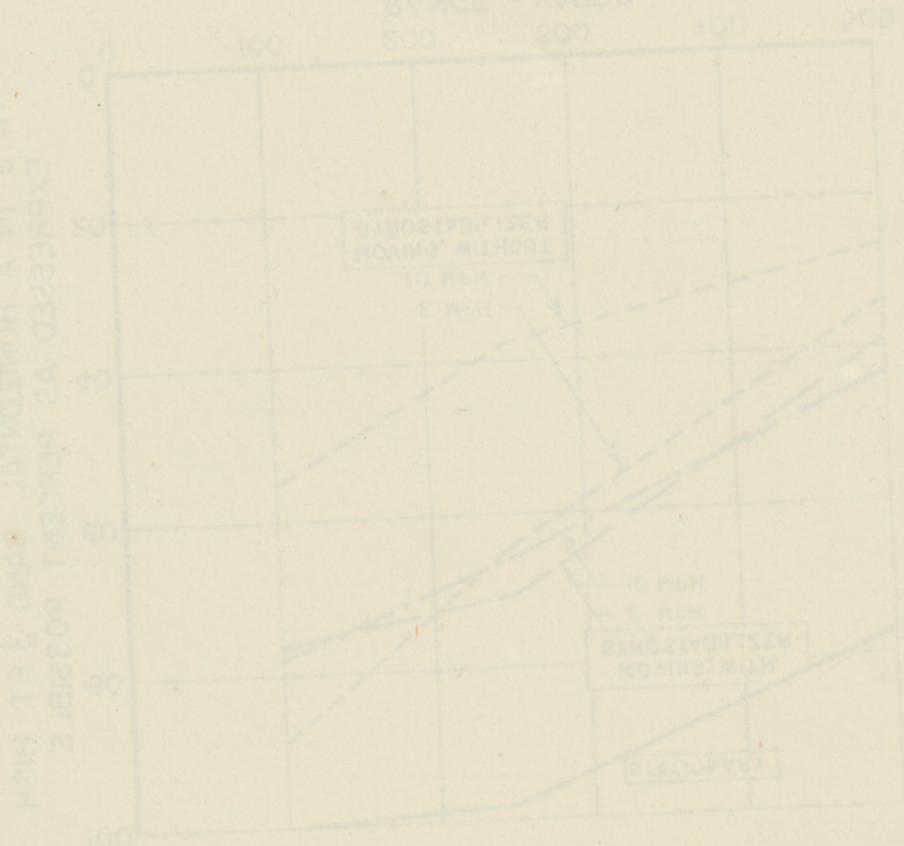


FIG. 17

CONCENTRATION OF HITS ON AREA TARGET 6 YARDS LONG IN RELATION TO RANGE

COMPARISON OF STATIONARY FIRE AND MOVING FIRE WITH AND WITHOUT GYROSTABILIZER AT 2 MPH AND 10 MPH

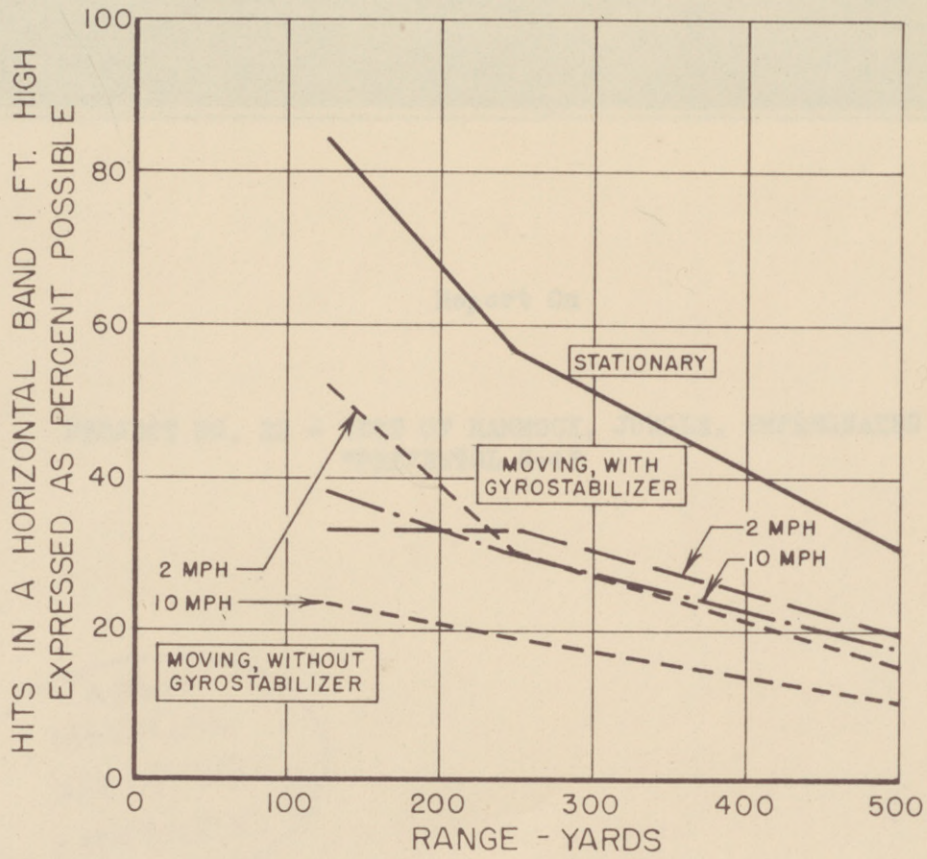


FIG. 17